

Spring 5-6-2011

## Supplemental assignments to increase the retention of knowledge for Biology I and II lecture

Krystyn Vitale  
*University of South Florida*

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Supplemental assignments to increase the retention of knowledge for Biology I and II lecture.

Krystyn Vitale

Dr. Kenyon Daniel

Spring 2011

Date Accepted: May 6, 2011

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## **Abstract**

Supplemental assignments for Biology I and II lectures were designed to increase the understanding of important biology concepts. Topics from each lecture, and frequently misunderstood details from that topic, were chosen as the concepts for each assignment. The questions posed allow students to process the information step-by-step and form a conclusion from their piece-wise work. This format allows students to foster their critical thinking skills and increase their retention of the knowledge learned through problem solving sessions<sup>1</sup>.

At the university level, in biology classes, the course material is rigorous and fast-paced. It has been shown that lecture-style teaching methods are not conducive to the retention of knowledge required<sup>4</sup>. However, alternative forms of teaching, including the process oriented guided inquiry learning, have been proven to decrease the failing rate (D/F) and increase the superior grades (A/B) in physiology lectures over three semesters<sup>3</sup>.

I have designed course work aimed at addressing important aspects of biology that I feel could be better learned through inquiry based teaching methods. The assignments were created in such a way that they allow students to think critically about the material and draw conclusions from the exercises. Not only does this involve processes that increase information retention, it also allows the students to think in a way that other university classes cannot offer from their passive learning teaching methods<sup>4</sup>. Critical thinking is an important skill in the scientific field, a skill that could be fostered through the completion of these assignments<sup>8</sup>. Another key component of these assignments is group work. That aspect of an assignment allows students the opportunity to practice working with a diverse group of people, a guaranteed component of any future profession.

The assignments were designed to be completed within a 50 minute class period, that students would be required to attend in addition to lecture, and, depending on the teacher, could supplement their lecture grade. The grading rubric allows for 10 possible points: 4 points from the quiz (1 point/question) and 6 points from the critical thinking question(s) (CTQ). For those assignments that have one CTQ, it would be worth the entire 6 points. For assignments with two CTQs, each question would be worth 3 points, et cetera.

Each quiz, except for the first quiz in each biology section, contains questions from the assignment of the previous week and from the pre-assignment of the current week. The pre-

assignment is required for students; if not completed, the students would not be allowed to take the quiz or stay for the class. However, if the student were to complete it quickly, before class starts, they would be allowed to stay for the class. If this format were to be used in a class, I would hypothesize that the pre-assignment introduces subjects which are detailed later in the assignment and therefore students in a group who have not completed the pre-assignment disadvantage the rest of the group.

Also, included are notes for the leader of the class. The assignments are not designed to be a lecture course; instead, it is necessary for students to work through the questions and exercises via group work to better understand the material<sup>3</sup>. The notes advise the leader on how to guide the students with the questions without giving them the answer. Answer keys for the quizzes, pre-assignments, and assignments are included.

While these assignments have not been tested on actual students, I believe that they would be effective in aiding the gain of knowledge of at least some of them. These assignments offer an opportunity to students to better learn the material, to help pass a biology lecture, and allow the subject of biology to be exposed as an amazing field.

## Works Cited

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### **Biology I Quiz Key**

Chemical Bonds- B C C D  
Carbohydrates and Lipids- B C C A  
Proteins and Nucleic Acids- B C A D  
Endomembrane System- C B A A  
Enzymes- C A C A  
Mitosis and the Cell Cycle-C B C D  
Meiosis- C C B B  
DNA Replication- D C B D  
Transcription- C A A D  
Translation- C B C C

### **Biology II Quiz Key**

Origin of Life- A B A C  
Population Genetics- B B C A  
Origin of Species- C A B D  
Bacteria and Archaea- B C B A  
Protists- B C D C  
Fungi- B C D C  
Plants- C C D C  
Invertebrates- C A D B  
Vertebrates- C C C A



# **Biology I**

## Chemical Bonds Quiz

1. The number of electrons the outer shell of an atom can hold are called what?
  - a. Covalent electrons
  - b. Valence electrons
  - c. Ionic electrons
  - d. Hydrophobic electrons
  
2. The name of the property of an atom that determines the strength of which electrons are attracted to it?
  - a. Polarity
  - b. Alkalinity
  - c. Electronegativity
  - d. Acidity
  
3. What is the number of valence electrons in the following atom?



- a. 2
  - b. 4
  - c. 6
  - d. 8
- 
4. Which atom is the most electronegative?
    - a. Carbon
    - b. Hydrogen
    - c. Nitrogen
    - d. Oxygen

## Chemical Bonds

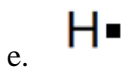
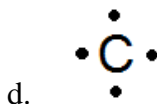
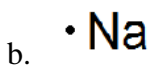
Chemical bonds and interactions are the mortar that holds the cell and its pieces together, and provide stability to its numerous reactions. Without them, the cell would cease to exist.

### Pre-Assignment:

1. Define the following terms:

- Valence electrons-
- Electronegativity-
- Polarity-
- Partial Charge-

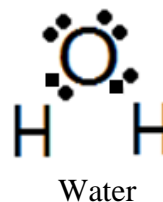
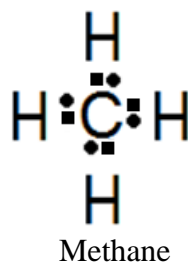
2. Indicate the number of valence electrons in each element:



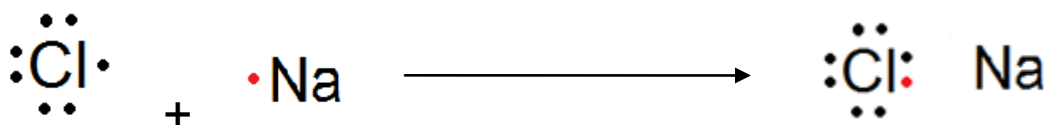
3. Order the following elements by electronegativity, least to greatest. Indicate any elements that are similar in electronegativity.

Carbon, Oxygen, Nitrogen, Hydrogen

Assignment:



1. Above is a methane molecule, CH<sub>4</sub>.
  - a. Describe the bond between the electrons.
  - b. What is the name of this strong bond? Is this bond easily reversible?
2. On the figures, indicate the charges of each atom as zero, positive, negative, partial positive, or partial negative.
3. How do the bonds of methane differ from those of water? Which one contains polar covalent bonds and which one contains non-polar covalent bonds?

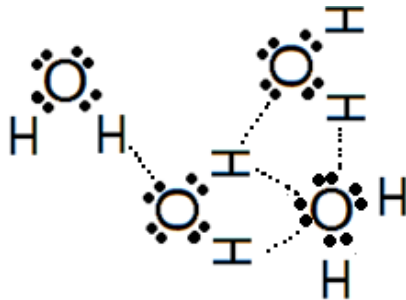


4. Explain what happened when chlorine and sodium bonded. Indicate on the picture the resulting charges of the atoms.

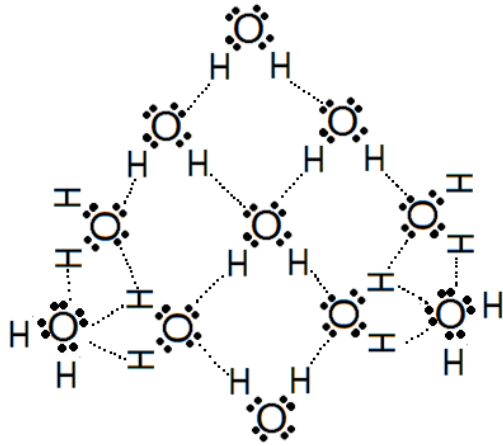
5. Why did the electron move from sodium to chlorine and not from chlorine to sodium?

In every molecule, even those with non-polar covalent bonds, positive and negative charges are not static. They continue to move around the region of the molecule, creating charged pockets. These weak forces are called van der Waals forces.

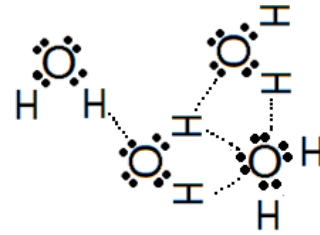
6. What would happen to two molecules if regions with the transient, opposite charges were near each other?



7. Use the picture to infer how hydrogen bonds form, using (3). Indicate another molecule that is able to hydrogen bond with hydrogen?



A.



B.

8. Use figures A and B to infer why weak interactions, such as hydrogen bonds or van der Waals, can create stable interactions in a biological system.

9. Van der Waals forces and hydrogen bonds are types of weak interactions. Are these interactions easily reversible?

10. Covalent and ionic interactions are considered strong interactions. Why, then, do organisms require weak interactions (e.g. hydrogen bonds, Van der Waals)?

## **Critical Thinking Questions**

Names:

---

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---

---

Write the answers to the critical thinking questions in the space below:

## Chemical Bonds Notes

This assignment is designed to help students understand concepts of chemistry that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2 and 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. While this first section is a review, the overall concept that the students should understand is the difference between non-polar and polar bonds.

Try to guide the class by asking thought provoking questions instead of volunteering a personal answer. It may be advantageous to draw a methane and an water molecule on the board to illustrate the point by asking about the electronegativity of the molecules.

### Questions 4, 5, and 6: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. For questions 4 and 5, try to lead the students to a discussion about why chlorine pulled the electron into its shell, leading them to the octet rule.

Question 6 begins the discussion about weak interactions. This question might be a little tricky for students to understand. If, after many thought provoking questions that do not elicit the correct answer, an example could be drawn on the board. However, if running low on time, do not spend past the allotted ten minutes on the question.



## Chemical Bonds Notes

### Questions 7, 8, and 9: (20 minutes)

Give the students five to seven minutes to read the questions and form answers. The next ten minutes should include a discussion about the answers. Students should connect the idea of electronegativity and polar bonds with question 7 as the reason for the formation of hydrogen bonds.

Question 8 and 9 are the most important questions. For question 8, if students are having trouble understanding why weak interactions can create stability within a cell through the sheer number of weak interactions occurring. For example, trying to pluck out one or two strands of your hair requires only a small amount of strength. However, trying to pull out a clump of hair made up of hundreds of strands can be very difficult to accomplish. Whatever technique used, it is important that students understand this question. **Question 8 is their first critical thinking question.**

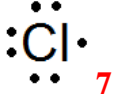
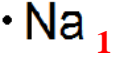

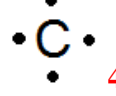
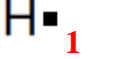
The purpose of Question 9 is for students to understand that interactions can be easily reversible and that organisms need weak interactions to accomplish those tasks. If possible, ask the students to come up with examples of weak interactions in the cell, such as enzyme-substrate interactions. **Question 9 is their second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 8 and 9 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Chemical Bonds

Chemical bonds and interactions are the mortar that holds the cell and its pieces together, and provide stability to its numerous reactions. Without them, the cell would cease to exist.

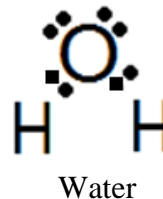
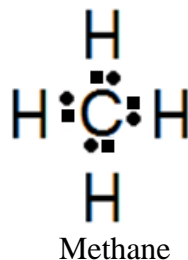
### Pre-Assignment:

- Define the following terms:
  - Valence electrons-**the electrons in the outer shell of an atom that can combine with other valence electrons to form molecules**
  - Electronegativity-**a property of an atom that allows it to attract electrons; more electronegative atoms attract electrons more than less electronegative atoms**
  - Polarity-**the direction of a magnetic or electric field**
  - Partial Charge-**a charge of less than one unit (i.e. less than -1 or +1) due to electronegativity**
- Indicate the number of valence electrons in each element:
  -  a. **7**
  -  b. **1**
  -  c. **6**
  -  d. **4**
  -  e. **1**
- Order the following elements by electronegativity, least to greatest. Indicate any elements that are similar in electronegativity.

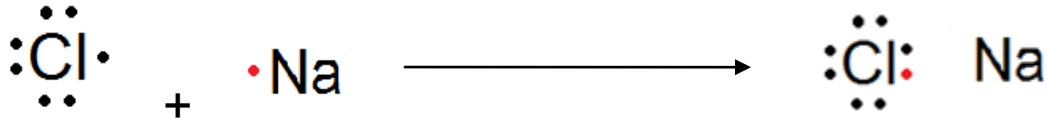
Carbon, Oxygen, Nitrogen, Hydrogen

**Hydrogen, Carbon, Nitrogen, Oxygen**

Assignment:



1. Above is a methane molecule, CH<sub>4</sub>.
  - a. Describe the bond between the electrons.  
**The atoms are sharing the electrons.**
  - b. What is the name of this strong bond? Is this bond easily reversible?  
**Covalent bond. No, this bond is not easily reversible.**
2. On the figures, indicate the charges of each atom as zero, positive, negative, partial positive, or partial negative.  
**Carbon and hydrogen in methane are zero. The oxygen atom of water is partially negative and the hydrogen atom of water is partially positive.**
3. How do the bonds of methane differ from those of water? Which one contains polar covalent bonds and which one contains non-polar covalent bonds?  
**The bonds of methane are non-polar covalent and the bonds of oxygen are polar covalent.**



4. Explain what happened when chlorine and sodium bonded. Indicate on the picture the resulting charges of the atoms.

**Sodium lost its lone valence electron to chlorine which completed its third shell by adding an eighth electron. Chlorine is negatively charged. Sodium is positively charged.**

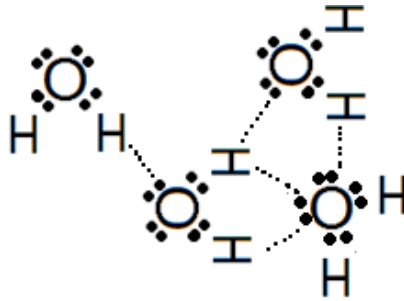
5. Why did the electron move from sodium to chlorine and not from chlorine to sodium?

**The atoms want to have an outer shell with eight electrons. If sodium gave up its one valence electron, its new outer shell would be complete. By accepting the electron, chlorine's outer shell became complete.**

In every molecule, even those with non-polar covalent bonds, positive and negative charges are not static. They continue to move around the region of the molecule, creating charged pockets. These weak forces are called van der Waals forces.

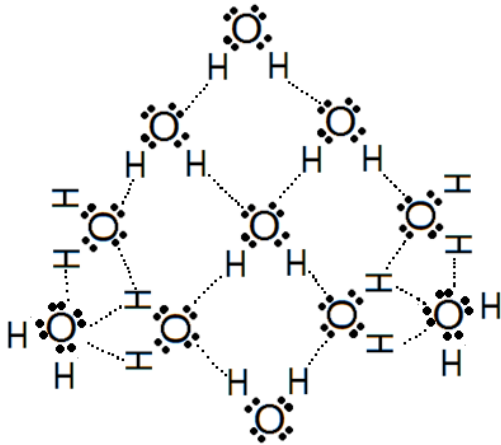
6. What would happen to two molecules if regions with the transient, opposite charges were near each other?

**If they were at the optimal distance, a weak interaction would occur. However, because the charges are transient, the interaction would be broken very quickly**

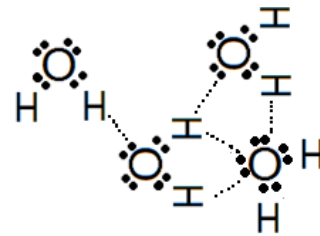


7. Use the picture to infer how hydrogen bonds form, using (3). Indicate another molecule that is able to hydrogen bond with hydrogen?

**Hydrogen bonds form between partially negative and partially positive molecules. A covalent bond cannot form because their octet is complete. However, the unequal sharing of the electrons (because of oxygen's electronegativity) causes a slight charge on the molecules creating an attraction.**



B.



B.

8. Use figures A and B to infer why weak interactions, such as hydrogen bonds or van der Waals, can create stable interactions in a biological system.

**Weak interactions are transient and not very powerful on their own. However, if they were coupled with millions of other weak bonds, the sum of all the weak forces would equal a strong force.**

9. Van der Waals forces and hydrogen bonds are types of weak interactions. Are these interactions easily reversible?

**Yes**

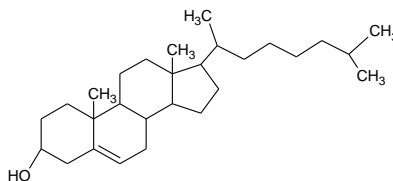
10. Covalent and ionic interactions are considered strong interactions. Why, then, do organisms require weak interactions (e.g. hydrogen bonds, Van der Waals)?

**Weak interactions are required in reversible reactions such as in enzymatic reactions and DNA basepairing. Without the weak interactions, life would not be flexible enough to adapt.**

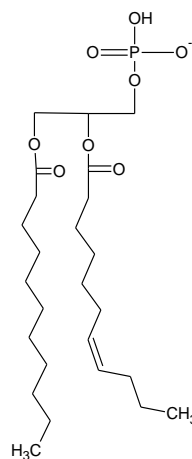
## Carbohydrates and Lipids Quiz

1. Which bond is **not** a weak bond?
  - a. Hydrogen Bond
  - b. Ionic Bond
  - c. Van der Waal
  - d. None of the above
2. Which reaction forms a covalent bond between two molecules that results in the loss of water?
  - a. Hydrolysis Reaction
  - b. Combustion Reaction
  - c. Condensation Reaction
  - d. None of the Above

3. What type of molecule is drawn below?



- a. Phospholipid
  - b. Unsaturated Triglycerol
  - c. Steroid
  - d. Saturated Triglycerol
4. What type of molecule is drawn below?



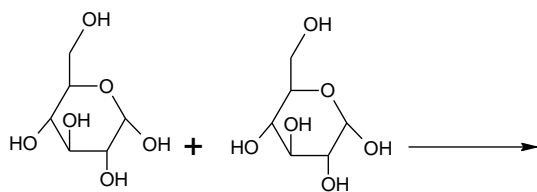
- a. Phospholipid
- b. Unsaturated Triglycerol
- c. Steroid
- d. Saturated Triglycerol

## Carbohydrates and Lipids

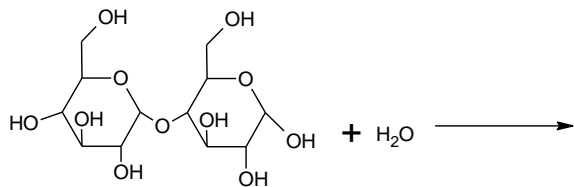
In organisms, the most common molecule digested for its energy is glucose, a carbohydrate. Because so many carbohydrates in the world are polymers of glucose, organisms have a ready supply of energy. However, though it is not as easy to digest, lipids actually produce more energy than carbohydrates when broken down. Is it no wonder, then, that the human body stores fat?

### Pre-Assignment:

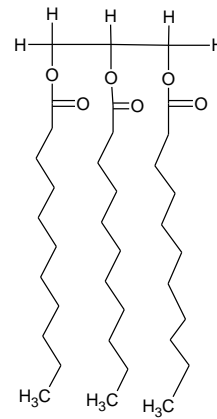
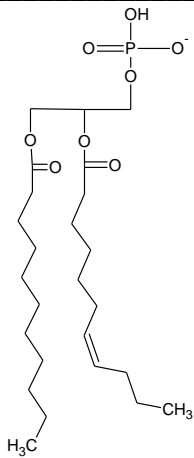
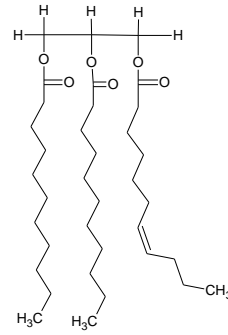
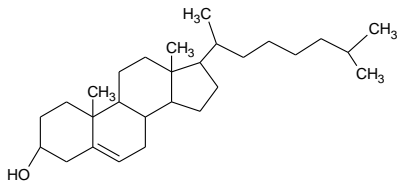
- Show the dehydration (condensation) reaction to form maltose. Circle the molecules lost.



- Show the hydrolysis reaction of maltose into two glucose molecules.

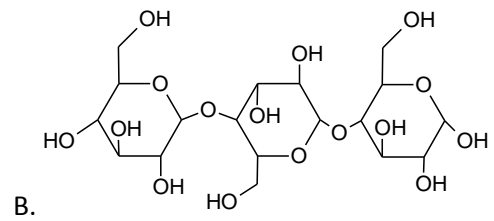
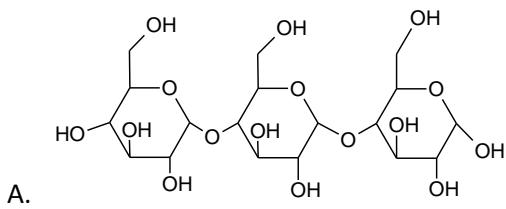


- Name the following disaccharides:
  - Glucose + Glucose  $\rightarrow$
  - Glucose + Fructose  $\rightarrow$
  - Glucose + Galactose  $\rightarrow$
- Match the types of fats with their structures.
  - Phospholipid
  - Saturated Triglycerol
  - Steroid
  - Unsaturated Triglycerol



Assignment:

**Carbohydrates:**



1. What is the structural difference between the glucose polymers of A and B?



The linkages of the polymer in A are called  $\alpha$ -linkages.  
The linkages of the polymer in B are called  $\beta$  linkages.  
Enzymes in the body can digest the  $\alpha$ -linkages, only.

2. Out of the three types of carbohydrates below, which one(s) can the human body digest?
  - a. Starch
  - b. Glycogen
  - c. Cellulose
  
3. Therefore, the carbohydrates that humans can digest are formed from which linkages?

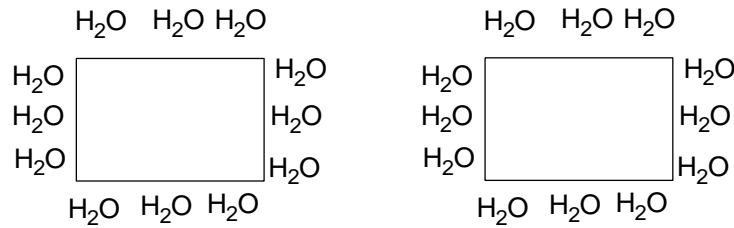
### **Lipids:**

Definition: The Second Law of Thermodynamics states that energy transfer increases the entropy (disorder) of the universe.

4. Which situation increases the disorder of the universe?
  - a. A room becoming messy from lack of tidying.
  - b. Cleaning up a messy room.
  
5. Which situation involves the input of the least amount of energy?
  
  
6. What is the relationship between increasing the disorder of the universe and the amount of energy needed?

7. Why does (6) benefit biological systems?

8. In the following figure, two fat droplets are suspended in an aqueous environment. They are surrounded by water molecules. Draw a new picture where the fat molecules are fused (a hydrophobic interaction), while keeping the amount of water molecules the same. (Note: no water molecules can be fused between the fat).



What has changed?

9. How does the accumulation of fat in an aqueous environment follow the Second Law of Thermodynamics?

10. According to (9), why then does the phospholipid bilayer form by fusing the hydrophobic tails of the phospholipid?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Carbohydrates and Lipids Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, and 3: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 includes analyzing the figures and determining the differences. It might not be obvious to students, so walk around the room, making yourself seem available for their inquiries. If asked a question, try to guide them towards parts of the structures that are different without giving them the answer. Do not spend too much time at one group.

Question 2 might be tricky if they have not read the book, but ask them if they can think of food examples of the three different glucose polymers. They can then use that knowledge to answer question 2.

**Question 3 is the first critical thinking question.** They may arrive at this answer easily, but it is an important concept in biology. Only certain animals have the ability to digest cellulose. You might want to ask if anyone can name one of those animals, e.g. cow, termite, and why they have the ability.

## Carbohydrates and Lipids Notes

### Questions 4, 5, 6, and 7: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The next four questions are designed to remind students about a chemistry concept that they may have forgotten. The Second Law of Thermodynamics is a very important idea when talking about lipid aggregation. During discussion, it is necessary to ensure that the class knows that increasing the disorder in the world takes no energy (in fact it releases energy) and that this reaction is favored in biological systems.

### Questions 8, 9, and 10: (15 minutes)

Give the students five to seven minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The remaining time should be given to completing the critical thinking page.

For question 8, ask a student volunteer to draw the aggregation of fat molecules on the board, including the displaced water molecules. With the figure on the board, it will be easy to facilitate a discussion about what has occurred.

During the discussion of question 9, make sure that the students understand that by lipids aggregating, water molecules are no longer in a rigid conformity around the lipid molecules; they are now free and increase the entropy of the aqueous system. Therefore, lipid droplet formation is favored. **Question 9 is the second critical thinking question.**

Question 10 builds on the answer from question 9 by applying a real world situation to lipid aggregation. While the answers might be similar, it is important for students to connect the concept in question 9 to biological systems.

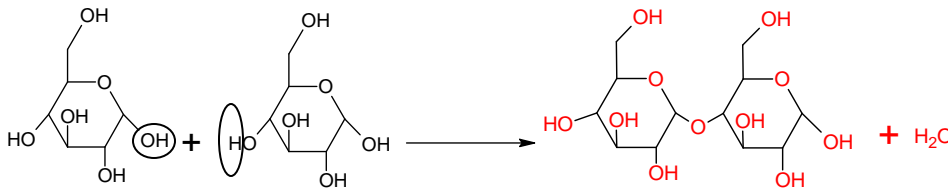
The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 3 and 9 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Carbohydrates and Lipids

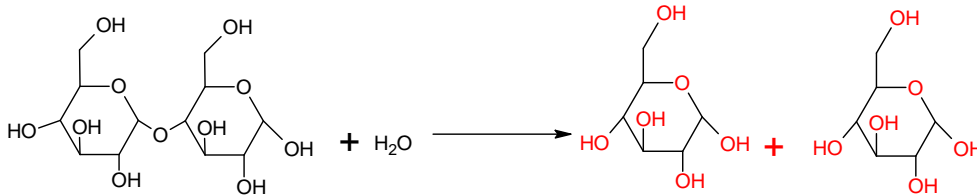
In organisms, the most common molecule digested for its energy is glucose, a carbohydrate. Because so many carbohydrates in the world are polymers of glucose, organisms have a ready supply of energy. However, though it is not as easy to digest, lipids actually produce more energy than carbohydrates when broken down. Is it no wonder, then, that the human body stores fat?

### Pre-Assignment:

1. a. Show the dehydration (condensation) reaction to form maltose. Circle the molecules lost.

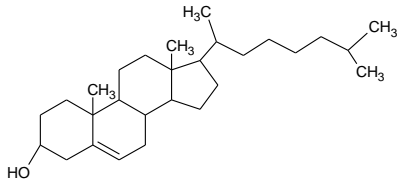


- b. Show the hydrolysis reaction of maltose into two glucose molecules.

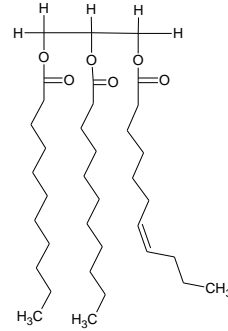


2. Name the following disaccharides:
  - a. Glucose + Glucose → **maltose**
  - b. Glucose + Sucrose → **sucrose**
  - c. Glucose + Galactose → **lactose**

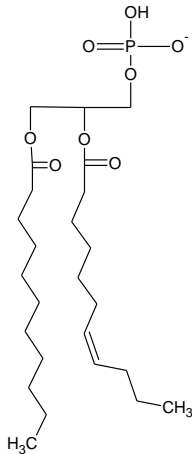
3. Match the types of fats with their structures.
  - a. Phospholipid
  - b. Saturated Triglycerol
  - c. Steroid
  - d. Unsaturated Triglycerol



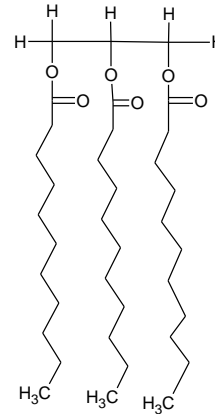
**Steroid**



**Unsaturated Triglycerol**



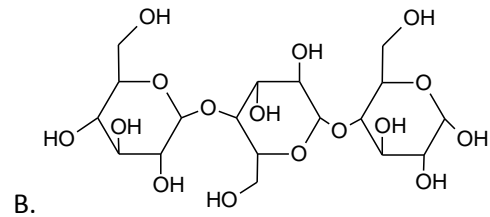
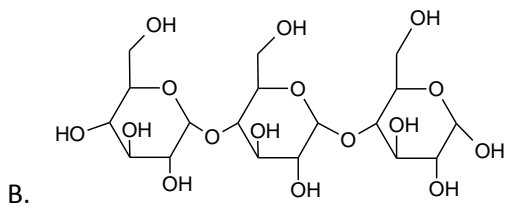
**Phospholipid**



**Unsaturated Triglycerol**

Assignment:

**Carbohydrates:**



1. What is the structural difference between the glucose polymers of A and B?

**The glucose polymers in A are all in the same orientation with the hydroxyl molecules pointed down. The glucose molecule in the middle of B is upside down; its hydroxyl molecule is pointed up.**

The linkages of the polymer in A are called  $\alpha$ -linkages.  
The linkages of the polymer in B are called  $\beta$  linkages.  
Enzymes in the body can digest the  $\alpha$ -linkages, only.

2. Out of the three types of carbohydrates below, which one(s) can the human body digest?
  - a. Starch-**yes**
  - b. Glycogen-**yes**
  - c. Cellulose-**no**
  
3. Therefore, the carbohydrates that humans can digest are formed from which linkages?  
**Alpha linkages**

### **Lipids:**

Definition: The Second Law of Thermodynamics states that energy transfer increases the entropy (disorder) of the universe.

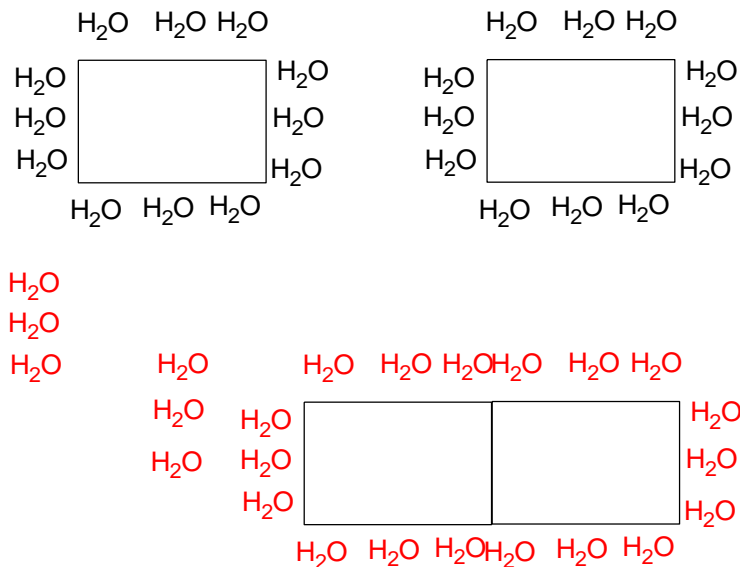
4. Which situation increases the disorder of the universe?
  - a. A room becoming messy from lack of tidying
  - b. Cleaning up a messy room.**A room becoming messy**
  
5. Which situation involves the input of the least amount of energy?  
**A room becoming messy**
  
6. What is the relationship between increasing the disorder of the universe and the amount of energy needed?  
**Increasing the disorder (entropy) of the universe releases energy. Decreasing the disorder requires the input of energy. Therefore it is the favored reaction direction.**



7. Why does (6) benefit biological systems?

**Biological systems use the energy released from reactions that increase entropy to fuel required reactions.**

8. In the following figure, two fat droplets are suspended in an aqueous environment. They are surrounded by water molecules. Draw a new picture where the fat molecules are fused (a hydrophobic interaction), while keeping the amount of water molecules the same. (Note: no water molecules can be fused between the fat).



What has changed?

**Six water molecules are free to randomly move in the environment instead of being sequestered around the fat molecule.**

9. How does the accumulation of fat in an aqueous environment follow the Second Law of Thermodynamics?

**The accumulation of fat droplets releases water molecules into the environment, increasing the entropy of the universe, when they decrease their collective surface area by aggregating.**

10. According to (9), why then does the phospholipid bilayer form by fusing the hydrophobic tails of the phospholipid?

**The hydrophobic tails of the phospholipid aggregate to form the lipid bilayer so that entropy can be increased. If the hydrophobic tails are sequestered inside the hydrophilic heads, no water molecule will be stuck in a rigid manner.**

## Proteins and Nucleic Acids Quiz

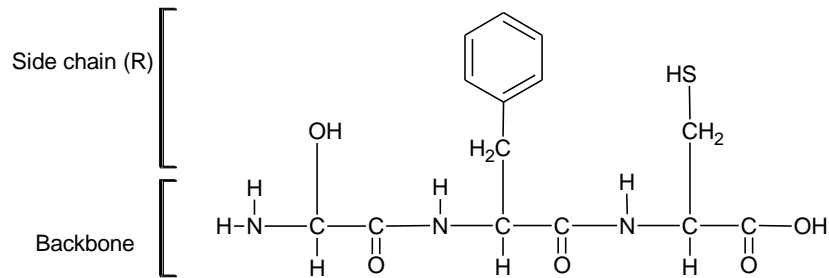
1. What type of linkages are found in starch and glycogen?
  - a. Ester linkages
  - b.  $\alpha$ -linkages
  - c. Disulfide Bridges
  - d.  $\beta$ -linkages
  
2. How does the accumulation of fat molecules in aqueous environments follow the Second Law of Thermodynamics?
  - a. It decreases entropy.
  - b. It releases energy.
  - c. It increases entropy.
  - d. It transfers energy.
  
3. Which of the following is **not** a component of the backbone of a polypeptide?
  - a. Phosphate group
  - b. Amino group
  - c. Carboxyl group
  - d. Central carbon
  
4. Which of the following is **not** a component of a polynucleotide?
  - a. Nitrogenous base
  - b. Phosphate group
  - c. 5-carbon sugar
  - d. Carboxyl group

## Proteins and Nucleic Acids

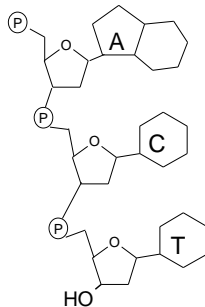
Proteins and nucleic acids are two of the most important macromolecules in the cell; nucleic acids are polymerized to create DNA and RNA and amino proteins are considered the work horses of the cell. Without nucleic acids, the information storage system would be non-existent. Without proteins, no life-sustaining reactions would take place.

### Pre-Assignment:

1. Below is a small polypeptide chain synthesized from three amino acids. Identify the three common groups of the backbone.



- a.
  - b.
  - c.
2. Name the four categories of the amino acid side chains and their charge, if present.
    - a.
    - b.
    - c.
    - d.
  3. Below is a polynucleotide chain. Identify its three components.



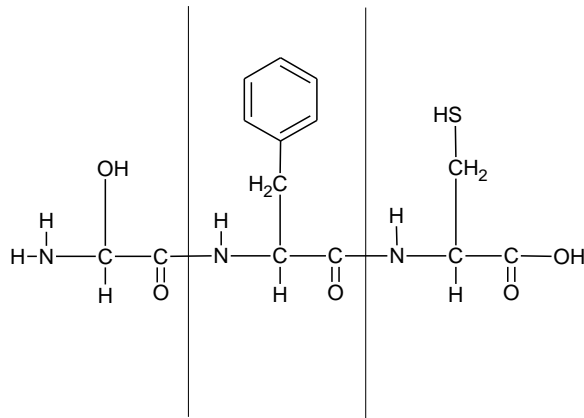
- a.
- b.
- c.

Assignment:

**Protein:**

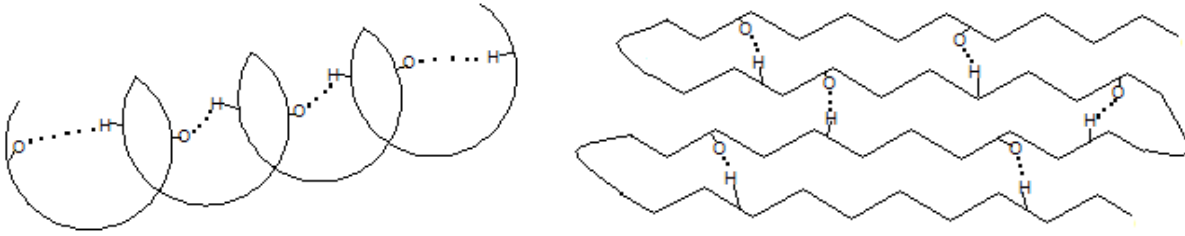
Protein structure consists of four levels or structures.

1. Primary structure:



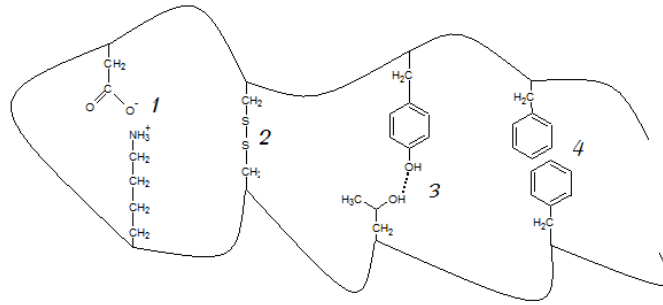
- a. What are the subunits of the primary structure of polypeptides? (i.e. what determines the primary structure?)
  
  
  
  
  
  
  
  
  
  
- b. What type of bond is used to synthesize the chain?

## 2. Secondary Structure:



- What are the names of the two types of secondary structures?
- According to the picture, which pair of molecules are bonded?
- What is this bond called?
- What is another molecule that can hydrogen bond with hydrogen? What categories of amino acids can bind to water?
- What locations on the polypeptide do the bonds of the secondary structure occur?

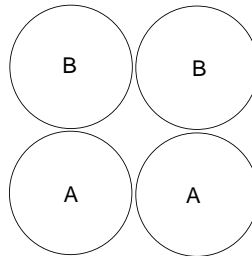
3. Tertiary Structure:



a. Label the types of interactions that occur in the tertiary structure.

b. What location on the polypeptide do the bonds occur?

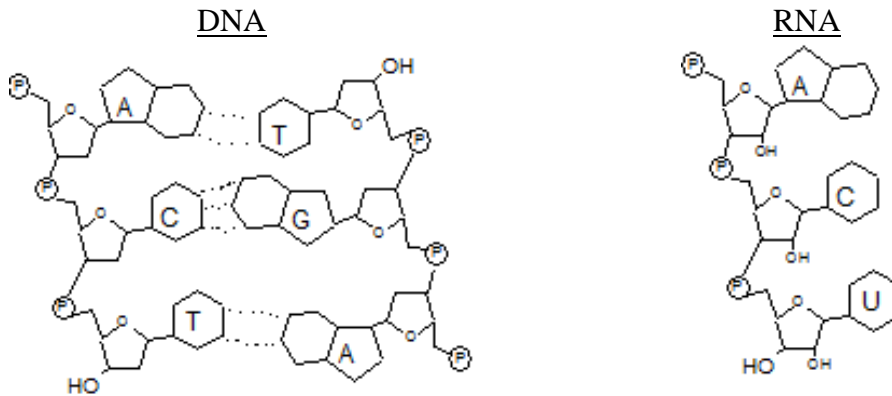
4. Quaternary Structure:



a. Describe how the polypeptides A and B form the quaternary structure.

5. List the four levels of protein structure. Include the types and locations of bonds that create each structure. Use (1), (2), (3) and (4).

**Nucleic Acids:**



6. Compare the pictures of DNA and RNA. Complete the table.

	DNA	RNA
Sugar		
Pyrimidine Bases		
Purine Bases		
Strand		

7. What is type of bond connects the phosphate and the sugar? What is the special name for the bond in nucleic acids?

8. What type of bonds connect the nitrogenous bases?
9. On the figure above, label the 5' and 3' ends of the DNA double helix. What determines the place of the 3' and 5' ends?
10. Is DNA parallel or anti-parallel? Explain.



## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Proteins and Nucleic Acids Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, 3, 4, and 5: (20 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 1, 2, 3, and 4 are designed to walk students through the four levels of protein folding and how they bond with other molecules to stabilize the folding. It is important that students understand which molecules create bonds in each level (e.g. backbone or R groups) and what type of bonds are formed (e.g. peptide bonds or hydrogen bonds).

The last five minutes of this section should be spent on question 5. This question brings together the work from questions 1 through 4 by requiring the students to list the differences between the levels in a concise format. **Question 5 is the first critical thinking question.**

### Question 6, 7, and 8: (5 minutes)

Give the students three minutes to read the questions and form answers. The next two minutes should include a discussion about the answers. Question 6 simply contrasts DNA and RNA. Briefly ask for answers, but this question should not take too much time.

## Proteins and Nucleic Acids Notes

Question 7 and 8 are meant to contrast the different types of bonds in the polynucleotide. If possible, pose this question: if hydrogen bonds connect the bases, what does that say about the stability or long-life of the bonds? Try to get them to discuss that the presence of hydrogen bonds hints that they are reversible, i.e. that they can be easily broken.

### Question 9 and 10: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 9 leads into question 10, about DNA's anti-parallel nature. If students are having trouble deducing that DNA is anti-parallel, try referring them to the figure that they have labeled with the 3' and 5' ends.

Discuss with the students what would make the molecule parallel (the two ends being identical) and ask them if the figure follows that definition. Because it does not, it must be anti-parallel.

**Question 10 is the second critical thinking question.**

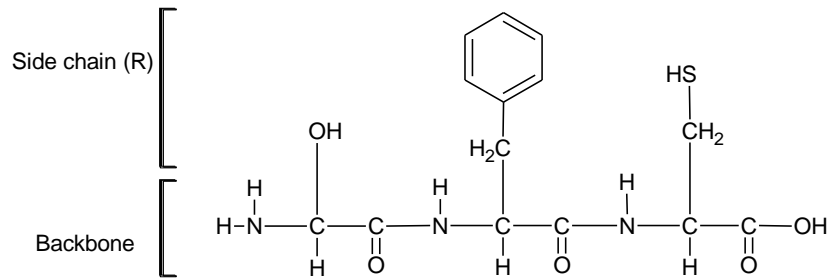
The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 5 and 10 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Proteins and Nucleic Acids

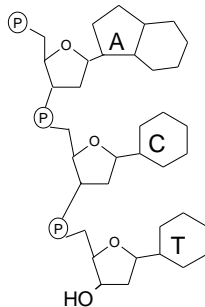
Proteins and nucleic acids are two of the most important macromolecules in the cell; nucleic acids are polymerized to create DNA and RNA and amino proteins are considered the work horses of the cell. Without nucleic acids, the information storage system would be non-existent. Without proteins, no life-sustaining reactions would take place.

### Pre-Assignment:

1. Below is a small polypeptide chain synthesized from three amino acids. Identify the three common groups of the backbone.



- a. **Amino**
  - b. **Carboxyl**
  - c. **Central carbon**
2. Name the four categories of the amino acid side chains and their charge, if present.
    - a. **Acidic (-)**
    - b. **Basic (+)**
    - c. **Polar uncharged (partially negative)**
    - d. **Hydrophobic**
  3. Below is a polynucleotide chain. Identify its three components.



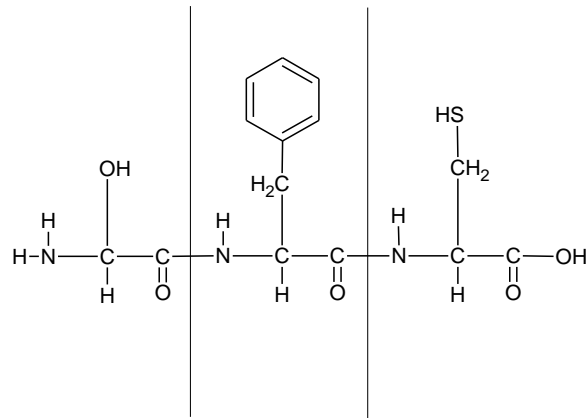
- d. **Nitrogenous base**
- e. **5-carbon sugar**
- f. **Phosphate group**

Assignment:

**Protein:**

Protein structure consists of four levels or structures.

1. Primary structure:



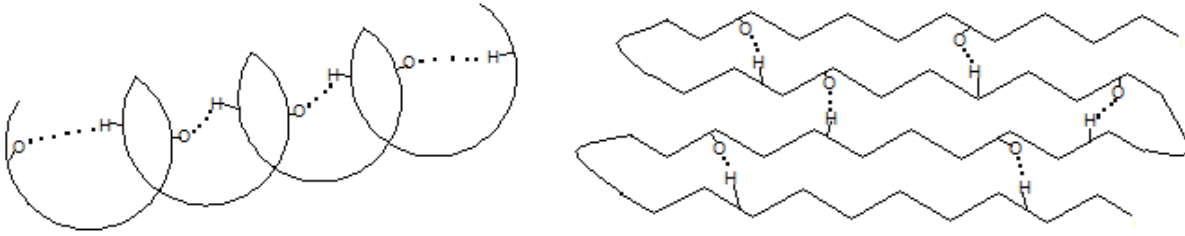
- a. What are the subunits of the primary structure of polypeptides? (i.e. what determines the primary structure?)

**Amino acids are the subunits of the primary structure.**

- b. What type of bond is used to synthesize the chain?

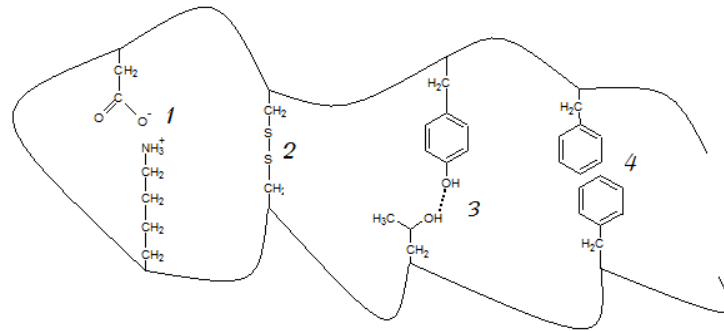
**Covalent bonds called peptide bonds are used to synthesize the chain.**

2. Secondary Structure:



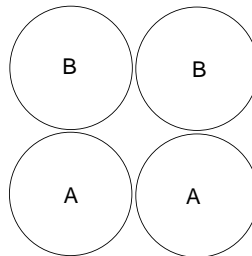
- What are the names of the two types of secondary structures?  
**Alpha helix and beta sheet**
- According to the picture, which pair of molecules are bonded?  
**Oxygen and hydrogen**
- What is this bond called?  
**Hydrogen bond**
- What is another of molecule that can hydrogen bond with hydrogen? What categories of amino acids can bind to water?  
**Nitrogen. Polar, acidic, and basic amino acids.**
- What locations on the polypeptide do the bonds of the secondary structure occur?  
**Bonds between the oxygen and hydrogen of the backbone bond in the secondary structure.**

3. Tertiary Structure:



- a. Label the types of interactions that occur in the tertiary structure.  
**(left to right starting at top left) Ionic interaction, Disulfide Bridge, Hydrogen Bond, Hydrophobic Bond**
- b. What location on the polypeptide do the bonds occur?  
**For the tertiary structure, bonds occur between the side chains (R groups)**

4. Quaternary Structure:



- a. Describe how the polypeptides A and B form the quaternary structure.  
**Polypeptides A and B aggregate to form a quaternary structure.**

5. List the four levels of protein structure. Include the types and locations of bonds that create each structure. Use (1), (2), (3) and (4).

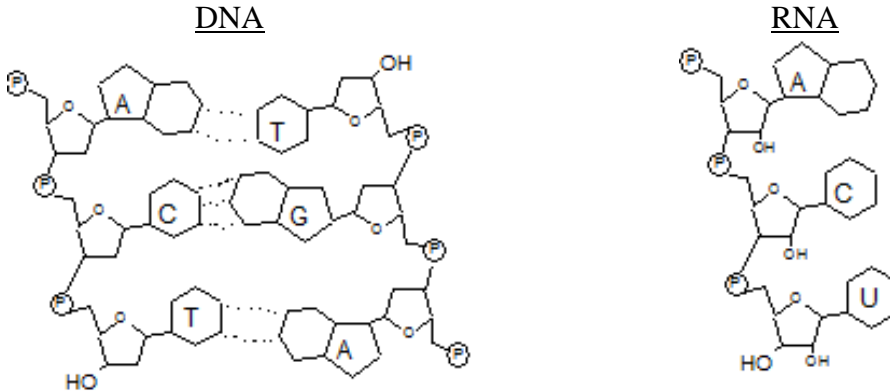
**Primary structure-covalent bond-peptide bond-between the amino groups, central carbons, and carboxyl groups of the backbone**

**Secondary structure-Hydrogen bonds-between the oxygens and hydrogens of the backbone**

**Tertiary structure-weak interactions with the exception of the disulfide bridge-between the side chains of the amino acids**

**Quaternary structure-weak interactions-between polypeptides to form a functioning protein**

**Nucleic Acids:**



6. Compare the pictures of DNA and RNA. Complete the table.

	DNA	RNA
Sugar	<b>Deoxyribose</b>	<b>Ribose</b>
Pyrimidine Bases	<b>T, C</b>	<b>U, C</b>
Purine Bases	<b>A, G</b>	<b>A, G</b>
Strand	<b>Double stranded</b>	<b>Single stranded</b>

7. What is type of bond connects the phosphate and the sugar? What is the special name for the bond in nucleic acids?

**A covalent bond connects the phosphate and the sugar. It is called a phosphodiester bond.**



8. What type of bonds connect the nitrogenous bases?

**Hydrogen bonds connect the nitrogenous bases.**

9. On the figure above, label the 5' and 3' ends of the DNA double helix. What determines the place of the 3' and 5' ends?

**The 3' end is denoted by the hydroxyl molecule. The 5' end is denoted by the phosphate molecule.**

10. Is DNA parallel or anti-parallel? Explain.

**DNA is anti-parallel. According to the figure of the small DNA strand, a 3' end and a 5' end are opposite each other on the top and bottom of the molecule. If it were parallel, both of the 3' molecules would be at one end and both of the 5' molecules would be at the other. Also, the sugars on the strands face in the opposite direction. If it was parallel, they would face in the same direction.**

## Endomembrane System Quiz

1. In which level of protein folding does bonding occur between the R groups?
  - a. Primary Structure
  - b. Secondary Structure
  - c. Tertiary Structure
  - d. Quaternary Structure
  
2. Which molecule is present at the 3' end of a DNA molecule?
  - a. P
  - b. OH
  - c. NH<sub>4</sub>
  - d. COOH
  
3. What is the term for the engulfing of a food particle by a cell?
  - a. Phagocytosis
  - b. Autophagy
  - c. Glycolysis
  - d. Cellular Respiration
  
4. Which side of the golgi apparatus receives vesicles from the rough ER?
  - a. cis
  - b. trans
  - c. Side
  - d. Bottom

## Endomembrane System

The endomembrane system is involved with many biological systems including the synthesis and transport of proteins for the creation of new membranes or secretion; lipid biosynthesis and secretion; and detoxification. Cells that have specialized functions in the body are rich in organelles that carry out that required task. However, no matter the specialization, the system is carried out in a process mediated by transport vesicles.

### Preassignment:

Define the following terms:

1. *cis* v. *trans* face of Golgi apparatus-
2. Glycoprotein-
3. Proteoglycan-
4. Phosphoprotein-
5. Polysaccharide-
6. Phagocytosis-
7. Autophagy-

### Assignment:

Interpret the functions of the organelles from the clues given:

1. Smooth ER-
  - a. Cells such as those in the testes, ovaries and the adrenal gland secrete these chemical that are made from the numerous smooth ER present in the cells. What does the smooth ER synthesize?
  - b. Liver cells are rich in smooth ER. Substance abuse can increase the proliferation of this organelle in liver cells because of their function of ridding the blood of drugs. How does the smooth ER clean cells of substances?
  - c. A specialized form of the smooth ER, called the sarcoplasmic reticulum, is present in muscle cells. When the cell is stimulated, the smooth ER releases  $\text{Ca}^{2+}$  to begin the contraction. What does the smooth ER store?

2. Rough ER-

- a. Molecules, such as insulin, are found in the lumen of the rough ER. What class of molecules does the rough ER synthesize?
  
  
  
  
  
  
  
  
  
  
- b. Insulin and other molecules that are found in the ER are also found in other locations of the cell, mainly the Golgi apparatus. How are the proteins transferred from the rough ER to the Golgi apparatus?

3. Golgi Apparatus-

- a. Proteins found at the *cis* face of the Golgi apparatus are identical to those found in the rough ER. What type of container does the *cis* face of the Golgi receive from the ER?
  
  
  
  
  
  
  
  
  
  
- b. Glycoproteins, proteoglycans, and phosphoproteins are found at the *trans* face of the Golgi apparatus. What happens to the received proteins as they travel through the cristae of the Golgi apparatus?
  
  
  
  
  
  
  
  
  
  
- c. Polysaccharides are found leaving from the *trans* face. However, the Golgi does not receive polysaccharides from the rough ER. How, then, are the polysaccharides synthesized?
  
  
  
  
  
  
  
  
  
  
- d. Lysosomes and vacuoles are found leaving from the *trans* face. However, the Golgi does not receive lysosomes and vacuoles from the rough ER. How, then, are they synthesized?

4. Lysosomes-

- a. Lysosomes fuse with food vacuoles in amoeba. After fusion, the food molecules are broken down. How does the lysosome break down the food?
  
  
  
  
  
  
  
  
  
  
  - b. Liver cells recycle half of their macromolecules and damaged material every week through the use of lysosomes. How do lysosomes acquire the material and break it down?
5. Order the structures below to describe the flow of the endomembrane system, beginning with the nuclear envelope and ending with secretion. Briefly explain the function of each location.

Golgi Apparatus, Nuclear Envelope, Secretion, Lysosomes/Vacuoles, Rough ER

6. Differentiate the function (and final location of proteins) between the ribosomes in the cytoplasm and the ribosomes attached to the rough ER.

## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Endomembrane System Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1 and 2: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Students may struggle with deducing the function of the organelles from the clues given. However, ask the students to identify what happened in each clue. For example, what do the function of the adrenal gland, ovaries, and testes have in common? What type of molecule do they release? The answer is that they all secrete hormones. If these types of cells are rich in smooth ER, then the smooth ER must secrete hormones.

If, after ten minutes, the students have not gotten very far, try opening up the discussion to the class so that the students can help each other.

### Questions 3 and 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. After having shown the students the process of elucidating the answers from questions 1 and 2, they should be able to work through questions 3 and 4 easily. If not, begin the discussion as before. Ask if any student has found the answer and ask them to explain.

## Endomembrane System Notes

### Questions 5 and 6: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 5 is intended to combine what students have learned about the function of the organelles into the pathway of the endomembrane system. They should be able to explain that: proteins are synthesized in the rough ER, transported to the cis face of the golgi apparatus, modified in the golgi, released in secretory vesicles or as lysosomes, and that the secretory vesicles merge with the plasma membrane to release the proteins. **Question 5 is the first critical thinking question.**

Question 6 asks the students to compare the functions of bound ribosomes and free ribosomes. During the discussion, make sure a student clarifies that bound ribosomes synthesize proteins that are secreted or inserted into membranes; free ribosomes synthesize proteins used for cell metabolism. **Question 6 is the second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 5 and 6 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.



## Endomembrane System

The endomembrane system is involved with many biological systems including the synthesis and transport of proteins for the creation of new membranes or secretion; lipid biosynthesis and secretion; and detoxification. Cells that have specialized functions in the body are rich in organelles that carry out that required task. However, no matter the specialization, the system is carried out in a process mediated by transport vesicles.

### Preassignment:

Define the following terms:

1. *cis* v. *trans* face of Golgi apparatus- **the *cis* face of the golgi usually faces the ER and accepts its vesicles; the *trans* face of the golgi faces away from the ER and new vesicles bud off of it**
2. Glycoprotein-**A protein with carbohydrates attached**
3. Proteoglycan-**A carbohydrate with proteins attached**
4. Phosphoprotein-**A protein with phosphate group attached**
5. Polysaccharide-**A polymer of monosaccharides**
6. Phagocytosis-**The uptake of large particles into a cell (endocytosis)**
7. Autophagy-**The breakdown of a cell's damaged organelles and other wastes**

### Assignment:

Interpret the function of the organelles from the clues given:

1. Smooth ER-
  - a. Cells such as those in the testes, ovaries and the adrenal gland secrete these chemical that are made from the numerous smooth ER present in the cells. What does the smooth ER synthesize?  
**Secretion of hormones**
  - b. Liver cells are rich in smooth ER. Substance abuse can increase the proliferation of this organelle in liver cells because of their function of ridding the blood of drugs. How does the smooth ER clean cells of substances?  
**Detoxification of a cell of many different substances, such as alcohol**
  - c. A specialized form of the smooth ER, called the sarcoplasmic reticulum, is present in muscle cells. When the cell is stimulated, the smooth ER releases  $\text{Ca}^{2+}$  to begin the contraction. What does the smooth ER store?  
**Storage of  $\text{Ca}^{2+}$**

2. Rough ER-

- a. Molecules, such as insulin, are found in the lumen of the rough ER. What class of molecules does the rough ER synthesize?

**Synthesis of proteins, specifically those to be secreted or integrated into membranes**

- b. Insulin and other molecules that are found in the ER are also found in other locations of the cell, mainly the Golgi apparatus. How are the proteins transferred from the rough ER to the Golgi apparatus?

**Gives rise to vesicles that contain the proteins to be secreted. They are sent to the Golgi.**

3. Golgi Apparatus-

- a. Proteins found at the *cis* face of the Golgi apparatus are identical to those found in the rough ER. What type of container does the *cis* face of the Golgi receive from the ER?

**Receives vesicles containing protein from the ER.**

- b. Glycoproteins, proteoglycans, and phosphoproteins are found at the *trans* face of the Golgi apparatus. What happens to the received proteins as they travel through the cristae of the Golgi apparatus?

**Modifies proteins as they move through the organelle to the *trans* face. They leave the golgi in secretory vesicles.**

- c. Polysaccharides are found leaving from the *trans* face. However, the Golgi does not receive polysaccharides from the rough ER. How, then, are the polysaccharides synthesized?

**Can also synthesize other molecules such as polysaccharides.**

- d. Lysosomes and vacuoles are found leaving from the *trans* face. However, the Golgi does not receive lysosomes and vacuoles from the rough ER. How, then, are they synthesized?

**Synthesizes lysosomes and vacuoles**

4. Lysosomes-
- Lysosomes fuse with food vacuoles in amoeba. After fusion, the food molecules are broken down. How does the lysosome break down the food?  
**Carry enzymes that aid in digestion of food.**
  - Liver cells recycle half of their macromolecules and damaged material every week through the use of lysosomes. How do lysosomes acquire the material and break it down?  
**Aids in the digestion of damaged organelles and material.**
5. Order the structures below to describe the flow of the endomembrane system, beginning with the nuclear envelope and ending with secretion. Briefly explain the function of each location.

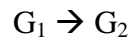
Golgi Apparatus, Nuclear Envelope, Secretion, Lysosomes/Vacuoles, Rough ER

**Nuclear Envelope, Rough ER, Golgi Apparatus, Lysosomes/Vacuoles, Secretion**

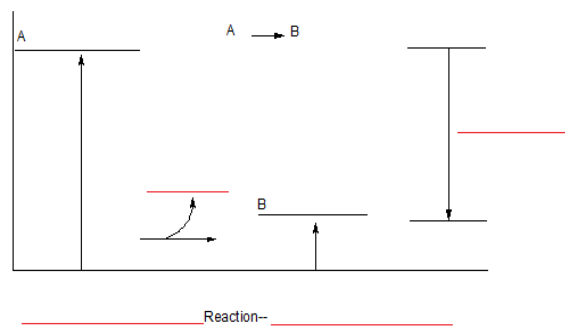
- 1. Proteins from the rough ER are synthesized**
  - 2. The proteins are packaged into vesicles and sent to the *cis* face of the golgi apparatus**
  - 3. Lysosomes and small vesicles bud off of the golgi apparatus**
  - 4. After the proteins are modified within the golgi, they are packaged into vesicles as they leave the *trans* face**
  - 5. The secretory vesicles fuse with the plasma membrane and release its contents**
6. Differentiate the function (and final location of proteins) between the ribosomes in the cytoplasm and the ribosomes attached to the rough ER.  
**Ribosomes attached to the rough ER synthesize proteins that are destined to be secreted or inserted into membranes. Free ribosomes synthesize proteins for the use of the cell.**

## Enzymes Quiz

1. The Smooth ER functions include everything **except**:
  - a. Secretion of hormones
  - b. Detoxification
  - c. Synthesis of protein
  - d. Storage of  $\text{Ca}^{2+}$
  
2. What is the correct flow of the endomembrane system?
  - a. Rough ER  $\rightarrow$  Golgi  $\rightarrow$  Lysosomes or Plasma membrane
  - b. Gogi  $\rightarrow$  Rough ER  $\rightarrow$  Lysosomes or Plasma membrane
  - c. Plasma membrane or Lysosomes  $\rightarrow$  Rough ER  $\rightarrow$  Golgi
  - d. Plasma membrane or Lysosomes  $\rightarrow$  Golgi  $\rightarrow$  Rough ER
  
3. If  $G_1 = 30$  kJ and  $G_2 = 40$  kJ, what is the  $\Delta G$  in the following reaction?



- a. +10, Spontaneous
  - b. -10, Non-spontaneous
  - c. +10, Non-spontaneous
  - d. -10, Spontaneous
- 
4. What is the best description for the reaction?



- a. Exergonic, Spontaneous
- b. Endergonic, Non-spontaneous
- c. Exergonic, Non-Spontaneous
- d. Endergonic, Spontaneous

## Enzymes

A portion of the population is lactose intolerant; they cannot digest any food product containing lactose. Why? Their bodies do not contain the enzyme lactase, necessary to break lactose into its monomeric components. Without that enzyme, the body cannot digest the dimer.

### Pre-Assignment:

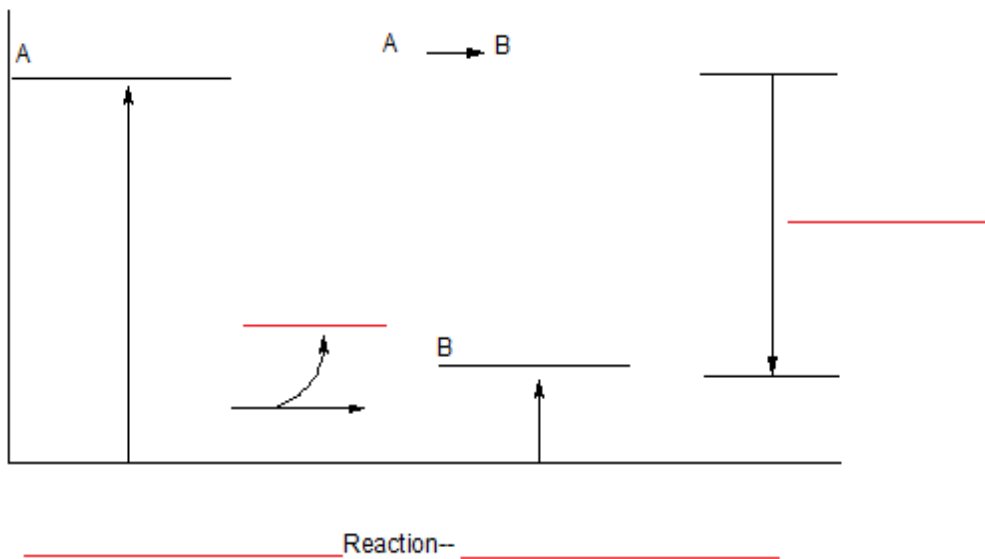
In biological systems, reactions work to increase or decrease the entropy ( $\Delta S$ ) of the environment. Entropy is defined as the disorder of the universe.

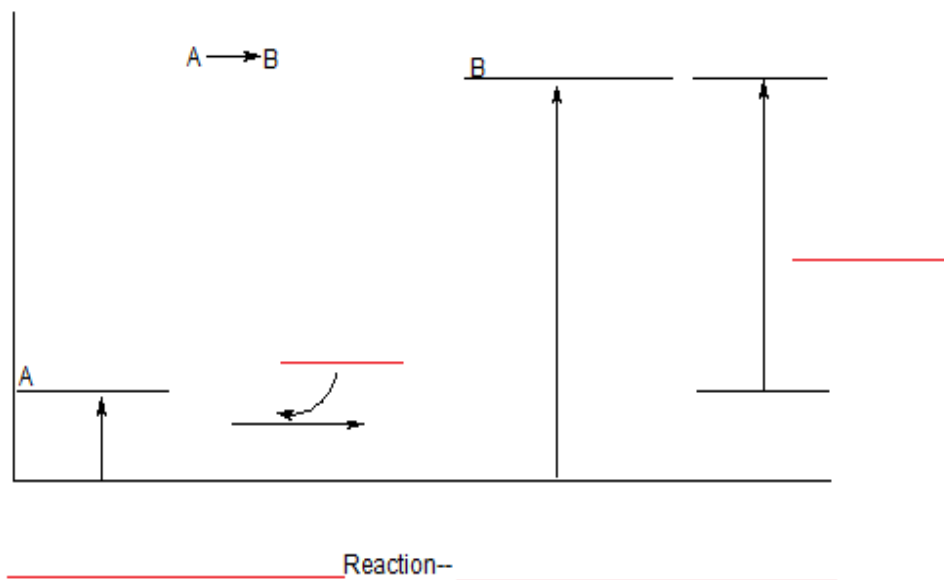
Reactions that *decrease* the entropy of the universe require an input of energy to complete the reaction.

Reactions that *increase* the entropy of the universe do not require an input of energy; they release energy.

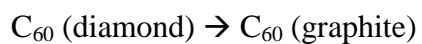
1. Place the phrases in the correct spots:

- A. Nonspontaneous
- B. Energy released
- C. Endergonic
- D. Amount of Energy released ( $-\Delta G$ )
- E. Spontaneous
- F. Amount of Energy required ( $+\Delta G$ )
- G. Energy absorbed
- H. Exergonic





2. Observe the chemical reaction below:



The  $G$  for the combustion of  $\text{C}_{60}$  (diamond) = -397 kJ

The  $G$  for the combustion of  $\text{C}_{60}$  (graphite) = -394 kJ

a. Calculate the  $\Delta G$  of the reaction (remember:  $\Delta G = G_{\text{final state}} - G_{\text{initial state}}$ )

b. Is the reaction spontaneous or nonspontaneous?

Assignment:

A biological system contains the possible reactions:

- A.  $A \rightarrow B$
- B.  $A \rightarrow B$
- C.  $C \rightarrow D$
- D.  $C \rightarrow D$

Reaction A requires 20kJ of energy to transform reactant A into product B. The reaction is spontaneous.

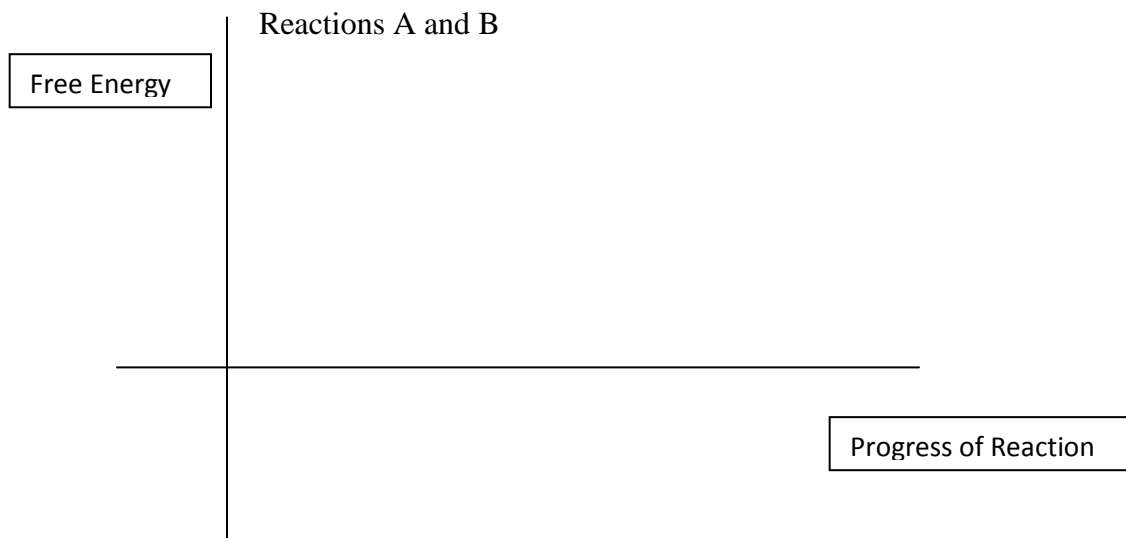
Reaction B requires 10 kJ of energy to transform reactant A into product B. The reaction is spontaneous.

Reaction C requires 20kJ of energy to transform reactant C into product D. The reaction is non-spontaneous.

Reaction D requires 10 kJ of energy to transform reactant C into product D. The reaction is non-spontaneous.

1. Name two potential biological energy sources that could transform the reactants into products.

2. Sketch the Free Energy graphs of the reactions, labeling the reactants, products and activation energy, and  $\Delta G$  (+ or -).



## Reactions C and D



3. If Enzyme 1 were added to Reaction A the result would be Reaction B.  
If Enzyme 2 were added to Reaction C, the result would be Reaction D.

What did the enzymes change, and how did it change it (Hint: use the information at the beginning of the assignment)? Would the Reactions A and C occur, if the enzymes were present, if the systems contained  $-15\text{kJ}$  of free energy?

4. If we only wished to progress Reaction A, would heating the biological system in a water bath prove to be a valid procedure? Why or why not?
5. What is a consequence of heating an enzyme?



6. If Enzyme 1 was added to the system, would Reaction C progress?
7. According to (3), (4), and (6), name two of the functions of enzymes in biological systems.
8. According to (2) of the Pre-Assignment, the transformation of diamond to graphite is a spontaneous reaction, its  $\Delta G$  is negative. Why then, do we not notice our diamond rings transforming into graphite? If the reaction of diamond  $\rightarrow$  graphite was desired, what could *possibly* be used to increase the rate of the reaction?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Enzymes Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1 and 2: (15 minutes)

Give the students five to seven minutes to read the questions and form answers. The next eight to ten minutes should include a discussion about the answers. Within the ten minutes that the students are working on the questions, draw the two blank free energy graphs on the board. Ask two of the groups to send someone to complete the graphs.

When discussing the graphs, make sure to ask about the differences on each graph. The students should point out that the activation is lower in one of them. Then ask about the differences between the two graphs. In the spontaneous graph, the energy of the products should be lower than the reactants; in the non-spontaneous graph, the energy of the products should be higher than the reactants. Discuss which one is exergonic and which one is endergonic.

### Question 3: (5 minutes)

Give the students three minutes to read the questions and form answers. The next two minutes should include a discussion about the answers. Question 4 should be used to help students realize that enzymes lower the activation energy of an enzyme so that a lower amount of energy would begin the reaction. If needed, reword the question to help the students better understand.

## Enzymes Notes

### Questions 4, 5, 6, and 7: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. These questions ask leading questions that allow students to infer two of enzymes' unique qualities: their specificity and their ability to lower activation energy. **Question 7 is the first critical thinking question** which asks them to list the functions.

### Question 8: (10 minutes)

Give the students three minutes to read the questions and form answers. The next two minutes should include a discussion about the answers. **Question 8 is the second critical thinking question.** It is designed to allow students to realize that while a reaction could have a  $-\Delta G$  and be spontaneous, it does not always occur quickly. Enzymes allow reactions to occur quickly.

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 7 and 8 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Enzymes

A portion of the population is lactose intolerant; they cannot digest any food product containing lactose. Why? Their bodies do not contain the enzyme lactase, necessary to break lactose into its monomeric components. Without that enzyme, the body cannot digest the dimer.

### Pre-Assignment:

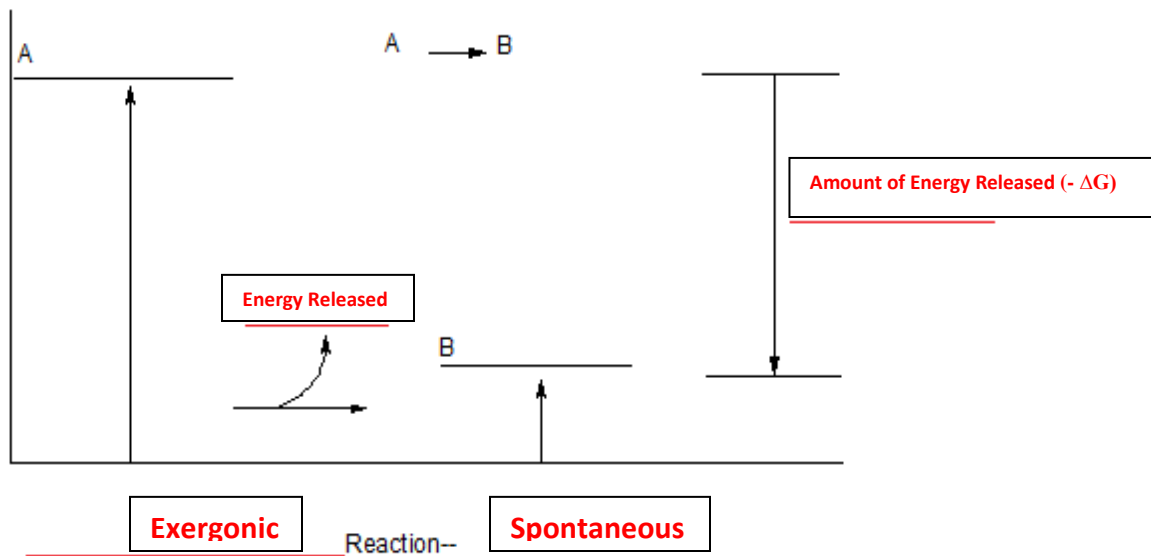
In biological systems, reactions work to increase or decrease the entropy ( $\Delta S$ ) of the environment. Entropy is defined as the disorder of the universe.

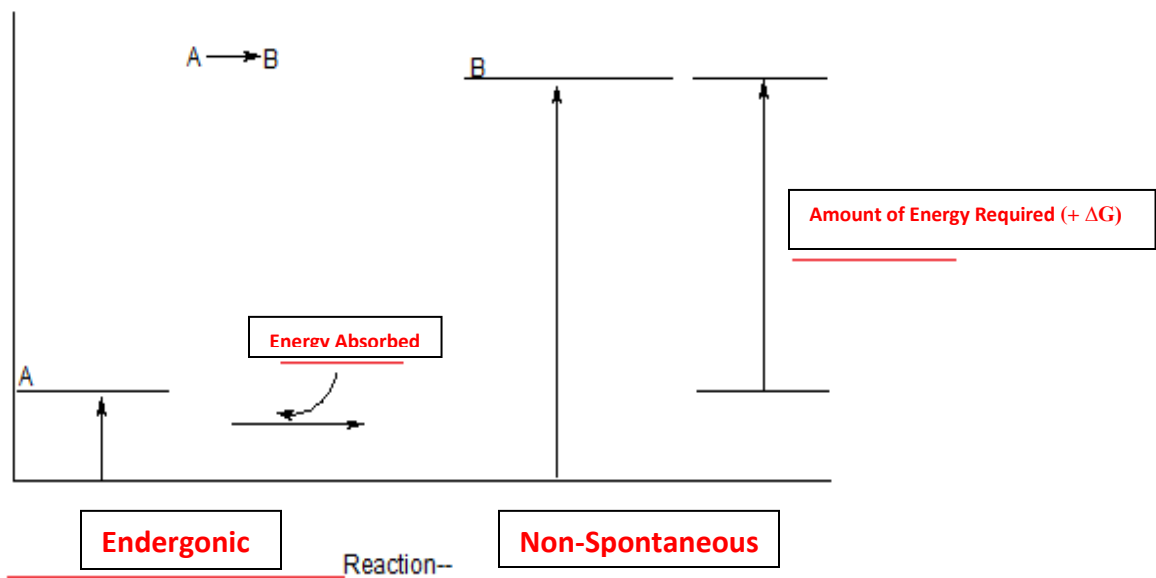
Reactions that *decrease* the entropy of the universe require an input of energy to complete the reaction.

Reactions that *increase* the entropy of the universe do not require an input of energy; they release energy.

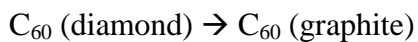
1. Place the phrases in the correct spots:

- A. Nonspontaneous
- B. Energy released
- C. Endergonic
- D. Amount of Energy released ( $-\Delta G$ )
- E. Spontaneous
- F. Amount of Energy required ( $+\Delta G$ )
- G. Energy absorbed
- H. Exergonic



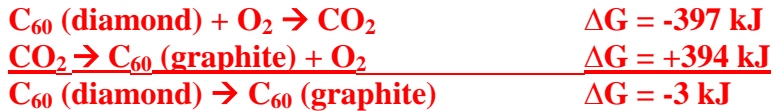


2. Observe the chemical reaction below:



(*Chemical principles*, Zumdahl 6<sup>th</sup> edition)

a. Calculate the  $\Delta G$  of the reaction (remember: balance the equation)



b. Is the reaction spontaneous or nonspontaneous?

**Spontaneous**

Assignment:

A biological system contains the possible reactions:

- E.  $A \rightarrow B$
- F.  $A \rightarrow B$
- G.  $C \rightarrow D$
- H.  $C \rightarrow D$

Reaction A requires 20kJ of energy to transform reactant A into product B. The reaction is spontaneous.

Reaction B requires 10 kJ of energy to transform reactant A into product B. The reaction is spontaneous.

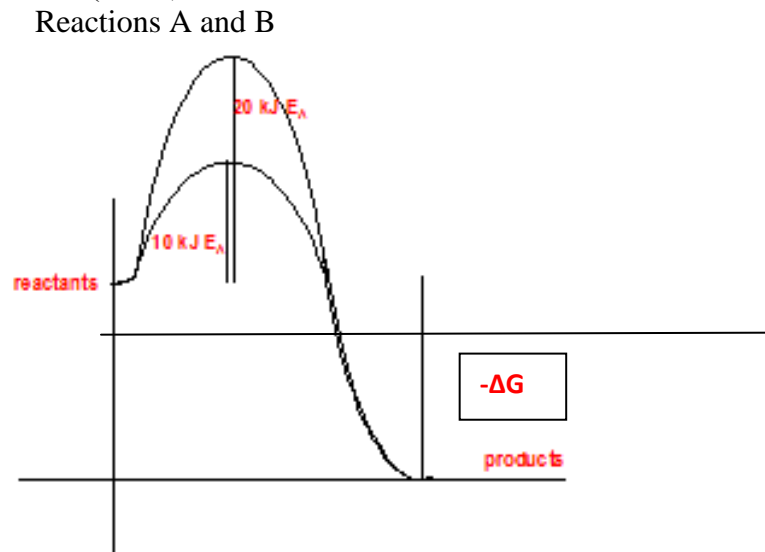
Reaction C requires 20kJ of energy to transform reactant C into product D. The reaction is non-spontaneous.

Reaction D requires 10 kJ of energy to transform reactant C into product D. The reaction is non-spontaneous.

