

Is the Earth Getting Warmer?



In 1975, a scientist named Wallace “Wally” Broecker wrote a paper in which he asked a simple question: was the Earth getting warmer? When the paper was published, some of Broecker’s colleagues laughed at him. Many of them believed that the world was actually cooling.

Historically, there have been periods in which the Earth’s temperature has slowly risen and cooled over thousands of years. This is a natural process that can be caused by many factors, including changes in radiation from the Sun, changes in the Earth’s orbit, and volcanic activity.

However, climate change can also be caused by changes in the amount of certain gases in the atmosphere. Broecker had noticed that the amount of carbon dioxide – a colorless, odorless gas -- was slowly building up. While some carbon dioxide is produced through natural processes, large quantities of it are also produced by humans. Carbon dioxide is generated in especially large amounts when we burn fossil fuels, such as oil, coal, and natural gas. This burning happens when we drive cars, use electricity, and make certain products. When released into the atmosphere, carbon dioxide traps heat. Broecker reasoned that if people produced a lot of carbon dioxide, then enough heat would be trapped that the Earth would begin to warm. He called this “global warming.”

Several decades later, many climate scientists agree with Broecker: the Earth is heating up and humans are largely responsible. This warming process is often referred to as “climate change.” More carbon dioxide is being produced than ever before. Every year, humans produce about 8 billion metric tons of carbon. 2012 was the hottest year in recorded history. Recently, scientists estimated that more carbon dioxide exists in the atmosphere than has in over three million years.

While scientists understand how climate change works, some of its effects are still difficult to predict. Some scientists expect an increase in so-called “extreme weather” events, such as hurricanes and floods. Others foresee a rise in levels of sea water. While exactly what changes will happen are unclear, Broecker has warned that people should be prepared for some large disturbances. In an interview with the *Guardian*, a British newspaper, in 2008, he compared the Earth’s climate to a wild animal. Sometimes, when provoked, the animal will react violently and unpredictably.

"If you're living with an angry beast, you shouldn't poke it with a sharp stick," he said.

Why are scientists able to understand some phenomena, like climate change, in a general way, but aren’t able to predict the changes they will have on the Earth? Part of the reason is because many large Earth systems involve “feedback loops” – processes that help amplify (positive feedback loops) or diminish (negative feedback loops) certain changes.

Feedback loops can occur in the climate system, too. If the temperature of the Earth rises, it can change the environment so that it produces even more heat.

There are a number of different ways in which this phenomenon occurs. Scientists who work in the Arctic, at the northern end of the Earth, have been reporting that, every year, more and more floating sea ice melts. In the last 30 years, more than one-third of the ice that appears in the Arctic during the summer has melted away.

This worries scientists because Arctic ice plays an important role in cooling the Earth – although not in the way you might think. While we add ice to our drinks to make them colder, Arctic sea ice cools the Earth in a different way. Ice, which is white colored, reflects light. This means that much of the sunlight that hits ice bounces off and is sent right back to space. Reflecting light away helps keep the Earth cool.

However, as the Earth heats up, ice begins to melt. As ice melts, this reveals more of the darker-colored land or ocean water, which doesn’t reflect heat, but absorbs it. So, less light is reflected back into space, causing the climate’s temperature to increase. As the world gets hotter, this causes the ice to melt even faster. This increase in temperature causes still more ice to melt, which causes the world to get hotter, etc... This is an example of a positive feedback loop, in which heat produces more heat.

Similarly, there are other climate systems that can get caught in feedback loops. There are many gases that, like carbon dioxide, contribute to global warming. Some of these gases are trapped in the frozen tundra across Alaska, Canada, Russia, and other northern lands. This soil,

whose temperature is below freezing, is called permafrost. When permafrost melts, much of this gas is released into the atmosphere. This causes the atmosphere to warm up, which melts more permafrost, which heats up the atmosphere, etc... Again, a feedback loop ensues, in which a warm climate leads to the creation of an even warmer climate.

A more complex example of a similar phenomenon involves the Amazon rainforest. When temperatures rise, the rainforest experiences more droughts and wildfires. This causes more trees to burn down. Just as when humans burn fossil fuels, the burning of trees causes large amounts of carbon dioxide to be released into the world. Trees play two important roles in preventing global warming: they help absorb carbon dioxide, which prevents it from trapping heat in the atmosphere, and rainforest trees help pump water into the atmosphere. When trees burn down, less water is pumped into the atmosphere, which leads to less rainfall, which leads to more trees burning – which leads to more carbon dioxide being produced. These are both examples of positive feedback, but feedback can be negative too. When negative feedback occurs, an original effect is diminished.

