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Home Instruction Packet for H – Earth Science

Name of Teacher and Class: Mr. Bangs

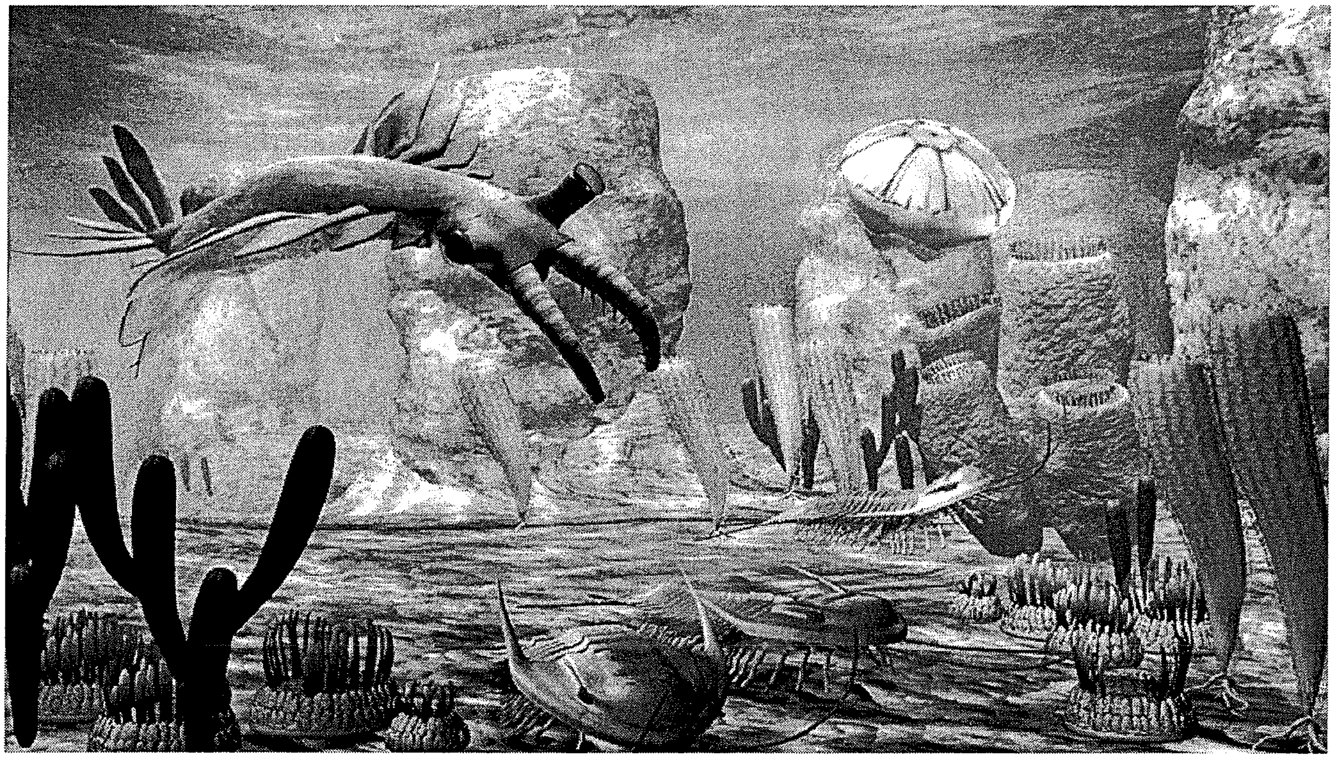
In this packet are materials and directions for students to complete for the above class. All written assignments will be collected on the day the school re-opens. These assignments will be reviewed and graded.	
I am available to support you during the hours 7:50 am-2:50 pm to answer any of your questions. I will be responding to your emails through the following contact: rbangs@rpsd.org	
Lesson:	Assignment Directions
Week 1-	a. Watch: NOVA – Making North America – Part 2 Life. You may have to find it on YouTube. It should be about 52 minutes in playtime. I encourage you to enjoy it with a family member or with several classmates. b. Read: Science News for Students "When Life Exploded". c. Complete all questions for "When Life Exploded".
Week 2-	a. Watch: NOVA – Making North America – Part 3 Human. You may have to find it on YouTube. It is about 53 minutes in playtime. I encourage you to enjoy it with a family member or with several classmates. b. Read: Science News for Students "Warning: climate change can harm your health". c. Complete all questions for "Warning: climate change can harm your health".
Week 3-	a. Watch: Nova – Treasures of the Earth: Power. You may have to find it on YouTube. It is about 47 minutes in playtime. b. Prepare a 2 paragraph Personal Reaction essay sharing with me how the program impacted you. (Times New Roman, 12 point font, dbl. space).
Week 4- Comments: Each written assignment for Weeks 1, 2, 3, 4 will be due on the day school re-opens.	a. Watch: NOVA – Treasures of the Earth: Metals. You may have to find it on YouTube. It is about 47 minutes in playtime. b. Prepare a 2 paragraph Personal Reaction essay sharing with me how the program impacted you. (Times New Roman, 12 point font, dbl. space). Budget time for researching and developing your biogeochemical cycle project.

ScienceNewsforStudents

EARTH

When life exploded

Scientists probe what happened 540 million years ago to trigger the biggest emergence ever of animal species



In this artist's conception of an ocean scene during the Cambrian Period, the fearsome predator at upper left, called *Anomalocaris canadensis* — or "unusual Canadian shrimp" — chases three trilobites.

COURTESY OF KEN DOUD

By **Beth Geiger**

November 13, 2014 at 8:30 am

Flash back 540 million years. It's the dawn of a new era, and something very, very big is about to happen to life on Earth. Over the next 10 million years — a blink of an eye in our planet's long history — dozens of new forms of animals will suddenly emerge in the oceans.

This burst of life marked the start of a period in Earth's history called the Cambrian. It was so dramatic and so fast that scientists call it the Cambrian Explosion.

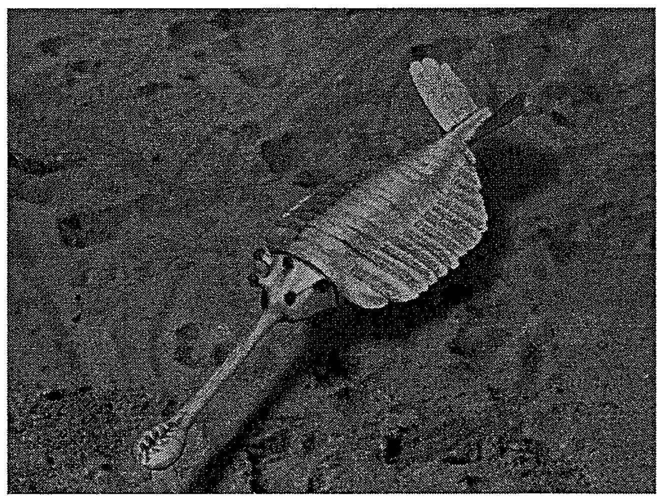
"The Cambrian Explosion was the biggest diversification in animals in the history of life," says David Harper. This paleontologist works at Durham University in England.

Before the Cambrian, Harper says, marine animals had been divided among just a handful of groups, or *phyla* (FY-luh). Life forms had been relatively simple, such as bacteria and some worms. Now, the oceans suddenly teemed with creatures. Some had hard shells. Others had nerve chords. Many could wiggle, burrow or swim. They had developed different organs for different functions, including eyes.

Ninety percent of the animal phyla that exist today appeared in that short window of time. The animals in each phylum generally share a similar body type or plan. One of the new groups was the chordates — animals with backbones. That group today includes all fish, reptiles, birds, amphibians and mammals. Another was the arthropods, which now includes insects, arachnids (A-RAK-nidz) and crustaceans (Krus-TAY-shuns). Animals with radial symmetry, such as the ancestors of starfish and sea urchins, also emerged at this time. These animals are known as echinoderms (Ee-KI-no-derms).

Never again have so many new types of animals emerged in such a short period of time. (Although since then several mass extinctions have wiped out nearly as many species just as quickly.)

No one really knows what actually triggered this burst of life, which was unique in our planet's history. But recently, studies have turned up new clues to how changes in the geology, chemistry and atmosphere of Earth influenced the Cambrian Explosion — and how this rapid growth in the diversity of life, in turn, affected the planet.



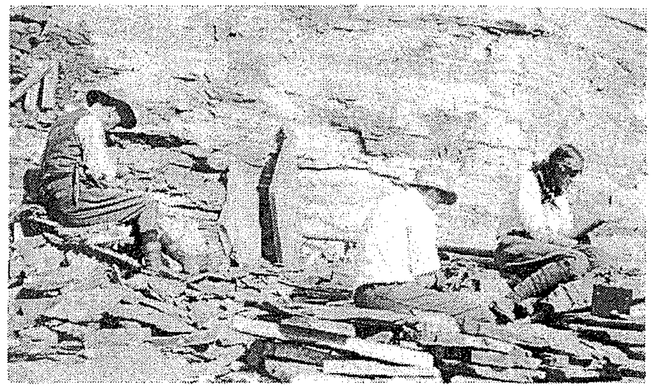
An artist's conception of an Opabinia, one of the truly strange Cambrian creatures. This thumb-sized creature had five mushroom-shaped eyes and a miniature trunk like an elephant's, with a handy gripper at its end.

NOBU TAMURA (HTTP://SPINOPS.BLOGSPOT.COM)/WIKIMEDIA COMMONS

Cambrian conundrum

An amazing glimpse into the Cambrian Explosion comes from a rock formation found in the Canadian Rockies of British Columbia. This Burgess Shale preserves countless fossils of Cambrian creatures. The organisms became fossilized after they were trapped in muddy marine sediments that later turned to stone. The fossils record fine details of these creatures. And not just of hard body parts such as bones and shells, but also of muscles, guts and other soft parts.

Some Burgess Shale creatures seem a little familiar. Others are just plain strange. Take *Opabinia,* for example. This thumb-sized creature had five mushroom-shaped eyes and a miniature trunk like an elephant's, with a handy gripper at its end. *Opabinia* kept odd company, too. One critter from its period, for instance, was almost all legs and spikes — like a walking, armored slug. It was so weird that biologists have named it *Hallucigenia* — as if only a hallucination could explain such a creature.



