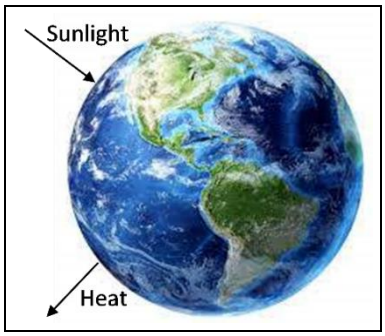
Carbon Cycles and Energy Flow through Ecosystems and the Biosphere[1]

The biosphere includes all of the Earth's organisms. Life in the biosphere depends on a continuous inflow of energy from the sun.



1a. Suggest a hypothesis to explain why life in the biosphere needs a continuous inflow of energy.

1b. Life in the biosphere requires carbon atoms. However, the biosphere does *not* receive an inflow of carbon atoms. Suggest a hypothesis to explain how life in the biosphere continues without an inflow of carbon atoms.

To better understand why the biosphere needs an inflow of energy, but not carbon atoms, we need to review three biological processes that transform energy and carbon-containing molecules.

In **photosynthesis**, plants use the energy from sunlight to make sugar molecules from CO_2 and H_2O.

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

$$\text{Sunlight} \longrightarrow \text{Chemical energy + heat}$$

The upper box shows changes in how the atoms are organized in molecules. The lower box shows the associated energy changes.

2a. Circle the sugar molecule (glucose) in the chemical equation for photosynthesis.

2b. Explain how photosynthesis illustrates the following general principle.
Atoms are neither created nor destroyed in biological processes.

2c. Explain how photosynthesis illustrates the following general principles.
Energy is neither created nor destroyed in biological processes, but energy can be transformed from one type to another. During energy transformations and transfers, some of the input energy is transformed to heat energy.

These equations summarize how **cellular respiration** produces ATP.

3a. Why do cells need ATP?

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

$$\sim 29\ ADP + \sim 29\ P \longrightarrow \sim 29\ ATP + \sim 29\ H_2O$$

$$\text{Chemical energy} \longrightarrow \text{Chemical energy + heat}$$

The curved arrows represent coupled chemical reactions; the top reaction provides the energy needed for the second reaction.

3b. How does glucose contribute to the production of ATP?

3c. What process produces the glucose that plant cells use for cellular respiration?

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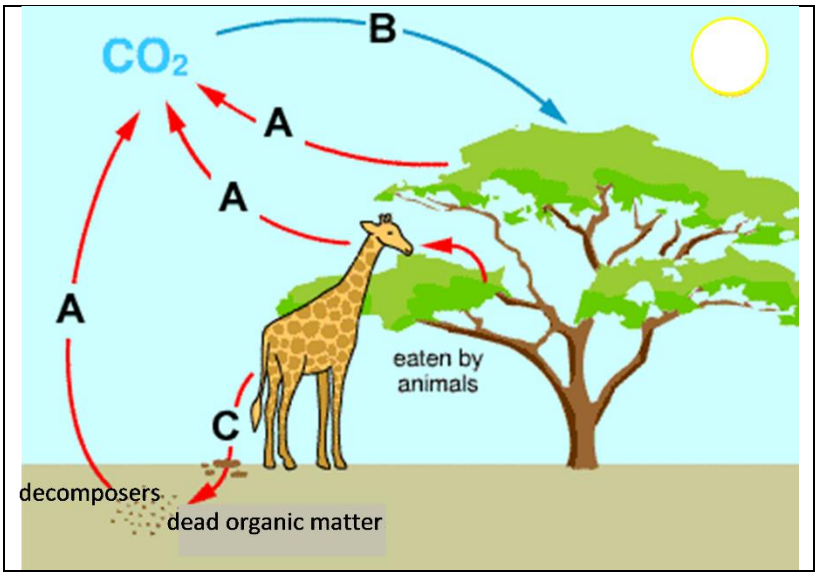
[1] By Dr. Ingrid Waldron, Dept Biology, University of Pennsylvania. © 2024. This Student Handout and the Teacher Notes with instructional suggestions and background information are available at https://serendipstudio.org/exchange/bioactivities/carboncycle.

