Student Edition

California Education and the Environment Initiative

Earth Science
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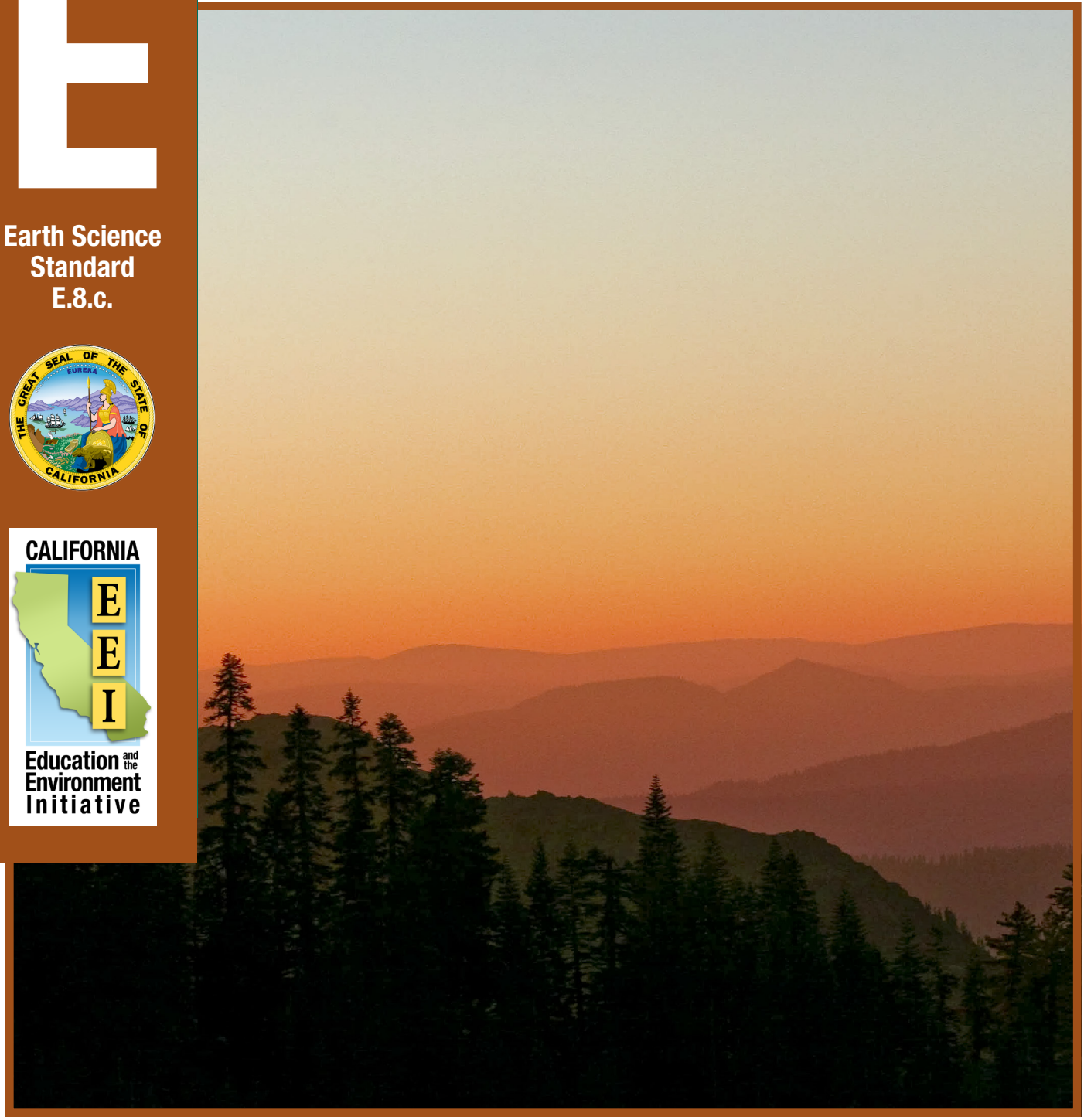

Living Under One Roof

California Education and the Environment Initiative

Approved by the California State Board of Education, 2010

The Education and the Environment Curriculum is a cooperative endeavor of the following entities:

California Environmental Protection Agency

California Natural Resources Agency

Office of the Secretary of Education

California State Board of Education

California Department of Education

California Integrated Waste Management Board

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Key Partners:

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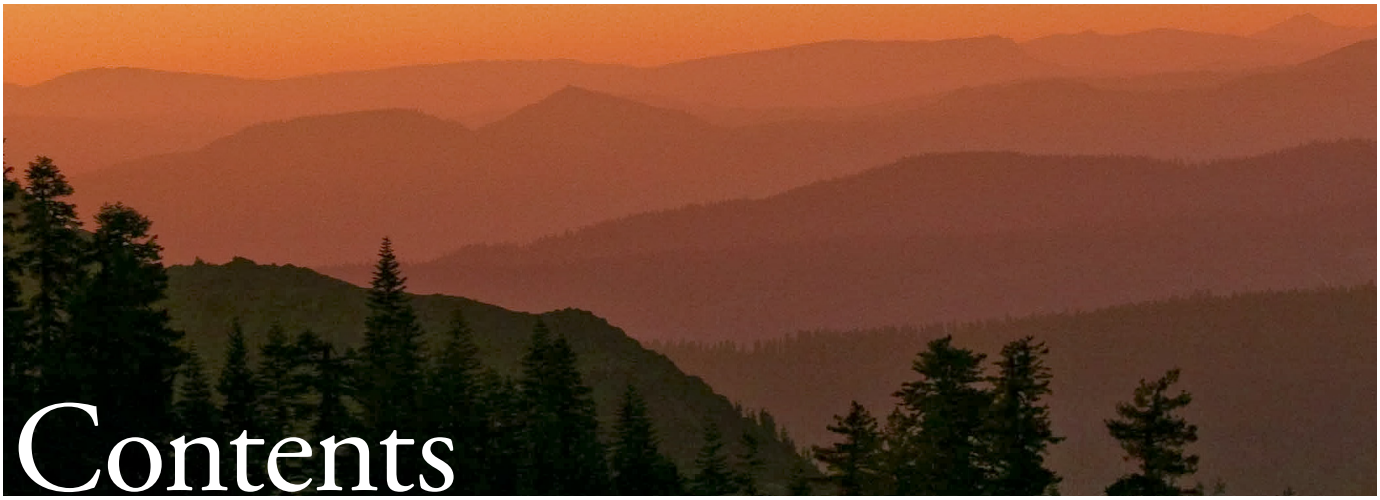


Contents

Don't Forget Your Sunscreen!