Charles Doolittle Walcott (left) discovered the Burgess Shale in the Canadian Rockies in 1909. Here, he searches through rocks for fossils with his son Sidney (center) and daughter Helen (right), circa 1913.

SMITHSONIAN INSTITUTION/WIKIMEDIA COMMONS

The Burgess fossils reveal a fascinating world. Yet the Cambrian Explosion was far more than just a lot of bizarre new animals. "The big thing about the Cambrian Explosion is that it was the first animal-based community," Harper told *Science News for Students*. "Before that, animals were there, but they weren't very diverse or common."

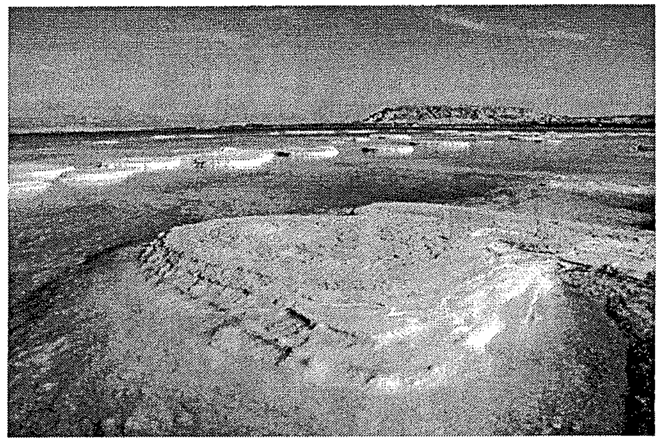
Oxygen on the rise

Earlier, during a very long stretch of time known as the Precambrian, life was simple. Bacteria dominated, quietly clumping into slimy mats. Then, starting around 3.5 billion years ago, some of those bacteria began producing oxygen as a byproduct of photosynthesis. Until then, there had been little or no oxygen, which complex animals need.

Around 2.3 billion years ago, oxygen levels in the atmosphere and oceans suddenly rose. Iron began to react with that oxygen in a process called oxidation. You might think of it as rusting. The rusting that accompanied that spike in the air's oxygen levels is permanently recorded in rock layers. These include some that are called banded iron formations.

What happened to oxygen levels over the next 1.8 billion years, leading up to the Cambrian Explosion, isn't clear. Scientists want to know: Did oxygen levels rise gradually over this period? Or did oxygen levels skyrocket, providing a quick trigger for life's great blossoming?

Time capsules



Halite is a mineral that forms when seawater evaporates. Researchers discovered seawater droplets inside 830 million-year-old halite crystals that allowed them to estimate oxygen levels in the Precambrian ocean. Such measurements allow experts to see how a steady increase in oxygen helped set the stage for the Cambrian Explosion.

IROPA/ISTOCKPHOTO

Imagine being able to test drops of actual Precambrian seawater to find out just how much oxygen the oceans contained at a given moment in the distant past. That's what Natalie Spear has done. Last year, this geologist and her team at Pennsylvania State University in State College discovered ancient seawater droplets in Australia. They were trapped in 830 million-year-old salt crystals. When saltwater evaporates, it leaves behind this mineral, called halite.

"The seawater was trapped as the salt crystals grew," Spear explains. Finding these crystals was "pretty remarkable," she adds. "It's difficult to find salt that old that is well-preserved." The halite samples contained seawater nearly 300 million years older than any ever analyzed!

Liquid trapped inside a crystal is called a fluid inclusion. "Fluid inclusions are little time capsules," explains Linda Kah. A geologist at the University of Tennessee, in Knoxville, she studies rocks from the Precambrian to determine the chemical conditions that existed when they formed.

Oxygen itself disappears when seawater evaporates. So Spear analyzed the ancient seawater for a form of sulfur. It's called sulfate. Measuring sulfate gave her team a way to estimate how much oxygen the ancient seawater once held.

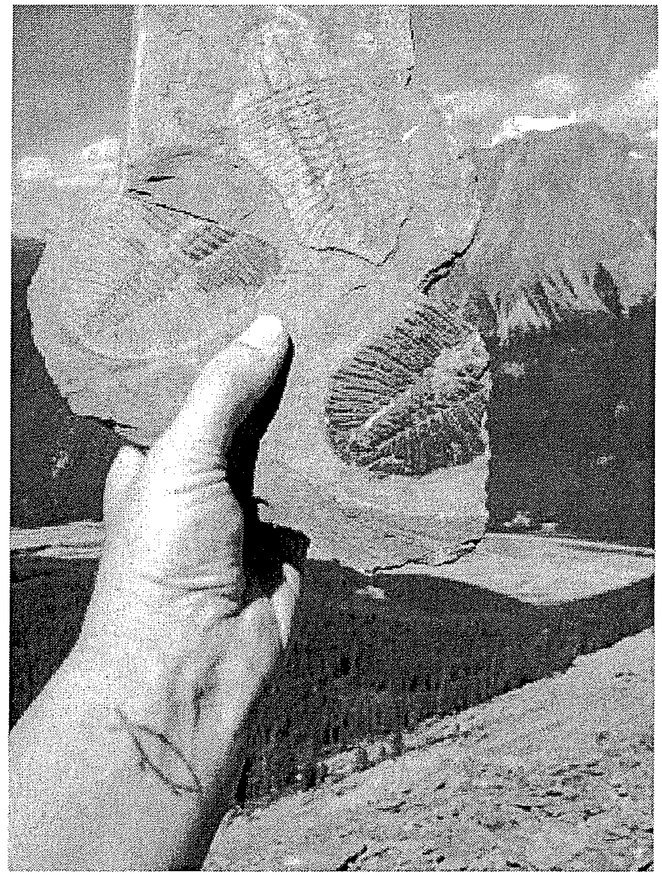
That may sound odd. But it works because oxygen in the air weathers, or erodes, rocks on land that contain iron and sulfur. "Even a little oxygen in the atmosphere will weather rocks," says Kah.

Rain then washes the eroded bits of rusted rock into the ocean, sulfur and all. There, oxygen reacts with sulfur to form sulfate. The more oxygen there is to weather rocks, the more sulfate that ends up in the ocean.

Spear's team found sulfate levels 830 million years ago were just 10 percent as high as they are today. That level would be consistent with an atmosphere containing about 2 percent oxygen.

For comparison, oxygen today comprises about 21 percent of the air.

Scientific studies of other seawater inclusions offer clues to sulfate levels — and oxygen — at points in time even closer to the Cambrian. They show that by the end of the Precambrian, about 540 million years ago, ocean sulfate levels had risen to between 50 percent and 80 percent of today's levels. Oxygen levels would have risen by a similar amount, says Spear at Penn State. Her team described its new findings in the February 2014 *Geology*.



A visitor to Canada's Burgess Shale formation holds up several fossilized trilobites. The marine animals were abundant during the Cambrian, when life exploded in diversity.

COURTESY OF MARY CAPERTON MORTON/THE BLONDE COYOTE (WWW.THEBLONDECOYOTE.COM).

Another recent study also showed that low oxygen levels played a role in delaying the great diversification of life. This study measured the rise of oxygen by analyzing trace metals in layers of ancient rock. An international team of researchers, led by Noah Planavsky of Yale University in New Haven, Conn., published its findings in the October 31, 2014, issue of *Science*.

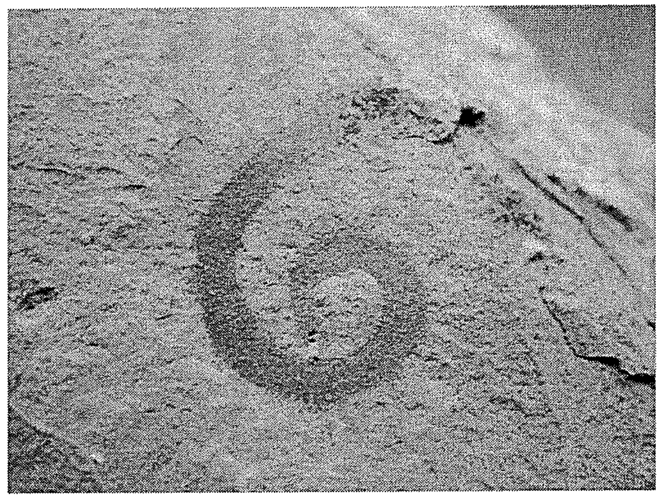
Together, these studies provide snapshots of how much richer in oxygen the world's oceans grew in the buildup to the Cambrian Explosion.

Habitat helpers

The steady increase in oxygen levels over hundreds of millions of years certainly could have set the stage for the upcoming explosion in animal life.

Yet oxygen wasn't the only thing that changed during the last 300 million years of the Precambrian. Major ice ages came and went. Along with cold weather, these ice ages made sea levels yo-yo up and down. Also, Earth's great tectonic plates were on the move. They changed the size and position of the continents — and in turn the circulation patterns in the oceans and atmosphere. All of these changes to Earth would have affected the life upon it.

The simpler life forms that had emerged before the Cambrian Explosion helped set the stage too, says Don Canfield. He's a geologist at the University of Southern Denmark, in Odense. There, Canfield studies the chemistry of ancient oceans.



This fossil from Utah reveals a Cambrian worm. The burrowin
these worms helped mix oxygen into sediments at the botto
shallow seas. More oxygen, in turn, made the sediments even
more habitable to other creatures. Courtesy of the Virtual Fos
Museum, <a
href="https://www.fossilmuseum.net">www.fossilmuseum.ne

Marine animals, such as worms, already were burrowing under the oceans, for example — 10 million years before the Cambrian began, he notes. And that churning likely changed the chemistry of the sediments blanketing the shallow seafloor, he told *Science News for Students*. Crucially, the action of the worms mixed in more oxygen, making the sediment even better habitat for animals.