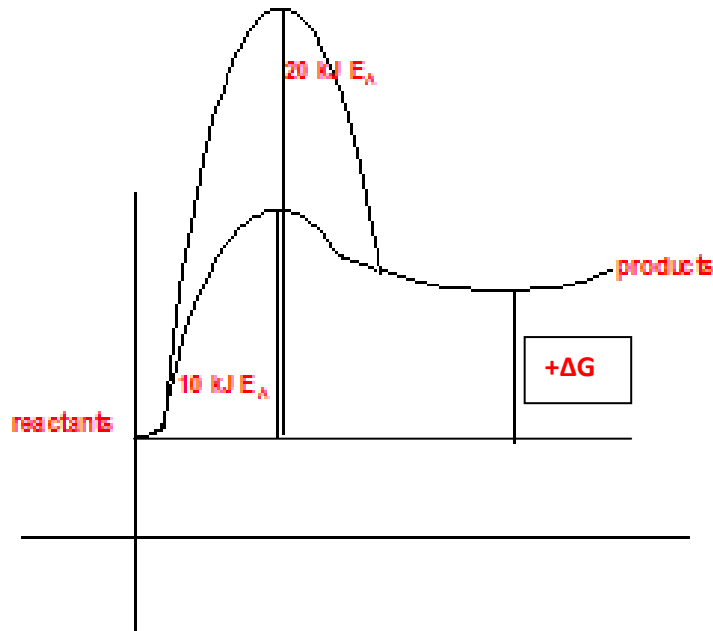
1. Name two potential biological energy sources that could transform the reactants into products.

**Heat, ATP**

2. Sketch the Free Energy graphs of the reactions, labeling the reactants, products and activation energy, and  $\Delta G$  (+ or -).



## Reactions C and D



- If Enzyme 1 were added to Reaction A the result would be Reaction B.  
If Enzyme 2 were added to Reaction C, the result would be Reaction D.

What did the enzymes change, and how did it change it (Hint: use the information at the beginning of the assignment)? Would the Reactions A and C occur, if the enzymes were present, if the systems contained -15kJ of free energy?

**The enzyme lowered the activation energy of Reactions A and C. Yes, Reactions A and C would occur in the presence of the enzymes with -15 kJ of energy. The enzymes lower their activation energies from 20 kJ to 10kJ. -15 kJ is enough energy to run the reaction.**

- If we only wished to progress Reaction A, would heating the biological system in a water bath prove to be a valid procedure? Why or why not?

**Heating the system would not be a valid option. Firstly, it would most likely kill the biological system. Secondly, if it didn't kill the system, all reactions would be activated. Not only the one we were interested in.**

- What is a consequence of heating an enzyme?

**Heat denatures an enzyme, stopping its catalyzing ability.**

- If Enzyme 1 was added to the system, would Reaction C progress?

**According to (3), Enzyme 1 only catalyzes Reaction A. Enzyme 2 catalyzes Reaction C. So, NO, if Enzyme 1 was added to the system Reaction C would NOT progress.**



7. According to (3), (4), and (6), name two of the functions of enzymes in biological systems.

**Enzymes lower activation energy so that a reaction can proceed; it increases the rate of reaction. Enzymes are specific to a reaction.**

8. According to (2) of the Pre-Assignment, the transformation of diamond to graphite is a spontaneous reaction, its  $\Delta G$  is negative. Why then, do we not notice our diamond rings transforming into graphite? If the reaction of diamond  $\rightarrow$  graphite was desired, what could *possibly* be used to increase the rate of the reaction?

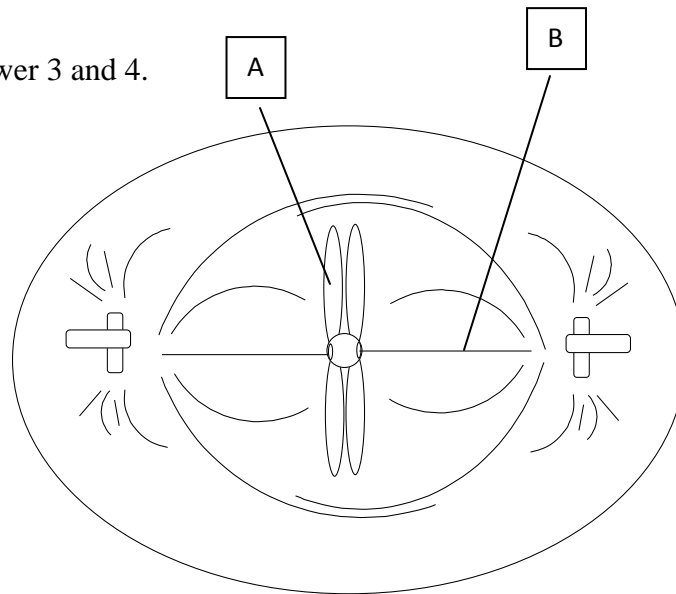
**Spontaneity of a reaction does not equal a quick rate of reaction. The  $\Delta G$  value only indicates whether the reaction would occur without absorbing energy. It says nothing about the rate.**

**If the reaction of diamond to graphite was desired, a catalyst (e.g. enzyme) could be used to increase the rate of the reaction.**

## Mitosis and the Cell Cycle Quiz

1. Which of the following is **not** a characteristic of enzymes?
  - a. Lowers the activation energy of a reaction
  - b. Specificity
  - c. Changes the reaction
  - d. It is not consumed by the reaction
  
2. True or False: Spontaneous reactions always occur quickly.
  - a. True
  - b. False

Use the figure to answer 3 and 4.

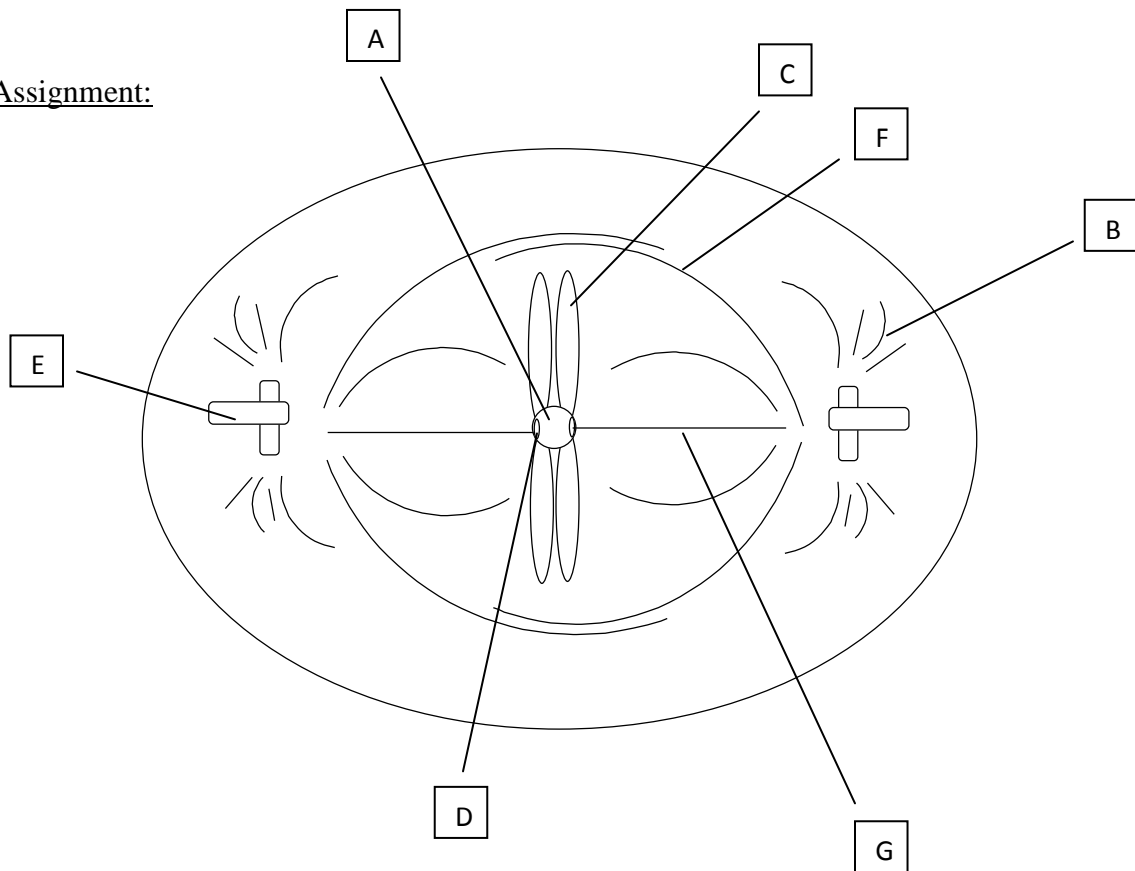


3. What is the name of structure A?
  - a. Centromere
  - b. Kinetochore
  - c. Sister Chromatid
  - d. Kinetochore Microtubule
  
4. What is the name of structure B?
  - a. Centromere
  - b. Kinetochore
  - c. Sister Chromatid
  - d. Kinetochore Microtubule

## Mitosis and the Cell Cycle

When you accidentally cut your arm, how does it heal? After a few days, new skin cells grow and cover the injury, eventually closing off the wound from the environment. But where did the new skin cells come from? Did they appear from thin air? On the contrary, every new cell is derived from an old cell.

Pre-Assignment:



1. Centrioles \_\_\_\_\_
2. Kinetochore microtubule \_\_\_\_\_
3. Aster \_\_\_\_\_
4. Sister chromatid \_\_\_\_\_
5. Centromere \_\_\_\_\_
6. Non-kinetochore microtubule \_\_\_\_\_
7. Kinetochore \_\_\_\_\_

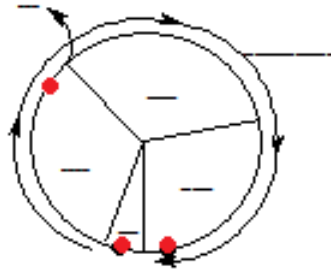
Assignment:

1. For each phase of mitosis, indicate the existence, non-existence, location, or form of each of the key terms:

	Interphase	Prophase	Prometaphase	Metaphase	Anaphase	Telophase/Cytokinesis
Nuclear envelope						
Nucleolus						
Mitotic Spindle						
Location of centrosome						
Packaging of DNA						
Location of Chromosomes						

Mitosis occurs in states that require a mass build up of cells, such as in embryonic development and when repairing damage in the body, such as a tear in the skin. However, most body cells are not in a continual dividing state; they cycle in and out depending on internal and external cues.

- Below is a model of the Cell Cycle. Read the statements and then label the stages of the cell cycle.



Interphase: The longest stage of the cell cycle. During this stage, the cell replicates its DNA, organelles, and cytoplasm in preparation for cell division.

G<sub>1</sub>: The first growth stage of Interphase. Contains a checkpoint for division.

G<sub>2</sub>: The second growth stage of Interphase. Contains a checkpoint for division.

S: The stage where DNA is duplicated. Occurs between the two growth stages.

M: Cell division, mitosis, occurs. This is the shortest stage.

G<sub>0</sub>: The nondividing stage. Most cells in the body are in this stage.

- During the cell cycle, there are three checkpoints that occur in G<sub>1</sub>, G<sub>2</sub>, and M as shown in the figure. Why would a cell need to employ checkpoints?

- What is a possible reason for the formation of cancerous tumors?

## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Mitosis and the Cell Cycle Notes

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### Question 1: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 should not be completed from memory; it is unrealistic to expect that the students have every phase of mitosis memorized. They should use their book to complete the table. While students are completing this exercise, you should draw the table on the board and ask one person from each group to fill in a row, to expedite the completion of the table. The discussion should include asking if anyone disagrees with what is on the board. If so, why?

### Question 2: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 2 should be fairly easy for students. The figure can be drawn on the board and students can fill in the blanks.

### Question 3 and 4: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. **Questions 3 and 4 are the critical thinking questions.**

### **Mitosis and the Cell Cycle Notes**

The discussion for question 3 should include that the cell needs to be sure that all the components needed for cell division have been synthesized and the replication of the DNA has been made with no errors. It should also include that the mitosis is not needed for all cells all the time; the checkpoints allow the cell to bring the cell into the G<sub>0</sub> if needed.

Question 4 discussion should be built off of the fact that tumors grow from the unregulated mitotic division of cells. A possible reason for the prolific nature of these cells could be due to lack of check points that halt division if the cells are not needed.

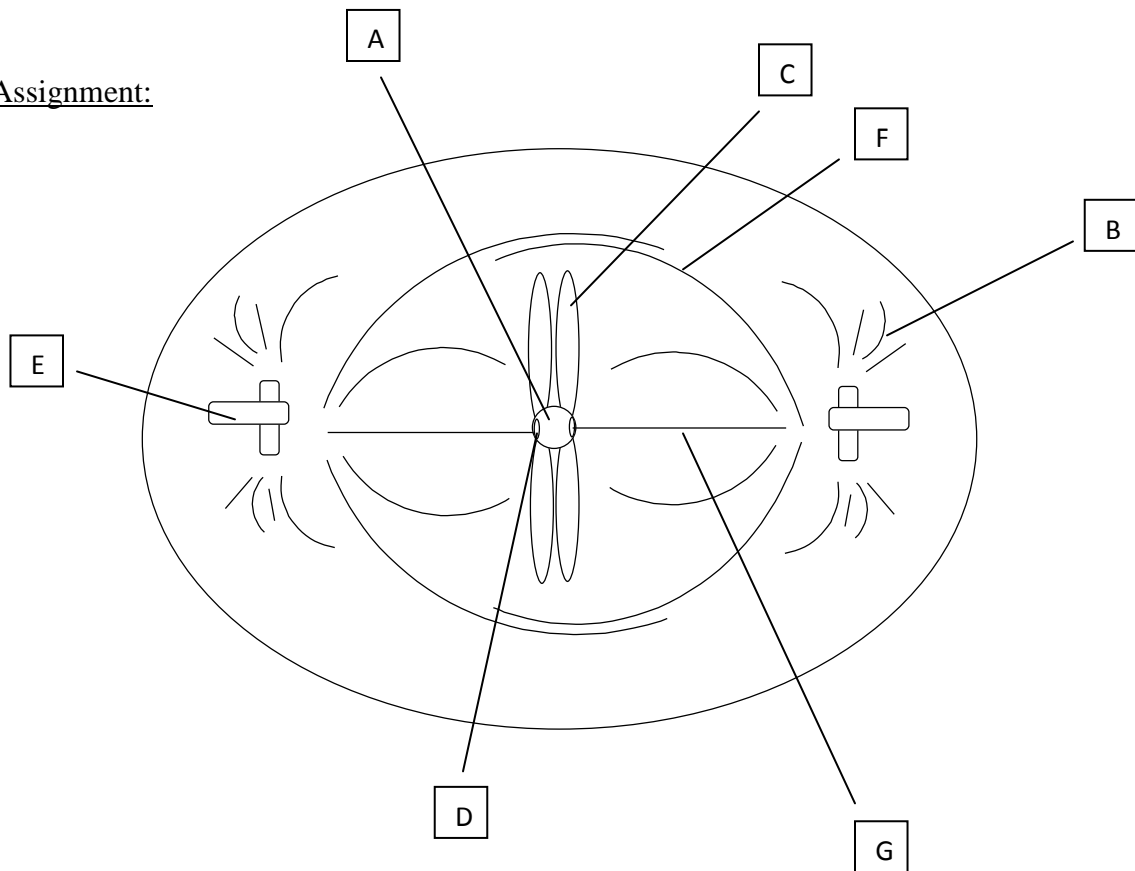
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## Mitosis and the Cell Cycle

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Pre-Assignment:



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2. Kinetochore microtubule
3. Aster
4. Sister chromatid
5. Centromere
6. Non-kinetochore microtubule
7. Kinetochore

**E**  
**G**  
**B**  
**C**  
**A**  
**F**  
**D**

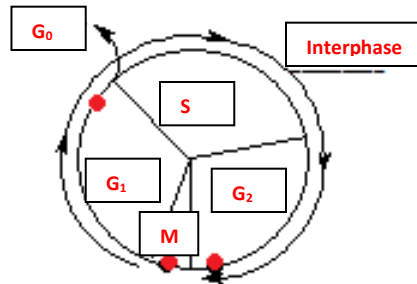
Assignment:

- For each phase of mitosis, indicate the existence, non-existence, location, or form of each of the key terms:

	Interphase	Prophase	Prometaphase	Metaphase	Anaphase	Telophase/Cytokinesis
Nuclear envelope	Present	Present	Breaks up	Not Present	Not Present	Reforms
Nucleolus	Present	Disappears	Not Present	Not Present	Not Present	Reforms
Mitotic Spindle	Not Present	Begins to Form	Micro-tubules attach to kinetochores	Micro-tubules move chromosomes to plate	Micro-tubules pull apart chromosomes to poles	Disappears
Location of centrosome	Present	Moves to poles	At poles	At poles	At poles	One in each new cell
Packaging of DNA	Chromatin	Condense into chromosomes	Chromosomes	Chromosomes	Chromosomes	Chromatin
Location of Chromosomes	Chromatin in nucleus	Chromosomes in nucleus	Chromosomes attached by spindle and begin to move	Chromosomes are moved to mitotic plate	Chromosomes are pulled to poles into sister chromatids	Chromatin in nucleus

Mitosis occurs in states that require a mass build up of cells, such as in embryonic development and when repairing damage in the body, such as a tear in the skin. However, most body cells are not in a continual dividing state; they cycle in and out depending on internal and external cues.

- Below is a model of the Cell Cycle. Read the statements and then label the stages of the cell cycle.



Interphase: The longest stage of the cell cycle. During this stage, the cell replicates its DNA, organelles, and cytoplasm in preparation for cell division.

G<sub>1</sub>: The first growth stage of Interphase. Contains a checkpoint for division.

G<sub>2</sub>: The second growth stage of Interphase. Contains a checkpoint for division.

S: The stage where DNA is duplicated. Occurs between the two growth stages.

M: Cell division, mitosis, occurs. This is the shortest stage.

G<sub>0</sub>: The nondividing stage. Most cells in the body are in this stage.

- During the cell cycle, there are three checkpoints that occur in G<sub>1</sub>, G<sub>2</sub>, and M as shown in the figure. Why would a cell need to employ checkpoints?

**A cell might employ checkpoints so that it can regulate the cycle. They check that all the materials have been synthesized before continuing. They also monitor signals outside the cell, identifying those that increase the likelihood of cell division and those that decrease the likelihood of cell division.**

- What is a possible reason for the formation of cancerous tumors?

**Cancerous tumors grow unchecked; there is no regulation mechanism in those cells. A possible reason for that characteristic is that the cancer cells have found a way to overcome the checkpoints that tell the cell to stop dividing.**

## Meiosis Quiz

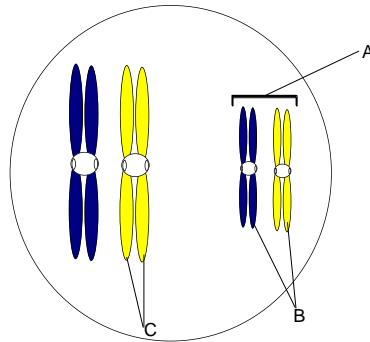
1. What phase of Mitosis do the sister chromatids separate?

- a. Prophase
- b. Metaphase
- c. Anaphase
- d. Telophase

2. What is the non-dividing state of Mitosis?

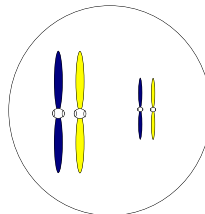
- a.  $G_1$
- b. S
- c.  $G_0$
- d.  $G_2$

3. Which letter represents the Non-sister chromatids of a homologous pair?



- a. A
- b. B
- c. C
- d. None of the above

4. What is the haploid number (n) of the following cell?



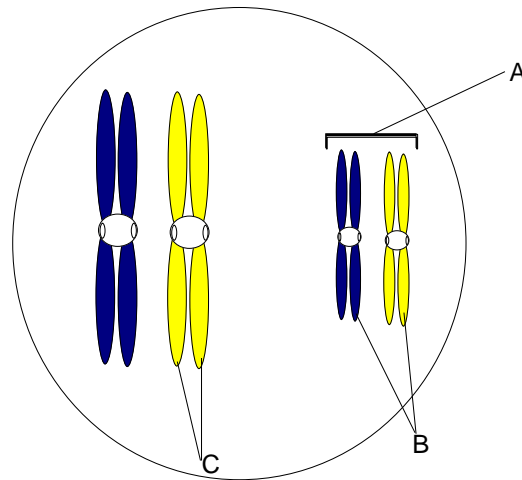
- a. 1
- b. 2
- c. 3
- d. 4

## Meiosis

Meiosis is the formation of gametes, egg or sperm, which unite to form offspring. The process of meiosis is similar to cell division, mitosis. Why, then, do offspring only look similar to their parents? Why don't they look identical?

### Pre-Assignment:

The genome of the cell below contains 4 chromosomes total. Two of the chromosomes are maternal (blue) and two of the chromosomes are paternal (yellow).



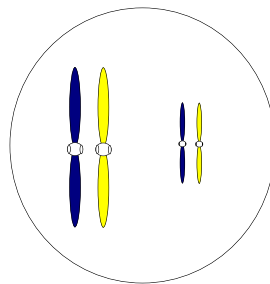
1. From the terms below, choose the correct labels for A, B, and C.

Homologous pair of a non-replicated chromosome

Sister chromatids

Non-sister chromatids of a homologous pair

Homologous pair of a replicated chromosome



2. How many chromosomes are in the cell?

Such a number is called the **diploid number**. It is considered to be equal to  $2n$ , where  $2n$  is the total number of chromosomes in the cell.

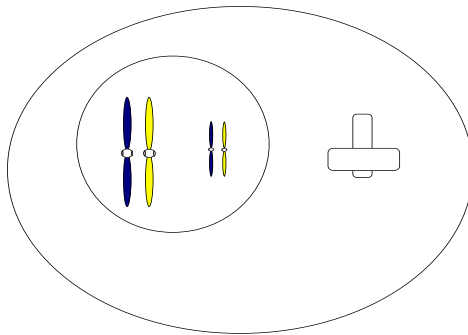
3. How many different types of (unique) chromosomes are in the cell?

Such a number is called the **haploid number**. It is considered to be equal to  $n$ , where  $n$  is the number of unique chromosomes in the cell and half the diploid number.

Assignment:

1. For each step of Meiosis, label and describe each phase:

**Parent cell before Meiosis begins:**

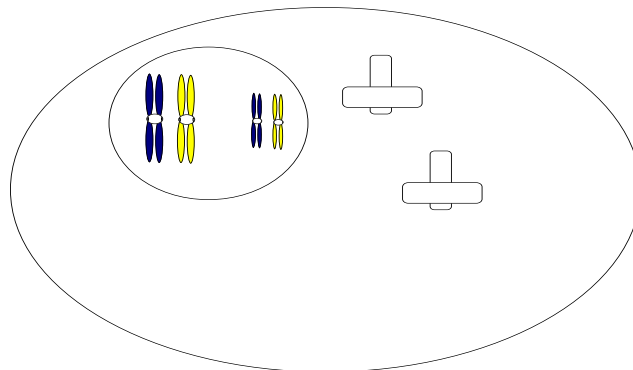


**Type of cell: Diploid ( $2n$ ) or Haploid ( $n$ )**

Phase: \_\_\_\_\_  
\_\_\_\_\_

\_\_\_\_\_

↓

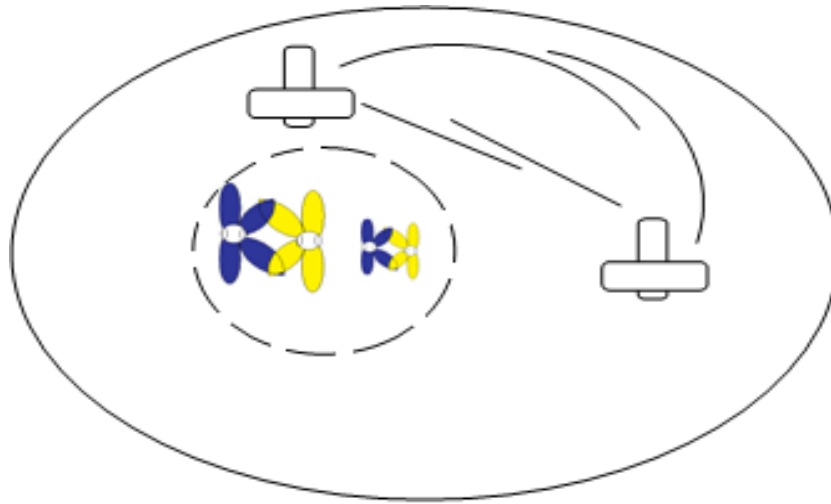


**Type of cell: Diploid ( $2n$ ) or Haploid ( $n$ )**

Phase: \_\_\_\_\_  
\_\_\_\_\_

\_\_\_\_\_

↓



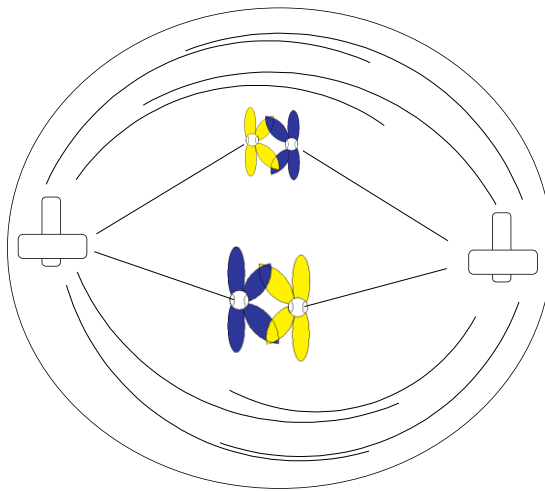
**Type of cell: Diploid (2n) or Haploid (n)**

Phase:

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**Type of cell: Diploid (2n) or Haploid (n)**

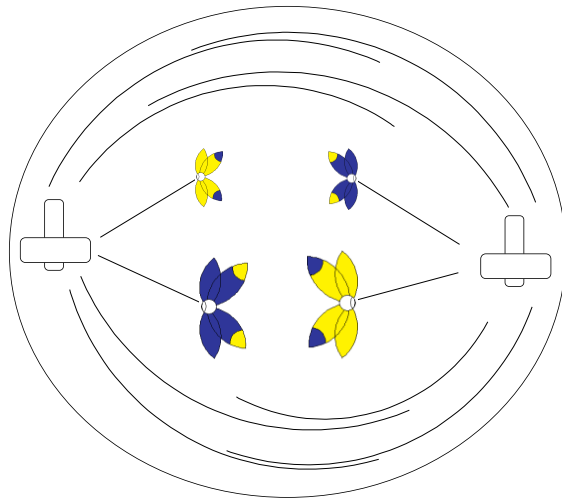
Phase:

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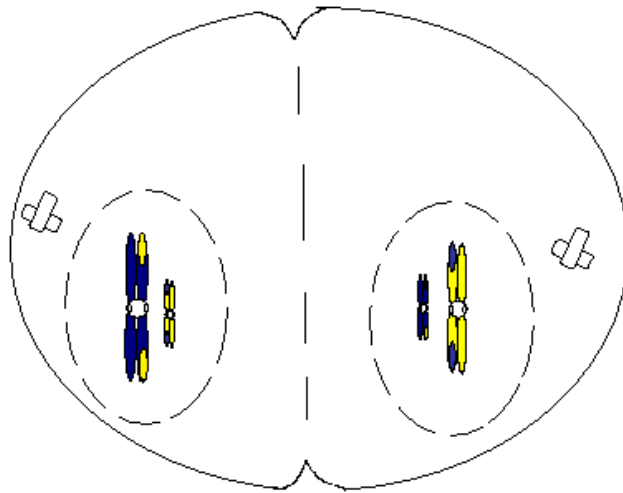
Type of cell: Diploid (2n) or Haploid (n)

Phase:

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Phase:

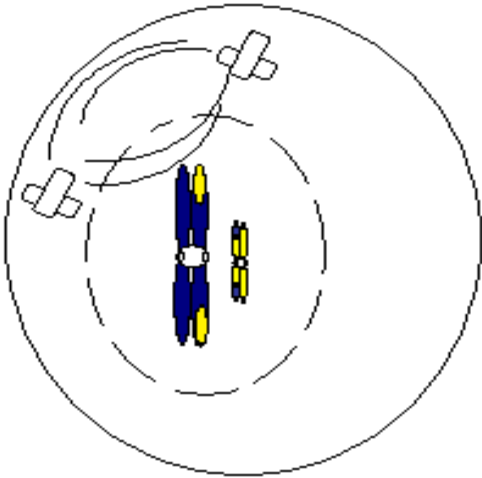
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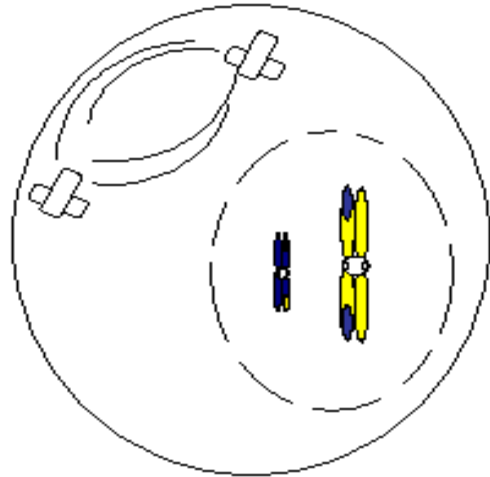
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Type of cell: Diploid (2n) or Haploid (n)



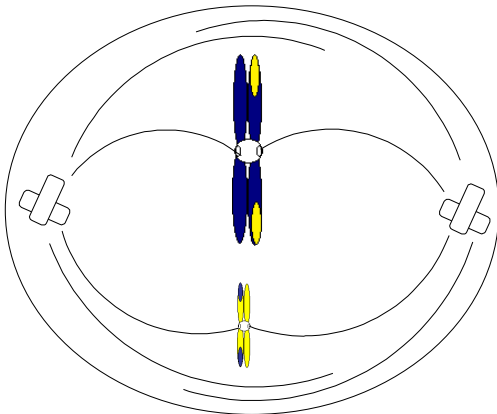
Type of cell: Diploid (2n) or Haploid (n)

Phase:

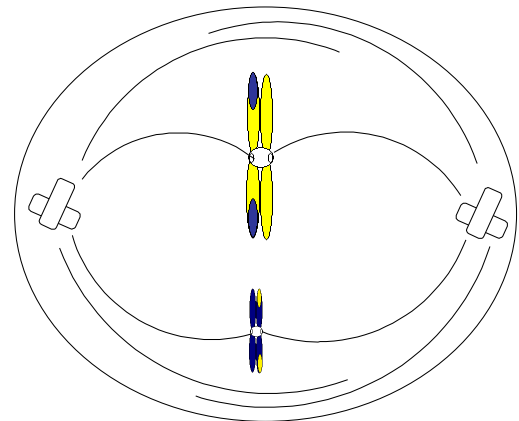
\_\_\_\_\_

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Type of cell: Diploid (2n) or Haploid (n)



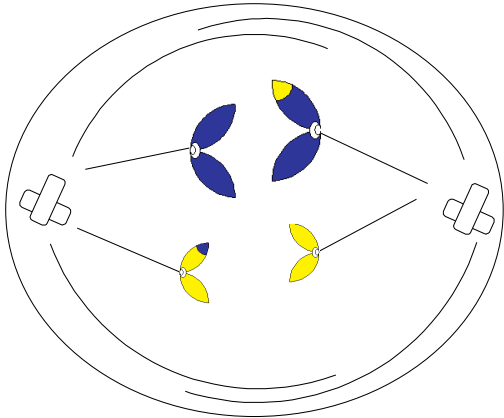
Type of cell: Diploid (2n) or Haploid (n)

Phase:

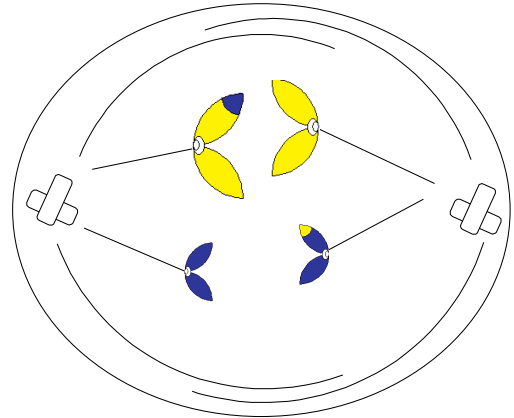
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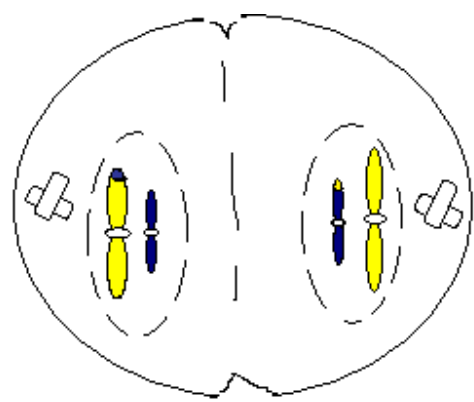
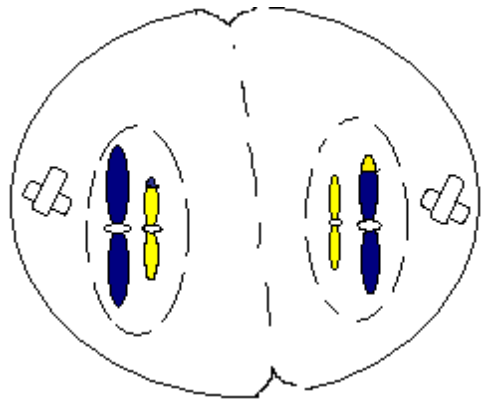


Type of cell: Diploid (2n) or Haploid (n)

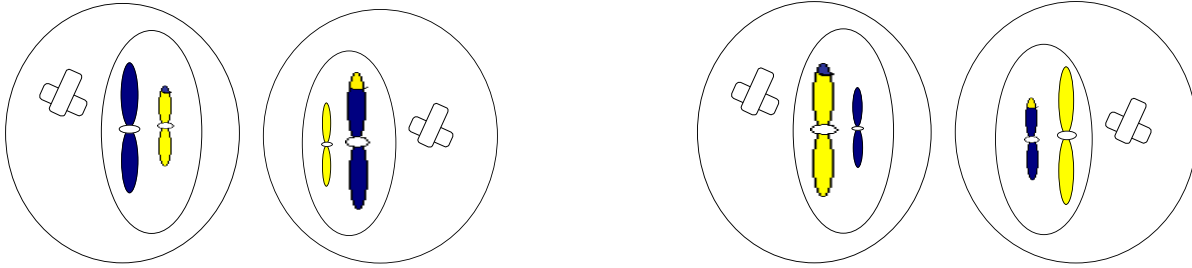


Type of cell: Diploid (2n) or Haploid (n)

Phase: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



Phase: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



**Type of cells: Diploid (2n) or Haploid (n)**

2. What stages of meiosis is the cell diploid? What stages of meiosis is the cell haploid?
3. At what stage of meiosis do the replicated **homologous chromosomes** separate?
4. When do the **sister chromatids** separate?
5. During Prophase I, non-sister chromatids of homologous pairs are attached at their arms. This phenomenon is called **crossing over**. Describe what occurs.
6. Draw another possible line-up of the chromosomes in Metaphase I. This phenomenon is called **Independent Assortment**.
7. *Crossing over, independent assortment, and random fertilization* create a very large amount of diversity between the resulting gametes. Explain why nature would have employed these processes to guarantee that each gamete had a slightly different genetic code.

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Meiosis Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1 and 2: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. For question 1, allow the students to complete the small descriptions of each step of meiosis and the indication of whether the cell is haploid or diploid. Students should learn the different phases of meiosis, but it is also important to know at which stages the cell is diploid and which stages the cell is haploid, question 2.

The cell is diploid during meiosis I and becomes haploid after cytokinesis of meiosis I. It is haploid beginning in meiosis II. This idea can be confusing to students as the beginning of meiosis II resembles mitosis. Try to lead the class, or point out if necessary, that though it looks like mitosis it must be compared to the original cell. Is the amount of maternal and paternal chromosomes different? If so, the cell is haploid.

### Questions 3 and 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 3 and 4 highlight the difference between Anaphase I and II. It is important to differentiate between homologous chromosomes

## Meiosis Notes

separating and sister chromatids separating. If the discussion is not progressing, it might be helpful to draw the homologous chromosomes and sister chromatids separating on the board and ask the students what phase corresponds to which. **Questions 3 and 4 are the first two critical thinking questions.**

Questions 5, 6, and 7: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The discussion of question 5 should include a student describing that genetic information from homologous chromosomes is traded during crossing-over.

While students are completing questions 5 and 6, it might be helpful to have a student draw the two possibilities of independent assortment on the board for question 6. The discussion could include asking the students why those two possibilities are possible. What is the factor that decides in which direction the chromosomes line up. The answer is that it is a random decision that cannot be predicted. If time allows, pose a question: For cell with only four chromosomes there are two possible assortments. How many possibilities would there be if a cell had forty-six chromosomes. Answer: a lot!

Question 7 poses the question of why meiosis employ mechanisms to ensure genetic diversity. The answer is that genetic diversity allows for evolution; those with the more fit traits adapt and live to pass on their genes to the next generation. Without genetic diversity, one event could wipe out the entire species if no individuals had the adaptive genes. **Question 7 is the third critical thinking question.**

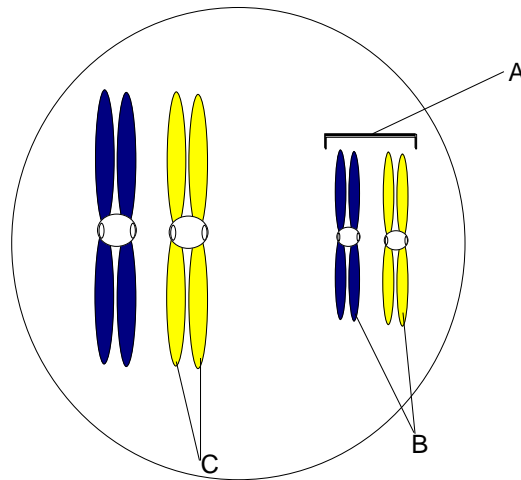
The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 3, 4, and 7 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Meiosis

Meiosis is the formation of gametes, egg or sperm, which unite to form offspring. The process of meiosis is similar to cell division, mitosis. Why, then, do offspring only look similar to their parents? Why don't they look identical?

### Pre-Assignment:

The genome of the cell below contains 4 chromosomes total. Two of the chromosomes are maternal (blue) and two of the chromosomes are paternal (yellow).



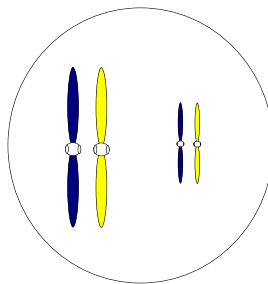
1. From the terms below, choose the correct labels for A, B, and C.

Homologous pair of a non-replicated chromosome

Sister chromatids-**C**

Non-sister chromatids of a homologous pair-**B**

Homologous pair of a replicated chromosome-**A**



2. How many chromosomes are in the cell?

**Four**

Such a number is called the **diploid number**. It is considered to be equal to  $2n$ , where  $2n$  is the total number of chromosomes in the cell.

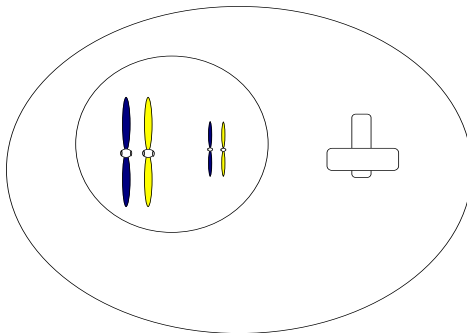
3. How many different types of (unique) chromosomes are in the cell?  
**Two**

Such a number is called the **haploid number**. It is considered to be equal to  $n$ , where  $n$  is the number of unique chromosomes in the cell and half the diploid number.

