COVER STORY

TTL

The Heat Is On

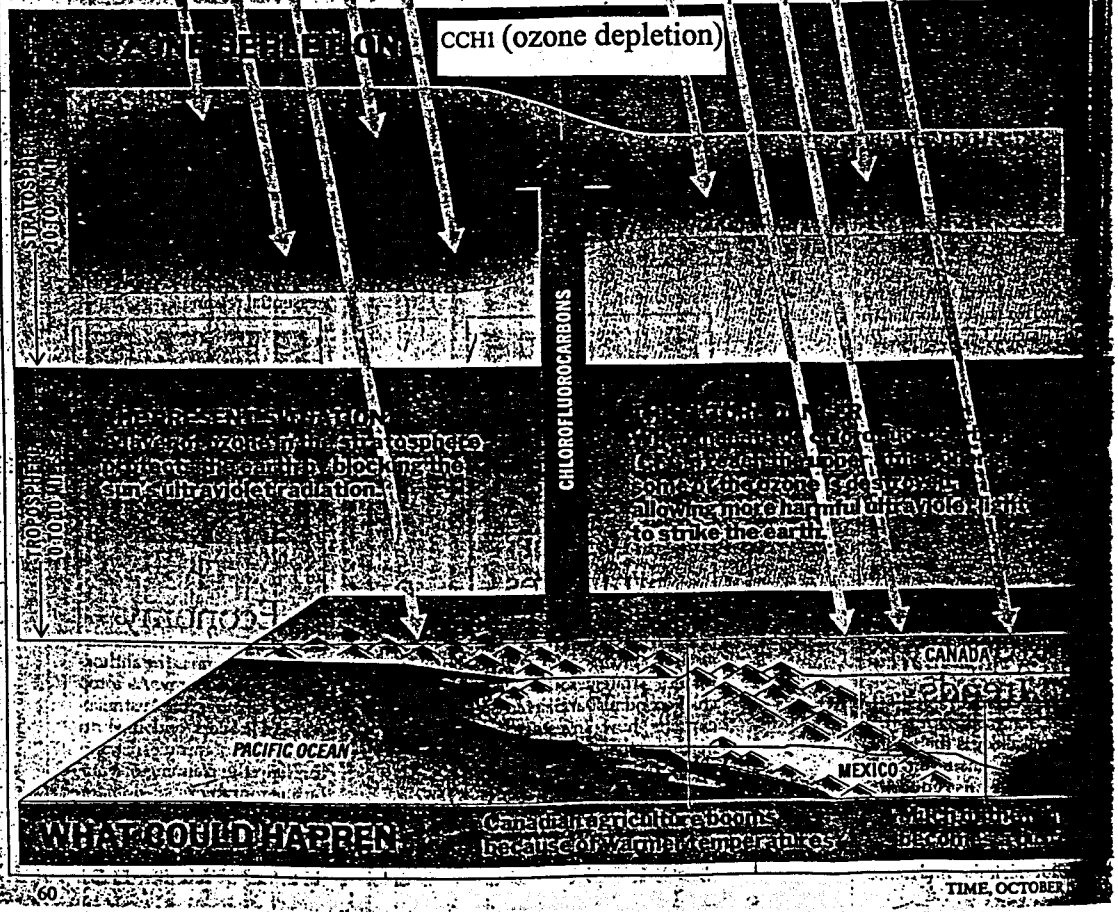
GLM

Chemical wastes spewed into the air threaten the earth's climate

SET

At this time of year, the Cabo de Hornos Hotel in Punta Arenas (pop. 100,000) is ordinarily filled with tourists who spend their days browsing in the local tax-free shops or mounting expeditions into the rugged, mountainous countryside just out of town. But the 120 mostly American scientists and technicians who converged on Chile's southernmost city for most of August and September ignored advertisements for hunting, hiking and ski tours. Instead, each day they scanned the bulletin board in the hotel lobby for the latest information on a different sort of venture.

Thirteen times during their eight-week stay, a specially outfitted DC-8 took off from the Presidente Ibañez Airport, twelve miles northeast of Punta Arenas. Often the 40-odd scientists and support crew listed for a given flight had to leave the hotel soon after midnight to prepare the plane and its research instruments. Once airborne, the DC-8 would bank south toward Antarctica, 1,000 miles away, fighting vicious winds before settling into a twelve-hour round-trip flight at altitudes of up to 40,000 ft. Along the way, the instruments continuously collected data on atmospheric gases, airborne particles and solar radiation high above the frozen continent. Meantime, parallel flights took off from Ibañez to gather additional atmospheric data at nearly twice the altitude. Manned by a lone pilot, a Lockheed ER-2, the research version of the high-altitude U-2 spy plane, made twelve sorties into the lower stratosphere, cruising at nearly 70,000 ft. or more



KEY:

TTL - TITLE	GLM - GLIMPSE	PRB - PROBLEM	SET - SETTING	PRO - PROPHECY
THR - THREAT	TLI - TECHNICAL LEAD-IN	SPC - SPECIFIC CLAIM	GCL - GENERAL CLAIM	BRG - BRIDGING
EVN - EVALUATION	ONP - ONGOING PROJECT	PRE - PREDICTION	CNS - CONCERNS	SLN - SOLUTION
SGN - SUGGESTION	SUM - SUMMARY	CON - CONCLUSION	ANX - ANXIETY	SPN - SPECULATION
COL - CALL FOR COLLABORATION		REC - RECOMMENDATION		

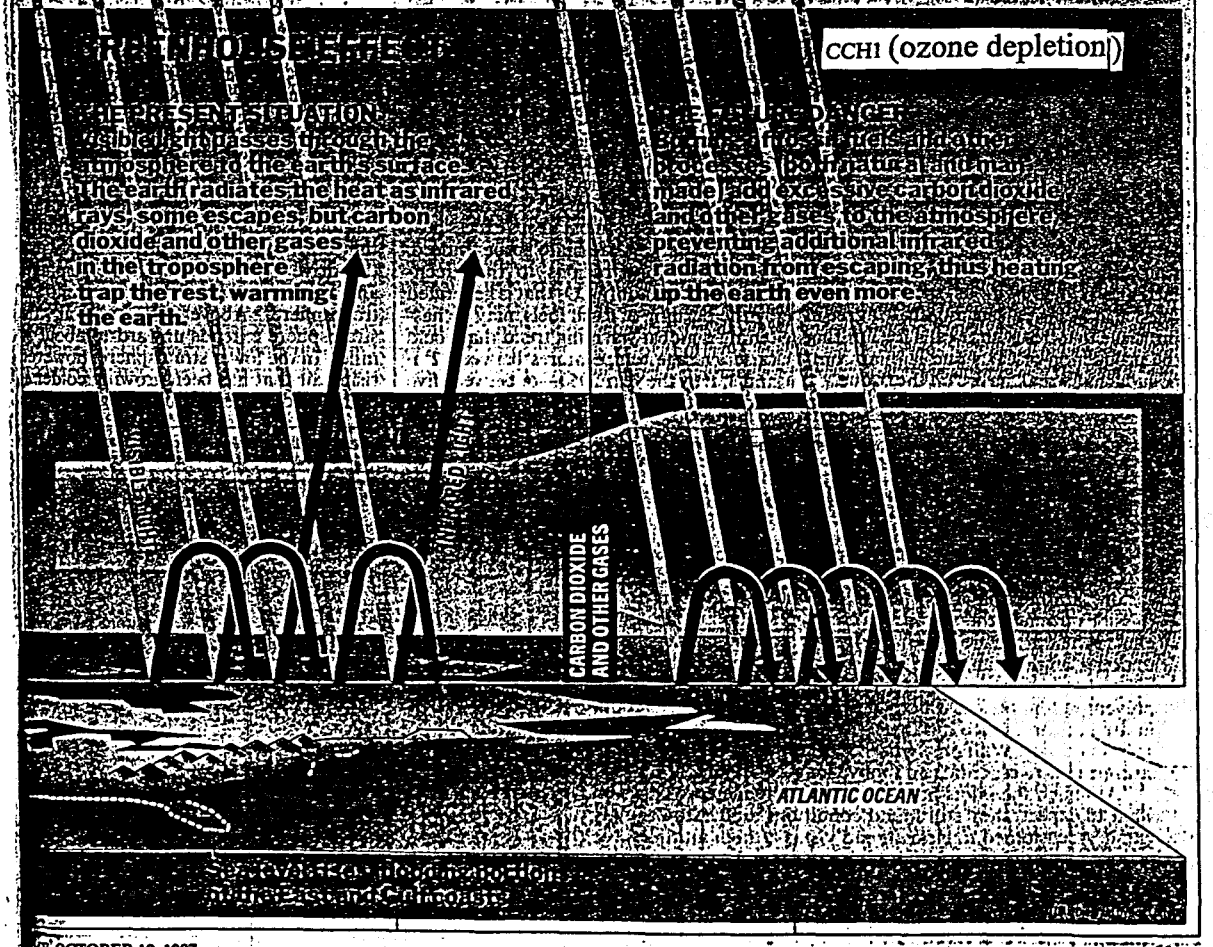
than 13 miles, for six hours at a time. Both aircraft were part of an unprecedented, $10 million scientific mission carried out by the U.S. under the combined sponsorship of NASA, the National Oceanic and Atmospheric Administration, the National Science Foundation and the Chemical Manufacturers Association. The purpose: to find out why the layer of ozone gas in the upper atmosphere, which protects the earth's surface from lethal solar ultraviolet radiation, was badly depleted over Antarctica. The scale of the mission reflected an intensifying push to understand the detailed dynamics of potentially disastrous changes in the climate. The danger of ozone depletion is only part of the problem; scientists are also concerned about the "greenhouse effect," a long-term warming of the planet caused by chemical changes in the atmosphere.

The threat to the ozone was first discovered in 1983, when scientists with the British Antarctic Survey made the startling observation that concentrations of ozone in the stratosphere were dropping at a dramatic rate over Antarctica each austral spring, only to gradually become replenished by the end of November. At first they speculated that the phenomenon might be the result of increased sunspot activity or the unusual weather systems of the Antarctic. It is now widely accepted that winds are partly responsible, but scientists are increasingly convinced that there is a more disturbing factor at work. The culprit: a group of man-made chemicals called chlorofluorocarbons (CFCs), which are used, among other things, as coolants in refrigerators and air conditioners, for making plastic foams, and as cleaning solvents for microelectronic circuitry. Mounting evidence has demonstrated that under certain conditions these compounds, rising from earth high into the stratosphere, set off chemical reactions that rapidly destroy ozone.

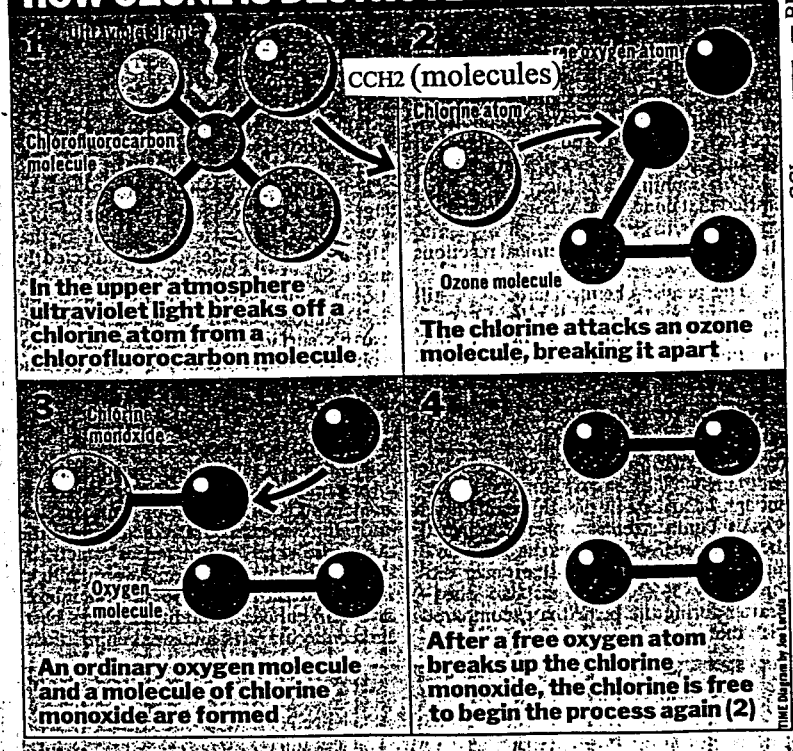
The precise chemical process is still uncertain, but the central role of CFCs is undeniable. Last month Barney Farmer, an atmospheric physicist at the Jet Propulsion Laboratory in Pasadena, Calif., announced that his ground-based observations as a member of the 1986 Antarctic National Ozone Expedition pointed directly to a CFC-ozone link. "The evidence isn't final," he said, "but it's strong enough." Earlier this month, results from NASA's Punta Arenas project confirmed the bad news. Not only was the ozone hole more severely depleted than ever before—fully 50% of the gas had disappeared during the polar thaw, compared with the previous high of 40% in 1985—but the CFC connection was more evident. Notes Sherwood Rowland, a chemist at the University of California at Irvine: "The measurements are cleaner, this time more detailed. They're seeing the chemical chain more clearly."

Atmospheric scientists have long known that there are broad historical cycles of global warming and cooling; most experts believe that the earth's surface gradually began warming after the last ice age peaked 18,000 years ago. But only recently has it dawned on scientists that these climatic cycles can be affected by man. Says Stephen Schneider, of the National Center for Atmospheric Research in Boulder: "Humans are altering the earth's surface and changing the atmosphere at such a rate that we have become a competitor with natural forces that maintain our climate. What is new is the potential irreversibility of the changes that are now taking place."

Indeed, if the ozone layer diminishes over populated areas—and there is some evidence that it has begun to do so, although nowhere as dramatically as in the Antarctic—the consequences could be dire. Ultraviolet radiation, a form of light invisible to the human eye, causes sunburn and skin cancer; in addition, it has been linked to cataracts and weakening of the



HOW OZONE IS DESTROYED



immune system. Without ozone to screen out the ultraviolet, such ills will certainly increase. The National Academy of Sciences estimates that a 1% drop in ozone levels could cause 10,000 more cases of skin cancer a year in the U.S. alone, a 2% increase. These dangers were enough to spur representatives of 24 countries, gathered at a United Nations–sponsored conference in Montreal last month, to agree in principle to a treaty that calls for limiting the production of CFCs and similar compounds that wreak havoc on the ozone.

Potentially more damaging than ozone depletion, and far harder to control, is the greenhouse effect, caused in large part by carbon dioxide (CO_2). The effect of CO_2 in the atmosphere is comparable to the glass of a greenhouse: it lets the warming rays of the sun in but keeps excess heat from reradiating back into space. Indeed, man-made contributions to the greenhouse effect, mainly CO_2 that is generated by the burning of fossil fuels, may be hastening a global warming trend that could raise average temperatures between 2° F and 8° F by the year 2050—or between five and ten times the rate of increase that marked the end of the ice age. And that change, notes Schneider, "completely revamped the ecological face of North America."

The relationship between CO_2 emissions and global warming is more than theoretical. Two weeks ago, a Soviet-French research team announced impressive evidence that CO_2 levels and worldwide average temperatures are intimately related. By looking at cores of Antarctic ice, the researchers showed that over the past 160,000 years, ice ages have coincided with reduced CO_2 levels and warmer interglacial periods have been marked by increases in production of the gas.

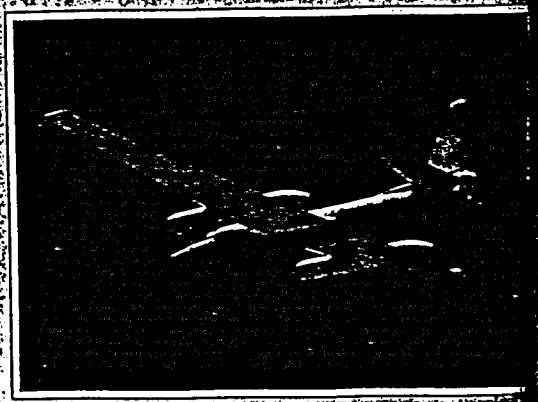
Although the region-by-region effects of rapid atmospheric warming are far from clear, scientists are confident of the overall trend. In the next half-century, they fear dramatically altered weather patterns, major shifts of deserts and fertile regions, intensification of tropical storms and a rise in sea level, caused mainly by the expansion of sea water as it warms up.

The arena in which such projected climatic warming will first be played out is the atmosphere, the ocean of gases that blankets the earth. It is a remarkably thin membrane: if the earth were the size of an orange, the atmosphere would be only as thick as its peel. The bottom layer of the peel, the troposphere, is essentially where all global weather takes place; it extends from the earth's surface to a height of ten miles. Because air warmed by the earth's surface rises and colder air rushes down to replace it, the troposphere is constantly churning. A permanent air flow streams from the poles to the equator at low altitudes, and from the equator to the poles at higher levels. These swirling air masses, distorted by the rotation of the earth, generate prevailing winds that drive weather across the hemisphere and aid the spread of pollutants into the troposphere. Above this turmoil, the stratosphere extends upward to about 30 miles. In the lower stratosphere, however, rising air that has been growing colder at higher and higher altitudes begins to turn

Flying High—and Hairy

From preflight preparation to landing, piloting NASA's specially equipped ER-2 high-altitude research aircraft is not for the fainthearted. The three pilots who flew the twelve solo missions through the Antarctic ozone hole found the task gruveling. An hour before zooming into the stratosphere, each had to don a bright orange pressure suit and begin breathing pure oxygen to remove nitrogen from the blood and tissues, thus preventing the bends, which can result from rapid reductions in air pressure. Once airborne, "you have to have patience," says Pilot Ron Williams, who flew the first mission. "You're strapped into a seat and can't move for seven hours."

Although the pilots had been briefed by meteorologists on what to expect, they still found conditions aloft astonishingly harsh. Accustomed to clear, broad vistas at high altitudes, the pilots—who took the ER-2 as high as 68,000 ft.—were startled to encounter layers of translucent mist composed of tiny ice



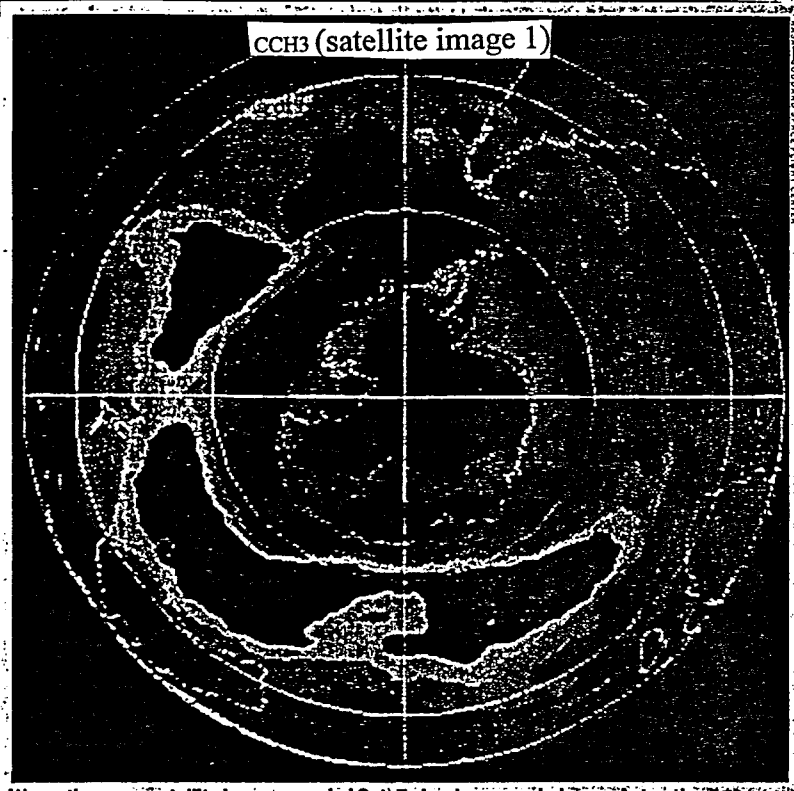
Harsh and lonely work: NASA's high-altitude ER-2 research plane

warmer. The reason, in a word: ozone.

