Crops Unit, Packet 1.2

First & Last Name: _____ Period/Hour:_____

NOTE: Packets are due after completing Part 5. Check each page to be sure all blanks are completed.

Driving Question: How can we explain crop growth using atoms?

Anchoring Phenomenon: Often one field of crops will outperform another. This can be partly explained by changes that occur to atoms and molecules. We will develop and use our understanding of atoms and molecules to explain differences in plant growth and productivity.

Deeper Questions

1. What is the difference between matter and energy?
2. How are the terms *atoms, mass,* and *molecules* similar and different?
3. How can differences in plant growth be explained by our understanding of matter & energy and atoms & molecules?

Schedule

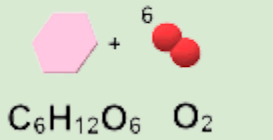
Part 1: Introduction
- Initial Ideas, Data Dive, & Initial Explanations

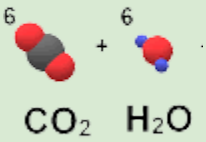
Part 2: Core Ideas
- Core Ideas & Revisions of Part 1 Explanations

Part 3: Investigation
- Part 3A: Leaf Bubbles
- Part 3B: Leaf Disk Experiment

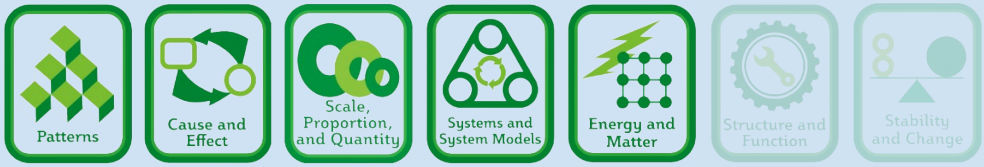
Part 4: Review & Assessment
- Review, Formative Assessment, & Lesson Check

Part 5: Career Connections
- Interview an Expert





AFNR Standards: PS.01.01. Determine the influence of environmental factors on plant growth. PS.02.03. Apply knowledge of plant physiology and energy conversion to plant systems. BS.02.01. Read, document, evaluate and secure accurate laboratory records of experimental protocols, observations and results. CRP.02.02. Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community. CRP.07.02. Evaluate the validity of sources and data used when considering the adoption of new technologies, practices and ideas in the workplace and community. CRP.08.02. Investigate, prioritize and solve problems in the workplace and community.
NGSS Standards (*PEs* & *CCCs are summarized below. SEPs are noted throughout the packet*). HS-PS1-7. Atoms and mass are conserved during reactions. HS-LS1-5. How photosynthesis transforms light energy into stored chemical energy.



Semester Schedule

1. Crops Unit
1.1: How can we improve crop productivity?
1.2: How can we explain crop growth using atoms?
1.3: How do we design plant experiments?

2. Livestock Unit
2.1: Why do different types of livestock need different feed?
2.2: How do digestive tracts of livestock differ?
2.3: How do we design animal experiments?

3. Genetics Unit
3.1: How can we predict genetic inheritance?
3.2: How do genetic outcomes vary in more complex cases?
3.3: How do we design genetic experiments?

4. Biotech Unit
4.1: How can DNA be modified to enhance species?
4.2 How do we design biotech experiments?

5. Sustainability Unit
5.1: What determines if food production is sustainable?
5.2: What methods improve sustainability in agriculture?
5.3: How do we design sustainability experiments?

These materials were partly developed with assistance from artificial intelligence.

Resource Links: Class Website; Core Ideas; Reading; Mastery Check;

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Part 1: Introduction – Elemental Plant Experiments (1.2.1)

Overview: In this activity, you will begin by discussing your initial ideas about how plant growth relates to changes to atoms and molecules. You will then analyze data and work in teams to develop initial explanations.

Initial Ideas - *Record your ideas separately (e.g., on a white board or scratch paper).*
SEP: Engaging in Argument from Evidence; Asking Questions & Defining Problems

1. Students are learning about molecules in science class and plant growth in agriculture class. They wonder if there's a connection between the two subjects. **Do you agree or disagree with each claim**?
    a. Daryll: "Plants grow by converting sunlight into the atoms that they are made from."
    b. Nina: "Plants use atoms from the air & water to form the molecules that they are made from."
    c. Oscar: "Plants primarily grow by absorbing atoms from the soil."
2. **Work in your small groups to discuss your ideas.** How are your ideas similar or different? Decide as a group whether each statement is correct (and why). Be prepared to present your ideas.

