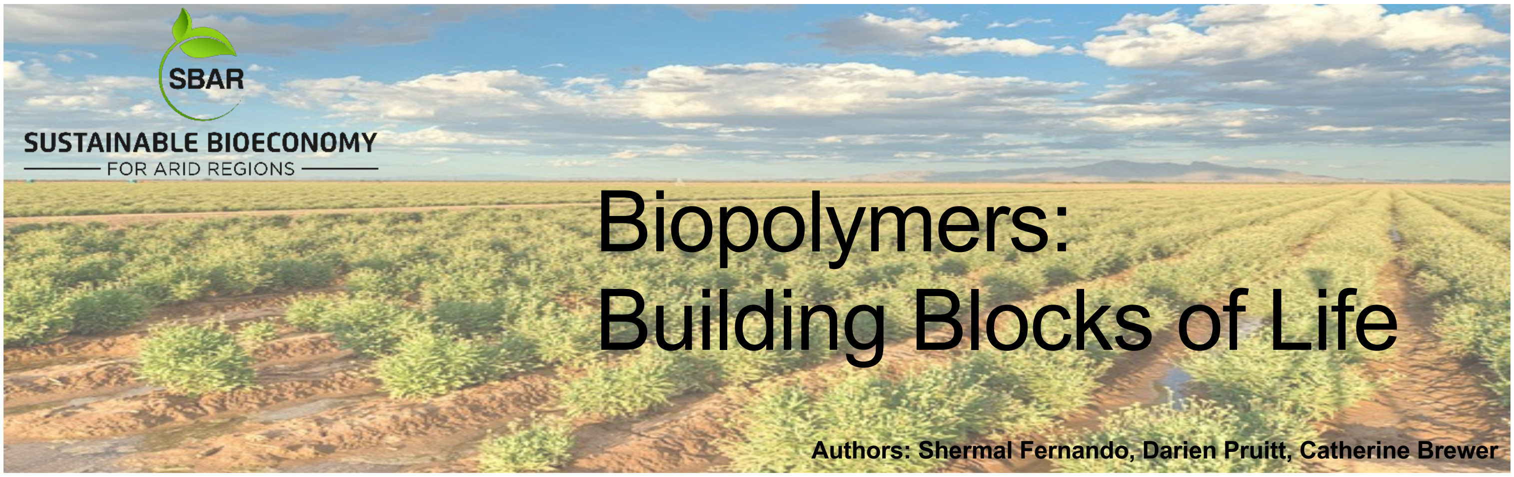

SUSTAINABLE BIOECONOMY FOR ARID REGIONS

Biopolymers: Building Blocks of Life

Authors: Shermal Fernando, Darien Pruitt, Catherine Brewer

Standards

NGSS

>**MS-PS1-3:** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

>**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Cross-cutting Concepts:
>**MS-LS1-2:** Develop and use a model to describe the function of a cell as whole and ways the parts of cells contribute to the function.

Grade Level: 6th – 10th

Materials

> **PowerPoint presentation "Biopolymers: Building Blocks of Life"**

> **Biopolymers Worksheet**

> **Chemical Reaction Decoder**

> **Paperclips for activities**

> **Activity 1: Straight-Chain Polymers**

Each pair of students needs:
50 gray paperclips
30 green paperclips
30 red paperclips

>**Activity 2: Polymers with Bends**

Each pair of students needs:
50 gray paperclips
30 green paperclips
30 red paperclips
30 blue paperclips

Overview

This lesson plan introduces the building blocks of living organisms: monomers and polymers. The activities will give hands-on learning to connect the concepts of structure and function, and to practice data analysis for identifying data descriptors and explaining their meanings. The lesson describes molecular structures to show plants' ability to form complex polymers for energy storage.

