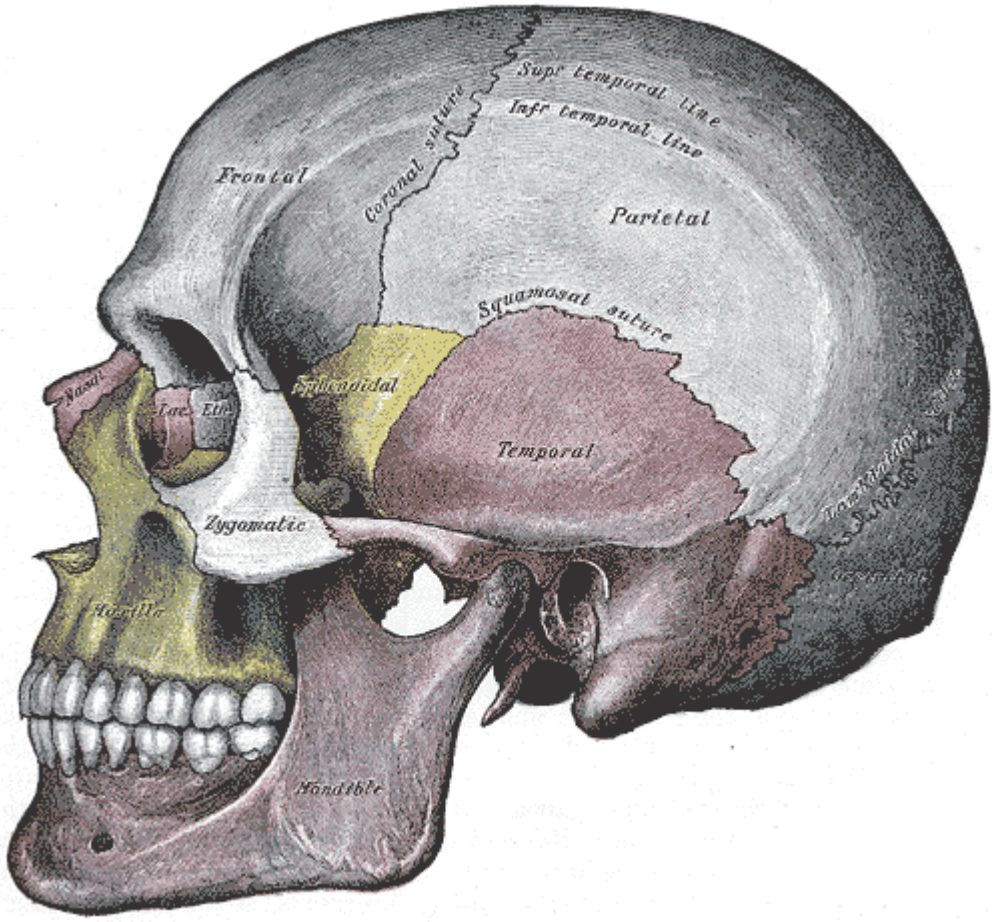
Biology 210
Human Anatomy & Physiology I
Lecture Coursepack

Fall 2020



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BIOLOGY 210: ANATOMY AND PHYSIOLOGY I

COURSEPACK & WORKBOOK

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Chapter References: Erin Amerman's *Human Anatomy and Physiology* (Pearson Publishers), 2nd edition, 2018

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Chapter 1: Introduction to Anatomy and Physiology

Homeostasis and Control Mechanisms

Homeostasis ("*same, standing still*") is defined as the maintenance of a constant internal environment within the body; it's a dynamic equilibrium. The body tries to maintain its values such as temperature, blood pressure, & blood pH within a narrow range of values. To maintain proper homeostasis we need:

- nutrients
- oxygen
- water
- body temperature of 98.6 ° F

Define Negative Feedback Loop: output inhibits **input**. The release of a product inhibits any further production to reach homeostasis. In other words, the role of the effector in negative feedback is to **cancel** the original stimulus (shut off the system) in order to restore homeostasis.

Negative Feedback Mechanism

- **stimulus** (= input) can be either internal or external
- **sensory receptor** carries the message ***to*** the brain or spinal cord
- **central nervous system** (= brain or spinal cord) interprets the information and turns on an effector
- **motor nerve** carries the message ***from*** the brain or spinal cord to the effector
- **effector** (= output) glands, muscles, or organs bring about a response that cancels the original stimulus

Example of a Negative Feedback Loop: *Stimulus:* body temperature heats up. *Sensory receptors*: notify the brain of the change in body temperature. *Central nervous system*: receives information about body temperature changes and turns on an effector (sweat glands in this case). *Motor nerve*: carries the message to the sweat glands to produce sweat. *Effector*: Sweat glands releases sweat as long as the motor nerve tells it to do so (as long as there's a stimulus).

Other Examples:

- most hormones
- maintenance of body temperature, blood pressure

Define Positive Feedback Loop: output enhances **input**. The effects trigger more change until homeostasis is reached. The response intensifies or enhances the original stimulus; the feedback is "positive" since you get the same action as the original stimulus. Positive feedback does not maintain homeostasis within a narrow range of values as does negative feedback. The effector **enhances** the stimulus to restore homeostasis.

Describe an example of a Positive Feedback Loop: *Stimulus*: Baby's head pushes against the cervix. *Sensory receptor*: notifies the brain. *Central nervous system*: The brain (pituitary gland) releases a hormone/neurotransmitter known as oxytocin. *Motor output*: Oxytocin's target organ is the uterus. Oxytocin promotes contractions to push the baby out. The more stimuli that travel to the brain, the more oxytocin is produced to promote uterine contractions.

Other Examples:

- blood clotting using platelets
- oxytocin
- chronic heart failure (CHF)

Chapter 1: Introduction to Anatomy and Physiology

Review of Chapter 1 Information: Negative and Positive Feedback

1. Describe how scratching an itch is an example of negative feedback using the mechanism for negative feedback.
2. Describe the role of the effector in negative feedback. How is the effector's role different in positive feedback?
3. Describe how sweating and shivering are ways to maintain your body's temperature via negative feedback. Employ the mechanism to describe the process of maintaining temperature homeostasis.
4. Do you think the defecation reflex is an example of a *positive* or *negative* feedback? Explain your choice.
5. The body maintains calcium levels through the action of hormones. Do you think the hormone calcitonin, which deposits excess calcium to bones when blood calcium levels are high, works by *negative* or *positive* feedback? Explain your choice.
6. Thirst is quenched when we drink fluids. Explain how thirst exemplifies the negative feedback mechanism.
7. The longer a baby suckles his mother's breast, the more milk is produced. Do you think lactation is a type of *positive* or *negative* feedback? Explain thoroughly to support your answer.

_____8. Effectors in negative feedback ____ the stimulus while the effector in positive feedback ____ the stimulus.
- A. enhance; inhibit
- B. cancel; increase
- C. increase; stop
- D. start; has no influence over the
- E. turns on; turns off

_____9. A homeostatic imbalance:
- A. must always be restored by negative feedback mechanisms
- B. is most commonly restored by negative feedback mechanisms
- C. is when the internal conditions of the body become more stable
- D. only occurs when positive feedback mechanisms are overwhelmed

_____10. We are no longer hungry once we satisfy that stimulus through eating. How would you classify hunger?
- A. negative feedback
- B. positive feedback
- C. hunger could work by both mechanisms
- D. not enough information to determine the mechanism

_____11. The role of the effector in any negative feedback situation is to:
- A. continue the effects of the stimulus
- B. enhance the imbalance
- C. restore balance through inhibition of the stimulus
- D. increase the stimulus
- E. restore balance through the sensory receptors

Answers: 1-7 *see me for help;* 8B, 9B, 10A, 11C

Chapter 2: The Chemistry of Life

Terms and Concepts to Understand for Chapter 2

- element (major vs. trace)
- matter
- atom and atomic structure
- subatomic particles
- atomic number
- mass number
- isotopes
- orbitals
- valence shell
- ionic bond formation
- covalent bond formation
- polar vs. nonpolar covalent bonds
- hydrogen bonds
- molecules
- compounds
- properties of water
- intracellular vs. extracellular fluid
- electrolytes
- acids
- bases
- pH scale
- neutralization reactions
- buffers
- monomers vs. polymers
- endergonic vs. exergonic reactions
- enzymes
- anabolism vs. catabolism
- organic compound monomers
- organic compound functions
- organic compound examples

Matter, Elements, and Atoms

Matter: anything that takes up space and has mass. Mass is equivalent to weight. Matter is composed of atoms.

Elements: are composed of the *same* types of atoms. Elements are the simplest substances on earth; they cannot be broken down. All matter is composed of elements. Elements are found on a Periodic Table represented by symbols.

Learn this chart for the test

Principal Elements in the Human Body	Symbol	General Role in the body
Oxygen	O	cellular respiration
Carbon	C	organic compound structure
Hydrogen	H	organic compound structure; pH balance
Nitrogen	N	protein structure
Calcium	Ca	major extracellular cation (bones, teeth)
Phosphorus	P	component of nucleic acids
Potassium	K	major intracellular cation; electrolyte
Sodium	Na	major extracellular cation; osmosis and water balance
Chlorine	Cl	stomach juices
Magnesium	Mg	intracellular cation
Sulfur	S	protein structure
Iron	Fe	hemoglobin
Iodine	I	thyroid hormone; metabolism

Trace elements, such as silicon, fluorine, copper, zinc, also exist in the body—just in *smaller* amounts than these principal elements.

Chapter 2: The Chemistry of Life, Continued

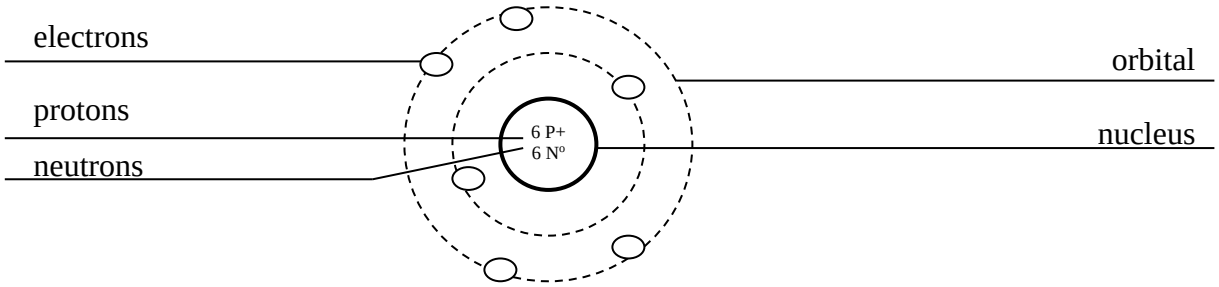
Atoms: This term means *indivisible* in Greek; atoms cannot be broken down any further and still retain the characteristics of the atom. Atoms of the same kind compose elements. Atoms can bond together to form molecules and/or compounds.

Three Subatomic Particles found in Atoms

Complete this table with the three subatomic particles of atoms.

Particle	Charge	Location in Atom

Structure of an Atom



Orbitals: electrons fill the orbitals of atoms.

- The innermost orbital holds a maximum of **2** electrons (known as the duet rule).
- The second orbital holds a maximum of **8** electrons (known as the octet rule).
- The third orbital holds a maximum of **18** electrons, but is stable with **8** electrons.
- Atoms are **stable** (**inert**) if they have a minimum of 8 electrons in their outermost orbitals.
- Atoms are **reactive** if they have less than 8 electrons in their outermost orbitals. Atoms can share, transfer (lose or gain) electrons to achieve the appropriate number of electrons.
- The outermost orbital of an atom is called its **valence shell**.

Chapter 2: The Chemistry of Life, Continued

Atomic Number = number of **protons** in an atom. The atomic number is unique to an atom. When the **number of protons = the number of electrons**, the atom's net electrical charge is zero and thus the atom is **neutral**.

Mass Number (also called the **atomic mass**) = **sum** of the atom's **protons** and **neutrons** in its nucleus. The proton and neutron account for most of the mass of the atom.

Isotopes: Atoms of the same element ("siblings") which have differing numbers of neutrons. The **atomic mass** also differs among isotopes.

- For example: Carbon 12 has 6 protons, Carbon 13 has 7 neutrons, Carbon 14 has 8 neutrons (but all types have 6 protons).

The "Rules" for working with Atomic Number, Mass, Protons, Neutrons, Electrons

1. *Atomic number = # protons*
2. *If # protons = # electrons, you have a neutral atom.*
3. *Atomic mass = # protons + # neutrons*
4. *To determine the # neutrons:*
   Atomic mass – atomic # = # neutrons
   Atomic mass - # protons = # neutrons
   Atomic mass - # electrons = # neutrons (IF the atom is neutral)

Practicing Atomic Numbers and Mass

1. Atomic # = 5
Atomic mass = 11
protons = _____
neutrons = _____
electrons = _____

2. Atomic # = _____
Atomic mass = 23
protons = 11
neutrons = _____
electrons = _____

3. Atomic # = _____
Atomic mass = 12
protons = _____
neutrons = _____
electrons = 6

4. Atomic # = 3
Atomic mass = _____
protons = _____
neutrons = 4
electrons = _____

5. Atomic # = 8
Atomic mass = 16
protons = _____
neutrons = _____
electrons = _____

6. Atomic # = _____
Atomic mass = _____
protons = _____
neutrons = 7
electrons = 7

7. Atomic # = _____
Atomic mass = 19
protons = 9
neutrons = _____
electrons = _____

8. Atomic # = 12
Atomic mass = _____
protons = _____
neutrons = 12
electrons = 12

9. Atomic # = _____
Atomic mass = 9
protons = 4
neutrons = _____
electrons = _____

10. Atomic # = _____
Atomic mass = 4
protons = _____
neutrons = 2
electrons = _____

11. Atomic # = 5
Atomic mass = _____
protons = _____
neutrons = 6
electrons = _____

12. Atomic # = 4
Atomic mass = 9
protons = _____
neutrons = 5
electrons = _____

Chapter 2: The Chemistry of Life, Continued

Review of the Atomic Numbers, Weight, Protons, Neutrons, & Electrons

Complete the Following Chart

Element	Symbol	Atomic Number	Atomic Weight (Mass Number)	# Protons	# Neutrons	# Electrons
Carbon-12	C	6	12	6	6	6
Chlorine-35			35	17		
Carbon-14	C					
Nitrogen-14	N	7	14			
Phosphorus-31		15	31			
Sodium-23		11	23			
Oxygen-16	O		16			8
Oxygen-17	O		17			

1. An atom with an atomic number of 7 means that it has _____ protons and _____ electrons.
2. If an atom has 8 protons and 8 electrons, what is the atomic number of that atom? _____
3. If an atom has 8 protons and 8 neutrons, what is the atomic weight of that atom? _____
4. If an atom has 14 as its atomic weight, and 7 neutrons, how many protons are there? _____
5. If an atom has 16 as its atomic weight, and 9 neutrons, how many electrons are there?_____
6. An atom with 5 electrons will also have 5 _____.
7. An atom with an atomic weight of 20 and an atomic number of 10 means that there must be ____ protons.
8. If an atom has 16 subatomic particles in the nucleus and an atomic number of 8, then this atom must have _____ protons.
9. If an atomic has 5 electrons, 5 protons, and 5 neutrons, what is the atomic number of this atom?_____
10. If an atom has 7 electrons, 7 protons, and 7 neutrons, what is the atomic weight of this atom?_____
11. If an atom has an atomic number of 8, how many positive charges does the atom have?_____
12. If an atom has an atomic number of 13, how many negative charges does the atom have? _____
13. An atom with 18 as its atomic weight will have 9 electrons and 9 _____
14. An atom with 17 positive charges should also have _____ negative charges.
15. An atom with 12 protons and 12 neutrons has atomic number of _____ and an atomic weight of _____
16. An atom with 6 neutrons, 6 protons, and 6 electrons has an atomic weight of _____
17. If an atom has 3 positive charges and 3 negative charges, the atomic number is _____
18. If an atom has 14 protons, how many electrons does it have?_____

Chapter 2: The Chemistry of Life, Continued

Review of the Atomic Numbers, Weight, Protons, Neutrons, & Electrons

Answers: Chart

Element	Symbol	Atomic Number	Atomic Weight (Mass Number)	# Protons	# Neutrons	# Electrons
Carbon-12	C	6	12	6	6	6
Chlorine-35	**Cl**	**17**	35	17	**18**	**17**
Carbon-14	C	**6**	**14**	**6**	**8**	**6**
Nitrogen-14	N	7	14	**7**	**7**	**7**
Phosphorus-31	**P**	15	31	**15**	**16**	**15**
Sodium-23	**Na**	11	23	**11**	**12**	**11**
Oxygen-16	O	**8**	16	**8**	**8**	8
Oxygen-17	O	**8**	17	**8**	**9**	**8**

Answers

1. 7 protons, 7 electrons
2. atomic number = 8
3. atomic weight = 8 + 8 = 16
4. 14- 7 = 7 protons
5. 16 – 9 = 7 electrons
6. 5 protons
7. 20 – 10 = 10 protons
8. 16 – 8 = 8 protons
9. atomic number = 5 = number of electrons = number of protons
10. atomic weight = number of protons + number of neutrons = 7 + 7 = 14
11. atomic number tells number of electrons and number of protons, so 8 positive charges
12. 13 (electrons)
13. 9 protons
14. 17 negative
15. atomic number = 12; atomic weight = 12 + 12 = 24
16. atomic weight = 6 protons + 6 neutrons = 12
17. atomic number = 3
18. 14 electrons

Chapter 2: The Chemistry of Life, Continued

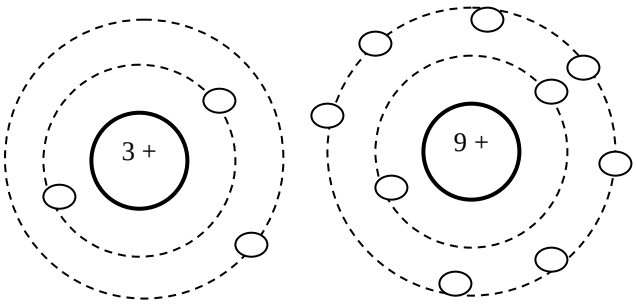
Chemical Bonding

⇨ **Why do atoms form bonds?** Atoms form bonds to stabilize their valence shell by transferring (ionic bonding) or sharing (covalent bonding) electrons. The number of electrons in that valence shell determines how an atom behaves.

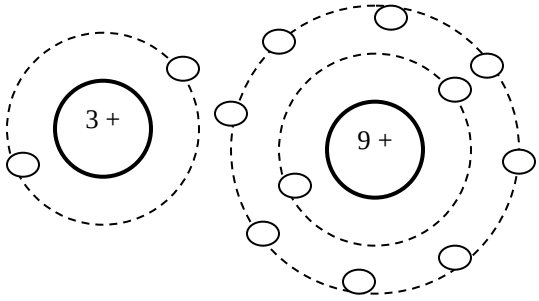
IONIC BONDS are formed when two or more atoms **transfer** electrons in order to complete the outermost orbitals.

- An **ion** is an atom that has lost or gained electrons.
- Ions carry a charge due to the loss or gain of electrons
  - Cations: the atom has lost electrons and has a **positive charge**, such as Na^+.
  - Anions: the atom has gained electrons and has a **negative charge**, such as Cl^-.
- Ionic compounds often dissolve in water (we often say they *ionize* or *break apart*).

Identify the cation and anion in the bond, below right.



Before the transfer



After the transfer

What does Li^+ indicate? _____ *And F^-?* _____

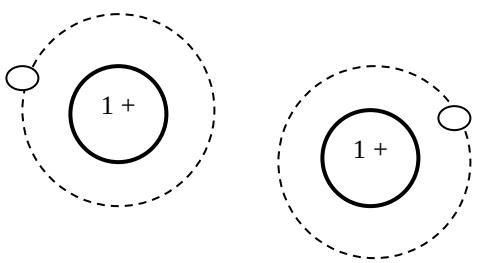
COVALENT BONDS are formed when two or more atoms **share** pair(s) of electrons. Atoms that do not have the proper number of electrons in their outer orbital shells will tend to form bonds with other atoms.

Two Types of Covalent Bonds:

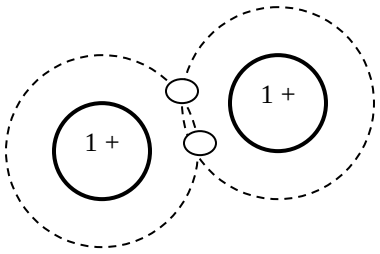
- **Nonpolar** covalent bonds in which the electrons are shared equally among atoms.
  - Examples: oil, fats, waxes
- **Polar** covalent bonds in which the electrons are **NOT** shared equally among atoms.
  - Examples: water, alcohol, and anything that dissolves in water

Polar and nonpolar substances do not mix!

Nonpolar covalent bond: H_2



Before sharing occurs

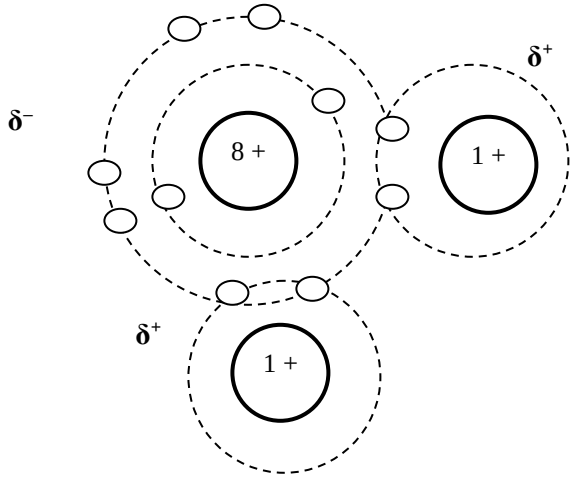


After the sharing of a pair of electrons

Chapter 2: The Chemistry of Life, Continued

COVALENT BONDS, continued

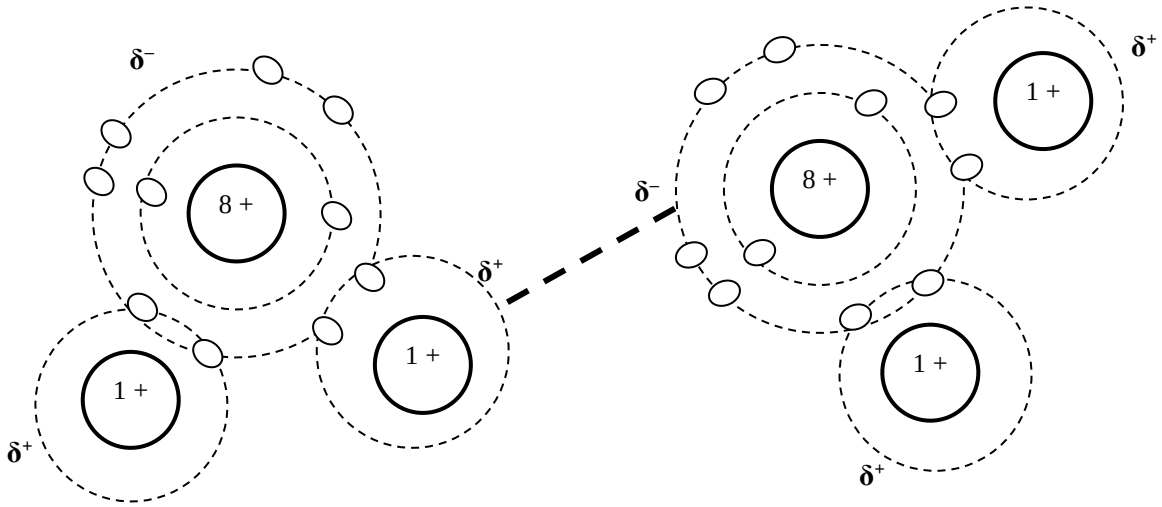
Polar covalent bond: H_2O



Chemical Formula: **H_2O or H–O–H**

- **Single covalent bonds** result when one pair of electrons are shared, such as C–C
- **Double covalent bonds** result when two pairs of electrons are shared, such as O= O
- **Triple covalent bonds** result when three pairs of electrons are shared, such as N ≡ N

HYDROGEN BONDS are weak bonds formed when hydrogen, with a weak partial positive charge, is attracted to a weak partial negative charge on another polar covalent bond (often oxygen, nitrogen, fluorine). Hydrogen bonds frequently occur between water molecules (*see the dotted line, below, which represents a hydrogen bond).* Hydrogen bonds are neither ionic nor covalent in nature.



Chapter 2: The Chemistry of Life, Continued

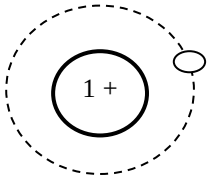
Molecules and Compounds

- **Molecules** result when two or more atoms have chemically combined together, typically from **covalent bonds**.
- **Compounds** contain atoms from two or more elements combined together in a fixed ratio, typically result from **ionic bonds**.

Look at these different scenarios:

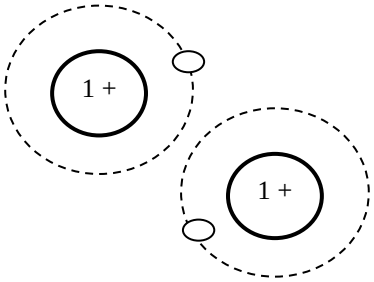
1 H atom

Symbol = H



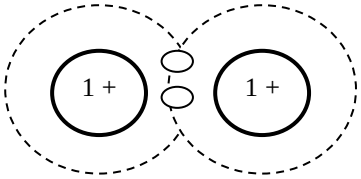
2 H atoms
not bonded together

Molecular Formula = 2H



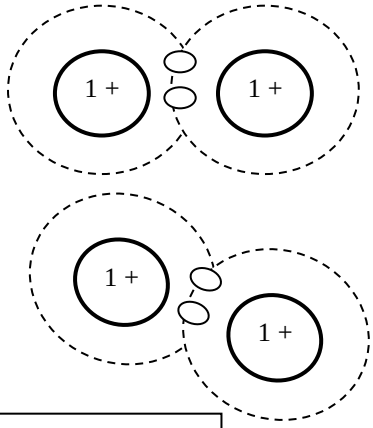
2 H atoms
bonded together

Molecular Formula = H_2



2 molecules of H_2

Molecular Formula = $2H_2$



The "Rules"

1. Coefficient tells us how many molecules or compounds there are. ($\mathbf{\underline{3}}H_2$)
2. Subscript tells us how many atoms of an element in a molecule or compound. ($3H_{\underline{2}}$)
3. Multiply the coefficient x subscript to get the total number of atoms. ($3H_2$ = 3 x 2 = 6 H atoms)

⇨ **Example:** Let's use calcium carbonate with the molecular formula $CaCO_3$

- How many atoms of calcium are in $CaCO_3$? _____
- How many atoms of oxygen are in $CaCO_3$? _____
- How many atoms of carbon are in $CaCO_3$? _____
- How many molecules do you have of $CaCO_3$? _____

⇨ **Example:** Let's use potassium phosphate with the molecular formula K_2PO_4

- How many atoms of potassium are in K_2PO_4? _____
- How many atoms of phosphorus are in K_2PO_4? _____
- How many atoms of oxygen are in K_2PO_4? _____

More Problems: How many atoms of each element in the following:

1. Na_2CO_3 _____
2. KCl _____
3. Mg_2SO_4 _____
4. $2H_3PO_4$ _____
5. 3HCN _____
6. $2K_2CO_3$ _____

Answers: 1. 2 atoms of Na, 1 atom C, 3 atoms O; 2. 1 atom K, 1 atom Cl; 3. 2 atoms Mg, 1 atom S, 4 atoms O; 4. 6 atoms H, 2 atoms P, 8 atoms O; 5. 3 atoms H, C, and N; 6. 4 atoms K, 2 atoms C, 6 atoms O

Chapter 2: The Chemistry of Life, Continued

Review of Matter: Elements, Atoms, and Compounds

Elements in Chemical Bonds

1. Write the names of the elements represented in each of the following compounds.

KCl _____ $MgCl_2$ _____

NaOH _____ $NaNO_3$ _____

H_2CO_3 _____ $Al_2(SO_4)_3$ _____

CaF _____ MgS _____

Numbers of Molecules and Atoms

2. A molecule of O_2 contains how many atoms of oxygen? _____

3. Each molecule of glucose, $C_6H_{12}O_6$, contains:
   _____ atoms of carbon
   _____ atoms of hydrogen
   _____ atoms of oxygen

4. A molecule of water, H_2O, contains _____ atoms of hydrogen & _____ atoms of oxygen.

5. A molecule of carbon dioxide, CO_2, contains _____ atoms of carbon & _____ atoms of oxygen.

6. How many molecules of water do you see here: $5H_2O$ = _____ molecules

7. How many atoms of hydrogen do you see here: $5H_2O$ = _____ atoms of hydrogen

8. What do the following represent?
   $3O_2$ _____
   $4N_2$ _____
   $7H_2O$ _____

9. The symbol, Na, indicates: (*choose one*)
   _____ 1 molecule of sodium
   _____ 1 atom of sodium

10. The formula $2H_2$ indicates _____ total atoms of hydrogen.

11. Chlorophyll has the formula $C_{55}H_{68}O_5N_4Mg$. List the elements and number of atoms that it contains:
   C = _____ Number of atoms = _____
   H = _____ Number of atoms = _____
   O = _____ Number of atoms = _____
   N = _____ Number of atoms = _____
   Mg = _____ Number of atoms = _____

12. The formula H_2 represents _____ molecules of hydrogen while the formula $4H_2$ represents ____ molecules of hydrogen.

13. What's the difference between a neutral and a stable atom?

14. How do ions and isotopes vary?

Chapter 2: The Chemistry of Life, Continued

Review of Matter: Elements, Atoms, and Compounds

Answers

1. List of elements in each compound:
   KCl = potassium, chlorine

   $MgCl_2$ = magnesium, chlorine

   NaOH = sodium, oxygen, hydrogen

   $NaNO_3$ = sodium, nitrogen, oxygen

   H_2CO_3 = hydrogen, carbon, oxygen

   $Al_2(SO_4)_3$ = aluminum, sulfur, oxygen

   CaF = calcium, fluorine

   MgS = magnesium, sulfur
2. 2
3. 6 atoms of carbon, 12 atoms of hydrogen, 6 atoms of oxygen
4. 2 atoms of hydrogen, 1 atom of oxygen
5. 1 atom of carbon, 2 atoms of oxygen
6. 5 molecules of water
7. 10 atoms of hydrogen (because 5 x 2 = 10)
8. $3O_2$ = 3 molecules of oxygen; $4N_2$ = 4 molecules of nitrogen; $7H_2O$ = 7 molecules of water
9. one atom because a molecule is defined as two or more atoms bonded together
10. 4 atoms
11. List of elements and number of atoms of each element

    C = Carbon = 55 atoms

    H = Hydrogen = 68 atoms

    O = Oxygen = 5 atoms

    N = Nitrogen = 4 atoms

    Mg = Magnesium = 1 atom
12. 1 molecule; 4 molecules

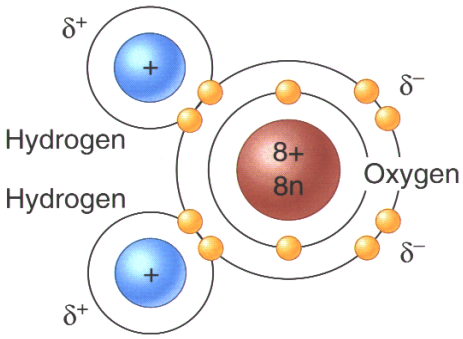
Chapter 2: The Chemistry of Life, Continued

Inorganic versus Organic Compounds

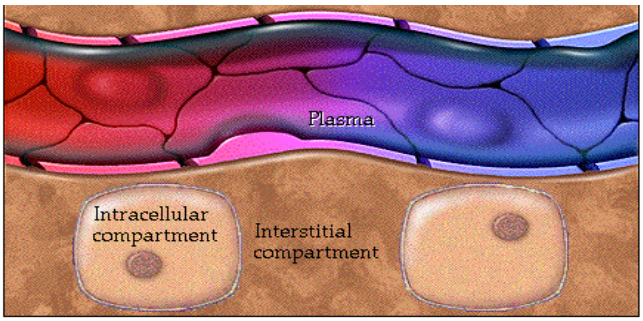
Inorganic Compounds
* usually lack chains of carbon & hydrogen atoms
* examples include carbon dioxide, water, oxygen (O_2), and inorganic acids, bases, & salts
* often ionically bonded

Organic Compounds
* contain chains of carbon & hydrogen atoms
* examples include carbohydrates, proteins, lipids, and nucleic acids
* often covalently bonded

WATER



- **Polarity:** results when electrons are unequally shared among atoms that are covalently bonded together. Oxygen pulls more strongly on the two hydrogen atoms involved in forming water.
- **Cohesion**: water molecules tend to stick together as a result of hydrogen bonding. Cohesion is what helps trees and plants to pull water up the lengths of their trunks. Surface tension is related to cohesion; it's the measure of how difficult it is to stretch or break the surface of a liquid. (Dip a paper clip in soap and watch it float on water's surface.)
- **Hydrogen Bonds**: result when hydrogen is weakly attracted to a partial negative charge present on another compound or molecule. These bonds are very weak. but they are the force that keeps water held together.
- **High Heat Capacity/High Heat of Vaporization:** water resists change in temperature. The high heat capacity means that it takes a certain amount of energy to increase one gram of water by 1° Celsius.
- **Chemical Reactivity**: water is a good solvent; it's involved in chemical reactions in your body.
- **Cushioning**: water provides a cushioning around many vital organs—such as the brain, spinal cord, it protects a baby during pregnancy for instance. Water is found in other places in the body:
  - **Intracellular fluid (ICF):** the nucleoplasm and cytosol; fluid inside cells; accounts for 66% of water in body
  - **Extracellular fluid (ECF):** fluid found outside cells; accounts for 33% of water in body
    - **Interstitial fluid:** the fluids that bathes the exterior of our cells; contains many nutrients
    - **Plasma**: the fluid found in blood



Chapter 2: The Chemistry of Life, Continued

ELECTROLYTES

- *What are electrolytes*? chemicals bonded together that ionize (break apart) when dissolved in water.
- *Common electrolytes:* Na^+, Ca^{2+}, K^+, Mg^{2+} Cl^-, HCO_3^-, PO_4^-
- *Major functions of electrolytes*? Hydration, muscle contraction, nerve impulse transmission.
- *What are some examples of electrolytes?* sodium chloride, potassium chloride, sodium bicarbonate, sodium sulfate

SALTS: electrolytes that ionize (break apart) in solution. Salts lack the H^+ and OH^- released by acids and bases. (**Examples** of salts are NaCl, K_3PO_4)

ACIDS: substances that donate hydrogen (H^+) ions when dissolved in water.

$$\mathbf{H}Cl \rightarrow H^+ + Cl^-$$

Examples include: _____

BASES: substances that donate hydroxide (OH^-) ions when dissolved in water.

$$Na\mathbf{OH} \rightarrow Na^+ + OH^-$$

Examples include: _____

The pH Scale

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

----------Acids----------Neutral----------Bases----------

Strong *Weak* *Weak* *Strong*

The pH Scale Fast Facts:

- pH is the measure of how many hydrogen ions are in solution.
- 7 is neutral. What does it mean to be neutral? _____
- Acids are found below 7.
- Bases are found above 7.
- The pH scale is based on logarithms (based on the number 10).
  - A change in pH from 6 to 5 is a 10-fold change in acidity.
  - The change in pH from 6 to 4 results in a solution that is 100 times more acidic (means 4 is 10 x 10 times or 10^2 more acidic than a pH of 6).
  - A pH of 12 is 10,000 or 10^4 times more alkaline (basic) than a pH of 8.
  - A pH of 2 releases _____ times more hydrogen ions than a pH of 5.
  - A pH of 3 releases _____ times less hydroxyl ions than a pH of 7.
  - A pH of 5 releases 1,000 times more _____ ions than a pH of 8.

Chapter 2: The Chemistry of Life, Continued

Review of the Inorganic Compounds

For questions 1-12, identify the following descriptions as:

A. Acid
B. Base
C. Salt
D. Water
E. pH Scale

_____1. The two products formed when an acid and base combine.

_____2. Substance that releases OH^- ions when dissolved in water.

_____3. Substances such as lemon juice, vinegar; bodily fluids urine, saliva.

_____4. Substance with a pH of 4.

_____5. Substance that releases H^+ ions when dissolved in water.

_____6. The scale based on the concentration of H^+ ions in the substance.

_____7. Substance with a pH of 9.

_____8. Many electrolytes fall into this category; calcium, potassium, sodium ions are examples.

_____9. Substances such as bleach, milk of magnesia, aspirin; bodily fluids blood, semen.

_____10. Substances that are slippery to the touch.

_____11. On this scale, 7 is considered "neutral"—neither acidic nor basic.

_____12. This inorganic compound is characterized by possessing a high heat capacity, it's a good solvent, it's a polar compound, and it provides cushioning around your delicate body organs.

Fill in the Blank

_____13. Tomatoes, with a pH of 4, are ___ times more acidic than black coffee, which has a pH of 5.

_____14. Stomach acid, with a pH of 1, is _____ times more acidic than urine, which has a pH of 6.

_____15. Bicarbonate of soda has a pH of 12, this has 10 times more _____ ions than household ammonia, with a pH of 11. In other words, bicarbonate of soda is ____ times more basic then ammonia.

_____16. The compounds KOH and NaOH:

A. are acids because they yield hydrogen ions in solution

B. are not acids because they do not yield hydrogen ions in solution

17. Indicate whether the following are acids, bases, or salts:

_____$Ca(OH)_2$ _____KOH

_____H_2SO_4 _____$MgCl_2$

_____H_2CO_3 _____KCl

18. Look at the following and determine:

Place a ✓ by the pH which is a strong basic solution; place an **X** by the weak basic solution.

_____3.2 _____6.9 _____7.3 _____13.2

Answers: 1C, D; 2B, 3A, 4A, 5A, 6E, 7B, 8C, 9B, 10B, 11E, 12D, 13: 10, 14: 10^5 or 100,000, 15: OH, 10, 16: B

17. Base = $Ca(OH)_2$ Base = KOH
Acid= H_2SO_4 Salt = $MgCl_2$
Acid = H_2CO_3 Salt = KCl

18. strong basic solution = 13.2; weak basic solution = 7.3

Chapter 2: The Chemistry of Life, Continued

Chemical Reactions

NEUTRALIZATION REACTIONS

1. Neutralization is the reaction between an _____ and a _____. Salt and water will yield (result). A commonly known neutralization reaction is the "homemade volcano" that many schoolchildren use for science projects. Vinegar, an acid, and baking soda, a base, are used to perform this reaction.

Example of a neutralization reaction (a type of double replacement reaction):

$$\underbrace{HCl + NaOH}_{\text{reactants}} \rightarrow \underbrace{NaCl + H_2O}_{\text{products}}$$

acid base salt water

2. *Why does your body perform neutralization reactions?* To maintain a proper pH balance. Your blood has a narrow range of pH values it must stay within (7.35 – 7.45). Buffers present in our blood stream and body help to shield against drastic changes in pH in the body.

a. **Acidosis:** when the blood pH falls below 7.35 toward the acid range.

b. **Alkalosis:** when the blood pH rises above 7.45 toward the basic range.

3. *What are buffers?* **Buffers** are chemical systems that resist changes in pH by accepting H+ ions when they are in excess and donating H+ ions when they are depleted. We will talk about various buffer systems in Bio 211 when we discuss acid-base balance.

BASIC INFORMATION FOR CHEMICAL REACTIONS

Chemical Reactions involve a change in energy and a rearrangement in molecular structure. First, we need to understand four terms:

Monomer: single unit; building block

Polymer: two or more units bonded together

Reactants: substances entering into a chemical reaction

Products: substances made as a result from a chemical reaction

$$A—B—C \rightarrow A + B + C$$

polymer 3 monomers

Energy IN or Energy OUT during chemical reactions?

Endergonic (endothermic) Reactions are chemical reactions that absorb ATP or require more energy to start the reaction than is actually released. Endergonic reactions do not spontaneously occur.

Anabolism is endergonic – building molecules requires energy.

Exergonic (exothermic) reactions release ATP or energy.

Catabolism is exergonic – breaking down molecules releases energy.

Activation Energy is the amount of energy needed to start a reaction. **Enzymes** are **catalysts** that help to lower activation energy.

Chapter 2: The Chemistry of Life, Continued

METABOLISM is the sum of all chemical reactions in the body. It includes anabolic and catabolic reactions.

SYNTHESIS REACTIONS (Dehydration Synthesis Reaction = Anabolism): occur when two or more atoms or molecules combine to form a larger, more complex molecule. It can be represented as **A + B → AB**. These reactions involve bond formation and are the anabolic reactions in your body (reactions in which substances are built or made). The dehydration synthesis reaction can be summarized as "**monomers building polymers through the removal of water**." These types of reactions are typically ***endergonic***.

Dehydration Synthesis: Monomers Joining To Form Polymers

Dehydration = removal of water
Synthesis = to make something

DECOMPOSITION REACTIONS (Hydrolysis Reaction = Catabolism): occur when a molecule is broken down into smaller molecules. It can be represented as **AB → A + B**. Hydrolysis reactions are the opposite of dehydration synthesis reactions. Bonds are broken in these reactions to produce smaller, simpler substances than the original substance. The hydrolysis reaction can be summarized as "**polymers breaking down into monomers through the addition of water**." These types of reactions are typically ***exergonic***.

Hydrolysis: Polymers Breaking Down Into Monomers

Hydro = water
Lysis = to split or rupture

Review of Chemical Reactions: Dehydration Synthesis and Hydrolysis

1. Describe the role of water in dehydration synthesis and hydrolysis.
2. Explain why it is recommended for us to drink around 8 cups of fluid every day for digestion, a type of hydrolysis, to occur properly.
3. In the body, amino acids are assembled into polymers known as proteins. Name the type of reaction that occurs between amino acids and describe this process.
4. Explain why muscle building, a type of dehydration synthesis, will generate water molecules.

