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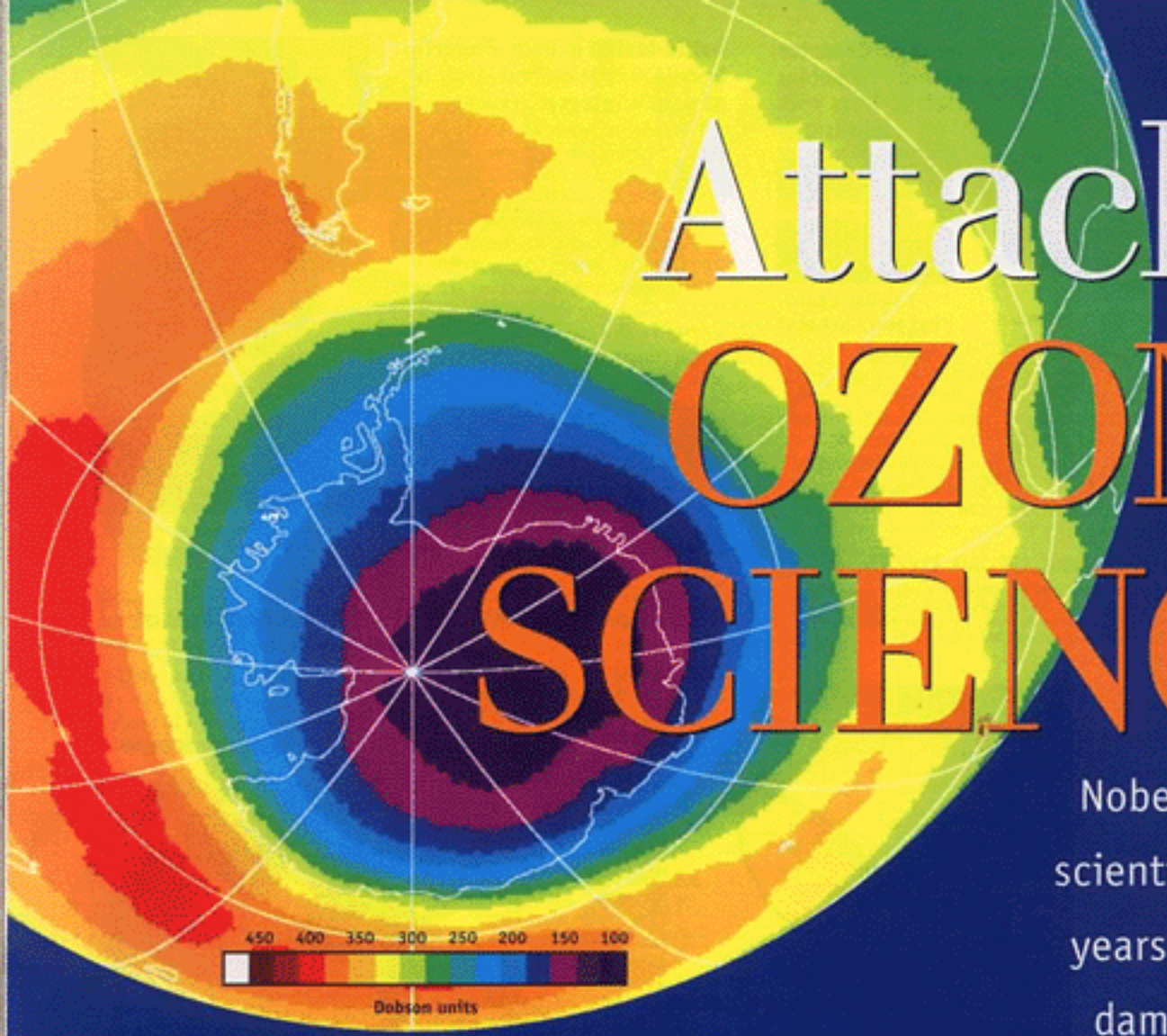
