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Biomolecule Builders: Matter, Energy, and Marine Organisms

Glucose in Biomolecule Synthesis

Grade Level	9th – 12th Grade	**Time Frame**	5-6 class period(s)
Subject	Science	**Duration**	300 minutes
Course	Biology I, Biology II		

Essential Question

Can people live on glucose alone, why or why not?

Summary

Students explore the molecular makeup of starch and gather evidence from a research article on marine cryptomonad nutrient requirements to answer the essential question:

Snapshot

Engage

Post WWII Japan story about eating research-grade glucose hidden in an oceanside cave. Taste corn syrup.

Explore

Use a digestive enzyme to break down starch into glucose. Detect the conversion using reagents. Initial evaluation of essential question.

Explain

Analyze claims and evidence from an article on marine cryptomonad nutrient requirements. Develop a class definition of growth in terms of biomolecule function and composition. Construct an explanation for why our bodies need more than just glucose to grow. Re-evaluation of essential question.

Extend

Analyze matter and energy in biomolecule synthesis pathways. Think Pair Share activity to make thinking visible. Students prepare their "molecule break and build" lesson and pair up to video and teach one another.

Evaluate

Video of "molecule break and build" lesson.

Standards

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Oklahoma Academic Standards (Biology)

B.LS1.6 : Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
B.LS1.6.1: The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into large molecules (such as proteins or DNA), used,for example,to form new cells.

Materials

- 1-2oz cups (condiment size)
- mini tasting spoons or popsicle sticks
- corn syrup
- Benedict's Solution or diabetes glucose testing sticks

Engage

Go to **slide 5**. Ask students the formative assessment questions and collect their answers using a digital polling tool like Mentimeter.

Teacher's Note: Poll Questions

Build these formative assessment questions into your polling program of choice. Students should have learned the concepts addressed by the first two questions in middle school, and depending on what science classes students have already taken in high school, they may or may not have learned the concept targeted by the third.

1. What organisms make sugars. [Answer: plants]
2. What do organisms use sugars for? [Answer: to build new molecules and release energy]
3. What types/parts of molecules can sugar be used to build? [Answer: the carbon and hydrogen parts of nucleotides and amino acids]

Ask for students to share the reasoning behind their ideas, specifically the correct ones, to establish accurate conceptions for the first two questions. **Do not** address the third question at this time. Let students know they'll be exploring the ideas as they continue through the lesson. Be sure to reinforce that information throughout the rest of the lesson where it is meaningful in context, particularly if students do not demonstrate a strong understanding based on this formative assessment.

Distribute cups with a very small amount of corn syrup and tasting spoons/popsicle sticks for the students to taste. Let them know that the corn syrup is also called glucose syrup. While students are tasting the syrup go to **slide 6**. Tell the story while it's projected on the screen for students to follow along.

> I once heard a story about this young person in Japan near the end of World War II. He and his family were close to starvation, but he looked in a cave near the coast and found that some researcher had hidden lab supplies there. Glucose was one of the supplies. The young person brought his siblings there and they all ate glucose out of syringes. After hearing this story, I made the partially serious comment that as long as these people had glucose to eat, they could survive.

Ask students: Why was this comment only partially serious?

Ask the students if the syrup can give them energy, then ask if it can sustain them for a long period of time. Students should agree that they get energy from the corn syrup, but cannot live on it alone.

Explore

Distribute the **Biomolecule Builders Activity Sheet** handout to students.

Teacher's Note: Biomolecule Builders Activity Sheet

The activity sheet should *not* be treated like a worksheet. It is intended to be used as a central place for students to record their ideas and data throughout the lesson, in place of an interactive science notebook. If students use science notebooks, have them complete the work in those instead of on the handout.

The lesson slide headings correspond to headings in the activity sheet to help navigate through the document.

Go to **slide 7.** ADD BIOMOLECULE DEFINITION HERE SOMEWHERE. Students draw the glucose structure. Use the I Think/We Think strategy. Students write a claim about the nutrient glucose (question 2 in Biomolecule Builder Activity Sheet). Have a class discussion to arrive at claims about the matter and energy in the nutrient glucose. Students record these claims (question 2 in Biomolecule Builder Activity Sheet).