Data Dive 1 - *Read the excerpt below. Record your ideas separately.* *SEP: Analyzing & Interpreting Data*

Researchers were interested in which types of atoms are found in biofuel crops. They predict that most elements (types of atoms) found in these crops did not come from the soil. They first collected samples from three types of energy crops. They then analyzed which elements were most abundant in each sample. Their data are shown below. Nitrogen and sulfur come from the soil. Carbon atoms come from carbon dioxide molecules in the air. Hydrogen atoms are obtained from water. Oxygen primarily comes from water molecules. *Data Source: www.researchgate.net/figure/Elemental-chemical-composition-of-soil-samples_tbl2_264286979*

Sample	C (wt%)	H (wt%)	N (wt%)	S (wt%)	O (wt%)
Sida	43.74 ± 0.036	5.68 ± 0.011	0.77 ± 0.043	0.24 ± 0.018	50.96 ± 0.422
Miscanthus	45.28 ± 0.765	5.74 ± 0.031	0.29 ± 0.017	0.08 ± 0.034	51.60 ± 0.695
Arundo	44.19 ± 0.041	5.70 ± 0.028	1.29 ± 0.022	1.29 ± 0.001	52.47 ± 0.039

1. What is the research question and hypothesis for this experiment?
2. What are the most important trends and patterns in this data?
3. Based on their data, what elements make up most of the mass of the plant? Is this true for all the species they analyzed?
4. A separate analysis found that most of a soil sample consists of SiO_2 (59.7%), Al_2O_3 (20.6%), and Fe_2O_3 (1.2%). Based on both studies, is it accurate to conclude that most of the mass of a plant is coming from the soil? (Note: the oxygen atoms in the plant do not directly come from the soil).
5. Does this data support or refute the researcher's hypothesis in the original experiment?
6. What key idea or conclusion can we reach based on this data?

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Data Dive 2 - *Read the excerpt below. Record your ideas separately.* *SEP: Analyzing & Interpreting Data*

Researchers were interested in what elements make up the dry mass of wheatgrass; they hypothesized that most of the atoms in this crop came from somewhere other than the soil. To test this, they grew wheatgrass without any soil using two different hydroponic systems. They then measured the elements in dried plant material. Their data are below. *Data Source: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0202441*

Elemental Composition (%)	Carbon (C)	Oxygen (O)	Nitrogen (N)	Potassium (K)	Phosphorus (P)
Well Water Hydroponics	51.71	33.08	6.95	3.34	1.62
Spring Water Hydroponics	54.27	32.14	7.08	2.75	1.32

1. What is the research question and hypothesis for this experiment?
2. What are the most important trends and patterns in this data?
3. Based on their data, what elements make up most of the mass of the wheatgrass?
4. In hydroponic systems, a small amount of soil minerals must be added to the water, but otherwise the crops never have access to soil. How can these crops gain mass if they aren't grown in soil?
5. Does this data support or refute the researcher's hypothesis in the original experiment?
6. What key idea or conclusion can we reach based on this data?

Discussion - *Record your ideas in the spaces below.* *SEP: Asking Questions & Defining Problems.*

As a class, discuss your ideas about this data. What are the ideas that most agreed on? Where did your ideas differ as a class? Record your ideas in the spaces below.

We generally agree that…	***We disagreed or were unsure if…***

Initial Explanations - *Record your ideas in the spaces below.* *SEP: Constructing explanations*

How does the growth of plants relate to changes that occur to atoms and molecules? Write down an initial explanation in the space below. Don't worry if you aren't completely sure about this. You will come back and revise this explanation as you gain more information during this unit.

Part 2: Core Ideas (1.2.2)

Overview: In this activity, you will use this reading to explore how changes at the atomic and molecular level affect plant growth. If feasible, you should create a shared document for your group or your class (based on your instructor's directions). Your instructor may choose to utilize this presentation template to make it easier to share your responses.

Driving Questions - *Record your ideas separately (e.g., on a white board or scratch paper).*

1. Crops gain mass as they grow. What causes this change: matter or energy? Explain.
2. What are atoms? What are molecules? How do these relate to the increase in crop mass?
3. How are elements similar to or different from atoms? What elements make up most of the mass of crops? Can these elements change?
4. How do crops acquire the atoms and elements that make up most of their mass?
5. What is photosynthesis? What happens during photosynthesis? What molecules are used for this process, and what molecules are created?
6. Where does photosynthesis occur within a plant? What do these structures look like? How does their color relate to their function?
7. True or false - when crops photosynthesize, they are turning sunlight into the atoms in order to gain mass. Explain.
8. Summarize the two key ways in which crops use the sugars made during photosynthesis.
9. What is cellulose? What is it made from? How does it relate to crop growth & productivity?
10. True or false: plants primarily gain their mass from soil. Explain.
11. True or false: a plant that has greater rates of photosynthesis is more likely to be a larger and more productive plant. Explain.
12. A field that is fertilized tends to have larger and more productive crops. What is the fertilizer actually doing to make this happen?