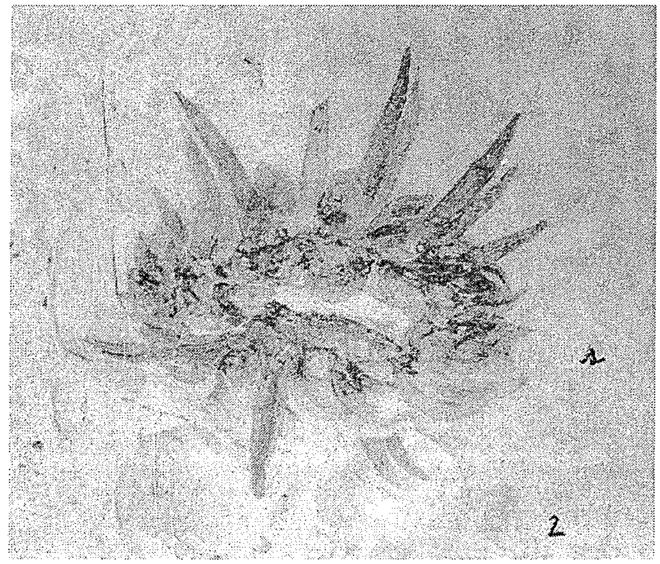
Cascade of events

Harper, the Durham University paleontologist, has considered all of the factors that may have contributed to the Cambrian Explosion. He's read about what others have found — Precambrian fossils, new estimates of ancient oxygen levels, shifting continents and evolving climates. He's also probed rocks and fossils for clues.

Last year, working with M. Paul Smith at England's Oxford University, Harper reached a conclusion about the cause of the Cambrian Explosion: "It was a cascade of events, not one thing." Life, he adds, got a lucky break as a series of changes built up. Harper and Smith published their assessment in the September 20, 2013, *Science*.

Harper calls these changes "feedback loops." What he means is that as one condition changed, another changed in response. And this caused the first condition to change some more. The process sped up adaptation and change.
Harper says predator-prey relations are a great example. As predators evolve, their prey must evolve too if it hopes to avoid being eaten. Prey may develop thicker shells or start burrowing. "Then," he says, "the predators respond by changing too." The results ripple throughout the

ecosystem, Harper says. For example, *Hallucigenia* most likely developed those nasty spines to discourage predators.



The Burgess Shale has revealed all sorts of odd animals, such as the spine-covered *Wiwaxia corrugate.* The relationship between predators and their prey probably helped drive the evolution of so many new organisms during the Cambrian, as species competed to eat — and not be eaten.
MARTIN R. SMITH/WIKIMEDIA COMMONS

Meanwhile, geological changes played a role, too. As ice melted, sea levels rose. Those rising seas flooded shorelines. This, in turn, created lots more shallow underwater habitat for animals, such as those burrowing worms that Canfield described. More burrowing would have moved more oxygen into sediments. And more oxygen in turn would have spurred more burrowing.

Rising seas also eroded more shoreline, says Harper. That, in turn, washed more minerals into the oceans. The elements in them included, of course, sulfur but also phosphorus and calcium. In fact, calcium levels in seawater tripled during the early Cambrian.

“Calcium is what builds shells,” Harper explains. Over time, animals in the seas developed thicker, more ornate shells. He says that’s one thing that “becomes very, very obvious during the Cambrian Explosion.”

Such feedbacks would have exaggerated the pace of change. They also likely would have led animal diversity to rapidly increase, Harper suspects.

The work by Harper and Smith shows us how closely Earth’s geology and biology are linked. Tweak one, and you alter the other. In the strangeness of the Cambrian, 540 million years ago, the results were as big as life itself.

Word Find (click here to enlarge for printing)

WHEN LIFE EXPLODED

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HISTORY
MINERAL
MUDDY
OXYGEN
PHYLA
SEAFLOOR
SEAWATER
SHALE
SHELL
SULFATE
TECTONIC
URCHINS

NGSS: HS-ESS1-1, HS-ESS1-2, HS-ESS1-3, HS-ESS2-7, HS-PS1-8, MS-ESS1-4, MS-PS1-1

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Classroom questions: When life exploded

ScienceNews for Students

CLASSROOM QUESTIONS

Questions for When life exploded

By Science News for Students

November 13, 2014 at 8:30 am

SCIENCE

Before reading

1. Take a deep breath: What is the source of the oxygen that you just inhaled?

2. How do you know there is oxygen in seawater?

During reading

1. In what context could 10 million years be considered a "blink of an eye?"

2. What happened during the Cambrian Explosion?

3. Define "phylum," and provide two examples.

4. Why are fossils found in the Burgess Shale so valuable to scientists?

5. Explain how *hallucigenia* got its name.

6. When did oxygen levels first begin to rise on Earth?

7. How does halite form?

8. How much oxygen did the oceans contain at the start of the Cambrian Period?

9. What would burrowing worms do to oxygen levels in marine muds?

10. Explain what a "feedback loop" is.

After reading

1. How are increased ocean levels of calcium linked to the Cambrian Explosion?

2. If you dug down deeper into the Burgess Shale formation, would you expect to find a greater or lesser diversity of fossilized creatures? Explain your answer.

SOCIAL STUDIES

1. Create a map that highlights the mountain chain that includes the Burgess Shale formation.

CITATIONS

Beth Geiger. "When Life Exploded." *Science News for Students*. November 13, 2014.

ScienceNewsforStudents

HEALTH & MEDICINE

Warning: Climate change can harm your health

Low-income people and vulnerable groups will be hit the hardest

In March, Cyclone Idai struck Mozambique, causing widespread flooding. It also sparked an outbreak of cholera.

CLIMATE CENTRE/FLICKR (CC BY-NC 2.0)

By **Kathiann Kowalski**

May 2, 2019 at 5:45 am

This is the ninth in a 10-part series about the ongoing global impacts of climate change. These stories will look at the current effects of a changing planet, what the emerging science suggests is behind those changes and what we all can do to adapt to them.

The city of Beira was overwhelmed when Cyclone Idai slammed into Mozambique on March 14 and 15. Floods swept across 3,000 square kilometers (1,200 square miles) of the nation. The area affected was about three-quarters the size of the state of Delaware. Homes were inundated. Roads and bridges washed away. More than 1,000 people died in this country, Malawi and Zimbabwe. The full death toll may never be known.

The waters laid waste to crops in areas around Beira. This set the stage for hunger. Floods shut down much of the city's water and sanitation systems. The threat of waterborne disease loomed.

As of April 10, Mozambique's health officials said more than 4,000 people had been infected with cholera. Bacteria in contaminated water cause this disease. Its symptoms include severe diarrhea, violent vomiting and dehydration. People who don't get prompt treatment can die. Clearly, the country faced a major health crisis.

Scientists can't yet say exactly what role climate change may have played in Cyclone Idai. But they do know that extreme storms will become more common with climate change. They know, too, that low-income countries in Africa and elsewhere will be hit harder than more well-to-do nations. And they know that there will be a wide range of health impacts — including more waterborne disease.

Climate change is acting in many ways that can harm health. Between 2030 and 2050, a quarter million more people will die each year than would if climate change were not a factor, the World Health Organization now predicts. And this estimate may be low. It doesn't include all the many ways that climate change can affect health.

We don't have to wait until 2030 to see impacts, either, says Kristie Ebi. She's a public health expert at the University of Washington in Seattle. "Climate change is already affecting our health," she notes.

Climate change poses mental health risks to children and teens

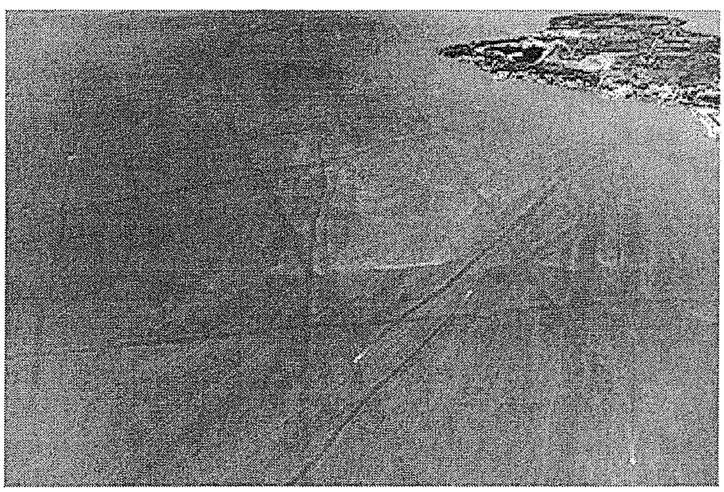
Extreme heat is one problem. More intense hurricanes, rainstorms and wildfires are others. Such events cause direct harm. They also can disrupt basic health services and promote the spread of disease. But climate change will alter the planet in less obvious ways that can harm health. Air and water pollution will worsen in many places. Infectious diseases will become more common at some sites, or spread to new ones.

The more scientists and engineers learn about climate change and its impacts, the better people will be ready to deal with them. "If we understand that we are part of the cause, it gives some hope that we can be a part of the solution," says Sarah Kew. She's a climate scientist with Vrije University Amsterdam in the Netherlands.

Muddy waters

Cyclone Idai was just the latest in a series of devastating storms, many of which have been intensified by climate change. Last September in the United States, for instance, Hurricane Florence flooded huge areas of North Carolina. The waters swept sewage, fertilizers, animal waste, coal ash and animal carcasses into waterways. Floodwaters also messed with water-treatment plants and sewage systems. Water systems shut down in about two dozen communities. Another 20 or so warned their residents to boil their water before use.

Climate change threatens water supplies in other ways, too. Storms can bring contamination. Sea level rise can overwhelm sewer pipes and treatment plants, sweeping more contamination into waterways. Droughts can take away once abundant water supplies.



Heavy rains in the spring of 2018 brought an early algal bloom to western Lake Erie in July. Extreme weather events such as heavy storms will be more frequent with climate change. Such storms and warmer summers could lengthen the season for harmful blooms.

