Carbon Sinks and Sources

Like all of the essential elements that make life on the planet possible, carbon, in the form of carbon dioxide and methane, is continuously recycled on Earth. Have you ever wondered how this cycling works?

Activity Time:
Part I: 15 minutes
Part II: 15 minutes

Setting:
Classroom or outdoors

Materials:
- Class set of carbon sink and source "Who Am I?" and Partner cards (see Black Line Masters)

Not included
- Candle and matches
- Green potted plant
- For Demo: red cabbage to be boiled, 2 small glass containers, white vinegar, 1 straw

Grade Level:
Intermediate, middle school, high school

Subject Areas:
Biology, Ecology, Earth Science, Geography, Physical Science, Resource Science, Science and Technology, Social Studies

Skills:
Compare and contrast, gather information, question

Group Size:
10+

Key Words:
Carbon, Carbon Cycle, Carbon Dioxide, Methane, Sink, Source

Summary
Through questioning and partnering, students gain an understanding of the complex system of carbon cycling that works to balance the levels of carbon in our atmosphere.

Objectives
Students will:
- Gain an understanding of how carbon cycling occurs
- Use questioning techniques to determine the differences between a carbon sink and a carbon source
- Discuss how humans can influence the amount of carbon in our atmosphere

Making Connections
We all have a role to play in combating climate change. However, the issue can seem so huge and the solutions so daunting that individual actions seem insignificant. It is important for students to understand that simple choices made every day can have profound impact in the mitigation of the effects of climate change.

Background
Carbon dioxide (CO_2) and it's sister greenhouse gas, Methane (CH_4), are continually recycled on Earth. Processes that release CO_2 to the atmosphere are called carbon "sources", while processes that absorb it are called carbon "sinks". Forests, soil, oceans, the atmosphere, and fossil fuels are important stores of carbon. Carbon is constantly moving between these different stores, that act as either "sinks" or "sources." A sink absorbs more carbon than it gives off, while a source emits more than it absorbs. The amount of carbon in the atmosphere at any one time depends on the balance that exists between the sinks and sources. This system of sinks and sources operates all over the planet and is known as the carbon cycle.

Natural sources of atmospheric CO_2 include volcanoes, fires, decomposition, respiration, digestion and, under certain conditions, oceans and fresh water bodies. The latter can release large amounts of dissolved CO_2 when waters warm up or are disturbed by storms or tremors.

Natural sinks for atmospheric CO_2 include photosynthesis, forests, oceans and freshwater bodies, fossil fuels and carbonate rocks.

Before the Industrial Revolution, the amount of carbon moving between trees, soil, oceans and the atmosphere was relatively

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balanced. The forests of the world are a big carbon sink however deforestation is reducing the size of this sink, allowing more carbon dioxide to remain in the atmosphere. Photosynthesis accounts for about half of the carbon extracted from the atmosphere. Photosynthesis equation: 6 H_2O (water) + 6 CO_2 + sunlight energy = $C_6H_{12}O_6$ (glucose) + 6 O_2 (oxygen). Land plants take most of their carbon dioxide from the air around them while aquatic plants in lakes, seas and oceans uses carbon dioxide dissolved in water. Phytoplankton is one of these important plants as they produce up to 50% of the atmospheric oxygen through photosynthesis. Other important sinks are the worlds oceans. The world's oceans are absorbing an unprecedented amount of carbon dioxide (CO_2), which is increasing their acidity and possibly threatening the long-term survival of many marine species, especially calcifying organisms including corals, shellfish and phytoplankton (UNESCO, 2004). See demo activity in Warm Up section to illustrate this point.

The cycling of carbon between the atmosphere, plants and animals can take place quickly, over the space of days or weeks. Individual carbon atoms may cycle through plants and animals several times a year. Other parts of the cycle, especially those involving the storage of carbon as an underground mineral, may take millions of years to complete. Human perturbations to the carbon cycle are impacting the maintenance of the concentration of atmospheric carbon. This is leading to an increase in the amount of carbon in the atmosphere as humans produce carbon dioxide and methane far faster than the natural sinks can absorb it. The extraction, processing and use of oil, gas and coal are the greatest contributors to this carbon loading.

Sources of methane (CH_4) include natural sources like wetlands, gas hydrates in the ocean floor, permafrost, termites, oceans, freshwater bodies, and non-wetland soils. Fossil fuels, cattle, landfills and rice paddies are the main human-related sources. All these sources cause significant carbon emissions. Methane (CH_4) is an important trace gas in Earth's atmosphere. Even though it only makes up 0.00017% (1.7 parts per million by volume) of the atmosphere, methane (CH_4) traps a significant amount of heat, helping the planet remain warm and habitable. The amount of methane (CH_4) in the atmosphere is the result of a balance between production on the surface and destruction in the atmosphere. Methane (CH_4) forms when organic matter decomposes in oxygen-poor environments, such as marshes, rice paddies, or the digestive systems of cattle. It also comes from combustion (burning) of carbon-based fuels. Each methane (CH_4) molecule holds about 23 times more heat than 1 molecule of carbon dioxide. Methane (CH_4) is 23 times more potent than carbon dioxide as a greenhouse gas, but CO_2 is much more abundant than methane and the predicted growth rate is far greater.