Both positive and negative feedback loops can occur in all kinds of Earth systems, not just in a system related to the climate. For example, the relationship between different species of animals is a kind of system as well. Periodically, the populations of certain animals will wax and wane. In some cases, the population of a species can become stuck in a negative feedback loop. This can occur if a predator becomes too powerful and its prey becomes too weak. For example, in the early 19th century, humans began hunting a species of bird known as passenger pigeons. Soon, fewer birds existed, which made it more difficult for the species to mate. As mating declined, fewer birds were born, which made it still more difficult for the birds. This created a negative feedback loop in which the population of the birds continued to fall until they are now extinct.

While scientists understand some of how these feedback loops work, they lack a deep knowledge of them, making them extremely unpredictable. This is because, like any complex system, these feedback loops include many variables. Many of these systems are also interdependent, which means that many of these feedback loops affect each other. For example, when permafrost melts, it makes the whole world hotter, not just the area around the permafrost. And these changes are not just limited to temperature. Changes in the amount of rainfall an area receives can lead to changes in its atmosphere. This, in turn, can affect the Earth's temperature, which can affect how much ice melts, which can affect how much rain falls, and so on. So, a small change to a very complex system can lead to very big consequences. This makes predicting the behavior of large systems incredibly difficult.

Some skeptics about climate change point to this uncertainty as a way of casting doubt on whether the world is actually warming. However, being unable to predict the effects of climate change does not mean that it is not happening. Think back to Broecker's analogy. If you poke a wild animal with a sharp stick, you may not be able to guess exactly how it will react. However, even if you don't know precisely what the animal will do – it may bite you or scratch you or just growl – it's still a very bad idea to provoke it.

Scientists continue to debate exactly what happens as the Earth's temperature rises. Among the most popular ideas are that dry areas will become increasingly dry, while wet areas will become increasingly wet; oceans, seas, and lakes will rise; and glaciers, ice caps and snow-covered areas will become smaller. However, many climate scientists agree that a potential way of reducing the effects of climate change is to cut down the amount of carbon dioxide in the atmosphere.

Name: _____ Date: _____

1. According to the passage, which gas is generated in especially large amounts when we burn fossil fuels?

- A carbon dioxide
- B methane
- C carbon monoxide
- D sulfur dioxide

2. The increase of carbon dioxide in the atmosphere has had which effect on the Earth's climate?

- A Average rainfall has decreased.
- B Extreme weather has become less common.
- C The Earth's temperatures are rising.
- D The Earth's temperatures are falling.

3. Arctic ice plays an important role in cooling the Earth. Which evidence from the passage best supports this statement?

- A In the last 30 years, more than one-third of the ice that appears in the Arctic during the summer has melted away.
- B Arctic ice reflects the Sun's light.
- C When Arctic ice melts, it reveals more of the darker-colored land or ocean water.
- D Darker-colored land absorbs the Sun's light, causing the climate's temperature to increase.

4. Some of the gases that contribute to global warming are trapped in permafrost. When permafrost melts, many of these gases are released into the atmosphere. This leads to an increase of the atmosphere's temperature, which causes more permafrost to melt.

What type of feedback loop is this an example of?

- A negative feedback loop
- B complex feedback loop
- C both a positive and negative feedback loop
- D positive feedback loop

5. What is the main idea of this passage?

- A Climate change is a complex and unpredictable process involving feedback loops.
- B Disagreements about climate change have prevented scientists from finding real solutions to global warming.
- C Wallace Broecker's theory may have been incorrect, but he presented some worthwhile ideas.
- D Climate change can be completely reversed if carbon dioxide production is changed.

6. Read the following sentences: "Some scientists expect an increase in so-called 'extreme weather' events, such as hurricane and floods. Others **foresee** a rise in levels of sea water."

Which word could best replace "**foresee**" as used in this sentence?

- A forecast
- B glimpse
- C pretend
- D discover

7. Choose the answer that best completes the sentence below.

Trees play important roles in preventing global warming, _____ absorbing carbon dioxide and pumping water into the atmosphere.

- A thus
- B finally
- C as a result
- D including

8. How does carbon dioxide increase the Earth's temperature?

9. What is a feedback loop?

10. How can heat produce more heat? Use information from the passage to support your answer.
