Cell Biology

Future of Agriculture Curriculum for Teaching Sustainability

Name: ______________________________________ Hour_______Date: ___________________

Date Packet is due:______________ Why late? ______________________________Score: ______
Day of Week Date — If your project was late, describe why

Overview: in this unit, you will be exploring nature of matter and energy. You'll be exploring the basic laws that govern all things that exist and how these principles relate to the function ecosystems.

Main Questions

- What does it take for something to be alive?
- How do atoms, molecules, cells, tissues, organs, and systems relate to each other?
- What are proteins, where do they come from, and how to they enable a cell to function and live?
- What are organelles? What are the functions of the mitochondria and the chloroplasts?
- What do mitochondria absorb and what do they produce? What do chloroplasts absorb and what do they produce?
- What is biosynthesis? What is biomass? How does the carbon cycle, photosynthesis, and cellular respiration relate to the biosynthesis of biomass from carbon dioxide and water?
- What processes increase the amount of biomass? What processes decrease the amount of biomass?
- What is the 10% rule? Why does this occur? How does this rule relate to the amount of different types of species that can exist in an ecosystem?
- Why do areas that are sunnier, warmer, and wetter usually have a wider variety of species and a greater number of living organisms than areas that are colder, drier, and cloudier?

Weekly Schedule

Monday:
- Introduction to Matter & Energy – Respiration in a Bag
- Model development – why does the bag inflate? What is happening to the matter inside the bag?

Tuesday:
- Nutshell Video & Notes
- Class discussion & revisions of explanations

Wednesday:
- Molecular Modeling Lab & Tabletop Ecosystem Set-up

Thursday:
- Review
- Group Quiz

Friday:
- Weekly Reflection
- Career Connections

Semester Schedule

Week 1: Introduction & Lab Safety

Atoms to Ecosystems

Week 2: Matter & Energy
Week 3: Cell Biology
Week 4: Biodiversity & Ecosystems
Week 5: Biodiversity & Habitats
Week 6: Midterm Assessments

Causes of Extinction

Week 7: Extinction
Week 8: Habitat Loss
Week 9: Invasive Species
Week 10: Land & Water Pollution
Week 11: Atmospheric Pollution
Week 12: Overharvesting
Week 13: Midterm Assessments

Sustainable Societies

Week 14: Natural Resources Management
Week 15: Societies & Sustainability
Week 16: Individual Sustainability
Week 17: Personal Campaigns
Week 18: Personal Campaigns

MICHIGAN STATE UNIVERSITY

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program, Grant No. DGE-1424871. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Day 1: - Respiration in a Bag

By the Great Lakes Bioenergy Research Center (glbrc.org). Modified and used with permission.

Overview

Students combine yeast and warm water with table in a "snack" size resealable zipper bag and observe as the yeast "eats" the feedstock.

Instructions

1. In a snack-size resealable zipper bag, combine 1 tsp. of sugar, and 1 tsp. (or 1 packet) of yeast.

2. Add 50mL (1/4 cup) of warm tap water (35-40 C) and zip the bag closed, removing as much air as possible. Mix gently. Lay bag on a flat surface and watch for results – fastest results should be achieved in 15 minutes. *If you have cool conditions in your classroom, it may be helpful to lay a towel or other insulating substance under the bag to keep them from losing heat too quickly.*

3. Warning: As the yeast perform cellular respiration, the bag may expand – it may even pop (and create a mess)! Be sure to monitor the bag and gently release the gas by slightly opening the seal if needed.

4. What was your start time? ____________________ What was your end time? ____________________

Predictions (complete after mixing ingredients)

1. I think that the following will occur in my bag after mixing the water, sugar, and yeast:

   ____

   ____

2. I think that these things will occur because…

   ____

   ____

   Be prepared to discuss your ideas as a class.

Questions (complete after the 15 minute period is completed)

3. Write your observations for each bag below. What happened after you combined all the ingredients? Did it happen immediately? Did the same changes occur across all the groups or were there differences?

   ____

   ____

   ____

4. Why do you think these changes occurred? *I hypothesize that…*____________________________________

5. Write a rationale for your hypothesis. *I think this is true because…*__________________________________

6. Draw a diagram showing what is happening in each of the bags below. Be sure to label all components of your diagram.

7. After a day or two, re-visit your hypothesis and explanation. Is there anything you would change about this? Was anything missing from your explanation that you can now add? Explain below.

Day 2: Notes & Discussion

Introduction & Directions: In this activity, you will begin by watching a short video about cell biology. This will help to clarify some of the questions you may have had yesterday. After the video, you will look at a short slideshow presentation that will provide you with specific information about this topic. Your instructor may decide to deliver the presentation as a classroom lecture or they may allow you to read the notes individually or in small groups (depending on your previous experience and capabilities with this content). After you have watched the video and finished with the slideshow, you will work in small teams to answer the questions listed below. You should take notes in a notebook, on a dry erase board, or on scratch paper so that you are prepared to deliver your responses during the class discussion that will follow. *Note: your instructor may assign your group to answer specific questions if time is limited.*

URL Links
YouTube Video: https://www.youtube.com/watch?v=JEnjph9miK4

Slideshow Presentation: https://www.factsnsf.org/uploads/1/4/0/9/14095127/2018-1-23_facts_cell_biology.pptx (or visit factsnsf.org and use the menu bar).