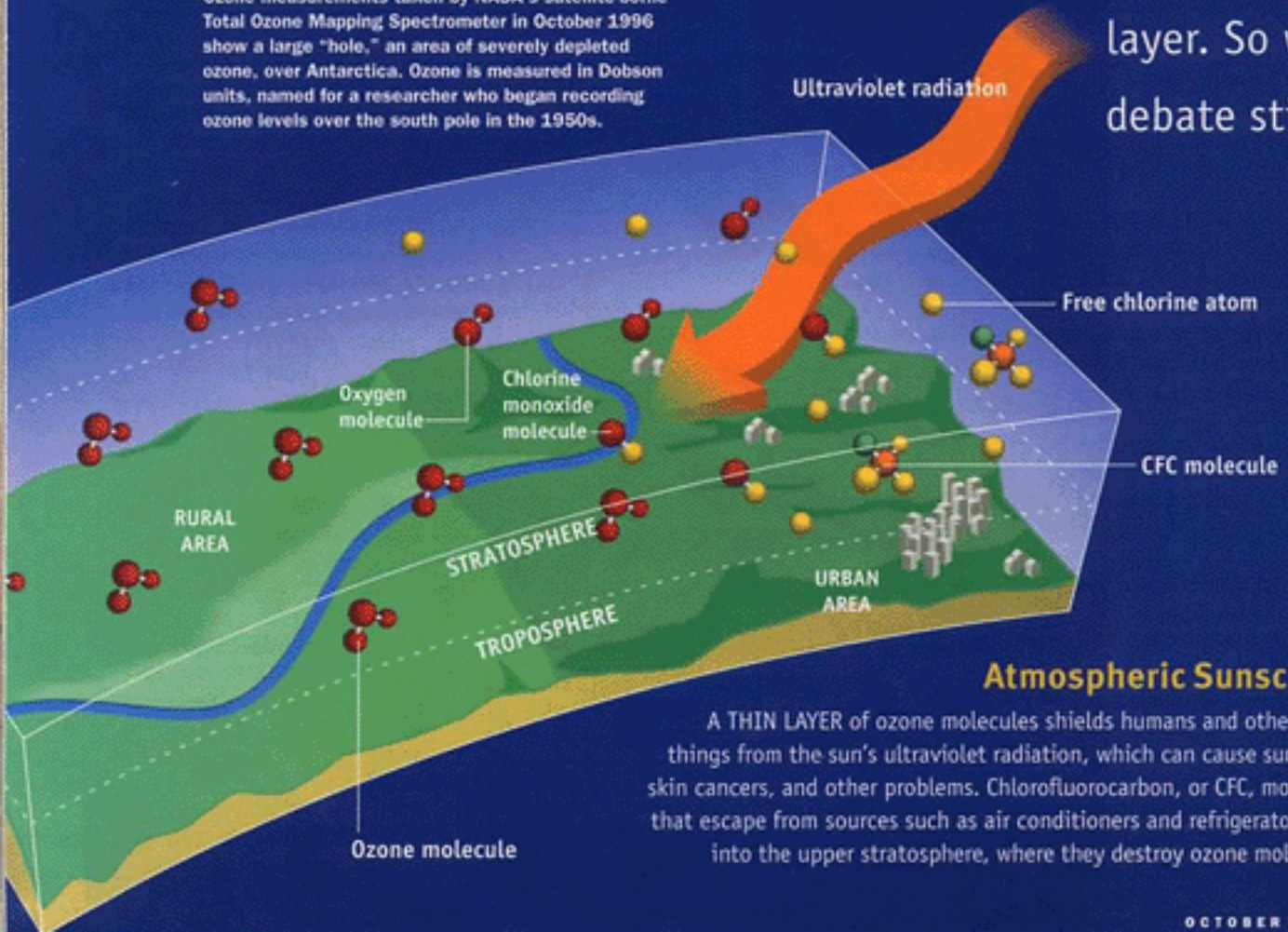
Attack on OZONE SCIENCE