Assignment:

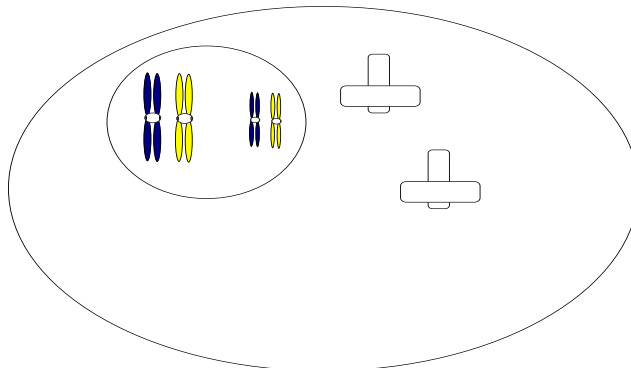
1. For each step of Meiosis, label and describe each phase:

**Parent cell before Meiosis begins:**



Type of cell: **Diploid (2n) or Haploid (n)**

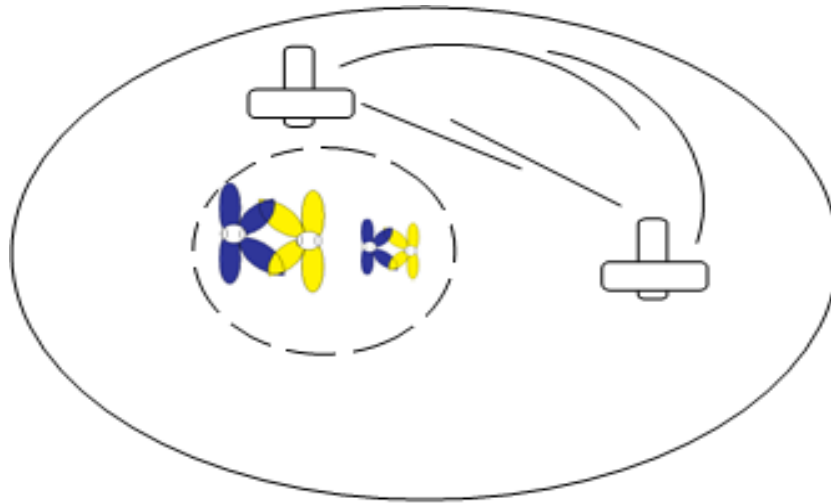
Phase: **Interphase → The chromosomes and the organelles replicate. The cell grows larger in anticipation of division.**



Type of cell: **Diploid (2n) or Haploid (n)**

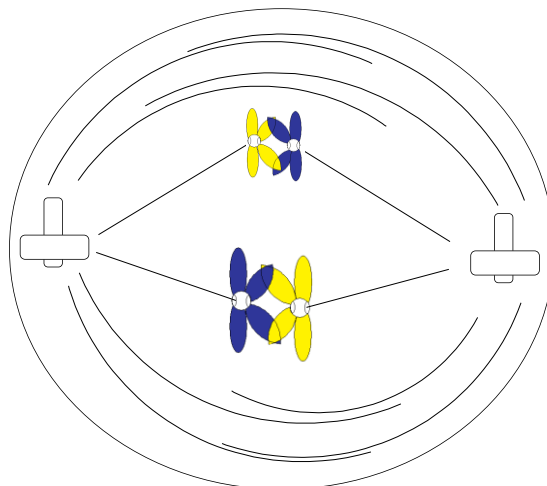
Phase: **Interphase → The cell continues to grow until it is ready to undergo meiosis.**





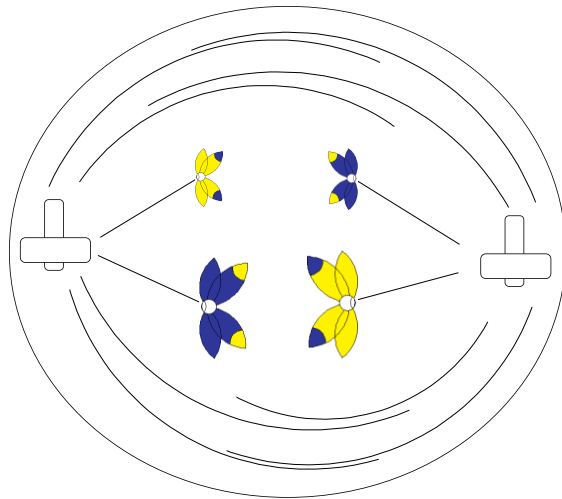
Type of cell: **Diploid (2n)** or Haploid (n)

Phase: **Prophase I** → The nuclear envelope begins to degrade and the centrosomes begin to move towards the poles. Inside the nucleus, homologous pairs begin the process of crossing over.



Type of cell: **Diploid (2n)** or Haploid (n)

Phase: **Metaphase I** → The nuclear envelope has completely disappeared and the spindle has reached the poles. Kinetochore microtubules attach to the kinetochores of the replicated chromosomes lined up on the metaphase plate.

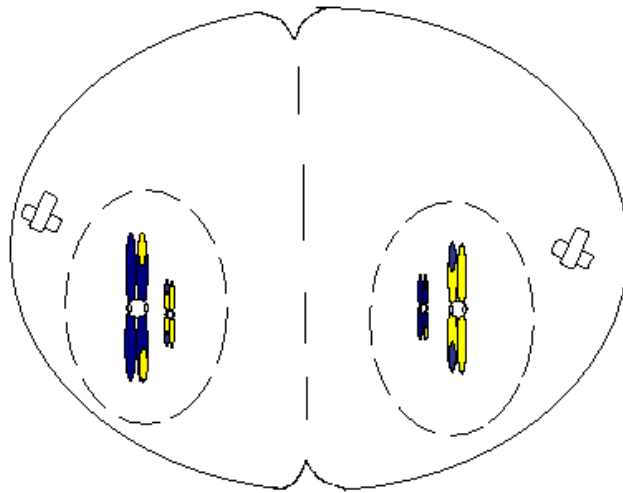


Type of cell: **Diploid (2n) or Haploid (n)**

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Phase: **Anaphase I** → As the kinetochore microtubules shorten, the homologous chromosomes separate. The non-kinetochore microtubules push against each other to lengthen the cell in preparation for the cytoplasmic division. Crossing over has completed.

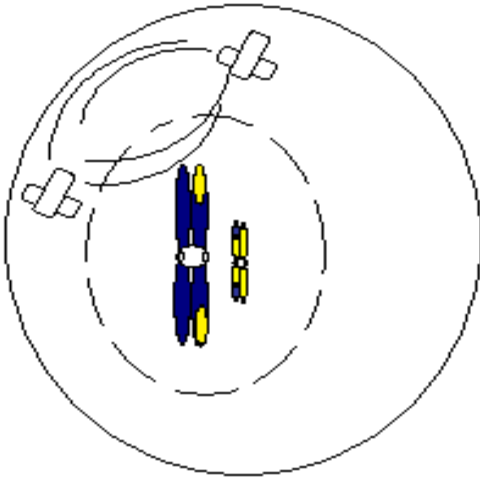
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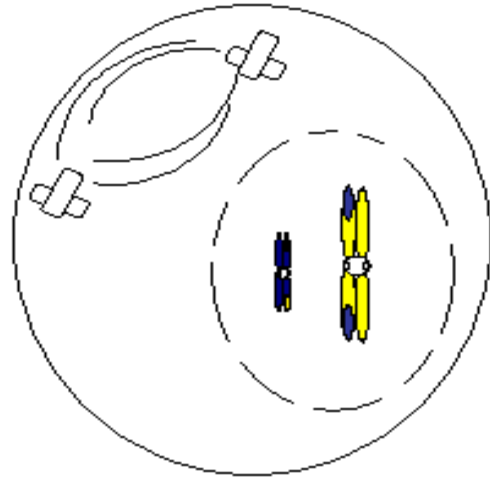
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Phase: **Telophase I and Cytokinesis** → The chromosomes have reached the poles of the cell. A new nuclear envelope forms. The cell forms a cleavage furrow and the cytoplasm divides.

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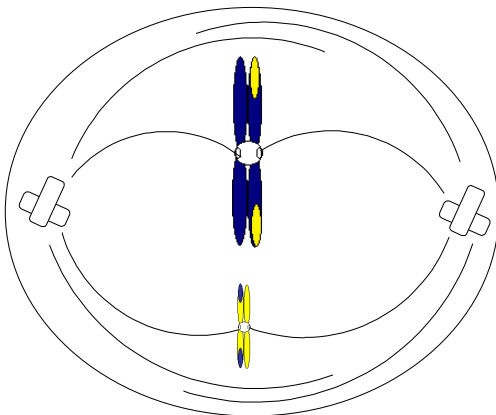


Type of cell: Diploid (2n) or **Haploid (n)**

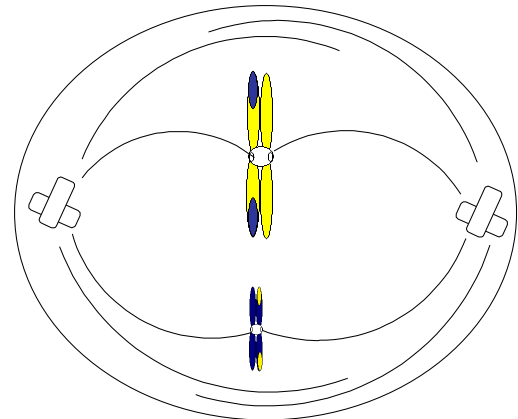


Type of cell: Diploid (2n) or **Haploid (n)**

Phase: **Prophase II** → **The new nuclear envelope begins to degrade and the centrosomes begin to migrate to the poles.**

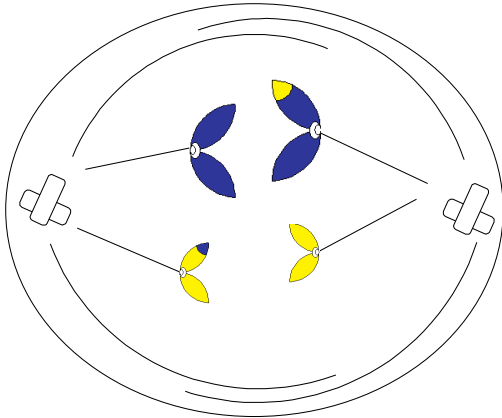


Type of cell: Diploid (2n) or **Haploid (n)**

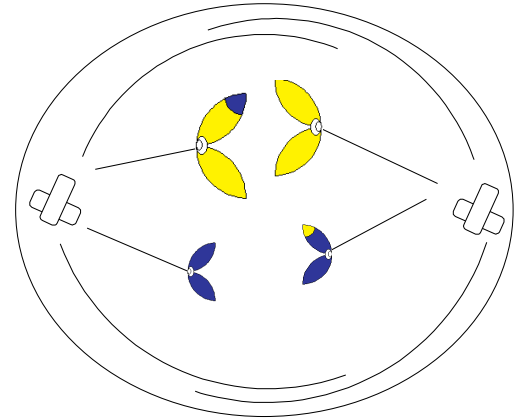


Type of cell: Diploid (2n) or **Haploid (n)**

Phase: **Metaphase II** → **the replicated chromosomes line up on the metaphase plate, randomly. kinetochore microtubules attach to the kinetochores of the Chromosomes.**

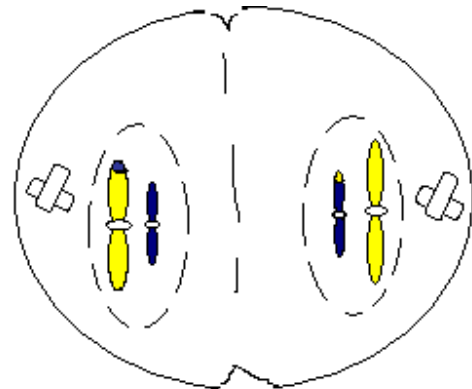
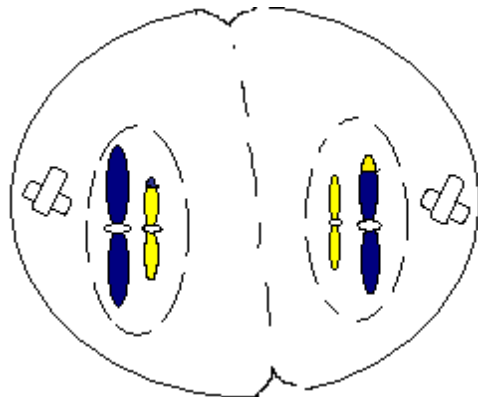


Type of cell: Diploid (2n) or **Haploid (n)**

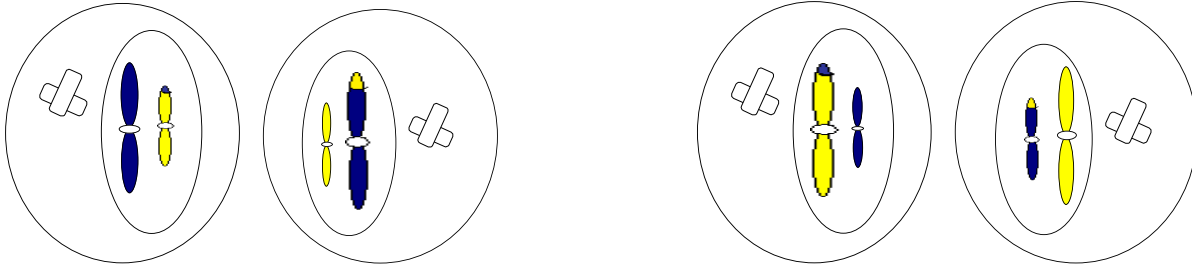


Type of cell: Diploid (2n) or **Haploid (n)**

Phase: **Anaphase II** → **The kinetochores being to shorten and separate the sister chromatids. The non-kinetochore microtubules push against each other to prepare the cell for cytoplasmic division.**



Phase: **Telophase II and Cytokinesis** → **The Chromosomes have separated and a new nuclear Envelope forms around the chromosomes. A Cleavage furrow forms in preparation for cytoplasmic Division.**



**Type of cells: Diploid (2n) or Haploid (n)**

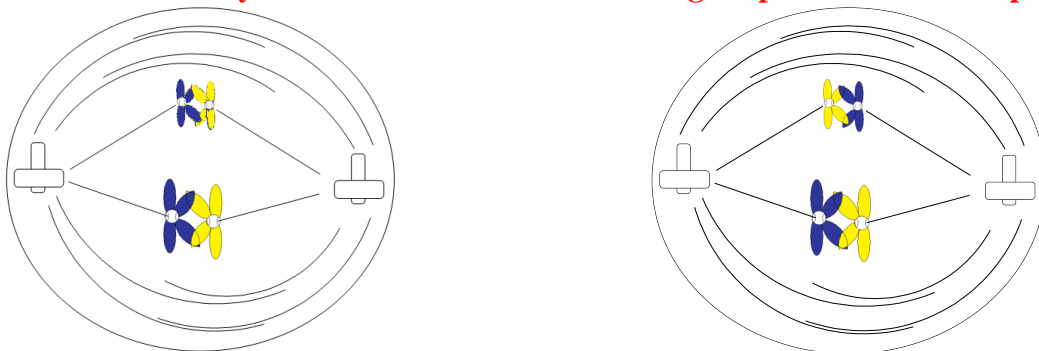
2. What stages of meiosis is the cell diploid? What stages of meiosis is the cell haploid?  
**The cell is diploid from Prophase I until after Telophase I/Cytokinesis. After the cell divides for the first time, it becomes haploid for the rest of the cycle.**

3. At what stage of meiosis do the replicated **homologous chromosomes** separate?  
**Anaphase I**

4. When do the **sister chromatids** separate?  
**Anaphase II**

5. During Prophase I, non-sister chromatids of homologous pairs are attached at their arms. This phenomenon is called **crossing over**. Describe what occurs.  
**During crossing over DNA between homologous chromosomes exchange DNA.**

6. Draw another possible line-up of the chromosomes in Metaphase I. This phenomenon is called **Independent Assortment**.  
**Another line-up would be one of the pairs of chromosomes rotating 180°, i.e. one of the blue and yellow chromosomes of a homologous pair would switch places.**



7. *Crossing over, independent assortment, and random fertilization* create a very large amount of diversity between the resulting gametes. Explain why nature would have employed these processes to guarantee that each gamete had a slightly different genetic code.

**Genetic diversity ensures that individuals have different traits that may result in increased fitness. The different traits allow individuals to adapt to the environment if a change occurs, resulting in evolution. If all individuals were genetically identical, and a large environmental change occurred, no individuals of the population would survive; the population would not have any adaptive traits.**

## DNA Replication Quiz

1. What is the first stage in which the cell is haploid?
  - a. Prophase I
  - b. Metaphase I
  - c. Anaphase I
  - d. Prophase II
  
2. At which phase do homologous chromosomes separate?
  - a. Metaphase I
  - b. Anaphase II
  - c. Anaphase I
  - d. Telophase I
  
3. Which enzyme unzips the DNA strand?
  - a. DNA Polymerase I
  - b. Helicase
  - c. Ligase
  - d. Topoisomerase
  
4. Which enzyme prevents supercoiling in the DNA strand?
  - a. DNA Polymerase I
  - b. Helicase
  - c. Ligase
  - d. Topoisomerase

## DNA Replication

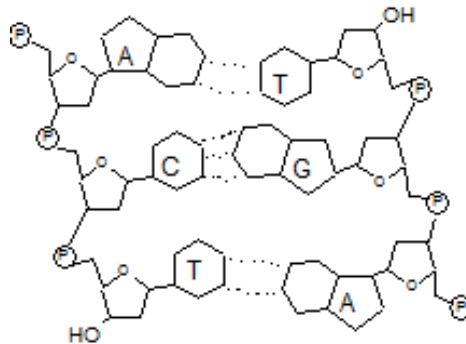
The genome consists of billions of base pairs that store all of the information a cell needs to program its life processes. How, then, does such a large molecule replicate itself with almost perfect accuracy?

### Pre-Assignment:

Below are the machinery for DNA Replication in bacteria. Describe the function of each component:

1. Helicase-
2. Single Strand Binding Proteins-
3. RNA Primase-
4. Topoisomerase-
5. DNA Polymerase III-
6. DNA Polymerase I-
7. DNA Ligase-
8. Origin of Replication-
9. Parent (Template) strand-
10. Daughter (New) strand-

11. Label the 5' and 3' end of the DNA molecule:

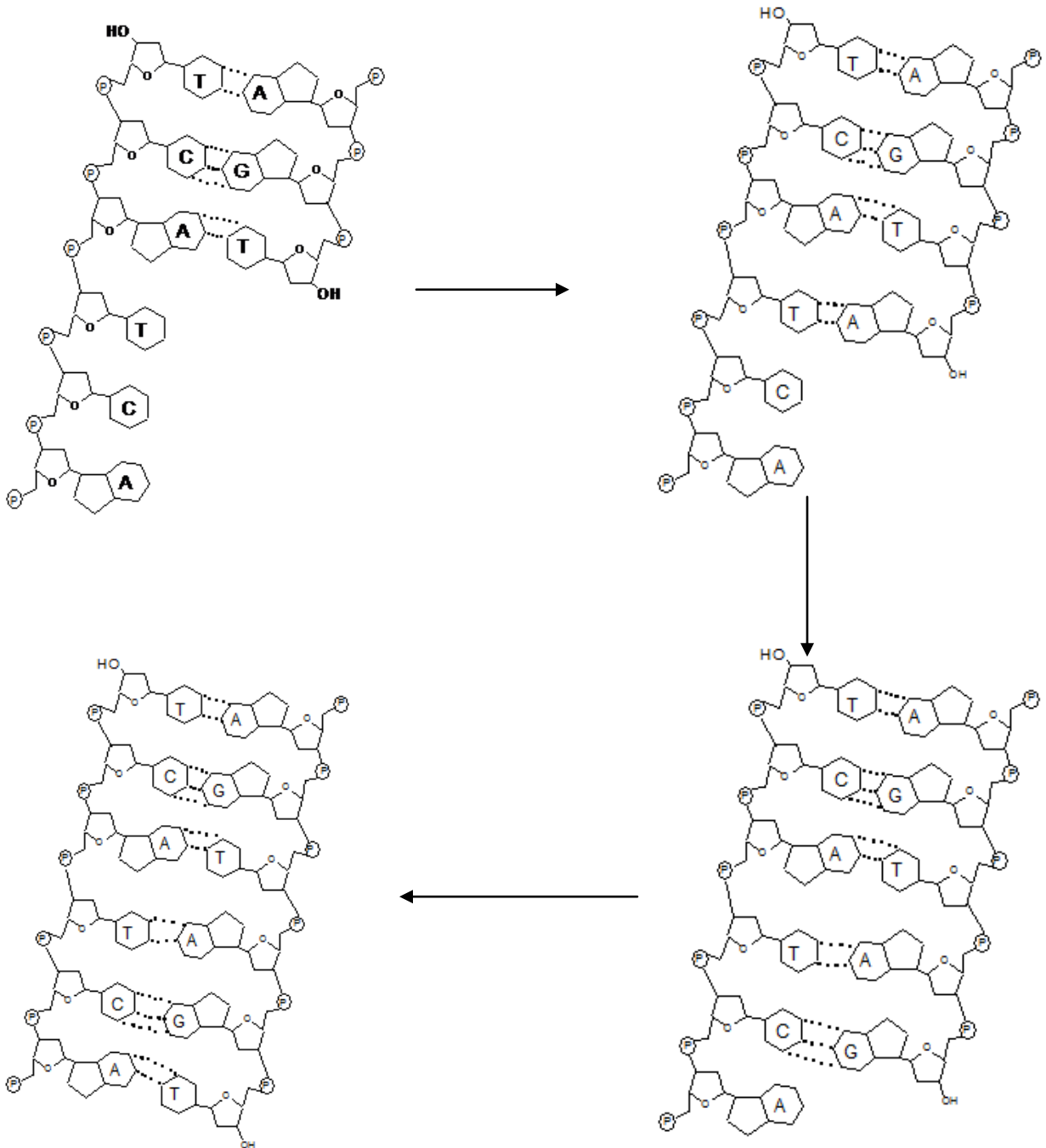




Assignment:

DNA Polymerase is synthesizing a new DNA strand.

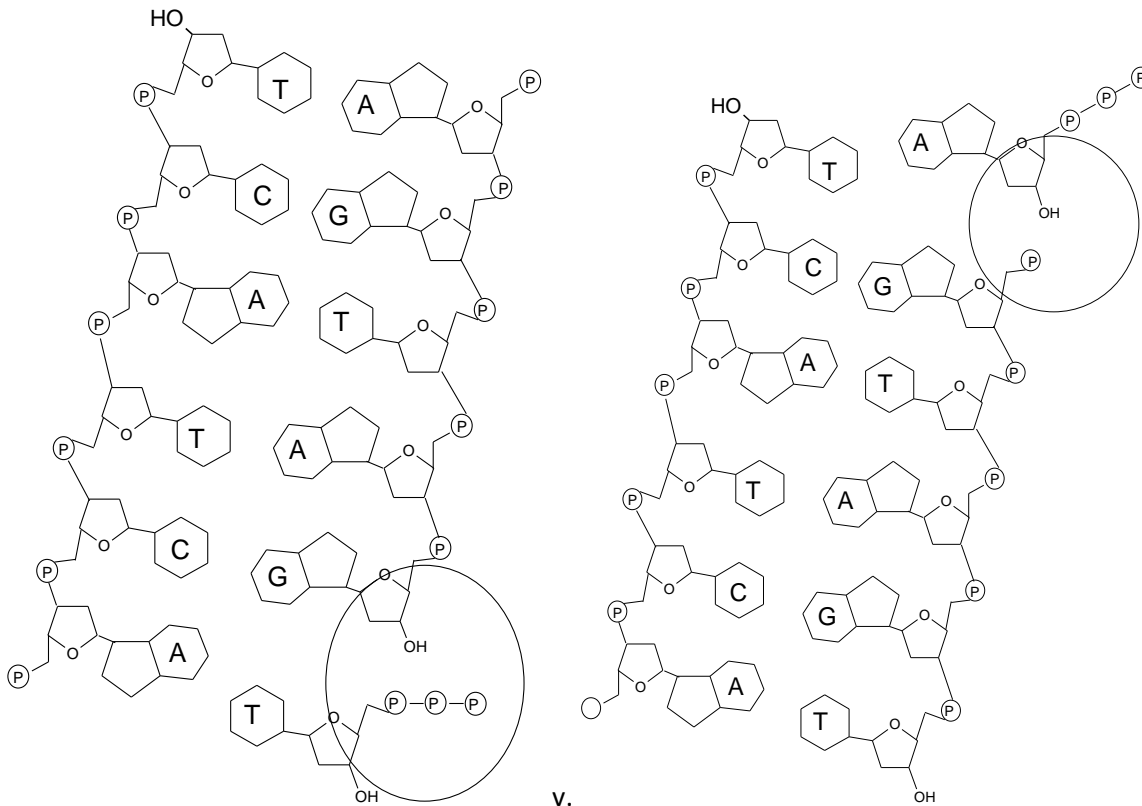
1. Label the 5' and 3' ends.
2. For each new nucleotide, identify the end (5' or 3') to which the new nucleotide was added. Indicate the answer over the arrows.



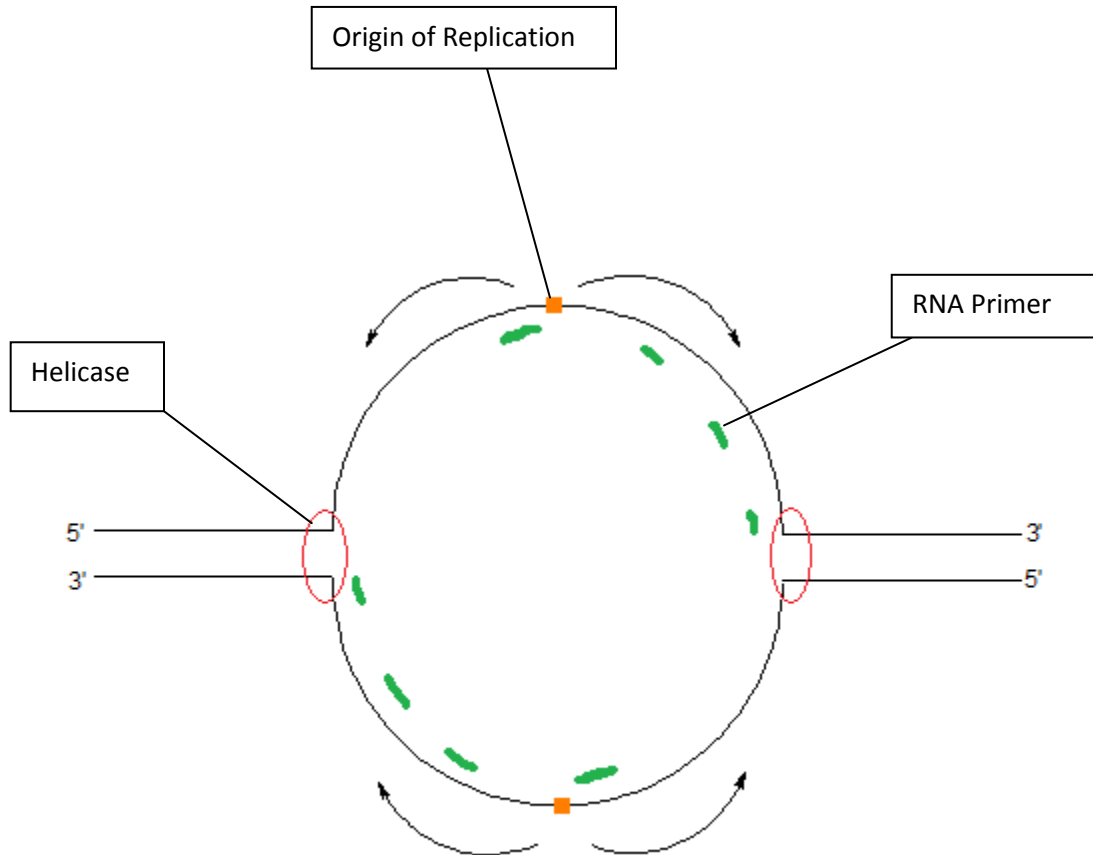
3. Using (2), explain how the nucleotides are added to the daughter strand, i.e. specify the direction in which the nucleotides are added.

Recall from general chemistry, that breaking a chemical bond releases energy into the environment. That free energy, commonly found when ATP is hydrolyzed into ADP + P<sub>i</sub>, can be coupled with other reactions.

In DNA replication, nucleotide triphosphates are used to catalyze the phosphodiester bond between nucleotides. The following reaction occurs



4. Label the 5' and 3' ends. Use the figure above to reason out why nucleotides can be added ONLY to the 3' end of the DNA strand.



Above is an example of a replication fork. Beginning at the origin of replication, the helicase molecules move away from the replication fork as indicated by the arrows.

- Using your answer from (3), draw the direction of DNA synthesis beginning from the RNA primers. Indicate the leading and lagging strands.

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## DNA Replication Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, and 3: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The goal of the first three questions is to walk the students through the idea of how daughter strands are synthesized. By analyzing the flow chart of figures, the students will clearly see the pattern of addition.

### Question 4: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. **Question 4 is the first critical thinking question.** The students are required to draw on previous knowledge (from lectures and these sessions) of the structure of and function of an ATP molecule and the nature of condensation reactions. Using that information and the two figures, students should be able to understand that nucleotides are only added to the 3' end of a daughter strand because that orientation includes a condensation reaction that can be coupled with the phosphodiester bond formation. The discussion of this question should be conducted by asking questions that begin with condensation reactions and lead up to which figure includes a condensation reaction that can be used to create a new bond.

## DNA Replication Notes

### Question5: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. **Question 5 is the second critical thinking question.** Students should draw the replication fork, with the RNA primers, and indicate the direction of DNA synthesis. The leading and lagging strands should also be indicated. If students are having problems with this question, tell them to first remember, from question 3, the direction of DNA synthesis. To help, they can also indicate on the drawing the 5' and 3' end of each primer. Knowing which end is the 3' end of the primer will allow students to know to which end the nucleotides are added.

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 4 and 5 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## DNA Replication

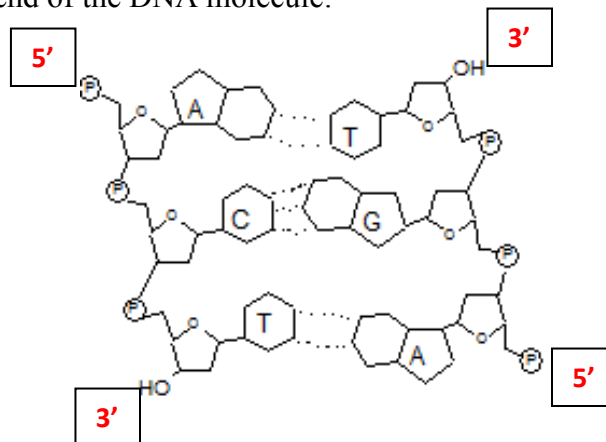
The genome consists of billions of base pairs that store all of the information a cell needs to program its life processes. How, then, does such a large molecule replicate itself with almost perfect accuracy?

### Pre-Assignment:

Below are the machinery for DNA Replication in bacteria. Describe the function of each component:

1. Helicase-**Unwinds DNA by breaking the hydrogen bonds between the bases**
2. Single Strand Binding Proteins-**Attach to the separated DNA strands to stabilize them so that they will not reform a helix**
3. RNA Primase-**Enzyme that attaches to the separated DNA molecule and lays down ribonucleotides as a primer for DNA synthesis**
4. Topoisomerase-**An enzyme that ensures there is no supercoiling of the helix as helicase separates the DNA. It nicks the DNA, swivels it to relieve the pressure and ligates the strands.**
5. DNA Polymerase III-**Synthesizes the new DNA strand by adding nucleotides to the RNA primer in the 5' → 3' direction**
6. DNA Polymerase I-**Removes the RNA primer and replaces them with deoxyribonucleotides**
7. DNA Ligase-**Connects the backbone of the DNA that was added in place of the RNA primer (Okazaki fragments)**
8. Origin of Replication-**Site where DNA replication begins**
9. Parent (Template) strand-**the old strand of DNA that DNA Polymerase III reads in order to add the correct new nucleotides**
10. Daughter (New) strand-**The new DNA strand created by DNA Polymerase III; it is complementary to the parent strand**

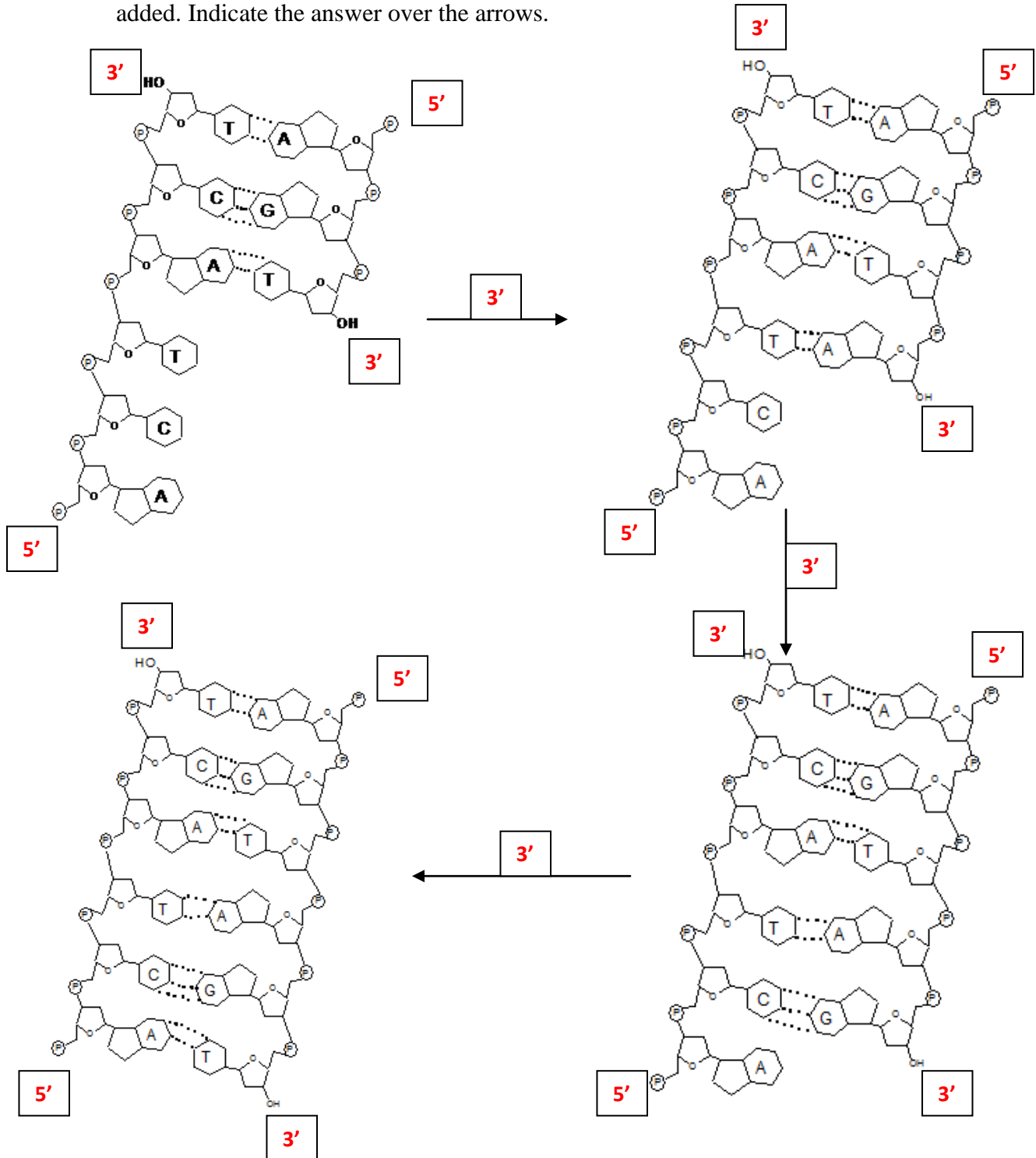
11. Label the 5' and 3' end of the DNA molecule:



Assignment:

DNA Polymerase is synthesizing a new DNA strand.

1. Label the 5' and 3' ends.
2. For each new nucleotide, identify the end (5' or 3') to which the new nucleotide was added. Indicate the answer over the arrows.



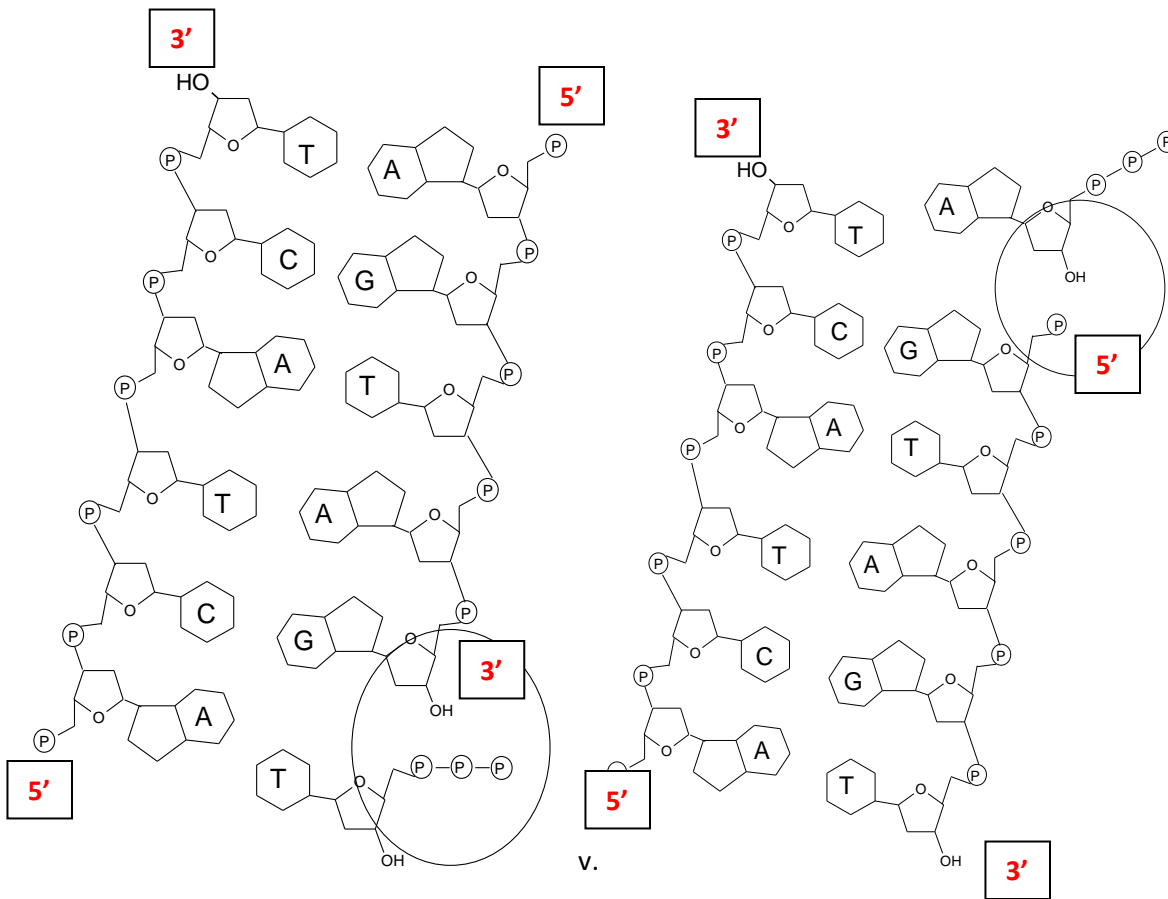


3. Using (2), explain how the nucleotides are added to the daughter strand, i.e. specify the direction in which the nucleotides are added.