You live in California, near the ocean, the bays, or rivers; in the mountains, in the desert, in the pine or woodland forests; near farmlands or wine country; or in a city where you spend time in the parks or skateboarding. Wherever you live, you are sure of two things—California sunshine and many outdoor adventure possibilities.

But today you and your friends are at the beach. You have everything together: towel, bathing suit, hat, your music, and a snack. The dogs are barking, telling you that your friend has arrived. You race for the door. "Bye, Mom!" you yell, as you push the dogs back. "Did you remember the sunscreen?" shouts your mom. "I checked the weather forecast for today and the UV (ultraviolet) forecast is 10 and that is high, you can easily get a sunburn." You stop in your tracks, turn, and climb the stairs two at a time. There it is, on the bathroom counter—SPF 30. You grab the bottle. Your mom waits for you as you slide down the stairs. "Have fun," she says. "Remember to put it on again, after you go swimming!"

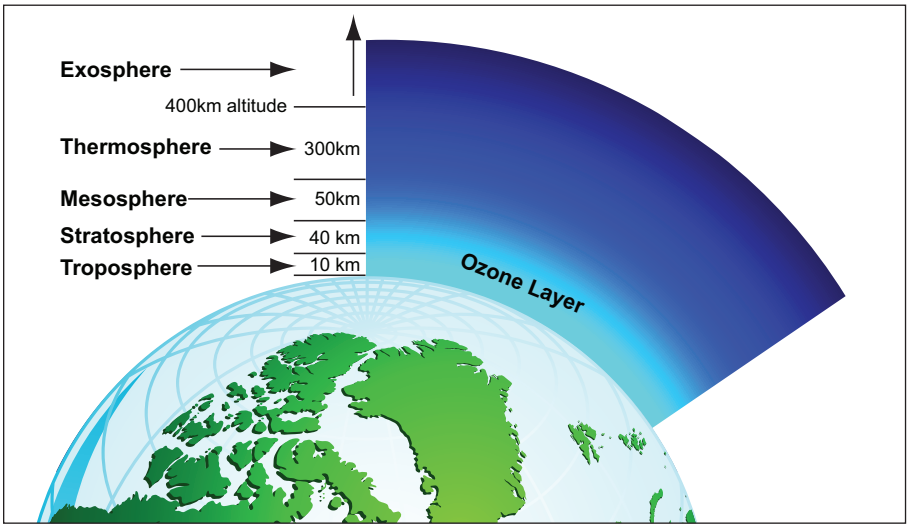
People at the beach

Why Worship the Sun?

Throughout history, human beings have had a special relationship with the Sun. In the past, ancient cultures worshipped the golden star as a god, praising it as the source of all living things. The Sun helped crops grow; it brought warmth and light to the people. They lived freely in the Sun, soaking up its generous rays. The ancient Greeks used olive oil as a primitive type of sunscreen, and no one seemed to notice when their skin turned red after a hot day in the Sun.

Sunscreen: A Solution to a Problem

In 1938, a Swiss chemistry student named Franz Greiter developed a simple sunblock after he was severely sunburned while climbing the mountain peak, Piz Buin. He called it "Glacier Cream." A few years later, it was considered healthy and attractive to go on vacation and come back with a tan. People flocked to beaches, lakes, and mountains to surf, swim, and ski. By the 1970s, a whole generation had baked their bodies in the Sun, not aware that harmful rays could cause serious damage.



Earth's atmosphere

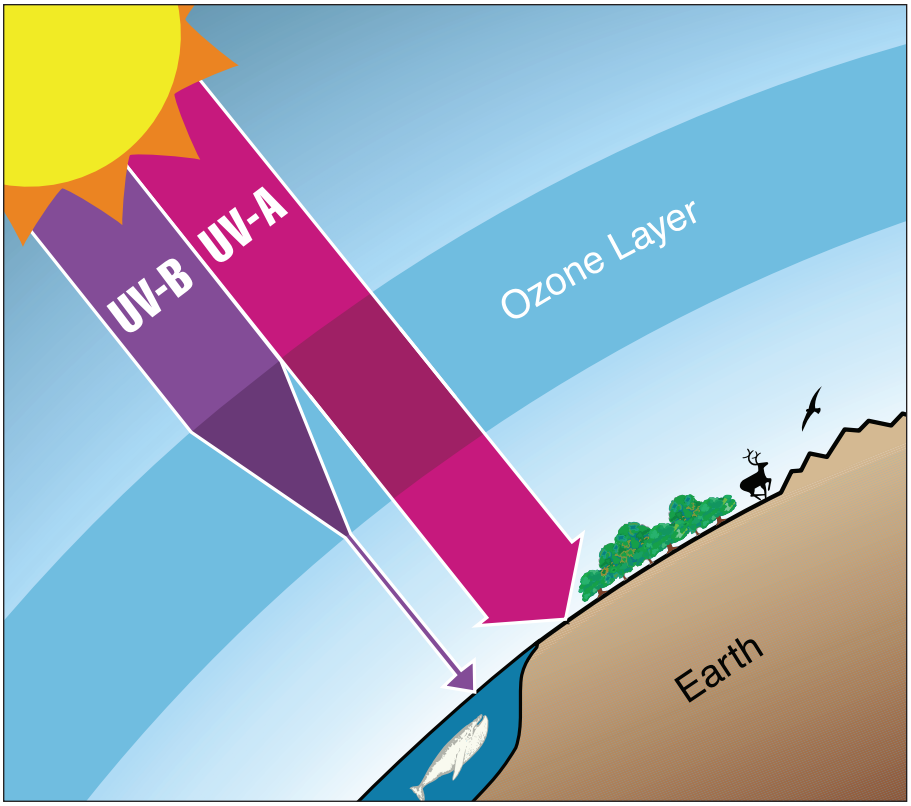
Sun and Ultraviolet Radiation

To understand how the Sun can sustain life and cause trouble at the same time, we need to look a little more closely at the bright star at the center of our solar system. Although the Sun broadcasts many different kinds of radiation, UV radiation is the main cause of tissue damage to human beings, animals, and plant life. UV radiation is associated with sunburn, skin cancer, and premature aging.