Teacher's Note: Example Claims

1. Glucose is a component of biomolecules.
2. Humans obtain glucose from food.
3. Plants produce and store glucose.
4. Glucose molecules contain chemical energy.

Go to **slide 8**. Ask questions that will prepare students to draw a conclusion about production and storage of glucose in the form of starch in plants. Expect that student answers will be incomplete at this time, but the investigation will help them develop more thorough understanding.

Teacher's Note

- Why would a plant ever need to store glucose energy?
  - In case there is a cloudy day when it cannot produce enough sugar by photosynthesis.
- Where do plants store glucose matter?
  - Glucose is stored in tubers or grains.
- How do plans store glucose matter?
  - The glucose molecules are linked together in a chain called starch.

Go to **slide 9** Show a video about extracting potato starch (a survival food): https://youtu.be/QjzdlYoIqrw. Stop this video around the 2:00 mark to avoid prematurely revealing that starch is converted to glucose. Tell students that they will do some tests on starch to construct an explanation about where and how plants store glucose molecules.

Students start Loaded Potato Investigation in Biomolecule Builder Activity Sheet, testing different combinations of iodine, amylase, and Benedict's solutions When added to starch, iodine should produce a purple mixture. Heated Benedict's solution should produce an orange solid when added to glucose.

Teacher's Note: Lab Prep

To prepare the solutions of iodine, amylase, and Benedict's solution, dilute these materials according the manufacturer's instructions such that one drop will deliver enough to produce an observable reaction. If a diabetes glucose testing strip will be used instead of Benedicts solution, adjust this in the instructions on the Biomolecule Builders Activity sheet.

Go to **slide 10** after students have finished all the tests they plan to do. Have students take notes from this slide. Each student writes a conclusion about the production and storage of glucose in the form of starch in plants (question 3 in Biomolecule Builder Activity Sheet). To answer question 4 in Biomolecule Builder Activity Sheet, students use evidence from the Loaded Potato Activity to support claims generated as a class on slide 4 (Claims Concerning the Nutrient Glucose).

Go to **slide 11**. Students answer question 5 in Biomolecule Builder Activity Sheet, which instructs them to cite evidence from the Loaded Potato Activity and give reasoning for their response. Tell students that to gather more evidence, we are going to read a scientific article about a marine cryptomonad and what types of molecules it can eat/survive on.

Teacher's Note: Sufficient Evidence?

Did the Loaded Potato activity generate evidence to support the claim that humans cannot survive by eating glucose alone?

No, there is evidence that potatoes starch is made of glucose, so it seems to be a molecule with diverse uses. There is a lack of evidence that glucose alone is insufficient for growth.

Explain

Go to **slide 11**. Ask students: Why does this title specifically mention nitrogen? Students are assigned to 9 groups to complete the Claim, Evidence, Reasoning section and question 6 of the Biomolecule Builder Activity Sheet. Divide the claims up among the groups to ensure that each claim is addressed as a class. Have each group present their assigned claim while classmates take notes in the table in the Biomolecule Builder Activity Sheet.

Teacher's Note

The Biomolecule Builder Activity Sheet can be modified to include the exact claims generated in the classroom on **slide 7**. If the claims generated by the class are added to the list, make sure to provide students with evidence that supports those claims.

Go to **slide 12**. The teacher will think aloud to the students while evaluating an example of weak evidence and an example of strong evidence. The teacher will ask the students to write down the key points from the teacher's example evaluation (question 7 in the Biomolecule Builders activity sheet). Students answer questions 8 and 9 in the Biomolecule Builders activity sheet.

Teacher's Note: Think Aloud Example

The claim is that marine cryptomonads have the enzymatic machinery to break down purines and recover their nitrogen atoms.