In addition to contributing significantly to carbon sources, human activities are also interfering with natural carbon sinks. For example, the clearing of tropical rainforests for agriculture and logging represents a significant loss to the earth's ability to absorb and store carbon.

Procedure

Warm Up

Light the candle and ask students what they observe – candle, wick, flame. What is burning here – the wick or the wax or both? Where do they go when they are burned? Do they just disappear forever? Blow out the candle.

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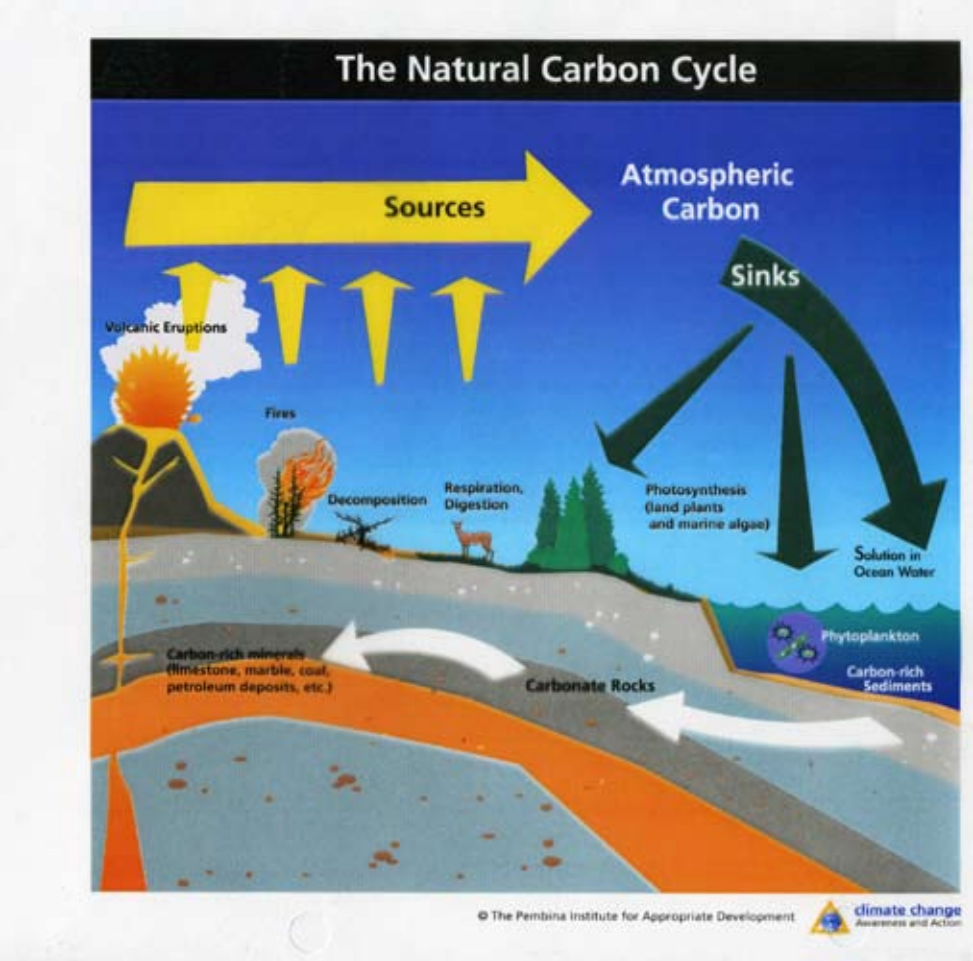

Demo Activity

This experiment shows the acidifying effect of CO_2. Make an organic, non-toxic pH indicator by boiling red cabbage.

1. *Boil cabbage in a covered pan for 30 minutes or microwave for 10 minutes. (Do not let the water boil away.)*
2. *Let cool before removing the cabbage.*
3. *Pour about 1/4 cup of cabbage juice into 2 see through containers. (Avoid buying plastic for this experiment. Plastic is a petroleum product. Its production process is a source of carbon emission and it doesn't decompose.)*
4. *Slowly pour white vinegar in one of the containers. Observe the change in colour.*
5. *Then, ask a student to blow through a straw in the other container. Eventually the cabbage juice will turn colour.*

Ask student what he or she is breathing out into the cabbage juice. What is the meaning of the juice changing colour? Debrief.

When dissolved in water, CO_2 combines with water to form carbonic acid H_2CO_3. This is a weak unstable acid. However, if concentrated enough this acid will over time dissolve the calcium shell of marine organisms. Driving too much could literally kill the Great Barrier Reef.

The Activity Part I

1. Draw a quick illustration of the carbon cycle on the board. Give a brief definition of sinks and sources.

- Processes that release CO_2 to the atmosphere are called carbon sources.
- Processes that absorb CO_2 are called carbon sinks.

