

LS 7C Notes

Lecture Notes

4/2 - Week 1

- Each individual cell is autonomous in that it can survive on its own. This is true even in multicellular organisms.
- One characteristic of life is to be able to process energy, most commonly as ATP.
- Cell must be able to have metabolism, reproduce, and to grow.
- Cells in our body have to communicate though, even though they can survive on its own. We need this in order to perform complex movement. This is characteristic of multicellular organisms.
- Cells need to communicate over short and long distances.
- Building a multicellular organism involves cell specialization, cell communication, and cell-cell adhesion (cells building tissues and organs).
- The smaller a cell is, the more efficient they are.
- Cell communication is integral in achieving homeostasis, which is keeping a constant internal environment regardless of the outside environment.
 - For example, the temperature in your body staying the same and changing behaviour depending on the outside temperature.
 - Another example is ATP production, where if the concentration is too high then less ATP will be made because PFK will be inhibited, and for low concentration, then PFK is activated and more ATP is made.
 - Both are negative regulation.
- Hormones are sometimes called chemical messengers. These can tell the body whether to raise/lower glucose for example.
 - Function of insulin is to lower the sugar level when it is high.
 - Function of glucagon is to raise the sugar level when it is low.
- Endocrine system is the system of hormones.
- Anything that travels in the blood means that every single cell will be exposed to that hormone/signal.
 - Every cell will be *seeing* that insulin, but only certain cells *respond* to that insulin.
- The cells that respond to a hormone are determined by whether or not the cell has the correct receptor.
- The messenger/hormone would be useless without meeting the cell with the correct receptor.
- If a cell has the right receptor for a messenger/hormone, then the cell will have some response.
- A receptor on the membrane of the cell is called extracellular receptor. Intracellular receptor is one that exists inside of the cell.
 - This depends on whether the messenger can permeate across the membrane.

- If so, have the receptor on the inside, and if not, then keep it on the outside.
- Messengers that are cholesterol based are permeable through the membrane.
 - Steroid hormones, in general, are also membrane permeable.
- The extracellular receptors will use a cascade of signals to pass the message of the arrival of the hormone to create some cellular response.
 - Intracellular receptors also do transduction as well though.

4/4 - Week 1

- Location of the receptor depends on the messenger and whether it can pass through the membrane.
- One type of intracellular receptor, but many types of extracellular ones (G protein, ion channel, etc).
- Intracellular receptors normally activate genes inside of a cell, thus causing a lot of change. With extracellular ones, the magnitude of effect varies a lot.
- Signal amplification happens with extracellular receptors because the signal increases a lot through the cascade effect.
- An example
 - Insulin binds to a receptor on a cell in the liver, and thus indicates that that cell should make more glycogen.
- The most important extracellular receptor is the G protein coupled receptor
- The messenger bound to the receptor will *eventually* disassociate from the receptor, but this also depends on binding affinity of the messenger. The receptor doesn't actually need to receive a termination signal.
 - Binding affinity describes how long the signal stays bound.
- A signal leaving the receptor doesn't necessarily mean that the signal pathway is terminated. We need some other termination signal.
- Insulin causes phosphorylation through a kinase, not through G protein.
- Kinase always phosphorylates, and adds a phosphate group. Phosphatase removes a phosphate group.
- All the proteins in the cell don't necessarily become active when you phosphorylate it.
- A tissue is a group of cells that have a common function. For the cells to have a common function, they have to have an efficient method of communication and they need a strong network so that they can adhere physically.
- The key is synthesizing a bunch of proteins that make up the cytoskeleton.
- Microtubules provide pathways in the cell so that material can be moved inside the cell. Motor proteins also help facilitate this.
- Energy released during hydrolysis of ATP is used to power the motor proteins.

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- Secretory means that the vesicle is transported to outside and that movement is facilitated by kinesin. Dynein takes material inside the cell.

- Smaller cells are more efficient than larger cells.
- Surface area of the cell refers to the size of the plasma membrane, and thus this determines how much exchange the cell can have with the outside cell. The volume refers to the capacity of the cell to have chemical reactions.
- Volume normally increases at a faster rate than that of surface area. Cell can exchange at a different rate than it can process when the cell gets very big. Thus, we need to keep that SA/V ratio as high as possible. The higher, the more efficient cell.
 - Smaller cells are better because they have a more adequate SA/V ratio.
- When we have lots of small cells, they need to communicate and stick together. Cell have proteins for those functions.
- Adherens and desmosomes are made for creating strong connections. This is used to muscle cells and in the bladder. Both are for strengthening. Adherens show ways to unite *all* the cells together (zipper), whereas as desmosomes unite one at a time (button).
- Gap junctions give communication between animal cells in order to make sure the entire organ is synchronized together. It allows material to be exchanged in the cells.
- Tight junctions create a seal in the outside of the cell that prevent anything going in and out. They prevent any leakages.
- When it comes to structural integrity of the *entire* tissue, adherens junctions would get affected the most.
- Desmosomes would be useful for anchoring cells together through their membranes.
- Epithelial cells need to adhere to neighboring cells as well as to the environment they are around which means the extracellular matrix.
- Epithelial cells are very close to each other. They are also polar in that the cells size are different. There is always one side that faces a cavity (apical side) and the other side connects to the ECM (basal side). The outside is the apical surface, that's what we're touching when we touch the skin.
 - Substances going from apical to basal side is absorption, and vice versa is secretion.
- Many functions for epithelial cells, and most are about anchoring to specific surfaces. Wherever cavities are, you'll probably find those epithelial cells.
- Fibroblasts enable collagen production, and this decreases when we age.

4/9 - Week 2

- The amount of the messengers/hormones circulating in the body has to be regulated.
- Maintaining the consistency level of internal environment is homeostasis. This involves maintaining the right level of hormones.
- The process of maintaining something X , there must be
 - A receptor/sensor which measures X.
 - A control center which is the decision maker, and the place that is evaluating whether X is too high or low. This must have a set point. We need to know what

is a low or high value for X. And after that, we need to decide what change to make.

- An effector which carries out the mechanism for regulation (the change decided in the previous step). This effector should restore the deviation and if that doesn't happen, something is wrong in this step.
- The cell response is not really part of the above feedback system.
- Pancreas is the receptor in the glucose/insulin example because it is the one that detects the blood glucose levels, and releases insulin as a result.
- We're not saying that temperature should be one constant value, but there should be a specific range in which temperature should be in. This gives us time to change in order to restore to set point.
- When you get a cold, you have pyrogens that enter the body, and these inhibit heat sensing neurons and excite cold sensing neurons, and this causes the brain to send a message that the body is colder than it really is, and the set point is raised.
- Receptors and control centers are almost always constant in the body, but the effector could change since different responses may be needed.
- Changing metabolism is a common response to different temperatures. There can also be behavioral changes as well.
- Negative feedback specifically refers to regulating X by opposing the influences from the environment.

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- Fight or flight response is because of epinephrine release which binds to some receptors and then those cells will turn glycogen into glucose which gives you that necessary energy.
- To analyze how the cell does this, we can use cell homogenization which breaks open cells and mixes everything together. Then, we do cell fractionation which separates different cellular components, for example into the membrane fraction and the cytosol fraction.
- Second signaling molecule generated by the cell in response to a signal which is the first messenger which in most cases is the hormone, like epinephrine for example.

4/11 - Week 2

- Animals can have behavior regulation as well as temperature regulation.
- Changing blood flow to the skin is an important effect of environment.
 - If it's very hot, then we turn red.
- Heat exchange can be concurrent flow or countercurrent flow.
- Homeostasis includes regulating sugar levels and also temperature.
- Endocrine system refers to keeping that homeostasis but also with the release and regulation of hormones.
- Endocrine system is a system of glands, and each of them release hormones, which go to target cells and make a specific function occur.

- Calcium is an important ion to regulate since a lot of tissues and cell get affected by it. It has a set point in the point, and that has to be regulated. It is regulated by two hormones.
 - Parathyroid hormone increases calcium concentration
 - Calcitonin decreases calcium concentration
 - These are antagonistic hormones.
- Peptide hormones are hydrophilic and therefore they can travel in the blood/water and therefore they don't need a protein to help it travel.
 - All peptide hormones bind to a transmembrane or extracellular receptor. This is because they are polar and cannot permeate through the membrane.
- Steroid hormones are normally the ones that have intracellular receptors.

4/13 - Week 2

- The thyroid gland responds to the level of calcium in the blood.
- Thyroid hormones are not steroids or peptides, but they are amines. T3 and T4 regulate metabolism, but they themselves are also regulated.
- *Every single hormone* in the endocrine system needs to travel to places using the blood.
- Hypothalamus commands the anterior gland by releasing TRH. That gland is in charge of the thyroid gland by releasing TSH. That thyroid gland releases T3 or T4. The hypothalamus knows when to release because it knows the set point of T3/T4.
- Thyroid is the only place that can store iodide. The steps are
 - Make thyroglobulin
 - Get iodine from diet
 - Incorporate iodine with the tyrosine and convert thyroglobulin into something else
- Low levels of iodine would cause decreased levels of T3/T4 since T3/T4 cannot be made without dietary iodine.
- Only the posterior pituitary releases neurohormones into the bloodstream.
- Only the anterior pituitary releases hormones to maintain homeostasis.
- Sperm have acrosomes that are enzymes that help it drill into the egg cell.
- Ovaries release estrogen and progesterone.
- Aromatase converts androgens to estrogens. Activity of aromatase is correlated with estrogen levels.
 - Highest activity in early to mid follicular phase.
 - Low levels would mean that testosterone isn't converted into estrogen, and thus we'd have increased levels of testosterone.

4/16 - Week 3

- Everything that your body does is controlled by the nervous system.
- Nervous system processes the information that we get from the senses.
- Hormones are slower than the nervous system. Neurons are quick because they exhibit electrical properties.

- Same way that your wire conducts electricity, neurons conduct as well. Electricity in bio is the movement of ions.
- Membrane potential refers to difference in voltage inside the neuron - outside of the neuron. Difference is created by differences in ion concentrations on either side of the membrane.
- Inside the neuron, we have very large negatively charged proteins that don't go anywhere and so the neuron will have a negative resting state.
- Only two ions, sodium and potassium, move in and out of the cell. By diffusion, sodium moves inward (b/c more sodium outside than inside) and potassium moves outward (b/c more potassium inside than outside).
- All cells, not just neurons, have a resting membrane potential.
- At rest, potassium tends to be more permeable than sodium. This potassium leak (caused by leak channels) is what causes the cell to have a negative membrane potential at rest.
- We never want the cell to reach equilibrium because we need that membrane potential. Sodium and potassium never reach that equilibrium because we have the sodium potassium pump which uses ATP to move sodium and potassium against their concentration gradient.
- Because the membrane is permeable only to a certain number of molecules, that's one of the reasons it can keep its negative membrane potential.
- Chemical gradients come from concentration differences. Electrical gradients come from charge separation.
 - When sodium diffuses inside, it is due to the chemical gradient because there is less sodium inside but also due to the electrical gradient because there is a difference in charge from the outside to the inside of the cell (which is negative at rest).
- Hyperpolarization is when membrane potential becomes more negative, and depolarization is when the membrane becomes less negative.
- The length of neuron connections to one another can be very large.
- On axons, they have myelin that are insulators which allow the signal to travel faster.
- If a neuron gets a signal from a neighbor neuron, the first action potential occurs at the axon hillock.
- Graded potential refers to the electrical activity in the dendrites and cell body.
- Action potential is always depolarizing, while graded potential can be either depolarizing or hyperpolarizing.
- Axon hillock is where the cell sums up the inputs and decides whether or not we get that action potential. At the axon hillock, you also have more permeability which means a greater chance to getting a specific membrane potential.
- 3 types of channels: Leak channels, voltage gated channels, ligand gated channels.
- Leak channels are found everywhere on the body of the neuron, on the axons, on the dendrites, etc. You'll also find ligand gated ion channels in the plasma membrane of a neuron's dendrites and the cell body. Ligand is the neurotransmitter. The channels are the main channels that start the graded potential.

- There are ligands that open specific channels and if that channel is permeable to positive ions, then you have EPSP which depolarizes the cell. If negative ions, then you have IPSP which hyperpolarizes.
- Neurons receive both IPSP and EPSP.
- Dendrites integrate signals from many synapse to make a single decision.

4/18 - Week 3

- Neurons influence the response of the receiving by sending excitatory or inhibitory signals. Because neurons receive lots of inputs at the same time, neurons sum up the inputs and decide whether or not to send an action potential based on a single threshold of voltage.
- The initial summation of the IPSP and EPSP brings the voltage from the resting potential to the threshold. That is the slow depolarization. After it gets to the threshold, there is rapid depolarization until a peak, and then repolarizes past the resting point, and then gradually reaches resting potential again.
- No such thing as small action potential or large action potential.
 - Graded potential can change the amplitude or duration
- That rapid depolarization happens because we have cations or positive charge entering the cell.
- Sodium comes in during depolarization, and potassium comes out during the repolarization phase.
- Repolarization refers to any stage when you're coming back to normal. The refractory stage is still hyperpolarization because of the overshoot.
- Myelin surrounding neurons (in vertebrates) let action potential signal travel faster.
 - Multiple sclerosis is a disease where the myelin are damaged
- For invertebrates, they don't have myelin and thus to compensate for that, the diameter of their axons are larger, and thus information can pass through at a faster rate.
- A synapse is a junction for communication between the axon terminal of the presynaptic cell and the dendrite of the postsynaptic cell.
- Presynaptic neuron will release neurotransmitters which are the messengers. The postsynaptic neuron will generate a graded potential based on the amount of neurotransmitters that activate the ligand gated channel and then ions enter the postsynaptic cell and then the receiving neuron will release an action potential if the voltage is high enough.
- Presynaptic neuron is always releasing the neurotransmitters because of the action potential.
- For people with depression, there are low levels of serotonin which is an example of a neurotransmitter. For drugs that help depression they try to manipulate the synapse so that the serotonin that the individual does have has a larger effect.
- Selective serotonin reuptake inhibitors block the function of those reuptake transports and thus make sure that serotonin stays around longer in the synaptic cleft and thus the concentration would increase.

- Graded potential happens in dendrites and cell body while the action potential starts in the axon hillock and moves to the axon terminal.

4/20 - Week 3

- Neuron, at the axon hillock, decides whether or not to fire an action potential, which depends on whether the additional voltage is enough to go from resting to threshold.
- Action potential takes time to propagate and thus some areas on the axon won't have any activity right at the moment the action potential is generated.
- Final outcome of an action potential is the release of neurotransmitters.
- A drug that blocks the calcium channels will block neurotransmitter release.
- Nervous system is split into central nervous system and peripheral nervous system
- Nervous system is responsible for detecting and responding to external influences.
- Brain and spinal cord makes up CNS and peripheral is everything else. PNS is connected to the external world and is sensing outside info. Then, that info will be sent to the CNS. Then CNS will make a decision and send info back to the PNS.
- Nervous system divide into two parts. CNS is for processing and PNS is for sensing.
- PNS is divided in 2 components
 - Somatic system is for voluntary actions.
 - Autonomic system is for involuntary actions and mainly controls our organs.
 - Broken up into sympathetic (fight or flight) and parasympathetic (rest and digest). Sympathetic doesn't always increase activity of *all* organs. It'll increase activity for some and decrease for others. But *in general*, fight or flight situations generally increase activity.
 - Never seeing both systems used simultaneously. Always under the influence of one.
 - Organs will receive information from both systems.
- In fight or flight situations, you'll see your heart rate increase and your pupils dilate, but not intestinal activity being increased, because that's not really necessary at the moment.
- Speech comprehension and speech initiation could be different areas within the brain, and people who have Wernicke's aphasia will be able to speak fluently but won't have much meaning or understanding in what the people are saying. They also cannot understand what other people are saying when they are being talked to. Broca's is kind of the opposite in that the patients can have trouble speaking fluently but the comprehension are relatively preserved.
- When a patient suffers a stroke, it cuts off the supply of blood to a region in the brain, and thus the patient will likely have trouble maintaining balance.
 - Inability to regulate body temperature is related to hypothalamus, problem seeing colors is occipital lobe, and muted sensory perception is peripheral lobe.
- A problem in one side of the brain affects the movement of the other side of the body.
 - Right brain controls left side, left brain controls right is the property of being contralateral.

- Primary motor cortex is the place for controlling the motion of our body.
- Interneurons process the information.
- Efferent transmission send info out, and afferent transmission brings info into the CNS.
- Sensory and motor neurons are located both in CNS and PNS. The interneurons, however, are only in the CNS.
- The knee jerk reflex is the fastest reflex in the body. It's the only one that doesn't have interneurons. This means less action potentials and only sensory to motor neuron connections.
- Somatosensory cortex is the main place that sensory information is processed and received.

4/23 - Week 4

- In all sensory structures, we must have a step that converts the stimulus to electrical activity because our brain can only understand electrical activity.
 - This is called a transduction or conversion step.
- We hear with our brain tbh because the brain interprets the info while the ear is just the passageway for this info.
- Endolymph fluid is found in the inner ear. Outer and middle ears are filled with air.
- Hair cells are the components that turn the sound vibrations into electrical signals.
- Hair cells in the cochlea as well as in the Organ of Corti. The hair cells will synapse with neurons. The hair cells are excitable and thus exhibit electrical activity.
- The bending of the hairs (stereocilia) on top of the hair cells cause a cascade of signals that end up with an electrical signal.
- If a stereocilia is permanently bent, then single pitch may be constantly perceived or a pitch may never be perceived. This depends on the bending direction.
 - Bending toward the tallest hair can lead to increase in frequency and vice versa.
- Brain detects sound through amplitude (loudness) and frequency (pitch).
- Different frequencies stimulate different hair cells along the basilar membrane.
- Hair cells don't exhibit an action potential, but show a graded potential which is enough to open the calcium channels and move the neurotransmitters.
- Mechanosensitive channels are dependent on movement. Bending in a specific direction will open the channel, while movement in the opposite direction will close it.
 - Potassium comes in and depolarization occurs.
- Kinocilium refers to the tallest hair. Movement in that direction causes the channel to open.
 - If the bending does happen, then neurotransmitters are released, but there is no action potential.

4/25 - Week 4

- With any sensation the only language the brain understands is through action potentials.

- The sensation of taste, of smell, of touch, all have an external stimulus and that stimulus needs to be converted to electrical activity. That step is called transduction.
- In hair cells, the unique thing is that potassium is the ion that causes depolarization.
- For vision, we have photoreceptors that respond to light. Light is energy and that energy becomes electrical signals.
- Accessory structures help get the stimulus to the right place.
 - In vision, we have structures that help to deliver light to the photoreceptors, which are the only cells that can respond to it.
 - In hearing, we have the eardrum to help relay the sound waves.
- Pupil will dilate to let more light in, pupil will constrict to let less light in.
- Photoreceptors are located on the retina, and we have two types: rods and cones
 - 1 type of rod
 - 3 types of cones, which help us detect different types of visual info
- The only cells that detect light are in the back of the retina. Info has to be relayed from neurons which are in the front. Light goes through the ganglion cells and then to the bipolar cells and then to the rods/cones.
- In vision, light is what stimulates a G protein complex, not a messenger binding to a receptor.
- In order for you to see, your photoreceptors have to be hyperpolarized and thus the sodium channels will be closed.
 - When a light turns on in a dark room, sodium will be shut off from entering the cell. The amount of neurotransmitters released will decrease because you don't have an action potential (b/c no depolarization) and thus you cannot bring in calcium and thus neurotransmitters cannot be released.
- Cones and rods hyperpolarize in response to light, and don't fire action potentials. Instead, they synapse with bipolar cells.
 - Cones and rods and hair cells all don't have action potentials, they instead just communicate with the surrounding cells to transmit information.
- When receptors are depolarized, no signal gets through the brain. When they are hyperpolarized, they communicate with the bipolar and then ganglion cells which are the ones that send the electrical signals.
 - "When we see, photoreceptors are hyperpolarized and signal is sent to the brain"
 - "When we cannot see (we're in a dark room), photoreceptors are depolarized and signal is not sent to the brain"
- Bipolar don't send action potentials either, but ganglion cells do.
- When the cones/rods communicate with bipolar cells, the bipolar cells will excite the retinal ganglion cells.
- Graded potentials come with photoreceptors and bipolar cells, but ganglion cells fire the action potentials.
- Muscles are excitable and exhibit electrical activity.
 - Normally, the end action of the action potential is the release of neurotransmitter

- In muscles, the neurotransmitters bind to the acetylcholine receptors which opens the channel, lets ions in, the postsynaptic cell depolarizes, and then that cell releases an action potential.
- Skeletal muscles respond to the nervous system, which means they respond to action potentials.

4/27 - Week 4

- When ACh receptor is filled, then sodium can come into the cell, which causes a depolarization in the membrane.
- Organophosphates can inhibit the activity of AChE and thus the motor neurons will increase their muscle stimulation because the ACh is not being removed, which is what the organophosphate does, I think.
- If a muscle is in the relaxed state, the actin is not attached to the myosin. The myosin has already absorbed the energy and is ready to go. The myosin has already broke down ATP and absorbed the energy.
- Calcium availability is also very important. Purpose of the action potential is to get the rise in calcium.
- Botox affects the movement of the vesicles and the release of their contents into the synaptic cleft.
 - In a muscle affected by Botox, the calcium channels in the SR will be closed because there is no action potential coming (because of the Botox). It will be constantly in the relaxed state. The cell will not be hyperpolarized because there is no inhibitory inputs and thus it will remain in the resting potential levels. The myosin will not be bound to ATP because ATP will have hydrolyzed into ADP and P. The tropomyosin will still be bound to the myosin.
- Muscle contraction is stimulation dependent. If neurons are firing multiple action potentials, the muscle will produce some force called a twitch for each firing.
- You have sustained force because the calcium channels open and before they have the chance to close, you get another action potential. The muscles don't even get a chance to relax and thus the force increases linearly until a plateau which is called a tetanus, and that's when the muscle fatigue begins.
- Muscle contraction requires calcium, and that's coming from intracellular sources.
- Calcium is tightly regulated in the cell and we don't want a large amount of it for a long period of time. You're depolarizing the muscle cells all the time, which is not great.
- Wrinkles are caused by overactive muscle neurons and overuse of those neurons.
- Tetanus inhibits the neurons that control the other neurons in the skeletal system.
 - "We are inhibiting the inhibition." This means that neurons are overexcited. All the muscles can lock up.
- All muscles cells have similarities, but they have different metabolic activities in how they use ATP.

4/30 - Week 5

- Cells need oxygen in order to make ATP. Obtaining the oxygen is a multicell process and focuses on the respiratory system.
- Oxygen goes into the lungs, and then we want to spread that to the lungs. This is where the cardiovascular system comes into play. Oxygen goes into the blood and that spreads to the other cells.
 - Oxygen into lungs -> respiratory
 - Oxygen in lungs to other parts of body -> cardiovascular
- CO₂ is one of the materials that we need to get rid of. CO₂ is a breakdown product of the carbohydrates oxidized in cellular respiration.
 - This is because C₆H₁₂O₆ loses electrons in the process.
- Lungs in the body are highly branched because this increases the surface area of the lungs. This is the most important because it maximizes the oxygen obtaining ability.
- Oxygen goes into the lungs during inhalation because gas wants to flow from high to low pressure.
- Oxygen gets into our blood through diffusion. Oxygen in the lungs must have a high pressure and the oxygen in the blood have a lower pressure, which allows for diffusion to occur.
- Blood comes into the lung have a very low oxygen pressure content, and then after coming out of the lung, the blood will have a high oxygen content because diffusion occurs in the lungs.
- Blood is composed of red blood cells which contain lots of hemoglobin molecules, which each are able to carry/bind oxygen molecules.
- The hemoglobin saturation levels is dependent on the partial pressure of the oxygen.
- When you exercise, the heat produced and CO₂ produced is increasing. pH goes down because H ions are produced, acidity goes up, and we start to use anaerobic respiration.
- When our cells are using/producing a lot of ATP, they are also producing a lot of CO₂ that will end up in the blood. Once it's in the blood, you'll have the following reaction.
 - CO₂ + H₂O -> H₂CO₃ -> HCO₃⁻ + H⁺
 - This is facilitated by the carbonic anhydrase enzyme.
 - When CO₂ increases, then H⁺ goes up because CO₂ reacts with water to form an acid.
- When the pH decreases, the dissociation curve shifts to the right, there is more dissociation and less saturation of oxygen in the hemoglobin. We want the hemoglobin to not hold onto the oxygen, but rather release the oxygen into the tissues where it is needed.
- Blood pH is lower at the muscle than at the lungs.
- If the carbonic anhydrase enzyme stops working, there will be a lot of CO₂ around and then oxygen production would decrease.
- As the amount of exercise increases, oxygen saturation in the hemoglobin will continue to decrease.
- Myoglobin has a higher affinity for oxygen as compared to that of hemoglobin.

5/2 - Week 5

- Majority of oxygen is bound to hemoglobin. The RBC has so many hemoglobin molecules in it.
- We want the affinity from hemoglobin to oxygen to change as the concentration of oxygen changes.
 - Oxygen molecule that is bound to hemoglobin cannot be used, so it has to dissociate in some way.
- Dissociation curves vary depending on conditions in the tissue. pH was one of the attributes.
 - Shift to the right reduces the affinity and vice versa.
- For lower pressures, the changes in saturation are much larger due to the sigmoidal shape.
- Respiration is aided by skeletal muscles which are related to the volume which is related to pressure.
- When volume of the lungs increases, the pressure in the lung decreases, and because of that pressure difference, air can flow into your body very easily.
- When the altitude increases, the partial pressure of oxygen is lower than that at sea level.
 - The percentage of oxygen in the air is the same, we're just not able to access it as easily.
- The average amount of oxygen bound to hemoglobin in RBC decreases when you get to higher altitudes.
- Chemoreceptors on the aorta are what sense oxygen levels in the blood.
- Skeletal muscles are what causes the changes in breathing.
- Pulmonary trunk is the blood vessel that takes oxygen poor blood away
- Pulmonary vein is the blood vessel that takes oxygen rich blood back to the heart from the lungs
- Deep sea creatures can't live near the surface because there is not enough pressure.
- Main purpose of cardiovascular system is to deliver blood to the tissues in the body.
- In the blood, we have the plasma components and the cellular elements
 - Plasma contains nutrients, hormones, fatty acids, etc.
 - Cellular elements include RBC, WBC, platelets, etc
- With blood, you can spin it in the centrifuge and that will separate the blood elements. The RBC will be at the bottom.
- The pulmonary vein will carry oxygenated blood since it is returning the blood to the heart from the lungs.
- Artery is any blood vessel that carries blood away from the heart, and vein is any blood vessel that brings blood back to the heart.
 - Whether or not that blood is oxygenated depends.
- Blood flows from high to low pressure down a pressure gradient. The heart is a muscle tissue and that is what is creating the pressure.

- When the heart is relaxing, it is filling up with blood (diastole) and when it is contracting, it is releasing the blood.

5/4 - Week 5

- Blood pressure is greater during systole than during diastole because when the ventricles are contracting (systole), they are squeezing the blood through the aorta.
- Atria contract first and then the blood flows to the ventricles and then the ventricles contract.
- Atria and ventricles don't contract at the same time.
- Any contractile tissue needs action potentials.
- Lots of gap junctions that allow for blood to move from left to right atrium.
- Cell depolarization causes muscle contractions and repolarization causes muscle relaxation.
- Contraction of heart muscles is almost identical to that of skeletal muscles.
- For skeletal muscles, there is release of acetylcholine.
- In skeletal muscles, we don't see hyperpolarization. In cardiac ventricles, it takes a very long time for the action potential to travel. This gives the heart ample time to contract and relax.
- The cardiac muscles do not need neurons, and thus they get their communication not by other neurons, but by the SA nodes that have their own rhythm and they fire on their own by depolarizing and hyperpolarizing.
- Pacemaker action potential is what leads the the cardiac action potential which is what leads to the heart contraction to occur.
 - Pacemaker -> Cardiac -> cross bridge cycle
- In those cardiac cells, we have a prolonged depolarization due to fast potassium channels closing and calcium channels opening. The high level reason is that we want to give the heart time to fill up with blood and we want to prevent tetanus from occurring. This also prevents fatigue from occurring.
- The atria relax during the QRS phase.
- Atria depolarize during the P wave and the ventricles depolarize in the QRS complex.
- Blood vessels are regulating through increasing the decreasing the radius.
 - When exercising, need to dilate. When not exercising, we can constrict because those muscles don't need as much blood.

