

Chapter 32 (Part 1) - Intro to Physiology/Homeostasis/Endocrine Sys.

Monday, April 1, 2019
10:28

Organisms use **homeostasis** to maintain a "steady state" or internal balance regardless of external (and technically internal) environment.

Not completely true --> "steady state" \neq static --> consider "steady state" as being in a range

Example: temperature can change but as long as it stays within a range, it's in a "steady state"

In humans, body temperature, blood pH (one of the *tightest* ranges for humans), and glucose concentration are each maintained at a constant level.

****Calcium is the most tightly regulated ion within the body.****

Regulation of room temperature by a thermostat is *analogous* to homeostasis.

Graphic is on Slide 3 of Week 1 PowerPoint. There is a beginning at a set point and a stimulus that will set off the sensor/control center and cause a response to which an action will occur to attempt to *return* to a set point.

Negative feedback - "sensor" will take actions *against* the stimulus

Physiological Thermostat

Medulla - in charge of keeping you alive --> heart beat, breathing

Hypothalamus - in charge of keeping you alive *and* well (comfortable)

Thermoregulation (regulation in temperature) in mammals is controlled by a region of the brain called the **hypothalamus**. The hypothalamus is made up of nervous tissue.

The regulation of temperature can affect the heart (circulatory system) which can in effect, change what goes to the brain.

The hypothalamus responds to changes to the set *range* for a body temperature (a stimulus).

The hypothalamus triggers heat loss or heat-generating mechanisms.

Example (slide 5): Begin at homeostasis of internal body temp of appx. 36-38 degrees Celsius. Stimulus of increased body temperature sets off the sensor/control center --> thermostat in the hypothalamus. Response to stimulus is **vasodilation** --> blood vessels in the skin dilating. This sends a larger percentage of blood to the surface of the skin which can help to *dissipate* heat --> release of heat. The result will be a decrease in body temperature.

Example (slide 6): Begin at homeostasis of internal body temp of appx. 36-38 degrees Celsius. Stimulus of decreased body temperature sets off the sensor/control center --> thermostat in the hypothalamus. Response to stimulus is **vasoconstriction** --> blood vessels in the skin constricting. This results in the response of shivering which causes movement in the organism (mini-vibrations) which can warm the body again.

Endocrine System

Within the body, endocrine cells and often groups in ductless (gland that secretes *directly* into the bloodstream) organs called **endocrine glands**. From here, these cells and glands secrete

hormones directly into the surrounding fluid --> from here, the hormones enter the circulatory system.

Endocrine system - organs *and* tissues that perform hormones; in this system, signaling molecules released into the blood stream by endocrine cells are carried to all locations in the body; their response, however, is limited to cells that have a receptor for the signal dispersed

Diffuse endocrine system -- individual endocrine cells that are imbedded in other organs not necessarily included within the endocrine system

Example: heart, stomach, etc.

Hormones - regulatory chemicals secreted into extracellular fluid and carried by the blood

- Depending on which cells have receptors for that hormone, it may have an effect in just a single location or in sites *throughout* the body --> they can act at a distance from a source.
- Only targets with *correct* receptors can respond.
- Effects are often long-lasting, however, because hormones can remain in the bloodstream for minutes or even hours.
 - Unused, deactivate hormones are removed by the liver and kidney.

Reduction of a signaling process involves its initiation *and* termination.

- **Negative feedback (feedback inhibition)** - a control circuit or loop that reduces, or "damps," the stimulus --> common in endocrine pathways that keep physiological systems *within* normal limits
- **Positive feedback** - a control mechanism in which the response reinforces the stimulus, leading to an even greater response (example: childbirth and oxytocin) --> helps drive a process to completion

3 Classes of Hormones --> sorted by their chemical origins

- Protein-based or peptide-based [hydrophilic]
- Amino acid derivatives (very few of them) [lipophilic]
 - Examples: Melatonin, thyroid hormones, catecholamines
- Steroids [lipophilic]
 - Examples: Sex steroids, corticosteroids
 - i. Primary reason steroid hormones usually act slowly is that they turn genes on/off and it takes time for gene products to become depleted or build up

Hormones can also be classified by either being:

- **Lipophilic** - lipid-soluble (soluble in fats or other liquids)
 - Steroid hormones and thyroid hormones (amino acid derived)
 - Travel on transport proteins in blood (can't enter the blood by themselves, are **not** soluble by blood due to blood being water-derived)
 - Bind to intracellular receptors (receptors *inside* of the cell) --> a lipophilic hormone will be able to *enter* the plasma membrane of a cell due to the plasma membrane consisting of a lipid bilayer
 - Tend to act over a brief time period
- **Hydrophilic** - water-soluble (soluble in water)
 - All other hormones (example: protein hormones)
 - Freely soluble in blood, do **NOT** need a medium to travel
 - Bind to extracellular receptors --> cannot enter the plasma membrane because it's *not* lipophilic in order to go through the lipid bilayer

- Tend to have much longer active periods

Pituitary Gland

This gland hangs by a stalk from the hypothalamus --> the hypothalamus *controls* both the anterior and posterior parts of the pituitary gland.

The pituitary gland consists of two parts:

- **Anterior pituitary**
 - Epithelial tissue in origin (true endocrine) --> thin tissue forming outer layer of a body's surface, covers most internal and external surfaces of the body and its organs
 - i. Contains cells that *produce anterior pituitary hormones*
 - These anterior pituitary hormones that target endocrine tissues often form part of a ***hormone cascade***.
 - Stimulus to hypothalamus --> hypothalamus secretes factor that regulates the release of a specific anterior pituitary hormone --> this hormone in turn stimulates an endocrine organ to secrete *another* hormone

Posterior pituitary

Only stores hormones, doesn't produce anything

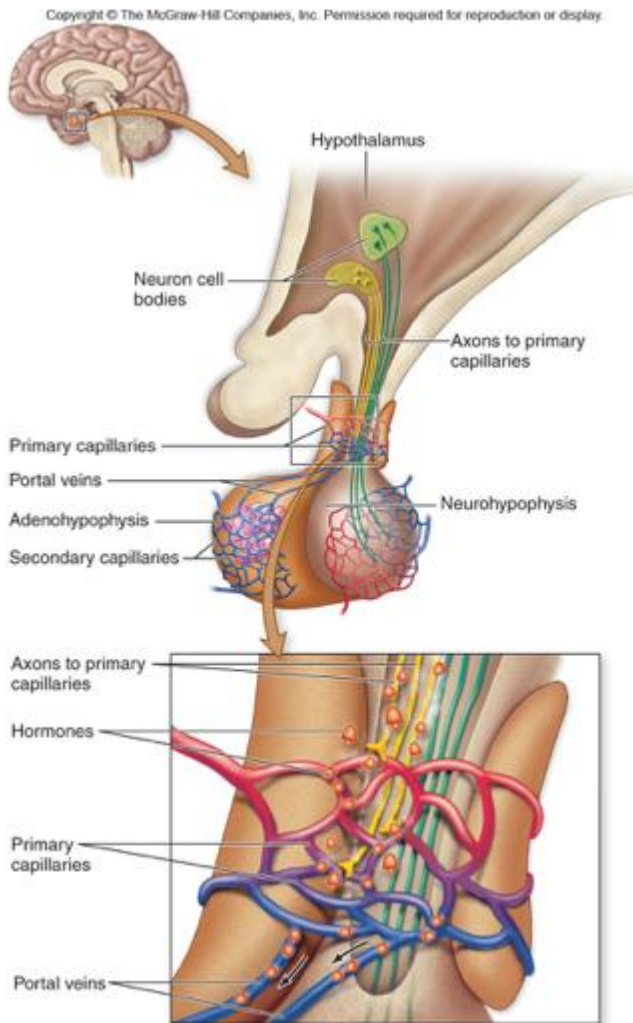
Nervous tissue in origin --> same material as hypothalamus, an "extension" of the hypothalamus

Stores and releases **two** hormones, both produced by neuron cell bodies in the *hypothalamus*:

- Antidiuretic hormone (ADH)** - peptide hormone that stimulates water reabsorption by the kidney, and thus inhibits diuresis (urine production)
- Oxytocin** - peptide hormone in mammals; it stimulates the milk ejection reflex and uterine contractions during labor, and it regulates reproductive behavior

Appears fibrous because it contains axons that originate in cell bodies within the hypothalamus and that extend along the stalk of the pituitary as a tract of fibers

- Develops from outgrowth of the brain.



The "green" axons release hormones to the **posterior** pituitary while the "yellow" axons release hormones to the **anterior** pituitary.

These axons release hormones into the bloodstream, specifically primary capillaries which then will travel to portal veins --> portal veins deliver from the first capillary bed to a second capillary bed, *not* general circulation.

The anterior pituitary is *controlled* by hormones from the hypothalamus --> are called tropic hormones because they *tell* other hormones to be released.

Hypothalamus secretes **releasing** hormones and **inhibiting** hormones, which diffuse into blood *capillaries* at the hypothalamus' base.

Capillaries - any of the fine branching blood vessels that form a network between the arterioles and venules

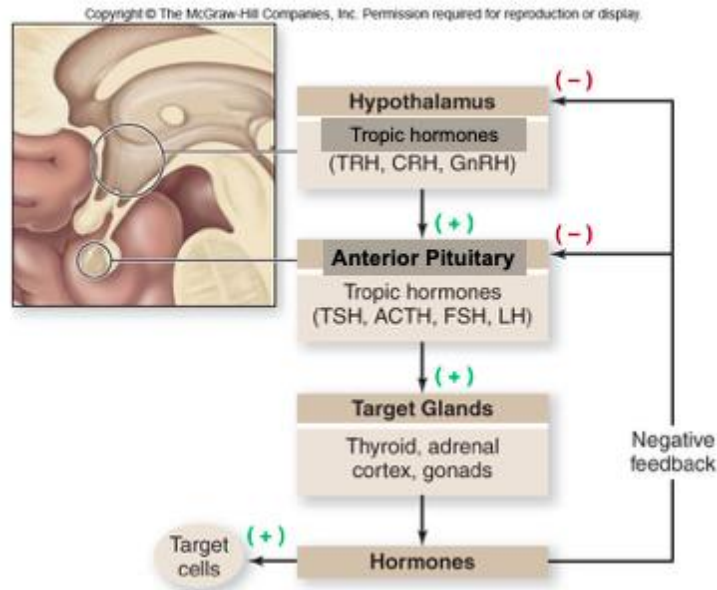
Each hormone delivered by the hypothalamohypophyseal portal system regulates a specific **anterior** pituitary hormone. **Does not occur in the posterior pituitary. The portal system is exclusive to the anterior pituitary.**

A portal system has 2 capillary beds, not 1 --> primary capillary, portal veins, secondary capillary

The hypothalamus and the anterior pituitary are partially controlled by the very hormones whose secretion they stimulate --> if there's the concentration is too small, then more hormones will be released while if the concentration is too large, hormones will be inhibited.

--> Negative feedback or feedback inhibition

Acts to maintain proper levels of the target cell hormone.



Chapter 34 (Part 1) - Circulation

Monday, April 8, 2019

11:12

A circulatory system has three basic components:

- A circulatory fluid
- A set of interconnecting vessels
- A muscular pump --> the heart

Functions of the Circulatory System

Functions of the circulatory system:

- Transports oxygen and CO₂ throughout the body --> important for body and blood pH
- Transports hormones
- Transports metabolic waste, ions
- Temporal regulation --> regulating your temperature

Blood and Its Contents

Blood --> consists of plasma and formed elements

Functions of circulating blood:

- Transportation
- Regulation
- Protection

Blood is a type of connective tissue composed of:

- a fluid matrix called plasma --> is 92% water and constitutes 55% of blood volume
 - Plasma also contains ions, plasma proteins (albumin, fibrinogen, immunoglobulins [antibodies])
 - Substances transported by blood are nutrients (such as glucose, fatty acids, vitamins), waste products of metabolism, respiratory gases (O₂ and CO₂), and hormones.
- formed elements (most are white blood cells)
- liquid extracellular matrix.

Blood is made up of 55% plasma and 45% cellular elements (majority are red blood cells).

- The remaining cellular elements are leukocytes (white blood cells), platelets, and erythrocytes (red blood cells)
 - White blood cells function in defense and immunity. (less than 1% of blood cells)
 - Platelets function to clot blood.
 - Erythrocytes function to transport O₂ and some CO₂.

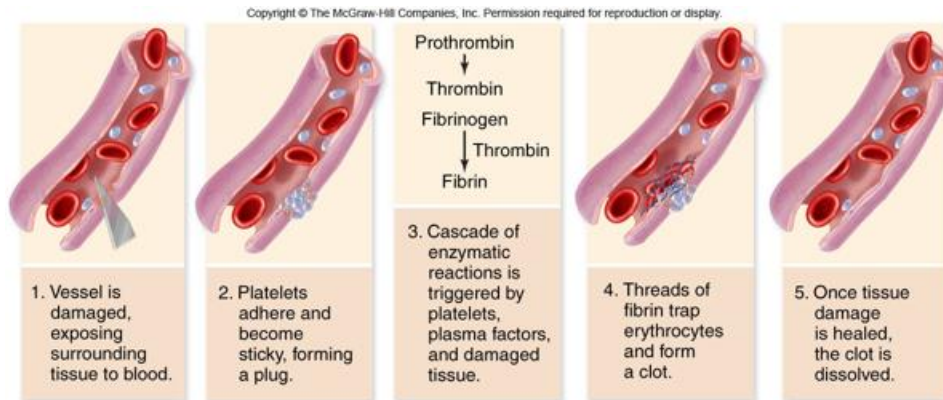
The small border between plasma and cellular elements is called the white part --> made up of white blood cells.

Formed Elements

Platelets --> cell fragments that pinch off from larger cells in the bone marrow; function in the formation of blood clots

Coagulation - the formation of a solid clot from liquid blood

- A cascade of complex reaction converts inactive fibrinogen to fibrin, which forms the framework of a clot.
 - A blood clot formed within a blood vessel is called a **thrombus** and can block blood flow.
 - Enzymatic cascade occurs: prothrombin --> thrombin which causes positive feedback to the enzymatic cascade as a whole --> inactive fibrinogen converts to fibrin to eventually form the framework for a clot.



Types of Circulatory Systems

- Open and closed systems exist of circulatory systems:
 - Open circulatory systems mean that this circulating fluid is **not always** enclosed within a vessel.
 - Within an open circulatory system, the circulatory fluid (called **hemolymph**), is also the *interstitial fluid* that bathes body cells.
 - Example: arthropods and some mollusks, such as clams, have open systems.
 - Closed circulatory systems mean that blood is always kept inside a blood vessel (vein, capillary, etc.) --> closed circulatory systems often called **cardiovascular system**
 - A circulatory fluid called **blood** is confined to vessels and is *distinct* from the interstitial fluid.
 - Benefits include relatively high blood pressure, which enables the effective delivery of O₂ and nutrients to the cells of larger and more active animals.
 - Example: Fish have a closed circulatory system --> called a closed circuit
 - For fish, there is only a single loop of circulation, single circulation --> heart to gills, gills to body, body back to heart

Organization of Vertebrate Circulatory Systems

Arteries, veins, and capillaries are the three main types of blood vessels. Within each type, blood flows only in **one** direction:

- **Arteries** - carry blood from the heart to the organs throughout the body *toward* capillaries

- Within organs, arteries branch into **arterioles**.
- **Capillaries** - microscopic vessels with very thin, porous walls that have blood conveyed to them from the **arterioles**; networks of these vessels are called **capillary beds**, which infiltrate tissues, passing within a few cell diameters of every cell in the body
 - Across the thin walls of capillaries, chemicals, including dissolved gases, are exchanged by net diffusion between the blood and interstitial fluid around the tissue cells.
 - At their "downstream" end, capillaries converge into **venules**, and **venules** converge into **veins**.
- **Veins** - vessels that carry blood back to the heart *from* capillaries

Organization: Heart --> artery --> arterioles --> capillaries --> venules --> veins --> heart

The hearts of all vertebrates contain two or more muscular chambers.

The chambers that receive blood entering the heart are called **atria** (atrium).

The chambers responsible for pumping blood *out* of the heart are called **ventricles**.

Amphibians and mammals have **double** circulation due to having a circulatory system of two circuits (for *amphibians*, the blood mixes, however, with mammals, it does not.):

- In animals with **double circulation**, the pumps for the two circuits are combined into a single organ, the heart.
 - Having two pumps within a single heart simplifies coordination of the pumping cycles.
 - One pump, the right side of the heart, delivers oxygen-poor blood to the capillary beds of gas exchange tissues, where there is a net movement of O₂ into the blood and CO₂ out of the blood.
 - This **gas exchange circuit** is called a **pulmonary circuit** if capillary beds involved are all in the lungs, as in reptiles and mammals.
 - It is called a **pulmocutaneous circuit**, if it includes capillaries in both the lungs and the skin, as in many amphibians.
 - After oxygen-enriched blood leaves the gas exchange tissues, it enters the other pump, the left side of the heart. Contraction of the heart propels this blood to capillary beds in organs and tissues throughout the body. Following the exchange of O₂ and CO₂, as well as nutrients and waste products, the now oxygen-poor blood returns to the heart, completing the systemic circuit.
 - **Systemic circuit** - the branch of the circulatory system that supplies oxygenated blood to and carries deoxygenated blood away from organs and tissues throughout the body
- Blood travels from the heart to lungs and skin, back to the heart, then to the body, back to the heart.

Mammals have a true "four-chamber" heart.

- 2 separate atria and 2 separate ventricles:
 - Right atrium receives deoxygenated blood from the body and delivers it to the right ventricle, which pumps it to the lungs.
 - Left atrium receives oxygenated blood from the lungs and delivers it to the left ventricle, which pumps it to the rest of the body.

Overall organization of cardiovascular system of mammals, beginning with pulmonary circuit:

- Contraction of the right ventricle pumps blood to the lungs via -->
- the pulmonary arteries. As blood flows through -->
- capillary beds in the left the right lungs, it loads O_2 and unloads CO_2 . Oxygen-rich blood returns from the lungs via pulmonary veins to the -->
- left atrium of the heart. Next, the oxygen-rich blood flows into the -->
- heart's left ventricle, which pumps the oxygen-rich blood out to the body tissues through the systemic circuit. Blood leaves the left ventricle via -->
- the aorta, which conveys blood to arteries leading throughout the body. The first branches leading from the aorta are the coronary arteries, which supply blood to the heart muscle itself. Then branches lead to -->
- capillary beds in the head and arms. The aorta then descends into the abdomen, supplying oxygen-rich blood to arteries leading to -->
- capillary beds in the abdominal organs and legs. Within the capillaries, there is a net diffusion of O_2 from the blood to the tissues and of CO_2 (produced by cellular respiration) into the blood. Capillaries rejoin, forming venules, which convey blood to veins.
 - Oxygen-poor blood from the head, neck, and forelimbs is channeled into a large vein -->
- the superior vena cava. Another large vein, -->
- the inferior vena cava, drains blood from the trunk and hind limbs. The two venae cavae empty their blood into the -->
- right atrium, from which the oxygen-poor blood flows into the right ventricle.

The heart has two pairs of valves:

- **Atrioventricular (AV) valves --> involves connection or coordination within the heart:**
 - Between each atrium and ventricle, you'll have a tricuspid valve and a bicuspid valve --> they maintain unidirectional blood flow *between atria and ventricles*.
 - Tricuspid on the right --> tricuspid = on the right
 - Bicuspid, or mitral, valve on the left
- **Semilunar valves:**
 - Between the ventricles and between the pulmonary artery/aorta (located at the two exits of the heart: where aorta leaves the left ventricle and where pulmonary artery leaves the right ventricle)
 - Ensure one-way flow out of the ventricles to the arterial systems
 - Pulmonary valve located at the exit of the right ventricle --> going to the lungs
 - Aortic valve located at the exit of the left ventricle --> going to the rest of the body

Right ventricle only has to send blood from the heart to the lungs --> not as much muscle needed

Left ventricle services the blood from the heart to the body --> much more muscles are needed

The Cardiac Cycle

Valves open and close as the heart goes through the cardiac cycle.

When ventricles are relaxed, they are able to fill with blood --> called **diastole**.

When ventricles are contracting, this state is called **systole**.

"Lub-dub" sounds heard with the stethoscope:

Lub --> AV valves closing, sound created from recoil of blood against the closed valves --> valves between atria and ventricles (ventricles contracting)

Dub --> closing of semilunar valves, sound due to vibrations caused by closing of valves --> valves between ventricles and pulmonary artery/aorta (ventricles are relaxed)

120/80 blood pressure --> systolic over diastolic

Cardiac Cycle:

- Atrial and ventricular diastole (0.4 sec)--> relaxed, able to fill with blood
- Atrial systole and ventricular diastole (0.1 sec) --> systole, contraction; diastole, relaxing
 - When ventricles contract, blood is sent out to the rest of the body.
 - Two atriums will contract, allowing blood to enter the ventricle.
 - Atriums and ventricles *cannot* contract at the same time.
- Ventricular systole and atrial diastole (0.3 sec)

Electrophysiology

Heart contains "self-excitable" autorhythmic fibers --> a muscle "fiber" = 1 cell

They also contain contractile cardiac muscle fibers.

These self-excitable fibers will self-generate action potential.

The most important is the sinoatrial (SA) node.

- This is a small body of specialized muscle tissue in the wall of the right atrium of the heart.
- Acts as a pacemaker by producing a contractile signal at regular intervals.
- Autonomic nervous system can modulate rate.
 - Sympathetic and parasympathetic divisions.
 - **Medulla** - cardiovascular control center

Steps of contraction from sinoatrial (SA) node:

- Signals from **SA node** spread through atria --> action potential moves laterally
- Signals are delayed at **AV node** --> gives time to allow atrium to contract and allow ventricle to fill in order to send blood out
- Bundle branches pass signals to **heart apex** (lowest superficial part of the heart, formed by the inferolateral part of the left ventricle) --> branches send signal to heart apex to prepare for ventricle contraction
- Signals spread throughout ventricles as a result from previous steps --> spread through **Purkinje fibers** which are a unique cardiac end-organ that are split in ventricles walls; the electrical origin of atrial fibers arrives from the sinoatrial node

Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium from the sinoatrial node to the atrioventricular node and right atrium.

AV node is the only pathway for conduction to ventricles.

This conduction spread throughout atrioventricular (relating to the atrial and ventricular chambers of the heart, or the connection and coordination between them) bundle, directly stimulating the myocardial (muscle cells of the heart) cells of both ventricles to contract.

Blood Flow, Pressure, and Regulation

Characteristics of Blood Vessels (blood only flows in *one* direction):

- **Arteries** - carry blood from the heart to the organs throughout the body *toward* capillaries
 - Characteristics: have a very thick layer of smooth muscle surrounding them
- **Capillaries (**should know three capillaries)** - microscopic vessels with very thin, porous walls that have blood conveyed to them from the ***arterioles***
 - Across the thin walls of capillaries, chemicals, including dissolved gases, are exchanged by net diffusion between the blood and interstitial fluid around the tissue cells --> can be called sites of exchange
 - At their "downstream" end, capillaries converge into ***venules***, and ***venules*** converge into **veins**.
 - Three types of capillaries exist:
 - Smooth capillaries
 - Fenestrated capillaries --> found in the kidneys
 - **Sinusoid** --> appears like swiss cheese, seen in liver and spleen (clean out worn out blood cells from circulation); blood must be able to leave the capillary in this case, thus its appearance
- **Veins** - vessels that carry blood back to the heart *from* capillaries
 - Has a similar structure to an artery, however has a much *thinner* layer of smooth muscle
 - Contain a one-way valve within them --> helps ensure blood is able to return to the heart against gravity and in general, in the correct direction

Revised Chapter 34 (Part 1) - Circulatory

Thursday, April 18, 2019

2:11 PM

A circulatory system has three basic components:

- A circulatory fluid
- A set of interconnecting vessels
- A muscular pump --> the heart

Functions of the Circulatory System

Functions of the circulatory system:

- Transports oxygen and CO₂ throughout the body --> important for body and blood pH
- Transports hormones
- Transports metabolic waste, ions
- Temporal regulation --> regulating your temperature

Blood and Its Contents

Blood --> consists of plasma and formed elements

Functions of circulating blood:

- Transportation
- Regulation
- Protection

Blood is a type of connective tissue composed of:

- a fluid matrix called plasma --> is 92% water and constitutes 55% of blood volume
 - Plasma also contains ions, plasma proteins (albumin, fibrinogen, immunoglobulins [antibodies])
 - Substances transported by blood are nutrients (such as glucose, fatty acids, vitamins), waste products of metabolism, respiratory gases (O₂ and CO₂), and hormones.
- formed elements (most are white blood cells)
- liquid extracellular matrix.