Nobel Prize-caliber scientists concluded years ago that CFCs damage the ozone layer. So why is the debate still raging?



Ozone measurements taken by NASA's satellite-borne Total Ozone Mapping Spectrometer in October 1996 show a large "hole," an area of severely depleted ozone, over Antarctica. Ozone is measured in Dobson units, named for a researcher who began recording ozone levels over the south pole in the 1950s.



Atmospheric Sunscreen

A THIN LAYER of ozone molecules shields humans and other living things from the sun's ultraviolet radiation, which can cause sunburns, skin cancers, and other problems. Chlorofluorocarbon, or CFC, molecules that escape from sources such as air conditioners and refrigerators drift into the upper stratosphere, where they destroy ozone molecules.

WHEN THE WINNERS of the Nobel Prize for Chemistry appeared at the flower-filled Stockholm Concert Hall in December 1995 to receive their awards from King Carl XVI Gustaf, they were met by pickets. Why?

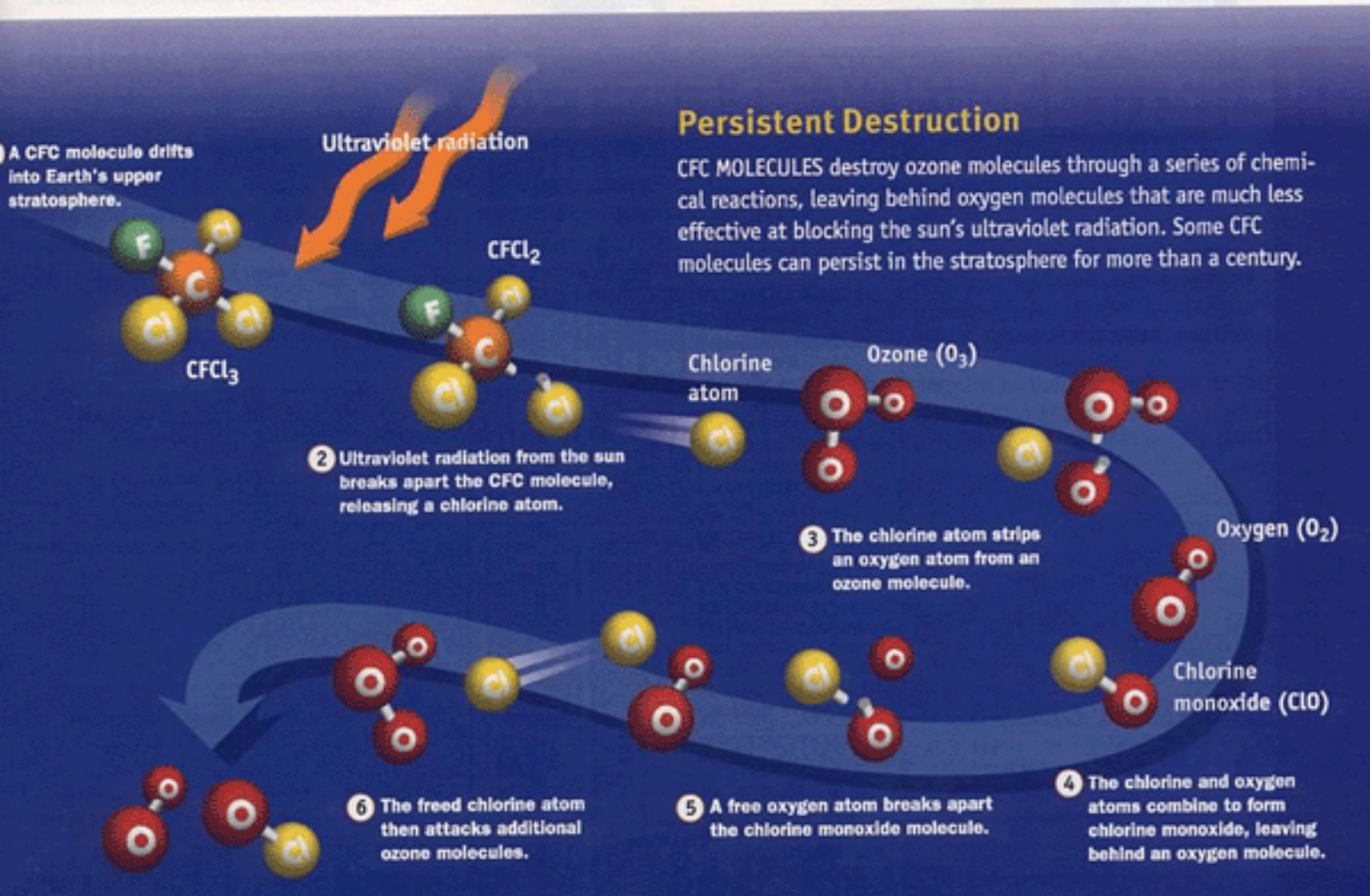
Because two of the three Nobelists, F. Sherwood Rowland and Mario Molina, were being rewarded for their pioneering work on the chemistry of ozone depletion. Their research showed that compounds called chlorofluorocarbons, or CFCs—once widely used as refrigerants and as propellants in spray cans—are responsible for the progressive thinning of the ozone layer, which shields us from the sun's ultraviolet radiation. The work of Rowland and Molina, along with that of other atmospheric scientists, has led to a worldwide phaseout of CFCs.

Arthur Fisher

The Stockholm pickets were from the Schiller Society, a European group affiliated with 21st Century Science Associates in the United States. The American group is run by supporters of Lyndon Larouche, a convicted felon whose baroque pronouncements have included labeling Queen Elizabeth II as the head of an international drug ring. Outside the Stockholm hall, the pickets distributed leaflets with quotes from a 1992 book published by 21st Century Science Associates, *The Holes in the Ozone Scare* by Rogelio A. Maduro and Ralf Schauerhammer. Rowland has called the book "a good job of collecting all the bad papers in the field in one place."

Larouche's followers are part of a continuing movement that has come to be known as the ozone backlash. Afforded ostensible respectability by a handful of contrarian scientists, it seeks to deny the environmental threat posed by the thinning of Earth's fragile ozone shield, and to roll back the ban on the chemicals that have contributed to it. The backlash movement has spawned a number of books, ranging from the late Dixie Lee Ray's 1992 *Trashing the Planet* to Gregg Easterbrook's 1995 *A Moment on the Earth*, which dismissed concern over ozone depletion by maintaining that being subjected to increased ultraviolet radiation would be no worse than moving to a different latitude.

The results of the so-called ozone backlash have been felt from coast to coast. The Nobel Prize Committee was criticized by *The Wall Street Journal* and even ridiculed on the editorial page of *The Orange County Register*, despite Rowland and Molina having done their work in that