5/7 - Week 6

- Kidney's main function is to maintain homeostasis of the blood, maintain proper amount of chemicals inside the blood.
- Kidney is excretory system used to get rid of unwanted material.
- Kidney regulates a very long list of substances, in particular water and sodium.
- Nitrogenous waste is a metabolic product that we need to get rid of.
- Concentration is about the quantity of particles, rather than the size of the molecules or solute.

- Osmolarity of a solution is the moles of osmotically active particles per liter of solution.
 - 1 molar solution of glucose = 1 osmolar
 - 1 molar solution of NaCl = 2 osmolar
- Salt regulation involves blood vessels and epithelial cells. Epithelial cell has to be permeable to sodium and there must be a diffusion gradient where it is higher in the lumen of the blood vessel and lower in the lumen of the secretory tubule..
- Blood must flow in the direction that is opposite to the salt secretion. We want to maximize diffusion gradient through countercurrent exchange which works a lot better than current flow. .
- In cells, we like positive and negative ions to get transported at the same time.
- Nitrogenous waste is the result of reactions with proteins and amino acids. That waste is converted to ammonia for fish, urea for mammals, and uric acid for birds and reptiles.
- If you have uric acid that is not soluble in water, then those organisms are able to conserve more water because after precipitation of the uric acid from the water, it doesn't impact solubility, and thus water returns to the hypertonic tissues.
- Functional unit of the kidney is called the nephron, which is lined by epithelial cells. .
- Filtrate is the component that flows through the nephron.
- Goal of kidney is to have a high concentration of waste products.
- Any renal system must have a lot of nephrons.
- In the proximal tubule, urea are secreted.
- Filtration means moving substances from blood to nephron. It's only at the beginning.
- Reabsorption is taking substances back from the nephron and putting them back into the bloodstream.

5/9 - Week 6

- Separating that concentrated urine from water is the goal of the nephron.
- At the top of the Loop of Henle, there is a lot of regulation of hormones. Mainly there is reabsorption of sodium from the lumen to the blood through active transport.
- Stuff moving out of the nephron eventually will go into the bloodstream.
- Too little water means decreased blood pressure, and thus body will have a difficult time getting blood to the brain. Lots of water in the blood will increase blood pressure.
- Kidneys play a role in getting rid of water.
- Water balance controlled by the hypothalamus, where the antidiuretic released from the posterior pituitary. Will be released in response to hypertonicity or high osmolarity/concentration. What it does is reabsorb water.
- ADH works with a G coupled protein receptor and the final cell change is an increase in the number of water channels on the membrane.
- Water loss and sodium loss are closely tied together.
- ANP decreases sodium reabsorption in collecting ducts, and aldosterone increases sodium reabsorption in the nephron.
 - Example of opposing hormones.

- ANP release is simple and is just based on the sodium levels, but aldosterone release is a little more complicated.
- Renin converts an inactive protein angiotensinogen into angiotensin I. Then, ACE converts angiotensin I to angiotensin II which is the active form. This releases aldosterone and that increases sodium reabsorption (makes the body hold onto sodium more) and also increase blood pressure.
- Renin production is correlated with the sodium levels which is also kinda related to water levels. An increased amount of sodium/water means that you want to get rid of some of it, and that means that you'd want less renin production.
- ACE inhibitors will interrupt aldosterone production, and thus sodium is not released, and thus blood pressure decreases.
- Ingredients for metabolism comes through the food that we consume. The conversion comes from the digestive system.
- Food is only accessible to blood after it goes through the digestive system.
- Stomach is one of the only places where we can tolerate a low pH. The stomach produces enzymes that break down proteins from the food we consume, and then HCl gets released from the cells that line the stomach, and the function of the acid is to activate the enzymes. The inactive pepsinogen form gets turned into the active form of pepsin because of the acid.
- Enzyme always starts in the inactive form, and it only turned active when the environment is right (low pH). We cannot just release pepsin because it's a very strong enzyme that breaks down proteins. Thus, we only want the pepsin in certain situations to make sure it's only interacting with dietary proteins and not cellular proteins.
- Pancreas releases enzymes into the small intestine where the final absorption and breakdown of the food occurs.
- Small intestine receives secretion from liver/gallbladder, enzymes from pancreas, and food from stomach.
- Small intestine is also an endocrine gland because it releases two hormones to communicate with pancreas and gallbladder.

5/11 - Week 6

- Duodenum receives all the food that has passed through the stomach.
- There is partial digestion in the mouth and partial digestion in the stomach but that's it.
- The duodenum relies on the enzymes released from the pancreas. Pancreas doesn't receive the food, and thus it doesn't know when to release. The duodenum communicates with the pancreas through hormones (CCK), and once the pancreas gets these hormones, it releases the enzymes.
 - Bile is somehow involved as well.
- Pancreas also releases bicarbonate in order to neutralize the acidity coming from the outputs of the stomach (which has a very acidic environment). It's good to have this pH of 7 because now the enzymes that catalyze the breakdown of carbohydrates are active.

I think the breakdown of proteins (which happens in stomach) is different from breakdown of carbohydrates. It also releases digestive enzymes into the small intestine.

- Pepsin is one of the only enzymes that prefers that acidic environment.
- Duodenum cannot tolerate acid and thus it tells the pancreas to release the bicarbonate when the H⁺ ion concentration is high. H⁺ concentration in the duodenum is the quantity that is homeostatically regulated.
- To absorb nutrients, we need to move nutrients from the lumen of the small intestine to the blood vessel.
- Absorption refers to movement to the blood.
- Goal of digestion is to break down molecules into smaller ones. Pepsin doesn't break down proteins into amino acids, it just breaks it down into smaller units. The units get broken down into smaller ones in the duodenum, and finally then we have an enzyme that is able to break them down into amino acids .
 - This is because transporters can only handle very small molecules, and thus they need to get broken down in the intestine and then once they are small enough, they can be transported to the blood.
- Lipids are digested only in the small intestine. The lipids tend to aggregate and thus the enzyme lipase is not efficient enough. This is where bile comes into play. It works to fragment that large fat globule and that helps the lipase since it will now have more surface area to work with and can make that break down easier.
- Bile also packages the lipids into vesicles called mysol. The lipase then breaks it down and the blood will get it through diffusion.

5/14 - Week 7

- First exposure to microorganisms is during birth.
- Domains of life consist of bacteria, archaea, and eukarya.

5/16 - Week 7

- 16s rRNA sequencing looks at that genes in the DNA, not the RNA specifically.
 - It seeks to identify and compare bacteria within a certain sample.
- Alpha diversity is a quantitative measure of different microbes present in a sample. Beta diversity is a qualitative measure to show how similar the microbes are.
 - PCA would be an example of beta. Even though they show the number of dots, that does not necessarily indicate an alpha or quantitative measure of the microbes. You can't determine diversity by looking at the beta graph, that only comes with alpha. Beta only shows you how the samples are related.
 - Abundance graphs would be an example of alpha.
- Neighboring area microbes would be related to each other.
- There are differences between males and females in terms of the type of microbes that they have. The numbers also differ from individual to individual.

5/18 - Week 7

- Mast cells don't have direct contact with pathogens, they instead are like the operators that make other things happen, such as increase inflammation by releasing histamine.
- Break in the skin is the easiest way for pathogens to enter the body.
- Redness from a cut comes from dilation of the blood vessels, causing an increase in blood flow, and also an increase in permeability as that blood will move to the injured tissue.
- Complement proteins help the immune cells do their job.
- An important protein is called the MAC and it attaches to the pathogen and causes cell lysis. Opsonization is the binding of the pathogen to the immune cell. Some proteins are also important in cell signaling.
- Fever is a common symptom of infection because temperature set point is increased in order to make it more difficult for the pathogens to survive.
- When you get a fever, then your set point increases, and thus your current temperature is less than the set point, which makes you feel cold and make you shiver.
- B cells are the immune cells that "remember" particular bacterium.
- When the body first gets infected with a pathogen, there are always B cells in the blood that can bind to that particular pathogen.
- Antibodies don't destroy the pathogens, but they just bind to the pathogen and hinder the pathogen from doing anything else. Then the macrophages can come in and destroy the pathogen.
- Memory B cells that recognize different pathogens don't have the same identical DNA sequences. They undergo a type of recombination where they rearrange certain DNA segments.
- Heavy chain will bind to the other immune cells, while I think the light chain will bind to the pathogen, which means it will be different between B cells.
- The cells that are injured release chemicals that get detected by the macrophages.

5/21 - Week 8

- Genome sometimes refers to set of chromosomes in an organism.
- Definition of cancer is uncontrolled cell division.
 - In normal cells, cell division eventually stops. The rate of cells dying is almost the same as the rate of birth in these normal cells.
- Mutation is a permanent change in the sequence of a gene.
- Human genome has 3.2 billion base pairs.
- Decile represents info from 10 patients altogether.
- Mutations can occur because of UV light, exposure to carcinogens (any chemical that has potential to cause mutation), normal mistakes in DNA polymerase during DNA duplication, exposure to X-rays, etc.
- Cancer refers to a set of diseases which means that one single goal is not likely to be found.
- Very small percentage of all the mutations are actually in protein coding regions since the percentage of protein coding regions in general is 1.5%.

5/23 - Week 8

- PCR is one way to sequence the human genome. It does this by amplifying the DNA through a primer sequence and then looking at the new strand that gets synthesized.
- For sequencing, first step is to fragment the entire genome into smaller fragments, add adapters to the ends of all DNA, denature and attach the fragments to a solid surface, and use that fragment to synthesize the complementary strand.
- Each primer for each of the DNA fragment is different because they have different base pairs in their fragment.
- Primer sequence is not included in the DNA fragment that gets synthesized. The sequencing read refers to the new sequence after the primer.
- DNA synthesis occurs 5' to 3'.

5/25 - Week 8

- Large scale mutations are common in cancer. These are different from the DNA level base pair mutations that could happen, and often happen in non-coding regions.
- Karyotype is a profile of your chromosomes.
- Aneuploidy refers to any chromosome level irregularities.
- Chromosome level mutations could include deletion, duplication, and inversion.

5/30 - Week 9

- In your genome, only 2% of it codes for protein. The other 98% serves as regulation for the coding region.
- Thickness of the rectangles showing the exons: Thin ones represent UTRs and the thick ones represent the actual coding exons.
- Metastasis is where the cancer cells spread to other organs in the body.
- Defining functionality
 - Biochemical approach measures evidence for molecular activity.
 - Protein binding to this part of the genome.
 - Evolutionary approach looks at similarities between generations.
 - If we see a particular coding region there in multiple generations, then we know that it is important.
 - Comparing genome of one organism to another.
 - Genetic approach looks at phenotypic consequence of genome variations.
 - Ask ourselves what the function of the protein is. What the expression/coding of the protein involved?

6/1 - Week 9

- If gene is mutated, then the protein produced has the possibility for different functionality.
- A protein receptor (HER receptor) is one that is linked to breast cancer. It is a membrane receptor. The number of receptors is homeostatically regulated. But in a HER2+ cell, we see amplification (multiple HER2 genes) and overexpression (many HER2 receptors).

- Proteins are not permeable to the plasma membrane and thus they would never be able to bind to any intracellular part of a membrane protein.
- Estrogen is a proto oncogene and thus it will increase the amount of HER2+ cells.
- Agonist is a molecule which when it binds to a receptor, the normal response is created, aka it does the same function. However, antagonist is a molecule which when binds to a receptor, an opposite response is created.
- Cancer progression comes from
 - Increase in mitosis, or cell proliferation. At this stage, it is just benign. The new cells have identical properties as the original cells.
 - New cells start becoming different and eventually the tumor is malignant, the cells have a different shape.
 - Metastasis is where cells lose association with the neighboring tissue, and leave the organ, and travel to nearby areas through the blood. The blood capillaries have very small openings, but the lymphatic system have bigger ones.
- Most cancer mutations come from noncoding regions.

6/4 - Week 10

- Genome is the instructions that tell us what protein to make.
- Noncoding regions affect regulation of the proteins created by the protein coding regions.
- Track A shows protein binding levels. Track B and C show evolutionary evidence.
- If the protein is made, then the fluorescence is shown in the protein. This is called GFP.
- GFP expression is correlated with genetic evidence. Biochemical evidence refers to the amount of binding for different proteins.
- Bacteria defend against the virus by trying to destroy the nuclease. They keep a sequence of that in the cell, and remember it for the next time that the virus comes around.
- CRISPR is a single chain RNA (which will attack the DNA) with an enzyme called Cas9.
- Immunity of bacteria is used so that we can edit certain genes.
- Cas9 and RNA bind, then that complex binds to the PAM sequence on the DNA of the virus, and then sgRNA hybridizes with the target DNA, and then the Cas9 cleaves the DNA.
- Repair of the DNA happens through homology directed repair or non-homologous end joining.
- With NHEJ, there is almost always a frameshift.
- Spacer in the Cas9/sgRNA complex is the part that will look for your gene of interest. Scaffold is the part that binds to your Cas9.
- PAM sequence is a sequence that is 5' NGG and the Cas9 is scanning for that. Once we find a PAM, then we make sure that the PAM is associated with the sequence of the spacer.

6/6 - Week 10

- Cas9 system is a way to edit genes to figure out the function, or you can try to repair a gene.
- You need to have an enzyme that will cut the DNA and a sgRNA which binds to the DNA to allow for hybridization.
- Unwinding the DNA has to happen first which then allows the sgRNA to hybridize with a single strand of that DNA. After hybridization the cut will occur 3 nucleotides upstream of the PAM.
- PAM sequence is important because it allows for the Cas9 to recognize it.
 - Specifically, the Cas9 will look for 5' - NGG - 3'
- There are millions and millions of those NGG sequences, but the sgRNA will only hybridize with the DNA beside the PAM sequence where the RNA matches with that sequence.
- If you only have the PAM or the PAM + partial complementation, then the Cas9 will not cut.
- Once there is a cut, you can either do HR or NHEJ to fill in the spots.
 - HR is almost always preferred.
- The resulting sequences that are there after the cut and after the adding of other nucleotides can be different depending on if you're using HR and NHEJ or both.
- Using NHEJ will likely result in double stranded breaks.
- With frameshift mutations, you'll always get a non functional protein since pretty much every amino acid gets messed up.
- Big difference between using NHEJ and HR is that NHEJ is used for frameshift and for HR, it is more for precise mutations.
- Number of PAM motifs is just the number of 5' - NGG - 3' sequences.
 - Includes both strands from 5' to 3' and from 3' to 5'.
- The Cas9 will always cut 3 nucleotides upstream (toward 5') from the PAM.
- sgRNA will bind to the opposite strand of where the PAM is.
 - So basically look for the PAM, and the sgRNA that we'll have is the exact following string on that strand.
- Cas9 will cut anything with a PAM so you have to be careful that the template DNA that you have does not contain a PAM sequence itself.

6/8 - Week 10

- Final Review
- Microbiome
 - Specifically gut bacteria.
 - Quantitative measure of the strains of bacteria and qualitative measure of similarity.
 - Alpha and beta (PCA graph) diversity
- Immune System

- What is innate immunity and what is adaptive? What does the immune system already have that is general whereas in adaptive, we're looking at the adjustments the body makes.
 - Know properties of macrophages, mast cells, B cells (antibodies + memory cells), cytotoxic T-cells, and cytokines.
 - Binding of antibodies to antigens, basically enables a macrophage to engulf that antigen.
 - Formation of B cells and how they bind to particular types of antigens. Happens through recombination which causes the variation.
- Genomes
 - Very small amount of genome is for protein coding. Other parts help with regulation.
 - When trying to sequence DNA, adapters allow you to add stuff to the ends of the DNA fragments and then you can use the same primer when you're trying to combine them.
 - The left side always refers to the 5' end.
 - What is the role of the reference sequence?
 - Protein expression related to certain biochemical, evolutionary, and genetic evidence.
- Cas9
 - Understand the steps
 - Know the PAM, sgRNA, location of the cut, etc
 - Know how the repair happens: NHEJ or HR and the pros/cons of each approach.
 - Large deletion or rearrangement may require 2 Cas9 proteins to make the cuts.

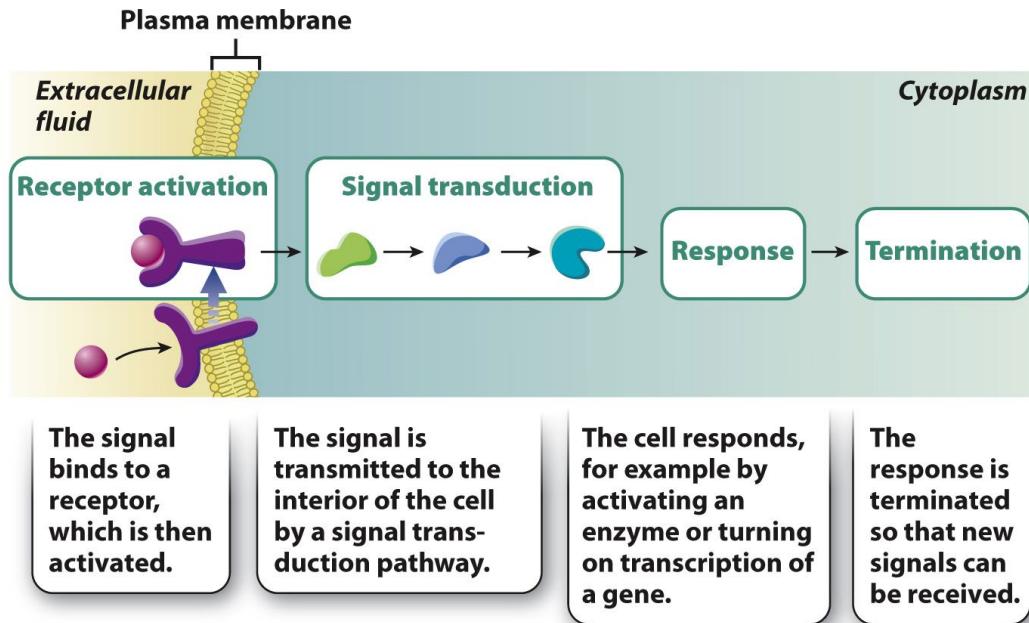
Textbook Notes

Chapter 9

9.1 Principles of Cell Communication

- Activities of all cells influenced by surroundings.
 - Physical environment and other cells give that information and the cell in question can change activity or divide as a response.
- Communication consists of a signaling cell, a signaling molecule, a receptor protein, and a responding cell.
 - The cell is the source of the molecule because the cell releases the molecules.
 - Molecule itself can be a peptide, lipid, or gas, but always will carry information from one cell to the next. Molecule will bind to a receptor protein on or in the responding cell causing a change in activity.
- In practice, the signal molecule is normally some sort of hormone, the signaling cells are the ones that detect the change and release the signal. The signal will then interact with the receptor proteins on nearby cells.

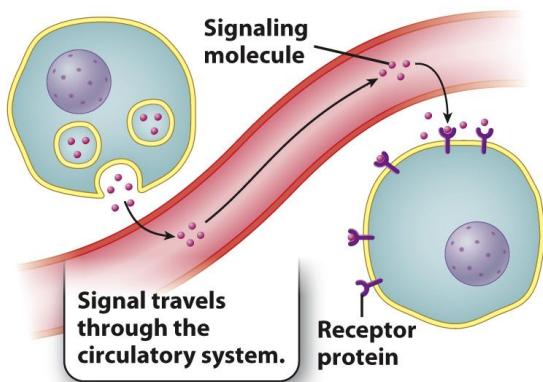
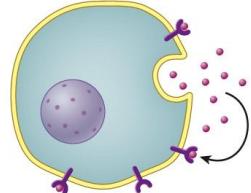
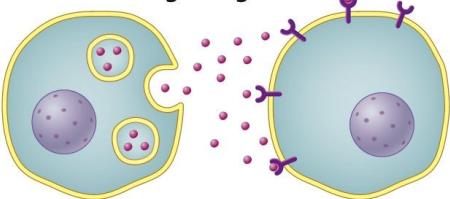
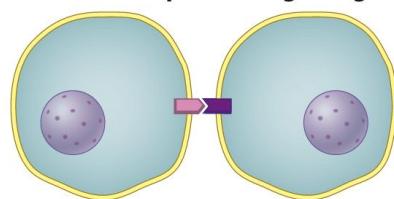
- Only cells that have receptors for the hormone will respond to the signal.
- Some bacteria can take DNA from environment and incorporate it into its genome. Once bacteria reach a certain population density, there will be an increased rate of DNA uptake. Bacteria are aware of the density because they communicate this info to each other through small peptides (signal molecule) and through the respective receptors. When concentration of the peptide gets high enough, it will bind to the receptors and then turn on the genes for DNA uptake.
- Quorum sensing is the process by which bacteria determine whether they are at low or high density, and subsequently turn on/off specific genes.



- When signal molecule binds to a receptor on a responding cell, first there is receptor activation (there is some change in the receptor), then the receptors bind to and activate other proteins inside of the cell, then there is signal transduction where to the signal is transmitted to the interior of the cell (signal amplified at each step in the chain reaction), then there is cell response (activate some enzyme, turn on some gene, change shape, etc), and finally termination when the cell response is stopped (protects cell from overreacting and have appropriate level of response).
- Ability of a specific tissue/organ to respond to the presence of a hormone is dependent on the presence of the appropriate receptors on the cells of the organ.

9.2 Cell Signaling Over Long and Short Distances

- In multicellular cells, the distance between communicating cells varies a lot. When far, signaling molecule transported by circulatory system, but when close, the molecule moves through diffusion.

a. Endocrine signaling**c. Autocrine signaling****b. Paracrine signaling****d. Contact-dependent signaling**

- Different types of signaling based on the distances ^ .
- Signaling by means of molecules that travel through the bloodstream is called endocrine signaling.
 - Adrenaline is example where the signal is produced in the adrenal glands but is carried through the bloodstream to cells far away.
 - Testosterone and estrogen are also examples.
- Signaling by diffusion between two cells is paracrine signaling. The signal is normally a small and water soluble molecule such as a growth factor, which is a type of signaling molecule that causes the responding cell to grow.
 - These growth factors only affect the neighboring cells.
- Special form of short range signaling is the communication between neurons, where neurotransmitters are the signaling molecules that are released from the neuron. They diffuse across the synapse which is the space between the signaling cell and the responding cell.
- Cases where the signaling cell and the responding cell are the same are called autocrine signaling. Important for the multicellular organisms during the development of the embryo.
- Sometimes cells can communicate through physical contact where a transmembrane protein acts as the signaling molecule and a protein on the other cell acts as the receptor, but in this case the signaling molecule doesn't actually leave the cell. Important during embryonic development with glia cells and neurons.
 - Notch (receptor) and Delta (signaling molecule) are transmembrane proteins involved in the communication of cells in developing nervous system.

- Signal molecules that are polar usually have their corresponding receptor on the surface of the responding cell because that molecule cannot cross through the plasma membrane of the other cell.
- Mammalian steroid hormones are the signaling molecules that function in endocrine signaling.
- Signaling molecules involved in paracrine and autocrine signaling travel by diffusion.
- Signaling: <http://www.mun.ca/biology/desmid/brian/BIOL2060/BIOL2060-14/CB14.html>

9.3 Cell Surface and Intracellular Receptors

- Signaling molecule is referred to as a ligand and the part of the receptor protein it binds to is called the ligand binding site. The bond is noncovalent and highly specific so that the molecule only binds to a particular receptor.
- After binding is complete, there is conformational change in the receptor and the receptor will pass the message to the interior of the cell.
- Location of a receptor in a cell depends on whether the signaling molecule is polar or nonpolar.
 - For polar signaling molecules, the receptor proteins are transmembrane and are on the outside of the responding cell. With binding occurs, the entire molecule will thus undergo a conformational change.
 - For small nonpolar signaling molecules, the receptors will be inside of the responding cell. The receptors will be in the cytosol or in the nucleus. For those in the nucleus, steroid-receptor complexes can be formed to regulate the expression of particular genes.
- There are many types of receptor proteins on the surface of any cell.
 - G-protein coupled receptor is a transmembrane protein where a ligand binds to the receptor, and the receptor associates with a G protein.
 - Another group is where the receptor itself is an enzyme and they get activated when a ligand binds to it. These are receptor kinases, which are enzymes that catalyze the transfer of a phosphate group from ATP to a substrate. Phosphorylation binds the ATP and the substrate. The protein then switches on.
 - Phosphatases are proteins that actually remove instead of add a phosphate group. Kinases are the ones that add.
 - Ion channel is another receptor which can alter the flow of ions across the membrane. They can open/close in response to being bound by a ligand (ligand-gated ion channels) or changes in voltage (voltage gated ion channels).
- Steroid receptors are not a cell surface-type receptor because they are located in the nucleus.

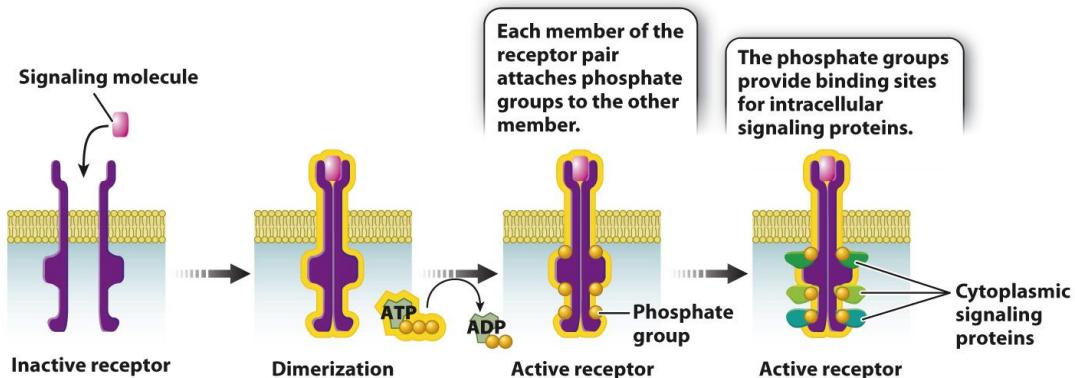
9.4 G Protein-Coupled Receptors and Short Term Responses

- G protein coupled receptors are found in lots of eukaryotic organisms, and they all consist of single polypeptide chain that have different regions with the ligand binding site on the outside and the part that binds to the G protein on the inside of the cell.

- Different G protein receptors are similar in the above, but can respond to variety of different signaling molecules and have different effects.
- The G protein can either be on or off. When the protein is bound to the GTP nucleotide it is on, and off when bound to GDP.
- When ligand binds, then the G protein releases GDP and binds GTP.
- G proteins have 3 subunits.
 - Alpha is the part that binds either GDP or GTP. This can indicate to you whether the ligand has bound or not.
 - When GTP replaces the GDP, then alpha separates from the gamma and beta units (and takes the GTP along with it). Then unit then binds to a target protein and activates it.
- When adrenaline binds, then alpha will activate adenylyl cyclase which converts ATP into cyclic cAMP which is a second messenger (whereas growth factors and original signaling molecules are first messengers). These second messengers pass information inside the actual cell. cAMP will bind to and activate a protein called protein kinase A (PKA), which will induce the faster contraction of heart cells.
- There can be multiple G protein coupled receptors on a cell and they can each respond to the adrenaline in the bloodstream.
- Cells are exposed to lots of signaling molecules and the particular receptors determine which signals the cell responds to. Also the set of proteins in the cell affect things. Thus, the same signaling molecule can have different effects on different types of cells.
- Termination happens because most ligands don't bind to receptors permanently. Length of time a signaling molecule is bound depends on strength of receptor holding to it, which is called binding affinity. When the ligand leaves, then the G proteins are no longer activated. Without an active receptor, transmission of the signal stops.
- Termination of adrenaline signal happens when the GTP bound to alpha hydrolyzes into GDP.
- Good other link: <https://courses.washington.edu/conj/bess/gpcr/gpcr.htm>

9.5 Receptor Kinases and Long Term Responses

- Cellular responses from receptor kinase activation involve changes in gene expression, which allow cells to grow, divide, or change shape.
 - The responses from G coupled protein receptors lead to short term changes.
- An example of a signal molecule is a platelet derived growth factor (PDGF) which binds to PDGF specific receptor kinases on the surface of cells at the site of the wound.
- The receptor kinases have an extracellular portion that binds to the signal molecule and an intracellular part that is a kinase, which is an enzyme that transfers a phosphate group from ATP to another molecule.