Blood is made up of 55% plasma and 45% cellular elements (majority are red blood cells).

- The remaining cellular elements are leukocytes (white blood cells), platelets, and erythrocytes (red blood cells)
 - White blood cells function in defense and immunity. (less than 1% of blood cells)
 - Platelets function to clot blood.
 - Erythrocytes function to transport O₂ and some CO₂.
- The small border between plasma and cellular elements is called the white part --> made up of white blood cells.

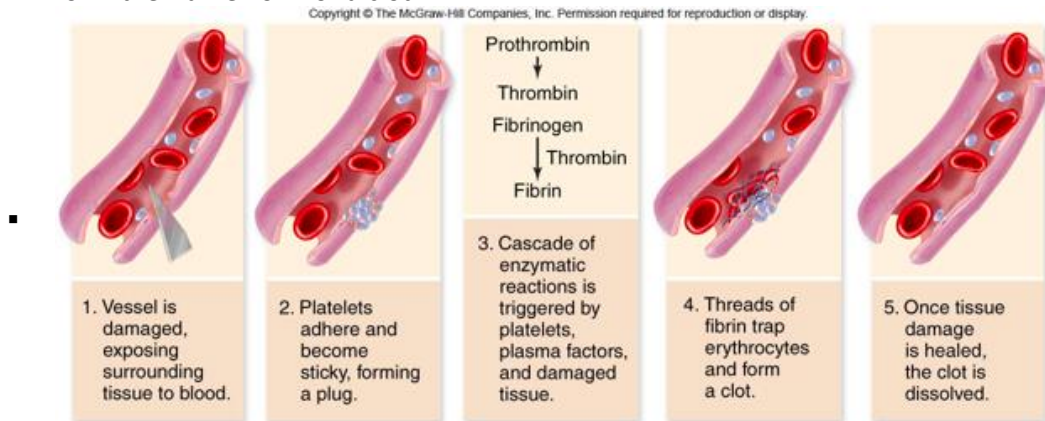
Formed Elements

Platelets - cell fragments that pinch off from larger cells in the bone marrow; function in the formation

of blood clots

Coagulation - the formation of a solid clot from liquid blood

- A cascade of complex reaction converts inactive fibrinogen to fibrin, which forms the framework of a clot.
 - A blood clot formed within a blood vessel is called a **thrombus** and can block blood flow.
 - Enzymatic cascade occurs: prothrombin --> thrombin which causes positive feedback to the enzymatic cascade as a whole --> inactive fibrinogen converts to fibrin to eventually form the framework for a clot.



Types of Circulatory Systems

- Open and closed systems exist of circulatory systems:
 - Open circulatory systems mean that this circulating fluid is **not always** enclosed within a vessel.
 - Within an open circulatory system, the circulatory fluid (called **hemolymph**), is also the *interstitial fluid* that bathes body cells.
 - Example: arthropods and some mollusks, such as clams, have open systems.
 - Closed circulatory systems mean that blood is always kept inside a blood vessel (vein, capillary, etc.) --> closed circulatory systems often called **cardiovascular system**
 - A circulatory fluid called **blood** is confined to vessels and is *distinct* from the interstitial fluid.
 - Benefits include relatively high blood pressure, which enables the effective delivery of O₂ and nutrients to the cells of larger and more active animals.
 - Example: Fish have a closed circulatory system --> called a closed circuit
 - For fish, there is only a single loop of circulation, single circulation --> heart to gills, gills to body, body back to heart

Organization of Vertebrate Circulatory Systems

Arteries, veins, and capillaries are the three main types of blood vessels. Within each type, blood flows only in **one** direction:

- **Arteries** - carry blood from the heart to the organs throughout the body *toward* capillaries
 - Within organs, arteries branch into **arterioles**.

- **Capillaries** - microscopic vessels with very thin, porous walls that have blood conveyed to them from the **arterioles**; networks of these vessels are called **capillary beds**, which infiltrate tissues, passing within a few cell diameters of every cell in the body
 - Across the thin walls of capillaries, chemicals, including dissolved gases, are exchanged by net diffusion between the blood and interstitial fluid around the tissue cells.
 - At their "downstream" end, capillaries converge into **venules**, and **venules** converge into **veins**.
- **Veins** - vessels that carry blood back to the heart *from* capillaries

The hearts of all vertebrates contain two or more muscular chambers.

The chambers that receive blood entering the heart are called **atria** (atrium).

The chambers responsible for pumping blood *out* of the heart are called **ventricles**.

Amphibians and mammals have **double** circulation due to having a circulatory system of two circuits (for *amphibians*, the blood mixes, however, with mammals, it does not.):

- In animals with **double circulation**, the pumps for the two circuits are combined into a single organ, the heart.
 - Having two pumps within a single heart simplifies coordination of the pumping cycles.
 - One pump, the right side of the heart, delivers oxygen-poor blood to the capillary beds of gas exchange tissues, where there is a net movement of O₂ into the blood and CO₂ out of the blood.
 - This **gas exchange circuit** is called a **pulmonary circuit** if capillary beds involved are all in the lungs, as in reptiles and mammals.
 - It is called a **pulmocutaneous circuit**, if it includes capillaries in both the lungs and the skin, as in many amphibians.
 - After oxygen-enriched blood leaves the gas exchange tissues, it enters the other pump, the left side of the heart. Contraction of the heart propels this blood to capillary beds in organs and tissues throughout the body. Following the exchange of O₂ and CO₂, as well as nutrients and waste products, the now oxygen-poor blood returns to the heart, completing the systemic circuit.
 - **Systemic circuit** - the branch of the circulatory system that supplies oxygenated blood to and carries deoxygenated blood away from organs and tissues throughout the body
 - Blood travels from the heart to lungs and skin, back to the heart, then to the body, back to the heart.

Mammals have a true "four-chamber" heart.

- 2 separate atria and 2 separate ventricles:
 - Right atrium receives deoxygenated blood from the body and delivers it to the right ventricle, which pumps it to the lungs.
 - Left atrium receives oxygenated blood from the lungs and delivers it to the left ventricle, which pumps it to the rest of the body.

Overall organization of cardiovascular system of mammals, beginning with pulmonary circuit (circuit involving the lungs):

- Contraction of the **right ventricle** pumps blood to the **lungs** via -->
- the **pulmonary arteries**. As blood flows through -->
- **capillary beds** in the **left to the right lungs**, it loads O₂ and unloads CO₂. Oxygen-rich blood returns from the **lungs** via **pulmonary veins** to the -->
- **left atrium** of the heart. Next, the oxygen-rich blood flows into the -->
- heart's **left ventricle**, which pumps the oxygen-rich blood out to the **body tissues through the systemic circuit**. Blood leaves the **left ventricle** via -->
- the aorta, which conveys blood to **arteries** leading throughout the body. The first branches leading from the **aorta** are the **coronary arteries**, which supply blood to the heart muscle itself. Then branches lead to -->
- **capillary beds** in the head and arms. The **aorta** then descends into the **abdomen**, supplying oxygen-rich blood to arteries leading to -->
- **capillary beds** in the abdominal organs and legs. Within the **capillaries**, there is a net diffusion of O₂ from the blood to the **tissues** and of CO₂ (produced by cellular respiration) into the blood. **Capillaries** rejoin, forming **venules**, which convey blood to **veins**.
 - Oxygen-poor blood from the head, neck, and forelimbs is channeled into a large vein -->
- the **superior vena cava**. Another large **vein**, -->
- the **inferior vena cava**, drains blood from the trunk and hind limbs. The **two venae cavae** empty their blood into the -->
- **right atrium**, from which the oxygen-poor blood flows into the **right ventricle**.

The heart has two pairs of valves:

- **Atrioventricular (AV) valves --> involves connection or coordination within the heart:**
 - Between each atrium and ventricle, you'll have a tricuspid valve and a bicuspid valve --> they maintain unidirectional blood flow *between atria and ventricles*.
 - Tricuspid on the right --> tricuspid = on the right
 - Bicuspid, or mitral, valve on the left
- **Semilunar valves:**
 - Between the ventricles and between the pulmonary artery/aorta (located at the two exits of the heart: where aorta leaves the left ventricle and where pulmonary artery leaves the right ventricle)
 - Ensure one-way flow out of the ventricles to the arterial systems
 - Pulmonary valve located at the exit of the right ventricle --> going to the lungs
 - Aortic valve located at the exit of the left ventricle --> going to the rest of the body

Right ventricle only has to send blood from the heart to the lungs --> not as much muscle needed

Left ventricle services the blood from the heart to the body --> much more muscles are needed

The Cardiac Cycle

Valves open and close as the heart goes through the cardiac cycle.

When ventricles are relaxed, they are able to fill with blood --> called **diastole**.

When ventricles are contracting, this state is called **systole**.

"Lub-dub" sounds heard with the stethoscope:

Lub --> AV valves closing, sound created from recoil of blood against the closed valves

--> valves between atria and ventricles (ventricles contracting)

Dub --> closing of semilunar valves, sound due to vibrations caused by closing of valves --> valves between ventricles and pulmonary artery/aorta (ventricles are relaxed)

120/80 blood pressure --> systolic over diastolic

Cardiac Cycle:

- Atrial and ventricular diastole (0.4 sec)--> relaxed, able to fill with blood
- Atrial systole and ventricular diastole (0.1 sec) --> systole, contraction; diastole, relaxing
 - When ventricles contract, blood is sent out to the rest of the body.
 - Two atriums will contract, allowing blood to enter the ventricle.
 - **Atriums and ventricles cannot contract at the same time.**
- Ventricular systole and atrial diastole (0.3 sec)

Electrophysiology

Heart contains "self-excitable" autorhythmic fibers --> a muscle "fiber" = 1 cell

They also contain contractile cardiac muscle fibers.

These self-excitable fibers will self-generate action potential.

The most important is the sinoatrial (SA) node.

- This is a small body of specialized muscle tissue in the wall of the right atrium of the heart.
- Acts as a pacemaker by producing a contractile signal at regular intervals.
- Autonomic nervous system can modulate rate.
 - Sympathetic and parasympathetic divisions.
 - **Medulla** - cardiovascular control center

Steps of contraction from sinoatrial (SA) node:

- Signals from **SA node** spread through atria --> action potential moves laterally
- Signals are delayed at **AV node** --> gives time to allow atrium to contract and allow ventricle to fill in order to send blood out
- Bundle branches pass signals to **heart apex** (lowest superficial part of the heart, formed by the inferolateral part of the left ventricle) --> branches send signal to heart apex to prepare for ventricle contraction
- Signals spread throughout ventricles as a result from previous steps --> spread through **Purkinje fibers** which are a unique cardiac end-organ that are split in ventricles walls; the electrical origin of atrial fibers arrives from the sinoatrial node

Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium from the sinoatrial node to the atrioventricular node and right atrium.

AV node is the only pathway for conduction to ventricles.

This conduction spread throughout atrioventricular (relating to the atrial and ventricular chambers of the heart, or the connection and coordination between them) bundle, directly stimulating the myocardial (muscle cells of the heart) cells of both ventricles to contract.

Blood Flow, Pressure, and Regulation

Characteristics of Blood Vessels (blood only flows in one direction):

- **Arteries** - carry blood *away* from the heart to the organs throughout the body *toward* capillaries; arteries branch off into **arterioles** which meet up with the bed of the capillaries (capillary beds)

- **Characteristics:** have layers of connective tissue and a very thick layer of smooth muscle surrounding the smooth endothelium
- **Arterioles** - can further control blood pressure by dilating and constricting to control blood distribution to tissues
- **Capillaries (**should know three capillaries)** - microscopic vessels with very thin, porous walls that have blood conveyed to them from the **arterioles**; single-celled layer of endothelium on a basement membrane and are the smallest and narrowest vessels in the body
 - Across the thin walls of capillaries, chemicals, including dissolved gases, are exchanged by net diffusion between the blood and interstitial fluid around the tissue cells --> can be called sites of exchange of anything between the blood and the body (gases, nutrients, anything dissolved in the blood)
 - Three types of capillaries exist:
 - **Smooth (continuous) capillaries** --> have *NO* perforations within its walls which are made up of a single layer of epithelial tissue
 - This type of capillary is a site of exchange for gases.
 - **Fenestrated capillaries** --> have pores perforating their walls, allowing for a flow of materials between the blood and surrounding areas
 - Found in the kidneys
 - **Sinusoid capillaries** --> have a number of holes perforating its walls which allow for an exchange between the blood cells and surrounding cells/tissues
 - Appears like swiss cheese
 - Seen in liver and spleen (clean out worn out blood cells from circulation); blood must be able to leave the capillary in this case, thus accounting for its appearance
 - At their "downstream" end, capillaries (capillary beds) converge into **venules** which converge into **veins**.
 - **Venules** - small, thin extensions of capillaries
- **Veins** - vessels that carry blood back *toward* the heart *from* capillaries
 - Has a similar structure to an artery, however has a much *thinner* layer of smooth muscle
 - Contain a **one-way valve** within them --> helps ensure blood is able to return to the heart against gravity and in general, in the correct direction (venous return)
 - Smooth muscle contractions help propel blood in the right direction
 - Valves inside veins squeezed by **skeletal muscles** ****think of toothpaste analogy****
 - The compression of the vein causes the blood to travel in the direction which allows for the pressure to be relieved.
 - Having a series of one-way valves allows for the blood to travel in the proper direction.
 - On the other side of the vein, you'll have **back pressure** from the compression which will cause for the valve to close, thus only giving the blood one way in which to travel.

Organization: Heart --> artery --> arterioles --> capillaries --> venules --> veins --> heart

1. When blood leaves the heart, it always leaves via a large artery (pulmonary artery/aorta) which then branches off to several smaller arteries.
2. These smaller arteries branch off into smaller arterioles.

- a. These arterioles typically hit only *ONE* capillary bed unless it's travelling to a portal system in which it would travel through *TWO* capillary beds.
3. Blood from the capillaries is gathered to the venules which further converge into smaller veins.
4. These smaller veins converge into large veins to eventually return to the heart.

Blood pressure - force exerted by blood on the walls of blood vessels

- Higher in arteries than veins

Resistance (R) - tendency of blood vessels to slow down the flow of blood

- Based on vessel radius, length and blood viscosity
- Change in arteriolar resistance is a major mechanism to control blood flow to a region in the body as the demand changes due to several factors. ****radius is the most important factor to consider**
- **Vasoconstriction** - makes the diameter of the blood vessel smaller, increases pressure which increases resistance
- **Vasodilation** - makes the diameter of the blood vessel larger, decreases pressure which decreases resistance
 - This is controlled by locally produced substances, hormones, and nervous system input.
 - Example: nitric oxide is a major inducer of vasodilation while peptide endothelin is an important inducer of vasoconstriction
 - Vasodilation and vasoconstriction are important means of regulating body heat in both ectotherms and endotherms.
 - Vasoconstriction sends less heat towards the surface of the skin which helps retain heat when cold.
 - Vasodilation sends more heat towards the surface of the skin to dissipate heat.

The Baroreceptor Reflex (has to do with blood pressure)

The Baroreceptor reflex has a negative feedback loop that responds to blood pressure changes.

Baroreceptors detect changes in arterial blood pressure.

Within the graphic given on slide 37, it displays the aorta sending blood to different parts of the body.

- One of the most important parts of the body it sends oxygenated blood to is the brain via the carotid artery.
 - This becomes a major site of monitoring blood pressure to ensure adequate delivery of blood to the brain to further ensure adequate O₂ is reaching the brain.
 - Specially, the site that monitors the blood pressure within the carotid arteries are **carotid artery baroreceptors**.
 - These baroreceptors only understand/use action potential to communicate with the body, specifically the medulla. It alternates from sending action potentials more or less rapidly, depending on the condition. The rate at which the medulla is receiving these action potentials lets it know what the blood pressure is in those sections → tells the autonomic nervous system to modulate the heart rhythm
 - An increase in blood pressure causes the baroreceptors to send more action potentials to the medulla.

- Ultimately results in blood pressure decrease due to medulla sending more activity along **parasympathetic** neurons to the sinoatrial node, which will release **acetylcholine** → causes decrease in heart rate
- A decrease in blood pressure causes the baroreceptors to send less action potentials to the medulla.
 - Ultimately results in blood pressure increase due to medulla sending more activity along **sympathetic** neurons, which will release **norepinephrine** → causes increase in heart rate
- Baroreceptors also exist on the aorta called an **aortic baroreceptor**.

Increase in blood volume causes an increase in blood pressure.

- Blood volume is primarily regulated by three hormones:
 - **Antidiuretic hormones (ADH)** → retains water within the body by regulating and balancing the amount of water in your blood
 - Higher water concentration increases the volume and pressure of your blood thus causing for a release of this volume in order to regulate the pressure
 - **Aldosterone** → influences **reclaiming** salt back into the body
 - **Atrial natriuretic hormone (peptide)** → produced by right atrium of the heart; if blood pressure is too high, the heart will release this which will help kidney to decrease fluid volume thus decreasing blood pressure

Chapter 34 (Part 2) - Respiratory

Tuesday, April 16, 2019

00:39

Outline of the lecture:

- Respiratory system functions/overview
- Types of respiratory systems/organs
 - Example: gills vs lungs
- Control of respiration
- Principles governing gas exchange --> **covered in AL activity
 - Partial pressure
 - Solubility
 - Gas levels in the blood monitoring and transport
 - Involves oxygen-hemoglobin dissociation curve

Respiratory System Functions/Overview

General functions of the respiratory system:

- Exchange of gases between the atmosphere and the blood
 - Moving O₂ into the blood and CO₂ out of the body
- Homeostatic regulation of body pH
 - Body pH further affects the blood pH which can *further* affect the pH balance of the body tissues
- Protection from inhaled pathogens and irritating substances
- Vocalization

Two types of respiration exist within the respiratory system:

- External respiration
 - Process involves having inhaled air entering the body and undergoing an exchange of O₂ between the lungs and the blood
 - Oxygen is spread out and traveling throughout the body for every cells to use in order to undergo cellular respiration while the CO₂ produced as a byproduct is carried through the blood to return to the lungs to be excreted via exhaled air
- Cellular respiration --> the metabolism of individual cells
 - Using O₂ a terminal electron acceptor, eventually producing CO₂ as a waste product with the end goal of producing ATP for the body to use as energy

Types of Respiratory Systems/Organs --> Gills vs Lungs

Adaptations for Gas Exchange

All respiratory organs share *certain common features* with each other:

- Moist surfaces in which gases dissolve and diffuse
 - The existence of moist surfaces allow for the gases to dissolve and diffuse across the respiratory membrane into the body.
 - Moist surfaces also allow for the transport of CO₂ out of the body, back into the mentioned respiratory membrane to be transported the alveoli in order to exit the body.
- Increased surface area for gas exchange

- More surface area = more opportunity for diffusion across the body, more efficiency (mechanism also seen in the digestive system)
- To allow for this, organs under the respiratory system are seen as branched out, allowing for an increase in surface area
- Extensive blood flow/supply surrounding our gas exchange tissues/areas
- Thin, delicate structure
 - This structure type is due to a reliance on diffusion:
 - Diffusion distance is to be kept to a minimum in order to *increase efficiency* within the respiratory system. It isn't ideal to have gases diffuse over a long distance across the body.

Gills

Gills are specialized extensions of tissue that project into the water --> out pockets of tissue that are very branched out

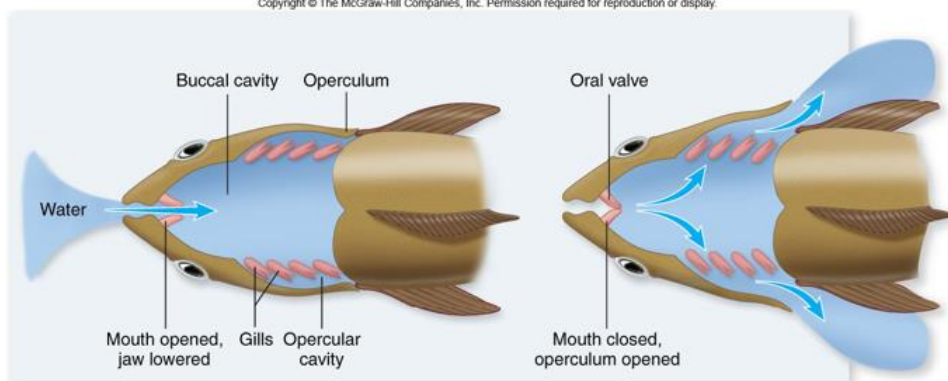
- They have an increased surface area for diffusion.
- They are the respiratory surface that allows for a gas exchange to occur between the outer environment and the fish themselves.

External gills are *NOT* enclosed within body structures:

- Found in immature fish and amphibians
- Pros: efficient due to having an increased surface area to allow for more diffusion to occur
- Cons: subject to damage, usually very flashy which can draw attention from predators; must be constantly moves to ensure contact with O₂-rich fresh water

Gills of bony fishes are located between the oral (buccal or mouth/throat) cavity and the opercular cavities.

- These two sets of cavities functions as pumps that *alternatively* expand
- Process: water moves into mouth of fish through the gills and fish closes its mouth to then flex the bottom portion of its mouth in order to push the water back over their gills.
 - As the water exits their body, it'll exit the body from the other side through an open operculum which is a gill cover.



The gas exchange system that is observed in fish is named the **countercurrent exchange system**:

- Looking closer at the gills, it is observed as being setup by several **gill arches** within them that are running next to each other.

- Coming off of each gill arch are **gill filaments** --> hair-like projections emerging from the gill arches.
 - The existence of these gill filaments increases surface area for the respiratory system to operate more efficiently.
- In order to allow for a good blood supply to allow for the respiratory system to become more efficient, small disks called **lamella** exist on the surface of the gill filaments.
 - Each lamella contains a capillary bed.
 - An important point to note is the direction of the flow of blood vs the direction of the flow of water:
 - Water flows into the gills from anterior to posterior.
 - The way in which the capillary beds are set up within the lamella causes for the direction of blood to be in the exact *opposite* direction in which water is flowing which is posterior to anterior.
 - This set up for gas exchange is why the exchange system was named as being **countercurrent**.
- This system of gas exchange is considered to be one of the most efficient to be observed in nature --> better than mammals; is used due to the extensive work that goes into extracting oxygen from water
 - Within this exchange, in the beginning, water will begin with a very *high* amount of oxygen. This is measured with respect to the partial pressure of O_2 .
 - Partial pressure is *NOT* the same as measuring concentration values but can be compared with each other.
 - Oxygen content is lost as the water travels over the gills.
 - The blood within the capillary bed in the lamella is very low in O_2 content due to coming from the heart which results in a low partial pressure of O_2 .
 - As the water begins to lose O_2 content, the blood begins to take up an increase in O_2 .
 - Due to this fact, the net direction of movement of oxygen will always be from the water to the blood because of this countercurrent exchange mechanism.
 - Running the capillary beds in this direction allows for there to be this exchange of blood and water flow to be *opposite* to each other which further always allows for there to be an exchange of O_2 across the gradient, *regardless* of how much oxygen is lost from the water. The O_2 content from water will always be higher than that of the blood in the capillary bed due to this countercurrent system.

Lungs

Gills were later replaced in terrestrial animals by lungs.

- This would be attributed to the fact that migrating from water to land would cause the gills to dry up.
 - Eventually, evolution would favor a system of respiration that had the gills become internalized, allowing for a successful migration from water to land.
- The lung system involves moving air through a branched tubular passage, contrasting the process that gills undergo for the absorption of O_2 .

- Major difference from gills: Gills underwent a one-way flow system in which water entered the body, passed over the gills, and exited the body through an open operculum.
 - Meanwhile, lungs undergo a two-way flow system in which air (a different medium) enters the mouth, into the lungs, eventually flowing back out of the body through the same path that it entered from.
- All organisms with lungs undergo this two-way flow system *EXCEPT* for birds.
 - Birds have a one-way flow system with lungs instead of the usual two-way flow system.