Discussion Questions:

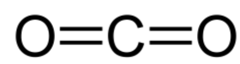
1. What is the smallest thing that can be alive? What is necessary for this thing to be alive and why?
2. Explain how each of the following relate to each other: Atoms, Cells, Tissues, Systems, and Bodies.
3. A protein is a macromolecule. What does this mean? Begin by explaining how proteins are assembled from amino acids. Explain how we know that an amino acid is a molecule and not an atom. Then explain how proteins are formed and how this results in a protein being a macromolecule.
4. Why are proteins important? How do they affect the function of cells and of organisms?
5. Chloroplasts and mitochondria are organelles. What are organelles? What do they do?
6. Summarize how cellular respiration occurs in the mitochondria. What goes into the mitochondria and what comes out during cellular respiration? What is the overall purpose of cellular respiration?
7. Summarize how photosynthesis occurs in the chloroplast. What goes into the chloroplast and what comes out during photosynthesis? What is the overall purpose of photosynthesis?
8. How are the substances that go into and out of the mitochondria during cellular respiration similar to what goes into and out of the chloroplast during photosynthesis?
9. Where does the carbon-based mass in a plant come from? Include the following in your answer: *biosynthesis; photosynthesis; sugar molecules; cellulose; carbohydrates*.
10. True or false: all of the carbon in your body began as carbon in a glucose molecule. Explain
11. What is biomass? Where does it come from? What process(es) increase the amount of biomass? What process(es) decrease the amount of biomass?
12. What is the 10% rule? How does it help to explain why there are so many more plants than animals in an ecosystem, and why there are so many more herbivores than carnivores?
13. Why do areas that are sunnier, warmer, and wetter usually have a wider variety of species and a greater number of living organisms than areas that are colder, drier, and cloudier? Explain using the 10% rule.

Be sure to revisit your explanations from the previous day's activity and add details or corrections as needed.

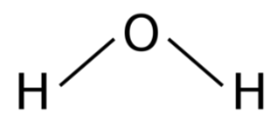
Day 3: Lab Activity - Molecule Modeling

Directions: In this lab, you will be using the Play-doh to create the atomic structures of carbon dioxide, water, and a sugar molecule. To do so, you will need to create the following:

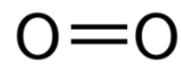
- **For carbon dioxide (CO_2)**
  - Two balls of the same color to represent oxygen atoms
  - One ball of a different color to represent a carbon atom



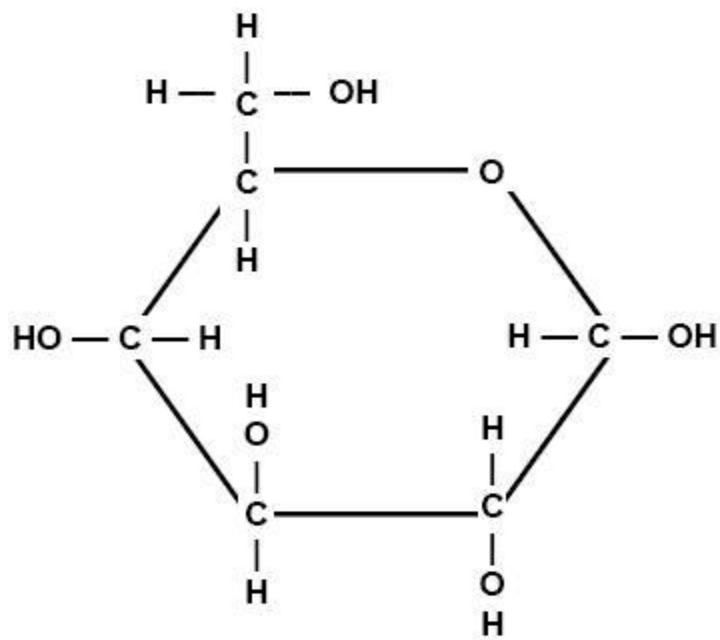
- **For water (H_2O)**
  - Two balls of a third color to represent hydrogen atoms
  - One ball of a different color to represent an oxygen atom (use the same color for oxygen as you did for carbon dioxide)



- **For oxygen (O_2)**
  - Two balls of the same color to represent oxygen atoms (use the same color for oxygen as you did for carbon dioxide).



