4. Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

   (a) The atmosphere is one important carbon reservoir.

      (i) **Describe** a biological process by which carbon is removed from the atmosphere and converted to organic molecules.

      (ii) **Describe** a biological process by which carbon is converted from organic molecules to a gas and returned to the atmosphere.

   (b) Oceans and terrestrial systems are also important carbon reservoirs.

      (i) **Explain** how atmospheric carbon is incorporated into two oceanic sinks.

      (ii) **Identify** one terrestrial sink, other than fossil fuels, that stores carbon for thousands to millions of years.

   (c) The burning of fossil fuels has been shown to increase the concentration of carbon in the atmosphere. **Discuss** TWO other human activities that increase the concentration of carbon in the atmosphere.

   (d) **Identify** an environmental problem that results from elevated atmospheric carbon concentrations. **Discuss** one consequence of the problem you identified.

   (e) Phosphorus is another element important to all organisms.

      (i) **Describe** one major way in which the phosphorus cycle differs from the carbon cycle.

      (ii) **Identify** one reason that phosphorus is necessary for organisms.

STOP

END OF EXAM

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Question 4

(a) The atmosphere is one important carbon reservoir.

(i) Describe a biological process by which carbon is removed from the atmosphere and converted to organic molecules.
(1 point for a correct description, with or without an equation: A student can earn the point even without explicitly identifying the process as photosynthesis if an accurate description is provided. No point is earned for naming photosynthesis without a description)

Example:
Photosynthesis: the process by which plants/autotrophs take in carbon dioxide from the atmosphere and convert it into food/glucose/sugar/complex carbohydrates; plants/autotrophs fix carbon into food/glucose/sugar/complex carbohydrates.

(ii) Describe a biological process by which carbon is converted from organic molecules to a gas and returned to the atmosphere.
(1 point for a correct description: A student can earn the point even without explicitly identifying the process if an accurate description is provided. No point is earned for listing a word as an answer; the answer must identify the form of carbon being released into the atmosphere as part of the description)

- Respiration breaks down food/glucose/sugar/complex carbohydrates and releases CO_2 into the atmosphere
- Animals digest food and produce gases such as methane that can be emitted either through belching or flatulence
- Decomposition of organic material by bacteria or fungi converts organic carbon into gases such as methane

(b) Oceans and terrestrial systems are also important carbon reservoirs.

(i) Explain how atmospheric carbon is incorporated into two oceanic sinks.
(2 points: 1 point for each correct description of carbon incorporation into an oceanic sink. Only the first two descriptions can earn points)

- Carbon (CO_2) can be taken up by organisms like phytoplankton for photosynthesis
- Carbon can be taken up by marine organisms and used for shells, skeletons, coral, etc.
- Biological pump (organisms in the upper ocean sink to the bottom of the ocean)
- Atmospheric CO_2 can dissolve directly into ocean water **OR** atmospheric CO_2 can dissolve into precipitation and ultimately reach the ocean
- Carbon can react with other elements/compounds and form carbonates/limestone/sedimentary rocks (just "rocks" is too vague to earn a point)

Question 4 (continued)

(ii) Identify one terrestrial sink, other than fossil fuels, that stores carbon for thousands to millions of years.
(1 point for the correct identification of a long-term terrestrial sink of carbon)

- Old growth forests/trees that live for thousands of years (just "forests" does not earn credit)
- Trapped/incorporated into ice caps/glaciers
- Limestone or sedimentary rocks
- Incorporation into soil
- Freshwater wetlands/bogs
- Peat formation/burial of plant material under anaerobic conditions
- Dissolved in aquifers

(c) The burning of fossil fuels has been shown to increase the concentration of carbon in the atmosphere. Discuss TWO other human activities that increase the concentration of carbon in the atmosphere.
(2 points: 1 point for each accurate discussion of a human activity that increases atmospheric carbon compounds NOT related to burning fossil fuels)

- Deforestation—cutting down trees reduces the reservoirs for carbon **OR** cutting down trees can result in carbon being released back into the atmosphere through the process of decay/decomposition
- Biomass burning releases carbon (CO, CO_2, carbon particulates)
- Trash/waste incineration can release carbon (CO_2, CO, carbon particulates)
- Slash and burn agricultural practices—burning organic matter releases carbon (CO_2, CO, carbon particulates)
- Deep plowing or strip mining disrupts soil and releases carbon (CO_2)
- Humans make landfills that can produce carbon-containing carbon-based gases (mainly methane)
- Raising cows and/or other ruminant animals releases carbon-containing gases (methane)
- Manufacture and use of CFCs/HCFCs/other carbon-containing compounds releases carbon
- Destruction of wetlands (releases CO_2/removes sink for CO_2)
- Production of cement releases CO_2

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Question 4 (continued)

(d) Identify an environmental problem that results from elevated atmospheric carbon concentrations. Discuss one consequence of the problem you identified.
(2 points: 1 point for identification of a specific environmental problem associated with elevated atmospheric carbon and 1 point for discussion of a consequence of the identified problem)

(Note: The discussion of a consequence must be connected to the stated environmental problem and must be connected to the environment. Examples of environmental problems and consequences are shown in the table below.)

Environmental problem	Environmental Consequence
Global climate change/global warming/increased global temperatures	• some species of plants and/or animals will not be able to survive temperature changes • climate zones will shift so some species may not be able to adapt • sea level rise which will flood habitats
Sea level rise	• coastal habitats will be flooded
Ice caps/glaciers melting	• flooding and habitat loss
Ocean acidification	• shells of marine organisms may dissolve • lower pH may be below the tolerance level of some species
Reduction in air quality due to (for example) increased CO in the atmosphere	• hazardous to animals breathing it in

(e) Phosphorus is another element important to all organisms.

(i) Describe one major way in which the phosphorus cycle differs from the carbon cycle.
(1 point for a correct description of a difference between the phosphorus and carbon cycles)

- Phosphorus cycle does not typically have a gas/atmospheric phase
- It is more difficult for living organisms to access phosphorus since it has to be weathered from rocks and minerals (phosphorus cycle is much "slower" than the carbon cycle; phosphorus has fewer sinks than carbon)

(ii) Identify one reason that phosphorus is necessary for organisms.
(1 point for a correct reason that phosphorus is necessary for organisms)

- Phosphorus is a component of nucleotides/ATP in cells
- It is necessary for the formation of DNA and RNA
- Phospholipids are a major component of all cell membranes
- Phosphorus is found in/gives strength to the bones and/or enamel of teeth in mammals