When fish first began to migrate to land, the first group of organisms to evolve to their new environment were amphibians.

- They evolved to have "true lungs," forming saclike outpouchings of the gut (or pharynx).
 - The pharynx began to evolve to have out pockets which is where these saclike outpouchings began to emerge.
- Example: Frogs have **positive pressure** breathing which they treat their air in a similar way that fish underwent in taking water in through their mouth and flexing it over its gills to exit the body.
 - Frogs open their mouths to allow for air to enter, close it, flex the muscles of their buccal cavity (floor of their mouth and back of their throat) which forces air out of their mouth and into their lungs.
 - This process causes an increase in pressure, thus the naming of its positive pressure mechanism. This physical push of oxygen into their respiratory membranes to inflate them is a cause of this increase in pressure.
- Example: Reptiles have **negative pressure** breathing **also includes mammals**
 - This is due to an expansion of the thoracic cavity (pulling ribs outward and diaphragm outward) through muscular contractions, which increases the volume of the cavity thus decreasing the pressure.
 - These organisms don't physically push air anywhere; instead, a type of vacuum is created when their thoracic cavity is expanded, thus decreasing pressure within their lungs, allowing for air to enter.

The lungs of mammals are packed with millions of **alveoli**, which are air sacs existing at the tips of bronchioles. They are the sites of gas exchange within the respiratory system.

- Inhaled air passes through the nasal cavity and lung, where it travels through the **larynx**, glottis, and **trachea**. The entire path of inhaled air is through the pharynx, larynx, trachea, bronchi, and bronchioles to the alveoli.
 - Air bifurcates into the right and left **bronchi**, which enter each lung and further subdivide into **bronchioles** to further increase the surface area within the respiratory membrane to allow for efficiency.
 - Oxygen diffuses through the moist film of the epithelium and into the capillaries of the **alveoli** which are at the ends of the bronchioles.
 - This structure is **tubular** within the lungs as well as very delicate, consisting of only one epithelial tissue.
 - Surrounding each alveolus sac is an extensive blood supply extending from capillary beds to allow for efficient exchange of oxygen.

- Carbon dioxide diffuses from the capillaries across the epithelium and into the air space.
 - Alveoli are **surrounded** by an extensive capillary network that allows for an exchange of gases.
- Cilia and mucus line the **epithelium** (thin tissue forming the outer layer of a body's surface and lining the alimentary canal and other hollow structures) of the air ducts and move particles up the pharynx.
 - This "mucus escalator" cleans the respiratory system and allows particles to be swallowed into the esophagus.
- Exhaled air passes over the vocal cords in the **larynx** to create sounds.
- Below the lungs exists the diaphragm which is a large muscle within the body.
 - When relaxed (during exhalation), the diaphragm has a dome shape.
 - When contracting (during inhalation), the diaphragm is flattened and pulled down.
 - These shapes are important to know when it comes to negative pressure breathing system.

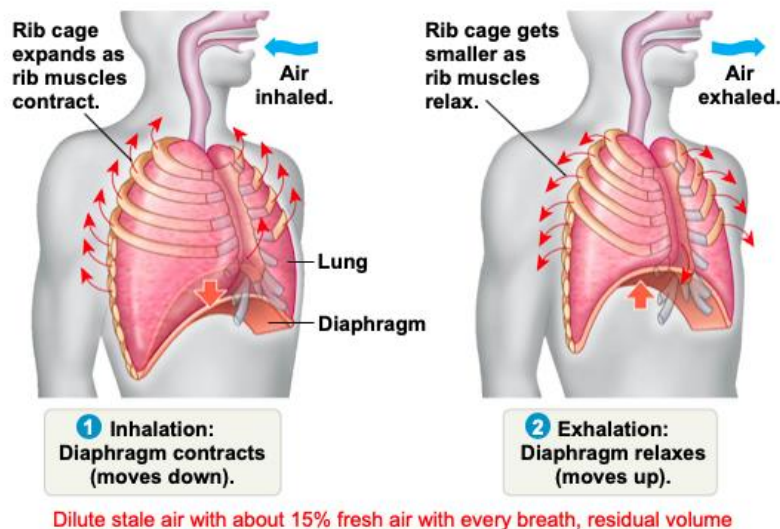
Outside of each lung is covered by the pleural membrane (touching the organ itself), which is a double membrane system around each individual lung--> having the pleural membrane and the visceral membrane.

- The **visceral pleural membrane** exists on the lung side of this double membrane system.
- Meanwhile, on the thoracic cavity side, the inner wall (muscles along the cavity) contains the **parietal pleural membrane**.
 - This double membrane system is important due to the fact that the lungs are not attached to the thoracic wall, which can prove to be an issue due to needing the lungs to move together.
 - To combat this, moisture exists which creates a sort of vacuum within the system to prevent significant movement from each other (keeps the lungs from collapsing).
 - Analogous to moving two wet slides from each other when looking at an organism on a microscope.
 - The space between the two membranes is called the **pleural cavity**.
 - This cavity is normally very small and filled with fluid, which allows for the membranes to adhere to each other.
 - Further causes the lungs to move with the thoracic cavity. Although there is no physical attachment, this moisture allows for an adherence to exist that allows for the synchronized movement of the lungs and thoracic cavity.
 - Lungs are also "vacuum-packed" to the diaphragm.

When expansion occurs, thoracic cavity is being expanded, which further decreases the pressure within the lungs (negative pressure).

- During inhalation (the active portion of breathing), thoracic volume increases through the contraction of two muscle sets:
 - Contraction of the external intercostal muscles expands the rib cage
 - Attached to the outside of the ribs and when contracted, they pull the ribs outward, increasing the space within the ribs/chest cavity space.
 - Contraction of the diaphragm expands the volume of thorax and lungs

- Again, when diaphragm contracts, it'll flatten out and move downward which pulls bottom of the lungs downward, thus increases volume and decreases pressure.
- This produces negative pressure which draws air into the lungs.
- With exhalation, it is the relaxation portion of breathing, shifting from the active portion which was inhalation.
 - Lungs will return to their normal positioning and size, as well as the diaphragm, due to elastic recoil. The diaphragm causes a decrease in volume within the lungs which causes an increase in pressure to allow for air to escape through the mouth.



The mechanism of two-way flow within mammals, reptiles, and amphibians is not very efficient:

- **Two-way system** - air enters the mouth, into the lungs, eventually flowing back out of the body through the same path that it entered from; type of negative pressure breathing within our respiratory systems
 - Due to this system, there is only an exchange of oxygen between 15% of the air that is inhaled.
 - Dilute stale air with about 15% fresh air with every breath, residual volume.
 - The rest is stale air inhaled (85%) is from air that was there from the previous breath.
 - This system, overall, is not very efficient. **not implemented by birds

Birds have a much more efficient system of exchange of oxygen, however, it is **NOT** more efficient than the countercurrent system seen in fish:

- Lungs of birds channel air through very tiny air vessels called **parabronchi**.
 - Birds breathe in and send the air throughout several different chambers throughout the body where oxygen exchange occurs through each one.

- Due to this unidirectional flow pathway, birds always have 100% oxygen flowing through their respiratory system with every breathe they undertake (technically takes two breaths for all of their air to flow through the entire body).
 - They do not dilute stale air with a portion of fresh air as other mammals do.
 - It takes two breaths in order to flow the air throughout the entire system.
 - While it does take two breaths, keep in mind that there is always 100% fresh air within the lungs with every breath.
- Their system of respiration has **unidirectional flow** which is achieved through the action of **anterior and posterior air sacs** that are unique to birds.
 - While the air does return through their mouth, most of the tubing/path that the air takes is distinct from the two-way system. Once the air enters the latter portion of trachea, the air goes from posterior air sac, lungs, anterior air sac, and back through the trachea again.
 - When considering unidirectional flow, we consider the air that goes through the lung, entering from one side (posterior side of the lung) and exiting through the other (anterior side of the lung). The flow of air from the lungs itself is unidirectional.
 - When air sacs are expanded during inhalation, they take in air.
 - When air sacs are compressed during exhalation, they push air in and through the lungs.

The path in which air travels throughout the body of the bird begins through inhalation through the mouth, through the trachea, entering the posterior air sacs.

- From here, the posterior air sacs are full of fresh air. This air further travels into the lungs of the birds.
 - In the lungs, there will be an exchange of oxygen with the blood of the bird. CO₂ will be released through exhalation.
- From the lungs, the air will now enter the anterior air sacs --> a storage area for air exiting the lungs.
 - Upon the next breath, the air will exit the anterior air sacs into the mouth where it will be exhaled into the surrounding environment.

Overall, the respiration of birds occurs in two cycles:

- **Cycle 1** - inhaled air is drawn from the trachea into the posterior air sacs, and is exhaled into the lungs
- **Cycle 2** - air is drawn from the lungs into anterior air sacs, and exhaled through the trachea

When it comes to an exchange of oxygen from the air to the blood in the lungs, birds undergo a similar process to fish --> **crosscurrent flow**:

- Blood flow within the capillaries runs 90° to the parabronchi (to the air flow)
 - Contrasts countercurrent as it does not run completely opposite to the air flow

Control of Respiration in Humans

In humans, the main breathing control center consists of neural circuits in the **medulla oblongata**, located near the base of the brain.

- This part of the brain controls the rate and depth of breathing in response to pH changes in the cerebrospinal fluid. Takes in information from the central and peripheral chemoreceptors that are monitoring CO₂ and pH levels.
 - **Cerebrospinal fluid** - the fluid that bathes the neurons in your brain
- The medulla adjusts breathing rate and depth to match metabolic demands.

Example displayed in PowerPoint:

- The system is in a state of homeostasis with the blood pH level at about 7.4.
 - A stimulus of a rising level of CO₂ in the tissues lowers blood pH.
- The stimulus triggers the sensor/control center as well as the carotid arteries and aorta.
 - This is due to there being an effect on the pH levels of the cerebrospinal fluid, which the medulla oblongata must adjust.
- The response to this stimulus by the sensor/control center is signals from the medulla to rib muscles and diaphragm to increase the rate and depth of ventilation.
 - This decreases the level of CO₂ in the blood, which causes a return to the homeostatic range of pH.

Principles Governing Gas Exchange

Chapter 32 (Part 2) - Osmotic Regulation and the Excretory System

Monday, April 15, 2019

10:55

The kidneys fix all of the problems caused by all of the other systems when they perform their own operations.

Functions of the Excretory Systems (three highlighted functions go together):

- Regulation of extracellular fluid volume and blood pressure
 - Important to regulating the blood volume which in turn regulates blood pressure.
- **Regulation of osmolarity**
 - Regulating the *complete* concentration of the fluids in the body
- **Maintenance of ion balance**
 - Regulate every single ion within the body individually while maintaining total osmolarity
- **Homeostatic regulation of pH**
 - Hydrogen and bicarbonate concentration regulated by the kidneys
- Excretion of wastes (and poisons)
 - All metabolic wastes are excreted by the kidneys
- Production of hormones (a part of the diffuse endocrine system)
 - ADH acts on the kidneys; aldosterone acts on the kidneys as well.

Water balance is constantly being manipulated by other organs in the body. (Slide 3)

Osmolarity and Osmotic Balance

Osmoconformers --> conforms to the environment that it's in:

- Organisms that are in osmotic equilibrium with their environment
- Among the vertebrates, only the primitive hagfish are strict osmoconformers --> analogous to a sponge that takes in its surrounding environment

- Sharks and relatives (cartilaginous fish) are also *isotonic*

Osmoregulators: (all other vertebrates)

- Maintain a relatively constant blood osmolarity despite different concentrations in their environment

Vertebrate Kidney, Evolutionary Development

Kidneys are made up of thousands of repeating units, the functional unit --> **nephrons**.

Although the same basic design has been retained in all vertebrate kidneys, a few modifications have occurred:

- All vertebrates can produce a urine that is isotonic or hypotonic to blood.
 - Make urine that is the same osmolarity as your blood or dilute to your blood.
- Only birds and mammals can make a hypertonic urine (more concentrated than blood).

Most aquatic animals produce *ammonia* as a nitrogenous waste.

Mammals, most amphibians, sharks, and some bony fishes produce urea as a nitrogenous waste.

Many reptiles (including birds), insects, and land snails produce uric acid as a nitrogenous waste.

Evolution of the Vertebrate Kidney

Kidneys are thought to have evolved among the freshwater teleosts (bony fishes).

- Body fluids (cells) are hypertonic (more solute on the outside environment) with respect to surrounding water, causing two problems --> these are issues due to being osmoregulators, wanting a relatively constant blood osmolarity:
 - Water enters body from environment.
 - Fishes do not drink water and excrete *large* amounts of dilute urine.
 - Solutes tend to leave the body.
 - Reabsorb ions across nephrons
 - Actively transport ions across gills into blood.
- Freshwater fish gain water and lose salt when they're ventilating gills ****"If you're a freshwater fish, in what direction will salt go?" and "How will they rid themselves of the salt?"**:
 - Kidneys produce copious dilute urine --> help to maintain osmolarity
 - Specialized gill epithelial cells transport Na^+ and Cl^- from the water into the fish's capillaries
- Saltwater fish gain salts and *lose* water across gills --> ultimately need to rid themselves of salt
 - Kidneys produce very little urine --> very concentrated urine to rid themselves of salts
 - Drink seawater to replace water lost --> must drink a lot of water
 - Expend energy to transport excess salt out of body through gill epithelial cells

Vertebrate kidneys are anchored to the muscles of the back.

The outer portion of the kidney is called the **renal cortex** while the inner portion is called the **inner renal medulla**.

The Mammalian Kidney

The kidney has three basic functions:

- **Filtration** --> also called bulk filtration

- Fluid in the blood is filtered out of the glomerulus (first capillary bed) into the tubule system
 - Is non-specific --> moves the blood into the filtrate that is within the kidney nephron
 - There are only two things that do not enter the filtrate:
 - **Blood cells** --> are too large in size
 - **Large plasma proteins** --> also too large in size
- **Reabsorption** --> goes in the opposite direction of filtration
 - Is specific, very selective --> selective movement of solutes (one-by-one) out of the filtrate *back into the blood* via peritubular capillaries (the second capillary bed)
- **Secretion** --> the same direction -- similar -- as filtration, however, it is very specific to what is secreted
 - Movement of substances from the blood into the extracellular fluid, then into the filtrate in the tubular system

The organization of two capillary beds within the function of the kidneys introduces us to the second portal system we've learned about called the **renal portal system** --> two capillary beds in the row which begin with the glomerulus and flow into the peritubular capillaries.

A nephron has two portions:

- The **vascular portion** is the renal portal system (having two capillary beds in a row).
- The **tubular portion** is the nephron itself which begins at Bowman's capsule --> a portion of the nephron surrounding the glomerulus where filtration occurs.
 - From the glomerulus, the blood enters the proximal convoluted tubule, moves down the medulla, back up into the cortex in the descending limb of loop of Henle.
 - Note: the descending loop of Henle is reabsorbing water --> more permeable to water
 - Within the proximal convoluted tubule, any nutrient that is useful to the body is reabsorbed.
 - The blood enters the ascending limb of loop of Henle.
 - This area of the loop will become excessively salty, depositing it within the surrounding tissue.
 - After leaving the loop, the fluid is delivered to a distal convoluted tubule in the cortex.
 - This further drains into a collecting duct (pulls out urea and water) that merges with others to empty its contents now called urine into the renal pelvis.

Hormones in the Kidney

Homeostatic function of kidneys are coordinated primarily by hormones:

- Kidneys maintain relatively constant levels of blood volume, pressure, and osmolarity.
- Also regulates the plasma K^+ and Na^+ concentrations and blood pH within narrow limits.

Aldosterone will act on mostly the distal tubule and parts of the collecting ducts (for when you have a massive blood loss --> reclaims water by manipulating salt levels):

- Secreted by the adrenal cortex
- Stimulated by low levels of Na^+ in the blood

- Causes distal convoluted tubule and collecting ducts to reabsorb Na^+
- Reabsorption of Cl^- and **water follows**
 - Low levels of Na^+ in the blood are accompanied by a decrease in blood volume
 - Renin-angiotensin-aldosterone system is activated

Atrial natriuretic hormone (ANH):

- **Opposes** the action of aldosterone in promoting salt and water retention
 - Promotes the excretion of salt and water in the urine by **lowering blood volume**
- Secreted by the right atrium of the heart in response to an increased blood volume

Antidiuretic hormone (ADH) acts on the collecting duct:

- Stimulated by an increase in the osmolarity of blood
- Causes the walls of the distal tubule and collecting ducts to become more permeable to water
 - Does so through the insertion of **aquaporins** --> small protein passages that are along the ducts of the distal tubule.
- More ADH increases reabsorption of water
 - Makes a more concentrated urine --> less water in the urine

Nutrition and Digestion

Friday, April 19, 2019

10:58

Animals have a **gastrointestinal tract**.

- Digestion begins in the mouth and food undergoes mechanical and chemical breakdown.
 - The salivary glands secrete salivary amylase which begins to digest starches and complex carbohydrates.
- The stomach was originally a storage organ and eventually evolved to have three layers of muscle to further process food with mechanical breakdown. Proteins are beginning to be broken down in the stomach as well by enzymes.
 - The stomach contains an oblique muscle, not contained by another organ to allow for food to continue to be mechanically broken down by mixing the food with gastric juice.
 - The stomach has gastric pits within them that contain mucous cells, chief cells, and parietal cells:
 - **Mucous cells** - secrete mucus to protect cells from digesting themselves
 - **Chief cells** - secrete pepsinogen --> a protein-digesting enzyme
 - **Parietal cells** - secrete HCl (hydrochloric acid) and intrinsic factor (for vitamin B12 absorption)
- Within the small intestine, folds exist within it, called a **villus**, which also contain **microvillus**. They're folded in order to increase surface area to allow for more absorption of nutrients.
 - Each villus has a:
 - **Capillary** - nutrients other than fat absorbed into the blood (protein and carbs, etc.)
 - **Lacteal (lymphatic vessel)** - allows for larger fat particles to enter, eventually dumped into the blood
- Protein, amino acids, and carbohydrates are transported through epithelial cells to the blood.
 - Blood carries these products to the liver via the **hepatic portal vein**.
- Fatty acids and monoglycerides diffuse into epithelial cells of small intestine.

- Reassembled into triglycerides and then chylomicrons to then enter the lymphatic system and **later** join the circulatory system.
- Almost all fluid leftover is reabsorbed in the small intestine.

Accessory Organs

- The liver produces bile to be stored within the gallbladder via the **common hepatic duct**.
- The gallbladder doesn't produce anything, only stores bile that is created by the liver.
 - The gallbladder then carried the bile to the small intestine via the **common bile duct**.
- The pancreas has two functions: endocrine and excretory (more focusing on excretory for now).
 - Secretes enzymes and HCO_3^-

Exam #1 Review Lecture

Monday, April 22, 2019

10:49

45 questions

14-15 Cardiovascular

9 Respiratory

13-14 Excretory

7-8 Digestive

****Must know the functions of all of the systems****

Cardiovascular (Circulatory) System

- Know the difference between plasma and formed elements ****must know the significance and importance of plasma proteins**
 - Know the purpose of the platelets and role of hemoglobin within the blood cells.
 - Be familiar with the proteins that are involved with the clotting of platelets and what makes up the fibers within the clot.
 - ****Question on open circulatory system, focusing on excretory system****
 - Know what organisms have open/closed and single/double circuit circulatory systems.
 - Know why amphibians have a double circuit circulatory system.
 - Know the difference chambers of the mammal heart ****slide 13 on PowerPoint****
 - ****Questions on what chambers have high/low oxygenated blood, when that occurs****
 - Example: what is the path of blood beginning from the right atrium?
- Know the difference between diastole and systole and the direction your blood is moving to.
 - Know the electrophysiology
 - Understand the animation of this electrophysiology process and what an autorhythmic cell --> understand electrical and mechanical sequence
 - Starts at SA node, spreads laterally across two atria, signals delays at the AV node, bundle branches pass signals to the heart apex, and then the signals spread throughout the ventricles through the Purkinje fibers
- Understand everything having to do with the baroreceptor reflex ****4 questions on them****
 - Parasympathetic vs sympathetic division of the nervous system, what is released based on action potentials
 - Look up YouTube video of animation
 - Know what the differences in blood pressure do to the baroreceptor reflex, whether actions potentials increase or decrease
- Know capillaries are the site of exchange
- Know major difference between arteries and veins
 - Significance of one-way valves within the veins (venous return)
- Know the pathway of a drop of blood leaving the major arteries of the heart from slide 31
 - Arterioles are what undergo vasoconstriction/vasodilation; these processes occur at the arteriole level ****important for baroreceptor reflex****
- Know that blood volume is regulated by ADH, aldosterone, and atrial natriuretic hormone
 - Also mentioned in the excretory system

Respiratory System

- Know types of respiratory systems
- Know differences between gills and lungs
- Know what is done by the systems to increase surface area
 - Gills: gill arches which further have lamella
 - Lungs: branching of bronchioles to allow for alveoli to increase surface area
- Know what countercurrent exchange is and the pattern of the partial pressure --> look at slide 11 in PowerPoint
- Know difference between positive pressure and negative pressure breathing
 - Positive pressure: forcing medium down to their respiratory membrane
 - Negative pressure: expand the ribcage, drop diaphragm down to increase volume that decreases pressure, allowing air to passively enter the lungs
 - Understand concept of air sacs in birds --> unidirectional flow
 - 100% O₂ air is always within their lungs
 - Understand crosscurrent exchange within their system
- **Will be asked about alveoli, site of gas exchange
- Know the different muscle sets within the lungs, slide 23
- Know the medulla is the respiratory control center of the respiratory system as a whole
- Know gas exchange process **went over in Active Learning**
 - Know oxygen-hemoglobin dissociation curve **2 questions on this concept
 - Know significance of pH, CO₂ levels, temperature
 - Understand the significance of shifting graph left or right --> increases hemoglobin affinity?

Excretory System

- Know difference between osmoconformer and osmoregulator **looking at chart must be able to tell whether organism is a osmoconformer and osmoregulator
- Skip slides 5 and 6 on sponges
- Know what organisms produce a different nitrogenous waste **question on this
- Know hypotonic, isotonic, and hypertonic
- Freshwater fish vs saltwater fish
 - Know challenges faced by them due to their environment
 - Know what each of them do to deal with their environment
- Understand functions of mammalian kidney
 - Know whether each function is specific or non-specific
 - Know renal portal system --> glomerulus to peritubular capillaries
 - Know significance of the ascending loop of Henle
 - Know what hormones are acting on the collecting duct
 - Know what hormones are acting on the convoluted tubules
- Know different hormones acting on the kidney **questions on ADH specifically
 - ADH
 - Understand why its released
 - Aldosterone
 - Where its created
 - What it causes
 - Atrial natriuretic hormone

- In response to what is it secreted?
- What does it cause the body to do?

Digestive System

- Everything from Active Learning PowerPoint is fair game for the exam
- Memorize the hormones mentioned **good portion of questions on digestive system about hormones**
 - Gastrin
 - Secretin
 - GIP
 - CCK
 - Where are they released from, what is the stimulus for release, what do they cause
- Memorize the enzymes --> amylase to amylase
 - Trypsin
 - Activated by HCl (hydrochloric acid)
 - Lipase
- Know where cecum is within the rabbit and its function within the digestive system
- Know that stomach has three layers of muscle
 - Three types of cells within the stomach
- Know where different substances are being absorbed (blood or lymphatic system)
- Know accessory organs and what they release and their functions

Chapter 35 - The Immune System

Wednesday, April 24, 2019

11:00

Functions and Overview of the Immune System

Function of the immune system:

- Protect the body from any pathogens (anything that can cause a pathology --> harm to the body such as a certain bacteria strain)
 - **Pathogens** - agents that cause disease, infect a wide range of animals, including humans
 - The immune system enables an animal to avoid or limit many infections.
- Protect against foreign molecules (example: toxins)
- Removes dead or damaged cells
- Attempts to recognize and remove abnormal cells

All animals have **innate immunity**, which is present at birth --> a defense that is active immediately upon infection.

- This type of immunity is always "ready-to-go."
- Present before ***any*** exposure to pathogens and is effective from the time of birth
 - It involves *nonspecific* responses to pathogens.
- Innate immunity consists of external barrier plus internal cellular and chemical defenses.
 - Skin and mucus membranes would be examples of external barriers.
 - Antimicrobial peptides is an example of internal cellular defenses.
- Has a rapid response to any type of pathogen.