- **For a sugar molecule ($C_6H_{12}O_6$)**
  - Using the same color as you used previously for oxygen, create six balls of that color for the 6 oxygen molecules
  - Using the same color as you used previously for carbon, create six balls of that color for the 6 carbon atoms
  - Using the same color as you used previously for hydrogen, create 12 balls of that color for the 12 hydrogen atoms
  - Note: all carbon atoms should have 4 toothpicks attached. All oxygen atoms should have 2 toothpicks attached. All hydrogen atoms should only have one toothpick each.



Using the pictures of each molecule as a guide, create each molecule out of the Play-doh atoms that you created. Use the toothpicks to represent the bonds between each atom in the molecule. <u>Hint</u>: *when making a sugar molecule, it is easier if you start by making the 5-carbon/1-oxygen ring and then add the side-chains*

When you think you have successfully created both molecules, <u>**raise your hand and show your instructor**</u>. While you are waiting for their approval and after they give their approval, complete the questions on the back.

Questions: Each of the following questions below will relate to at least one the molecules that you created for this lab on the opposite page.

1. Which carbon-based molecule exists as a gas in the atmosphere? Write the molecules formula and name below.

   Molecule Name: carbon dioxide ________ Molecular Formula: ____________

2. Which carbon-based molecule exists as a solid? Write the molecules formula and name below.

   Molecule Name: ____________ Molecular Formula: $C_6H_{12}O_6$ ______

3. Which non-carbon molecule is released during photosynthesis but absorbed during cellular respiration?

   Molecule Name: ____________ Molecular Formula: ____________

4. What 2 molecules are used to create a sugar molecule? Write their names and formulas below:

   1. Molecule Name: ____________ Molecular Formula: ____________

   2. Molecule Name: ____________ Molecular Formula: ____________

5. What 2 molecules do carbon-based molecules become when they are digested, burned, or decomposed? Write their names and formulas below:

   1. Molecule Name: ____________ Molecular Formula: ____________

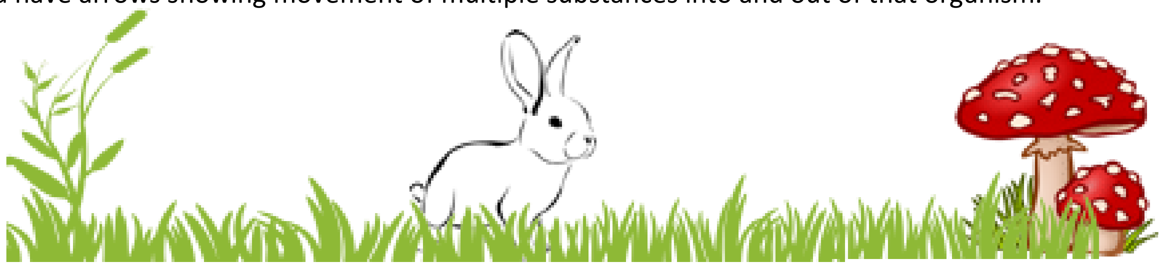
   2. Molecule Name: ____________ Molecular Formula: ____________

6. How are the substances that are absorbed and released during photosynthesis similar to the substances that are absorbed and released during cellular respiration?

   ____

   ____

7. In the space below, draw a picture showing how the carbon cycle works. The following have been provided: 1) **grass** (which can perform photosynthesis <u>and</u> cellular respiration), a **rabbit** (which can only perform cellular respiration), and a decomposing **mushroom** (decomposition is a form of cellular respiration). Draw arrows to show the movement of carbon dioxide (CO_2), oxygen (O_2), water (H_2O), and glucose ($C_6H_{12}O_6$). Each organism should have arrows showing movement of multiple substances into and out of that organism.



Day 3: Lab Activity - Tabletop Ecosystems

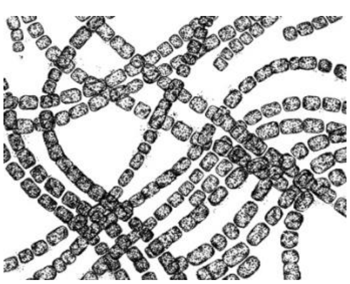
Introduction: Bioreactor Ecosystems use a very simple model of an ecosystem to help students understand the relationships between different species and nonliving resources that enable an ecosystem to function. In this case, brine shrimp (*Artermia salina*) and phytoplankton (*Tetraselmis sp.*) represent the two primary living species. The phytoplankton serve as the basis of the food chain as the photosynthesizing producers, while the brine shrimp are the consumers. Bacteria and other microbes naturally present in the water serve as the decomposers. While all the species will perform cellular respiration, only the phytoplankton will perform photosynthesis and the microbes will perform decomposition.

Materials: FACTS bioreactor (or a sealed 1000 ml Pyrex beaker or glass jar), artificial seawater (e.g. *Instant Ocean* and unchlorinated water such as spring water), phytoplankton solution (e.g. *Kent Phytoplankton*), brine shrimp (e.g. *Decapsulated Brine Shrimp Eggs*), pipette or syringe, stir plate or aerator.