Biosynthesis makes the many different types of organic molecules in an organism. Biosynthesis in plants uses some of the sugar molecules produced by photosynthesis, plus minerals from the soil. Animals and decomposers use digested food molecules as inputs for biosynthesis.

In a **carbon cycle**, carbon atoms cycle between CO_2 in the air and organic molecules in living organisms or in dead organic matter. The figure below shows a carbon cycle that includes a simple food chain. Questions 4-5 will help you understand how photosynthesis, cellular respiration, and biosynthesis contribute to carbon cycles.

4a. The B arrow shows CO_2 entering a plant. How do the carbon atoms in CO_2 become carbon atoms in organic molecules in the plant?



4b. The A arrows show CO_2 leaving the plant, animal and decomposers. How do carbon atoms in the organic molecules of plants, animals and decomposers become carbon atoms in CO_2?

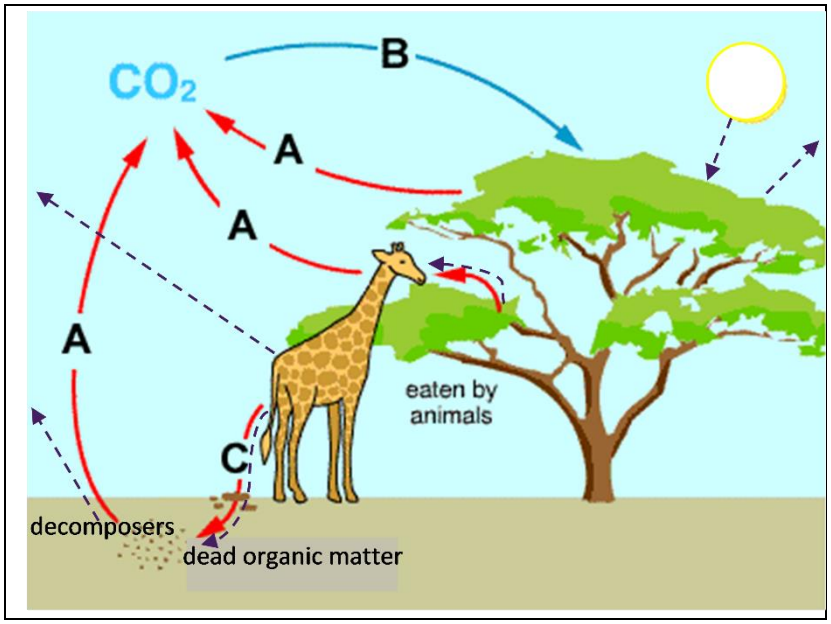
4c. The C arrow leads to dead organic matter via death or feces. Add another C arrow to show part or all of the tree dying and becoming dead organic matter.

5a. In the figure, circle the letters for the arrow from the giraffe and the arrow to the tree.

5b. Explain how a carbon atom in an organic molecule in a giraffe could become a carbon atom in an organic molecule in a tree. (Hint: Use the information in the figure and in your answers to questions 4a and 4b.)

5c. Explain how a carbon atom in dead organic matter could become a carbon atom in a giraffe.

In this figure, energy flows have been added to the carbon cycle (see dashed arrows). This figure doesn't show the energy transformations and transfers inside living organisms. For example, photosynthesis transforms light energy to chemical energy. Cellular respiration transfers chemical energy from sugars to ATP.



6a. Each energy transformation or transfer produces _____, which is radiated away from the biosphere.

6b. Label each dashed arrow in the above figure with one of these abbreviations:

S = arrow that shows the inflow of light energy from the sun.
CE = arrows that show chemical energy moving from one trophic level to another.
H = arrows that show that biological processes produce heat, which leaves the organisms and ultimately is radiated out to space.

7a. Explain how the sun's energy can be transformed and transferred to provide the energy that a giraffe uses to move. Be specific about the multiple steps that are required.

7b. In your answer to question 7a, underline at least three processes that produce heat.

8a. Explain why life in the earth's biosphere needs a continuous inflow of energy.

8b. How can life continue in the earth's biosphere without an inflow of carbon atoms?