Need help with these questions? Please come see me!

Chapter 2: The Chemistry of Life, Continued

Organic Compounds

Helpful Hint! *The next few pages on organic compounds are commonly missed on exam 1…try flash cards with monomer(s), function, types, and/or examples.*

CARBOHYDRATES

Building Block or Monomer: monosaccharide

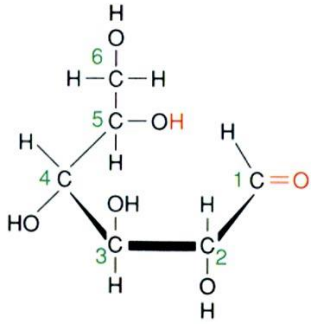
mono = simple or one; *saccharide* = sugar

carbo = carbon; *hydrate* = oxygen + hydrogen (water) in the ratio of CH_2O or 1:2:1

Function: to give energy.

Types of Carbohydrates

- **Monosaccharide = Simple Sugars**: contain between 3 and 7 carbon atoms and can be quickly broken down by the body to give energy. Examples of monosaccharides include glucose and fructose. These two molecules are also **isomers** of each other. **Isomers** have the same molecular formula but different structures.
  - **Glucose** ($C_6H_{12}O_6$) = the preferred fuel of mitochondria from which to make ATP
  - **Fructose** ($C_6H_{12}O_6$)
  - **Galactose** ($C_6H_{12}O_6$)



Glucose

- **Disaccharides =** monosaccharide + monosaccharide (assembled through dehydration synthesis reactions)
  - **Maltose** = glucose + glucose
  - **Sucrose** = glucose + fructose (table sugar)

- **Polysaccharides = Complex Carbohydrates**: complex carbs are made of many monomers and require more energy for the body to break the bonds between them. Complex carbs give energy over a longer period of time; pasta, breads, and starches are examples of these polymers. There are three polysaccharides common in animals and plants: starch, cellulose and glycogen.
  - **Glycogen** (animal polysaccharide) is the storage form of **glucose** in humans. This polysaccharide is stored in the **liver** by the hormone **insulin**. The body tries to maintain the blood glucose level at 0.1%.
  - **Starch** (plant polysaccharide) is how plants commonly store excess glucose. Starch is also known as "soluble fiber."
  - **Cellulose** (plant polysaccharide) is commonly known as fiber. Humans are unable to digest cellulose because we do not have the necessary enzyme for cellulose digestion; it passes through the digestive tract as roughage. Cellulose is also known as "insoluble fiber."

- **Food Examples**: honey, soft drinks, starches, sweets, breads, pasta, muffins, cereals, grains

Chapter 2: The Chemistry of Life, Continued

LIPIDS

Building Blocks or Monomers: fatty acid + glycerol

carbon and hydrogen are found in the ratio of 1:2 but have less oxygen than carbohydrates

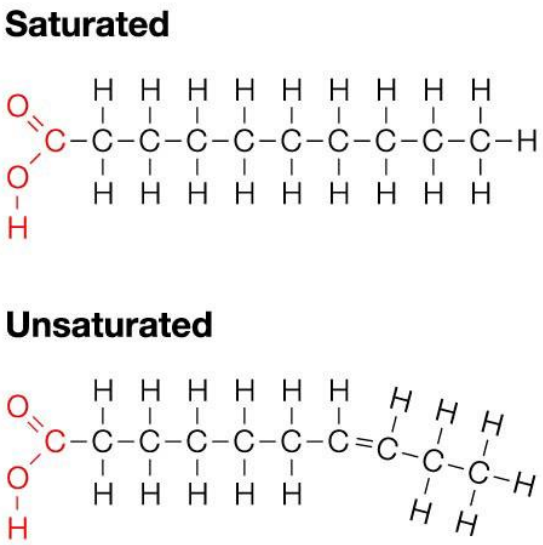
Function: to store energy, form structures of cells, insulate around organs lipids have a *nonpolar* region which causes portions to be hydrophobic ("water-fearing")

Anabolic and catabolic reactions: glycerol heads and fatty acids chains are either joined or broken apart from each other.

2 Types of Fatty Acids Chains

- **Unsaturated Fats**: unsaturated fats do not have hydrogens bonded to every possible bonding site. In other words, they lack the maximum number of hydrogen atoms on their fatty acid chains and are thus, unsaturated. The carbon atoms form **DOUBLE** bonds in places where they may be only one hydrogen atom. Since these fats don't have the max number of hydrogens, the molecules "kink" up and trap air between the fatty acid chains. Therefore, they are typically **LIQUID** at room temperature (think of unsaturated oils like canola oil, vegetable oil, oils coming from **PLANTS**)
    - **Monounsaturated fats** have only one double bond in the fatty acid chains
    - **Polyunsaturated fats** have _____ double bonds in the fatty acid chains.

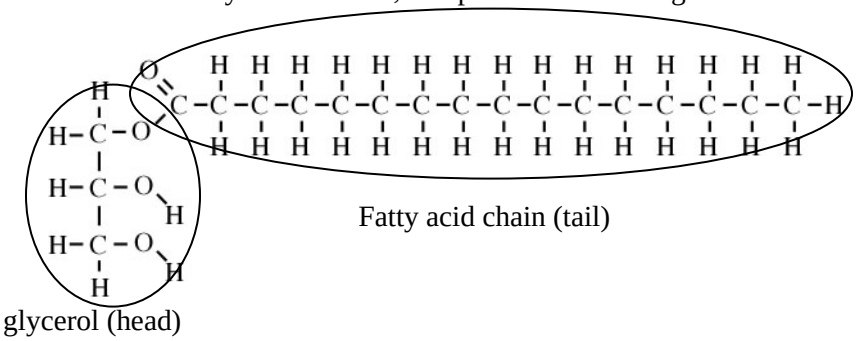
- **Saturated Fats**: saturated fats have the maximum number of hydrogen atoms bonded to the molecule; in other words, they have no double bonds between the carbon atoms. Therefore, we use the word "saturated". These fats "lie flat" unlike the unsaturated fats; thus, they are **SOLID** at room temperature because there is less space between the fatty acids (animal fats like butter).



Chapter 2: The Chemistry of Life, Continued

LIPIDS, continued

- **Glycerides**: contain one glycerol and some number of fatty acid chains.
  - **Monoglycerides** = one glycerol + one fatty acid chain
  - **Diglycerides** = one glycerol + _____ fatty acid chains
  - **Triglycerides** = one glycerol + _____ fatty acid chains. These neutral fats serve as energy sources, insulate in the subcutaneous layer of the skin, and protects around organs.

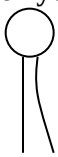


Fatty acid chain (tail)

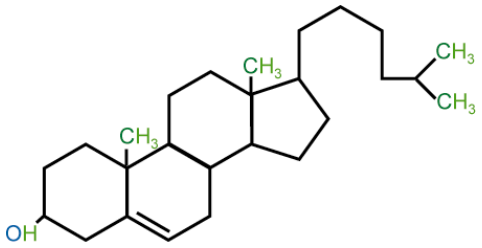
glycerol (head)

Is this molecule pictured at left a mono-, di-, or triglyceride?

- **Phospholipids**: these are lipids that contain a phosphate group that contains both phosphorous and nitrogen. These phosphate groups are carrying a charge and become the polar heads of the plasma membrane while the nonpolar tails forms the rest of the membrane bilayers. Since the tails are **nonpolar**, they are **hydrophobic** (*water-fearing*). The heads, being **polar**, are **hydrophilic** (*water-loving*).



- **Steroids**: have a backbone of 4 fused carbon ring; their structures differ entirely from other fats (different functional groups are attached to the basic structure).
  - **Cholesterol** is a type of steroid that is a precursor to other steroids (like aldosterone, estrogen, and testosterone). Cholesterol is obtained in two ways in the body:
    1. absorbed from animal products in the diet (can be controlled through diet)
    2. made in the body (can be controlled through medication)
  - Other hormones such as corticosteroids and calcitriol are steroids; steroids also form part of bile salts.



Chapter 2: The Chemistry of Life, Continued

PROTEINS

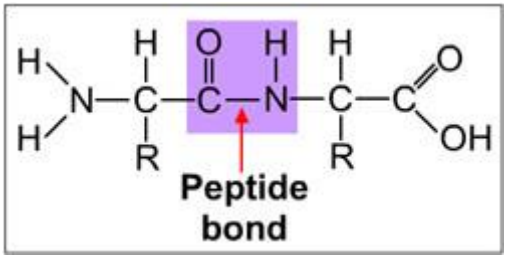
Building Blocks or Monomers: amino acid

Proteins contain C, H, O, N, smaller amounts of P, S.

Functions: Proteins have a variety of functions, such as:

- **Structural** proteins serve as a framework for the body as support for cells, tissues, and organs (such as integral and peripheral proteins found in plasma membranes; cytoskeleton; collagen fibers, keratin)
- **Functional proteins** serve as:
  - **Transport** proteins bind to substances for movement in the blood stream (such as insoluble lipids, minerals, gases). For instance, hemoglobin is a transport protein on RBC and transports gases like oxygen and carbon dioxide.
  - **Contractile** proteins provide muscle contraction
  - **Hormones** made from proteins control activities in the body
  - **Buffers** help maintain blood pH
  - **Enzymes** speed up the rate of chemical reactions
  - **Defense proteins** such as nails, hair, or antibodies

Unique Characteristic: Amino acids are joined together with **peptide** bonds (a special type of covalent bond composed of C, O, H, and N).



During **protein synthesis** (a type of dehydration synthesis) amino acids are joined together to form:

- A **dipeptide** contains 2 amino acids
- A **polypeptide** can have hundreds of amino acids.

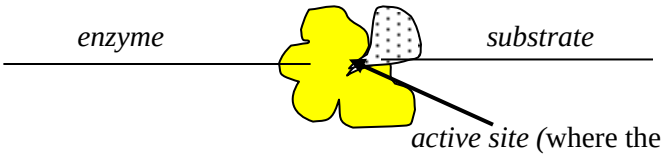
Structure of Proteins: Some proteins have 1 polypeptide chain while others have more than one; yet, each polypeptide chain has its own unique structure.

- **Primary**: linear sequence
- **Secondary**: *alpha helix* (most common form; shaped like a twist or curl) is created when H bonding occurs (the other form is known as a *pleated sheet*; shaped like a folded piece of paper)
- **Tertiary**: 3D shape results from interactions between chains and water; disulfide bonds are created
- **Quaternary**: 2 or more linked polypeptides (some proteins have this fourth level of structure). Collagen, hemoglobin, and keratin exist in this structure

Chapter 2: The Chemistry of Life, Continued

PROTEINS, Continued

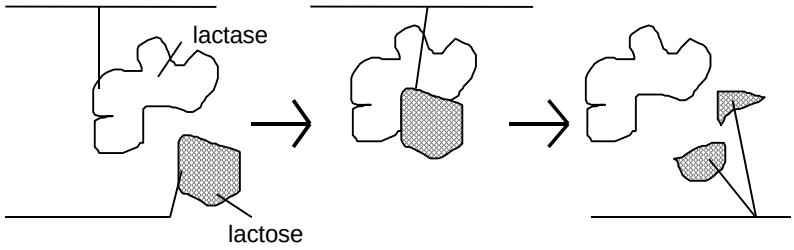
- **Metabolism**: the sum of all chemical reactions that occur in your body. Enzymes aid these chemical reactions.
- **Enzymes and Substrates**: substances that help to speed up a reaction, but are not used up by the reaction. Enzymes are specific to a particular substrate; they only work on certain substances that they have a particular "fit" with. Enzymes are proteins and catalysts (since catalysts are a general group of substances that speed up reactions).
  - Enzymes often have an ending of *–ase.* For example, *maltase* is an enzyme that acts on *maltose*, a carbohydrate substrate.
  - Substrate is the substance acted on by the enzyme. The substrate can end with *–ose* if the substrate is a sugar.
- **Active Site**: The location where the enzyme and substrate fit together. Think of it like a piece of a puzzle. The active site is like a lock and key fit.



*active site (*where the enzyme and substrate join)

- **Activation Energy**: Enzymes ↓ the activation energy of a chemical reaction.
- **Denaturation** is when the tertiary or quaternary shape of an enzyme is changed so that the active site no longer fits with the enzyme. The protein is nonfunctional.
- **Factors Influencing Enzyme Activity**
  - **Acids**: acidic pH denatures enzymes (normal blood pH is 7.35-7.45)
  - **Heat:** fever or high heat denatures enzymes (normal body temperature is 37.0 °C or 98.6 °F)
  - **Concentration** of reactants or products drive the reaction either toward the right or the left

Identify the parts of this enzyme reaction. On the lines provided, label the:
enzyme, substrate, active site, and products.



Does this reaction represent catabolism **or** *anabolism?*

Chapter 2: The Chemistry of Life, Continued

NUCLEIC ACIDS

Building Block or Monomer: nucleotide

Function: store genetic information, make proteins, and serve as an energy molecule.

General Characteristic of nucleotides: Nucleotides contain the following three items:

1. some number of phosphate groups
2. some type of sugar molecule
3. some type of nitrogenous base

} **see details below!**

3 Specific Types of Nucleic Acids

- **DNA = Deoxyribonucleic Acid**. DNA is the way genetic information is stored in the body. DNA is built of nucleotides--2 strands are wound like a helical staircase. The backbones of the two DNA strands are composed of repeating sugar and phosphate groups. The "rungs" of the ladder are composed of bases paired together (adenine with thymine; cytosine with guanine).
    - A nucleotide of DNA contains:
        1. phosphate
        2. 5 carbon sugar = deoxyribose
        3. nitrogen base (either adenine, guanine, cytosine, or thymine*)*

- **RNA = Ribonucleic Acid**. RNA is used to create proteins. RNA is written from a template of DNA and therefore, they are similar in their composition. RNA is also built from nucleotides—however there is only 1 strand. *What are three differences between DNA and RNA structure?*
    - A nucleotide of RNA contains:
        1. phosphate
        2. 5 carbon sugar = ribose
        3. nitrogen base (either adenine, guanine, cytosine or uracil)

- **ATP = Adenosine Triphosphate**. ATP is an energy molecule that is "spent" in the body when work needs to be performed. When energy is required, the 3rd phosphate group is removed and the molecule becomes ADP. The phosphate group is readded via glucose metabolism (aerobic cellular respiration). *Why is ATP placed into this general category of organic compounds?*
    - A nucleotide of ATP contains:
        1. 3 phosphate groups
        2. 5 carbon sugar = ribose
        3. nitrogen base (adenine)

Chapter 2: The Chemistry of Life, Continued

Review of the 4 Organic Compound Groups

Complete this chart and make **flash cards** *to learn these characteristics of the organic compounds!*

	Carbohydrates	Lipids	Proteins	Nucleic Acids
Building Block (*Monomer)*	Monosaccharide *mono*=simple *saccharide*=sugar		Amino acids … linked together by peptide bonds to form polypeptides	
Function		Stores energy, serves as insulation for organs		Serves the body as the blueprint for life as DNA
Contains these elements or functional group	Contains the elements Carbon, Hydrogen, Oxygen in a ratio of CH_2O			
Characteristics or Types	Monosaccharides Disaccharides Polysaccharides	Unsaturated Fats Saturated Fats Phospholipids Steroids	Can be denatured by heat and acids. Denaturation: the protein changes shape and can no longer perform its function.	
Examples	Sucrose, fructose, galactose, lactose	Oil, wax, steroids, some hormones	Muscle, hair, nails, enzymes, some hormones	DNA, RNA
Food in which this organic compound is found	Pasta, bread, candy, cookies, cakes, muffins, some vegetables, fruits, soft drinks	Oil, butter, lard, cheese, some meats, beeswax	Fish, red meat, pork, turkey, peanut butter, some legumes (beans)	N/A

Chapter 2: The Chemistry of Life, Continued

Review of the 4 Organic Compound Groups

Identify each description, example, monomer, or function as:

A. carbohydrates
B. nucleic acids
C. proteins
D. lipids

_____ 1. Building block are the nucleotides
_____ 2. Function is to provide quick energy
_____ 3. Function is to store energy and provide insulation around organs.
_____ 4. Building block are monosaccharides.
_____ 5. Examples include sugars, starches.
_____ 6. Function is to provide genetic blueprint for life.
_____ 7. Examples include DNA and RNA.
_____ 8. Building block are amino acids.
_____ 9. Examples are muscles, nails, enzymes, hormones, hair.
_____ 10. Function is to provide structure and molecules for the body.
_____ 11. Examples are phospholipids and oils.
_____ 12. Form the two layers of the plasma membrane
_____ 13. Embedded in the two layers of the plasma membrane as channels or pumps
_____ 14. Stored in the nucleus of a cell
_____ 15. Produced by the rough endoplasmic reticulum
_____ 16. Produced by the smooth endoplasmic reticulum
_____ 17. Composed of Carbon, Hydrogen, and Oxygen.
_____ 18. Twists into a 3-D structure as primary, secondary, tertiary, and even quaternary structures.
_____ 19. Not considered necessary in our diets.
_____ 20. Some of these are considered hydrophobic (do not mix with water.)
_____ 21. ATP is an example; it's an energy molecule
_____ 22. Can have a primary, secondary, or tertiary structure.

Answers: 1B, 2A, 3D, 4A, 5A, 6B, 7B, 8C, 9C, 10C, 11D, 12D, 13C, 14B, 15C, 16D, 17A, 18C, 19B, 20D, 21B, 22C

Chapter 2: The Chemistry of Life, Continued

Review of Organic Compound Groups—Do You Know the Details?

_____ 1. How is excess sugar stored in human beings?

_____ 2. Name an example of an unsaturated fat.

_____ 3. DNA is a type of this organic compound group.

_____ 4. Name an example of a polysaccharide.

_____ 5. Name a monosaccharide.

_____ 6. Name an example of an organic compound group that is nonpolar.

_____ 7. Name an example of a steroid.

_____ 8. ATP is a type of this organic compound group.

_____ 9. Glucose + fructose → water + _____

_____ 10. Which type of lipid has "kinky" fatty acids chains?

_____ 11. An enzyme and its substrate come together at the ___ ___.

_____ 12. Name the monomer of the carbohydrates.

_____ 13. Is cellulose produced by human beings?

_____ 14. Proteins are held together by special bonds, called ___ bonds.

_____ 15. A polypeptide in a linear sequence is in its ___ formation.

_____ 16. Name an example of a nucleic acid.

_____ 17. Which type of lipid is constructed from 4 fused carbon rings?

_____ 18. Which organic compound group is constructed from a sugar, a phosphate group, and a nitrogenous base?

_____ 19. Which stores more energy: glucose or saturated fat?

_____ 20. Name a disaccharide.

_____ 21. How many strands does DNA have?

_____ 22. Give one example of a saturated fat.

_____ 23. List two differences between DNA and RNA.

_____ 24. Glycogen is the storage form of ___ in humans.

_____ 25. ATP is a type of nucleic acid that serves as an ____ molecule.

Answers: 1. glycogen, 2. olive oil, 3. nucleic acid, 4. cellulose, 5. glucose, 6. lipid, 7. cholesterol, estrogen, 8. nucleic acid, 9. sucrose, 10. unsaturated fats, 11. active site, 12. monosaccharide, 13. no, made by plants, 14. peptide, 15. primary, 16. DNA, RNA, or ATP, 17. steroid, 18. nucleic acids, 19. saturated fat, 20. sucrose, 21. 2, 22. lard, 23. DNA is composed of 2 strands while RNA has only 1 strand. DNA contains the nitrogenous base thymine while RNA contains the nitrogenous base uracil, 24. glucose, 25. energy

Chapter 3: The Cell

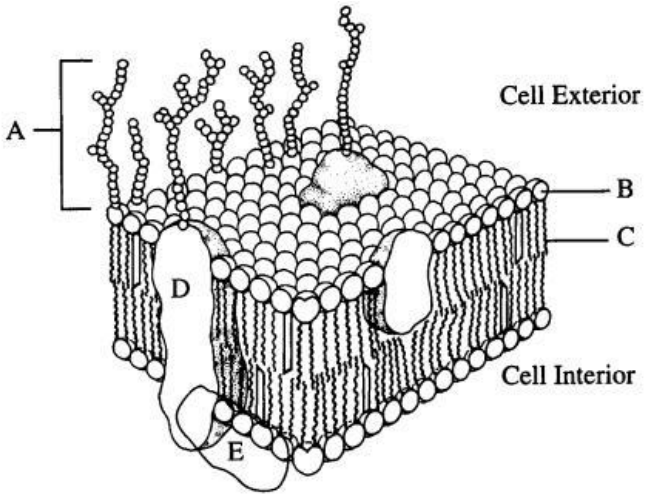
Over the next several pages, we will be discussing the characteristics of **eukaryotic cells**. *What characteristics must a cell have in order to be classified as eukaryotic?* All eukaryotic cells have a plasma membrane, and most cells have cytoplasm and a nucleus. Exceptions include red blood cells, which lack nuclei at maturity; sperm lack cytoplasm.

Plasma Membrane

Structure:

- **Lipid component**: 2 layers of _____ with portions that are hydrophobic ("water-fearing"). The nature of these phospholipids create a selectively permeable membrane. Cholesterol is also part of the membrane structure which helps regulate fluidity.
- **Protein component**: The double layer of phospholipids are embedded with **integral** (more common) and **peripheral** proteins. Membrane proteins serve as:
  1. **Recognition proteins**; many are classified as **glycoproteins**
  2. **Receptor proteins** which bind to molecules, generically called **ligands**.
  3. **Carrier proteins** to transport solutes across the plasma membrane; some may require ATP.
  4. **Channel proteins** contain a pore to permit water and small solutes to move across the membrane.
- **Carbohydrate component**: Carbohydrates associated with the outer portion of the plasma membrane form the **glycocalyx**. These carbohydrates provide:
  1. Recognition as "self"
  2. Anchoring, locomotion, lubrication, protection

Function: (1) provides a boundary around the cell to physically isolate it; (2) acts as a place for chemical reactions to occur, (3) regulates the exchanges of ions and nutrients with the environment as a semipermeable or selectively permeable membrane; (4) receptors allow the cell to respond to the environment; (5) structural support.



Cytoplasm is a generic term for the material found between the plasma membrane and the nucleus.

Structure: semi-fluid (jelly-like) medium containing electrolytes and organelles. **Intracellular fluid** or **cytosol** forms the liquid part of cytoplasm.

Function: hold the organelles in place inside a cell, provides a location for chemical reactions to occur.

Chapter 3: The Cell, Continued

Nucleus

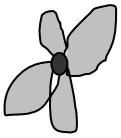
Structure:

- **Nuclear envelope** (a membrane) surrounds the DNA. The nuclear envelope has pores so that ions and molecules can leave the nucleus. The *nucleus* is a collective term for the DNA + its nuclear envelope.
- **Nucleoplasm** is the fluid contents of the nucleus.
- **Nucleoli** are nuclear organelles that make ribosomes (rRNA) by assembling the 2 ribosome subunits there.

- **DNA Structure:** composed of nucleotides built from 3 items: 1) _____ (deoxyribose), 2) _____, and 3) one of four bases: _____.
  DNA is arranged into two strands, known as a double helix due to its twisted nature.
  DNA exists either as **chromatin** ("relaxed" DNA) or chromosomes (tightly coiled DNA).

Chromatin

Single stranded chromosome



Double stranded chromosome

Function: The nucleus is part of the cell that houses the _____. DNA is the genetic blueprint for life; it's necessary for cell reproduction. Nucleus is the genetic control center of cells. DNA also controls protein synthesis, as described on the next page.

Steps of DNA Replication

DNA replication occurs during the S phase of interphase (cell cycle)

- First, the double strand of DNA must unwind using an enzyme known as DNA helicase. Then, another enzyme must help the DNA strands to unzip from one another. The strands of DNA unwind at "bubbles" all along the length of the DNA.
- Next, enzymes bring complementary base pairs to the unwound, unzipped DNA to match the bases. Base pairing occurs on each strand, but run in opposite directions (for speed). The bases adenine(A) and thymine (T) pair while cytosine (C) and guanine (G) pair together.
- Last, the two new strands of DNA must wind together. Each new double strand of DNA contains a _____ strand and a _____ strand.

During mitosis, the double stranded chromosomes are separated into single-stranded chromosomes.

parent strand A T C A T G G C A T C G A T A C
daughter strand

daughter strand
parent strand T A G T A C C G T A G C T A T G

Chapter 3: The Cell, Continued

Protein Synthesis

Two steps:

Step #1: **Transcription** rewrites DNA into mRNA in the nucleus. mRNA leaves the nucleus through a pore.

Step #2: **Translation** involves three types of RNA, below, to make amino acids. This process occurs on ribosomes.

The three types of RNA and their functions are:

1. **mRNA** is known as **messenger** RNA because it carries the code for the amino acid. The mRNA also carries the codon that is a group of three nucleotides in a specific order. Each codon codes for a specific **amino acid**.
2. **tRNA** is known as **transfer** RNA because it transfers the appropriate amino acid to the growing polypeptide strand. Each tRNA is complementary to the codon; therefore, the tRNA carries the **anticodon.** For example, if the mRNA codon is AUG, the tRNA anticodon is UAC. It uses this information to retrieve amino acids.
3. **rRNA** is known as ribosomal RNA because it is composed of 2 ribosome subunits.

Perform protein synthesis on the following strand of DNA.
Use the codon chart, below for translation.

strand of DNA T A C C G C A C A G C T T G C A T T

Transcription

strand of mRNA A U G / G C G / U G U / C G A / A C G / U A A

Translation

amino acids start-/-alanine-/-cysteine-/-arginine-/-threonine-/-stop

Codon Chart
Do NOT memorize this chart.

UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine
UUC	Phenylalanine	UCC	Serine	UAC	Tyrosine	UGC	Cysteine
UUA	Leucine	UCA	Serine	UAA	STOP	UGA	STOP
UUG	Leucine	UCG	Serine	UAG	STOP	UGG	Tryptophan
CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine
CUC	Leucine	CCC	Proline	CAC	Histidine	CGC	Arginine
CUA	Leucine	CCA	Proline	CAA	Glutamine	CGA	Arginine
CUG	Leucine	CCG	Proline	CAG	Glutamine	CGG	Arginine
AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine
AUC	Isoleucine	ACC	Threonine	AAC	Asparagine	AGC	Serine
AUA	Isoleucine	ACA	Threonine	AAA	Lysine	AGA	Arginine
AUG	Start (Methionine)	ACG	Threonine	AAG	Lysine	AGG	Arginine
GUU	Valine	GCU	Alanine	GAU	Aspartic Acid	GGU	Glycine
GUC	Valine	GCC	Alanine	GAC	Aspartic Acid	GGC	Glycine
GUA	Valine	GCA	Alanine	GAA	Glutamic Acid	GGA	Glycine
GUG	Valine	GCG	Alanine	GAG	Glutamic Acid	GGG	Glycine

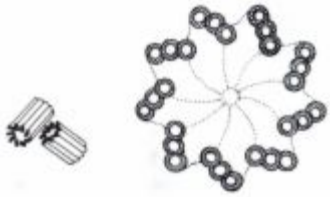
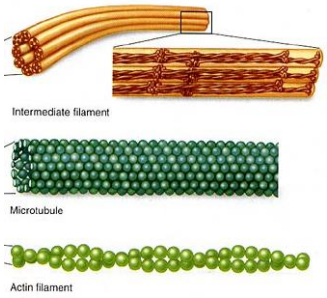
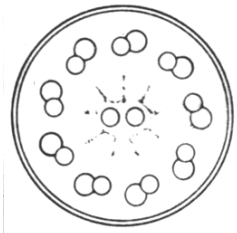
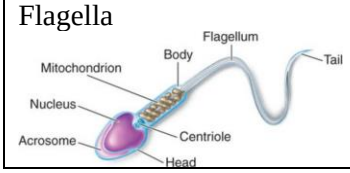
Chapter 3: The Cell, Continued

Other Organelles and their Structures and Functions

Organelles are small "organs" found within a cell. The role of an organelle is to perform a specific function for the cell.

Organelle/Structure	Structure	Function
Ribosomes	*Some* = body. These small bodies can be found 1) free in the cytoplasm or 2) attached ("fixed") to the rough endoplasmic reticulum.	Ribosomes make proteins that are to be used WITHIN the cell.
Endoplasmic Reticulum 	The endoplasmic reticulum (ER) is a network of membranes connected to the nucleus. These organelles receive their directions directly from the nucleus. • Rough ER has fixed ribosomes on the surface. • Smooth ER lacks them.	• Rough ER synthesizes proteins that are secreted OUT of the cell. • Smooth ER synthesizes lipids (such as phospholipids, steroid hormones) and carbohydrates. Smooth ER is also involved in drug detoxification.
Golgi Apparatus 	This organelle appears as a stack of flattened pancakes.	• Modify, package, and secrete hormones and enzymes from the cell in secretory vesicles. • Processed proteins become part of new vesicles that are passed from stack to stack and become modified. These vesicles either 1) fuse with the plasma membrane and secrete out contents by exocytosis or 2) form lysosomes to stay within the cell
Lysosomes	Some = body. These spherical bodies are larger than ribosomes and are found free in the cytoplasm. They are produced by the Golgi apparatus.	These sacs contain digestive enzymes that • Recycle worn-out organelles • Digest unneeded parts • Perform autolysis (cell rupture) in which cell proteins and organelles are destroyed.

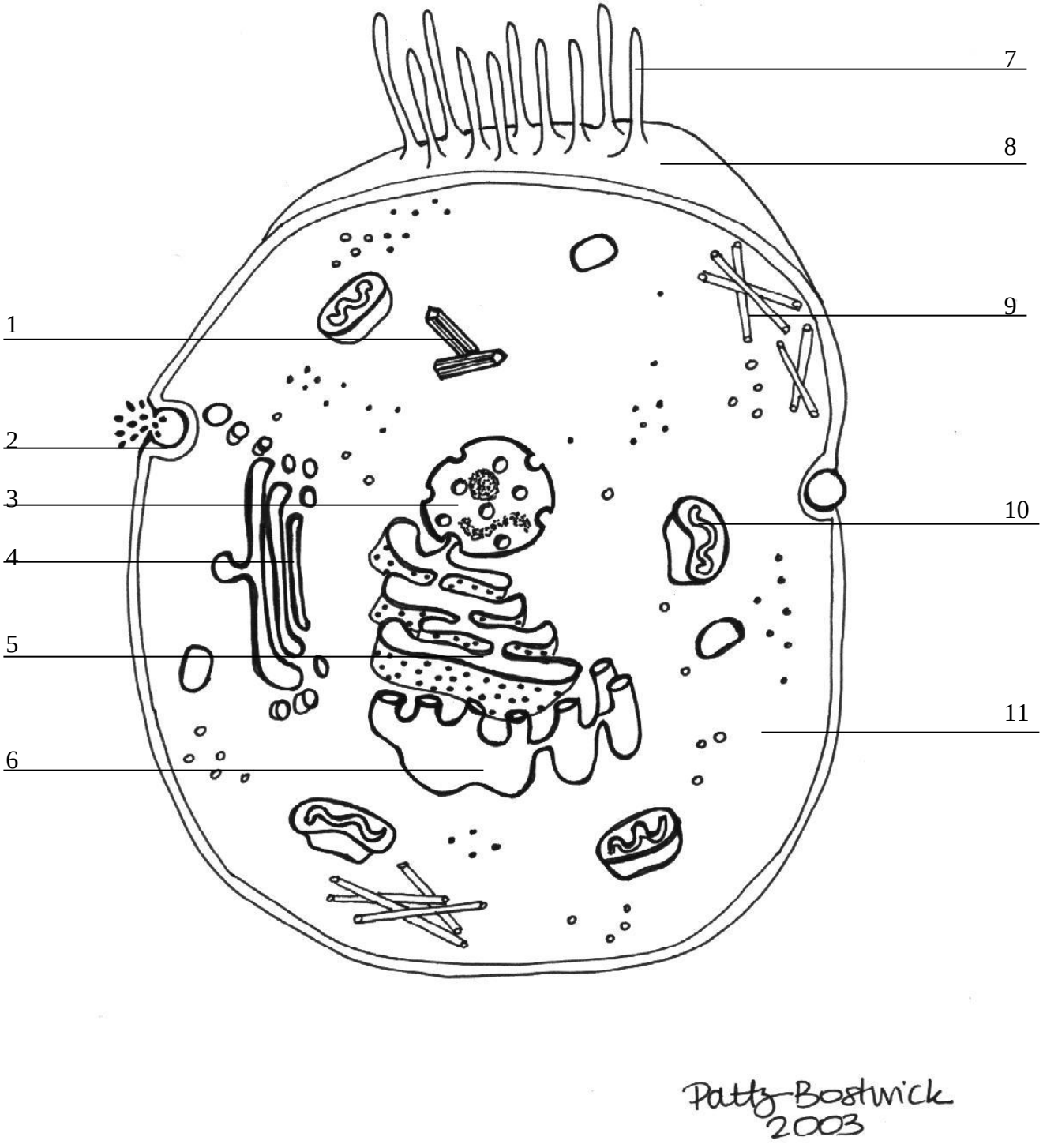
Chapter 3: The Cell, Continued

Organelle/Structure	Structure	Function
Peroxisome	*Some* = body. This is a sac-like organelle found in the cytoplasm.	The peroxisome contains enzymes that detoxify toxins like alcohol, formaldehyde, and free radicals and change them into hydrogen peroxide (which is converted to water).
Mitochondria 	Double-layered membrane with an inner membrane holding enzymes	Cellular respiration occurs here. The reaction is: glucose + oxygen → CO_2 + ATP + water
Centrioles 	Composed of tubes of protein called microtubules in an arrangement of 9 triplets of microtubules with no central microtubules (called a 9+0 array).	• Used in mitosis and meiosis to form the spindle fibers that help pull the chromosomes apart. Cells lacking centrioles can NOT divide. • Form the basal bodies (found just beneath the cell's surface) that give rise to cilia and flagella.
Cytoskeleton 	Network of proteins called microtubules and microfilaments form right under the plasma membrane. • **Microfilaments** are composed of a protein called **actin**. • **Microtubules** are composed of a protein called **tubulin**.	• Cytoskeleton forms a flexible, strong, internal framework for the cell and forms the shape of the cell. • Microtubules that form the cytoskeleton both assist in cell movement and also help to form the spindle apparatus during mitosis to move chromosomes. • Microtubules also anchor organelles and help to form centrioles and cilia.
Cilia 	• Hair-like extensions of the plasma membrane in the respiratory tract, lining of parts of the reproductive tract. • Arrangement is 9 pairs of microtubules surrounding a central pair (called a 9+2 array).	Beat rhythmically in unison to move fluids or secretions such as mucus. • Cleans the respiratory tract of debris • Moves an egg from the fallopian tube to the uterus.
Flagella 	• Long tail-like whip found on sperm. • 9+2 array of microtubules	Allows sperm to swim.

Chapter 3: The Cell, Continued

Label the Organelles & Structures of the Eukaryotic Cell

Use the names of organelles and structures found on the previous pages to label this cell.



Chapter 3: The Cell, Continued

Review of the Organelles & Structures of a Eukaryotic Cell

Identify each of the following organelles or structures by its function or description.

_____1. modifies, packages, secretes substances from the cell.

_____2. recycling center where damaged organelles can be sent.

_____3. site of cellular respiration where glucose and oxygen are converted to ATP

_____4. forms an envelope around the cell; described as "selectively permeable"

_____5. synthesizes lipids **or** proteins upon receipt of directions from nucleus

_____6. genetic control center of the cell where DNA is housed

_____7. contains hydrogen peroxide to detoxify substances such as free radicals.

_____8. can be found on endoplasmic reticulum or free in the cytoplasm; produces proteins

_____9. can be described as rough or smooth.

_____10. short hair-like structures that can create a current by beating in unison.

_____11. long tail-like whip that propels sperm.

_____12. semi-fluid medium that helps hold the organelles in place.

_____13. composed of microtubules; help form the bases of cilia and flagella.

_____14. stores nucleic acids

_____15. "powerhouse" of the cell

_____16. connected to the nucleus by a network of membranes

_____17. composed of 2 layers of lipids embedded with proteins

For Discussion:

18. Describe the role of the nucleus in the cell.
19. Describe the structure and role of the plasma membrane in the cell.
20. Compare and contrast the functions and structures of the 2 types of endoplasmic reticulum.
21. Explain what might result if your ribosomes weren't working in your cells.
22. Explain the working relationship between the nucleus, endoplasmic reticula, and Golgi apparatus.
23. Describe the roles the Golgi apparatus and endoplasmic reticula play in forming and maintaining the plasma membrane.
24. Describe the various functions of the proteins associated with the plasma membrane.
25. Explain how these terms are related: cytosol, cytoplasm, intracellular fluid.
26. Discuss the role and arrangements of microtubules and microfilaments in forming other cellular structures.
27. Differentiate among the sizes of the ribosome, lysosome, and peroxisome.

Answers: 1. Golgi apparatus, 2. lysosomes, 3. mitochondria, 4. plasma membrane, 5. ER, 6. nucleus, 7. peroxisomes, 8. ribosomes, 9. ER, 10. cilia, 11. flagella, 12. cytoplasm, 13. centrioles, 14. nucleus, 15. mitochondria, 16. ER, 17. plasma membrane, 18-27. *If you have trouble answering any of these questions, please see your instructor!*

Chapter 3: The Cell, Continued

Membrane Transport

Membrane Transport is how membranes move substances into/out of the cell.

Basic Terminology:

- **Solutes** are substances (solid, liquid, or gas) dissolved by solvents in a solution (lesser amount).
- **Solvents** are the substances that dissolve solutes (greater amount).
- **Solutions** contain a solvent and the solute.

Example: Salt dissolved in water; salt is the solute while water is the solvent. The result is a salt water solution. Or, carbon dioxide becomes dissolved by the blood plasma. Which part is the solute? _____ The solvent? _____

Types of Membrane Transport

I. PASSIVE METHODS means that the movement of the substance across the membrane is passive, no ATP energy is required. The type of passive transport used by the cell is dictated by the 1) charge of the substance moving through the membrane and 2) size of the substance. *We'll cover the following 3 types over the next few pages:*

A. Diffusion

B. Osmosis

C. Facilitated Diffusion

II. ACTIVE METHODS means that the movement of the substance across the membrane is active, energy or ATP is required. Three types of active transport methods are:

A. Solute Pumping

B. Endocytosis

C. Exocytosis

Use this space to keep track of the differences between passive and active transport:

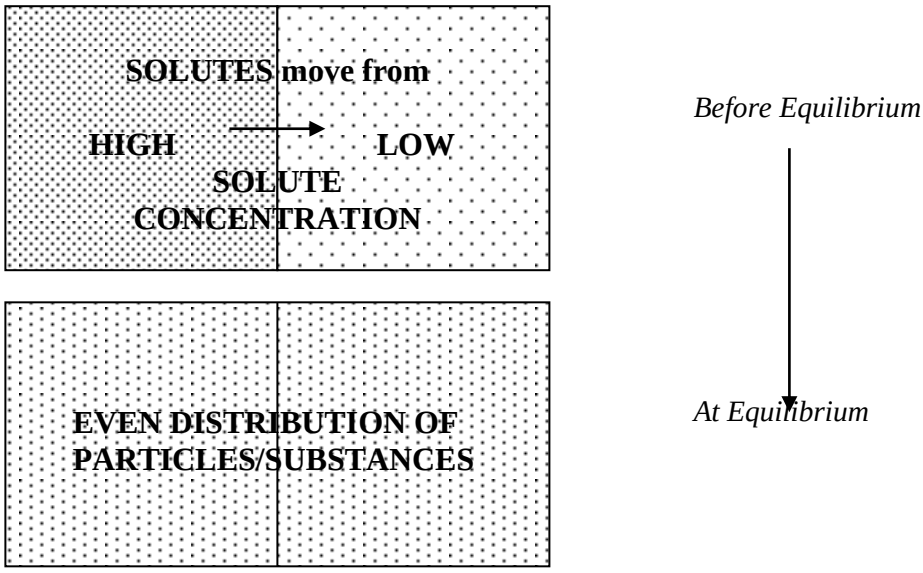
Passive Transport	**Active Transport**
1. _____	_____
2. _____	_____
3. _____	_____
4. Examples:	Examples:
a. _____	a. _____
b. _____	b. _____
c. _____	c. _____

Chapter 3: The Cell, Continued

I. PASSIVE TRANSPORT

A. SIMPLE DIFFUSION is the movement of solutes across the membrane from HIGH to LOW concentration in an attempt to evenly distribute the solutes. Certain substances can easily move through the phospholipid bilayer because of (1) small size or (2) solubility (nonpolar lipids).

1. Diffusion occurs when molecules are unevenly distributed. A concentration gradient exists when there is an unequal distribution of solutes. The solutes will move along or with the concentration gradient from high to low concentration.



2. Diffusion results from the random movement and kinetic energy of atoms and molecules.
3. **<u>No energy (ATP) is required</u>** for diffusion to occur.
4. What are some examples of substances that move by diffusion?
   a. _____
   b. _____
5. Net movement of a substance across a membrane slows when **EQUILIBRIUM** is reached.

Diffusion Rates Are Affected by:

- **Temperature:** cooler temperatures slow diffusion while warmer temperatures _____ diffusion.
- **Viscosity:** the more fluid the environment, the faster diffusion (in other words, diffusion rates increase) occurs while the thicker the fluid, the _____ diffusion occurs. *Imagine blue dye traveling through Vaseline versus blue dye traveling through water.*

What are the main points you've learned so far about diffusion?