Once every question has been answered, address the following questions as a class, in groups, or individually. If sharing a document, consider flagging any areas of concern with comments and/or highlighting:

1. Are there any concerns about any responses to these questions regarding completeness, accuracy, or precision? Can we collectively improve any of the responses to make them more useful for our needs?
2. Are all the sources sufficiently credible, accurate, reliable, relevant, and up to date?
3. Do we have any new questions or any questions that are still not fully answered?

Revising Explanations - *Record your ideas in the spaces below.* *SEP: Constructing Explanations & Developing Solutions*

How does the growth of plants relate to changes that occur to atoms and molecules? Based on this new information, how would you now respond to this question?

_____

_____

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Part 3A: Leaf Bubbles (1.2.3a)

Pre-Investigation Questions - *Work as a group to prepare verbal responses for these questions. When you think you are all ready to provide responses, raise your hand. Your instructor will listen to your explanations, provide feedback, and determine if you are ready to move on to the investigation.*
SEP: Developing & Using Models

1. How are the following different from each other? *Matter, energy, atoms, mass, elements, molecules*.
2. Where do plants acquire most of their atoms? How do plants gain the atoms needed to gain more mass?
3. How are molecules changed during photosynthesis? How does this relate to plant mass & productivity?
4. What is cellulose? How does it relate to plant growth and productivity?

This activity was completed _____ (*instructor signature*)

Overview: In this investigation you will observe tiny bubbles of oxygen gas that escape from submerged leaves as photosynthesis occurs. You will use this to explain how plants change molecules to gain mass.

Hypothesis - *Discuss your ideas and record your predictions in the spaces below.*
SEP: Planning and Carrying Out Investigations

1. Leaves will be submerged under water in two different trays. Some leaves will be exposed to light; others will be kept in the dark. What differences do you expect to observe between the two trays?

   _____

   _____

2. Explain your reasoning: _____

   _____

Directions - *Carefully read the directions below before beginning. Record info where prompted.*

1. ☐ At least one hour in advance, your instructor should place fresh green leaves in a shallow dish and carefully submerge them in water (rocks or weights may be needed to keep leaves submerged).
   a. They should place one set of leaves in full light (either full sunlight or strong grow lights) and keep the other set of leaves in a dark or shady location.
   b. If this is not feasible or if absent, you can find sample data for this by clicking here.
2. ☐ Observe both sets of leaves (both those in the light and those in the dark). What differences can you observe between the two treatments? Record your observations in the Results section.
3. ☐ Collaboratively develop an explanation for why these differences occurred and write it in Results.
4. ☐ Your instructor may also choose to have microscopes set up to get a closer look if time allows.

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Results - *Record your ideas in the spaces below.* *SEP: Constructing Explanations & Developing Solutions*

1. **What differences did you observe between the submerged leaves that were in light compared to those that were kept in the dark?**

2. **Explain why these differences occurred. What was occurring in the leaves in the light that was not occurring in the other leaves?** What evidence supports your claim? *Check your notes and resources from this packet if needed.*

3. Three students are debating where the bubbles on the submerged leaves came from.
   Avery thinks that the leaves are creating oxygen atoms that they release.
   Bristol argues that the leaves are turning carbon dioxide (CO_2) into oxygen that is released.
   Chandra claims the plant rearranged water and carbon dioxide to make sugar and oxygen.

   Which claim seems most accurate? _____ **Why**? _____

4. **How do your observations in this investigation relate to how plants acquire the atoms they need to gain mass?**

Part 3B: Leaf Disk Experiment (1.2.3b)

Overview: you will use disks punched out of spinach leaf cells and a syringe full of water & baking soda to measure rates of photosynthesis (the baking soda provides a source of carbon dioxide needed for photosynthesis). The syringe changes the pressure and removes oxygen from the leaf disk, causing them to sink to the bottom. When the leaf disks photosynthesize, they produce oxygen and become more buoyant again. The faster the leaf disks rise to the top of the syringe, the greater the rates of photosynthesis.

Materials needed (per group): A 10+ cc syringe, tap water, spinach leaves, paper punch, 20% sodium bicarbonate (baking soda) solution, dish soap, light source, ruler.