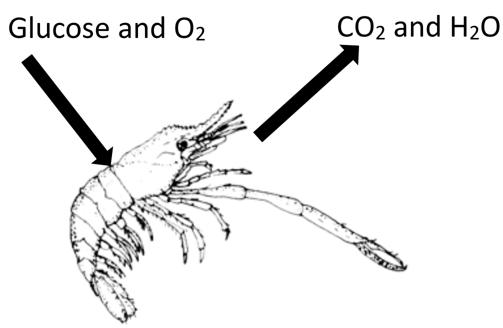
Directions: To set up your ecosystem, use the following steps:

1. Obtain a clean FACTS bioreactor (or sealable jar or beaker).
2. Add 400 ml of artificial seawater (this can be created using a product such as *Instant Ocean*; follow the instructions on the packet).
3. Add 1 ml of the phytoplankton to the bioreactor.
4. Add small pinch of the brine shrimp cysts (eggs) to the bioreactor (if possible, add the eggs to an aerated flask of water a day or two earlier so that they are hatched and ready).
5. Place bioreactor in a sunny, well-lit location at constant room temperature (or place a fluorescent bulb near the bioreactors to provide a source of light).
6. Aeration and/or gentle stirring may be necessary initially to enable the ecosystem to get started.
7. Bioreactor ecosystems will need to be checked daily to ensure that they have sufficient levels of algae and shrimp. Add more algae if it cannot be detected. Add more shrimp cysts if none can be seen.

Questions: In the space below, draw arrows showing which organisms will give off CO_2, H_2O, and O_2 and which organisms will absorb it. Also, draw arrows showing which organisms will produce glucose ($C_6H_{12}O_6$) and which will consume it. An example has already been started for you. Note that some organisms may produce the same substances that they are consuming (and vice versa).



Phytoplankton



Brine Shrimp

Bacteria &
Other Microbes

Day 4: Review & Assessment

Directions: you will begin by reviewing the unit objectives in your small groups. For each objective, rank it as a 1 (*completely unsure*), 2 (*somewhat unsure*), or 3 (*completely sure*) based on your comfort with that objective. After a few minutes of review, your instructor will lead a whole-class review. This is your chance to ask any questions you still might have about the concepts in this unit. Begin with anything you ranked as a "1".

After you have completed the unit review, you will be taking an individual multiple choice quiz and/or a group short answer quiz. These quizzes may be graded in class to help you better understand the question and the correct answer.

Unit Objectives:

1. What the smallest thing that can exist and still be alive? What is necessary for it to be alive?
2. How do atoms relate to molecules? How are these related to cells, tissues, organs, and systems?
3. How are proteins made? Why are they important to cells? What does it mean that they are macromolecules?
4. If a person gains weight, what is happening to the amount of matter in their body? What is happening to the amount of atoms and molecules in their body?
5. What are organelles? How do we know that mitochondria and chloroplasts are both organelles? In what kinds of cells are mitochondria found? In what kinds of cells are chloroplasts found?
6. How do mitochondria and chloroplasts transform matter and energy? How are these processes similar in both organelles and how are they different?
7. What is photosynthesis? What is cellular respiration? How does these processes relate to cellular organelles?
8. What is biosynthesis? What is biomass? What is cellulose? From where does living tissue come from?
9. What processes increase the amount of biomass? What processes decrease the amount of biomass?
10. What is the 10% rule? How does this relate to photosynthesis and cellular respiration?
11. Why are the habitats with the greatest numbers of species found in warmer, wetter, sunnier locations?

Day 5: Career Connections

Directions: Begin with a group and class discussion about the topics of this week. What is still unclear? What is still confusing? What seemed most important to remember? How does this relate to Natural Resources?

Then complete your Career Profiles. To complete this activity, see the College Profile section of the Supervised Career Experience Packet.

Cell Biology Individual Quiz

Name: ____Hour______Date:________Score:________/___

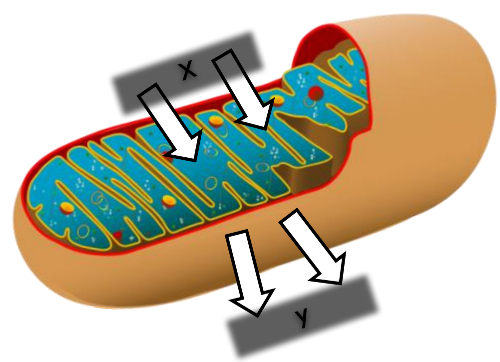
Directions: This quiz should be completed on an individual basis. A 3x5 notecard with handwritten notes can be used on this quiz.