UV radiation is subdivided into three different wavelengths: UV-A, UV-B, and UV-C radiation. UV-C radiation has the highest energy and is possibly the most dangerous of all UV radiation. Luckily, most UV-C radiation is filtered out by Earth's atmosphere. Too much UV-A and UV-B radiation exposure from the Sun damages the skin, eyes, and immune systems of human beings. UV-A radiation penetrates more deeply into the skin than UV-B radiation. It does not cause sunburn, but scientists think it may be the primary cause of wrinkles and even cancer. UV-B radiation is the type of solar radiation that we usually associate with sunburn and skin cancer.

Ozone in the Atmosphere

Earth's atmosphere is made up of many layers that protect



UV radiation and the ozone layer

the surface from dangerous levels of solar radiation. The layer of Earth's atmosphere closest to the surface is called the troposphere. The layer above it is the stratosphere. Ozone, a strong-smelling, pale blue, reactive gas consisting of three oxygen atoms, is found in both layers. Ozone in the troposphere (or ground-level ozone; a major component of smog) forms when air pollutants are directly emitted from motor vehicles, refineries, industrial plants, and other sources react in the presence of sunlight. It is also formed naturally by lightning.

Ozone causes acute and chronic respiratory difficulties and other health problems in human beings. However, most ozone is found in the stratosphere, 10 to 30 miles above Earth, where it absorbs ultraviolet radiation from the Sun. Scientists call this the ozone layer and recognize it as Earth's natural "sunscreen."

Scientific evidence shows that certain man-made chemicals, especially chlorofluorocarbons (CFCs), are causing the slow destruction of our protective ozone layer. Other factors, such as global climate change, also play a part. This dangerous depletion of the ozone layer allows more harmful UV radiation to enter the troposphere.

So far, most of the damage to the ozone layer has occurred over the North and South Poles during the winter months. However, there is now evidence of thinning over more densely populated areas in the Northern Hemisphere. Scientists are afraid that a continued thinning of the ozone layer will cause a huge increase in skin cancer, infectious diseases, and problems with human and animal eyesight. It may also cause a decrease in food production on Earth due to crop yield losses.

Rating and Using Sunscreen

In 1979, the Food and Drug Administration (FDA) developed a rating for Sun Protection Factors (SPFs) in sunscreen or sunblock. Sunscreen contains chemicals that absorb UV-B

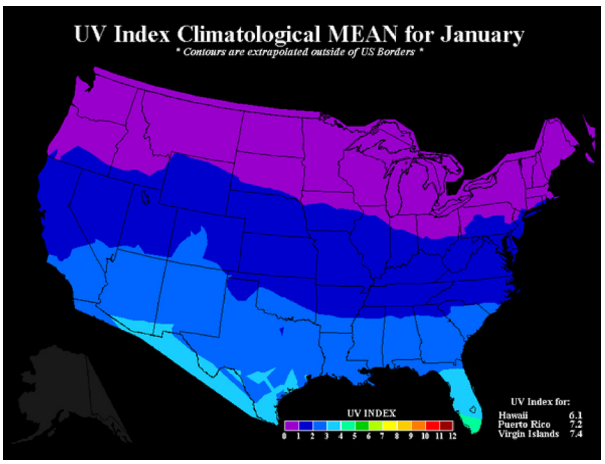
radiation (chemical blocks), and sunblock generally contains an opaque material that reflects UV-B radiation (physical blocks). Some products contain both. The number rating after "SPF" on the bottle indicates the amount of time you can be exposed to sunlight without getting a sunburn, provided you use the recommended dosage. Unfortunately, many sunscreens do not protect the skin from UV-A radiation, which can also be dangerous.

Does wearing sunscreen or sunblock prevent sunburn from harmful UV-B radiation? The answer is "yes." However, there are a few things to consider. In small amounts, UV-B radiation has a positive effect, creating vitamin D in the skin. Ironically, studies show that vitamin D may prevent certain cancers. The vitamin is also necessary for healthy bones and teeth. Luckily, you can take vitamin D in pill form, which is one way to make up for the loss of UV-B radiation.

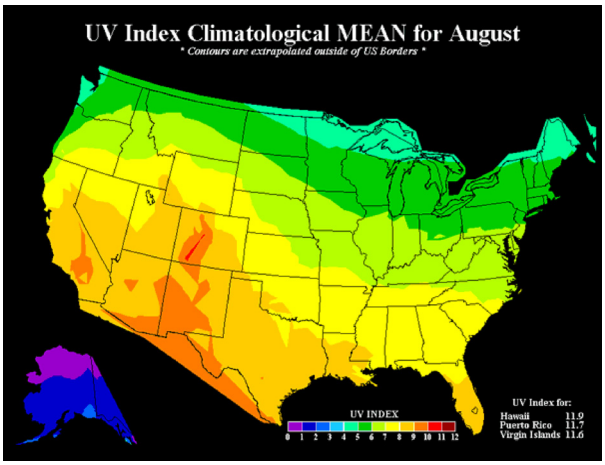
Sunscreen has come a long way since Franz Greiter went climbing on Piz Buin. Currently, the FDA recommended dosage is approximately one ounce of sunscreen or sunblock to cover exposed skin on the body. Studies show that sunscreen is most effective if applied 15 to 30 minutes before you go out in the Sun, followed by one reapplication 15 to 30 minutes later. After swimming, remember to apply more.

Sunscreen products

By the time you get to the beach, the sand is already so hot that you and your friend have to wear flip-flops to keep your feet from burning. You can feel the radiant heat off the bright sand burning your legs. You shout, "Run!" and race each other to the cool dampness of the shore, where you shed your cover-ups and throw down your towels and bags. Suddenly, your mother's voice rings in your head. "Hey," you say to your friend, "Let's put on sunscreen." "Why?" she asks. "Don't you want to get a tan?" "The ozone layer is thinning," you tell her. "A tan is not what it used to be." "Ozone?" She looks at you as if you have just told her to stand on her head. "I'll tell you later," you say, as you cover yourselves with a generous amount of SPF 30, wait until it dries, and run straight into the waves.



Source: U.S. EPA SunWise Program



Source: U.S. EPA SunWise Program

What Is the UV Index?

The UV Index is a forecast or prediction of how much UV radiation is expected to reach Earth's surface on a given day. You can find a report of the current UV Index in the newspaper or on a weather Web site, such as the one sponsored by the National Weather Service. To help people across the United States know the risk from damaging UV rays, the National Oceanic and Atmospheric Administration (NOAA) measures UV radiation in all the major cities across the nation.