Learning Objectives

Students will be able to:

- Define monomers and polymers
- Describe how structure is related to function
- Give examples of polymers
- Name plants that form unique polymers

Vocabulary

- **Average (Mean)**: (noun) a number that is calculated by adding quantities together and dividing the sum by the number of quantities
- **Carbohydrate**: (noun) an organic compound that made of carbon, hydrogen and oxygen that can be found in living organisms and foods and that can be digested by living things to provide energy
- **Function**: (noun) the ability to do a specific task
- **Glucose**: (noun) a simple sugar that is an important energy source for living organisms and can be a component of carbohydrates
- **Glycosidic bonds**: (noun) covalent bonds between carbohydrates and other molecules
- **Median**: (noun) the middle value in a list ordered from smallest to largest
- **Monomer:** (noun) a single molecule that is used to build a chain of molecules; glucose is an example of a sugar monomer that can be used to build cellulose or starch
- **Polymer:** (noun) a chain of many monomers. Polymers can be natural, such as cellulose or starch, or man-made, such as plastics.
- **Polymerization:** (noun) the process of linking monomers together to form polymers
- **Photosynthesis:** (noun) A chemical process that plants and some microorganisms use to transform carbon dioxide and water into carbohydrates and oxygen for energy:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

- **Starch**: (noun) a carbohydrate that is made by plants as a form of stored energy
- **Structure**: (noun) the arrangement of different parts or elements of a complex object that gives a particular shape

Biopolymers: Building Blocks of Life

Set Up

Step 1: For the two activities in this lesson, students will work in pairs. Each pair of students will need a bag of paperclips for each activity. Sort paperclips into small containers or bags, and ensure they are well mixed.

a. For Activity 1, Building Straight-Chain Polymers, each pair will need one container with a mix of paperclips: 50 grey, 30 green, and 30 red.
b. For Activity 2, Building 2-D Polymers with Bends, each pair will need one container with a mix of paperclips: 50 grey, 30 green, 30 red, and 30 blue.

Step 2: Set up "Biopolymers: Building blocks of life" PowerPoint for presentation to the class. Provide each student with the Building Polymers Worksheet.

Online Format: For online/remote lesson delivery, follow the notes in the lesson plan and the process outlined on the PowerPoint slides. Synchronous delivery is recommended for the entire lesson. For the two activities, provide paperclips to students or instructions on paperclip requirements.

Lesson Procedure

Part 1: Overview of Polymers and Activity 1: Building Straight Chain Polymers (40 to 50 minutes)

Begin "Biopolymers: Building Blocks of Life" PowerPoint Presentation.

Slide 2: Discuss the questions on the slide with the class. Help students connect how the hammer is structured to make the "job" (function) of the hammer effective.

Slide 3: Introduce the vocabulary used in this lesson: monomer, polymer, and polymerize.

Slide 4: **Activity 1: Building Straight-Chain Polymers (25 to 30 minutes)**

Review the rules on slides 4 and 5. Explain the following to students:

In this activity, polymerization is the straight chain-making process by linking the paper clips as molecular pieces, monomers, together. "Monomer" means "one piece". There are similar words based on "mer": "dimer" (pronounced dye-mer) is "two pieces," "trimer" (pronounced try-mer) is "three pieces,", and "polymer" is "many pieces." The stages of the polymerization reaction are initiation (start), lengthening, and termination (end). After the 10-minute polymerization reaction time, the created polymers will be characterized by size and shape.

1. Divide students into pairs. Each pair receives one container of the mix of 50 grey paperclips, 30 green paperclips, and 30 red paperclips (see setup for details). The container makes it easier for the paperclips to be well mixed and for the students to pick paperclips at random for a more realistic "reaction".
2. Have students select 5 green paperclips from their containers and set them on their work surface in a vertical row. Green paperclips are "initiators" and represent the start of a polymer chain.
3. Explain that once the reaction starts, students will randomly draw paperclips, one at a time, from their containers and follow the paperclip rules. They will add pieces "evenly" to the available chains based on the following rules:
    a. Green paperclips start a new chain.
    b. Red paperclips are "terminators" and represent the end of the chain. As soon as a chain is terminated, students will set that chain aside and not add any more paperclips to it.
    c. Grey paperclips are "regular" monomers and are used to lengthen the chains.
4. Confirm that students understand the rules and have their 5 green paperclips ready to start. Set a timer for 10 minutes and tell the students to begin. Circulate among students to check for understanding.
5. When the timer goes off, signifying that the reaction has ended, tell the students "STOP".