Ozone (O_3) is a form of oxygen that rarely occurs naturally in the cool reaches of the troposphere. It is created when ordinary oxygen molecules (O_2) are bombarded with solar ultraviolet rays, usually in the stratosphere. This radiation shatters the oxygen molecules, and some of the free oxygen atoms recombine with O_2 to form O_3. The configuration gives it a property that two-atom oxygen does not have: it can efficiently absorb ultraviolet light. In doing so, ozone protects oxygen at lower altitudes from being broken up and keeps most of these harmful rays from penetrating to the earth's surface. The energy of the absorbed radiation heats up the ozone, creating warm layers high in the stratosphere that act as a cap on the turbulent troposphere below.

Ozone molecules are constantly being made. But they can be destroyed by any of a number of chemical processes, most of them natural. For example, the stratosphere receives regular injections of nitrogen-bearing compounds, such as nitrous oxide, produced by microbes and fossil-fuel combustion, the gas rides the rising air currents to the top of the troposphere. Forced higher still by the tremendous upward push of tropical storms, it finally enters and percolates slowly into the stratosphere.

Like most gaseous chemicals, man-made or natural, that reach the stratosphere, nitrous oxide tends to stay there. Indeed, a recent National Academy of Sciences report likened the upper atmosphere "to a city whose garbage is picked up every few years instead of daily." As long as five years after it leaves the ground, N_2O may finally reach altitudes of 15 miles and above, where it is broken apart by the same ultraviolet radiation that creates ozone. The resulting fragments—called radicals—attack and destroy more ozone molecules. Another ozone killer is methane, a carbon-hydrogen compound produced by microbes in swamps, rice paddies and the intestines of sheep, cattle and termites.



Worse than ever: satellite image recorded Oct. 5 showing ozone hole over Antarctica

For millenniums, the process of ozone production and destruction has been more or less in equilibrium. Then in 1928 a group of chemists at General Motors invented a nontoxic, inert gas (meaning that it does not easily react with other substances) that was first used as a coolant in refrigerators. By the 1960s, manufacturers were using similar compounds, generically called chlorofluorocarbons, as propellants in aerosol sprays. "As industrial chemicals, they were ideal. The propellants had to be inert," says Chemist Ralph Cicerone, of the National Center for Atmospheric Research. "You didn't want the spray in a can labeled 'blue paint' to come out red. Since then the growth of CFCs has been fabulous, and they've been pretty useful." Indeed, CFCs turned out to be a family of miracle chemicals: produced at a rate of hundreds of thousands of tons yearly, they seemed almost too good to be true.

They were. In 1972 Rowland heard a report that trace amounts of CFCs had been found in the atmosphere in both the northern and southern hemispheres. What were

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particles. "I went into clouds at 61,000 ft., and I didn't come out the whole time," says Williams of the first flight. Another surprise: temperatures did not warm when the plane soared into the stratosphere. Instead, they plummeted to −130°F., low enough to cause worries about a fuel freeze-up.

At 60,000 ft., winds as high as 150 knots buffeted the aircraft. Even so, the real difficulty came from 40-knot gusts that tossed the plane around during landings. With special scientific instruments installed in pods on its long, droopy wings, the ER-2 is "like a big albatross—it's heavy-winged," says Operations Manager James Cherbonneaux of NASA's Ames Research Center. While watching a particularly hairy approach to the runway at Punta Arenas, he recalls, "I chewed a little bit of my heart out."

Conditions aboard the DC-8 were considerably better. The plane, which carried up to 41 scientists, flew no higher than 42,000 ft. on its 13 missions, and those on board were free to move about. But heavy clouds obscured views of Antarctica most of the time, and the flights were a tedious eleven hours long. Observes Atmospheric Scientist Ed Browell, of NASA's Langley Research Center in Virginia: "I sort of likened what we were doing to taking off from the East Coast, flying to the West Coast to do our work, then flying back East to land."

To break the monotony, scientists took aboard a variety of stuffed animals, including a seal, cat and penguin, and warmed up snacks of pizza, empanadas, popcorn and hamburgers in the microwave oven. Cabin temperature was kept cool to avoid overheating the high-tech instrumentation. Says Atmospheric Physicist Geoffrey Toon, of the Jet Propulsion Laboratory in Pasadena, Calif.: "If you tried to sleep during your off hours, usually you froze."

Williams suits up for takeoff

they doing there? The answer, as Rowland and his colleague, Mario Molina, soon found, was that there was nowhere else for them to go but into the atmosphere. CFCs in aerosol cans are sprayed directly into the air; they escape from refrigerator coils, and they evaporate quickly from liquid cleaners and slowly from plastic foams.

In the troposphere, CFCs are immune to destruction. But in the stratosphere, they break apart easily under the glare of ultraviolet light. The result: free chlorine atoms, which attack ozone to form chlorine monoxide (ClO) and O_2. The ClO then combines with a free oxygen atom to form O_2 and a chlorine atom. The chain then repeats itself. "For every chlorine atom you release," says Rowland, "100,000 molecules of ozone are removed from the atmosphere."

In 1974 Rowland and Molina announced their conclusion: CFCs were weakening the ozone layer enough to cause a marked increase in skin cancers, perhaps enough to perturb the planet's climate by rejuggling the stratosphere's temperature profile. In 1978 the U.S. banned their use in spray cans. "People assumed the problem had been solved," recalls Rowland. But the Europeans continued to use CFCs in aerosol cans; other uses of CFCs began to increase worldwide. Says Rowland: "All along, critics complained that ozone depletion was not based on real atmospheric measurements—until, that is, the ozone hole appeared. Now we're not talking about ozone losses in 2050. We're talking about losses last year."

For several years NASA's scientists failed to accept data on the Antarctic ozone hole that was before their eyes. The reason: computers prescreening data from monitoring satellites had been programmed to dismiss as suspicious presumably wild data showing a 30% or greater drop in ozone levels. After British scientists reported the deficit in 1985, NASA went back to its computer records, finally recognizing that the satellite data had been showing the hole all along.

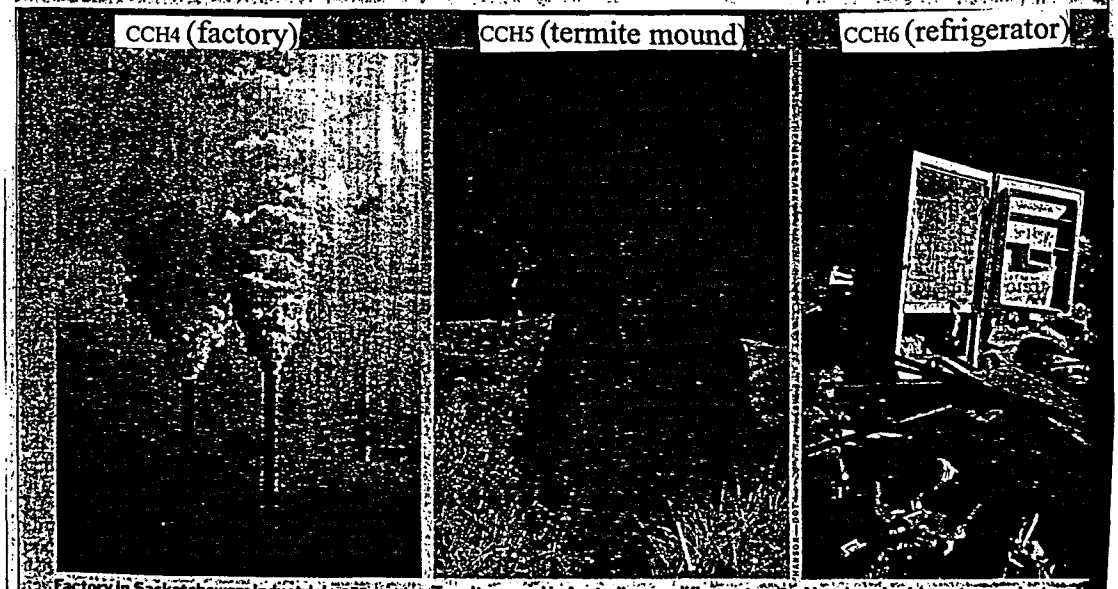
Still, the existence of an ozone hole did not necessarily mean CFCs were to blame, and a number of alternative explanations were proposed. Among them, says Dan Albritton, director of the Federal Government's Aeronomy Laboratory in Boulder, was the notion that the "hole did not signify an ozone loss at all, just a breakdown in the distribution system." An interruption in the movement of air from the tropics, where most ozone is created, to the poles could easily result in less ozone reaching the Antarctic. Another theory: perhaps the sunspot activity that peaked around 1980 created more ozone-destroying nitrogen radicals than usual, which would be activated each spring by sunlight.

But while most scientists agree that atmospheric chemistry and dynamics are major causes, the increased scrutiny of the Antarctic atmosphere following the discovery of the hole has seriously undercut the sunspot theory. Data from Punta Arenas, says Robert Watson, a NASA scientist involved in that study, made the verdict all but final. Nitrogen and ozone levels were down, but concentrations of chlorine monoxide were 100 times as great as equivalent levels at temperate latitudes. Says Watson: "We can forget the solar theories. We can no longer debate that chlorine monoxide exists and that its abundance is high enough to destroy ozone, *if* our understanding of the catalytic cycle is correct. We need to go back to the lab and resolve the uncertainty."

That is not all. Scientists are still not completely sure why the hole remains centered on the Antarctic or why the depletion is so severe. It may have to do with the peculiar nature of Antarctic weather. In winter the stratosphere over the region is actually sealed off from the rest of the world by the strong winds that swirl around it, forming an all but impenetrable vortex. Says Cicerone: "Looking down at the South Pole is like watching fluid draining in a sink. It's like an isolated reactor tank. All kinds of mischief can occur."

One likely source of mischief making clouds of ice particles in the polar stratosphere. Explains Rowland: "Mostly, you don't get clouds in the stratosphere because most of the water has been frozen out earlier. But if the temperature gets low enough, you start freezing out the rest." Indeed, they may prove to be a central cause of the ozone hole, since it provides surfaces for the kind of chemistry only recently associated with reactions in the atmosphere. In a gaseous state, molecules bounce around and eventually some hit one another. But adding a surface for the molecules to collect on speeds up the reactions considerably.

It is not yet clear whether ozone depletion in the Antarctic is an isolated phenomenon or whether it is an ominous warning signal of more slowly progressing ozone destruction worldwide. Data that do indicate that the decline over the past eight years is 4% to 5%. Scientists estimate that



Factory in Saskatchewan: industrial emissions increase airborne CO_2

Termite mound in Australia: a prolific producer of methane gas

Abandoned refrigerator: coolants are made up of ozone-attacking CFCs

natural destruction of the ozone could account for 2% of that figure. The Antarctic hole could explain an additional 1%. The remaining 1% to 2% could simply be the result of normal fluctuations. As Albritton's research team reported, "A depletion of this magnitude would be very difficult to identify against the background of poorly understood natural variation."

The same can be said for the greenhouse effect: it is too soon to tell whether unusual global warming has indeed begun. Unlike ozone depletion, the greenhouse effect is a natural phenomenon with positive consequences. Without it, points out Climate Modeler Jeff Kiehl, of the National Center for Atmospheric Research, "the earth would be uninhabitable. It is what keeps us from being an ice-frozen planet like Mars." Indeed, if gases like CO_2 did not trap the sun's energy, the earth's mean temperature would be 0° F, rather than the current 59°.

Still, as far back as the late 1890s, Swedish Chemist Svante Arrhenius had begun to fret that the massive burning of coal during the Industrial Revolution, which pumped unprecedented amounts of CO_2 into the atmosphere, might be too much of a good thing. Arrhenius made the startling prediction that a doubling of atmospheric CO_2 would eventually lead to a 9° F warming of the globe. Conversely, he suggested, glacial periods might be caused by diminished levels of the gas. His contemporaries scoffed. Arrhenius, however, was exactly right. In his time, the CO_2 concentration was about 280 to 290 parts per million—just right for a moderately warm, interglacial period. But today the count stands at some 340 p.p.m. By 2050, if the present rate of burning fossil fuels continues, that concentration will double, trapping progressively more infrared radiation in the atmosphere.

The consequences could be daunting. Says National Center for Atmospheric Research's Francis Bretherton: "Suppose it's August in New York City. The temperature is 95°; the humidity is 95%. The heat wave started on July 4 and will continue through Labor Day." While warmer temperatures might boost the fish catch in Alaska and lumber harvests in the Pacific Northwest, he says, the Great Plains could become a dust bowl; people would move north in search of food and jobs, and Canada might rival the Soviet Union as the world's most powerful nation. Bretherton admits that his scenario is speculative. But, he says, "the climate changes underlying it are consistent with what we believe may happen."

Such changes may already be under way. Climatologists have noted an increase in mean global temperature of about 1° F since the turn of the century—within the range predicted if the greenhouse effect is on the rise. But, warns Roger Revelle, of the University of California at San Diego, "climate is a complicated thing, and the changes seen so far may be due to some other cause we don't yet understand." The absence of a clear-cut signal, however, does not disprove the theory. Scientists expect any excess greenhouse warming to be masked for quite some time by the enormous heat-absorbing capacity of the world's oceans, which have more than 40 times the absorptive capacity of the entire atmosphere.

"Right now," declares University of Chicago Atmospheric Scientist V. Ramanathan, "we've committed ourselves to a climatic warming of between one and three degrees Celsius [1.8° F. to 5.4° F], but we haven't seen the effect." This extra heat, now trapped in the oceans, he says, should be released over the next 30 to 50 years—unless, of course, an event like a big volcanic eruption counteracts it. Notes Ramanathan: "By the time we know our theory is correct, it will be too late to stop the heating that has already occurred." Schneider sees no need to wait. Says he: "The greenhouse effect is the least controversial theory in atmospheric science."

Maybe. But climate is governed by an array of forces that interact in dizzyingly complex ways. The atmosphere and oceans are only two major pieces of the puzzle. Also involved: changes in the earth's movements as it orbits the sun, polar ice caps, and the presence or absence of vegetable and animal life. "The feedbacks are enormously complicated," says Michael MacCracken, of the Lawrence Livermore National Laboratory in California. "It's like a Rube Goldberg machine in the sense of the number of things that interact in order to tip the world into fire or ice."

One of the most fundamental elements of the Rube Goldberg machine is the three astronomical cycles first described by Serbian Scientist Milutin Milankovitch in the 1920s. The swings, which involve long-term variations in the wobbling of the earth's axis, its tilt and the shape of its orbit around the sun, occur every 22,000, 41,000 and 100,000 years, respectively. Together they determine how much solar energy the earth receives and probably cause the earth's periodic major ice ages every 100,000 years or so, as well as shorter-term cold spells.

CCH7 (Amazon deforestation)

Clearing the Amazon: deforestation adds to the greenhouse effect

CCH8 (rubbish)

Fast-food leftovers: deteriorating plastic foam containers give off CFCs

CCH9 (paddies)

Sichuan paddies: underwater bacteria generate heat-absorbing gases

But Milankovitch cycles only scratch the surface of climatic change. Volcanoes, for example, send up veils of dust that reflect sunlight and act to cool the planet. Deserts, with their near white sands, also reflect sunlight, as do the polar ice caps. Tropical rain forests, however, have the opposite effect: their dark green foliage, like the dark blue of the ocean, absorbs solar radiation; both tend to warm the planet.

Clouds, which shade about half the earth's surface at any given time, are another important climatic factor. Says James Coakley of the National Center for Atmospheric Research: "If you heat up the atmosphere and pump more water in, clouds will change. But how? We don't know." Water vapor, for example, is yet another greenhouse gas, but the white-gray surfaces of clouds reflect solar energy. Which effect predominates? Answer: it depends on the cloud. The bright, low-level stratocumulus clouds reflect 60% of incoming solar rays. But long, thin monsoon clouds let solar heat in while preventing infrared radiation from escaping.

Another contributor to climatic change is the biosphere—scientific jargon for the realm of all living things on earth. And it is the biosphere that threatens to tip the balance. To be sure, many of its effects are natural and as such have long been part of the climatic equilibrium. Termites, for example, produce enormous amounts of gas as they digest woody vegetation: a single termite mound can emit five liters of methane a minute. The methane escapes into the atmosphere, where it can not only destroy ozone but also act as a greenhouse gas in its own right. "Termites," says Environmental Chemist Patrick Zimmerman, of the National Center for Atmospheric Research, "could be responsible for as much as 50% of the total atmospheric methane budget."

Actually, the biosphere becomes a problem only when humans get involved. In Brazil the Amazon rain forest, which once covered 3 million sq. mi., has been slashed by an estimated 10% to 15% as the region has been developed for mining and agriculture; an additional 20% has been seriously disturbed. When the downed trees are burned or rot, CO_2 and other greenhouse gases are released. The same kind of deforestation in Africa, Indonesia and the Philippines, say experts, may already be helping to make the world warmer.

To make matters worse, a host of other gases are now known to add to the greenhouse effect. In 1975, Ramanathan was amazed to discover that Freon, a widely used CFC, was an infrared absorber. "It had a very large impact," he says. "Since then, tracking down the role of other trace gases has become a cottage industry. There are dozens of them, and they are rivaling the effects of increasing CO_2." In fact, by the year 2030 the earth will already face the equivalent of a doubling of CO_2, thanks to these other rapidly increasing gases, including methane, nitrous oxide and all the CFCs. "These are the little guys," says Schneider. "But they nickel and dime you to the point where they add up to 50% of the problem."

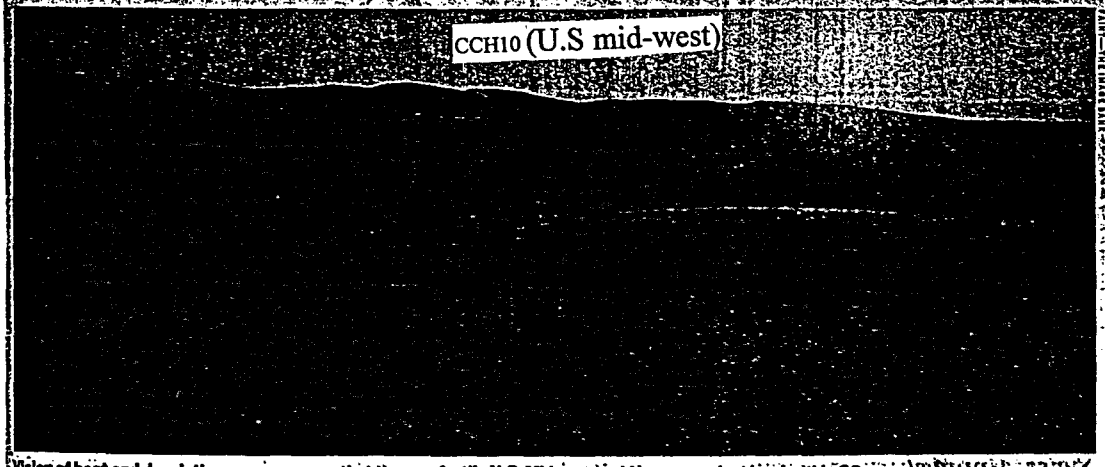
Is there any way to slow either the greenhouse effect or the depletion of the world's ozone? The Montreal accord, agreed to last month after nearly five years of on-and-off negotiations, is a good start on ozone. It calls on most signatory countries to reduce production and consumption of CFCs by 50% by 1999. Developing nations, however, will be allowed to increase their use of the chemicals for a decade so they can catch up in basic technologies like refrigeration. The net effect, insist the treaty's advocates, will be a 35% reduction in total CFCs by the turn of the century.

Some experts do not believe the projected cutback is good enough. Says Rowland: "The Montreal agreement simply isn't sufficient to protect the ozone. We should have signed a treaty that reduced CFC production by 95%—not 50%." Nonetheless, the Environmental Protection Agency has calculated that without the accord, a staggering 131 million additional cases of skin cancer would occur among people born before 2075.

