NO PREP

Nitrogen and Phosphorus in the Ocean

Vital Nutrient Cycles

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

Name: Period: Date:

Nitrogen and Phosphorus in the Ocean: Vital Nutrient Cycles

Why Nitrogen and Phosphorus Matter

Marine ecosystems depend on nutrient cycles to supply the building blocks of life. Among the most critical nutrients are nitrogen (N) and phosphorus (P). These elements are essential for producing proteins, DNA, and energy molecules like ATP. Without them, marine productivity would collapse. Even though nitrogen gas (N_2) makes up about 78% of Earth's atmosphere, most organisms cannot use it directly. Instead, nitrogen must be "fixed" into forms such as ammonium (NH_4^+), nitrate (NO_3^-), or nitrite (NO_2^-) through microbial processes. Similarly, phosphorus comes mainly from rock weathering on land, transported by rivers to the

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The Nitrogen Cycle in the Ocean

The marine nitrogen cycle is complex, involving several transformations: Nitrogen fixation: Specialized bacteria and archaea convert N_2 into ammonium. Nitrification: Ammonium is oxidized into nitrate and nitrite. Assimilation: Phytoplankton absorb nitrate and ammonium to build organic matter. Denitrification: In oxygen-poor zones, microbes convert nitrate back into N_2 gas, releasing it into the atmosphere. These processes maintain balance, but they are sensitive to environmental changes. For example, oxygen minimum zones often promote denitrification, reducing the pool of available nitrogen. Human activities, such as fertilizer use, also disrupt the cycle by adding excessive nitrogen, fueling algal blooms and hypoxic zones.

The Phosphorus Cycle and Ocean Productivity

Unlike nitrogen, phosphorus has no gaseous phase. Its main source is weathered rock that delivers phosphate ions (PO_4^{3-}) into rivers and eventually the ocean. Once in the ocean, phosphate cycles between organisms and sediments. When phytoplankton die, phosphorus

can sink and accumulate in the seafloor. Over geological time, these deposits may eventually uplift to form new rock. Phosphorus is often the ultimate limiting nutrient in marine systems because of its slow input compared to nitrogen. While nitrogen can be fixed from the atmosphere, phosphorus depends on erosion and river transport. This means that regions with low phosphorus can remain unproductive even if nitrogen is abundant. Together, the nitrogen and phosphorus cycles regulate where and when marine ecosystems flourish. Disruptions to these cycles not only affect local waters but also alter the global carbon cycle, since nutrient availability controls how much carbon phytoplankton absorb.

Key Information: Table: Key Steps in Marine Nitrogen and Phosphorus Cycles

Cycle	Key Process	Description	Impact on Ecosystems
Nitrogen	Fixation	$N_2 \rightarrow NH_4^+$ by microbes	Adds usable nitrogen
Nitrogen	Denitrification	$NO_3^- \rightarrow N_2$ in low-oxygen zones	Removes nitrogen pool
Nitrogen	Assimilation	Uptake of nitrate by phytoplankton	Fuels productivity
Phosphorus	River input	Weathered rock delivers phosphate	Supplies base nutrient
Phosphorus	Sediment storage	Phosphate sinks into seafloor	Long-term nutrient lock

Case Study: Phosphorus Runoff and the Baltic Sea

The Baltic Sea has long struggled with nutrient pollution, particularly phosphorus. Agricultural fertilizers, sewage, and industrial waste release large amounts of phosphorus into rivers that flow into the sea. Once there, phosphorus stimulates the growth of algae. While some algae are harmless, massive blooms block sunlight and reduce oxygen as they decay. The result is eutrophication, where large areas of the sea become hypoxic and unsuitable for many species. One major challenge with phosphorus is that it cycles slowly. Even when inputs are reduced, phosphorus stored in sediments can leak back into the water, continuing to fuel blooms for decades. This "legacy phosphorus" makes recovery difficult. For countries around the Baltic Sea, managing phosphorus pollution has required international cooperation, stricter regulations, and improved farming practices. This case study demonstrates how human changes to nutrient cycles ripple through ecosystems, threatening biodiversity and the people who rely on fisheries. It also shows that once nutrient cycles are disrupted, solutions are not quick or easy.

1. Why does phosphorus pollution remain a problem in the Baltic Sea even after fertilizer inputs are reduced?

_____

_____

2. What are some ecological impacts of eutrophication in marine ecosystems?

_____

_____

Multiple Choice

1. Why can't most organisms use atmospheric nitrogen directly?
    a) It dissolves poorly in water and becomes inaccessible
    b) It reacts too quickly with oxygen
    c) It must first be converted into usable compounds
    d) It is toxic in its natural form

2. What is one major difference between the nitrogen and phosphorus cycles?

a) Phosphorus is recycled much faster than nitrogen in seawater

b) Nitrogen has a gaseous phase, phosphorus does not

c) Only nitrogen is essential for life

d) Phosphorus comes mainly from atmospheric inputs

3. Which process removes nitrogen from the marine environment and returns it to the atmosphere?

a) Nitrification

b) Nitrogen fixation

c) Denitrification

d) Assimilation

Matching

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

Term	Definition
1. ___ Conversion of nitrogen gas into ammonium	A) Assimilation
2. ___ The ultimate limiting nutrient in many oceans	B) Weathering
3. ___ Microbial process in oxygen-poor waters that removes nitrogen	C) Nitrogen fixation
4. ___ Main source of phosphorus for the ocean	D) Denitrification
5. ___ Uptake of nitrate by phytoplankton	E) Phosphorus

Fill-in-the-Blank

1. The process of _____ converts atmospheric nitrogen into forms usable by life.

2. Excess nutrients entering the ocean often lead to _____, or algal blooms.

3. Unlike nitrogen, phosphorus has no _____ phase.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why is phosphorus considered the ultimate limiting nutrient in many marine ecosystems?

2. How do human activities disrupt the nitrogen cycle in the ocean?

3. Why is managing nutrient cycles important for sustaining global marine productivity?