INFOGRAPHICS BY ALEX REARDON

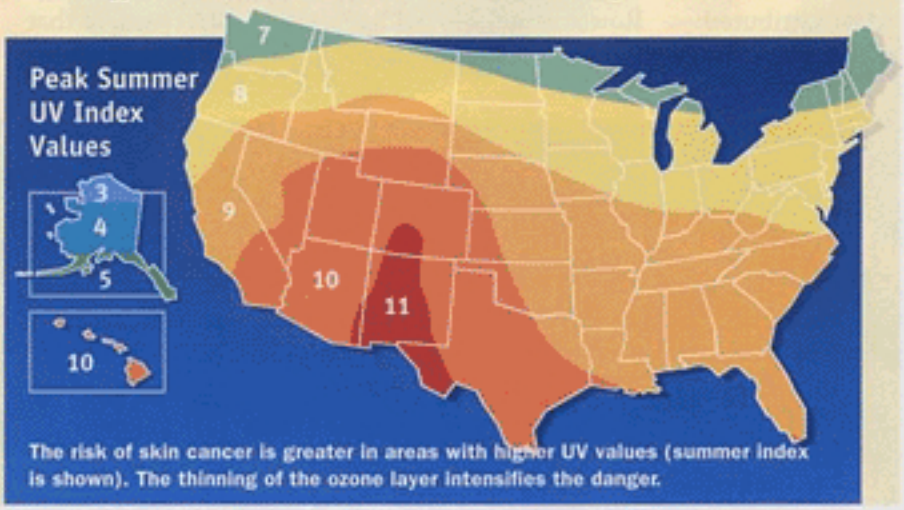
The Cancer Connection

THE UNITED NATIONS Environment Program, the National Cancer Institute, and the Environmental Protection Agency predict that a 1 percent decrease in stratospheric ozone could produce a 3 percent increase in the incidence of nonmelanoma skin cancers. That's because reductions in ozone allow more ultraviolet radiation to reach Earth's surface, where this radiation can induce cancer-causing genetic mutations in human skin cells.

Skin cancers have a long latency period, so it could take 20 years or more for the effects of increased radiation to appear. "One in five Americans will get skin cancer in their lifetime," predicts Dr. Rex A. Amonette, president of the American Academy of Dermatology. An estimated 900,000 Americans will develop nonmelanoma skin cancers this year, according to the American Cancer Society. Nonmelanomas (mostly basal and squamous cell carcinomas) are usually curable when detected early enough.

Increased ultraviolet radiation can also cause melanomas, which are far more lethal. Melanoma cases have almost doubled over the past two decades, with 40,300 new cases expected this year and 7,300 deaths. At the present rate—a 6 percent annual increase—the American lifetime risk will reach one in 75 by the year 2000.

A study by the Netherlands Institute of Public Health and the Environment released in early 1997 calculated that controls on ozone-destroying chemicals will have prevented 1.5 million cases of skin cancer in the United States alone by 2100.—*A.F.*



The risk of skin cancer is greater in areas with higher UV values (summer index is shown). The thinning of the ozone layer intensifies the danger.

county at the prestigious University of California, Irvine.

In 1995, the U.S. Congress saw an effort to roll back the ban on CFCs. In 1996, there were efforts in the California and Arizona state legislatures to do the same thing. And in 1997, members of the Nevada legislature unsuccessfully attempted to pass a bill allowing CFC manufacturing in that state.

Meanwhile, ozone destruction has reached peak levels in recent years. The infamous ozone hole observed over Antarctica during the Southern Hemisphere's springtime has been opening earlier and lasting longer, and ozone measurements over the Northern Hemisphere dipped to an all-time low last winter.

Maybe it's time for a little refresher on just what we do know about the ozone layer and its meaning for life on Earth. Ozone is a relatively rare blue-tinged gas. Each molecule of this gas consists of three oxygen atoms. (A molecule of the oxygen we breathe has two atoms.)

Although some ozone exists near ground level—it's an ingredient of smog—most appears in the stratosphere, roughly 10 to 50 kilometers above Earth's surface, with the greatest concentration around 20 to 30 kilometers. Even there it is quite rarefied, only a few parts per million. If all the ozone in the atmospheric column were

A Brief History of the Ozone Hole

Follow CFC's path from seemingly inert refrigerant to environmental hazard.

1930
Thomas Midgely, a General Motors chemist, invents CFC-12,

a refrigerant, first of the chlorofluorocarbons.

1945
By this date, most U.S. refrigerators use CFC-12.

1950
CFC production reaches 76 million pounds annually. CFCs are increasingly used as blowing agents to manufacture Styrofoam.

1960s
Air conditioners using CFCs proliferate in homes and offices. Vehicles eventually account for more CFC consumption than all other uses combined.

1970
Paul Crutzen shows that nitrogen oxides spewed from the proposed supersonic transport could damage the ozone layer.

1974
Richard Stolarski and Ralph Cicerone

warn that chlorine in the exhaust of the proposed space shuttle could decompose ozone.

1974
F. Sherwood Rowland and Mario Molina propose that CFCs reaching the stratosphere catalyze the destruction of ozone. They call for an immediate ban on CFC aerosol propellants, by now accounting for half of CFC use in the United States.

1976
Experiments support the Rowland-Molina theory. The U.S. government bans CFC propellants starting in 1978.

1985
The international Vienna Convention for the Protection of the Ozone Layer pledges action.

1985
Joseph Farman of the British

compressed to sea-level pressure, it would have a thickness of a mere 3 millimeters.

Nevertheless, this gaseous wraith plays a profoundly important biological role. Without it, life on Earth's surface could not survive. Ozone blocks all wavelengths of the ultraviolet radiation known as UV-C, which is lethal; most wavelengths of UV-B, which is harmful to most life forms; and a few wavelengths of UV-A, which is relatively harmless but can irritate skin.