If you are traveling far from home, the UV Index for your city may not be the same as where you are going. This is because some places get more UV radiation than others. For example, there is more UV radiation near the Equator than near the poles. The Earth's ozone layer is not the same thickness across the globe, but is thinner at the Equator than over the mid-latitudes where much of the United States lies. This means that people living in northern California near Oregon normally do not get as much UV radiation as people living in southern California near Mexico. On the maps (above), you can see that the UV Index for northern California may be "3" in January and "8" in August.

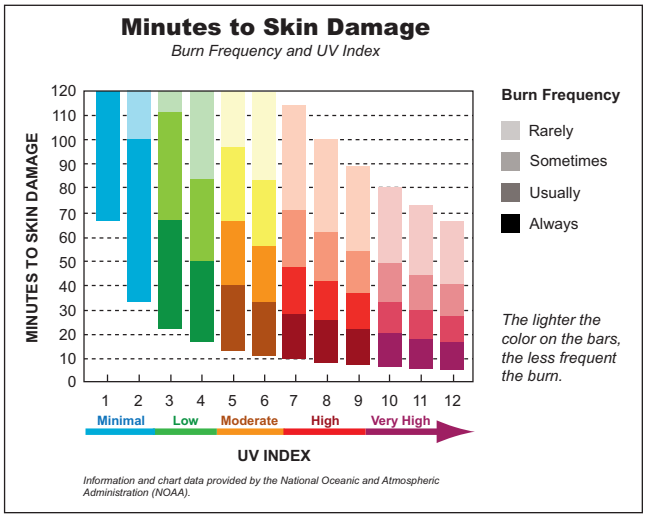
Besides latitude, the UV Index is based on several other factors. These include:

- The Sun's elevation in the sky: UV radiation is stronger when the Sun is directly overhead than when the Sun is rising or setting.
- Cloud cover: clouds can block or filter UV radiation.
- Elevation or altitude: places that are higher in elevation, such as mountains, are closer to the Sun; therefore, UV rays are stronger at higher elevations than they are at sea level.

The main thing to know is that the higher the UV Index, the larger the amount of UV radiation and the less time it takes before you burn.

How Much Sun Is Too Much for You?

Knowing the day's UV Index will not protect you from the Sun's damaging rays. You also need to know how long you can stay in the Sun before you will get burned. Some people burn more easily than others. Because of this, NOAA has made a chart to help you figure out your chance of getting a burn that might lead to skin damage. This chart helps you identify your skin type, compare it to the UV Index, and determine the number of minutes you can safely stay in the Sun.



How to use the chart to find your skin type and burn frequency:

1. Figure out your individual "Burn Frequency" by answering the question, "How often do you burn?" (Rarely, sometimes, usually, or always). Note the color block that matches your answer.
2. Find today's UV forecast on the x-axis, labeled "UV Index." Follow up the column until you reach your colorblock.
3. Look at the y-axis, "Minutes to Skin Damage," to see how long you can stay in the Sun before you might get burned.

UV Index	Protective Actions
0, 1, 2	Apply SPF 15 sunscreen.
3, 4	Apply SPF 15 sunscreen and wear protective clothing (hat).
5, 6	Apply SPF 15 sunscreen and wear protective clothing and UV-blocking sunglasses.
7, 8, 9	Try to avoid more than a few minutes in the Sun between 10 a.m. and 4 p.m. If you must go outside, apply SPF 15 sunscreen and wear protective clothing and UV-blocking sunglasses.
10+	Avoid going outside between 10 a.m. and 4 p.m. If you must go outside, apply SPF 15 sunscreen, and wear protective clothing and UV-blocking sunglasses.

The United States Environmental Protection Agency (U.S. EPA) has a chart to help you understand how you can take protective action against getting a burn. If you have the type of skin that "always burns," you should probably play it safe and use a stronger sunscreen than what the U.S. EPA recommends.

Effects of UV Radiation on Human Health

Applying sunscreen

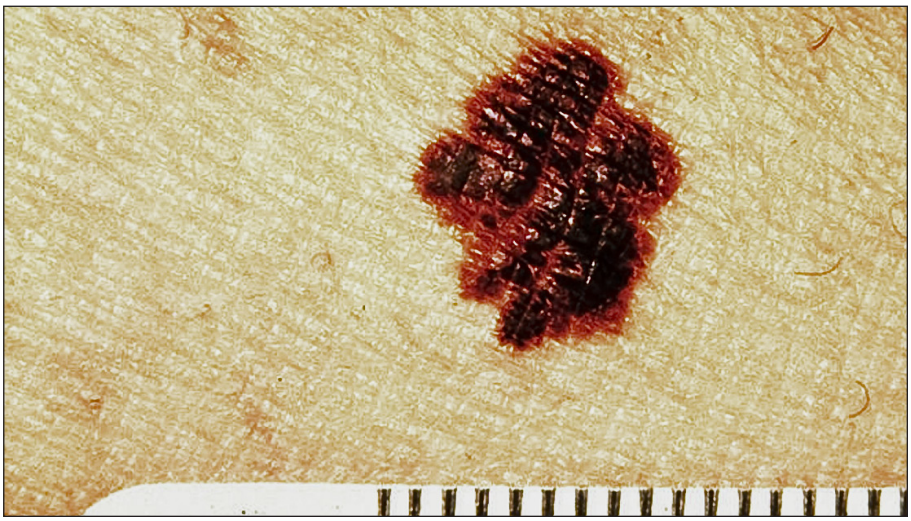
The DNA in human tissue absorbs UV radiation. DNA—deoxyribonucleic acid—is the material inside the cell that carries genetic information and gives you your genetic characteristics, like skin and eye color. DNA also contains instructions for rebuilding damaged cells. When DNA absorbs UV radiation, it breaks, causing small changes to the genetic code. Once DNA is damaged, cells may not survive.