- _____
- _____
- _____

Chapter 3: The Cell, Continued

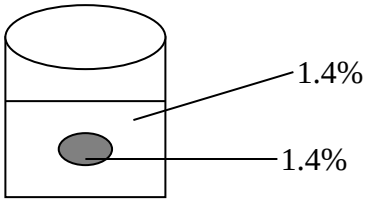
I. PASSIVE TRANSPORT, CONTINUED

B. OSMOSIS is the movement of **<u>water</u>** across a selectively membrane through protein channels called **aquaporins** toward an area of higher *solute* concentration. Plasma membranes are impermeable to some solutes and permeable to others – this is why they are called semipermeable or selectively permeable membranes..
To equalize concentrations, water moves to the area of highest solute concentration since the solute may not be able to move.

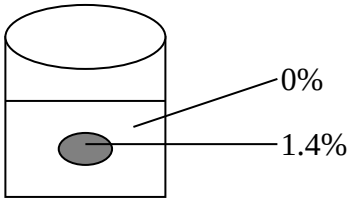
WATER ALWAYS FOLLOWS SALT!

Three Osmotic Scenarios

1. **Isotonic Solutions**: the cell and its surrounding solution or environment have the same concentrations! There is no net movement of water across the membrane; the cell is in equilibrium with its environment.
(*Iso* = _____)



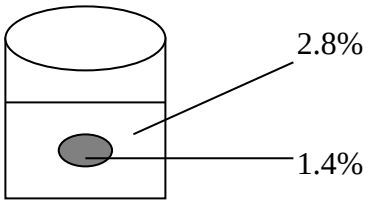
2. **Hypotonic Solutions**: the cell is placed in a solution which has a lower solute concentration than the cell's solute concentration. The cell will allow water to enter to equalize concentrations.
(*Hypo* = _____) BLOAT/LYSIS
Hypotonic solutions can rehydrate or HYDRATE cells. Hypotonic solutions also promote EDEMA (swelling in the interstitial space).



What are two reasons water enters the cell when placed in a hypotonic solution?

1. _____
2. _____

3. **Hypertonic Solutions**: the cell is placed in a solution which has a higher solute concentration than the cell's solute concentration. The cell will allow water to leave to equalize concentrations.
Hypertonic solutions can promote DEHYDRATION of cells.
(*Hyper* = _____) SHRIVEL/CRENATE



What are two reasons water leaves the cell when placed in a hypertonic solution?

1. _____
2. _____

Chapter 3: The Cell, Continued

Understanding Osmotic Solutions

Scenario #1

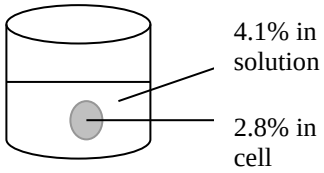
Where is the higher concentration of solutes? ***Outside the cell***

Will water move in or out of this cell? ***Water will move out of the cell***

Will this cell bloat or shrivel? ***Shrivel***

Hypertonic/Hypotonic/Isotonic? ***Hypertonic***

Why is water leaving this cell? ***The water is moving out of the cell in an attempt to equalize solute concentrations on the inside and outside of the cell's membrane. Water is moving to the 4.1% area to dilute it to 2.8% (value inside cell).***



Scenario #2

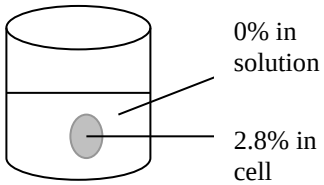
Where is the higher concentration of solutes? ***Inside the cell***

Will water move in or out of this cell? ***Water will move into the cell***

Will this cell bloat or shrivel? ***Bloat and rupture (lysis)***

Hypertonic/Hypotonic/Isotonic? ***Hypotonic***

Why is water entering this cell? ***The water is entering this cell to dilute the solute concentration inside the cell. The water is attempting to bring the 2.8% concentration down to 0%--same as the concentration outside the cell. However, the cell will rupture before it can take in enough water to reach the concentration outside the cell.***



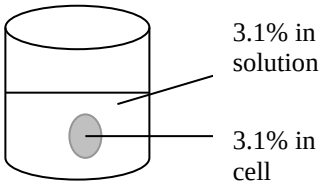
Scenario #3

Where is the higher concentration of solutes? ***Same***

Will water move in or out of this cell? ***No net movement into or out of cell***

Will this cell bloat or shrivel? ***Neither, it's in equilibrium***

Hypertonic/Hypotonic/Isotonic? ***Isotonic***

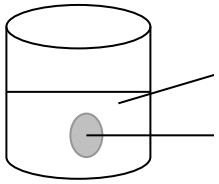


Chapter 3: The Cell, Continued

Review of 3 Types of Osmotic Solutions

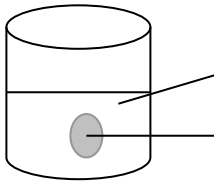
Practice Problem #1

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



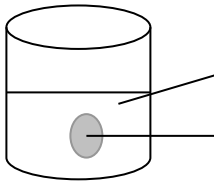
Practice Problem #2

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



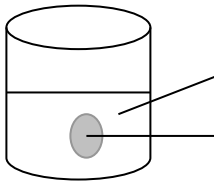
Practice Problem #3

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



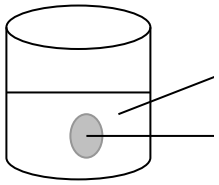
Practice Problem #4

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



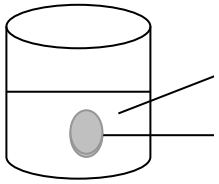
Practice Problem #5

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



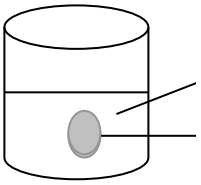
Practice Problem #6

_____Is there an area with a higher concentration of solutes?
_____Will there be a net movement of water?
_____Will this cell bloat, shrivel or remain at equilibrium?
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



Practice Problem #7

_____Where is the higher concentration of solutes?
_____Will water move in or out of this cell?
_____Will this cell bloat or shrivel?
The solution is (*more* / *less*) concentrated than the cell.
The solution is (*Hypertonic* / *Hypotonic* / *Isotonic*) to the cell.



Answers: #4 (cell bloats; hypotonic; solution is *less* concentrated than cell), #5 (cell shrivels; hypertonic; solution is *more* concentrated than cell), #6 (cell remains at equilibrium; isotonic), #7 (cell bloats; hypotonic; solution is *less* concentrated than cell)

Chapter 3: The Cell, Continued

Review of 3 Types of Osmotic Solutions, *Continued*

For Discussion:

1. Explain why a cell with a high solute concentration than its surrounding environment will bloat.
2. Explain why an injection should be isotonic for maintainence of blood homeostasis for a patient.
3. Explain why a cell with a lower solute concentration than its surrounding environment will shrivel.
4. Explain why a patient injected with a hypotonic solution will experience lysis of the red blood cells.
5. Explain why a patient injected with a hypertonic solution will experience a shriveling of the red blood cells.

_____6. A cell with a higher solute concentration than the solution in which it is placed will:
- A. gain water
- B. lose water
- C. gain salt
- D. be in equilibrium with its environment

_____7. A cell with the same solute concentration as its environment will experience:
- A. water loss
- B. lysis
- C. no net movement of water into or out of the cell
- D. water gain

_____8. In order to rehydrate the eyes, eyedrops should be ____ in relation to the saline of the eyes.
- A. hypotonic
- B. hypertonic
- C. isotonic
- D. mesotonic

_____9. A patient is receiving a drip of 5% dextrose. At this rate, the concentration of dextrose is isotonic to the blood stream. If we increase the concentration of dextrose, then dextrose becomes ___ to the bloodstream.
- A. hypotonic
- B. hypertonic
- C. isotonic
- D. none of these

_____10. If you were to drink sea water as opposed to tap water, you would expect your body's cells to:
- A. bloat with water to equalize concentration
- B. lose water to equalize concentration
- C. do nothing as the cells are already in equilibrium with the salt water environment

Answers

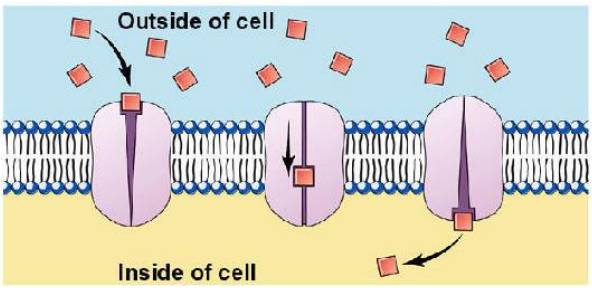
1-5. *Please come see me if you have any difficulty with these questions!*
6. A, 7. C, 8. A, 9. B, 10. B

Chapter 3: The Cell, Continued

I. PASSIVE TRANSPORT, CONTINUED…

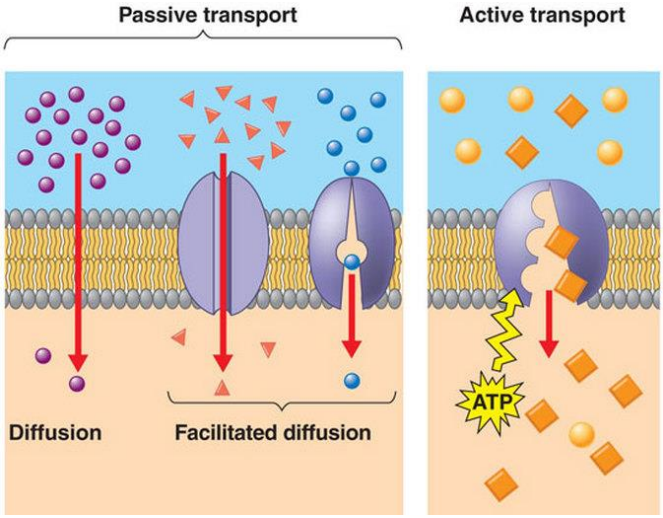
C. FACILITATED DIFFUSION is a type of selective transport in which specific substances are moved into a cell by means of type of integral protein known as a **protein channels**. These substances are typically too large (such as glucose) or are polarized and cannot pass through the membrane as in simple diffusion. These protein channels are gated to open and close for regulation of passage of substances.

- With facilitated diffusion, protein channels assist/facilitate diffusion of substances such as larger molecules.
  - **No energy (ATP) is required!** (Because we're still moving solutes from HI to LO concentration)
  - How does diffusion differ from facilitated diffusion? (1)_____
    (2) _____



II. ACTIVE METHODS

A. SOLUTE PUMPING: requires energy **(ATP)** for movement across a membrane. The cell employs protein pumps to move substances from LO to HI concentration. Equilibrium will not be reached.



B. **Endocytosis**: import of large molecules into a cell. The plasma membrane forms a pit around a molecule. The pit will pinch closed to form a vacuole (phagocytosis) or vesicle (pinocytosis) that carries the molecule into the cytoplasm. Once inside, the membrane is broken down and contents are released into the cell. Some endocytosis is receptor-mediated (meaning a receptor binds to a molecule).

1. **Phagocytosis**: (*cell eating*) in which the cell incorporates large sacs (vacuoles).
2. **Pinocytosis**: (*cell drinking*) in which the cell incorporates smaller sacs (vesicles).

C. **Exocytosis**: export of large molecules from a cell. First the membrane enclosed vesicle fills with macromolecules. Then the vesicle moves to the plasma membrane. Next, the vesicle fuses with membrane and the contents spill out of the cell.

Chapter 3: The Cell, Continued

Review of Membrane Transport

Answer these questions about membrane transport.

_____1. Type of passive transport involving the use of a protein channel

_____2. Type of transport requiring the use of energy

_____3. Passive transport type involving movement through the phospholipid bilayer

_____4. Type of transport requiring the use of a protein pump to move substances against the concentration gradient

_____5. Diffusion of water

_____6. Any type of transport in which the substances move with the concentration gradient

_____7. Movement of large substances with the concentration gradient requires the use of a protein channel

_____8. Type of transport in which substance is moved against its concentration gradient

_____9. Water always follows what substances during diffusion and osmosis?

_____10. A cell is moving some small molecules with their concentration gradient through the phospholipids. What type of membrane transport is the cell using?

_____11. A cell is moving a large sac out by having it fuse with the plasma membrane; then the sac ruptures once outside the cell to release its contents. What type of membrane transport is this?

For Discussion:

12. When would a cell use facilitated diffusion rather than simple diffusion?

13. Describe the roles that proteins play in facilitated diffusion and active transport.

14. Describe how the size and composition of substances influences the type of membrane transport used.

15. Describe when a cell would use endocytosis rather than diffusion.

16. A cell is importing oxygen with its concentration gradient. The cell will move oxygen through the phospholipid bilayer. Name the type of membrane transport and describe what's happening here.

17. Explain why a cell could not perform active transport if there was no ATP present.

18. Explain why a cell could not transport substances by active transport or facilitated diffusion if the ribosomes weren't working properly.

19. A cell is moving a protein against its concentration gradient. The cell will move the protein through the protein pump. Name the type of membrane transport and describe what's happening here.

20. A patient with heart disease has trouble with edema (swelling). What type of osmotic solution would you place into the drip to return the cells to homeostasis? Explain why.

21. Cortisone is a steroid hormone; it travels by passive transport into its target cell. Which type of passive transport do you think will allow cortisone to travel across the plasma membrane? Explain.

22. You're stranded on an island and have two sources of water to drink – contaminated fresh water and the salty ocean water. Which source of fluids do you choose to drink? Explain how each water source will affect your cells.

Answers: 1. facilitated diffusion, 2. active transport, 3. diffusion, 4. active transport, 5. osmosis, 6. passive transport, 7. facilitated diffusion, 8. active transport, 9. salt or the highest solute concentration, 10. diffusion, 11. exocytosis, 12-22. *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 4: Histology

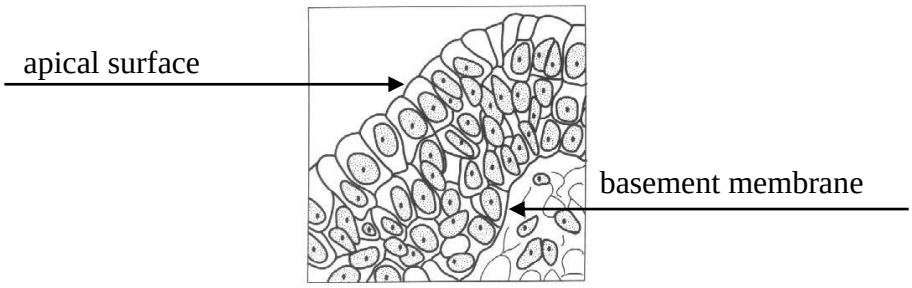
Tissues are a cooperative unit of many very similar cells that perform a special function.

Histology = study of tissues. There are 4 major groups: epithelial, connective, muscle, and nervous.

EPITHELIAL TISSUE

Structure (Morphology): Epithelial tissue occurs in sheets of cells.

- Upper free surface, is called the **apical surface**
- Deeper surface is attached to tissue beneath, called a **basement membrane**



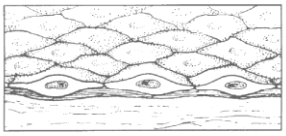
- *Avascular* – because there are **no** blood vessels…blood supply reaches these cells by diffusion.
- *Innervated* – a nerve runs through the tissue (notice how your arm hairs stand on end when cold!)

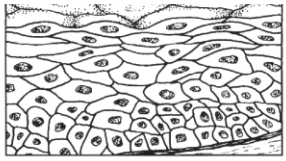
Where would you find this tissue?

- Covering outside of body = skin
- Lining internal cavities that open to the outside = lungs, where urine forms in our kidneys,
- Organs of our digestive tract (esophagus, stomach, intestines)
- Lining both endocrine and exocrine glands

Function: cover and line body surfaces; built for secretion, absorption, filtration, and diffusion

How is epithelial tissue classified?





1. Number of cell layers (1 or more)
   a. **simple** epithelium has 1 layer of cells

   b. **stratified** epithelium has 2 or more layers of cells

2. Shape of most of the cells composing them
   a. _____: (shaped like floor tiles) 
   --nucleus is **flattened**
   b. _____: (shaped like dice) 
   --nucleus is **round**
   c. _____: (shaped like bricks or cones on end) 
   --nucleus is **oblong**

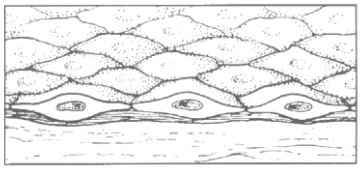
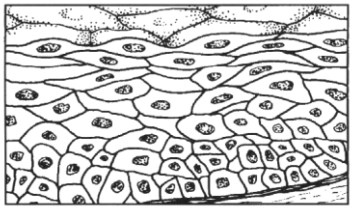
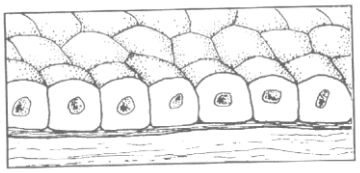
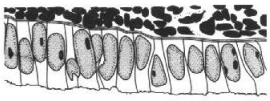
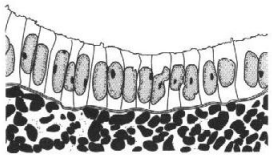
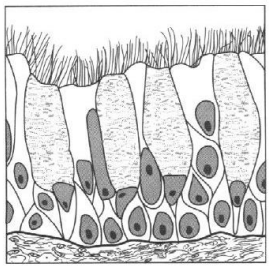
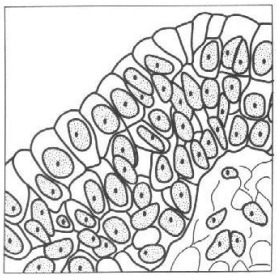
Cell junctions associated with tissues, such as ET:

1. **Tight junctions (occluding junctions)** = form an impermeable barrier to the passage of fluids.

2. **Gap junctions (communicating junctions)** = connection between cytoplasm for ions/molecules to flow. Form the intercalated discs of the heart.

3. **Desmosomes** = structure used to adhere types of squamous ET together (prevents stresses). Desmosomes account for the reason our skin peels off in sheets.

Chapter 4: Histology, Continued

Specific Type of ET	# Cell Layers	Characteristics	Function	Location
Simple Squamous 	_____	**Squamous** cells regenerate rapidly by division of the cells at its attached surface—true for both simple and stratified!	filtration, diffusion, secretion, reduces friction and abrasion	endothelium, lung alveoli, serous membranes, capillaries, kidney glomeruli
Stratified Squamous 	_____	**Keratinized** (waterproofing protein, keratin) stratified squamous = areas such as the skin **Nonkeratinized** stratified squamous = esophagus, nose, mouth, anal canal, & vagina	protection from abrasion, pathogens, or chemical attack	epidermis, lining of the mouth, esophagus, vagina, anal canal
Simple cuboidal 	_____	Found frequently in **glands** (salivary, thyroid, pancreas) where it functions in secretion.	secretion and absorption	ovary surface, lining of kidney tubules, ducts and secretory portions of glands
Simple columnar  	_____	Has numerous **goblet cells** which produce mucus. Has modifications known as **villi** cells which help to increase surface area.	secretion and absorption	lining of digestive tract (from stomach to rectum), gallbladder, collecting ducts of kidneys, uterine tubes
Pseudostratified columnar 	appears stratified but is actually simple since each cell touches the basement membrane	Typically associated with **ciliated** cells	protection, secrete and propel mucus	lining of nasal cavity, trachea, bronchi, portions of the male reproductive tract
Transitional 	stratified	Unusual because it returns to its original shape after repeated stretching	distension, stretching	lining of ureters, urinary bladder, renal pelvis of kidneys

Chapter 4: Histology, Continued

CONNECTIVE TISSUE

Structure: sparse cells scattered through a nonliving substance called a matrix. The cells synthesize the matrix, usually a web of fibers embedded in a liquid, jelly, or solid matrix. *All tissue types have a matrix (known as ECM or extracellular matrix) but it may not be very prevalent or visible.*

Fiber Types: The matrix may have fibers of 3 main types:

1. _____ or _____ fibers are built like a rope for flexibility and strength
2. _____ or _____ fibers contain elastin proteins; wavier and stretchier than collagen fibers
3. _____ fibers are built from collagen, but are thin and branched; form a delicate supporting network

Cell Types: identify by *suffix*

1. --_____: cells that are able to grow; secrete matrix and fibers
   a. fibroblasts: cells that form fibers in loose and dense connective tissues
   b. chondroblasts: cells that form cartilage
   c. osteoblasts: cells that form bone
   d. hemocytoblasts: cells that form blood
2. --_____: cells involved in destruction of connective tissue
   a. osteoclasts
3. --_____: mature cells that can no longer grow or destroy
   a. osteocytes, chondrocytes, leukocytes

Function: connect, protect, and provide structure/support for the body

- connects: ligaments and tendons connect muscle to bone and bone to bone
- protects: bones protect delicate organs such as the brain, spinal cord, and heart/lungs
- structure: cartilage provides flexible support for the ear, nose, and between vertebrae

Types of Connective Tissue

Fibrous CT (CT Proper)

- loose areolar
- loose adipose
- loose reticular
- dense regular
- dense irregular
- dense elastic

Cartilage

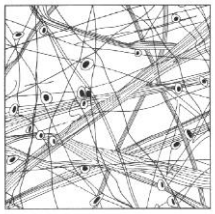
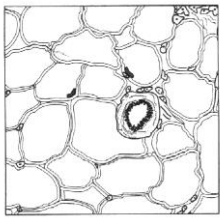
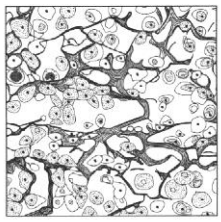
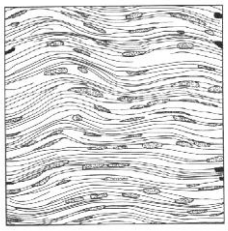
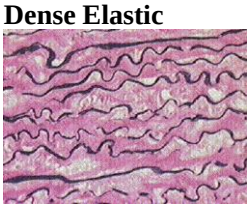
- hyaline cartilage
- elastic cartilage
- fibrocartilage

Compact Bone (Osseous Tissue)

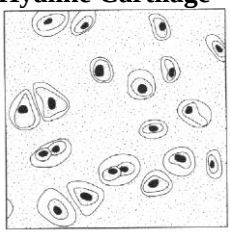
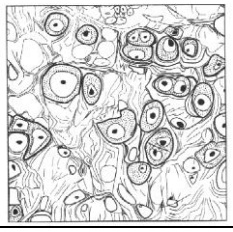
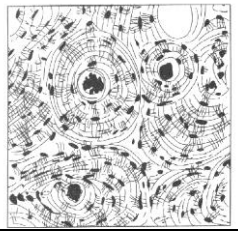
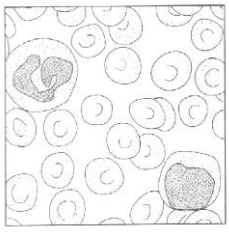
Blood

Chapter 4: Histology, Continued

Fibrous CT (CT Proper)

Specific Type of CT	Cell Type	Fiber Type	Function	Location
Loose Areolar 	fibroblasts	fibers consist of strong, ropelike protein, collagen; contains all 3 types immersed in a fluid matrix	wrap/cushion organs; binding and packing material. Together with loose adipose, this tissue forms superficial **fascia** and separates skin from underlying organs	deep to all epithelial tissue (such as skin), surrounding organs
Loose Adipose 	fibroblasts	collagen and elastic fibers	insulation, protection, energy storage. Adipocytes are amitotic, they swell when fat is stored and shrink when fat is used as fuel. --White fat composes most fat in the body --Brown fat is highly vascularized, found between shoulder blades, neck	hypodermis (subcutaneous layer), within the abdomen, breasts
Loose Reticular 	fibroblasts	only reticular fibers	support via a "soft tissue skeleton"	liver, lymph nodes, bone marrow, spleen, kidneys
Dense Regular 	fibroblasts	matrix of densely packed parallel bundles of collagen fibers	forms **tendons** (holds muscles to bone) and **ligaments** (join bones together) and **aponeuroses** (joins muscle to muscle or muscle to bone)	strong attachment of body parts in *one* direction
Dense Irregular 	fibroblasts	collagen fibers running in many directions	strong attachments of body parts in *different* directions; provides strength and support; this tissue forms deep fascia that connects to the periosteum of bones, ligaments, and tendons.	dermis of skin, fibrous capsules of joints
Dense Elastic 	fibroblasts	elastic fibers	stretch without deformation; cushions shock, stabilizes organs, and allows expansion and contraction of organs	between vertebrae as intervertebral discs, vocal cords, wall of aorta

Chapter 4: Histology, Continued

Specific Types of Cartilage CT	Cell Type	Fiber Type	Function	Location
Cartilage = IN GENERAL	*chondroblasts chondrocytes*	*collagen fibers*	*forms a strong, flexible skeletal material; lacks nerves and is avascular*	*see below*
Hyaline Cartilage 	chondroblasts, chondrocytes	collagen fibers (smooth appearance)	flexible support, reduces friction between bony surfaces	ends of long bones (movable joints), embryonic skeleton, costal cartilage, nose, trachea, larynx
Fibrocartilage 	chondroblasts, chondrocytes	collagen fibers (appears dense)	resists compression, shock absorber, prevents bone-to-bone contact	intervertebral disks, pubic symphysis, and menisci of knee
Elastic Cartilage 	chondroblasts, chondrocytes	collagen and elastic fibers	maintain shape with flexibile support	outer ear and epiglottis
Remaining Specific Types of CT	**Cell Type**	**Fiber Type**	**Function**	**Location**
Compact Bone (Osseous Tissue) 	osteoblasts, osteoclasts , osteocytes	matrix reinforced by calcium salts that is deposited around collagen fibers; this arrangement gives strength & elasticity	protection, support, movement with aid of muscles, hematopoesis (blood cell formation), mineral storage	shaft of long bones, outer surface of bones
Blood 	erythrocytes, leukocytes, platelets	matrix of liquid plasma	transportation of blood gases, nutrients, wastes, hormones, amino acids, proteins, etc.; thermoregulation and immunity	traveling in the blood vessels of the cardiovascular system (heart, arteries, veins, capillaries)

Chapter 4: Histology, Continued

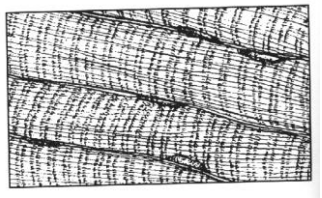
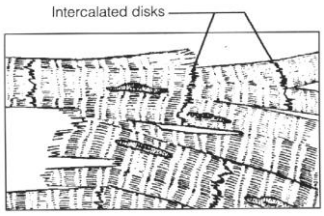
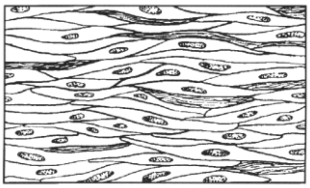
MUSCLE TISSUE

Structure

1. bundles of long, cylindrical cells called muscle fibers
2. most abundant tissue in a typical animal

Function

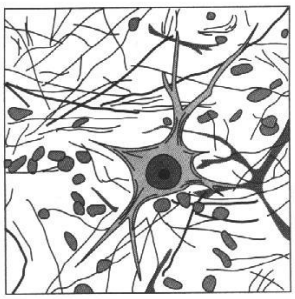
1. movement of…
   a. the skeleton (skeletal muscle)
   b. substances such as blood, urine, food, etc. (smooth muscle)
   c. blood through the heart (cardiac muscle)
2. generate heat through the conversion of glucose and oxygen into ATP

Specific Types of MT	Control is…	Characteristics	Function	Location
Skeletal Muscle 	voluntary	**striations** due to light and dark banding patterns **cylindrical cells** **multinucleate**	voluntarily move bones, & make facial expressions; thermoregulation, involuntary shivering	attached to skeleton and facial tissue
Cardiac Muscle 	involuntary	**striations** **branched cells** separate fibers that are bound end to end with **intercalated disks** **amitotic**	contract the heart to pump blood through vessels; contractions are involuntary	heart
Smooth Muscle 	involuntary	**NO striations** **spindle-shaped cells** **uninucleate**	propel to push substances through the tubes of the body (peristalsis)	walls of hollow organs of digestive tract, urinary tract, and blood vessels

NERVOUS TISSUE

Structure: Neurons are nerve cells which conduct nerve signals (*conductivity*)

1. Axon is the portion of the neuron which conducts messages away from the cell body.
2. Dendrites are the portions of the neuron that conduct messages toward the cell body.
3. The cell body is the site of the nucleus and metabolic center of the nerve cell.



Other support cells in nervous tissue are known as **neuroglia**.

Function: Nervous tissue senses stimuli (*irritability*) and controls effector organs (such as glands, muscles)

Chapter 4: Histology, Continued

For Discussion

1. Explain the two ways in which epithelial are classified.

2. Bone is a hard connective tissue while blood is a fluid connective tissue. Provide two reasons and explanations for why these tissues are found in the same general category.

3. Explain how cardiac and skeletal muscle tissues are similar. How are they different?

4. What general category of tissue contains a non-living matrix? What role does that matrix serve?

5. What three fiber types are associated with connective tissues? Explain their various functions.

6. What types of tissues are avascular? How do they receive nutrients, gases, and remove waste products?

7. Irritability and conductivity are features of nervous tissue. Explain what these two terms mean.

8. Tendon tears or breaks are difficult to repair both physiologically and surgically. Explain why.

9. What types of tissues are classified as fascia? What is the role of fascia in the body?

10. On a microscope slide, how would you differentiate epithelial tissue from muscle tissue?

Fill in the Blank – General Tissue Types

_____1. What kinds of tissues have a matrix?

_____2. What general types of tissues possess a basement membrane and apical surface?

_____3. What type of tissue conducts electrical impulses?

_____4. What type of tissue is found in the heart, walls of organs, and moves the bones?

_____5. What type of tissue can be described as cuboidal, squamous, columnar?

_____6. What type of tissue can be described as skeletal, cardiac, smooth?

_____7. What type of tissue can be described as simple or stratified?

_____8. What type of tissue can be classified as “loose” or “dense?”

_____9. What type of tissue contains neurons and neuroglia?

_____10. What type of tissue has a subcategory known as “proper?”

_____11. What type of tissue lines body surfaces (both inside and outside)?

_____12. What type of tissue lines inside of digestive tract, forms the epidermis of the skin, etc.?

_____13. What type of tissue that connects epithelial tissue to underlying layers

Fill in the Blank – Specific Tissue Types

_____14. Which type of connective tissue binds skin to underlying muscle?

_____15. Which type of connective tissue stores fat?

_____16. Which type of muscle tissue moves the bones and makes facial expressions?

_____17. Which type of epithelial tissue possess goblet cells?

_____18. Which type of connective tissue creates tendons and ligaments?

_____19. Which type of muscle tissue is found only in the heart?

_____20. Which type of connective tissue forms the skeleton?

_____21. Which type of epithelial tissue that forms the epidermis of the skin?

_____22. Which type of connective tissue has a rubbery or jelly-like matrix?

Answers: 1-10, *please see me with questions;* 1. CT, 2. ET, 3. NT, 4. MT, 5. ET, 6. MT, 7. ET, 8. CT, 9. NT, 10. CT, 11. ET, 12. ET, 13. CT, 14. loose areolar; dense irregular, 15. loose adipose, 16. skeletal, 17. simple columnar, 18. dense regular, 19. cardiac, 20. compact bone, 21. stratified squamous, 22. cartilage

Chapter 4: Histology, Continued

Tissue Injury

Injury to tissues leads to **inflammation** (**inflammatory response**) then is followed by **regeneration**.

Tissues that heal quickly	**Tissues that heal slowly or poorly**
_____	_____
_____	_____
_____	_____
_____	_____

1. **Inflammation**
   - **mast cells** release **histamine** and **prostaglandins** which causes changes in circulation (vasodilation).
     - increased blood flow due to dilated vessels delivers nutrients and oxygen while removing wastes and toxins.
     - increased activity of more phagocytes to remove dead tissue
   - increased vessel permeability in response to chemicals released by mast cells
   - **necrosis** is tissue destruction of damaged or dead cells and is caused by lysosomal enzymes
     - **pus** is an accumulation of dead or dying cells, and other necrotic components
     - **abscess** is an accumulation of pus in a closed tissue space
   - phagocytes and microphages protect from infection and clean-up the area

   Four Cardinal Signs of Inflammation:
   - swelling
   - redness
   - warmth due to increased local temperature (more blood flow)
   - pain

2. **Regeneration** is the process of restoring normal tissue conditions.

How does tissue regenerate?

- **fibroblasts** form a network of collagen fibers to stabilize the site which forms a framework known as **scar tissue** or **fibrous tissue**
- **scar tissue** is mostly collagen fibers. This tissue is remodeled when cells migrate to the site to complete the regeneration of the tissue

In Chapter 5, we'll break the *regeneration* phase into three steps:

1) migration
2) proliferation
3) maturation

Chapter 4: Histology, Continued

Classification of Body Membranes

Body membranes cover surfaces, line body cavities, and form protective sheets around organs.

There are two major groups of membranes:

1. epithelial membranes (cutaneous, mucous, serous)
2. connective membranes (synovial)

EPITHELIAL MEMBRANES

What 2 types of tissues are found in an epithelial membrane?

1. ET
2. CT

Three Types of Epithelial Membranes

Cutaneous Membrane

- **Cell/Tissue Types:** stratified squamous epithelium tissue overlying a layer of loose areolar CT reinforced by dense irregular CT
- **Location:** skin
- Cutaneous membranes are unusual as they are the only dry membranes. *What makes them dry?*

  _____

Mucous Membrane

- **Cell/Tissue Types:** moist stratified squamous epithelium (mouth, esophagus), simple columnar epithelium (digestive tract) superficially resting on a loose areolar connective tissue (called the *lamina propria*)
- **Locations:** Lining all body cavities that open to the exterior, such as the hollow organs of the respiratory (lungs), digestive (stomach, esophagus), urinary (bladder), and reproductive tracts (uterus, urethra).
- What is the purpose of mucus? _____

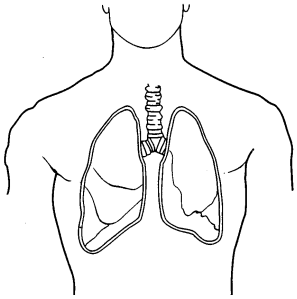
Serous Membrane

- **Cell/Tissue Types:** simple squamous epithelium
- Composed of 2 layers that cover/surround the outside of an organ:
  - Outermost layer: **parietal** layer folds in to form the innermost layer
  - Innermost layer: **visceral** layer covers the organ in that cavity.
  - Layers are separated by fluid, called **serous fluid.** It is secreted by both membranes. What is the purpose of serous fluid? _____
  - These serous membranes cover the outer surfaces of organs in the ventral body cavities (both thoracic and abdominopelvic).

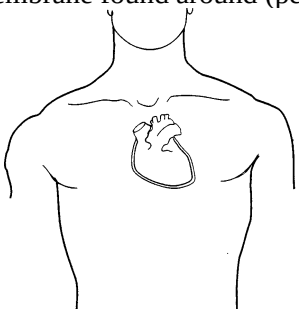
Chapter 4: Histology, Continued

Epithelial Membranes, *Continued*

- **3 Major Locations of Serous Membranes in the Body:**
  - **Peritoneum** is the serous membrane found around the _____
    - **mesentery** is a term that describes how the peritoneum membrane comes together to cover the visceral organs.
  - **Pleura** is the serous membrane found around the _____



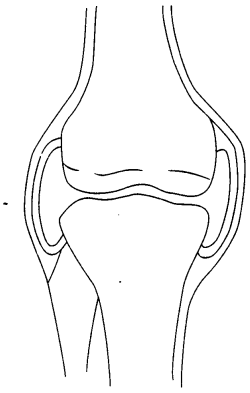
  - **Pericardium** is the serous membrane found around (peri-) the _____(card-).



CONNECTIVE MEMBRANES

Synovial Membranes

1. What types of tissue are found in a connective membrane?_____
2. Where are synovial membranes found? _____
3. Synovial membranes line the inside of joint cavities; synovial fluid fills the cavity. What's the purpose of synovial fluid? _____



Chapter 4: Histology, Continued

Review of Membranes

Label each of these descriptions as epithelial membrane (and/or its specific type) or synovial membrane.

_____1. cutaneous

_____2. lines joints

_____3. the only dry membrane

_____4. secretes mucous

_____5. found as skin

_____6. lines the mouth, digestive tract, reproductive, urinary system tracts

_____7. composed of an layer of epithelial tissue and a layer of connective tissue

_____8. forms the pleura around the lungs

_____9. contains serous fluid between two layers of membrane

_____10. epithelial tissue rests on a connective tissue membrane called lamina propria

_____11. contains synovial fluid inside the joints

_____12. forms the peritoneum around the abdominal organs

_____13. has a parietal and a visceral layer with fluid between the 2 layers

_____14. general membrane type composed of connective tissue only

For Discussion - Membranes

15. How are epithelial membranes and tissues different? How are they similar?

16. What are the three types of serous membranes? Where are they found?

17. Aunt Jessie woke up one morning with excruciating pain in her chest. She had trouble breathing for several weeks. Following a visit to the doctor, she was told she had pleurisy. Explain pleurisy and what it affects.

18. How are serous and synovial membranes somewhat similar in their functions?

19. What makes cutaneous membrane unique? Where are cutaneous membranes found?

20. Why are mucous membranes moist? What types of cells secrete mucous?

21. What types of epithelial tissues compose mucous membranes? And, what types of connective tissues compose mucous membranes?

Answers: 1. a type of epithelial membrane, 2. connective membrane, the specific type here is synovial membrane, 3. cutaneous membrane, a type of epithelial membrane, 4. mucous membrane, a type of epithelial membrane, 5. cutaneous membrane, a type of epithelial membrane, 6. mucous membrane, a type of epithelial membrane, 7. epithelial membrane, 8. serous membrane, a type of epithelial membrane, 9. serous membrane, a type of epithelial membrane, 10. epithelial membrane, 11. synovial membrane, a type of connective membrane, 12. serous membrane, a type of epithelial membrane, 13. serous membrane, a type of epithelial membrane, 14. connective membrane, 15-20. *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 5: The Integumentary System

Some fast facts about skin:

- Skin forms the integumentary system and is also classified as a cutaneous membrane
- Skin is the largest organ of the body
- Skin is made of 2 layers: the epidermis and the dermis
- *Why do we need our skin?*

Structure of Skin

A. Epidermis: the outer and thinner layer of the skin.

1. **Types of Cells**: (These cells **protect** the skin and underlying layers)

- _____: make **keratin** and provides a waterproofing for the skin
- _____: make a pigment called **melanin** for skin/hair color; protection from UV light. Patches of melanin form freckles. Asians have a yellowish tint to their skin due to a pigment called *carotene*; Caucasians have a pink tint from the hemoglobin of the blood.
- _____: a type of macrophage (a WBC, "large eater") for protection against microbes; found in the lower epidermis.

2. **Layers of cells** from most *superficial* to the *deepest*:

- Stratum _____ is the most superficial layer. It's composed of 15-30 layers of dead keratin-filled cells that can flake off as dandruff or form a callus or corn. This layer serves as a protection again microbes, assisted by *sebaceous glands* (oil glands). Cells remain at this layer for about 2 weeks before being shed or washed away.
- * Stratum _____ is only found in thick skin such as palms/soles. * *Not in all skin.*
- Stratum _____ is a thin layer of about 3-5 layers of keratinocytes. Cells have usually stopped dividing by the time they reach this layer and started making large amounts of keratin.
- Stratum _____ forms keratin and consists of 8-10 layers of keratinocytes and Langerhans cells. The cells in this layer are held together by *desmosomes*, interconnections between cells that held them to withstand mechanical stress.
- Stratum _____ is the deepest layer. This layer contains stem cells to replace keratinocytes at the epithelial surface. Skin surfaces that lack hair also contain specialized epithelial cells known as *Merkel cell*s. It takes 15-30 days for cells to move from this layer to the stratum corneum.
- *Remember, **C**orny **L**ucy's **G**randma **S**pent **B**illions or **B**etter **S**tudents **G**ive **L**ove and **C**are*

3. **Pigmentation**

- **Carotene**: is orange-yellow pigment found in vegetables such as carrots, squash, pumpkin. Accumulates in stratum corneum of the skin and in fatty tissues. Naturally produced in some populations (Asian heredity).
- **Melanin**: is brown-black pigment produced by melanocytes in stratum basale. Produce vesicles of melanin in melanosomes (larger vesicles in darker skin). Melanocytes respond to UV by ↑ production of melanin.

Chapter 5: The Integumentary System, Continued

Structure of Skin, continued

3. **Pigmentation, continued**

- **Hemoglobin** is a red blood cell pigment that is bright red when bound to oxygen and gives the skin a reddish tone when the skin is hot and flushed (called **erythema**).
- **Cyanosis** occurs when oxygen is released from hemoglobin and the color is dark red. The skin (such as lips, underneath fingernails) appears blue from the surface; indicates cold or cardiovascular/respiratory disorders. *Why do you think bruises sometimes appear blue?* _____
- **Jaundice** is yellow skin coloring caused by liver problems.
- **Bronzing** is a problem associated with adrenal gland disorders (such as Addison's disease).
- **Vitiligo** occurs when people lose their melanocytes; skin pigmentation disappears.
- **Freckles** are small pigmented areas with irregular borders.
- **Liver spots** (senile lentigos) develop with age on sun-exposed skin; they have regular borders.
- **Albinism** is a genetic condition that results in melanocytes that are incapable of producing melanin.

B. Dermis: the deeper and thicker layer of the skin.

There are 2 layers:

1. **Papillary layer:**

- **Superficial** of the two layers; deep to the stratum basale of the epidermis
- Composed of loose areolar connective tissue
- **Dermal papillae**: found in the upper portions of the **dermis**; these papillae project into and anchor the epidermis. In the overlying epidermis, they form **epidermal ridges** (fingerprints) to increase friction and provide a better gripping surface. Think "egg crate" appearance for these papillae.
- **Sensory nerve fibers** are found here
- **Blood vessels** are plentiful here as well.