ZACHARY HASLICK/AERIAL ASSOCIATES PHOTOGRAPHY, INC./NOAA GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

Blooms of harmful algae happen when some single-celled species grow out of control. Some of them make poisons that cause breathing problems. Others algal toxins can harm the liver, damage the nervous system or affect the brain (and memories).

A bad bloom in Lake Erie forced the city of Toledo, Ohio, to shut down its water system for two days in 2014. Climate change will likely bring more bad blooms. One way they can do this: Climate-intensified storms can wash more fertilizer into waterways. Those nutrients can feed toxic algal species in lakes and along coastlines. Warmer waters also are expanding the areas where algal blooms are likely to emerge.

Christopher Gobler is a coastal ecologist at Stony Brook University in New York. He and other scientists found that since 1982, the *niche* for harmful algal blooms had grown in the northern Atlantic and Pacific oceans. The timing of when blooms might erupt could shift as well. The group reported its findings in 2017 in the *Proceedings of the National Academy of Sciences.*

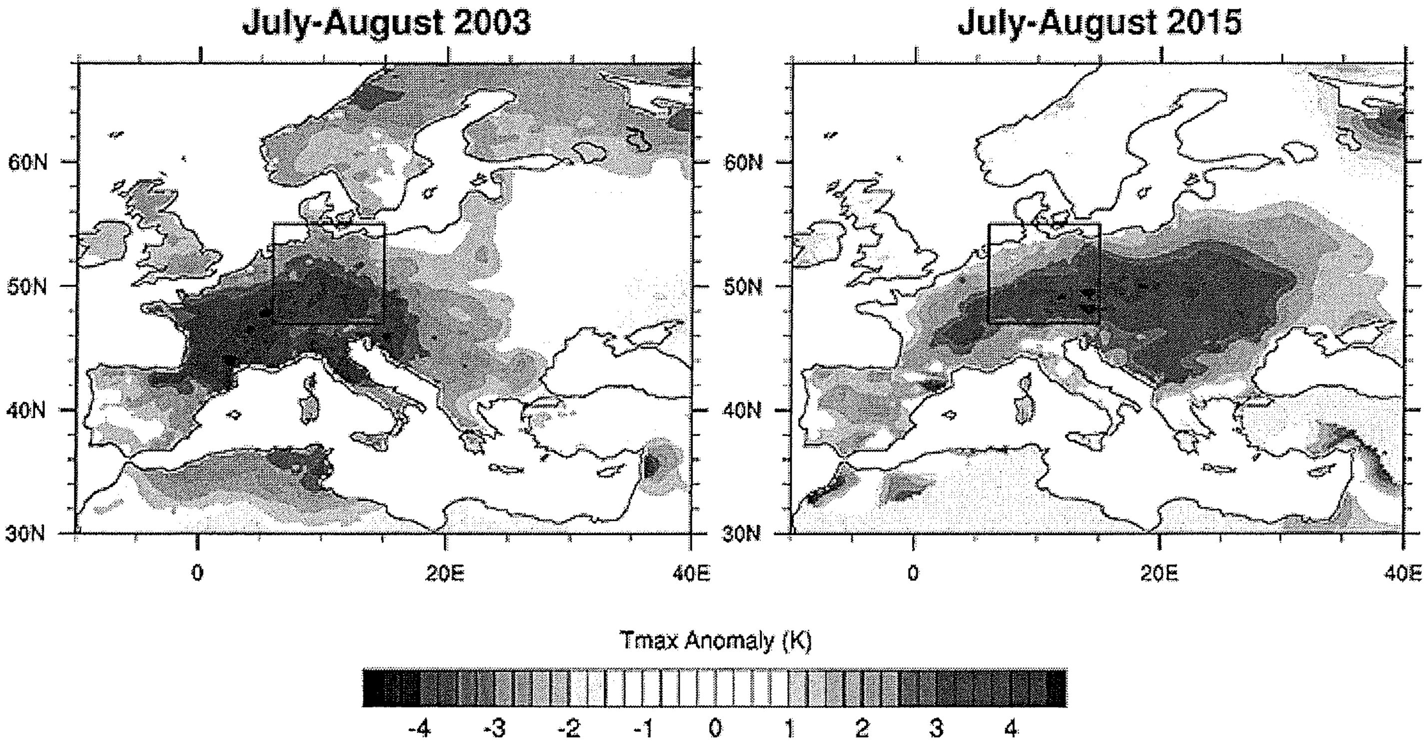
"Water is the primary medium through which we will feel the effects of climate change," reports UN-Water, a United Nations agency. Water supplies, water cleanliness and water-delivery systems are all at risk. Yet the health impacts of climate change don't stop there.

Turning up the heat

Explainer: How heat kills

In folklore, Lucifer is a name for the devil. But in 2017, Lucifer took on an extra meaning. It was the name given to a heat wave that made many people think about fires in hell. In parts of southern Europe that August, temperatures topped 40° Celsius (104° Fahrenheit). Even at night, those hot spots didn't dip below 30 °C (86 °F). So public health officials issued warnings. Find cooler shelter, they said. Limit physical activity. Drink extra fluids. Their concern: Heat can kill.

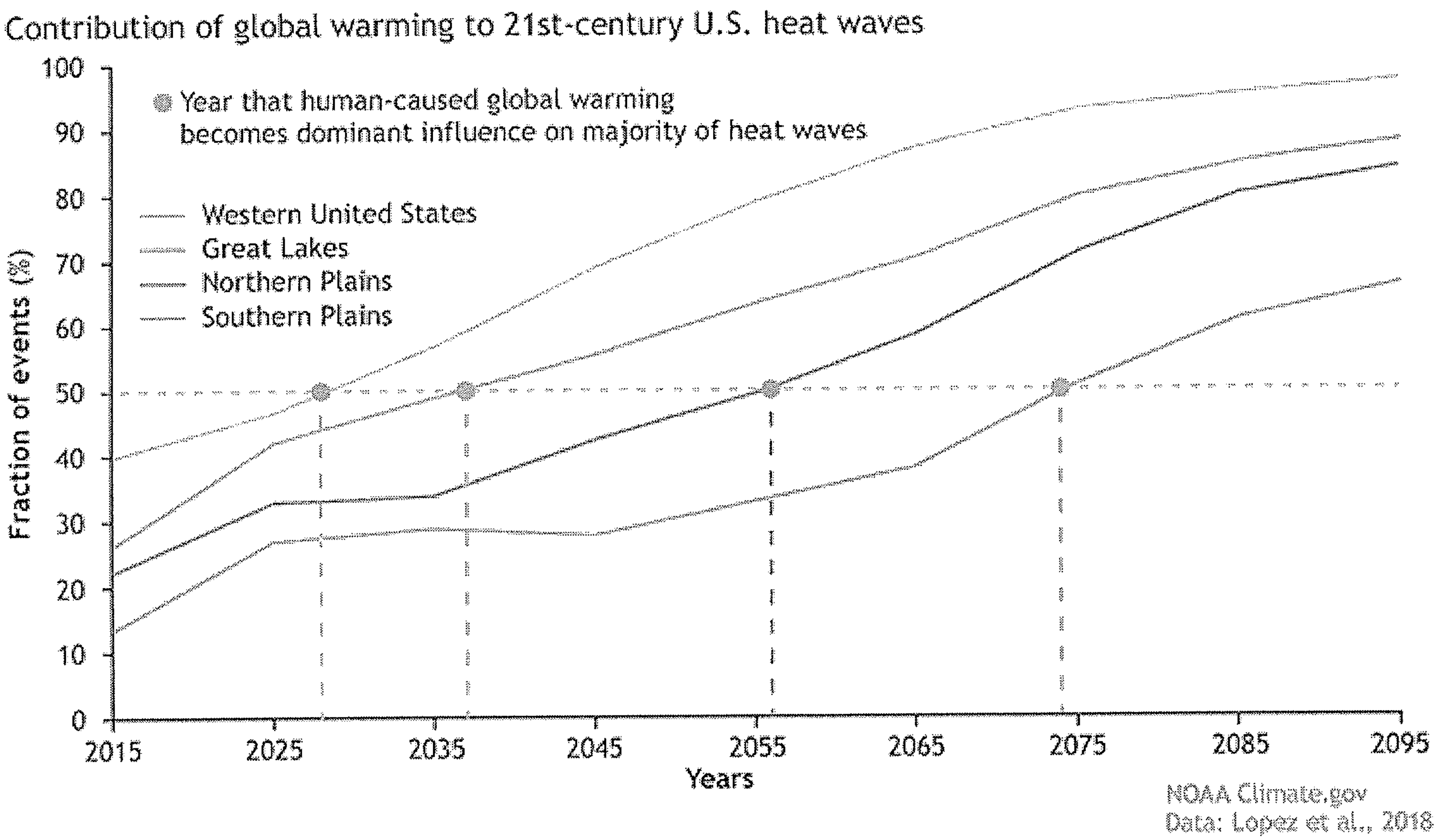
Lucifer-like heat waves were once rare. Now, southern Europe can expect them about once every 10 years. "We estimate that human-caused climate change has increased the odds of such an event more than threefold since 1950," says Kew. She led the study behind that forecast.



These maps show variations from normal summer temperatures in Europe in 2003 and 2015. Redder areas were hotter than normal. On average, areas in the blue boxes were 2.8° C (5° F) warmer than usual.

S. MUTHERS *ET AL/ATMOSPHERE* 2017

There's a similar forecast for the United States. Hosmay Lopez is a climate scientist in Florida with the National Oceanic and Atmospheric Administration and the University of Miami. "Without human influence, half of the extreme heat waves projected to occur in the future wouldn't happen" in most of the United States, he says. And by human influence, he's referring to the burning of fossil fuels and other activities that have been playing a role in warming Earth's climate.



Climate change will soon be the main factor that drives most heat waves in much of the United States. Or so reports scientists at NOAA and universities in Florida.

GRAPH: NOAA/CLIMATE.GOV, DATA: LOPEZ *ET AL/NATURE CLIMATE CHANGE* 2018

An increased risk of death from heat waves exists worldwide, says Yuming Guo. As a biostatistician, he's a numbers man. He's also an epidemiologist — a disease detective — at Monash University in Melbourne, Australia. He and other scientists calculated the added risks for heat-wave deaths in 20 countries and regions. They compared the risks that have been forecast to occur between 2031 and 2080 to those seen between 1971 and 2020.