The Immune System

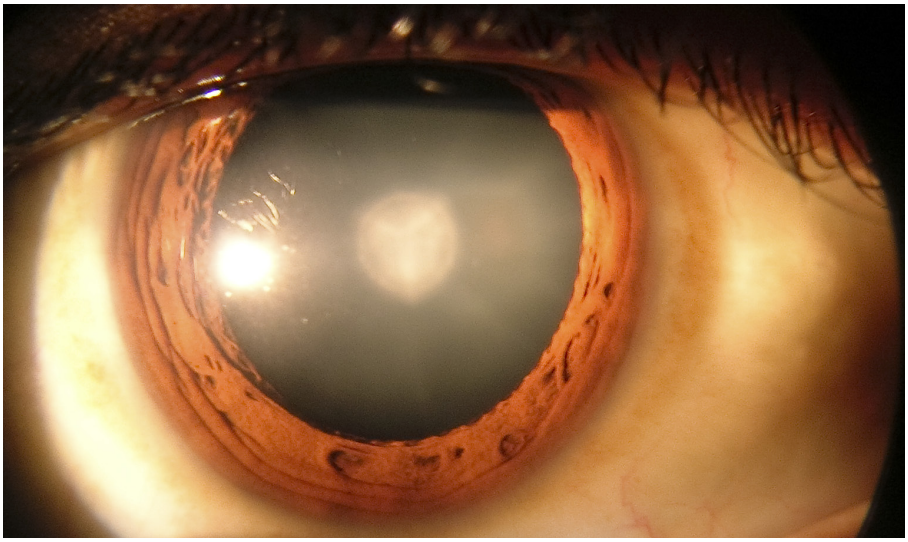
The immune system protects our bodies against infections and foreign substances or objects. It protects against infection by identifying and eliminating viruses, bacteria, and toxins. The immune system can tell the difference between normal cells and bacteria, viruses, or foreign objects, such as a thorn.

Some cells that are part of the immune system are located in the skin. They work to capture invading microorganisms and carry them to the lymph nodes, one of the body's first defenses against viruses and disease. Your lymph nodes are located all along your neck and under your arms. When a virus is identified by your immune system, it is carried to your lymph nodes.

If the immune cells in your skin are damaged by UV radiation, they may no longer be able to identify invading organisms or toxins. If not identified, these substances can cause serious damage to the body or to the rest of the immune system. When your immune system is damaged, you get sick more often. A large portion of Earth's population is battling immune-system diseases, such as acquired immune



Close-up of Melanoma



Close-up of eye with cataract

deficiency syndrome (AIDS), arthritis, diabetes, and lupus.

Eyes

Cataracts are a form of eye damage that causes cloudiness in the eyes. Normally, the lens of the eye is clear, but when a cataract forms, the lens becomes cloudy. This blocks light from flowing freely into the eye and also causes the image that is being viewed to look blurry or distorted. People with cataracts cannot see well. Without medical care, a cataract can grow, expanding across the lens and causing a person to become blind.

Cataracts are not fatal, but they are debilitating. Research has shown that UV radiation increases the chance of getting certain types of cataracts. Millions of Americans have poor vision because they have cataracts. Cataracts usually develop slowly. By age 65, over 90% of people have a cataract. Surgery is the only treatment. Cataract treatment costs many millions of dollars in medical care each year.

Skin

When UV radiation damages DNA in the skin, it can lead to premature wrinkling and aging and to skin cancer. Some skin cancers are fatal. Melanoma is a form of skin cancer that originates in the cells that produce the skin pigment melanin. Melanoma is the most serious form of skin cancer and one of the fastest-growing types of cancer in the United States. In fact, the rate of melanoma has increased by almost 700% from 1950 to 2000. Melanoma cases in the United States have more than doubled in the past two decades, and the rise is expected to continue. More than 60,000 people each year get melanoma, which causes several thousand deaths. The American Cancer Society notes that one in five Americans will develop skin cancer in their lifetime, and one American dies every hour from this disease.

Non-melanoma skin cancers are less deadly than melanomas, but if left untreated they can spread, causing scars and more serious health problems. More than 1.2 million Americans develop non-melanoma skin cancer each year, and more than 1,900 die from it. Worldwide health costs are rising because of the increased demand for cancer care and treatment.

Effects of UV Radiation on the Oceanic Food Web

A beam of sunlight can travel into pure water to a depth of more than 500 meters. That is nearly five football fields deep! In clear ocean or lake waters, UV radiation can penetrate up to 100 feet. In cloudy rivers and wetlands, UV radiation is often completely absorbed within the top few centimeters of the water. Most marine "producers"—the plants and algae—live in this "photic" (light) zone, in which sunlight penetrates. This makes sense: plants and algae need sunlight for photosynthesis. This also means that they are exposed to UV radiation.

Every spring, the waters around Antarctica receive some of the highest levels of UV radiation on Earth. These waters are very clear. Organisms that live near the surface of the water during the spring can be damaged by incoming UV radiation. Studies have shown that phytoplankton—microscopic organisms that photosynthesize—have trouble photosynthesizing