Vertebrates also have **adaptive immunity (acquired immunity)**.

- This allows for vertebrates to specialize and target specific pathogens --> very specific response to pathogens
- Develops ***after*** exposure to agents such as microbes, toxins, or other foreign substances.
- Has a slower response in comparison to innate immunity but highly specific.
 - After the first response, it takes about two weeks for adaptive immunity to begin to act against a certain pathogen, resulting in a slower response time than innate immunity.
 - After the second response, the response is much faster in comparison to the first response.

Innate Immune System

The innate immune system consists of skin and mucous membranes, leukocytes/phagocytosis/TLR, antimicrobial peptides (complement proteins, interferons, etc.), and the inflammatory response.

Within this immune system, barrier defenses exist:

- Skin
 - Is the largest organ of the body and provides a nearly impenetrable barrier that is reinforced with chemical weapons.
 - The pH level of the skin is very low, which kills off some pathogens before they can enter the body.

- Oil and sweat glands give skin a pH of 3-5.
- Lysozyme breaks bacterial cell walls.
 - **Lysozyme** - an enzyme (typically a protein) that catalyzes the destruction of the cell walls of certain bacteria, occurring notably in tears and egg white
- The skin also contains many normal **flora** --> microorganisms that are always present on or in a person and usually do not cause any disease.
 - Nonpathogenic microorganisms that out-compete pathogenic ones.
- Mucous membranes of the respiratory, urinary, and reproductive tracts
 - Can trap pathogens before entering the body, allowing for removal of microbes
- Secretions
 - May be toxic to certain pathogens

Internal defenses also exist:

- Phagocytic cells
- Natural killer cells
- Antimicrobial proteins and peptides
- Inflammatory response

White Blood Cells

Kinds of defending leukocytes (general term for white blood cells):

- **Macrophages**
 - Kill microorganisms through **phagocytosis**
- **Neutrophils**
 - Most abundant circulating leukocyte
 - Also use phagocytosis
- **Natural killer cells (suicide-inducing cells)**
 - Do not attack invading cells directly
 - Latch onto invading cells to induce apoptosis in the target cell
- **Eosinophils**
 - Discharge destructive enzymes beneath mucosal surfaces
 - Battle parasitic invaders

Pathogens entering the mammalian body are subject to phagocytosis.

A general immune response is targeted at **each class** of pathogen:

- Example: the immune system recognizes bacteria and fungi by structures on their cell walls
 - The leukocytes recognize material that is foreign to the body that it currently inhabits.

Internal Defenses

Phagocytic cells recognize groups of pathogens by **toll-like receptors (TLRs)**

- Each mammalian TLR binds to fragments of molecules characteristic to a set of pathogens.
 - Somewhat specific to a certain pathogen, however is **not** the same as the adaptive immune system.
 - These mammalian TLRs bind to **PAMPs (pathogen-associated molecular patterns)** that are present in whole groups of pathogens, but not the host.

- Example: If a lipopolysaccharide is detected by TLRs, it can signal the presence of a gram-negative bacteria which should be phagocytized. If flagellin is detected (a protein within flagella, associated with outside cells), phagocytosis occurs.

Natural killer cells circulate throughout the body and detect abnormal cells.

- Purpose: by inducing apoptosis, an infection is compartmentalized to break down in a controlled manner; if cell was lysed, the virus would spread, thus making infection worse
- They release chemicals leading to cell death, inhibiting the spread of virally infected or cancerous cells.
- Process:
 - Natural killer cell (NK cell) binds tightly to the target cell.
 - In the NK cell, vesicles containing perforin molecules and granzymes move to the plasma membrane and release their contents by exocytosis into the space between the two cells.
 - **Granzymes** - proteases that are released by cytoplasmic granules within cytotoxic T cells and NK; purpose is to induce apoptosis within virus-infected cells thus destroying them
 - The perforin molecules polymerize in the plasma membrane of the target cell forming pores in the membrane.
 - Granzymes pass through the pores and activate caspase enzymes that induce apoptosis in the target cell.
 - **Caspase** - the executioners of apoptosis; protein cutting enzymes that chop up strategic proteins in the cell; name refers to the properties of these enzymes --> first they are cysteine proteases that use the sulfur atom in cysteine to perform the cleavage reaction; second, they cut proteins next to aspartate amino acids in their chains
 - They don't cut indiscriminately; instead, they are designed to make exactly the right cuts needed to disassemble the cell in an orderly manner.
 - During apoptosis, the target cell is broken down into membrane enclosed vesicles containing the cellular contents. Macrophages phagocytose these vesicles to prevent release of their contents into the tissues.

Antimicrobial peptides and proteins are released or impeded to be reproduced by the stimulus of pathogen recognition.

- Leukocytes release antimicrobial peptides that disrupt the plasma membranes of fungi and bacteria.
 - **Interferons** - provide *innate* defense, interfering with viruses to inhibit replication and helping active macrophages through signaling to the surrounding healthy cells
- The **complement system (another type of antimicrobial peptides and proteins)** consists of about 30 proteins that are activated by substances on microbe surfaces.
 - Activation can lead to lysis of invading cells.

Inflammatory response, such as pain and swelling is brought about by molecules released upon injury or infection and involves several body systems.

- Inflammation can be either local or systemic (throughout the body).
 - A fever is a systemic inflammatory response triggered by substances released by macrophages.
 - **Septic shock** is a life-threatening condition caused by an overwhelming inflammatory response.
 - Chronic inflammation can also threaten human health.
- Injured cells release chemical alarms (messenger molecules), including histamine and prostaglandins.
 - **Prostaglandins** - locally acting messenger molecules (lipid-based)
- **Mast cells** release **histamine**, which triggers nearby blood vessels to dilate and increase in permeability.
 - Brings more blood cells to the affected area, prevents migration or transport to the rest of the body.
- Activated macrophages and neutrophils release **cytokines**.
 - **Cytokines** - signaling molecules that modulate the immune response and promote blood flow to the site of injury or infection
- Promote phagocyte accumulation.
- **Hallmark signs**: redness, warmth, swelling (edema), pain, and potential loss of function
- **Overall process**:
 - Histamines and cytokines released. Capillaries dilate.
 - This is due to damaged cell releasing cytokines, setting these cells off.
 - Antimicrobial peptides enter tissue. Neutrophils are recruited.
 - Neutrophils digest pathogens and cell debris. Tissue heals.

Adaptive Immune System

B and T lymphocytes produce a humoral immune response or a cell-mediated immune response, where helper T cells play a central role in both response types.

In the **humoral (any of the body fluids/antibody-mediated) immune response**, antibodies help neutralize or eliminate toxins and pathogens in the blood and lymph (pathogens that are within your bodily fluids).

- This response is characterized by secretion of **antibodies** by clonally selected B cells.
- Activation of B cells helps helper T cells and proteins on the surface of pathogens.
 - In response to cytokines from helper T cells and an antigen, a B cell proliferates and differentiates into memory B cells and antibody-secreting effector cells called **plasma cells**.

In the **cell-mediated immune response** specialized T cells destroy infected host cells.

- Two types of T cells exist:
 - Cytotoxic T cells
 - Helper T cells

Adaptive immunity is specific to vertebrates only, consisting of a recognition of traits **specific** to particular pathogens, using a *vast array of receptors* --> potentially millions of types of receptors.

Slow response than innate immunity, but has a *very specific* response to pathogens.

This adaptive response relies on two types of **lymphocytes** (white blood cells):

- Lymphocytes that mature in the **thymus** above the heart are called **T cells (lymphocytes)**.
 - Further divides into cytotoxic and helper T cells.
- Lymphocytes that mature in the **bone marrow** are called **B cells (lymphocytes)**.

Antigens (antibody-generating substance) - substances that can elicit a response from a B or T cell that it's foreign

Recognition occurs when a B or T cell binds to an antigen via an **antigen receptor**.

The immune system produces millions of different antigen receptors but the receptors, on a single B or T cell are all identical to each other. Only will be able to elicit a response from **one** antigen.

- The small accessible part of an antigen that binds to an antigen receptors is called an **epitope**.
 - What the B or T cell will be able to recognize. Analogous to reaching out your hand and having the B or T cell recognize your finger as being foreign would be similar to talking about the **epitope**.
 - The more B or T cells present, the more of a chance that they'll bind to an epitope.

B Cells

Each B cell antigen receptor is a Y-shaped molecule with two identical **heavy chains** and two identical **light chains**. Without the cell, the Y-shaped molecule is the shape of an antibody.

The constant (C) regions of the chains vary little among B cells, whereas the variable (V) regions differ greatly.

- Together the V regions of the heavy and light chains form an antigen-binding site.

These unique receptors only bind to antigens with specific three-dimensional shapes.

The binding of a B cell antigen receptor to an antigen (solely) is an early step in B cell activation. Once activated, the B cell is stimulated, it undergoes multiple cell divisions to produce a clone of identical cells referred to as **clonal selection**.

- **Two types of clones are produced:**
 - Short-lived activated ***effector (plasma) cells*** that act *immediately* against the antigen.
 - Immediately replicate within themselves and release **antibodies (also called immunoglobulin [Ig])** in increasing amounts. The number of antibodies existing reaches a peak of 10 to 17 days after the activation of the original B cell.
 - The antibodies released flow through the body's fluids and tag these foreign cells and molecules, containing the original antigen, for destruction. They defend against pathogens rather than the B cells do.
 - These antibodies are *similar* to B cell receptors but are NOT membrane bound.
 - This overall process of releasing antibodies in response to fighting an infection is known as the **humoral immune response**.
 - This response often requires the help of helper T cells.

- Long-lived **memory cells** that can give rise to effector cells if the same antigen is encountered again.
 - These cells wait around, prepared to come into contact with their same antigen which accounts for the rapidity of the secondary immune response when exposed to an antigen twice.

Upon a B cell binding directly to the antigens of a microbe, the B cell takes it inside by **endocytosis**.

After the microbe's digestion, its antigens bind with class II MHC proteins and move to the cell surface (similar to how an infected macrophage would act) to allow for the receptor of the helper T cell to bind.

- Once binding occurs, interleukin-2 is secreted and other cytokines to activate the B cells.
 - These activated B cells divide repeatedly into memory B cells and plasma cells.
 - Plasma cells produce and secrete large numbers of antibodies that are specific to the original antigen.

Antibody Responses

In **neutralization**, antibodies bind to the viral surface proteins, preventing infection of a host cell.

Antibodies may also bind to toxins in body fluids and prevent them from entering body cells.

- A neutralizing antibody will bind onto the pathogen itself to coat it, covering it with antibodies to prevent its binding sites from binding with any other cells so it's not active anymore, blocking the activity of the antigen.
- Microbes and soluble antigens that are coated with these antibodies are then eliminated by phagocytosis.
 - In the process, **opsonization**, the bound antibodies enhance macrophage attachment to the microbes, further allowing for them to be easily engulfed and destroyed by phagocytosis.

Agglutination is similar to neutralization where the antibodies still cover the pathogens with antibodies, however, forces the pathogens to clump together, allowing white blood cells to phagocytize them.

More officially, it's the process whereby bacteria or viruses are effectively neutralized by clumping.

- Antibodies have at least two binding sites, allowing them to crosslink microbes by binding to identical antigens on two different cells.

Microbes that are tagged by antibodies are eventually eliminated by phagocytosis.

- Opsonization is also performed here.

Precipitation is the cross linking of soluble antigens molecules dissolved in body fluids to form immobile precipitates.

The antibodies coat the toxin or pathogen to precipitate it out of solution.

Soluble antigens that are coated with antibodies are eliminated by phagocytosis and opsonization is also performed.

Complement fixation is the activation of a series of serum proteins, leading to the lysis of a microbe.

Firstly, complement proteins bind to antibodies that have already tagged a foreign cell.

- Complement proteins can lyse any cells that has been tagged by IgM or IgG antibodies.
- Some complement proteins are activated to form a membrane attack complex that creates a pore in the target cell.
 - This pore created allows ions and water to rush into the cell, causing the cell to swell and lyse.

Antibodies can serve to be the **activating the complement proteins**, thus causing these proteins to enter themselves within the plasma proteins of the foreign cell to cause them to lyse themselves.

T Cells

T cells also have variable and constant regions as B cells do --> Only the variable regions can bind to the antigen.

T cells only bind to antigen fragments displayed or presented on a host cell:

MHC (major histocompatibility complex) molecules are *host proteins* that display the antigen fragments on the cell surface.

- In regular cells, the MHC will be alone and the T cell doesn't bother it, moving on to check the rest of the cells within the body.
- In infected cells, antigens are cleaved into smaller peptides by enzymes.
- MHC molecules bind and transport the antigen fragments to the cell surface, a process called **antigen presentation**.
 - A T cell can then bind both the antigen fragment and MHC molecule.
 - This interaction is necessary for the T cell to participate in the **adaptive immune response**.

Cytotoxic T Cells

Cytotoxic T cells are the effector cells in the cell-mediated immune response.

These cells recognize fragments of foreign protein produced by infected cells and possess an accessory protein that binds to **class I MHC molecules (usually on body cells)** that are on the surface of an infected cell --> this is what cytotoxic T cells are looking for.

The activated cytotoxic T cell secretes proteins that disrupt the membranes of target cells and trigger apoptosis.

In nucleated cells of the body, bacterial, viral or tumor antigens are gathered and presented on the surface by class I MHC proteins.

These proteins are recognized by cytotoxic T cell receptors and cytotoxic T cell surface protein CD8.

- Upon first activation, the cytotoxic T cell multiplies and differentiates to produce a clone of itself to attack other infected host cells that display the same viral antigen.
- Cytotoxic T cells are further stimulated by contact and by interleukin-2 to release the protein perforin (think perf --> create pores).
 - These perforin molecules puncture the target cell, allowing water and ions to rush inside, causing swelling and lysis.
 - These T cells deprive pathogens of their host cells so they can't reproduce. This process is repeated until the infection is eliminated from the body.
 - This overall response is known as the **cell-mediated immune response**.

Helper T Cells

A type of T cell called a **helper T cell** triggers both the *humoral* and *cell-mediated* immune responses.

The helper T cell is activated, proliferates, and forms a clone of helper T cells, which then activates the appropriate B cells or cytotoxic T cells.

Antigen-presenting cells are recognized based on their **class II MHC molecules** (only found on phagocytic cells/immune system cells).

- Antigen receptors on the surface of helper T cells bind to the antigen and the class II MHC molecule.
- Signals are then exchanged between the two cells.
 - The helper T cell is activated, proliferates, and forms a clone of helper T cells, which then activate the appropriate B cells.

During the beginning of an immune response from a helper T cell, there is first an interaction between the infected cell and a macrophage (phagocytic leukocyte --> WBC).

The macrophage recognizes these antigens on the pathogen as foreign and engulf the microbe by phagocytosis.

- The foreign body is broken down inside the macrophage, to where its antigens then combine with class II MHC molecules to move to the surface of the macrophage (called **antigen presentation**) --> this complex stimulates the next cell in the immune response.
- Helper T cells interact with the phagocytic leukocytes to fight foreign bodies through its T cell receptors and the cell surface protein CD4.
 - Each helper T cell receptor is unique, meaning only few helper T cell receptors can bind to this antigen-class II MHC combination.
- The helper T cell is stimulated by this contact, as well as by the cytokine **interleukin-1** that is produced and secreted by the macrophage.
 - Interleukin-1 and class II MHC interaction stimulates the helper T cells to grow and divide into many cells with the same specific receptors.

Helper T cells activate other cells (such as cytotoxic T cells and B cells) in the immune system by secreting the cytokine **interleukin-2**.

- The secretion of interleukin-2 causes helper T cells to divide more rapidly and increase cytokine production.

Cytotoxic T cells are further stimulated to become active killer cells and B cells are stimulated to develop into plasma cells.

Chapter 37 - The Nervous System

Wednesday, May 1, 2019

11:03

The nervous system and endocrine system aid the body in responding to stimulus.

Nervous system organization:

- All animals must be able to respond to environmental stimuli
 - **Sensory receptors** - detect stimulus
 - **Motor effectors** - respond to it
 - The nervous system links the two, consisting of neurons and supporting cells, helping both receptors and effectors work together.

The **central nervous system** consists of the brain and spinal cord.

The **peripheral nervous system** consists of the neural pathways extending from the central nervous system --> sensory and motor neurons

- For this class, we'll be focusing on the motor pathways of the *peripheral nervous system*.
 - The motor pathways are divided into the **somatic (voluntary) nervous system** and **autonomic (involuntary) nervous system**.
 - The **somatic nervous system** stimulates the skeletal muscles.
 - The **autonomic nervous system** stimulates the smooth and cardiac muscles, as well as glands.
 - The **autonomic nervous system** is further divided into the **sympathetic** ("fight or flight") nervous system and **parasympathetic** ("rest and repose") nervous system.
 - These two divisions counterbalance each other. There will rarely be more than one response from one system in comparison to the other.

Cells of the Nervous System

Two types of cell exist in the nervous system:

- **Neurons** - cells which conduct electrical impulses
 - General structure:
 - **Cell body (soma)** - the part of the neuron that appears like a "regular cell" with a nucleus, etc; where information from dendrites are processed
 - **Dendrites** - extensions from the neuron that bring information into the cell body; short, cytoplasmic extensions that receive stimuli
 - **Axon** - sends information out to other body cells/neurons, away from the cell body
 - **Node of Ranvier** - the area on the axon where action potentials are regenerated
 - Neurons only speak in action potential --> all-or-nothing release of an action potential
 - These action potentials are formed where the axon meets the cell body (axon hillock).

- Within the brain, Purkinje cells exist due to their extensive network that allows for communication.
- **Neuroglia cells** - "support cells"
 - These cells nourish, support, protect, and maintain the neurons.
 - These cells outnumber the neurons by 50-100x.
 - **Schwann cells** (peripheral nervous system) and **oligodendrocytes** (central nervous system) produce myelin sheaths surrounding axons.
 - **Schwann cell (peripheral nervous system)** - is a *glial cell* which activates the axon of a neuron, helps it create an action potential within the neuron
 - Within these cells, they circle around the axon over and over again, until they move their cytoplasm basically out to where the nucleus is incredibly close to the axon.
 - In the central nervous system, myelinated axons form white matter.
 - Dendrites/cell bodies form grey matter.
 - In the peripheral nervous system, myelinated axons are bundles to form nerves.

Vertebrates have three types of neurons:

- **Sensory neurons (afferent neurons)** carry impulses to the central nervous system (CNS).
 - The cell body is positioned around the middle of the sensory neuron to prevent a reaction to every stimulus. Thus requires a strong signal to occur to merit a response.
 - If strong signal occurs, signal travels to the interneurons within the central nervous system to then determine whether to send a signal to the motor neurons.
- **Motor neurons (efferent neurons)** carry impulses from the CNS to effectors (muscles and glands).
- **Interneurons (association neurons)** provides more *complex* reflexes and associative functions like learning and memory.
 - **Purkinje fibers** are a type of interneuron.

Electrical Physiology of a Neuron

Resting Membrane Potential

A potential difference exists across every cell's plasma membrane.

- Cytoplasmic side vs. Extracellular fluid side

When a neuron is **NOT** being stimulated, it maintains a **resting membrane potential**.

- The charge of inside of the neuron ranges from -40 to -90 millivolts (mV)
- The average of the value of voltage is at about -70mV ****MUST KNOW****
 - Must be thought about in comparison to the inside and outside of the neuron.
 - The neuron has a charge of 70mV LESS than the outside of it.
 - The interior of the cell is negatively charged relative to the outside.
 - During this membrane potential equilibrium, an ion has balanced electrical and diffusion forces, thus creating NO net movement of that ion across the membrane potential.
- Almost all of these resting membrane potentials are due to the presence of potassium (a cation -> positively charged ion, missing an electron).

- The cell membrane is **not** freely permeable to every ion, however, is more permeable to potassium than anything else, allowing the potassium to enter/leave the cell as freely as it likes.
 - "70mV less positive than the outside of the cell."
- The sodium-potassium pump ensure a reestablishment of potassium entering the cell.
 - This causes **less positivity** to occur within the neuron.
 - This further prevents equilibrium from ever occurring, leaving the neuron at a resting potential.
- Overall, there is a net flow of positive ions to the outside of the cell with potassium constantly leaving the cell and sodium occasionally entering.

The inside of the cell is more negatively charged (less positive) than the outside due to:

- **Sodium-potassium pump** --> 50x more than ion leakage channels
 - Brings 2 K⁺ into the cell for every three Na⁺ it pumps **out**, thus slowly causing a negative charge to accumulate.
 - Uses an immense amount of ATP to maintain the difference of membrane concentration.
 - More potassium within the cell and more sodium outside of the cell.
 - Process:
 - ATP phosphorylates the membrane protein to cause a conformational change in protein to first reduce its affinity for Na⁺ and increase its affinity for K⁺.
 - Once potassium is binded, dephosphorylation of the membrane protein occurs, causing a low affinity for K⁺, causing it to reenter the cell.
- **Ion leakage channels** --> are always open
 - Allow more K⁺ to diffuse **out** than the Na⁺ to diffuse **in**.
 - More potassium leak channels exist in comparison to sodium leak channels.

Two major forces act on ions in establishing the resting membrane potential.

- **Electrical potential** produced by unequal distribution of charges.
 - This is accounting for the difference of -70 mV from the inside of the cell.
- **Concentration gradient** produced by unequal concentrations of molecules from one side of the membrane to the other.
 - This gradient further makes the resting potential possible.

Graded (graded --> gradual, slight) potentials - any slight disruption to the resting membrane potential; small, transient changes in membrane potential due to the activation of **gated ion channels**

- **Gated ion channels** are typically at rest without stimulus and once stimulated, they become permeable to a certain ion --> they are very selective, usually to one specific ion type
 - If a stimulus is strong enough, they may cause these channels to open/close to cause a disruption in the resting membrane potential.
 - **Chemically gated ion channels** - will become active/inactive based on the chemical binding of a ligand (hormone/neurotransmitter) to it ****important to when action potential is traveling to other cells****
 - Causes a change in the electrochemical gradient across the cell.

- **Voltage gated ion channels** - these channels respond upon a certain voltage value being reached --> "trigger voltage value"
 - Some ion channels are activated at +30mV while others aren't until -55mV.
- Both types of channels in gated ion channels cause changes in the cell membrane's permeability.
- The size of a graded potential depends on either the strength of the stimulus or the amount of ligand available to bind with their receptors.
 - They can reinforce or negate each other.
 - **Summation** - the ability of graded potentials to combine with each other
 - Smaller graded potentials can be combined to have a larger effect.
 - Opposite graded potentials can result in negating each other.

Every stimulus a cell receives disrupts the membrane potential *slightly* (depolarization or hyperpolarization) which results in graded potentials.

- **Hyperpolarization** - when the membrane potential becomes more negative at a particular spot on the neuron's membrane
 - Bring the membrane potential farther away from threshold.
- **Depolarization** - when the membrane potential becomes less negative (more positive)
 - Brings the membrane potential to a value known as **threshold** at -55mV.

Generation of an Action Potential

Action potentials are formed when depolarization reaches the threshold potential of -55mV.

- This is caused by voltage-gated ion channels, specifically:
 - Voltage-gated Na⁺ channels
 - Results in more sodium entering the cell, causing more positive charges to enter, causing further depolarization to reach threshold further.
 - Is closed when the membrane potential is at rest. Can be closed in two ways:
 - Activation gate --> at rest, this is closed while the inactivation is open
 - Inactivation gate
 - Transient influx of Na⁺ causes the membrane to depolarize
 - Voltage-gated K⁺ channels
 - Results in more potassium leaving the cell, causing less positive charges to be within the cell, causing a certain level of hyperpolarization in the cell.
 - Has only **one** activation gate that is closed in the resting state.
 - Channels open slowly.
 - The efflux of K⁺ repolarizes the membrane, attempting to return to resting membrane potential.

The action potential has three phases:

- **Rising** --> depolarization
- **Falling** --> repolarization
- **Undershoot** --> a true, hyperpolarization referred to as the refractory period

Action potentials are **DIFFERENT** from graded potential as they cannot build off of each other (no summation). They are always separate, all-or-none events with the **same** amplitude.