**Nucleotides are added to the 3' end of the daughter strand. Therefore, they are synthesized in the 5' → 3' direction.**

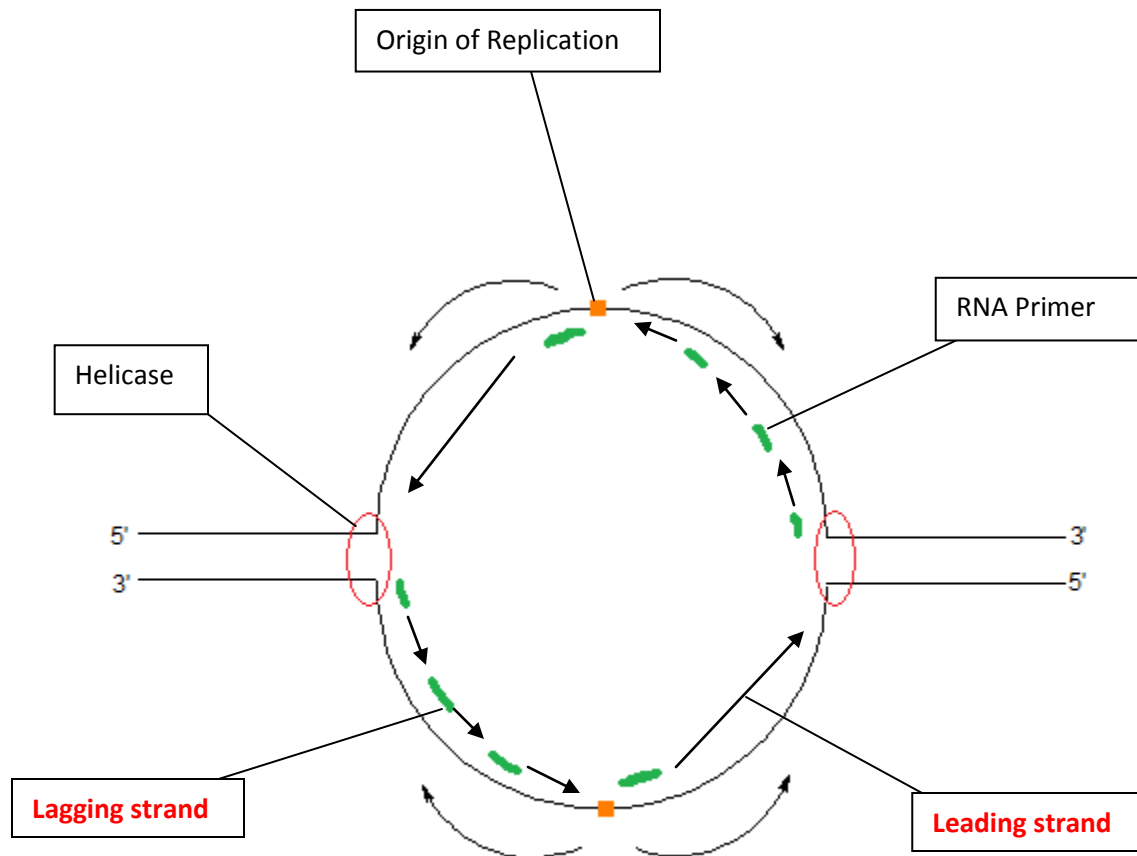
Recall from general chemistry, that breaking a chemical bond releases energy into the environment. That free energy, commonly found when ATP is hydrolyzed into ADP + P<sub>i</sub>, can be coupled with other reactions.

In DNA replication, nucleotide triphosphates are used to catalyze the phosphodiester bond between nucleotides. The following reaction occurs



4. Label the 5' and 3' ends. Use the figure above to reason out why nucleotides can be added ONLY to the 3' end of the DNA strand.

**Nucleotides can only be added to the 3' end because of the orientation of the nucleotide. In the first picture, the triphosphate groups are close to the hydroxyl group. Once the 2P<sub>i</sub> break off, the bond can be easily formed. In the second picture, however, there is only the one phosphate group from the daughter strand near the hydroxyl. There are no extra phosphates to catalyze the reaction.**



Above is an example of a replication fork. Beginning at the origin of replication, the helicase molecules move away from the replication fork as indicated by the arrows.

5. Using your answer from (3), draw the direction of DNA synthesis beginning from the RNA primers. Indicate the leading and lagging strands.

## Transcription Quiz

1. What direction is the daughter strand synthesized?
  - a.  $N \rightarrow C$
  - b.  $3' \rightarrow 5'$
  - c.  $5' \rightarrow 3'$
  - d.  $C \rightarrow N$
  
2. True or False: the new nucleotide is added to the 3' end in DNA Replication.
  - a. True
  - b. False
  
3. What molecule contains a list of codons?
  - a. mRNA
  - b. tRNA
  - c. rRNA
  - d. None of the above
  
4. How many possible codons can be made from the sequence of three nucleotides?
  - a. 4
  - b. 16
  - c. 20
  - d. 64

## Transcription

The genome of an organism is the library from which proteins are synthesized. How, then, is a sequence of amino acids elucidated from a sequence of nucleotides?

In all biological organisms, this basic concept holds true:



RNA, another type of nucleic acid, is the carrier of information between DNA and polypeptides. To begin this information transfer process, deoxyribose polynucleotides are first transcribed into another form of polynucleotides made with ribose sugar.

### Pre-Assignment:

Define the following terms:

- a. mRNA-
- b. RNA Polymerase-
- c. Promoter-
- d. Terminator-

There are 20 different amino acids that are synthesized from DNA. Determine how long the nucleotide sequence should be to be able to express all 20 amino acids.

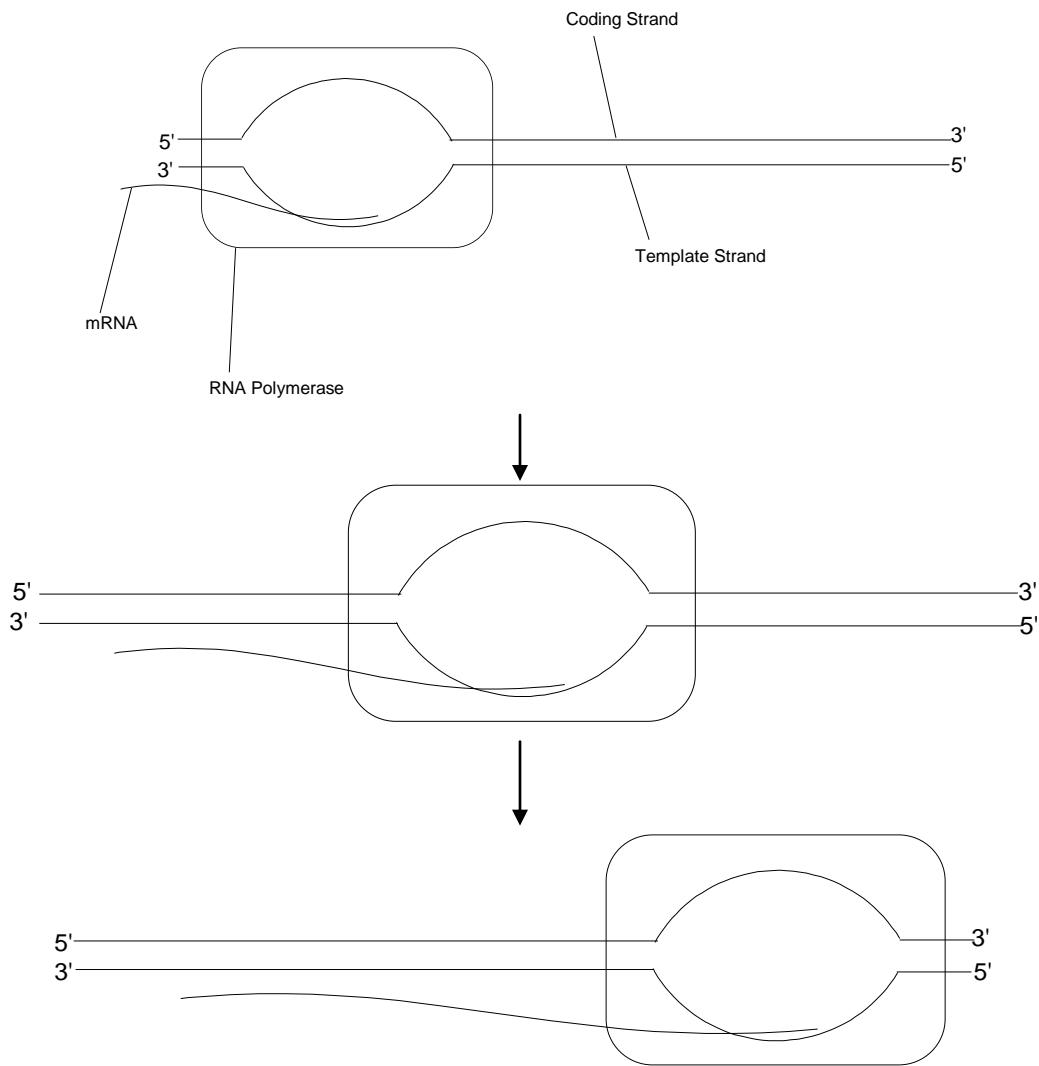
1. If each amino acid were represented by one nucleotide (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: A
2. If each amino acid were represented by two nucleotides (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: AA or CA or GA or TA
3. If each amino acid were represented by three nucleotides (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: AAA or CAA or GAA or TAA

4. Therefore, what is the least amount of nucleotides in a sequence that can account for all 20 amino acids?

These sequences are called **codons**.

Assignment:

1. Use the figures below to determine in which direction the mRNA strand is synthesized.



In what direction is mRNA synthesized?

Template Strand            3'-TACTGAACG-5'  
Coding Strand            5'-ATGACTTGC-3'

mRNA                      5'-AUGAUUGC-3'

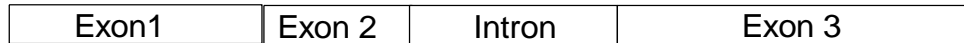
2. What is the relationship between the Coding Strand and the mRNA?
  
  
  
  
  
  
  
  
  
  
3. What is the relationship between the Template Strand and the mRNA?

Template Strand            5'-GGCCATCGTA-3'  
Coding Strand            3'-CCGGTAGCAT-5'

4. Write the mRNA sequence, from 5' to 3', from the DNA molecule above.

All mRNA molecules contain regions called introns and exons. Exons are the regions that code for one polypeptide; introns are removed in a process called splicing.

5. In the mRNA below, draw out all the possible exon combinations (least being one exon) for modified mRNA molecules. What would the different combinations produce after translation?



6. Eukaryotes employ what is called alternative splicing, where one pre-mRNA molecule can be spliced into many mature mRNA molecules. Why would this process be beneficial to humans?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:



## Transcription Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. For question 1, students should be able to follow the flow of the figures to determine the direction of mRNA synthesis. However, if students are getting stuck, you could suggest that they label the 5' and 3' ends of the mRNA to help them elucidate the synthesis.

### Questions 2, 3, and 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers.

For question 2, the students should be able to identify the relationship between the strands of DNA and mRNA. They might say that the mRNA strand is almost identical to the coding strand except for the addition of uracil. You can point out in the discussion that it is considered identical because in RNA uracil is analogous to thymine.

## Transcription Notes

For question 3, students might provide answers similar to “mRNA is opposite of the template strand.” However, you want to try to ask questions to the class so that they realize that the correct vocabulary word is “complementary.”

**Question 4 is the first critical thinking question.** This question puts into practice what the students have learned in questions 2 and 3. However, the strands have been written backwards; the correct answer involves re-writing the strands so that the template reads 3' → 5' (and the coding reads 5' → 3'). If you notice, as you walk around, that students are not executing this extra step, you might want to just mention that to complete this problem, refer to (1).

### Question 5: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. For question 5, ask a student to draw their answers on the board, whether they are correct or not. This question has the possibility for a good discussion about the different combinations of exons (exon1, exon2, exon3, exon1exon2, exon1exon3, exon2/3, exon1exon2exon3). What would the different combinations produce?

### Question 6: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. **Question 6 is the second critical thinking question.** Alternative splicing would be beneficial to humans because they could employ a smaller genome but still have the same amount of genes (or more) as an organism that has a larger genome and that does not use alternative splicing. If students are having a hard time grasping this answer, ask them to refer to (6). What is the purpose of alternative splicing? To create many different proteins from one mRNA molecule. Ask them to compare humans with a smaller genome that uses alternative splicing and other organisms that have a larger genome that do not use alternative splicing

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 4 and 6 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Transcription

The genome of an organism is the library from which proteins are synthesized. How, then, is a sequence of amino acids elucidated from a sequence of nucleotides?

In all biological organisms, this basic concept holds true:



RNA, another type of nucleic acid, is the carrier of information between DNA and polypeptides. To begin this information transfer process, deoxyribose polynucleotides are first transcribed into another form of polynucleotides made with ribose sugar.

### Pre-Assignment:

Define the following terms:

- mRNA-**Specifies the primary structure of polypeptides**
- RNA Polymerase-**Enzyme that unwinds the DNA helix while simultaneously synthesizing RNA from the template strand**
- Promoter-**Specific sequence of DNA that binds to RNA polymerase so that it can begin transcription in the correct location**
- Terminator-**Sequence of DNA that signals the RNA polymerase to stop transcription and detach**

There are 20 different amino acids that are synthesized from DNA. Determine how long the nucleotide sequence should be to be able to express all 20 amino acids.

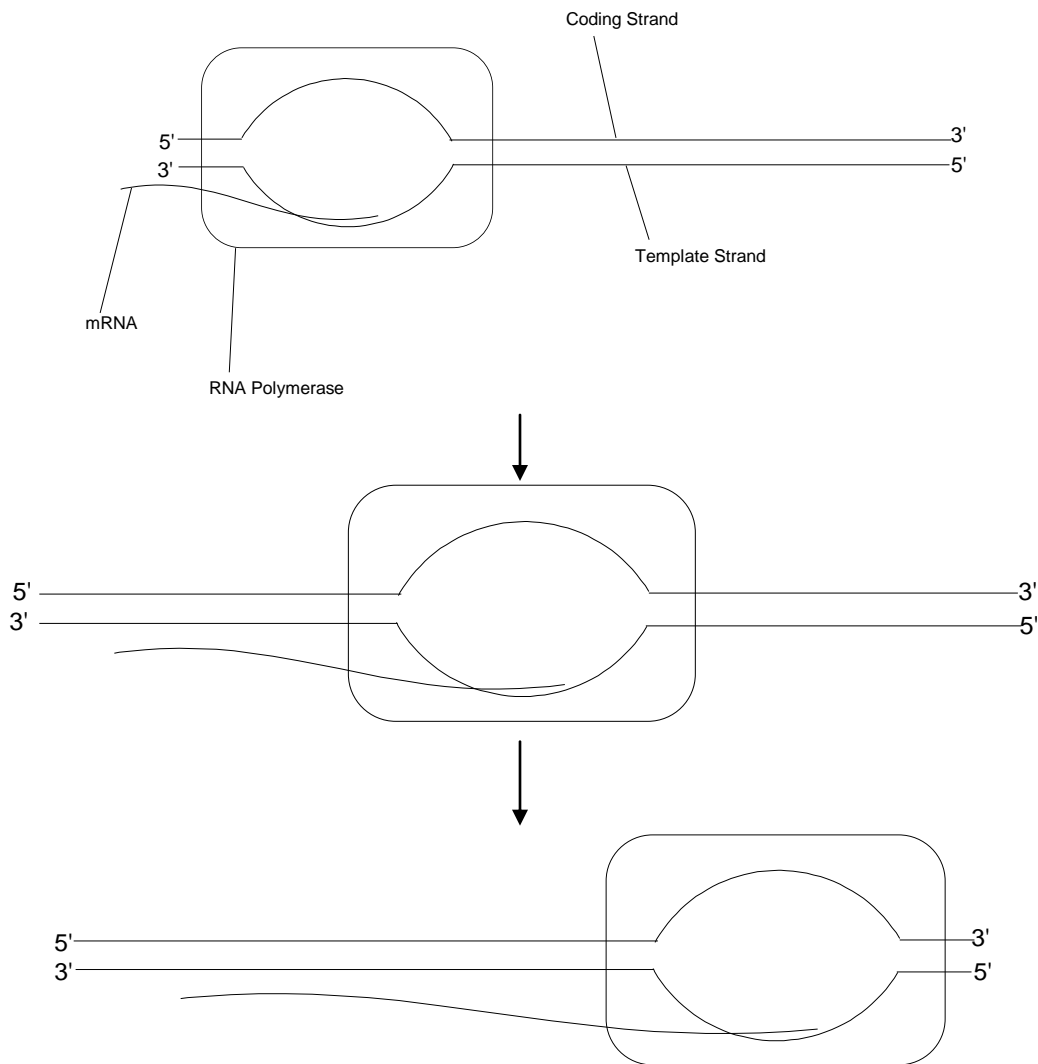
- If each amino acid were represented by one nucleotide (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: A  
 **$4^1 = 4$**
- If each amino acid were represented by two nucleotides (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: AA or CA or GA or TA  
 **$4^2 = 16$**
- If each amino acid were represented by three nucleotides (A,C,G, or T), how many possible amino acids could be synthesized?  
For example: AAA or CAA or GAA or TAA  
 **$4^3 = 64$**

4. Therefore, what is the least amount of nucleotides in a sequence that can account for all 20 amino acids?  
**Three nucleotides (gives the smallest possible number of sequences greater than 20)**

These sequences are called **codons**.

Assignment:

1. Use the figures below to determine in which direction the mRNA strand is synthesized.



In what direction is mRNA synthesized?

**5' → 3'**

Template Strand            3'-TACTGAACG-5'  
Coding Strand            5'-ATGACTTGC-3'

mRNA                    5'-AUGAUUGC-3'

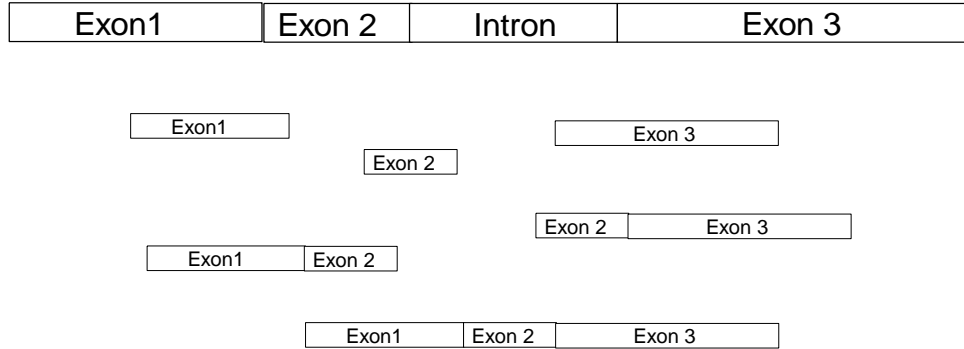
2. What is the relationship between the Coding Strand and the mRNA?  
**The mRNA is identical to the coding strand, except that uracil is substituted for thymine.**
3. What is the relationship between the Template Strand and the mRNA?  
**The mRNA is complementary to the template strand.**

Template Strand            5'-GGCCATCGTA-3'  
Coding Strand            3'-CCGGTAGCAT-5'

4. Write the mRNA sequence, from 5' to 3', from the DNA molecule above.  
**5' UACGAUGGCC 3'**

All mRNA molecules contain regions called introns and exons. Exons are the regions that code for one polypeptide; introns are removed in a process called splicing.

5. In the mRNA below, draw out all the possible exon combinations (least being one exon) for modified mRNA molecules. What would the different combinations produce after translation?



**Each different combination of exons produces a different protein after translation**

6. Eukaryotes employ what is called alternative splicing, where one pre-mRNA molecule can be spliced into many mature mRNA molecules. Why would this process be beneficial to humans?

**This process is beneficial because it is possible to synthesize many different proteins from one mRNA molecule. It would allow organisms, such as a humans, to survive with a relatively small genome while still producing the diverse proteins necessary for life.**

## Translation Quiz

1. In what direction is mRNA synthesized?
  - a.  $N \rightarrow C$
  - b.  $3' \rightarrow 5'$
  - c.  $5' \rightarrow 3'$
  - d.  $C \rightarrow N$
  
2. True or False: the mRNA is identical to the template strand.
  - a. True
  - b. False
  
3. The aminoacyl-tRNA arrives at which site?
  - a. P site
  - b. E site
  - c. A site
  - d. D site
  
4. Which site holds the tRNA with the next amino acid to be added?
  - a. P site
  - b. E site
  - c. A site
  - d. D site

## Translation



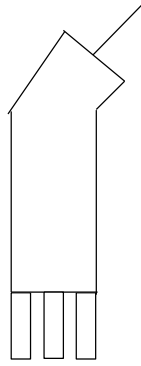
To complete the process of building protein from DNA, the mRNA molecule synthesized in transcription must now be used to translate nucleic acids into proteins. In organisms, the translator is tRNA, a molecule that reads the codons on the mRNA strand and attaches the correct amino acid to the polypeptide chain.

### Pre-Assignment:

	U		C		A		G		
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys	AGA	A	
	AUG	Met	ACG		AAG		AGG	G	
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu	GGA		A
	GUG		GCG		GAG		GGG		G

- Translate the following codons into amino acids using the above table.
  - AAU
  - GCG
  - UGU
  - AUA
  - GGG
  
- Label the location of the anticodon and the amino acid attachment site in the following tRNA molecule.

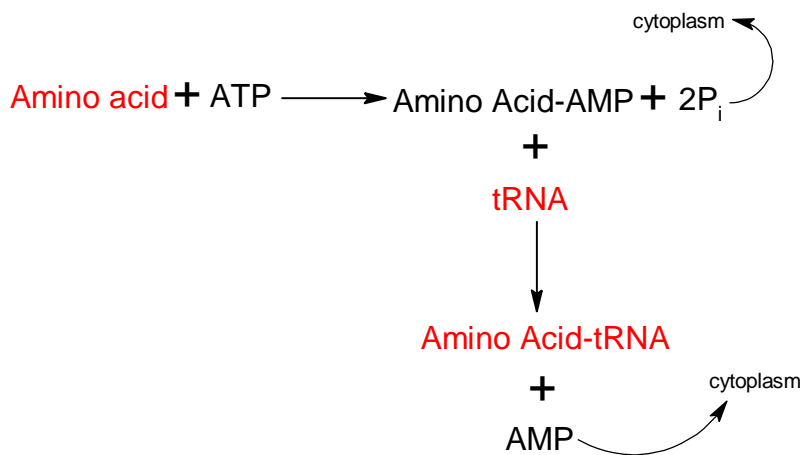




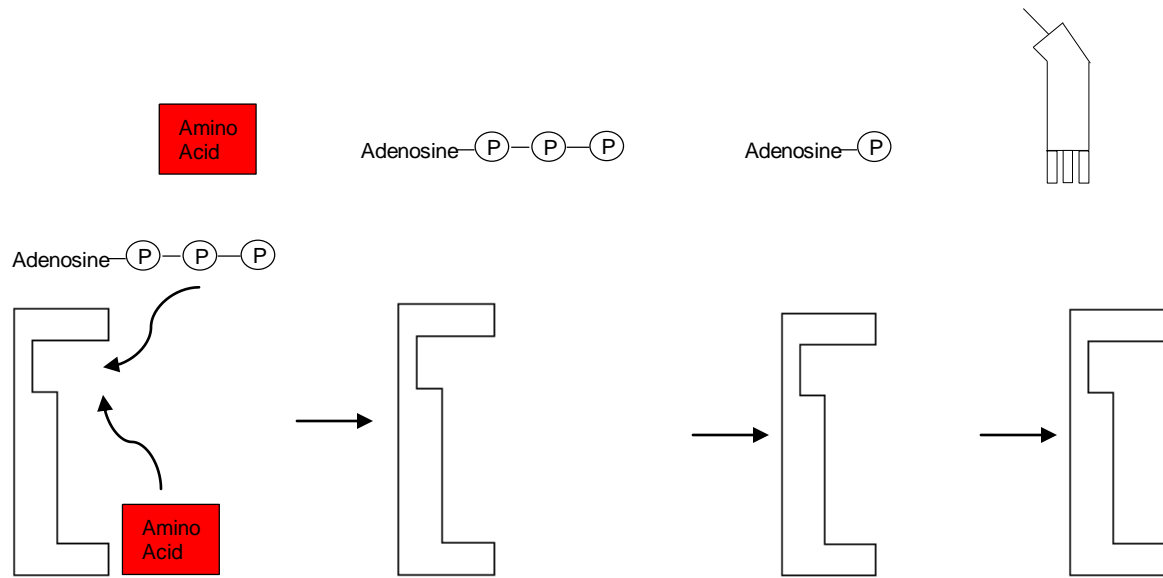
3. Name and describe the function of each of the three sites in a ribosome
- A-site
  - P-site
  - E-site

Assignment:

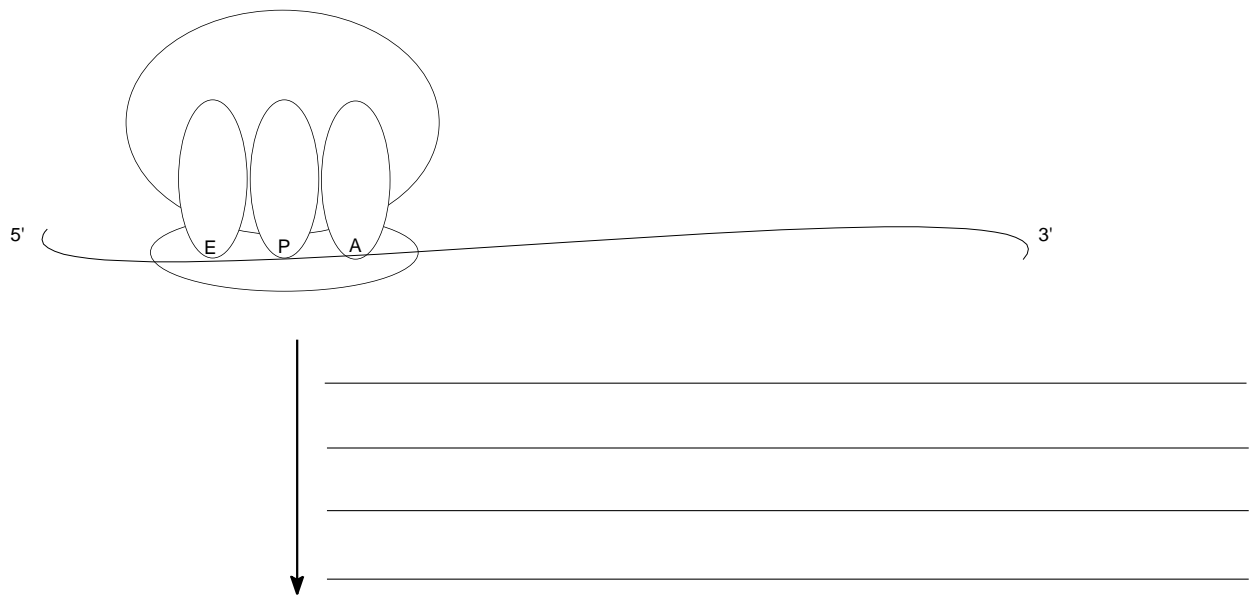
Before a tRNA can add an amino acid to the growing polypeptide chain, it must first locate the specific amino acid for its codon and bind to it. Below is the reaction, catalyzed by the enzyme Aminoacyl-tRNA synthetase, that binds tRNA and an amino acid. The resulting molecule is called the **Aminoacyl-tRNA**.

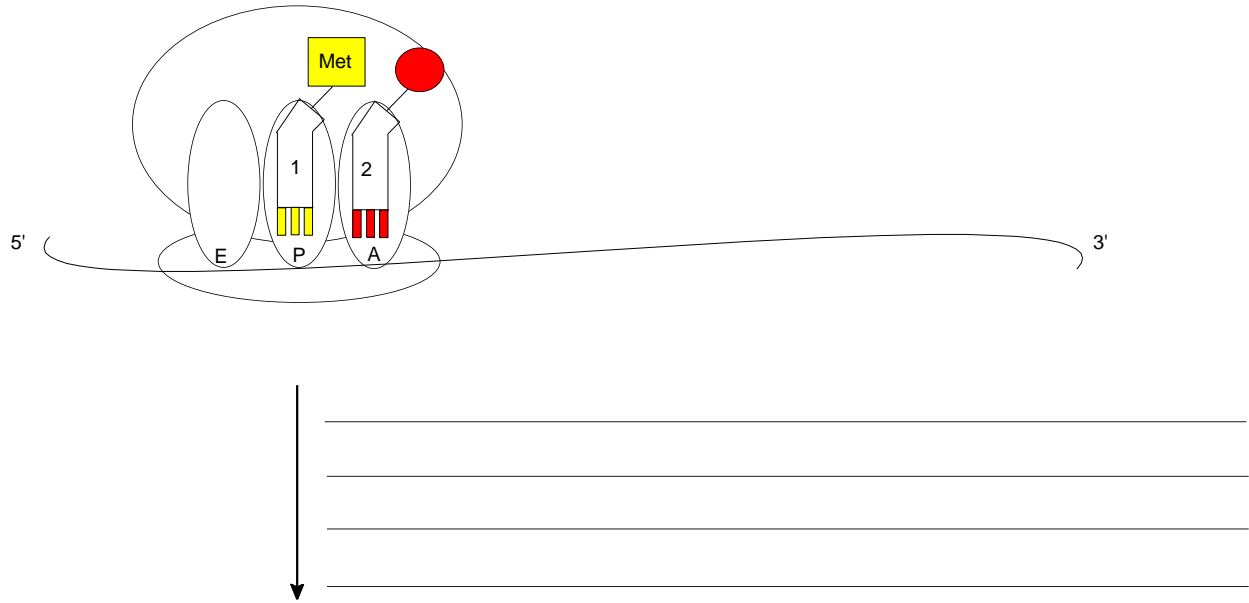
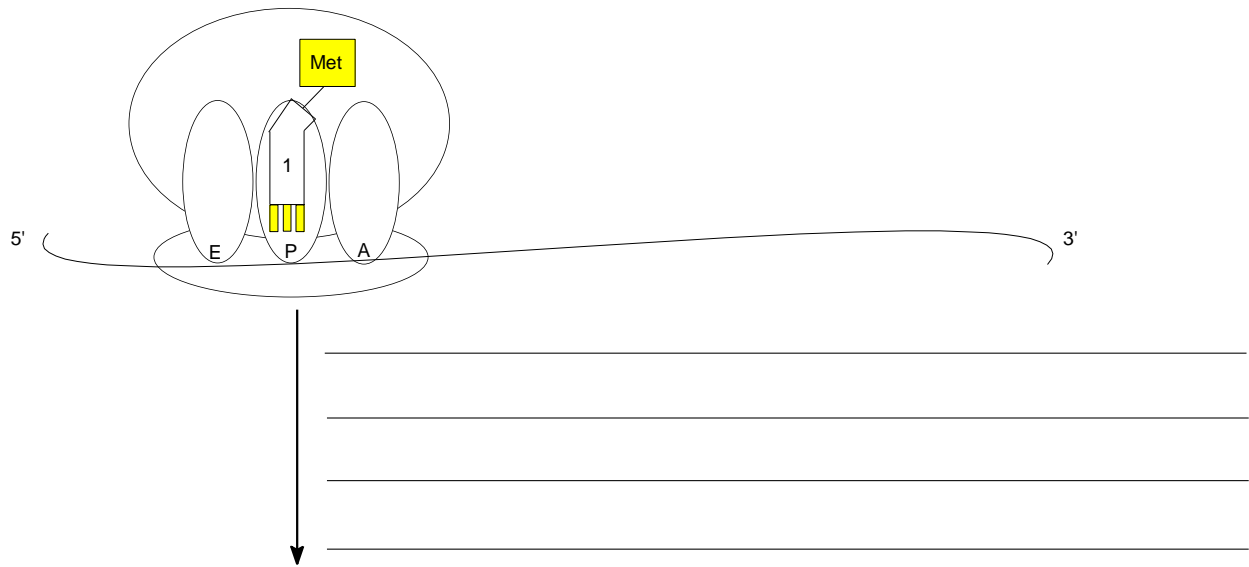


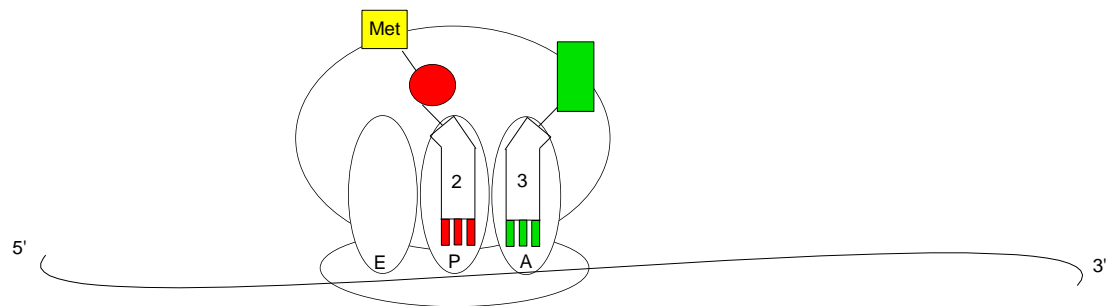
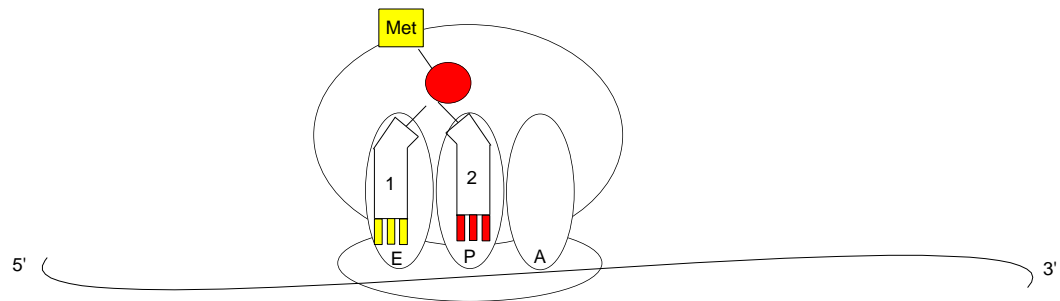
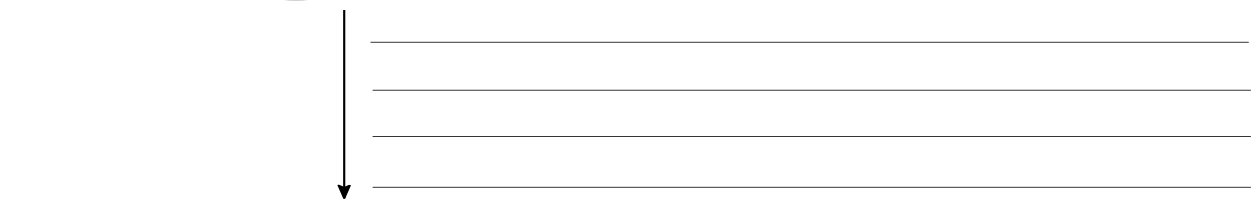
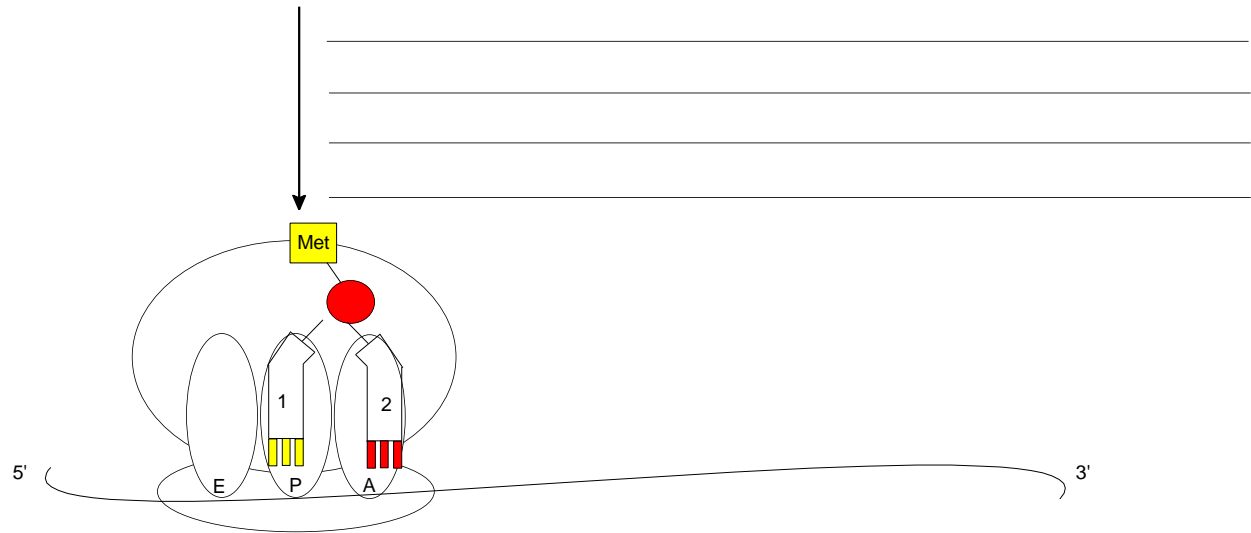
- Use the reaction scheme and the components to draw out the reaction.

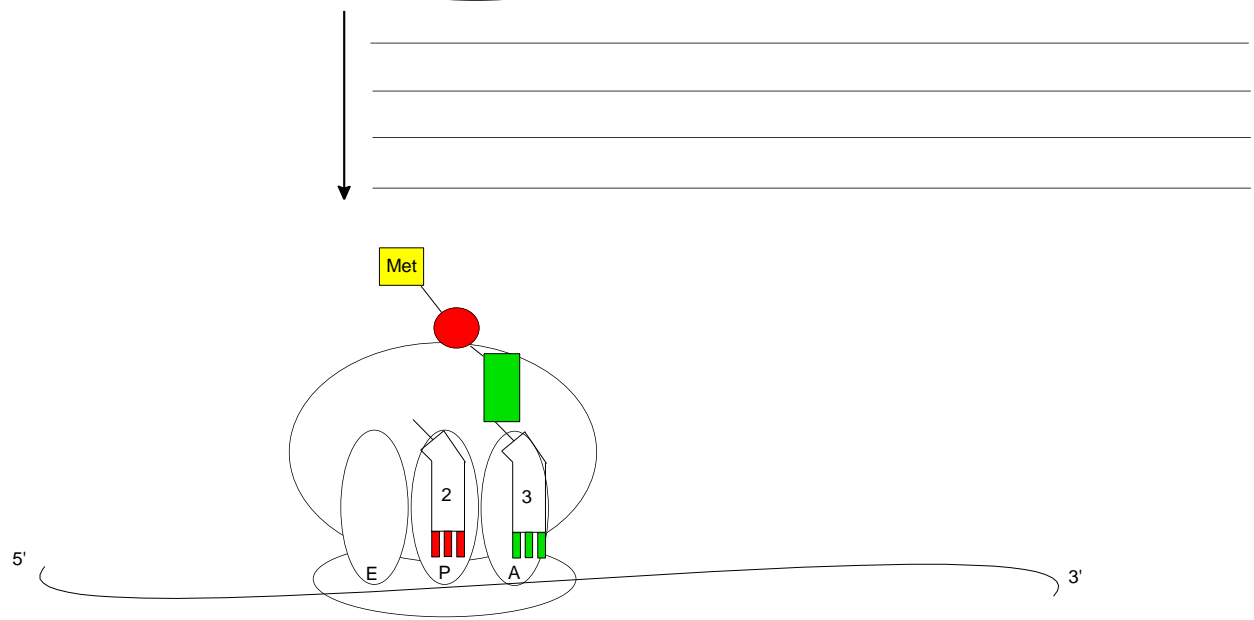
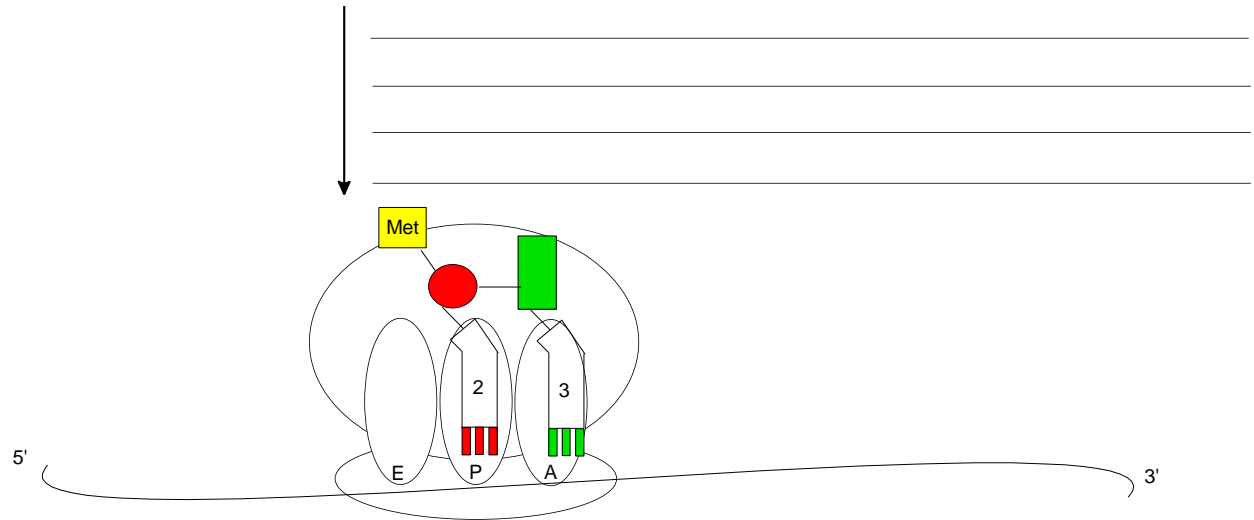


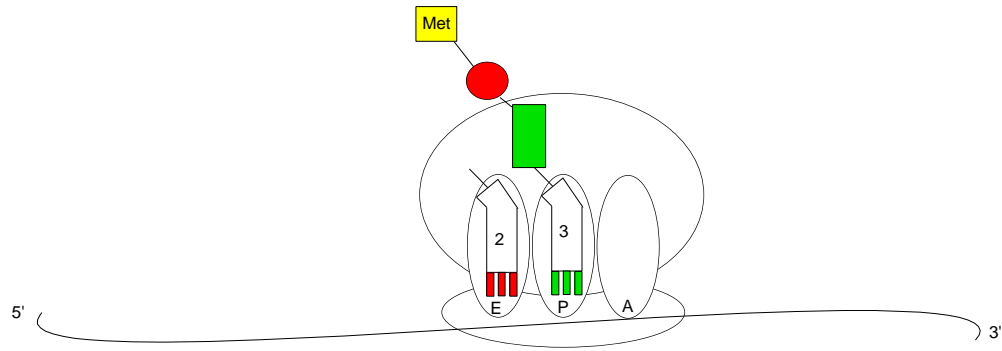
2. Describe what happens during each step of translation elongation. Include which site of the ribosome the tRNA binds, the movement of the tRNA, and when new amino acids are bound to the polypeptide chain.