1. **The smallest that something can be and still be alive is a…**
   a. Molecule b. Protein c. Cell d. Organism

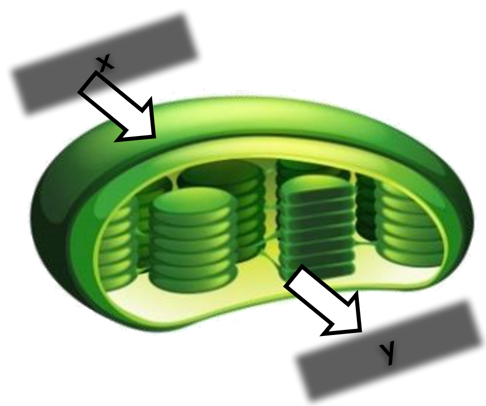
2. **Which correctly lists the following items in the correct order from smallest to largest?**
   a. Molecules < Atoms < Cells < Tissues < Organs < Systems < Organisms
   b. Cells < Atoms < Molecules < Organs < Tissues < Organisms < Systems
   c. Atoms < Molecules < Cells < Tissues < Organs < Systems < Organisms
   d. Atoms < Cells < Molecules < Organs < Tissues < Organisms < Systems

3. **Which of the following correctly describes the relationships between proteins and cells?**
   a. Some cells are proteins and these cells perform the functions of the body.
   b. All cells contain proteins which are large molecules that perform the functions of the body.
   c. All proteins are made of cells that enable their function in the body.
   d. Proteins and cells are different words that mean the same thing.

4. **The mitochondria and chloroplasts are examples of ______ in cells because they are _______.**
   a. Proteins / large molecules that perform most of the functions of the cell.
   b. Organelles / large molecules that perform most of the functions of the cell.
   c. Proteins / specialized structures inside of cells
   d. Organelles / specialized structures inside of cells



5. **Which would be X and Y in the top image to the right?**
   a. X = CO_2 and H_2O; Y = Glucose & O_2
   b. X = Glucose & O_2; Y = CO_2 and H_2O
   c. X = CO_2 & Glucose; Y = O_2 and H_2O
   d. X = O_2 and H_2O; Y = CO_2 and Glucose



6. **Which would be X and Y in the bottom image to the right?**
   a. X = CO_2 and H_2O; Y = Glucose & O_2
   b. X = Glucose & O_2; Y = CO_2 and H_2O
   c. X = CO_2 & Glucose; Y = O_2 and H_2O
   d. X = O_2 and H_2O; Y = CO_2 and Glucose

7. **Which of the following are found in plant cells?**
   a. Only Mitochondria
   b. Only Chloroplasts
   c. Both Mitochondria & Chloroplasts
   d. Neither Mitochondria or Chloroplasts

8. **In the picture below, which of the following could be #3 (taken in by an animal)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these

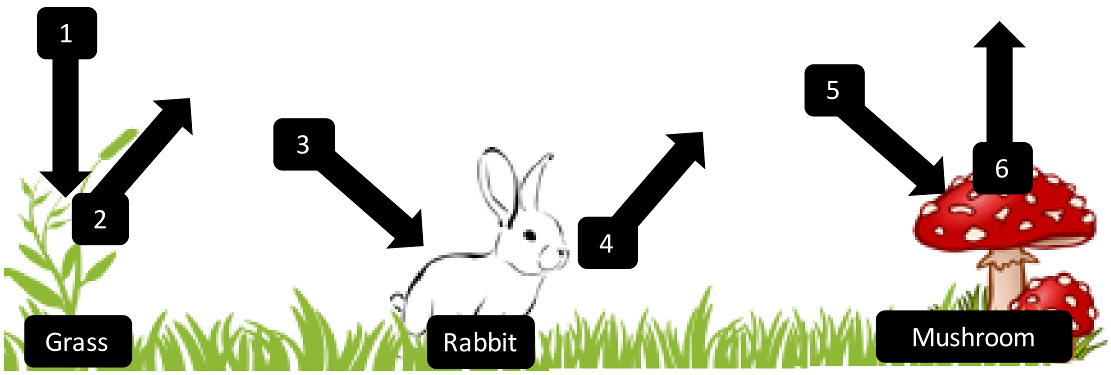
9. **In the picture below, which of the following could be #4 (released by an animal)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these

10. **In the picture below, which of the following could be #5 (taken in by a fungi)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these

11. **In the picture below, which of the following could be #6 (released by a fungi)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these

12. **In the picture below, which of the following could be #1 (taken in by a plant)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these

13. **In the picture below, which of the following could be #2 (released by a plant)?**
   a. H_2O and CO_2 b. Glucose and O_2 c. Either H_2O and CO_2 OR Glucose and O_2 d. None of these



14. **The process in which an organism produces its own tissue from the food it consumes is…**
   a. Biomass b. Biosynthesis c. Cellulose d. 10% Rule e. Carbohydrate

15. **This is made from long chains of glucose and gives plants its rigid structure.**
   a. Biomass b. Biosynthesis c. Cellulose d. 10% Rule e. Carbohydrate

16. **This is the amount of organic living tissue that exists in an organism or in a given area.**
   a. Biomass b. Biosynthesis c. Cellulose d. 10% Rule e. Carbohydrate

17. **This is why the number of plants must be much greater than the number of animals.**
   a. Biomass b. Biosynthesis c. Cellulose d. 10% Rule e. Carbohydrate

18. **Why do warmer, wetter, sunnier locations tend to have more organisms and more species?**
   a. These areas have higher rates of photosynthesis.
   b. More biomass can be produced in these areas.
   c. More plants can grow in these areas, and they can support more animals & decomposers.
   d. All of the above.