- The intensity of a stimulus is coded by the frequency, **not** amplitude, of action potentials.
 - If you have a stronger stimulus, it does not make a stronger action potential but instead forms more rapid action potentials.

Overall, these are the processes that the neuron undergoes during the formation of an action potential:

- **Resting state** - corresponds to when resting potential is at -70mV
 - All voltage-gated channels are closed and leak channels are always open.
- **Depolarization** - an increase to -55mV, threshold
 - Stimulus that the cell received caused the Na⁺ channels to open, thus allowing for them to enter the cell, causing more positive ions to enter.
 - At threshold, the potassium channels begin to open, however, are very slow acting.
- **Rising phase of the action potential** - an increase in positive ions within the cell due to the opening of the Na⁺ channels
 - The membrane potential skyrockets to around +30mV.
 - By the time the membrane potential reaches this value, the potassium channels have already opened fully.
- **Falling phase of the action potential** - by this point, sodium voltage-gated channels are beginning to be closed at this point.
 - Causes positive ions to leave the cell eventually to cause a drop in the membrane potential due to the potassium channels opening, less positive charges.
 - The membrane potential drops to -90mV, below the threshold value and resting membrane value.
 - **Repolarization** occurs at this stage.
- **Undershoot** - also known as the refractory period
 - At this point, the neuron is unable to form or receive any action potentials.
 - Begins to reset all voltage gated-channels back to their initial positioning where leak channels are the only ones open, further returning the neuron back to its **resting membrane potential**.

Propagation of an Action Potential

Each action potential, in its rising phase, reflects a reversal membrane polarity.

- Means that we go from a negative membrane potential to a significant jump to a positive membrane potential.

Positive charges due to a flux of Na⁺ can depolarize the adjacent region to threshold.

- The act of forming an action potential within one region can disrupt the portion of the axon ahead of it so that it eventually hits threshold to form an action potential.
 - Think of the formation of these action potentials as a domino effect/wavelike motion.
 - The action potential at the beginning of the axon will eventually dissipate, and in the meantime before that, stimulates the region next to it to form its own action potential.

- The previous region repolarizes back to the resting membrane potential with a temporary refractory period.
- An action potential is able to stimulate the region ahead of it, **NOT** behind it.
- Overall, the result is a wave of action potentials formed along the length of the axon.

There are two ways in which you can increase the velocity of conduction:

- **Increase in axon diameter**
 - Seen in invertebrates
 - Less resistance to current flow due to a decrease in having to deal with the viscosity of the cytoplasm
- **Myelination of the axon**
 - Having to deal with there being a myelin sheath wrapped around the axon
 - Action potentials are only produced at the nodes of Ranvier.
 - Impulses jump from node to node along the inside of the neuron's plasma membrane.
 - Referred to as saltatory conduction.
 - Think of the analogy of going up stairs by 5 steps. Allows for more efficiency when having an action potential reach the end of the axon.

Events at Synapses - Communication Between Cells

Synapse - where a neuron's end meets the cell next to it --> could be a gland, muscle, the dendrites of another neuron etc.

- **Presynaptic cell** transmits the action potential.
- **Postsynaptic cell** receives the action potential.
- Two basic types of synapses exist:
 - **Electrical synapses** - involves direct cytoplasmic connections between the two cells formed by gap junctions
 - Relatively rare in vertebrates
 - **Chemical synapses** - have a synaptic cleft (space) between the two cells
 - End of the presynaptic cell contains synaptic vesicles packed with neurotransmitters (chemical language of the nervous system)
 - Action potential triggers an influx of Ca^{2+} within the cell which fuses with the synaptic vesicles to cause them to migrate to the cell membrane to fuse.
 - From here, the synaptic vesicles will empty into the synaptic cleft (calcium-induced exocytosis).
 - Neurotransmitters are released by **exocytosis**.
 - This neurotransmitter further diffuses to the other side of the cleft and binds to the **chemical (ligand-gated) receptors proteins**.
 - Graded potentials are produced in the postsynaptic membrane --> depending on whether it's strong enough, it can form another action potential

- Neurotransmitter action is terminated by enzymatic cleavage or cellular uptake to ensure that it doesn't stay in the synaptic cleft.
 - Parts of It will be recycled back into the first cell.

Neurotransmitters

Acetylcholine - crosses the synapse between the motor neuron and muscle fiber

- Also referred to as the neuromuscular junction
- Tells a muscle to contract
- Will bind to the receptor in the post-synaptic membrane and cause ligand-gated channels to open.
 - Causing a **depolarization** called an **excitatory postsynaptic potential (EPSP)** due to being pushed closer to threshold.
- Acetylcholinesterase (AChE) degrades Ach which results in muscle relaxation.

Different types of neurotransmitters:

- Amino acids
 - Glutamate
 - Major excitatory neurotransmitters in the vertebrate CNS
 - Glycine and GABA are inhibitory neurotransmitters
 - Open ligand-gated channels for Cl⁻
 - Produce a **hyperpolarization** called an **inhibitory postsynaptic potential (IPSP)** due to being pushed farther away from threshold.

Exam #2 Review Lecture

Monday, May 6, 2019

10:57

Questions are evenly split between immune system and nervous system.

The Immune System

- Understand what MHC complexes are and what types of immune cell they would interact with
 - Will not be asked about Class I or Class II
- Know what an antigens and antibodies are (their four functions and what they can do)
- Know difference between innate and adaptive (acquired) immune systems
 - Innate immune system
 - Know which immune system is more general
 - Know toll-like receptors, barrier defenses, antimicrobial peptides and proteins
 - Know difference between cell-mediated/humoral immunity responses (whether its within the adaptive/innate system)
 - Know different classes of what toll-like receptors respond to --> lipopolysaccharide/flagellin
 - Understand complement proteins/interferons/lysozymes
 - Know which cells in the innate immune system are phagocytes
 - Know about natural killer cells (a type of leukocyte --> white blood cell)
 - Know enzymes that are active within the NK cells
 - Know about the inflammatory response --> what is released, essentially what occurs
 - Adaptive Immune System
 - Know difference between B and T cells (both are a type of white blood cell)
 - Know difference between helper T cells and cytotoxic T cells
 - Helper T cells don't directly attack the pathogen; they instead sound the alarm for cytotoxic T cells to act
 - Know what an antigen and an epitope is
 - Know about antigen receptors on each cell
 - **2 questions on exam on AL exercise with game on HIV/AIDS --> are more general about the role of antibodies, what target cells are, receptors/coreceptors
- Know how to apply immune system knowledge to general questions
 - Example question: how would a lack of cytotoxic T cells/B cells affect the immune system?

Extra Notes:

- A pathogen is an umbrella term for an agent that can cause disease.
- An antigen is a smaller piece of a pathogen that is recognized by other cells in the immune system.
 - One pathogen can have **multiple** antigens.

The Nervous System

- Understand division of the nervous system --> central vs. peripheral

- Understand further subdivisions to sensory neurons, motor neurons (afferent/efferent neurons); know what's voluntary vs. involuntary
 - Know differences between sensory neuron, motor neuron, and interneuron
- Know where autonomic nervous system is sending signals, their destination
 - Know division of autonomic nervous system --> sympathetic and parasympathetic
- Know the general structure of neurons and neuroglial cells
 - Know where a Schwann cell would be vs oligodendrocytes
 - Schwann cells are within the peripheral nervous system while oligodendrocytes are within the central nervous system
- Know resting membrane potential --> look at animations on BBL
 - Review homework on MasteringBiology
 - Know difference between voltage channel and leakage channel
 - Know forces that generate resting membrane potential
 - Need electrochemical gradient across plasma membrane
 - Know which ions are in higher numbers on each side of the cell
 - Know where ions are --> makes it easier to think about problems with thinking about there being an abundance of one element on one side...question could ask where these extra elements would flow
 - **Several questions on movement of ions/concentration gradient across plasma membrane**
 - Voltage gated channel --> opens or closes at a certain voltage
 - Leak channels --> are always open
 - Know significance of potassium/sodium pump within the propagation of an action potential
 - Be able to tell whether membrane potential will be made more positive or less positive by changing a gradient's concentration
 - Know about sheaths on axons and their effect on the travel of the action potential
 - How do we speed up the propagation of a action potential? Through the myelin sheath (insulation)
 - Think of analogy of going up the steps by 5 steps instead of just one
 - **3-4 questions on this** Understand what happens when action potentials reaches the end of the axons --> How does it travel to other surrounding cells?

Extra Notes (needs to be checked for accuracy) :

- Know when voltage is hit at a certain threshold, many sodium-gated channels open, making the inside of the cell more positive (to -30mV) to then close the sodium-gated channels
 - Potassium-gated channels then open to leave the cell, making the inside of the cell negative, causing a drop in voltage, hitting -90mV (the refractory period --> voltage that resets back to resting potential, opening leak channels again), keeps action potential from moving backwards
- Most action potentials originate near the axon hillock of the cell body, traveling the entire length of the axon. --> know how action potential travels from axon hillock till the end of the axon (think about action potential travelling as if it was a domino)
 - During an action potential, voltage-gated sodium channels open, adjusting the permeability of the cell membrane for sodium/potassium.
 - Depolarization occurs which causes the cell to become more positive.

- Begins to occur at +30mV charge
- Inactivation gate closes, potassium-gated channels open, to repolarize to a negative voltage --> potassium *leaves* the cell
- **Repolarization** is when the cell becomes negative again, going beyond the resting potential
- **Hyperpolarization** Ions return to state of -70mV to return to resting action potential.
 - This is done through the opening of voltage-gated potassium channels and the closing of sodium channels.
- Must be able to look at graph from resting action potential animation and understand it to know what direction ions move and its effect on the voltage
 - -55 mV is the threshold value at which an action potential is generated

Chapter 39 (Partial) - Neuromuscular Junction

Wednesday, May 8, 2019

11:02

Events at a Neuromuscular Junction

Neuromuscular junction - junction (intersection) of the motor neuron's axon and muscle fiber

- The axon divides into terminals containing vesicles of acetylcholine.
 - **Acetylcholine (ACh)** - are at the end of an axon meeting up with a muscle fiber; the receptor of this neurotransmitter is a **ligand-gated ion channel**
 - As a result, Na^+ flows **into** the muscle cell leading to depolarization (less negativity) of the postsynaptic membrane and an action potential.
 - Within the synaptic cleft, after an action potential is formed, acetylcholinesterase begins to break down acetylcholine to smaller parts to be recycled by its presynaptic membrane to form *more* ACh.

Structure of a Muscle

Muscle (muscle fibers) - is a grouping of cells bound together by connective tissues

- **One muscle cell = one muscle fiber**
- Within these muscle fibers, we have "protein cables" bundled together *surrounding* them, called a **myofibril**, which have a striped appearance. These are cylindrical bundles of myofilaments in muscle fibers --> myofilaments make up myofibrils
 - Protein fibers slide over each other to cause constriction.
 - **Sarcomere** - the functional unit of a muscle constriction, a unit of measure; shortening the sarcomere, shortens the myofibril, then shorten the muscle fibers and thus the muscle as a whole --> causes contraction to occur
- **Sarcolemma** - the name for the plasma membrane of a muscle cell
 - **T-tubule (transverse tubule)** - is an **invagination** of sarcolemma
 - Allow for the travel of an action potential to go deep into the cell. Appear as holes into the cell, however, can be compared to tunnels from the surface of the cell, traveling to the internal part of the muscle cell.
 - As an action potential travels down the muscle cell, calcium is released by a gated-ion channel into the muscle cell by the **sarcoplasmic reticulum**.
 - **Sarcoplasmic reticulum (SR)** - the name for the endoplasmic reticulum of the muscle cell
 - This organelle is filled with Ca^+ ions.
 - As mentioned above, the action potentials traveling down the T-tubule stimulates the release of Ca^+ which triggers a contraction response.
 - Ion pumps will return calcium to the sarcoplasmic reticulum, causing contraction to stop. These pumps are powered by ATP.
- **Muscle fascicles** - a bundle of muscle fibers
- **Skeletal muscle** - an entire grouping of muscle fascicles
 - Skeletal muscle cells are capable of generating and propagating action potentials.

Tendons - link a bone to skeletal muscle

Contraction of a Muscle Cell

1. Excitation - Contraction Coupling

Myofibrils are striped in appearance.

- These myofibrils are broken up into sarcomere units, Z line to Z line.
- **Thick filaments** - are made of myosin
- **Thin filaments** - are made of actin and other proteins
 - **Proteins involved:** troponin and tropomyosin
 - Troponin's function is to declare the position of tropomyosin move and further expose a binding site for myosin myofilament's heads.

Thin filaments:

- **Actin**
 - Each actin molecule contains a binding site for myosin heads (at rest, it is blocked/covered)
 - Once Ca^+ ions are introduced, myosin-binding sites from actin are exposed.
 - Actin molecules form 2 intertwined helical chains associated with troponin and tropomyosin.
 - Chains are closely associated with two proteins called tropomyosin and troponin that play important roles in regulating contraction.
- **Tropomyosin** - rod-shaped molecule composed of 2 intertwined proteins
 - Arranged along the length of actin thin filaments
 - In the absence of Ca^+ , covers the myosin-binding sites
- **Troponin** - smaller proteins bound to both tropomyosin and actin
 - Binds Ca^{2+} and drags tropomyosin off of myosin-binding sites and contraction begins.
 - Removal of Ca^{2+} reverses the process and contraction stops.

Thick filaments:

- **Myosin** - 6 protein subunits combine to form a protein with **2 heads and a long tail**
 - The tail lies along the axis of thick filament and stays relatively immobile.
 - 2 heads form cross bridges --> the connection between the myosin and tropomyosin.
 - Each head contains binding sites for actin and ATP.

2. *Sliding Filament Theory: Cross-Bridge Cycle*

Sarcomeres shorten as thin filaments (A) slide past stationary thick filaments (M).

- Myosin cross-bridges attach to thin filament and force thin filament toward the center of the sarcomere.
 - Cross-bridge repeats the motion as long as stimulation to contract continues.
- In a relaxed muscle, myosin-binding sites on actin are **blocked** by a protein complex; each myosin head is bound to ADP and a phosphate.
 - An action potential causes the ER to release Ca^+ ions that bind to the protein complexes on actin to expose the myosin-binding sites.
 - The myosin head then binds to actin. When ADP and phosphate are released, head bends, pulling the actin in an act called the **power stroke**.
 - ATP binds to the myosin head, causing it to release the actin.
 - When ATP is broken down to ADP and a phosphate, the head extends again.
 - The sequence repeats as long as Ca^+ ions are present.

Sensory Systems

Friday, May 10, 2019
10:59

Overview of Sensory Receptors

Sensory info is conveyed to the CNS and perceived in a four-step process:

- Stimulation
- Transduction (think of it as a change)
 - Interacting with the signal to change it into something your body can understand
 - Changes a stimulus into receptor potential in sensory receptor
- Transmission
 - Transmits an action potential in sensory neurons
- Interpretation
 - Evaluate what type of reaction is warranted by the central nervous system

Sensory receptors respond to stimuli via stimulus-gated ion channels in their membranes:

- In most cases, a depolarization of the receptor cell occurs
 - Analogous to the ***excitatory postsynaptic potential***
 - Referred to as receptor potential

Receptors can be grouped into three classes:

1. Mechanoreceptors are stimulated by ***mechanical forces*** such as pressure
2. Chemoreceptors detect ***chemicals or chemical changes***
3. Electromagnetic receptors react to ***heat and light energy***

Mechanoreceptors

- Cutaneous receptors
 - Receptors in the ***skin*** that respond to stimuli at the border between internal and external environments
 - Receptors for pain, heat, cold, touch, and pressure
- Nociceptors (noci = to cause harm, injury, or pain)
 - Have some sort of cap at which they begin to transduce signals to a sensory receptor
 - Transmit impulses perceived as pain and are sensitive to noxious substances and tissue damage
 - Most of them consist of ***free nerve endings*** located throughout the body, especially near surfaces
 - Transient receptor potential (TRP) ion channel
 - One responds to capsaicin --> sensation of heat and pain
- Thermoreceptors
 - Naked dendritic endings of sensory neurons that are sensitive to changes in temperature
 - Contain TRP ion channels that are responsive to hot and cold
 - When these channels are opened/closed, it changes the rate at which each ion is on each side of the plasma membrane of a cell.
- Proprioceptors (propius = "own")
 - Monitor muscle length and tension
 - Provide information about the relative position or movement of animal's body parts
 - Examples:
 - Muscle spindles - monitor ***stretch*** on ***muscle*** - receptors that lie in parallel with muscle fibers - knee jerk reflex

- **Golgi tendon organs** - monitor **tension** on **tendons** - reflect inhibits motor neurons - prevents damage to the tendons
- **Baroreceptors**
 - Monitor blood pressure
 - Located at carotid sinus and aortic arch
 - Detect tension or stretch in the walls of these blood vessels
 - As blood pressure decreased, the frequency of impulses produced by the baroreceptors decrease, resulting in increased heart rate and vasoconstriction

Several types of mechanoreceptors in the skin detect the sense of touch:

- Contain sensory cells with ion channels that open in response to membrane distortions
- **There are 2 types of membrane distortions:**
 - **Phasic** - intermittently activated; only fires to say that the stimulus happened and does not stay as long as the stimulus is present
 - Hair follicle receptors, Meissner corpuscles, Pacinian corpuscles
 - **Meissner corpuscles** - receptors sensitive to fine touch, concentrated in hairless skin
 - **Pacinian corpuscles** - pressure-sensitive receptors deep below the skin in the subcutaneous tissue
 - **Tonic** - continuously activated; continues to fire as long as a stimulus is present
 - Ruffini corpuscles, Merkel's disks
 - **Merkle cell** - tonic receptors located near the surface of the skin that are sensitive to touch pressure and duration
 - **Ruffini corpuscles** - tonic receptors located near the surface of the skin that are sensitive to touch pressure and duration
- During the example of a piece of paper landing on your arm, Merkel cells and Meissner corpuscles are stimulated.
- During the example of a textbook landing on your arm, Merkel cells, Meissner corpuscles, Ruffini corpuscles, and Pacinian corpuscles.

Chemoreceptors

These receptors bind to particular chemicals in the **extracellular fluid**.

- The membrane of the sensory neuron becomes depolarized and produces action potentials.
- Chemoreceptors are used in the senses of **taste and smell**.
 - They are also important in monitoring the **chemical composition of blood**, having an important dictating effect on the respiratory system.

Taste (Gustation)

Taste is a mixture of physical and psychological factors and are broken down into five categories:

- Sweet, sour, salty, bitter, and umami (hearty)

Taste buds are collections of **chemosensitive** cells associated with afferent neurons (sensory neurons).

In fish, taste buds are scattered all over the body surface.

In land vertebrates, however, taste buds are located in the epithelium of the tongue and oral cavity within raised area called **papillae**.

- Salty and sour tastes act directly through ion channels.
- Other tastes act indirectly by binding to specific G protein-coupled receptors.
- Saliva is very important to be able to taste anything.

Many arthropods have taste chemoreceptors.

- Flies have their sensory hairs located on their feet.

Smell (Olfaction)

In land vertebrates, it involves neurons located in the upper portion of the **nasal passages**.

- Receptors project into the nasal mucosa, and their axons project directly into the cerebral cortex.
- Particles must first dissolve in extracellular fluid before they can activate the olfactory receptors.
- Humans can detect thousands of different smells.

The stimulus of the olfactory hairs causes the plasma membrane to be stimulated, causing depolarization of the sensory neuron, causing an action potential to be fired directly into the cerebral cortex.

pH

- **Peripheral chemoreceptors**
 - Found in the **aortic and carotid bodies**
 - Sensitive primarily to the **pH of plasma**, as well as PO₂ and PCO₂ levels.
 - This further affects the respiratory system, causing either an increase or decrease of respiration rate to change pH levels.
 - Increased CO₂ in the blood lowers pH levels which stimulates the respiratory control center
- **Central chemoreceptors**
 - Found in the **medulla oblongata of the brain**
 - Sensitive to the **pH of cerebrospinal fluid**

Electromagnetic Receptors

A discussion on electromagnetic receptors begins with a discussion on **vision**:

- Vision begins with the capture of light energy by photoreceptors.
 - Humans have three types of photoreceptors while mantis shrimp have 16 types.
- It can be used to determine both the direction and distance.
- Invertebrates have simple visual systems with **photoreceptors clustered in an eyespot**.
- Flatworms, on the other hand, can perceive the direction of light but **cannot** construct a visual image.

Insects have lenses, a retinular cell, and an optic nerve.

Mollusks have a lens, a retina, and an optic nerve.

Chordates have a lens, a retina, and an optic nerve.

Behavioral Ecology

Monday, May 13, 2019

11:06

Ecology - studying biotic and abiotic interactions within an environment

- Example of biotic-biotic interaction --> competition between species
- Example of biotic-abiotic interaction --> a human drinking water
- Example of abiotic-abiotic interaction --> erosion, water hitting rocks to break them down

Organismal Ecology

Behavioral Ecology

Behavior - the observable response of organisms to internal or external stimuli

- Behavior types:
 - **Nature (Innate)** - obvious that genes guide development of nervous system and potentially the behavioral responses
 - **Ethology** - study of the genetic and physiological causes of behavior
 - This behavior type is instinctive and does **not** require learning.
 - Preset paths exist in the nervous system.
 - Genetic --> *fixed action pattern (FAP)*
 - **Fixed action patterns** - innate or genetically programmed behavior
 - Egg retrieval behavior is triggered by a **key or sign stimulus** --> such as an egg being out of nest
 - Innate releasing mechanism
 - Perception of key stimulus and triggering of motor program (fixed action pattern)
 - Once pattern begins, it goes to completion, even if the egg is removed.
 - Example: A goose replacing an egg from her nest.
 - Further examples: Stickleback fish territoriality and Rueben's sweeping
 - **Nurture (learned)** - animals may also develop in a rich social environment and have experiences that guide behavior

Behavioral ecology - studies how behavior contributes to the differential survival and reproduction of organisms

- Tinbergen observed gull nestlings hatch and parents remove the shells of the eggs.
- Placed broken eggs by the nests:
 - Predators (crows) found nests with broken eggs and ate the hatchlings.
 - Nests *without* egg shells had *less predation*.
- Concluded that eggshell removal behavior is **adaptive**:
 - It reduces predation and thus increases the offspring's chances of survival.

Nervous and Endocrine Systems

Question: What happens in between releasing stimulus (key or sign stimulus) and behavior?

- This is where neuroethology is introduced.

Internal signals help drive the reaction to the stimulus:

- Endocrine hormones: cortisol, norepinephrine, epinephrine
- Neurotransmitters: dopamine, serotonin

Techniques of neuroethology include:

- Identifying and mapping individual neurons, their dendrites, and connections to other neurons.
- How their impulses and neurochemicals regulate behavior.

Functional magnetic resonance imaging (fMRI):

- Example:
 - How the human brain responds to seeing food
 - Response does not occur in the visual cortex (as expected)
 - Occurs in the nucleus accumbens in the forebrain instead
 - Normally involved in reward and pleasure
 - Note: Important to note when considering Pavlovian example.

Behavioral Genetics

Certain behaviors have been genetically described:

- Example: Mice *fosB* gene (single gene)
 - Determines whether female mice nurture their young.
 - If both *fosB* alleles are disabled, the mothers ignore their young.
 - Normal mothers = protective maternal behavior

Learned Behavior

Learned behavior - altered behavior as a result of previous experience

- **Nonassociative learning** - does *not* require an animal to form an association between two stimuli between a stimulus and response
 - Example: bouncing your leg up and down
 - Has no positive or negative consequence
 - **Habituation** - decrease in response to a repeated stimulus
 - Example: eventually getting used to a smell after living with it for so long
- **Associative learning** - an association between two stimuli or between a stimulus and response
 - Conditions behavior through association
 - Differ in the way associations are established
 - Two major types:
 - **Classical conditioning** - the *involuntary* response becomes association positively or negatively with a stimulus that did ***not originally*** elicit the response
 - Example: conditioning of Pavlov's dog
 - **Operant conditioning** - an animal's behavior is reinforced by a consequence, either a reward or punishment
 - Example: Skinner's box where a rat bumps into a lever and gets food
 - The rat associates the lever with food.
 - Also called trial-and-error learning
 - There is ***no*** need for a secondary stimulus.
 - Helps animals in the wild by helping them to avoid bad tasting butterflies.