Workers won't work as well in a very warm world

In general, poorer countries in warm regions will be hit hardest, they found. If people do nothing about climate change, for example, Colombia in South America could have roughly 20 times more deaths from heat waves. Moldova in Eastern Europe would have about 50 percent more deaths. The team shared its results in *PLOS Medicine* on July 31, 2018.

"Climate change affects all of us," Madeleine Thomson says, "except some of us have a lot more resources [money and experts] to be able to tackle it." She's an insect biologist and environmental health scientist at Columbia University in New York City.

Not breathing easy

Climate change isn't just warming the air. It's also making that air harder to breathe for many people. Some of the reasons include rising levels of pollen, pollution and other air quality problems.

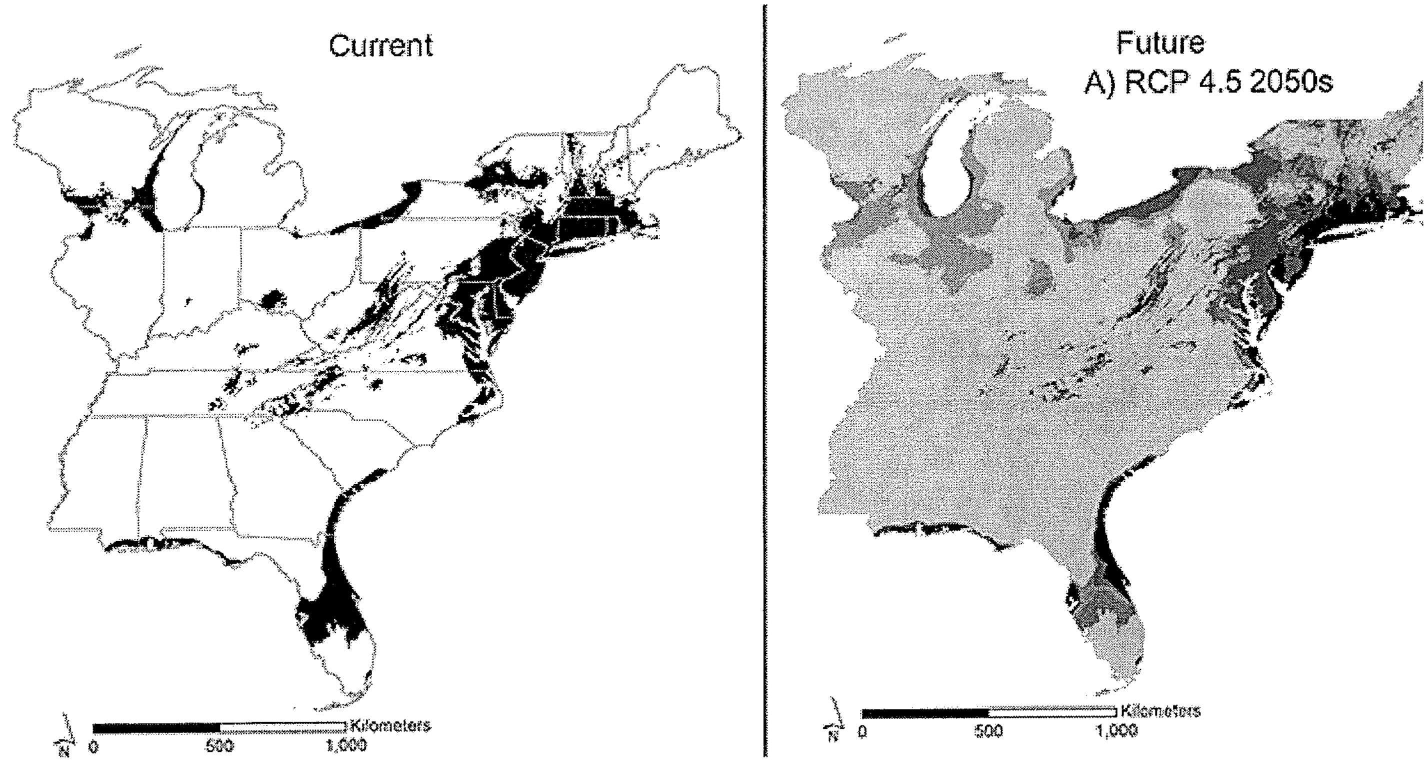
Plant pollen can cause hay fever. Its misery includes sneezes, runny noses, sore throats, headaches and itchy eyes. Pollen also can trigger asthma attacks, making it hard to take a breath. Climate change may lengthen the growing season for the pesky sources of pollen in many areas. Higher levels of carbon dioxide may also promote more plant growth.

Allergy season will shift in different areas of North America as climate change shifts the range for common ragweed (shown here).

YEVHENII ORLOVI/STOCK/GETTY IMAGES PLUS

"I personally suffer from spring-time allergies and fear a longer and potentially worse pollen season," says Michael Case. He's a climate scientist at the University of Washington in Seattle. Case and ecologist Kristina Stinson looked at how sneeze zones for ragweed pollen could shift in the eastern United States. She works in Massachusetts at the University of Amherst. The duo shared their work in *PLOS ONE* on October 31, 2018.

Climate change will bring warming and a shift in rainfall patterns. That will push ragweed farther north into new places, such as the northeastern United States. The plant also could spread northwest into Wisconsin, Minnesota and Canada. Meanwhile, parts of Florida and the Appalachian mountains may become less ragweed-friendly. "These changes will have real effects on people's health," Case says, "making it worse in some areas and potentially better in other areas."



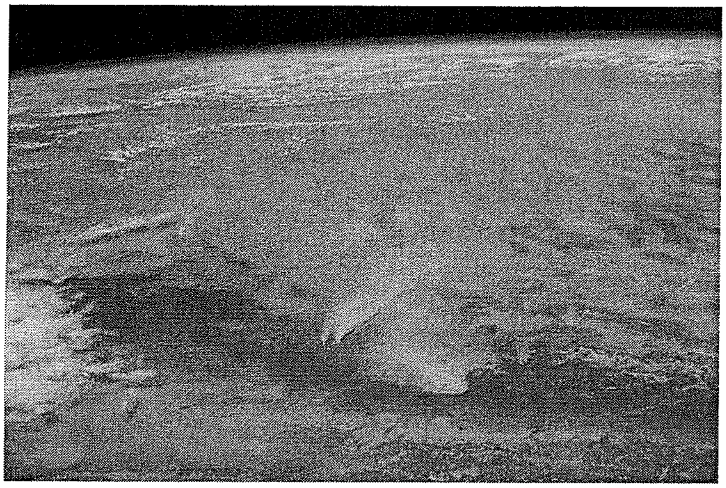
The map on the left shows current places in the eastern United States where ragweed pollen can pose allergy problems. Blue areas on the map on the right show where the plant's distribution will likely expand by the 2050s due to a moderate increase in greenhouse-gas emissions. Brown areas show where there may be less ragweed by then.

M. CASE AND K. STINSON/*PLOS ONE* 2018

Trees, too, can trigger allergies and asthma. Patrick Kinney is an epidemiologist at Boston University in Massachusetts. He was part of a team that looked at how changes in when oak trees release their pollen will affect asthma sufferers in the eastern United States. Oak pollen led to 21,000 emergency room trips there for asthma in 2010. Severe climate change could up that by another 5 to 10 percent by 2050 to 2090, the team reported in the May 2017 issue of *GeoHealth*.

A bigger concern, though, may be pollution. Last year Kinney looked into research on the interactions of climate change, pollution and health. Burning of fossil fuels and other activities release chemicals called *nitrous oxides* and *volatile organic compounds*, or VOCs. Sunlight triggers chemical reactions in both types of chemicals. That brews up ground-level ozone. And ozone is a trigger for asthma attacks and other breathing problems.

"VOC emissions go up as the temperature goes up," Kinney notes. "And that promotes ozone formation because there's more of that stuff" in the air. Also, people will need more air



When wildfires swept through large swaths of California in 2018, the smoky air triggered health warnings for vast areas. The International Space Station captured this shot of the wildfire pollution near Lake Tahoe on August 5.