19. **If a beef animal consumes 1000 kg of carbon atoms in its hay and grain, roughly how much of those carbon atoms will remain a part of the animal's body?**
   a. 5 kg b. 50 kg c. 100 kg d. 500 kg e. 1000 kg

20. **Based on the 10% rule, if a wolf consumes 1000 kg of carbon atoms from elk meat per year, how much carbon from plants would be needed?**
   a. 10 kg b. 100 kg c. 1000 kg d. 10,000 kg e. 100,000 kg

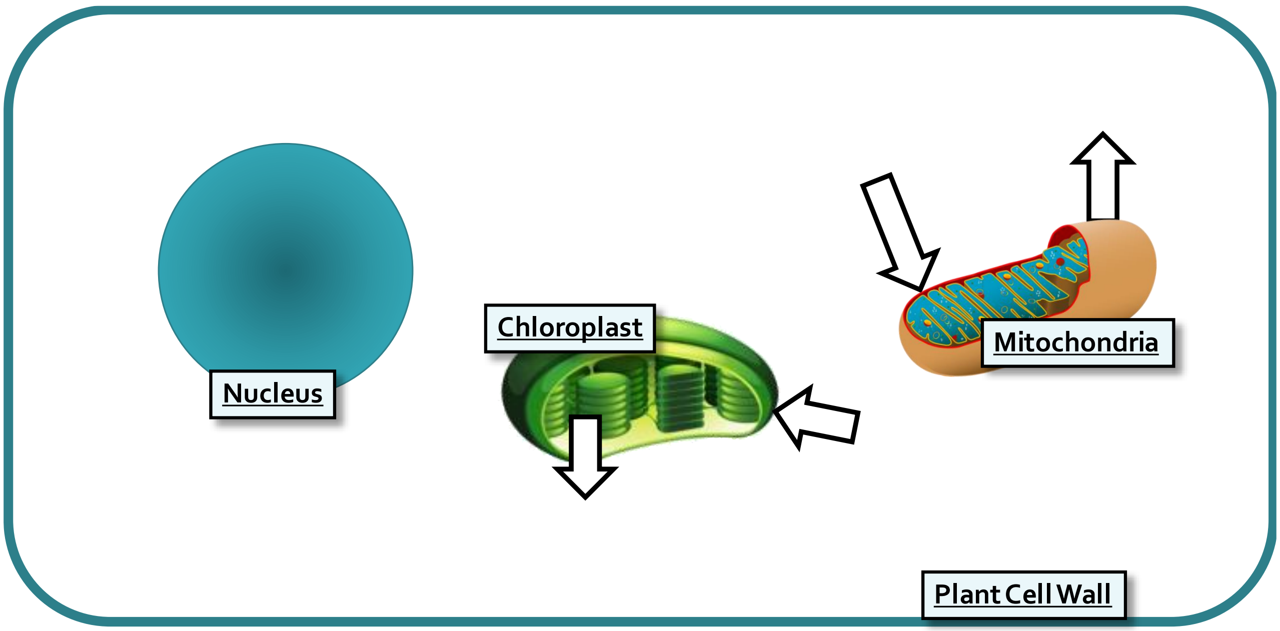
Cell Biology Group Quiz

Names (F&L): ____

____Hour________Date:________Score:_________/___

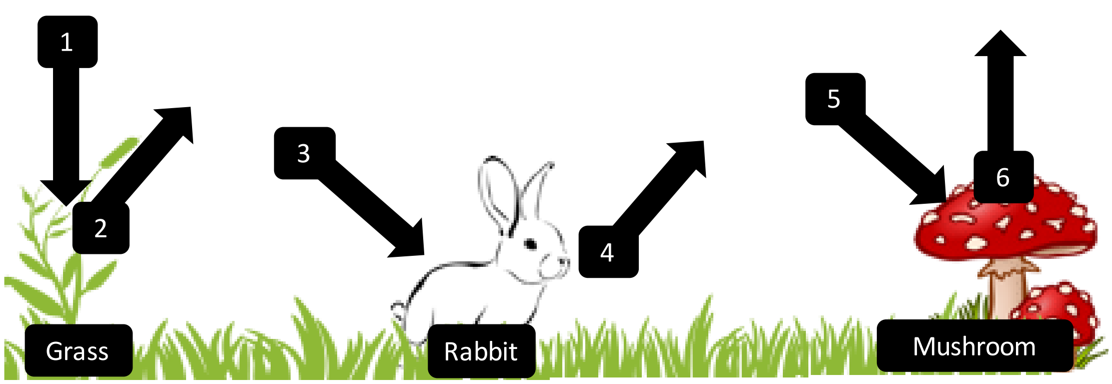
Directions: This quiz should be completed in your assigned groups. A 3x5 notecard with handwritten notes can be used on this quiz. Each person should take turns writing an answer. Those not writing should be actively working together to create their group's answer. Those who are not actively involved in answering every question may be asked to complete this quiz alone. Record the writer's name after each question.