Any similar attempt to ease the greenhouse effect by imposing limits on CO_2 and other emissions is unlikely. John Topping, president of the Washington-based Climate Research Institute, argues that adjustments in agricultural production, like limiting the use of nitrogen-based fertilizers, would have only a slight effect. A more important step would be to protect the tropical rain forests, a move that would certainly be resisted by developers. Obviously, the most far-reaching step would be to cut back on the use of fossil fuels, a measure that would be hard to accomplish in industrialized countries without a wholesale turn to energy conservation or alternative forms of power. In developing countries, such reductions might be technologically feasible but would be all but impossible to carry out politically and economically.

Until now, the earth's climate has been a remarkably stable, self-correcting machine, letting in just the right amount and type of solar energy and providing just the right balance of temperature and moisture to sustain life. Alternating cycles of cold and warmth, as well as greater and lesser concentrations of different gases, have forced some species into extinction. The same changes have helped others evolve. The irony is that just as we have begun to decipher the climatic rhythms that have gone on for hundreds of millions of years, we may have begun to change them irrevocably. And as the unforeseen discovery of the ozone hole demonstrates, still more unexpected changes may be on the way.

—By Michael D. Lemonick. Reported by J. Madeleine Nash/Boulder, with other bureaus



Vision of heat and desolation: new concerns that the now fertile U.S. Midwest could become a dust bowl within 60 years

COVER STORIES

TTL

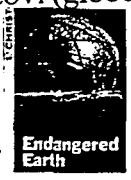
The Ozone Vanishes

GLM

And not just over the South Pole. A hole in earth's protective shield could soon open above Russia, Scandinavia, Germany, Britain, Canada and northern New England.

By MICHAEL D. LEMONICK

CCOV1 (globe)



THR

What does it mean to redefine one's relationship to the sky? What will it do to our children's outlook on life if we have to teach them to be afraid to look up?

—Senator Al Gore, *Earth in the Balance*

PRB

The world now knows that danger is shining through the sky. The evidence is overwhelming that the earth's stratospheric ozone layer—our shield against the sun's hazardous ultraviolet rays—is being eaten away by man-made chemicals far faster than any scientist had predicted. No longer is the threat just to our future; the threat is here and now. Ground zero is not just the South Pole anymore; ozone holes could soon open over heavily populated regions in the northern hemisphere as well as the southern. This unprecedented assault on the planet's life-support system could have horrendous long-term effects on human health, animal life, the plants that support the food chain and just about every other strand that makes up the delicate web of nature. And it is too late to prevent the damage, which will worsen for years to come. The best the world can hope for is to stabilize ozone loss soon after the turn of the century.

THR

SPC1

If any doubters remain, their ranks dwindled last week. The National Aeronautics and Space Administration, along with scientists from several institutions, announced startling findings from atmospheric studies done by a modified spyplane and an orbiting satellite. As the two craft crossed the northern skies last month, they discovered record-high concentrations of chlorine monoxide (ClO), a chemical by-product of the chlorofluorocarbons (CFCs) known to be the chief agents of ozone destruction.

SPC1

Although the results were preliminary,

NASA

The red patch is a cloud of chlorine monoxide, as seen by NASA's Upper Atmosphere Research Satellite last month. Ozone destruction is most likely to take place north of 50° latitude and could start as early as late February.

CCOV2 (ozone map)

Chlorine monoxide 11 Jan 1

SPC1

they were so disturbing that NASA went public a month earlier than planned, well before the investigation could be completed. Previous studies had already shown that ozone levels have declined 4% to 8% over the northern hemisphere in the past decade. But the latest data imply that the ozone layer over some regions, including the northernmost parts of the U.S., Canada, Europe and Russia, could be temporarily depleted in the late winter and early spring by as much as 40%. That would be almost as bad as the 50% ozone loss recorded over Antarctica. If a huge northern ozone hole does not in fact open up in 1992, it could easily do so a year or two later. Says Michael Kurylo, NASA's manager of upper-atmosphere research: "Everybody should be alarmed about this. It's far worse than we thought."

PRE

BRG

And not easy to fix because CFCs are ubiquitous in almost every society. They are used in refrigeration and air conditioning, as cleaning solvents in factories and as blowing agents to create certain kinds of plastic foam. In many countries CFCs are still spewed into the air as part of aerosol sprays.

SLN

EVN

Soon after the ozone hole over Antarctica was confirmed in 1985, many of the world's governments reached an unusually rapid consensus that action had to be taken. In 1987 they crafted the landmark Montreal Protocol, which called for a 50% reduction in CFC production by 1999. Three years later, as signs of ozone loss mounted, international delegates met again in London and agreed to a total phaseout of CFCs by the year 2000. That much time was considered necessary to give CFC manufacturers a chance to develop substitute chemicals that do not wipe out ozone.

But the schedule now seems far too leisurely. Last week's grim news spurred new public warnings and calls for faster action. In Denmark an Environment Ministry spokesman went on television to urge fellow Danes not to panic—but to use hats and sunscreen. German Environment Minister Klaus Töpfer called on other countries to match Germany's pledge to stop CFC production by 1995. Greenpeace activists in Britain met with Prime Minister John Major and implored him to halt the manufacture of all CFCs immediately.

SLN

The U.S. Congress passed a law in 1990 that called for an accelerated phaseout of CFCs if new scientific evidence revealed a greater threat to ozone than expected. Last week the Senate, by a 96-0 vote, found the evidence alarming enough to justify a faster phaseout. "Now that there's the prospect of a hole over Kennebunkport," Senator Al Gore said, "perhaps Bush will comply with the law." William Reilly, administrator of the Environmental Protection Agency, said that the U.S. might seek to end CFC production as early as 1996.

SLN

The vital gas being destroyed is a form

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ccov3 (skin protection)

PHOTOGRAPHS BY JAMES W. KAY

of oxygen in which the molecules have three atoms instead of the normal two. That simple structure enables ozone to absorb ultraviolet radiation—a process that is crucial to human health. UV rays can make the lens of the eye cloud up with cataracts, which bring on blindness if untreated. The radiation can cause mutations in DNA, leading to skin cancers, including the often deadly melanoma. Estimates released last week by the United Nations Environment Program predict a 26% rise in the incidence of nonmelanoma skin cancers worldwide if overall ozone levels drop 10%.

Excess UV radiation may also affect the body's general ability to fight off disease.

As the ozone gets thinner, people may have to cover up year-round to guard against harmful radiation from the skies. The pale look could become sexier than a deep tan.

Says immunologist Margaret Kripke of the M.D. Anderson Cancer Center in Houston: "We already know that ultraviolet light can impair immunity to infectious diseases in animals. We know that there are immunological effects in humans, though we don't yet know their significance."

Just as worrisome is the threat to the world's food supply. High doses of UV radiation can reduce the yield of basic crops such as soybeans. UV-B, the most dangerous variety of ultraviolet, penetrates scores of meters below the surface of the oceans. There the radiation can kill phytoplankton (one-celled plants) and krill (tiny shrimplike animals), which are at the very bottom of the ocean food chain. Since these organisms, found in greatest concentrations in Antarctic waters, nourish larger fish, the ultimate consumers—humans—may face a maritime food shortage. Scientists believe the lower plants and animals can adapt to rising UV levels by developing UV-absorbing cell pigments. But that works only up to a point, and no one knows what that point is.

The impact of ozone loss will be felt first in Antarctica, where levels of the gas have been severely depleted each spring for several years. Populations of marine organisms are not shrinking so far, but they have begun to produce UV-absorbing pigments. In Australia scientists believe that crops of wheat, sorghum and peas have been affected, and health officials report a threefold rise in skin cancers. There are an-

PRE anecdotal reports of more cancer in Argentina too. While no increase in cancers or cataracts has shown up yet in Chile or New Zealand, experts note that these diseases can take years to develop.

SLN Many people are reducing their risks. In Punta Arenas, Chile's southernmost city, some parents keep their children indoors between 10 a.m. and 3 p.m., and soccer practice has been moved from midafternoon to later in the day. The Australian government issues alerts when especially high UV levels are expected, and public-service campaigns warn of the dangers of sunbathing, much as U.S. ads counsel people not to smoke. In New Zealand schoolchildren are urged to wear hats and eat their lunches in the shade of trees.

BRG Scientists are also concerned about the potential effect of ozone depletion on the earth's climate systems. When stratospheric ozone intercepts UV light, heat is generated. That heat helps create stratospheric winds, the driving force behind weather patterns. Says Sherwood Rowland, a chemist at the University of California at Irvine, who first discovered the dangers of CFCs: "If you change the amount of ozone or even just change its distribution, you can change the temperature structure of the stratosphere. You're playing there with the whole scheme of how weather is created."

Weather patterns have already begun to change over Antarctica. Each sunless winter, steady winds blow in a circular pattern over the ocean that surrounds the continent, trapping a huge air mass inside for months at a time. As the sun rises in the spring, this mass, known as a polar vortex, warms and breaks up. But the lack of ozone causes the stratosphere to warm more slowly, and the vortex takes longer to dissipate. This leads to even more ozone destruction: the polar vortex acts as a sort of pressure cooker to intensify chlorine's assault on ozone molecules.

BRG

SPC2 EVN When Rowland and his colleague, Mario Molina, issued the first ozone alert back in 1974, they had no idea that depletion would be particularly severe in Antarctica or in any other part of the world. What they did predict was that CFCs would not disintegrate quickly in the lower regions of the atmosphere. Instead the hardy chemicals would rise into the stratosphere before dissociating to form ClO and other compounds. The highly reactive chlorine would then capture and break apart ozone molecules. Each atom of chlorine, it was later determined, could destroy up to 100,000 molecules of ozone—at a far faster rate than the gas is replenished naturally.

But Rowland and Molina had deduced only the broadest outlines of the process. The details had to wait until the mid-1980s, when atmospheric scientists realized belatedly that while worldwide ozone levels had declined somewhat, there was an enormous deficit in Antarctica every year.

SPC2

SPC3 Determined to understand whether CFCs were the culprit, NASA mounted a series of flights from Punta Arenas into the Antarctic in 1987. They revealed unusually high concentrations—up to 1 part per billion—of ClO. They had found the smoking gun Rowland and Molina had predicted.

Rowland and others figured it was a combination of factors that made the ozone over Antarctica particularly vulnerable. First, the polar vortex collects CFCs that waft in from the industrialized world. Second, the superfrigid air of the Antarctic night causes clouds of tiny ice crystals to form high up in the stratosphere. When the CFCs break down, the resulting chemicals cling to the crystals, where they can decompose further into ClO, among other substances. And finally, when the sun rises after the long winter night, its light triggers a wholesale demolition of ozone by chlorine monoxide.

BRG In Antarctica winds circulate unimpeded over the frozen landmass. In the north, though, the polar vortex is less well defined. Winds travel alternately over land and water, whose differing temperatures disrupt the smooth flow of air. The vortex wobbles and sometimes breaks up entirely. Moreover, the Arctic stratosphere is not as cold as that over the Antarctic, and ice clouds are less likely to form. So while scientists knew that some ozone destruction should take place, they presumed it would not be nearly as severe as the southern hole. A reanalysis of 10 years' worth of ground-based and satellite data, completed last year, revealed a relatively mild but widespread depletion over the northern hemisphere, with losses of 4% to 8% over much of the continental U.S.

SPC4

SPC5 When NASA's ex-spy plane, the ER-2, began a series of flights out of Bangor, Maine, in October, it quickly became clear that something strange was happening. For one thing, volcanic ash, lofted into the stratosphere from last year's Mount Pinatubo eruption, was evidently taking the place of ice crystals, giving CFC byproducts the platform they needed for their chemical reactions. Moreover, the scientists found that naturally occurring nitrogen oxides, compounds that tend to interfere with and slow down these reactions, were virtually gone from the atmosphere. Why? Besides enhancing the reactions that create ozone-destroying forms of chlorine, explains Susan Solomon, a chemist with the National Oceanic and Atmospheric Administration, "the volcanic aerosols provide a surface for chemical reactions that suppress nitrogen oxides."

Hats On!

Ozone depletion is cause for caution, but it's no reason to stay barricaded indoors or put on an astronaut suit before venturing outside. Excessive exposure to the sun's ultraviolet (UV) rays has always been dangerous; the ozone problem just adds to the risk. Says NASA's Michael Kurylo: "We're not talking about a single exposure to a death ray. It takes repeated exposure over long periods of time."

Even if there were no atmospheric damage, an estimated one-sixth of all Americans would still develop skin cancer during their lifetime. Most cases are curable, if detected early. The 4% to 8% loss of ozone over the past decade could raise the risk at least 15%. A significant increase in cataracts, which now afflict 1 of every 10 Americans, could also occur.

As the ozone depletion gets worse, health risks will rise, but the odds of getting cancer or cataracts can be dramatically reduced by following guidelines that doctors recommended long before ozone depletion became a big issue. Their suggestions:

- When out in the sun for prolonged periods, wear protective clothing. That means choosing fabrics that have a tight weave and donning a wide-brimmed hat. A baseball cap is not adequate because it leaves the delicate rims of the ears exposed.
- In summer, when comfort calls for shorts and T shirts, use a broad-spectrum sunscreen with a sun protection factor of at least 15.
- Minimize the time spent in the sun between 10 a.m. and 3 p.m.
- Wear sunglasses when outdoors in bright sunlight. Ask for ones that are treated to absorb UV radiation or that meet the American National Standards Institute Guidelines for eye wear. Poorly designed sunglasses that do not block UV rays could do more harm than good. Under dark lenses, the pupils dilate, making it easier for UV light to damage the delicate membrane of the retina. ■

Appendix 1.10

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Another flight that took off from Maine on Jan. 20 provided the clincher. The polar vortex had temporarily dipped as far south as Bangor—"It was almost as if we were deployed over the North Pole," says geophysicist Darin Toohey of U.C. Irvine—just in time for the sensitive instruments on board to detect ClO in a world-record concentration of 1.5 parts per billion. Data from the Upper Atmosphere Research Satellite had already found comparable levels of ClO over Northern Europe, and the evidence pointed to a potential ozone loss of 1% to 2% a day.

Even with all these factors in place, there is still one element necessary before a certified ozone hole can form: the sun. If the polar vortex breaks up before the sun rises after months of darkness to trigger the reaction, there will be no hole this year. If the vortex holds together until late February or early March, keeping its brew of dust particles and chemicals intact, ozone levels will almost certainly drop. Says Harvard chemist James Anderson: "We are now protected only by the hope of a rapid breakup of this vortex." But even if the hole does not appear within a few months, says Anderson, it will almost certainly appear within the next few years.

When it does, the area of greatest ozone depletion and greatest danger will most likely be north of 50° north latitude, a line that nearly coincides with the U.S.-Canada border and also takes in all the British Isles, Scandinavia, the Netherlands and much of Belgium, Germany and Russia. Regions farther to the south could be affected too, albeit not so severely. Life in the far north could come to resemble that in Australia, with ozone alerts and stern warnings to wear sunglasses and sunscreen.

Some scientists are equally concerned about the smaller but worsening ozone loss at mid-latitudes. The mechanism behind polar ozone holes was not predicted before its discovery. Could there be an undiscovered reason for ozone to vanish over temperate zones as well? Maybe so. On Jan. 12 the ER-2 swooped south instead of north. Says Anderson: "We discovered to our shock that there was ClO all the way down to the Caribbean." It was a very thin layer with concentrations of only 0.1 part per billion—but this was much higher than anyone had predicted.

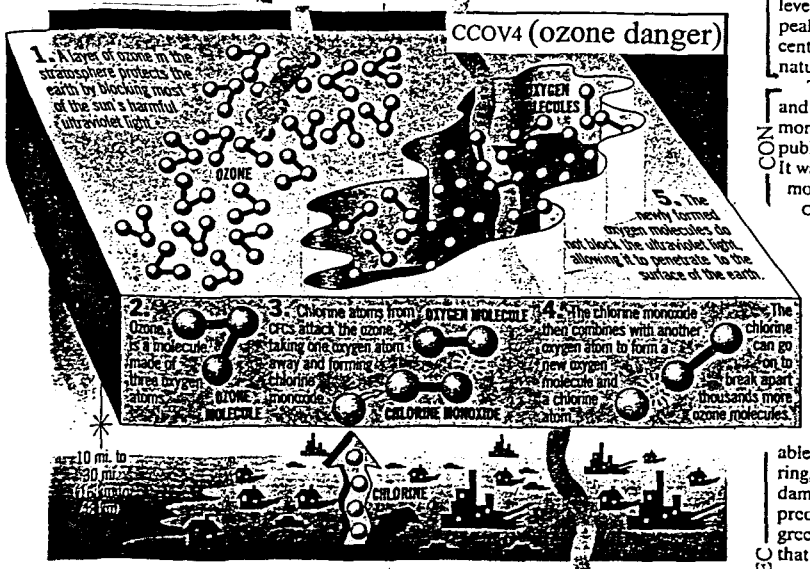
[No one is sure just how such concentrations of the chemical got there or whether it is destroying ozone. It may be that some of the ClO-rich air from the polar vortex has split off and headed south on its own—a phenomenon that has been observed in the past. And while ozone depletion has not been directly observed, the chemistry over the Caribbean appears to be right. There is ClO; there are plenty of dust particles from Pinatubo; there is sunlight. NASA's Kurylo thinks significant ozone loss is in fact happening in the tropics. Says Harvard's Anderson: "This is cause for extreme concern. It is the mechanism we most fear."]

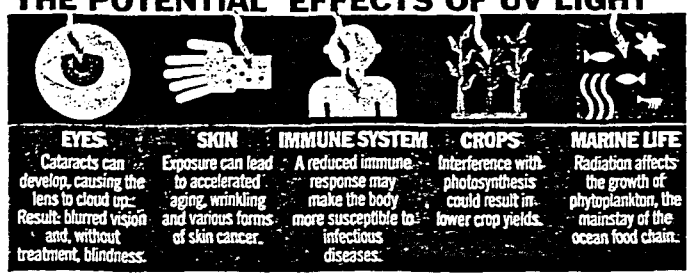
What also frightens scientists is the fact that CFCs remain in the atmosphere for decades after they are emitted. In their original research, Rowland and Molina estimated that CFCs can last 100 years or more. Even if CFC production stopped today, researchers believe that stratospheric levels of chlorine would continue to rise, peaking during the first decade of the next century and not returning to anything like natural levels for at least a century.

The ozone story is a tragic saga of doubt and delay. Rowland recalls that for several months after his original ozone paper was published in 1974, "the reaction was zilch." It was not until 1978 that the U.S., but not most other countries, banned the use of CFCs in hair sprays and other aerosols. Not until the Antarctic ozone hole was confirmed in 1985 did nations get serious about curbing all uses of CFCs. By now as many as 20 million metric tons of these potent chemicals have been pumped into the atmosphere.

World leaders should remember ozone when they think about other threats to the planet. If they always wait until there is indisputable evidence that serious damage is occurring, it may be much too late to halt the damage. Consider the widespread scientific predictions of global warming from the greenhouse effect. No one knows for sure that anything terrible will happen. But humanity has boosted the amount of carbon dioxide in the atmosphere by at least 25%. It is reckless to subject nature to such giant experiments when the outcome is unknown and the possible consequences are too frightening to contemplate.

At least nations now seem to agree on a crash effort to save the ozone. But the cure will not be instantaneous. The world may not know for decades how costly the years of recklessness will be. And whether children should be afraid to look up. —*Reported by Dan Cray/Irvine and Dick Thompson/Washington, with other bureaus*





TTL

AS THE OZONE THINS, THE PLOT THICKENS

Francesca Lyman

SET [PRB]

For all but the people of Australia, New Zealand, southern Chile, and other places at the bottom of the globe, the "hole" in the earth's ozone layer over Antarctica has seemed reassuringly far away. Since the alarming phenomenon came to light in 1985, the world has watched the scientific missions come and go, exploring uncharted territory at the coldest, furthest edge of the earth. High-flying spy planes have rocketed to maximum heights to take readings of ozone and other chemicals in the stratosphere; cargo planes have touched down on runways of ice for ground-level research; and robotic eyes aboard National Aeronautics and Space Administration (NASA) satellites have kept vigil on "the hole in the sky." Yet these probes of our own planet's vital signs have seemed more abstract than the moon landings.

