NO PREP

The Ocean's Carbon Cycle

Biological Pump and Sequestration

Includes: Student reading, case study, differentiated questions, teacher key

Name: Period: Date:

The Ocean's Carbon Cycle: Biological Pump and Sequestration

The Carbon Cycle in the Ocean

The carbon cycle is one of Earth's most important systems, and the ocean plays a central role in it. While forests on land are often called the "lungs of the planet," the ocean absorbs more carbon than all terrestrial ecosystems combined. Roughly one-quarter of the carbon dioxide (CO_2) released by human activity each year is absorbed by seawater. Without this oceanic uptake, Earth's atmosphere would contain much more CO_2, and climate change would be far more severe. Carbon in the ocean moves through a network of physical, chemical, and biological processes. At the surface, CO_2 dissolves directly from the atmosphere into seawater. From there, marine organisms, especially phytoplankton, use it for photosynthesis, producing oxygen and organic

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How the Biological Pump Works

The biological pump is a natural conveyor system that transports carbon from surface waters to the deep ocean. When phytoplankton take up CO_2, they incorporate it into organic matter. Some of this carbon is consumed by zooplankton and higher organisms, fueling marine food webs. But not all carbon remains in circulation near the surface. When plankton die, their bodies, along with fecal pellets and other organic debris, sink toward the seafloor. As they sink, some material is decomposed by bacteria, releasing CO_2 back into the water. However, a significant portion continues downward. Once carbon reaches deep waters, it can remain trapped there for hundreds to thousands of years. This long-term storage is what makes the biological pump so vital for climate regulation. If the pump were to weaken, more CO_2 would remain in the atmosphere, accelerating global warming. Conversely, if it strengthens, the ocean can act as an even greater carbon sink, slowing

climate change. Understanding this system helps scientists predict how human actions will shape Earth's future climate.

Carbon Sequestration and Climate Stability

When carbon is transported to the deep ocean, it undergoes sequestration—long-term storage away from the atmosphere. Sequestered carbon may remain in deep waters or eventually be buried in marine sediments, where it can stay locked for millions of years. These processes are part of Earth's natural thermostat, regulating atmospheric CO_2 over geologic time. Humans are now investigating ways to enhance carbon sequestration artificially, such as fertilizing the ocean with iron to stimulate phytoplankton growth. While experiments show this can increase CO_2 uptake, the long-term ecological impacts are uncertain. Altering delicate marine systems could have unintended consequences, and most scientists caution that natural processes should not be manipulated lightly. What is clear, however, is that the biological pump and sequestration processes are essential in moderating climate change. Without them, atmospheric CO_2 would climb at an even faster rate, and Earth's climate would be far less stable. This table highlights how carbon moves through different ocean processes, with storage times ranging from short-term recycling to geological-scale sequestration.

Key Information: Table: Carbon Pathways in the Ocean

Process	Mechanism	Carbon Storage Time
Dissolution	CO_2 dissolves from atmosphere into ocean	Days to years
Photosynthesis	Phytoplankton absorb CO_2	Hours to weeks
Biological Pump	Organic matter sinks to deep ocean	Hundreds to thousands of years
Sequestration in Sediments	Burial of carbon in seafloor sediments	Millions of years

Case Study: The Southern Ocean as a Carbon Sink

The Southern Ocean, surrounding Antarctica, is one of the most important regions for carbon sequestration. Strong winds and upwelling bring nutrient-rich waters to the surface, fueling massive phytoplankton blooms. These blooms absorb large amounts of CO_2 during photosynthesis. When the plankton die, their remains sink, carrying carbon to the deep ocean. Research shows that the Southern Ocean alone may account for as much as 40% of the global ocean's carbon uptake. This makes it a critical region in regulating Earth's climate. However, the system is sensitive. Warming temperatures, melting sea ice, and changes in circulation patterns threaten to alter how effectively carbon is stored. If the pump weakens in this region, atmospheric CO_2 could rise much faster. The Southern Ocean illustrates how local processes can have global consequences. Protecting and understanding such regions is essential for predicting climate change and designing solutions.

1. Why does the Southern Ocean absorb so much carbon compared to other regions?

_____

_____

2. How might climate change reduce the effectiveness of the Southern Ocean as a carbon sink?

_____

_____

Multiple Choice

1. What is the biological pump?

    a) The process of storing CO_2 in the roots of land plants

    b) The release of carbon from volcanic vents

    c) The mixing of oxygen into deep water

    d) The sinking of organic carbon from surface waters

2. Which region absorbs the largest share of oceanic CO_2?

a) The Arctic Ocean

b) The Southern Ocean

c) The Mediterranean Sea

d) The Indian Ocean

3. Why is carbon sequestration in sediments significant?

a) It allows CO_2 to be recycled back to the surface quickly

b) It locks carbon away for millions of years

c) It increases surface productivity

d) It prevents phytoplankton blooms

Matching

Write the letter of the correct definition on the line next to each term.

Term	Definition
1. ___ The ocean region taking in 40% of absorbed CO_2	A) Photosynthesis
2. ___ Conversion of CO_2 into organic matter by plankton	B) Dissolution
3. ___ Long-term burial of carbon in seafloor layers	C) Biological pump
4. ___ Process where sinking material transfers carbon to deep ocean	D) Southern Ocean
5. ___ Uptake of CO_2 directly from atmosphere into seawater	E) Sequestration

Fill-in-the-Blank

1. The movement of carbon from surface waters to the deep ocean is called the _____.

2. Phytoplankton use _____ to fuel photosynthesis in the ocean.

3. Burial of carbon in _____ keeps it stored for millions of years.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why is the biological pump critical for regulating Earth's climate?

2. How does carbon sequestration in the deep ocean differ from sequestration in sediments?

3. Why do some scientists caution against artificially fertilizing the ocean to increase sequestration?