1. In the space below, show how carbon dioxide (CO_2), water (H_2O), oxygen (O_2), and glucose move between different parts of a plant cell. Be sure to show arrows showing what goes into and out of mitochondria and into and out of chloroplasts.



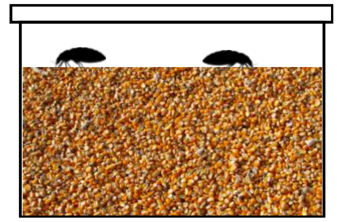
Writer's Name:

2. In the space below, show how carbon dioxide (CO_2), water (H_2O), oxygen (O_2), and glucose move between different organisms in an ecosystem.



Writer's Name:

3. **A pheasant farmer keeps corn for feeding his birds in a sealed container. Some bugs get into this container and eat the corn. The farmer decides that this is not problem because whatever corn the bugs eat will stay inside the bugs, and when the pheasants eat the bugs, they will obtain whatever the bugs ate. Is this accurate? Explain. Be sure to address cellular respiration, CO_2, and the 10% rule in your response.**



Writer's Name:

4. **Define biomass and biosynthesis. Then briefly summarize how the rates of cellular respiration and photosynthesis affect the amount of biomass that exists in an area.**

Writer's Name:

5. Which would be expected to have a greater number of species and organisms, a national park at a high elevation, or a wetland near the equator? Why? In your explanation, include all of the following: 1) photosynthesis; 2) biomass; 3) 10% rule; 4) biosynthesis.

Writer's Name:

6. Juan suggests that levels of plants and animals in an area must be about the same so that the amount of CO2 produced by animals is negated by the amount absorbed by plants. Cindy thinks that the number of plants must be much greater than the number of animals because she thinks that plants also produce CO2. Anna argues that plants depend on animals to produce CO2 in order to make their sugars, and so the number of animals must be greater than the number of plants. Who, if anyone, is correct? Explain who has the correct answer and why the other responses are incorrect.

Writer's Name:

Appendix: Fermentation in a Bag

Orginal Source:
https://www.glbrc.org/sites/default/files/document/Fermentation%20In%20A%20Bag.pdf

Overview: In this simple experiment, students investigate the process of fermentation in resealable bags with bakers yeast, warm water and various sources of plant sugar. Students observe and measure evidence of the chemical changes associated with respiration/fermentation: bag inflation (CO2) and indicators of conversion of organic carbon molecules into inorganic CO2. This activity works well in a variety of formal and nonformal educational settings. In the classroom setting, it can serve as an engaging activity to launch more in-depth investigations into cellular biology and help students grasp the conservation of matter during biological and chemical transformations of matter and energy.

Fermentation in a Bag – Recommended Procedure:
1. In a snack-size resealable zipper bag, combine 1 teaspoon of sugar (or another feedstock) and 1 teaspoon of yeast.
2. Add 50 mL (1/4 cup) of warm tap water (approx 40° C) and seal bag closed, removing as much air as possible.
3. Mix gently. Lay bag on a flat surface and watch for results – fastest results should be achieved in 15 minutes.**
4. Optional: Measure and compare ethanol and/or CO2 production using ethanol probes, breathalyzers, rulers, etc. Discuss and interpret results.

**Warning: As the yeast produce carbon dioxide, the bag will expand – it may even pop! Be sure to monitor the bag and release the gas if it becomes too inflated.

The Investigation (*for additional investigation*)
Using table sugar (sucrose) as a feedstock will yield the most rapid results. Some alternate feedstocks include corn meal, ground corn stover, sawdust, finely ground grass clippings, dead leaves, composting materials, etc. Feedstocks with a starchy or fibrous composition will not ferment as well. For an inquiry version, have students bring in and choose their own feedstocks. Students can also develop their own methods to measure fermentation and extend the investigation by changing variables to increase fermentation rates.

Master Materials List: *Required:*
• Dry active yeast (one 4 oz. jar contains approximately 36 teaspoons of yeast, which will make 36 bags)
• Warm water source
• Small graduated cylinders (100mL)
• Measuring spoons (one teaspoon for each feedstock source and the yeast to avoid cross-contamination)
• Feedstock(s): sugar, cornmeal, corn stover, sawdust, etc.
• Resealable zipper bags ("snack" size) with fill-in labels (see Supplementary Materials for label template).