Strong evidence: Cell concentration was high when purines were provided to cells (Table 5). This evidence is strong because it connects high cell concentration (growth) to the cell's ability to get the nitrogen out of pyrimidines. To use this nitrogen, enzymes (cellular machinery) must be present to break the bonds that hold the nitrogen in the pyrimidine structure.

Weak evidence: The marine organisms could grow with some molecules, but not with others.This evidence is weak because it does not address pyrimidines specifically.

Go to **slide 13**. The teacher asks the students what happens when cells grow. Guide discussion to work towards a class definition of growth (question 10 in the Biomolecule Builders activity sheet). At minimum students should determine that:

- The cell will multiply.
- The DNA will be replicated.
- Proteins will be produced to do the work.

Students will draw on the cell picture to illustrate these three points and any additional points the class comes up with.

Go to **slide 14**. Students draw adenylate (question 11 in Biomolecule Builders activity sheet). Have a class discussion to prepare students to explain why people cannot live on glucose alone (question 12 on Biomolecule Builders activity sheet). Ask students to count the number of carbons in glucose and ribose and describe what would have to occur for the glucose to be used as a starting material to build adenylate. An example response is that one carbon would have to be ejected from glucose to form ribose.

Teacher's Note: Example Questions and Answers

- What parts adenylate looks most familiar?
  - The ribose looks similar to glucose.
- What would have to occur for the glucose to be used as a starting material to build adenylate? (Hint: count the number of carbons in glucose and ribose.)
  - One carbon would have to be ejected from glucose.
- What parts of adenylate cannot possibly come from glucose?
  - The phosphate and nitrogen.

Extend

Go to **slide 15**. Tell students that researches have actually already discovered the exact mechanism cells use to convert glucose to ribose to build nucleotides and eventually nucleic acids. Part of the nucleotide synthesis pathway called the pentose phosphate pathway is on slide 12. Give students the instructions below. Students will use the image of the pentose phosphate pathway on slide 12 as a reference to complete steps 1-2 below.

1. In the drawing for question 11 on the Biomolecule Builders Activity sheet, circle the atoms in glucose that are removed in the process of converting glucose to ribose.
2. Draw a red slash across the chemical bonds that were broken when these atoms were removed.

To reinforce the conservation of matter, use the pentose phosphate pathway mechanism to show that the "removed" carbon is ejected as CO_2.

Go to **slide 16**. In steps 1 and 3-9 below, students answer questions 13-20 in the Biomolecule Builders Activity sheet. In step 2, the teacher will give verbal instructions.

1. Answer question 13: What is exchanged in the formation and breaking of chemical bonds? [Answer: energy]
2. Draw an arrow from the answer "energy" to one of the red slashes.
3. Answer question 14: Does breaking complex glucose down into simple CO_2 and ribose release or use energy? [Answer: release]
4. Answer question 15: What example from nature demonstrates this relationship between energy and breaking down molecules? [Answer: When people eat glucose, it is fully formed, but our bodies gain energy by breaking glucose down]
5. Answer question 16: What is it called when a complex molecule is broken up into more simple molecules? [Answer: catabolism]
6. Answer question 17: Does building ribose together with other carbons and nitrogens release or use energy? [Answer: use]
7. Answer question 18: What example from nature demonstrates this relationship between energy and building up molecules? [Answer: Photosynthesis shows that building a sugar requires energy because plants use light energy to build sugars.]
8. Answer question 19: What is it called when simple molecules are used to build a more complex molecule? [Answer: anabolism]
9. Answer question 20: Why is both matter and energy needed from glucose to build new biomolecules? [Answer: Because the C and H are needed for some parts of biomolecules (like the ribose of adenylate) and energy is needed to form chemical bonds to build up new molecules via anabolism.]

Possible misconception #1) Ribose looks more complicated than glucose, so going from glucose to ribose must require energy. To correct this, point out how simple CO_2 is. Possible misconception #2) Breaking bonds should use/require energy. To correct this, ask the student whether breaking down sugar or building a sugar molecule releases energy. Building a sugar requires energy (plants use light energy to do this) but breaking down a sugar releases energy (our bodies do this to get energy).