Every year brings fresh evidence that the ozone layer, the earth's protective shield against ultraviolet rays, is eroding. In 1986, Canadian scientists detected another bald spot, a thinning of ozone over the Arctic region. In 1988, NASA reported that the ozone layer over the entire globe was eroding much faster than predicted. And this year, with little media fanfare, NASA scientists released new findings that ozone depletion over the northern hemisphere's mid-latitudes was twice and even possibly three times as great during late winter and springtime as scientists had believed a few years ago. In July, British scientists reported that the ozone layer over Europe—[illegible] from northern Britain to south Spain—had been depleted [illegible] during the last decade, a rate twice that of the previous decade.

GCL [PRB]

[Environmental Protection Agency Administrator William Reilly called] [illegible] latest findings "shocking and disturbing." He predicted they [would result in] [illegible] skin cancer rates for humans and [other] [illegible] damage to plants, animals and ecological systems. [Senator Albert Gore (D-Tennessee) said:] "The problem is not just over [Antarctica] and not just in the winter. It's over our heads here, now." [illegible] glimpse, scientists were [illegible] that the chemistry [illegible] over much of the globe [illegible] as much as 100 percent at [illegible]

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CCOT2 (Anderson)

CCOT3 (Solomon)

Dann Tuohey

At the South Pole, chemist Susan Solomon, who led the first mission to probe the ozone hole in 1986, alights from a helicopter. Harvard University's James Anderson (left) will head a mission this fall to study the northern hemisphere's ozone losses.

GCL certain times and altitudes) is spreading or that some unknown factor has come into play. One new development has been compared in magnitude to the discovery of the ozone hole: scientists found that tiny sulfate particles at the densely populated mid-latitudes may be creating a stratospheric chemistry similar to that formed by ice crystals in stratospheric clouds of the Antarctic and, to a lesser extent, in the Arctic.

SPC1 "It's now quite clear that these dust particles [in the temperate and tropic regions] do affect the stratospheric chemistry and contribute to ozone depletion. The real question is how much," says Susan Solomon, an atmospheric chemist with the National Center for Atmospheric Research in Boulder, Colorado. Solomon led the first expedition to investigate the Antarctic ozone hole in 1986, and it was she who originated the hypothesis that the ozone-hole mystery was a case partly of cold temperatures and partly cloud chemistry: Antarctica was cold enough for clouds to form in its stratosphere, and these cloud surfaces catalyze the chemical reactions.

BRG Why ozone depletion is occurring faster than scientists believed possible is still a puzzle. But if the crime is still unfolding, the culprits have long been known. They are a group of compounds called chlorofluorocarbons used in a host of common products from refrigerators to foam mattresses. Once hailed as "miracle chemicals," they are now the target of a worldwide ban. A landmark international agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer, which originally required only a 50 percent cut in CFCs by the year 1998, was strengthened at a meeting in London in June 1990. At present, the protocol calls for a total ban on CFCs and halons (another, more potent ozone-depleting compound used primarily in fire extinguishing), and a ban on two chemicals used as cleaning solvents: carbon tetrachloride by the year 2000 and methyl chloroform by 2005. The agreement also calls for a program to help Third World countries phase out their use of CFCs.

SLN

"The problem is not just over Antarctica . . . It's over our heads, here, now."

PRE SLN EVN [Even these stronger measures now appear to many as too little, too late.] The new NASA data has upped the ante for a speeded up phase-out of CFCS, while sending a strong message to the industry to speed its search for substitutes. At an international meeting held in Nairobi, Kenya, in mid-June, delegates set the stage for another round of strengthened amendments. Observers say that negotiators are likely to move up the ban of CFCs from 2000 to 1997. EPA is considering speeding up its regulations, too.

As fast as industry now moves away from these chemicals, environmentalists insist it has to be faster. "Every time the ratchet has been tightened, industry has found new places they can cut their use of CFCs," said David Doniger, a senior attorney at NRDC, who has worked on the issue for the last seven years.

To spur a faster CFC phaseout, some countries have introduced their own more stringent domestic laws. Germany, for example, has passed a law that will ban CFC production by the year 1995. Australia, Sweden, and Norway are banning halons as of 1995. Canada will cease CFC production in 1997 and phase out use of methyl chloroform by 2000. And in the United States, nearly two dozen states have laws limiting or banning CFC-bearing products.

Meanwhile, with several provisions regulating CFCs coming into effect under the Clean Air Act in 1992, consumers can use their purchasing power to spur the recycling of CFCs (see "CFCs: Just Say No," page 29) and put pressure on manufacturers to develop truly ozone-safe products.

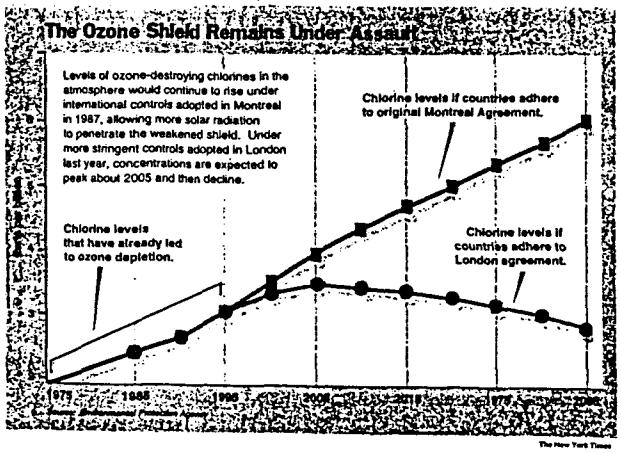
A deep blue, acrid-smelling poisonous gas, ozone is toxic when found in the smog around us. But in its rightful place—a distance of eighteen to thirty miles above the earth—ozone is vital to the planet's health, protecting the DNA of all living things from dangerous ultraviolet rays. Considering that scientists link the origin of ozone in the stratosphere with the birth of life on earth, it is hard to imagine a more catastrophic risk than ozone depletion. Little wonder that EPA today regards it as one of the highest-risk environmental problems.

As far back as 1974, scientists Sherwood Rowland and Mario Molina, of the University of California at Irvine, theorized that CFCs, whose uses were soaring at the time, could—because of their stable chemistry—waft up undisturbed to the stratosphere, where ultraviolet light could release their constituent element, chlorine, which could then destroy ozone. They soon realized that not just one ozone molecule was destroyed by each chlorine atom released, but a chain reaction left chlorine to wander off to destroy 100,000 or more ozone molecules.

Environmentalists considered the threat of ozone depletion so great that they made banning CFC use in aerosol spray cans one of their biggest causes during the 1970s, as Lydia Dotto and Harold Schiff wrote in their memoir of the controversy, *The Ozone Wars*. EPA began regulating CFCs before they were firmly pinpointed as a major cause of ozone depletion and officially outlawed "non-essential" uses of CFCs in spray cans in 1978. By then the markets for these products had all but disappeared anyway, thanks largely to consumer boycotts. Like companies now trying to catch the green consumer wave, "Arrid Extra Dry came out with a new product that said 'safe for the ozone' right on the can" in the late seventies, according to Dotto and Schiff.

EPA's ban of "non-essential" CFCs (90 percent of aerosol sprays) left for future regulation other sources of CFCs in refrigerants, air conditioners, coolants. Not until ten years later did EPA get around to regulating the chemicals, dragging its feet because of a combination of politics, bureaucratic oversights, and intense lobbying by industry, say people working on the issue. With hindsight, it is easy to say that a lot of time was lost debating the scientific facts. The government followup plans on CFCs gradually disappeared, laments scientist Sherwood Rowland, "and so did further research on substitutes. We lost eight years!"

CCOT4 (chlorine levels)



During the early 1980s, the incoming Reagan administration took the stance that ozone depletion was yet another case of environmental alarmism; then-EPA administrator Anne Gorsuch Burford, in her book *Are You Tough Enough?*, wrote, "Remember a few years back when the big news was fluorocarbons that supposedly threatened the ozone layer?" Concern died down, too, because worldwide demand for CFCs dropped, because of the U.S. spray can ban, followed by bans in Canada and Sweden, and because of a global economic recession. A 1983 National Academy of Science study tended to downplay the threat of CFC emissions, and EPA nearly halted work on the issue.

Industry, in the meantime, stopped research on CFC substitutes. A newly formed industry group, Alliance for a Responsible CFC Policy, campaigned in the early 1980s against a draft proposal to place a cap on CFC emissions. Quietly, world CFC production started to rise again, and was diverted to new markets—coolants, foamers, and cleaning solvents for electronic components. Between 1978 and 1986 CFC emissions grew at a rate of about 5 to 7 percent a year worldwide.

Fortunately, when Burford left EPA in 1983, high EPA officials began listening to a few staffers who questioned the low-depletion forecasts, according to NRDC's Doniger. They also recognized that CFCs were not simply ozone-depleters but also potent contributors to global warming, as every CFC molecule is

The Ultraviolet Zone

A biological experiment on a grand scale, started when the first ozone-depleting chlorofluorocarbons (CFCs) were produced in the 1930s, is now unfolding. These chemicals are being phased out, but for the next thirty to fifty years, the earth's surface will be exposed to mounting levels of ultraviolet radiation.

The ozone layer filters out solar rays on the high-energy end of the ultraviolet spectrum, called ultraviolet-B (UVB). Since UVB damages DNA, the protein code every living cell holds, the biological effects of UVB are wide-reaching: Crops, trees, human and animal immune systems, as well as the microscopic phytoplankton at the base of the food chain, are all vulnerable. Without the protective ozone veil, UVB would scrub the earth clean of life.

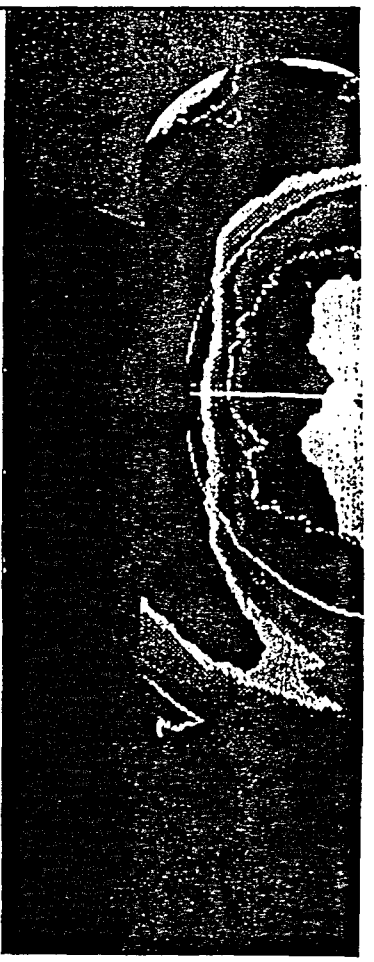
The recent findings by NASA that ozone depletion is more than twice what had been expected a year ago has scientists worried. A 5 percent loss of ozone, detected over the southern United States this spring could increase UVB by 10 percent. Depletion is no longer focused at the polar extremes but has moved over heavily populated regions.

The numbers of human skin cancers—the biological injury scientists understand best—will leap as a result, to 12 million in the United States alone according to William Reilly, administrator of the Environmental Protection Agency. U.S. skin cancer deaths over the next fifty years will increase twenty-fold, to 200,000, from the 9,300 EPA predicted in 1988.

Worldwide, higher doses of UVB are likely to have much more widespread effects on plants, animals, and ecosystems, but these impacts are the least understood. Biological researchers are now trying to answer a host of questions about ultraviolet radiation: What regions of the world will be most affected? Might sea mammals be deprived of their diet and die out? How is radiation linked to tropical diseases such as malaria? How much more susceptible are children?

While some scientists predict catastrophe, others take a less alarmist stance. Henry Lee, who heads EPA's team researching ozone depletion's effects on marine life, puts himself somewhere in between. "I don't think [those effects] will be catastrophic, but a change in UV may have a minor effect on oceans, but those effects will be extremely widespread, because water covers 70 percent of the earth's surface," Lee says.

Except for the plants and animals inhabiting the dark reaches of the oceans where ultraviolet cannot penetrate, all life has had to adapt to natural levels of UVB. Ultraviolet radiation has even become necessary to sustain life, in some instances. Humans, for example, require UV to synthesize vitamin D.



equivalent to at least 20,000 molecules of carbon dioxide. Pressed by a 1984 lawsuit by NRDC against EPA, the agency agreed in 1985 to start formulating CFC regulations under the Clean Air Act.

While policy was shifting, the real turning point in the story, of course, was the emergence of the ozone hole over Antarctica. This event jolted scientists from their typically cautious stance and eventually led to the 1987 Montreal Protocol. Yet, the largest producer of the chemicals, DuPont, waited until 1988 to announce that it would get out of the CFC business (and stop producing its big seller Freon), switch to safer substitutes, and support worldwide controls. Brad Allenby, a lawyer with AT&T, said, "DuPont's move earned credibility in the industry and a lot of companies realized the writing was on the wall."

Some observers attribute DuPont's move to fear of vast potential liability, because of the cancers caused by ozone depletion. Others point to genuine corporate concern. Whatever the reason, industry stopped fighting, fourteen years too late.

Within a few years, the tables had completely turned. As the Antarctic ozone hole expanded and NASA in 1988 reported "surprising" new erosion of the ozone layer, nations went back to the negotiating table. The Montreal Protocol, which called for a 50 percent reduction in the chemicals, also contained a

But for the most part, UVB is injurious to life. Human skin fends off UVB by thickening and producing melanin, the pigment that blocks UV. By absorbing or blocking UV, sunscreens perform the same role.

Certain animals and plants produce substances that act like sunscreens, according to Deneb Karentz, a researcher at the University of California studying the effects of UVB on Antarctic species. Eighty-six percent of fifty-seven marine species Karentz studied in Antarctica—including algae, sponges, sea anenomes, leeches, sea spiders, and krill—all produce such substances. Land animals cloaked in fur or feathers are also shielded. However, these adaptations may prove less effective as exposure to UV is intensified.

Among the members of a species, ability to handle UV varies widely; there is a 100-fold range among Antarctic plankton in susceptibility to UV, Karentz has found. As UV levels grow, populations will shift toward those best able to survive, she predicts. Whether or not these resistant species can satisfy appetites up the food chain is one of the big questions. Herbivores that are very selective about what they eat may find less appealing or less nutritious food. Such changes will trickle up to the upper levels of the food chain, says Karentz, but so far scientists do not have enough data to predict what those changes might be.

Human skin cancer has been the most studied impact of UV exposure. Skin cancer has three manifestations: basal and squamous cell carcinomas are for the most part disfiguring rather than fatal, and are linked to the amount of UV absorbed over a lifetime; melanoma is rarer and often fatal, and is believed to result from a bad sunburn early in life, according to Margaret Kripke, chairman of the department of immunology at M.D. Anderson Hospital and Tumor Institute in Texas.

In recent decades, skin cancer has become dramatically more prevalent in the United States and Europe because of the popularity of outdoor recreation and tanned skin. Under EPA's newly revised ozone data, both melanoma and non-melanoma skin cancers will rise even more dramatically.

Children are especially susceptible. By age eighteen, most people incur half of the damaging effects of sunlight that they will incur over the course of their lifetime. "Children born in the last ten years are most vulnerable," says Janice Longstreth, a risk assessment expert at Battelle Laboratories who is updating a report on the health effects of ozone depletion for the United Nations Environment Program (UNEP).

Ultraviolet radiation may induce

clause saying that the treaty could be strengthened if warranted. A total global phaseout, unthinkable only a few short years before, was agreed to in June 1990.

Before 1986, "few people could have conceived of a CFC-free world," Doniger told a group of industrialists gathered for the November 1990 International Conference on CFC and Halon Alternatives. "It was conventional wisdom that even a freeze on production would leave whole industrial sectors high and dry and impose ruinous costs on the American economy. . .Now virtually every firm that uses these chemicals knows how it will eliminate them. Many of you already have."

"Children born in the next ten years are most vulnerable to the increased ultraviolet radiation."

As fast as industry developed new CFC markets in the 1980s, it is disinvesting in them in the 1990s. That is no small task, considering the indispensability with which these chemicals had been regarded and industry's resistance to change. EPA estimates that the CFC phase-out will cost the American economy $3 billion over the next decade.

AT&T's Allenby, who now heads an indus-

skin cancer by lessening the skin's ability to fight off invasive organisms—including the body's own cells made malignant by exposure to UVB, says Kripke. UV exposure has also been linked to herpes simplex, leprosy, tuberculosis, lupus, and other genetic and metabolic diseases; exposure to UVB may also make the skin more permeable to parasites carried by insects or that live in water, such as Lyme disease and malaria, Kripke says. UV may even shift the AIDS virus infecting skin cells from an inactive to active state, according to a 1988 report in the journal *Nature*. UV can also cause conjunctivitis, and later in life, cataracts and blindness.

Because the ozone shield will thin unevenly around the globe, some regions will be bathed in more radiation than others. Australia, the most populated land mass near Antarctica, had skin cancer levels that topped those worldwide before ozone depletion began. In the skies above the continent, ozone loss is 17 to 22 percent greater during the summer than at corresponding latitudes in the northern hemisphere. San Francisco and Melbourne, Australia are at about the same latitude north and south, yet the rates of melanoma are 33.8 percent higher for men, and 82.8 percent higher for women in Melbourne.

Because the nation's exposure is so severe, Australia has taken an aggressive stance in public education and public policy. Campaigns now encourage Australians to protect themselves from the sun's rays with sunscreens, hats, and clothing. Aussies have begun planting trees in schoolyards and have regimented outdoor programs for children around the time of day when they will get the least exposure, and the government has even mandated hats as part of the school uniform.

Countries that are not close to the poles may be jeopardized in other ways; increased radiation could endanger global food supplies. Fisheries may be damaged by even small increases in UVB, and fish provides more than half of the diet for many peoples.

Two-thirds of about 300 crops and other plants tested for their tolerance to UVB are also sensitive to it, according to a 1989 report by the UNEP. Among the most vulnerable were peas and beans, melons, mustard, and cabbage; also hurt were tomatoes, potatoes, sugar beets, and soy beans.

Forests appear to be vulnerable too, according to studies carried out by Alan Teramura, a researcher at the University of Maryland. About half of the conifers Teramura has studied were adversely affected by UVB. "Small changes [in UV] can accumulate and ultimately have catastrophic effects," Teramura told *New Scientist* magazine last fall.

UVB damages not only living things but polymers used in buildings, paints, packaging, and countless other substances, which it degrades and turns brittle. Increased radiation could cause damage running into the billions of dollars each year, according to UNEP.

Scientists are working toward a better understanding of the impacts of UV, yet they have scant data about the amount of radiation now hitting the earth. One reason, ironically, is that ground-level ozone pollution due to smog is obscuring information about ground-level UV. Ultraviolet is measured at meterologic stations at airports, which are mostly found in smog-blanketed cities, says Longstreth.

Studies of UVB could light the way as we try to adapt to its growing intensity, yet basic science research is losing funding. "EPA has decided that because we have a [CFC] protocol, we don't need to look at the health effects anymore—we've got a regulatory fix," said Longstreth. EPA's own program, too, is in jeopardy, said Bob Worrest, its director, as its already small budget hangs in the balance for 1992.

Former Secretary of the Interior Donald Hodel was ridiculed in 1987 for his suggestions that U.S. policy be based on "personal protection"—that we rely on hats, sunscreens, and sunglasses rather than a meaningful global accord to protect the ozone layer. Yet in Australia, hats have become public policy, as the reality of life under the ozone hole has hit home. How far away is that scenario for the rest of the world?

—*Beth Hanson*

try consortium called the Industry Cooperative for Ozone Layer Protection, says he initially faced an uphill battle. "We would go around and tell companies, 'You guys are going to have to get out of CFCs,' and they'd say to us, 'We don't have to worry. . ..All we use is Freon.' Well, we realized very quickly that we had an information gap here!"