Directions - *Carefully read the directions below before beginning. Record info where prompted.*
SEP: Planning and Carrying Out Investigations

1. Prior to this lab, your instructor should soak the spinach leaves in water overnight in a refrigerator. Fresh, dark green spinach leaves will work best. Your instructor will also need to prepare a 20% sodium bicarbonate solution by mixing 20 g of baking soda in one liter of water. Add a drop of dish soap to this solution for more reliable results.
2. Using a paper punch, cut out 10-20 leaf disks from the freshest portions of the spinach leaves (extras are good to have in case you need them). Try to avoid veins, stems, and other non-leafy portions.
3. Add 10 leaf disks to your 10 cc syringe (if it is larger than 10 cc's, that is ok). Suck up 10 cc's of the sodium bicarbonate solution your instructor has provided.
4. Hold your finger over the end of the syringe. Pull back on the plunger as far as you reasonably can; you are creating a vacuum to suck the air out of the inside of the leaf disks. You should be able to visibly see air bubbles coming out of the disks.
5. As you are sucking the air out, sodium bicarbonate is going into the spongy layer of the leaf cells. This is how the cells will get the carbon dioxide needed for photosynthesis
6. Gently squirt out the sodium bicarbonate solution into a sink or beaker (whichever your instructor has provided). Suck up 10 cc's of untreated water.
7. Make sure the leaf disks sink in the water in the syringe. If not, remove the water and repeat the steps on the previous page until they do.

8. Move your syringes to a well-lit location. Record the start time here: _____
9. While waiting, start the questions in the next section. Occasionally turn & lightly agitate the syringe.
10. Record the time at which at least half of the disks have floated halfway to the top of the syringe (i.e. the time at which at least 5 disks are at 5 cc's or higher).

11. Time: _____Total time elapsed from start to this time: _____min
12. If time allows, repeat this experiment with a second set of 10 disks newly punched from the spinach leaves your instructor has provided.
13. Record the start time for your second trial of spinach leaf disks here:
14. Record the end time at which 5 or more disks reached 5 cc's or higher here: _____

15. Record the total time elapsed here: _____min. Finish the questions in the next section.

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Results - *Record your ideas in the spaces below.* *SEP: Constructing Explanations & Developing Solutions*

1. **Why was the sodium bicarbonate (baking soda) necessary?** (Re-read the Overview if unsure).

   _____

   _____

2. **What would happen if the sodium bicarbonate was not used? How would photosynthesis be affected?**

   _____

   _____

3. **What made the leaf disks rise?** _____

   _____

4. Predict how the following scenarios would impact the rate at which the leaf disks rise. **Circle "faster", "slower", or "no change" next to each scenario:**

   Increased light intensity: *Faster / Slower / No Change*
   Increase the sodium bicarbonate concentration: *Faster / Slower / No Change*
   Raise the temperature: *Faster / Slower / No Change*

5. Be prepared to discuss your ideas and your findings as a class.

Part 4: Review & Assessment (1.2.4)

Step 1: Review the content for this packet. Identify any concepts that are still unclear to you.
Step 2: Identify and discuss any remaining confusion with your instructor.
Step 3: Complete the Lesson Check (individually or small groups). Compare responses as a class.
Step 4: If your responses show more help is needed, your instructor will provide further support.

Part 5: Interview an Expert (1.2.5)

Background - *Complete the reading before answering the questions below.*

In this activity, you will have an opportunity to interview an individual with professional expertise in this week's content topics, or watch a pre-recorded interview. This activity will be reflective of *social science* research, or gathering, analyzing and interpreting information about human interactions. Often this work is conducted using *qualitative interviews*, which are interviews designed for research and data collection.

Part 1 - Planning

1. Briefly summarize the topics that were covered in class this week in one sentence:

   This week in class, we tried to figure out _____

   _____

2. As a group, discuss what questions you still have about this week's topics. Ideally, use some of the following to start your questions: *Who, What, When, Where, Why, How*

   _____

   _____

   _____

   Once you have developed three questions, ask for your instructor to provide you with some feedback.

3. From this list, choose a research question for your group and complete the prompt below:

   We are unsure _____

   _____

4. Turn your research question into a hypothesis. What do you think is the answer to your research question given what you currently know?

   We hypothesize that _____

   _____

5. Create three interview questions that you could ask this individual that may provide information related to your research question. Try to focus on their particular area of expertise as you craft your questions.

   1. _____

   2. _____

   3. _____

6. Be prepared to briefly describe your research question and hypothesis. Explain how your interview questions will provide you with information that will help to address your research question.