Each 1 percent decrease in ozone allows a 2 percent increase in the amount of ultraviolet radiation reaching Earth's surface, with a corresponding **increase in the incidence of human skin cancers,** cataracts, and immune system disorders.

Increases in ultraviolet radiation penetrating to Earth's surface are also responsible for damage to animal and plant life, especially to oceanic phytoplankton supporting the aquatic food chains on which fish depend. People worldwide consume 18 percent of their food protein as fish; in Asia the number is 40 percent. So ozone depletion could have a profound effect on an important food source.

No wonder then that worldwide concern resulted when Paul Crutzen (the third winner of the 1995 Nobel Prize for Chemistry) demonstrated in 1970 that the proposed supersonic transport airplane, or SST, could endanger the ozone layer by spewing nitrogen oxides into the stratosphere.

Then in 1974, Richard Stolarski and Ralph Cicerone warned that chlorine in the exhaust of the proposed space shuttle could decompose ozone. A few months later, Rowland and Molina put forth their contention that CFCs would eventually work their way into the stratosphere, break down in reaction to powerful ultraviolet radiation, and release chlorine atoms that would catalyze the destruction of ozone molecules. Rowland and Molina estimated that if CFCs continued to be used at the 1974 rate, the ozone layer would be weakened by 7 to 13 percent by the year 2100. They said an immediate ban on aerosol propellants, which accounted for half the CFCs used in the United States, was essential, even though no physical evidence to substantiate their hypothesis had been found.

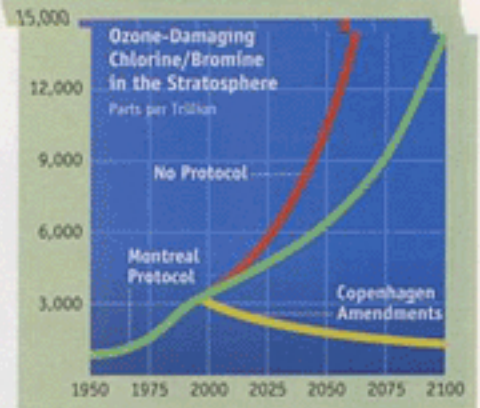
But soon afterward, the presence of CFCs and dissociated chlorine atoms in the stratosphere was confirmed by other researchers. By 1976, the evidence was strong enough to persuade the U.S. government to ban the use of CFC propellants as aerosol sprays beginning in 1978. That alone, however, was not enough to reduce the worldwide production of CFCs, which averaged about a million tons a year from 1974 to 1990.

Initially, the chemical industry fiercely attacked the Rowland-Molina hypothesis—and sometimes the scientists themselves. According to *The Los Angeles Times*, the president of one aerosol-manufacturing company complained that the accusations against CFCs were "orchestrated by the ministry of disinformation of the KGB." Du Pont, the largest manufacturer of CFCs, criticized the research but declared that if evidence showed that CFCs were a threat to health, the company would stop producing them.

The 1985 report of the discovery of the Antarctic ozone hole—an annually occurring severe drop in ozone levels over the south polar region—was a shocker that helped dispel complacency about CFCs. The discovery led to a 1987 international agreement to

Reducing the Danger

INTERNATIONAL agreement will stem levels of ozone-destroying compounds.



Antarctic Survey reports that for three consecutive years, major ozone losses have occurred over Halley Bay—creating the notorious ozone hole. The discovery spurs action worldwide.

1987
The United Nations Montreal Protocol on Substances that Deplete the Ozone Layer is agreed to by 140 countries. It plans to stem the influx of chlorine and bromine into the stratosphere by freezing CFC and halon consumption in 1989 and cutting it in half by 1998.

1988
The Ozone Trends Panel, established by NASA with the United Nations Environment Program and the World Meteorological Organization, reports that significant ozone depletion has already occurred over heavily populated areas of the Northern Hemisphere.

1988
Du Pont, the largest manufacturer of CFCs, announces it will halt production as soon as possible.

1992
The Copenhagen Amendments to the Montreal Protocol mandate a halt to the production of CFCs by 1996 in developed countries and by 2010 in undeveloped countries.

1995
A new Vienna Convention, subscribed to by 100 countries, accelerates an earlier timetable for the phaseout of hydrochlorofluorocarbons, or HCFCs, substitutes for CFCs that are damaging to the ozone layer but less so than CFCs. The convention also agrees on a phaseout of methyl bromide, an agricultural chemical that is 50 times more destructive to ozone than CFCs, but persists in the atmosphere for a shorter time. The U.S. Clean Air Act calls for a halt to methyl bromide production in 2001.

1996
NOAA scientist D.J. Hofmann predicts that, barring any noncompliance with the Montreal Protocol, the first signs of ozone hole "healing" will be detectable early in the 21st century.