- The PDGF binds to two of these receptors, dimerization occurs, phosphorylation occurs on multiple places on the tails, and thus the addition of these phosphate groups gives places on the receptor where other proteins bind and become active.
- Because of the activated receptor kinase, a G protein called Ras can get activated and exchange GDP for GTP, which causes the activation of another protein kinase, and a series after that (called the MAP kinase pathway). The final kinase goes to the nucleus and phosphorylates target proteins.
- Signals received by the receptor kinases get amplified at every step.
- For termination, protein phosphatases inactivate the receptor kinases and other enzymes in the MAP kinase pathway, and then Ras hydrolyzes GTP to GDP and becomes inactive.
- Cancer can arise because of the overproduction of a signaling molecule, or production of altered form of the molecule, or an abnormal number of receptors on the cell, or mutant forms of the Ras protein where the Ras may not be able to convert GTP to GDP, or Ras will always/never activate the MAP kinase pathway.
- A cell's final response depends on all of the interactions with each of the pathways caused by the different signaling molecules.
 - Pathways occurring at the same time can enhance or inhibit one another.
 - For example, enzymes in the MAP kinase pathway can be inhibited by active PKA.

Chapter 10

10.1 Tissues and Organs

- Most cells in multicellular organisms are physically attached to other cells.
- A tissue is a collection of cells that work together to perform a specific function.
 - 4 types of tissues are epithelial, connective, nervous, and muscle.
- Two or more tissues combine to function as an organ.
- Shape of cells is determined by structural protein networks in cytoplasm called the cytoskeleton. This affects how cells themselves can connect with each other. The connection depends on structures called cell junctions. Also depends on their ability to

adhere to a meshwork of proteins outside of the cell called the extracellular matrix. These play a role in structural support.

- Skin has two layers, the outer one which is the epidermis, and the inner one is the dermis which supplies nutrients to the epidermis.
- An epithelial tissue is made up of layers of epithelial cells and those tissues cover the outside of the body. They are defined as collections of cells that line cavities or outside surfaces (Connective tissue on the other hand is for the inner organs).
 - The epidermal layer of skin is made of epithelial cells called keratinocytes and they protect underlying tissues and organs.
 - Adjacent cells are held together by filaments, and bottom layer is connected to an extracellular matrix called the basal lamina. This is found beneath all epithelial tissues. Without this, the epidermis will not be connected to the dermis.
- Dermis is made of connective tissue, and the main cell type is the fibroblast, which synthesizes the matrix.
- Microvilli are associated with increased surface area for nutrient absorption.

10.2 The Cytoskeleton

- Protein fibers of the cytoskeleton provide internal support for cells.
- Eukaryotic cells have microtubules and microfilaments, while animal cells also have intermediate filaments.
 - These are long chains made up of proteins and they provide structural support. They help a cell maintain its size and shape.
- Microtubules are made of protein dimers, and each dimer is made of an alpha and a beta tubulin protein. The whole structure is a hollow tube. The microtubules help maintain cell shape and internal structure. They radiate outward from the centrosome. They also make up the spindles that attach to chromosomes during division.
- Microfilaments have actin monomers and form a helix. They are in the cell cortex (area of cytoplasm beneath the plasma membrane) and they reinforce the plasma membrane and organize proteins associated with it.
- Microtubules are larger in diameter than microfilaments, and the diameter of the intermediate filaments are in between.
- Both of them can grow/shrink based on additions of subunits to the ends. The rate of addition depends on the concentrations of tubulin and actin.
- The faster assembling end is the plus end, and the slower end is the minus end.
 - Tubulin dimers can be added/removed from either end though.
- For microtubules only, they have cycles of polymerization and depolymerization and this is called dynamic instability. This is how they can lengthen and shorten.
 - The ability to rapidly depolymerize and then slowly polymerize is associated with the ability of the spindle apparatus to explore the cell and locate chromosomes.
 - The instability means that the protein units are held by noncovalent interactions.
- Both can also have motor proteins which increase the range of movement.
- 2 proteins associated with microtubules are kinesin (carries material to the plus end) and dynein (carries material to the minus end). These provide tracks for transport in the cell.

- Microtubules also found in cilia and flagella, which propel the movement of cells surrounding the cell. Dynein helps with the movement.
- Microfilaments associate with myosin to transport vesicles inside of cells. Also, I think kinesin is involved too.
- Intermediate filaments provide cell with mechanical strength. Proteins making up this filament differ from one cell type to another.

TABLE 10.1 Major Functions of Cytoskeletal Elements.

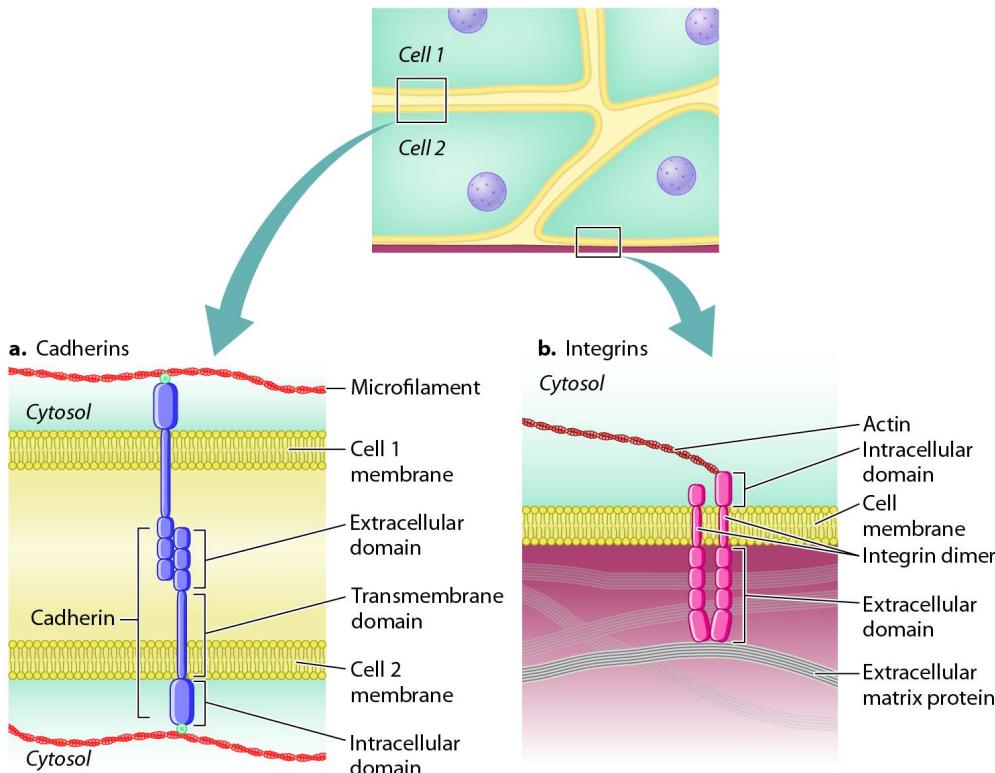
CYTOSKELETAL ELEMENT	SUBUNITS	MAJOR FUNCTIONS
Microtubules	Tubulin dimers	Cell shape and support Cell movement (by cilia, flagella) Cell division (chromosome segregation) Vesicle transport Organelle arrangement
Microfilaments	Actin monomers	Cell shape and support Cell movement (by crawling) Cell division (cytokinesis) Vesicle transport Muscle contraction
Intermediate filaments	Diverse	Cell shape and support

- Prokaryotes also have some proteins similar to the cytoskeletal elements of eukaryotic cells.
- Contraction of muscles shows how motor protein myosin interacts with actin filaments to create movement.
- Movement of cilia and flagella shows how motor protein dynein interacts with microtubules to create movement.
- Motor proteins cause movement by undergoing conformational change, getting energy from ATP, and binding to the cytoskeleton. Motor proteins are also specific for the type of filament that they bind to.

10.3 Cell Junctions

- Tissues are held together and function as a unit because of cell junctions, which physically connect one cell to the next and anchor the cells to the extracellular matrix.
- Cells are able to sort themselves because of the presence of surface proteins called cell adhesion molecules that attach cells to one another.
 - Cadherins in particular are especially important in the adhesion of cells to other cells. It is a cell adhesion molecule.
 - There are many types of cadherin, each for different types of cells.

- A cadherin is a transmembrane protein and its extracellular domain binds to that of a cadherin of the same type on an adjacent cell. They bind to both intermediate filaments and microfilaments.



- Cells are not only attached to other cells but they also attach to proteins on the extracellular matrix. Those cell adhesion molecules are called integrins. They also act as receptors that communicate info about the matrix to the interior of the cell.
- There are two types of anchoring cell junctions. They both attach cells to other cells and are made of cadherins.
 - Adherens junctions are where you have a band of actin attached to the plasma membrane by cadherins. The cadherins in the junction of one cell attach to the cadherins in the junction of adjacent cells.
 - Desmosomes are similar but have specific points of adhesion.
- Epithelial cells are connected to each other and to the underlying extracellular matrix. Those cells are anchored to the matrix by a hemidesmosome. Intermediate filaments help maintain this connection.
- A tight junction is another type of cell junction that establishes a seal between cells so that the only way you get from one side to the other is through the cells using a transport mechanism.
- Gap junctions in animals and plasmodesmata in plant cells permit materials to pass directly from the cytoplasm of one cell to that of another cell.
 - Gap junctions made up of a ring of connexin proteins.

- Plasmodesmata has continuous plasma membrane, larger opening.

TABLE 10.2 Types and Functions of Cell Junctions.

CELL JUNCTION	MAJOR COMPONENT	CYTOSKELETAL ATTACHMENT	PRIMARY FUNCTION
Anchoring			
Adherens junction	Cadherins	Microfilaments	Cell–cell adhesion
Desmosome	Cadherins	Intermediate filaments	Cell–cell adhesion
Hemidesmosome	Integrins	Intermediate filaments	Cell–extracellular matrix adhesion
Barrier			
Tight junction	Claudins, occludins		Epithelial boundary
Communicating			
Gap junction	Connexins		Communication between animal cells
Plasmodesma	Cell membrane		Communication between plant cells

- All types of cell junctions ^ .
- Tight junctions prevent passage of material through the space between cells, while adherens junctions and desmosomes attach cells to one another.

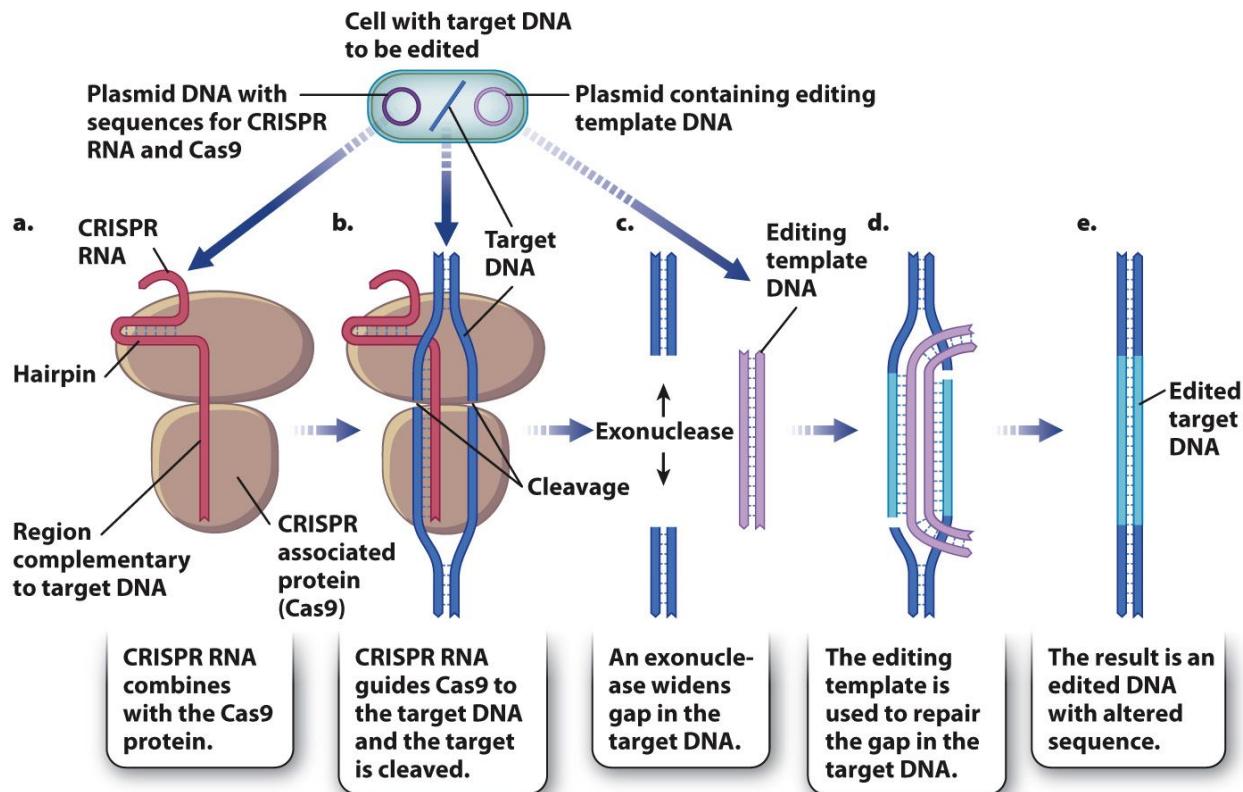
10.4 The Extracellular Matrix

- Extracellular matrix is a mixture of proteins and polysaccharides secreted by cells. The matrix is negatively charged. Can be found a lot in animal connective tissue.
- The matrix determines the properties of different types of connective tissue.
- Collagen is the most important protein in the extracellular matrix for animals because it provides support for the overlying epidermis. It has a strong triple helix structure.
- The basal lamina is the extracellular matrix under all epithelial tissues and they give a foundation for those tissues, and they have a special type of collagen.
- In plants, the extracellular matrix forms the cell wall, where the main component is polysaccharide cellulose.
- Cell wall composed of middle lamella, primary cell wall, and secondary cell wall from the outside to inside.
 - Middle lamella is main mechanism by which plant cells adhere to one another.
 - Primary cell wall made of cellulose
 - Secondary cell wall constructed when the cell stops growing, and has both cellulose and lignin which hardens the wall and makes it water resistant.
- The structure and composition of the extracellular matrix can influence cell shape and the gene expression of the cells that are grown in it.
- Extracellular matrix is particularly important for connective tissues. The basal lamina is specifically important for epithelial tissues.
- A tumor cell could lose connection to the basal lamina because of the loss of integrin proteins from the cell surface or a change in the type of protein present.

Chapter 12

12.4 Genetic Engineering

- Recombinant DNA technology is where we isolate genes from one species and introduce them into another. It involves cutting DNA with restriction enzymes, isolating them, and then ligating them with enzymes used in DNA replication.
- This can only make use of existing DNA sequences.
- DNA editing is when we rewrite the nucleotide sequence to introduce specific mutations into genes to understand their function.



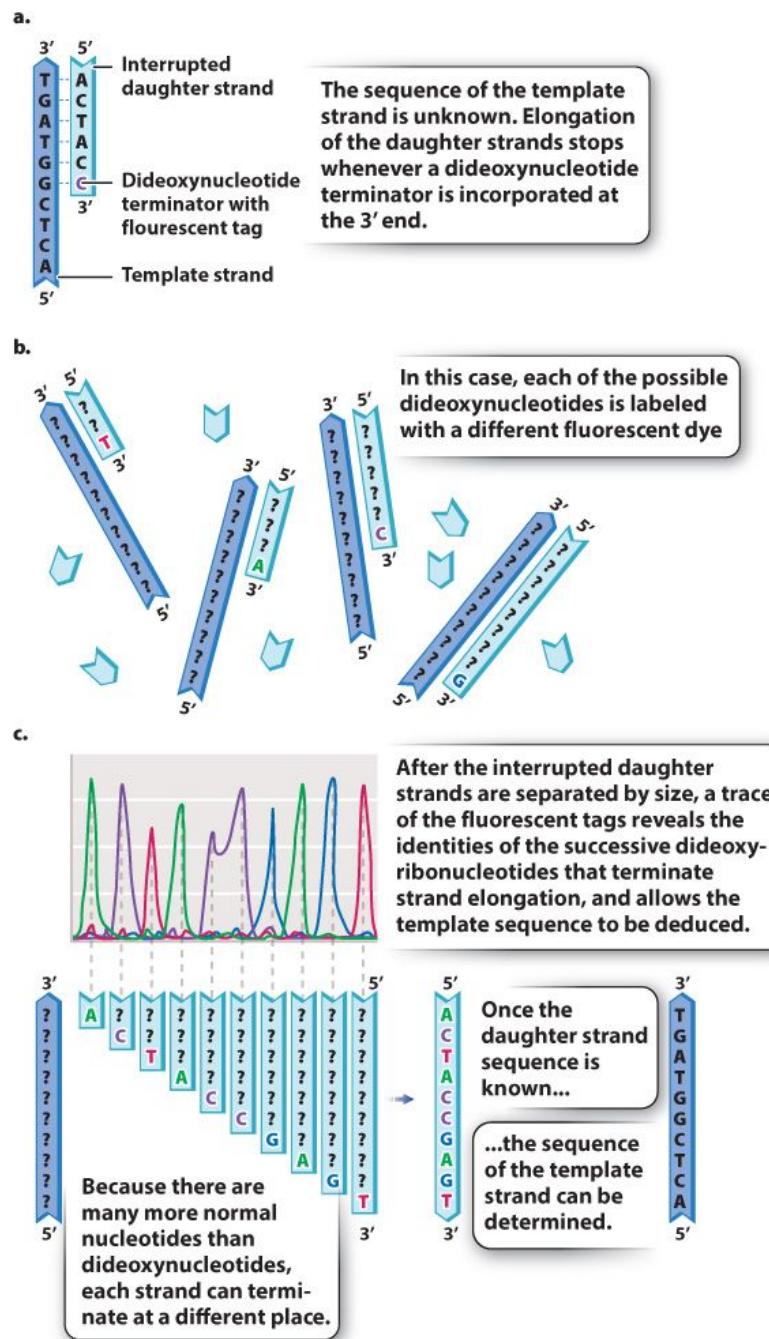
- CRISPR mechanism is used to alter the nucleotide sequence.
 - Transform a cell with a plasmid containing sequences that code for a CRISPR RNA as well as the associated Cas9 protein.
 - RNA undergoes base pairing with the target DNA, and Cas9 cleaves the target DNA.
 - We then add sequence of interest to replace the degraded sequence of the target DNA.

Chapter 13

13.1 Genome Sequencing

- A free 3' hydroxyl group is essential for each step in the elongation of the duplicated daughter strand.

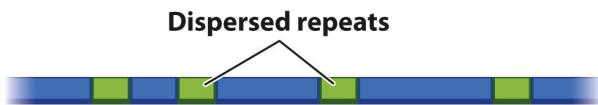
- Synthesized dideoxynucleotides are where the 3' hydroxyl group on the sugar ring is absent and thus when it is part of the daughter strand, the growth is stopped since there is no hydroxyl group to attack the incoming nucleotide, and thus the dideoxynucleotide is a chain terminator.



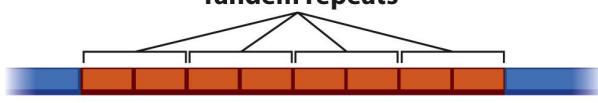
- Sanger sequencing uses these interruptions to figure out the contents of that template DNA. Gel electrophoresis is used to separate the interrupted daughter strands and we can study those to determine the full sequence of the template.
- Genome is the genetic material transmitted from parent to offspring.

- To sequence all of the 250 million nucleotides that are part of human chromosome 1, we can break the DNA molecule into small fragments (b/c we cannot sequence DNA molecules the size of a whole chromosome yet), sequence those fragments, and then put them into the correct order through sequence assembly. This is done through looking at the overlaps between the short sequencing.

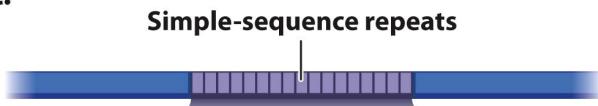
a.



b.



c.



...ATATATATATATATATATATATATATATAT...
...TATATATATATATATATATATATATATATA...

- Problem with this type of sequencing is that handling repetitive DNA is difficult.
- No way of determining the number of copies of the repeat.
- Identical twins will have the same genome.

13.2 Genome Annotation

- In multicellular organisms, not all DNA is transcribed into RNA and not all RNA is transcribed into protein, and thus even if we have the whole DNA sequence, we can't be sure to know everything that will get created from that sequence.
- Genome annotation works to identify the different types of sequence present.
- Most single copy genes are protein coding genes.
- Problem is that we're still trying to figure out the right classifications so a sequence that is classified as nonfunctional today might be functional at some other point once we have more info on the interactions of macromolecules.
- Sequence motifs are markers of patterns that indicate some sort of classification.
 - A promoter is a motif that shows you when a coding region will start.
 - Open reading frame is another motif where it starts with a long string of nucleotides that, if turned into RNA, would result in a set of codons for amino acids that doesn't have a stop codon.
 - Transcription factors can also be motifs.
- You can also use mRNA to look for motifs since mRNA is a processed version of DNA where you have the introns removed and the codons spliced together. So we can try to

determine which portions of the genome sequence correspond to sequences in mRNA transcripts.

- Analysis of similarities and differences in protein coding genes in the genomes of different species is called comparative genomics.
 - Sequences similar in different organisms are said to be conserved.
- Virus is a agent that binds to receptor proteins on the cells of the host. It has a nucleic acid genome packaged inside a protein coat called a capsid. The viruses will replicate, transcribe, and translate their genome in order to make more viruses.
- More closely related viruses have closely related hosts.
- Exons can be distinguished from introns in a DNA sequence because the sequence of exons will complement mRNA molecules in the cell.
- An ORF may not actually correspond to the amino acid sequence because the ORF could be due to chance and the DNA may not be transcribed into RNA.

13.3 Gene Number, Genome Size, and Organismal Complexity

- The complexity of an organism is not related to the number of protein encoding genes there are or the size of the genome.
- Genome size is measured in the number of base pairs. A million base pairs is a megabase, or Mb.
- The smallest genome is 580 kb and the largest is 1.2 Mb.
- For bacteria and archaeons, 90% of their genome consists of protein coding genes.
- Disconnect between genome size and organism complexity is called the C-value paradox.
- Polyploidy is the characteristic of having more than two sets of chromosomes and this is what could cause the genome to grow so large.
- Large genomes among eukaryotes are because of the large amount of introns and repeated DNA sequences and noncoding DNA.
- There are also transposable elements called transposons which are DNA sequences that can replicate and insert themselves into new positions in the genome. Because of that, they can increase their copy number in the genome over time.
 - DNA transposons replicate and transpose by DNA replication and repair.
 - Retrotransposons transpose by means of an RNA intermediate. The RNA is used as a template to synthesize complementary strands of DNA.
- Transposable elements contribute to C value paradox hypothesis because copies of those elements can appear on multiple chromosomes, the copy number can increase from one generation to the next, and their replication is controlled by genes found on the element itself.
- Differential gene expression, genes encoding multiple proteins, and different combinations of proteins is what accounts for the diversity of cell types and functions in humans.

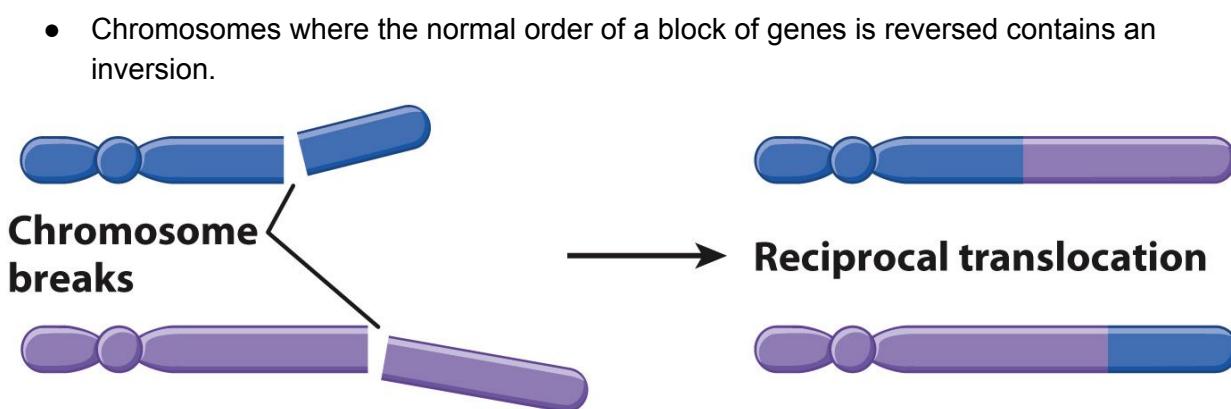
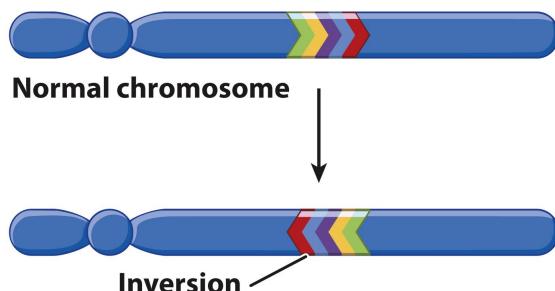
Chapter 14

14.2 Small Scale Mutations

- Mutation is chance in the nucleotide sequence of a genome.
- Point mutation is where one base pair is replaced by a different one. Some of these mutations don't have any effect because it was a mutation in a noncoding region.
- Synonymous mutation is called silent mutation if the amino acid that is coded for is actually the same as the original. Missense mutation is when the acid gets changed as a result of the mutation.
- Nonsense mutation creates a stop codon that terminates the translation.
- Frameshift mutations caused by the addition or removal of one base. If the number of nucleotides affected is not a multiple of 3, then you'll most likely see a nonfunctional protein.

14.3 Chromosomal Mutations

- Chromosome in which a region is there twice has a duplication. Deletion is where region in the chromosome is missing.
- Creating new genes from duplicates of old ones is called duplication and divergence.
- Group of genes with related functions is called a gene family.
- Relative constancy of rates of change in DNA is called the molecular clock.



- Reciprocal translocation is where nonhomologous chromosomes undergo an exchange of parts.
 - The breaks likely occur in noncoding DNA so no gene function is disrupted.

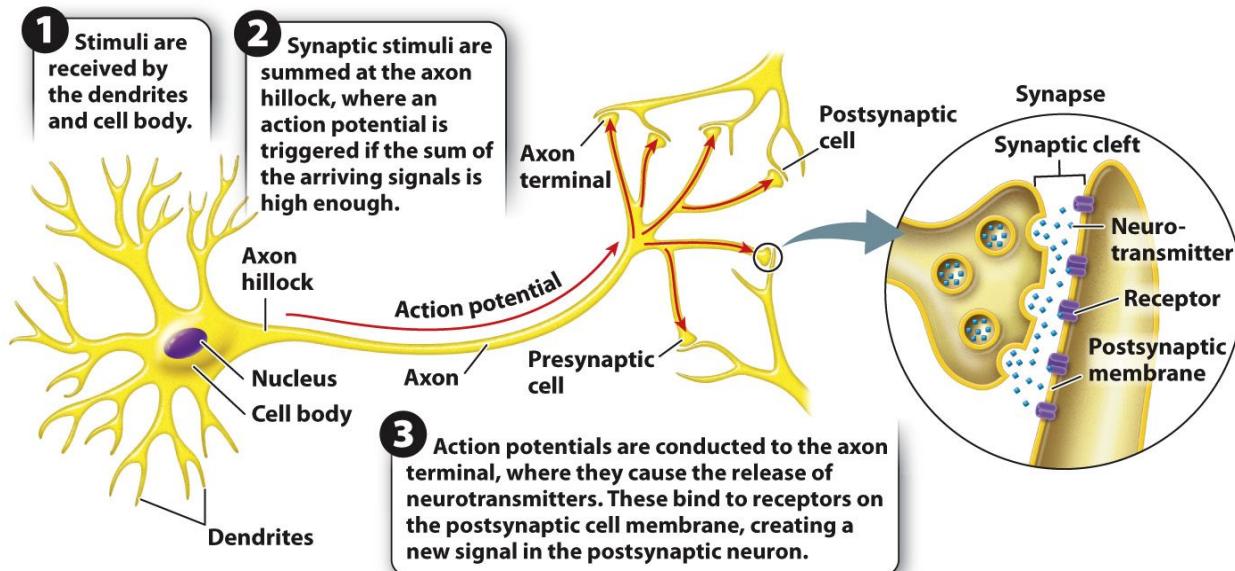
Chapter 35

35.1 Nervous System Function and Evolution

- Nervous system is network of interconnected nerve cells which allow animals to sense and respond to the environment. Neurons are the units of the nervous system.
 - These sensors to the environment enable to animal to coordinate the action of muscles and control the internal function of its body.
- 3 types of nerve cells which each have a different function.
 - Sensory neurons: Receive and transmit info about animal's environment or its physiological state. Respond to light, touch, or chemical signals.
 - Interneurons: Process the info from the sensory neurons and transmit to different body regions and also transfer info to motor neurons.
 - Motor neurons: May stimulate a muscle to contract to produce movement.
- Nerve cells have fiber extensions. Some receive info and others transmit the info.
- Ganglia are groups of nerve cell bodies that process sensory information received from a local region, which results in a signal to motor neurons to do something.
- Nervous system in animals guide homeostatic regulation of their bodies and coordinate more complex behaviours.
- Sponges are only multicellular animals with no nervous system.
 - Instead, local groups of cells are specialized for different functions and they respond to local chemical and physical cues.
- Nerves are the bundles of fiberlike extensions from multiple nerve cells and that is the way info gets transmitted to certain regions.
- Ganglia serve to regulate key processes in local regions and organs of the animal's body.
- Concentration of nervous system components at one end of the body is called cephalization and evolved in different animal groups.
 - Adaptation to forward locomotion.
- Vertebrates have this cephalization and they have a jaw/teeth/tongue with are adaptations for acquisition of food.