Optional:
• Rulers to measure bag inflation. See Supplementary Materials for instructions.
• Classroom-grade ethanol probe (Vernier or PASCO) or breathalyzer for detecting ethanol levels. See Supplementary Materials for instructions.
• 2-4 liter thermos (with spout) for dispensing warm tap water
• Paper towels

Appendix: Play-Doh Molecule Modeling

Introduction: this lab was designed to provide students with a kinesthetic and conceptual means of visualizing the fundamental components of the carbon cycle at the cellular and molecular level. While the overall premise of the lab is quite simple, the ideas inherent in this activity are quite complex. Often students are surprised to find that the products of cellular respiration are identical to the inputs of photosynthesis (and vice versa) despite having learned this the previous day. This lab is often the moment that these ideas finally 'click' with students.

Materials Needed: 3 colors of Play-doh per group; toothpicks; lab activity sheet; pen/pencil

Tips: for the sake of time, it is easiest to have students determine the number of balls they need to make of each color and then make them in advance. Encourage students who feel more comfortable with this to take on the challenge of producing glucose while students who are less confident should try the simpler molecules. Be sure to point out that some molecules have double bonds, requiring two toothpicks instead of one.

Guidance for Learning: there are two main objectives for learning in this lab.

1. Students should be guided in observing that the atoms in glucose and O2 are the same as those found in CO2 and H2O.
    a. Students sometimes are led to believe that plants turn the energy of light into sugar; this should help to students to observe that the "ingredients" for glucose are found in CO2 and H2O.
    b. Students are sometimes led to believe that plants turn CO2 into oxygen. This should help them to understand that oxygen is leftover from the combination of multiple molecules of CO2 and H2O.

2. Students should be guided in observing that the products of photosynthesis become the inputs for cellular respiration, and that the products of cellular respiration become the inputs for photosynthesis.
    a. This should help students to appreciate that the carbon cycle occurs at multiple levels – both at the cellular/atomic level (as is the case with chloroplasts and mitochondria) and at the organismal level (as is the case with producers like plants, consumers like animals, and decomposers like bacteria and fungi).
    b. Students may think that plants only produce glucose and oxygen; students should be reminded that plants also have mitochondria and therefore also produce CO2 and H2O.

Limitations: for the sake of time, each group can really only produce one of each molecule. However, it takes six molecules of CO2 and six molecules of water to produce one molecule of glucose. It is important to point this out in order for students to understand that matter is conserved. Verbally acknowledging this is important for student clarification and comprehension.

Appendix: Setting up your Bioreactor Ecosystems

Introduction: Bioreactor Ecosystems use a very simple model of an ecosystem to help students understand the relationships between different species and nonliving resources that enable an ecosystem to function. In this case, brine shrimp (*Artermia salina*) and phytoplankton (*Tetraselmis sp.*) represent the two primary living species. The phytoplankton serve as the basis of the food chain as the photosynthesizing producers, while the brine shrimp are the consumers. Bacteria and other microbes naturally present in the water serve as the decomposers.

Materials: FACTS bioreactor (or a sealed 1000 ml Pyrex beaker or glass jar), artificial seawater (e.g. *Instant Ocean* and unchlorinated water such as spring water), phytoplankton solution (e.g. *Kent Phytoplankton*), brine shrimp (e.g. *Decapsulated Brine Shrimp Eggs*), pipette or syringe, stir plate or aerator.

Directions: To set up your ecosystem, start the following steps <u>at least a couple of days prior</u> to the class in which this set-up will be used.

1. Obtain a clean FACTS bioreactor (or sealable jar or beaker).
2. Add 400 ml of artificial seawater (this can be created using a product such as *Instant Ocean*; follow the instructions on the packet).
3. Add 1 ml of the phytoplankton to the bioreactor.
4. Add 4 g of the brine shrimp cysts (eggs) to the bioreactor (if possible, add the eggs to an aerated flask of water a day or two earlier so that they are hatched and ready).
5. Place bioreactor in a sunny, well-lit location at constant room temperature (or place a fluorescent bulb near the bioreactors to provide a source of light).
6. Aeration and/or gentle stirring may be necessary initially to enable the ecosystem to get started.
7. Bioreactor ecosystems will need to be checked daily to ensure that they have sufficient levels of algae and shrimp. Add more algae if it cannot be detected. Add more shrimp cysts if none can be seen.

Amazon Prime Purchasing Keywords

- Artificial Seawater: “Instant Ocean Sea Salt for Marine Aquariums, Nitrate & Phosphate-Free”
- Phytoplankton: Kent Phytoplex Plankton
- Brine Shrimp: Decapsulated Brine Shrimp Eggs (Artemia Cysts) (2 oz.)

Guidance for Learning: as students are setting up their ecosystems, guide them back to the grass/rabbit/fungi diagrams from earlier in this lesson (see the Molecule Modeling lab). Ask students if they can identify the correlating organisms in these ecosystems based on their roles and place in the carbon cycle.

Limitations: if it is not feasible to set up the ecosystems after completing the molecule modeling lab, it is possible to delay this until later in the week (such as on Friday before the career connections activities).