During the last few years, the industry has stepped up its drive to avoid unnecessary releases of CFCs, cut easily replaced uses, and speed research into harder-to-find substitutes. "Business is doing a great job on this stuff," says John Hoffman, an official in EPA's climate change division. "Companies are cutting use of CFCs far in advance of compliance deadlines." Some signs of progress:

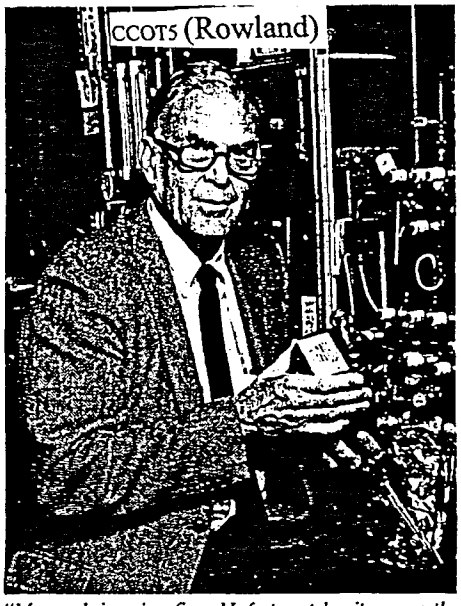
* By 1989, the food packaging industry had largely stopped using the worst ozone-depleters, CFC-11 and CFC-12, for blowing foam used in fast-food containers and moved to lesser depleters like HCFC-22 (which it must also abandon by 1994).

* Companies have reduced their use of halon in fire extinguishers by as much as 30 percent during the last few years.

* The electronics industry, which a few years ago complained it could not get away from CFC-based solvents for cleaning sensitive components, is rapidly switching to alternatives, and, in many cases, even using soapy water instead. Some have modified their circuit boards to avoid having to clean them to begin with—saving time and money to boot.

What has been harder than expected is finding good CFC substitutes in refrigeration and air-conditioning that can be used on existing equipment. In general, while the larger companies like Northern Telecom and AT&T have been moving quickly to phase out their use of CFCs, a vast number of smaller companies are less able to keep up, says Doniger.

By 2000, DuPont and other producers hope to supply nearly 40 percent of their markets with hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs), according to a chemical industry trade journal *R&D*. But HFCs, which do not deplete the ozone layer (they are made with hydrogen instead of chlorine) still contribute to global warming. And HCFCs (made with hydrogen so they will degrade in the troposphere and slow their rendezvous with the stratosphere) still deplete ozone, although at a rate only 2 to 10 percent of the most powerful CFCs. While industry wants to get a go-ahead from government to commercialize these new technologies, EPA is reluctant to approve them except for a transitional period, and then, with strict limits on production and consumption.



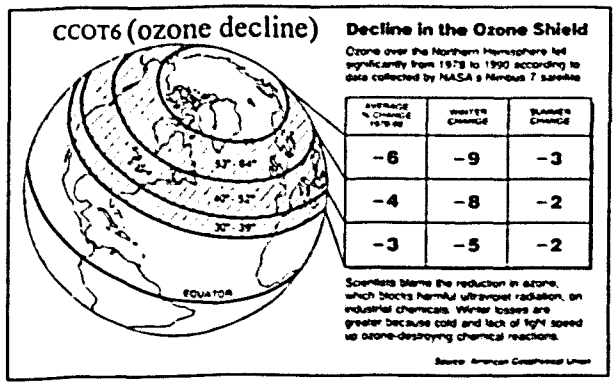
"My work is going fine. Unfortunately, it means the world is ending," said chemistry professor Sherwood Rowland. Fifteen years ago, he calculated that CFC molecules could wreak havoc on ozone.

Some of the non-CFC replacements have their downsides as well, such as toxicity or flammability. Ironically, says EPA's Stephen Anderson, a number of industries are going back to the future with compounds that date back to the 1920s or 1930s. It is quite possible, for example, that we might see refrigerators running on ammonia, the flammable substance that CFC-12 replaced. "People still think of ammonia as unsafe," says Anderson. "But if we'd known what we know now, we'd regard the chlorofluorocarbon as the most dangerous chemical ever invented!"

Industry has shown that it can move quickly when it wants to; the nations of the world have also shown that they can come together to bring the world back from the brink of global environmental catastrophe. But despite these signs of progress, it

is important to recognize how much damage we continue to inflict on the stratosphere. Yes, CFC producers are holding these compounds at or below 1986 levels. But more than 20 billion pounds of CFCs, about half as much as the total that has been manufactured since the 1930s, could be made before the phase-out is accomplished.

The challenge of ridding industry of CFCs illustrates poignantly that we cannot turn off the faucet so easily. Because of the slow pace at which manufacturers replace machinery, there is a tremendous lag time between regulation and results.



Then there is the pace of atmospheric chemistry. CFCs have lifetimes of up to thirty years per molecule. Because the chlorine (in CFCs) and bromine (in halons) that unravel the ozone layer participate in chemical chain reactions in which they can escape undamaged, they can continue breaking down hundreds of thousands of molecules of ozone before they themselves disintegrate. And each molecule of these compounds takes six to eight years to get to the stratosphere. Not counting the CFCs now escaping from car air conditioners and other products, there is an enormous bank of CFCs that have yet to leak out to the air—gas bubbles in old refrigerators, air conditioners, and even Styrofoam containers lying in landfills.

It would be nice to be able to "zap" these chemicals before they make their way up to the stratosphere, but there is no technology, as yet, for safely getting rid of CFCs on earth. For now, the focus is on recycling CFCs.

The world is not going to feel the full impact of ozone depletion until literally decades from now. Peak levels of ultraviolet radiation hitting earth will not occur until 2010 or 2020; scientists know very little at this point how severe those impacts will be. Atmospheric chemists say the ozone hole will not be closed until about a century from now, 2075. Not surprisingly, pioneers like Sherwood Rowland get little satisfaction from being vindicated in sounding the alarm on the perils of CFCs. When asked by his wife how his work on CFCs was going, Rowland answered, "My research is going fine. Unfortunately, it means the world is ending!"

Perhaps the most sobering aspect of the ozone issue is scientists' realizations that, with the discovery of ozone holes and the anomalous chemistry causing them, our models of how ozone depletion occurs in the atmosphere have been faulty at best. Beginning this fall, a team of scientists led by James Anderson, a Harvard University atmospheric chemist, will be launching a new expedition to determine more precisely why ozone is being lost over the mid-latitudes and to what extent this loss is connected to ozone thinning over the Arctic. "For eight months we will be looking at the continental United States and Canada," says Darin Toohey, an atmospheric chemist on the mission. "We don't have good models for projecting the rate of future ozone depletion. We need more data." Besides looking at ice crystals, they will be looking at the role of fine sulfate particles from natural and manmade sources found over our latitudes. Instead of Antarctica, the venue this time is Bangor, Maine, and Fairbanks, Alaska.

If policymakers had known fifteen years ago what we know now, they would have realized how foolish it was not to phase out all CFCs and to begin a speedy search for substitutes. Many, like Richard Benedick, U.S. state department negotiator on the Montreal Protocol, would argue that a strong hypothesis is a good enough argument for action: absolute proof is not needed when we are conducting an experiment on our own planet.

(continued on page 30)

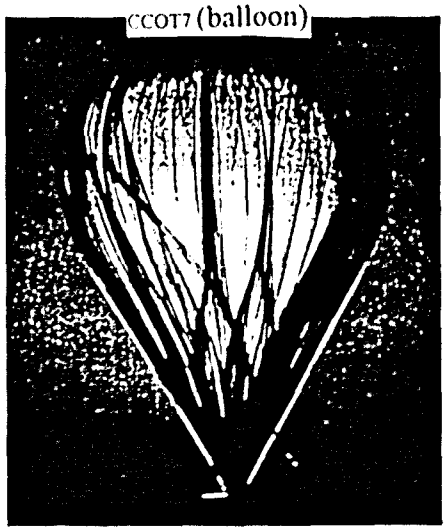
The lessons learned from the ozone story should not be lost; they should be applied to the global warming debate, as Michael Oppenheimer of the Environmental Defense Fund wrote recently in a *New York Times* op-ed piece. The perils of global warming, like those of ozone depletion, allow for little margin of error, since their impacts are far-reaching, multifaceted, and will last for many years to come. There is a virtual scientific consensus that global warming will occur; the questions that remain ask how much warming there will be and where. Just as DuPont and the CFC industry poured millions of dollars into debunking studies that sounded the alarm on ozone depleting chemicals, major manufacturers and energy users have mounted a similar campaign to debunk greenhouse effect theories and projections of global warming.

The ozone story has some happy twists, however. Karim Ahmed, a chemist who worked on the issue for NRDC in the 1970s, says, "We were lucky to have banned CFC-propelled aerosol spray cans back in the seventies." This act of prudence, he points out, took care of about 60 percent of the problem at the time. "With this we were able to buy a tremendous chunk of time," he adds. "So even though we lost time in the 1980s, can you imagine how much more draconian our measures would have had to be now?"

Energy conservation to reduce fossil fuels' carbon dioxide emissions could be the aerosol spray cans of the 1990s. Mandating energy efficiency, in everything from cars and appliances to huge industrial applications and building construction, has long been advocated by environmentalists as a way to contain pollution and gain time in the fight against global warming.

But that time is running out. By the time global warming can be measured, it will be too late to do much about it. We are already seeing 4 to 5 percent ozone depletion all over the globe, which models did not predict would happen until around 2025, when only a fraction of CFC production has been scaled back. [Given errors in computer models, most scientists predict that percentage will rise.]

[The Bush administration has failed to act on global warming, arguing that more scientific study is needed, and has even suggested that by regulating CFCs (because of their role as greenhouse gases) we have already done enough without having to consider regulating carbon dioxide. Most other countries of the world disagree. Environmentalists argue that both problems have to be tackled simultaneously.]



Sunrise on Easter Sunday, 1991, as a new balloon instrument takes its first readings in the stratosphere over New Mexico.

The more scientists probe, the more they find ozone depletion and global warming interconnected. Paradoxically, for example, global warming encourages ozone depletion, as greater concentrations of greenhouse gases tend to raise the earth's surface temperatures while decreasing the temperature of the stratosphere. At the same time, greater ozone depletion creates greater ultraviolet radiation, which spurs the formation of ground-level ozone, another greenhouse gas.]

Some fear it will take a freak event in climate—a thermal version of the ozone hole—before policymakers act to prevent global warming. "The proof hasn't come to climate change scientists," says Harvard's Darin Toohey. "I wish we could do the same thing in terms of detective work on global warming, because by the time they determine the mechanism of warming, it may be too late."

It is a tragedy to simply watch the ozone layer slip away—and the earth heat up—while waiting for scientists who work so hard to unravel the atmosphere's mysteries. □

Francesca Lyman *is the editor of this journal.*

TTL-

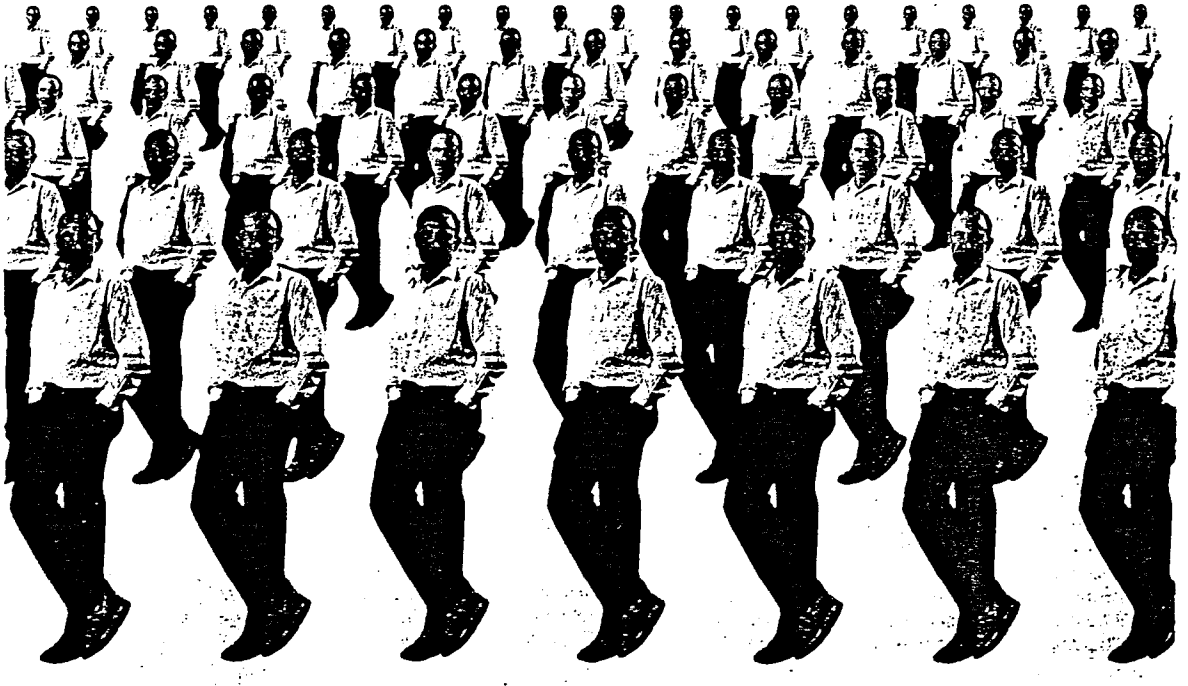
THE NUMBERS GAME

GLM-

By the year 2000 the world will have more than 6 billion people. Are we doing ourselves in? Or are we upping the odds of producing lots of Einsteins?

BY DAVID BERREBY

Paul Ehrlich says that we have overloaded the planet's biological circuits and are breeding ourselves to oblivion.



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KEY:				
TTL - TITLE	GLM - GLIMPSE	PRB - PROBLEM	SET - SETTING	PRO - PROPHECY
THR - THREAT	TLI - TECHNICAL LEAD-IN	SPC - SPECIFIC CLAIM	GCL - GENERAL CLAIM	BRG - BRIDGING
EVN - EVALUATION	ONP - ONGOING PROJECT	PRE - PREDICTION	CNS - CONCERNS	SLN - SOLUTION
SGN - SUGGESTION	SUM - SUMMARY	CON - CONCLUSION	ANX - ANXIETY	SPN - SPECULATION
COL - CALL FOR COLLABORATION		REC - RECOMMENDATION		

In 1968, when Stanford biologist Paul Ehrlich published *The Population Bomb*, there were 3.5 billion human beings. That was more, he warned, than the planet could support. "In the 1970s," he wrote, "the world will undergo famines—hundreds of millions of people are going to starve to death." We now know that didn't happen in the seventies. What did happen was that food production soared worldwide, prices dropped, and growers who could not sell enough of their surplus went bankrupt.

This month Ehrlich and his wife, Anne, are coming out with *The Population Explosion*, a sequel to the 1968 best-seller. The message is much the same; the timetable, however, is revised. "The human population is now 5.3 billion, and still climbing," they write. "Yet the world has hundreds of billions *fewer* tons of topsoil and hundreds of trillions *fewer* gallons of groundwater with which to grow food crops than it had in 1968." Now, they warn, our excess numbers have overloaded both the environment and human communities. Global warming, acid rain, the hole in the ozone layer, rampant crime, viral epidemics, homelessness—all these problems and more stem from overpopulation. If we don't heed the warning this time, they write, we can look forward to "a billion or more deaths from starvation and disease," and possibly "the dissolution of society as we know it."

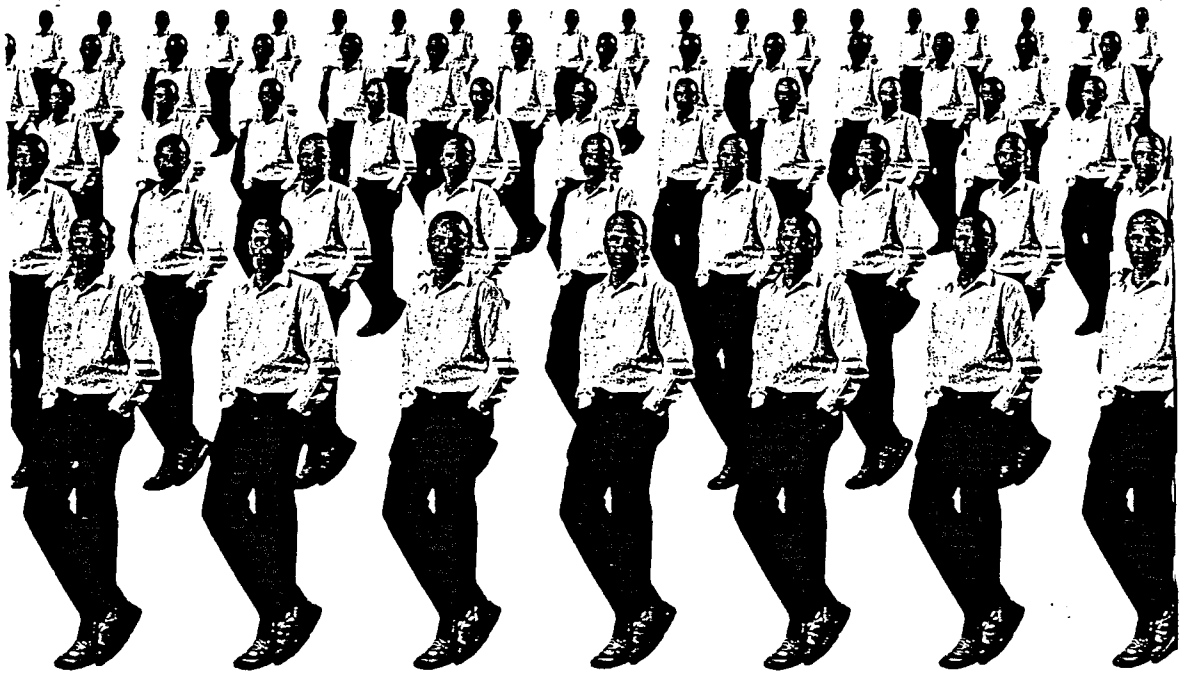
The Population Explosion, like the original *Bomb*, is full of statistics to back these claims. Like many sequels, though, this new effort may not get as friendly a reception as the original. These days fear of overpopulation is not what it used to be. Over the past 20 years many social scientists, in particular, have turned skeptical. "A good number of true believers," says Dennis Ahlburg of the University of Minnesota's Center for Population Analysis and Policy, "have become agnostics." They are now framing new hypotheses to explain the world's problems. "We're in a bit of a predicament," says Ahlburg, "because we can't keep saying that population is a horrible thing. The evidence isn't there."

In parts of Asia, Africa, and Latin America, exploding populations are often blamed for poverty, famine, crowding in cities, deforestation, pollution, and practically everything else that goes wrong. But in case after case, says Ahlburg, it's not population that causes the problem: in general the resources exist to support more people—the problem is that societies encourage waste. There are countless ways to do this, from misguided government policies to spectacular blunders like wars. Population growth, Ahlburg argues, is an easy scapegoat for political failures.

Such revisionism is clear in the changing stand of the National Academy of Sciences. In a report issued in 1971 the academy declared rapid population growth a clear danger to the survival of the human race. But in 1986 a new report found that the effects of population growth had been exaggerated in earlier studies. The academy noted that "despite rapid population growth, developing countries have achieved unprecedented levels of income per capita, literacy, and life expectancy." The report concluded that slower population growth is probably desirable in developing countries because it would give them more time to adjust—not because they are breeding themselves into oblivion.

As fear of the teeming billions has subsided, developed nations have reduced spending on contraceptive research. And the United States, in particular, has cut back its funding of international programs aimed at reining in reproduction in the Third World, where up to 90 percent of future population growth is expected.

Meanwhile, in much of the industrial world, birthrates have fallen so low that native populations are leveling off or



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actually declining. This drop in fertility surprised many planners, and it dramatically changed their projections. In the late sixties the United Nations estimated that the world's population in the year 2000 would be 7.5 billion; the projection now is 6.1 billion.