35.2 Neuron Structure

- Neurons have extensions that receive and transmit info. Neurons can differ in size and number of extensions.
- All neurons have a cell body. Dendrites are the input ends and axons are the output ends.
- At the junction of the cell body and the axon, the axon hillock, the signals are summed, and the neuron fires the action potential if the value is high enough. That action potential travels down the axon.

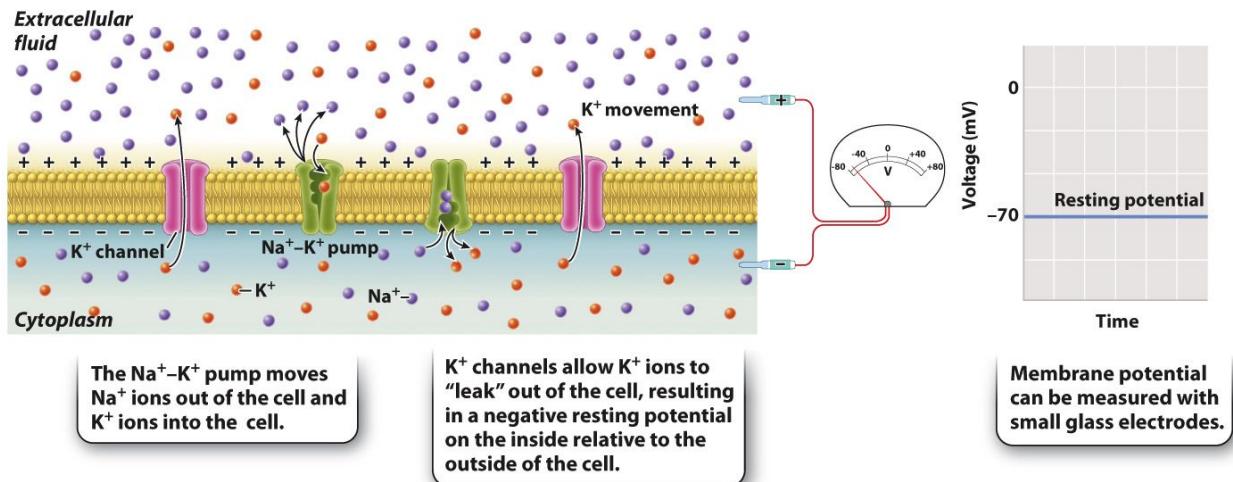


- The end of the axon is called the axon terminal and that communicates with a neighboring cell through a synapse. The synaptic cleft separates the end of the axon of the presynaptic cell with the neighboring postsynaptic cell.
- For signals to pass through the cleft, neurotransmitters are released from the axon terminal and they diffuse across the synapse and bind to receptors on the plasma membrane of the neighbor cell.
- The nerve signals are transmitted electrically through action potentials and chemically through neurotransmitters across a synapse from one neuron to another.
- Neurons differ in size are interneurons are short and motor neurons can be longer.
- Signals from all the dendrites determine the strength and timing of signals carried by the neuron's axon.
- The degree of branching and the number of synapses reflect how info is processed and integrated by the cell.
- Glial cells are supporting cells that don't transmit electrical signals. They provide neurons with nutrition and support.
 - Astrocytes are types of glial cells and they support endothelial cells that make up blood vessels in the brain.
 - Those endothelial cells are linked by tight junctions that form the blood brain barrier which prevent pathogens from entering the brain.

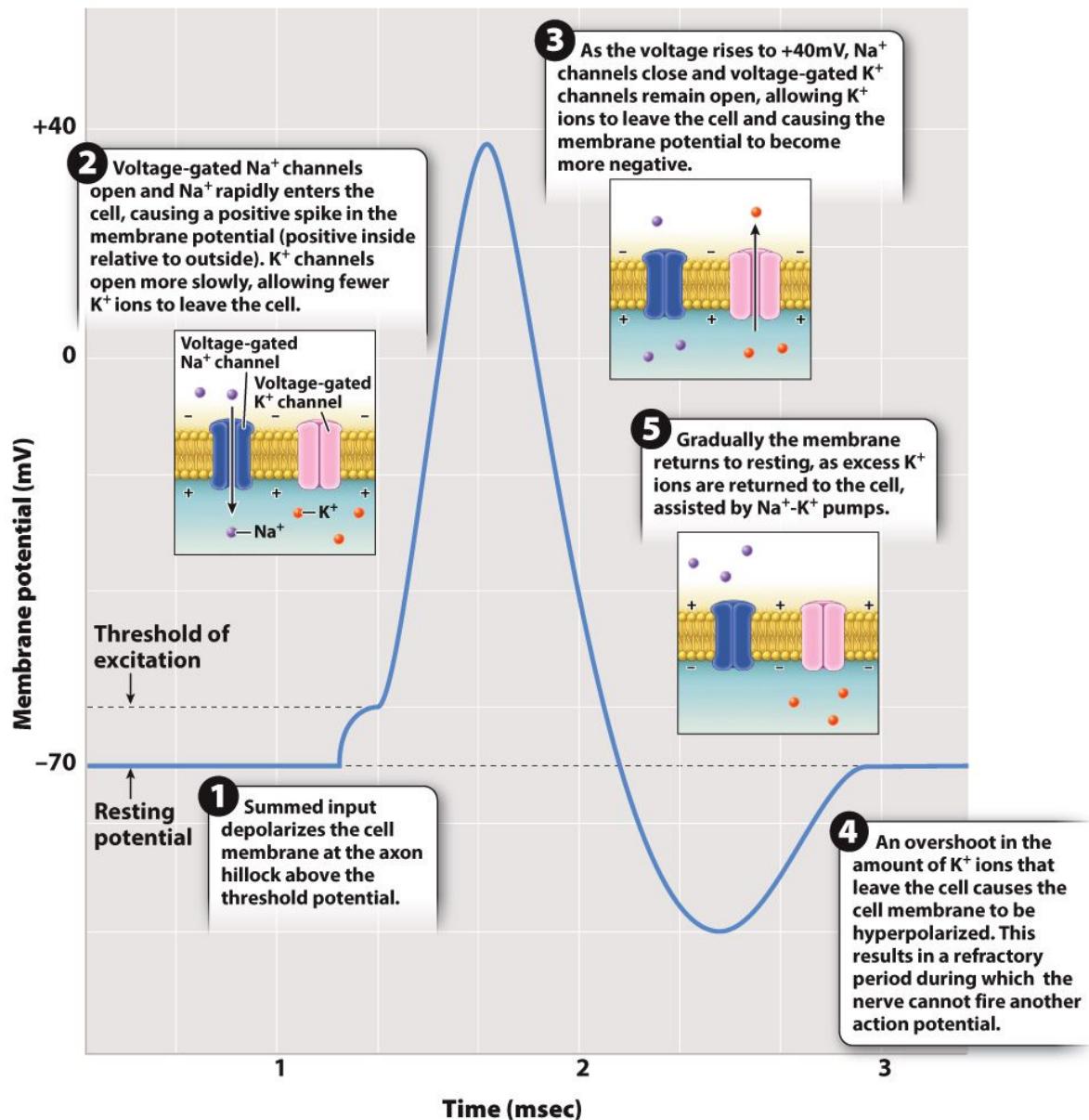
35.3 Neuron Function

- Once the receptor on the neighbor cell binds the neurotransmitter, signal is sent electrically from one end of the cell to the other.
- Charged difference between the inside and outside of a neuron due to the differences in charge is called the cell's membrane potential.
 - Cells respond to changes in their potential.

- When neuron is at rest, membrane voltage is negative on its inside relative to its outside. The resting membrane potential is polarized which means negatively charged ions on the inside and positively charged ones on the outside.

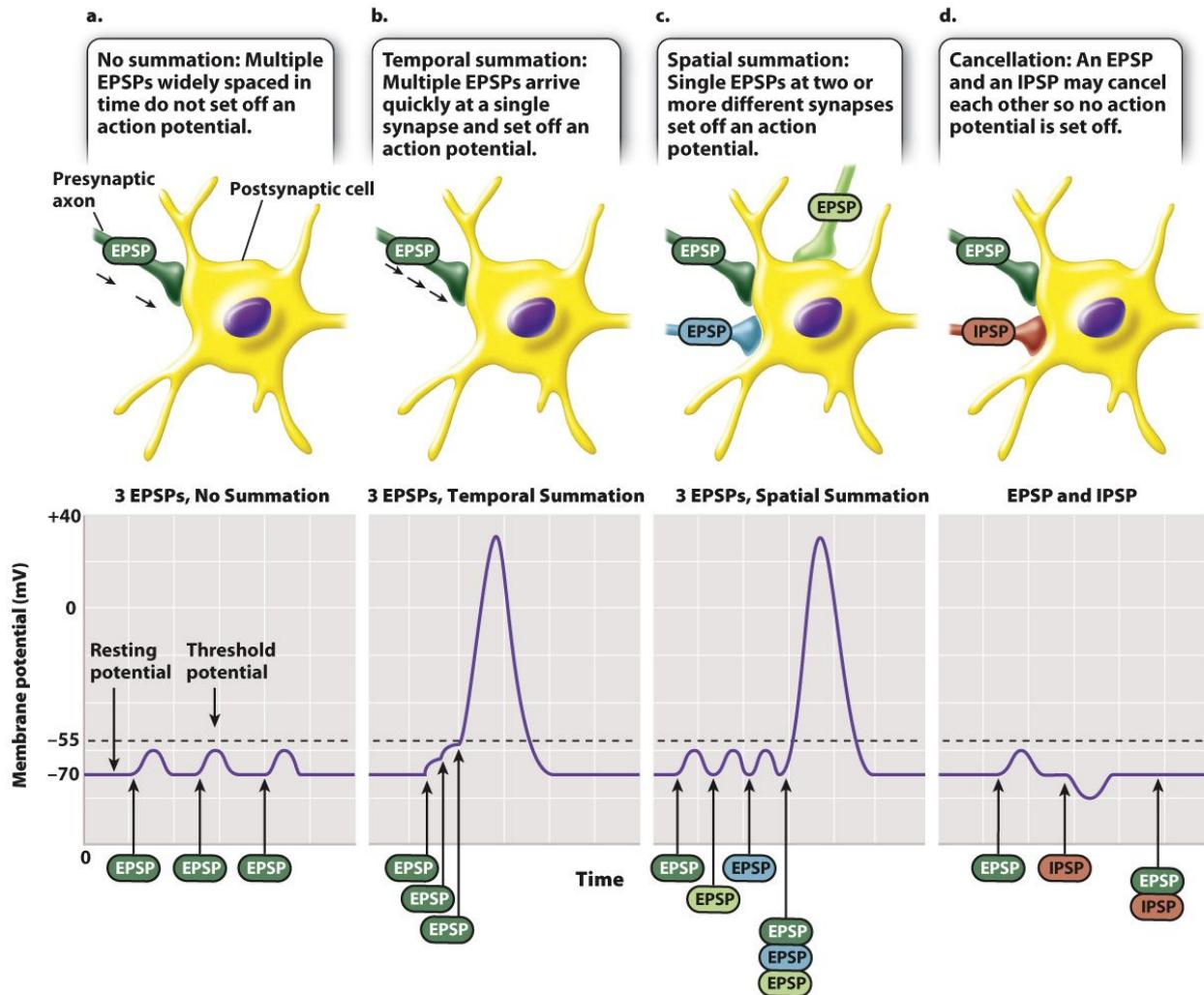


- At rest, cells have greater concentration of sodium ions outside than inside and have greater concentration of potassium ions inside than outside.
 - These levels are controlled by the sodium potassium pump which uses ATP to create that movement of ions.
- We also have potassium ion channels that do the passive diffusion.



- When cell is excited, the membrane potential becomes less negative (inside becomes less negative than outside of the cell) because the potassium ions will slowly leak out. That increase is called depolarization of the membrane. The process starts at the terminal end of dendrite and travels to cell body, and if the depolarization is strong enough at the axon hillock, the cell fires the action potential which is when sodium channels open, which lets sodium ions in and that causes a flow of positive charge. This creates a rapid rise and fall in membrane potential. At the peak, the voltage of the cell will turn positive.
- The depolarization voltage is called the cell's threshold potential.
- Magnitude of the action potential is always the same and independent of the strength of the input.

- The opening of sodium ion channels results in more channels to open which is called positive feedback.
- The sudden fall of the membrane potential is explained by the sodium channels beginning to close once the membrane potential becomes positive, and because the potassium channels will also open, albeit slowly. At the peak of the action potential, the membrane becomes more permeable to potassium ions.
- The refractory period is caused by the overshoot (too many potassium ions leave and thus the cell becomes really negative) and during this period the neuron cannot fire again. This is because when the channels close, a certain amount of time needs to pass before they can open again.
- Neurons can code information by changing the rate and timing of action potentials.
 - Higher firing frequency = more intense stimulus.
- Action potentials are always all or nothing which means once the threshold voltage is reached, result is a rapid spike and then fall in voltage.
- The action potential propagates along the axon, more and more sodium channels open, and the depolarization can occur. The opening of potassium channels is what restores a resting membrane potential.
- Conduction speed of action potentials is limited by width of the axon.
- Glial cells form layers called myelin that wrap around axons of sensory neurons. It insulates the axon's membrane and spreads the charge from a local action potential over a greater distance along the axon's length.
- Saltatory propagation is where the action potentials in myelinated axons jump from node to node which increases the speed of signal transmission.
- Two types of synapses.
 - Electrical ones provide direct electrical communication through gap junctions. They enable rapid communication but limit ability to process and integrate information.
 - Chemical synapses are more common and the signals that are conveyed at those synapses are neurotransmitters. When the action potential gets to the terminal, calcium channels open and ions diffuse into the cell and that's when vesicles fuse with the presynaptic membrane and release the neurotransmitters through exocytosis, and they then bind to the postsynaptic receptors of the neighbor cell. The binding then opens and closes ion channels which causes a change in that cell's membrane potential. This is how the signal is able to propagate.



- When the neurotransmitters go to the neighbor cell, whether or not an action potential is triggered will depend on magnitude of depolarizing excitatory postsynaptic potentials (EPSPs) or magnitude of hyperpolarizing inhibitory postsynaptic potentials (IPSPs). Basically, the membrane receptors can either stimulate or inhibit the firing of action potentials in the postsynaptic neuron.
 - EPSP is created when sodium channels open and sodium ions diffuse into the cell.
 - IPSP is created when membrane potential becomes more negative and that can be caused by opening of Cl⁻ or K⁺ channels.
- A single nerve cell releases only one type of neurotransmitter.
- Temporal summation is when frequency of the synaptic stimuli determine whether the postsynaptic cell fires or not. Spatial summation is when the number of stimuli from different regions determine whether it fires or not.

35.4 Nervous System Organization

- Nervous system organized into peripheral and central components.

- Nerve cell bodies grouped together in sensory organs and a main nerve cord that extends from the brain.
- Sensory and motor nerves make up the peripheral nervous system and they communicate with the central nervous system which is made up of the brain and a nerve cord.
- Afferent neurons send info toward the CNS. Efferent neurons send info away from CNS.
- There can also be ganglia that lie outside segments of their primary nerve cord that coordinate localized function within a region of their body.
 - Bulk of info processing through, happen in the CNS.
- Spinal cord helps pass info between brain and periphery of the body. Each segment of the cord controls body movement in a particular region. Each segment has axons from sensory neurons, a set of interneurons, and a set of motor neurons.
- PNS organized into left and right sets of cranial nerves in the head and spinal nerves running from the spinal cord to the periphery.
 - Cranial nerves link eyes/ears/tongue to the brain.
 - Spinal nerves thread through trunk and limbs of an animal body and pass info back to spinal cord.
- Conscious reactions are under control of the voluntary component of the nervous system, unconscious ones under the control of involuntary component.
 - Voluntary handles sensing and responding to external stimuli.
 - Involuntary handles internal bodily functions.
- PNS divided into somatic/voluntary and autonomic/involuntary components.
 - Autonomic normally controls the internal functions of the body like heart rate and blood flow.
- Autonomic nervous system divided into sympathetic division and parasympathetic division. Both regulate internal functions and normally oppose each other.
 - Sympathetic nervous system results in arousal and increased activity. Pathway activated when animals are exposed to threatening conditions. The nerves here leave the CNS from the middle region of the spinal cord.
 - Parasympathetic enables body to rest and digest. The nerves here leave the CNS from the brain by the cranial nerves and from lower levels of the spinal cord.
- In negative feedback, a stimulus acts on a sensor that communicates with an effector, which produces a response that opposes the initial stimulus.
 - When lower body temperatures, hypothalamus activates somatic nervous system to induce shivering and production of metabolic heat to raise the temperature. Also, hypothalamus tells autonomic nervous system to cause peripheral blood vessels to constrict.
- Ability to maintain a constant body temperature is known as thermoregulation.
- Fast responses are made possible by reflex circuits (sensory neurons directly connecting with motor neurons) that bypass the brain.
 - Knee extension reflex is an example: Let's follow this reflex pathway. It starts with specialized "stretch" receptors located on the dendrites of a sensory neuron in the extensor muscles of the leg. These dendrites extend to cell bodies in ganglia

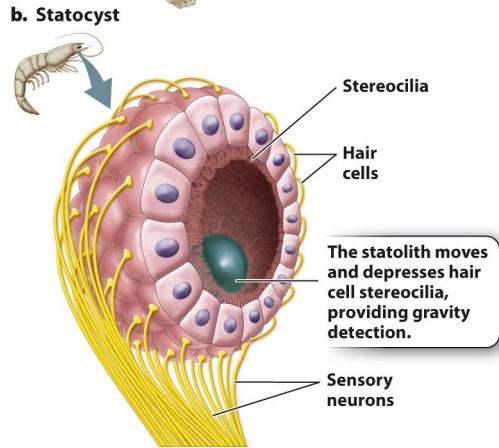
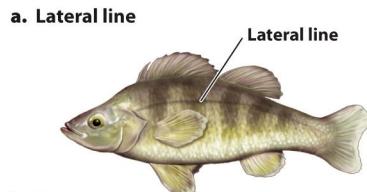
alongside the spinal cord. These cell bodies have axons that extend into the spinal cord. The stretch receptors sense the stretch of the muscle that occurs during movement or in response to a physician's strike of a reflex hammer. In response to a stretch, a signal is sent from the stretch receptor, through dendrite and cell body to the axon. In the spinal cord, the axon of the sensory neuron forms synapses with motor neurons that travel from the spinal cord back to the muscle where the stretch originated. The signal from the muscle stretch receptor stimulates the motor neurons to increase the activation of the muscle: the muscle contracts, and the leg extends at the knee.

- Reciprocal inhibition is when one set of muscles activate and the activity of opposing muscles are inhibited.
- Hypothalamus plays the role of the sensor in all of this.

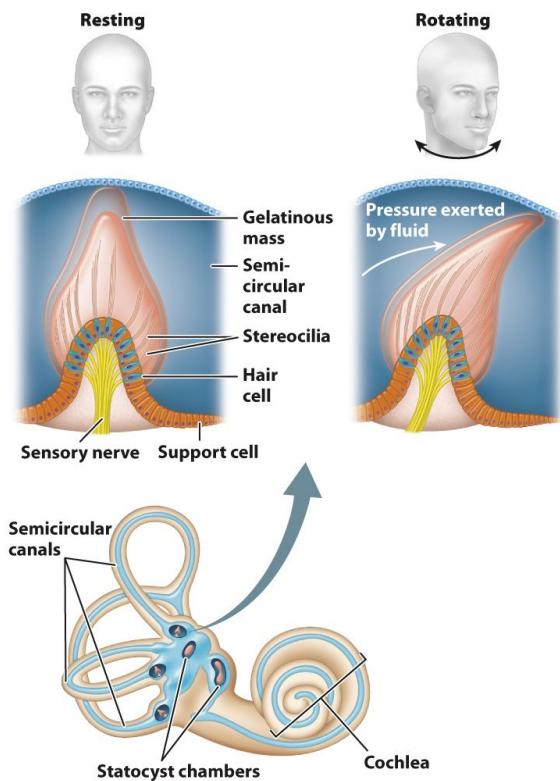
Chapter 36

36.3 Gravity, Movement, and Sound

- Lateral inhibition allows the determination of the location of a source by stimulating local sensory receptor neurons, but also inhibiting adjacent interneurons.
- Accommodation is when the frequency of a signal decreases after it has been there a little bit of time.
- Hair cells are those that are mechanoreceptors and they sense movement and vibration. They sense vibrations which move hairlike projections from the surface of the hair cell called stereocilia. This motion of stereocilia causes depolarization of cell's membrane by opening or closing ion channels.
- Hair cells don't fire action potential but they release neurotransmitters that alter the firing rate of adjacent neurons.
- Hair cells contained in the lateral line system of aquatic animals sense water vibrations that indicate things in the environment.



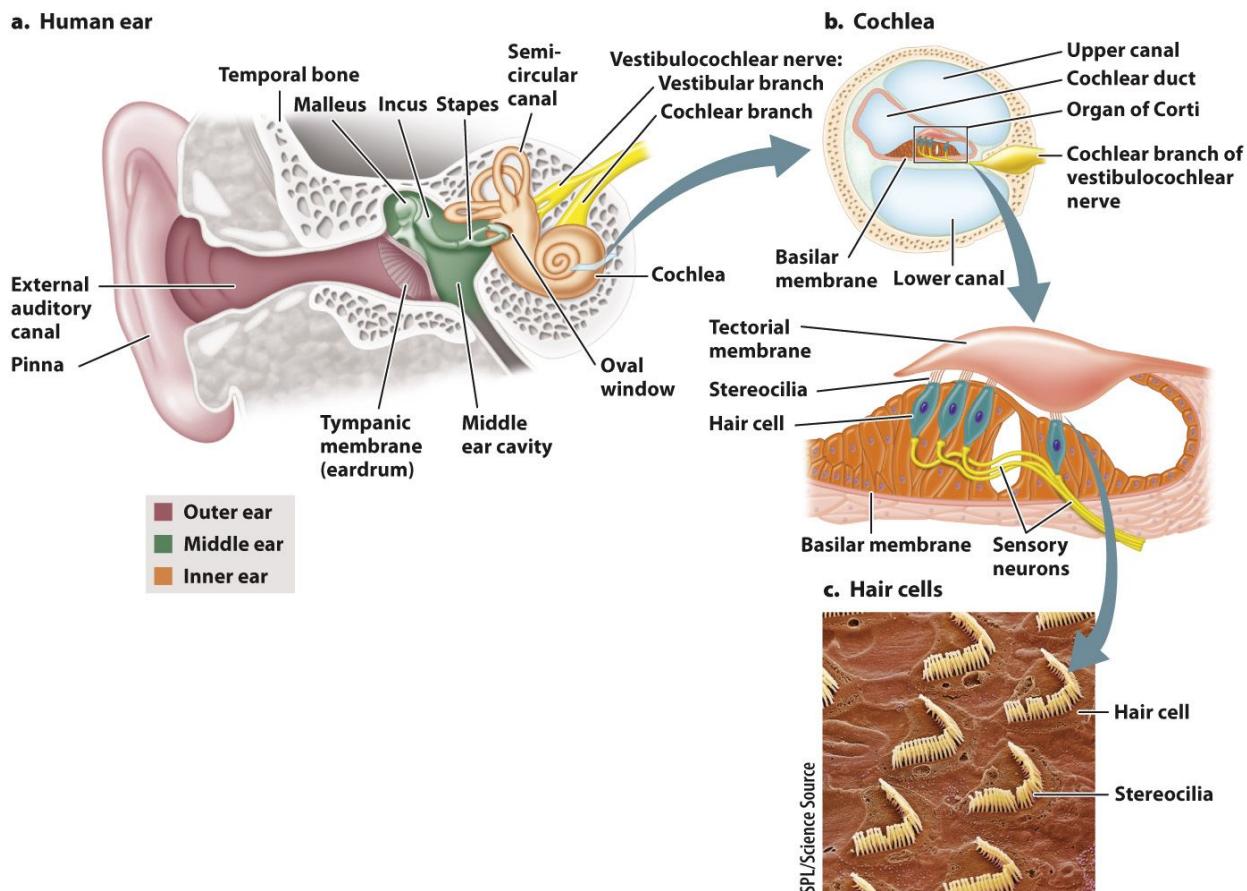
- To detect gravity, we have organs called statocysts which are internal chambers lined by hair cells. There is a particle called a statolith that is free to move in the organ. When we press down on hair cells at the bottom of the chamber, the statolith activates those cells. The primary function of statolith is to determine the direction of gravity.



- To sense motions of the head and head orientation, we have organs in the ear that make up the vestibular system. It has two statocyst chambers and three semicircular

canals. The hair cells in those canals sense gravity and body orientation. Brain interprets differences in the motion of hair cells to resolve the angular motions of the head.

- Because we have this fluid and then stereocilia of hair cells to detect the fluid, and stereocilia which also activates sensory neurons, the brain can react to head motion faster than visual cues.
- Frequency of sound waves determines pitch and amplitude determines the loudness.
- When the stereocilia of hair cells bend because of the waves, they get excited and depolarize and release neurotransmitters.
- Insects have special ears that send sound by a tympanic membrane which is at the surface of the ear and it vibrates in response to sound waves.



- Ears of mammals have the pinna which enhances reception of sound waves. Pinna is part of outer ear. Outer ear includes ear canal and tympanic membrane (eardrum) that transmits sounds into the ear.
- Middle ear has malleus, incus, and stapes which amplify waves that strike the membrane.
 - Sound amplification happens because of the movement of bones in the middle ear and differences in the surface area of the eardrum versus the oval window.

- Stapes connects to membrane called oval window of the cochlea in the inner ear. The cochlea is chamber that contains hair cells that convert pressure waves to electrical impulse that is sent to brain.
- Hearing involves amplification, stapes transmitting energy, transfer of sound vibration to fluid pressure waves, and mechanoreception by hair cells within the cochlea.
- Louder sounds create larger fluid vibrations that cause stereocilia to bend more and increase the number of neurotransmitters released.
- Sound amplitude and frequency and vestibular sensing of gravity and head motion are transmitted by vestibulocochlear nerve to the brain.

