FROM THE
HORSE'S MOUTH
SCIENTISTS ON THE SCIENCE OF GLOBAL CHANGE

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What does the biosphere breathing look like?

Active Listening Questions:

- Why does Dr. Matson say the graph's "wiggles" are the biosphere breathing?
- A scientist in the audience asks Dr. Matson the meaning of the word "heterotroph." What living things are examples of heterotrophs?

WHAT: In this clip from the 1990 presentation "N_2O Ecological Approaches to Estimates of Global Fluxes," Dr. Pam Matson brings her perspective as an ecologist to describe the wiggles in the famous Keeling Curve. She states that seasonal changes in concentrations of atmospheric carbon dioxide represent the "biosphere breathing." In the curve, the "inhalation and exhalation" of plants shows up in atmospheric CO_2 level rise during Fall/Winter, when plant growth slows, and CO_2 uptake by plants declines. Decreases of atmospheric CO_2 occur in Spring/Summer when plant growth is booming, and CO_2 levels drop due to increased plant CO_2 uptake. Note that another scientist pauses Dr. Matson to ask for the definition of the term heterotroph.

HOW: The data that Dr. Matson references is from Dr. Keeling's monitoring site at Mauna Loa in Hawaii. The Mauna Loa site is located high on a barren volcano, so there are no nearby plants that might directly impact CO_2 levels near the instruments. CO_2 is a trace gas, and very sensitive instruments are required to measure it. As a result, the Mauna Loa site initially used detectors created by Keeling himself because there were no existing tools that could effectively make the measurements he sought.

"THIS IS A PLUG FOR ECOLOGY AND ITS IMPORTANCE IN GLOBAL SIGNALS AND GLOBAL PROCESSES."

WHY: Dr. Matson's explanation of the wiggles in the Keeling graph helps clarify why scientists feel confident that the Mauna Loa instruments successfully measures the concentration of atmospheric CO_2. The wiggles represent a seasonal rise and fall of CO_2 levels that matches the growing and dormant seasons of the northern hemisphere, which fits the expectations that atmospheric CO_2 concentrations will fall when plants are growing rapidly and take up more CO_2, and concentrations will rise when many plants lose their leaves in the fall, decreasing photosynthesis and CO_2 uptake. Confirming observations against logic or already known facts help scientists determine whether or not their conclusions are reasonable. Scientists using the Keeling curve also draw confidence from the correlation of the Mauna Loa record with other records of CO_2 taken by other stations around the world. In the associated graphic from the Scripps Institute for Oceanography, you can see the Mauna Loa (MLO) in comparison to other trends at Point Barrow Alaska (PTB), Lo Jolla, California (LJO), Christmas Island (CHR) , Samoa (SAM) and the South Pole (SPO).

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SO WHAT: The link that Dr. Matson draws between plant activity and the atmospheric carbon cycle provides insight into the deep interrelations between different Earth systems and different fields of science. It illustrates how a combination of individual organisms impact the chemistry of the global atmosphere. Without understanding ecological cycles, the wiggles on the Keeling Curve, an important environmental indicator, would be a mystery.

BIO: Pamela Matson currently works for the Stanford University School of Earth Sciences. Her research focuses on the cycling of carbon, nitrogen, and other elements through soil, water, and the atmosphere. Her MS is in environmental science, and her PhD is in forest ecology. At the time of her 1990 talk, Dr. Matson worked for the Ames Research Center for the National Aeronautics and Space Administration, with a focus on ecology.

TAKING THE REINS

Discussion Questions:

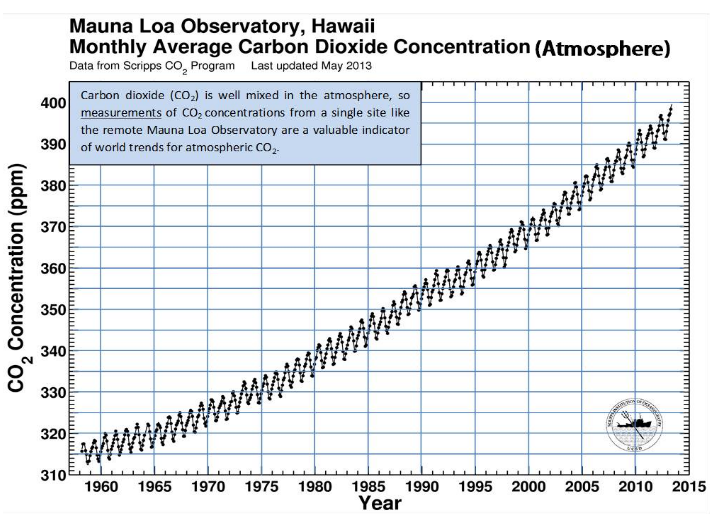
Discuss with a friend or record your thoughts in a journal.