When a nation's birthrate drops, its population ages: the ratio of old people to young people grows larger. Some governments now worry about supporting growing numbers of retired people, and others fear that languages and cultures may die out. In the French-speaking province of Quebec, where the birthrate is lower than in the rest of Canada, the provincial government started offering cash bonuses this past year for babies. In Singapore, where the number of children born to the average woman dropped from 4.7 in 1965 to 1.4 in 1987, the government started a match-making service to coach career-driven nerds (as they are universally known) in the subtle arts of courtship.

Today's apparent lack of alarm over population growth compelled the Ehrlichs to title the first chapter of their new book "Why Isn't Everyone as Scared as We Are?" An important part of the answer to their question is the work of Julian Simon, a professor of business administration at the University of Maryland. For two decades Simon has pushed the idea that "population growth, along with the lengthening of human life, is a moral and material triumph." Although widely reviled in the seventies, Simon, like the Ehrlichs, persevered. His work has dealt the conventional wisdom two severe blows: first, by challenging the widely held assumption that our numbers are driving the planet to the end of its rope; and second, by outlining a theory that gradual population growth not only doesn't harm us and the environment but actually accelerates our progress.

"I find it difficult to understand how they can see some things as only problems when I see them as miracles," says Simon. "The fact we can keep five billion people alive now is an incredible accomplishment. We've escaped nature's domination, and all they see is problems. 'Escaped' doesn't mean we've beaten it into submission. It means we've killed the mosquitoes and the smallpox germs."

The Ehrlichs are worse than wrong, says Simon; their efforts to persuade people to have fewer children are morally repugnant. "I'm unhappy about it when I get a letter from a guy saying, 'My wife and I believed, on the basis of what Ehrlich said, that to bring a baby into the world is a negative act against society. So I had myself sterilized and now I can't reverse it.' That makes me sad." He becomes even sadder when a government as powerful as China's campaigns to limit every couple to only one child. "The cost," he says, "is the second child for a hundred million Chinese couples. A hundred million human beings who would never enjoy life as you and I and Ehrlich enjoy it."

Much current thinking on population

"It's beyond my comprehension that we should run an experiment to see how many people we can cram on the planet before all its systems collapse."

lies between Simon on one coast and Ehrlich on the other. They heartily despise each other, and each would have you believe that the other is scarcely able to understand, much less contribute to, the population debate. "If you were doing a story on the solar system, would you talk to someone who thinks the Earth is flat?" Ehrlich asks. Meanwhile the index to Simon's most influential work, *The Ultimate Resource*, includes the entry, "Ehrlich, Paul, respect for human life lacking in." Still, they share more than mutual contempt. Each is a gifted polemicist. Each sees himself as an island of sanity in a world that has gone over to the other side. And most important, each considers the other's discipline to be arrogantly wrong in its fundamental assumptions about human populations.

The National Academy of Science's "revisionist" report was prepared entirely by social scientists, says Ehrlich, and thus was "never reviewed by anybody who knew anything about the subject." Ehrlich belongs to the Club of Earth, which in its own report in 1988 reached a conclusion opposite that of the academy. Every one of those dissenting researchers, Ehrlich points out, also belongs to the academy, but they are all biologists rather than social scientists. As for Simon, he is now working on a paper titled "Why Are Biologists Usually the Most Vocal Doomsayers?"

In the 1960s Ehrlich was a young biology professor at Stanford. He had first noticed the effects of human population growth years before, when as an undergraduate at the University of Pennsylvania he gathered butterflies in New Jersey. "We found out we couldn't raise our butterflies because there was so much pesticide in everything that it killed the caterpillars, and my favorite places to collect were disappearing under Levittowns." In graduate school at the University of Kansas, he met and married Anne, who is now a biological researcher at Stanford. They have only one child—"a contribution you can make toward being socially responsible," he says.

When *The Population Bomb* came out in 1968, headlines were filled with news of Vietnam, protests, and riots. In that apocalyptic year, people were receptive to a book that began, "The battle to feed all of humanity is over." Johnny Carson was certainly receptive; he invited Ehrlich to appear on *The Tonight Show*. Despite a few qualms ("I'd be canceling my ticket with my colleagues"), Ehrlich decided to accept the invitation ("I don't care about glory in science. It's more important that I do this"). He has maintained two careers ever since—as academic scholar and population polemicist.

Ehrlich believes that human populations are subject to the same natural constraints as those of, say, checkerspot butterflies. The absolute limit on any species's success, he says, is the "carrying capacity" of its environment—the maximum number of individuals a habitat can support. "Humanity," Ehrlich argues, "will pay the price for exceeding the carrying capacity of its environment as surely as would a population of checkerspots."

According to Ehrlich, the key limit on the carrying capacity of the planet is photosynthesis—the ability of green

PGN2 (1989 population)

plants, algae, and many kinds of bacteria to convert the energy of sunlight into living tissue. Some animals consume those plants and microbes, and bigger animals eat smaller ones. But no matter how high or low on the food chain any species may dine, its numbers are ultimately limited by photosynthesis.

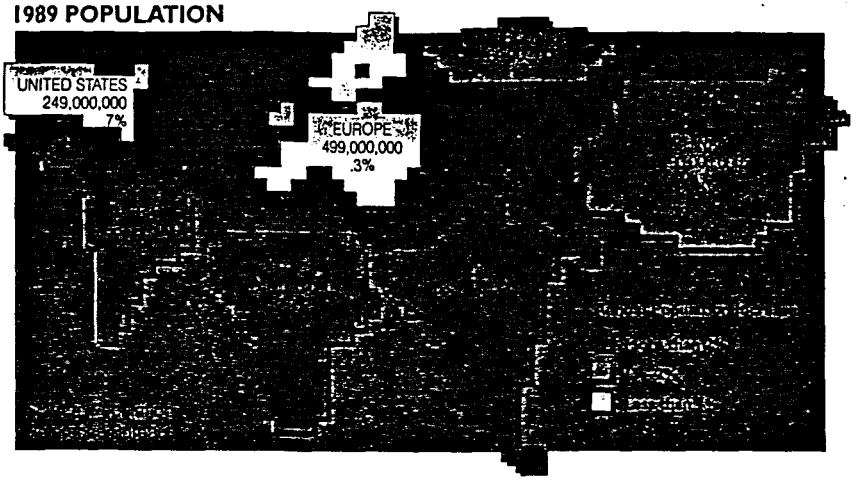
In their new book the Ehrlichs estimate that human beings and their domestic animals now consume 4 percent of the solar energy that photosynthesis captures on land. Adding the amount of this energy we don't directly consume but destroy (such as plants killed when forests are burned) and the amount we prevent from growing (as when we pave productive land) raises the human share to nearly 40 percent. But even 4 percent, in the Ehrlichs' opinion, is a disproportionate share for only one of Earth's 30 million species.

How do the Ehrlichs know we are crowding other species? A population exceeds carrying capacity, they write, when it "can't be maintained without rapidly depleting nonrenewable resources." And by this standard, they declare, "the entire planet and virtually every nation is already vastly overpopulated." Humans are different from butterflies, however, in one important ecological respect: they have more control in choosing what to eat and how to live. This is why the planet's carrying capacity for humans is not a fixed number. The world can support more vegetarian Indians on bicycles than hamburger-eating Americans in cars. Yet the limit on our species, says Ehrlich, is nonetheless real. "And it's beyond my comprehension," he says, "that we should run an experiment to see how many people we can cram on the planet before all its systems collapse."

That concept is essentially the one British economist Thomas Malthus advanced in 1798. In his famous "dismal essay" on the principle of population, Malthus wrote that humans will increase their numbers beyond their means of subsistence until famine, war, and disease wipe out the excess. History may not have worked out the way Malthus expected, but that's only because of what Ehrlich calls a onetime bonanza based on the use of coal and oil to power our industrial civilization. "Malthus," he says, "wasn't wrong."

The problem for this argument—and the foundation of Simon's—is that things haven't yet given way. "Every one of these prophets' dire predictions has failed to come to pass," Simon says.

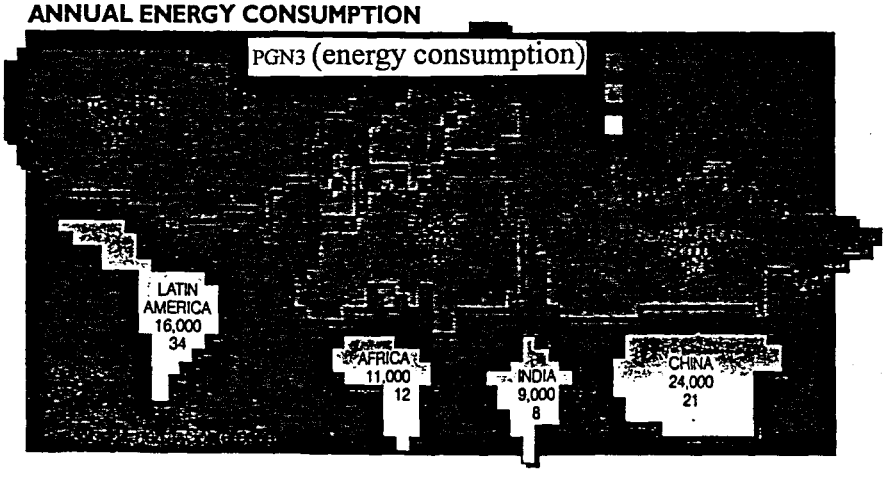
1989 POPULATION



The Third World dominates a map drawn so that land area is proportional to population. The top figures represent total population; the bottom figures, annual growth rate.

ANNUAL ENERGY CONSUMPTION

PGN3 (energy consumption)



The United States and Europe loom large on a global energy map, drawn so that land area is proportional to energy use. The top figures represent total energy consumption (in petajoules, or 10^{15} joules); the bottom figures, annual consumption per capita (in gigajoules, or 10^{9} joules). These figures are based on 1986 data for commercial energy and 1987 data for firewood and charcoal.

"They've been wrong on food, on energy, on resources, on the environment, on everything."

Simon believes that the most relevant measure of human well-being is life span. Our average life expectancy has increased dramatically, he argues, and this tells you right away that everything we need to sustain us is also increasing. He notes that food production per capita has increased since World War II and says the same holds true for every other resource people worry about.

Global 2000, a projection of global environmental trends to the end of the century, is one of the "doom and gloom" reports that Simon relishes attacking. "The report came out in 1980 saying there was a plateau in world fisheries," he says. "Since then the amount of increase in the world fish catch has been astounding." To refute the report's analysis, Simon refers to statistics compiled by marine biologist John Wise from United Nations reports. In 1979, Wise finds, the world fish catch totaled 78 million tons; in 1987 it was 102 million tons. "Sure, you can say it's because of new methods of extraction," says Simon, "but that doesn't alter the fact that they said it was going to be the other way around."

What such statistics mean, Simon argues, is not that we've been lucky so far. "They mean we're on a permanent roll," he says, "with no limit yet in sight. If the biologists don't see this, it's because they've left something out of their theories."

In 1968, when Ehrlich was taking to the airwaves to promote *The Population Bomb,* Simon was teaching economics at the University of Illinois. Simon's main claim to fame was having written the basic how-to book on running a mail-order business. By 1968 he had already read about the population explosion, become duly concerned, and turned his attention to possible solutions.

One beautiful spring day in 1969, while on the way to an appointment in Washington, Simon had an epiphany. He described it twelve years later in his book *The Ultimate Resource*: "I thought, Have I gone crazy? What business do I have trying to help arrange it that fewer human beings will be born, each of whom might be a Mozart or a Michelangelo or an Einstein—or simply a joy to his or her family and community, and a person who will enjoy life?" His nagging doubts about the way economic data did not square with the prevailing view of the world's "population crisis" kindled into a crusade to correct the idea.

During the 1970s Simon was denounced as a religious maniac, an emotional wreck, a mere mail-order specialist, and a shabby scholar. At the very first Earth Day in 1970, a fellow faculty member at the university ridiculed him before 2,000 students at a teach-in. (Simon retaliated at a faculty party with three well-aimed gin and tonics.)

"There is no meaningful physical limit—even the commonly mentioned weight of the earth—to our capacity to keep growing forever."

But in 1981, the year that Simon published *The Ultimate Resource,* political currents were changing. Ronald Reagan had been elected president in a landslide; vigorous economic development, skepticism of environmentalism, and "family values" were back in style. In the opinion-influencing game of newspaper editorials, seminars, symposia, and government reports, Simon's star began to rise. At the same time, more and more social scientists were becoming convinced by their own data that there was something to his critique of the standard assumptions.

Simon now lives just outside Washington, where he is a figure of some influence. He and his wife, sociologist Rita Simon, have decorated their comfortable, middle-class house with sculptures and framed posters—many of which depict a mother and child. They have three children.

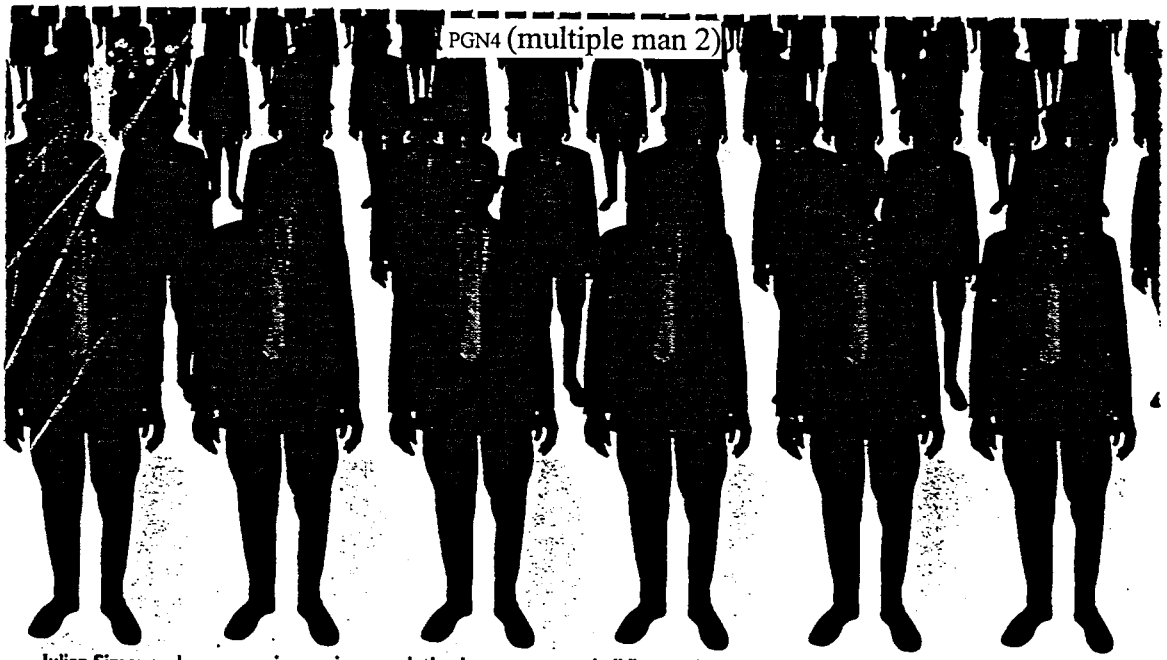
The concept of carrying capacity, Simon argues, shouldn't be applied to human beings at all. Malthus and all who follow in his footsteps pay too little attention to an important fact: humans are producers as well as consumers. As a resource becomes more difficult to obtain, people find ways to get more of it or to use it more efficiently. Or they develop substitutes. Firewood yields to coal, which yields to oil, which yields to nuclear, solar, or some other source of power. Simon argues that our resources expand rather than shrink, because we don't really want coal or oil—we want energy. The same holds true even for apparently fixed resources like soil. Farmland isn't just dirt; it's wilderness that was cleared, desert that was irrigated, swamps that were drained. We don't really want dirt—we want nutrition. And humans are the one species that can invent more ways of applying energy (not only the sun's) to materials (not only today's crops and farmland) to get nutrition—as well as all the other things we enjoy in life.

So people are constantly escaping the Malthusian trap. In fact, Simon argues, population growth applies a needed spur. In the short run, new people are a burden: more babies mean more mouths to feed, so the parents work harder and have less of everything for themselves. But in the long run, Simon contends that those babies are the solution to the apparent problem: as adults they add more to our stock of resources than they consume. "It is your mind that matters economically, as much or more so than your mouth or hands," he says.

"Taken in the large," Simon writes, "an increased need for resources usually leaves us with a permanently greater capacity to get them, because we gain knowledge in the process. And there is no meaningful physical limit—even the commonly mentioned weight of the earth—to our capacity to keep growing forever."

This is the economist's vision at its purest. To Simon it is the lesson of the past few centuries. To most any biologist it's beyond strange. "The physical and biological systems are prior," says Ehrlich. "You can change economics, but the laws of nature are out there." Moreover, he argues that Simon's faith in technology is misguided. "It's usually economists or social scientists who expect science to be able to do all these wonderful things. Scientists don't."

That's the sort of argument to the



Julian Simon welcomes our increasing population because we are building up the ultimate resource: human minds.

PHOTOGRAPH BY TERESA ZABALA

future that gets Simon's goat. He doubts anyone's ability to predict the limits of technology, whether it's genetic engineering or just ordinary farming done more efficiently. In 1968 Ehrlich wrote, "I have yet to meet anyone familiar with the situation who thinks India will be self-sufficient in food by 1971, if ever." Now, despite a population jump from 500 million in 1966 to 835 million today, Simon points out that India has managed to feed itself.

And *that's* the sort of argument from the past that irritates Ehrlich. India's impressive achievement, he says, was bought at the expense of its future. "They managed to up their grain production by throwing away their soil and their groundwater, and that makes the long-term situation worse." The same is true, he argues, for most of the other encouraging statistics. When there are too many people, technology doesn't really solve our problems—it only postpones them. "Electricity was going to be too cheap to meter because of nuclear power, remember. Many technological rabbits that have been pulled out of hats in the past have had nasty droppings."

In short, Ehrlich has not conceded the past. And neither he nor Simon is conceding the present. In their book, the Ehrlichs use every bit of bad news—children starving in Africa, malaria on the rise again in Asia—as ammunition for their claim that our bubble is finally bursting. "We've got 5.3 billion people on the planet now," says Ehrlich. "At least a billion of them are living at a standard that you wouldn't trade for in a million years. The estimates are that at least two hundred million people have died of hunger-related diseases over the past twenty years." Can the Einsteins or Mozarts that Simon is counting on develop their talents, he asks, in utter destitution and misery?

Simon dismisses that distressing information as old news. Some people have always struggled even while the average situation was improving. "Their paradigm," he says of the other side, "is that the present and the future will be unlike the past, that we're at a turning point in history. But you find that sentiment in every generation. There is absolutely no way to tell if we are at a turning point in history."

Accordingly, Simon has made a one-man cottage industry of assaulting alarming reports. He is a relentless sifter of statistics. "When people say, for instance, 'The world is being deforested,'" he says, "I go look for the aggregate data. I found that in fact the world is *not* being deforested; it is being reforested in general. Yes, there are some tropical countries where deforestation is taking place. Is that bad? Is that good? Who knows?"

New Scientist, a British weekly, published Simon's article on deforestation in 1986. He gets a hearing for such contrary views because there are no precise, comprehensive data for many global trends. Current opinion is often based on spot surveys rounded out by estimates, which can be argued up or down. With forests, for instance, not even the record of photographs from satellites shows enough of the globe for enough years to prove whether the loss of a forest in, say, the Philippines has been offset by a gain in Finland.

Researchers debate everything, Ehrlich acknowledges, from the rate of deforestation to the rate of global warming. Nonetheless, he adds, "there isn't a competent scientist who doesn't believe that the world is facing these problems." As long as the data are still coming in, there will always be need for revision. But "you can't wait for absolute proof before acting."