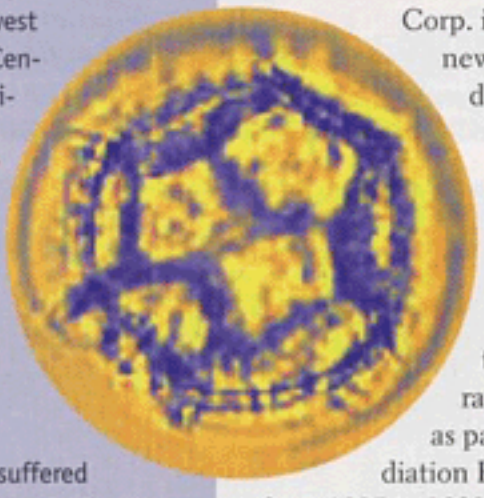
Ocean Life at Risk

THE WORLD'S PEOPLES derive 18 percent of their food protein from fish. Now there are signs that this critical nutrient source could be endangered by ultraviolet radiation penetrating Earth's ozone layer.

Ultraviolet radiation can impair the production of phytoplankton, microscopic organisms at the base of the aquatic food chain. Biological oceanographers Ray C. Smith and Karen Black of the University of California, Santa Barbara, followed the Antarctic ozone hole's effect on phytoplankton from the late 1980s until 1993. Even on the fringes of a mild ozone hole, productivity declined by 6 to 15 percent.

Last February, biologists from Northeastern University in Boston and the University of Texas reported that increased ultraviolet radiation during the opening of the Antarctic ozone hole damages the DNA of the eggs and larvae of icefish.

However, the effects of ultraviolet radiation can vary dramatically by species. A team led by Russell Vetter of the National Oceanic and Atmospheric Administration 's Southwest Fisheries Science Center in La Jolla, California, studied UV effects on DNA in three species. The northern anchovy suffered the most damage, the California halibut about half of that, and the white sea bass less than one-tenth. "Are we shifting the playing field by reducing ozone and increasing ultraviolet levels?" Vetter asks. "Are we favoring animals who are more resistant? We certainly are."—*A.F.*



Ultraviolet radiation harms phytoplankton such as this, which form the base of the ocean food chain.

reduce CFC consumption, which was followed five years later by amendments that mandated a halt to CFC production in developed countries by 1996.

Without the sterner controls on CFC production, ozone-damaging chlorine and bromine levels would have continued to rise steeply until 2100 and beyond. That was the conclusion of the World Meteorological Organization's 1994 Scientific Assessment of Ozone Depletion, the most comprehensive and authoritative statement to date on the ozone question, prepared with input from NASA, the National Oceanic and Atmospheric Administration, and the United Nations Environment Program. It is the product of 295 scientists from both developed and developing countries. Therefore, it represents an overwhelming consensus of the world's scientists about the severity of the threat to the ozone layer.

Making exact forecasts of declining ozone levels is difficult, because computer models must account for the variability of cloud cover. Cloud calculations, however, have been clarified with a new satellite-mapping technique developed by Dan Lubin, a research physicist at the California Space Institute in La Jolla, California; and Elsa Jensen of SeaSpace Corp. in San Diego. The new method combines data from NASA's Total Ozone Mapping Spectrometer, which monitored global trends in ozone from 1978 to 1993, with data that measured solar radiation from clouds as part of the Earth Radiation Budget Experiment from 1985 to 1990. The comparison shows that change in ozone levels is at least as great as variability due to changing cloud cover. The conclusion is that the negative effects of ozone depletion should be observed by the end of the century in many of the world's temperate regions—large parts of continental Europe, North and South America, New Zealand, Australia, and southern Africa.

The results, says Lubin, "should give the naysayers pause. You can't deny what the best NASA data on cloud cover and ozone, combined with what we know of physics, show—that we're dealing with a potential source of environmental stress." Why then do some continue to insist that the ozone problem has been exaggerated?

"I can't think of a single explanation of why there should be an ozone backlash now," says atmospheric scientist Ralph Cicerone, dean of physical sciences at UC Irvine, and a key player in unraveling the ozone conundrum. "Among all the environmental issues that have come up in the past 15 to 20 years, this is the one where the science is rock solid."

Cicerone suspects that the ozone backlash may be part of a general anti-government hysteria: "Anything the government is involved in can't be trusted." People don't realize, Cicerone says, that government intervention averted a catastrophe. Because CFCs, halons, and other halocarbons are so long-lived, ozone losses will continue for many years, even with a ban on the production. Scientists predict that the ozone layer will not fully recover until the middle of the next century.

"If the ozone-damaging chemicals had not been banned," says Cicerone, "if the world had continued to produce and use CFCs at the increasing rates of the mid-'80s, we would have been in a real pickle now in terms of biological damage."