2. **Reticular layer:**

- **Deeper** of the two layers
- Composed of dense irregular connective tissue
- **Collagen** and **elastic fibers** provide strength. Collagen fibers are strong and resist stretching and are easily bent or twisted while elastic fibers permit stretching and recoil to original length.

Incidents Associated with the Dermis:

- **Striae** (stretch marks) are due to tearing and overstretching in the dermis (during weight gain or pregnancy). Healing results in a scar (collagen fibers).
- **Blisters** are due to the separation of the epidermis from the dermis. Fluid fills the area. Can also form as a result of 2nd degree burns.
- **Lines of cleavage** follow the bundles of fibers in the skin. Cuts parallel to a line of cleavage heal with little scarring while cuts perpendicular to the line of cleavage result in greater scarring/longer heal time.

Chapter 5: The Integumentary System, Continued

Subcutaneous Layer = Hypodermis: found beneath the dermis but not technically part of the skin.

- **Composed** of loose areolar connective tissue and loose adipose connective tissue
- **Anchors** skin to underlying muscles
- **Measurement** of total body fat
- **Hypodermic injections** are placed into the body into this region

---

Review of Layers of Skin

Identify the descriptions to the correct layer of skin.

_____1. Skin layer responsible for fingerprints.
_____2. Scale-like cells full of keratin that constantly flake off (dandruff)
_____3. Vascular region
_____4. Site of elastic and collagen fibers
_____5. Major skin area from which the derivatives (hair, nails) arise
_____6. Epidermal region involved in rapid cell division; most inferior layer
_____7. The oldest epidermal cells are found in the ___.
_____8. The newest epidermal cells are found in the ___.
_____9. Portion of epidermis where melanin is made.
_____10. Waterproofing protein called keratin is found in the ___ as a whole.
_____11. The ___ contains Langerhans' cells, melanocytes, and keratinocytes.
_____12. This layer of the epidermis serves as a mechanical barrier against microbe invasion.
_____13. This layer of the epidermis is found just superior to the dermis.
_____14. Avascular layer
_____15. The hypodermis layer is inferior to the ___ layer.
_____16. ___ is a layer of the epidermis found only in thickened areas such as the palms.
_____17. This layer of the epidermis is superior to the spinosum but inferior to the lucidum.

A. Stratum corneum
B. Stratum basale
C. Stratum granulosum
D. Stratum lucidum
E. Epidermis as a whole
F. Dermis as a whole

For Discussion

18. Explain how the stratum corneum protects against disease.
19. Explain why the stratum basale is so important.
20. If you stepped on a splinter and it entered the foot, list all of the epidermal layers the splinter pierced.
21. What types of cells are present in the epidermis that provide protection for underlying tissues?
22. Explain why there are skin color differences among people.
23. Describe the various cell types associated with the epidermis and their role in protecting the skin.
24. Explain the function of the epidermal ridges.
25. Explain why there are more keratinocytes in the deeper strata of the epidermis and less of them toward the surface.
26. Describe the causes of erythema and cyanosis. What color would the skin appear with each of these disorders?

Answers: 1F, 2A, 3F, 4F, 5E, 6B, 7A, 8B, 9B, 103, 11E, 12A, 13B, 14E, 15F, 16D, 17C, 18-26. *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 5: The Integumentary System, Continued

Accessory Structures of the Skin

A. Hair

1. **Location**: on all body parts except for _____
2. **Structure**

- Projects from hair **follicle** (stratum basale) located in the dermis of the skin. The follicle provides growth of new cells for the hair root. If the follicle is damaged, what happens to hair growth? _____
  - The portion of the hair within the follicle is called the hair **root**. How is hair growth affected if the root is damaged and the hair falls out?_____
  - The portion that extends beyond the skin is called the hair **shaft**.
- Made of _____, a protein; pigment is due to _____
  - **Arrector pili muscle** is attached to the follicle so that hair stands on end when scared or cold.

3. **Types of hairs**

- **Vellus hairs** are fine "peach fuzz" hairs found on much of the body's surface.
- **Terminal hairs** are heavy, more pigmented, and sometimes curly. Head hairs, eyebrows, eyelashes, pubic hairs, armpit hairs…

B. Nails

1. **Location**: distal ends of phalanges (fingers and toes)

2. **Structure**: composed of keratin; _____ is a fold of skin that hides the nail root. Like the hair, the nail follicle provides growth to the nail bed (root).

C. Exocrine Glands: release substance onto epithelium of skin through a duct lined with simple cuboidal ET.

1. **Sweat Gland** = **Sudoriferous Gland** produce sweat and are present in all regions of skin.

- _____ Sudoriferous Glands open into hair follicles in the anal region, groin, and armpits. Develop at puberty; activate under stress. The function of sweat produced by these glands is unknown.
- _____ (Merocrine) Sudoriferous Glands open onto the surface of the skin. These glands are more numerous than apocrine glands. These glands cool body temperature and become active when body temperature is too hot. Sweat contains water and electrolytes, waste products such as urea.
- **Ceruminous Glands**: modified sweat glands that produce earwax.
- **Mammary Glands**: modified sweat glands that produce milk for women after childbirth.

2. **Oil Gland = Sebaceous Glands** produce oil (sebum) and are associated with a _____ .
Function is to:_____

- **Blackhead** and **whiteheads** result from sebaceous glands that fail to discharge oil.
  - **Whiteheads** are pores clogged with sebum (oil) and covered with the epidermis.
  - **Blackheads** occur when sebum is at the surface with melanin at the top layer covering the pore.
- **Acne vulgaris** is an inflammation of the sebaceous glands.

Chapter 5: The Integumentary System, Continued

Review of Skin's Accessory Organs

Identify each of these descriptions to the correct accessory organ of skin.

_____1. A blackhead is an accumulation of oily material produced by the ___.

_____2. Tiny muscles attached to hair follicles that pull the hair upright during fright or cold are called ___ muscles.

_____3. ____ is found everywhere on the body except the palms of the hands, soles of feet, and lips.

_____4. ____ become more active at puberty.

_____5. Sebum is an oily mixture of lipids, cholesterol, and cell fragments produced by the _____ glands.

A. Arrector pili
B. Hair
C. Hair Follicle
D. Sebaceous glands
E. Sweat gland (apocrine)
F. Sweat gland (eccrine)

For Discussion

6. Describe the types of glands associated with hairs. What purpose does each type of gland serve?

7. John, a 13 year old, has acne vulgaris. Tell him the gland at the root of his problem and explain to him what causes whiteheads and blackheads.

8. Compare and contrast the two major types of glands in the skin based on structure and secretion.

9. Structurally, how are nails and hair similar?

10. What happens to vellus hairs in the pubic and axillary regions after puberty?

11. Explain why hairs need oil glands.

12. Explain the difference between eccrine and apocrine sweat glands. Which type is responsible for regulating body temperature?

13. What is the difference between the hair root and the hair shaft? What is the difference between the hair follicle and the hair root?

14. Why do hairs that have been plucked from the root still grow back?

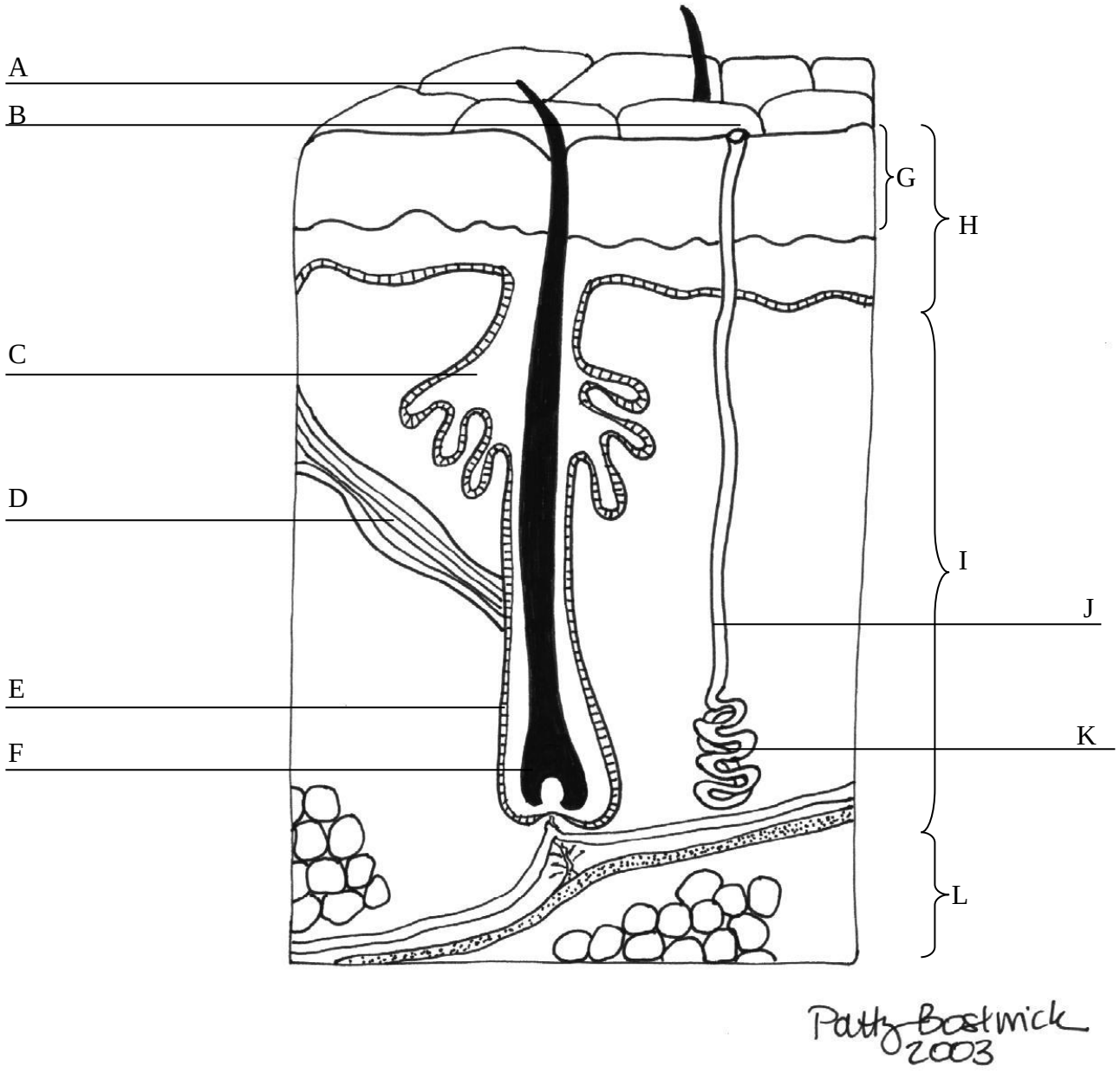
Answers: 1D, 2A, 3B, 4D, E, 5D, 6-14 *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 5: The Integumentary System, Continued

Identifying Parts of Skin

Identify and label the following parts:

- epidermis (H)
- dermis (I)
- hypodermis (L)
- hair shaft (A)
- hair root (F)
- hair follicle (E)
- eccrine sweat gland (K)
- pore (B) and duct (J) of sweat gland
- oil gland (C)
- arrector pili muscle (D)
- stratum basal (E)
- stratum corneum (G)



Chapter 5: The Integumentary System, Continued

Functions of the Skin

A. Skin forms the first line of defense and a protective barrier against microbes:

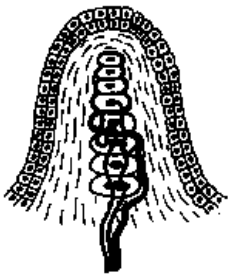
- Secretions from oil glands are acidic and sweat glands are salty
- Waterproofing due to the protein keratin
- Thick stratum corneum prevents bacteria from traveling to dermis where blood vessels are found
- Langerhans cells in the epidermis

B. Synthesis of Vitamin D

- Vitamin D is made by cells in the skin upon sun exposure and transported to the liver and kidneys where it is converted to a hormone called **calcitriol** that regulates calcium and phosphorus metabolism in the body.

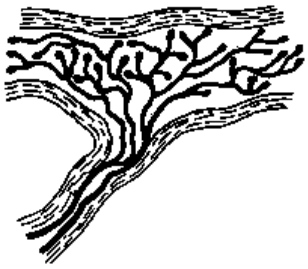
C. Sensory Reception and Communication

- Sensory receptors detect touch, pressure, pain, hot and cold. We'll talk more about these tactile mechanoreceptors later on in the nervous system.
  - **Tactile discs (Merkel discs, Meissner corpuscles)** = fine touch, pressure, and vibration receptors
  - **Lamellated corpuscles (Pacinian corpuscles)** = deep pressure receptors
  - **Ruffini corpuscles** = pressure and distortion of the skin reception



Tactile (Meissner) corpuscle

Lamellated (Pacinian) corpuscle



Ruffini corpuscle http://faculty.washington.edu/chudler/

D. Regulation of Body Temperature (normal body temperature is 98.6 °F or 37 ° C)

- **How does the body respond to a drop in body temperature? When too cold:**
  - Sweat glands remain inactive – no need to produce sweat
  - Muscles start to _____ to produce heat
  - Vasoconstriction _____ flow of blood to the area to prevent heat loss. Why does cold skin appear blue? _____
  - Arrector pili muscles stand hairs on end…why?_____
- **How does the body respond to an increase in body temperature? When too hot:**
  - Eccrine _____ glands activate; cooling results when sweat evaporates from skin
  - Vasodialation _____ flow of blood to the area for cooling. Why does hot skin appear red? _____
- **What happens during heat stroke?** _____

_____

Chapter 5: The Integumentary System, Continued

Wound Healing Specific to Skin

- Injury to epidermal and dermal tissues
- Damaged tissue releases histamine (inflammatory response)

Describe briefly the four steps of the process of wound healing:

1. **Inflammatory Phase**: Blood clot forms first (will eventually forms a scab).
2. **Migratory Phase**: White blood cells and fibroblasts migrate to the wound site; scab has formed.
3. **Proliferation Phase**: New epidermis grows into the wound by one week after the injury. Fibroblast activities grow new fibers, such as collagen, into the wound.
4. **Maturation Phase**: Scarring takes place if the wound is deep. Scar tissue is composed of many collagen fibers; does not contain the accessory organs of the skin (no glands, no sensory receptors, no feeling). Scab falls off.

Burns

Burns can be caused by heat, chemicals, water, electricity, or radiation (such as sunlight or otherwise).
Burns result in:

- **fluid loss** which leads to electrolyte imbalance. Treatment is IV fluids.
- **loss of protective covering** which is the first line of defense in preventing infections. Treatment is sterile padding.
- **protein denaturation** and **cell death**. Treatment is IV drip with a high protein diet.

Assessment of Burn Severity

- 1st degree: epidermis only is burned
  - erythema and brief pain
  - minor sunburn can cause 1st degree burns
- 2nd degree: epidermis and superficial dermis
  - blisters, erythema, pain
  - heals with minimal scarring
- 3rd degree: epidermis and dermis
  - blackened or reddened with no pain (why?)
  - skin grafts and IV fluid are needed
- 4th degree: burns penetrate muscles and other organs

Rule of Nines (9%)

- The body is divided into 11 areas; each area is approximately 9% of the skin's surface area. Used to calculate amount of fluids needed for healing.
  - Anterior arms – 4.5%, posterior arms – 4.5% (each arm is a total of 9% each)
  - Anterior legs – 9%, posterior legs – 9% (each leg is a total of 18% each)

Chapter 5: The Integumentary System, Continued

Cancer

Cancer occurs when cells undergo uncontrolled growth and are not regulated by signals involved with controlling the cell cycle.

- Normal cells undergo cell cycle 50 times then die through programmed cell death
- Cancer cells undergo cell cycle repeatedly and do not die. It's not that they undergo the cell cycle more rapidly, it's that they do not die after 50 mitotic events.
- All cancers involve mutations in DNA.

Types of Tumors

- **Benign**: limited to a particular tissue.
- **Malignant**: cancer has metastasized. Metastasis = cancer cells spread to other tissues through blood or lymph and establish new tumors throughout body.

Types of General Cancers

- **Carcinomas**: occur in epithelial tissues; includes melanomas (most dangerous form of skin cancer). Carcinomas include skin cancer, breast cancer, colon cancer, etc.
- **Adenocarcinomas**: cancers of glandular epithelial tissues (such as salivary gland cancer)
- **Sarcomas**: cancers of muscles, connective tissues (such as bone cancer)
- **Lymphomas**: cancers of lymphoid tissues (such as tonsil cancer)
- **Leukemias**: cancers of the blood (such as white blood cells)

Skin cancer is usually due to UV radiation in sunlight or tanning beds; can be a genetic component as well.

Types of Skin Cancers

- **Basal cell carcinomas**: least dangerous but most common; starts in stratum basale. It's rarely malignant, but it does metastasize to surrounding tissues.
- **Squamous cell carcinomas**: is the second most common type of skin cancer; usually forms due to sun exposure. Occurs in the keratinocytes of the stratum spinosum. Lung cancer, penis and cervix cancer, and esophagus cancer usually are this type.
- **Melanoma**: is a malignant tumor of melanocytes. It is less common than other skin cancers but responsible for most of the skin cancer deaths, thus it is the most dangerous form of skin cancer. Look for abnormal "ugly duckling" freckles and moles. To detect melanomas, remember the **ABCDE** rule:
  - **A**symmetrical skin lesion (meaning, the left and right sides do not look the same)
  - **B**order of the lesion is irregular (meaning, the border is not smooth).
  - **C**olor: melanomas usually have multiple colors such as blue, black, brown, or yellow.
  - **D**iameter: moles greater than 6 mm are more likely to be melanomas than smaller moles.
  - **E**nlarging: a mole that changes or grows larger

Chapter 6: Bones and Bone Tissue

Functions of The Skeletal System

1. _____
   - Bones form the internal framework that supports and anchors all soft organs.
2. _____
   - Bones protect soft body organs such as the skull protects the brain.
3. _____ (leverage)
   - Skeletal muscles attached to bone allows for movement. Tendons are attached to bones which use the bones as levers.
4. _____
   - Fat is stored in internal cavities called marrow cavities.
     - *Yellow marrow*, found in bones, stores energy reserves.
     - *Red marrow*, fills the internal cavities of many bones, makes blood cells through hematopoesis.
   - Minerals such as calcium and phosphorus are also stored
     - Calcium is used in muscle contraction and nervous system to transmit messages.
     - Calcium is stored as calcium salts in the bones
     - When the body is low on calcium, it can get more calcium ions from the bones.
5. _____
   - **Hematopoeisis** is the process of blood cell formation (red, white, platelets). Occurs in bone marrow cavities of certain bones (such as skull, ribs, sternum, ends of long bones, vertebrae)

Sizes and Shapes of Bones

All bones have a smooth outer surface of compact bone and a spongy internal framework of spongy (cancellous) bone.

1. _____: longer than wider. Mostly compact bone on the shaft while spongy is found concentrated at the ends.
   - **Examples**: All of the bones of the limbs except carpals and tarsals. Femur, ulna, radius, humerus, fibula, tibia
2. _____: cube-shaped and contain mostly spongy bone.
   - **Examples**: carpals and tarsals bones
3. _____: thin, flattened, and usually curved. Two thin layers of compact bone sandwiching a layer of spongy bone between them.
   - **Examples**: parietal skull bones and other skull bones, ribs, sternum
4. _____: do not fit into one of the other categories.
   - **Examples**: vertebrae, bones of the pelvis, some skull bones
5. _____: (Wormian bones) are found between flat bones in the skull.
6. _____: small, flat and develop inside tendons. Commonly located near joints of the knees, hands, and feet.
   - **Example**: patella

Chapter 6: Bones and Bone Tissue

Review of Bone Classifications and Types

Identify each of these bones as long, short, flat, or irregular.

_____1. carpals, tarsals

_____2. two layers of flat bone are found covering spongy bone

_____3. ribs, skull

_____4. femur, tibia, humerus

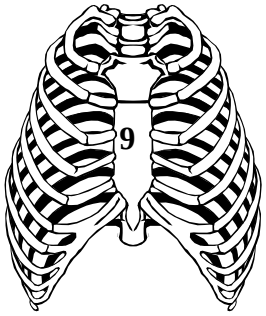
_____5. vertebrae, os coxa

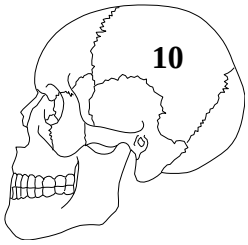
_____6. cube-shaped bones

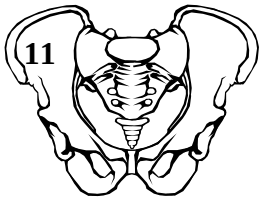
_____7. bones that are longer than they are wide

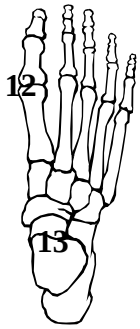
_____8. bones that fit into none of the other categories

Identify 9-13 on the bones, below, as long, short, irregular, or flat.









Identify each description as compact or spongy bone.

_____14. Short bones contain mostly this type of bone.

_____15. Flat bones contain a layer of spongy bone inside two ___ layers.

_____16. Irregular bones contain mostly ___ bone.

For Discussion

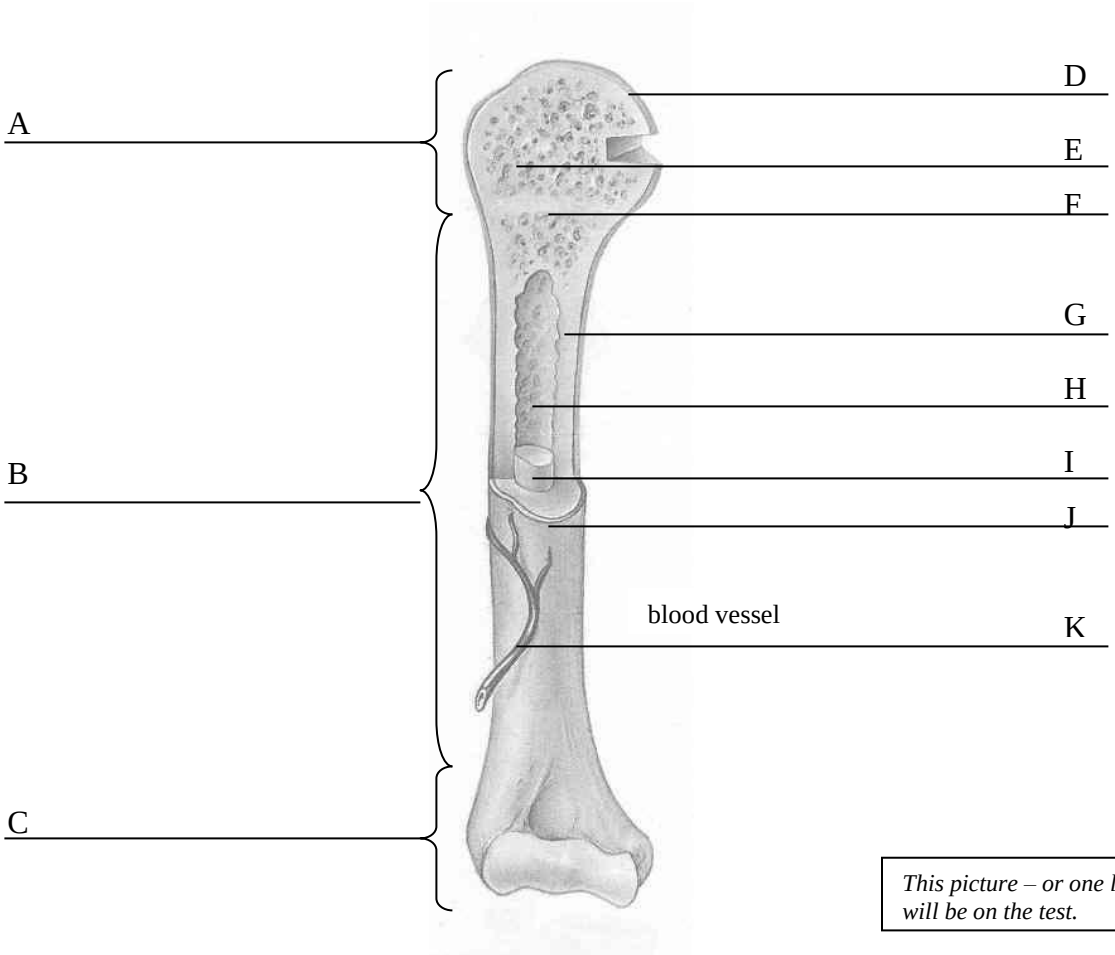
17. Functionally, how are yellow and red marrow different?
18. Why isn't the patella classified simply as a short bone and rather as a sesamoid bone?
19. What types of elements are commonly stored in bones?
20. What is hematopoesis and where does it occur in bones? In what type of marrow?

Answers: 1. short, 2. flat, 3. flat, 4. long, 5. irregular, 6. short, 7. long, 8. irregular, 9. flat, 10. flat, 11. irregular, 12. long, 13. short, 14. spongy, 15. compact, 16. spongy; 17-20 *please see me for help*

Chapter 6: Bones and Bone Tissue

Macroanatomy of Bone

1. _____(B): the shaft which makes up the bone's length; composed of compact bone.
   a. This **medullary** (marrow) **cavity** (H) contains **yellow bone marrow** which is a storage area for fat (I)
   b. The medullary cavity is lined with **endosteum** (G), a thin layer of squamous epithelium tissue.
2. _____(J): covers the diaphysis and the bones (except at joints). It's a fibrous, connective tissue. Hundreds of connective tissues, called *perforating (Sharpey's) fibers* made of dense irregular CT connect the periosteum to the underlying bone. Tendons and ligaments are bonded through these perforating fibers and those perforating fibers anchor them to the bone. The periosteum is associated with two cell types:
   a. **Osteoblasts** form/grow bone through a process called **osteogenesis**. Osteocytes develop from osteoblasts that have become completely surrounded by bone matrix.
   b. **Osteoclasts** are giant cells whose job is to break down bone. They raise blood calcium levels.
3. _____(A, C): the proximal and distal ends of the long bone. Consists of a thin layer of compact bone enclosing an area filled with spongy bone (E).
4. _____(D): covers the external surface of the epiphysis rather than periosteum. Reduces friction at the movable (diarthroses) joints of the body (such as elbow, knee, shoulder, ankle).
5. _____: flat plate of hyaline cartilage seen in young, growing bone (up to age 18-21).
6. _____(F): in adult bones, there is a thin line of bony tissue spanning the epiphysis that is a remnant of the epiphyseal plate. Seen in people age 21 and older.



This picture – or one like it - will be on the test.

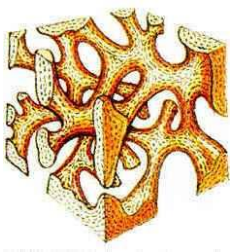
Chapter 6: Bones and Bone Tissue, Continued

Compact (Osseous) Bone Structure

1. _____: mature bone cells which account for most of the cell population in a bone. They cannot divide and can no longer secret matrix materials. Osteocytes are located in a **lacuna** (air pocket).
2. The _____ of bone tissue is made of **calcium salts**. The layers of the matrix are called **lamellae** (rings that surround the central canal, *below*.) The matrix contains:
   a. Calcium phosphate crystals $Ca_3(PO_4)_2$ are hard but brittle and make up 2/3 of the bone's weight. Calcium phosphate combines with calcium hydroxide to form crystals of *hydroxyapatite* which includes other ions (calcium, sodium, magnesium, fluorine). Lack of calcium phosphate makes bones rubbery and unsupportive.
   b. Collagen fibers constitute 1/3 of the bone's weight. Lack of collagen makes bones brittle and not flexible.
   c. Cells make up 2% of the bone's weight.
3. Canals:
   a. **Canaliculi** are tiny, narrow passageways through bone matrix which form a branching network of nutrients, wastes, and gases. These canals penetrate the lamellae and connect lacunae (and osteocytes) with one another and back to the central canal.
   b. The matrix is arranged in concentric circles (called lamellae) around **central** or **Haversian canals**, which carry blood vessels and/or nerves vertically through bone. Each central canals is in the center of one **osteon (Haversian system)**.
   c. **Perforating (Volkmann's) canals** run perpendicular to the surface and connect together central canals.
4. **Osteon (Haversian system)** = central canal + the lamellae (matrix rings)**.** Compact bone covers the exterior of all bones.

Use this space to drawn an osteon and associated canals.

Spongy (Cancellous) Bone



1. Composed of bony bars known as _____ are designed to handle stress and for strength.
2. **Bone marrow** is located between trabeculae of spongy bone in long and flat bones.
   a. **Red bone marrow** makes blood cells through a process called hematopoiesis.
   b. **Yellow bone marrow** (loose adipose CT) is used for energy reserves (fat storage).

Chapter 6: Bones and Bone Tissue, Continued

Review of Bone Macroanatomy and Microanatomy

Bone Physiology

Fill in the blank the following descriptions about bones.

_____1. the articular cartilage is consumed and this creates an area where yellow ____, an adipose tissue, is found.

_____2. the marrow of a bone is the location of red ____ cell formation

_____3. the pull of ___ can reshape a bone

_____4. blood cell formation is called:

_____5. lengthwise bone growth occurs at the epiphyseal ___.

_____6. blood cell formation is called:

Gross Anatomy of a Long Bone

Identify each of the following parts of a long bone.

_____1. connective tissue found covering of the diaphysis

_____2. shaft of a long bone

_____3. the location of spongy bone

_____4. the location of compact bone

_____5. ends of a long bone

_____6. connective tissue found covering the epiphysis

_____7. the marrow cavity contains this type of storage connective tissue

_____8. the process of bone formation

_____9. the process of blood cell formation

_____10. the location where blood cell formation occurs

_____11. evidence of lengthwise growth in an adult is found at…

Microanatomy of Compact Bone

Identify each of these parts of an osteon.

_____1. an alternate name for a Haversian system

_____2. mature bone cells are called ____.

_____3. the canal where a blood vessel travels through the bone

_____4. the nonliving/inorganic portion of the compact bone

_____5. a central (Haversial) canal contains…

_____6. the space in an osteon where osteocytes are located

_____7. canals connecting central canals

Answers to Bone Physiology: 1. marrow, 2. blood, 3. gravity, 4. hematopoesis, 5. epiphyseal plate, 6. hematopoesis.
Answers to Gross Anatomy of a Long Bone: 1. periosteum, 2. diaphysis, 3. epiphysis, 4. diaphysis, 5. epiphysis, 6. articular cartilage, 7. adipose tissue, 8. osteogenesis, 9. hematopoesis, 10. marrow cavity, 11. epiphyseal line
Answers to Microanatomy of a Compact Bone: 1. osteons, 2. osteocytes, 3. central or Haversian canal, 4. matrix of calcium salts, 5. blood vessels or nerves, 6. lacunae, 7. perforating canals

Chapter 6: Bones and Bone Tissue, Continued

Ossification (Osteogenesis)

Ossification is the process of replacing other tissues with bone. **Calcification** (calcium deposits) occurs during ossification.

Three Types of Ossification:

1. **Endochondral Osteogenesis & Ossification** = long bones lengthen

   Step 1: The hyaline cartilage model (fetus) becomes calcified due to activity of **osteoblasts.** Blood vessels grow into the shaft and a **periosteum** forms.

   Step 2: A **primary ossification center** is located in the middle of the diaphysis. It splits apart and grows toward each epiphysis. Cartilage cells in the epiphyseal plate undergo mitosis to push the ends of the epiphyses longer. When the **chondrocytes** (cartilage cells) die, they are converted to bone by **osteoblasts** (bone-forming cells) in the approaching secondary ossification center. Remodeling occurs by:

   Lysosomes – these organelles digest dead cartilage cells.

   Osteoclasts – these bone-destryoing cells erode the trabeculae in the center of the diaphysis.

   Together, the lysosomes and osteoclasts form the **marrow cavity** within the newly formed bone.

   Step 3: The epiphyses calcify. The **secondary ossification center** was created when the primary ossification center separated and traveled to each end of the bone.

   By birth, most hyaline cartilage models have been converted to bone except for two regions:

   1. **Articular cartilages** cover the bone ends. These persist for life and reduce friction at joint surfaces.
   2. **Epiphyseal plate** – made of cartilage; provide longitudinal growth of long bones during childhood. This disk is present as long as the cartilage cells continue to divide, until age 18-20.

   Step 4: At the end of bone growth (around age 18-20), the **epiphyseal disk (plate)**, once made of cartilage, now calcifies and bones can no longer elongate. The secondary ossification center has now caught up with the epiphyseal plate and calcified it. The epiphyseal plate would only be visible as an **epiphyseal line. Calcification** is complete by age 25.

2. **Appositional Growth** increases the diameter of the bone by adding bone to the periosteum. The periosteum's inner layer differentiates into osteoblasts and deposits bone matrix. Over time, the circumference of the bone increases as the lamellae are replaced by osteons and the marrow cavity becomes larger from inside the bone.
3. **Intramembranous ossification:** bone growth in the facial and cranium bones

Chapter 6: Bones and Bone Tissue, Continued

Exercise, Hormones and Nutrition

Information on this page is commonly missed on tests!

Hormones

Hormones Involved in Homeostasis of Ca^{2+} and Phosphate Levels

1. _____ (PTH) is a hormone that causes 1) **osteoclasts** to destroy bone to release calcium into the bloodstream.

→**PTH** is released when blood Ca^{2+} levels are low. It raises blood Ca^{2+} levels by activating **osteoclasts**.

2. _____ is a hormone that causes calcium to be deposited to bone. **Osteoblasts** are bone-forming cells that aid in this process. They can get caught in the matrix and become **osteocytes**, bone cells that can no longer secrete matrix or destroy bone.

→**Calcitonin** is released when blood Ca^{2+} levels are high. It lowers blood Ca^{2+} levels by activating **osteoblasts.**

Hormones Involved in Normal Bone Growth and Maintenance

3. _____ causes lengthwise growth of skeletal muscles and bone during childhood.

- Hypersecretion of GH (too much) as a child can cause **giantism (gigantism)** –may be 7/8 ft or taller
- Hypersecretion of GH in an adult causes **acromegaly** – enlargement of the bones through appositional growth
- Hyposecretion of GH (too little) as a child can cause **pituitary dwarfism** – below average height

4. **Calcitriol** is made in the kidneys and needed for calcium and phosphate absorption in the digestive tract. Remember that calcitriol is made from vitamin D_3 which can be produced in the skin during sun exposure.

- What is the cause of **osteomalacia**? _____
  How are bones affected? _____
  What age group is affected? _____
- What is the cause of **rickets**? _____
  How are bones affected? _____
  What age group is affected? _____

5. **Thyroid hormone, thyroxine** to be specific, promotes cell metabolism and increases osteoblast activity. Lack of thyroxine leads to a congenital problem known as cretinism (congenital hypothyroidism).

6. **Sex hormones** stimulate to produce bone faster than epiphyseal cartilage can expand. Over time, the epiphyseal cartilage narrows and closes (hardens).

Exercise

How do bones respond to stress? _____

Why is exercise necessary? _____

What happens to bones that aren't stressed (such as those in a cast)? _____

_____

Disorders

What is the cause of **osteoporosis**? What populations are affected? _____

_____

Chapter 6: Bones and Bone Tissue, Continued

Review of Hormones and Bone Cells

_____1. bone-forming cells involved in the process of ossification

_____2. mature bone cells found interspersed in the lacunae of the matrix

_____3. bone-destroying cells involved in breaking down bone to release calcium; these cells respond to PTH.

_____4. hormone involved in prompting osteoclasts to remove calcium from bones.

_____5. bone cells that form bone over the articular cartilage during bone growth.

_____6. hormone that causes osteoblasts to deposit calcium to bones.

_____7. hormone that responds to low blood calcium levels

_____8. hormone that responds to high blood calcium levels

_____9. hormone responsible for giantism and acromegaly

_____10. hormone responsible for making bones stronger

For Discussion

1. How do the hormones calcitonin and PTH reshape a bone?
2. List and describe several of the functions of bone.
3. Compare and contrast the functions of the osteoblasts, osteoclasts, and osteocytes.
4. Describe the structure and functions of the parts of a long bone.
5. Describe how a bone grows in length during childhood.
6. If 6 year-old Jimmy fell and broke his femur, damaging the epiphyseal plate, what might he expect as he grows older and taller?
7. How are endochondral and appositional ossification different?
8. Describe the role of the epiphyseal plate in bone growth.
9. Explain why an adult can no longer have lengthwise growth of his or her bones.
10. Compare and contrast central (Haversian) canals and the osteon.
11. Contrast the functions of yellow marrow and red marrow.
12. Describe three disorders associated with hypersecretion or hyposecretion of growth hormone.
13. Explain the effect of exercise on bone structure.
14. Name the three types of canals found in compact bone. Discuss the function of each canal.
15. Differentiate between lamellae and lacunae in compact bone structure.
16. How are the bone disorders osteomalacia and rickets similar?
17. Explain how a marrow cavity forms inside of a long bone.
18. What roles do osteoblasts and osteoclasts play in lengthwise bone growth?

Answers: 1. osteoblasts, 2. osteocytes, 3. osteoclasts, 4. PTH (parathyroid hormone), 5. osteoblasts, 6. calcitonin, 7. PTH, 8. calcitonin, 9. growth hormone, 10. calcitonin

For Discussion: 1-18. *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 6: Bones and Bone Tissue, Continued

Healing a Bone Fracture

Types of Fractures

1. **Open (compound)**: involves bone protruding beyond the skin (at risk for **osteomyelitis** = bone infection)
2. **Closed (simple)** occur when the bone is not protruding beyond the skin

Healing by Reduction

1. **Open reduction**: the bones are put back together with pins through surgery.
2. **Closed reduction**: the bones are manually put back together.

Time to Heal

1. Simple fracture time is 6-8 weeks
2. Period of time for healing is longer in larger bones and for the elderly

How the Bone Heals

Step 1: Hematoma Formation: A hematoma forms from the broken blood vessels. Bone cells deprived of nutrition die. Dead bone is found along the shaft of the bone along the break.

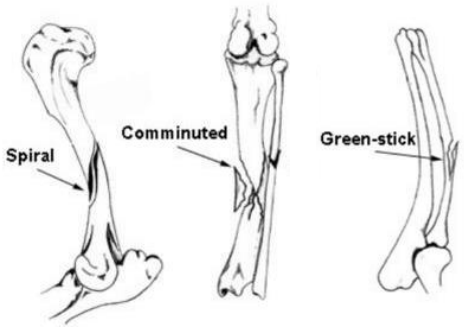
Step 2: Fibrocartilage Callus Formation: The break is splinted by a fibrocartilage callus. This callus contains cartilage matrix, bony matrix, and collagen fibers to help begin the healing process. Early tissue repair; growth of new capillaries; disposal of dead tissue.

Step 3: Bony Callus Formation: A bony callus is formed when the fibrocartilage callus is replaced by a callus made of spongy bone. Osteoblasts and osteoclasts move into the area and multiply.

Step 4: Bone Remodeling: Remodeling of the bony callus using the activity of osteoclasts and osteoblasts. When the remodeling is complete, the bone of the calluses is gone and only living tissue is left.

Types of Fractures

- **Greenstick**: incomplete bone break; one side breaks and the other bends. Often found in children (why?)
- **Compression**: crushed bone; common with osteoporosis
- **Depressed**: bone portion is pressed inward (such as a skull fracture)
- **Spiral**: twisting force creates a ragged break (such as a sports injury)
- **Comminuted**: bone is broken in 3 or more places (often found with osteoporosis)



http://www.familyvet.com

Chapter 8: Articulations

Articulations: are sites where two or more skeletal elements come together, a "joint." Articulations are found between bones, between cartilage and bones, and between teeth and bones. The study of articulations is called **arthrology**, *arthro*=joint and *ology*=study.

This chapter contains difficult new terms – use flash cards to learn them and practice your spelling for

Joints can be classified on *structural* basis or *functional* basis.

Functional	Structural
Synarthroses	Fibrous
Amphiarthroses	Cartilaginous
Diarthroses	Synovial

SYNARTHROSES - Joints with No Movement (Immovable)

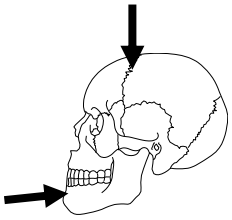
Structural Classification: the bones are held together by **fibrous** (collagenous) connective tissue or **cartilaginous** tissue.

Examples

a. **Suture**: a **fibrous** type of synarthrosis joint that unites the bones of the skull. Irregular, interlocking edges of sutures give them added strength and decrease their chance of fractures. (**Fontanels** are unossified sutures in infant skulls—allows for brain growth.)

b. **Gomphosis**: a **fibrous** type of synarthrosis joint that binds teeth to sockets in the mandible and maxilla.

c. **Synchondrosis**: a **cartilaginous** joint between 2 articulating bones such as between the ribs and sternum. Another example of a synchondrosis is the epiphyseal plate which connects the epiphysis to the diaphysis.



Examples
- skull sutures
- teeth
- epiphyseal plate

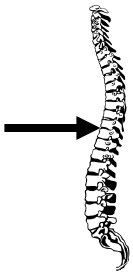
AMPHIARTHROSES - Joints with Some Movement (Slightly Movable)

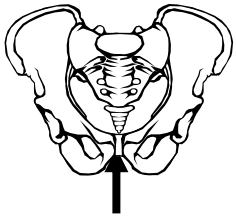
Structural Classification: the bones are held together either by **cartilage** or **fibers**.

Examples

a. **Symphysis**: ("*growing together"*) is a **cartilaginous** joint in which the connecting material is a broad, flat disc of fibrocartilage; pubic symphysis, intervertebral discs between the bodies of vertebrae.

b. **Syndesmoses** are bones connected by **ligaments** such as the distal joint between tibia and fibula.





Examples
- intervertebral disks
- pubic symphysis
- between tibia and fibula

Chapter 8: Articulations, Continued

DIARTHROSES - Freely Movable Joints

Structural Classification: Synovial Joints have a synovial cavity filled with synovial fluid (to lubricate the joint). The bones forming the joint are united by a surrounding **articular capsule** and frequently by accessory ligaments.

