

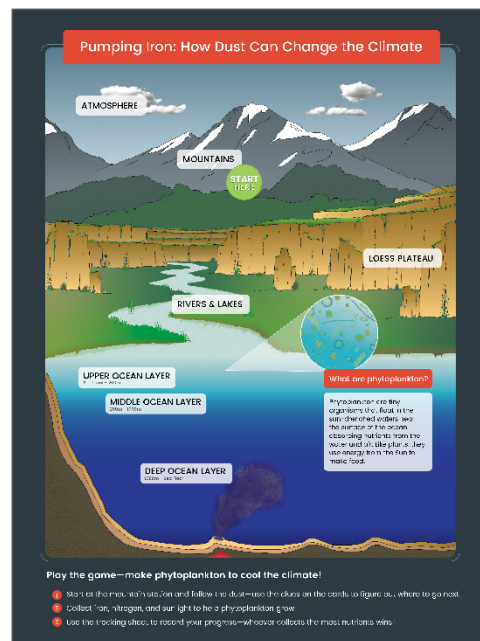
Pumping Iron: How Dust Can Change the Climate

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Pumping Iron is a station-based game meant to illustrate the movement of dust throughout different parts of the Earth system and the effects on the climate when iron-rich dust settles into the ocean and stimulates phytoplankton growth, which then leads to the drawdown of carbon dioxide from the atmosphere through photosynthesis.

Players draw cards and are sent to different stations, collecting nutrients that phytoplankton need to live along the way - iron, nitrogen, and sunlight. Whoever has collected the most nutrients wins! But players might get stuck at the bottom of the ocean, become part of a cloud, or be eaten by a whale along the way.

The game will take ten or more minutes to play, including about three minutes to explain gameplay, 5-7 minutes to play the game, and 2-3 minutes for the conclusion.



Required Materials

*Print materials listed below can be downloaded as pdf files from the Exploring Atmospheric Dust and Climate website: scied.ucar.edu/atmospheric-dust-climate

- **Introduction Poster:** is the visual anchor for how the stations fit together as a system.
- **Station Signs:** (7 total) able to stand up on a tabletop or floor.
- **Game Cards:** (cards that match each station) provide instructions for how to move through the game.
- **Card Placement Mats:** (7 total) show where to place the draw pile and discard pile at each station.
- **Tracking Sheet:** one ½ sheet per player (could be a paper consumable or laminated for write-on/wipe-off reusability); allows players to track which stations they have visited and keep track of nutrients they have collected throughout the game.
- **Conclusion Sign:** provides wrap-up and connection between dust, phytoplankton, and climate.
- **Golf pencils or dry erase pens:** one for each player; to record on the tracking sheet.

Additional Materials:

**additional materials are optional but recommended*

- Small clipboards (6"x9") to use with the tracking sheet
- Small baskets to keep the draw piles and discard piles organized
- Easel or stand to display the Introduction Poster
- Sign holders (horizontal/landscape orientation) for station signs

Tip: using small baskets to hold the card decks will help keep the stations tidy. Print out extra copies of the card placement mat and cut out the picture showing where to place the cards. Tape into the bottom of the baskets.



Instructions for set up

- The *Pumping Iron* game requires enough space for multiple players to move easily between stations throughout the game. The picture (below) shows stations set up along one side of a long table, but other options include using two tables arranged in an L-shape or parallel, or even three tables in a U-shape.



- Display the Introduction poster in a place that is easy to gather players around for instructions, such as on an easel or stand, or leaning up against a wall.
- Place the station sign, card placement mat, and matching card deck at each station.
- Have tracking sheets and pencils ready for players, ideally on small clipboards.
- Keep the conclusion sign with the facilitator to reference during the game wrap-up.

Number of players

- While there is no limit to the number of players who can join in, consider the best size for game management (more than eight players per round can be a bit chaotic unless you have a large space!).
- Use only Deck A for a small group of players (1-4).
- Add Deck B (expansion deck) if there are five or more players.

Instructions for Facilitating the Game

- **Gather players around the introduction poster and introduce the game storyline:**

"This game tells the story of dust that travels all over the Earth and ends up in the ocean. The dust has lots of iron in it. Iron is a mineral that is needed by all living things, but there is very little iron in the ocean. When iron-rich dust gets into the ocean, it helps tiny organisms called phytoplankton live and grow. And when there are more phytoplankton in the ocean, it helps cool Earth's climate!"

To play the game, collect all the things that phytoplankton need to grow - iron, nitrogen, and sunlight. The more you collect, the more phytoplankton you make. And the more phytoplankton you make, the more it helps to cool the climate."