3. Using (2), in what direction does the ribosome move along the mRNA?
4. What is the name of bond formed between the amino acids?
5. Describe the steps of elongation from when the aminoacyl-tRNA arrives until it exits.

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Translation Notes

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### Pre-Assignment:

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 was designed so that students can visually represent how a tRNA molecule becomes charged with an amino acid. If students are having trouble completing the diagrams, tell them to read the reaction scheme out loud, specifying what occurs in each step. The auditory cue could help them make sense of the process enough to be able to draw it.

### Question 2: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question two show students how two amino acids are added to a growing polypeptide chain. After they have had ten minutes to work on the explanations, it would be very beneficial to have a discussion where groups volunteer answers. This ensures that every student understands the process.



## Translation Notes

Questions 3, 4, and 5: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. After discussing the process of translation in the previous question, questions 3 and 4 ensure that the students also understand some of the details. The ribosome reads the mRNA molecule in the 5' → 3' direction and helps catalyze peptide bonds between the amino acids. **Question 3 is the first critical thinking question.**

Question 5 ensures that the students completely understand the process. By writing the steps in a sequential pattern, it might help them remember the process better. **Question 5 is the second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 3 and 5 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Translation

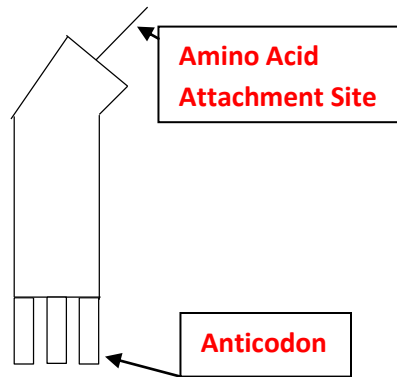


To complete the process of building protein from DNA, the mRNA molecule synthesized in transcription must now be used to translate nucleic acids into proteins. In organisms, the translator is tRNA, a molecule that reads the codons on the mRNA strand and attaches the correct amino acid to the polypeptide chain.

### Pre-Assignment:

	U		C		A		G		
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys	AGA	A	
	AUG	Met	ACG		AAG		AGG	G	
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu	GGA		A
	GUG		GCG		GAG		GGG		G

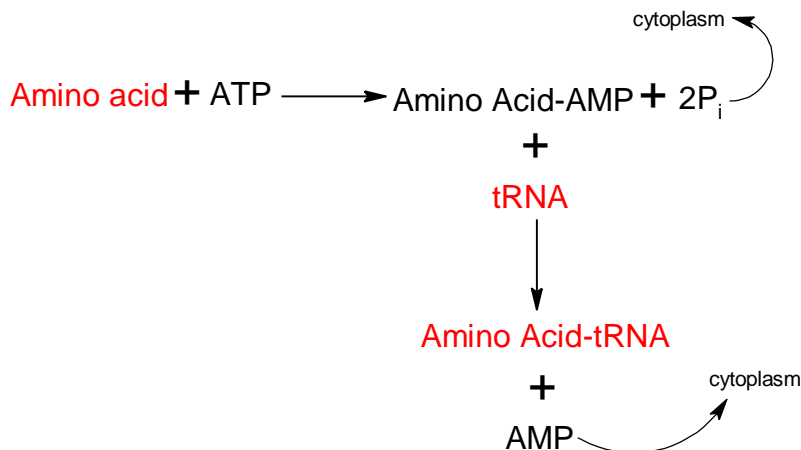
1. Translate the following codons into amino acids using the above table.
  - a. AAU-**Asparagine (Asn)**
  - b. GCG-**Alanine (Ala)**
  - c. UGU-**Cysteine (Cys)**
  - d. AUA-**Isoleucine (Ile)**
  - e. GGG-**Glycine (Gly)**
  
2. Label the location of the anticodon and the amino acid attachment site in the following tRNA molecule.



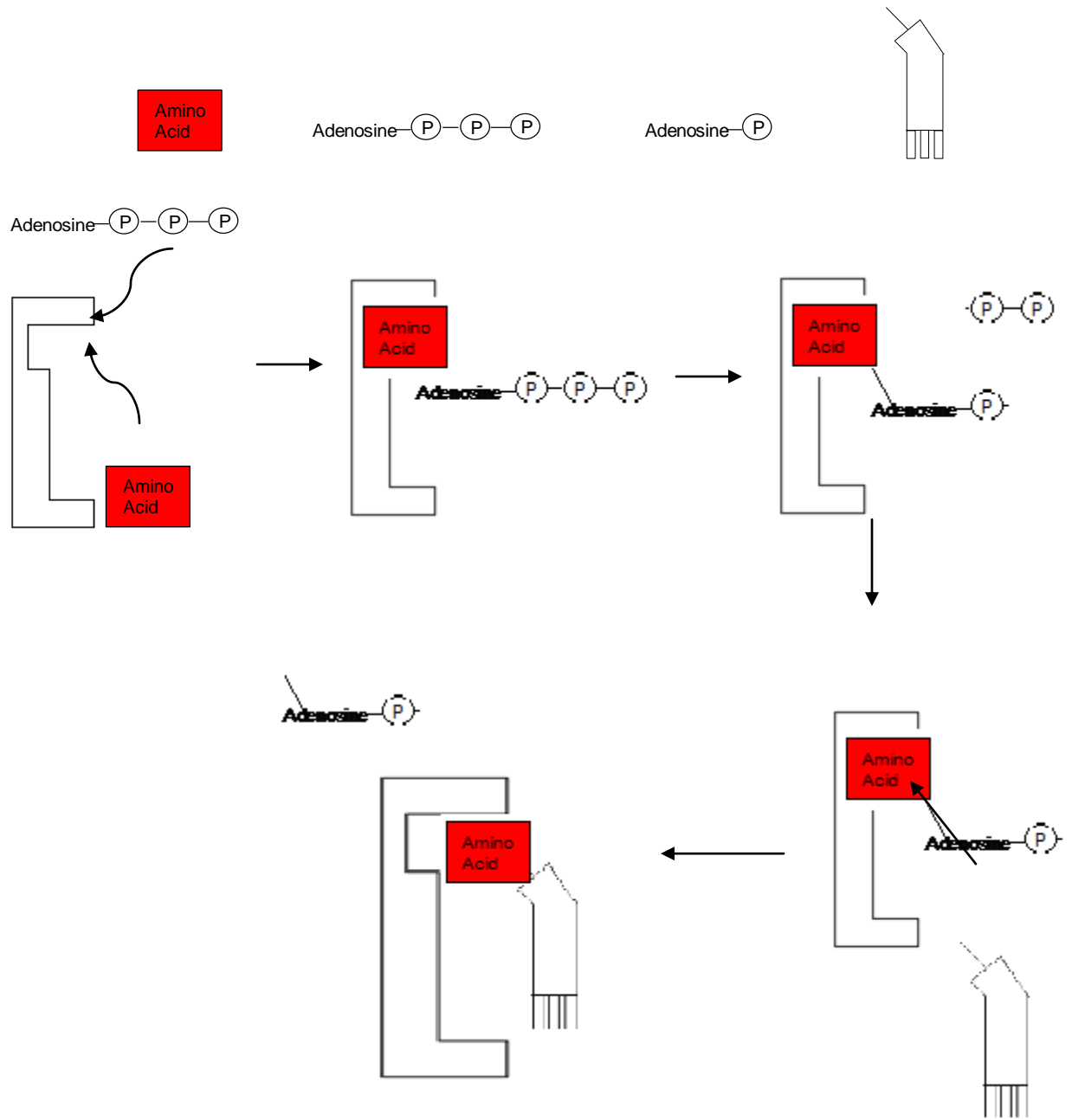
3. Name and describe the function of each of the three sites in a ribosome
- A-site-the tRNA molecule carrying an amino acid arrives at this site on the ribosome
  - P-site-Holds the tRNA with the growing polypeptide chain
  - E-site-the site where the tRNA molecule (that has given up its amino acid) leaves the ribosome

Assignment:

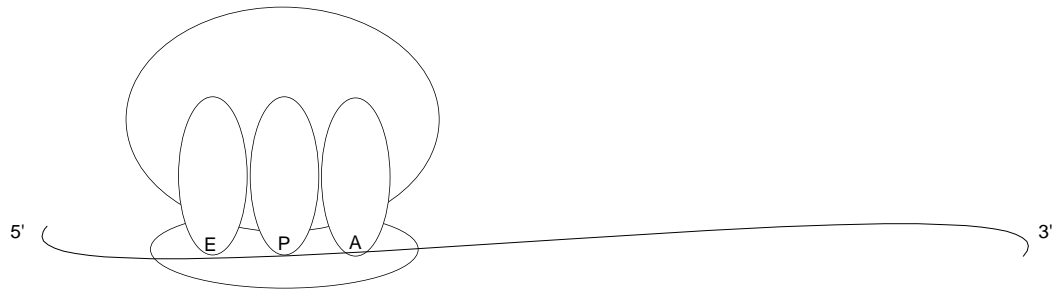
Before a tRNA can add an amino acid to the growing polypeptide chain, it must first locate the specific amino acid for its codon and bind to it. Below is the reaction, catalyzed by the enzyme Aminoacyl-tRNA synthetase, that binds tRNA and an amino acid. The resulting molecule is called the **Aminoacyl-tRNA**.



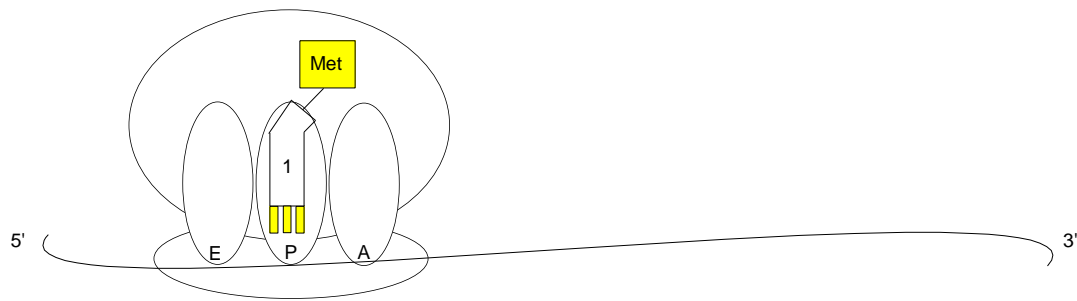
- Use the reaction scheme and the components to draw out the reaction.



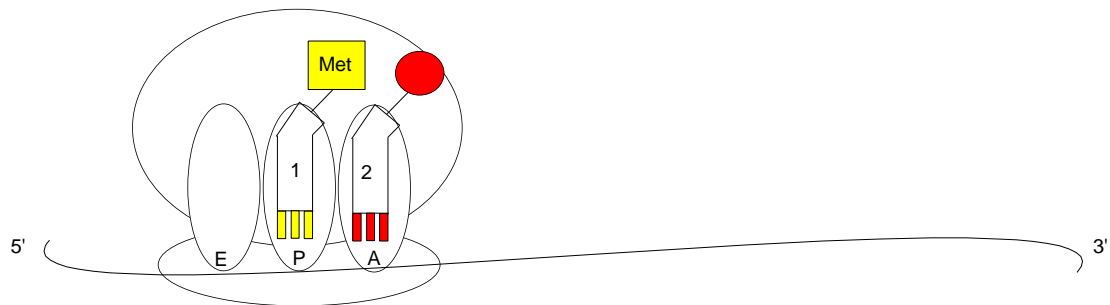
- Describe what happens during each step of translation elongation. Include which site of the ribosome the tRNA binds, the movement of the tRNA, and when new amino acids are bound to the polypeptide chain.



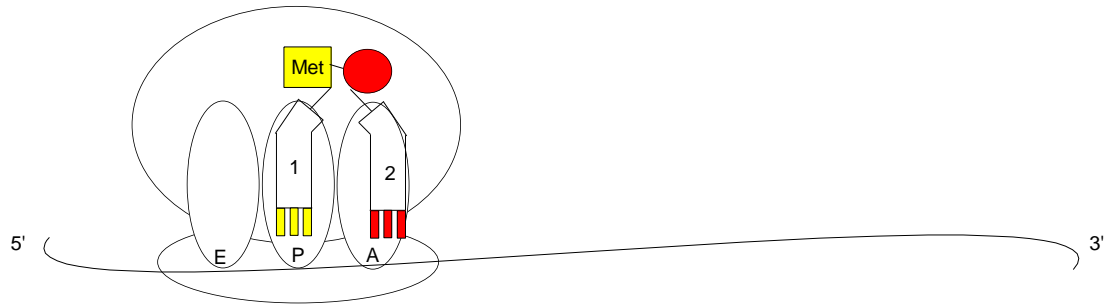
**The ribosome attaches to the mRNA.**



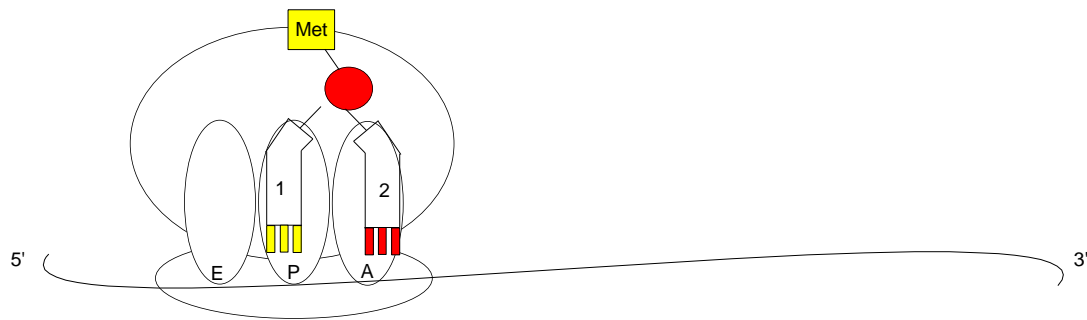
**Every polypeptide begins with methionine. The tRNA molecule (1) attached to the methionine enters the ribosome in the P-site.**



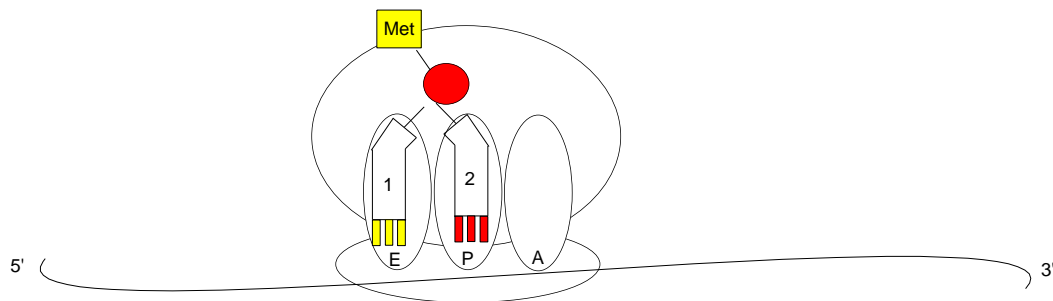
**The tRNA carrying the next amino acid (2) to be attached arrives in the A-site.**



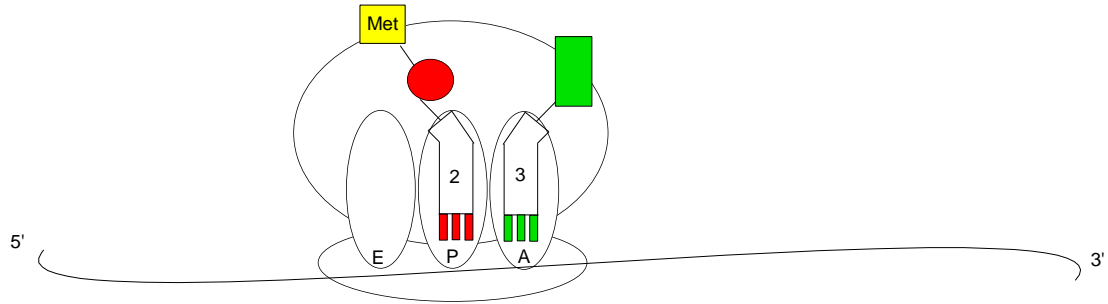
The amino acid on the (2) tRNA makes a peptide bond with the amino acid on the (1) tRNA.



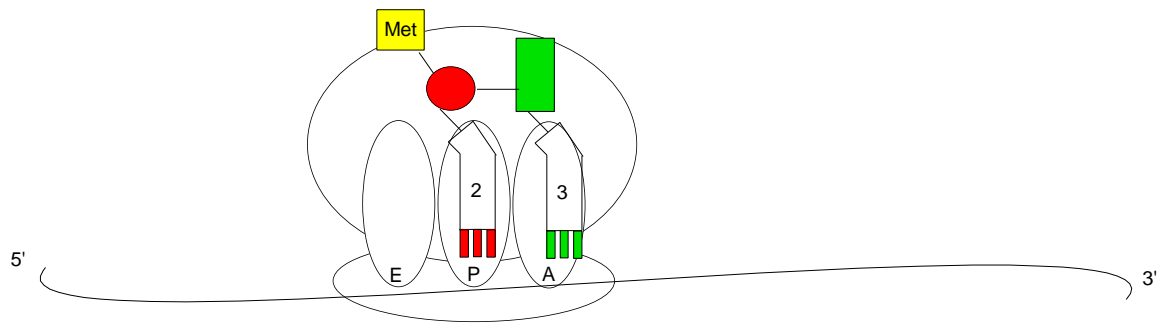
The growing polypeptide transfers from (1) tRNA in the P-site to (2) tRNA in the A-site.



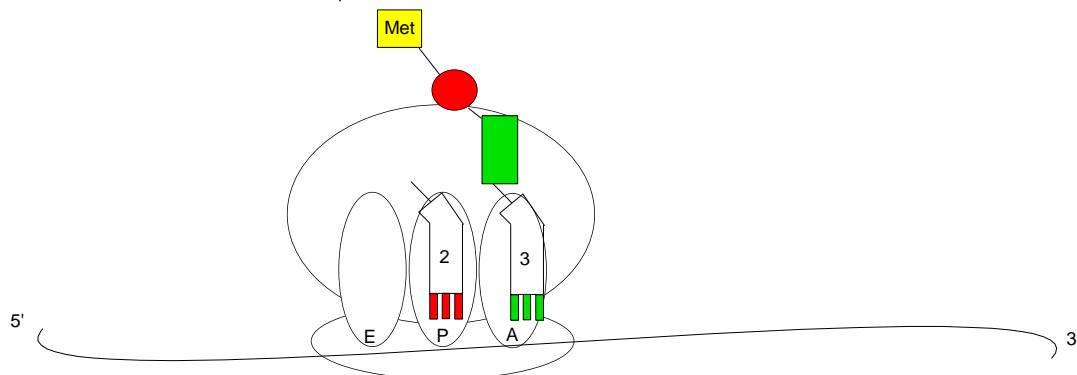
The ribosome moves down the mRNA strand. This moves the (1) tRNA into the E-site and the (2) tRNA into the P-site.



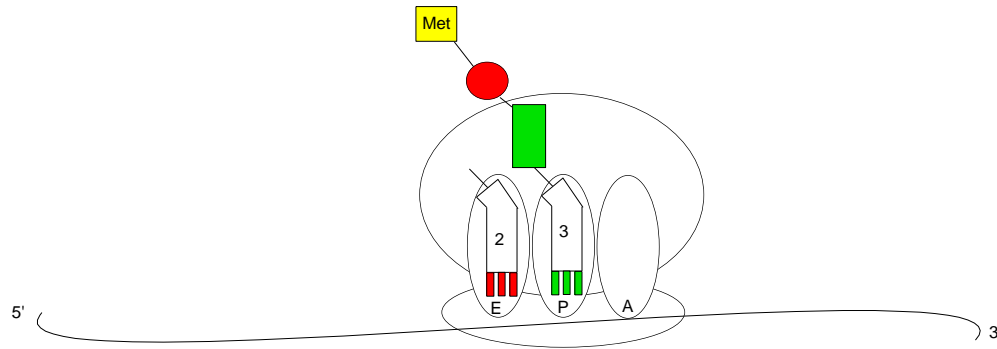
**A new tRNA molecule (3) with an attached amino acid arrives in the A-site.**



**A peptide bond forms between the growing polypeptide chain on (2) tRNA and the amino acid on (3) tRNA.**



**The growing polypeptide is transferred to the (3) tRNA in the A-site.**



**The ribosome moves down the mRNA molecule, moving the (2) tRNA into the E-site and the (3) tRNA into the P-site**

3. Using (2), in what direction does the ribosome move along the mRNA?  
**The ribosome moves along the mRNA in the 5' → 3' direction.**
  
4. What is the name of bond formed between the amino acids?  
**A peptide bond is formed between the amino acids.**
  
5. Describe the steps of elongation from when the aminoacyl-tRNA arrives until it exits.
  - 1. The aminoacyl-tRNA arrives at the ribosome in the A-Site; its anticodon is complementary to the codon on the mRNA.**
  - 2. The amino acid on the aminoacyl-tRNA forms a peptide bond with the amino acid on the tRNA in the P-site.**
  - 3. The growing polypeptide chain is transferred from the tRNA in the P-site to the tRNA in the A-site.**
  - 4. The ribosome then translocates down the mRNA to the next codon. The aminoacyl-tRNA is now in the P-site and the other tRNA is in the E-site. It exits the ribosome.**
  - 5. A new aminoacyl-tRNA, whose anticodon is complimentary to the next codon, arrives at the A-site. The process starts over.**



Supplemental assignments to increase the retention of knowledge for Biology I and II lecture.

Krystyn Vitale

Dr. Kenyon Daniel

Spring 2011

Date Accepted: May 6, 2011

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# **Biology II**

### Origin of Life Quiz

1. True or False: Reproduction is a characteristic of life.
  - a. True
  - b. False
  
2. True or False: Energy release and anabolism are characteristics of life.
  - a. True
  - b. False
  
3. True or False: Regulation and homeostasis are characteristics of life.
  - a. True
  - b. False
  
4. A biological catalyst that is made of RNA.
  - a. Rhizobia
  - b. Rhodopsin
  - c. Ribozyme
  - d. Resolution

## Origin of Life

More than 3.5 billion years ago, life first emerged on the planet. Scientists, however, do not (and cannot) know exactly how the first organisms evolved. Theories on the origin of life are numerous and ever-changing as new research is performed and discoveries are made. The question to be answered: What happened to evolve the molecules, structures, and processes that define living organisms?

### Pre-Assignment:

Name the seven characteristics of Life:

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.

Define ribozyme:

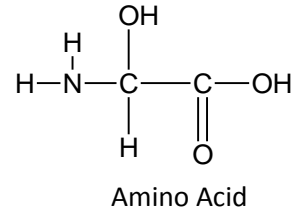
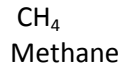
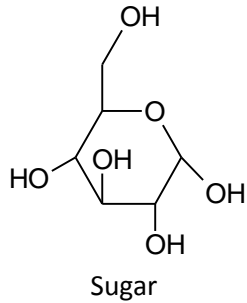
### Assignment:

In the beginning of the evolution of life, the following three hypotheses have been proposed:

- Reducing Atmosphere Hypothesis-organic molecules were formed from reducing molecules (e.g.  $\text{CH}_4$ ,  $\text{NH}_4$ ) in the atmosphere.
- Extraterrestrial Hypothesis-organic molecules arrived on the planet from meteorites crashing to Earth.
- Deep-Sea Vent Hypothesis-organic molecules have formed from the reaction of  $\text{H}_2\text{S}$  released from deep-sea vents and the hot and cold water.

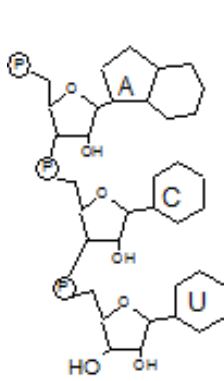
1. All three hypotheses have proposed the formation of specific molecules.
  - a. What molecules are formed from all three hypotheses?

- b. What biologically important, organic molecule do all of the following molecules in (a) have in common?

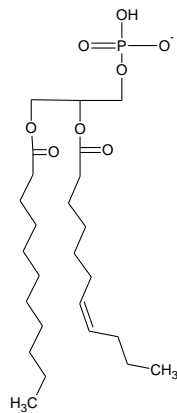


- c. What can be deduced is the first stage in the origin of life?

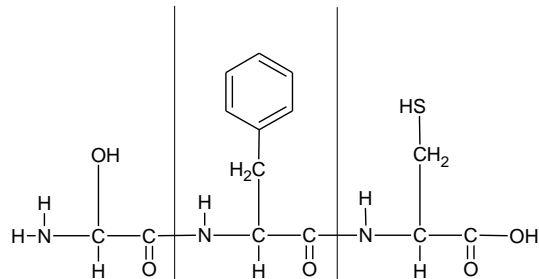
2. When molecules, such as in (1b) were deposited on a surface such as clay, the following molecules were formed:



Nucleic Acid



Phospholipid



Polypeptide

- a. How do some of the molecules in (1b) relate to those in (2)?

- b. What can you deduce is the second stage in the origin of life?

3.
  - a. If many copies of the second molecule in (2) aggregated in an aqueous environment, what is a possible structure formed? How would that structure create a cell?
  
  
  
  
  
  
  
  
  
  
  - b. What can you deduce about the third stage in the origin of life?
  
4. After the structure in (3a) evolved, the new cell began to show signs of a genetic storage molecule, replication of that molecule, and enzymatic activity.
  - a. What one molecule has the capacity to encompass all three of the traits from the new cell? (Hint: think back to the pre-assignment)
  
  
  
  
  
  
  
  
  
  
  - b. What can be deduced about the fourth stage in the origin of life? What processes of a living cell are needed? What had to evolve to take care of these processes?
  
  
  
  
  
  
  
  
  
  
5. Summarize the four proposed stages in the origin of life.

## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:



## Origin of Life Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. In deducing the four stages of life, you might have to ask many leading questions to help the students understand. The first stage is the formation of organic molecules, without which life would not be possible. Students might have a range of different answers for (1b), but try to lead them towards the MOST important molecule, carbon. Also, ask what other structures are made up of the example molecules such as DNA, RNA and protein. This should help them as they are answering question 2.

### Question 2: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The second stage in the origin of life is the polymerization of the organic molecules into nucleic acids, proteins, and lipids. Try to use the example molecules to lead students to this idea. Also, it is important that they understand this has to happen on clay. Ask them: what would happen if the organic molecules were in a polar environment such as water? The point at hand is that the aqueous environment would compete with the synthesis of polymers.

## Origin of Life Notes

### Question 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The third stage in the origin of life is the formation of a boundary between the cell and the environment. By using lipids as an example, students should figure out that a phospholipid bilayer could form thus creating a barrier. If students are having trouble understanding what happens when phospholipids aggregate, ask them to draw out the picture of phospholipids in an aqueous environment. The picture should help them understand.

### Question 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The fourth stage in the origin of life is the formation of cellular processes such as genetic storage, genetic replication, and enzymatic activity. In the proposed theory, RNA was the molecule formed that possessed all three traits. The pre-assignment includes the definition of a ribozyme. That definition, along with knowing nucleic acids have already been formed, should enable the students to elucidate the answer. If not, refer them back to the pre-assignment and question 2.

### Question 5: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 5 asks students to summarize the four stages in the origin of life: formation of organic molecules (*include the three hypotheses*); polymerization of organic molecules *on clay*; formation of a barrier; evolution of cellular process by the evolution of RNA. **Question 5 is the critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that question 5 is their critical thinking question and that they should write their answer in complete sentences on the critical thinking page before turning it in.

## Origin of Life

More than 3.5 billion years ago, life first emerged on the planet. Scientists, however, do not (and cannot) know exactly how the first organisms evolved. Theories on the origin of life are numerous and ever-changing as new research is performed and discoveries are made. The question to be answered: What happened to evolve the molecules, structures, and processes that define living organisms?

### Pre-Assignment:

Name the seven characteristics of Life:

1. **Cells and organization**
2. **Energy use and metabolism**
3. **Response to environmental change**
4. **Regulation and homeostasis**
5. **Growth and development**
6. **Reproduction**
7. **Biological evolution**

Define **ribozyme**-**An RNA molecule that functions as an enzyme**

### Assignment:

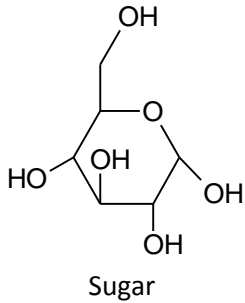
In the beginning of the evolution of life, the following three hypotheses have been proposed:

- **Reducing Atmosphere Hypothesis**-organic molecules were formed from reducing molecules (e.g. CH<sub>4</sub>, NH<sub>4</sub>) in the atmosphere.
- **Extraterrestrial Hypothesis**-organic molecules arrived on the planet from meteorites crashing to Earth.
- **Deep-Sea Vent Hypothesis**-organic molecules have formed from the reaction of H<sub>2</sub>S released from deep-sea vents and the hot and cold water.

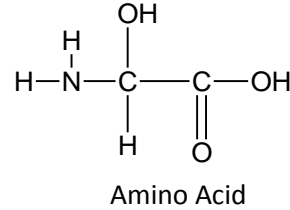
1. All three hypotheses have proposed the formation of specific molecules.
  - a. What molecules are formed from all three hypotheses?

**Organic molecules**

- b. What biologically important, organic molecule do all of the following molecules in (a) have in common?



CH<sub>4</sub>  
Methane

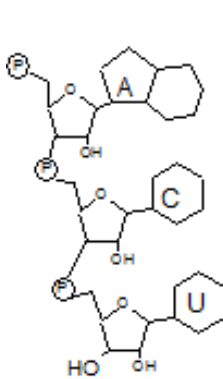


### Carbon

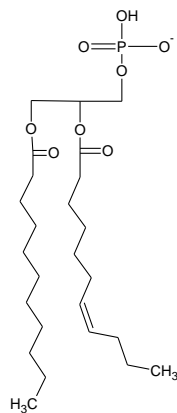
- c. What can be deduced is the first stage in the origin of life?

**The first stage in the origin of life involves the evolution of organic molecules, without which nothing can be built.**

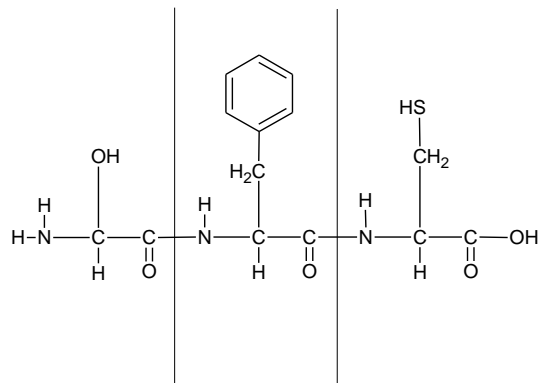
2. When molecules, such as in (1b) were deposited on a surface such as clay, the following molecules were formed:



Nucleic Acid



Phospholipid



Polypeptide

- a. How do some of the molecules in (1b) relate to those in (2)?

**The nucleotide in (1b) is a building block of the nucleic acid. The amino acid in (1b) is the building block of the polypeptide. Many methane molecules combine to form the hydrophobic tail in the phospholipid.**

- b. What can you deduce is the second stage in the origin of life?

**The second stage in the origin of life involves polymerizing the organic molecules created in the first stage into macromolecules.**

3.

- a. If many copies of the second molecule in (2) aggregated in an aqueous environment, what is a possible structure formed? How would that structure create a cell?

**If phospholipids aggregated, a phospholipid bilayer would form. The phospholipid bilayer separates the inside of a cell from the environment, allowing it to regulate itself.**

- b. What can you deduce about the third stage in the origin of life?

**The third stage in the origin of life requires barriers to be made, such as plasma membrane, which differentiates a cell from its environment. Only then can it begin to evolve the processes a cell requires.**

4. After the structure in (3a) evolved, the new cell began to show signs of a genetic storage molecule, replication of that molecule, and enzymatic activity.

- a. What one molecule has the capacity to encompass all three of the traits from the new cell? (Hint: think back to the pre-assignment)

**An RNA molecule has the ability to store genetic information, replicate itself, and also exhibits enzymatic activity (ribozyme).**

- b. What can be deduced about the fourth stage in the origin of life? What processes of a living cell are needed? What had to evolve to take care of these processes?

**A molecule that has the three traits mentioned above must have evolved. The most likely is RNA. Processes that a living cell requires are metabolism, regulation, growth, and reproduction. To complete these requirements, organelles needed to evolve.**

5. Summarize the four proposed stages in the origin of life.

- 1. Formation of organic molecules → Three hypotheses: Reducing Atmosphere, Extraterrestrial, and Deep-Sea vent hypotheses**
- 2. Polymerization of organic molecules into nucleic acids, polypeptides, and lipids**
- 3. Creation of a barrier to separate the evolving organism from the environment**
- 4. Evolution of a molecule that stores genetic information, replicates itself, and exhibits enzymatic activity → RNA**

## Population Genetics Quiz

1. What is the third stage in the origin of life?
  - a. Formation of organic molecules
  - b. Creation of an environmental barrier
  - c. Evolution of cellular processes
  - d. Polymerization of organic molecules
  
2. What is the fourth stage in the origin of life?
  - a. Polymerization of organic molecules
  - b. Evolution of cellular processes
  - c. Formation of organic molecules
  - d. Creation of an environmental barrier
  
3. The number of alleles in a population divided by the total alleles in a population.
  - a. Phenotype
  - b. Genotype frequency
  - c. Allele frequency
  - d. Genotype
  
4. The physical characteristics of an individual.
  - a. Phenotype
  - b. Genotype frequency
  - c. Allele frequency
  - d. Genotype

## Population Genetics

Population genetics is a field of biology concerned with studying the genetic variation within a population and calculating how that variation changes from generation to generation. Knowing the variation of a gene pool can be useful when analyzing the genetic inheritance of diseases.

### Pre-Assignment:

Define the following terms:

1. Population-
2. Population Genetics-
3. Gene Pool-
4. Genotype-
5. Phenotype-
6. Allele Frequency-
7. Genotype Frequency-
8. Why is genetic diversity important in a population?

### Assignment:

You are a biologist interested in the conservation of wolves in Montana. You track a population of 100 wolves and want to verify the genetic diversity within the population. Your results are as follows:

37 Brown (BB)  
52 Tan (Bb)  
11 White (bb)

1. You are asked to first calculate the *genotype frequency* for each genotype.

Genotype frequency =  $\frac{\# \text{ individuals with the genotype}}{\text{Total individuals in a population}}$

- a. How many individuals are in the total population?

- b. How many wolves have the BB genotype?
  - c. What is the genotype frequency of BB?
  - d. How many wolves have the Bb genotype?
  - e. What is the genotype frequency of Bb?
  - f. How many wolves have the bb genotype?
  - g. What is the genotype frequency?
2. You are asked to calculate the *allele frequency* of the B allele.
- a. How many alleles are present in one genotype, e.g. BB?
  - b. How many alleles are present in the 37 wolves with BB?
  - c. How many alleles are present in the 52 wolves with Bb?
  - d. How many alleles are present in the 11 wolves with bb?



- e. How many alleles are present in the *total population*? **Circle the answer.**
- f. How many alleles of B are present in the genotype *BB*?
- g. How many alleles of B are present in the 37 wolves with *BB*?
- h. How many alleles of B are present in the genotype *Bb*?
- i. How many alleles of B are present in the 52 wolves with *Bb*?
- j. How many alleles of B are present in the *total population* of 100 wolves (*BB*, *Bb*, *bb*)? **Circle the answer.**
- k. Use (2e) and (2j) to calculate the frequency of the B allele in the population.

$$\text{Frequency of B} = \frac{\# \text{ of B alleles}}{\# \text{ total alleles}}$$

- 3. Calculate the allele frequency of the b allele.
- 4. Write the sum of the two allele frequencies.
- 5. Write the above equation in terms of the alleles, i.e. B and b.

6. While the equation in (6) describes the frequency of one allele in a gene, it does not describe what occurs in nature. In nature, a gene contains two alleles, e.g. bb. To solve this problem, both sides must be multiplied by themselves. Square both sides and expand (FOIL).
7. If  $p = B$  (dominant allele) and  $q = b$  (recessive allele) rewrite (7) in terms of  $p$  and  $q$ .

The derived equation is called the **Hardy-Weinberg equation** and it is used to predict the frequency of genotypes in a population.

8. What does  $p^2$  represent in terms of genotypes? What does  $2pq$  represent? What does  $q^2$  represent?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Population Genetics Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 introduces the students to the calculation of frequencies when given a set of data. Calculating genotype frequencies should be relatively easy for students as it is set up. It might be beneficial to ask a student to write the answers to the parts of question 1 on the board.

### Questions 2, 3, and 4: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 2 and 3 might be a little more difficult for students to understand. They have to take into consideration that each genotype contains two alleles and that the total population contains double the amount of alleles as individuals. If students are having a difficult time understanding the individual steps of the process, you might want to stop the class after question 2 to make sure that the students are all heading in the right direction and then let them move on to question 3. Possibly, have students write the answers to question 2 on the board, discuss it, then let them continue. **Question 4 is the first critical thinking question.** It is included to apply the knowledge learned from questions 2 and 3.