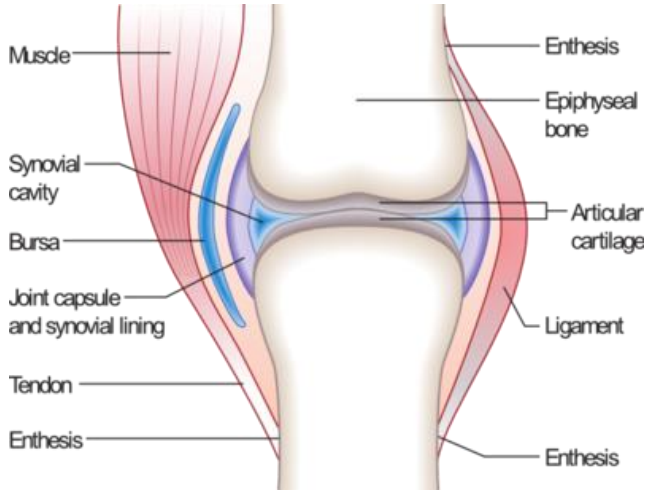
Examples: elbow, knee, hip, fingers, wrist, ankle

Main Parts of a Synovial Joint:

- **Articular cartilage:** are found on the articulating surfaces of bones; composed of hyaline cartilage.
- **Synovial fluid:** is a clear, viscous fluid found in joint cavities. It 1) lubricates the joint and reduces friction between moving surfaces. 2) Shock absorption in joints subject to compression (such as knee, hip, ankle).

Accessory Parts of a Synovial Joint: *Describe the functions of these structures:*

- **Articular Cartilage:** found covering the epiphyses; reduce friction at the bones' ends
- **Fat Pads**: cushions around the joint
- **Ligaments:** anchor bones to _____
- **Tendons:** anchor muscles to _____
- **Bursae**: sacs of fluid surrounding the joint that secrete synovial fluid into the joint.



Chapter 8: Articulations, Continued

Types of Motion in a Synovial Joint

- **Linear motion**: is a gliding type of motion. Think of the type of movement that occurs between articulating carpal bones in your wrist.
- **Angular motion**: changes the *angle* between the two parts of the joint. Think of flexion, extension…

Angular Motions

Bracketed movements are "opposite" or antagonistic motions.

1. **Flexion** decreases the angle between articulating bones.
   Example: *bend the knee or elbow*

2. **Extension** increases the angle between articulating bones.
   Example: *restoring head to normal anatomical position; returning palm to normal*

3. **Dorsiflexion** flexes (bends) the foot in the direction of the dorsum
   Example: *lift toes off floor*

4. **Plantar flexion** flexes (bends) the foot in the direction of the plantar surface (sole)
   Example: *move foot in direction of toes down*

5. **Abduction** is the movement of a bone away from the midline
   Example: *move the arms upward from the sides of the body (like a bird); move fingers apart*

6. **Adduction** is the movement of a bone toward the midline
   Example: *replace arms by sides ("adding" your limbs to your trunk); put fingers together*

7. **Circumduction** is a combination of flexion-extension and abduction-adduction in succession, in which the distal end of a part of the body moves in a circle.
   Example: *combined method of movement--moving arm around body like propeller blade*

8. **Rotation** is the movement of a bone around its longitudinal axis (medial or lateral).
   Example: *pivot joint; atlas pivoting*

9. **Pronation** is the movement of the forearm in which the palm is turned posteriorly or inferiorly. Some textbooks classify this motion as a type of *rotation*.

10. **Supination** is the movement of the forearm in which the palm is turned anteriorly or superiorly. Some textbooks classify this motion as a type of *rotation*.

11. **Inversion** is the movement of the foot so that the sole is turned inward.

12. **Eversion** is the movement of the foot so that the sole is turned outward.

13. **Elevation** is the lifting up of a body part.
    Example: *shrugging one's shoulders*

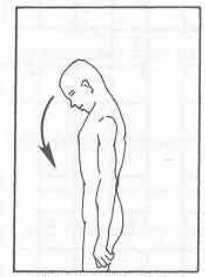
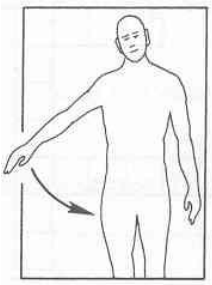
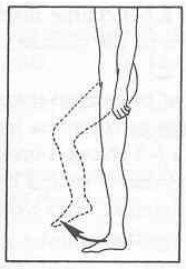
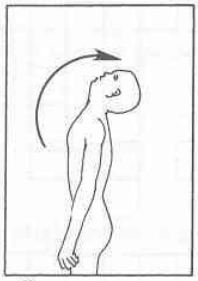
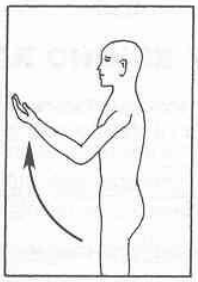
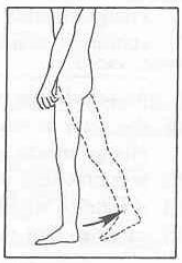
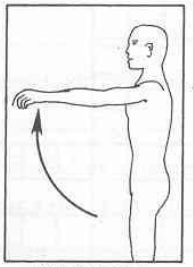
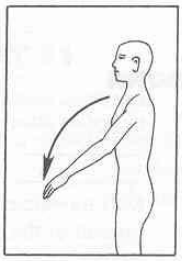
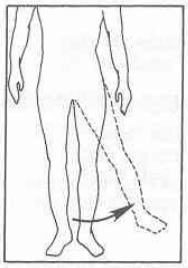
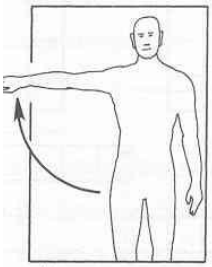
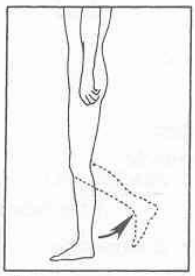
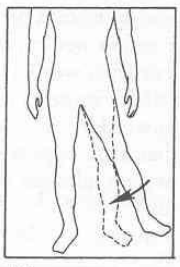
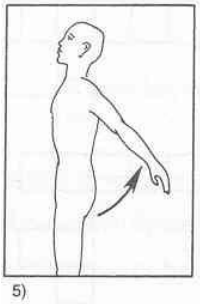
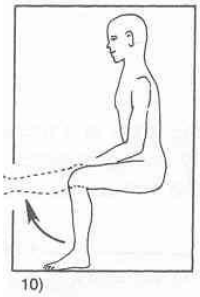
14. **Depression** is the opposite of elevation; replacement of body part after elevation.

15. **Protraction** is the movement of a body part anteriorly in the horizontal plane.

16. **Retraction** is the reverse movement of #15.

Chapter 8: Articulations, Continued

Identifying Synovial Joint Movements

Movement	Movement	Movement
 1) Flexion of head	 6)	 11)
 2)	 7)	 12)
 3) Flexion of arm	 8) Extension of forearm	 13) Abduction of thigh
 4)	 9)	 14)
 5)	 10)	

Answers: 2) extension, 4) abduction, 5) extension, 6) adduction, 7) flexion, 9) flexion, 10) extension (or elevation), 11) elevation (or flexion), 12) extension, 14) adduction

Chapter 10: Muscle Tissue and Physiology

Functions of Skeletal Muscles

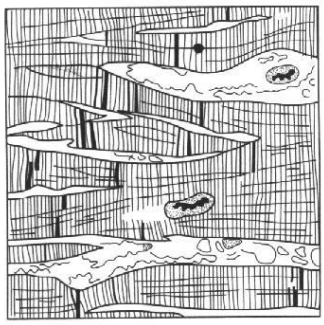
1. **Movement:** muscles move bones and provide for facial expressions.
2. **Posture**: the ability to support the body against gravity.
3. **Stabilize Joints:** muscles (and tendons and ligaments) help to stabilize poorly articulating joints.
4. **Generate Heat**: mitochondria make ATP from glucose and oxygen; skeletal muscles use ATP for contractions and create heat as a bi-product. *How is excess heat removed?*

Muscle Characteristics

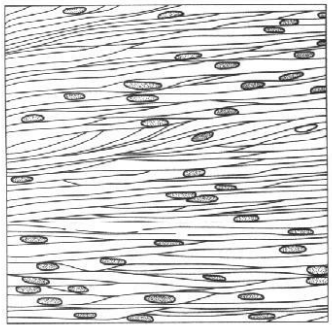
1. **Excitability**: muscle's ability to react to a stimulus
2. **Contractility**: muscle shortens upon stimulation
3. **Elasticity**: muscle returns to normal length after stretching

Labeling the Three Types of Muscle

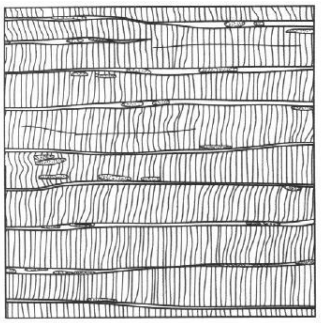
Identify each of the following as skeletal, smooth, *or* cardiac *muscle.*



involuntary
location: heart
striated
unique features:
- branching pattern
- intercalated discs
- muscle fibers are separate



involuntary
location: walls of hollow organs
performs peristalsis
unique features:
- spindle-shaped
- lacks striations



voluntary
location: attached to bones
striations
unique features:
- cylindrical-shaped
- multinucleate
- fibers are close together

For Discussion

1. How are cardiac and skeletal muscle tissue similar? What makes these tissues different from each other?
2. Can a muscle exhibit contractility without exhibiting excitability? Explain.
3. What features make each muscle type unique?

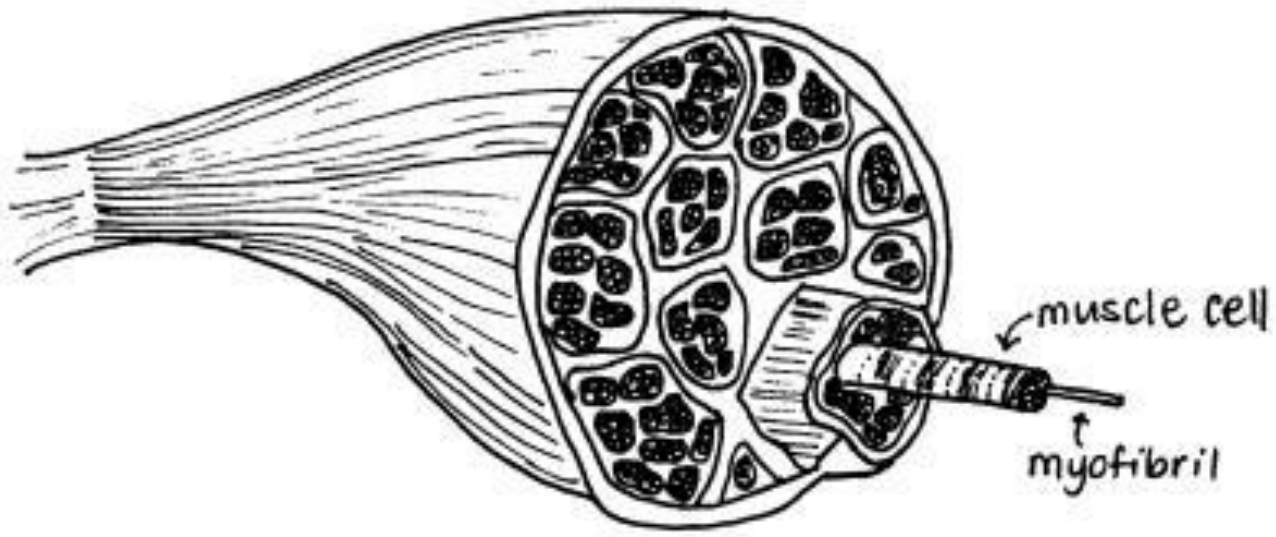
Chapter 10: Muscle Tissue and Physiology, Continued

Macroscopic Anatomy of a Skeletal Muscle

1. _____: the connective tissue that covers the outside of the entire muscle. This layer is connected to the fascia.
2. _____: wraps around a fascicle. Several muscle fibers bundled together are called a fascicle. The perimysium contains collagen and elastic fibers, nerves and blood vessels.
3. _____: each individual muscle cell (or *myofiber*) in the fascicle is also wrapped by this connective tissue. Think of this as the "membrane layer on the inside (*endo*)."
4. At the end of each muscle, the collagen fibers of the endomysium and perimysium come together to form either a **tendon** or an **aponeurosis.** Both connect skeletal muscles to bone. Aponeuroses also connect muscle to muscle.

On this picture of a skeletal muscle, below, be able to identify the following:

- Epimysium
- Perimysium
- Sarcolemma
- Fascicle
- Endomysium (draw it in)
- Muscle Cell = Muscle fiber = Myofiber
- Myofibril



Microscopic Anatomy of a Skeletal Muscle

1. _____: "flesh husk"—the plasma membrane of a muscle cell surrounds the _____ (cytoplasm) of the muscle cell. In order for the entire muscle cell to contract at the same time, **transverse (T) tubules** extend into the cell at right angles to the cell's surface. T tubules are extensions of the sarcolemma that connect to the SR. Impulses travelling along the sarcolemma can continue on into the cell's interior along the T tubules.
2. _____: long organelles found inside the muscle cell. These are the tiny contractile units that help to shorten the muscle during muscle contraction. The myofibrils have a banding pattern (= striations).

Chapter 10: Muscle Tissue and Physiology, Continued

Review of Muscles

Types of Muscle Tissue

Identify each of these descriptions as skeletal, smooth, *and/or* cardiac.
More than one answer may be appropriate for some of these.

_____1. striated

_____2. lacks striations

_____3. one nucleus

_____4. more than one nucleus

_____5. branched

_____6. unbranched

_____7. voluntary

_____8. involuntary

_____9. branched, involuntary, striated

_____10. multi-nucleate, striated, voluntary

_____11. one nucleus, involuntary, lacks striations

_____12. intercalated disks

_____13. contracts to beat the heart and pump blood

_____14. lines the walls of blood vessels, digestive organs, urinary tubes

_____15. contracts to move bones of skeleton

Membranes covering a Muscle

Identify each of these descriptions as epimysium, perimysium, *or*, endomysium.

_____1. Wraps an entire muscle (say, for example, the biceps brachii)

_____2. Wraps the individual muscle cells

_____3. Wraps fascicles (bundles) of muscle cells

For Discussion

1. Explain the difference between the sarcolemma and the endomysium. Where is each found?
2. Put these structures in order from the smallest part of a muscle to the largest part of a muscle:

   myofibril, epimysium, fascicle, muscle cell, sarcolemma
3. What does a fascicle contain and what type of membrane encloses it?
4. What is the function of the transverse (T) tubules?
5. Where are myofibrils located? What is their relationship to myofibers?
6. Which muscle tissues are involuntary? Which muscle tissues are striated?

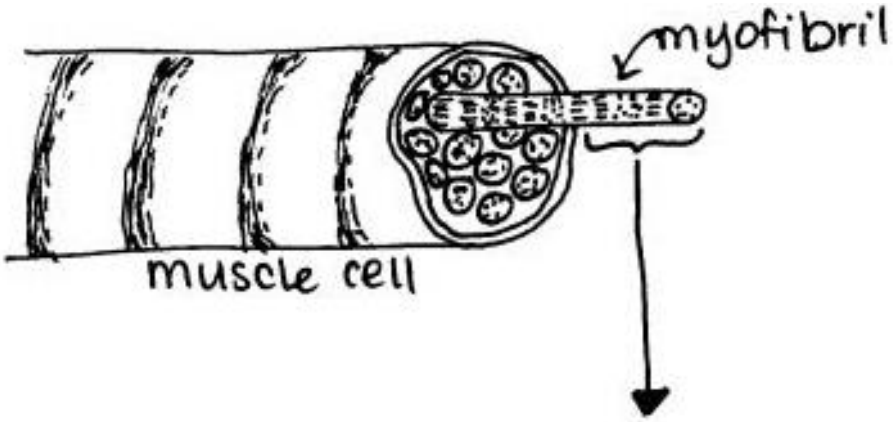
Types of Muscle Answers: 1. skeletal, cardiac; 2. smooth, 3. smooth, cardiac; 4. skeletal; 5. cardiac; 6. smooth, skeletal; 7. skeletal; 8. smooth, cardiac; 9. cardiac, 10. skeletal, 11. smooth, 12. cardiac, 13. cardiac, 14. smooth, 15. skeletal
Membranes covering a Muscle Answers: 1. epimysium, 2. endomysium, 3. perimysium
For Discussion: 1-6. *Think about these questions; if you have trouble answering any of them, please see your instructor!*

Chapter 10: Muscle Tissue and Physiology, Continued

Identifying Parts of a Muscle Cell

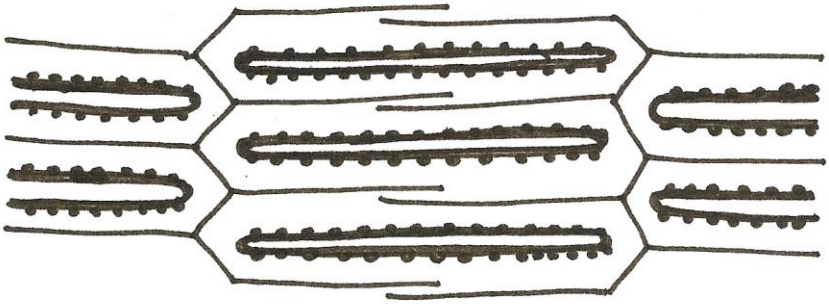
Locate and label the following structures on the muscle cell:

- Sarcolemma
- H zone
- Myosin filaments
- Thick filaments
- Sarcomere
- A band
- Myosin heads
- I band
- Z line (disc)
- Actin filaments
- Thin filaments
- Myofibril
- Muscle Cell
- Myofibril



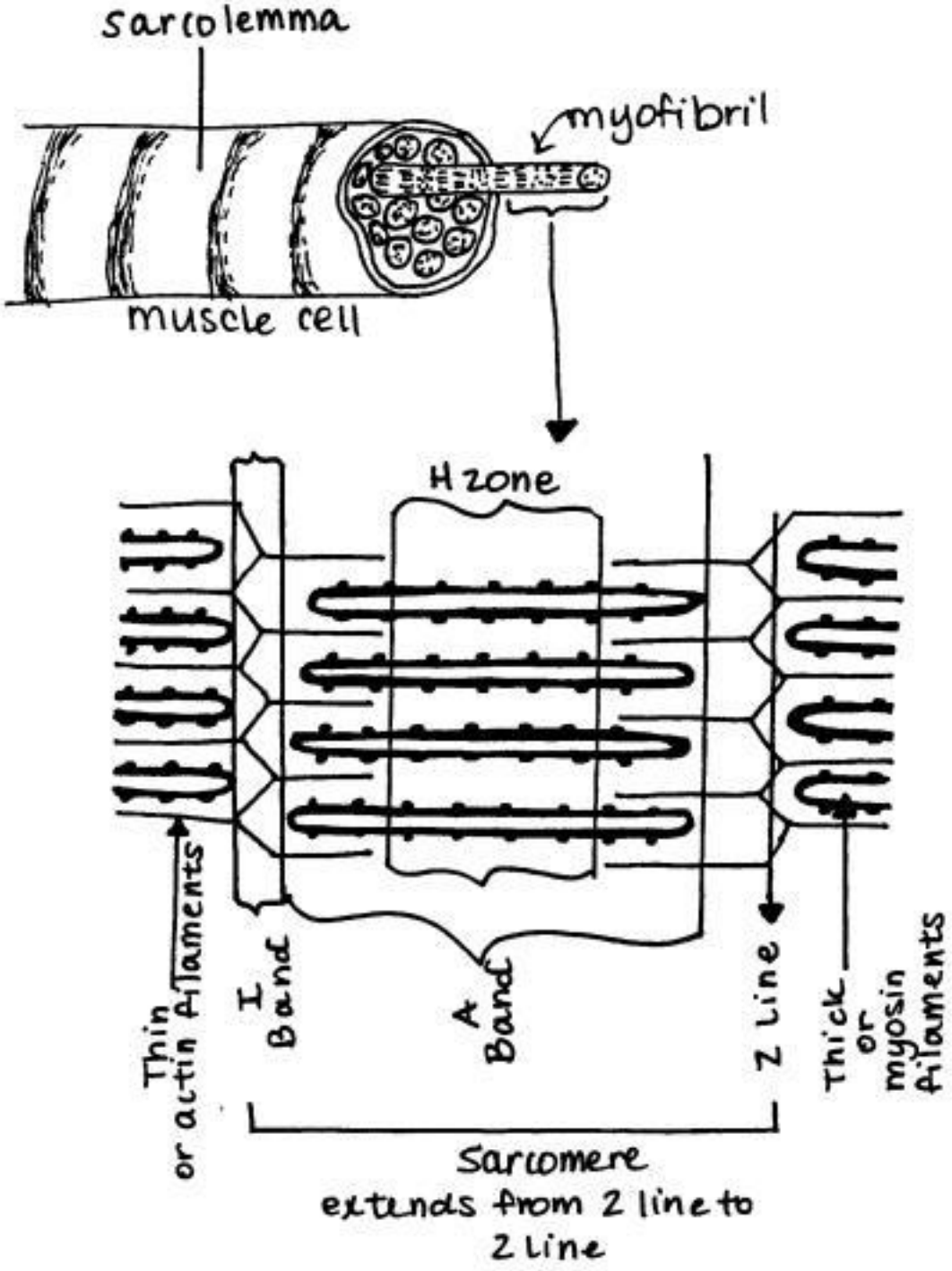
Contracted Muscle

What has changed about the sarcomere?



Chapter 10: Muscle Tissue and Physiology, Continued

Identifying Parts of a Muscle Cell—Labeled



Chapter 10: Muscle Tissue and Physiology, Continued

Microscopic Anatomy of the Skeletal Muscle Cell, *Continued*

1. **Sarcomere:** this is a portion of the myofibril. It's a unit that runs from one Z line to the next Z line.
    - *During muscle contraction (sliding filament theory), what happens to the sarcomere? it shortens as the Z lines are pulled closer together.*
2. **Parts of the sarcomere**
    a. **A band (DARK band):** a portion of the sarcomere which contains all of the thick filaments and only a portion of the thin filaments.
        1. **H zone:** portion within the A band which contains only the thick filaments. No thin filaments are found in this zone when the muscle is relaxed.
        - *During muscle contraction (sliding filament theory), what happens to the H zone? disappears since the thin filaments invade the H zone*
    b. **I band (LIGHT band):** a portion of the sarcomere which contains the Z line and only the thin filaments.
        - *During muscle contraction (sliding filament theory), what happens to the I band? disappears since the thick filaments invade the I band*
    c. **Z line (disc):** this zig-zag shaped line is a membrane where the thin filaments are attached.
        - *During muscle contraction (sliding filament theory), what happens to Z lines (disc)? slide closer together since the myosin heads attach to the thin filaments and pull them*
3. **Myofilaments**: these are long proteins made either of actin or myosin.
    a. **thick filament/myosin filament:** these thick filaments possess heads which are crucial for muscle contraction. The thick filaments are made of the protein **myosin**. The myosin heads of the thick filaments attach to certain sites on the thin filaments so that muscle contraction can occur.
        1. Myosin heads are knobby, "golf club" shaped portions of thick filaments. These heads are made of proteins which attach to a particular site on the thin filaments during muscle contraction. When the myosin heads attach to the thin filaments, they are then called **cross bridges**.
        - *During muscle contraction (**sliding filament theory –** see page 86), what is the role of the myosin heads? Myosin heads attach to the thin filaments, pull them, release & repeat. The thin filaments slide toward the center of the sarcomere. In turn, the Z lines are moved closer together & the sarcomere shortens.*
    b. **thin filament/actin filament:** these thin filaments are anchored to the Z line (disc). Thin filaments are made of the protein **actin, tropomyosin**, and **troponin.** For muscle contraction to occur, troponin-tropomyosin must change positions and expose active sites on actin. Tropomyosin is a "rope" that covers active sites on actin and prevents actin and myosin heads from interacting. Tropomyosin is connected to **troponin**. Calcium binds troponin and allows the movement of tropomyosin so that myosin heads can attach to the actin filaments.
4. **Sarcoplasmic reticulum:** this organelle wraps around the myofibril like a lacey sleeve. For a muscle contraction to begin, calcium ions are released from the SR into the sarcoplasm. The ions diffuse into the sarcomere. The SR reabsorbs calcium ions after muscle contraction to help the muscle relax.

Chapter 10: Muscle Tissue and Physiology, Continued

Review of Microanatomy of a Muscle & The Sliding Filament Theory

Match the following descriptions with the letters at right.

____1. Zone of the A band that contains only thick filaments
____2. Plasma membrane of the muscle cell
____3. Heads of the thick filaments attach to receptors sites on the ___.
____4. Contractile unit of a myofibril, running from Z line to Z line
____5. These filaments contain "heads" made of the protein myosin
____6. Long, filamentous organelle found in muscle cells; banded appearance
____7. Band containing thick/myosin filament and some thin filaments
____8. Band containing only thin filaments and the Z line
____9. Organelle which stores and releases calcium for muscle contraction
____10. These membranes move closer together during the sliding process
____11. These filaments are anchored to the Z lines

A. A band
B. I band
C. H zone
D. Z lines
E. myofibril
F. sarcolemma
G. sarcomere
H. sarcoplasmic reticulum
I. thick (myosin) filament
J. thin (actin) filament

For Discussion

12. Explain what is responsible for the light and dark banding pattern seen in skeletal muscle cells.
13. Describe the role of the myosin heads in muscle contraction.
14. Explain and list the events that occur during the sliding filament theory.
15. Explain *why* the H zone and I band disappears during muscle contraction.
16. Since the myofilaments don't shorten during muscle contraction, how does the muscle contraction actually accomplish shortening of the sarcomere?
17. Why is the sarcoplasmic reticulum important for muscle contraction?
18. What is the role of calcium in muscle contraction?
19. How are the M line and H zone related to the A band?
20. How is ATP involved in muscle contraction?
21. How does troponin-tropomyosin regulate muscle contraction?
22. What structure(s) in the sarcomere are not found within the I band?
23. Explain what happens to shorten the sarcomere during muscle contraction.

Answers: 1. C, 2. F, 3. J, 4. G, 5. I, 6. E, 7. A, 8. B, 9. H, 10. D, 11. J. *If you need help with 12-23, please see me for help!*

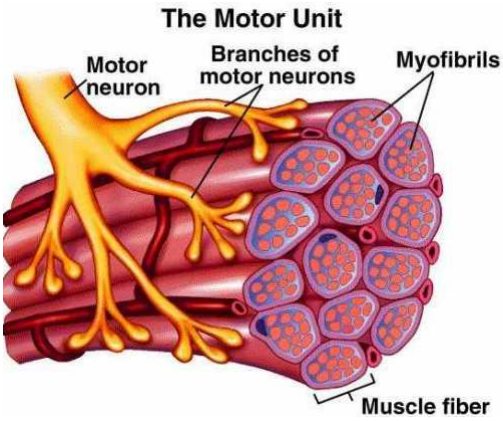
Chapter 10: Muscle Tissue and Physiology, Continued

Spend lots of time telling the story of excitation and contraction to anyone who will listen! Over and over...

Excitation-Contraction Coupling

How Does a Nerve Impulse Trigger the Contraction of a Muscle?

Excitation-contraction coupling is the link between the generation of an action potential and the start of a muscle contraction. In other words, the events that must occur in order for the action potential to create a muscle contraction are about 0.3 seconds.



- Skeletal muscle is stimulated by a nerve cell (specifically a nerve called a *motor neuron*). The motor neuron and all the skeletal muscle cells it stimulates are called a **motor unit.**
- The location where individual axon terminals stimulate ONE muscle cell is called a **neuromuscular junction.** This neuromuscular junction is where the nerve cell nearly comes into contact with the sarcolemma of the muscle cell.
- The gap between the sarcolemma of the muscle cell and the axon terminals (synaptic knobs) of the nerve cell is called the _____.

Excitation

1. As the action potential (= nerve impulse) reaches the axon terminals of the nerve cell, **calcium ions** diffuse into the axon terminal through calcium channels. Calcium prepares vesicles of neurotransmitter for exit from the cell.

2. Next, a chemical called a **neurotransmitter** (packaged in vesicles) is released into the synaptic cleft by **exocytosis**. The specific neurotransmitter that communicates with muscle cells is **acetylcholine** (**ACh**). Ach travels across the synaptic cleft and binds to receptors on the sarcolemma of the muscle cell. When ACh binds the receptor, sodium protein channels are opened. The voltage of the cell changes and the muscle cell becomes *excited*. (The back story: Muscles at rest have a negative charge on the inside. The action potential changes the charge from **negative** to **positive** on the interior of the muscle cell.)

The enzyme, **acetylcholinesterase** (**AChE**), breaks down Ach. *Why*? _____

_____

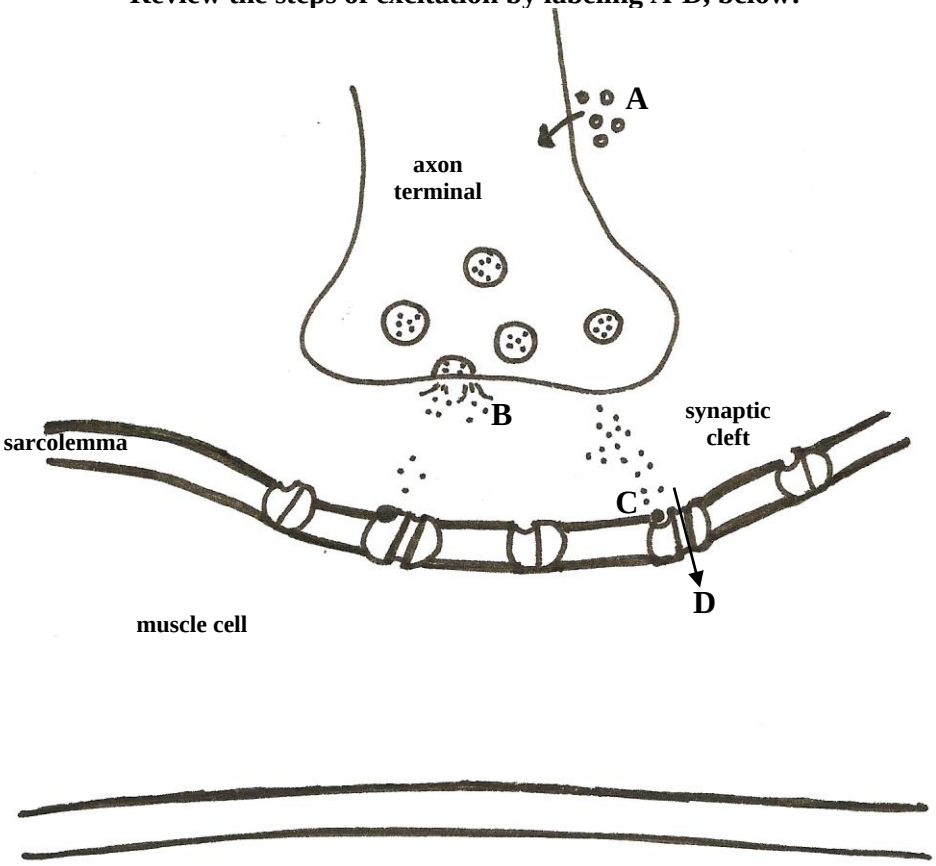
3. Acetylcholine causes the sarcolemma to become temporarily permeable to _____ ions that rush into the muscle cell. Sodium ions are normally located *outside* the membrane while potassium ions are *inside.*

4. Sodium ions are cations that carry a positive charge; they can create an electrical impulse. The influx of Na^+ ions into the muscle cell causes a flow of electrical current. This electrical current is called the **action potential**.

Chapter 10: Muscle Tissue and Physiology, Continued

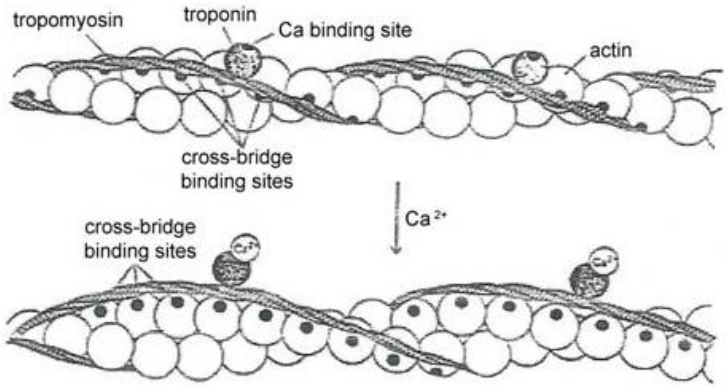
Excitation-Contraction Coupling

Review the steps of excitation by labeling A-D, below:



Contraction

1. The action potential moves into the **sarcoplasm** and down through **T tubules** so the action potential can reach all the myofibrils. The action potential causes the _____ to release stored calcium. Now, calcium binds **troponin** and it changes shape. **Tropomyosin** moves as a result and the **active sites** on actin filaments are exposed. The active site has to be exposed so that the myosin heads can attach to binding sites on the actin filaments to form cross bridges.



Chapter 10: Muscle Tissue and Physiology, Continued

Excitation-Contraction Coupling

2. **Sliding Filament Theory of Muscle Contraction:** The myosin heads form **cross bridges** when they attach to binding sites on actin filaments. The myosin heads pivot and pull the actin filament toward the center of the sarcomere, creating a **power stroke**. The heads detach from the actin filament when ATP binds the myosin head. (**Rigor mortis** occurs when there's no ATP available—muscles are locked in contracted state until muscle degrades).

The hydrolysis of ATP into ADP and a phosphate groups powers the activity of these myosin heads. The myosin head becomes ready for another cycle if the active sites are exposed again. A full muscle contraction involves many repetitions of cross bridge formation and power strokes. To stop the muscle contraction, calcium is pumped back into the SR and the power stroke is stopped.

3. When the muscle contracts, the I bands and H zones disappear, the sarcomere shortens as Z lines move closer together. The filaments slide past one another to shorten the muscle. The filaments themselves do not change length nor does the A band change length!

4. Contractions that shorten and produce movement are known as **isotonic contractions**. Examples include flexion, extension, abduction, adduction. Contractions that **do not** shorten or produce movement are known as **isometric contractions**. Examples include pushing against a stationary wall or object.

Relaxation

How does a muscle contraction stop?

1. Acetylcholinesterase (AChE) breaks down ACh. ACh is recycled and returned to the axon terminal.
2. SR reabsorbs calcium ions.
3. Troponin-tropomyosin complex re-covers the binding sites on actin and prevents the myosin heads from attaching.
4. Without cross-bridge interaction, the contraction ends.
5. Muscle relaxes and returns to its resting length.

How do smooth muscles contract?

Although smooth muscles lack sarcomeres, troponin, and striations, they do contract using the same sliding filament mechanism used by all other muscle tissues. Smooth muscle, however, can contract quickly and relax or it can contract slowly and sustain the contraction. Smooth muscle needs elasticity for the stretching that occurs as substances pass through their openings (lumen).

- In blood vessels, airways, and some sphincters, smooth muscles may sustain contractions for long periods of time. Think about the anal or urinary sphincters (rings of smooth muscle) staying tightened and closed.
- In the digestive system, smooth muscles contract rhythmically to propel substances through the lumen.
- Smooth muscle responds to hormones to constrict blood vessels and increase blood pressure.

Chapter 10: Muscle Tissue and Physiology, Continued

For Discussion

1. Explain two instances in which calcium plays a role in muscle contraction.
2. What role do troponin and tropomyosin play in regulating the muscle contraction?
3. When are myosin heads called "cross bridges?"
4. What role does acetylcholinesterase play in regulating the transmission of the nerve impulse?
5. What is a "power stroke?"
6. *When* and *how* is ATP used for during a muscle contraction event?
7. Name and briefly list the functions of the chemicals necessary for a muscle contraction to occur.
8. What role does the SR play in muscle contraction? When does it release calcium?
9. Describe the structure of the T tubules. What function do those T tubules serve?
10. How do muscles accomplish moving the Z lines closer together?
11. When acetylcholine binds to the receptor on the muscle cell, what ions can enter the cell through protein channels?
12. What is the name of the neurotransmitter used to transfer the action potential to muscle cells?
13. When is exocytosis employed during the synapse? And, when is diffusion employed?
14. Can you place in order the events of transmission of a nerve impulse from axon terminal to muscle cell starting from the release of the neurotransmitter until the ultimate return of calcium to the SR?
15. Some neuromuscular drugs are often given during surgery to promote paralysis. The most common type of drug is given *postsynaptically* to prevent acetylcholine from binding to receptors. Explain how this type of drug stops muscle contractions.
16. Discuss why the theory of muscle contraction is known as the *sliding filament* theory.
17. Since the myofilaments don't actually shorten during muscle contraction, how does the muscle contraction actually accomplish shortening of the sarcomere? Explain.

Need help with 1-17? Please come see me!

Chapter 10: Muscle Tissue and Physiology, Continued

Review of Muscle Contractions

Microanatomy of a Muscle

Identify each of these descriptions about the parts of a muscle cell or myofibril.

_____1. band containing the Z line and thin filaments

_____2. organelle that performs contractions in a muscle cell

_____3. plasma membrane of a muscle cell is also called this

_____4. organelle found storing and releasing calcium ions

_____5. contractile unit running from one Z line to the next Z line

_____6. membrane where the thin filaments are attached

_____7. another name for thin filaments

_____8. another name for thick filaments

_____9. only these myofilaments have "heads" for sliding

_____10. band containing all the thick filament and some thin filament

Neuromuscular Junction & Nerve Impulse

Identify these steps or parts of a neuromuscular junction.

_____1. one nerve cell and all the muscle cells it stimulates is called a ___

_____2. axon terminals of one nerve cell and its muscle cell

_____3. space or gap where the nerve and muscle cells nearly meet

_____4. chemical released into the synaptic cleft

_____5. specific neurotransmitter released in muscle contraction

_____6. these two types of ions are necessary for muscle contraction

_____7. the influx of sodium ions causes a change in the charge, called a ___

_____8. these ions rush into a cell during the change in the sarcolemma

_____9. action potential causes the Z lines to move ____

_____10. Z lines move closer together cause myosin heads attach to ___ filaments.

Answers: Microanatomy of a Muscle

1. I band
2. myofibril
3. sarcolemma
4. sarcoplasmic reticulum
5. sarcomere
6. Z line
7. actin filaments
8. myosin filaments
9. myosin (thick) filaments
10. A band

Answers: Neuromuscular Junction & Nerve Impulse

1. motor unit
2. neuromuscular junction
3. synaptic cleft
4. neurotransmitter
5. acetylcholine
6. potassium, sodium
7. action potential
8. sodium
9. closer together
10. actin (thin) filaments

Chapter 10: Muscle Tissue and Physiology, Continued

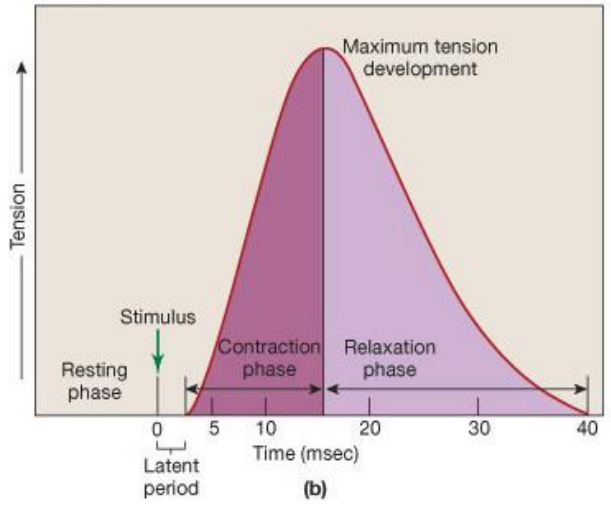
Contraction of Skeletal Muscle as a Whole
Types of Muscle Contraction

Muscle tension is produced by cross-bridges – and a constant state of mild stimulation. The frequency of stimulation of individual muscle fibers impacts muscle tension as does the fiber's resting length at the time of stimulation.

Graded response: different degrees of muscle shortening. Affected by:

1. changing the ***frequency*** of muscle stimulation (see below)
2. changing the ***number*** of muscles being stimulated (see next page)

1. **Here are four types of muscle responses to the 2 items (frequency & number) listed above**:
    1. **Twitch:** single, brief, jerky contraction
        - Not the normal way for a muscle to operate; sometimes result from nervous system problems
        - Twitches have three phases:
            - **Latent period**: excitation period – the contraction cycle has not yet begun, but the action potential is sweeping across the sarcolemma. SR is in the process of releasing calcium.
            - **Contraction phase**: tension rises as calcium ions bind to troponin and active sites on the thin filaments are now exposed. Cross-bridge interactions occur.
            - **Relaxation phase**: calcium levels fall and active sites are covered by tropomyosin. Cross-bridges detach and tension falls.



2. **Treppe**: If a skeletal muscle is stimulated immediately after the relaxation phase has ended, the contraction will produce a slightly higher tension than the first stimulus. Tension rises like steps in a staircase (clinical but not something you actually experience.)

3. **Summation of twitches (wave summation)**: the addition of twitches. If stimulation continues and the muscles is not allowed to relax completely, tension will continue to rise above treppe. There is still calcium left over from the first twitch and the second twitch releases more calcium. Great calcium causes greater contraction. A muscle reaches **incomplete tetanus** if peak tensions are reached.

4. **Fused** or **Complete Tetanus** in most types of muscle activity, the nerve impulses are sent so rapidly that the cells do not get a chance to relax completely between stimuli. The effects of the stimulation are "summed" together so that the muscle is stimulated so rapidly that there is no evidence of relaxation. So, increased frequency results in higher muscle tension.