Animal Cognition

It has been discussed whether animals display cognitive behavior:

- Japanese macaques learned to wash sand off of their potatoes.
- Chimps pull the leaves off of a tree branch to use it as a tool for picking termites.

Cognitive learning - ability to solve problems with conscious thought and without direct environmental feedback

- Example: Chimps have been shown to display problem solving to get a suspended banana by stacking boxes.
- Other examples: Birds manipulating their environment to reach a goal or otters using rocks to break their food down

Behavior is often a mix of innate and learned factors:

- Example: Birds are genetically programmed to learn but they will sing the correct song only if the correct songs are heard.
 - Their intent to sing is genetically programmed into the bird, however, if they hear a song specific to their species, they'll sing it accurately.
 - Evolutionarily, this action of singing the correct song will increase the bird's fitness.

Optimality theory - an animal should behave in a way that maximizes benefits of a behavior minus its costs

- Animals will attempt to benefit itself the best way that it can.

Optimal foraging theory - an animal seeks to obtain the most energy possible with the least expenditure of energy

- Selection for the *maximum* return on investment
 - The more net energy gained, the greater the reproductive success.
- Example: Shore crabs will eat different sized mussels
 - Preference exists for intermediate mussels with the highest rate of energy return
 - Larger mussels yield more energy by take longer to open
 - Smaller mussels are easier to open but yield less energy

Animal Behavior and Sensory Biology – Active Learning

Wednesday, May 15, 2019

11:16

The environment in which communication occurs interacts directly with the information that is being communicated to receivers.

- From here, the receivers take in the information and begin to analyze it through the four steps of sensory stimulation.

Types of Communication

- Olfactory communication
- Verbal communication
 - Using vibrations in the air to communicate
- Body language/tactile communication
- Visual communication
- Pheromones --> associated with olfactory communication

Applications for Communication

Relationship to Sender	Auditory	Visual	Chemical	Tactile
Conspecific (same sex)				Dogs marking their territories
Conspecific (opposite sex)	Birds singing species-specific song to call for mates	Blue-footed boobies dancing for mates	Pheromones	
Prey	Calling for more of its species to help back it up in the case of attack from a predator	Coloration of poisonous frog to warn predators	Skunks releasing odor	
Predator	Roaring to display dominance	Fish displaying its spikes (stickleback)		
Offspring	Mother calling for their offspring/offspring calling for help	Seeing a baby's face distort to uncomfortableness	Cat brushing up on another	Handshakes between humans

Process of Communication

The communication process has 5 parts to it:

- Sender
- Information
- Environment
- Non-target audience
- Receiver

Communication leads to sociality.

Group Life

Advantages:

- Many-Eyes Hypothesis
 - States that as the size of the group increases, the task of scanning the environment for predators can be spread out over many individuals.
- Pack dynamics in hunting

Disadvantages:

- More competition for food/mates
- More organisms = more chances for risk
- Increased potential for the spread of disease

Chapter 36 - Reproduction

Friday, May 17, 2019

10:25

Aspects of Reproduction Studied by Physiologists:

- Asexual vs. Sexual
- Mate Association
- Cycles of Reproduction
- Reproductive Cells and Organs
- Coordination by Endocrine and Neural Mechanisms
- Parental Investment
- Physiology of the Offspring

Reproductive Strategies

Parthenogenesis (partheno = virgin, genesis = creation)

- Females produce offspring from unfertilized eggs
- Does not receive the benefit of mixing different alleles together amongst future generations, however, allows for regeneration of these species
- Examples: arthropods
- In vertebrates:
 - 1958 -> Ilya Darevsky
 - *Lacerta* - asexual reproduction in the absence of sperm
 - Examples: lizards, fish, salamanders

Hermaphroditism

- Have both testes and ovaries
- Tapeworm - need one in order to reproduce
- Earthworm - need two in order to reproduce
 - Have the benefit of crossing different alleles

Sequential hermaphroditism

- When organisms when they change their sexual organs based on social cues
- Involves many fish, mollusks
- Social control involved
 - Protogyny and protandry
 - **Protogyny** - Organisms that start as female and shift to male
 - **Protandry** - Organisms that start as male and shift to female
 - Social cues are interpreted by organisms thus forcing a certain leaning towards shifting sex to what's warranted by the group of organisms
 - Example: Within the species of bluehead wrasse, females sometimes turn into males.
 - A large male, which had been a female before changing sex, is seen among females, which are typically much smaller.

Sex Determination

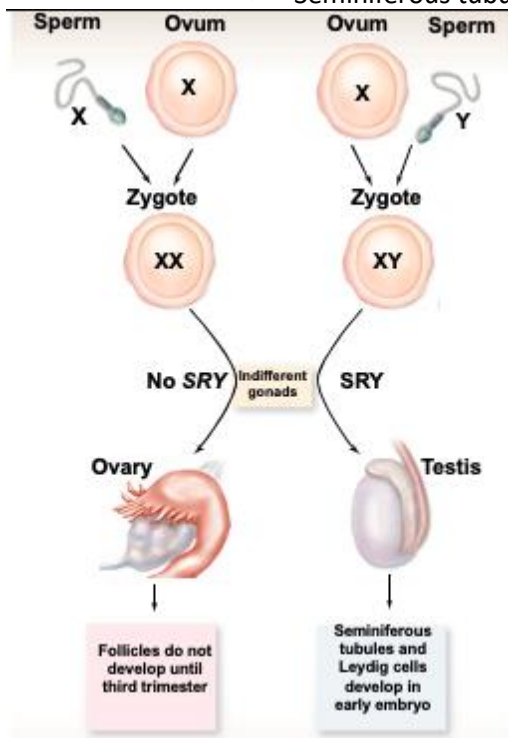
Temperature-sensitive

- Potential exists for either the production of ovaries and testes
 - The transcription factors for each organ developed are temperature-sensitive.
- Potential for the environment to affect sex ratios within a population of a species

- Are in many fish and reptiles
- Has evolved many times

Genetic

- XX or XY
- Humans
 - Embryonic gonads indifferent for the first 40 days.
 - *SRY* gene on Y converts gonads to testes.
 - If this gene is not activated, ovary development occurs instead.
 - Testosterone promotes male development.
- The ovum always has an X chromosome --> sperm decides development of reproductive organs due to carrying either an X or a Y chromosome.
 - If a zygote carries XX chromosomes, they have no *SRY* gene, thus begin to develop ovaries.
 - Follicles do not begin to develop until the third trimester.
 - If a zygote carries XY chromosomes, they do have *SRY* gene, thus begin to develop testes.
 - Seminiferous tubules and Leydig cells develop in the early embryo.



Three Major Sex Determination Systems in Vertebrates

- XX/XY - Mammals
- TSD - some fish, some reptiles
- ZZ/ZW - frogs, amphibians, turtles, snakes, and birds
 - Similar to the mechanism in which XX/XY operates

External/Internal Fertilization

External Fertilization (also called broadcast fertilization)

- Seen in a majority of aquatic animals
- Small, lightly provisioned eggs
- Females release eggs into the water, males release sperm in the vicinity of these eggs

Internal Fertilization

- Sperm is introduced into the female reproductive tract
 - Sperm needs to flow in an aqueous solution
- Eggs are in a hard case or shell --> portable pond that carries what the zygote needs to survive
- Placental organisms

Three strategies for development:

- **Oviparity (ovi = egg, parity = to carry)** - fertilized eggs placed outside mothers body to complete development in an amniotic egg
- **Ovoviviparity** - fertilized eggs are kept in the parent to complete gestation; nourishment from egg yolk or cannibalism; not parent
 - Sometimes appears to be viviparity
- **Viviparity** - young develop in their mother and get nutrition from her blood
 - These offspring already emerge from their mothers with skills and having been stimulated by inner stimulus

With time, internal fertilization and live birth and vertebrates has evolved.

- In fish, internal fertilization has evolved over 40 times while live births have evolved over 15 times.
- In squamates, live birth has evolved over 100 times.
- In placental mammals and marsupials, live birth has evolved only once.

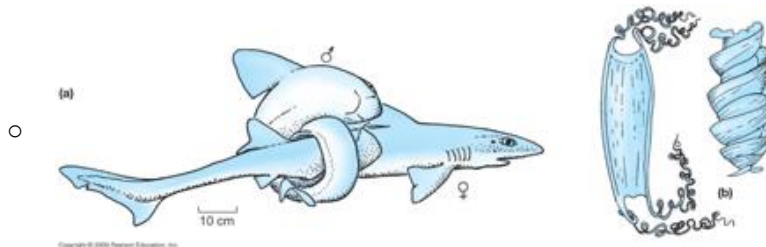
Fishes

In most species of **bony fish**, fertilization is external.

- Thousands of eggs are fertilized, but only a few individual grow to maturity

Cartilaginous fish are internal fertilizers.

- **Spermatophores (packets)** - claspers as intermissive organs for sperm deposition --> modified pelvic fin



- Appendages
 - Crabs, octopuses

Vertebrate Fertilization

Amphibians

In most species, fertilization is external.

- Eggs of most species develop in water in order to distribute their sex cells.
- There are also some interesting exceptions:
 - Male carries tadpoles on his back.

- Froglets develop in brood pouches.
- Female carries developing larvae on her back.
- Male holds developing froglets in his vocal pouch.

Reptiles

With reptiles, amniotic eggs are developed:

- Amniotic eggs are extraembryonic membranes and are adapted for life on land.
- Most oviparous reptiles lay eggs and abandon them.
 - Leathery shell on egg
- Other species of reptiles are ovoviviparous --> develop an egg within them and once they're ready to hatch, they're born, appearing to be a live birth
- Some species are viviparous which is rare.

Birds

All birds are oviparous:

- Internal fertilization occurs
- Most have no intermissive organs:
 - Exceptions: swans, geese, ostriches, ducks
- Use a cloacal kiss
 - This is where reproductive cells exchange with each other
 - Genetic material is exchanged throughout this practice.

Mammals

Three types of pregnancies in mammals exist:

- **Monotremes** - like platypus, lay eggs
- **Marsupials** - like kangaroo, have extremely underdeveloped young that must complete development in the pouch where nourishment is developed
- **Eutherian (eu = true, thero = beast)** mammals retain their young for a prolonged period and nourish via a placenta.

Human Reproduction (Organ Structure, Fertilization and Implantation)

The Male Reproduction System

When beginning to look at the human male reproductive system, we begin with the **seminiferous tubules**, which are the sites of sperm production.

- The outer portions of the seminiferous tubules is where meiosis occurs beginning with a diploid germ cell to end up with spermatozoans.
- Path of sperm in male reproductive system:
 - Testis --> epididymis --> vas deferens to wrap around the bladder (leading to the prostate) --> interacts with seminal vesicles --> passes through the prostate --> runs down the urethra --> passes out through the penis
 - Sperm are delivered into the ***epididymis*** for storage and maturation.
 - From here, the sperm enters the vas deferens and then to the urethra.

Shortly before birth, the testes descend into the scrotum because the sperm need a cooler temperature to develop.

- Sperm developed through spermatogonium (germ cells) that divide by mitosis to produce two diploid cells called spermatocytes.
 - One later undergoes meiosis, the other remains as a spermatogonium.

- The spermatocyte that begins meiosis is referred to as the primary spermatocyte.
 - This primary spermatocyte undergoes meiosis I to produce two haploid secondary spermatocytes.
 - Each secondary spermatocyte undergoes a second meiotic division to produce 2 haploid spermatids.
 - The result of this process are 4 haploid spermatids that eventually become spermatozoa.

Sperm structure:

- **Head** - contains a nucleus
 - Capped by the acrosome, which aids in penetration of the egg and determining if the sex cells fertilizing are of the same species.
- **Body** - consists of many mitochondria
 - Provide energy
 - Centriole acts as basal body for the flagellum
- **Tail** - consists of a flagellum
 - Provides locomotion

Penis structure:

- Consists of erectile tissue columns
 - During erection, these tissues fill with blood
- Parasympathetic nerves release nitric oxide (NO) which stimulates the dilation of the arteries.
- Ejaculation is the ejection from the penis of about 2-5 mL of semen containing an average of 300 million sperm.

Hormonal interactions occur between the testes and anterior pituitary gland to initiate the process of sperm production.

Mammalian Reproductive Hormones

Males:

- **Follicle-stimulating hormone (FSH)** - stimulates spermatogenesis via Sertoli cells
- **Luteinizing hormone (LH)** - stimulates the secretion of testosterone by Leydig cells
- **Testosterone** - stimulates development and maintenance of male secondary sexual characteristics, accessory sex organs, and spermatogenesis

Female:

- **Follicle-stimulating hormone (FSH)** - stimulates growth of ovarian follicles and secretion of estradiol
- **Luteinizing hormone (LH)** - stimulates ovulation, conversion of ovarian follicles into corpus luteum, and secretion of estradiol and progesterone by corpus luteum
- **Estradiol (estrogen)** - stimulates development and maintenance of female secondary sexual characteristics; prompts monthly preparation of uterus for pregnancy
- **Progesterone** - completes preparation of uterus for pregnancy; helps maintain female secondary sexual characteristics
- **Oxytocin** - stimulates contraction of uterus and milk-ejection reflex
- **Prolactin** - stimulates milk production

The Female Reproductive System

The female reproductive cycles initially commence during puberty:

- Each cycle averages at about 28 days, consisting of changes within the ovaries and uterus.
- During each cycle, gonadotropin-releasing hormone (GnRH) from the hypothalamus stimulates the anterior pituitary to release two gonadotropic hormones, targeting the ovaries:
 - Follicle-stimulating hormone (FSH)
 - Luteinizing hormone (LH)
- Each reproductive cycle has two components:
 - Ovarian Cycle --> regulated by changing levels of FSH and LH
 - The 14 days prior to ovulation are known as the **follicular phase**.
 - During the **first 5 days**, increased GnRH stimulates the anterior pituitary to increase the production of FSH and LH.
 - Increased FSH and LH stimulates primordial follicles in the ovary to mature into primary follicles, each containing a diploid primary oocyte that is arrested in prophase I of meiosis I.
 - During the **second part of this phase (days 6-13)**, a small number of primary follicles form secondary follicles.
 - **2 days before ovulation**, under the influence of increasing levels of FSH and LH, the follicle expands to form a swelling on surface of the ovary.
 - About **16 hours before ovulation**, the levels of FSH and LH surge to cause the final maturation of the follicle, now called a mature, or Graafian follicle.
 - As LH peaks, proteolytic enzymes produced in the follicle cause its wall to weaken and rupture.
 - **Prior to ovulation**, the primary oocyte completes meiosis I to form a haploid secondary oocyte.
 - **Ovulation** occurs on day 14 of the 28-day ovarian cycle.
 - The process of ovulation is the release of the secondary oocyte from the mature follicle.
 - The 14 days following ovulation constitutes the **luteal phase**.
 - During this period, the remaining ovarian follicular cells form a corpus luteum, which produces the hormones progesterone and estrogen.
 - Uterine Cycle --> regulated by estrogen and progesterone
 - The 14 days prior to ovulation are split into a **menstrual phase** (days 1-5) and proliferative phase (6-14).
 - During the **first 5 days**, decreasing levels of progesterone lead to the shedding of the endometrial lining.
 - **After the shedding**, the endometrial lining reforms under the influence of estrogen produced by the ovarian follicular cells.
 - Also called the **proliferative phase** of the uterine cycle.
 - Ovulation occurs on day 14 of the 28-day uterine cycle.
 - The 14 days after ovulation are the **secretory phase**.
 - The release of progesterone and estrogen from the corpus luteum stimulates further thickening of the endometrium in this phase.
 - If fertilization and implantation occur, cells at the implantation site in the uterus begin to produce human chorionic gonadotropin (hCG).

- hCG prevents the corpus luteum from degenerating, maintaining elevated progesterone and estrogen levels are maintained to prevent the shedding of the uterine lining at the end of the uterine cycle.
- After 8-12 weeks, the corpus luteum ceases to produce progesterone and estrogen and degenerates to become the corpus albicans.
 - The placenta in the uterus replaces the corpus luteum in producing progesterone and estrogen.
- If fertilization doesn't occur, the corpus luteum becomes a corpus albicans by the end of the cycle.
 - This causes decreased levels of progesterone and estrogen, resulting in menstruation and the beginning of the next uterine cycle.

Ovarian Events In Depth

Follicular phase - the phase in which a follicle matures (passed out during ovulation) to prep the endometrial layer of the uterus for the fertilization of an egg

- Several follicles are stimulated to grow under FSH stimulation.
 - However, only one achieves full maturity as a tertiary, or Graafian, follicle.
- Estrogen causes the growth of the endometrium.
 - This is the proliferative phase of the endometrium.
- As a follicle matures, it accumulates more cumulus mass, containing an oocyte.
- Steps undertaken to form a follicle:
 - Primary oocytes begin to mature within growing follicles.
 - i. **Oocytes** - cells in an ovary which undergo meiotic division to form an ovum
 - ii. **Follicles** - a fluid-filled sac that contains an immature egg (oocyte)
 - A primary oocyte completes meiosis I to become a secondary oocyte.
 - i. After meiosis I, homologous chromosomes separate.
 - The secondary oocyte begins meiosis II and matures into an ovum, which is released during ovulation when the follicle ruptures.
 - Corpus luteum developed from remnants of follicle.
 - i. **Corpus luteum** - essential for establishing and maintaining pregnancy in females --> secretes progesterone; a temporary endocrine structure in female ovaries
 - Corpus luteum degenerates if fertilization of egg does not occur.

Ovulation - the event that occurs between the follicular phase and luteal phase, consisting of an oocyte from a matured follicle

Luteal phase - after ovulation, progesterone and estrogen are pushed out

- In the **absence** of fertilization, the corpus luteum degenerates due to decreasing levels of FSH and LH.
 - Built-up endometrium is sloughed off with accompanying bleeding.
 - Menstrual phase of endometrium
- If the ovulated oocyte is fertilized, the corpus luteum is maintained by human chorionic gonadotropin (hCG).
 - The hCG is a signal that comes from the developing embryo, not the mother.
 - It keeps high levels of estrogen and progesterone, and *prevents* menstruation until placenta takes over.
 - hCG is produced by the embryo and is tested for in pregnancy tests.

- The path of FSH and LH is from the anterior pituitary to the ovaries.

****MUST KNOW SLIDE 36 VISUALS****

Contraception

The study of physiology of organisms has increased the attempts to effective birth control:

- **Abstinence**
 - No sexual intercourse at all
 - Most reliable way to avoid pregnancy
- **Sperm blockage**
 - Prevention of sperm entry into the uterus
 - Condoms, cervical caps, and diaphragms
- **Sperm destruction**
 - Elimination of the sperm *after* ejaculation
 - Douches have a failure rate of 40%
- **Sterilization**
 - Vasectomy in males
 - The vas deferens is cut and tied, put within the spermatic cord.
 - Tubal ligation in females
 - The connection between the ovaries and uterus is disrupted, hindering the eggs from entering the uterus.
 - **NOTE:** Chemical production of gametes does not cease with these sterilization methods. Sperm and eggs are still maturing within their respective reproductive organs.

Alteration of the Female Cycle:

- ***Prevention of Ovulation:***
 - Birth control pills or oral contraceptives
 - Contain analogues of progesterone, sometimes with estrogens
 - Attempts to keep these levels of hormones stable to prevent ovulation and maturation of follicles
 - *Prevents follicle development*
 - Hormone-containing capsules can also be implanted beneath the skin
- ***Prevention of Embryo Implantation:***
 - Intrauterine devices (IUD)
 - Implants on the wall of the uterus, agitating enough so the endometrium doesn't engorge enough to allow for fertilization of an egg
 - "Morning-after" pill or Plan B
 - Analogous to an "eject" button
 - Is a concoction of hormones that causes a drop of the endometrial layer.

Exam #3 Divider

Monday, May 27, 2019
22:16

Population Ecology

Wednesday, May 22, 2019

11:03

Population - group of interbreeding individuals occupying the same habitat at the same time; a genetic unit with a specific gene pool

- Must keep in mind evolutionary context and evolutionary constraints
- Examples:
 - Water lilies in a particular lake
 - Humans in NYC

Population ecology - study of what factors affect population size and how these factors change over space and time

- **Range** --> how far a population spreads out; inability to leave a designated area
 - Population ranges and species ranges exist within this criteria.
 - **Population ranges** - has a specific geographic range
 - A reproductive barrier exists, preventing the population from copulating with other populations. Barrier could be chemical, physical, or environmental.
 - **Species ranges** - has the possibility be substantial; contains all individuals of a certain species
 - This range will never be smaller than the population range.
 - Most species have a limited geographic range.
 - Devil's hole pupfish lives in a single spring in southern Nevada.
 - Polar bears are well adapted for the Arctic but you won't find them in the tropics.

Demography - the study of how births and deaths change populations over time

- **Tools of demography:**
 - Birth rates
 - Death rates
 - Age distributions
 - Sizes of populations
- **Dynamics**
 - Changes through time resulting from birth, death and movement of individuals
- **Structure --> a snapshot of what a population looks like at a given moment**
 - Density
 - Proportion of individuals in various age classes
 - Spacing of individuals relative to each other

Understanding Populations

Density - the number of organisms in a given unit area

- **Population growth** affects population density.
 - Density-dependent reproductive impacts occur --> "density affects reproductive strategies"
 - Example:
 - Competition between sexes for mates.
 - Resource availability can affect the effort put into reproduction.
 - Sequential hermaphroditism based off sex ratio (demographics).
- Examples:

- Rare vs. common
- Recovery after a serious threat
- Knowledge can help us make decisions about the management of species.
 - Classifications of endangered species
 - Hunting/fishing seasons
 - Protected/conserved areas
- **Dispersion patterns:**
 - **Clumped**
 - Most common dispersal pattern
 - Resources tend to be clustered in nature
 - Social behavior may promote this pattern
 - May attributed to the Many Eyes hypothesis
 - Asexual reproduction may promote this pattern as well
 - **Uniform**
 - Competition may cause this pattern
 - Example: The uniform distribution of shrubs is due to the level of competition present for water
 - May also result from social interactions
 - **Random**
 - Most rare dispersal pattern
 - Resources are rarely randomly spaces
 - Means that no specific environment is better for the organism is better than another
 - Small population issues
 - In the American ginseng, as population size *decreases*, the fruit production decreased. Smaller populations had fewer visits by pollinators.
 - This decline in reproduction with small population size is known as the **Allee Effect**.
 - This effect is characterized by a correlation between population size or density and the mean individual fitness of a population.

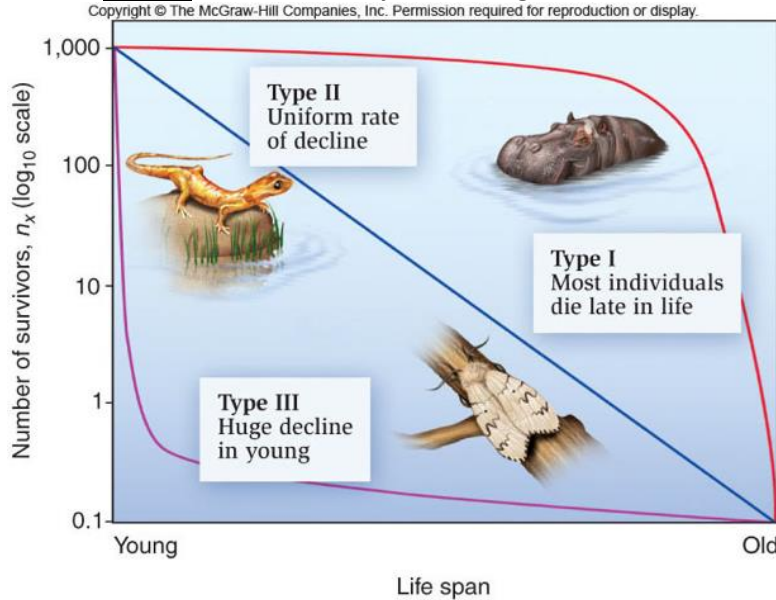
Methods of quantifying population density:

- Simple visual count
- Sampling methods to extrapolate captured organism number to the size of a population
 - Taking a sample of a small area of land and applying it to a large distribution of area
- Mark-recapture method
 - Captured animals may learn to avoid traps or seek out food baited traps.
 - Consists of taking a subpopulation of a larger population and marking it
 - Return a certain amount of time later, and take another subpopulation and mark them, let them go, repeating the process a certain amount of time later.
 - Method isn't applicable to migratory organisms or small organisms that are unable to be tagged.
 - There must also be a consideration of a sex bias, trying not to take too much data about one sex.
 - Dispersal must exist within a population for this method to work.