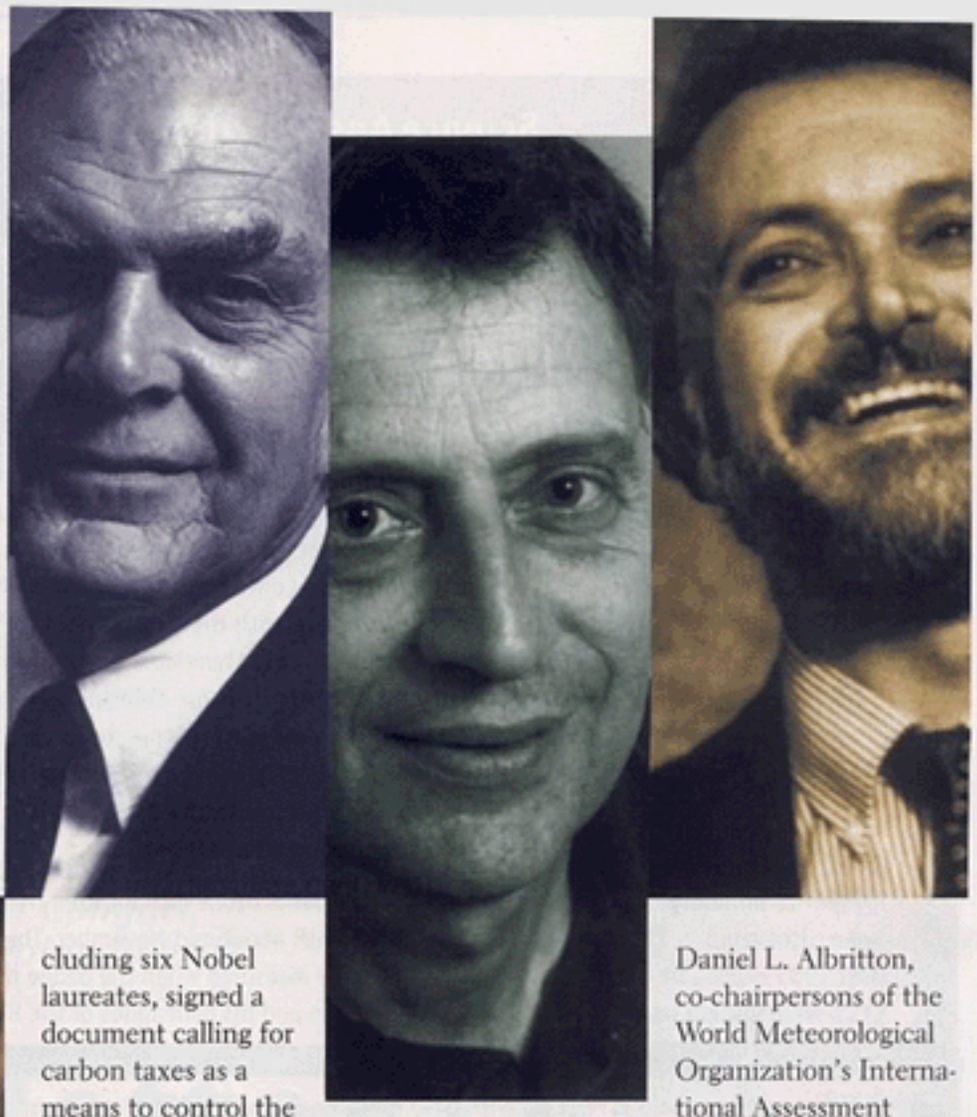
Another source of the backlash is that people are now paying to substitute other chemicals—which are far more expensive—for CFCs. "People are complaining about price-gouging when they need to retrofit their car air conditioners to accommodate other coolants," Cicerone says.

The high cost of CFC substitutes, $10 to $20 a pound, has also inspired a flourishing black market in the banned chemicals. It costs only 50 cents a pound to make CFCs. So CFC factories have sprung up in Russia and China. (Russia, a developing

The ozone hole as seen from space www.popsci.com

country where CFC production is now banned, has been out of compliance with international agreements since the beginning of last year.) Patrols on the Mexican and Canadian borders are now on the lookout for cars carrying not just illicit drugs, but canisters of Freon in their trunks.

In fact, according to the Washington-based organization Ozone Action, it can be more profitable to smuggle CFCs into the United States than drugs. Because developing countries like Mexico are allowed to continue producing CFCs for their own use until 2010, factories in these countries can be legal sources of CFCs that then enter black market channels. Ozone Action has dubbed one smuggling operation "the case of the Frio Banditos."



S. Fred Singer (below) dismisses the environmental risks from chlorofluorocarbons, or CFCs. But the vast majority of scientists say CFCs are harmful to the ozone layer. Prominent in the field are (left to right): F. Sherwood Rowland, Ralph Cicerone, and Mario J. Molina.

Economic interests are a critical ingredient in the ozone backlash. "There is a serious connection between groups that oppose limiting carbon dioxide emissions and those that dismiss the ozone hole as insignificant," says Cicerone. "A lot of the climate-change backlash—denying that human activity can materially increase global warming—is being orchestrated by people who saw the ozone layer problem, and the establishment of controls on CFCs, as a dangerous precedent they don't want to see repeated. They don't want to see carbon taxes that would reduce the burning of fuels like coal and oil." Last February, more than 2,000 economists of various political stripes, including six Nobel laureates, signed a document calling for carbon taxes as a means to control the emission of carbon dioxide, a powerful greenhouse gas.