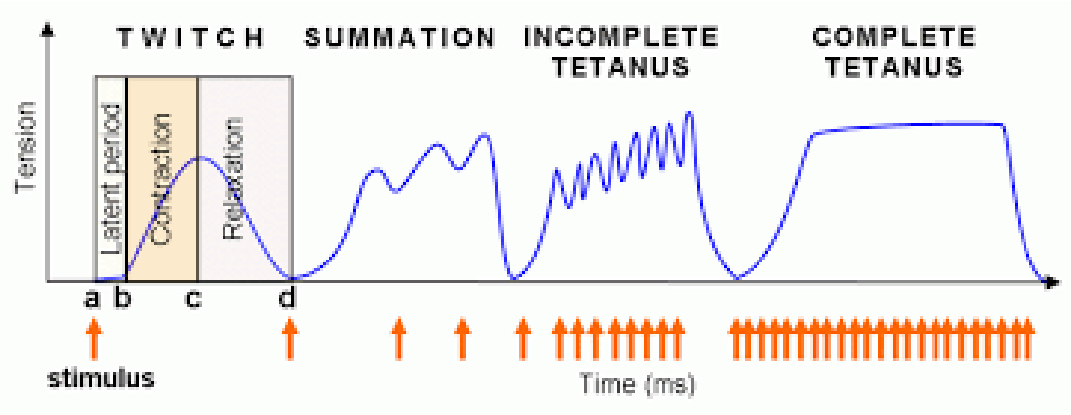
Until this point, the muscle is said to be exhibiting *unfused* or *incomplete tetanus*.

Muscles can be recruited – strength is increased by increasing the number involved.

Chapter 10: Muscle Tissue and Physiology, Continued

Reading a Myogram

Stimuli vs. Tension (grams)



2. *How do muscles increase tension?* **Recruitment** of additional motor units will produce higher tension.

Additional Information about Muscle Contractions (To Read at Home):

- **Muscle tone** is resting tension—not enough tension to produce movement, but enough tension to tense and firm the muscle. Low tone = hypotonia while great tone = hypertonia

- **Fast fibers** (fast-twitch fibers) can reach peak tension quickly (in 0.01 seconds). These are 1) larger fibers and possess 2) many packed myofibrils, 3) large amounts of glycogen, and 4) few mitochondria. Fast fibers 5) fatigue quickly. *White meat* found in chicken breasts are composed of fast fibers because chickens use those muscles for brief intervals of flight or fleeing from predators.

- **Slow fibers** (slow-twitch fibers) are 1) smaller in diameter than fast fibers. They are specialized to 2) continue contractions over longer periods of time. Slow fibers do have mitochondria and contain a pigment called 3) **myoglobin** which can bind oxygen molecules. The oxygen reserves found in slow fibers make them less dependent on anaerobic cellular respiration. *Dark meat* found in chicken legs contains muscles powered by slow fibers since chickens often walk around on their legs all day.

- **Hypertrophy** is an enlargement of muscle due to repeated stimulation. To build muscle mass, body builders often work muscle groups. To bulk a muscle, it can be torn and rebuilt thicker.

- **Atrophy** is the loss of muscle size, tone or power. Muscle atrophy can be caused by wearing a cast or spending time in zero gravity space.

Chapter 10: Muscle Tissue and Physiology, Continued

3 Pathways for Generating ATP in a Muscle

How is energy supplied for muscles during exercise?

Resting muscle fibers contain only enough ATP to sustain a contraction until additional ATP can be generated by:

1. **Aerobic cellular respiration:** The most common way to generate ATP in a resting muscle is to transform fatty acids into ATP. Once exercise begins, ATP is made from pyruvic acid (a bi-product of the breakdown of glucose) in the reaction, below.

glucose + oxygen → carbon dioxide + water + 34-36 ATP

2. **Direct phosphorylation** of ADP by **creatine phosphate** (CP) is the fastest way to regenerate ATP when supplies run low. CP can be stored (unlike ATP) when muscles are inactive. So, when muscles are inactive, ATP transfers energy to creatine and it becomes creatine phosphate. This type of ATP regeneration can be exhausted in 15 seconds of exercise. Creatinine is removed by the kidneys and should appear in the urine.

CP interacts with ADP → Creatine and ATP

3. **Anaerobic cellular respiration** (**glycolysis or lactic acid fermentation**) generates 2 ATP molecules for each glucose molecule broken down. Glucose is retrieved from glycogen stored in the sarcoplasm. Painful lactic acid builds up on the muscles during heavy exercise but allows the muscle contractions to continue for extended periods. Lactic acidosis results, causing blood pH to fall and respiration rates to increase.

glycogen stored in muscle cells → glucose → 2 ATP + lactic acid

Of these three ways for generating ATP, which is the method that:

- Makes the most ATP? _____
- Makes the least ATP? _____
- Produces painful lactic acid? _____
- Turns glycogen into glucose into ATP? _____
- Used during rest? _____
- Used during heavy exercise? _____

What is muscle fatigue? Muscles that **lack ATP, blood, oxygen, or healthy structure** cannot produce a muscle contraction. Without one of these requirements, the muscle cannot contract even with nerve stimulation.

What is the cause of excess post-exercise oxygen consumption (EPOC – formerly known as oxygen debt)? Recall that glucose and oxygen are needed to make ATP aerobically through cellular respiration. When ATP and CP supplies run low, and without oxygen, the breathing rate increases to repay the oxygen debt incurred through hard exercise. In the absence of oxygen, cellular respiration converts to anaerobic respiration in which ATP is made from glucose, but not oxygen. Anaerobic respiration allows ATP to continue to be made, but at the risk of lactic acid buildup on muscles (creates sore muscles over short-term). Lactic acid must be removed by the liver. Long-term soreness results from ripping of muscle fibers that must be repaired.

Chapter 10: Muscle Tissue and Physiology, Continued

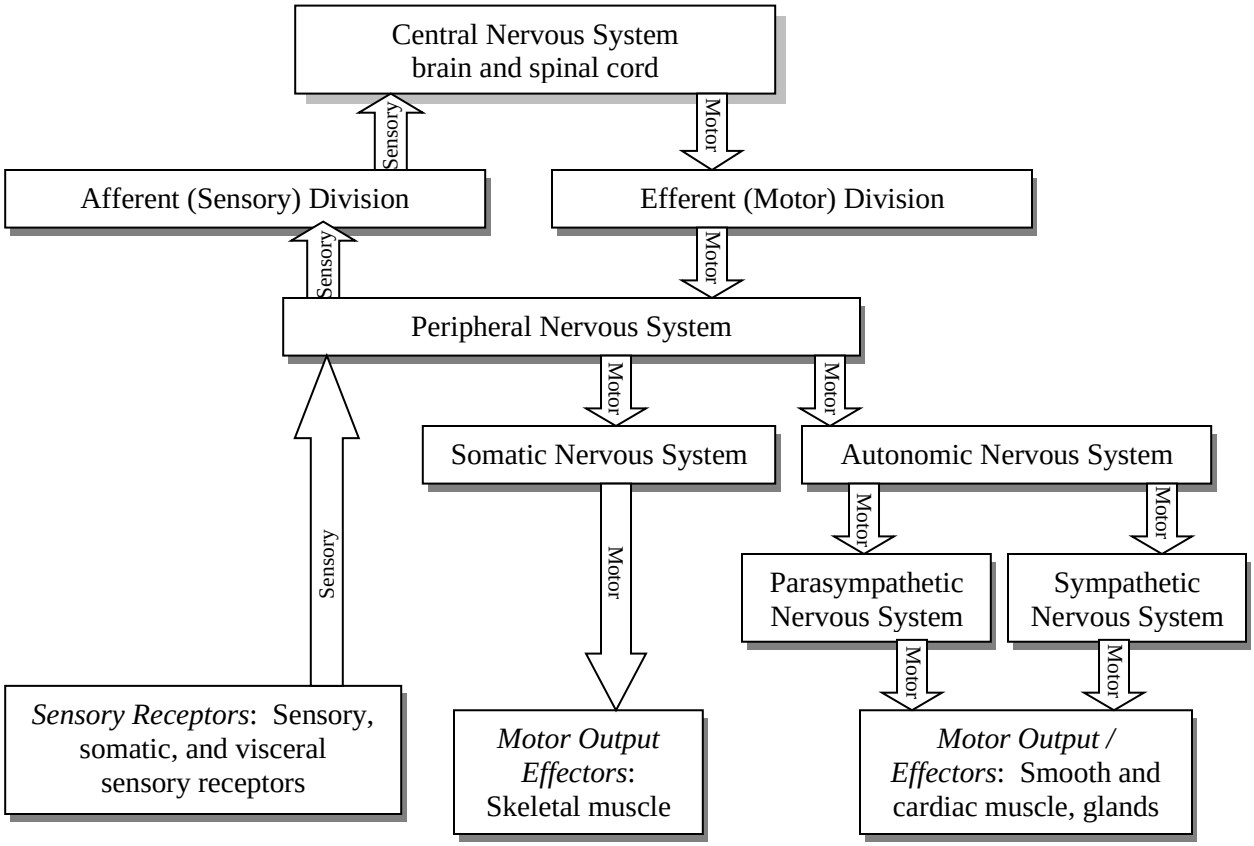
Review of the Muscular System, For Discussion:

1. Compare the amount of calcium available during the latent period, contraction period, and relaxation period of a twitch.
2. Say you've just starting a jog. Which method will your muscles use for ATP? After 30 minutes, you're breathing hard. What method does your body use now to generate ATP?
3. Differentiate between isometric and isotonic contractions.
4. How do myofilaments differ from the myofibril?
5. Would weight lifting cause hypertrophy or atrophy of muscles? Explain.
6. Compare and contrast the three types of muscle tissue.
7. Read a myogram to determine when a stimulus has caused complete or fused tetanus.
8. Which type of muscle contraction (*twitch, treppe, full tetanus*) involves no relaxation of the muscle due to constant stimulation?
9. Compare and contrast the three methods of generating ATP in a muscle.
10. What events occur during the latent period of muscle contraction? How about during the relaxation period?
11. What is happening at the axon terminal during excitation? What is happening within the myofibril during contraction?

Think about these questions; please ask me for help if you have trouble with any of them!

Chapter 11: Introduction to the Nervous System and Nervous Tissue

Structural & Functional Divisions of the Nervous System



	Central Nervous System CNS	**Peripheral Nervous System PNS**
What structures are found here?		
What is the function of this system?		
Are there any FUNCTIONAL subdivisions in this system?		
If so, what are they, and what are their functions?		

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Functions of the Nervous System

1. **Sensory input (afferent)**: receptors in _____ and _____ send information to the brain and spinal cord in the CNS. Gather information about the internal environment of the body and external stimuli (touch, taste, sound, sight)
2. **Performs integration**: The CNS processes all incoming sensory input and sends out nerve impulses to effector organs: muscles and glands.
3. **Stimulates motor output (efferent)**: The CNS sends out nerve impulses to effectors such as _____ and _____. In response to stimulation, the muscles contract and the glands secrete.

Cells Associated with Nervous Tissue

A. **Neurons:** long-lived cells that 1) conduct nerve impulses and 2) lose the ability to divide. These neurons are classified by their functions:

1. **Sensory Neurons (or Afferent Neuron)**: conduct nerve impulses from the body's sensory receptors *toward* the CNS. Gather information from receptors that detect information from skin, muscles, joints, or internal organs. Sensory receptors can be **interoceptors** (carry info from internal systems, taste, pressure, pain), **exteroceptors** (carry info from touch, temperature, sight, smell, hearing), or **proprioceptors** (carry info about skeletal muscles and joints).
2. **Interneuron (or Associated or Integration Neuron)**: found only within the _____. Conducts nerve impulses between various parts of the CNS (such as from one side of brain to the other side).
3. **Motor Neurons (or Efferent Neuron)**: conduct nerve impulses from interneurons and *from* the CNS to effector organs (muscles or glands) so they are said to "innervate" these structures. Motor neurons cause muscles to contract and glands to secrete.

B. **Neuroglial Cells**: "nerve glue," these cells 1) support, protect, nourish neurons; 2) do not conduct nerve impulses, 3) do not lose the ability to divide.

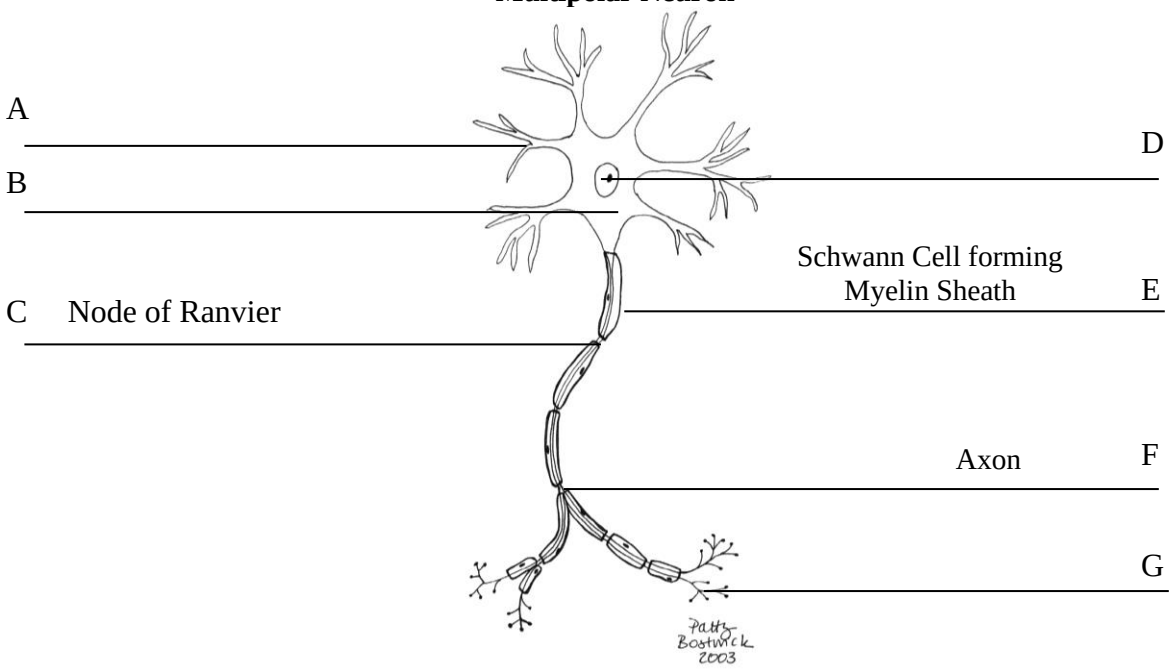
1. **Supporting Cells in CNS** (known as *glia* or *neuroglia*)
   a. **Microglia**: phagocytes that travel to injury sites to <u>fight infections</u>
   b. **Astrocytes**: form bridges between neurons & capillaries to supply nutrients to neurons. These cells also create the <u>blood-brain barrier</u> to isolate the CNS from the general circulation.
   c. **Oligodendrocytes**: produce the <u>myelin sheath</u> for neurons in the CNS
   d. **Ependymal cells**: help circulate <u>cerebrospinal fluid</u> in cavities of the CNS using cilia.
2. **Supporting Cells in the PNS**
   a. **Satellite cells**: surround cell bodies of neurons located within ganglia
   b. **Schwann cells**: produce the _____ _____ for neurons in the PNS

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Multipolar Neuron Structure

1. **Cell Body** (B): contains the nucleus(D) and other organelles; metabolic center of the cell.
2. **Axon** (F)**:** a type of fiber that conducts nerve impulses away from the cell body.
   - Usually only 1 per neuron (for multipolar neurons)
   - Can be 3-4 feet in length (such as length of leg)
   - The region where the cell body and axon join is called the **axon hillock**
   - Branches at the end are called **axon terminals** or **synaptic terminals** (G)
   - **Functions:** Axons conduct nerve impulses away from the cell body & help create a new one in neighboring neuron. The action potential causes the axon terminals (synaptic knobs) to release a chemical called a _____ in order to excite / inhibit other nearby neurons.
3. **Dendrites** (A): a type of fiber that conducts nerve impulses toward the cell body.
4. **Myelin Sheath**: a whitish, fatty protein covering on long axons
   - **Function**: wrap, insulate, and protect the axons of the nerve fibers
   - _____(E): form the myelin sheaths around nerve fibers that are found in the **PNS**. They are specialized supporting cells that wrap themselves tightly around the axon.
   - A myelin sheath is formed from the wrappings of Schwann cells around the axon.
   - _____(C): gaps between Schwann cells (myelin sheaths). Nerve impulses (action potentials) jump from one node to the next node thus speeding up nerve impulse transmission.
   - **White Matter**: myelinated nerves (with Schwann cells in PNS or oligodendrocytes in CNS)
   - **Gray Matter**: unmyelinated axons, dendrites, and cell bodies

Multipolar Neuron



Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Nerve Impulse Transmission

How to Transmit a Nerve Impulse Along an *Unmyelinated* Axon

A. Resting Potential of a Neuron

1. The plasma membrane of a resting neuron is "*polarized*."

2. *Polarized* means charges are unequally distributed on either side of the cell's membrane. This unequal distribution results in a "membrane potential" that can be measured by a voltmeter.

   a. Potassium has the symbol of K and a +charge. It is a cation.

   Potassium (K+) is one of the cations normally found *inside* the neuron in the ICF.

   b. Sodium has the symbol of Na and a +charge. It is a cation.

   Sodium (Na+) is one of the cations normally found *outside* the neuron in the ECF.

3. Cell remains inactive in **Resting Potential** as long as inside is more **negative** than the outside. *Do you know why the inside is more negative than the outside when we're dealing with two positively charged ions?* The charge comes from the location of the ions – most are outside the cell so the exterior has a + charge while there are less ions inside, thus a – charge. Potassium can permeate (and leaks) through the plasma membrane easier than sodium, so the interior of the cell is left with a negative charge due to the negatively charged proteins there. The plasma membrane is more *resistant* to the movement of sodium ions across the membrane, so sodium stays on the outside of the cell unless the permeability of the membrane is changed.

4. The overall charge for the interior of the neuron at rest is **–70 mV**. The negative charge indicates that the interior of the cell contains less ions in comparison to the outside of the cell.

5. The **electrochemical gradient** (remember, a gradient is created when there is a high concentration of ions or molecules in one area) of sodium ions is greater outside the membrane.

Summary of Events

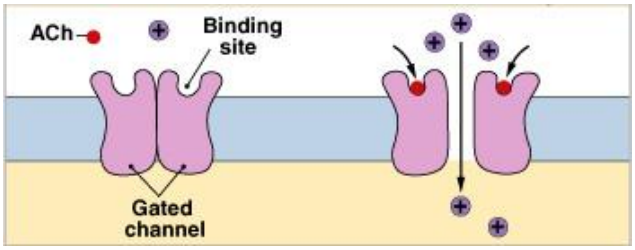
	Resting Potential	**Depolarization**	**Action Potential**	**Repolarization**	**Hyperpolarization**
Charge inside neuron	negative (-70 mV)	negative, but becoming positive	positive (+30 mV)	negative (due to leaky K+ channels)	more negative than resting potential (-90 mV)
Charge outside neuron	positive	positive	negative	positive	positive
Location of Na+ ions	outside cell	entering the cell	entering cell through Na+ channels	inside, then pumped out by Na-K pump	outside cell
Location of K+ ions	inside cell	leaking from the cell	leaving cell through K+ channels	outside, pumped in by Na-K pump	inside, but leaking out

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

B. Depolarization & Creation of an Action Potential = Conducting a Nerve Impulse

1. A nerve impulse (stimulus such as a neurotransmitter) changes the permeability of the cell's plasma membrane for a brief moment. Recall that acetylcholine binds to receptors at the neuromuscular junction; these receptors are **chemically-gated channels**. → The **chemical event** involves a **neurotransmitter**.

2. Normally, sodium ions cannot diffuse through the plasma membrane, but the stimulus allows the sodium ions to enter through activation gates in the membrane. These **voltage-gated protein channels** let sodium into the cell. Voltage gated channels respond to a change in voltage and create an open potential. Normally, these channels are closed when the cell is in resting potential. → The **voltage event** involves movement of **sodium ions** into the cell.

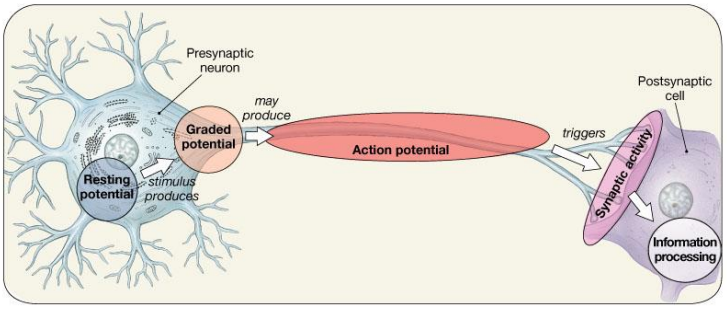


3. The movement of positively charged sodium ions into the cell changes the *polarity* and the *voltage* of the cell. Now, the inside of the neuron becomes **positively charged** while the outside becomes **negatively charged**.

4. If the stimulus is strong enough and **threshold** is reached (**-55 mV**), the action potential is generated (+30 mV) and the nerve impulse is sent along the cell. (Threshold is the voltage that must be overcome in order for the neuron to become depolarized. Once threshold is reached, the action potential propagates. There's no such thing as a weak or strong action potential). Action potentials are **all-or-none** meaning that if a stimulus is strong enough to overcome the threshold, then the stimulus will cause an action potential. Likewise, if the stimulus is *not* stronger than the threshold, then the action potential will *not* propagate along the cell.

   a. **Graded potential**: occurs at dendrites; localized flow of current ↓ with distance; *NOT* an action potential.

   b. When the stimulus changes the environment and gates open, either sodium can rush in causing **depolarization** or potassium can leak out causing **hyperpolarization.** Hyperpolarization creates an environment inside the cell that is even *more negative* than polarization…making it difficult to reach action potential.



5. Ultimately, the change in voltage is called **depolarization** and it occurs when the resting potential shifts toward a more positive value (resting potential is -70mV while the values shift to -45 mV, -10mV, +10mV…etc.)

6. The more channels open → the more sodium ions enter the cell →the greater the area of the membrane is affected → the greater the degree of depolarization. And, the greater the degree of depolarization, the better chance of reaching threshold and creating an action potential.

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

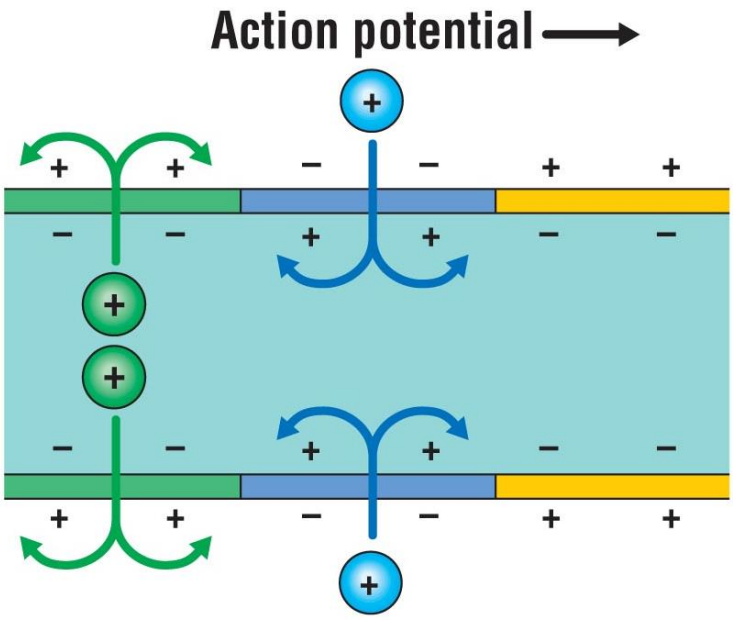
C. Repolarization (restoring the resting potential)

1. As soon as sodium ions rush into the membrane, the permeability changes again and the membrane becomes impermeable to sodium ions. **Repolarization** follows the pathway of **depolarization**. (Think of repolarization as the clean-up crew following behind depolarization)

2. We have two problems to fix during repolarization that were created by depolarization:
   a. The inside is positive (must reset it to negative to be back at resting potential)
   b. The sodium ions are now inside (must place them back outside the membrane to be at resting potential)

3. Part of the problem mentioned in #2a, above, is resolved when **potassium** ions diffuse out during action potential, which begins to restore the **negative charge** on the inside of the membrane and the positive charge on the exterior of the neuron.

4. And, #2b is fixed when An ATP powered pump called the **sodium-potassium pump** completely restores the resting state condition. The sodium-potassium pump returns the sodium ions back outside and moves the potassium ions back inside. For every 3 Na+ ions moved out, 2 K+ ions move into the cell. *Why the inequity*?



In the picture above, can you identify the areas of:
1) resting potential, 2) action potential, and 3) repolarization

- The **refractory period** is the amount of time that must pass before an action potential can be generated again from a stimulus. The refractory period depends on the state of the sodium-potassium pumps.
- **Saltatory** (= *leaping*) **progations** occur in *myelinated axons*. The nerve impulse jumps from nodes between Schwann cells and results in faster propagation.

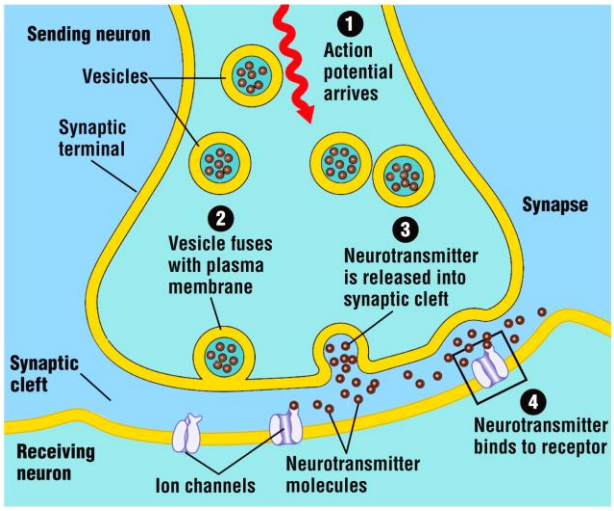
Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

D. **Synapse: How does the electrical impulse travel from one neuron to the next?**

1. The nerve impulse travels to the end of the neuron, into endings called **synaptic terminals** or **axon terminals.**
2. The axon membrane is called the **synaptic terminal (axon terminals)** while the dendrite membrane that's receiving the message is called the **postsynaptic membrane (dendrites).** Only the postsynaptic membrane has receptors for the neurotransmitter which ensures the message travels only in one direction.
3. The small gap between the two membranes is called the **synaptic cleft.** So, when the nerve impulse travels to the end of the axon terminals, the message travels to the next neuron via a chemical called a **neurotransmitter**.
4. Action potentials are electrical signals. To carry this signal across the synaptic cleft to the neighboring neuron, the signal must b e changed to a chemical signal by means of a neurotransmitter.

Here's what has to happen for the action potential to be carried to the next cell:

5. The action potential activates calcium channels; calcium enters the axon and causes neurotransmitter vesicles to release the neurotransmitter by exocytosis into the synaptic cleft.
6. The neurotransmitter binds to receptors on the postsynaptic membrane.
7. Binding causes **chemically-gated channels** to open. Once the message has been transferred, enzymes break down the neurotransmitter so the effect is not continued.
8. The neurotransmitter will cause a graded potential (will be either local depolarization or hyperpolarization).



9. **Types of responses** (depend on the type of receptor activated):

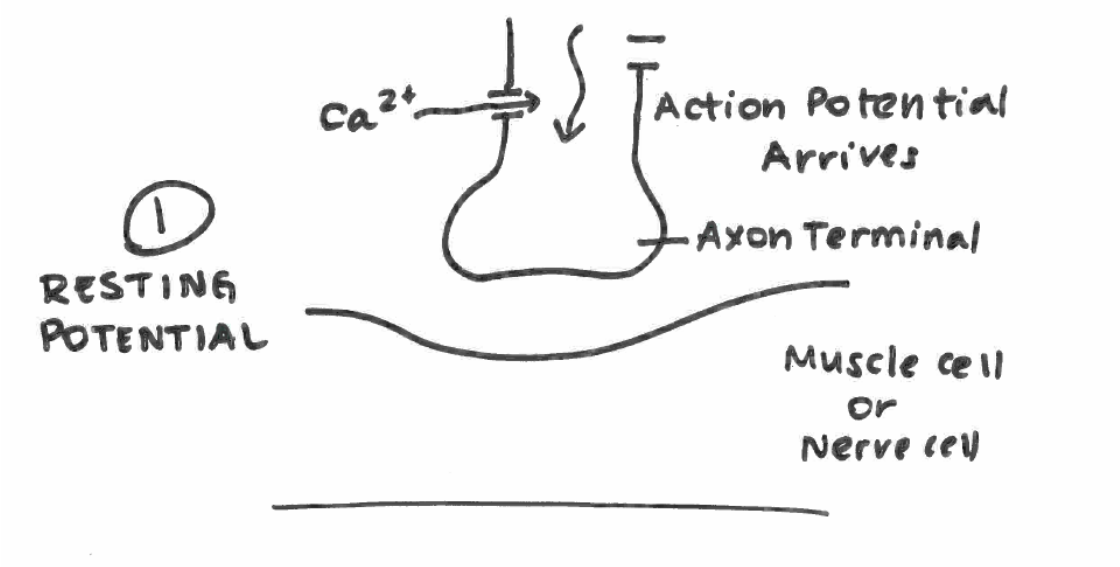
a. **Excitatory postsynaptic potential (EPSP)**: **depolarization** occurs due to open sodium channels and *sodium rushes into the cell*. If strong enough, threshold will be reached and an action potential created.

b. **Inhibitory postsynaptic potential (IPSP)**: **hyperpolarization** occurs due to open potassium channels and allows *potassium leaks out of the cell*. Now, it's more difficult to reach threshold and the chance of forming an action potential is lowered since the internal environment is -90mV instead of -70 mV.

c. Since dendrites create synapses with many axons, how can a cell reach action potential when some cells are sending inhibitory signals and other send excitatory signals? If the signals allow the cell to reach threshold, then the action potential will proceed.

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

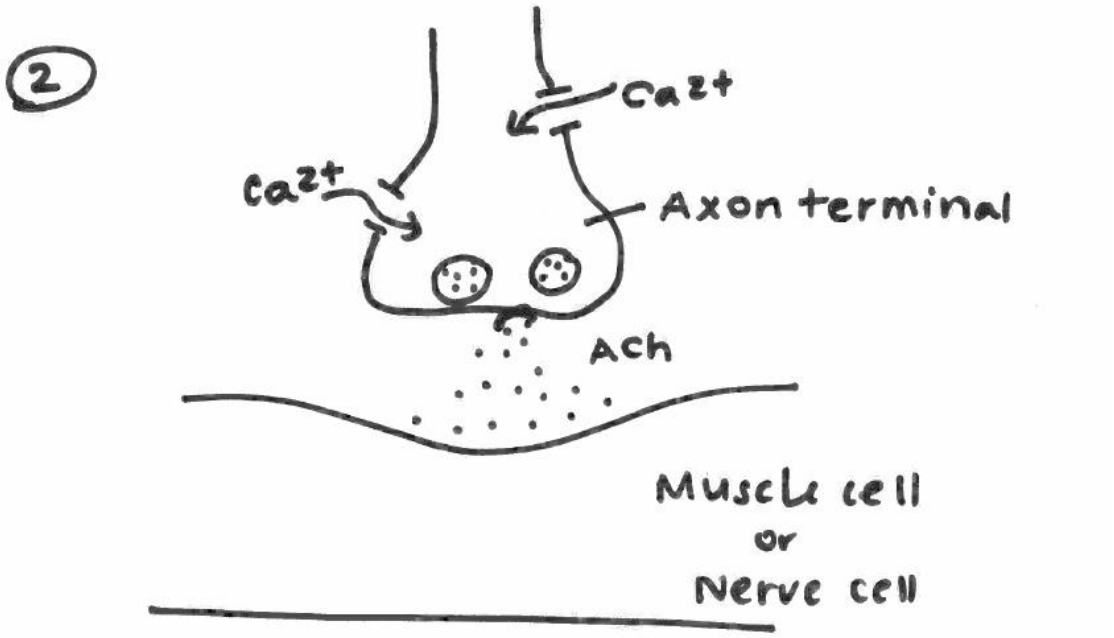
Nerve Impulse Transmission Summary



1. What stimulates the opening of calcium channels in the axon terminal? _____
2. Where are sodium and potassium ions located in respect to the postsynaptic cell during resting potential?

_____

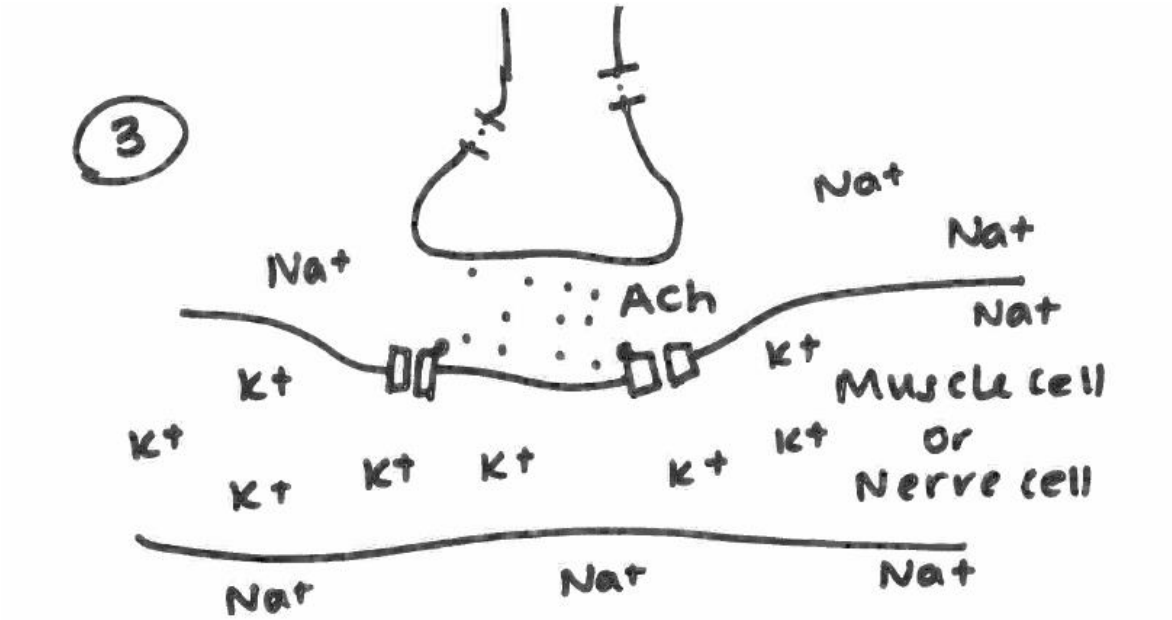
3. Label the charges (+ and -) during resting potential for the postsynaptic cell.



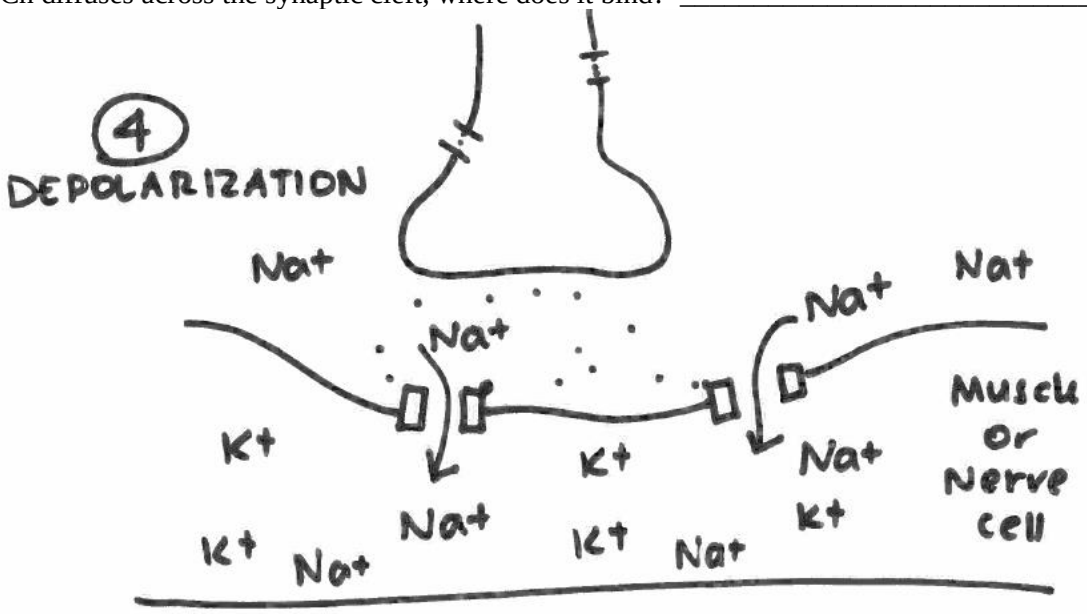
4. What ion must enter the axon terminal in order for vesicles of ACh to leave the axon terminal? _____
5. Label the charges (+ and -) during resting potential for the postsynaptic cell.

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Nerve Impulse Transmission Summary



6. Once ACh diffuses across the synaptic cleft, where does it bind? _____



7. Why do sodium channels open on the postsynaptic cell? _____

8. Describe the change in polarity in the postsynaptic cell when sodium channels open. _____

_____

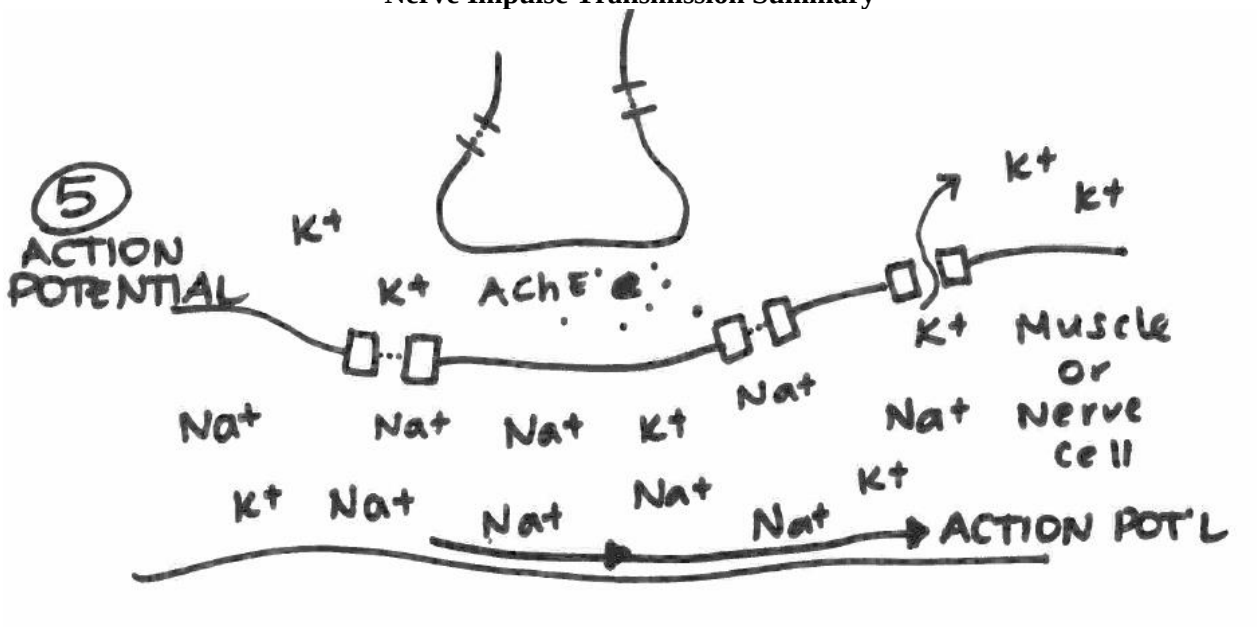
9. Label the charges (+ and -) during resting potential for the muscle/nerve cell.

10. Does depolarization guarantee an action potential? Explain. _____

_____

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Nerve Impulse Transmission Summary

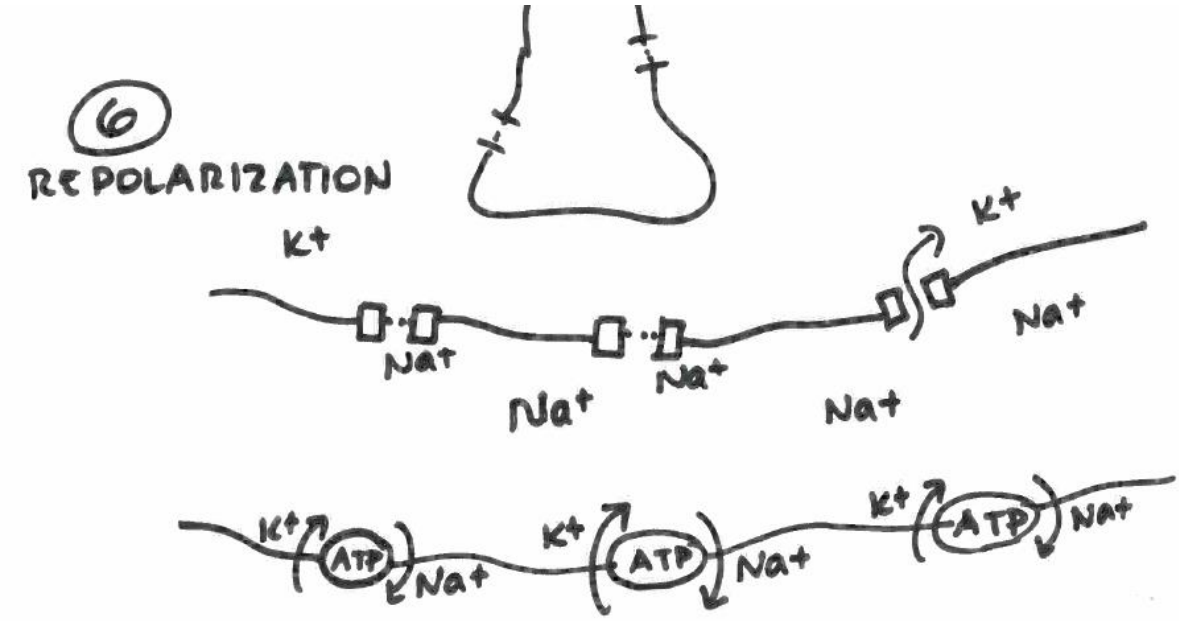


11. What is the role of AChE? _____

_____

12. What charge is inside the postsynaptic cell during action potential? _____

And the charge outside the cell? _____



13. As potassium leaves the cell through channels, what happens to the charge inside the cell? _____

14. What does the sodium-potassium pump accomplish? _____

15. What is the refractory period? _____

Can you teach or talk this out loud to someone else?
Yes *– you've got it!* ***No****? Practice more, come see me, or seek help with a tutor.*

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

Review of Nervous Systems Basics

Neuron Anatomy and Function

Match the correct letter with the description.