- What is the biosphere?
- Dr. Matson refers to ecology at several points in her presentation. What is the relationship between the atmosphere and plant/ecosystem function?

Quiz Questions:

Quiz 1. Dr. Matson describes a graph that shows the trend of rising atmospheric CO_2 from 1958 to the mid 1980's. According to the *trend* in the updated graph above, how has the concentration of carbon dioxide changed in the 25 years from 1985 to 2010?
The CO_2 concentration (amount of CO_2 measured in ppm = *parts per million*) has…

a.) stayed the same except for annual variations
b.) increased by about 390 ppm
c.) increased by about 40 ppm.
d.) decreased by about 315 ppm



The graph to the left is a more current version of the one used by Dr. Matson in 1990 to show how CO_2 concentration was changing with time. The graphs depict data from the same location on Earth (Mauna Loa). Credit: NOAA.

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Taking the Reins: Further Activities

Quiz Questions-Continued

Quiz 2. Dr. Matson described the annual "wiggles" in atmospheric carbon dioxide concentration as evidence of the biosphere breathing. Which statement best explains this?

As the Spring/Summer growing season begins, photosynthesis causes the CO_2 concentration to...

a.) decrease (as growing vegetation *takes in* more CO_2), and then CO_2 levels go up in Fall/Winter

b.) increase (as growing vegetation *releases* more CO_2), and then CO_2 levels go down in Fall/Winter when photosynthesis is more active.

c.) decrease (as growing vegetation *takes in* more CO_2), and then CO_2 levels go up the following Spring**.**

d.) increase (as growing vegetation *releases* more CO_2), and then CO_2 levels go down the following Spring**.**

Clip Activity- Understanding the Graph

Considering an updated version of the Keeling Curve (on the precious page), answer the following questions, either with a friend or in a science journal.

1. What does the line of the graph represent, and why is it not a smooth, straight line?

2. When is your birthday, and which hemisphere do you live in? Is the seasonal flux of CO_2 likely to be rising or declining around the time of your birthday?

3. What does the direction of the line over the course of time (the x-axis) indicate?

Glossary Term: Biosphere

"The term biosphere can be used one of two ways. It can either refer to the part of the Earth system comprising all ecosystems and living organisms in the atmosphere, on land (terrestrial biosphere), or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter, and oceanic detritus."

IPCC: Climate Change 2007, Working Group II: "Impacts, Adaptation and Vulnerability," Glossary A-D.)

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GO BEYOND: Understanding the Invisible, PPM

Many scientific measurements of liquids or gases use the unit "parts per million," (ppm). If we have a mixture of one million molecules, say carbon dioxide, nitrogen, and oxygen and 200 of those total molecules are oxygen, then the mixture of molecules is 200ppm oxygen. But how can we understand this type of unit in a way we can sense? By using a gas that we can smell.

Materials: a plate and a gas (or rapidly vaporizing liquid) with a strong odor that is non-toxic to breathe, e.g. perfume.

1. Close the doors and windows of your room. Calculate the volume of the room you are in, using the unit cubic meters.
2. Record the volume of perfume (or other liquid/gas) you will be using for the experiment. If you are using a liquid, you may need to determine this number at the end of your experiment by subtracting remaining fluid from the amount of fluid you started with. **Do not use a liquid or gas other than perfume unless you have been advised to do so by a science teacher!** You do not want to use anything that could make you sick.
3. Without doing a complete calculation, make some guesses: what do you think the ratio of normal air to perfume will be after 10 minutes? How long to you think it will take for the perfume to diffuse to the farthest side of the room?
4. Have one person hold the bottle of perfume while the others spread out to different distances in the room. Once all participants have taken their places. Everyone *except for* the person holding the perfume (the recorder) should close their eyes.
5. Without announcing when the experiment has begun, the recorder should empty the gas onto a dish on the floor or spray a measureable amount of perfume into the air.
6. As each participant is able to smell the perfume, he or she should raise a hand. Once a person raises his or her hands, he (she) may then open his (her) eyes. As soon as a person raises a hand, the recorder writes down the time and that person's name.
7. Once everyone's eyes are open, the recorder should announce how long it took the odor (in other words, the perfume gas) to reach each person. Was the diffusion faster or slower than you expected?
8. Based on the volume of the room, calculate the ratio of regular air to perfume. Be sure to record all observations and calculations. Convert this ratio into parts per million (e.g. the volume of air becomes 1 million cm^2).

FURTHER READING:

"The History of the Keeling Curve," The Keeling Curve. 2013. Scripps Institution of Oceanography: April 3, 2013. http://keelingcurve.ucsd.edu/the-history-of-the-keeling-curve/