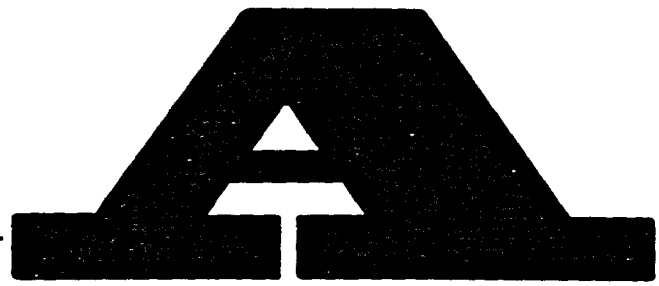
On and on they go, each confident that the other's statistics distort the truth about what our growing population means to our future well-being. Meanwhile, in the most private and secret places, humanity in its billions is deciding for itself how many people to add to the planet, without reference to either Simon or Ehrlich. ❑

This is David Berreby's first DISCOVER *article. He lives in Brooklyn.*

TTL

HOW MANY PEOPLE CAN EARTH HOLD?

PRO



ccording to the United Nations, which follows these things closely, some 5.3 billion people enlivened our planet in 1990. By the time you read this, that number will have increased to 5.5 billion, an addition nearly equal to the population of the United States. Of course no one, including the UN, has a reliable crystal ball that reveals precisely how human numbers will change. Still, people have to plan for the future, and so the UN's analysts and computers have been busy figuring what might happen. ■ *One possibility they consider is that future world fertility rates will remain what they were in 1990. The consequences of this, with accompanying small declines in death rates, are startling. By 2025, when my 16-year-old daughter will have finished having whatever children she will have, the world would*

GLM

Our urge to go forth and multiply could, a century and a half from now, leave Earth with more than 694 billion people—some 125 times our current population.

BY JOEL E. COHEN

ILLUSTRATIONS BY BRIAN CRONIN

DISCOVER 114 NOVEMBER 1992

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have 11 billion people, double its number today. Another doubling would take only a bit more than 25 years, as the faster-growing segments of the population become a larger proportion of the total. At my daughter's centennial, in 2076, the human population would have more than doubled again, passing 46 billion. By 2150 there would be 694,213,000,000 of us, a little over 125 times our present population.

There, in 2150, the projections of the United Nations Population Division stop. Perhaps they stop because the numbers were growing too long to print in their allotted column widths. Perhaps they stop because the computers grew weary of the thought of so many births to celebrate, so many marriages to consummate, so many dead to bury. At any rate, there, in 2150, the computers—and an unchanging urge to go forth and multiply—leave us, with a hypothetical 12,100 people for every square mile of land, or 3,500 people for every square mile of Earth's surface, oceans included. At this rate of growth the population would, before 2250, surpass 30 *trillion*, more than 200 people for every *acre* of the planet's surface, wet or dry.

Surely the United States, though, with its wide-open spaces and its much more leisurely population growth, could never suffer such a crowded fate, right? Wrong. Back in 1970 Ansley Coale, a demographer at Princeton, observed that the population of the United States had increased by half since 1940. At that growth rate, he calculated, the U.S. population would "reach a billion shortly before the year 2100. Within six or seven more centuries we would reach one person per square foot of land area in the United States, and after about 1,500 years our descendants would outweigh the Earth if they continued to increase by 50 percent every 30 years. We can even calculate that, at that rate of increase, our descendants would, in a few thousand years, form a sphere of flesh whose radius would, neglecting relativity, expand at the velocity of light."

Here is what Coale concluded: "Every demographer knows that we cannot continue a positive rate of increase indefinitely. The inexorable arithmetic of compound interest leads us to absurd conditions within a calculable period of time. Logically we must, and in fact we will, have a rate of growth very close to zero in the long run."

I know of no qualified scientist who disagrees: The human population must ultimately approach a long-term average growth rate of zero. That is a law from which no country or region is exempt. According to every plausible calculation that's ever been done, Earth could not feed even the 694 billion people that the UN projected for 2150 if present fertility rates were to continue. Though there is tremendous uncertainty about the details of when, where, and how, the long-term constraint of an average population growth of zero is likely to come into play within the next century and a half.

Theories regarding the limitations on population growth have come and gone over the years. In an essay published in 1798, the English clergyman Thomas Robert Malthus argued that human numbers always increase more rapidly than food supplies and that humans are condemned always to breed to the point of misery and the edge of starvation. The two centuries since his famous essay have not been kind to Malthus's theory. In that time human numbers have increased from fewer than one billion to today's 5.5 billion. In many parts of the world, food production has grown faster than the population, thanks to the opening of new lands, mechanization, fertilizers, pesticides, better water control, improved breeds of plants and animals, and better farmer know-how. Though many of today's bottom billion people live in misery on the edge of starvation, Malthus would be astonished at the relative well-being of most of a vastly enlarged population.

That Malthus's theory failed widely during the past two centuries does not prove that it will remain wrong for the next two. Some observers see a coming vindication of Malthus in the recent faltering of growth rates of per capita food production in some regions. Many scientists have adopted Malthus's general strategy of supposing that limiting factors constrain populations, and in fact the theory has gained some scientific support from agricultural experiments. For example, if the yield of a crop field is limited by the paucity of nitrogen in the soil, then when nitrogen is added, the yield jumps until it is again limited by the shortage of another essential nutrient, such as phosphorus. When phosphorus is added to the nitrogen supplement, yield jumps again until, say, the crop becomes water-limited. In this way, crop yields are limited by the most constraining factor in a whole series of limiting factors. By analogy, human populations may be limited by land (for farming, living, and recreation), food (from marine as well as terrestrial sources), fresh water, energy, or biological diversity (to provide ecosystem services such as decomposition of organic wastes, the regeneration of oxygen, and natural enemies for pest species).

Naturally, different limiting factors may interact. For example, high-intensity fertilization of farmlands may pollute water supplies while increasing food yields. Since World War II computers have made it practical to study how limiting factors interact, and in recent years complex computer models have become useful for clarifying what will happen if certain assumptions about the future turn out to be true. Some models assume, for example, that agricultural production is ultimately limited; others, that it is ultimately limitless. Because assumptions are inevitable and arguable, complex system models, like demographic projections, are controversial as a means of making predictions about the future.

One of the assumptions that may pop up in such models involves the idea of "carrying capacity," which refers to the number of individuals of a species that an environment can support for some period. Carrying capacity is a useful concept in ecology because the behavior and ecological relationships of nonhuman species rarely change very rapidly. The human application of the concept, however, raises many questions. What level of technology is assumed? (Hunter-gatherers usually have a lower carrying capacity than farmers.) What levels of physical and human capital are assumed? What social and political institutions provide human infrastructure? (Is the parental plot of land inherited by a single child, or is it divided among several children?) What regional and international trade is permitted or encouraged? (Hong Kong does not depend on its topsoil to support its more than 14,000 people per square mile.) What is the culture of the people; that is, what do they want from life? (It has been re-

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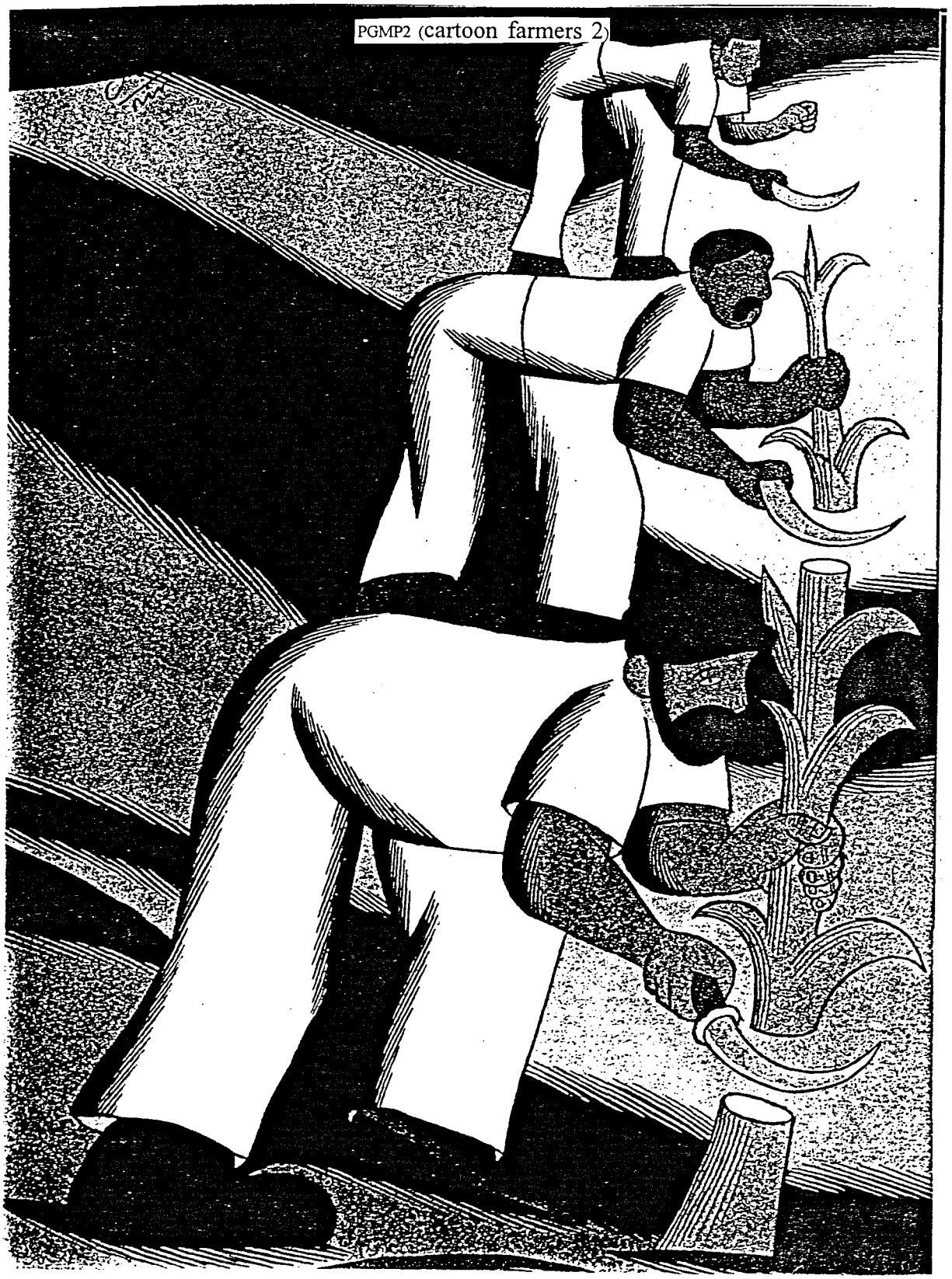

PGMP2 (cartoon farmers 2)

ported that when African slaves were first brought to Haiti, they were adequately nourished because they brought with them the African practice of consuming rodents, which provided a plentiful source of animal protein. Once the slaves learned from the French colonists to disdain the eating of rats and mice in favor of French white bread, the nutritional state of the slaves fell rapidly.)

Moreover, every estimate of the carrying capacity of humans assumes some time horizon. The population that can be supported for 20, 50, or 100 years may differ substantially from the population that is sustainable indefinitely at a given level of well-being.

The use of topsoil dramatizes the difference between temporary and indefinite sustainability. Suppose a newly opened crop field has 60 inches of topsoil over bedrock. Suppose the crop requires 18 inches of topsoil to keep its roots happy, and farming practice wastes an inch of topsoil with each annual crop. For the first 42 years (60 minus 18) the crop yield gives no indication that the wastage of topsoil has any adverse effect. In the forty-third year the roots confront bedrock and as a result yields worsen.

If the farmer could foresee that the crop's roots were approaching bedrock, he might have time to modify his erosive farming or breed a miraculous crop with roots insensitive to rock. If he cannot foresee the problem, he may not have time to take corrective action.

The question of what population can be supported indefinitely is very difficult to ask in a quantitatively useful way. In cartoon form, the argument goes like this:

Ecologist: When a natural resource is being consumed faster than it is being replenished, an asset is being depleted, to the potential harm of future generations.

Technologist: If new knowledge and technology can produce an equivalent or superior alternative, then future generations may be better off.

Taxpayer: Which depleting natural resources are substitutable by technology yet to be invented, and which are not? Will there be enough time to develop an alternative technology and, when it exists, to implement it without avoidable pain and suffering? (No answer from ecologist or technologist.)

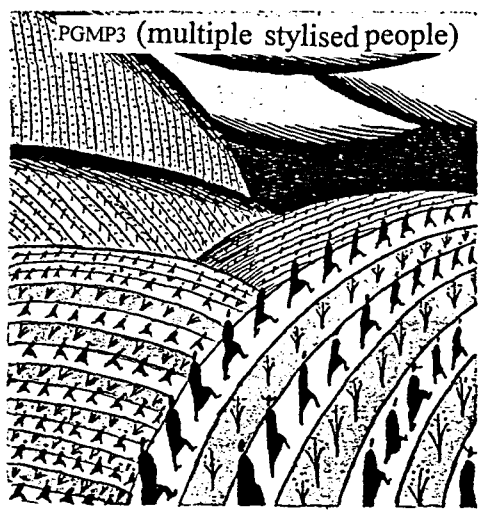
The human population that could be supported by Earth's capacity to produce food has been estimated many times, by many different means, and with many different results. In outline, if food is the limiting factor, the potentially supportable population equals the potentially arable land area times the yield per unit of area divided by the consumption per person. Easy enough. But of course, there is much uncertainty about the numerical values of arable area, yield, and consumption per capita. Estimates of agricultural carrying capacity have ranged from a low of 902 million in 1945 to a high of 147 billion in 1967. In 1965 Walter Schmitt of the University of California estimated that 30 billion people ultimately may lead "fairly free and enriched lives on this planet."

"At the moment," he wrote when the world population was estimated at 3 billion, "shortages in many areas of the world are caused not so much by lack of physical resources for food production but by economic and sociopolitical factors. . . . Socioeconomic restraints control food production before physical factors do because the potential of each major mode—agriculture, silviculture, aquaculture, and microbial culture—in terms of the production of organic matter, is greater than the requirements of 3 billion people, or even of the 30 billion projected for the future. Yet food shortages exist."

The World Hunger Program at Brown University estimates that, with present levels of food production and an equal distribution of food, the world could sustain either 5.5 billion vegetarians, 3.7 billion people who get 15 percent of their calories from animal products (as in much of South America), or 2.8 billion people who derive 25 percent of their calories from animal products (as in the wealthiest countries).

Globally, food supply is limited physically by the plant energy available for consumption by animals and decomposers. Ecologists call this quantity the net primary production (NPP). It is the total amount of solar energy annually converted into living matter, minus the amount of energy the plants themselves use for respiration. NPP is equivalent to about 225 billion metric tons of organic matter a year, an amount that contains enough calories to feed about 1,000 billion people. But that's only if every other consumer of green plants on Earth (including bacteria) were eliminated and at the same time people learned how to enjoy eating wood.

In 1986 Stanford biologists Peter Vitousek, Paul Ehrlich, and Anne Ehrlich and NASA ecologist Pamela Matson estimated that the 5 billion people then on Earth and their domestic animals directly consumed—that is, ate—about 3 percent



A TRIPLING OF THE HUMAN POPULATION WOULD COME AT THE EXCLUSION OF MOST OTHER SPECIES.

Ten Myths of Population

BY JOEL E. COHEN

How do we save the world from the burden of too many people? We can start by clearing up a few misconceptions.

FEARS ABOUT EARTH'S BURGEONING human population have long been at the back of many people's minds. Now, it seems, as the threat of nuclear annihilation recedes from the headlines, those fears can move up to claim center stage. Moving along with the anxiety, of course, is a great deal of confusion, not the least of which is about how to recognize a population problem when you see one. Population problems are entangled with economics, the environment, and culture in such complex ways that few people can resist the temptations of unwarranted simplification. The result is a loose and widely accepted collection of myths, all of which wrap a heavy coating of fiction around a nugget of truth. During the 30 years I have spent studying population dynamics, I have become quite familiar with these myths, in all their guises. Here, in their essential form, are ten of the ones that I have encountered most often.

1. The human population grows exponentially.

In 1798 the Reverend Thomas Robert Malthus wrote that any human population, "when unchecked," doubles in a certain unit of time, and then keeps on doubling in the same unit of time. For example, according to his statistics, in "the English North American colonies, now the powerful People of the United States of America, . . . the population was found to double itself in 25 years."

The fact is that hardly any human populations keep doubling in the same unit of time for very long. Two thousand years ago, there were about 250 million people on the planet. It took about 1,650 years for the population to double to 500 million. But the next doubling took less than 200 years—by 1830 Earth's human population had passed 1 billion. After that the doubling time continued to shrink: just another 100 years to reach 2 billion, then only 45 years more to get to 4 billion. Never before the twentieth century had any human being lived through a doubling of Earth's population.

But things have begun to change. In 1965 the global population growth rate peaked at around 2 percent per year (a rate sufficient to double the global population in 35 years, if it were sustained) and then began to fall. It has now dropped to 1.5 percent per year, which yields a doubling time of 46 years. For the first time in human history, the population growth slowed, despite a continuing drop in death rates, because people were having fewer children. The myth of exponential growth misses this human triumph.

2. Scientists know how many people there will be 25, 50, and 100 years from now.

Most demographers no longer believe they can accurately predict the future growth rate, size, composition, or distribution of populations. It's not that demographers are a particularly humble bunch; it's

ILLUSTRATIONS BY JONATHON ROSEN

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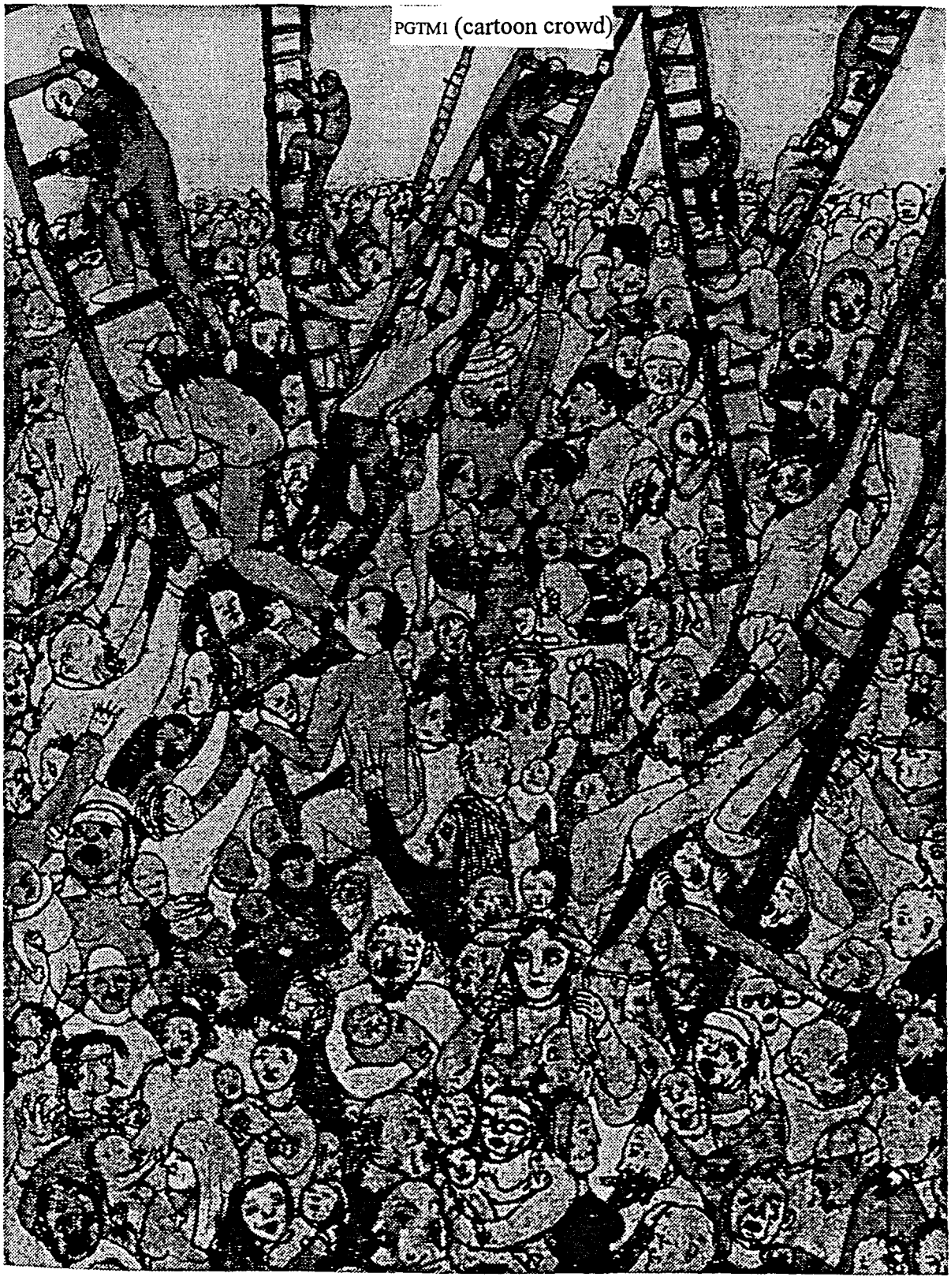


PGTM1 (cartoon crowd)

simply that so many of their past predictions have failed. Researchers could not and cannot predict changes in birthrates or the changes wrought by large migrations of peoples; nor did any of them anticipate that the death rates in poor countries would fall as rapidly as they did after World War II.