36.4 Vision

- Most animals have photoreceptor cells that respond to light.
- Opsin is the light sensitive protein that converts light energy to electrical signals in the receptor cell. They are G protein coupled receptors. The cellular response here is a change in the membrane potential.
- The way the visual world is perceived depends on the structure of the eye in which the receptors are embedded.

a. Eyecup



David M. Dennis/age fotostock

b. Compound eye

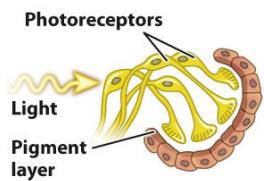


Eye of Science/Science Source

c. Single-lens eye

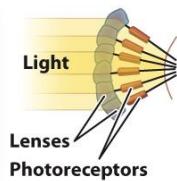


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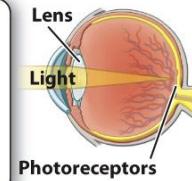
Photoreceptors
Light
Pigment layer

The flatworm *Planaria* uses simple photoreceptors and a pigmented epithelium to sense the direction of light.



Light
Lenses
Photoreceptors

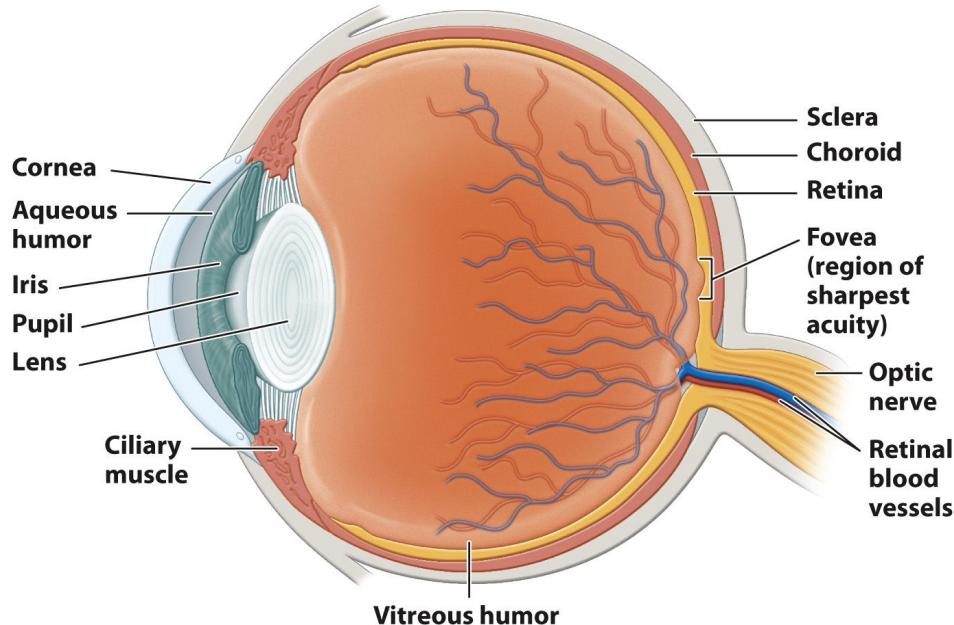
The compound eye of insects, such as the common housefly, is composed of hundreds of ommatidia, each with a lens, that individually sense light.



Lens
Light
Photoreceptors

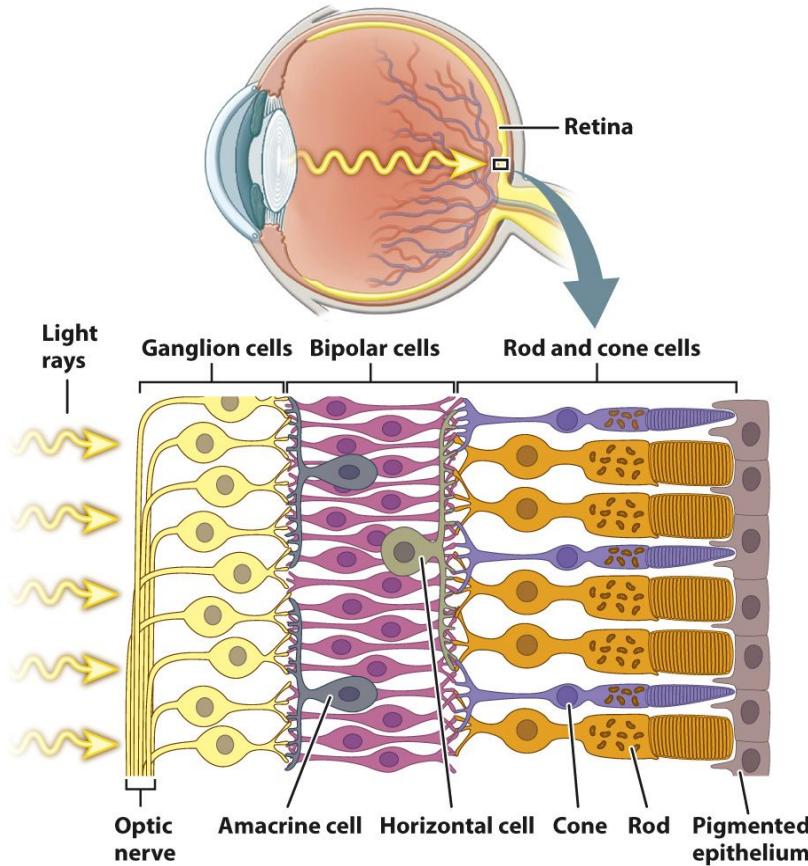
The single-lens eye of a squid focuses light on a retina and allows for a high degree of acuity.

- Eyecup structure has photoreceptors that point up and to the left/right and they get light only from above and in front of the animal. Most of the time, these flatworms will look for areas with less light intensity received by the photoreceptors.
- Compound eye structure has a lot of light focusing elements called ommatidia which each have a lens and the number of ommatidia determines the resolution of the image.
 - In one ommatidium, light gets focused through the lens onto a region formed from multiple overlapping photoreceptors.
 - Structure allows animals to be good at detecting motion and rapid flashes of light.
- Single lens structure can focus light rays on a particular region of photoreceptors which improves the image quality.



- Eye is surrounded by the sclera, which is a tough and white outer layer. Beneath it is the choroid which is a moist layer that carries blood vessels. Light passes through cornea (part of the sclera), then to the pupil, and then through a convex lens.
- Iris surrounds the pupil and opens/closes to adjust amount of light that enters.
 - When it gets bright, pupils get smaller to reduce the amount of light that comes in.
- Clear and watery liquid in front of lens is aqueous humor. Cavity behind the lens with gel substance is the vitreous humor.
- To see an image, cornea and lens bend the incoming light rays, focus them on the retina, light rays cross, image inverts, and then the photoreceptors and nerve cells initially process the stimuli.
- When object is close range, lens becomes more rounded to bend light rays more.
- When object is long range, lens becomes more flat to bend light rays less.
- For more visual field, have eyes at the sides. For more visual sharpness, have them at the front.
- Opsin molecules arranged in cylindrical groups in plasma membrane. Each opsin protein has light absorbing pigment molecule called retinal, which changes conformation when it absorbs a photon.
- Photoreceptors have leaky sodium channels (more ions come inside) and thus the resting membrane potential is less negative than nerve cells and it releases glutamate constantly. When retinal gets a photon of light, it changes from cis to trans which causes sodium channels to close completely which cause cells to be hyperpolarized and release of glutamate is reduced. This reduction affects the ESPNs and ISPNs of other neurons which provides info on the intensity and location of light.
- Color vision comes through cone cells which have opsins sensitive to different wavelengths.

- Cone cells have one of three opsins which absorb blue, green, or red wavelengths.
 - Located in the fovea of the retina and they provide the sharpest vision.
 - Higher concentration of cone cells in the center of the retina gives you better vision for stuff in front of you rather than on the periphery.
- There are also rod cells that all have the same opsin. They are really sensitive which lets animals see in low light.
 - Located in the periphery
- Cone cells require higher levels of light than rod cells to be affected.



- Light passes through several layers before reaching the rods and cones. When it reaches them, they don't fire action potentials, but rather synapse on to bipolar cells which then adjust the release of neurotransmitters. Bipolar cells synapse on to ganglion cells and ganglion cells transmit action potentials to visual cortex in the brain.
- Horizontal cells communicate between groups of photoreceptors and bipolar cells and this helps enhance contrast and adjust sensitivity to light levels.
- Amacrine cells communicate between bipolar and ganglion cells, which helps motion detection and reinforces the adjustment of photoreceptor light sensitivity.

36.5 Brain Organization and Function

- Particular brain regions control particular aspects of a person's behavior and cognitive function.
- Vertebrate brain organized into
 - Hindbrain: Control basic body functions and behaviors.
 - Midbrain: Control basic body functions and behaviors.
 - Forebrain: Specifically the cerebral cortex governs more advanced functions. That cortex is the largest region in a mammalian brain.
- Hindbrain turns into cerebellum and pons and the brain stem when you grow older.
- Cerebellum coordinates complex motor tasks by integrating motor and sensory information.
- Brain stem initiates and regulates motor functions. It activates forebrain by relaying info from lower spinal levels.
- Forebrain consists of inner brain region that forms thalamus and hypothalamus.
 - Thalamus is relay station for sensory info that is sent to higher brain centers. It works with the endocrine system to regulate physiological state.
 - Forebrain also contains components that constitute limbic system, which controls physiological drives, instincts, and emotions. Stimulation of this system can produce emotions.
 - Hippocampus is a region in the limbic system and is involved in long term memory.
- Sensory information reaches the cerebral cortex from the cranial nerves and nerves passing through the spinal cord. This information passes through the brainstem, and then through the thalamus, the central relay station for sensory information. From the thalamus, information for each of the senses goes to a different region of the brain specialized to further process that information, in a manner discussed next.
- Cerebral hemispheres composed of folded gray matter with densely packed neuron cell bodies (which is what makes it look gray) and dendrites.
- Inside the cerebral cortex is white matter, which has axons of cortical neurons.
 - The myelin makes this region white.
- Frontal lobe is in cerebral cortex and is important in decision making and planning. Parietal lobe controls body awareness. Temporal lobe processes sound and language. Occipital lobe processes visual info.
- Central sulcus separates primary motor cortex or frontal lobe from primary somatosensory cortex of parietal lobe.
 - Command neurons in the former control skeletal muscles
 - Neurons in the latter relay info to motor cortex.
- Motor cortex is organized into different regions that control different body parts, and the sensory cortex is organized into regions to detect pressure and touch sensations from a body part. .
- Neurons in auditory cortex are organized by pitch where neurons sensitive to low frequencies are at one end, and higher frequencies at another end.

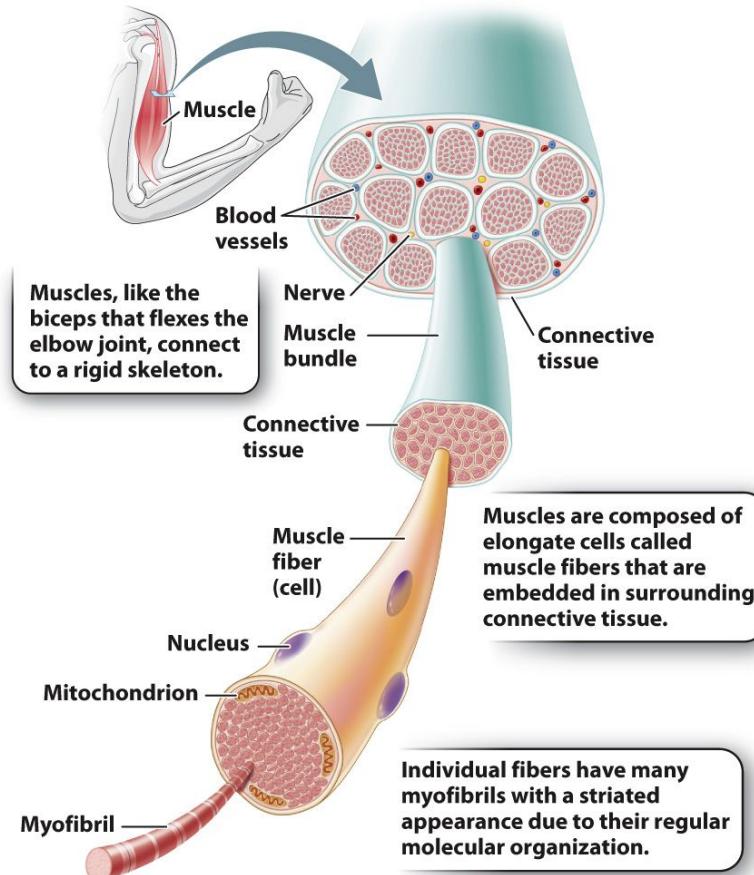
36.6 Memory and Cognition

- Cognition refers to ability of the brain to process and integrate complex sources of info and remember past events, etc.
- Memory is formed by changes to neural circuits and by changes in the synaptic connections between neurons in a circuit.
- Hippocampus transforms reinforced short term memories into longer term ones. Does this by relaying info to regions of the cerebral cortex. There has to be established neural circuits (connections between neurons) in the hippocampus and the cerebral cortex.
- Ability to adjust synaptic connections is called synaptic plasticity.
 - Long term potentiation is an example. Neurons in excited circuits release neurotransmitter called glutamate which opens sodium and calcium channels, which stimulate signaling pathways to lead to protein synthesis, and thus new receptors and dendrites are formed (only on the postsynaptic cell), which strengthens the signaling between the two cells which make it more responsive to subsequent stimulation. This creates memory that can be retrieved over long periods of time.
- The three areas of the brain that are used to remember and recognize a face are the occipital cortex for processing visual information, the hippocampus for forming long-term memory of a face, and the temporal lobe for facial recognition.

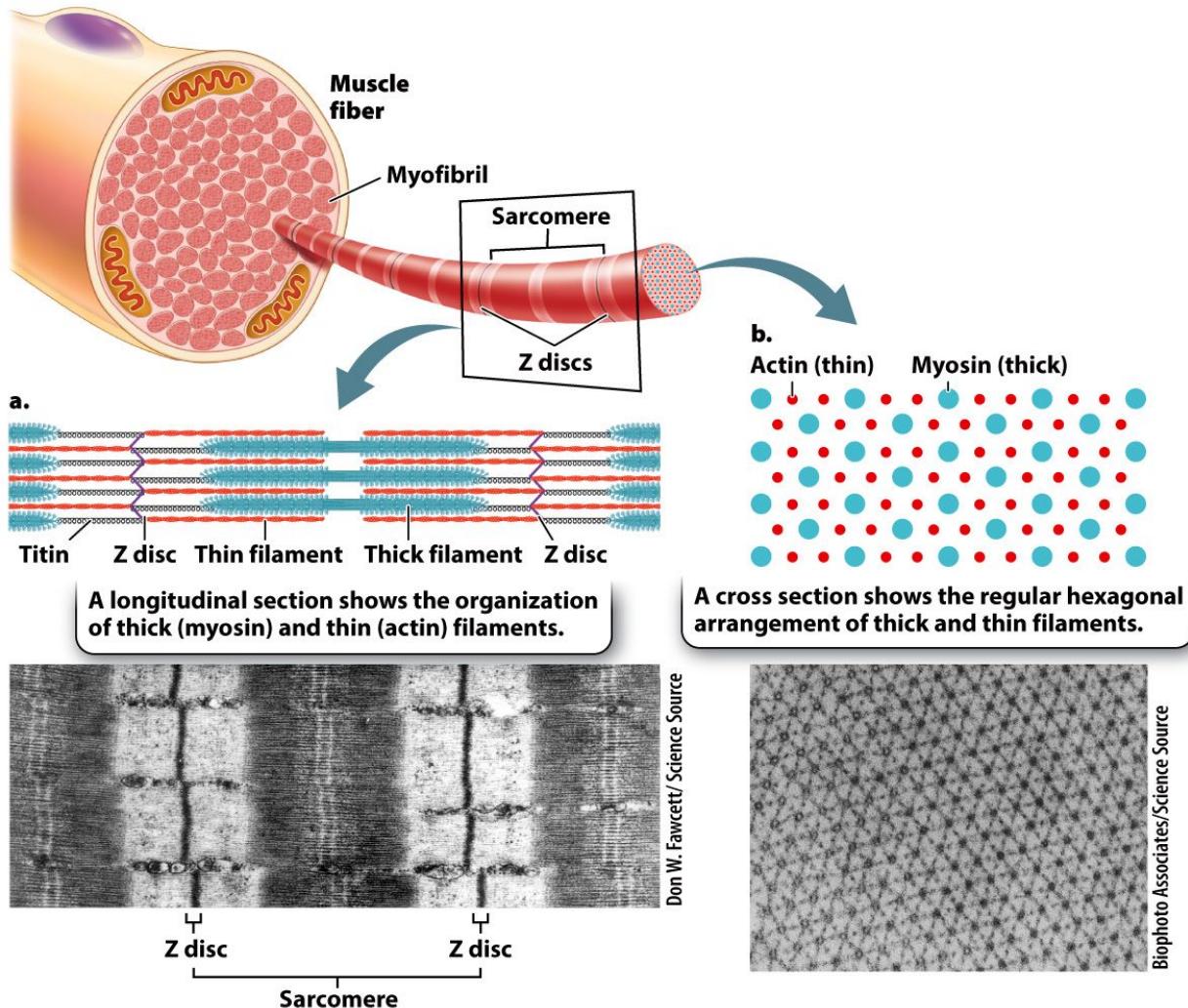
Chapter 37

37.1 Muscles: Biological Motors that Generate Force and Produce Movement

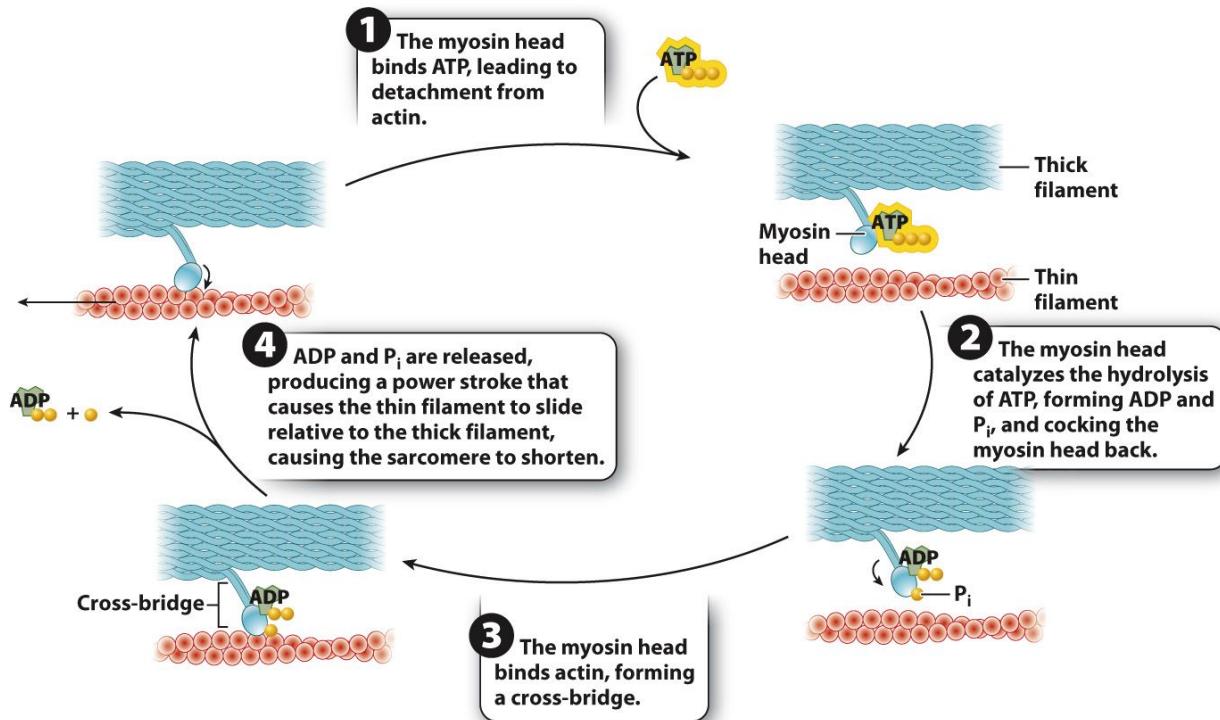
- Muscle's ability to produce movement depends on the electrically excitable muscle cells that have proteins that can be activated by the nervous system.
- Muscles have elongated cells called muscle fibers which use ATP to generate force and change length.
 - Force is a push or pull by one object on another.
- Pairs of muscles are arranged to produce movements in two opposing directions at specific joints.
- Actin and myosin are the proteins that allow muscles to shorten and produce force.
 - Filaments are arranged differently in each type of muscle.
- Striated muscles have actin and myosin filaments that are arranged in a regularly repeating pattern.
 - They also include skeletal and cardiac muscle.
- Smooth muscles are non-striated because the organization of those filaments is irregular. They contract slowly.



- Muscles made of parallel bundles of individual muscle fibers which each have hundreds of long rodlike structures called myofibrils which contain parallel arrays of actin and myosin filaments.
- Myosin molecules have two long polypeptide chains coiled together. They arrange in parallel to form a thick filament.
- Actin units are arranged in a double helix to form a thin filament. Tropomyosin is a protein that runs in the grooves.
- Thin filaments attached to protein backbones called Z discs. Region from one Z disc to another is called the sarcomere.
 - They are arranged in series along the length of the myofibril.
- In the middle of the sarcomere, not directly contacting the Z discs, are myosin thick filaments. The thin filaments overlap with the myosin thick filaments, forming two regions of overlap within a sarcomere.

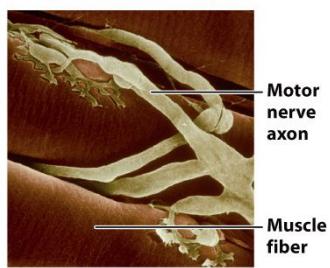


- Muscles produce force and change length by sliding of actin filaments relative to myosin filaments.
- When myofibrils contract to short lengths, sarcomeres increase the actin-myosin overlap and vice versa.
 - Length change of the whole muscle is a sum of the fractions by which each sarcomere shortens.
- Muscle's ability to generate force and change length is determined by the properties of the sarcomeres.
 - Longer sarcomeres allow a greater degree of shortening.
 - Shorter sarcomeres mean that you can produce movements more quickly.



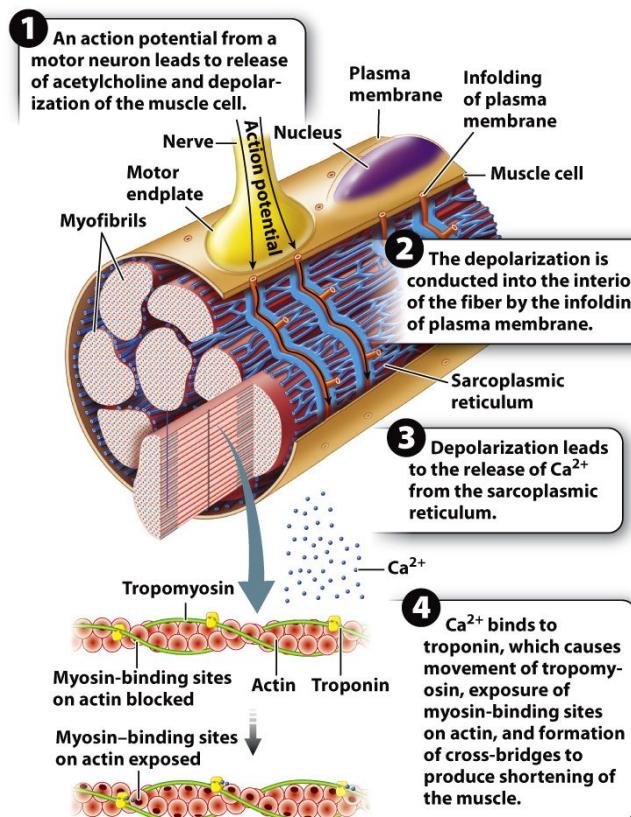
- Video explanation: <https://www.youtube.com/watch?v=zopoN2i7ALQ>
- Another good one: https://www.youtube.com/watch?v=7O_ZHyPeIIA
- Interactions between myosin and actin filaments are what cause a muscle fiber to shorten and produce force.
 - Cross bridges are formed when one of the two heads of myosin binds to an actin at a specific site.
 - Ability for the myosin head to pivot back and forth is what allows the filaments to slide relative to each other.
- Individual muscle contractions are result of many cycles of cross bridge formation and detachment. The cells convert chemical energy released by ATP into force and KE of movement.
- Muscle fibers that contract quickly have faster rates of cross bridge cycling.
- If an organism doesn't have enough ATP, then the myosin cross bridges with actin cannot detach and thus they remain in the bound state and they make the muscle stiff.

a. Scanning electron micrograph of a motor nerve endplate



Don W. Fawcett/Science Source

b. Muscle excitation–contraction coupling



- Skeletal and smooth muscle fibers are activated by the nervous system.
 - Skeletal muscles innervated by somatic nervous system.
 - Smooth muscles innervated by autonomic nervous system.
- Muscle fibers are electrically excitable. Motor neuron axons have branches that let them synapse with multiple muscle fibers.
- Good video: <https://www.youtube.com/watch?v=IRJd56BCidg>
- When action potentials traveling down a motor neuron arrive at the neuromuscular junction, the neurotransmitter acetylcholine is released into the synaptic cleft. The neurotransmitter binds with postsynaptic receptors on the muscle cell at a region called the motor endplate, triggering the opening of Na^+ channels. The resulting influx of Na^+ ions in turn initiates a wave of depolarization that passes from the neuromuscular junction toward both ends of the muscle fiber. The depolarization leads to the release of calcium from the sarcoplasmic reticulum which is like a reservoir for calcium. This is called calcium induced calcium release. That calcium then binds to troponin which causes it to change shape which then causes movement of tropomyosin, exposure of myosin binding sites on actin and formation of cross bridges to produce that relative movement and the shortening of the muscle.
 - At rest, the myosin binding sites on actin are blocked by tropomyosin, so that's what it has to move away first.

- Process by which membrane depolarization leads to calcium release and the formation of myosin actin cross bridges is called excitation contraction coupling.
- Myofibrils of muscle cells surrounded by organelle called sarcoplasmic reticulum.
- In smooth muscles, the calcium that gets released also enters voltage gated and stretch receptor calcium channels in the cell's plasma membrane.
- Smooth muscles also don't have troponin-tropomyosin. Instead they have activation through the protein calmodulin binding with calcium released from the SR. This new complex activates a myosin kinase that causes the myosin heads to bind to actin and start the cycle.
 - Smooth muscle thus contracts more slowly
- SR of smooth cells have less calcium pumps than SR of skeletal cells and thus calcium is returned more gradually from the microfibrils to the SR

37.2 Muscle Contractile Properties

- Summed force of individual myofibrils of activated muscle fibers determines the force the whole muscle can exert.
- The more overlap between actin and myosin filaments, the more force can be produced.
 - When muscle is pulled to long lengths, then contracts, the force is reduced because less overlap.
 - At short lengths, less force because myosin begins to run into the Z disc at each end of the sarcomere.
 - Overlap is greatest at the intermediate lengths.
- Muscle shortens fastest when producing low forces. Muscle needs to shorten at slower velocities to produce large forces.
- Isometric force is when muscle will generate a force but will stay the same length and does not shorten.
- Muscles stretch when the external load against which they contract exceeds the force the muscle produces, which is called active lengthening contraction.
- Antagonist muscles are those that pull in opposite directions. Flexion moves bone segments closer, and extension moves them farther apart.
- When muscles combine to produce similar motions, they are termed muscle agonists.
- Skeletal muscles stimulate motor nerves which send action potentials which indicate amount of calcium that gets released for cross bridge formation. More action potentials mean more calcium release.
- Muscle contraction of sustained force is called a tetanus.
- Motor neurons and the population of muscle fibers are collectively called motor unit.
- Slow twitch fibers are found in muscles that contract slowly and consume ATP more slowly to produce force. Fast twitch is for rapid movements that consume ATP more quickly.
- Slow twitch get energy through aerobic respiration, while fast twitch get from glycolysis.
- Slow twitch have a lot of myoglobin which facilitates oxygen delivery to the mitochondria. Fast-twitch fibers express a chemically "fast" form of myosin with a high rate of ATP hydrolysis, favoring rapid force development and movement.

- Muscle is built through increasing the size of muscle fibers through synthesis of additional myosin and actin filaments.
- Good overview:
<https://courses.lumenlearning.com/boundless-ap/chapter/introduction-to-skeletal-muscle/>

Senses Video

- Sensory receptors are either ionotropic or metabotropic
 - Ionotropic receptors are where the sensation gates a channel directly. The protein that senses the signal is itself a channel.
 - Metabotropic receptors are normally coupled to other proteins and activate channels indirectly.