## Population Genetics Notes

Questions 5, 6, 7, 8, and 9: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The rest of the lab illustrates how scientists Hardy and Weinberg created the Hardy-Weinberg equation. While it does not let students practice how to use the equation, they will know what each term of the equation stands for.

Questions 5 and 6 are simple arithmetic problems concerning the data. However, if you notice, as you walk around, that students are not coming to the correct conclusion, you might want to have a class discussion before moving on. When the students have the correct equation for question 6 ( $B + b = 1$ ), the squaring of both sides, question 7, should draw on previous math skills.

From there, question 8, writing the equation in terms of  $p$  and  $q$  will show the students how they derived the Hardy-Weinberg equation. To make sure, though, that they understand the relationship between the terms of the equation and the genotypes, students are asked to explain what each Hardy-Weinberg term represents in terms of genotypes. **Question 9 is the second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 4 and 9 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Population Genetics

Population genetics is a field of biology concerned with studying the genetic variation within a population and calculating how that variation changes from generation to generation. Knowing the variation of a gene pool can be useful when analyzing the genetic inheritance of diseases.

### Pre-Assignment:

Define the following terms:

1. Population-**A group of individuals from the same species that can interbreed**
2. Population Genetics-**The study of genes and genotypes in a population**
3. Gene Pool-**All of the genes in a population**
4. Genotype-**Genetic composition of an individual**
5. Phenotype-**Physical characteristics of an individual, deriving from the proteins expressed from the genome**
6. Allele Frequency-**The number of copies of an allele divided by the total number in a population**
7. Genotype Frequency-**The number of individuals with a genotype divided by the number of individuals**
8. Why is genetic diversity important in a population?  
**Genetic diversity is important for evolution of a species. Without evolution, a species might become unfit in their environment and go extinct.**

### Assignment:

You are a biologist interested in the conservation of wolves in Montana. You track a population of 100 wolves and want to verify the genetic diversity within the population. Your results are as follows:

37 Brown (BB)  
52 Tan (Bb)  
11 hite (bb)

1. You are asked to first calculate the *genotype frequency* for each genotype.

$$\text{Genotype frequency} = \frac{\# \text{ individuals with the genotype}}{\text{Total individuals in a population}}$$

a. How many individuals are in the total population?

**100**

b. How many wolves have the BB genotype?

**37**

c. What is the genotype frequency of BB?

**Genotype Frequency =  $37/100 = 0.37$**

d. How many wolves have the Bb genotype?

**52**

e. What is the genotype frequency of Bb?

**Genotype Frequency =  $52/100 = 0.52$**

f. How many wolves have the bb genotype?

**11**

g. What is the genotype frequency?

**Genotype Frequency =  $11/100 = 0.11$**

2. You are asked to calculate the *allele frequency* of the B allele.

a. How many alleles are present in one genotype, e.g. BB?

**2**

b. How many alleles are present in the 37 wolves with BB?

**$2 \times 37 = 74$**

c. How many alleles are present in the 52 wolves with Bb?

**$2 \times 52 = 104$**

d. How many alleles are present in the 11 wolves with bb?

**$2 \times 11 = 22$**

- e. How many alleles are present in the *total population*? **Circle the answer.**  
**1.  $104 + 74 = 200$  or  $2 \times 100$  genotypes = 200**

3.

- a. How many alleles of B are present in the genotype *BB*?

**2**

- b. How many alleles of B are present in the 37 wolves with *BB*?

**$2 \times 37 = 74$**

- c. How many alleles of B are present in the genotype *Bb*?

**1**

- d. How many alleles of B are present in the 52 wolves with *Bb*?

**$1 \times 52 = 52$**

- e. How many alleles of B are present in the *total population* of 100 wolves (*BB*, *Bb*, *bb*)? **Circle the answer.**

**$74 + 52 = 126$**

- f. Use (2e) and (2j) to calculate the frequency of the B allele in the population.

$$\text{Frequency of B} = \frac{\# \text{ of B alleles}}{\# \text{ total alleles}} = \frac{126}{200} = 0.63$$

4. Calculate the allele frequency of the b allele.

$$\text{Frequency of b} = \frac{\# \text{ of b alleles}}{\# \text{ total alleles}} = \frac{22 + 52}{200} = \frac{74}{200} = 0.37$$

$$2 \times 11 \text{ bb} = 22$$

$$1 \times 52 \text{ Bb} = 52$$

$$\text{or } 200 - 126 = 74$$

5. Write the sum of the two allele frequencies.

$$0.63 + 0.37 = 1$$



6. Write the above equation in terms of the alleles, i.e. B and b.

$$\mathbf{B + b = 1}$$

7. While the equation in (6) describes the frequency of one allele in a gene, it does not describe what occurs in nature. In nature, a gene contains two alleles, e.g. bb. To solve this problem, both sides must be multiplied by themselves. Square both sides and expand (FOIL).

$$\mathbf{(B + b)^2 = (1)^2}$$

$$\mathbf{B^2 + 2Bb + b^2 = 1}$$

8. If  $p = B$  (dominant allele) and  $q = b$  (recessive allele) rewrite (7) in terms of p and q.

$$\mathbf{p^2 + 2pq + q^2 = 1}$$

The derived equation is called the **Hardy-Weinberg equation** and it is used to predict the frequency of genotypes in a population.

9. What does  $p^2$  represent in terms of genotypes? What does  $2pq$  represent? What does  $q^2$  represent?

$\mathbf{p^2 \rightarrow pp \rightarrow BB \rightarrow \text{the frequency of the homozygous dominant genotype}}$

$\mathbf{2pq \rightarrow 2Bb \rightarrow \text{the frequency of the heterozygous genotype}}$

$\mathbf{q^2 \rightarrow qq \rightarrow bb \rightarrow \text{the frequency of the homozygous recessive genotype}}$

## Origin of Species Quiz

1. What does  $p^2$  represent?
  - a. The frequency of the homozygous recessive genotype
  - b. The frequency of the heterozygous genotype
  - c. The frequency of the homozygous dominant genotype
  - d. The frequency of the dominant phenotype.
  
2. What does  $q^2$  represent?
  - a. The frequency of the homozygous recessive genotype
  - b. The frequency of the heterozygous genotype
  - c. The frequency of the homozygous dominant genotype
  - d. The frequency of the dominant phenotype.
  
3. Separate species are defined by their inability to produce fertile offspring.
  - a. Phylogenetic species concept
  - b. Ecological species concept
  - c. Biological species concept
  - d. Evolutionary species concept
  
4. Two organisms that have a common ancestor are a member of the same species.
  - a. Phylogenetic species concept
  - b. Ecological species concept
  - c. Biological species concept
  - d. Evolutionary species concept

## Origin of species

In biology, a species is defined by the similarity of attributes within the population. However, if a population is suddenly separated due to a change in the geography for a long period of time, what changes could occur in the population? Would those changes affect the similarity of attributes between the populations? If so, are the two populations the same species, or has a new species originated?

### Pre-Assignment:

Define the following terms:

1. Phylogenetic species concept-
2. Biological species-
3. Evolutionary species concept-
4. Ecological species concept-
5. Reproductive Isolation-
6. Cladogenesis-
7. Allopatric speciation-
8. Sympatric speciation-
9. Anagenesis-

Assignment:

Match the reproductive isolation mechanisms, which stop different species from mating, to their descriptions:

Gamete isolation	Hybrid inviability
Hybrid breakdown	Behavioral isolation
Habitat isolation	Hybrid sterility
Mechanical isolation	Temporal isolation

1. Cat 1 comes into heat between the months of January and February. Cat 2 comes into heat during the months of August and September.
2. A male Great Dane and a female Chihuahua attempting to mate.
3. Dog 1 and Dog 2 have attempted to mate. However, the two gametes fail to form a zygote.
4. Dog 1 and Dog 3 have successfully mated and created a zygote. However, the zygote never develops into an embryo.
5. Cat 1 and Cat 2 successfully mate and produce a viable offspring, Cat 3. However, when Cat 3 tries to produce offspring, most of the zygotes fail to form an embryo.
6. Bird 1 only exists on an island in the Pacific Ocean. Bird 2 only exists in South America.
7. A male lion and a female tiger produce offspring. However, the offspring is infertile.
8. The eastern meadowlark and western meadowlark use different songs to attract mates.

9. Which definition (from the pre-assignment) did the above questions substantiate?

Place the mechanisms into three categories:

10. Prezygotic mechanisms before attempted mating

Prezygotic mechanisms after attempted mating

Postzygotic mechanisms

Speciation can occur by many different mechanisms. However, cladogenesis, separated into allopatric and sympatric speciation, is the most common mechanism.

Read the examples below and deduce what caused the populations to become isolated.

11. Allopatric speciation

- a. A population of goats lives in a mountainous environment. After an earthquake, a range of small mountains, too high for the goats to traverse, has separated the population. Due to natural selection, the goats have evolved into two different species.
  
- b. A population of monkeys lives near a river. One night, a small group of monkeys is washed far away in a flash flood. The monkeys survive by swimming to an island. Due to natural selection, the monkeys have evolved into two different species.

12. Sympatric speciation

- a. In an environment, a population of Plant A exists. Half of the population, now called Plant B, spontaneously loses two chromosomes. The gametes of the two plants will no longer fuse, gametic isolation.

## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Origin of Species Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, 3, 4, 5, 6, 7, 8, and 9: (20 minutes)

Give the students ten minutes to read the questions and form answers. The next ten minutes should include a discussion about the answers. The first part of this assignment, questions 1 through 8, are designed to help students understand the barrier that prevent individuals of different species from creating viable offspring. During the discussion, ask students to volunteer their answers. If an answer is incorrect, facilitate a class discussion indicating why it is incorrect and what the correct answer would be. Question 9 is used to show the relationship between the biological definition of a species and the reproductive isolation mechanisms.

### Question 10: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 10 expands upon the questions at the beginning of the assignment. While it is important to know what the reproductive isolation mechanisms are, it is also important to know at what stage do the mechanisms take place: before or after fertilization. **Question 10 is the critical thinking question.**



## **Origin of Species Notes**

Questions 11 and 12: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. The last part of the assignment consists of showing how new species can originate. Students are asked to read the situations and decide what type of change occurred that allowed the evolution of a new species. If students are having a difficult time elucidating the cause of speciation, ask them to identify what event occurred. By naming the event, they should be able to deduce the general cause of speciation, the first being a geographical barrier and the second being reproductive isolation.

The rest of the time should be used by students to complete their critical thinking questions. Tell students that question 10 is their critical thinking question and that they should write their answer in complete sentences on the critical thinking page before turning it in.

## Origin of species

In biology, a species is defined by the similarity of attributes within the population. However, if a population is suddenly separated due to a change in the geography for a long period of time, what changes could occur in the population? Would those changes affect the similarity of attributes between the populations? If so, are the two populations the same species, or has a new species originated?

### Pre-Assignment:

Define the following terms:

1. Phylogenetic species concept-**members of a species have unique characteristics**
2. Biological species-**A species is defined at those that can interbreed and create viable, fertile offspring**
3. Evolutionary species concept-**A species is defined by having a clear ancestor**
4. Ecological species concept-**Each species occupies its own ecological niche**
5. Reproductive Isolation-**Mechanisms that prevent one species from successfully interbreeding with another species**
6. Cladogenesis-**A type of speciation where a species is divided into two or more species**
7. Allopatric speciation-**A type of speciation that produces two distinct species because of a geographical barrier**
8. Sympatric speciation-**A form of speciation where a species initially occupies the same habitat, but diverge into different species**
9. Anagenesis-**A form of speciation where a new species evolves over the course of many generations**

Assignment:

Match the reproductive isolation mechanisms, which stop different species from mating, to their descriptions:

Gamete isolation	Hybrid inviability
Hybrid breakdown	Behavioral isolation
Habitat isolation	Hybrid sterility
Mechanical isolation	Temporal isolation

1. Cat 1 comes into heat between the months of January and February. Cat 2 comes into heat during the months of August and September.

**Temporal Isolation**

2. A male Great Dane and a female Chihuahua attempting to mate.

**Mechanical Isolation**

3. Dog 1 and Dog 2 have attempted to mate. However, the two gametes fail to form a zygote.

**Gametic Isolation**

4. Dog 1 and Dog 3 have successfully mated and created a zygote. However, the zygote never develops into an embryo.

**Hybrid Inviability**

5. Cat 1 and Cat 2 successfully mate and produce a viable offspring, Cat 3. However, when Cat 3 tries to produce offspring, most of the zygotes fail to form an embryo.

**Hybrid Breakdown**

6. Bird 1 only exists on an island in the Pacific Ocean. Bird 2 only exists in South America.

**Habitat Isolation**

7. A male lion and a female tiger produce offspring. However, the offspring is infertile.

**Hybrid Sterility**

8. The eastern meadowlark and western meadowlark use different songs to attract mates.

**Behavioral Isolation**

9. Which definition (from the pre-assignment) did the above questions substantiate?  
**Biological species concept**

Place the mechanisms into three categories:

10. Prezygotic mechanisms before attempted mating  
**Habitat Isolation, Temporal Isolation, Behavioral Isolation**

Prezygotic mechanisms after attempted mating  
**Mechanical Isolation, Gametic Isolation**

Postzygotic mechanisms  
**Hybrid Inviability, Hybrid Sterility, Hybrid breakdown**

Speciation can occur by many different mechanisms. However, cladogenesis, separated into allopatric and sympatric speciation, is the most common mechanism.

Read the examples below and deduce what caused the populations to become isolated.

11. Allopatric speciation

- a. A population of goats lives in a mountainous environment. After an earthquake, a range of small mountains, too high for the goats to traverse, has separated the population. Due to natural selection, the goats have evolved into two different species.

**Geographical barrier → formation of new mountain range**

- b. A population of monkeys lives near a river. One night, a small group of monkeys is washed far away in a flash flood. The monkeys survive by swimming to an island. Due to natural selection, the monkeys have evolved into two different species.

**Geographical barrier → the distance between islands**

12. Sympatric speciation

- a. In an environment, a population of Plant A exists. Half of the population, now called Plant B, spontaneously loses two chromosomes. The gametes of the two plants will no longer fuse, gametic isolation.

**Reproductive Isolation → due to some individuals changing chromosome number**

### **Bacteria and Archaea Quiz**

1. Cat 1 comes into heat between the months of January and February. Cat 2 comes into heat during the months of August and September. What is the reproductive isolation mechanism?
  - a. Behavioral Isolation, Pre-zygotic
  - b. Temporal Isolation, Pre-zygotic
  - c. Temporal Isolation, Post-zygotic
  - d. Behavioral Isolation, Post-zygotic
  
2. An earthquake creating a new mountain range separates population. The population evolves into two distinct species due to natural selection. This is the definition for:
  - a. Allopatric speciation-anagenesis
  - b. Sympatric speciation-cladogenesis
  - c. Allopatric speciation-cladogenesis
  - d. Sympatric speciation-anagenesis
  
3. An organism that lives in a hot spring is an example of:
  - a. A bacteria
  - b. An extremophile
  - c. A protist
  - d. A fungus
  
4. True or False: Horizontal gene transfer is the transfer of genes between species.
  - a. True
  - b. False

## Bacteria and Archaea

Bacteria and Archaea are the oldest and smallest life on Earth, originating approximately 3.5 billion years ago when life first began. Together, they are found in almost every part of the world, from deep sea vents, to soil, and even our own intestines.

### Pre-Assignment:

Define the following terms:

1. Extremophile-
2. Producer-
3. Horizontal Gene Transfer-
4. Binary Fission-

### Assignment:

1. Archaea are extremophiles. Give three examples of viable environments.
  
  
  
  
  
  
  
  
  
  
2. Is bacteria or archaea more closely related to eukaryotes? What evidence is there to support the claim?
  
  
  
  
  
  
  
  
  
  
3. Draw the four different shapes of microbes:

Cocci

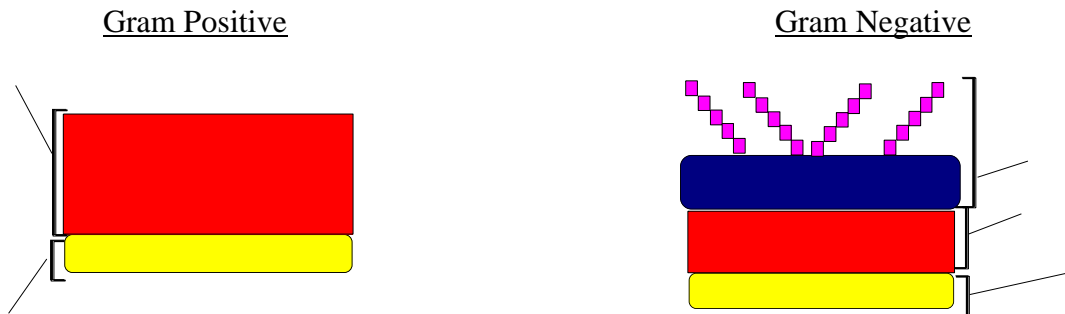
Bacilli

Vibrios

Spirochaetes

4. What polymer does the bacterial cell wall contain that archaea does not?
5. Use the terms to label the cell walls of the Gram-Positive and Gram-Negative Bacteria. Describe the differences below.

Terms: Peptidoglycan, Plasma membrane, Lipopolysaccharide envelope



6. Match the terms with their definitions:

Obligate anaerobe  
 Autotroph  
 Photoautotroph  
 Chemoautotroph  
 Heterotroph

Photoheterotroph  
 Chemoautotroph  
 Obligate aerobe  
 Facultative aerobe  
 Aerotolerant anaerobe

- a. An organism capable of producing its own nutrition.
- b. An organism that requires the lack of oxygen to produce energy, and will die in the presence of oxygen.
- c. An organism that requires oxygen to produce energy.



- d. A bacteria that converts ammonia to nitrate. It produces this energy to synthesize its nutrition.
- e. An organism that is required to ingest nutrition; they cannot produce their own.
- f. A cyanobacteria producing its own nutrition from photosynthesis.
- g. An organism that requires the lack of oxygen to produce energy, but will not die in the presence of oxygen.
- h. An organism that must ingest nutrition for a source of energy and organic molecules for carbon molecules.
- i. An organism that can synthesize ATP, but must still ingest nutrients (organic molecules) for a source of carbon.
- j. An organism that can use oxygen to produce energy, but it is not required.

## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Bacteria and Archaea Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, and 2: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 asks students to differentiate the different extremophile archaea in the world, as there are many different environments in which they live.

Question 2 asks students to explain why archaea are more closely related to eukaryotes than bacteria. The students are not expected to have this prior knowledge, so they may use their books. You should facilitate the discussion, indicating the similarities of the eukaryotic and archaeic nucleui and cytoplasm. **Question 2 is the first critical thinking question.**

### Questions 3, 4, and 5: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 3 through 5 walk the students through characteristics of bacteria, including their shapes and cell wall composition.

## Bacteria and Archaea Notes

Question 5 is an important question, as it defines the difference between gram-negative and gram-positive bacteria. **Question 5 is the second critical thinking question.** Students should draw the two cell walls on their paper and label them, correctly.

### Question 6: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 6 is an exercise in learning definitions. Students may use their book, if needed. Be sure to have students volunteer their answers during the discussion.

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 2 and 5 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Bacteria and Archaea

Bacteria and Archaea are the oldest and smallest life on Earth, originating approximately 3.5 billion years ago when life first began. Together, they are found in almost every part of the world, from deep sea vents, to soil, and even our own intestines.

### Pre-Assignment:

Define the following terms:

1. Extremophile-**An organism that occurs in primarily in extreme habitats**
2. Producer-**An organism that synthesizes organic compounds that can be used by other organisms**
3. Horizontal Gene Transfer-**Transfer of genes between different species**
4. Binary Fission-**Reproductive mechanism where the cell divides into two cells; occurs in bacteria and archaea**

### Assignment:

1. Archaea are extremophiles. Give three examples of viable environments.  
**Deep-sea thermal vent (high temperature)**  
**Extremely salty ocean (high salinity)**  
**Habitats with high methane or pH**
2. Is bacteria or archaea more closely related to eukaryotes? What evidence is there to support the claim?  
**Archaea are more closely related to eukaryotes. Common features in their nucleus and cytoplasm have been found.**
3. Draw the four different shapes of microbes:

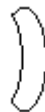
Cocci



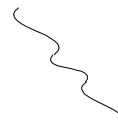
Bacilli



Vibrios



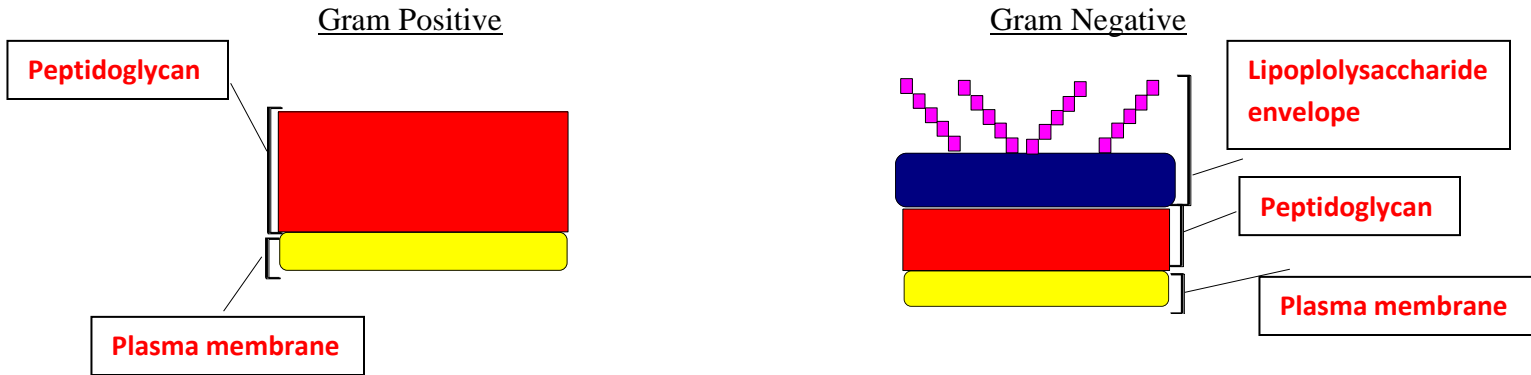
Spirochaetes



4. What polymer does the bacterial cell wall contain that archaea does not?  
**Peptidoglycan**

5. Use the terms to label the cell walls of the Gram-Positive and Gram-Negative Bacteria.  
Describe the differences below.

Terms: Peptidoglycan, Plasma membrane, Lipopolysaccharide envelope



**The Gram-positive bacteria has a thick outer layer of peptidoglycan.  
The Gram-negative bacteria has a small inner layer of peptidoglycan and an outer layer of lipopolysaccharides.**

6. Match the terms with their definitions:

Obligate anaerobe  
Autotroph  
Photoautotroph  
Chemoautotroph  
Heterotroph

Photoheterotroph  
Chemoautotroph  
Obligate aerobe  
Facultative aerobe  
Aerotolerant anaerobe

- a. An organism capable of producing its own nutrition.  
**Autotroph**
- b. An organism that requires the lack of oxygen to produce energy, and will die in the presence of oxygen.  
**Obligate anaerobe**

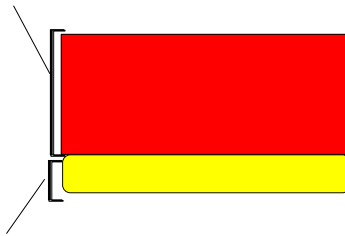
- c. An organism that requires oxygen to produce energy.  
**Obligate aerobe**
- d. A bacteria that converts ammonia to nitrate. It produces this energy to synthesize its nutrition.  
**Chemoautotroph**
- e. An organism that is required to ingest nutrition; they cannot produce their own.  
**Heterotroph**
- f. A cyanobacteria producing its own nutrition from photosynthesis.  
**Photoautotroph**
- g. An organism that requires the lack of oxygen to produce energy, but will not die in the presence of oxygen.  
**Aerotolerant anaerobe**
- h. An organism that must ingest nutrition for a source of energy and organic molecules for a carbon supply.  
**Chemoautotroph**
- i. An organism that can synthesize ATP, but must still ingest nutrients (organic molecules) for a source of carbon.  
**Photoheterotroph**
- j. An organism that can use oxygen to produce energy, but it is not required.  
**Facultative aerobe**

## Protists Quiz

1. An organism that must ingest nutrition for a source of energy and organic molecules for carbon molecules.

- a. Autotroph
- b. Chemoheterotroph
- c. Photoheterotroph
- d. Chemoautotroph

2. Below is a diagram of the cell wall of what kind of bacteria?



- a. Extremophile
- b. Gram-negative
- c. Gram-positive
- d. Protist

3. Which type of protists feed off of living organisms?

- a. Heterotrophs
- b. Decomposers
- c. Mixotrophs
- d. Parasites

4. What type of protists can produce their own food and engulf food?

- a. Heterotrophs
- b. Decomposers
- c. Mixotrophs
- d. Parasites



## Protists

Protists are a very important part of life as we know it. They produce half the world's oxygen and provide oil for machinery. However, they also include many of the world's worst parasites including *Plasmodium falciparum*, the origin of malaria.

### Pre-Assignment:

Define:

1. Phagotrophs-
2. Heterotroph-
3. Autotroph-
4. Mixotroph-
5. Decomposers-
6. Parasites-
7. Primary Plastid-
8. Secondary Plastid-
9. Tertiary Plastid-
  
10. In what type of habitat can protists be found?

### Assignment:

1. Match the classification of the protest to its ecological role:
  - a. Fungus-like
  - b. Algae
  - c. Protozoa

\_\_\_\_\_ A type of protist that includes mostly photosynthetic organisms and some non-photosynthetic organisms.

\_\_\_\_\_ Heterotrophic protists that use specialized organelles, flagella or cilia, to move around the environment.

\_\_\_\_\_ Heterotrophic protists with long, filamentous bodies.

2. Match the classification of the protists to its habitat:

- a. Phytoplankton
- b. Periphyton
- c. Seaweeds

\_\_\_\_\_ Protists that live in communities attached to underwater stationary items such as rocks by mucilage material.

\_\_\_\_\_ Protists that float on the surface of a body of water, using its access to the sun for photosynthesis

\_\_\_\_\_ Large collections mostly multi-cellular algae, some large single-cellular, that grow near the surface of bodies of water. They are attached to stationary items such as rocks.

3. Match the classification of the protists to its motility ability:

- a. Pseudopodia, amoeba
- b. Flagella, flagellates
- c. Cilia, ciliates

\_\_\_\_\_ Movement by redirecting cytoplasm in the intended direction. This extends the cell wall and causes movement of the protist.

\_\_\_\_\_ Long, single or paired, motor proteins attached to a protist. It can move the organism by pushing and pulling the water or by spinning.

\_\_\_\_\_ Small, hair-like, motor proteins that cover the entire cell body.

4. For each supergroup of Protista, define its characteristics including, if applicable, any subgroups:

a. Excavata

b. Euglenozoa

c. Archaeplastida

d. Alveolata

e. Stramenopila

f. Rhizaria

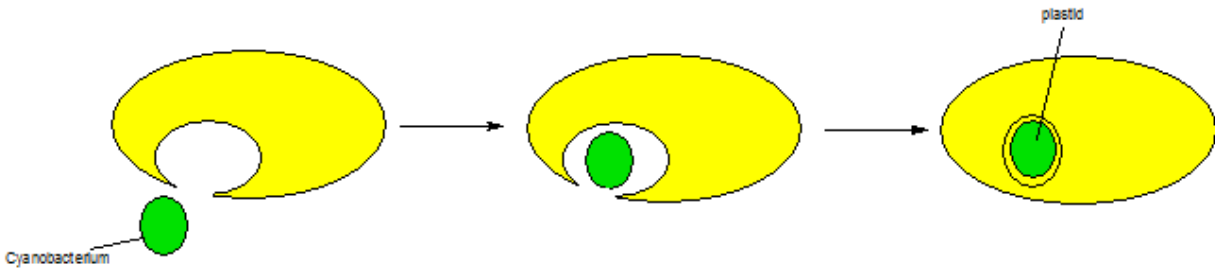
g. Amoebozoa

h. Opisthokonta

5. Which supergroups contain protists with pseudopodia?

6. Which supergroups contain photosynthetic protists?

7. Using the figure below, explain what happens to the cyanobacterium? How many membranes does the new cell have?



The figure above illustrates primary endosymbiosis.

8. How many membranes would the plastid have if another protist engulfed the yellow one (secondary endosymbiosis)?
9. How many membranes would the plastid have if tertiary symbiosis occurred?
10. Which supergroups show evidence of primary symbiosis? Secondary symbiosis?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Protists Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, and 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Students should be able to complete questions 1 through 3 without using a book. This exercise is to expose the students to the different types of classifications of protists. The discussion should include verifying that everyone has arrived at the correct answers.

### Questions 4, 5, and 6: (25 minutes)

Give the students fifteen minutes to read the questions and form answers. The next ten minutes should include a discussion about the answers. Question 4 is designed to give students the opportunity to outline the different types of protists they may not have the time or inclination to do outside of class. Questions 5 and 6 ask the students to apply the information they gathered in a more critical manner. The supergroups that contain protists with pseudopodia are Rhizaria and Amoebozoa. The supergroups with photosynthetic protists are Euglenozoa, Archaeplastida, Stramenopila, and Rhizaria. **Question 5 is the first critical thinking question.**

## Protists Notes

Questions 7, 8, 9, and 10: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 7 through 10 pose questions about the different levels of endosymbiosis and the number of membranes present on the plastids. It is important to differentiate between the membrane number, especially if a student was researching protists and had to differentiate the levels of endosymbiosis. If students are having a hard time differentiating between the levels, it might be beneficial to have students draw the plastid resulting from primary endosymbiosis being engulfed, etc. **Question 9 is the second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 5 and 9 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Protists

Protists are a very important part of life as we know it. They produce half the world's oxygen and provide oil for machinery. However, they also include many of the world's worst parasites including *Plasmodium falciparum*, the origin of malaria.

### Pre-Assignment:

Define:

1. Phagotrophs-**An organism that uses phagocytosis as a form as nutrition**
  2. Heterotroph-**An organism that cannot produce their own food and must obtain it from an outside source**
  3. Autotroph-**An organism that produces its own food**
  4. Mixotroph-**An organism that can produce its own food or obtain it from an outside source**
  5. Decomposers-**An organism that obtains energy from dead organisms and waste**
  6. Parasites-**An organism that obtains nutrition from a live organism**
  7. Primary Plastid-**A plastid that arose from a prokaryote that underwent endosymbiosis**
  8. Secondary Plastid-**A plastid that arose from endosymbiosis of a primary plastid**
  9. Tertiary Plastid- **A plastid that arose from endosymbiosis of a secondary plastid**
10. In what type of habitat can protists be found?  
**Moist habitats**

### Assignment:

1. Match the classification of the protest to its ecological role:

- a. Fungus-like
- b. Algae
- c. Protozoa

\_\_\_ **B** \_\_\_ A type of protist that includes mostly photosynthetic organisms and some non-photosynthetic organisms.

\_\_\_ **C** \_\_\_ Heterotrophic protists that use specialized organelles, flagella or cilia, to move around the environment.

\_\_\_ **A** \_\_\_ Heterotrophic protists with long, filamentous bodies.



2. Match the classification of the protists to its habitat:

- a. Phytoplankton
- b. Periphyton
- c. Seaweeds

- \_\_\_ **B** \_\_\_ Protists that live in communities attached to underwater stationary items such as rocks by mucilage material.
- \_\_\_ **A** \_\_\_ Protists that float on the surface of a body of water, using its access to the sun for photosynthesis
- \_\_\_ **C** \_\_\_ Large collections mostly multi-cellular algae, some large single-cellular, that grow near the surface of bodies of water. They are attached to stationary items such as rocks.

3. Match the classification of the protists to its motility ability:

- a. Pseudopodia, amoeba
- b. Flagella, flagellates
- c. Cilia, ciliates

- \_\_\_ **A** \_\_\_ Movement by redirecting cytoplasm in the intended direction. This extends the cell wall and causes movement of the protist.
- \_\_\_ **B** \_\_\_ Long, single or paired, motor proteins attached to a protist. It can move the organism by pushing and pulling the water or by spinning.
- \_\_\_ **C** \_\_\_ Small, hair-like, motor proteins that cover the entire cell body.

4. For each supergroup of Protista, define its characteristics including, if applicable, any subgroups:

- a. Excavata
  - unicellular flagellates
  - specialized feeding groove
  - modified mitochondria in parasites
  - Jakobida
- b. Euglenozoa
  - unicellular flagellates
  - disk-shaped mitochondria
  - secondary plastids
  - Kinetoplastea
  - Euglenida
  - eye-spots

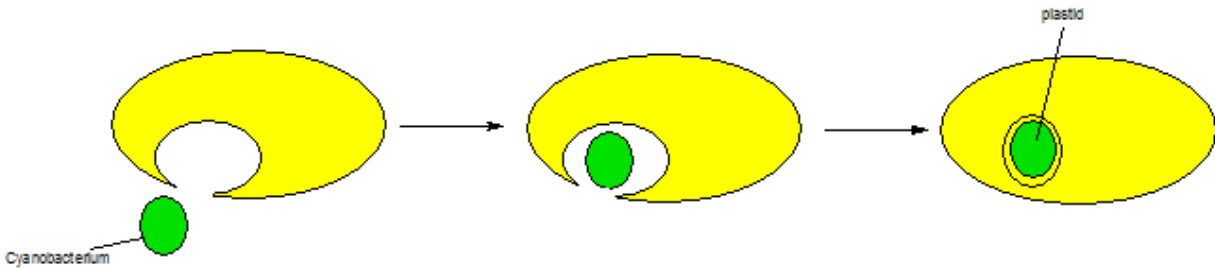
- c. Archaeplastida
  - Primary plastids
  - Glaucophyta
  - Rhodophyta
  - Chlorophyta
- d. Alveolata
  - Membrane sacs → alveoli
  - some secondary plastids or tertiary plastids
  - Dinofzoa
  - Ciliophora
  - Apicomplexa
- e. Stramenopila
  - Straw-like flagellar hairs
  - Bacillariophyta
- f. Rhizaria
  - Thin, cytoplasmic projections similar to pseudopodia
  - secondary plastids
  - Chlorarachniophyta
  - Radiolaria
  - Foraminifera
- g. Amoebozoa
  - pseudopodia
  - Dictyostelia
- h. Opisthokonta
  - swimming cells with a single flagellum
  - Choanomonada

5. Which supergroups contain protists with pseudopodia?  
**Amoebozoa, Rhizaria**

6. Which supergroups contain photosynthetic protists?  
**Euglenozoa, Archaeplastida, Alveolata, Rhizaria**

7. Using the figure below, explain what happens to the cyanobacterium? How many membranes does the new cell have?

**The cyanobacterium is engulfed by the cell and lives symbiotically. It now contains two membranes.**



The figure above illustrates primary endosymbiosis.

8. How many membranes would the plastid have if another protist engulfed the yellow one (secondary endosymbiosis)?

**Three**

9. How many membranes would the plastid have if tertiary symbiosis occurred?

**Four**

10. Which supergroups show evidence of primary symbiosis? Secondary symbiosis?

**Euglenozoa, Archaeplastida, Alveolata, Rhizaria,**

## Fungi Quiz

1. Which supergroup of protists has a functional eye-spot?
  - a. Excavata
  - b. Alveolata
  - c. Euglenozoa
  - d. Rhizaria
  
2. Plasmids resulting from tertiary endosymbiosis have how many membranes?
  - a. 2
  - b. 3
  - c. 4
  - d. 5
  
3. What is the term for hyphae with two distinct nuclei?
  - a. Diploid
  - b. Monokaryotic
  - c. Karyotype
  - d. Dikaryotic
  
4. What is the reproductive organ of fungi?
  - a. Hyphae
  - b. Mycelia
  - c. Fruiting body
  - d. Spores

## Fungi

Fungi are very diverse and benefit humans and just as easily harm. Fungi have been used as a food production (e.g. yeast), treatment of toxic waste, and in the production of chemicals of interest (e.g. penicillin).

### Pre-Assignment:

Define:

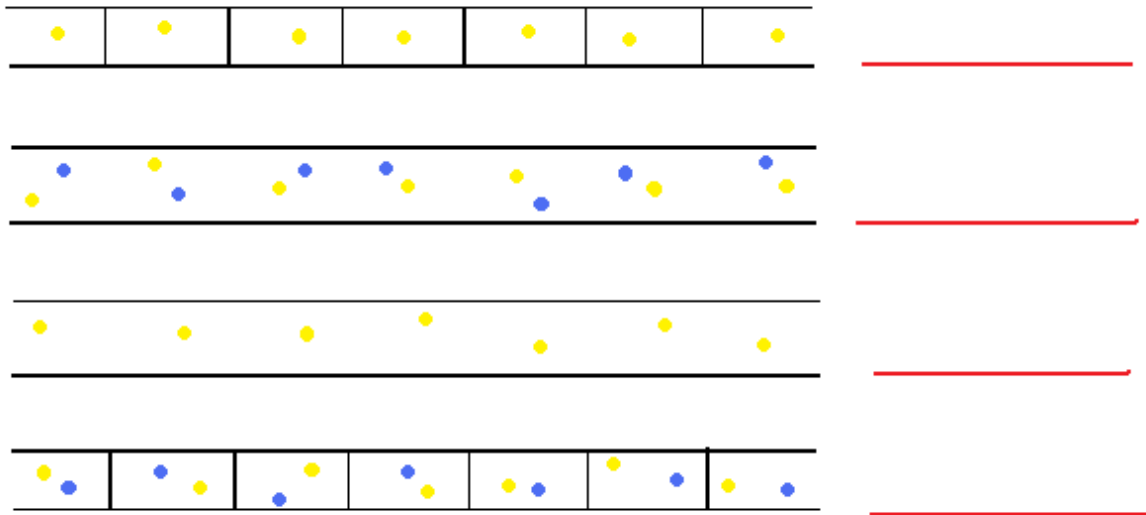
1. Mycelia-
2. Hyphae-
3. Septa-
4. Aseptate-
5. Fruiting Bodies-
6. Spores-
7. Dikaryotic-

### Assignment:

1. Fungal walls contain a distinct compound, chitin, which produces a very rigid cell wall. Read the statements below and deduce the result of having a rigid cell wall.
  - a. Fungi are heterotrophic organisms. Can they practice phagocytosis?
  - b. If not, how then can they ingest the needed nutrients? What would they have to do to the organic material prior to ingestion?
  - c. How would the rigid cell wall affect motility?

2. Match the following terms with the figure:

- a. Unmated aseptate hypha
- b. Mated septate hypha
- c. Unmated septate hypha
- d. Mated aseptate hypha



3. In sexual reproduction of fungi, two hyphae fuse. However, while the cytoplasm fuses, they nuclei may not fuse until the conditions for reproduction are conducive. Below are the steps of sexual reproduction in fungi. Order the steps from 1-4.

- \_\_\_\_\_ A fruiting body forms in anticipation for sexual reproduction
- \_\_\_\_\_ The nuclei of the dikaryotic hyphae fuse and undergo meiosis. Spores are formed and released.
- \_\_\_\_\_ Dikaryotic hyphae grow underground.
- \_\_\_\_\_ Spores released from the hyphae land on a conducive substrate and produce mycelia.

4. Fungal sexual reproduction occurs to introduce genetically unique individuals (via meiosis). What is the advantage of genetically unique individuals, especially in a new environment?

5. If the nutrients in the environment were plentiful, and there was no risk of change, would a fungus spend the energy to undergo sexual reproduction? If not, what type of reproduction would be more beneficial?