- **Point out the steps for gameplay at the bottom of the introduction poster with the players:**
 - Start at the Mountain Station and follow the dust -- use the clues on the cards to figure out where to go next.
 - Collect iron, nitrogen, and sunlight to help phytoplankton grow.
 - Use the tracking sheet to record your progress - whoever collects the most nutrients wins!
 - Encourage players to read the info on each station poster to learn why each place is important.
- **Give each player a tracking card and explain how to use it during gameplay:**
 - Players will mark on the tracking card to keep track of iron, nitrogen, and sunlight cards drawn during gameplay.
 - For younger players, point out that Fe stands for iron, N for nitrogen.
 - Players can also keep track of where they travel during the game by drawing lines or arrows to show the path taken from one station to the next.
 - Other options: circling all the places visited or making tic marks to keep track of how many times each place is visited.
- **Starting the game:**
 - Players start at the Mountain station and draw a card to figure out what to do next.
 - With more than one player: If more than one person is playing, the youngest player should draw first. Then other players take turns drawing cards. After this

station, players' paths in the game will likely diverge as the cards send them to different locations. For example, one person may be sent to the atmosphere, while another is sent to the loess plateau.

- **Playing the game:**

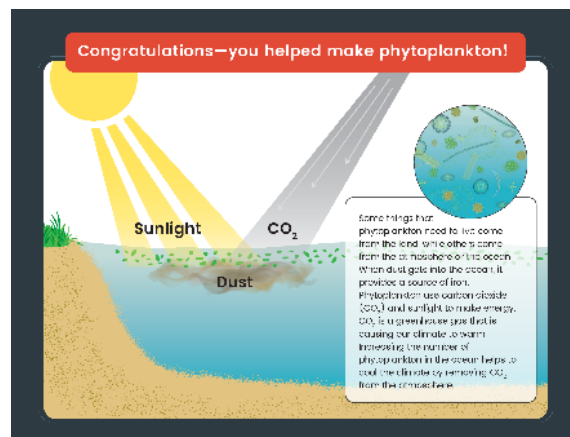
- Players proceed at their own pace-- take turns if more than one player is at the same station. Tell players that you will announce when the game is over.
- Players mark on their tracking sheet each time they draw an iron, nitrogen, or sunlight card and return the card to the discard pile. They can also keep track of the places they visit throughout the game.
- Shuffle the discard pile back into the deck and continue drawing cards if the draw pile runs out.
- Players draw cards and move from station to station for 5-7 minutes, but adjust the time based on the number of players and player engagement.

- **Ending the game:** At the end of the 5 to 7-minute gameplay period, gather players together to debrief and share connections between phytoplankton and climate (illustrated on the conclusion sign).

- Ask players about the nutrients they collected: Which did you collect the most of? Which was the hardest to find?
- Ask players about the stations they visited: Did you visit every station? Which stations did you visit the most? What order did you visit the stations in? If multiple people played at the same time, did everyone visit the same stations?

- **Explain the connection between dust, phytoplankton, and climate using the conclusion sign:**

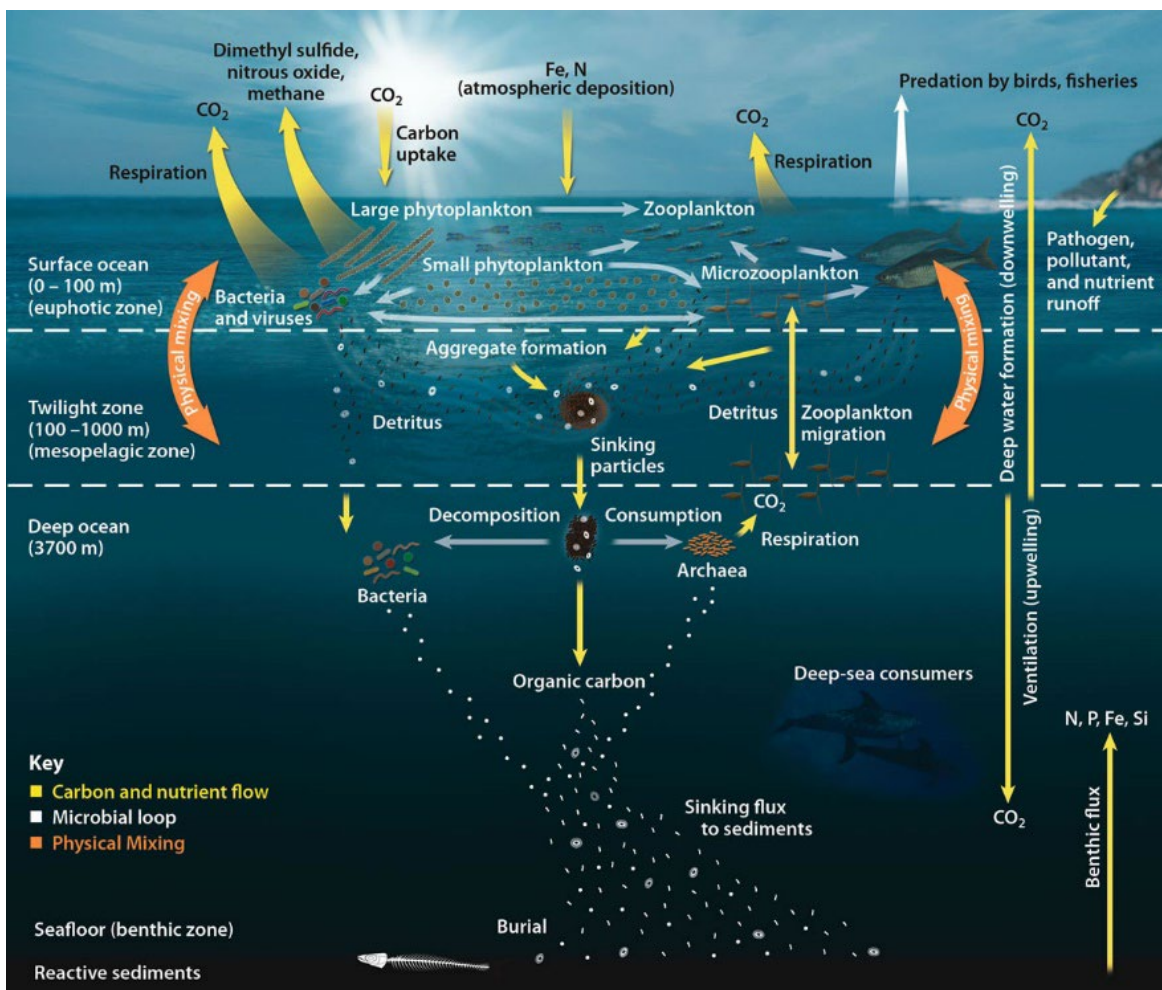
- Explain the connections between CO₂ and climate change. Ask players if they know how CO₂ gets into the atmosphere.
- For teen and adult visitors, point out that the phytoplankton are removing CO₂ from the atmosphere through photosynthesis, just as plants do.