Chapter 38

38.1 An Overview of Endocrine Function

- Hormones regulate an organism's response to the environment and help to maintain stable physiological conditions within cells or within the animal.
 - Changes in the environment will stimulate changes in the animal.
- Endocrine responses triggered by sensory signals, received by nervous system and relayed to endocrine system, which reinforce the proper physiological changes.
- Release of hormones from the endocrine system regulate how animals grow.
- Shedding of the exoskeleton is known as molting.
- Molting and metamorphosis are regulated by hormones released from tissues in the insect's head.

TABLE 38.1 Major Invertebrate Hormones

SECRETING TISSUE OR GLAND	HORMONE	TARGET GLAND OR ORGAN	ACTION
Brain	Brain hormone (PTTH) (peptide)	Prothoracic gland	Stimulates release of ecdysone to trigger molt and metamorphosis
Corpora allata	Juvenile hormone (peptide)	All body tissues	Inhibits metamorphosis to adult stages; stimulates retention of juvenile characteristics
Prothoracic gland	Ecdysone (steroid)	All body tissues	Stimulates molt and, in absence or low levels of juvenile hormone, stimulates metamorphosis
Nervous system	Ecdysone (steroid)	All body tissues	Stimulates growth and regeneration in sea anemones, flatworms, nematodes, annelids, snails, and sea stars
Brain	Melanocyte-stimulating hormone (peptide)	Chromatophores	Stimulates pigmentation changes in cephalopods (octopus, squid, and cuttlefish)
Brain and eye stalks	Chromatotropins (peptides)	Chromatophores	Stimulates pigmentation changes in crustaceans
Reproductive gland	Androgen (peptide)	Reproductive tract	Regulates development of testes and male secondary sexual characteristics of crustaceans

- Hormones and the resulting responses to insects.

- PTTH triggers molting by stimulating the release of ecdysone which is a steroid hormone that coordinates growth and reorganization of body tissues.
- Hormone can coordinate broad changes in body organization and function, which is in contrast to the specific regulation that nerves provide.
 - Relatively few hormones can have a large end effect.
- Brains of insects contain neurosecretory cells, which are neurons that release hormones, which act on endocrine glands.
- Growth hormone is produced by the pituitary gland.
- Endocrine control of internal body functions is central to homeostasis, which is the maintenance of a steady physiological state.
- Maintaining homeostasis depends on feedback from the target organ to the endocrine gland that secretes the hormone.
 - The feedback tells the gland whether to secrete more or less which refers to positive and negative feedback.
- The workflow is that there is a change in level of _ and that is found by sensor _ inside of an organ _ which releases a hormone _ that causes a response in the body that opposes the original change.
- When blood glucose rises, beta cells in the pancreas release insulin which cause the muscle and liver cells to take up glucose from the blood which decreases the amount in the blood itself. The glucose is stored inside the cells as glycogen.
- When the levels fall low, then alpha cells in the pancreas will release glucagon which has the opposite effects. It stimulates the breakdown of glycogen into glucose.
- When control of blood glucose levels through insulin fails, you have disease called diabetes mellitus.
 - Decreased insulin production is type 1
 - Decreased effect of insulin on target cells is type 2.
- Positive feedback is when the response tells the glands to release more of the hormone.

38.2 Properties of Hormones

- Hormones are chemical signals that allow cells to communicate with each other.
- Peptide and amine hormones are hydrophilic and thus only go to cells that have extracellular receptors.
 - These can still cause changes in gene expression or can affect the function of metabolic enzymes in cells.
- Steroid hormones on the other hand are hydrophobic and go to cells with intracellular receptors, either in the cytosol or the nucleus. The complex eventually binds to DNA and activates transcription from target genes.
 - They thus exert more profound and long lasting effects than peptide or amine hormones.
 - Testosterone is example of a steroid hormone.
- Two main classes of hormones are amine/peptide and steroid hormones.

38.3 The Vertebrate Endocrine System

- The vertebrate endocrine system regulates changes in the animal's physiological and behavioral states in response to sensory cues received by its nervous system both from the environment and from internal organs.
 - Basically the nervous system interacts with the hypothalamus to control endocrine function in the body.
- Some sensory signals communicate with endocrine glands, but most are processed within the brain and transmitted to the endocrine system by the hypothalamus which relays the signals to the pituitary gland which is the central regulating gland in the system.
 - The glands control the growth and maturation of the body.
 - They communicate with more cells, tissues, and organs and they will secrete hormones in response to the signals.
- Vertebrate endocrine system is not localized in one part of the body, but is throughout.
- Hypothalamus relays signals to the pituitary gland, which is divided into anterior and posterior regions. Anterior forms from epithelial cells that push from the roof of the mouth whereas posterior develops from neural tissue at the base of the brain.
 - Both develop into glands that lie adjacent to each other.
- Hypothalamus will communicate to the anterior gland through neurosecretory cells which communicate by secreting releasing factors into the blood which causes cells in the anterior gland to release hormones which circulate throughout the body.
 - The hormones released will act on endocrine gland with releases more hormones. Hormones that control the release of other hormones are tropic hormones.
 - Other examples are TSH, FSH, LH, and ACTH
 - TSH is thyroid stimulating hormone and acts on the thyroid gland, which release T3 and T4 which are hydrophobic hormones and bind to intracellular receptors which increase metabolic rate. TSH is negatively regulated by T3 and T4.
 - Overproduction of thyroid hormones = overly metabolic state
 - Thyroid hormone deficiency = Fatigue and sluggishness
 - FSH and LH target ovaries and testes which secrete sex hormones which are estrogen and testosterone.
 - Testosterone is a steroid that stimulates synthesis of proteins for sperm production.
 - ACTH acts on the cortex of adrenal glands, which secrete cortisol which affects blood glucose levels, immune function, and blood pressure.
- Communication between hypothalamus and the posterior gland happens because the axons of those neurosecretory cells are connected to the cell bodies in the hypothalamus. The axons themselves just release the hormones into the bloodstream.
 - Basically, action potentials will get created in that neuron, and this stimulates hormone release.
 - The hormones released here include oxytocin and antidiuretic hormones which play roles in reproduction and kidney function respectively.

- The release of the above hormones also plays a role in affecting human behavior, which is likely related to natural selection.
- Endocrine organs don't need to get all their info from the hypothalamic-pituitary axis, but rather can respond to internal physiological states of the body or to external cues.
 - Parathyroid gland is an example. It secretes PTH which controls the levels of calcium in the blood. They do this by regulating the actions of bone cells.
- When calcium levels fall low, parathyroid gland releases PTH, which stimulates the osteoblasts which reabsorbs bone material and releases calcium into the blood.
- Pineal gland secretes melatonin in response to darkness. The hormone helps control state of wakefulness. Secretion is inhibited when environmental light cues sensed by the retina are conveyed to the gland via the nervous system.
 - Rise in melatonin levels at night. For some animals, the rise causes them to be sleepy and for some, causes them to be awake.
- The nervous system sends axons to the adrenal medulla (which is inside the adrenal gland) and then the cells secrete epinephrine and norepinephrine which target a lot of cells in the body to trigger the fight or flight response.
- Set points can be changed when an animal acclimatizes to a new environment. The change in body function is called acclimatization.
 - Example would be an increase in red blood cells for those in higher altitudes.

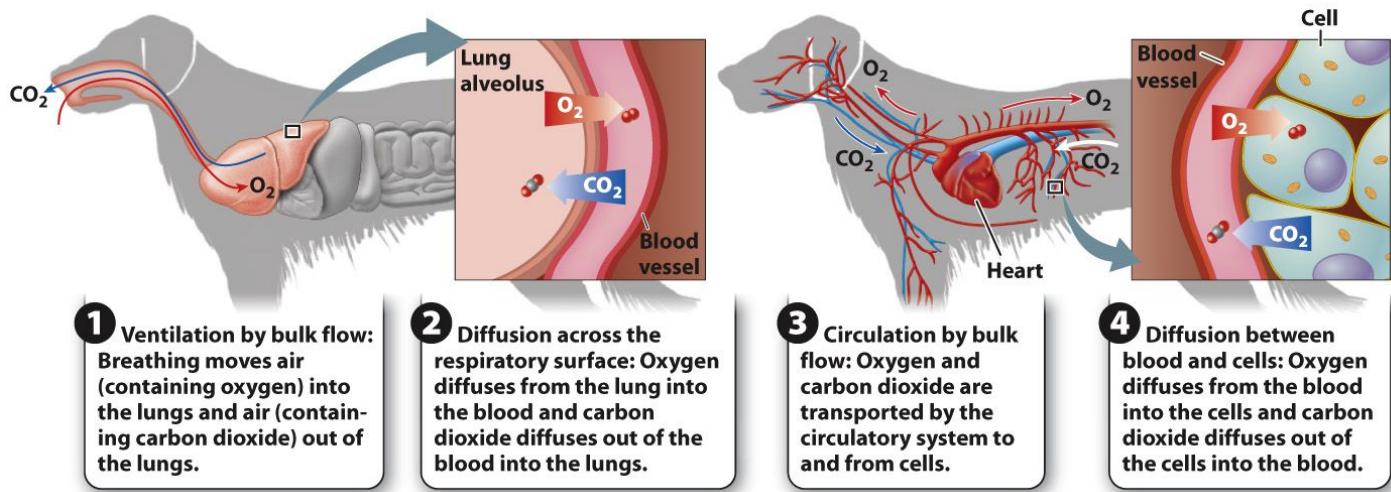
38.4 Other Forms of Chemical Communication

- Hormones that enter the bloodstream typically go to distant cells. Other chemical compounds act more locally.
- Chemical compounds that act locally have paracrine function.
 - Growth factors and histamine are examples.
 - Growth factors enhance differentiation and growth of tissues. When tissues are damaged, cells release histamine which triggers dilation of blood vessels, which allow blood proteins and white blood cells to move in and repair.
- Chemical signaling can also come through release of neurotransmitters into the synapse between communicating nerve and muscle cells at junctions. This form of signaling is rapid and brief and is called synaptic signaling.
- Animals can release chemical compounds to the environment to influence the behavior of members of their species. These compounds are pheromones.
 - They are detected by others through organ with chemosensory neurons.
- Release of sex pheromones is common type of pheromone signaling.
- These can be used to communicate with one another about food, mates, and potential danger.

Chapter 39

39.1 Delivery of Oxygen and Elimination of Carbon Dioxide

- Eukaryotic cells use oxygen to burn organic fuels for ATP. In this process, CO₂ gets released. Transport of oxygen and carbon dioxide between an animal and environment is called gas exchange.
- Single celled organisms can do that process through diffusion.
 - Rate is proportional to the surface area and the concentration difference. This is why a lot of early animals were flat.
- When considering diffusion of gas, we think of pressure instead of concentration.
- For larger animals, we also need bulk flow which is the physical movement of fluids over a given distance.
 - First, ventilation is needed to move animal's respiratory medium past a special respiratory surface.
 - Then, we need circulation which is the movement of a special body fluid that carries oxygen and carbon dioxide.
 - This is called blood in vertebrates.
- Both ventilation and circulation require a pump to drive the flow.
 - The flow rate is inversely proportional to the flow resistance.

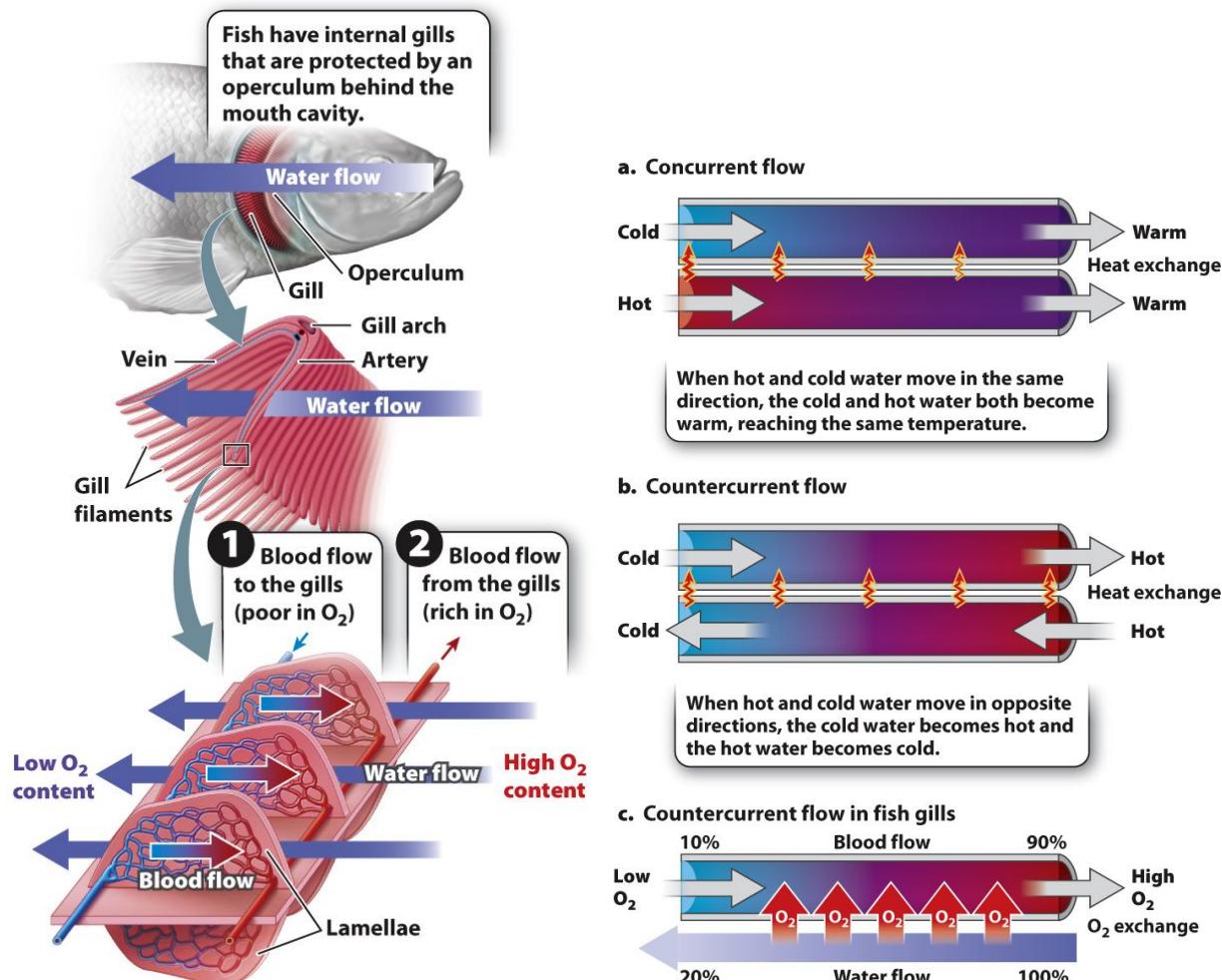


- To deliver O₂ to the mitochondria in an animal's cells, (1) fresh air or water moves past the respiratory exchange surface in the process of ventilation (in bulk flow). Ventilation maximizes the concentration of O₂ in the air or water on the outside of the respiratory surface. (2) The buildup of O₂ favors the diffusion of O₂ into the animal across its respiratory surface. (3) Following diffusion into the blood, O₂ is transported by the circulation (in bulk flow) to the tissues. Internal circulation again serves to maximize the concentration of O₂ outside cells. (4) Oxygen then diffuses from the blood across the cell membrane and into the mitochondria, where it burns fuels for ATP production.
 - Same steps occur in reverse to move CO₂ outside the body.

39.2 Respiratory Gas Exchange

- Aquatic animals take in oxygen from water using gills.
- Animals developed internal respiratory exchange surfaces (lungs) because we don't want those surfaces to dry out in a terrestrial environment.

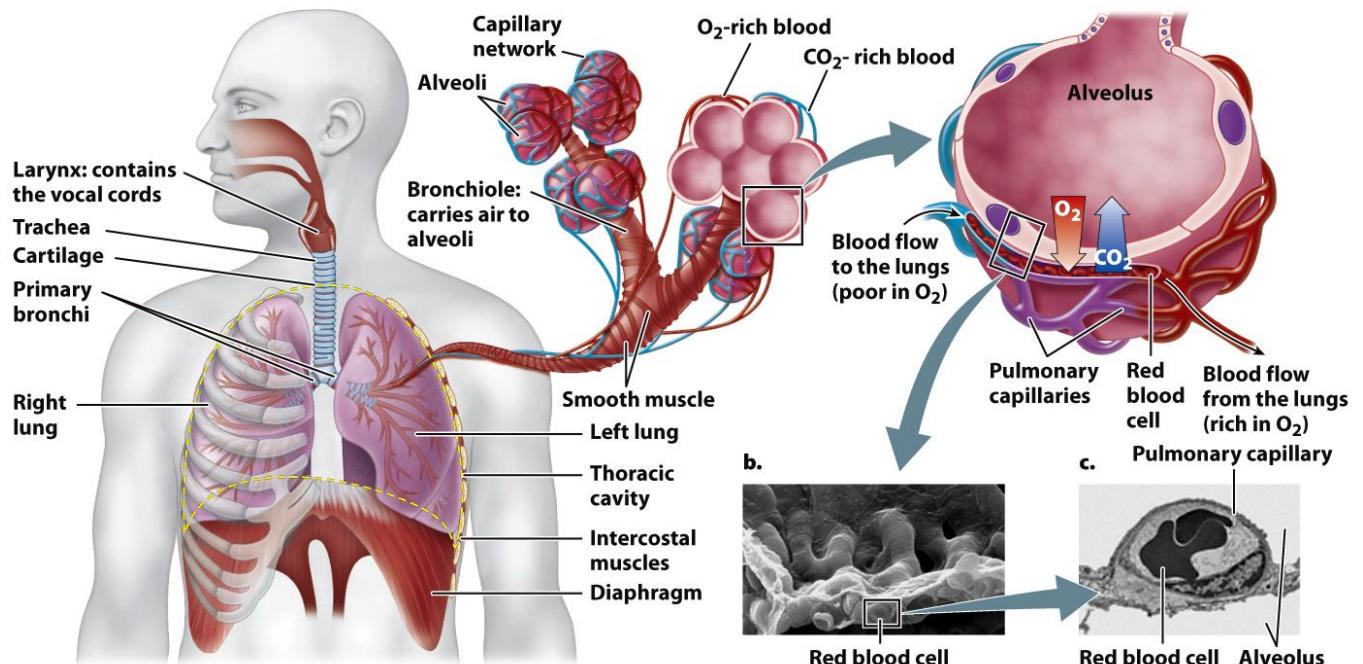
- Some insects, instead, have air tubes called tracheae which branch from openings along their abdominal surface.
- For both aquatic and terrestrial animals, ventilation supplies O₂ to gas exchange surfaces, and then O₂ crosses the surface through diffusion.
- Internal gills different from external because external relies on the natural motions of water to move the water past the gills, which those with internal gills have cilia that direct the water over the gill's surface.



- Gills have gill arches that have two stacked rows of leaf structures called gill filaments. Each filament has lamella. When oxygen poor blood comes into contact with the lamella, diffusion occurs, and the blood becomes rich in oxygen.
 - The blood flowing through the lamella moves opposite to the direction of the flow of water past the gills. (concurrent flow)
- This allows fish gills to extract all the oxygen from the water that passes over them. Blood vessels from the oxygen rich blood away from the gills to supply the fish's body.
- Oxygen uptake increased with animals because there's more oxygen in air than water, oxygen diffuses faster, and requires less energy to pump.

- Insects use spiracles to ventilate air through air tubes directly to the cells, then diffusion occurs at the cell, and then carbon dioxide diffuses out and is eliminated by the tracheae.
- Tidal ventilation is when air is drawn into the lungs during inhalation and moved out during exhalation.
 - We can do this because air has a low density and high oxygen content relative to water.
- For reptiles, thoracic cavity is expanded to draw air on inhalation, pressure difference draws the air into the lungs, and elastic recoil creates pressure that drives the air out of the lungs.
- For mammals, inhalation is driven by contraction of the diaphragm, and exhalation happens through the elastic recoil of the lungs and chest wall.
- Intercostal muscles help the diaphragm by elevating the ribs on inhalation and depressing them during exhalation.
- Tidal volume of the lungs represents the amount of air we can inhale and exhale at every cycle.
 - During exercise, the breathing frequency and tidal volume have to increase in order to elevate the ventilation rate.

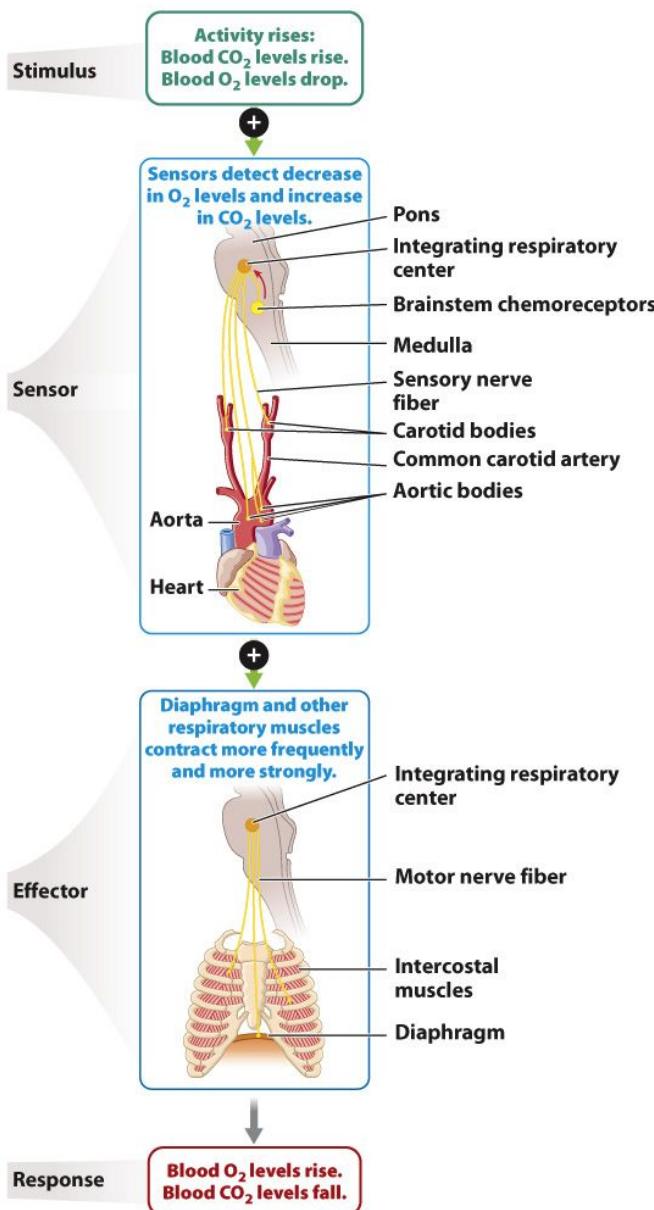
a.



Reprinted from *Respiratory Physiology & Neurobiology*, 148, E. Weibel, B. Sapoval, M. Filoche, Design of peripheral airways for efficient gas exchange, 3–21. Copyright 2005, with permission from Elsevier.

- We take in air through the mouth and then it goes to the larynx, then to trachea which divides into two airways that go to each lung. The airways/bronchi divide into finer bronchioles and they end with sacs called alveoli where the gas exchange by diffusion takes place.
- Small blood vessels called pulmonary capillaries supply the alveolar wall.
- Keeping the alveoli surface moist is critical so that oxygen can diffuse across the wall.

- Birds have two air sacs, where air is pumped continuously to them, the sacs are compressed by surrounding muscles.
- After losing O₂ and gaining CO₂, the air leaves the lungs and enters the set of anterior air sacs. Fresh air is again inhaled into the posterior air sacs, and then the stale air in the anterior air sacs is exhaled out of the bird's trachea and mouth. As a result, birds achieve a continuous supply of fresh air into the lung during both inhalation *and* exhalation.
- Animal's need for oxygen varies with activity level and thus respiratory rate is adjusted as well.
- Respiration is controlled by voluntary and involuntary components of the nervous system.



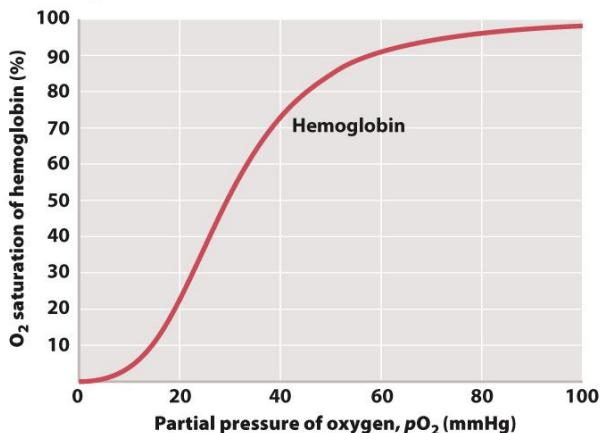
- Sensors and chemoreceptors that detect O₂ and CO₂ levels are carotid and aortic bodies.
 - Carotid sense O₂ concentrations of blood going to brain and aortic monitor their levels in blood moving to the body.
 - Chemoreceptors in the brain stem monitor CO₂ concentration.

39.3 Oxygen Transport by Hemoglobin

- Once oxygen is taken from the environment, it is transported to respiring cells through circulation by body fluids, like blood.
- Blood has the function of O₂ and CO₂ transport as well as heat transport for temperature regulation and nutrient transport, and hormone transport, and waste transport.
- Blood is separated into cellular fraction and fluid fraction.
 - Cellular fraction is made up of red blood cells that carry hemoglobin, which is a molecule for oxygen transport. 1% of cells are WBC which defend body against pathogens. The remaining cells are platelets.
 - Fraction of RBC in blood is called hematocrit. Blood with less hematocrit flows with less resistance but carries less oxygen.
- Blood plasma can only hold as much O₂ or CO₂ as can be dissolved in the solution. O₂ is 30 times less soluble than CO₂ and thus hemoglobin seeks to bind to O₂ and remove it from solution.
- The general goal of hemoglobin is to bind and transport oxygen within the cell.
- Hemoglobin exists in large concentrations within RBC. It is a protein with 4 units. Oxygen comes into the blood and then binds to the heme groups in hemoglobin. This act removes the O₂ from solution which keeps the pressure of oxygen of the RBC below that of blood plasma so oxygen keeps coming into the cell.

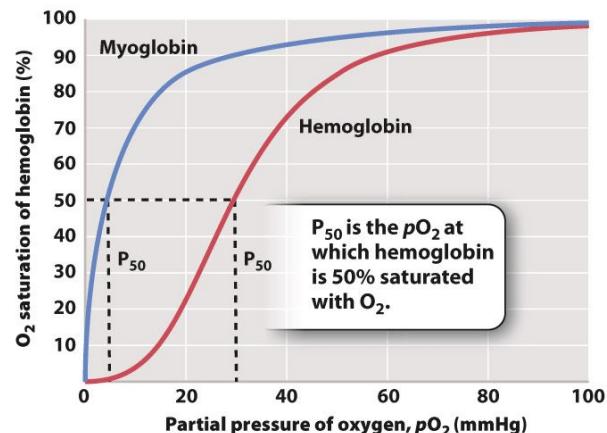
a.

The curve is sigmoidal due to cooperative binding of oxygen by hemoglobin. In the middle of the curve, small increases (or decreases) in pO₂ result in large increases (or decreases) in hemoglobin saturation.



b.

At any given pO₂, myoglobin binds oxygen more readily than hemoglobin. As a result, hemoglobin delivers oxygen to myoglobin in muscle tissues.



- The partial pressure of oxygen impacts the saturation of oxygen in hemoglobin. The ability of hemoglobin to bind to O₂ is different at different oxygen partial pressures.
 - At 25%, each hemoglobin can bind to 1 O₂ molecule. When it binds to that oxygen, it undergoes a conformational change that increases the binding affinity for the remaining heme groups. This increase is called cooperative binding.
- Myoglobin is an O₂ carrier within the cells of vertebrate muscles. They have only one heme group and they have a greater affinity for O₂ than hemoglobin does and binds O₂ more tightly.