ACTIVE LEARNING, 5-24-2019

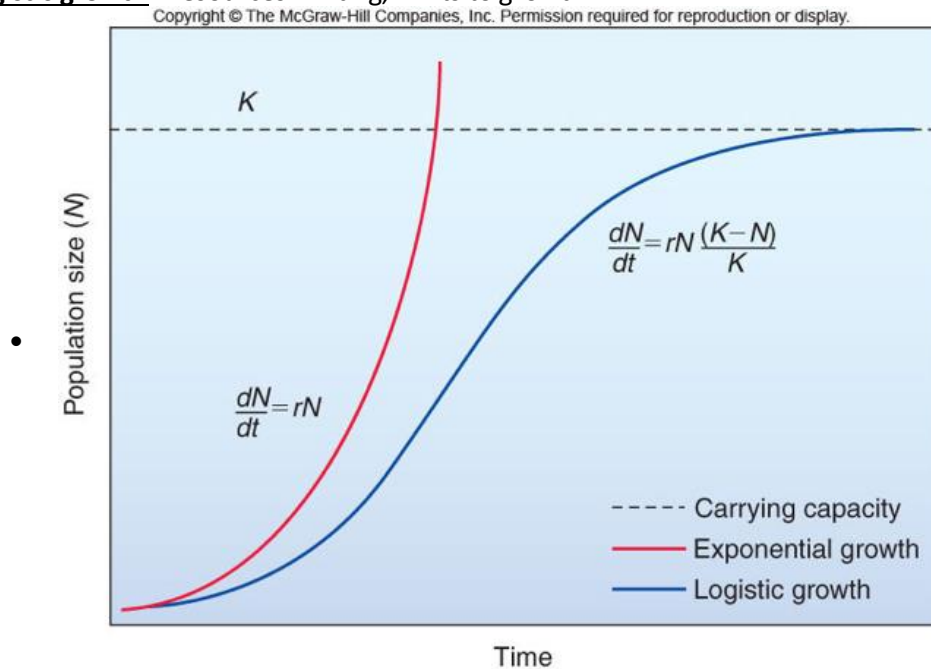
3 Patterns of Survivorship Curves

- **Type I** - rate of loss of juveniles low and most individuals lost later in life
- **Type II** - fairly uniform death rate
 - Example: Beavers
- **Type III** - rate of loss of juveniles high and most individuals lost **earlier** in life



Life tables can provide accurate information about how populations grow from generation to generation:

- Simpler models can give insight to shorter time periods
 - **Exponential growth** - resources NOT limiting, prodigious growth
 - Not realistic in natural or laboratory setting
 - **Logistic growth** - resources limiting, limits to growth



WEDNESDAY LECTURE, 5-29-2019 - Part 2 Lecture

Reproductive Strategies --> Factor Affecting Population Size

Semelparity (semel = together, parity = to bear) - produce all offspring in a single reproductive event

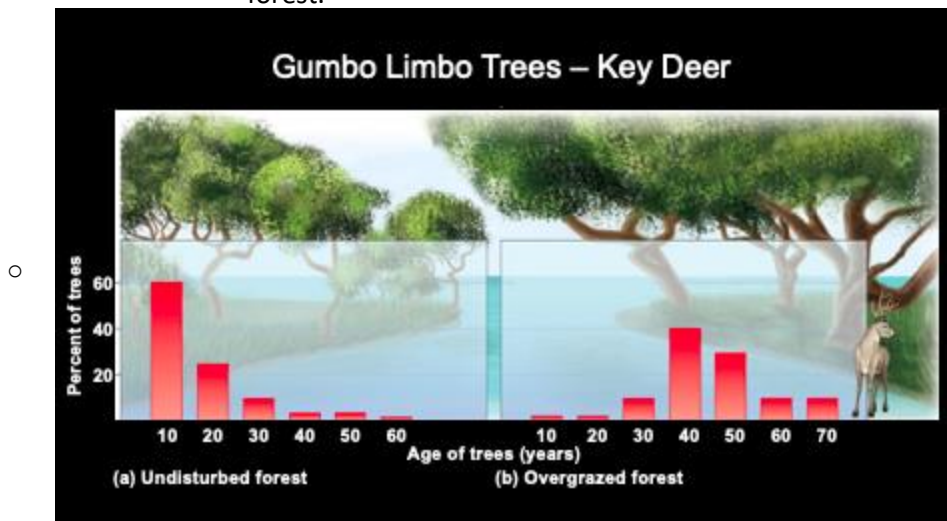
- Individuals reproduce once and die
 - Once reproduction occurs, the individual no longer has a purpose and takes up resources --> left to die off
- Other factors can affect semelparity other than seasons:
 - Sexual selection
 - Overall availability of mates
 - Climate
- Example: salmon, agave

Iteroparity (itero = repeat, parity = to bear) - reproduce in successive years or breeding seasons

- **Seasonal iteroparity** - distinct breeding seasons
 - Example: Blue tit (type of bird)
- **Continuous iteroparity** - reproduce repeatedly at any time of the year
 - Example: Chimpanzee

Age classes:

- Reproductive strategy has a strong effect on the subsequent age classes of a population
- **Cohorts** - semelparous organisms with groups of same-aged young
 - Iteroparous organisms have young of different ages
- Expect a population increasing in size to have many young and a decreasing population to have few young
 - Example: Gumbo Limbo Trees - Key Deer
 - With grazing occurring, there are fewer younger trees than in an undisturbed forest where no grazing occurs.
 - In 50 years, the undisturbed forest is better off than the overgrazed forest.



Life tables - data on the number of individuals alive in a particular age class

- Typically referring to females since males are usually not included.

- Example: North American beaver
 - Trapped provided mandibles
 - Teeth extracted for age classification
- **Age-specific fertility rate (m_x)** - proportion of female offspring born to females of reproductive age
 - 100 females produce 75 female offspring, $m_x = 0.75$
- **Age-specific survivorship (L_x)** - use survivorship data to find the proportion of individuals alive at the **start** of any given age class
 - **Equation** --> (current individuals alive)/(individuals alive at start)
 - **$L_x M_x$** - contribution of each age class to overall population growth (multiply the two values)



- **Net reproductive rate (R_0)** - overall growth rate per generation
 - Represents the number of offspring born to females of all ages
 - **Equation** --> $R_0 = \sum L_x M_x$ (sum of the [age survival * age fertility])
 - If $R_0 > 1$, the population is growing.
 - If $R_0 < 1$, the population is declining.
 - If $R_0 = 1$, the population is at equilibrium.
 - **$N_{t+1} = N_t R_0$** --> future population size = current population size * net reproductive rate

Life History Strategies

r-selected species - high *rate* of per capita population growth, r , but poor competitive ability (weeds)

- These species place a high emphasis on high growth rate, and typically exploit less-crowded ecological niches and produce *many* offspring, each of which have a relatively low probability of surviving to adulthood (high r , low K).
- Opportunists --> rapid growth, short life span
- Examples: most small mammals, birds and amphibians, wide dispersing plants

K-selected species - more or less stable populations adapted to exist at or *near* carrying capacity, K

- Display traits associated with living at densities close to carrying capacity, and typically are strong competitors in such crowded niches that invest more heavily in fewer offspring, each of which has a relatively high probability of surviving to adulthood (low r , high K)
- Competitors --> slow growth, long life span
- Lower reproductive rate but better competitors (trees)
- Examples: elephant, sharks, and rhinoceroses, (are prone to extinction)

Table 56.2 Characteristics of *r*- and *K*-Selected Species

Life history feature	<i>r</i> -selected species	<i>K</i> -selected species
Development	Rapid	Slow
Reproductive rate	High	Low
Reproductive age	Early	Late
Body size	Small	Large
Length of life	Short	Long
Competitive ability	Weak	Strong
Survivorship	High mortality of young	Low mortality of young
Population size	Variable	Fairly constant
Dispersal ability	Good	Poor
Habitat type	Disturbed	Not disturbed
Parental care	Low	High

Community Ecology

Wednesday, May 29, 2019

11:41

Community - several populations exist within this unit; assemblage of many populations that live in the same place at the same time

Community ecology - studies how groups of species interface and form functional communities

Community Structure

Species richness - the number of different species found in the community

- The number of species of most taxa varies according to geographic range.
 - Increasing from polar to temperate to maximum in tropical areas.
 - Increases by topographical variation.
- This value varies with latitude.
 - As a general rule, the **closer** a community is to the equator, the **more species** it will contain.
 - Due to the availability of sunlight in this environment for primary producers.
- Species richness is greatest in the tropical rainforests.

Species diversity - the relationship between the number of species in the community to the **relative abundance of each species**

- Two communities can have the same species richness, however, may have varying species diversity.
- **Shannon diversity index** - measures the diversity in a community
 - $H_s = \sum p_i \ln(p_i)$
 - p_i = proportion of individuals belonging to species i (individuals of a species/total organisms OR n/N)
 - \ln = natural logarithm
 - Σ = summation sign
 - Compare the **absolute value**
 - A higher absolute value of the Shannon index means higher diversity.
 - Values typically fall between 1.5 - 3.5

Roles in the Ecosystem

Keystone species - species whose effects on the compositions of communities are **disproportionately high** based on abundance; keeps the community stable

- Keystone species can manipulate the environment in ways that create new habitats for other species
 - Examples:
 - Beavers
 - Sea star predation on barnacles greatly alters the species richness of the marine community
 - Starfish eat barnacles, allowing other species to thrive instead of being crowded out by the explosive population of barnacles

Habitat engineers - species that change the composition of the environment around them by creating new habitats for many plants and animals

- These species effects are disproportionately high on diversity and environment

- Example: Beavers construct dams and transform flowing streams into ponds and vice versa
- Other examples: Elephants, bees

Niche - the total of all the ways an organism uses the resources of its environment

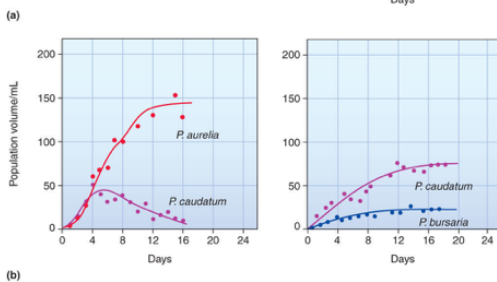
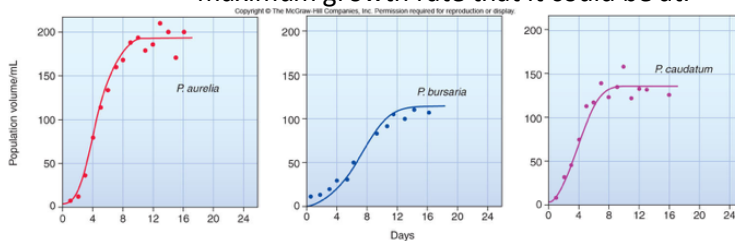
- Examples: Space utilization, food consumption, temperature range, appropriate conditions for mating, requirements for moisture and more
- **Fundamental niche** - entire niche that a species is capable of using, based on physiological tolerance limits and resource needs
- **Realized niche** - *actual* set of environmental conditions, presence or absence of other species, in which the species *can* establish a stable population
- Causes of Niche Restriction:
 - Predator absence or presence
 - Absence of pollinators
 - Presence of herbivores

Niche-Driven Principles

Competitive Exclusion Principle

Competitive exclusion principle - when two organisms are competing for the same resource, something typically wins and one fails

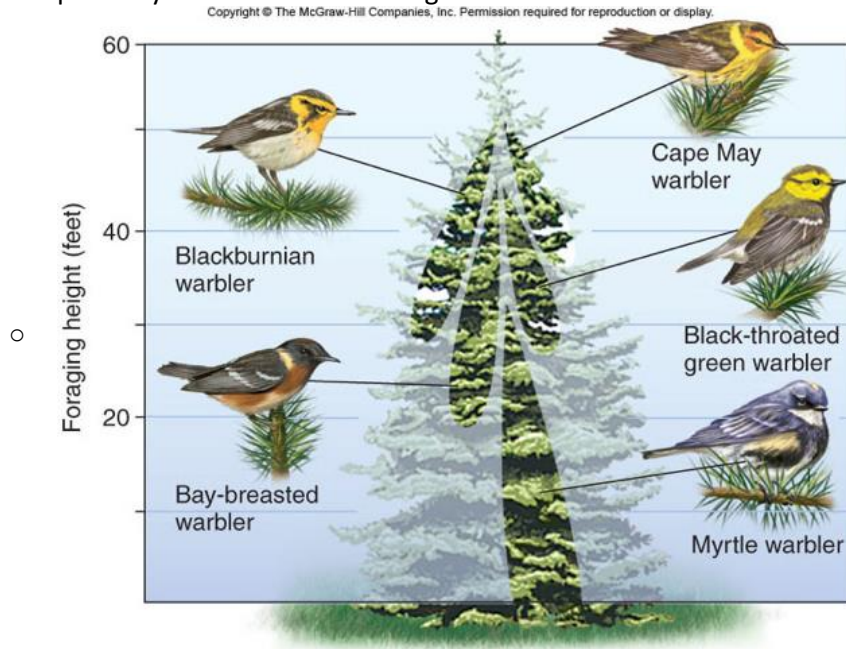
- Example: An invasive kudzu smothers and strangles any other plant in its path.
 - It dramatically dominates surrounding species in the ecosystem.
- Complete competitors *cannot* coexist
- Gause experiment - worked with 3 protists (*Paramecium aurelia*, *Paramecium bursaria*, *Paramecium caudatum*)
 - Grown separately, all 3 protists grew logistically
 - When *P. caudatum* and *P. aurelia* were grown together, *P. caudatum* went extinct.
 - When *P. caudatum* and *P. bursaria* were grown together, neither went extinct.
 - Concluded that 2 species with exactly the same requirements cannot live together in the same place and use the same resources, that is, occupy the same niche.
 - Within this principle, both species end of losing since *P. aurelia* isn't at its maximum growth rate that it could be at.



Resource Partitioning

Resource partitioning - differentiation of niches, both in space and time, that enables similar species to coexist in a community

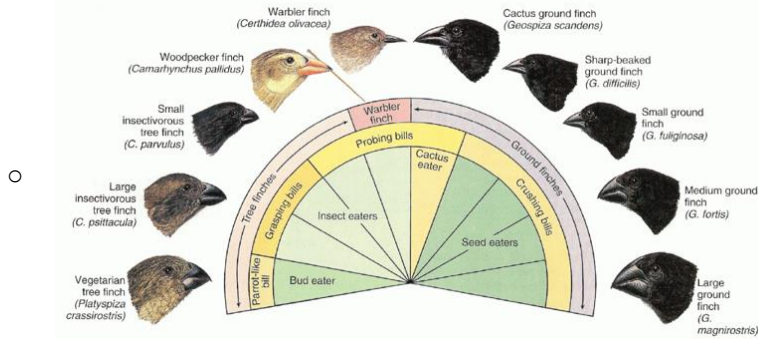
- This affects competition by causing the rate of competition to drop due to less overlap between each species' resources.
 - Competition is *most intense* between closely related species that require the same resources.
 - When similar species coexist, each species uses only part of the available species.
- Robert MacArthur examined coexistence between five species of warblers feeding within spruce trees in New England
 - Found that the species occupied different heights and portions in the tree and thus each probably fed on a different range of insects.



Character Displacement

Morphological difference allows coexistence:

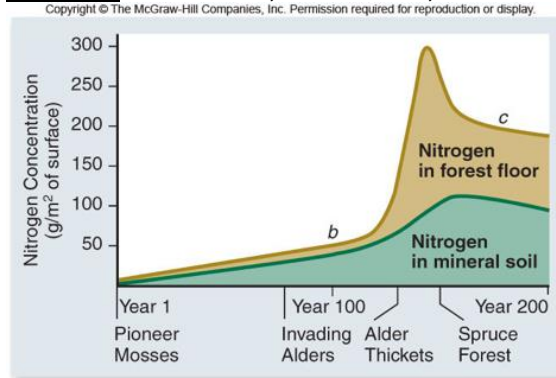
- Some partial level of competition between complete competitors can exist if it is not severe enough to drive one competitor extinct
- G. Evelyn Hutchinson compared size difference in feeding apparatus between **sympatric (same geographic area)** and **allopatric (different geographic areas)** species
 - When species were sympatric, feeding apparatus size changed to specialize on different food.
 - **Character displacement** - tendency for 2 species to diverge in morphology and resource use due to competition
 - Occasionally, when two species are intense competitors, one of both species may evolve niche difference of anatomical difference that **lessen** the intensity of the competition.



Community Dynamics

Disturbance - an event, such as a storm, fire, flood, drought, overgrazing, or human activity that *changes* a community by **removing organisms** from it or **altering resource availability**

- **Succession** - the gradual, sequential regrowth of an area following a disturbance; two types exist:
 - **Primary succession** - the development of a community in an area that has **NOT** previously supported life
 - Not seen as often, but has occurred during glacier retreating recently
 - Primary succession often occurs very slowly.
 - Minerals necessary for plant growth are unavailable.
 - Over time, rocks will begin to break down due to weathering and erosion, introducing an amount of minerals.
 - Lichens are usually the first to colonize these barren areas.
 - A lichen is the **mutualistic relationship** between an algae and a fungus -- > photosynthesis from algae and break down from fungi
 - The combination of minerals from rocks, and the organic matter from the lichens will begin to form a thin layer of soil in which grasses and mosses grow.
 - As these plants die, they add more decayed organic matter to the soil and soon a few shrubs will appear. Shrubs are then followed by trees.
 - **Examples:** A bare rock, a sand dune, or an island formed by a volcanic eruption



a.

© Tom Bean

- **Secondary succession** - the replacement of a species that follows a disturbance in an already existing community

- Soil is mainly intact, causing a spike in growth rates due to the destruction of communities by fire.
- **Pioneer organisms** - generally the first to colonize the area; may also be seeds in the seed bank coming from birds
- Disturbance can be helpful in preventing the emergence of k-selected species that are incredibly competitive which may cause a decrease in the level of diversity within a community.

Interspecific Competition

Red Queen Hypothesis - "You need to keep running to stay in the same place."

- There must be a constant level of adaptation in order to survive.
- Within competition, both involved species have a negative effect on them.
 - Each species aren't able to reach their full potential.
- **Amensalism** - one species has a negative effect on them while the other has no effect
- **Commensalism** - one species has a positive effect on them while the other has no effect

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Table 57.1 Summary of the Types of Species Interactions

Nature of interaction	Species 1*	Species 2*
Competition	—	—
Amensalism	—	0
Predation, herbivory, parasitism	+	—
Mutualism	+	+
Commensalism	+	0
Neutralism	0	0

*+ = positive effect; — = negative effect; 0 = no effect.

Predation

Categories of predation can be classified according to how lethal they are for the prey (lethality) and the length of association between consumer and prey (intimacy):

- **Examples:**
 - Lions have a high level of lethality with low intimacy.
 - Parasites have a low level of lethality and high level of intimacy.
 - Gazelles have a low level of lethality and low level of intimacy.
 - Parasitoids have a high level of lethality and high level of intimacy.
 - Adding "-oids" to the end of a word means "kind of."
 - This organism is kind of a parasite but is actually lethal.

Anti-Predatory Strategies

Natural selection favors adaptations that make organisms better suited for their environment. Predators have become more efficient over time by developing adaptations (through natural selection) that increase their **success/efficiency**.

Just as the predator must be highly adapted to catch the food, the prey must have adaptations that help them avoid being captured and eaten:

- **Chemical defense**
 - Example: Bombardier beetle ejects caustic hot spray
 - **Aposematic coloration (warning coloration)** - advertises an organism's unpalatable taste
 - Many tropical frogs have bright coloration to advertise their skin's lethality
- **Cryptic coloration** - camouflage
 - Stick insects mimic branches
 - Sea horses adopt coloration to mimic habitat
- **Mimicry** - a form of deception used by the prey as a means of defense against attack
 - In this anti-predatory strategies, one species resembles another species.
 - The king snake is a mimic of the very poisonous coral snake.
 - **Müllerian mimicry (convergent, reinforce a warning)** - noxious species *converge* to reinforce warning
 - **Batesian mimicry** - palatable mimic resembles unpalatable model
- **Displays of intimidation**
 - Porcupine fish inflates itself
 - Deceive predator about easy of eating prey
- **Fighting**
 - Horns and antlers can be used in defense
- **Agility**
 - Grasshoppers powerful jumping ability
- **Armor**
 - Shells of turtles provide strong defense
 - Beetle exoskeleton
- **Masting**
 - Synchronous production of progeny satiate predators and allow some young to survive
 - Seed herbivory
 - Periodical cicadas

Plants and Herbivores

Herbivory Defenses - adaptations that have developed to protect plants from being eaten by animals

- **Physical defenses** - sharp spines, thorns, sticky hairs, and tough leaves
- **Chemical defenses** - compounds that are poisonous, or bad tasting; array of unusual and powerful chemicals
 - **Secondary metabolites** - not part of primary energy generating metabolic pathway
 - Alkaloids (nicotine in tobacco, morphine in poppies, cocaine in coca, and caffeine in coffee), phenolics (lignin in wood and tannin in leaves) and terpenoids (in peppermint)
 - Over 25,000 compounds

Herbivores can overcome plant defenses:

- **Detoxify using 2 pathways**
 - **Oxidation** - catalysis of secondary metabolite to corresponding alcohol by mixed-function oxidases
 - **Chemical conjugation** - unites results of oxidation with another molecule to create inactive and readily excreted product

Symbiosis

Symbiosis - a close and permanent relationship between organisms of different species; three types exist

- **Parasitism** - one organism feeds off another, but does not normally kill it outright; predatory organism is termed a parasite and the prey a host
 - *Parasitic Flowering Plants*
 - **Holoparasites** - lack chlorophyll and are **totally dependent** on the host plant for their water *and* nutrients
 - *Rafflesia arnoldii*, lives most of its life within the body of its host with only the flower developing externally (largest known flower in the world)
 - Smells like a dead body
 - **Hemiparasites** - generally do photosynthesize, but they lack a root system to draw water and thus depend on their hosts for that function
 - Example: Mistletoe
- **Commensalism** - one species has a positive effect on them while the other is neither helped nor harmed
 - **Epiphytes** - plants that live atop other plants
 - Some epiphytes growing in trees do not harm the trees
 - **Phoresy** - one organism uses another for transportation; can have a large impact on reproductive success
 - Flower-inhabiting mites use hummingbird nostrils.
 - **Cheating** - when we see organisms exploiting a member of this relationship
 - Examples:
 - Grass-pink orchid produces no nectar, but it mimics the nectar-producing rose pogonia and is therefore is still visited by bees
 - Bee orchid - looks and smells like a female bee
 - Male bees pollinate inadvertently when they try to "mate"
 - Plants cheat seed-dispersal agent (such as a mouse) out of a meal with barbs or hooks on seeds.
 - Common examples:
 - "Hitchhiking" on another organism such as a shark to reduce the need to waste energy on swimming
 - Barnacles are mollusks that attach to the skin of whales. The barnacle does *not* hinder nor aid the whale.
 - The barnacle is a filter feeder and benefits from the constant flow of water.
- **Mutualism** - both species benefit from this relationship
 - **Trophic mutualism** - utilize a common resource
 - Examples:
 - Leaf-cutting ants and fungus
 - Ants chew up leaves to feed to fungus they care for
 - **Defensive mutualism** - animals *defends* a plant or herbivore
 - **Facultative mutualism** - since they *can* live apart
 - Ants protect aphid and aphid secretes honeydew.
 -
 - **Obligatory mutualism** - since neither can live without the other

- Ants nesting in acacia trees defend the tree and trim away competing plants.
 - The ants nest inside the acacia's large thorns and receive food and shelter from the plant. The ants protect the acacia from herbivory.
- **Dispersive mutualism** - involve pollination and seed dispersal
 - Allows the fruit to have its offspring dispersed and the organism eating it gets nutrition from its fruit
- **Broader examples:**
 - A bird eating the ticks of the back of an antelope,
 - Flowers and insects have a mutualistic relationship
 - Between flowers and insects, the flower provides the insect with nectar, and the insect helps the flower to reproduce by spreading pollen.
 - Termites have a particular bacterium that lives in their guts to help digest the wood eaten and the termite provides the bacteria with shelter, warmth, food, and water.