Part 2 – Interview Field Notes - Use the space below to record some field notes as the guest speaker presents to the class. Record anything that you hear or observe that might be relevant to your research question.

_____

_____

_____

_____

_____

_____

Part 3 – Analysis & Debrief *(your instructor may choose to use verbal discussion instead of written responses)*

7. Does your data (your observations and field notes from this interview) support or refute your hypothesis? Circle one: Supports it / Refutes it / Not sure

   Explain: _____

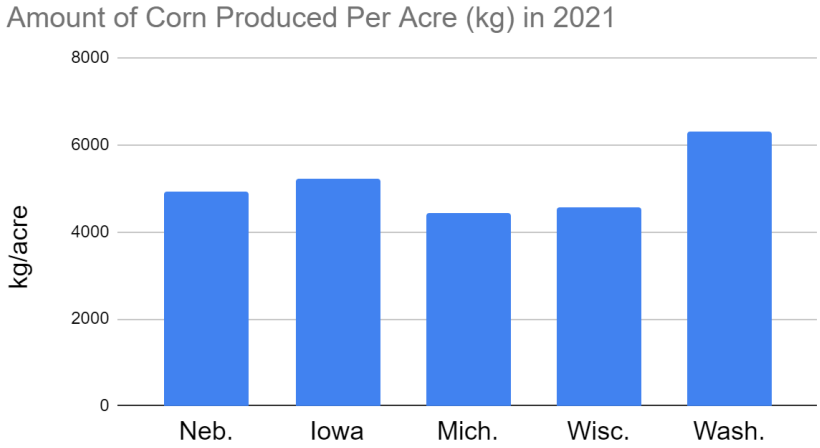
   _____

Packet 1.2 Lesson Check (1.2.4)

Name: _____ Hour____ Date:_____ Score:_____

Directions: A 3x5 notecard with *handwritten* notes can be used to guide your answers. Your instructor may allow you to work in assigned groups. If so, have a different person write each response while others assist.

Background: several states had record high corn yields in 2021. This graph shows the average corn yield per acre (in kilograms, or kg) for five of those states. Use this data to answer the following questions.



1. **Which of the following claims are supported by this data**?

A. Avery believes that Iowa produced the most corn per acre of any state. AGREE/DISAGREE

B. Bristol argues that Washington's corn fields added more atoms to its corn than any other state shown. AGREE/DISAGREE

C. Chandra states that Washington & Iowa likely had greater rates of photosynthesis than the other states. AGREE/DISAGREE

Provide an explanation. Why did you agree or disagree with each student's claim?

a) _____

b) _____

c) _____

Writer:

2. **Over the summer, a corn plant grows larger. As such, we can assume that…**
   a. Its mass **decreases,** meaning the number of atoms in the plant *increases*.
   b. Its mass **increases,** meaning the number of atoms in the plant *increases*.
   c. Its mass **decreases,** meaning the number of atoms in the plant *decreases*.
   d. Its mass **increases,** meaning the number of atoms in the plant *decreases*.

3. Corn plants in Washington produced a greater mass (kg) of corn per acre than corn plants in Michigan. **How did the movement of atoms into the corn differ between the plants in different states? Did the corn in one state acquire more atoms on average than the corn in the other state?** Justify your ideas with evidence and reasoning.

_____

_____

_____

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4. **Where do most of the atoms in corn come from? Circle one option and explain.**
   a. The soil b. Sunlight c. Water & CO_2 d. Fertilizer e. None of the above

Provide an explanation: _____

_____

_____

Writer:

5. **Most of the dry mass of a corn plant is composed of carbon atoms. Carbon is an example of…**
   a. A type of energy b. An element, or type of atom c. A molecule d. Mass

6. **What occurs during photosynthesis, and how does this relate to how a corn plant gains mass?**

_____

_____

_____

Writer:

7. **Photosynthesis requires light. How is light energy transformed during photosynthesis?**

_____

_____

_____

Writer:

8. **During photosynthesis, a plant produces sugar molecules. What are two ways in which the plant can use these sugar molecules to function and grow?** Include the term *cellulose* in your response.

_____

_____

_____

Writer:

9. **In an earlier experiment, we observed that a submerged leaf produces visible bubbles of oxygen. Where did this oxygen come from?**
   a. The plant changes sunlight into oxygen atoms.
   b. The plant turned soil minerals into oxygen atoms.
   c. The plant turned carbon atoms into oxygen atoms.
   d. The plant rearranged water and carbon dioxide into sugar and oxygen.