teacher guide

Carbon cycle 2: Feedback loops

Components

	NAME	DESCRIPTION	AUDIENCE
	Feedback loops teacher guide	This guide describes an activity in which students identify potential climate change tipping points.	teachers
	Carbon cycle feedbacks game board	Students identify positive feedback loops in the carbon cycle, using a board and cards.	students
	Carbon cycle cards game cards	Statement cards set a context for students to identify a feedback loop. Students select three feedback cards that create a positive feedback loop.	students

Purpose

To **Explain** how processes in the carbon cycle are affected by human actions and that these have potential to cause catastrophic climate change, through positive feedback loops.

Outcomes

Students:

- understand the concept of positive and negative feedback cycles;
- understand that plant photosynthesis in the carbon cycle has links to ocean temperature, currents, depth and clarity; and
- are aware of links between human activities, the carbon cycle and climate change.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Teacher prepares A3 game boards and cards.	
Students use board and cards to create feedback loops.	individually or in small groups
Class discusses feedback loops identified, and likelihood of tipping points being reached.	teacher-led class discussion

Teacher notes

The carbon cycle contains many feedback mechanisms, some positive, some negative. Negative feedback helps maintain the status quo. For example, ocean buffering resists change in ocean pH (to a degree). Positive feedback may reinforce change through feedback loops that lead to runaway processes. Such processes are also known as tipping points.

With increasing warming, some physical and ecological systems are at risk of abrupt and/or irreversible changes.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Page 72.

Playing the game

Print out (A3) boards and cards. Cut out and laminate as required.

Organise students into small groups.

Ask students to read statement and feedback cards, and study the board. Through discussion, and trial and error, students generate a feedback loop (that fits on the board) for each of the four statement cards.

Teachers may choose one statement card for each group, or give groups all statement cards and allow them to work through all loops.

Two statement cards are about phytoplankton and two about seagrass. Emphasis in each statement leans towards a certain feedback cycle, but there are alternative solutions.

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Some feedback cycle cards are red herrings (they don't fit in any loops) although all feedback statements are valid.

Ahoy! Tipping points dead ahead

Positive feedback is associated with tipping points. A tipping point occurs when a changing process goes beyond a point where it can be reversed — the glass has tipped over, liquid is spilt and can't be put back in the glass. Climate scientists have identified various tipping points where climate change could escalate uncontrollably.

Feedback cards, that create a feedback loop associated with each statement card, are listed below.

STATEMENT	FEEDBACK LOOP
Seagrass is a plant that grows in shallow seawater. Seagrass makes its own food through photosynthesis which requires sunlight.	Warming air and oceans lead to ice melting and ocean expansion, which results in a rise in sea levels. Sea level rise increases depth of water above existing seagrass beds and reduces light to seagrass plants. This lessens the amount of photosynthesis in leaves. Reduced photosynthesis leads to reduced oxygen and increased carbon dioxide levels in the ocean (and air).
Phytoplankton are autotrophs (make their own food) found in vast numbers in the ocean. Phytoplankton are primary producers: they provide oxygen and food for other organisms. Phytoplankton need sunlight and nutrients.	Warming of oceans and air causes Arctic sea ice to melt, pouring less dense, fresh water onto the top of the saltwater ocean. This disrupts ocean currents. Ocean currents usually carry nutrients around the globe and, in certain places, bring them to the surface. There are less nutrients when currents are disrupted. Reduced nutrients decrease the amount of phytoplankton. Less phytoplankton reduce food and oxygen for sea animals. It also means there's more carbon dioxide in the surface ocean (and air).
Phytoplankton sequester (store away) carbon in deep ocean through a biological pump. This is when dead, ingested, and defecated phytoplankton sink, aided by their carbonate or silicate shells clumping together.	Acidification affects production of carbonate shells in some phytoplankton. The shells become less dense and less able to clump together. Changes in their shell composition means dead or defecated phytoplankton don't sink easily, so fewer will sink. Less phytoplankton sink to deep ocean. This means less carbon is sequestered, so there's more carbon dioxide in the ocean.
Seagrasses are fragile plants. They sequester (store away) carbon because the below ground part doesn't decompose when it dies, so it builds up over many years. Seagrasses capture three times more carbon dioxide, than the equivalent area of land plants.	Air and ocean surface temperature changes affect winds and currents. This disrupts weather patterns and climate systems, such as El Nino. The result is more severe weather events and storms occurring in new places. Storms cause large waves and tidal surges that destroy sea grass meadows. Less sea grass means less carbon sequestration and hence more free carbon dioxide.
'Red herring' cards	Building new coastal developments destroys sea grass meadows. This is because water cloudiness increases, and sunlight can't filter through. Intensive farming practices, and fertilizer run-off, lead to harmful algal (a type of phytoplankton) bloom. Fish and other animals die because they feed on poisonous algae, or are starved of oxygen that's used by blooming algae. White sea ice reflects sunlight. Warming of the ocean and air melts sea ice. So, with less sea ice, the ocean absorbs more of the sun's energy. Global warming causes sea ice to melt. Warmer air passing over the sea replaces cold air over sea ice. Warmer air causes Arctic permafrost (permanently frozen soil) to warm up releasing the greenhouse gas methane trapped underneath. Loss of sea ice affects polar bears' ability to hunt and feed on seals. The polar bear population is reduced, affecting the food chain and Arctic ecology balance. Acidification of the ocean reduces its ability to absorb carbon dioxide.

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Technical requirements

The teacher guide, game board and cards require Adobe Reader (version 5 or later), which is a free download from www.adobe.com.

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Associated SPICE resources

Carbon cycle 2: Feedback loops may be used in conjunction with related SPICE resources to address the broader topic of the carbon cycle.

DESCRIPTION	LEARNING PURPOSE
Carbon ocean (overview) This learning pathway shows how a number of SPICE resources can be used in teaching students about the carbon cycle and the significance of the oceans in the carbon cycle.	
Carbon cycle 1: Carbon ocean Students do a variety of hands-on and media watching activities that focus on phytoplankton, seagrass and ocean chemistry.	**Explore**
Carbon cycle 2: Feedback loops Students undertake an activity, with board and cards, involving small group discussion. Students identify positive feedback cycles that link human-induced climate change to the carbon cycle in oceans.	**Explain**
Carbon cycle 3: Carbon neutral Students watch a short video, then undertake a classroom or school audit to consider how a school can move towards carbon neutrality.	**Elaborate**