Dynamics of Ecosystems - Biogeochemical Cycles

Wednesday, June 5, 2019

11:12

Ecosystem - includes all the organisms that live in a particular place, **PLUS the abiotic environment** in which they live and interact

Overall Biogeochemical Cycles

- Carbon Cycle
- Water Cycle
- Nitrogen Cycle
- Phosphorus Cycle
- Sulfur Cycle

The Carbon Cycle

Carbon dioxide travels efficiently through water.

Ways Carbon Travels Through Ecosystems

A major way that carbon travels through ecosystems is **photosynthesis**:

- Plants use carbon dioxide (CO₂) along with water and sunlight to produce glucose (sugar) and release oxygen
- Chemical reaction:
 - $6\text{H}_2\text{O} + \text{CO} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

Cellular respiration:

- Taking sugars *from* consumed plants/food, using oxygen to break them down, and release CO₂ in the process
 - Is a way for carbon to *return* in a gaseous state from its turned solidified state
 - Along with photosynthesis, these form the basis of the carbon-oxygen cycle
- Chemical reaction:
 - $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2$

Consumption:

- This is a heterotrophic feature of the ecosystem.
- Animals pass along organic compounds feeding
 - Wastes that are produced are broken down by decomposers such as bacteria and fungi from this act of consumption
 - CO₂ is added to the atmosphere of an ecosystem as a whole

Decomposition:

- **Decomposers** - organisms that feed on dead organic material (detritus)
 - "Detritus" -> breaking down materials from other organisms
 - Decomposers exist to break down organisms into organic compounds
 - CO₂ is *returned* to the atmosphere during this process
 - **Microbial decomposers (bacteria and fungi = microflora)**
 - **Bacteria** are major decomposers of dead animals
 - Aerobic bacteria
 - Anaerobic bacteria (no oxygen; use other electron acceptors)
 - **Fungi** are major decomposers of dead plants
 - **Detritivores** – animals that feed on detritus, including dung
 - Microfauna and microflora – protozoans and nematode worms

- Mesofauna – mites, potworms (annelid) and springtails (insect)
- Macrofauna and megafauna (> 20mm):
 - Terrestrial environments: Earthworms, snails, millipedes
 - Aquatic environments: Annelid worms amphipods and isopods, crabs and mollusks
- Microbivores – feed on bacteria and fungi (amoebas, springtails)

Combustion:

- Any burning of fossil fuels such as oil, coal, natural gas, wood, etc.
 - Releases the energy stored in these organic compounds
 - Large amounts of CO₂ are released

Overall, globally, the carbon cycle may proceed faster in one direction:

- This can cause large consequences if continued for many years
- Earth's present reserves of coal, and other fossil fuels were built up over geological time
 - The human burning of fossil fuels is creating large imbalances in the carbon cycle due to this uneven burning of these reserves.
 - The concentration of CO₂ in the atmosphere is going up year by year.

The Water Cycle

Water is a taxing surface in which other chemicals/elements can travel around:

- All life depends on the presence of water.
- 60% of the adult human body weight is water
- The amount of water available determines the nature and abundance of organisms present in an ecosystem
 - It can be synthesized and broken down:
 - Synthesized during cellular respiration
 - $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$
 - Broken down during photosynthesis
 - $6H_2O + CO \rightarrow C_6H_{12}O_6 + 6O_2$
- Water has a very dynamic structure that allows for it to change states and carry other chemicals with it
 - Known as the "universal solvent"
- Acid rain - any form of precipitation that is unusually acidic
 - Usually around a pH of 5
 - The production of acid rain is caused by nitrogen and sulfur dioxides originating from air pollution

Any changes in the supply of water to an ecosystem can radically alter the nature of the ecosystem:

- Deforestation - disrupts the local water cycle
 - Water that falls in ecosystems affected by deforestation *drains away*
 - Tropical rain forests turn into semiarid deserts
 - The trees and other plants act as sponges to keep the water in that ecosystem
 - Act as reservoirs to retain water

The Nitrogen Cycle

Nitrogen is abundant around us, however, not in a form that we can technically use:

- Nitrogen is a component of all proteins, nucleic acids, and chlorophyll
 - Usually the element in the shortest supply

- Plants and animals (all living things) need nitrogen to make proteins
- The atmosphere is 78% nitrogen
- Availability of nitrogen:
 - Most plants and animals cannot use N_2
 - Instead, they use NH_3 and NO_3^- from bacteria in the soil; they convert the unusable nitrogen from the air into nitrates that plants can use, where animals eat the plants to then receive their proteins
 - Ammonia and nitrates

Nitrogen Cycle Processes:

1. **Nitrogen fixation** – only certain bacteria are able to convert to N_2 and release ammonia (NH_3) or ammonium (NH_4^+)
 - a. "Fix" the nitrogen to be in a form that is usable
2. **Nitrification** – soil bacteria convert NH_3 or NH_4^+ used by plants
3. **Assimilation** – plants and animals incorporate ammonia and nitrates
4. **Ammonification** – conversion of organic nitrogen to NH_3 or NH_4^+ by bacteria and fungi
 - a. This is the most common pathway for nitrogen to enter the soil
5. **Denitrification** – reduction of nitrate (NO_3^-) to gaseous nitrogen (N_2) by bacteria returns a small amount of nitrogen to the atmosphere

Ways to Modify Nitrogen

- **Nitrogen-fixing bacteria** - convert nitrogen in the air into ammonia (nitrogen fixation)
 - This allows for the nitrogen to be converted into a form that can be used
- **Decay bacteria** - organisms that take nitrogen from dead organisms and convert it into ammonia
- **Nitrifying bacteria** - takes ammonia from other processes to turn it into nitrates (nitrification)
 - To be used by plants
- **Denitrifying bacteria** - release nitrogen (N_2) back into the air (denitrification)
 - Occurs in oxygen-poor soils
 - Allows for the nitrogen to travel throughout the atmosphere to other ecosystems

The Phosphorus Cycle

There is ***no atmospheric aspect*** of phosphorus present within this cycle:

- Travel occurs aqueously and through tissues
- Phosphorus is required by all organisms
 - Occurs in nucleic acids, membranes, ATP
 - There is no significant gas form
- Phosphorus is a ***limiting element*** in most aquatic system
 - To have phosphorus, it must be deposited into the system first
 - Most phosphorus = more aquatic productivity
 - **Eutrophication** - elevated nutrient levels leads to an overgrowth of algae and subsequent depletion of water oxygen levels
 - There is an initial boost of algae levels in the water
 - Can cause aquatic life to suffocate
 - Real-life occurrence:
 - Lake Erie became eutrophic in the 1960s due to fertilizer runoff
 - Reduction of discharge by 80% has led to recovery

The Sulfur Cycle

A large aspect of sulfur is the buildup of sulfur that accompanies the burning of fossil fuels:

- Fossil fuel burning has altered the sulfur cycle the most
 - Large amounts of SO_2 produced
 - SO_2 is soluble in water and returns to Earth as weak sulfuric acid (H_2SO_4), or natural acid rain (pH 5.6, sometimes even as low as pH of 4.1-4.5)

Ecosystem Ecology - Energy and Climate Change

Friday, June 7, 2019

11:00

Energy and **matter** move through an ecosystem in very different ways:


- Energy moves through an ecosystem in a one-way path.
 - Energy enters an ecosystem in the form of **sunlight** and exits the ecosystem in the form of **heat**.
 - This energy **cannot** be recycled.

Primary producers - these organisms undergo photosynthesis, converting sunlight into chemical energy (where some heat escapes)

Primary consumers - those organisms that consume primary producers and gain the energy that they gained from the photosynthesis that they performed

Energy **reflects off of** and **absorbs into** materials:

- Reflecting energy keeps a surface cool
- Absorbed energy heats up the surface
- **Albedo measure** - a measure that describes how reflective a surface is
 - Low albedo level = more absorbent of energy
 - Brings energy in = heating up
 - High albedo level = more reflective of energy
 -

	Surface	Albedo
Reflective  Absorptive	Snow	0.4-0.9
	Desert Sand	0.4
	Grasslands	0.25
	Forest	0.1-0.2
	Ocean	0.1

Map Activity

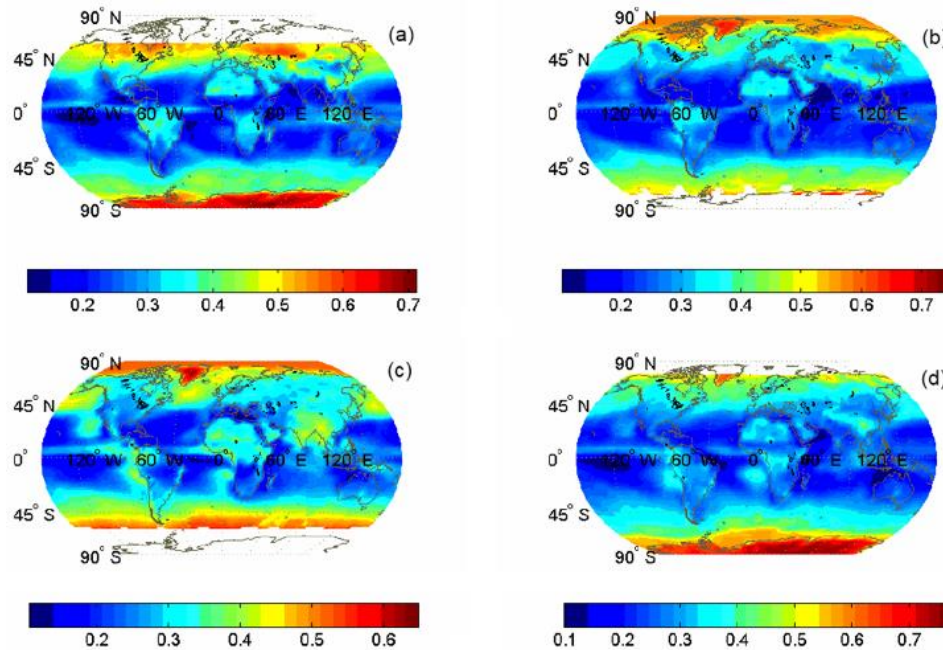


Fig. 2. Long-term (1984–1997) average global distribution of planetary albedo (in %) at the top-of-atmosphere for the mid-seasonal months of (a) January, (b) April, (c) July, and (d) October.

Objectives

- Determine the direction of the scale
 - Low = more absorbent, low albedo --> blue
 - High = more reflective, high albedo --> red
- Determine the northern hemisphere season for each map
 - A = Winter
 - B = Spring
 - C = Summer
 - D = Autumn
- Explain the variation over time for:
 - North America
 - Northern Africa

Feedback Loops

Positive feedback loop:

- As ice melts, this water enters the ocean, causing an increase in temperature
- Loop: Climate warming --> ice melts --> lower surface albedo --> energy absorbed instead of reflected (loop starts again)

Negative feedback loop:

- High temperatures lead to dense low cloud coverage over water
 - Low clouds have a high albedo (more reflection, less absorption)
- Loop: Climate warming --> more evaporation (cloud coverage lowers in their location) --> increased cloud coverage --> higher albedo levels --> energy reflected instead of absorbed (temperature will decrease) [reflected energy leaves Earth] --> climate cooling

CO₂ gas (along with other gasses) insulates the atmosphere:

- Ways that CO₂ is added to the atmosphere?

- Cellular respiration
 - Burning of fossil fuels
 - Decomposition of dead organisms
- Ways it's removed?
 - Through the process of photosynthesis
- Effects of deforestation?
 - Increase of CO₂ and decrease amount of organisms that reclaim the CO₂

Biodiversity and Conservation Ecology

Biodiversity Crisis

The majority of recent extinctions have occurred in the past 150 years

- Increase in the rate of extinction is the heart of the biodiversity crisis
 - Birds were recognized as critically endangered increased 8% from 1996 to 2000
 - Half of Earth's plant species may be threatened
 - 2/3 of vertebrate species could perish by the end of this century

Factors Responsible

Variety of causes for extinctions:

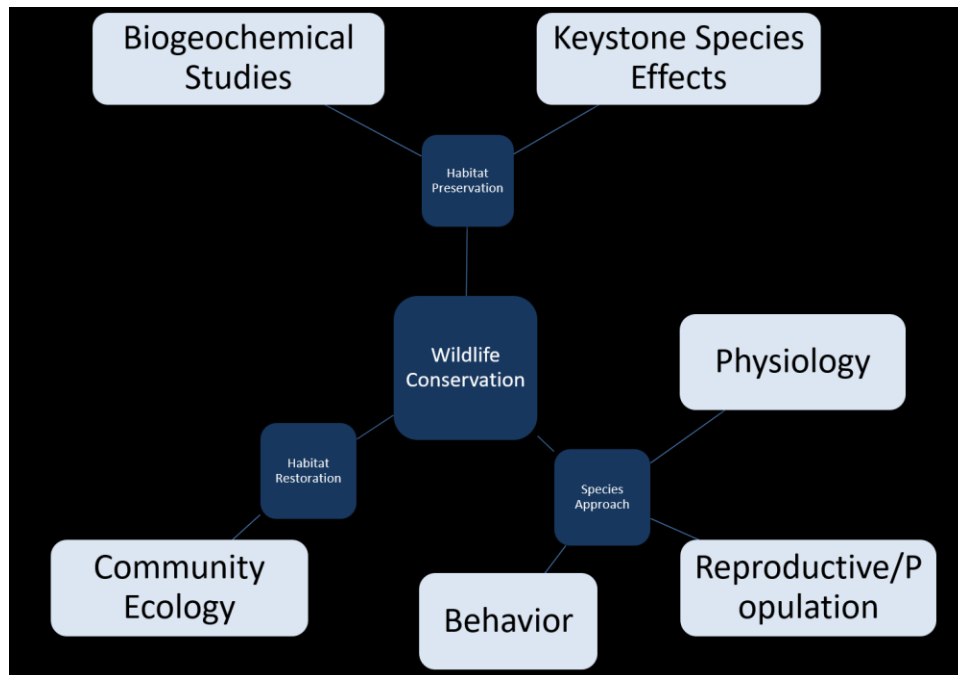
- Overexploitation
- Habitat loss
- Introduced species
- Disruption of ecosystem interactions
- Pollution
- Loss of genetic variation
- Catastrophic disturbances

Conservation Strategies

Habitat conservation focuses on:

- **Megadiversity countries** - greatest number of species
 - Just 17 species are home to nearly 70% of all known species
 - Brazil, Indonesia, and Columbia are at the top of the list
 - Don't necessarily contain the most unique species
 - 208 mammals species are shared between Peru and Ecuador (part of the 17)
- Areas rich in **endemic species**
 - Found only in a particular place and nowhere else
 - Hot spots have the widest variety of endemic species with at least 1,500 species of vascular plants *and* lost 70% of original habitat
 - **Hotspots** - areas where species have high endemism and are disappearing at a rapid rate; red areas are hotspots
 - Usually around the Equator, allowing for more energy to be gained
- Single species approach:
 - **Indicator species** - species whose status confirms the overall health of an ecosystem
 - Corals are good indicators of siltation
 - Proliferation of the dark variety of the peppered moth (*Biston betularia*) has been shown to be a good indicator of air pollution
 - Polar bears are an indicator for global climate change
 - **Umbrella species** - habitat requirements are so large that protecting them also protects many other species in the same habitats

- A Northern spotted owl pair needs 800 hectares of old-growth for survival and reproduction
 - To protect the *Zea diploperennis* grass
- **Flagship species** - single large or instantly recognizable species
 - Attractive and engendered public support
 - Examples: American buffalo, giant panda, Florida panther
- **Keystone species** - species within a community that have a role out of proportion with their abundance
 - Beavers --> habitat engineers
 - Palm nuts and figs produce fruit during otherwise fruitless times and are critical resources
- Restoration ecology:
 - Full or partial **repair or replacement** of biological habitats and/or population that have been damaged
 - Can restore or rehabilitate a habitat
 - Can return species into the wild following captive breeding
 - **Bioremediation** – use of living organisms to detoxify polluted habitats



Final Exam Study Guide

Tuesday, June 11, 2019

11:40

BIO126 Final Exam will cover:

- 30% Cumulative for Ecology and Relevant Physiology
 - Intro to Physiology/Homeostasis/Endocrine System
 - Homeostasis
 - Negative Feedback loops
 - Endocrine System - Hormones
 - Classes of Hormones
 1. Protein-based or peptide based (hydrophilic)
 2. Amino acid derivatives (lipophilic)
 3. Steroids (lipophilic)
 4. Lipophilic - lipid-soluble; travel on transport proteins in blood --> bind to intracellular receptors, allowing it to enter the plasma membrane thru a lipid bilayer
 5. Hydrophilic - water-soluble; all other hormones are freely soluble in blood and do not need a medium to travel --> bind to extracellular receptors
 - Have longer active periods
 - Pituitary Gland --> controlled by the hypothalamus
 - Anterior pituitary
 1. Epithelial tissue in origin, containing cells that produce *anterior pituitary hormones*
 - These hormones that target endocrine tissues often form part of a hormone cascade
 - Posterior pituitary
 1. Only STORES hormones, doesn't produce anything
 2. Nervous tissue in origin --> same material as the hypothalamus, an "extension" of the hypothalamus
 3. Stores and releases two hormones, both produced by neuron cell bodies in the hypothalamus
 - ADH
 - Oxytocin
 - Cardiovascular (Circulatory) System
 - Functions of the Circulatory System
 - Blood and Its Contents
 - Formed Elements
 - Types of Circulatory Systems
 - Organization of Vertebrate Circulatory Systems
 - The Cardiac Cycle
 - Electrophysiology
 - Blood Flow, Pressure, and Regulation
 - Baroreceptor Reflex
 - Respiratory System
 - Functions of the Respiratory System
 - Types of Respiratory Systems/Organs

- Adaptations for Gas Exchange
 - Example: Gills vs Lungs
- Control of Respiration
- Principles governing gas exchange
 - Partial pressure
 - Solubility
 - Gas levels in the blood monitoring and transport
 1. Oxygen-hemoglobin dissociation curve
- Osmotic Regulation/Excretory System
 - Functions of the Excretory System
 - Regulation of extracellular fluid volume and blood pressure
 - Regulation of osmolarity
 - Maintenance of ion balance
 - Homeostatic regulation of pH
 - Excretion of wastes and poisons
 - Production of hormones (part of the diffuse endocrine system)
 1. ADH acts on the kidneys and aldosterone acts on the kidneys
 - Osmolarity and Osmotic Balance
 - Vertebrate Kidney,
 - Evolutionary of the Vertebrate Kidney
 - Hormones in the Kidney
- Nutrition and Digestive System
 - Gastrointestinal Tract
 - Stomach
 1. Contains mucous cells, chief cells, and parietal cells
 - Accessory Organs
- Immune System
 - Functions of the Immune System
 - Innate Immunity
 - External defenses
 - Internal defenses
 1. Phagocytic cells
 2. Natural killer cells
 3. Antimicrobial proteins and peptides
 4. Inflammatory response
 - Adaptive Immunity --> exclusive to vertebrates
 - Humoral response
 1. B cell
 - Cell-mediated immune response
 1. Cytotoxic T cells
 2. Helper T cells
- Nervous System
 - Organization of Nervous System
 - Central Nervous System
 - Peripheral Nervous System
 1. Sensory pathways
 2. Motor pathways

- Somatic (voluntary) nervous system
 - Stimulates the skeletal muscles
 - Autonomic (involuntary) nervous system
 - Sympathetic ("fight or flight") nervous system
 - Parasympathetic ("rest and repose") nervous system
- Cells of the Nervous System Electrical Physiology of a Neuron
 - Resting Membrane Potential
 - Generation of an Action Potential
 - Propagation of an Action Potential
 - Events at Synapses - Communication Between Cells
 - Neurotransmitters
- Neuromuscular Junction
 - Events at a Neuromuscular Junction
 - Structure of a Muscle
 - Contraction of a Muscle
 - Excitation - Contraction Coupling
 - Sliding Filament Theory: Cross-Bridge Cycle
- Sensory Systems
 - Overview of Sensory Receptors
 - Four-step process:
 1. Stimulation
 2. Transduction (think of a change)
 3. Transmission
 4. Interpretation
 - Three major classes of receptors:
 1. Mechanoreceptors
 2. Chemoreceptors
 3. Electromagnetic receptors
- Behavioral Ecology
 - Organismal Ecology
 - Behavior Types
 - Nature
 - Nurture
 - Nervous and Endocrine Systems
 - Behavioral Genetics
 - Learned Behavior
 - Animal Cognition
- Animal Behavior and Sensory Biology
 - Types of Communication
 - Applications for Communication
 - Process of Communication
- Reproduction
 - Reproductive Strategies
 - Sex Determination
 - External/Internal Fertilization
 - Vertebrate Fertilization

- Human Reproduction System
 - Male Reproduction System
 - Female Reproduction System
 1. Ovarian Cycle --> regulated by FSH and LH
 2. Uterine Cycle --> regulated by estrogen and progesterone
 - Mammalian Reproductive Hormones
- Contraception
- 70% Untested Material
 - Population Ecology
 - Demography
 - Density
 - Survivorship Curves
 - Type I
 - Type II
 - Type III
 - Life Tables
 - Reproductive Strategies
 - Semelparity
 - Iteroparity
 - Age classes
 - Life History Strategies
 - r-selected species
 1. Opportunists --> rapid growth, short life span
 - K-selected species
 1. Competitors --> slow growth, long life span
 - Community Ecology
 - Community Structure
 - Species richness
 - Species diversity
 - Roles in the Ecosystem
 - Keystone species
 1. Habitat engineers
 - Niche
 1. Fundamental niche --> entire niche that a species is capable of using, based on physiological tolerance limits and resource needs
 2. Realized niche --> *actual* set of environmental conditions, presence or absence of other species, in which the species *can* establish a stable population
 - Niche-Driven Principles
 - Competitive Exclusion Principles
 - Resource Partitioning
 - Character Displacement
 - Community Dynamics
 - Disturbance
 1. Succession
 - Primary succession

- Secondary succession
 - Pioneer organisms
 - Interspecific Competition
 - Red-Queen Hypothesis
 - Predation
 1. Anti-Predatory Strategies
 - Chemical defense
 - Aposematic coloration (warning coloration)
 - Cryptic coloration (camouflage)
 - Mimicry --> form of deception used by prey as a means of defense against attack
 - Displays of intimidation
 - Fighting
 - Agility
 - Armor
 - Masting
 2. Herbivory Defenses
 - Physical defenses
 - Chemical defenses
 - Secondary metabolites
 - Symbiosis
 - Parasitism
 - Commensalism
 1. Epiphytes
 2. Phoresy
 3. Cheating
 - Mutualism
 1. Trophic mutualism
 2. Defensive mutualism
 3. Dispersive mutualism
 - Facultative mutualism --> can live apart from each other
 - Obligatory mutualism --> neither can live without the other
- Dynamics of Ecosystems – Biogeochemical Cycles
 - Carbon Cycle
 - Methods of travel:
 1. Cellular respiration
 2. Consumption
 3. Decomposition
 4. Combustion
 - Water Cycle
 - Nitrogen Cycle
 - Cycle Processes:
 1. Nitrogen fixation
 2. Nitrification
 3. Assimilation

- 4. Ammonification
 - 5. Denitrification
 - Ways to Modify Nitrogen:
 - 1. Nitrogen-fixing bacteria
 - 2. Decay bacteria
 - 3. Nitrifying bacteria
 - 4. Denitrifying bacteria
 - Phosphorus Cycle
 - Sulfur Cycle
- Ecosystem Ecology – Energy and Climate Change
 - Primary producers
 - Primary consumers
 - Energy reflection/absorption
 - Albedo measure
 - 1. Low albedo measure = more absorbent of energy
 - Brings energy in = heating up
 - 2. High albedo measure = more reflective of energy
 - Biodiversity and Conservation Ecology
 - Biodiversity Crisis
 - Conservation Strategies
 - 1. Megadiversity countries
 - 2. Endemic species
 - 3. Single species approach:
 - Indicator species
 - Umbrella species
 - Flagship species
 - Keystone species
 - 4. Restoration ecology
 - Bioremediation