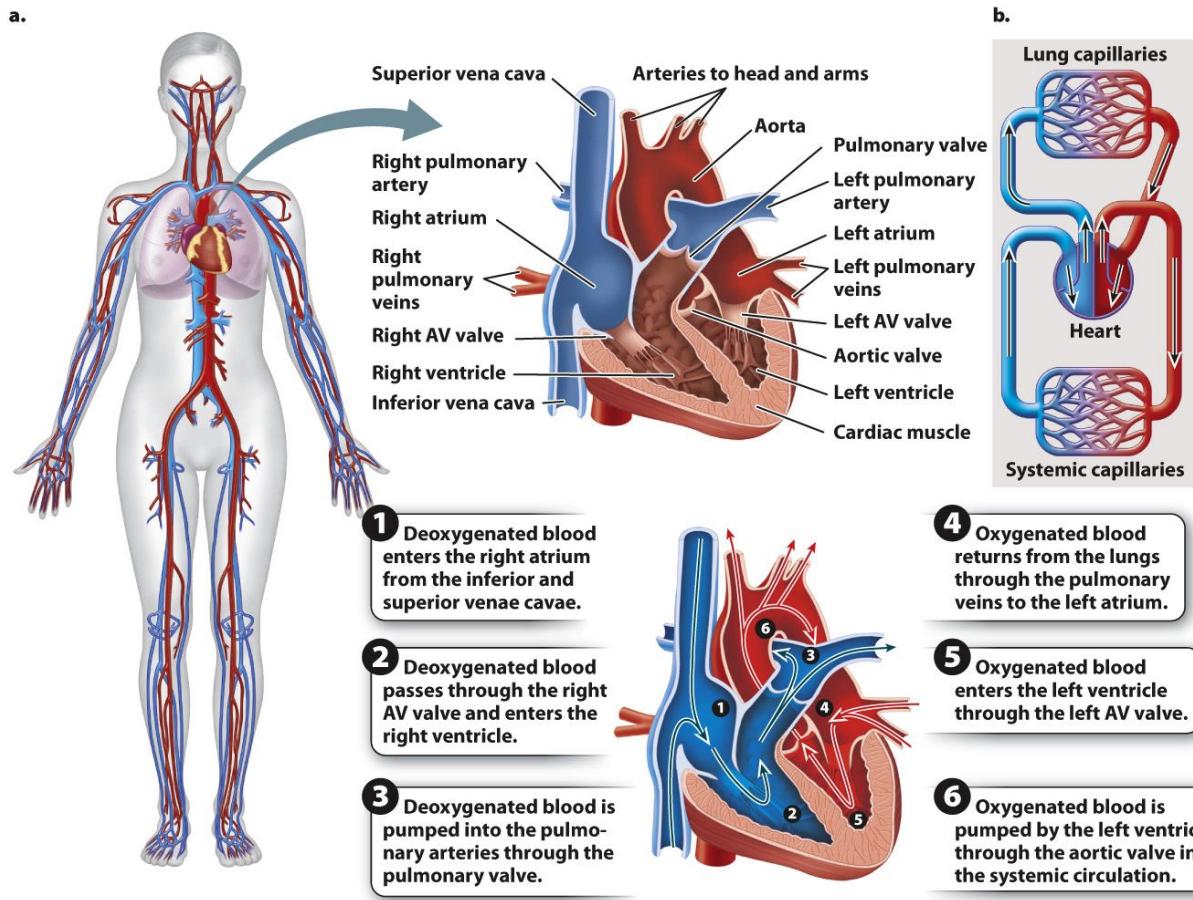
39.4 Circulatory Systems

- Small animals have open circulatory systems that have only a few blood vessels. Most of the fluid, hemolymph, is contained in the animal's body cavity.
 - There is limited control of where the fluid goes in these systems.
- Closed circulatory systems have a set of internal vessels and a pump that transport blood to the different regions in the body.
 - Have to have high pressure for pumping the blood but the pressure and blood rate cannot be too high for those smaller vessels.
- Benefit of closed is that you can deliver oxygen at high rates to exercising tissues, which open systems have low pressure and limited transport capacity.
- Insects have an open system but they can also obtain oxygen through tracheal system which is independent of the circulatory system.
- Rate of blood flow increases with an increase in pressure and decreases with increase in resistance.
- Liquid viscosity and vessel length are proportional to resistance. Vessel radius is inversely proportional.
- Blood flow thus, along long distances, happens in large diameter vessels.
- Arteries are large, high pressure vessels that move blood from heart to tissues Veins are low pressure vessels that return blood to the heart.
 - Arterioles and capillaries are smaller subtypes of arteries.
- In the capillaries, gases are exchanged by diffusion with the surrounding tissues.
- Lots of capillaries drain into larger venules, and those drain into veins that return blood to the heart.
- Increased resistance to flow in the capillaries is offset by the large increase in the number of capillaries.
- The radius of vessels can be changed to reflect the new amount of blood flow that might be needed during exercise.
- Artery walls can withstand pressure pulses because they have multiple elastic layers with two proteins called collagen and elastin. They resist the expansion of the arterial wall and they provide an elastic rebound of the wall once the pulse has passed.
- The two largest veins that blood drains into are the venae cavae. There is little pressure in these veins and thus blood accumulates in these veins. The mechanism that returns blood to the heart is the voluntary muscle contractions that occur with exercise.

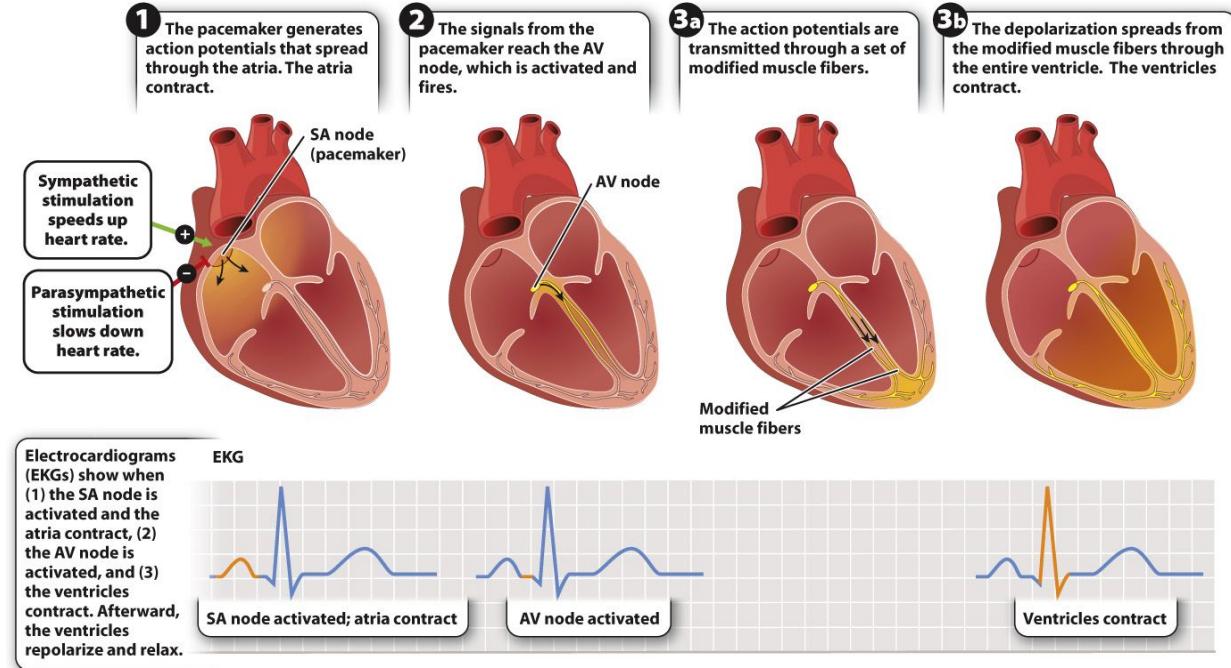
- Excess interstitial fluid is returned to the bloodstream by means of the lymphatic system which are vessels that are distributed throughout the body. The fluid that enters the lymphatic system is called lymph.

39.5 The Evolution, Structure, and Function of the Heart

- Pressure required to drive blood through blood vessels is generated by the heart. Pumps in the heart contract to produce the pressure.
- Hearts can have chambers where one receives blood and the other pumps blood to the body.
- There is a separation of circulation to the gas exchange organ from circulation to the rest of the body.
- Mammals have pulmonary circulation to the lungs and systemic circulation to the rest of the body. This increases the supply of oxygen rich blood to the tissues and increases the uptake of oxygen at the gas exchange surface.
- Fish have two chambers, an atrium and a ventricle. Oxygen poor blood goes to the atrium, and then the blood is pumped through a main artery for uptake of oxygen and then the blood goes to the tissues through a large artery called the aorta.
- Land vertebrates evolved hearts that separated the circulation of deoxygenated blood pumped to their gas exchange organs from circulation of oxygenated blood delivered to their body tissues
- Amphibians have another atrium, which kind of separates pulmonary from systemic circulations.
- Mammals have 4 chamber hearts which completely separates blood flow to the lungs and blood flow to the tissues. This allows us to pump blood to lungs under lower pressure which increases the uptake of oxygen. We can also supply blood at higher pressures to our tissues.



- Oxygen poor blood enters right atrium, and moves through AV valve, and then blood is pumped through pulmonary valve, and then to the lungs for oxygenation. Then, the oxygen rich blood enters the left atrium, and then when that contracts, blood moves through the aortic valve and then flows to head and rest of the body through an artery called an aorta.
 - Diastole is the relaxation of the ventricles and systole is the contraction of the ventricles.
- For heart to act as a pump, cardiac muscle must contract in a coordinated fashion.
- Atrial muscle cells must be activated to contract in synchrony during diastole to fill the ventricles, and ventricular muscle cells must contract in synchrony during systole to eject the blood from the heart.
 - In order to act in synchrony, the muscle cells must be depolarized in unison by an action potential.



- Cardiac cells can generate action potentials on their own and they can communicate electrically with each other through gap junctions. These characteristics allow the cells to act in unison.
- For pacemaker cells, their membrane potential gradually gets lower and lower which allows it to fire an action potential on its own, without any external input.
- Activations of the AV node transmit the action potential to the ventricles which cause them to contract in unison.
- Volume of blood pumped by heart over a time interval is the cardiac output which is the product of heart rate and stroke volume (amount pumped during each beat).
 - Humans rely on heart beat while fish rely on volume.
- Output rises and falls in response to the demand for oxygen at the current moment.
- Nervous system controls the heart rate. Heart rate speeds up when the pacemaker cells depolarize more rapidly.
- Stroke volume adjusts in response to changes in blood flow caused by changes in activity. When you exercise, the amount of blood returned to the heart is increased, which causes the volume of the atria to increase, which means the contraction will be more forceful, and thus more blood is ejected with each heartbeat.
- Relationship between volume of blood filling the heart and stroke volume is called Starling's Law.
- Cardiac Cycle Video: <https://www.youtube.com/watch?v=IS9TD9fHFv0>
- Another one: <https://www.youtube.com/watch?v=RYZ4daFwMa8>
- Circulatory System Video: https://www.youtube.com/watch?v=7XaftdE_h60

Chapter 40

40.2 Animal Nutrition and Diet

- Source of energy in animals is the diet and that energy is used to do work.
- Energy required for basic life processes are 70% of the energy used.
- Fat deposits grow over time if animal eats more food than required and animal switches to anabolic processes that build energy stores.
- When starving, animals will consume internal fuel reserves through glycogen and fat reserves, and then to protein stores in muscle tissue.
- Many nutrients necessary for life cannot be synthesized by an animal's metabolism and must be acquired in the food that they eat.
- Essential amino acid is one that cannot be made by the body, and so must be ingested.
 - 8 of them for humans
- Animals must also eat vitamins, organic molecules that are required in very small amounts.
 - 13 of them for humans
- "Essential" means that the nutrients must be obtained in the diet.
- Vitamin C = Building connective tissue. Without it, loss of teeth and bleeding gums
- Vitamin B = Nervous system disorders and forms of anemia.
- Vitamin D = Absorption of calcium, and thus for skeletal growth
- Vitamin E = anemia

40.4 Digestion and Absorption of Food

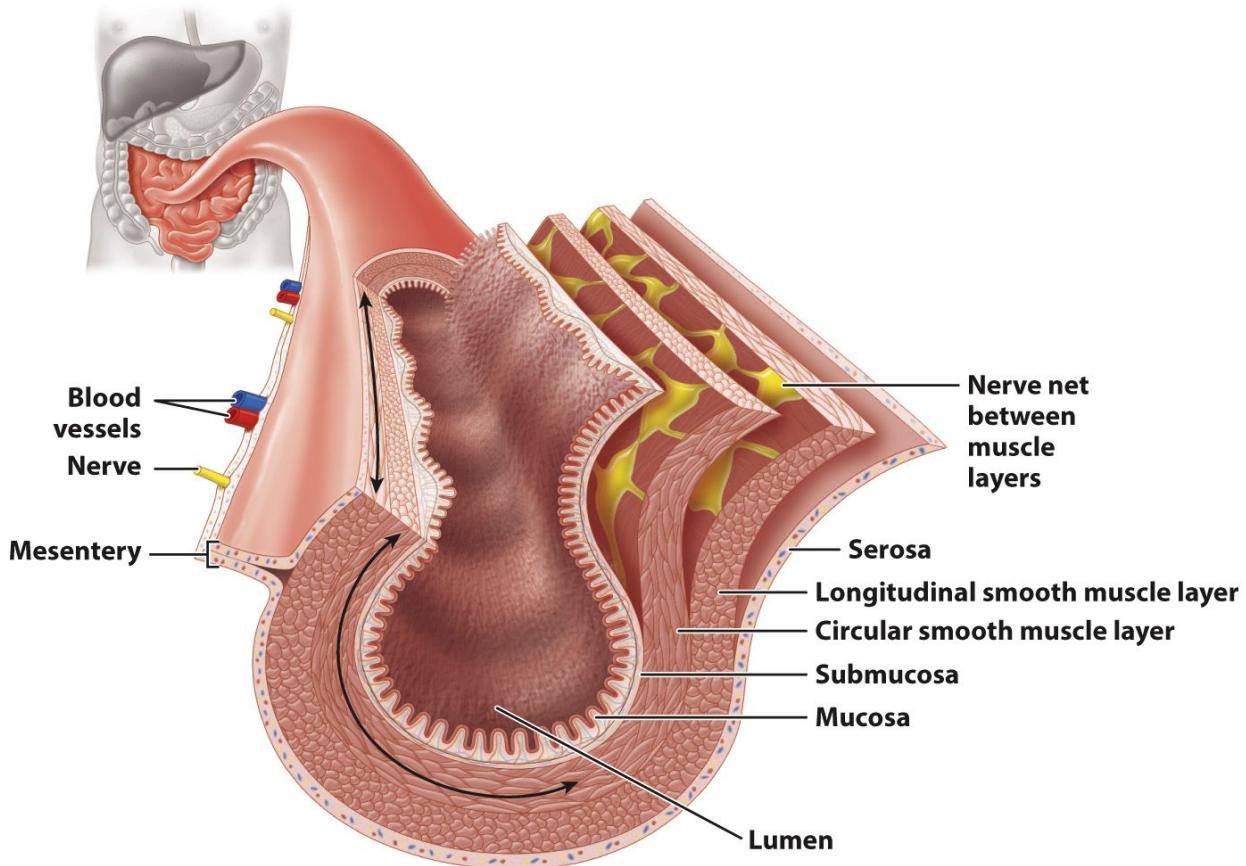
- Extracellular digestion is where food is isolated and broken down outside a cell in a body compartment. Breakdown products are taken into the bloodstream through absorption.
- In digestive tract, there is foregut, midgut, and hindgut.
 - Foregut is mouth, esophagus, and stomach. The latter is place of initial storage.
 - Midgut is small intestine. Most of the digestion and nutrient absorption takes place here.
 - Hindgut is large intestine and rectum. Water and inorganic molecules are absorbed, and the waste products are stored in the rectum.
- Products move through the tract by peristalsis, waves of smooth muscle contraction and relaxation.
- Digestion carried out by enzymes that break bonds between units of molecules. Enzymes do better or worse in different pH environments.

TABLE 40.3 Major Sites of Chemical Digestion of Macromolecules

MACROMOLECULE	SITE OF DIGESTION	ENZYME
Protein	Stomach	Pepsin
	Small intestine	Trypsin
Carbohydrate	Mouth	Salivary amylase
	Small intestine	Pancreatic amylase, lactase
Lipid	Mouth	Lingual (tongue) lipase
	Stomachs	Gastric (stomach) lipase
	Small intestine	Pancreatic lipase

- Amylase is an enzyme that breaks down carbohydrates. Lipase breaks down lipids.
- Pharynx is region of throat that connects nasal and mouth cavities.
- Swallowing reflexes are involuntary and under control of ANS.
- Food goes through the pharynx, over the epiglottis, and into esophagus. Peristalsis moves the food to the stomach.
- Stomach is a site for protein and lipid breakdown. Maintained at a low pH so that specific enzymes can work.
- When food comes, gastrin is released, which makes cells increase production of HCl. If pH is too low, then release is stopped.
- Stomach wall is protected from the acidity through mucus.
- Some enzymes like pepsin are only activated when the surrounding pH gets to a certain level.
- When food goes to small intestine, final digestion of protein, carbohydrates, and fats occurs and the nutrients are absorbed by the body and the acid is neutralized.
- Small intestine made up of duodenum where food enters from stomach, .
- Enzymes produced in small intestine are lactase which breaks down lactose into glucose.
- Pancreas releases a lot of the other digestive enzymes. The pancreas produces a variety of digestive enzymes, including lipase, which breaks down fats; amylase, which breaks down carbohydrates; and trypsin, which breaks down proteins
 - Trypsin is first produced in the inactive form, trypsinogen.
- Pancreas also releases bicarbonate ions which neutralize the acid. The release is controlled by the hormone secretin, which is released by cells in duodenum.
- Liver produces bile which helps fat digestion by breaking clusters of fats into smaller pieces in process called emulsification. Bile is stored in the gallbladder. When fats enter duodenum, CCK is released causing gallbladder to contract and release bile into duodenum.

- Small intestine also has villi and microvilli which increase SA for absorption of nutrients.
- Nutrient molecules co-transported into cells with sodium from the gut. Absorption of the nutrient is driven by the movement of the sodium ion down its concentration gradient.
 - Basically the lumen of the small intestine will have a large sodium concentration and lots of glucose from the food that you eat. There are co-transporters that will move the sodium into the intestinal cell down its concentration gradient and the glucose will come along with it. Then, the glucose will move from those epithelial cells to the blood vessels through channel proteins given that there is a channel protein and that there is more glucose inside the intestinal cell, so it moves down the gradient.
- Water and inorganic ions absorbed in the large intestine, or colon.
- Bacteria in the small and large intestines help extract nutrients that the animal's body can't extract.



- Digestive tract made of layers of tissues. Central space is lumen through which the contents travel. Inner tissue layer is mucosa, which secretes enzymes and absorbs nutrients. Outside the layers of two smooth muscle layers. Inner circular muscle contracts to reduce size of lumen. Outer longitudinal muscle contracts to shorten small sections of the gut. They contract alternatively to move contents along. Serosa is outermost layer and it covers and protects the gut. Mesentery is membrane through which blood vessels, nerves, and lymph travel to supply the gut.

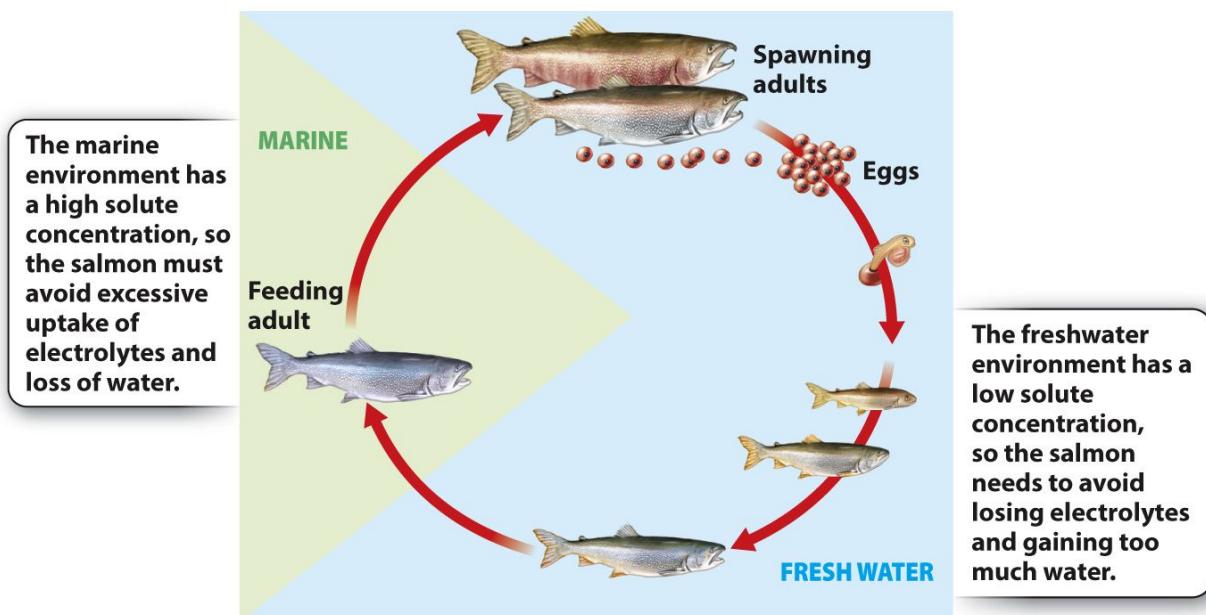
- Because animals don't have cellulase which is the enzyme that breaks down cellulose (plant compound), animals have compartments in digestive tract that contains large bacterial populations, which do produce cellulase.
- Rumen and reticulum are the two chambers in a 4 chambered stomach that have lots of bacteria that break down cellulose through fermentation.
- Chewing increases the surface area available for bacterial digestion in the rumen.
- Co₂ and methane gas are produced as a result of bacterial fermentation.
- Mixture of food and bacteria go into a 3rd chamber called the omasum where water is absorbed. Then it goes into the abomasum where protein digestion begins. Bacteria is killed and the nutrients are absorbed in the small intestine.
- Bacteria reproduction can happen in the rumen.
- Another type of fermentation called hindgut fermentation which occurs in the colon and in the cecum which is a chamber that branches off the large intestine.
- Cecum includes appendix which is a vestigial structure, one that lost its original function and is now reduced in size.

Chapter 41

41.1 Water and Electrolyte Balance

- When barrier allows movement of some molecules but not others, it is selectively permeable.
 - Water moves across that membrane through a process called osmosis.
- Water can move through channels called aquaporins by facilitated diffusion.
- Pressure needed to prevent water from moving across a selectively permeable membrane is called osmotic pressure.
 - Higher the concentration of solute, the higher the osmotic pressure of that solution.
- As water diffuses across a selectively permeable membrane into a region with a higher solute concentration (higher osmotic pressure), the hydrostatic pressure of the more concentrated solution increases.
 - When osmotic equals hydrostatic pressure, the net movement of water stops and equilibrium is reached.
- Regulation of osmotic pressure is called osmoregulation.
- Osmoconformers are those organisms that match their internal osmotic pressure to that of their external environment.
 - They don't have to expend a lot of energy regulating osmotic pressure.
 - They sometimes expend energy to regulate the concentrations of certain ions like potassium and sodium.
 - They also have high internal concentration of urea, which is a waste product that gets excreted so it doesn't build up to high concentrations. It allows an animal to have a low internal concentration of solute + high amount of urea which makes the overall concentration equal to that on the outside.

- Osmoregulators maintain internal solute concentrations different from that of the environment.
 - They spend energy pumping ions across the membrane.
 - Allows the organisms to be able to live in diverse places.



- Chloride cells in gills allow fish in saltwater to pump chloride ions into the surrounding water. This is the opposite in freshwater.

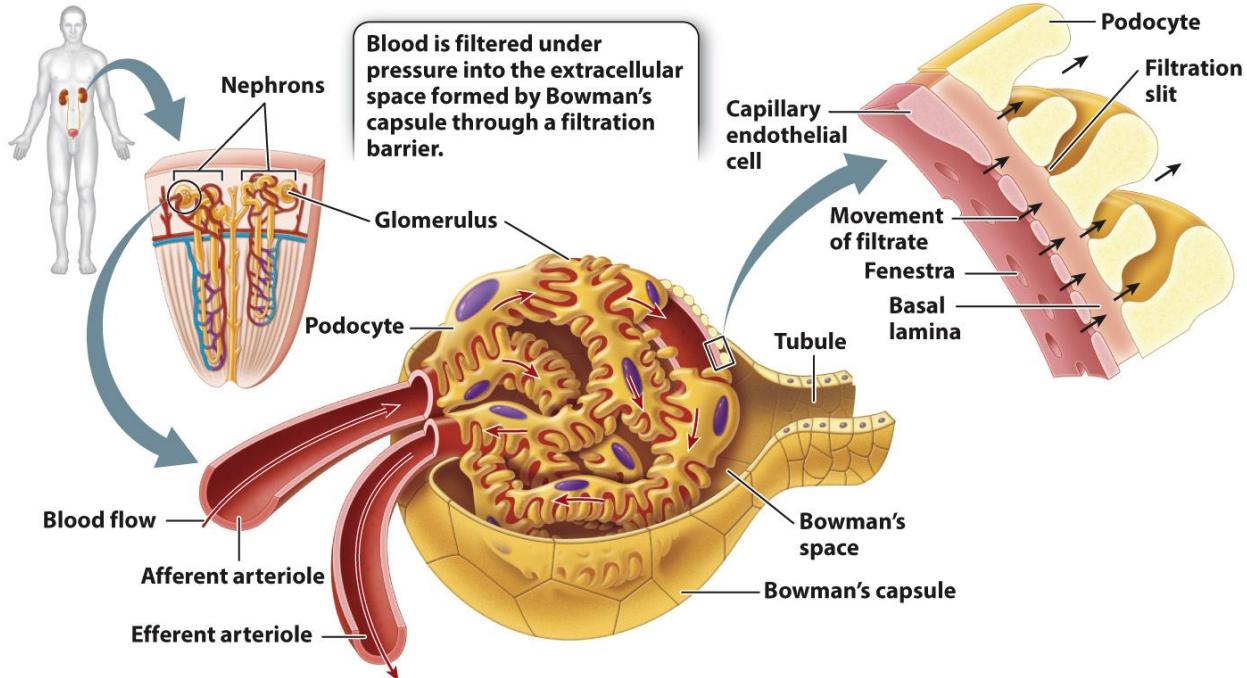
41.2 Excretion of Wastes

- Excretion is the elimination of waste products and toxic components from the body.
 - Multicellular animals have special organs to do this.
 - The organs eliminate waste and maintain water and electrolyte balance.
- Ammonia is a type of nitrogenous waste because it can disturb the pH of cells and damage neurons.
- For aquatic animals, the nitrogenous waste could just diffuse into the water. With land based animals, nitrogenous waste comes in the form of urea which is less toxic, but requires energy to produce and water to eliminate.
- Ammonia can also be converted to uric acid which is the least toxic.
- Organisms can eliminate waste by filtration or secretion.
 - Filtration is when blood is filtered into an extracellular space. Least energetically expensive. Removes the bad compounds, but removes some of the good ones too. Reabsorption is required to get those good components back into the blood.
 - Secretion is the active transport of molecules from blood to extracellular space. This is specific but expensive in terms of energy.
- Wastes are isolated in contractile vacuole that eliminates waste through exocytosis from the cell.

- Animals with pressurized circulatory systems isolate waste from blood by filtration. Filtrate drains into excretory tubules that connect to the outside. Afterwards, there is reabsorption of key ions and solutes from filtrate into the blood.
- Secretion can eliminate things that were not filtered from the blood.
- For flatworms, waste can be excreted without being filtered, where the fluid from the body cavity is put into organs called protonephridia. The tubules inside eliminate excess fluid along with waste products. Cells inside the tubule modify the fluid contents through reabsorption and secretion. Fluid from the body enters in without being first filtered. Reabsorption happens through cells in tubules.
- For earthworms, blood filtered through capillaries into organs called metanephridia. Comes through a funnel shaped opening. Blood vessels in the tubules reabsorb and secrete compounds as urine is formed. Reabsorption happens through capillaries.
- Our excretory organs are the kidneys. Blood filtered through capillaries with openings in the walls, they form a loop called glomerulus. Wastes move through the holes into a extracellular space surrounded by a capsule, filtrate goes through renal tubules, filtrate is processed by reabsorption and secretion, then goes into the collecting ducts which converge on larger tube called ureter, and then goes to bladder for storage.
- Glomerulus, renal tubules, and collecting ducts make up a nephron.
 - Nephrons perform the three basic steps of excretion and osmoregulation: filtration of blood passing through the glomerulus, reabsorption from the renal tubule back to the bloodstream of key electrolytes and solutes, and secretion of additional wastes and electrolytes by the renal tubules.
- Protein breakdown during metabolism is where most nitrogenous waste comes from.