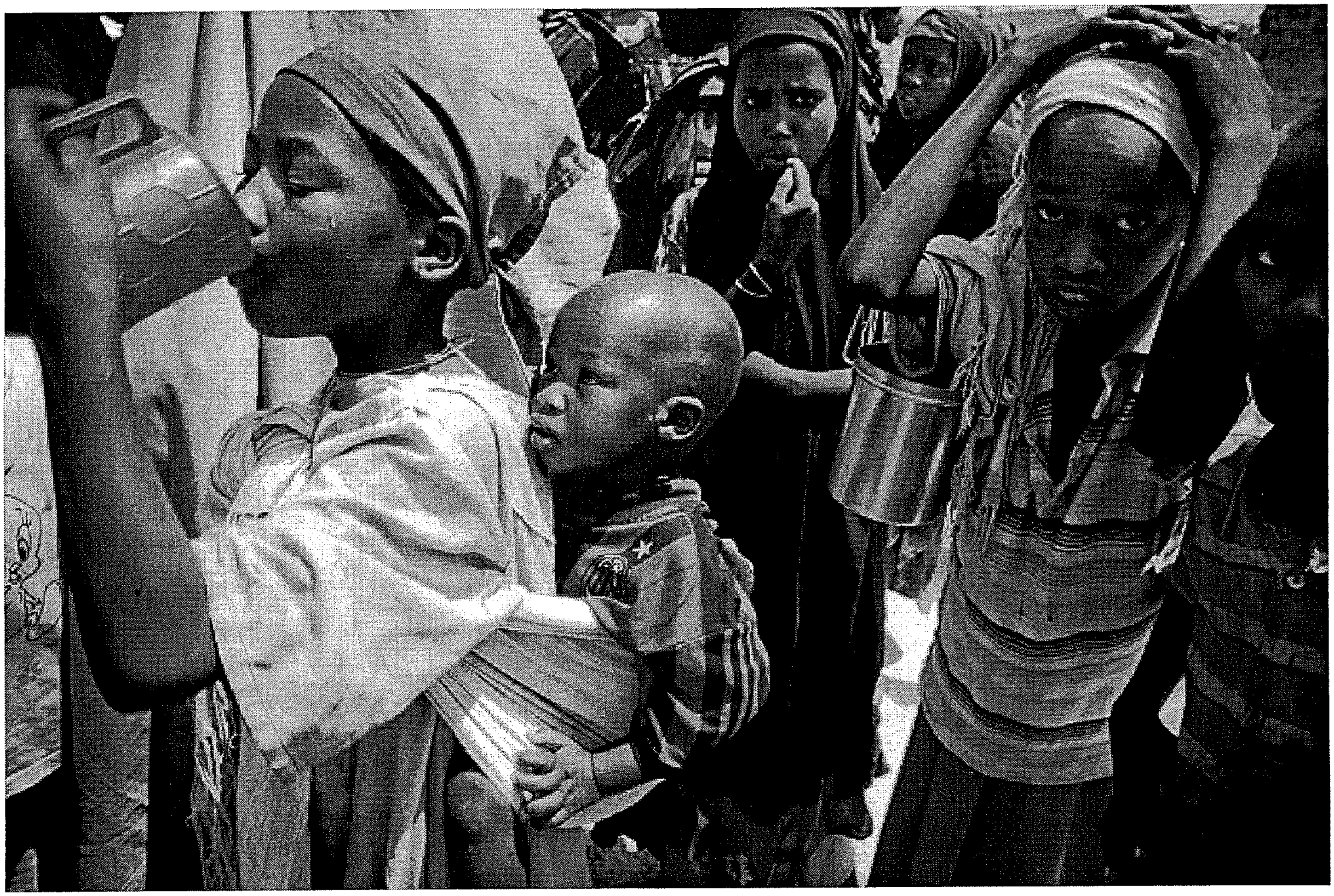
NASA JOHNSON/FLICKR (CC BY-NC-ND 2.0)

conditioning during hot spells. But burning fossil fuels to make electricity will end up releasing even more ozone-forming chemicals.

The burning of fossil fuels also fills the air with teeny, tiny pollutant particles. More of these *particulates* can form as sunlight breaks down other air pollutants. Particulate pollution can cause lung disease. But that's not all. "There's all sorts of gunk in the particles that gets absorbed into the bloodstream," Kinney notes. Studies show those tiny bits can cause heart and circulation problems. They also may mess with hormone levels and some brain functions. Kinney shared his findings in the March 2018 *Current Environmental Health Reports*.

Wildfires spew particulates, too, along with other pollutants. Bad air quality affected vast areas of the western United States, where wildfires raged last year. And there are more to come. From 2046 to 2051, 440 western U.S. counties will have at least one high-pollution smoke day. The total 5-year increase across all those counties: almost 5,000 more high-smoke days than had plagued them during the 5-year span of 2004 to 2009. That's because bigger fires will affect multiple counties. So concludes a 2016 study in *Environmental Research Letters*.

Even droughts can make breathing harder. Dry spells make the ground dusty. Winds can kick that dust into the air. Breathing it in can irritate lungs. Dry soil also kick-starts the growth of a harmful fungus. It causes a disease commonly known as valley fever. A team of scientists found a link between the number of valley fever cases in California and Arizona and soil-moisture levels the fall and winter before. Their report was in *GeoHealth* in 2017.



Up to 400,000 children were at risk for starvation when Somalia suffered a severe drought in 2011. Climate change increases the risk for more severe droughts in many places around the world.

KATE HOLT/UNICEF/DFID – UK DEPARTMENT FOR INTERNATIONAL DEVELOPMENT/FLICKR (CC BY-NC-ND 2.0)

Dealing with disease

Scientists describe an organism that can spread disease as a vector. Insects, ticks and various other animals can be culprits. Climate change will affect where such vectors thrive, notes Anna-Sofie Stensgaard. She's a disease ecologist at the Natural History Museum of Denmark in Copenhagen.

For instance, she and her colleagues looked at how climate change might affect three types of parasitic worms. These worms cause schistosomiasis (Shis-toh-so-MY-uh-sis). The disease affects more than 200 million people worldwide. Infected children grow weak and poorly nourished. They also may develop learning problems.

The team examined climate data and experimental evidence on how temperature affects the snails that host these parasites. And, she notes, "It is not just a matter of warmer equals more disease." For instance, warming might bring some areas of Africa fewer cases of schistosomiasis. But that warming might also spread these infections to places that hadn't seen the disease before. Those new sites will mainly be at the edge of current high-risk regions. Recent cases that popped up in southern Europe could be the first sign of this spread, Stensgaard suggests.

Her team's study appeared in the February 2019 issue of *Acta Tropica*.

Many insects carry disease. That's why "any change to climate is expected to have a big influence on the importance and distribution of insect-borne diseases," says Jennifer Lord. She's a biologist at the Liverpool School of Tropical Medicine in England. One of her recent studies looked at how that will likely play out for tsetse flies. These insects carry the parasites that cause sleeping sickness in people and nagana in cattle. Both diseases can be deadly.

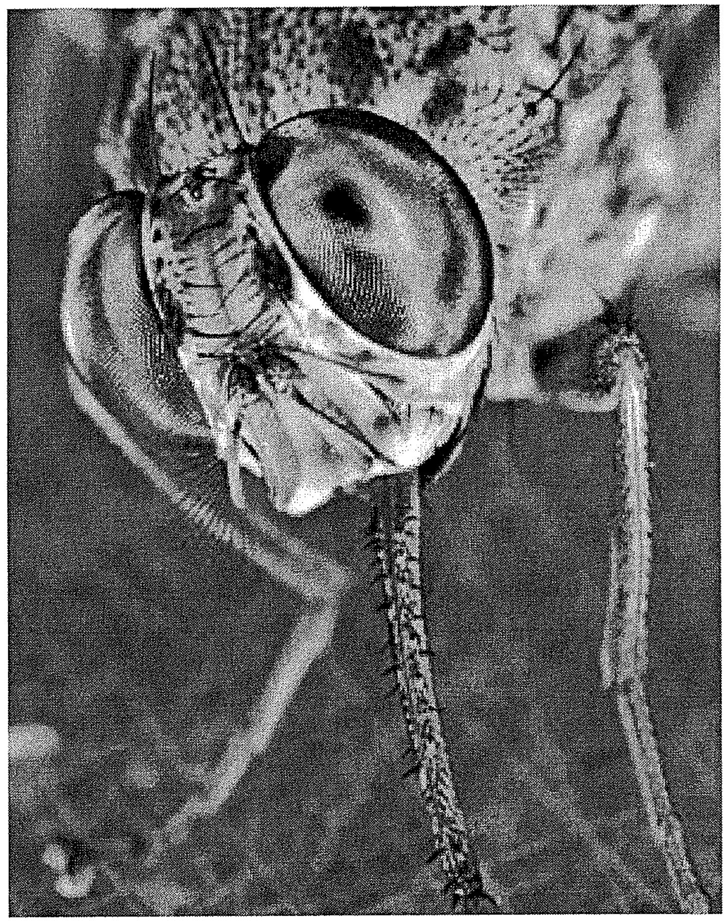
Explainer: What is a computer model?

Lord and other scientists built a *computer model* based on the fly's biology. They also analyzed 27 years of climate data and tsetse-fly counts from Mana Pools National Park in Zimbabwe. This park is in a valley, so it's warmer than higher-altitude areas nearby. The model predicted temperatures to climb over the next several decades. It also projected the park's fly population would drop. The team expects that trend will continue.

But what could happen outside the park, at higher elevations, is worrisome. "Rising temperatures may have made some higher, cooler areas of Zimbabwe more suitable for tsetse," Lord says. Many of those places don't have the flies now. But they do have many more people and cattle than the valley does. So, she notes, "Any arrival of tsetse there may increase disease."

A warmer climate also may drive disease-carrying mosquitos into new regions, including higher elevations that used to be too cool for them. Some of those migrating mosquitos are likely to spread malaria to those higher-altitude sites. That's the conclusion of one 2014 study in *Science*.

Malaria parasites attack the liver and blood cells. People with mild cases suffer with fevers, headaches and chills. In worse cases, the blood can't carry enough oxygen. Sometimes malaria also attacks the lungs and brain. Roughly 435,000 people died from the disease in 2017, notes the World Health Organization.



A tsetse fly's bite can infect a person with the parasite that causes African sleeping sickness. Recent research shows that where the fly can comfortably live will likely shift to new areas in a warming world.
GEOFFREY M. ATTARDO/YALE SCHOOL OF PUBLIC HEALTH

Mosquitoes can also carry dengue (DEN-gay) into new areas. This virus causes fevers and severe joint pain. Most new areas are likely to be next to or near to places where the mosquitoes live now. This shift would present risks to people on all continents except Antarctica, note Ebi at the University of Washington and a colleague. They published their 2016 study in *Environmental Research*.

Similar shifts may occur for other diseases as well. But there's no one-size-fits-all forecast. That's because different species will not all respond the same way to changes in their environment. In general, though, low-income countries will be hit the hardest. And within those places, women, children and the elderly are expected to fare worst.

Even in richer countries, children and older people are more apt to get certain diseases. Among the reasons why: Poor people often lack the means to eat well, to get good healthcare and to avoid living in high-risk regions.