2. Ask students for examples of processes that release CO_2 to the atmosphere - carbon sources. List the sources on the board

- Point to the candle
- Us - we breathe out CO_2 – we are carbon sources along with all air-breathing organisms
- Volcanoes
- Fires
- Oceans and fresh water bodies (CO_2 dissolves easily in water)
- Agriculture - grazing animals

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(cows, sheep, pigs) produce methane
- Burning fossil fuels – gas energy plants, coal, oil, gas, tar sands
- Fossil fuel production: coals, oil gas, tar sands – including the burning of natural gas during oil extraction (water, oil and gas mix) and the escape of methane (CH_4) during extraction and processing of oil, gas and coal.
- Decomposing garbage in landfills/ dumps (methane)
- Rice farms (produce methane)
- Degrading farm soils: release of carbon from soils when plowed
  - causes it to oxidize creating CO_2
- Wetland destruction
- Deforestation
- Urban sprawl
- Decomposition of dead animal and plants with oxygen (aerobic) produces CO_2
- Decomposition of dead animal or plants without oxygen (anaerobic) produces methane (CH_4)

3. Ask students for examples of processes that absorb carbon dioxide from the atmosphere - carbon sinks. List the sinks on the board
- Point to a green plant - photosynthesis in plants. All green plants, peat bogs (these are green plants in storage), growing forests: photosynthesis equation 6 H_2O (water) + 6 CO_2 + sunlight energy = $C_6H_{12}O_6$ (glucose) + 6 O_2 (oxygen) glucose = carbon storage.
- Diatoms, algae
- Fossilized organic remains become fossil fuels like coal, oil and gas stored safely underground
- Oceans can absorb CO_2 directly from the atmosphere. CO_2 will stay in storage for a long time provided oceans stay cool and undisturbed. The carbon hydrate is in the slurry at the bottom in the form of sediments
- Shells, coral
- Carbonate rocks
- Permafrost
- Wetlands – organic matter builds up at bottom of ponds providing long-term storage of carbon
- Soil
- Limestone / dolomite sedimentary rocks: shale, mudstone, and coal. The Rocky Mountains are a good example of this.

4. Reiterate that this system of sinks and sources operates all over the globe and is known as the Carbon Cycle.

5. Explain to students that they are about to become either a carbon sink or a carbon source. They will not know which they are but will have to figure it out by asking questions that can be answered only by yes or no. Note: it may be necessary to demonstrate what yes/no questions sound like.

6. Hang a card on each student's back so the wearer cannot see it. Participants must circulate and ask others just one Yes or No question to determine what they are. They then must move onto another person, show the card and ask a question. Students should repeat until they have determined what they are.

7. Have sinks and sources group themselves into 2 groups in the room and describe who they are and how they work as carbon sinks or carbon sources.

Part II

1. Explain to students that the climate change problem lies with sinks that become sources.
- Oceans: Warming oceans leading to a number of events that result in the release of carbon. Coral die-offs, extermination of algae that take up carbon, dissolved CO_2 releasing from warmer water
- Limestone mining
- Forests: Deforestation and forest fires

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- Burning of fossil fuels

2. It is the transformation from sink to source that is leading to increased global temperatures and global climate change.
As more carbon is released than can be absorbed by the naturally occurring carbon cycle, this causes changes in the amount of carbon in the atmosphere and affects how solar energy is absorbed and reflected on earth.

3. Discuss with students how the transformation of a carbon sink to a carbon source occurs.
This does happen naturally, as in the case of forest fires or volcanic eruptions, but it is the increase in human activity that is upsetting the balance of carbon. Why is this happening? Is it necessary for us to undertake the activities that are releasing carbon? Point out that the amount of carbon in the atmosphere has increased 30% since the Industrial Revolution.

4. Explain that there are many small things we do every day that can either enhance or combat climate change.
Invite each student to take a Climate Change Partner card. When everyone has a card, inform students that their task is to find their partner who is, in fact, their opposite. Read out a few matching examples before playing the game, so that the students understand their task. The person with the Climate Change Combater card must find the person with the Climate Change Enhancer card, and vice versa. Once pairs have found one another, they can discuss the topic depicted on their card.

5. Once everyone has found their partners, have each pair review their cards with the rest of the class.
Make note of how simple it is to make choices that combat climate change. Invite students to give other examples of simple ways to combat climate change.

Assessment

Have students:

- Illustrate the carbon cycle
- Give three examples each of carbon sinks and carbon sources
- Explain the process by which a carbon sink becomes a carbon source
- Create posters depicting two or three simple ways to combat climate change.

Extensions

- As a class, pledge to make two changes in order to combat climate change (use natural light rather than turning the lights on, bike or walk to school, compost vegetable and fruit scraps). Graph your success on a daily/weekly basis.
- Create a Combating Climate Change manual that could be distributed to parents and/or throughout the school.
- Do a garbage inventory to determine how much recyclable and compostable material is being thrown away at your school. Develop an action plan (if necessary) to cut down on the amount of material being taken to the landfill in school garbage. Climate Change Partner cards.

References

Grant and Littlejohn. 2001. Teaching About Climate Change: Cool Schools Tackle Global Warming. Toronto, Ont.: Green Teacher & Gabriola Island, B.C. New Society Publishers.

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