41.3 Structure and Function of the Mammalian Kidney

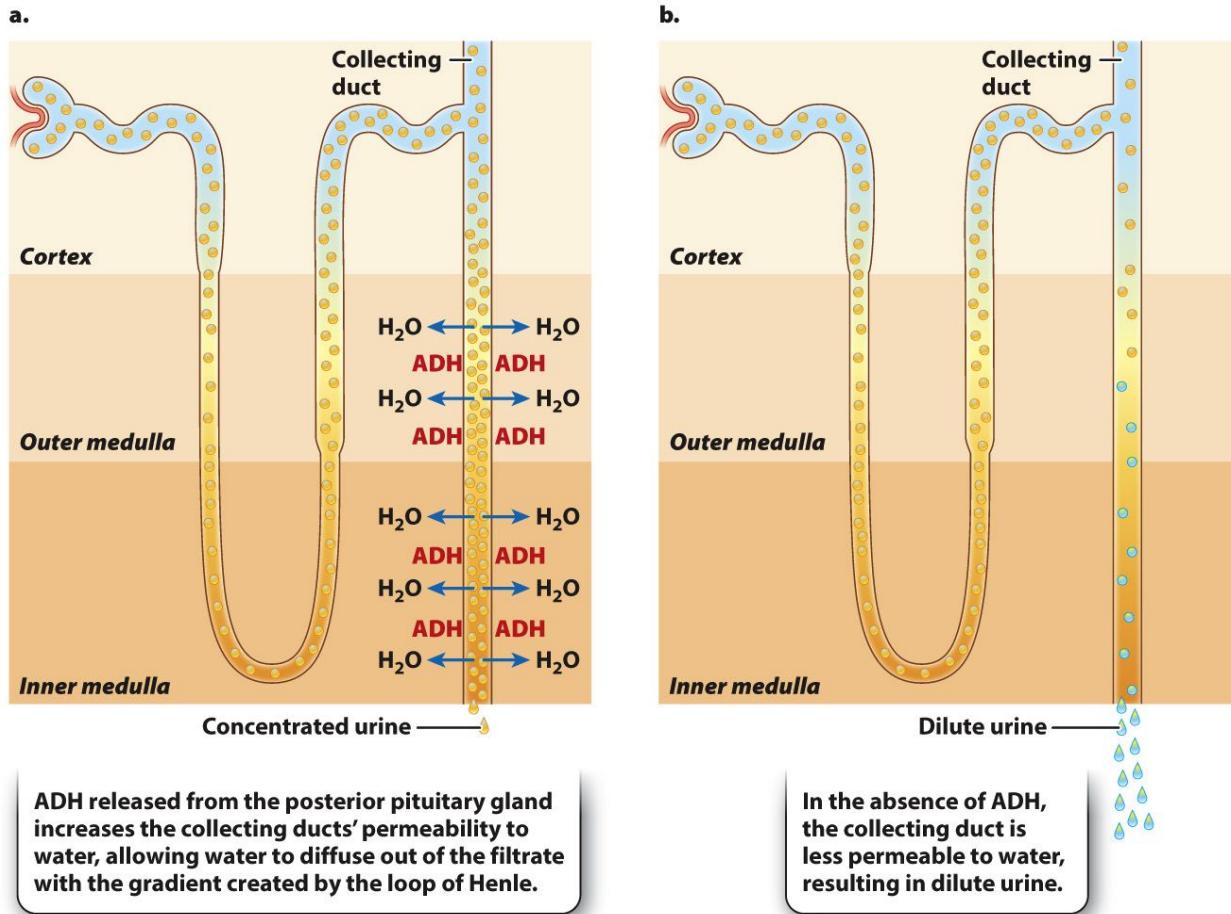
- Mammals need to excrete urea without losing too much water. Do this by removing water from waste containing fluid by osmosis when it moves through the kidney.
- When filtrate goes through collecting ducts, water moves out and into the hypertonic interstitial fluid that lies in the kidneys.



- Glomerulus has a tuft of capillaries inside Bowman's capsule. Blood is filtered as it goes through the capillaries.
- Cells inside the capillaries are endothelial cells that have pores called fenestrae which let fluid pass through. The filtration barrier of the glomerulus is made up of those cells, a basal lamina, and layer of cells called podocytes. These 3 layers create filter that allows lets some molecules pass. Then fluid goes to renal tubule.
- Renal tubule has 3 sections, proximal convoluted tubule, loop of Henle, and distal convoluted tubule. Filtrate goes into the proximal where nutrients and water are reabsorbed into the blood, then to loop of Henle which create concentration gradient in the interstitial fluid from the cortex to the medulla so the interstitial fluid of the cortex is less concentrated in solutes and the interstitial fluid of the medulla is more concentrated in solutes. This lets water be reabsorbed.
- Ascending limb is impermeable to water, but not to electrolytes. The interstitial fluid becomes more concentrated and the filtrate going through the limb is less concentrated.
- Descending limb is permeable to water, and thus water moves out, and the filtrate becomes more concentrated.
- The gradient results from the combination of active transport of electrolytes in the ascending limb, osmosis of water in the descending limb, and the movement of the filtrate through the loop of Henle. The filtrate is most concentrated at the base of the loop, and the concentration of solutes inside and outside the loop is about the same, leaving the medulla more concentrated than the cortex.
- Blood vessels in the kidney are called vasa recta and they have these ascending and descending vessels in a countercurrent organization.
- Then the filtrate goes through the distal tubule where the entering filtrate is dilute, and only really contains urea. Then additional wastes are secreted into the tubule and

necessary electrolytes. H⁺ and HCO₃⁻ are secreted into or out of the tubule as needed to regulate pH.

- Filtrate leaving the distal convoluted tubule and entering the collecting ducts is dilute and contains mainly urea and other wastes.
- Then filtrate goes to collecting duct where water moves out of ducts and into fluid depending on permeability of ducts to water, which is adjusted by how dilute/concentrated the urine is.



- Permeability also controlled by hormone ADH or vasopressin, which is released by posterior pituitary.
 - When solute concentration is high, ADH is secreted and then the walls become more permeable to water and thus the urine becomes more concentrated.
- Cells in the efferent arteriole leaving the glomerulus form the juxtaglomerular apparatus. These cells release renin when there is a drop in BP. Renin converts angiotensinogen to angiotensin I which is converted by an enzyme to angiotensin II which causes smooth muscles of arterioles to constrict and increase BP and direct more blood back to the heart.
- Angiotensin II stimulates release of aldosterone which makes the collecting ducts increase reabsorption of electrolytes and water back into the blood.

Chapter 42

42.2 Movement Onto Land and Reproductive Adaptations

- Egg and sperm require a wet environment, which means aquatic organisms can release them into the water by external fertilization.
 - To increase probability of fertilization, you can increase the quantity, or be selective about where you release.
 - Generally associated with r strategists and unstable environments.
- Internal fertilization takes place inside the body of the female, but is not exclusive to land dwellers.
 - Generally associated with low number of offspring but large parental effort and stable environments, which are k strategists.
- Eggs that are externally fertilized have a yolk which provides all the nutrients to the embryo.
- Movement onto land meant that diffusion of key substances in watery environment isn't enough. The amnion is membrane surrounding a fluid filled cavity that allows the embryo to develop in the watery place.
- The second membrane called the allantois is where the wastes collect.
- The third membrane called the chorion surrounds the entire embryo along with the yolk and the sac.
- Yolk sac, amnion, allantois, and chorion are all extraembryonic membranes.
- Animals that lay eggs and are internally fertilized are oviparous. In these cases, all the nutrients come from the yolk.
- Animals that get the nutrients from the mother are viviparous.
 - In some, the chorion and the allantois fuse to form the placenta which facilitates the transmission of nutrients from mother to offspring.
- Amniotic egg was the most important adaptation that led to uncoupling of reproduction with the need for aquatic environment.

42.3 Human Reproductive Anatomy and Physiology

- Humans are amniotes, reproduce sexually, use internal fertilization, and are viviparous.
- Sperm are male gametes and are produced in two testes. Male's reproductive success is correlated with number of sperm and that means better chance of fertilizing the egg.
- Sperm are haploid cells with function of delivering genetic info to the egg. It has small head with densely packed nucleus. Head is surrounded by acrosome which allows sperm to transverse the outer coating of the egg. Sperm have a long tail or flagellum which moves the cell.
- Testes located in a sac called the scrotum.
- Sperm produced within the testes in series of tubes called the seminiferous tubules. The sperm mature as they go through the reproductive system. They then go to the

epididymis and then to vas deferens. Along the path, glands produce semen, which nourishes the sperm.

- One gland is the prostate gland which produce thin fluid that maintains sperm motility and counteracts acidity of female tract.
- Two seminal vesicles secrete protein and sugar rich fluid that makes up most of the semen and gives energy for motility.
- Bulbourethral glands produce clear fluid that lubricates urethra for passage of sperm.
- Female reproductive system produces gametes but specialized to support embryo.
- Oocytes are female gametes and they are produced by ovaries.
- Oocyte is largest cell by volume. It will travel from the ovary through the fallopian tube to the uterus. End of the uterus called the cervix.
- External genitalia are collectively called vulva which has two folds of skin which are labia majora and labia minora.
- Testes and ovaries not only site of gamete production but are part of the endocrine system. They respond to hormones and secrete hormones.
- Hypothalamus releases GnRH which causes anterior gland to secrete LH and FSH which cause the (Leydig cells inside of) testes and ovaries to release testosterone and estrogen. FSH also acts on Sertoli cells to stimulate sperm production.
- Secondary sexual characteristics are the traits that characterize and differentiate the two sexes but aren't related to reproduction.
- Menstrual cycle is where an oocyte matures and released from ovary under influence of hormones.
- Cycle has follicular phase and luteal phase. In the former, oocyte develops and is released from ovary. Oocyte located in shell of cells called follicle. FSH stimulates these follicles to secrete estradiol which causes one oocyte to mature. Estradiol also reduces secretion of GnRH, FSH, and LH by negative feedback by interacting with the hypothalamus. At the end of follicle phase, negative changes to positive feedback which causes rapid increase and then decrease of LH levels produced from anterior gland. This causes ovulation which releases oocyte from the follicle in the ovary.
- Ovulation marks end of follicle and beginning of luteal phase. Follicle doesn't have the oocyte anymore so it is converted to a corpus luteum which is a temporary endocrine structure that secretes progesterone which inhibits secretion of GnRH, FSH, and LH.
- Oocyte is swept into fallopian tube and goes to uterus. If fertilized, then the luteum will continue to releases progesterone for the embryo. But if not, then luteum degenerates and uterine lining is shed in process called menstruation.
- Cessation of menstrual cycles is called menopause.,

Human Microbiome Part 1

- We have coevolved with trillions of microorganisms that inhabit the human body.
- Microbiota refer to microorganisms that include bacteria, viruses, archaea, fungi, and protozoa that inhabit a particular environment.
 - Symbionts are the organisms that live together.
 - Can be mutualistic (+/+), commensal (+/none), and parasite (+/-).

- Pathogen is a microbiome that causes disease to the host, while the microbe benefits.
- Metagenome is collection of genes and genomes from a microbial community.
- Microbiome: Entire habitat of microbes, their genomes and their environment.
- Metagenomic sequences hopes to look at the genes of microbes, and determine whether they are useful or not.
- 16S rDNA sequencing measures species identify and abundance.
- Metatranscriptomics measures gene expression in a community of microbes from RNA.
- Metabolomics will do the above, but by looking at small molecules in a sample.
- There are up to 10x more bacteria inside of you than there are human eukaryotic cells.
- Similar or close body sites mean that you have more of an overlap with the diversity of microbiota.
- Microbiome is inherited through the birthing process.
- After we acquire that biome initially, then the microbiota mature over the first few years of life in humans.
 - The phylogenetic diversity in the microbiome will increase as time goes on.
 - Microbiota gets stability, though, after human reaches adulthood.
- Superorganism is a collection of single creatures that together posses the functional organization implicit in the formal definition of an organism.
- Holobiont is an organism and all of its symbiotic microorganisms.
 - Hologenome is its genetic material so it has info about the host eukaryotic cells as well as the genetic material of the bacteria.

- 1) The microbiome inspires a redefinition of “self”
 - 2) The microbiome points to a large knowledge gap in biology
 - 3) The microbiota seems to be inherited
 - 4) The microbiota undergoes maturation
 - 5) The microbiota acquires stability
 - 6) The microbiota can be modified
 - 7) The microbiome is a part of normal host physiology
 - 8) The composition of the microbiota differs based on environment
- Hologenome concept says that the holobiont and its hologenome act as a unit when it comes to natural selection and evolution.

Human Microbiome Part 2

- As the microbiota is developing, you have new species of bacteria form and then leave.
- Early microbiota is the milk oriented microbiota since mammals drink their mother's' milk.
- That early milk has lactose, lipids, and proteins. You also get immune factors and digestive enzymes.

- Human milk Oligosaccharides are the component that is most abundant after lipids and lactose.
 - No host cells can digest these HMOs, but the bacteria can.
- Infants have bifidobacteria which has enzymes that can help digest the milk oligosaccharides.
- Nondigestable carbs are those that the host cells cannot digest, but only bacteria cells can through microbial fermentation.
- Bacteroides are adult microbes that have starch utilization systems for degrading complex polysaccharides (host nondigestable fibers). They need to degrade the fibers for their own food.
 - Particulate bacteroid species have different attractions to different foods.
 - Fiber deficient diet would result in the loss of bacteroid species.
 - When you lose those species, you can't ever gain them back.
- Microbiota changes can be inherited over generations.
- Syntrophy refers to functional interdependence of particular microbes.
- Functional/metabolic specialization refers to members of a community that provide complementary functions.

Human Microbiome Part 2

- Stability inside our products refers to how the microbes interact with each other and with our host cells.
 - Stability in particular is the resistance to change in response to changing environmental conditions.
- Adult microbiota shows colonization resistance which protects against disease causing microbes. They do this by filling up the physical space making it hard for the others to colonize that area, and maybe removing the nutrition from that area.
- Some microbes have defenses where they secrete toxins against invading bacteria.
- Adult microbiota shows resistance in that it will return to original state after perturbation.

- 1) The microbiota is initially inherited
 - 2) The maturation of the microbiota corresponds with key milestones in development, including consumption of breastmilk vs table foods, and impacts of infection and antibiotic use
 - 3) During infancy, human milk oligosaccharides are uniquely consumed by bacteria in the microbiota
 - 4) During adulthood, host nondigestible polysaccharides are uniquely consumed by bacteria in the microbiota
 - 5) Bacteria utilize glycosidases (=glycosyl hydrolases) to break down HMO, dietary and mucous-derived glycans
 - 6) These enzymes target very specific linkages and particular sugars (fucose vs sialic acid vs galactose, etc.)
 - 7) As such, different bacteria have different food preferences
 - 8) The glycobiome is an active area of research because of its promising therapeutic applications for modulating microbes that impact health & disease
- Some microbes, under specific conditions, will turn into something that causes disease instead of being a normal part of the body. This is normally when the colonization conditions have been breached.

Chapter 43

43.1 - An Overview of the Immune System

- Immune system is not in a centralized place, it consists of organs, cells, and proteins throughout the body.
 - The common goal is to protect organism from pathogens.
- Pathogens are agents that cause disease.
- Viruses that infect bacteria are called bacteriophages.
- Some pathogens destroy a particular type of cell, some interfere with an organ's function, and some produce toxins that cause disease.
- Immune system has to recognize which molecules are from host/self and which are nonself.
 - The ability to distinguish depends on proteins that are on the surface of cells.
- Autoimmune diseases are ones where the immune system attacks its own cells.
- Immunodeficiency is when infections and disease can compromise the functionality of the immune system.
- Immune cells and processes are kept in an inactive state, and only activated when in contact with a foreign cell.
- Immune system consists of two parts.
 - Innate immunity provides protection against all kinds of infections. Does not depend on prior exposure to a pathogen.

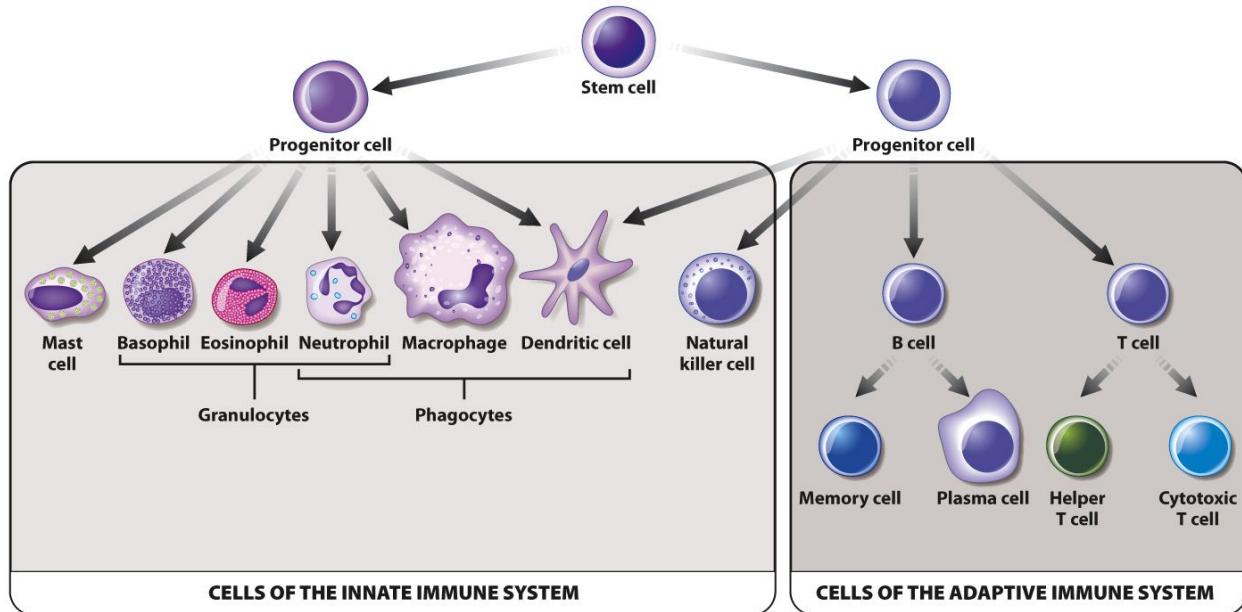
- Adaptive immunity is specific to a given pathogen. The immunity remembers past infections, and the next encounters will generate stronger responses. Immunity is basically acquired after the initial exposure.

TABLE 43.1 Comparison of the Innate and Adaptive Immune Systems

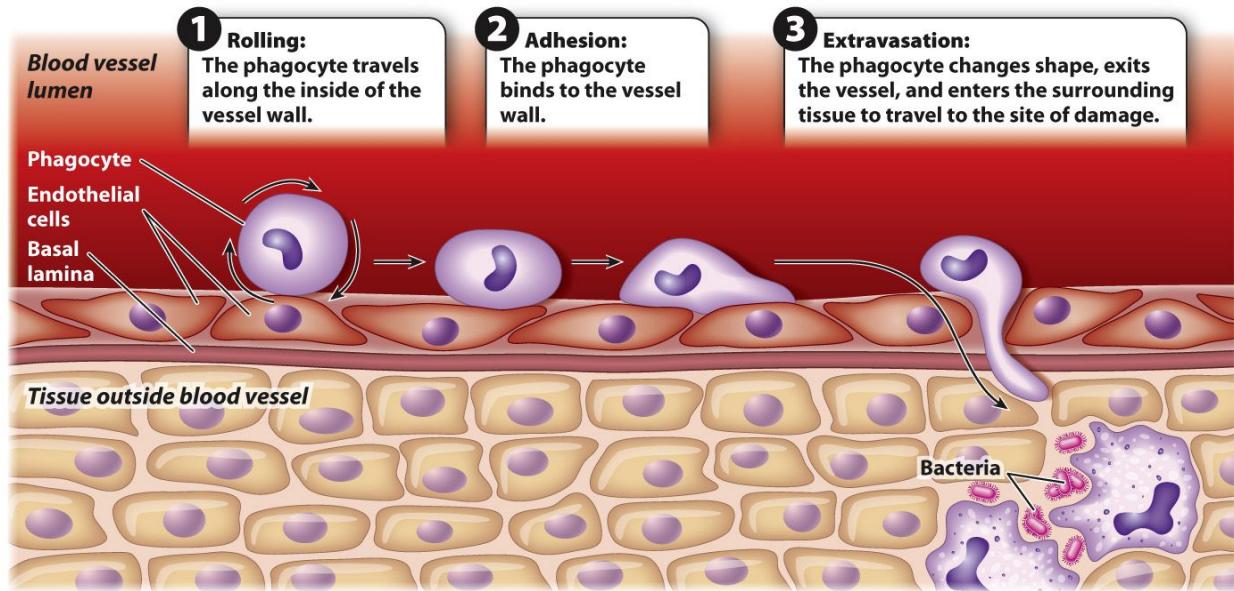
	INNATE IMMUNE SYSTEM	ADAPTIVE IMMUNE SYSTEM
Targets	Diverse pathogens	Diverse pathogens
Ability to distinguish self from nonself?	Yes	Yes
Specificity?	No	Yes
Memory?	No	Yes
Organisms	All organisms	Vertebrates

43.2 - Innate Immunity

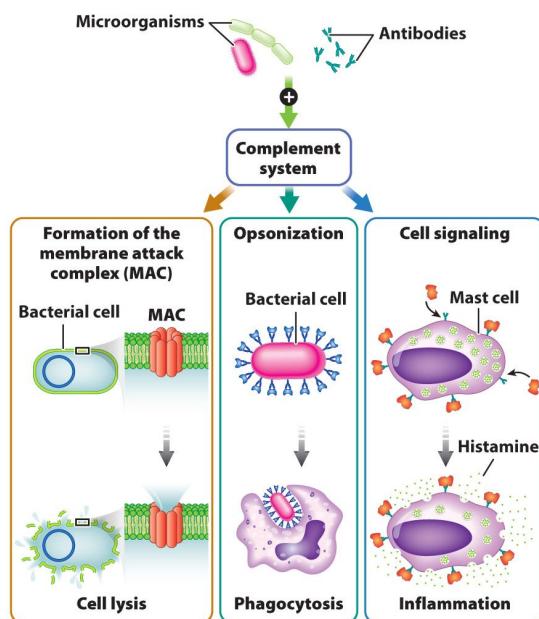
- Cholera is caused by bacterium.
- Innate immune system provides general and nonspecific defenses against pathogens.
 - Includes tissues (like the skin), sentry cells, and proteins that detect presence of an infection.
 - All defenses are nonspecific, act immediately, and don't depend on prior exposure.
- Part of respiratory tract have cilia, which are hairlike projections that get mucus containing trapped particles out of the body.
 - Without cilia, there will be a higher likelihood that the organs won't be able to sweep out the harmful microorganisms and thus higher probability of infection.
- Saliva has enzymes that protect itself against bacteria.
- Stomach, with its low pH, is inhospitable to many microorganisms.
- Skin and mucous membranes also provide places where nonpathogenic microorganisms can compete with the pathogenic ones for food and space.
- After the membranes, next line of defense is the white blood cell. They are the internal defense. Different white blood cell types for innate and adaptive immune systems.



- Phagocytes are white blood cells that destroy foreign cells or particles. Engulfing of a cell by another is called phagocytosis.
- Process of phagocytosis is that phagocyte recognizes foreign molecule, binds to it, extends membrane around it, and digest it using lysosomes.
- 3 types of phagocytic cell: Macrophages (large and will patrol the body), dendritic cells (have long cellular projections found in the membrane defenses), and neutrophils (have granules in cytoplasm and are first to respond to infection).
- Eosinophils and basophils defend against parasitic infections.
- Mast cells release histamine, which is a contributor to allergic reactions and inflammation.
- Natural killer cells destroy host cells that have been infected by a virus.
- Toll like receptors are proteins on the surface of the phagocyte which recognizes and binds to molecules on pathogens.
 - Binding of TLRs to surface molecules on the pathogen is a signal to the phagocyte to engulf and destroy its target. After binding, another signal is sent to the immune system that the body is under attack by the phagocyte releasing cytokines that recruit other immune cells to the site of injury or infection.
- Inflammation is response of body to injury that removes the inciting agent and then begins the healing process.
 - Characterized by redness, heat, pain, and swelling.
- Process following tissue injury: Dendritic and mast cells recognize pathogen, cytokines released, more white blood cells recruited, histamine causes increased blood flow/permeability, vasodilation causes redness and heat, WBC go from blood vessel to tissue (extravasation), increased fluid in tissue causes swelling, and chemical messengers act on nerve fibers which cause pain.



- How WBC enters the tissue ^
- The WBC that participate in adaptive immunity are activated by a set of proteins that circulate in the blood.
 - The proteins make up the complement system. The proteins in this group circulate in the blood in an inactive form, and the system is activated when the proteins bind to molecules on foreign agents.



- Activation of complement system causes those proteins to form a pore called a membrane attack complex that causes bacteria cell to lyse, bacteria is coated with proteins that phagocytes recognize (opsonization), and there is production of activated proteins that attract other components of the immune system, like mast cells.

- If you have a complement deficiency, then fewer pathogens will undergo cell lysis and thus you are more likely to get a bacteria infection.
- The two signs of infection, swelling and redness, are caused by the effect of histamines on blood vessels.
- Macrophage destroys pathogens by phagocytosis.

43.3 Adaptive Immunity: B Cells and Antibodies

- Adaptive immune system has specificity in that it creates lots of molecules that each have the potential to target a specific pathogen it has never seen before. The AIS also has memory in that it remembers past infections and mounts a stronger response on re-exposure.
- Two WBC cell types are important for memory and specificity.
 - B Cells mature in bursa of Fabricius and in bone marrow
 - T cells mature in thymus.
 - Both circulate in blood vessels and go through spleen, liver, etc where they look for pathogens.
- An antibody is a protein found on the surface of B cells. They bind to molecules on the surface of foreign cells called antigens.
 - There are lots of types of antibodies, and lots of types of antigens.
- Each antibody has a variable region and a constant region. Constant region is same in all antibodies. Variable region is unique to each antigen that the antibody targets.
- Function of antibody is to recognize the pathogen, and then recruit other cells of the immune system or activate the complement system.
- There are 5 classes of antibody.
 - IgG is Y-shaped and circulates in blood, effective against bacteria and viruses.
 - IgM is pentamer and monomer on the surface of B cells, important in early response to infection.
 - IgA is a dimer and on mucosal surfaces like on the respiratory and gastrointestinal tract.
 - IgD is a monomer found on the surface of B cells and helps initiate inflammation.
 - IgE plays role in allergies and other immediate hypersensitivity reactions.
- To get all the diversity there is for antibodies, the two hypothesis depend on whether the antigen selects B cell with preexisting surface antibody or if it instructs the B cell to make a specific antibody.
- You have a lot of B cells, each with a different antibody on its surface, but each antibody only recognize one or a few antigens, binding with an antigen leads the cell to divide. Plasma cells are the daughters that give off antibodies that bind the antigen and get an immune response while the memory cells contain antibody having the same antigen specificity as the parent cell.
 - Plasma cells secrete antibodies.
 - Memory cells are pretty much duplicates of the parent and they have cell surface antibodies.
- Process by which antigen binding generates clone of B cells is clonal selection.

- First encounter with an antigen leads to primary response, where there is a lag before antibody is produced. The lag is required so B cells can divide and for plasma cells to secrete antibodies.
- But on re-exposure, the secondary response is quicker and stronger. The B cells respond more quickly, and there is more of them.
- Vaccination is used to give a patient an antigen from a pathogen to induce primary response, but not the disease, thus giving future protection.
- Different antibody types are created by separate gene segments brought together by recombination.
- As a B cell differentiates, different gene segments are joined in genomic rearrangement which creates a specific antibody.
- DNA in each mature B cell is different from that in every other mature B cell.

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