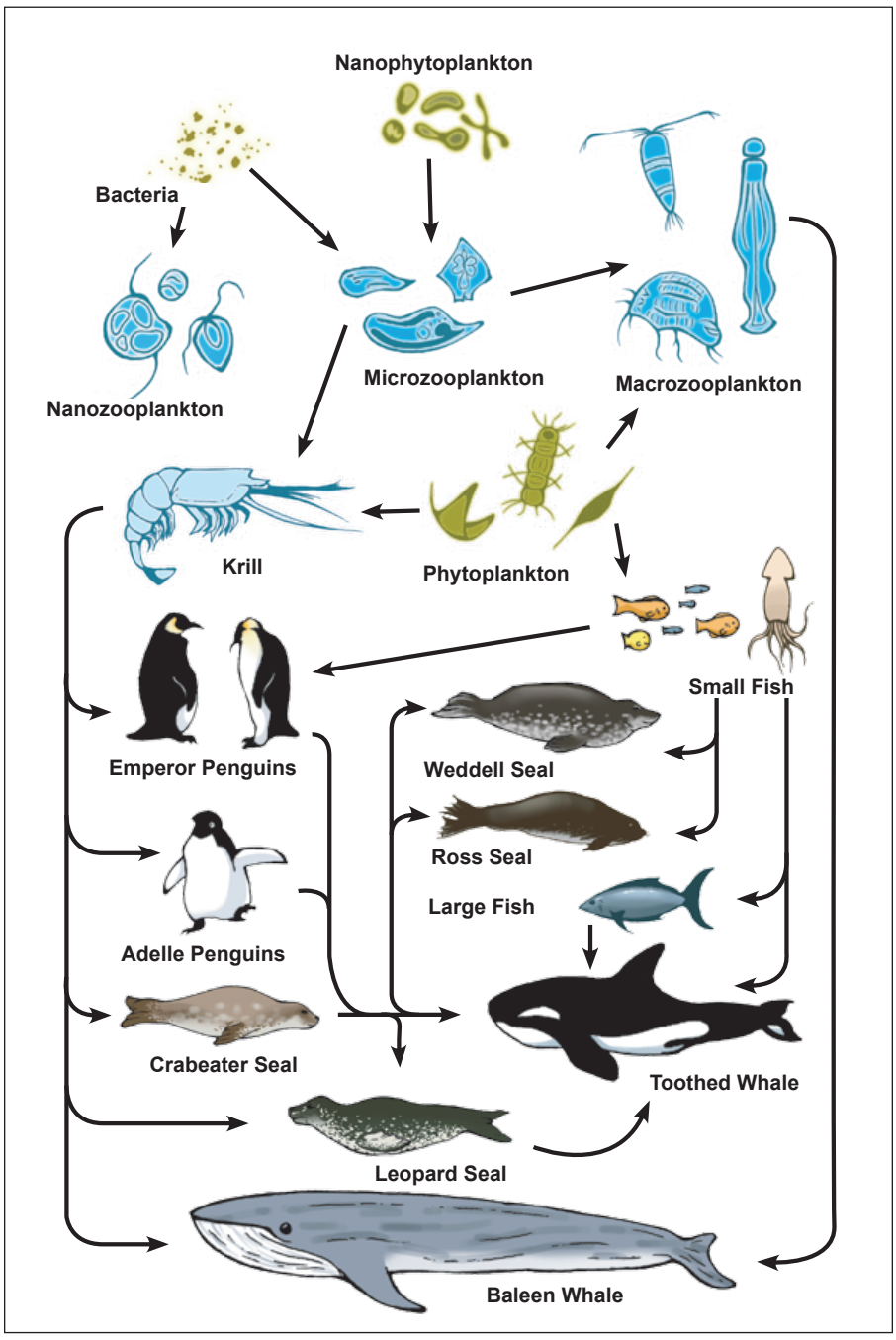


Diagram of a polar ocean food web

Humpback whales feeding

and growing when exposed to high levels of UV radiation. This can cause a reduction of about 15% in phytoplankton populations. Krill, small shrimp-like crustaceans, are affected similarly.

Fifteen percent might not sound like much of a change, but how might this loss affect the organisms that feed on phytoplankton and krill? As you can see from the diagram, phytoplankton and krill are the foundation of oceanic food webs. A food web is a complex pattern of several interacting food chains.

UV radiation affects some shallow-water fish, too. They develop skin cancer and other UV-related diseases. The eggs and larvae of many fish are hypersensitive to UV exposure, which can kill them. Fewer fish hatch to become food for other organisms, which also affects the food web.

Scientists have identified the harmful UV-B radiation effects on some marine species, but the effects on the ecosystem—sets of interdependent species that interact with each other and the abiotic components found in a specific area—is not well understood. How will ecosystems respond to changes in populations of individual species or the stress caused by UV radiation? Will the loss of individual species have any measurable effect on food webs? Scientists and ecologists want to know more.

One area scientists want to research is how a decline in phytoplankton may affect the rise of carbon dioxide in the atmosphere. In addition to their important role in food webs, phytoplankton consume carbon dioxide—a greenhouse gas—and release oxygen into the air during photosynthesis. If phytoplankton populations decrease by 15%, they will then consume 15% less carbon, and more carbon dioxide will remain in the atmosphere.

Although scientists are unsure how or if changes to phytoplankton and krill populations may affect the ocean, because these organisms are the foundation of the polar food web, changes to their populations would affect organisms that feed on them. If fish populations that rely on phytoplankton and krill are reduced, this could affect the resources upon which many countries rely for food and other products. Increasing human population growth trends already mean an increased demand for these foods and products, so fish populations would be even more reduced.

Effects of UV Radiation on Crop Production

Of the 80 or so plant species that have been domesticated and are grown as crops, just 15 species supply nearly all the food calories humans consume and three-quarters of the world's protein. Rice, wheat, and soybeans represent 31% of this total.

Studies show that rice, wheat, and soybean crop yields—the amount harvested from a plant in one period of time—can be affected by UV radiation. This is because plant DNA absorbs UV radiation. DNA—deoxyribonucleic acid—is the material inside cells that contains genetic information and instructions for rebuilding damaged cells. Once the DNA is damaged, cells mutate or die. This can affect a plant's growth.

Irrigated field

Most plants have natural UV protection. One form of protection that plants have is thick membranes on their leaves and stems. Some plants can increase their UV-absorbing pigments or produce thicker leaves. However, studies show that when a plant is focusing on repairing damaged cells or increasing UV protection, it fails to produce the fruits and seeds it uses for reproduction, which humans and other animals eat for food.

Plants, like animals, are susceptible to disease. Studies have shown that exposure to UV radiation can affect the ability of plants to fight off parasites and diseases and to repair damaged leaves and root cells critical to the plant in photosynthesis. Of the world's food crops, rice seems to be particularly sensitive to changes in UV-B radiation. Because over two-thirds of the world's population depends on rice in its daily diet, and most rice is grown in areas where

increasing levels of UV-B radiation have been measured, the effect of UV radiation on crops is getting more attention.

Researchers warn that the connection between UV radiation and lower crop yield is not a clear one. Some of the studies were conducted in greenhouses using "grow lights" rather than the Sun's full spectrum of ultraviolet radiation. Only a few tests have been conducted in natural settings. In these tests, production was sometimes down and sometimes unchanged. Most studies have been focused on large-scale agricultural crops like rice, wheat, and soybeans. Very little is known about the possible effects UV radiation might have on plants in forest, grassland, and the tundra ecosystems—or the sets of species that interact with each other and the abiotic components found in each of these ecosystems.

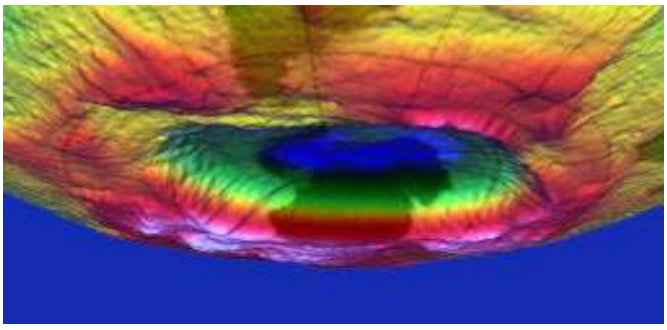
Wild grasses

Should lower crop yields result, more land than what is used today will be needed for crop production to feed the world's population. The ever-increasing world population will strain food supplies, especially in countries already experiencing difficulty feeding their people. Using more land for agriculture will change how ecosystems function; deforestation and increased farming result in increased soil erosion, which in turn often has a detrimental effect on water quality due to runoff of nutrients and sediments. Wildlife that depends on natural ecosystems will suffer as more space and natural resources are used by human communities to farm.