6. **Slide 5 - 6**: **Data Analysis**: Have students arrange their chains by size on their work surface from smallest to largest.
7. Determine the average (mean), minimum, maximum, and median of the chain lengths.
    a. Provide the definitions for the data analysis from the PowerPoint presentation.
    b. For the determination of the median, make sure the students sort the chains from shortest to longest. If the students have an odd number of chains at the end of the activity, the median would be the chain in the middle. If students get an even number of chains, the median is calculated as the average of the two chain lengths in the middle. (For example, if a student has 6 chains, the median is calculated by taking the average of the number of paperclips in the 3^{rd} and 4^{th} chains, using the average formula.)
8. Have the students complete the Activity 1 Data Table portion of the worksheet with their data.

Lesson Procedure (*continued*)

9. (Optional) Use the collections of polymers that the students have made to expand on data analysis and sorting. For example, students could calculate the mean, median, minimum and maximum for all of the polymers made by the class. Students could also use their chains to build a physical chart of polymer size distribution on a table or the floor using masking tape to mark the axes.

Part 2: Learning about polymers (15 to 20 minutes including setup)

Continue Biopolymers: Building Blocks of Life PowerPoint Presentation on slide 8.

Slide 7: After the activity, reintroduce the vocabulary used in this lesson: monomer, polymer, and polymerize. Ask the students to answer the questions on the slide (*saccharide is monomer, rubber is a polymer).*

Slide 8: Explain that photosynthesis is the process where a plant uses sunlight/light source, carbon dioxide (CO_2) and water (H_2O) to produce glucose and oxygen (O_2). The glucose is the monomer that a plant can use to make starch (a polymer).

Slide 9: Explain that plants can form polymers with different structures using glucose monomers that enable different functions. For example, plants form long, straight chains of glucose that can be stacked on top of each to form strong structures so that the plant can stand up straight against gravity. Emphasize the diagram on the slide for better representation of the structure.

Slides 10: Explain that plants use the excess glucose produced during photosynthesis to produce starch, the plants' reserve food source. The "n" is the number of glucose monomers that are linked to form the starch molecules.

Slide 11: Show that glucose is a monomer and starch is a polymer that is made from glucose monomers (a polysaccharide, that is a "many sugars").

Slide 12 - 14: Guar (*Cyamopsis tetragonoloba*) and guayule (*Parthenium argentatum*) are plants that produce special polymers that have special functions. Guar gum powder is a polysaccharide like starch but is made from a different combination of monomers. Guar guam is used in ice cream and other foods as a thickener. Guayule produces natural rubber, a polymer called polyisoprene ("many isoprenes") that can be used for tires or latex gloves.

After introducing guayule, explain that the natural rubber from guayule (*Parthenium argentatum*), and Hevea rubber trees (*Hevea brasiliensis*), are made from a monomer called n-isoprene monomer to form polyisoprene (rubber). Show the reaction and explain that large numbers (thousands) of n-isoprene monomers are needed. The rubber in guayule is found just under the bark of the guayule stems. Guayule is also a special plant for sustainability in dry regions since it needs less water and fertilizer than many other crops.

Slide 15: Show that ethylene is another example of a monomer. Polyethylene plastic products are polymers made from thousands of ethylene molecules.

Slide 16: Repeat the questions to the students about the function of the hammer and the structure of the hammer. This is the introduction to the concept that different polymer structures have different functions.

Slide 17: To link the structures built in the paperclip activity relate to polymers, explain that some starch polymers are formed as branched structures and other starch polymers are formed as linear chains. The different structures will result in different function.

Slide 18: Explain that the branched starch structure has more ends for enzymes to "attack" to break down the starch into glucose to provide quick energy for the plant. The linear chains can only be "attacked" on the two ends, so they are not intended to be broken down quickly.