Taking action

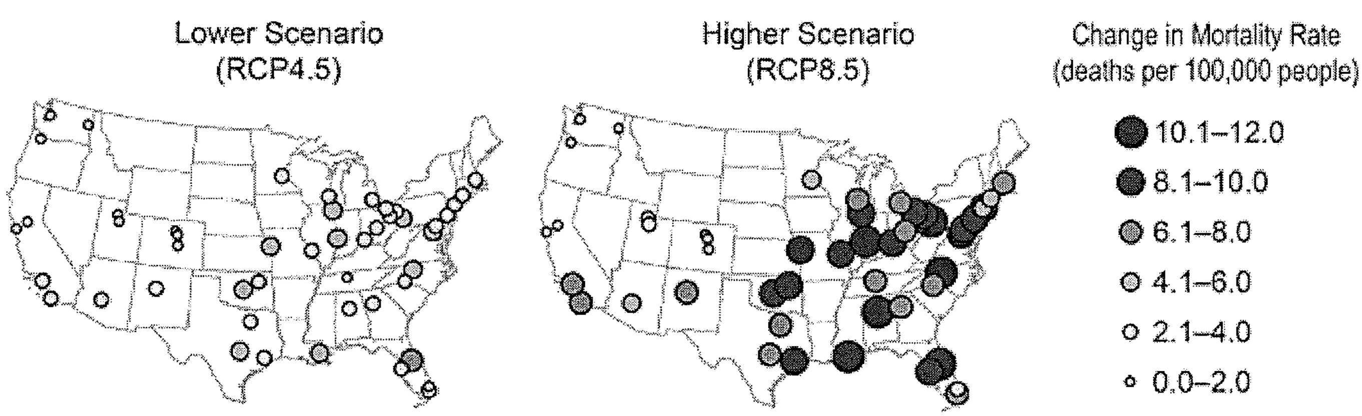
The more the average global temperature climbs, the worse climate's health impacts will be. "Each additional unit of warming will increase the risks for adverse health outcomes," says Ebi.

Fortunately, she adds, "There's a lot we can do now to reduce the number of people who are suffering and dying from climate change."

Governments and health agencies can help people plan and adapt. Timon McPhearson is an ecologist at the New School in New York City. His work on *resilience* looks at how cities can adapt to climate change. "Every city is getting hotter — and getting hotter faster than the global average," McPhearson says. Yet while cities are hot spots, some areas are hotter than others.

To explain that variation, he says, "all we need to do is look at [what sits on] the land and the building height." One of his studies showed this with data for New York City. "What you get," he says, "is if it's paved, it's hot."

Such information can help planners bring help to those places that will need it most. For example, older and low-income people have less money for air conditioning. So cities might focus efforts on hot spots with higher concentrations of people in those groups, McPhearson suggests. Cities might also make those places a priority for planting more trees, which can bring cooling shade. And they can set up neighborhood programs to make sure people are safe or cool places to find refuge in when heat waves strike.



These maps show projected changes in annual deaths due to very hot and cold days for 49 U.S. cities, based on two possible levels of greenhouse-gas emissions between 2080 and 2099. Those numbers are compared to rates in 1989 to 2000. (The lower scenario assumes that governments will make some cuts in emissions. The higher scenario does not.) A 2018 report from the U.S. Global Climate Change Program projects an additional 3,900 deaths per year under the lower scenario and roughly 9,300 more deaths per year under the higher emissions level.

U.S. GLOBAL CHANGE RESEARCH PROGRAM

One way to slow climate change is to cut emissions of the pollutants responsible. And people can do that by using energy very efficiently or switching their sources of energy from fossil fuels to renewable fuels (such as wind). Too often, people focus only on the costs for those actions, Ebi says. In fact, she notes, "almost all the *mitigation* policies benefit our health — and they benefit our health now."

Indeed, pollution already imposes huge costs to society. "We can save hundreds of millions of dollars in hospitals and people not dying early by mitigating [climate change] now," Ebi says.

Classroom questions

And while climate change is a global issue, cuts in emissions also provide local health benefits, Kinney notes. People there get cleaner air and cleaner water very quickly. "It's a win-win if we take action," he says. "It always turns out the health benefits far outweigh the costs."

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ScienceNews*for*Students

CLASSROOM QUESTIONS

Questions for 'Warning: Climate change can harm your health'

In March, Cyclone Idai struck Mozambique, causing widespread flooding. It also sparked an outbreak of cholera.

CLIMATE CENTRE/FLICKR (CC BY-NC 2.0)

By **Science News for Students**

May 2, 2019 at 5:25 am

To accompany feature "Warning: Climate change can harm your health"

SCIENCE

Before Reading:

1. Scientists predict more health problems will emerge as Earth's climate changes over the next few decades. What types of problems will worsen or develop?

2. What aspects of climate change do you expect will trigger these health effects? Name at least three.

During Reading:

1. Describe at least five things that impacted health when Cyclone Idai came ashore in Africa.

2. What is cholera and why did it become a problem in Idai's aftermath?

3. How many more people are expected to die between 2030 and 2050 due to climate change, according to the World Health Organization?

4. What are at least three health risks posed by algal toxins, according to the story?

5. Lucifer was the name given to what 2017 event in Europe? How much has the risk that such events will occur increased since 1950, according to the story?

6. Yuming Guo's team calculated new risks of heat-wave-related deaths for 20 nations between 2031 and 2080. How much higher are they projected to be (compared to 1971 to 2020) in Colombia? How much higher in Moldova? (For bonus points, where are those two nations located?)

7. According to the story, what pollutants combine in the air to make ozone? And why is the formation of ozone a health concern?

8. What are particulate pollutants and what types of health risks do they pose, based on the story?

9. What is a disease vector. Give several examples from the story?

10. How many people die from malaria each year, based on the story? How might the areas at risk for malaria change with climate change? Which continents would be affected. (Bonus points if you can name each continent that would be affected.)

After Reading:

1. Choose one of the health risks from climate change that could affect a town near you. Now do some research and design a campaign to describe actions local community or government leaders might take to limit the conditions leading to these risks. Describe what you would have them do. If you have time, prepare a poster to present your campaign.

2. Some people have argued that because climate change is a global problem, all nations should share in addressing ways to combat warming and ways to adapt. Others have argued that those nations whose actions have contributed most should pay the most. Still others have argued that each nation should pay to take care of themselves. What do you think is the best strategy? Explain your reasoning, describing both the costs and benefits to your choice — both for people in your country and to those half a world away.

MATH

1. Oak pollen sent 21,000 people to U.S. emergency rooms for asthma in 2010. By 2090 the rate could climb another 5 or 10 percent. If true, what would the numbers then be? Show your work.

2. The story says that Lucifer-like events used to be rare. But since 1950 they have tripled. Now they can be expected about once every decade. What does that imply was the rate back in 1950? Show your work.

Lancet commission says the same. The Experts write: " What we're doing now is unsustainable," "The only thing we can hope is that a sense of urgency will permeate. We're running out of time." "Until now, undernutrition and obesity have been seen as polar opposites of either too few or too many calories," "In reality, they are both driven by the same unhealthy, inequitable food systems, underpinned by the same political economy that is single-focused on economic growth, and ignores the negative health and equity outcomes. Climate change has the same story of profits and power,"[298]

Measures for achieving environmental sustainability can improve health. For example, cycling reduces greenhouse gas emissions[299] while promoting Active living at the same time.[300]

Reducing the use of screens can help fight many diseases[301][302] and lower greenhouse gas emission[303]

Cultural dimension

The cultural dimension of sustainability is known as cultural sustainability. Important in the advancement of this notion have been the United Nations, UNESCO, and in particular their Agenda 21 and Agenda 21 for culture (now also known as Culture 21), a program for cultural governance developed in 2002–2004 and coordinated by United Cities and Local Governments (UCLG), created in 2004.

Tourism

Sustainability is central to underpinning feelings of authenticity in tourism.[304] Experiences can be enhanced when substituting the contrived for the genuine, and at the same time inspire a potentially deleterious appetite for follow-up visits to the real thing: objectively authentic sites untouched by repair or rejuvenation. Feelings of authenticity at a tourist site are thus implicitly linked to sustainable tourism; as the maximisation of existential "felt" authenticity at sites of limited historical provenance increases the likelihood of return visits.[305]

Threats to sustainability

The section describes shortly the main threats to sustainability, according to current scientific understanding.

In 2009 a group of scientist described nine planetary boundaries. Transgressing even one of them can be dangerous to sustainability. Those boundaries are:

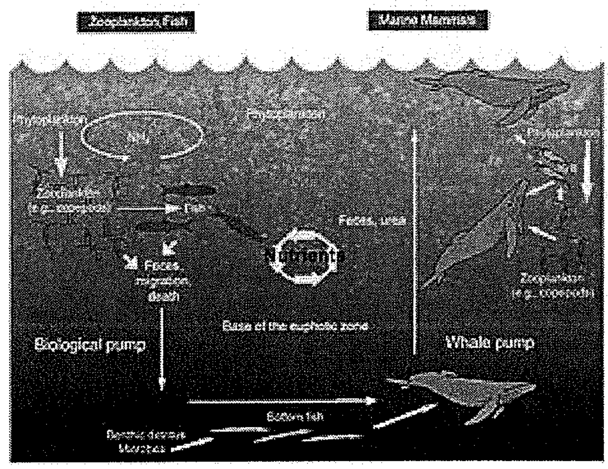
Planetary Boundaries[306]

Earth-system process	Control variable[307]	Boundary value	Current value	Boundary crossed	Preindustrial value	Commentary
1. Climate change	Atmospheric carbon dioxide concentration (ppm by volume)[308]	350	400	yes	280	[309]
	Alternatively: Increase in radiative forcing (W/m^2) since the start of the industrial revolution (~1750)	1.0	1.5	yes	0	[310]
2. Biodiversity loss	Extinction rate (number of species per million per year)	10	> 100	yes	0.1–1	[311]
3. Biogeochemical	(a) anthropogenic nitrogen removed from the atmosphere (millions of tonnes per year)	35	121	yes	0	[312]
	(b) anthropogenic phosphorus going into the oceans (millions of tonnes per year)	11	8.5–9.5	no	~1	[313]
4. Ocean acidification	Global mean saturation state of aragonite in surface seawater (omega units)	2.75	2.90	no	3.44	[314]
5. Land use	Land surface converted to cropland (percent)	15	11.7	no	low	[315]
6. Freshwater	Global human consumption of water (km^3/yr)	4000	2600	no	415	[316]
7. Ozone depletion	Stratospheric ozone concentration (Dobson units)	276	283	no	290	[317]
8. Atmospheric aerosols	Overall particulate concentration in the atmosphere, on a regional basis	not yet quantified				[318]
9. Chemical pollution	Concentration of toxic substances, plastics, endocrine disruptors, heavy metals, and radioactive contamination into the environment	not yet quantified				[319]

WIKIPEDIA

Biogeochemical cycle

In ecology and Earth science, a **biogeochemical cycle** or **substance turnover** or **cycling of substances** is a pathway by which a chemical substance moves through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth. There are biogeochemical cycles for the chemical elements calcium, carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, selenium, and sulfur; molecular cycles for water and silica; macroscopic cycles such as the rock cycle; as well as human-induced cycles for synthetic compounds such as polychlorinated biphenyl (PCB). In some cycles there are *reservoirs* where a substance remains for a long period of time.