_____1. Portion that releases neurotransmitters
_____2. Part that conducts electrical currents toward the cell body
_____3. Substance that increases speed of impulse transmission
_____4. The portion of the nerves in the CNS that lack myelin sheaths are:
_____5. Part that generally conducts impulses away from the cell body
_____6. The part of the neuron that can be myelinated
_____7. Typically only one of these on a neuron
_____8. There are usually many of these processes on a neuron
_____9. Forms the myelin sheath by wrapping the axon
_____10. Another name for the axon terminals is:
_____11. The portion of the nerves outside the CNS that have been myelinated are:
_____12. Location of the nucleus and metabolic center of the nerve cell
_____13. Collections of these in the CNS are called tracts.
_____14. Collections of these in the PNS are called ganglia.

A. axon
B. axon terminal
C. cell body
D. dendrite
E. gray matter
F. myelin sheath
G. Schwann cell
H. synaptic knobs
I. white matter

Review of Nervous Systems Basics

Types of Neurons

Match the correct letter with the description.

_____1. Another name for an afferent neuron is:
_____2. Cause muscles to contract and glands to secrete.
_____3. These neurons are found only within the CNS.
_____4. Conduct nerve impulses from interneurons away from the CNS.
_____5. Conduct nerve impulses from sensory organs to the brain or spinal cord.
_____6. Conduct nerve impulses between parts of the CNS.

A interneuron
B. motor neurons
C. sensory neurons

Neuron Anatomy and Function Answers: 1C, 2D, 3F or G, 4D, 5A, 6A, 7A, 8D, 9G, 10H, 11A, 12C, 13C, 14C; **Types of Neurons Answers:** 1C, 2B, 3A, 4B, 5C, 6A

Chapter 11: Introduction to the Nervous System and Nervous Tissue, Continued

For Discussion:

1. What is the difference between a *hyperpolarized* and a *polarized* neuron? How would each respond to a nerve impulse? Which situation is more likely to produce an action potential?
2. What is the difference between a *polarized* and a *depolarized* neuron? Where are sodium and potassium during each situation?
3. What is the difference between a *depolarized* and a *repolarized* neuron? Include in your answer the location of charges and ions.
4. What are the roles for sodium and potassium in nerve impulse transmission during an action potential?
5. Depression may involve the lack of neurotransmitters, such as acetylcholine. How would muscles respond to less neurotransmitter present at the synaptic cleft? Would neurons be able to reach threshold?
6. A cell in its refractory period receives a stimulus to transmit a nerve impulse. Describe how the cell responds.
7. How does information travel from the brain to effectors? What is the pathway taken?
8. Describe the function of the supporting cells in the CNS and PNS.
9. Explain the function of interneurons in the nervous system.
10. Name and describe the functions of two branches of the peripheral nervous system (PNS).
11. Describe the type of nerve impulse transmission that occurs along a *myelinated* axon.
12. Describe the role that a neurotransmitter plays in transmitting a nerve impulse.
13. Explain the difference in electrical states inside & outside the neuron during action & resting potentials.
14. Explain why myelination helps to speed a nerve impulse.
15. Discuss the role of the Schwann cell in transmitting nerve impulses.
16. Describe the different functions of a motor nerve and a sensory nerve.
17. Differentiate between the function and structure of the axon and dendrites.
18. Describe the difference between the CNS and the PNS both in structures and function.
19. What does it mean for an impulse to reach “threshold?”
20. Cocaine, like novocaine and other anesthetics, blocks sodium channels. How do muscles respond?

Chapter 12: The Central Nervous System & Chapter 13: The Peripheral Nervous System

Brain and Spinal Cord compose the CNS

Bony Protection comes from the skull and vertebrae.

- The skull forms the cranial cavity and houses the brain.
- The vertebrae forms the spinal (vertebral) cavity and houses the spinal cord.

Spinal Cord

Structure: Extends 18" from the foramen magnum of the skull to the first or second lumbar vertebrae (L_1 or L_2). It is found within the vertebral foramen, a hollow area of the vertebrae. The tapered end of the spinal cord is called the **conus medullaris** and the branching spinal nerves form the **cauda equina**. The **filum terminale** is a thin strand of fibrous tissue that continues to the second sacral vertebra.

Protection: Like the brain, the spine is covered by three **meninges** (membrane) layers:

- **Dura mater**: tough, outer covering. Between the dura mater and the walls of the vertebral canal is the *epidural space* containing adipose tissue and blood vessels.
- **Arachnoid**: the middle layer composed of a spider-web like network of collagen and elastic fibers. It is within the *subarachnoid space* that the *cerebrospinal fluid* (CSF) circulates as a shock absorber and a diffusion medium for nutrients, wastes, gases, and chemical messengers.
- **Pia mater**: innermost layer composed of elastic & collagen fibers; anchored to underlying brain/spinal cord.

Parts of the Spinal Cord:

- **31 pairs** of spinal nerves (part of the PNS) are named for the vertebrae each is inferior to. For instance, the spinal nerve emerging inferior to T_1 vertebra is known as spinal nerve T_1. However, in the neck region, each spinal nerve takes the name of the cervical vertebra immediately beneath it.
- All spinal nerves are mixed nerves (means they contain both motor and sensory neurons). There are no spinal nerves that serve the head, but here are the areas those 31 pairs do serve:
  - 8 cervical
  - 12 thoracic
  - 5 lumbar
  - 5 sacral
  - 1 coccygeal

Spinal Nerve: considered a "**mixed nerve***" since it contains both motor and sensory neurons. Each spinal nerve passes through the **intervertebral foramen** between the vertebrae. (*For comparison, some cranial nerves are *mixed*.)

- **Dorsal Roots**: contains afferent axons of **sensory** receptors going **<u>to</u>** the spinal cord from sensory receptors.
- **Dorsal Root Ganglion**: contains cell bodies of **sensory** neurons which bring information to the spinal cord.
- **Ventral Roots**: contains **motor** axons coming **<u>from</u>** the spinal cord. These motor neurons control **somatic** (voluntary) and **visceral** (involuntary) effectors.
  - **Somatic (SNS) motor neurons** stimulate the skeletal muscles = VOLUNTARY
  - **Autonomic (ANS/visceral) motor neurons** stimulate glands, smooth muscle, or organs = INVOLUNTARY.

Chapters 12 & 13: CNS and PNS, Continued

Gray Matter and White Matter of the Spinal Cord

Gray matter of the spinal cord contains cell bodies, dendrites, and unmyelinated axons. It's shaped like a letter H or a butterfly connected by the gray commissure with the central canal in the center.

Three parts of the gray matter:

- **Anterior (Ventral) Horns**: contains cell bodies of *SNS* **motor** neurons which control voluntary events like those of skeletal muscles. Axons exit via **ventral roots**.
- **Lateral Horns**: contains cell bodies of *ANS* **sympathetic motor** division. Axons of motor neurons also exit via ventral roots. ANS controls **involuntary** events like those of, smooth muscle, glands and organs.
- **Posterior (Dorsal) Horns**: contains **interneurons** (only the CNS contains interneurons). *What's the job of an interneuron?*
- **Gray commissure** takes nerve impulses horizontally across the spinal cord for transport to/from the brain. *Remember* that the left brain controls the right side of the body and vice versa (called **contralateral**).

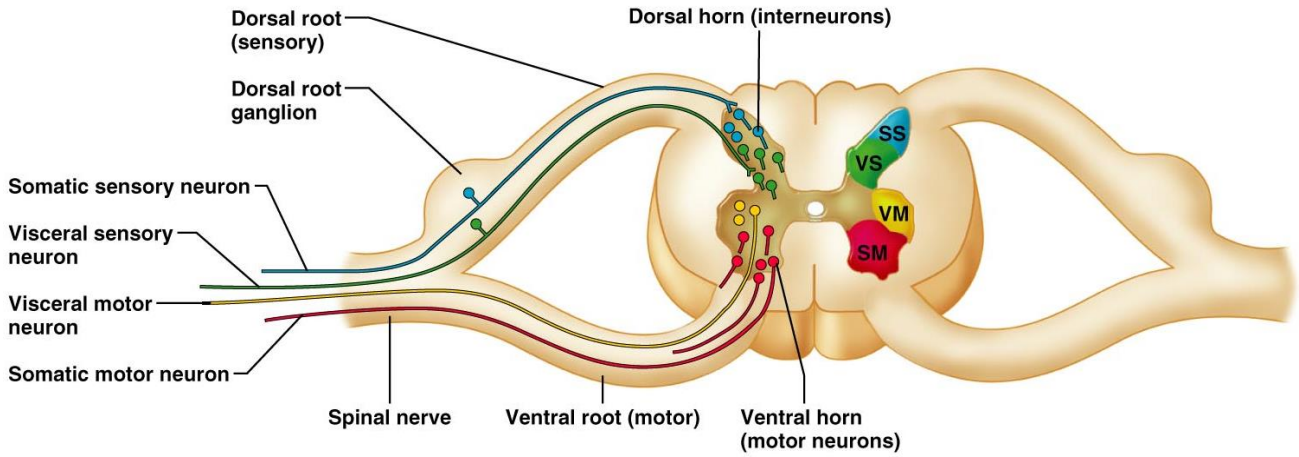
White matter surrounds the gray matter. It contains bundles of myelinated fibers (and some unmyelinated fibers) that form **funiculi** (columns).

Classification of tracts based on direction of impulse:

- **Ascending tracts** take SENSORY nerve impulses up through the spinal cord TO the brain.
    - *Spinothalamic* tracts take **pain** and **temperature** sensory information to the **thalamus** (a brain structure which serves as a relay station for sensory information) through the **lateral white columns**
    - *Spinocerebellar* tracts take **joint** and **muscle** sensory information from proprioreceptors to the **cerebellum** (coordinates and smooths out skeletal muscle activity) through the **lateral white columns**
- **Descending tracts** take MOTOR nerve impulses FROM the brain and down the spinal cord to product motor output and a involuntary or voluntary action.

Phantom limb pain *occurs in people with amputated limbs; due to activity in sensory neurons or interneurons in the spinothalamic pathway.*

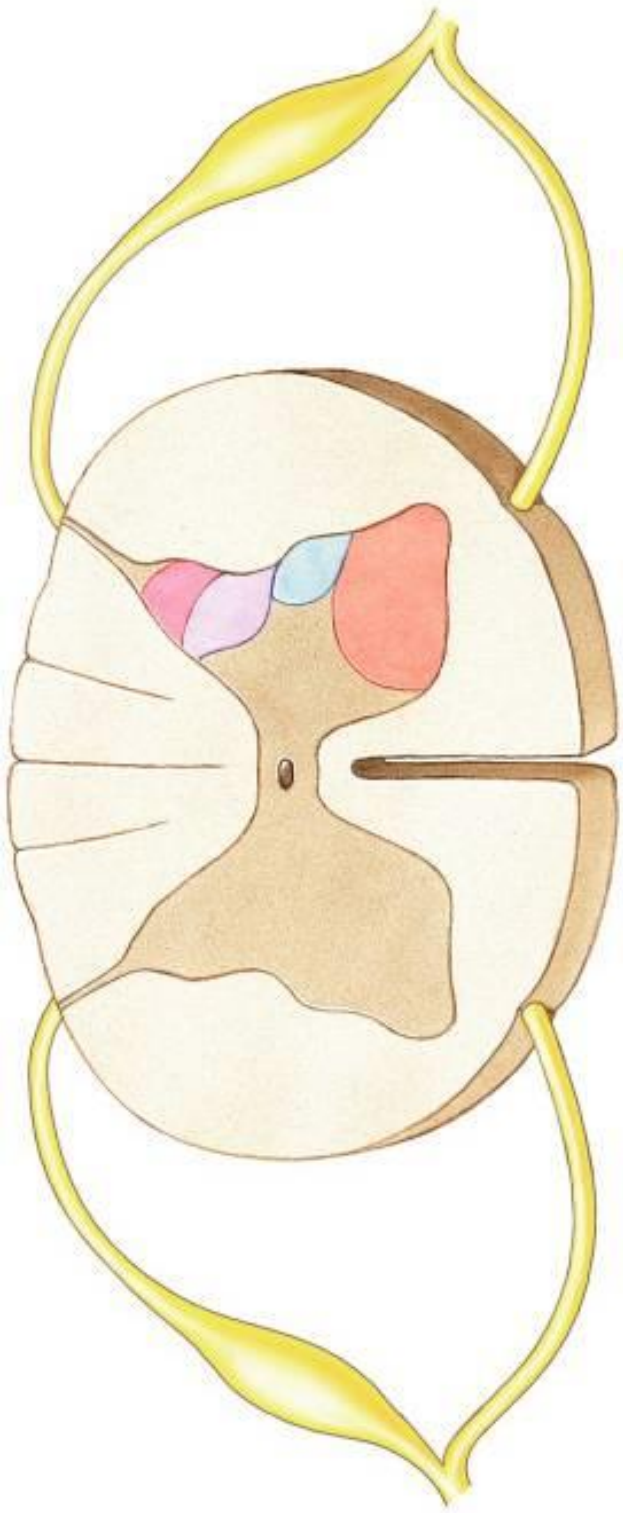
Referred pain *occurs because of strong pain in a particular body area; interneurons in the spinothalamic pathway in the spinal cord can stimulate the primary sensory cortex. That's why heart attack pain is often felt in the left arm or jaw and appendicitis pain is felt around the navel and then the right lower quadrant.*



Chapters 12 & 13: CNS and PNS, Continued

On this picture of the spinal cord/spinal nerve cross section, label the following:

- Dorsal (posterior) and ventral (anterior) orientations
- Dorsal root ganglion
- Dorsal (sensory) root of the spinal nerve and ventral (motor) root of the spinal nerve
- Gray matter with dorsal, lateral, ventral horns with location of interneurons, ANS motor horns, SNS motor horns
- White matter with dorsal, lateral, ventral columns
- Gray commissure
- CNS and PNS



Chapters 12 & 13: CNS and PNS, Continued

Macroanatomy → Microanatomy of a Nerve

Nerve: the entire structure (nerve implies PNS)

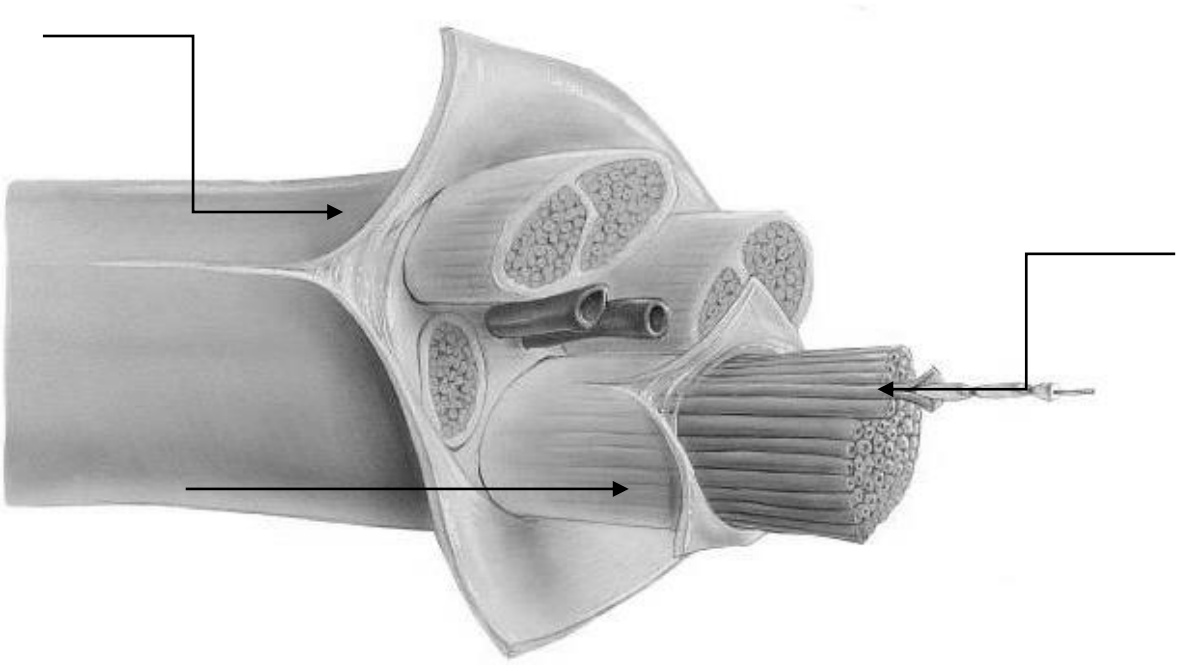
Epineurium: tough, fibrous, sheath of nerve; outermost covering

Fascicle: a bundle of nerve fibers

Perineurium: connective tissue that wraps around a fascicle

Endoneurium: tough, fibrous, sheath of the individual nerve fibers (nerve fiber = nerve cell = neuron)

Can you label the structures, from the list above, on this nerve?



Nerves

Groups of nerves have special names:

- "**Tracts**" are nerves in the CNS.
    - Example: we just talked on the previous page about ascending and descending *tracts;* olfactory tracts are found in the brain (CNS) and carry sensory info (smell) to the appropriate lobe for processing
- "**Nerves**" or "**Ganglia**" are collections of nerves in the PNS (outside the CNS).

  There are 3 functional classifications of nerves:
    - **Afferent/Sensory nerves**: send sensory input **to** the CNS
    - **Efferent/Motor nerves**: send motor output **from** the CNS to effector organs.
    - **Mixed nerves (such as spinal nerves)**: contain both efferent and afferent fibers.

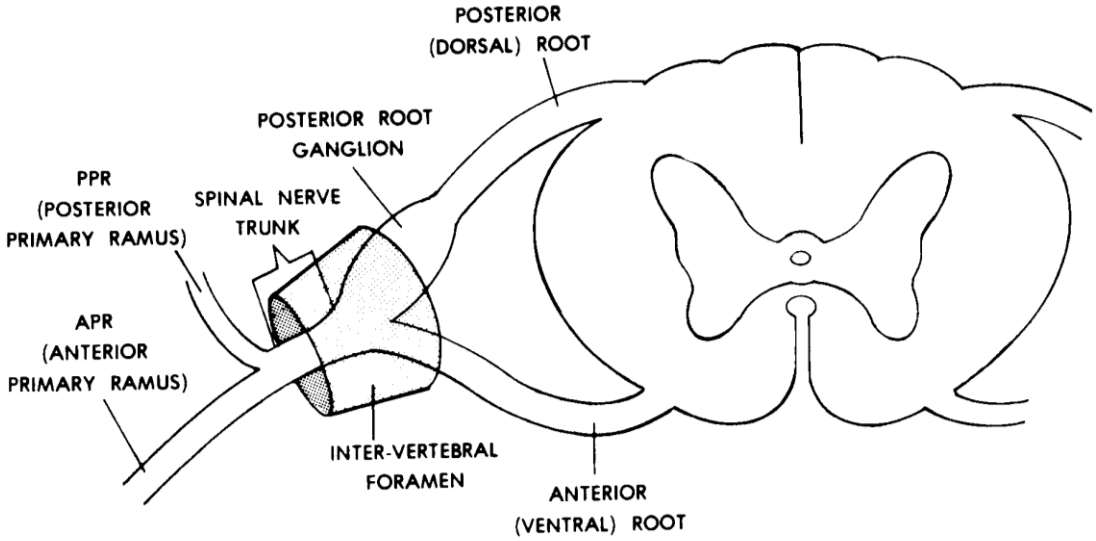
Chapters 12 & 13: CNS and PNS, Continued

PNS: Spinal Nerves

Ramus

Rami are branches of the spinal nerve. (***Roots*** *of the spinal nerve are classified as either sensory or motor while* ***rami*** *are mixed branches containing both sensory and motor neurons*).

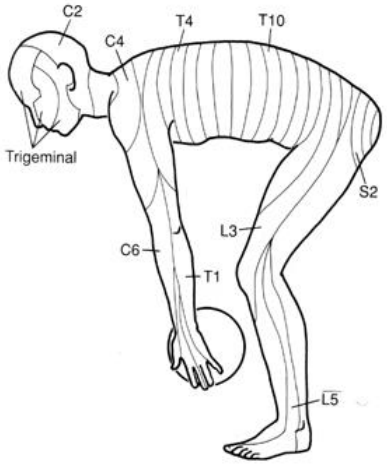
- **Dorsal ramus**: mixed spinal nerve branch traveling toward the dorsal body parts
- **Ventral ramus**: mixed spinal nerve branch traveling toward the ventral body parts



Dermatomes

A **dermatome** is a region of skin served by a single cutaneous spinal nerve. We have mapped the entire human body and its dermatomes. Useful for determining spinal nerve damage (although there's some overlap in some areas).

Shingles and chicken pox (*Varicella* virus) travel along a dermatome typically since the virus causing these two diseases inflames the nerves.



Example of a Dermatome

Chapters 12 & 13: CNS and PNS, Continued

Plexus

A **nerve plexus** is a network of branching/joining of spinal nerves. *Why*? So, if a portion is damaged, other spinal nerves can accommodate. Here are several of the nerve plexus in the body:

Cervical plexus: serves neck

- includes the **phrenic nerve** which stimulates the diaphragm (breathing muscle)

Brachial plexus: serves arms to the hands

- includes 5 major peripheral nerves – **musculocutaneous, median, ulnar, radial, axillary**

Lumbar plexus: serves front of the legs to the feet

- includes **femoral nerve**

Sacral plexus: serves buttocks to the back of the legs to the feet

- includes **sciatic nerve** (longest in the body; runs down the back of the leg)

Solar plexus: serves internal organs and is behind the stomach

- includes **splanchic nerves** and part of the **vagus nerve** (serves heart, lungs, digestive organs)

Reflex Arc

Reflexes are rapid, predictable, automatic, and involuntary responses to a stimulus. Usually reflexes are unlearned, but some reflexes can become acquired and learned (typing). Once it begins, the reflex always travels in the same direction. These reflexes occur over neural pathways called **reflex arcs**.

Reflex Arc Pathways

- General Pathway of a Polysynaptic Reflex: sensory neuron: dendrites → cell body in dorsal root ganglion → axon →transmitted to the interneuron → motor neuron: axon portion conducts messages to the muscles (effector organ) so that they can contract. *What part of the nervous system have we bypassed here?* _____
- *What part of this polysynaptic pathway is missing for a monosynaptic pathway?* _____

Monosynaptic Reflexes	Polysynaptic Reflexes
• Sensory and motor neurons are involved *only*	• Sensory, *interneurons*, & motor neurons
• **Monosynaptic** means "one synapse" – less complicated / faster	• **Polysynaptic** means "many synapses" – more complicated / fast, but not as quick as monosynaptic
• **Stretch reflex:** simplest reflex which involves proprioreceptors (detect stretch in joints). When a muscle is stretched, the automatic response is to **contract**. The purpose is to maintain muscle tone and posture. • **Knee jerk reflex:** leg extends when patellar ligament is struck.	• **Tendon reflex** occurs when muscle contracts, the response is to **relax** the muscle (prevents tearing or breaking of tendons). Antagonistic to the stretch reflex. • **Flexor reflex** causes limb to bend or flex (such as **withdrawal reflex**)

Chapters 12 & 13: CNS and PNS, Continued

For Discussion

1. Explain how the stretch and tendon reflexes are antagonistic.
2. Define reflex. What is the difference between a monosynaptic and polysynaptic reflex?
3. Which type of reflex arc pathway is the fastest? Why?
4. Where are interneurons located (PNS *or* CNS)? What purpose do they serve?
5. What type of information does the dorsal root carry? What about the dorsal root ganglion?
6. What does a visceral (autonomic) motor neuron innervate?
7. What is a nerve plexus? Describe one of the five discussed previously. What body parts are served by the nerve plexus you chose?
8. Why would a blow to the solar plexus knock the breath out of a person? Explain.
9. How could a person continue to have vital organ functions despite a spinal cord injury that prevents communication with the brain? Which nerve plexus is responsible?
10. Discuss how a plexus differs from a ramus.
11. Describe why damage to the cervical plexus could interrupt the process of breathing.
12. Why is a ramus considered a mixed nerve - yet the roots of a spinal nerve are not?
13. Explain how a “tract” differs from a “nerve.”
14. When is the gray commissure utilized and why?
15. Contrast the type of information transmitted over the spinothalamic versus the spinocerebellar pathways.
16. Is a spinal *cord* injury below L_1 or L_2 possible? Explain.
17. Where is conus medullaris located? What happens to the spinal cord inferior to this structure?
18. Contrast the type of information that travels via the dorsal root versus the ventral root of the spinal nerve.
19. Explain the difference between a motor and a sensory neuron.
20. Explain the difference between the terms “efferent” and “afferent.”

Chapters 12 & 13: CNS and PNS, Continued

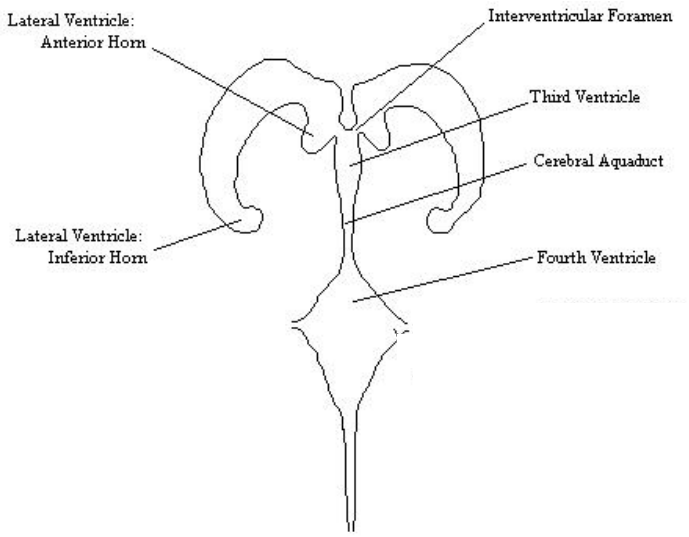
CNS: Brain

Protection: Like the spinal cord, the brain is covered by three **meninges** (membrane layers). These meninges *1)* cover and protect both spinal cord and brain; they also have *2)* blood vessels that create the *3)* cushioning cerebrospinal fluid (CSF) and *4)* secure the brain to the skull.

- **Dura mater** ("tough mother") outermost double-layered structure which contains the *dural sinuses*. The dural sinuses (veins) are in between those two layers and collect blood from the brain and drain it back into the *internal jugular veins* in the neck.
  - **Longitudinal fissure**
    - Midsagittal fissure between the right and left hemispheres of the cerebrum
    - Houses the **superior/inferior sagittal sinuses** (large veins)
  - **Transverse fissure**
    - Horizontal fissure between the cerebrum and cerebellum
    - Houses the **transverse sinus** (large vein)
  - **Cerebellum**
    - Midsagittal fissure between the cerebellum
- **Arachnoid** ("spidery mother") contains the *subarachnoid space* which has threadlike extensions connecting it to the pia mater. This layer does not travel into the brain's folds (sulci). The subarachnoid space is filled with CSF and blood vessels.
- **Pia mater** is the thin layer directly connected to the brain, like shrinkwrap, by astrocytes.

Cerebrospinal fluid (CSF) is a fluid similar to blood plasma that circulates around, cushions, and nourishes brain/SC.

- Formed by *ependymal cells* of the *choroid plexus* located near the ventricles and moved by cilia.
- **Ventricles**: arise from fluid-filled space within the neural tube (early on during development). All are interconnected with the central canal of the spinal cord and lined with ependymal cells and house CSF. The lateral ventricles are separated by the septum pellucidum.
  - 2 lateral ventricles are connected to the third ventricle by the interventricular foramen (foramen of Monro)
  - Third ventricle is connected to the fourth ventricle by the cerebral aqueduct (of Sylvius).
  - Fourth ventricle



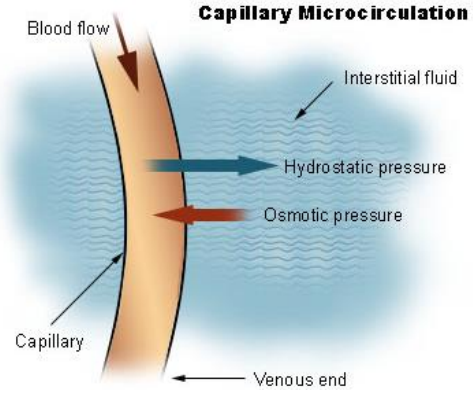
Ventricles of the Brain (Anterior View)

(at right)

Chapters 12 & 13: CNS and PNS, Continued

CSF Flow and Ventricles of the Brain

- **CSF Formation from Blood Involves Filtration -** hydrostatic pressure pushes fluids out of choroid plexus



- **Pathway of CSF**
  - choroid plexus
  - lateral ventricles
  - interventricular foramen (foramen of Monro)
  - 3rd ventricle
  - cerebral aqueduct (of Sylvius)
  - 4th ventricle
  - central canal of the spinal cord
  - subarachnoid space
  - CSF is reabsorbed back into the blood via arachnoid villi in dural sinuses
- **Blood-Brain Barrier**: neural tissue and impermeable capillaries prevent many items from moving into the brain. Generally, lipid-soluble compounds can diffuse into the interstitial fluid of the brain and spinal cord. Only the emetic (vomiting) center in the 1) medulla oblongata and the 2) hypothalamus (for monitoring chemical composition of blood) *lack* the blood-brain barrier.
- **Benefit:** some drugs do not reach the brain
- **Disadvantage**: some cancer drugs do not reach the brain; alcohol can cross the blood-brain barrier

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For Discussion

1. Name the protective layers covering the brain, starting with the skull, from superficial to deep.
2. Where does cerebrospinal fluid originate (form)? Where does it rejoin blood flow?
3. What structures form the blood-brain barrier? What items can pass through this barrier?
4. What regions of the brain are missing the blood-brain barrier? Why?
5. "Sinus" is another name for…
6. What are the names of the dural folds that travel between the 1) left and right cerebral hemispheres, 2) cerebrum and cerebellum, and 3) the cerebellum?
7. What is the function of the dura mater? And the arachnoid mater?

Please see me if you need help with any of these questions!

Chapters 12 & 13: CNS and PNS, Continued

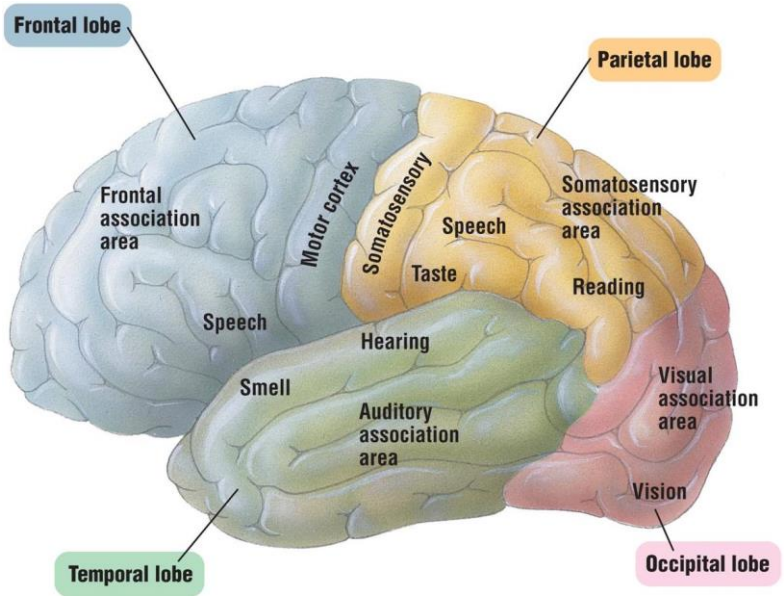
CNS: Brain

Major Regions and Landmarks of the Brain (*discussed below and over the next several pages*)

1. Cerebrum
2. Cerebellum
3. Diencephalon (Thalamus, Hypothalamus, and sometimes the Pituitary Gland is included)
4. Brain stem (Mesencephalon = Midbrain, Pons, Medulla Oblongata)

Cerebrum

- **Location**: larger, outermost, wrinkly portion of the brain that includes gray matter cortex, white matter, and basal nuclei
  - **Lobes**: frontal, temporal, parietal, occipital (and a fifth lobe, called the insula, is deep to the cerebrum)
- **Function of the Cerebrum**: consciousness: perception, communication, understanding, and voluntary movement. Contains interneurons for motor, sensory, and integration of decision-making functions.
  - ***White Matter vs. Gray Matter in the Brain***
    - *White matter is found inside the cerebrum*
    - *Gray matter serves as the outer 1/8" of the cerebral surface (called the* **cerebral cortex***) and in pockets deep within the brain. We'll take a look at* both types next.
- ***GRAY* Matter of the brain (**known as *cerebral cortex*)
  - The outermost 1/8" of the cerebrum; a **gyrus** is a raised hill while a **sulcus** is a grooved valley.
  - Includes motor & sensory areas and integration functions (decision making). Major job of the cerebral cortex is consciousness, perception, communication, understanding, voluntary movement.
  - **Brodmann areas** are functional areas of the brain (such as speech, hearing, primary motor, etc.)
- ***WHITE* Matter of the brain** is found in the interior of the cerebrum (axons myelinated by oligodendrocytes).
  - **Association fibers** interconnect areas of the cortex within a single hemisphere (length of brain A to P)
  - **Commissural fibers** permit communication between left/right hemispheres; include the **corpus callosum**
  - **Projection fibers** link the cerebral cortex to the rest of the brain (information is carried to/from cortex)



Chapters 12 & 13: CNS and PNS, Continued

Practice labeling this info on the pic from page 116!

CNS: Cerebrum of the Brain

	Location	Function	Disorder
MOTOR			
Voluntary	**Frontal lobe** Premotor cortex Primary motor cortex (Precentral gyrus)	Coordinates conscious motor control	Cannot move
Subconscious	Basal nuclei (gray matter in cerebrum)	Coordinates subconscious voluntary motor control – such as swinging arms when walking	Parkinson's and Huntington's disease result from lack of dopamine to regulate the basal nuclei.
SENSORY			
Somatic Sensory Area and Association Area	**Parietal lobe** (Postcentral gyrus)	Receive and interpret somatic sensory information from skin, joints, muscles, touch, pressure, pain, vibration, taste, temperature	Primary Somatic Sensory Area: Cannot feel touch Somatic Sensory Association Area: Unable to make sense of what is felt.
Visual (Primary and Association Areas)	**Occipital lobe**	Receive and interpret visual information	Primary Visual Area: Blindness Visual Association Area: Unable to identify what you see
Auditory (Primary and Association Areas)	**Temporal lobe**	Receive and interpret sound information	Primary Auditory Area: Deafness Auditory Association Area: Unable to identify sounds, voices
Smell (Olfactory)	**Temporal lobe**	Smell perception	Unable to smell
Taste (Gustatory)	**Parietal lobe**	Taste perception	Unable to taste
GENERAL INTERPRETATION			
General Interpretive Area	**LEFT Hemisphere**	Receives information from all sensory areas and creates memory	Unable to interpret what is seen or heard although words are understood as individual entities
Speech	**LEFT Hemisphere**	Coordinates breathing and vocalization necessary for speech	Make sounds, but no words
Prefrontal cortex	**Frontal lobe**	Coordinates information from all association areas –personality, decorum, toilet training	*Prefrontal lobotomies* damage the frontal lobe functions
HEMISPHERIC LATERALIZATION			
	Left Hemisphere	Reading, writing, speaking, languages, math, logic (usually dominates)	
	Right Hemisphere	Visual/spatial skills, emotion, intuition, spontaneity	

Chapters 12 & 13: CNS and PNS, Continued

Review of the Cerebral Cortex

	Functions	Disorder
Frontal Lobes	1. Primary _____ area which controls movements of _____ muscles. Since motor neurons cross each other creating an "X", the right side of the brain controls the left side of the body. 2. Prefrontal association area in which intellectual processes such as those required for concentrating, planning, complex problem solving, judging behavioral consequences occur.	1. Loss of _____ 2. Loss of judgment, personality changes, loss of decorum, toilet training.
Parietal Lobes	1. Primary _____ area responsible for the sensations of _____, touch, _____, and pain from the skin. 2. Sensory association area functions in understanding speech and using words to express thoughts and feelings.	1. Loss of _____ 2. Can't identify items by touch alone; must see or use another sense
Temporal Lobes	1. Primary _____ area which is responsible for hearing. 2. Auditory association area interprets pitch, rhythm, loudness of sounds, visual scenes, and complex sensory patterns.	1. Deafness 2. Can't identify sounds
Occipital Lobes	1. Primary _____ area which is responsible for vision and recognizing what is seen (like letters of the alphabet) 2. Visual association area that combines visual images with other sensory experiences.	1. Blindness 2. Can't identify items by sight.

Sensory, Motor, and Association Areas

We can organize lobes by their function as primary or association areas; identify the lobe(s) responsible for:

Primary motor area _____

Primary sensory area _____

Primary auditory area _____

Auditory association area _____

Visual association area _____

Prefrontal association area _____

Sensory association area _____

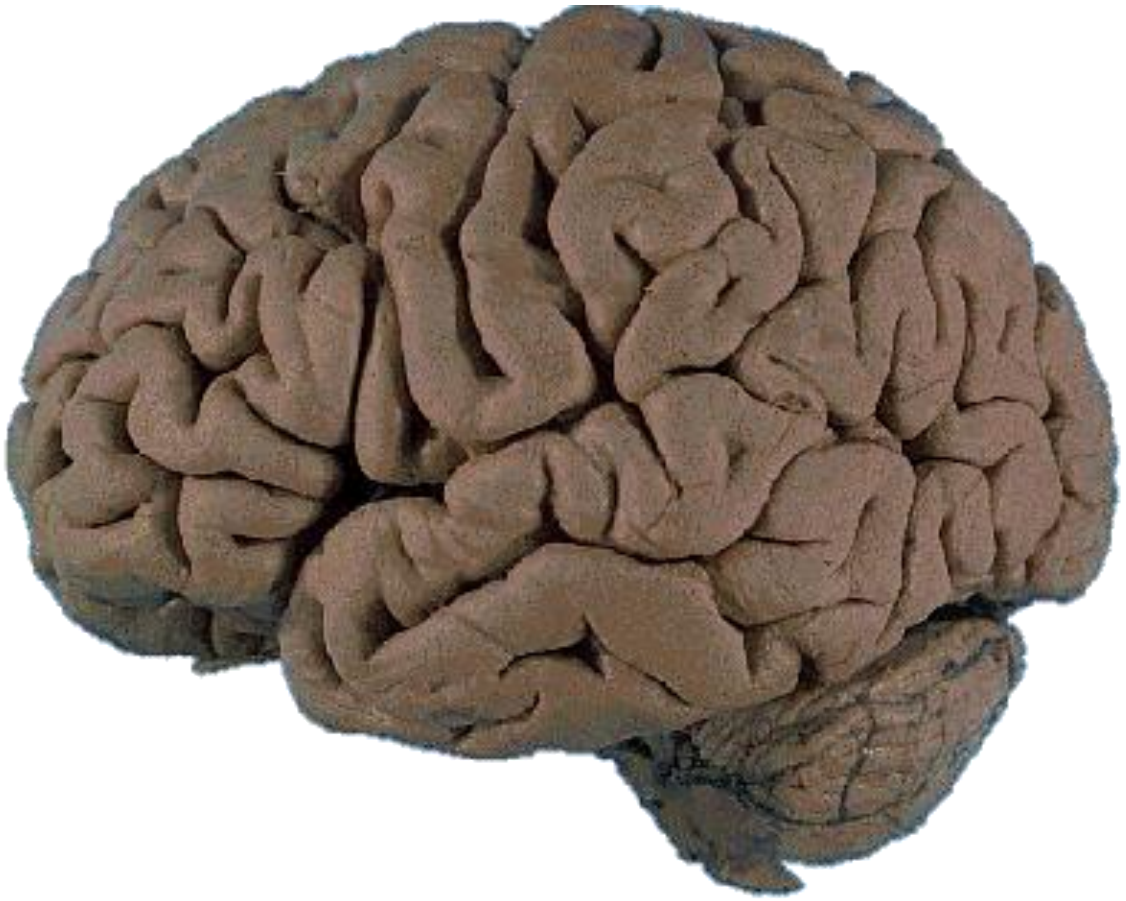
Primary visual area _____

Chapters 12 & 13: CNS and PNS, Continued

Review of the Brain

Locate and label the following on this brain:

frontal lobe
temporal lobe
occipital lobe
parietal lobe
cerebellum
transverse fissure
sulcus (any)
gyrus (any)
central sulcus
precentral gyrus
postcentral gyrus
prefrontal cortex
primary motor cortex
primary somatic sensory cortex
primary visual cortex
primary auditory cortex
speech center
general interpretive area



Chapters 12 & 13: CNS and PNS, Continued

CNS: Brain

Cerebellum

- **Location**: posterior to the cerebrum; separated from the brain by the 4th ventricle; it's two masses of tissue connected in the middle by the vermis; has outer gray matter and inner white matter (arbor vitae).
- **Functions**: integration center for inner ear and **muscle coordination** of voluntary movements.