One scientist who has taken part in both the ozone and global-warming backlashes is S. Fred Singer, director of the Science and Environmental Policy Project in Fairfax, Virginia. He is an emeritus professor of environmental sciences at the University of Virginia, and the inventor of a satellite-borne ozone sensor, but has done no original research on ozone depletion since the 1970s. When the House Subcommittee on Energy and Environment held hearings in September 1995 on the need for eliminating ozone-depleting chemicals, Singer upheld the minority view that the case against these chemicals was exaggerated, and proposed rolling back the ban on them to the year 2000 instead of 1996. He said that the subcommittee members were being "misled, bamboozled, and otherwise manipulated by the testimony you have just heard," referring to statements by Robert T. Watson and Daniel L. Albritton, co-chairpersons of the World Meteorological Organization's International Assessment panel. Watson and Albritton were paired against Singer and another contrarian, astrophysicist Sallie Baliunas, at the subcommittee hearings.

Testifying at the hearings, Republican Congressman Tom DeLay of Texas, who had previously introduced legislation to cancel the phaseout and relevant provisions of the Clean Air Act, said, "I believe that the science underlying the ban on CFCs and the connection between health and ozone depletion is debatable." Republican Congressman John T. Doolittle of California vowed to introduce legislation to delay the ban until 2000, "so that more research could be performed on the link between ozone depletion and CFCs." Both said they based their reservations on Singer's work.

When DeLay was asked why he believed Singer rather than the hundreds of scientists who collaborated on the World Meteorological Organization's Scientific Assessment, he answered that he had not seen it. "My assessment is from reading people like Fred Singer," he said.

Science Answers the Ozone Critics

Here are some of the most frequently raised objections to ozone concerns, and the scientific responses to them:

Chlorofluorocarbons are much heavier than air, so they can't rise to the stratosphere.	In a refrigerator or other enclosed space, CFCs do collect at the bottom. But the atmosphere is dynamic; its gases are constantly mixed by the wind-driven motion of large air masses that distribute light and heavy molecules equally rapidly. Thousands of measurements have proven that CFCs are present in the stratosphere.
Volcanic eruptions, not CFCs, are the most important source of chlorine in the stratosphere.	Volcanoes emit hydrochloric acid, which is soluble in water. The acid dissolves in volcanic steam, and rains out long before it gets to the stratosphere. CFCs are not water-soluble. One of the worst backlash bloopers appears in *Trashing the Planet*, by the late Dixie Lee Ray and Lou Guzzo. They confused a theory about the eruption of California's Long Valley Caldera 700,000 years ago with the 1976 eruption of Mount St. Augustine in Alaska, which led them to the outrageous statement that Augustine had belched 289 billion kilograms of hydrochloric acid, "50 times more chlorine than an entire year's production of CFCs." Rush Limbaugh later applied the inaccurate figures to the eruption of Mount Pinatubo.
How could the "ozone hole" that appears over Antarctica annually have been discovered in 1956 and 1957—long before CFCs were widely used?	Researcher Gordon Dobson did indeed measure ozone over Antarctica in 1956. However, he discovered not the ozone hole, but a meteorological phenomenon now called the Antarctic polar vortex, which prevents ozone-rich air from the temperate latitudes from sweeping into the polar region until about mid-November. The ozone levels Dobson measured were much higher than those measured when the ozone hole was actually discovered in the early 1980s by Joseph Farman and his colleagues of the British Antarctic Survey.
If the ozone shield is being depleted, why isn't more ultraviolet radiation being detected on Earth?	It is. With a 50 to 60 percent decrease in ozone measured at Antarctica's Palmer Station in late October 1993, UV-B rays were at a skin-damaging level, more intense than the UV-B measured in San Diego, California, at any time during the whole year. The intensity of sunshine reaching San Diego is normally far higher than near the pole, because the ultraviolet light received at any given point on Earth's surface depends in part on the sun's position above the horizon. Measurements taken in Toronto and at various sites in Europe also show a correlation between falling ozone and rising ultraviolet radiation.—*A.F.*

Today, Singer maintains that "the concern over the ozone hole is overdone. Certainly there is no health concern that should be raised here. There's no global threat it imposes. My view is that CFCs probably should be controlled. I don't like to see any uncontrolled human influences on the atmosphere that we're not sure about. But CFCs are not the most important chemical in the world. I don't see any urgency in controlling them, and I'm much opposed to speeding up the phaseout of production. Chlorine may not be the most important ozone de- [illegible] of ozone depletion has been completely worked out. There is much to be resolved," Singer says.

The fact remains that few scientists agree with Singer. So how is it that a tiny minority of scientists has managed to keep alive the ozone debate? Says Steven Schneider, a senior fellow at the Institute for International Studies at Stanford University and no stranger to environmental controversies: "The tactic of arranging what seems to be an even-handed presentation, whether in a courtroom or in a 10-minute-per-side debate or before a Congressional committee, can be very effective in getting equal status for a very-low-probability position. And it's used [illegible] People tend to look at this kind of setup as a Ping-Pong match, U.S. Undersecretary of State for Global Affairs Tim Wirth has said. "But you have 2,500 scientists—the world leaders—on one side of the Ping-Pong table, and seven scientists on the other side."

In a 1993 address to the American Association for the Advancement of Science, Rowland spoke of the ozone backlash and said he had "a great concern over the role of science in a democracy in which the general population has not enough understanding of science itself, does not entirely trust 'science experts,' and is left with no way to distinguish between the competing claims of apparent experts on [illegible] ecy, he said, "is increasing the deficit level of knowledge of science, and communication about science."