An illustration of the oceanic whale pump showing how whales cycle nutrients through the water column

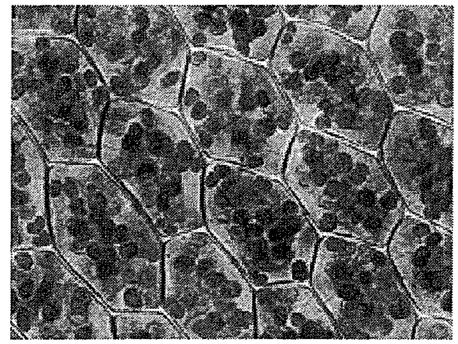
Contents

Systems

Ecological systems (ecosystems) have many biogeochemical cycles operating as a part of the system, for example the water cycle, the carbon cycle, the nitrogen cycle, etc. All chemical elements occurring in organisms are part of biogeochemical cycles. In addition to being a part of living organisms, these chemical elements also cycle through abiotic factors of ecosystems such as water (hydrosphere), land (lithosphere), and/or the air (atmosphere).[1]

The living factors of the planet can be referred to collectively as the biosphere. All the nutrients—such as carbon, nitrogen, oxygen, phosphorus, and sulfur—used in ecosystems by living organisms are a part of a *closed system*; therefore, these chemicals are recycled instead of being lost and replenished constantly such as in an open system.[1]

The flow of energy in an ecosystem is an *open system*; the sun constantly gives the planet energy in the form of light while it is eventually used and lost in the form of heat throughout the trophic levels of a food web. Carbon is used to make carbohydrates, fats, and proteins, the major sources of food energy. These compounds are oxidized to release carbon dioxide, which can be captured by plants to make organic compounds. The chemical reaction is powered by the light energy of the sun.



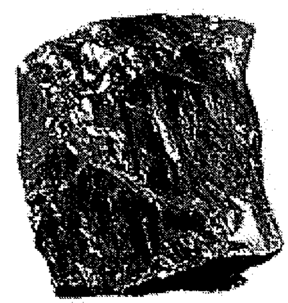
Chloroplasts conduct photosynthesis and are found in plant cells and other eukaryotic organisms. These are Chloroplasts visible in the cells of *Plagiomnium affine* — Many-fruited Thyme-moss.

Sunlight is required to combine carbon with hydrogen and oxygen into an energy source, but ecosystems in the deep sea, where no sunlight can penetrate, obtain energy from sulfur. Hydrogen sulfide near hydrothermal vents can be utilized by organisms such as the giant tube worm. In the sulfur cycle, sulfur can be forever recycled as a source of energy. Energy can be released through the oxidation and reduction of sulfur compounds (e.g., oxidizing elemental sulfur to sulfite and then to sulfate).

Although the Earth constantly receives energy from the sun, its chemical composition is essentially fixed, as additional matter is only occasionally added by meteorites. Because this chemical composition is not replenished like energy, all processes that depend on these chemicals must be recycled. These cycles include both the living biosphere and the nonliving lithosphere, atmosphere, and hydrosphere.

Reservoirs

The chemicals are sometimes held for long periods of time in one place. This place is called a *reservoir*, which, for example, includes such things as coal deposits that are storing carbon for a long period of time.[2] When chemicals are held for only short periods of time, they are being held in *exchange pools*. Examples of exchange pools include plants and animals.[2]

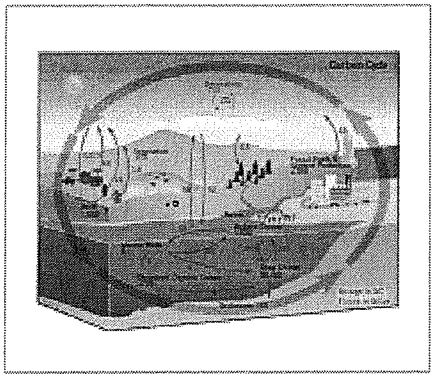


Coal is a reservoir of carbon.

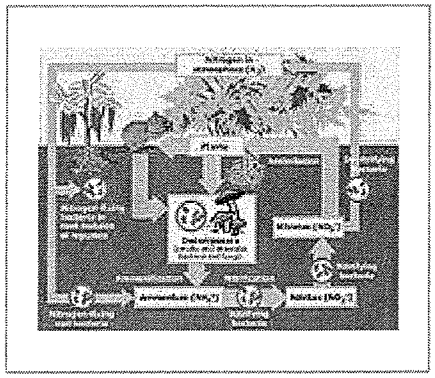
Plants and animals utilize carbon to produce carbohydrates, fats, and proteins, which can then be used to build their internal structures or to obtain energy. Plants and animals temporarily use carbon in their systems and then release it back into the air or surrounding medium. Generally, reservoirs are abiotic factors whereas exchange pools are biotic factors. Carbon is held for a relatively short time in plants and animals in comparison to coal deposits. The amount of time that a chemical is held in one place is called its *residence time*.[2]

Important cycles

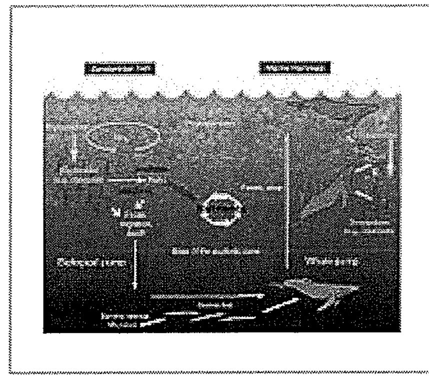
The most well-known and important biogeochemical cycles are shown below:



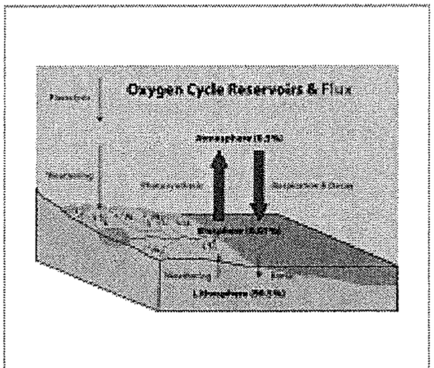
Carbon cycle



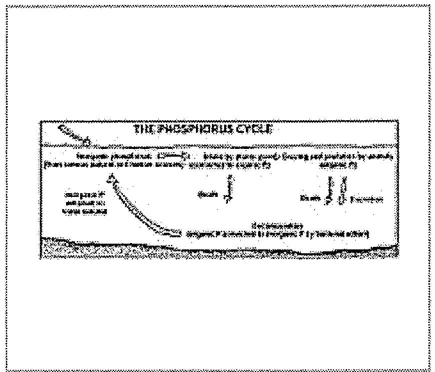
Nitrogen cycle



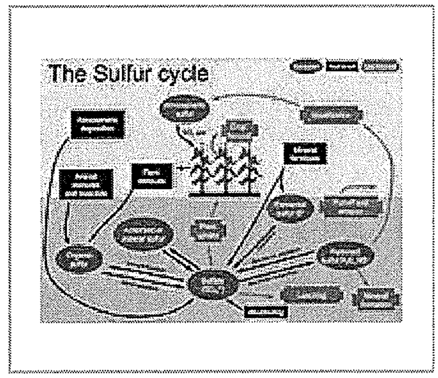
Nutrient cycle



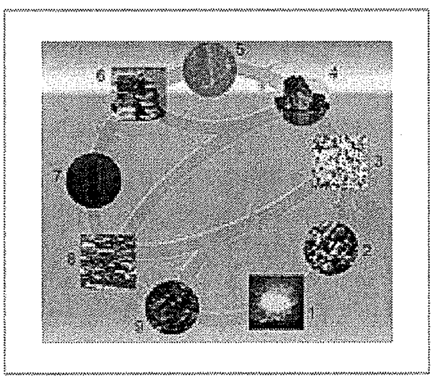
Oxygen cycle



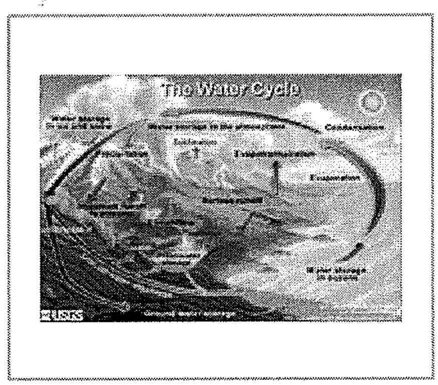
Phosphorus cycle



Sulfur cycle



Rock cycle



Water cycle

There are many biogeochemical cycles that are currently being studied for the first time as climate change and human impacts are drastically changing the speed, intensity, and balance of these relatively unknown cycles. These newly studied biogeochemical cycles include

- the mercury cycle,[3] and
- the human-caused cycle of PCBs.[4]

Biogeochemical cycles always involve hot equilibrium states: a balance in the cycling of the element between compartments. However, overall balance may involve compartments distributed on a global scale.

As biogeochemical cycles describe the movements of substances on the entire globe, the study of these is inherently multidisciplinary. The carbon cycle may be related to research in ecology and atmospheric sciences.[5] Biochemical dynamics would also be related to the fields of geology and pedology.[6]

See also

- Carbonate-silicate cycle
- Recycling (ecological)
- Hydrogen Cycle

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