Lesson Procedure (*continued*)

Part 3: Activity 2: Building 2-D Polymers with Bends (30 to 45 minutes)
Continue "Biopolymers: Building Blocks of Life" PowerPoint Presentation beginning with slide 19.

Slide 19 – 21: Remind students of the first paperclip building activity. For this activity, students will add blue paperclips to create 90-degree turn, or bends, in their polymers and will conduct another data analysis after the 10-minute reaction time. Note: do not *bend* any paperclips (no paperclips should be hurt in this experiment).

1. Divide students into pairs. Each pair receives one container of the mix of 50 grey paperclips, 30 green paperclips, 30 red paperclips and 30 blue paperclips (see setup for details). The container makes it easier for the paperclips to be well mixed and for the students to pick paperclips at random for a more realistic "reaction".
2. As before, Have students select 5 green paperclips from their containers and set them on their work surface in a vertical row. Green paperclips are "initiators" and represent the start of a polymer chain.
3. Explain that once the teacher says go, students will randomly draw new paperclips, one at a time, from the container and follow the paperclip rules. They can add pieces "evenly" to the available chains based on the following rules:
    a. Green paperclips start a new chain.
    b. Red paperclips are "terminators" and represent the end of the chain. As soon as a chain is terminated, students will set that chain aside and not add any more paperclips to it.
    c. Grey paperclips are "regular" monomers and are used to lengthen the chains.
    d. Blue paperclips create a 90-degree bend to the chain. After the "bend", the chain will continue in a straight line unless another blue paperclip is added.
    e. Remind students to create a bend in their chains, <u>not</u> *bend* the actual paperclips.
4. Select 5 green paperclips from the container and set them on the work surface in a vertical row. Green paperclips are "initiators" and represent the start of every chain.
5. Confirm that students understand the rules and have their 5 green paperclips ready to start. Set a timer for 10 minutes and tell the students to begin. Circulate among students to check for understanding.
6. When the timer goes off, signifying that the reaction has ended, tell the students "STOP".

7. **Slide 22**: **Data analysis**: Have students sort their chains by the number of bends in each chain (i.e. no bends, 1 bend, 2 bends, 3 bends, etc.). Once the chains are sorted, have the students arrange chains within each group from shortest to longest based on the number of paperclips in each chain.
8. Ask the students to complete the Activity 2 Data Table portion of the worksheet with their data.
    a. The objective is to fill out the table accounting for both the number of bends and the chain lengths.
    b. Encourage the students to fill out their tables in pencil and to double check that they have carefully analyzed the number of bends and the number of paperclips. (For example, if a student has three chains that each contain one bend and five paperclips, that student should put a "3" the table under column 1 and row 5 of the Activity #2 data analysis worksheet.)
9. (Optional) As before, use the collections of polymers that the students have made to expand on data analysis and sorting. For example, students could create the bend and chain length table for the whole class by piling their chains into a table on the floor marked off with masking tape.

10. **Slide 23**: Explain that starch is used to store energy in plants. Explain that the two structures, amylose chains and amylopectin chains, store energy in different ways: amylose chains are spiral-shaped and can compact tightly to pack lots of energy into a smaller space, while amylopectin chains are very branched to provide many places to enzymes to break the chain down for quick energy release.

11. **Slide 24**: Ask the questions on the slides:
    a. What else do we make (products) from plants? (*medicine, soaps, textiles, furniture*)
    b. How did the plants make these materials?
        i. Furniture: Tree trunks/parts of a tree are milled, sawed, planed, sanded, and assembled with glue and screws.
        ii. Medicine: From turmeric or mint plants, the leaves or branches are ground to get the essential bio-active (medicinal) components
        iii. Soap: Plants with high concentration of saponins (such as yucca) can be used to produce soap and shampoo.
        iv. Textiles: The seeds and fruit of plants are often attached to hairs or fibers or encased in a husk that may be fibrous, such as cotton, coir, and kapok. These fibers are used to make textiles/clothes
    c. What other polymers do we use that are <u>not</u> made by plants? (*nylon, polyethylene, epoxy, polyester, Teflon*)