Diencephalon [hypothalamus, thalamus, and the pituitary gland]

Hypothalamus

- **Location**: forms the floor of the 3rd ventricle; inferior to the thalamus
- **Function**: maintains **homeostasis** (maintenance of a constant internal environment) and 1) controls the ANS, 2) emotional responses, 3) regulatory of body temperature, 4) regulation of food intake (hunger), 5) regulation of water balance and thirst, 6) regulation of sleep-wake cycles, 7) control of endocrine functions/hormones

Thalamus

- **Location**: forms the lateral walls of the 3rd ventricle
- **Function**: 1) **relay station** for incoming **sensory information** (except smell) on the way to the cerebral cortex for interpretation (such as somatic sensory); 2) suppresses unimportant information (such as clothes touching your body); 3) regulates sleep and wake cycle (with the hypothalamus and pineal body).

Pituitary Gland

- **Location**: hangs from a stalk, the *infundibulum*, from the hypothalamus
- **Function**: with the hypothalamus, it integrates nervous and **endocrine system** function.

Brain Stem [medulla oblongata, pons, and midbrain]

Medulla oblongata

- **Location**: found between the spinal cord and the pons; anterior to cerebellum.
- **Function**: Houses four centers:
    1. **Cardiovascular center** for control of heart rate
    2. **Respiratory center** for control of respiration rate
    3. **Emetic center** for vomiting
    4. **Vasomotor center** for control of blood pressure via the diameter of certain vessels
- **Contains**: tracts that ascend or descend between the spinal cord and brain's higher centers.

Pons

- **Location**: superior to the medulla oblongata
- **Function**: assists with **breathing** (switch from inspiration to expiration)
- **Contains**: bundles of axons that travel between the cerebellum and the rest of the CNS.

Midbrain

- **Location**: encloses the cerebral aqueduct
- **Function**: 1) **reflex centers** for visual, auditory, and tactile responses. 2) brain arousal via RAS (see next page for the Reticular Activating System)

Chapters 12 & 13: CNS and PNS, Continued

This page is commonly missed on tests!

Limbic System

- **Location**: beneath the cerebral cortex and includes the hippocampus, amygdala, among other structures
- **Function**: emotional control (fear, anger, love, hate, etc.), motivation, learning, imagination, memory; stimulation of the difference senses brings about a complex memory. It can be acted upon by smell (perfume, a gas, etc.). Too much stress can lead to psychosomatic illness.
- **Contains**: basal nuclei which may have some control over voluntary muscle action. Contains the nuclei of the **hippocampus** (long-term memory storage and retrieval) and **amygdala** (fight or flight response) and the diencephalon (thalamus and hypothalamus).

Reticular Activating System (RAS)

- **Location**: reticular formation in the brain stem
- **Function**: keeps brain alert and aroused; helps filter out unnecessary sensations; controls the ANS. Alcohol puts this system to sleep while LSD turns the filtering part off (person gets sensory overload, hallucinations). Hypnosis also allows a person to be more receptive to suggestions (stop smoking). This system controls the ANS and has both cholinergic and adrenergic components (*we'll talk about these later on*.)

Review of 4 Major Divisions of the Brain

Identify each division of the CNS based on its function or description.

_____1. Integrates the functioning of the ANS
_____2. Relay station for sensory information
_____3. Coordinates voluntary movement
_____4. Responsible for thinking and memory
_____5. Regulates body temperature
_____6. Regulates muscle tone and equilibrium
_____7. Suppresses unimportant sensations
_____8. Regulates endocrine secretions of pituitary gland
_____9. Regulates blood pressure
_____10. Regulates heart rate and breathing
_____11. Center for hate, love, anger, emotion
_____12. Contains the cardiovascular & respiratory centers
_____13. Pituitary gland is most closely associated with the:
_____14. Contains the corpora quadrigemina
_____15. Hungry? Thirsty?
_____16. Contains primary and association centers for visual information
_____17. Alcohol puts this *system* to sleep

A. Cerebellum
B. Cerebrum
C. Hypothalamus
D. Medulla Oblongata
E. Midbrain
F. Pons
G. Thalamus
H. Limbic system
I. RAS

Answers: 1C, 2G, 3A, 4B, 5C, 6A, 7G, 8C, 9D, 10D, 11H, 12D, 13C, 14E, 15C, 16B, 17I

Chapters 12 & 13: CNS and PNS, Continued

Brain/Spinal Cord Problems

FYI – Read at Home

Infectious

- **Meningitis** can be viral or bacterial; inflammation of brain or spinal cord membranes.

Damage

- **Paralysis** is caused by loss of motor function
    - stroke, trauma, spina bifida, botulism
- **Flaccid paralysis** occurs when motor neurons directly serving muscles are damaged; no activity and loss of muscle tone results
    - broken neck, polio, botulism
- **Spastic paralysis** is a CNS disorder causing muscles to tighten and contract
- **Paresthesia** is sensory loss. If temporary due to pressure on nerve, it is often described as "pins and needles." Long-term (chronic) loss can be caused by peripheral vascular disease (PAD), diabetes, carpal tunnel syndrome.
    - cerebral palsy
- **Paraplegia** results from a break between T_1 and L_1 causing lower limb paralysis.
    - spinal cord injury, spina bifida
- **Quadriplegia** results from loss of limbs and torso due to illness or injury; break in the cervical area. Depending on where the break is, a quadriplegic can have fully functional arms but fingers that do not work. Autonomic function can be disrupted.
    - fall, sports injury, car crash
- **Spinal shock** results in temporary total loss of functions due to spinal cord injury
    - whiplash

Developmental Disorders

- **Cerebral palsy** is a group of disorders related to problems with voluntary muscle movement. Can occur before, during, or after birth due to a variety of conditions such as lack of oxygen at birth, viral infection, excessive smoking by the mother, radiation, drugs, alcohol.
- **Spina bifida** results from incomplete formation of vertebral arches—vertebrae do not totally encase the spinal cord. Usually linked to lack of folic acid (a type of vitamin B) during fetal development. Can cause hydrocephaly.
- **Anencephaly** results from no development of the cerebrum and parts of the brain stem; can result from spina bifida. Alpha-fetoprotein (AFP) screening performed during pregnancy tests for spina bifida and anencelphaly. Death occurs within hours or days of birth from anencephaly.

Pathologies

- **Stroke (cerebral vascular accident; CVA; aphasia)** results from clots, hemorrhage, or edema. The lack of oxygen leads to the death of brain cells. Paralysis.
- **Concussion** is mild trauma to the brain while **contusion** is severe trauma that can lead to a coma
- **Cerebral edema** results from swelling of the brain due to trauma

Chapters 12 & 13: CNS and PNS, Continued

For Discussion

1. Trace the pathway of cerebrospinal fluid from its point of formation until it is reabsorbed back into the blood.
2. Identify the four major regions of the brain.
3. What are the major functions of the hypothalamus, pons, medulla oblongata, thalamus, and midbrain?
4. Why do people with head trauma die from damage to the brain stem when it was not the portion of the brain that was traumatized?
5. Which system, found beneath the cerebral cortex, responds to emotions such as love and hate?
6. Why can a person with spinal cord injury still exert control over breathing? Which nerve plexus is responsible?
7. What functions are housed in the precentral and postcentral gyri?
8. Why would excess cerebrospinal fluid adversely affect brain function in an adult? Why is a child, under age 1, less susceptible?
9. Which portions of the brain lack the blood-brain barrier? Why do these particular areas lack the barrier?
10. Which structure and which brain region controls homeostasis?
11. Which brain region coordinates movement of skeletal muscles with balance and equilibrium from the ear?
12. What separates the precentral gyrus from the postcentral gyrus?
13. Which lobe of the brain interprets visual images?
14. Julie had a stroke that affected her ability to move the left side of her body. What specific cortex of the brain, what specific lobe, and which hemisphere was affected? Explain.
15. Where does subconscious motor control originate in the brain?
16. Which portions of the brain control auditory and visual reflexes?
17. A person who can identify a coin as a quarter, but cannot say the name of the coin has an impairment in which cortex?
18. Would damage to the thalamus have more of an impact on motor or sensory information?
19. Mr. Thorn had a stroke in his right thalamus. His family was told he would have trouble moving the right side of the body. Did the family get the right news? Explain.
20. Mrs. L. had brain damage that affected her ability to hear any sounds from her left ear. What specific cortex of the brain, what specific lobe, and which hemisphere was affected? Explain.
21. Bell's palsy affects one cranial nerve only. It has caused the right side of Mickey's face to drop. Which specific cranial nerve (name and number) has been affected?
22. Which region of the brain is responsible for regulating breathing and heart rate? Which structures within that region are responsible?
23. Which tracts of the spinal cord bring sensory information to the thalamus? And to the cerebellum?

Chapter 14: The Autonomic Nervous System & Homeostasis

Autonomic Nervous System vs. Somatic Nervous System

- Recall that the **autonomic nervous system** is part of the PNS. The autonomic nervous system (ANS) does not receive incoming sensory information from sensory receptors. Rather, the ANS sends involuntary motor output directions to smooth or cardiac muscles, glands, or organs. Therefore, we call this system the "Involuntary Nervous System" since you can't control its actions! Think *autonomic = automatic*. The ANS has two motor subdivisions, the sympathetic (excitability) and parasympathetic (calming) nervous systems.
- You also might remember we talked about the **somatic nervous system** (SNS). The SNS sends motor output information to *skeletal* muscles. The somatic nervous system is under *voluntary* control.

SNS	ANS
Controls **voluntary** motor events	Controls **involuntary** motor events
Control **skeletal** muscles	Controls **smooth** and **cardiac** muscles, glands, and organs
Uses **one** neurotransmitter (acetylcholine)	Uses **several** neurotransmitters (acetylcholine, epinephrine, norepinephrine, etc.)
Fast	Slow
One-neuron system	**Two**-neuron system
Controlled by the **primary motor cortex** (precentral gyrus of the frontal lobe)	Controlled by the **hypothalamus** (diencephalon region of cerebrum)

Before we go any further, can you answer these questions?

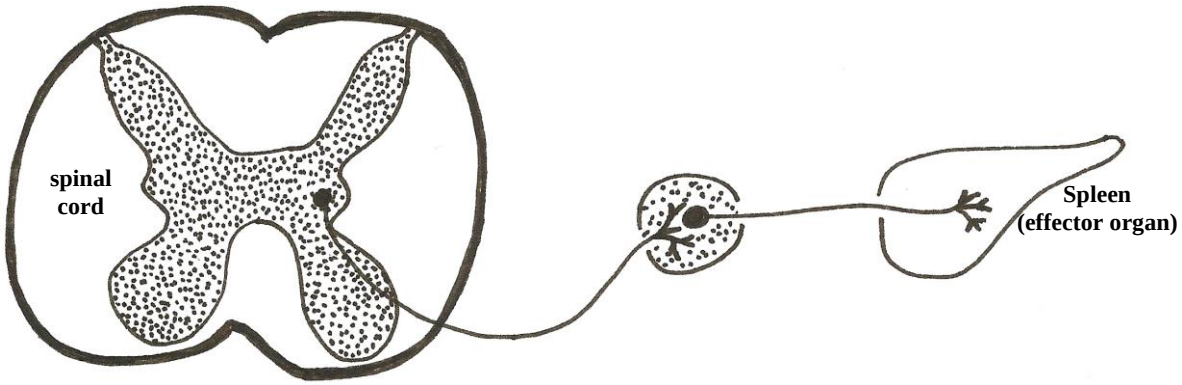
1. What's the difference between a **nerve** and a **tract**?
2. What is a **ganglion**?
3. What's the function of the **lateral horns** vs. **ventral horns** of gray matter?
4. How do **sensory** vs. **motor** functions differ?
5. How do the terms **efferent** vs. **afferent** differ?
6. What is the difference between **voluntary** and **involuntary?**
7. What is **white matter**?
8. What is **gray matter**?
9. How do **autonomic** and **somatic** functions differ?
10. What is the role of **acetylcholine**?
11. What happens at a **synapse?**
12. Where are **visceral** and **somatic** motor neurons located within the gray matter of the spinal cord?

Chapter 14: The Autonomic Nervous System & Homeostasis, Continued

Autonomic Nervous System

- **Efferent Pathway of Nerve Impulses:** Remember, the ANS carries efferent motor information AWAY from the CNS to an effector organ in response to unconsciously perceived sensory information. So, we are following the pathway of the neurons from the CNS to the gland, organ, or muscle being stimulated. For each nerve impulse, one autonomic (ANS) ganglion and **2** motor neurons are involved. A **ganglion (= nerve)** is a group of nerve cell bodies outside the CNS.
  1. **Preganglionic neuron** is the **1st motor neuron**. It has a cell body within the CNS (the axons are called **preganglionic fibers)**. Preganglionic neurons are located in the brain stem and spinal cord and are motor neurons. The preganglionic neuron doesn't make it all the way to the effector organ. So, it connects to…
  2. **Ganglion**. Between the 1st motor neuron (preganglionic) and the 2nd motor neuron (postganglionic) are many (hundreds to thousands) of nerves in this pathway.
  3. **Postganglionic neuron** is the **2nd motor neuron**. This motor neuron is outside of the CNS. It synapses with the effector organ that is being stimulated.
- **Summary of the Pathway**: CNS → preganglionic neuron → ganglion → postganglionic neuron → effector organ (gland, organ, smooth or cardiac muscle)

Can you identify the preganglionic neuron & its cell body, ganglion, postganglionic neuron & its cell body?



Somatic Nervous System

- **Efferent Pathway of Nerve Impulses:** The somatic nervous system sends motor output information to voluntary skeletal muscles in response to consciously perceived sensory information. This information travels over ONE neuron to the effector organ (a skeletal muscle motor unit)

Chapter 14: The Autonomic Nervous System & Homeostasis, Continued

Two Motor Divisions of the ANS

- **Two ANS Motor Divisions: Sympathetic** and **Parasympathetic** Divisions; both operate automatically and subconsciously in an involuntary manner. That's consistent with the concept of the ANS—automatic/autonomic.
- **Antagonistic Relationship**: The sympathetic division overrides the parasympathetic in emergencies and causes the heart to increase activity while decreasing activities of the digestive system. How do you respond to being startled or scared? Heart rate increases, rate of digestion decreases.
- **How do each of these divisions work?** These divisions are antagonistic (work as opposites) to one another:
  - **Sympathetic Division of the ANS**:
    - The body prepares for heightened physical activity that results in:
      - ↑ mental alertness
      - ↑ metabolism, ↑ blood flow to brain and skeletal muscles
      - ↑ dilation of respiratory passageways, ↑ heart rate, ↑ blood pressure
      - activation of energy reserves (break down fat to make glucose)
      - activation of sweat glands
      - ↓ digestive and urinary functions
    - Prepares the body for the "fight or flight response" - a crisis
    - Think of **E** activities (exercise, excitement, emergency, embarrassment)
  - **Parasympathetic Division of the ANS**:
    - The body conserves energy (rests) and promotes sedentary activities such as digestion. (Think rest/digest).
      - ↓ metabolism
      - ↓ dilation of respiratory passageways, ↓ heart rate, ↓ blood pressure
      - ↑ digestive and urinary activities
      - ↑ motility and blood flow in the digestive tract
      - ↑ the process of making urine; ↑ defecation
    - Think of **D** activities (digestion, defecation = bowel movements, diuresis = urination)

How are the sympathetic and parasympathetic divisions different?

Division	Origin of Fibers	Length of Fibers	Location of Ganglia	Neurotransmitters
Sympathetic	Thoracolumbar region of the spinal cord	Short preganglionic & long postganglionic	Close to the spinal cord	Acetylcholine Epinephrine Norepinephrine
Parasympathetic	Craniosacral segment of peripheral nerves (including vagus)	Long preganglionic & short postganglionic	In the visceral effector organs	Acetylcholine

Chapter 14: The Autonomic Nervous System & Homeostasis, Continued

Adrenergic and Cholinergic Receptors in the ANS: How do Neurotransmitters Work?

Receptor Type	Neurotransmitter	Effect	What happens at the receptor site?	Which Nervous System is in Control?
Adrenergic Receptors				
• alpha	norepinephrine (NE) epinephrine (epi)	Alpha receptors on the heart **excite** the heart; heart rate increases or Alpha receptors on digestive and urinary organs **inhibit** digestion & urination	Calcium entry into cells increases when NE and epi bind to alpha receptors. Calcium is needed for muscles to contract.	sympathetic
• beta	norepinephrine (NE) epinephrine (epi)	Beta receptors on the heart **excite** cells of the heart and lungs; heart rate increases, respiratory passageways dilate	Cell metabolism increases when NE and epi bind beta receptors.	sympathetic
Cholinergic Receptors				
• nicotinic	acetylcholine (ACh)	Nicotinic receptors **excite** digestion & urination activities	When ACh binds nicotinic receptors on digestive and urinary organs, cells become excited (EPSP)	parasympathetic or sympathetic
• muscarinic	acetylcholine (ACh)	Muscarinic receptors on digestive and urinary organs **excite** digestion & urination activities And/or ACh binding muscarinic receptors on the heart will slow heart rate and constrict respiratory bronchioles	When ACh binds receptors on digestive and urinary organs, cells become excited (EPSP) When ACh binds muscarinic receptors on the heart and bronchi, cells rest (IPSP)	parasympathetic

Acetylcholine is released by neurons of the parasympathetic division. Receptors that bind ACh are **<u>cholinergic</u> receptors. ACh** causes vasodilation (relaxation) of peripheral arteries while **NE** causes their vasoconstriction. That way, blood flow increases to skeletal muscles while blood flow is reduced to other tissues.

- *Why do you think we're often told not to swim immediately after eating a meal? Where is blood flow increasing after a meal? And decreasing?*
- *Beta blockers block the sympathetic NS response in the heart. What happens to heart rate when a person takes a beta blocker? Why?*

Chapter 14: The Autonomic Nervous System & Homeostasis, Continued

Detection of Stimuli

Free nerve endings are dendrites that are not protected by accessory structures. The area monitored by the free nerve endings of a nerve is called the *receptive field*. These nerve endings are exposed to many different stimuli.
Encapsulated nerve endings are wrapped with connective tissue layers and accessory cells; found in complex receptors such as those of the eye.

Types of Sensory Receptors
Classified by the stimulus that excites them

Classification by Location:

- **Exteroreceptors**: detect information about the external environment; most are cutaneous receptors
- **Interoreceptors**: detect information from the body's organs and their functions
- **Proprioreceptors**: detect information about the skeletal muscles, joints

Types of Receptors:

- **Tonic receptors** are sensory neurons and are *always* actively generating action potentials if a stimulus is present (such as pain receptors).
- **Phasic receptors** are sensory receptors but are normally *inactive*, providing information only when changes occur in the normal conditions. **Adaptation** occurs in phasic receptors; adaptation is the reduction in sensitivity in the presence of a constant stimulus (such as the temperature of a room).

General Sensory Receptors:

- **Nocioceptors** detect pain (all receptors will send a signal of pain if overstimulated).
- **Thermoreceptors** detect temperature. These are phasic.
- **Mechanoreceptors** detect physical distortion.
    - **Tactile receptors** include fine touch and pressure receptors in the skin.
    - **Baroreceptors** detect pressure changes in an organ (full stomach, full bladder), blood pressure
    - **Proprioreceptors** detect joint position, tension in tendons/ligaments
- **Chemoreceptors** detect concentrations of specific chemicals, such as blood pH, carbon dioxide, or oxygen.

Chapter 14: The Autonomic Nervous System & Homeostasis, Continued

For Discussion

1. Describe what the ANS and SNS have in common; describe how they're different.
2. Why do you think there are different types of neurotransmitters?
3. What roles do the parasympathetic and sympathetic nervous systems play?
4. Which nervous system division responds to control motor output of voluntary skeletal muscle?
5. An 18-wheeler just nearly missed hitting Sam head-on while driving. Exasperated, he pulls over to the side of the road with his heart pounding. Which division of the ANS is taking control right now? What other symptoms do you think he's experiencing?
6. What type of drug is a "beta-blocker?" What exactly is being blocked?
7. Maria was so nervous about giving her last speech for SPC 205. She found her hands sweaty and her heart racing. Explain to her how epinephrine is affecting her body.
8. What type of drug is an "alpha-blocker?" What type of receptor is being blocked, which neurotransmitter is prevented from binding, and what do you think happens as a result?
9. Mr. H. takes a beta blocker to reduce his heart rate. Explain how this drug works.
10. Compare the pathways for motor information over the ANS and SNS pathways.
11. Explain the difference between tonic and phasic receptors.
12. Differentiate between the function of nicotinic and muscarinic receptors.
13. Differentiate between the function of alpha and beta receptors.
14. Which system is faster – the ANS or the SNS? Explain why.
15. Where do the motor neurons originate in the ANS? And in the SNS?
16. After having a large meal for lunch, Sally decided to go for a swim. As she changed into her swimsuit, she found herself too sleepy to go. Which ANS division is in control? Why? Explain why a swim was not a good choice after her lunch.
17. How does acetylcholine promote the activities of the digestive system during parasympathetic control?

If you have any trouble answering them, come see me!

Chapter 15: The Special Senses

The five special senses are: olfaction (smell), gustation (taste), vision, equilibrium (balance), and hearing. We'll be covering vision and hearing, and a bit of equilibrium.

Anatomy of the Eye

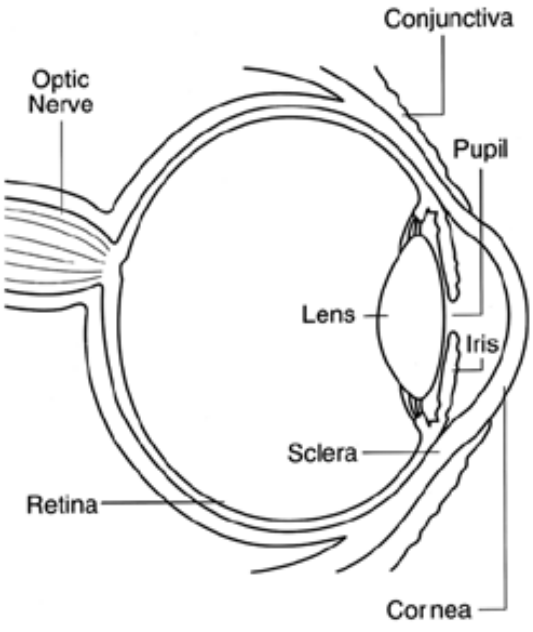
Accessory Structures

- **Eyelids** (**palpebrae**) blink to lubricate the eye and prevent dust and debris from entering the eye. **Tarsal glands** (Meibomian glands) secrete a substance that helps keep the eyelids from sticking together. Recall that *orbicularis oculi* is the muscle responsible for closing the eyelid.
  - **Eyelashes** prevent foreign matter from entering the eye (like insects).
- **Conjuctiva** is a mucous membrane lining the inner surface of the eyelid; it also continues to form the outer surface of the eye. An inflammation of the conjunctiva is known as *conjunctivitis* (or pinkeye). It can be caused by allergens, physical contaminants, or chemical irritants.
- **Lacrimal apparatus** is a combination of the lacrimal gland and other structures responsible for distributing and removing tears. The **lacrimal gland** is situated on the lateral side of each eye and provides most of the volume of tears. Tears drain into the sinuses by way of the *nasolacrimal duct.*
- **Extrinsic (external) eye muscles** move the eye position. Double vision can result when the eye muscles aren't coordinated; a situation called *diplopia*. *Strabismus* results from weak eye muscles and the result can be cross-eyed.
  - **Lateral rectus** moves the eye laterally
  - **Medial rectus** moves the eye medially
  - **Superior rectus** moves the eye superiorly
  - **Inferior rectus** moves the eye inferiorly
  - **Superior** and **inferior oblique muscles**

Eye Structure

Three Layers (superficial layer to deep):

1. Fibrous Tunic = sclera + cornea
2. Vascular Tunic = iris + ciliary body + choroid
3. Neural Tunic = retina
   a. pigmented layer
   b. neural layer



Chapter 15: The Special Senses/Eye, Continued

1. **Fibrous** (outer) **Tunic**

   Two components:

   1. **Sclera**
      a. forms the "white" of the eye
      b. composed of dense fibrous CT with collagen and elastin fibers; blood vessels & nerves
      c. is the site of insertion of the extrinsic eye muscles
   2. **Cornea**
      a. forms a transparent layer that is continuous with the sclera; it's the clear portion over the pupil and iris
      b. no blood vessels (avascular) but it does have nerves makes it a good tissue for transplant

2. **Vascular** (middle) **Tunic** *(*or *uvea*)

   Three components:

   1. **Iris**
      a. contains pigment to limit amount of light reaching the retina
      b. smooth muscles control the size of the pupil
         --too bright or too close, the pupil constricts (gets smaller)
         --too dim or too distance, the pupil dilates (gets larger)
      c. located between the cornea and lens; and forms the most anterior portion of the uvea
   2. **Ciliary body**
      a. contains muscles for focusing; somewhat connected to the lens
   3. **Choroid**
      a. vascular layer that feeds the retina with oxygen and nutrients
      b. also contains melanocytes

3. **Neural Tunic** (= **retina**)

   Two layers:

   1. **Pigmented layer** (thin, outer layer)
      a. absorbs light that passes through the neural layer and prevents it from bouncing back
      b. stores vitamin A (beta carotene) for photoreceptors
   2. **Neural layer** (thick, inner layer)

      Two types of photoreceptors are found here (rods and cones). Rods are found along the lateral portions of the retina and they decrease toward the center. The cones are concentrated in the **macula lutea** (yellow spot) where images are formed. The highest concentration of cones is in the **fovea centralis** in the center of the *macula lutea* (that's why this is the area of sharpest vision). ① Rods and cones send sensory (sight) information to ② **bipolar cells** which then send it to ③ **ganglion cells**. The ganglion cells fuse and form the ④**optic nerve**. The optic nerve lacks photoreceptors, a spot called the **blind spot (optic disc)**. The nerve exits the eye at the optic disc.

Chapter 15: The Special Senses/Eye, Continued

3. **Neural Tunic** (retina), continued

2. **Neural layer** (thick, inner layer)

a. **rods**

1. most numerous of the photoreceptor cells; common in peripheral vision
2. detect black and white images in dim light and movement in peripheral vision
3. provide a fuzzy or grainy black and white image in low light levels
4. **night blindness** results from birth problems or from lack of vitamin A. Often a result of retinosa pigmentosa, a genetic disorder that leads to blindness.

b. **cones**

1. photoreceptor cells that detect color vision; common in the central vision
2. produce sharp, colorful images
3. three types of cones: blue, green, and red. Each is sensitive to a different wavelength of light.
4. **color blindness** results from the inability to distinguish between colors; genetic disorder. Typical problem is inability to distinguish red/green colors; more common in males.

Cavities and Chambers of the Eye

Two cavities are divided by the **lens**:

1. **Anterior cavity**: contains the **aqueous humor**, a fluid similar to plasma that forms and drains at a constant rate to maintain constant intraocular pressure. This fluid pushes against the cornea. If intraocular pressure is too high, pressure builds up on the optic nerve and can cause blindness.

Two chambers are divided by the **iris**:

a. **anterior chamber** is the area from the cornea to the iris

b. **posterior chamber** is the area from the iris to the ciliary body/lens

2. **Posterior cavity**: is posterior to the lens and contains the **vitreous humor**, a clear gel that transmits light. This particular humor is formed during development and not replaced.

Lens

1. Located posterior to the cornea and held in place by suspensory ligaments associated with the ciliary body.
2. Convex shape allows the lens to refract and focus light on a specific portion of the retina. As we age, the flexibility of the lens decreases (why people need reading glasses or bifocals as they approach their 40's)
3. Transparency of the lens allows light to pass through; changes in this transparency results in **cataracts**. The lens is cloudy with cataracts; the lens can be replaced with an artificial substitute.
4. **Astigmatism** occurs when light passing through the lens and cornea is not refracted properly. Minor astigmatisms are common.

Visual Pathway of Information

1. Through the eye, light passes first through the cornea → aqueous humor (anterior cavity) → pupil → lens → vitreous humor (posterior cavity) → photoreceptor cells located in the fovea centralis of the retina → optic nerve
2. Notice the visual pathway from the each eye → optic nerve → optic chiasma → optic tract → thalamus → association fibers → occipital lobe. Note left eye vision travels through the right optic tract.

Chapter 15: The Special Senses/Eye, Continued

Physiology of the Eye

Refraction of Light on the Retina

1. The lens must focus on an object.
2. Light is **refracted** or bent as it passes through the eye because of the fluid (aqueous humor) through the lens, to the gel (vitreous humor) found in the eye.
3. Light focused by the lens lands on a **focal point** (fovea centralis) on the retina. The distance between the lens and its focal point is known as the **focal distance**.
4. The distance from an object to the lens increases the focal distance.

Accommodation

1. The lens changes shape to change the focal length and be able to focus, a process called **accommodation**.
2. Normal vision is known as **emmetropia** because the lens focuses the image on the retina's surface.
3. Accommodtion problems:
   a. **Myopia** (nearsighted) results when the eyeball is too oblong; so objects form the focal point in front of the retina and appear blurry. If you're myopic, you cannot see far objects clearly.
   b. **Hyperopia** (farsighted) results when the eyeball is too short; objects form the focal point behind the retina. If you're hyperopic, you cannot see objects clearly in the close range.
   c. **Presbyopia** ("old eyes") results from age as the lens loses elasticity; reading glasses can correct this problem if mild. Some people wear bifocals if they are both myopic and presbyopic.

Review of the Eye

1. Describe how the lens accommodates images close up and far away so that each image seen is focused.
2. Explain how glasses or contact lenses fix myopic, hyperopic, and presbyopic problems.
3. What is the purpose of aqueous humor? Vitreous humor?
4. Which types of cells do you think are affected in a color-blind person?
5. What types of cells are most common around the macula lutea?
6. How is the conjunctiva different from the sclera? How is the sclera related to the cornea?
7. Why do you think the lacrimal glands are situated on the lateral sides of each eye?
8. Tommy touched a dirty, germy door knob. Then, he rubbed his eyes. He ended up catching a cold and has a sniffly, runny nose How did the virus travel into his sinuses if it was contracted through his eyes?
9. Once light is focused on the macula lutea, where do the images travel next on its way to the brain?
10. From the superficial layer to the deep layer, name the layers of the eye.
11. Which layer houses rods and cones? What is the function of rods? And cones?
12. How does visual stimulation travel to the optic nerve? Can you trace the pathway to the occipital lobe?
13. What type of fiber carries visual stimulation to the occipital lobe?
14. What lobe of the brain receives and interprets visual information?

Please see me if you need help with these questions!

Chapter 15: The Special Senses/Ear, Continued

Anatomy of the Ear

External Ear (Outer Ear)

Includes these three structures:

1. **Auricle (pinna)** is the fleshy outer portion composed of elastic cartilage and skin; it directs sound waves to the external auditory meatus.

2. **External acoustic (or auditory) meatus** is the ear canal or ear hole. It's actually a depression in the temporal bone lined with skin, sebaceous, and ceruminous glands (which make earwax).

3. **Tympanic membrane** is the eardrum; a thin sheet that separates external ear from middle ear. The job of the tympanic membrane is to transmit sound waves through to the middle ear.

Middle Ear (Tympanic Cavity) – air filled

This portion of the ear is an air-filled chamber. It is separated from the external auditory meatus by the tympanic membrane. The middle ear opens to the nasopharynx through the **auditory** (Eustachian or pharyngotympanic **tube**. This portion of the ear's structure includes:

1. **3 Auditory ossicles** = "ear bones" These ear bones are connected with the tympanic membrane and transmit sound waves into the inner ear.
   a. **Malleus = hammer** is the bone attached to the tympanic membrane
   b. **Incus = anvil** is the middle bone
   c. **Stapes = stirrup** is the innermost ossicle which is anchored to the **oval window**.

2. **Oval window** is an opening in the stapes; surrounds the inner ear. Sound is focused here by the movement of the ossicles.

3. **Round window** is a thin membrane that separates the fluid-filled inner ear from the air-filled middle ear. *Otitis media* is middle ear infection; can occur when microbes travel from the nasopharynx into the middle ear. More common in children due to the angle of the auditory tube; treatment with antibiotics. Some cases need tubes placed so that fluid can drain into the nasopharynx.

Inner Ear – fluid filled

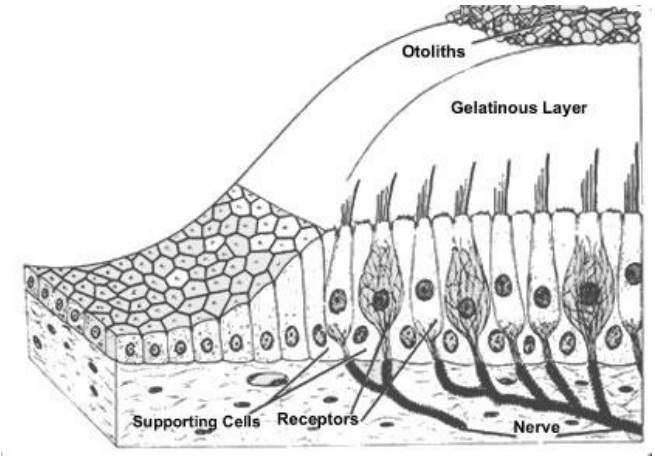
The inner ear has a **bony labyrinth** which is part of the temporal bone. The **membranous labyrinth** is a network of fluid-filled tubes. The inner ear receptors are found within those tubes. Two types of fluid are found in the inner ear: **perilymph** is fluid in between the bony & the membranous labyrinths in the canals; **endolymph** is found in the membranous labyrinth.

1. **Cochlea** is the organ of <u>hearing</u>. It is a spiral, snail shaped organ. Within the cochlea are receptors that provide a sense of hearing by producing action potentials when stimulated. The **organ of Corti (spiral organ)** contains *hair cells* and the whole structure sits on the **basilar membrane.**

2. **Vestibule** detects <u>balance</u> and <u>spatial orientation</u>. The *hair cells* within the vestibule contain *otoliths* that help us detect movement and deal with equilibrium. They are suspended in a gelatinous mixture and move with head motion.

Chapter 15: The Special Senses/Ear, Continued

Inner Ear, continued



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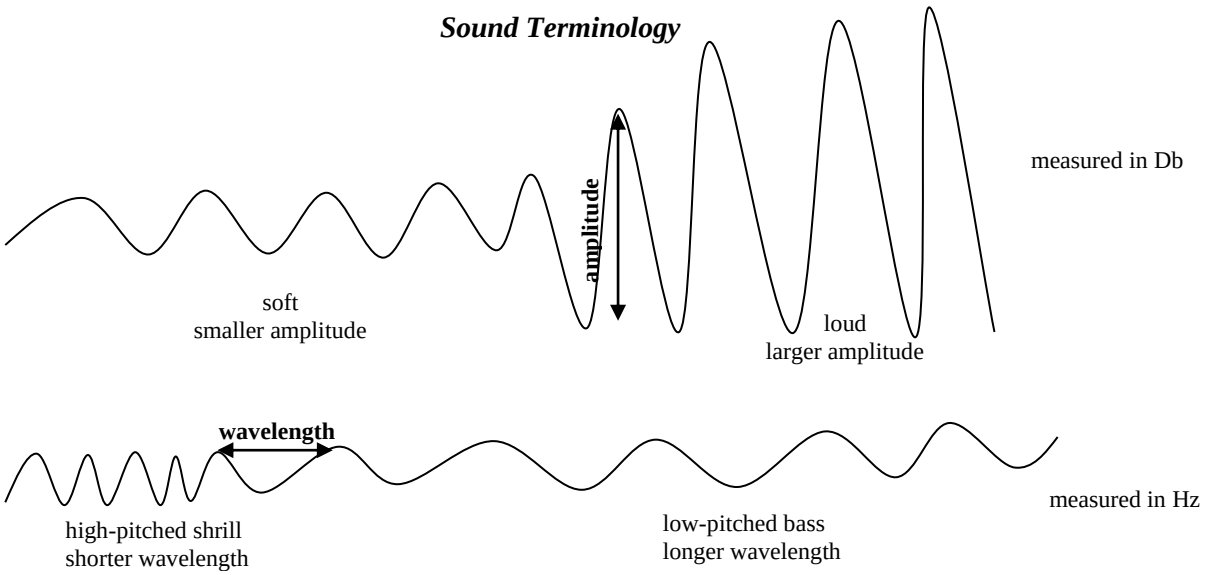
3. **Semicircular canals** function in rotational movement of the head. The three canals enclose fluid-filled ducts. There are three semicircular canals: **anterior, lateral,** and **posterior**. Each canal has hair cells that respond to various types of movement and provide information about the direction and strength of movement. *Upper respiratory infection can affect the semicircular canals and promote vertigo.*

Equilibrium and Balance

- **Static equilibrium** is no motion of the head.
- **Dynamic equilibrium** is the head in motion. Information about balance and equilibrium are carried to the brain via the vestibular branch of the vestibulocochlear nerve.
  - **Direction of movement - semicircular canals** (head in motion to the left, right, how quickly the head is moved, angular motion) to the brain. Semicircular canals help maintain balance.
  - **Position** of your head with respect to gravity **- vestibule**. This input helps to control eye movement relative to the head's position or linear acceleration.



Chapter 15: The Special Senses/Ear, Continued

- **Sound** travels in **waves**. Waves have peaks and valleys known as crests and troughs. Sound waves can travel through air entering the external auditory canal (air conduction) or through the bones via bone conduction.
- **Pitch:** The number of peaks to pass by in a certain period of time is known as the **frequency**, measured in Hertz (Hz). The **wavelength** is the measurement of one wave, from crest to the next crest. The hearing range is 20-20,000 Hz. Low bass tones range around 50 Hz while high-pitched shrill tones are around 10,000 Hz.
- **Loudness:** The **amplitude** is the height of the wave and is controlled by how much energy is stored in the wave. The amplitude is measured from trough to crest. The **intensity** of the sound is equivalent to its loudness and amplitude. (Amplification also occurs in the ossicles).
    - Amplitude is measured in **decibels (dB)**. Sounds range from a whisper, at 20 dB, to the roar of a jet engine at 140-180 dB.

The Pathway of Sound and Nerve Impulse into the Brain

Step 1: Sound travels from ① auricle → ② external auditory meatus → ③ tympanic membrane.

Step 2: Tympanic membrane moves and displaces the auditory ossicles. The vibration of the tympanic membrane causes the ④ malleus → ⑤ _____ → ⑥ _____ to vibrate. Sound is now amplified (louder).

Step 3: Stapes at the ⑦ oval window produces pressure waves in the perilymph of the vestibular duct.

Step 4: Pressure waves distort the basilar membrane as they travel to the round window of the tympanic duct.

Step 5: The basilar membrane vibrates and causes vibration of hair cells of the ⑧ organ of Corti/spiral organ of the cochlea. The movement of these hair cells causes neurotransmitters to be released and the stimulation of sensory neurons (*remember the creation of an action potential from Chapter 8?*). The more hair cells that are stimulated, the louder or more intense the sound. Only a few rows of hair cells stimulated means the sound is soft.

Step 6: The cochlear branch of ⑨ cranial nerve VIII (*remember what VIII is called?* _____) sends information to the medulla oblongata for distribution to other centers in the brain. The auditory information is send to the auditory complex of the temporal lobe for sound to be interpreted.

Ear Pathologies:

- **Conduction deafness** results when sounds cannot be conducted due to situations when ossicles fuse, ear wax builds up, otitis media.
- **Sensorineural deafness** results when nerve damage has occurred; cochlear implants aid the situation.
- **Tinnitis** is ringing, roaring, hissing, or clicking sound; possibly caused by exposure to loud noises and linked to deafness.

Chapter 15: The Special Senses/Ear, Continued

Review of the Ear

1. Describe the role of the ossicles in sound transmission.
2. How do we interpret sounds as soft or loud? How are hair cells in the ear affected in response to soft/loud sounds?
3. What is/are the difference(s) between the jobs of the round window and the oval window?
4. How would a noise sound if its wavelength increased in frequency? Increased in amplitude?
5. What structure serves as the barrier between the fluid-filled inner ear and the air-filled outer ear?
6. Why could someone with a sinus infection experience dizziness?
7. What type of deafness would repeated, constant use of headphones lead to?
8. What is the role of the organ of Corti (spiral organ)?
9. Once sound is transmitted by the tympanic membrane, name the structures it travels through to finally stimulate the cochlear branch of the vestibulocochlear nerve.
10. What are the parts of the cochlea involved in hearing?

Please see me if you need help with these questions!

Study Tips for Chapter 15 for the Final Exam

Eye

1. Identify the structure composing each tunic of the eye; provide the function of each tunic.
2. What role does the lacrimal gland play in eye function? The conjunctiva? Tarsal glands?
3. Trace the pathway of vision through the eye and into the brain.
4. What is the role of the lens in the vision pathway?
5. What roles do rods and cones play in vision?
6. Compare a normally shaped eye to myopic and hyperopic eyes. How has the focal point changed in those conditions?
7. Which lobe of the brain receives and interprets vision information?

Ear

1. Name the three regions of the ear.
2. What are the names of the three bones in the ear? What role do they serve in transmission of sound waves?
3. How does sound travel into the vestibulocochlear nerve? Can you trace the pathway to the temporal lobe?
4. Which organ of the inner ear is responsible for the sense of gravity and linear acceleration? Hearing?
5. How are the functions of the cochlear and vestibule different?
6. Which region of the ear is air-filled? Fluid-filled?
7. What lobe of the brain receives and interprets sound information?
8. Which region of the ear contains stones known as otoliths? What is their function?