- **Play another round of the game if there is interest:** Players can continue where they left off or start again at the Mountain Station, continuing to add nutrients to their tracking sheets. Debrief again, discussing differences between rounds to illustrate that the path dust takes as it travels around the Earth is not always the same.

Science facts related to the game

- Iron is very limited in the ocean, even though marine life, like phytoplankton, need iron to survive. Nitrogen is much easier to come by but often gets used up in the surface layer because there are so many living things there. All living things need nitrogen as well.
- Iron enters the ocean in three ways: as iron-rich dust settles on the surface and is consumed by marine organisms or sinks deeper into the water; from erosion of continental margins as the moving ocean breaks away pieces of rock from the edges of the submerged portion of the continents; and from hydrothermal vents on the ocean floor that spew minerals, including iron, into the water.
- The ocean works as a biological pump. Nutrients are consumed by marine organisms and are released back into the water as the dead organisms decompose and chemical interactions occur between marine life and the ocean environment. Sometimes nutrients are sequestered in the ocean floor for millennia, and sometimes the mixing of ocean layers brings nutrients from the ocean floor closer to the ocean surface.



Credit: [Wikipedia & Office of Biological and Environmental Research of the U.S. Department of Energy Office of Science](#)

- There are some places in the ocean where iron is limited, like the North Pacific Ocean, and some places where nitrate is limited, like the Atlantic Ocean. Conversely, nitrate is readily available in the North Pacific, and iron is available in higher concentrations in the Atlantic. The irregular distribution of nutrients throughout the ocean is influenced by many factors, including deep ocean circulation.
- When dust increases the amount of iron in the ocean in areas where iron is limited, like the North Pacific Ocean, more phytoplankton can grow. Phytoplankton remove CO₂ from the atmosphere through photosynthesis. As the climate continues to warm, these connections between iron, phytoplankton, and the drawdown of CO₂ are of increasing interest. Iron fertilization has been suggested as a climate intervention strategy, but there are concerns about potential negative impacts to ocean ecosystems.
 - [How Can Adding Iron to the Oceans Slow Global Warming?](#)
- In addition to being an important nutrient for life, nitrate is also a good indicator of where there is excess carbon at the surface. Because the phytoplankton are limited by iron (and light) in the North Pacific and the Southern Ocean, they can't use as much of the nitrate and carbon that is available at the surface, and thus these regions leak CO₂ into the atmosphere. Conversely, in the Atlantic, where there is plenty of light and iron, the phytoplankton use up the available nitrate and draws down atmospheric CO₂. In these regions, the lack of nitrate limits the phytoplankton's capacity for carbon uptake, which is why iron is present at a high concentration. Carbon concentrations are important for understanding changes in climate.
- While phytoplankton play a key role in the drawdown of carbon dioxide and production of oxygen (they produce an estimated 80% of the world's oxygen), an overabundance of phytoplankton in the ocean is associated with the formation of dead zones, where oxygen-depleted waters lead to the death of marine life in that area. Dead zones are common along coastlines and where pollutants like nitrogen-rich chemical fertilizers enter the ocean, providing excess nitrate that leads to phytoplankton blooms.
 - [Learn more about phytoplankton.](#)
- The geologic record suggests that an increase of dust in the North Pacific Ocean may have influenced global cooling during the Pliocene (around 2.7 mya).