Go to **slide 17**. Students do the Think, Pair, Share, and the teacher ask the students to correct phrases containing misconceptions discussed during the "share" time. The teacher asks the students if they need further clarification on any phrases they have written.

Sample answer for Think:

Think - write a description of adenylate synthesis using the terms matter, carbon, nitrogen, catabolism, anabolism, and energy. [The matter from glucose changes slightly because a carbon is lost, but the rest of the carbons become part of adenylate. The nitrogen has to come from a different source since glucose molecules do not contain nitrogen.]

Go to **slide 18**. Give the following instructions to students: 1. On a slip of paper, write two misconceptions, questions, or knowledge gaps a student in this class may have about building biomolecules. 2. Select a biomolecule present in marine cryptomonads to find something other than adenylate that can be formed using the glucose hydrocarbon backbone and glycine, urea, and/or purines. 3. In the Biomolecule Builders Activity sheet, prepare a "teacher key" containing the following items:

- 1 min description of the role of that biomolecule in the human body
- explanation of the release of energy from chemical bonds in the catabolism process (specific atoms like C, O, H, N, and P should be mentioned)
- explanation of the use of energy in the anabolism process (state the energy source and in what form it was stored).

The teacher will collect the slips of paper with the misconceptions, questions, or knowledge gaps and a basket.

Example misconceptions, questions, or knowledge gaps:

- Energy is used in catabolism since it is difficult to break chemical bonds right? [No, energy is released because breaking down sugar is what supplies our bodies with energy]
- Our bodies store energy in the form of glucose, so we could survive by eating only glucose. [Energy is only one of the things our body needs. The need for diverse forms of matter (like nitrogen) is not met by glucose intake alone because these molecules contain only carbon and hydrogen and oxygen.]
- Light energy the drives anabolism in human cells right? [No, light energy does drive photosynthesis in plants to anabolize CO_2 and H_2O into sugars, but human cells use chemical energy stored in sugar molecule bonds to drive anabolism. That is why we have to take sugars into our bodies by eating plants.]
- What is a hydrocarbon backbone? [It is the chain of C, O, and H in molecules like glucose]
- Glucose is made of hundreds of different elements right? [No, only C, O, and H are in glucose]
- What types of nitrogen sources can humans take into their systems? [Proteins]
- What types of nitrogen sources can organisms like marine cryptomonads take into their systems? [glycine, urea, and purines]
- What other types of matter besides nitrogen and hydrocarbons are needed to form amino acids like methionine? [Sulfur and nitrogen and phosphorus]
- Why do our bodies synthesize nucleotides? [To make DNA polymers to store genetic information]
- What human body processes could not occur if nucleotides were not synthesized in our cells? [Transcription and cell replication and translation]
- Why do our bodies synthesize amino acids? [To build proteins]
- What human body processes could not occur if amino acids were not synthesized in our cells? [Enzymatic reactions]

Go to **slide 19**. Give students the following instructions: 1. Draw a slip of paper. 2. write a response to the misconception, knowledge gap, or question. 3. pair up and make a video recording the following:

- each give a 1 min presentation of the function of their choice biomolecule
- each look at the other's biomolecule, and explain what would have to occur in the catabolism and anabolism process to build that molecule
- each look at the teacher key and add an extra detail their partner's catabolism/anabolism explanation
- each present the misconception, knowledge gap, or question to the other, give the other a chance to respond, and then help the other completely address it

Evaluate

Students will record the molecule break and build lesson they teach to their partner.

To give opportunity for revision and further mastery of the material, students may write a written explanation to earn back any point lost on the video.

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Resources

- Anita, N.J. & Chorney, V. (1968), Nature of the Nitrogen Compounds Supporting Phototrophic Growth of the Marine Cryptomonad *Hemiselmis virescens* *. The Journal of Protozoology, 15: 198-201. doi:10.1111/j.1550-7408.1968.tb02111.x
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- Think, Pair, Share https://learn.k20center.ou.edu/strategy/139