6. Name three types of mutualistic fungi and how they benefit their host.

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:



## Fungi Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1b should give students a problem if they have not already learned about fungi. Fungi are heterotrophs, needing to absorb nutrients, yet they cannot engulf the food due to their rigid cell walls. How then, do they do it? They release chemicals that break down the organic material outside of the cell. They then absorb the much smaller organic molecules for nutrients. To guide the student to the answer, ask leading questions such as if a fungus were trying to digest a large, dead animal through small openings in its cell wall, what would it have to do to make the large animal smaller? If they are still having trouble, ask what could they secrete to make the animal smaller? **Question 1 is the first critical thinking question.**

### Questions 2 and 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 2 and 3 are definitions and processes that students should know. Briefly make sure that students have the correct answers by asking for volunteers.

## Fungi Notes

### Questions 4 and 5: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 4 should remind students to put sexual reproduction into perspective. In the fungal world, using excess energy for sexual reproduction is only required when necessary. Only if natural selection demanded it (e.g. by changing the environment) would the fungus sexually reproduce. To help students, ask them what the advantage of meiosis is in the “grand-scheme of thing.” **Question 4 is the second critical thinking question.**

Question 5 expands on the idea that if the environment is in order, sexual reproduction is not required. Instead, it utilizes asexual reproduction. **Question 5 is the second critical thinking question.**

### Question 6: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 6 allows students to outline the mutualistic fungi. If time allows, briefly discuss the three mutualistic fungi (lichens, mycorrhizae, and endophytes).

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 1, 4, and 5 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Fungi

Fungi are very diverse and benefit humans and just as easily harm. Fungi have been used as a food production (e.g. yeast), treatment of toxic waste, and in the production of chemicals of interest (e.g. penicillin).

### Pre-Assignment:

Define:

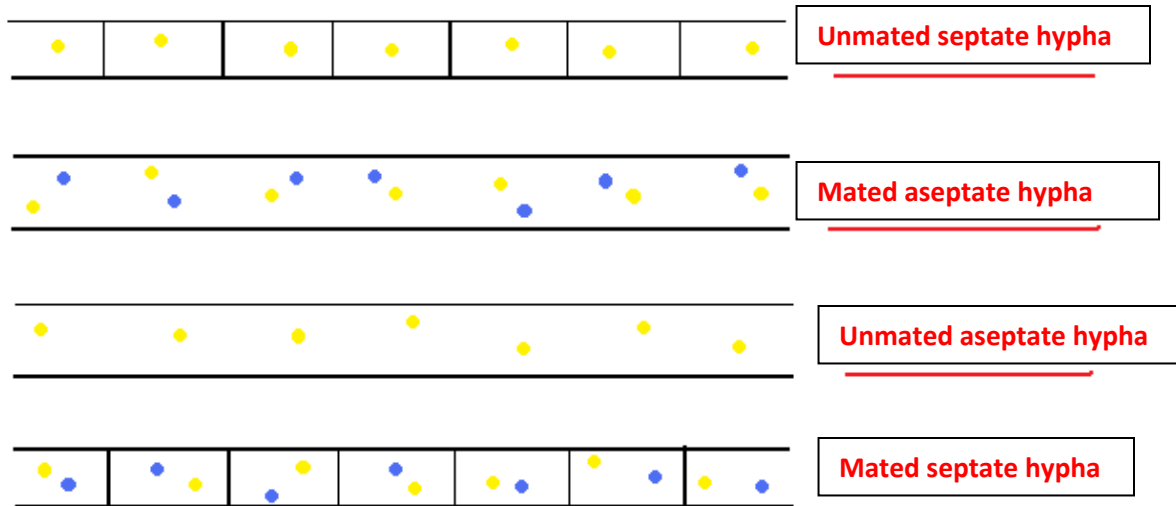
1. Mycelia- **Body of a fungus; composed of filamentous branches known as hyphae**
2. Hyphae- **Microscopic, branched filament of a fungal body**
3. Septa- **Cross wall, e.g. divides hyphae of fungi**
4. Aseptate- **Hyphae that are not partitioned**
5. Fruiting Bodies- **Visual reproductive organs of fungi; composed of tightly packed hyphae**
6. Spores- **Single-celled reproductive organ that disperses into the environment to grow into new fungi**
7. Dikaryotic- **The presence of two genetically distinct nuclei in a cell, e.g. in fungi**

### Assignment:

1. Fungal walls contain a distinct compound, chitin, which produces a very rigid cell wall. Read the statements below and deduce the result of having a rigid cell wall.
  - a. Fungi are heterotrophic organisms. Can they practice phagocytosis?  
**No, because their rigid cell walls prevent them from distorting the plasma membrane to engulf a food particle**
  - b. If not, how then can they ingest the needed nutrients? What would they have to do to the organic material prior to ingestion?  
**Fungi secrete chemicals onto the organic material of interest breaking it down into its organic components. They then absorb the smaller organic pieces through the cell wall.**
  - c. How would the rigid cell wall affect motility?  
**Fungi have decrease mobility due to the rigidity of the cell wall**

2. Match the following terms with the figure:

- a. Unmated aseptate hypha
- b. Mated septate hypha
- c. Unmated septate hypha
- d. Mated aseptate hypha



3. In sexual reproduction of fungi, two hyphae fuse. However, while the cytoplasm fuses, they nuclei may not fuse until the conditions for reproduction are conducive. Below is a figure of sexual reproduction. The order of sexual production is A, B, C, and D. Match the steps with the explanations below.

- 2   A fruiting body forms in anticipation for sexual reproduction
- 3   The nuclei of the dikaryotic hyphae fuse and undergo meiosis. Spores are formed and released.
- 1   Dikaryotic hyphae grow underground.
- 4   Spores released from the hyphae land on a conducive substrate and produce mycelia.

4. Fungal sexual reproduction occurs to introduce genetically unique individuals (via meiosis). What is the advantage of genetically unique individuals, especially in a new environment?

**Genetically unique individuals offer unique traits to the species that allow them to adapt to the environment. Without this ability of adaptation, any environmental change could kill the entire species. It allows for evolution**

5. If the nutrients in the environment were plentiful, and there was no risk of change, would a fungus spend the energy to undergo sexual reproduction? If not, what type of reproduction would be more beneficial?

**No, it would not. Sexual reproduction only occurs when the fungus needs to preserve the species by creating unique individuals. However, if there is no risk in the environment, the fungus will simply asexually reproduce, perfectly copying its genome and replicating.**

6. Name three types of mutualistic fungi and how they benefit their host.

**Mycorrhizae are fungi that works together with plant roots. The hyphae of the mycorrhizae absorb water and nutrients better than the plant roots and therefore provides those goods to the plant. The plant, in turn, provides organic molecules to the fungus.**

**Endophytes live within the stems and leaves of plants. Plants provide the endophytes with organic molecules and the fungi provide the plant with defense mechanisms such as toxins. They also may give the plant a growth advantage in hot climates.**

**Lichens are fungi that are characterized by the thick layer of cyanobacteria that grows close to its surface. The cyanobacteria provides the lichen with organic molecules and oxygen. The lichen provides carbon dioxide, water, and minerals to the cyanobacteria. It can also help the cyanobacteria to grow in less favorable climates by protecting them from exposed light and creating toxins.**

## Plants Quiz

1. If an environment was undergoing a change in the nutrient composition what type of reproduction would a fungus employ?
  - a. Asexual
  - b. Sporic
  - c. Sexual
  - d. None of the above
  
2. Which is not a mutualistic fungus?
  - a. Lichen
  - b. Endophyte
  - c. Mycorrhizae
  - d. Ergot
  
3. True or False: The gametophyte is diploid.
  - a. True
  - b. False
  
4. True or False: The sporophyte is haploid.
  - a. True
  - b. False

## Plants

Plants are prolific. Wherever you look, whatever you eat, whatever you use a plant probably contributed to its existence. How *did* plants become so abundant? What advantages did it have that allowed its longevity?

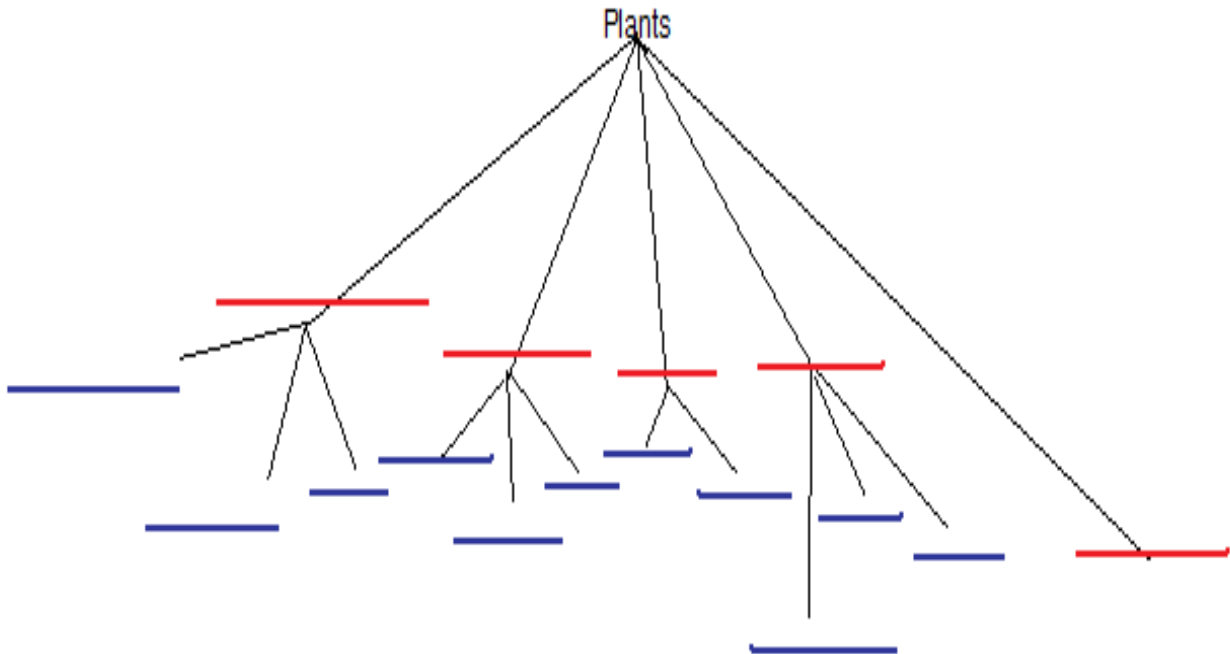
### Pre-Assignment:

Define:

1. Alternation of generations-
2. Sporic life cycle-
3. Gametophyte-
4. Sporophyte-
5. Multicellular haploid-
6. Multicellular diploid

### Assignment:

1. Fill in the hierarchy of the plants. The phyla are in blue and the characteristic designations are in red.



2. Identify which of the 10 phylums fit into each category.
  - a. Land plants

- b. Non-vascular plants

- c. Vascular plants

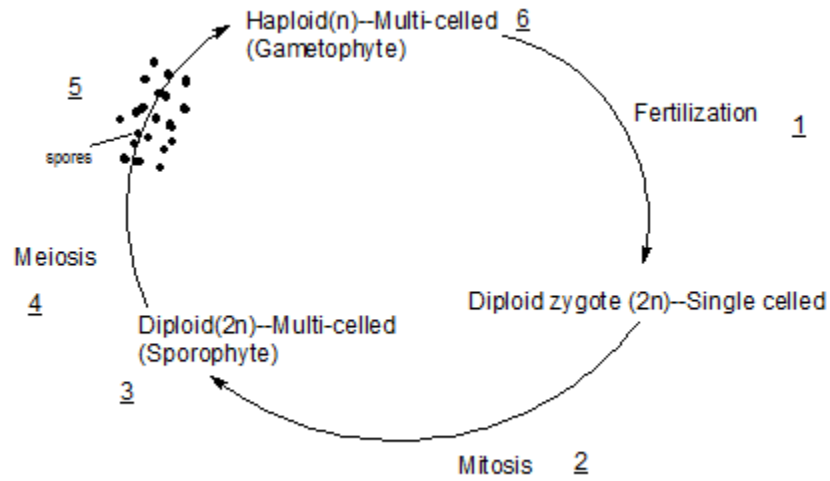
- d. Seedless vascular plants

- e. Euphyllophytes



f. Seed plants

3. Use the figure below the list the steps of the alternation of generations of a plant.



- 1.
- 2.
- 3.
- 4.
- 5.
- 6.

Spores are produced from the fertilized multicellular diploid cell as it undergoes meiosis. However, before it can form spores, the fertilized cell undergoes mitosis and forms the sporophyte (many copies of the fertilized cell).

4. Why is it advantageous for plants to undergo mitosis of the embryo before undergoing meiosis to create spores?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Plants Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Students should use their book to answer question 1. The idea of this question is to help students visualize the categorical breakdown of the 10 plant phyla. After allowing them time to look up the answers, briefly go over the answers by asking for volunteers.

### Question 2: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Students should use their book to answer question 2. This question expands upon question 1; it does not just group the plants by similarity but on actual morphological characteristics. Briefly go over the correct answers.

### Question 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 3 introduces the idea of alternation of

## Plants Notes

generations. Students should be able to follow the numbering on the figure to narrate what occurs during the alternation of generations.

### Question 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 4 builds upon question 5. It has been proven that plants undergo alternation of generations. But for what reason? In this questions, students will infer from the given information that by creating copies of the zygote (which forms the sporophyte) each new copy creates spores compared to one fertilized cell without mitosis. More spores equals more opportunity for perpetuation of genes, an evolutionary advantage.

**Question 4 is the critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that question 4 is their critical thinking question and that they should write their answer in complete sentences on the critical thinking page before turning it in.

## Plants

Plants are prolific. Wherever you look, whatever you eat, whatever you use a plant probably contributed to its existence. How *did* plants become so abundant? What advantages did it have that allowed its longevity?

### Pre-Assignment:

Define:

1. Alternation of generations-**The phenomenon where a plant's life occurs in two stages: multi-cellular diploid and multi-cellular haploid**
2. Sporic life cycle-**Synonym for alternation of generations**
3. Gametophyte-**Multi-cellular haploid stage of a plant; undergoes mitosis to produce gametes**
4. Sporophyte-**Multi-cellular diploid stage of a plant; undergoes meiosis to produce haploid spores that grow into gametophytes**
5. Multicellular haploid-**Consisting of more than one cell, but each cell has only one copy of each chromosome**
6. Multicellular diploid- **Consisting of more than one cell, but each cell has two copies of each chromosome**

### Assignment:

1. In the space below, organize the phyla of plants into five categories.

#### **Green Algae**

- Other green algae
- Simple charophyceans
- Complex charophyceans

#### **Bryophytes (non-vascular)**

- Liverworts
- Mosses
- Hornworts

#### **Seedless (vascular)**

- Lycophytes
- Pteridophytes

#### **Gymnosperms**

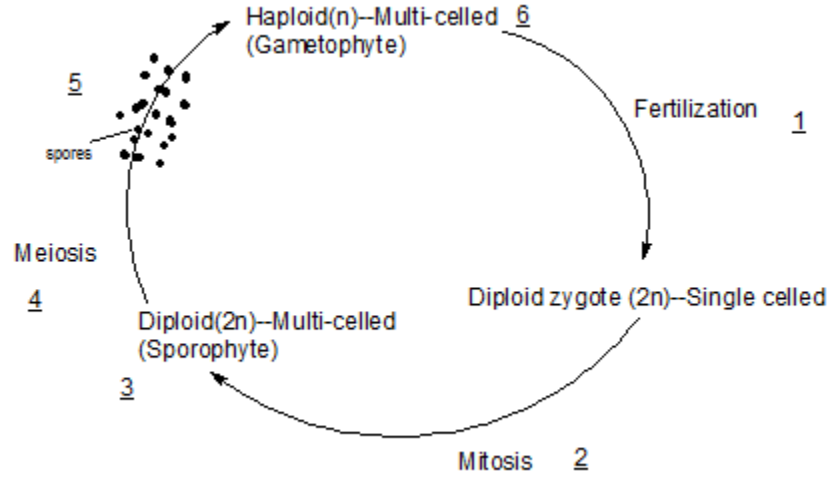
- Cycads
- Ginkgo
- Conifers and Gnetophytes

#### **Angiosperms**

2. Identify which of the 12 phylums fit into each category.

- a. Land plants
  - Liverworts
  - Mosses
  - Hornworts
  - Lycophytes
  - Pteridophytes
  - Cycads
  - Ginkgo
  - Conifers and Gnetophytes
  - Angiosperms
  
- b. Non-Land Plants
  - Other green algae
  - Simple charophyceans
  - Complex charophyceans
  
- c. Non-vascular plants
  - Liverworts
  - Mosses
  - Hornworts
  
- d. Vascular plants
  - Lycophytes
  - Pteridophytes
  - Cycads
  - Ginkgo
  - Conifers and Gnetophytes
  - Angiosperms
  
- e. Seedless vascular plants
  - Lycophytes
  - Pteridophytes
  
- f. Euphyllophytes
  - Pteridophytes
  - Cycads
  - Ginkgo
  - Conifers and Gnetophytes
  - Angiosperms
  
- g. Seed plants
  - Cycads
  - Ginkgo
  - Conifers and Gnetophytes
  - Angiosperms

3. Use the figure below the list the steps of the alternation of generations of a plant.



1. **Gametes unite to form a diploid zygote**
2. **The diploid zygote undergoes mitosis**
3. **A multi-cellular diploid plant called a sporophyte forms**
4. **The sporophyte undergoes meiosis to form haploid spores**
5. **Spores are released**
6. **Spores grow undergo mitosis and form a multi-cellular haploid plant called a gametophyte. It contains gametes and when it is fertilized, the process begins again.**



Spores are produced from the fertilized multicellular diploid cell as it undergoes meiosis. However, before it can form spores, the fertilized cell undergoes mitosis and forms the sporophyte (many copies of the fertilized cell).

4. Why is it advantageous for plants to undergo mitosis of the embryo before undergoing meiosis to create spores?

**Each fertilized diploid cell can undergo meiosis and form four spores. However, if the fertilized cell replicates itself before undergoing meiosis, there are many more copies of the cell. Therefore, each of the copies can undergo meiosis and form many more spores. Releasing more spores increases the chance of a new plant growing, ensuring the plant's genes are passed on to the next generation.**

## Invertebrates Quiz

1. What process occurs between the formation of the zygote and the formation of the sporophyte?
  - a. Meiosis
  - b. Apoptosis
  - c. Mitosis
  - d. Endocytosis
  
2. What process occurs between the formation of the sporophyte and the formation of the gametophyte?
  - a. Meiosis
  - b. Apoptosis
  - c. Mitosis
  - d. Endocytosis
  
3. What percentage do invertebrates represent animals?
  - a. 80%
  - b. 85%
  - c. 90%
  - d. 95%
  
4. True or False: Invertebrates have a backbone.
  - a. True
  - b. False

## Invertebrates

Invertebrates represent over 95% of the animals on Earth. From sponges to flatworms their diversity is great. The taxonomy from the earliest invertebrates, Porifera, to the most similar to vertebrates, Chordata, is vast. However, understanding the diversity is paramount in understanding evolution.

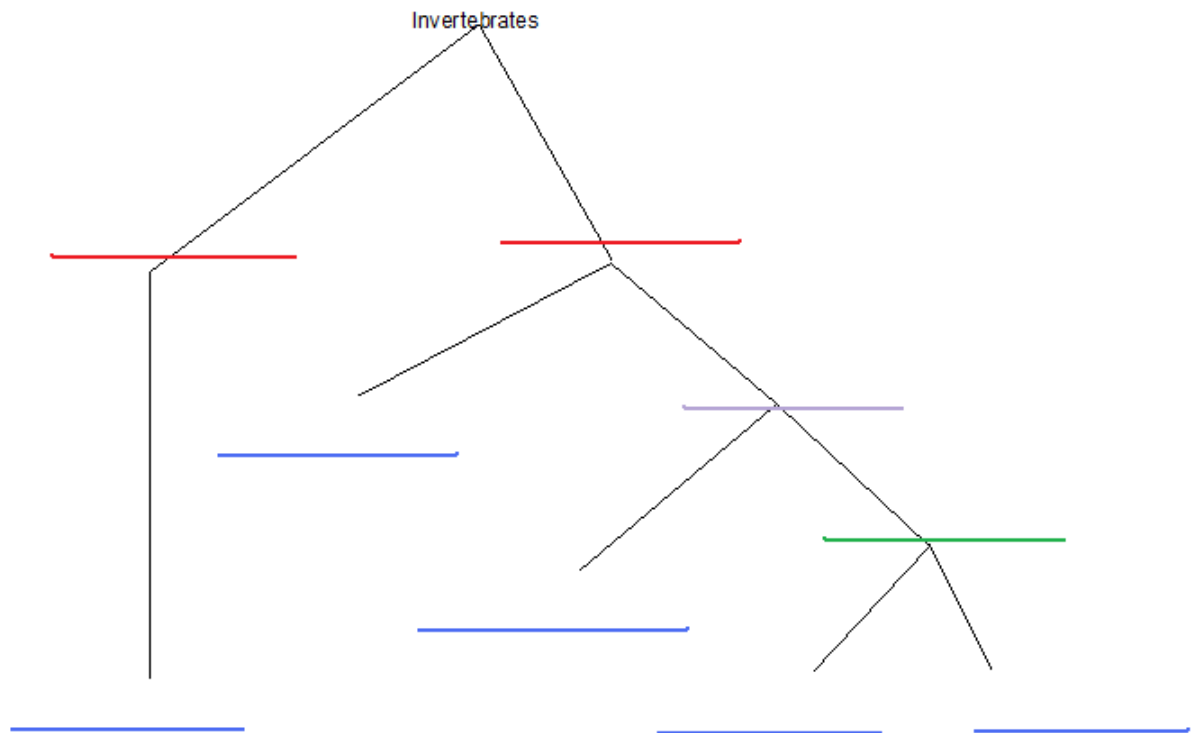
### Pre-Assignment:

Define:

1. Notochord-
2. Dorsal hollow nerve cord-
3. Pharyngeal slits-
4. Postanal tail-

### Assignment:

1. In the chart, organize the clades of invertebrates.



2. For each phylum, write characteristics and examples

a. Porifera

b. Radiata

c. Lophotrochozoa

d. Ecdysozoa

e. Deuterostomia

3. Which animal was the first to possess organs?

4. Which organism possesses (or most of the organisms) possess and endoskeleton?

5. What are the characteristics of the phylum Chordata and, subsequently, the subphylum Cephalochordata?

- a.
- b.
- c.
- d.

6. Why is Cephalochordata considered the closest invertebrate relative to chordates?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:

## Invertebrates Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Question 1: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 1 should be completed with the book. This question introduces students into the idea of invertebrates. By completing the web, students will be able to see more clearly the breakdown of the invertebrate phyla. To discuss this question, ask for students to volunteer their answers.

### Question 2: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 2 should be completed with the book. It builds upon question 1 by allowing the students to note down the key characteristics of each phylum. While students will not have the time nor space to write down each small difference, they will be able to see the bigger picture. Before the students begin, encourage them to not down the key differences. Diagrams and detailed anatomy can be learned at a later date.

## Invertebrates Notes

### Questions 3 and 4: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 3 and 4 allow the students to analyze the data. Flatworms were the first to evolve organs and most echinoderms possess an endoskeleton.

### Questions 5 and 6: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Questions 5 and 6 are meant to link the invertebrates to the vertebrates. Chordata is the phylum, specifically the subphylum Cephalochordata, which is the most closely related to vertebrates. Students should be able to deduce, from their answers to question 5, that because this phylum is the most closely related to vertebrates because it contains organisms that have anatomy similar to the spinal cord. If students are having difficulty relating the two concepts, ask them what the dorsal hollow nerve cord in the invertebrates is comparable to in the vertebrates. **Questions 5 and 6 are the critical thinking questions.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 5 and 6 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.



## Invertebrates

Vertebrates represent over 95% of the Animals on Earth. From sponges to flatworms their diversity is great. The taxonomy from the earliest invertebrates, Porifera, to the most similar to vertebrates, Chordata, is vast. However, understanding the diversity is paramount in understanding evolution.

### Pre-Assignment:

Define:

1. Notochord-**Rod that lies between the digestive tract and nerve cord in a chordate**
2. Dorsal hollow nerve cord-**A nerve ventral to the digestive tract**
3. Pharyngeal slits-**A filter-feeder device in chordates**
4. Postanal tail-**A tail that extends past the anal opening; in aquatic chordates it could be used for motility; in terrestrial chordates it might not be present**

### Assignment:

1. In the space below, organize the clades of invertebrates.

**Parazoa**

-Porifera

**Emetazoa**

-Radiata

-Cnidaria

-Ctenophora

-Bilateria

-Deuterostomia

-Protostomia

-Ecdysozoa

-Lophotrochozoa

-Annelida

-Mollusca

-Lophophorata

-Rotifera

-Platyhelminthes

2. For each phylum, write characteristics and examples

a. Porifera

**Sponges**

-lack true tissues

-adults are sessile, larvae are motile

- b. Radiata
- mostly found in marine environments, although hydra is a freshwater species
  - have only two embryonic layers
    1. ectoderm-gives rise to the epidermis
    2. endoderm- gives rise to the gastrodermis
  - gastrovascular cavity→used in extracellular digestion
  - most have tentacles to help catch food
  - nerve net
  - Cnidarians→hydra, jellyfish, box jellies, sea anemones, corals
  - Ctenophora→comb jellies
- c. Lophotrochozoa
- Possess either ciliated tentacles or a larval stage called a trochophore
  - Platyhelminthes→Flatworms
    - no coelem (body cavity)
  - Rotifera→Rotifers
    - pseudocoelom
  - Mollusca→ Mollusks
    - Foot (motility), Visceral mass (internal organs), and Mantle (shell)
    - Snails, slugs, nudibrachs, clams, mussels, oysters, octopuses, squids, nautilus, chitons, polyplacophora
  - Lophophorata→Phoronida (marine worms), Bryozoa (look like plants), Brachiopoda (looks like a clam)
    - lophophores (ciliary feeding device)
  - Annelida→segmented worms
    - segmentation
    - coelem
- d. Ecdysozoa
- shed cuticle (protection)
  - Nematodes→most are parasitic
  - Arthropodes→insects, spiders, centipedes, millipedes→cuticle made of chitin
- e. Deuterostomia
- Echinoderms**
- radial symmetry
  - bilateral, free-swimming larvae
  - endoskeleton
- Chordata→lancelets and tunicates**
- Notochord
  - Dorsal hollow nerve cord
  - Pharyngeal slit
  - Postanal tail

3. Which animal was the first to possess organs?  
**Platyhelminthes (flatworms)**
4. Which organism possesses (or most of the organisms) possess an endoskeleton?  
**Echinoderms**
5. What are the characteristics of the phylum Chordata and subsequently the subphylum Cephalochordata?
  - a. **Notochord**
  - b. **Dorsal hollow nerve cord**
  - c. **Pharyngeal slit**
  - d. **Postanal tail**
6. Why is Cephalochordata considered the closest invertebrate relative to chordates?  
**As part of the phylum Chordata, they possess the four characteristics above that are the precursors to structures in vertebrates. Their body shape and muscle structure create movement related to modern-day fish.**

## Vertebrates Quiz

1. Which one is not a characteristic of Chordata?
  - a. Notochord
  - b. Esophageal slits
  - c. Dorsal hollow nerve cord
  - d. Postanal tail
  
2. Which phylum is most closely related to vertebrates?
  - a. Cnidaria
  - b. Mollusca
  - c. Cephalochordata
  - d. Echinodermata
  
3. About how many species exist within Vertebrata?
  - a. 22,000
  - b. 38, 000
  - c. 48, 000
  - d. 65, 000
  
4. True or False: The size range for species within Vertebrata is very large.
  - a. True
  - b. False

## Vertebrates

The subphylum Vertebrata, Vertebrates, makes up the largest percentage of the phylum Chordata. The evolution of this subphylum has conquered almost all of the different environments on Earth from the oceans to the land and to the air.

### Pre-Assignment:

1. About how many species exist within Vertebrata?
2. What is the size range of species within Vertebrata?

### Assignment:

1. Define the characteristics of craniates:
  - a. Cranium
  - b. Neural crest
2. Define the unique characteristics of vertebrates:
  - a. Vertebral column
  - b. Endoskeleton of cartilage or bone
  - c. Internal organs
3. While vertebrates do contain the unique characteristics in (2), what other characteristics do they also possess? (Hint: think back to the two close relatives of vertebrates.)

4. Name the five major classes of vertebrates and their characteristics.

5. Name and describe the four unique characteristics of mammals. Name and describe two characteristics that only some mammals possess.

6. Name and describe four characteristics unique to primates.

a.

b.

c.

d.

7. How does the evolution binocular vision help primates navigate treacherous habitats?

## **Critical Thinking Questions**

Names:

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Write the answers to the critical thinking questions in the space below:



## Vertebrates Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

Check the pre-assignment of every student entering the classroom. If it is not completed, they cannot receive the scantron and they cannot take the quiz. If they complete the pre-assignment in the classroom, before the quiz begins, however, they may receive a scantron.

### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1 and 2: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. For this entire assignment, students will need to use their books. To begin this section on vertebrates, students are asked in question 1 to describe the characteristics of craniates. Craniates are animals evolutionarily in between Cephalochordata and Vertebrates. This question transitions the students from invertebrates to vertebrates.

Question 2 allows students to grasp the unique evolution of vertebrates by requiring them to list the characteristics of Vertebrata. The discussion for these questions involves asking for volunteers to read their answers.

### Question 3: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 3 is designed to make students think about the evolutionary pathway of vertebrates. While vertebrates have developed unique characteristics, it is important to note that they do also possess those characteristics that make Chordata and craniates unique. **Question 3 is the first critical thinking question.**

## Vertebrates Notes

### Questions 4, 5, and 6: (20 minutes)

Give the students ten minutes to read the questions and form answers. The next ten minutes should include a discussion about the answers. Question 4 asks students to outline the classes of vertebrates. Students should be able to find the answers in the book.

This lab was specifically chosen to focus on a specific class of Vertebrata: mammals. Otherwise, there would have been too much information to process. Therefore, for question 5, students are asked to note the characteristics of mammals. And even more specifically, primates in question 6. After the class has finished these questions, verify that the correct answers have been found.

### Question 7: (10 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 7 asks students to critically evaluate the evolutionary advantage of one of the characteristics of primates: binocular vision. Binocular vision creates a disparity between the images from the two eyes. The brain processes those images and computes depth given the disparity. Students can reference the book. **Question 7 is the second critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that questions 3 and 7 are their critical thinking questions and that they should write their answers in complete sentences on the critical thinking page before turning it in.

## Vertebrates

The subphylum Vertebrata, Vertebrates, makes up the largest percentage of the phylum Chordata. The evolution of this subphylum has conquered almost all of the different environments on Earth from the oceans to the land and to the air.

### Pre-Assignment:

1. About how many species exist within Vertebrata?  
**48,000**
2. What is the size range of species within Vertebrata?  
**0.1 g - 100,000 kg**

### Assignment:

1. Define the characteristics of craniates:
  - a. Cranium  
**Protective covering, bone or cartilage, of the brain**
  - b. Neural crest  
**Cells that give rise to neurons and cells in their peripheral system**
2. Define the unique characteristics of vertebrates:
  - a. Vertebral column  
**Column that provides support and protect the nerve cords**
  - b. Endoskeleton of cartilage or bone  
**Supporting structure inside the body, covered by soft tissue**
  - c. Internal organs  
**Specialized structures in an organism that provide support for life**
3. While vertebrates do contain the unique characteristics in (3), what other characteristics do they also possess? (Hint: think back to the two close relatives of vertebrates.  
**Characteristics from Chordata and also Craniates**

4. Name the five major classes of vertebrates and their characteristics.

**Fishes**

- Aquatic
- Jawless v. Jawed
- Gills v. Lungs
- External fertilization

**Amphibians**

- Terrestrial as adults, Aquatic while young
- Oxygen is obtained through gas exchange in the skin
- External fertilization

**Amniotes → Reptiles**

- Terrestrial
- Shelled egg → Amniotic
- Skin to resist desiccation
- Thoracic breathing
- Kidneys that preserve water
- Internal fertilization

**Birds**

- Feathers
- Lightweight skeleton
- Air sacs
- Reduction of organs

**Mammals**

- Mammary glands
- Hair
- Specialized teeth
- Enlarged skull
- In some, ability to digest plants
- In some, horns/antlers
- Internal fertilization

**Primates**

- Grasping hands (opposable thumb)
- Large brain
- Nails, not claws
- Binocular vision

5. Name and describe the four unique characteristics of mammals. Name and describe two characteristics that only some mammals possess.

**Mammals**

- Mammary glands-secrete milk**
- Hair-insulator, sensory, defense mechanism**
- Specialized teeth-for different diets**
- Enlarged skull-larger brain**
- In some, ability to digest plants-possess multiple stomachs that work mutualistically with bacteria**
- In some, horns/antlers**

6. Name and describe four characteristics unique to primates.

- Large brain-increases the acuity of the senses and understanding**
- Nails, not claws-manipulation of the environment**
- Binocular vision-see depth**
- Grasping hands (opposable thumb)-manipulate the environment better**

7. How does the evolution binocular vision help primates navigate treacherous habitats?  
**Because of binocular disparity, the brain receives two pictures of the world. The brain can compute the differences and the relative distance between objects which results in depth perception**

## Species Interactions Quiz

1. Which is **not** a feature of only vertebrates?
  - a. Vertebral column
  - b. Notochord
  - c. Endoskeleton
  - d. Internal organs
  
2. Which is **not** a feature of only mammals?
  - a. Cranium
  - b. Opposable thumb
  - c. Large brain
  - d. Grasping hands
  
3. Molecules produced by some plants as a defense mechanism against predation.
  - a. Sugar
  - b. Poison
  - c. Secondary metabolite
  - d. Primary metabolite
  
4. Factors, such as space and time, which allow the same species to occupy the same niche.
  - a. Resource partitioning
  - b. Resource competition
  - c. Interference competition
  - d. Herbivory

## Species Interactions

In nature, populations do not live in isolation; they live in the same communities and ecosystems. How then, do they impact each other? Do they compete for the same food sources? Help each other survive? And if so, how do these interactions affect each species?

### Pre-Assignment:

Define:

1. Competitive exclusion hypothesis-
2. Resource partitioning-
3. Secondary metabolites-

### Assignment:

Match the species interactions with the examples. Indicate how the interaction affects both species. For example, if the interaction would benefit both species indicate (+/+). If the interaction benefits one and does nothing to the other indicate (0/+).

Mutualism	Amensalism	Neutralism
Interspecific competition	Resource competition	
Parasitism	Predation	
Herbivory	Interference competition	
Intraspecific competition	Commensalism	

1. *Plasmodium falciparum*, the protist that causes malaria commandeers a human's red blood cell to perpetuate itself.
2. In Montana, wolves keep the rabbit population in check.
3. A type of competition in which two wolves compete for the same rabbit.
4. A deer eats the leaves off of a tree.

5. In Africa, animals drink as much water as they can during a drought, whenever possible
  
6. Rhizobium bacteria live in the roots of legumes. They fix nitrogen for the plant and the plant provides it nutrients.
  
7. In Montana, wolves and cougars both eat the small population of sheep.
  
8. Bee 1 only eats nectar from Plant 1 and Bee 2 only eats nectar from Plant 2.
  
9. A cow walks through a field, disturbing the insects. A frog sits nearby, eating the disturbed insects.
  
10. In Africa, after a cheetah kills a zebra a male lion comes and roars. The cheetah runs away and the lion eats the zebra.
  
11. Two species of plant grow in the same area. However, Plant 1 absorbs the nutrients better than Plant 2. Plant 2 quickly dies out of that area.
  
12. Plants seem to be doomed to predation by herbivores. Why, then, is the world still full of plants? What do plants do to protect themselves?



## Critical Thinking Questions

Names:

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Write the answers to the critical thinking questions in the space below:

## Species Interactions Notes

This assignment is designed to help students understand concepts of biology that lecture cannot spend time discussing. To maximize the knowledge gained, allow the students to work through the assignment without knowing which questions are their critical thinking questions. Tell them with five minutes left of class. If they are told in the beginning, they will only worry about those questions and not the rest of the exercise.

### Pre-Assignment:

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### Quiz and forming groups: (10 minutes)

Pass out the quiz at the beginning of the class period and allow the students five minutes to work. Those who arrive late, but within the five minutes, can take the quiz but with a reduced amount of time. Collect the quizzes and tell them to arrange into groups of four. Once the students are in their groups, give them the first set of questions, as stated below, and the amount of time they have to complete them. Continue to monitor the time so that the entire assignment can be completed.

### Questions 1, 2, 3, 4, and 5: (15 minutes)

Give the students ten minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. This assignment was designed to allow students to practice recognizing different species interactions and indicating how the interaction affects both species. After the students have completed questions 1 through 5, go over the answers with the class by asking for volunteer answers. Discuss any that seem difficult for the students.

### Questions 6, 7, 8, 9, 10, and 11: (20 minutes)

Give the students ten minutes to read the questions and form answers. The next ten minutes should include a discussion about the answers. For questions 6 through 11, follow the same procedure above.

### Question 12: (15 minutes)

Give the students five minutes to read the questions and form answers. The next five minutes should include a discussion about the answers. Question 12 builds upon the ideas of the rest of

### Species Interactions Notes

the assignment. Yes, herbivores prey upon plants. But plants do have defense mechanisms such as chemical secretions and thorns. **Question 12 is the critical thinking question.**

The rest of the time should be used by students to complete their critical thinking questions. Tell students that question 12 is their critical thinking question and that they should write their answer in complete sentences on the critical thinking page before turning it in.

## Species Interactions

In nature, populations do not live in isolation; they live in the same communities and ecosystems. How then, do they impact each other? Do they compete for the same food sources? Help each other survive? And if so, how do these interactions affect each species?

### Pre-Assignment:

Define:

1. Competitive exclusion hypothesis-**Two species with the same nutritional requirement cannot occupy the same niche**
2. Resource partitioning-**The splitting up of a niche spatially or the time it is being used so that species with similar needs can occupy the same space**
3. Secondary metabolites-**Chemicals not necessary for survival, but give an advantage, such as in defense**

### Assignment:

Match the species interactions with the examples. Indicate how the interaction affects both species. For example, if the interaction would benefit both species indicate (+/+). If the interaction benefits one and does nothing to the other indicate (0/+).

Mutualism	Amensalism	Neutralism
Interspecific competition	Resource competition	
Parasitism	Predation	
Herbivory	Interference competition	
Intraspecific competition	Commensalism	

1. *Plasmodium falciparum*, the protist that causes malaria commandeers a human's red blood cell to perpetuate itself.  
**Parasitism (+/-)**
2. In Montana, wolves keep the rabbit population in check.  
**Predation (+/-)**
3. A type of competition in which two wolves compete for the same rabbit.  
**Intraspecific competition (-/-)**
4. A deer eats the leaves off of a tree.  
**Herbivory (+/-)**

5. In Africa, animals drink as much water as they can during a drought, whenever possible  
**Resource competition (-/-)**
  
6. Rhizobium bacteria live in the roots of legumes. They fix nitrogen for the plant and the plant provides it nutrients.  
**Mutualism (+/+)**
  
7. In Montana, wolves and cougars both eat the small population of sheep.  
**Interspecific competition (-/-)**
  
8. Bee 1 only eats nectar from Plant 1 and Bee 2 only eats nectar from Plant 2.  
**Neutralism (0/0)**
  
9. A cow walks through a field, disturbing the insects. A frog sits nearby, eating the disturbed insects.  
**Commensalism (+/0)**
  
10. In Africa, after a cheetah kills a zebra a male lion comes and roars. The cheetah runs away and the lion eats the zebra.  
**Interference competition (-/-)**
  
11. Two species of plant grow in the same area. However, Plant 1 absorbs the nutrients better than Plant 2. Plant 2 quickly dies out of that area.  
**Amensalism (-/0)**
  
12. Plants seem to be doomed to predation by herbivores. Why, then, is the world still full of plants? What do plants do to protect themselves?  
**To protect against herbivores, plants have developed defense mechanisms. Chemical mechanisms are the production of secondary metabolites that are secreted. These chemicals could be toxins and poisons. Also, they have developed morphological defense mechanisms such as thorns.**