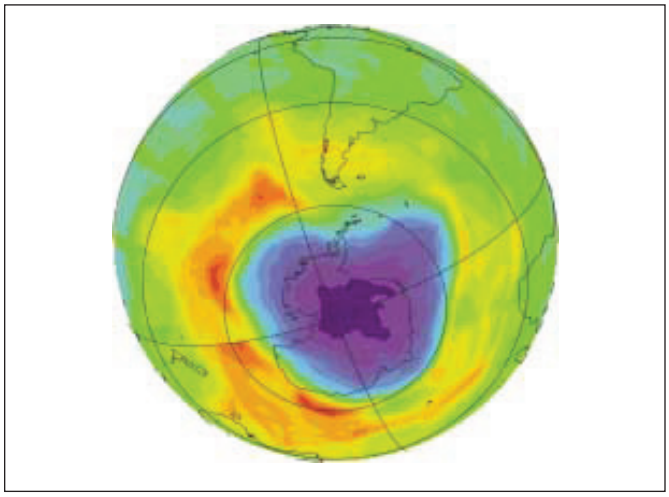
What Could Be Causing the Antarctic Ozone Hole?

Scientists have been studying the atmosphere and the ozone layer over Antarctica since the late 1950s. Because it is so remote, and cold and dark in the winter months, people other than scientists do not live on Antarctica year-round. There is no industry on Antarctica. Because of the lack of industry and human population, scientists believed that the atmosphere over Antarctica was the perfect place to study an atmosphere that had no pollution.

In 1985, a British team of scientists measuring ozone received such low ozone readings that they first thought their spectrometer was broken. They called England to send another spectrometer. At the same time, NASA scientists were also measuring the amount of ozone in the ozone layer from a space satellite using the TOMS (Total Ozone Mapping Spectrometer). They also found very low ozone levels over Antarctica. The TOMS computer software was programmed to interpret extremely low ozone readings as "bad data" and to ignore this data. When the NASA scientists heard that the British team had also measured very low ozone levels, they took a second look at their raw data. The data showed what nobody wanted to believe: ozone levels over Antarctica were 60% below normal, measuring just 124 DU. The world's scientists were dumbfounded to find that a "hole" was forming in the ozone layer over the Antarctic. "How and why was this happening?" they wondered.



Ozone levels (darker colors indicate lower levels)



Ozone levels (darker colors indicate lower levels)

The Antarctic ozone "hole" is not really a hole, but an extreme thinning of the ozone layer over the South Pole. The three-dimensional computer-generated image shows how the ozone layer becomes a concave-shaped depression—like an upside-down crater. Since 1985, when measurements began, this ozone-layer thinning has been happening each spring.

News Reports

Mt. St. Helens erupting, May 18, 1980

Report 1: Could the Sun Be Responsible for Severe Ozone Layer Thinning?

In 2001, the Sun sent out an explosion of UV radiation that was the third largest in the last 30 years. The Sun has a regular 11-year cycle of sunspot or flare activity. The 2001 period provided a good demonstration of what the Sun can produce during its most active time period.

Solar flares are the most energetic explosions in the solar system. They send out an intense amount of energy in the form of radiation—the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time!

When UV radiation bombards Earth's upper atmosphere, it breaks up molecules of nitrogen and oxygen, producing nitrogen oxides. Nitrogen oxides then act as catalysts in the process of ozone destruction. More ozone is destroyed, and the ozone layer becomes thinner. This burst of UV radiation into Earth's atmosphere can destroy ozone over a period of weeks to months.

"Solar flare events help us test our computer models," said Charles Jackman, a researcher from NASA's Goddard Space Flight Center. "Factors that affect the ozone layer can be big or small, short-term or long-term. You have to first be able to separate the natural effects on ozone, before you can tease out humankind's impacts," Jackman advised.

Do we ever experience the effects of solar flares here on Earth? You bet! Solar flares in 1859 were the largest recorded in history. Newspapers across the nation reported that the massive flare caused:

- A huge magnetic storm causing telegraph lines to spark and catch on fire;
- Power surges that enabled telegraph lines to work even without power;
- A historic aurora borealis light show, also known as the northern lights.

The radiation from this storm would have killed an astronaut had one been on the moon during the time. Not possible in 1859, but when a 10-day flare occurred in 1972 during the height of the Apollo launches, it could have happened.

The solar flare cycle is 11 years, and the next solar flare max is expected in the year 2012. Should you watch the skies, or put on your sunscreen?

Report 2: Could a Volcanic Eruption Cause a Need for More Intensive Sunscreen?

When volcanic eruptions are big enough, they can spew ash, hydrogen chloride gas, and other gases high into the atmosphere. Very large eruptions, like Mount Pinatubo in the Philippines in 1991, can propel gases and volcanic debris as far as the stratosphere. When this chlorine gas is exposed to

intense UV radiation, complex chemical reactions generate free chlorine atoms that act as catalysts in the destruction of ozone molecules.

Mount St. Helens is an active volcano in the state of Washington in the Pacific Northwest. Its eruption in 1980 was the deadliest and most economically destructive volcanic eruption in the history of the United States, killing 57 people and destroying 250 homes. The eruption blew off over 1,000 feet of the mountain's elevation. A blast of volcanic rock and debris swept over the ridge, killing vulcanologist (one who studies volcanoes) Dave Johnson. In 2004, Mount St. Helens was active again.

Mount St. Helens' eruptions were small compared to Mount Pinatubo. Who knows when another big one will blow its top again?

Scientists wonder if the next big volcanic eruption could cause a setback in ozone layer recovery.

Report 3: Can Beautiful Clouds Affect Your Health?

"Ooh……ahhhhh," sighs the crowd of people gathered to watch a colorful winter cloud show in Canada. What these people may not know is that these colorful clouds contain harmful chlorine gases that can destroy ozone, thinning Earth's protective ozone layer.

Clearly, these are not your typical clouds. Stratospheric polar clouds are among the highest and coldest clouds formed in Earth's atmosphere. In fact, instead of being formed from water vapor, these clouds are made of ice crystals. During cold winter months, very cold air starts swirling around Earth's poles. This can happen at both the North and South Poles, but not at the same time since it is winter at one pole while it is summer at the other.

This air is swirling like a whirlpool; the air and water vapor get trapped in this whirlpool and begin to rise high into the stratosphere. These clouds can rise 13 miles above Earth. As they rise, the clouds get colder and colder and can reach temperatures of -100° F (-73° C). The water vapor forming the cloud's molecules solidifies into tiny ice crystals. The beautiful colors come from sunlight passing through the ice crystals as through a prism, forming a rainbow of colored clouds.

Air pollution can be found within the air that rises from Earth's surface up into stratospheric polar clouds. Ice crystals in the clouds provide a surface on which pollutants in the air can settle. If this pollution contains chlorine, increased UV radiation in the spring can cause the release of free chlorine atoms—catalysts that can break apart ozone molecules.

An annual springtime ozone "hole" has been happening over the Antarctic for decades. In recent years, because of these cold clouds, the ozone layer has been thinning over the Arctic, too. "A thinner ozone layer in the Northern Hemisphere can be worse for human beings than the Antarctic ozone hole," said Brian Toon, professor at the Laboratory for Atmospheric and Space Physics at Colorado University, Boulder. The thinner ozone layer from the Arctic drifts south toward North America, Europe, and Russia each spring, allowing harmful UV radiation to reach Earth's surface in highly populated countries. UV radiation can cause skin cancer and reduce crop production.

Meeting on the Montreal Protocol

The History of the Montreal Protocol

The discovery that CFCs were a leading cause of the Antarctic ozone "hole" got the attention of scientists, politicians, and chemical manufacturers from around the world. Scientific and political leaders quickly gathered to figure out what to do about the thinning ozone layer. Twenty countries attended the first meeting held in Vienna, Austria, in 1985. Representatives from these countries signed a treaty (a legal agreement) known as the "Vienna Convention for the Protection of the Ozone Layer." At this meeting, the group agreed to study how the ozone layer was changing, but they did not yet decide to stop using ozone-depleting substances (ODSs). Instead, the group agreed that in order to make decisions about using ODSs, they needed more scientific research and data about how chlorine and bromine gases were destroying ozone.

The 1987 Montreal Protocol

Two years later, 24 countries sent representatives to meet in Montreal, Canada. By this time, the Antarctic ozone hole was getting worse. The group decided that in order to slow down the rate at which the ozone layer was thinning, they needed to reduce the amount of certain ODSs that were being made and used. "The Montreal Protocol on Substances That Deplete the Ozone Layer" is the 1987 international treaty established by these 24 countries to protect the ozone layer by phasing out the production of ozone-depleting substances. This protocol was the first step toward saving the ozone layer.

Who Is in Charge of the Montreal Protocol?

The United Nations Environmental Programme (UNEP) is an international group formed in 1972 to lead and encourage countries to care for the environment. The UNEP calls itself "the voice for the environment." Within the UNEP is a special group in charge of the Montreal Protocol. The group holds meetings to talk about new scientific findings about the ozone layer or chemicals that destroy ozone. They make sure that all new scientific information gets to policy makers so that any new rules are based on the most up-to-date science. Based on their findings, they may decide to outline a new rule about making and using an ODS. They also make sure that the countries that have signed the Montreal Protocol are in compliance—in other words, that they are following the rules and policies that their group has set forth.

The Effects of the Montreal Protocol on the Ozone Layer

The Montreal Protocol is an example of a remarkable international effort to address a global problem—the depletion of the ozone

layer caused by man-made chemicals. Has the Montreal Protocol had any effect on the amount of ozone in the ozone layer or the amount of ODSs in the stratosphere? Can we expect that the ozone layer will recover to what it once was before the 1980s?

The products that use ODSs have become a part of our lives. It is hard to imagine life without a refrigerator or going to the movies on a hot day in a theater without air conditioning. These examples may seem trivial to some people, but what about the lives and homes saved each year by fire extinguishing equipment? Or, the person who suffers from asthma and needs a metered-dose inhaler? In consideration of these types of uses, the Montreal Protocol outlined a "phaseout" schedule that allows industry to gradually stop using ODSs. This gives manufacturers time to find safer chemicals to replace them. The first chemicals the Montreal Protocol listed to phase out were CFCs; their use was to be reduced by 50% by 1999.

The Montreal Protocol has been amended (changed) several times since it was first written in 1987. Scientists from all over the world provide UNEP with up-to-date information. UNEP uses this information in making decisions about changing the protocol. Sometimes a change was needed because the ozone layer was not improving the way scientists had hoped. For example, the Antarctic ozone hole continued to get larger instead of smaller for many years. Other times, scientists discovered that some chemicals were worse for the ozone layer than they had originally thought.

Fire Extinguisher

Because of this new scientific information, new rules have been needed regulating the use of ODSs. Usually this has meant that we have needed to stop using certain ODSs sooner. This was the case with CFCs; UNEP decided that we needed to stop using CFCs sooner than 1999. Protocol members agreed to reduce the use of CFCs by 75% by 1994, and to stop all use of CFCs by 2010. By reducing the amount of ODSs we use, in time we will also reduce the amount of chlorine and bromine gases in the stratosphere. These reductions should help the ozone layer recover to where it was before the invention of CFCs and other halon chemicals.

These changes to the Montreal Protocol are called either "Amendments" or "Adjustments" depending on how big the change is. Because the Montreal Protocol is a legal agreement, each time it is changed, the member countries have to sign the new ruling. With each change,

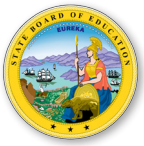
CFC recovery operation

the rules seem to get tougher. Still, more and more countries have signed the protocol and are working to reduce the amount of ODSs they use. As of 2007, 191 countries have signed the Montreal Protocol and are looking for more ways to improve the condition of the ozone layer.

How Do We Know if the Montreal Protocol Is Working?

In addition to outlining a schedule for reducing ODSs, the Montreal Protocol also requires members to conduct on-going research. Scientists study whether the ozone layer is improving, and if the amount of ODS pollution is decreasing. Sometimes the scientific data does not seem to match up. For example, even though the Antarctic ozone hole has grown larger, scientists are beginning to see signs that there are less ODSs in the stratosphere. Some scientists say we reached a peak of stratospheric ODS pollution in about 1995 and that the ozone layer should soon show signs of getting better. Scientists call this "recovery."

The demand for scientific data has led to new and improved technology to measure ozone, as well as many new research projects that should help us get a better understanding of the atmosphere. The United States has led this effort through agencies, such as NOAA, NASA, and the U.S. EPA. Universities across the nation help by doing research and developing new technologies.



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