Yet demographers can safely predict some things. They know, for example, that everyone who will be at least 18 years old 18 years from now is already born, and that everyone who will be 65 years old or older 20 years from now is at least 45 years old today. This means that if death rates do not change abruptly, demographers can predict with some confidence how many people of working age there will be 18 years from now, and how many potentially retired people 20 years hence.

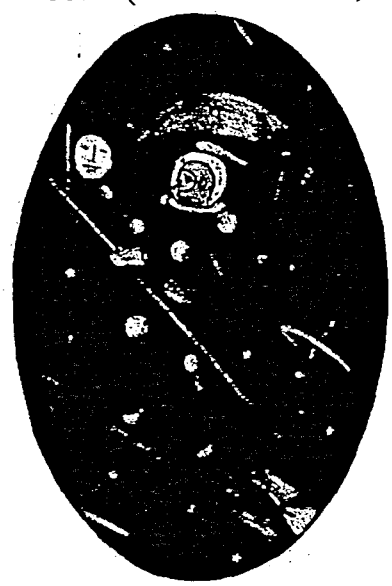
3. There is a single factor that limits how many people Earth can support.

This myth has a long, distinguished history. In 1679, Antoni van Leeuwenhoek, the inventor of the microscope, estimated how many people the planet could support. He assumed that what limited Earth's population was population density alone—that is, the number of people per unit of land area. He further assumed that Earth could not be more densely inhabited than the Holland of his day, which had an estimated 1 million people at a density of around 300 per square mile. He calculated that Holland then occupied one part in 13,400 of Earth's habitable land. Therefore, he concluded, the planet could support at most 13.4 billion people.

Things turned out to be more complex than Leeuwenhoek imagined. In 1989 a third of the world population lived at densities greater than 300 people per square mile. People, it turns out, can and will live at higher population densities when technologies and environments make it possible, economic incentives and trade make it affordable, and cultural values make it acceptable or even desirable.

Just behind the "standing room" hypothesis in popularity—at least, among those who have not thought much about the problem or the facts—is the belief that what limits global population is the availability of food. In fact, except for people who are actually starving, humans today do not have more or fewer children according to whether they have more or less food. On the contrary, the average number of children per woman is lowest in the rich countries where food is most abundant (such as in Japan and in Europe and North America) and is highest where food availability per person is lowest (as in Africa south of the Sahara).

PGTM2 (cartoon astronaut)



Since Leeuwenhoek, some 65 estimates of how many people Earth can support have been published, using a wide range of limiting factors—everything from food to land to freshwater, phosphorus, photosynthesis, fuel, nitrogen, waste removal, and human ingenuity. The estimates have ranged from fewer than 1 billion to more than 1 trillion, and in the past few decades they have grown increasingly divergent. But there are a number of problems with all these studies. The advocates of a single limiting factor can rarely determine whether some other factors might intervene before the assumed constraint comes into play. Moreover, even if these determinations were scientifically possible, many of the isolated factors are not independent of one another. True, the amount of available water determines how productive the land will be, but it itself is partially determined by how much energy is available for pumping the water or desalinating it. And that energy capacity depends in part on the amount of water available to flow through hydroelectric dams and to cool nuclear reactors. Everything affects everything else.

Most important, many limiting factors are subject to changing cultural values. If a peasant farmer in Kenya believes that educating her children matters greatly, and if school fees begin to rise, then she may choose to have fewer children not because land is scarce but because she values her children's future more than their labor as farmhands.

4. Earth's population problems can be solved by colonizing outer space.

Let's review the numbers: the world's population of 5.7 billion people is currently growing by roughly 1.5 percent per year. Now, let's say you wanted to use space travel to bring the growth rate down a tiny notch to 1.4 percent. That would require .001 x 5.7 billion = 5.7 million astronauts to blast off in the first year—and increasing numbers in years that followed. Space shuttle launches cost $450 million apiece, so if you ferried ten people to space in each shuttle, the cost per person would be $45 million. Exporting 5.7 million people would cost $257 trillion, roughly ten times the world's annual economic product. Your mass migration would bankrupt the remaining Earthlings, who would still be saddled with a population that doubled every 50 years.

Demographically speaking, space is not the place.

5. Technology can solve any population problem.

People once feared that shipbuilding would be hampered by the scarcity of tall trees for sailing masts, that railroads would be crippled by a shortage of timber for railroad ties, and that the U.S. economy would grind to a halt with the exhaustion of coal. Yet people figured out

how to switch to metal masts (and then steam power); they invented concrete railroad ties and built superhighways; and they found better ways to extract coal, as well as oil, gas, and other fuels. But these solutions brought new problems, such as acid rain, dramatically rising atmospheric carbon dioxide, stripped lands, and oil spills. Still, technological optimists argue that industrial societies will go on solving problems as they arise.

In technology, as in comedy, timing is everything. For every timely success of technology, doubters can point to problems where solutions did not come in time to avert great human suffering and waste. For example, medical technology's solution for tuberculosis so far is partial at best. One in three humans are infected with tuberculosis (including half the population of Africa), and 3 million of them are dying of it every year. Yet despite decades of medical research, drug-resistant forms of the disease are spreading. Technology will take time to solve such problems—which are ultimately related to population through culture, the environment, and the economy—if it can solve them at all.

6. The United States has no population problem.

When people are born whose parents don't want them, there is definitely a population problem, and the United States suffers this problem in a big way: in 1987, of the 5.4 million pregnancies among American women, about 3.1 million (57 percent) were unintended at the time of conception. Of these, about 1.6 million were aborted; 1.5 million resulted in a live birth. Young and poor women were more likely than average to have unintended pregnancies. In 1987, 82 percent of pregnancies among American teenagers 15 to 19 years old were unintended, as were 61 percent of pregnancies among women 20 to 24 years old. Women with family incomes below the poverty level in 1987 reported that 75 percent of their pregnancies were unintended. The trend is not good: among all U.S. women 15 to 44 years old, the fraction of all births that resulted from intended pregnancies shrank from 64 percent in 1982 to 61 percent in 1988 to 55 percent in 1990.

The inability of the United States to assure that every conception is an intended one is entwined with other social problems. The United States ranks first or second (always behind Australia) among industrial countries in rates of intentional homicides by males, reported rapes of women aged 15 to 59, drug crimes, injuries from road accidents, income disparity between the richest 20 percent of households and the poorest 20 percent, prisoners, and divorces. Unintended births are partly a cause and partly an effect of all these other troubles.

PGTM 3 (people and snake)

7. Population problems of developing countries are not a problem for the United States.

The myth that the United States is immune to the population problems of the rest of the world ignores migration, infectious diseases, international labor markets, and the shared global commons of crust, oceans, atmosphere, and wildlife. Refugees and immigrants are driven from home by political upheavals, ethnic conflict, poverty, and environmental degradation—all problems that may be exacerbated by rapid population growth—and already play visible roles in the domestic politics of Florida, Texas, and California, as well as in American foreign policy. The health of Americans depends on the health of people outside our borders—infectious diseases do not carry a passport. The rapid population growth of developing countries, leading to fierce wage competition, may even play some role in the movement of jobs out of the United States, although the extent of this role is still controversial because it has not been accurately measured. American workers may do well to recognize their self-interested stake in lowering population growth rates of developing countries.

8. The Roman Catholic Church is responsible for the population explosion.

In some countries church policies have certainly hindered access to contraception and have posed serious obstacles to family planning programs. In practice, however, religion isn't the critical factor for fertility levels among Catholics, not to mention Muslims, Jews, or members of most other religions. Last year Spain and Italy—two Catholic countries—tied with Hong Kong for the lowest levels of fertility in the world, with an average of 1.2 children per woman. In largely Catholic Latin America, fertility has fallen rapidly to the world average of 3.1 children per woman, thanks mainly to modern contraceptive methods. The fertility of American Catholics has gradually converged over the years with that of Protestants. Polls show that nearly four-fifths of them think that couples should make up their own minds about family planning and abortion.

Within the church hierarchy, Catholicism shelters a diversity of views. In 1994, for example, the Italian bishops' conference issued a report stating that falling mortality and improved medical care "have made it unthinkable to sustain indefinitely a birthrate that notably exceeds the level of two children per couple." By promoting literacy for adults, education for children, and the survival of infants in developing countries, the church has helped bring about social conditions that favor a decline in fertility.

9. Plagues, famines, and wars are nature's (or God's) way of solving population problems.

This venerable myth traces back at least to 1600 B.C. According to an ancient Babylonian history, when human commotion disturbed the gods' peace and quiet, the gods inflicted plagues to rid the Earth of humans.

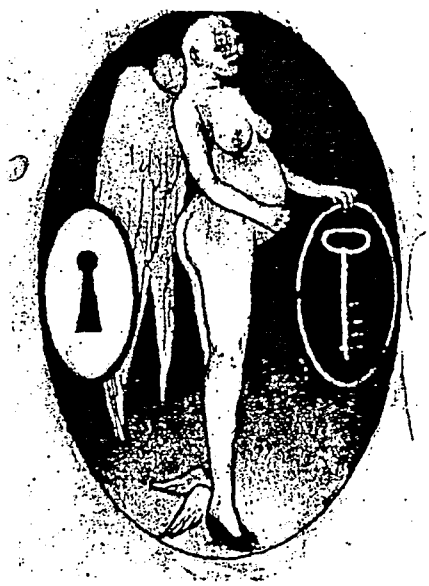
Plagues, of course, are directly caused by viruses, bacteria, and other microorganisms that take advantage of human behavior in a favorable environment. After the last ice age, when sedentary agriculture greatly increased the population density in permanent human settlements, the inhabitants became surrounded by their own wastes and those of their domestic animals and hangers-on like rats and fleas. By the time the Babylonians recorded their creation myths a few thousand years later, people could well have observed that denser settlements were subject to strange new infectious diseases and could have interpreted these diseases as divine interventions. Now we know that humble humans can at least partially control disease. Inexpensive public health measures controlled lethal infectious diseases of childhood in developing countries after World War II, and population growth then accelerated in an unprecedented way.

Modern epidemics, while causing great suffering, have yet to show any probability of putting a brake on population growth. The highly reported Ebola outbreak last year killed 244 people—fewer than are born every minute. As for AIDS, a 1994 United Nations report on the 15 countries in central Africa where it is most prevalent estimated that by 2005 their population growth rate would be 2.88 percent per year in the presence of AIDS. If AIDS were not present, it would be 3.13 percent. These rates correspond to doubling times of 24 years and 22 years, respectively.

Famines today are only partly a result of natural events. Many readers may remember a Pulitzer Prize–winning photograph from 1993, showing a starving Sudanese girl collapsed on a trail, with a vulture looming behind her. At the time, the Sudanese government was just opening parts of its famine-stricken countryside—the scene of a long-running civil war—to relief operations. If aid workers had gotten in sooner, they could have prevented a crop failure from leading to a famine, but the Sudanese government stopped relief from reaching its own people. This is not divine intervention or an act of nature.

Finally, war has not been a major obstacle to human population growth. It's a safe estimate that fewer than 200 million people have been killed in the wars of this century (combined, World Wars I and II may have killed 90 million people, including civilians; since World War II, perhaps 50 million people have lost their lives on conventional battlefields). Yet the population increased from fewer than 1.7 billion in 1900 to 5.7 billion today. This 4-billion-person increase is more than 20 times greater than the number killed by wars.

PGTM4 (pregnent angel)



10. Population is a women's issue, and women are the key to solving it.

If we don't improve the education, welfare, and legal status of women, there is little hope of solving many population problems. Women bear babies, and they are obviously key players in improving the survival of children and lowering fertility. But they are not the only key players. In most of the world, men too need similar help. As demographer Uche Isiugo-Abanihe of the University of Ibadan in Nigeria has pointed out, it is as important to educate African men about the consequences of high fertility as it is African women. In the United States, a 1995 report on unintended pregnancy by the Institute of Medicine concluded that "the prevailing policy and program emphasis on women as the key figures in contraceptive decision-making unjustly and unwisely excludes boys and men." Scientists have discovered it takes two to tango.

Last October a neurophysiologist I was chatting with claimed that the people of India are poorer, more miserable, and more fecund than ever. I quoted him statistics showing that India's average gross national product per person rose 3 percent per year from 1980 to 1993 and that its life expectancy rose from 39 years during the period of 1950 to 1955 to 58 years during the period of 1985 to 1990. I added that in that same period of time the average number of children per woman fell from 6 to 4.1. "Oh, that doesn't matter!" he said. Population myths have a life of their own.

Yet behind the neurophysiologist's exaggerations are valid, urgent concerns. Too many people in India and around the world are far poorer than the means available require them to be. Too many children are born without the prospect of sufficient love, food, health, education, or dignity in living and dying. But only by clearing the myths from our vision of population can we focus on the real problems and find hope without complacency. One way or another, human population growth on Earth must ultimately end. Ending it through voluntary reductions in fertility will make it easier to reduce the poverty of the 4.5 billion people who live on an average of $1,000 a year. At the same time, reducing poverty will make it easier to end population growth through voluntary reductions in fertility. The alternatives are coerced reduction of fertility or the misery of rising death rates. The choice is ours, for now.

TTL

"Of all things people are the most precious"

GLM

China's long-term objective is a balance between populace, resources, and welfare. As the author found on a recent visit, after only 15 years of active campaign China is on the verge of a demographic breakthrough

Dr Norman Myers is an FAO Regional Wildlife Officer for Africa, based in Ghana, and a writer on conservation and human ecology of development

PRB

Every fifth person may be Chinese, but not every fifth baby is. During the 1950s, almost every fourth baby was Chinese. Now the position is less than every sixth, and by 1980 should be only one in seven. A mere 20 years ago China's population was growing at well over 3 per cent per year, as is now happening in many explosively expanding countries of the Third World. China's population of 800 million (plus 20 million or minus 30 million) is currently growing at 1·7 per cent per year (plus or minus a point). More relevant than the precise figures is the fact that the rate is falling so rapidly that China is likely to be the first developing country to drop to a 1 per cent growth rate. China and India account for 40 per cent of the world's population increase each year, yet although China contains almost 200 million people more than India, it contributes fewer additional mouths.

Some indications of what has triggered this exceptional fall in the growth rate emerged during the course of a recent visit I made to China. Following a rush-around tour one can draw no hard and fast conclusions for the situation overall in a country so extensive and for a population so large. One can merely speculate about isolated insights. Each day I visited a string of factories, communes, neighbourhood gatherings, recreation centres, and the like. These visits allow one to gauge, for example, how pervasive is the climate of persuasion to birth control. And while viewing one million people during a short stay (as is easy in the rush-hour traffic of two or three cities and along busy country roads), one can form an opinion as to whether people in the main are properly nourished and free from debilitating disease—with all that means for parents' readiness to limit family size. By talking to birth control workers in clinics, hospitals, high schools, universities and production units of varying kinds in city and countryside (the Revolutionary Committee in charge of institutions of every sort seems to have somebody engaged in family planning), one can collect all manner of statistics, for comparison with findings of other visitors to China. Despite the extremely restricted data base, it is possible to come up with informed estimates.

Development patterns

BRG EVN EVN

As was stressed at the 1974 population Conference in Bucharest, birth control campaigns need to be considered within the total context of development. Many aspects are relevant: economic advancement, health and associated forms of community hygiene, social stability, women's status, education, security at various stages of life, and mobility within the social order. It is in this respect that China has been especially successful. Before "liberation", as the Chinese call the communist revolution of 1949, China was the epitome of a developing—or not developing—nation. People were short of most things, especially prospects for any improvement in their lot. Now conditions are clearly much improved, and equally clearly they are going to improve even more. The Chinese seem to be confident of their future, both as individuals and as a society.

BRG

These factors help to explain why China has achieved so much in family planning. After a long period before 1949 when the population was growing at only 0·4 per cent per year, the growth rate shot up to well over 3 per cent in the 1950s. Population planning was instituted from 1956, with a break during the drought of 1959-61 (when the populace feared that exhortations about smaller families were a portent of famine ahead). After only 15 years of an active campaign, the country seems on the verge of a demographic breakthrough. It has reached this point with the notional GNP per head of under $200—well short of the $500 GNP per head often considered the threshold to security before people will contemplate "risking" smaller families. The significance of this Chinese accomplishment is all the greater in view of the social scientists' apprehension about population growth in much of the Third World. An exploding populace may absorb almost the entire capital investment of a nation merely to hold current (albeit depressed) levels of welfare. This may preempt the possibility of worthwhile economic growth altogether, thus deferring indefinitely the magic goal of $500 income per head.

SGN

China's success offers fresh hopes for these impoverished countries, which likewise contain three-quarters of emergent regions' population. But these countries would have to mobilise the political capacity to implement something of the "fair shares for all" spirit which characterises China's approach to development. The political input need not necessarily be socialist of the extreme form practised in China. But developing countries would certainly have to try to eliminate the grosser forms of maldistribution of wealth and income between the top 10 per cent and the bottom 60 per cent (a more extreme disproportion in many cases than the United Kingdom or the United States). Otherwise the bottom sector remains impoverished—and resistant to family planning.

BRG

Likewise significant in China's success is its system of health care. In 1949 there was one doctor in China for every 25 000 people. Most of the doctors practised in the half dozen largest cities, so the mass of population was virtually doctorless. A similar situation obtains in many developing countries today. Now China has one modern-trained doctor or professional medical auxiliary for every 4000 people (India has one doctor for every 6000, the United States one for every

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Chairman Mao Tse-tung

660). In addition, China has over one million barefoot doctors—para-medical personnel who have helped to eliminate pandemic diseases and deliver community hygiene generally. Barefoot doctors also provide birth control facilities (including abortion, by the suction method) in the remotest sectors of the country.

All medical practitioners share the cultural and social milieu of the peasants and workers whom they treat. Many of them labour on the land or at the factory bench for part of the working week. Their clients can thus be confident that they understand the problems of daily life of ordinary individuals, which makes parents more receptive to guidance about family planning. The birth control adviser as an aquaintance from down the street contrasts sharply with the anonymous white-coated "expert", in other parts of the developing world.

Extent of birth control practice

I found highest levels of birth control practice in large cities such as Peking, lower ones in provincial towns such as Changsha and Kweilin, and lowest figures among peasant communities. In large cities, birth control seems to be practised by 70 per cent or more of women at risk, counting abortions, sterilisation and other methods besides the usual ones (oral contraceptives are popular in cities, IUDs in the countryside). In rural areas, practice ranges from below 20 per cent to above 40 per cent. But the 80 million married women of reproductive age among the rural populace of 650 million people should soon enjoy access to "paper pills". These are sheets of progesterone impregnated paper, measuring 6×4cm, perforated into 22 squares for one month's supply. Being easily produced, light to transport, and simple to use, this Chinese device seems well suited to large rural communities. Because the rural populace represents a huge amount of slack to be taken up in the birth control programme, and considering that health services give priority to the countryside, contraception practice can be expected to rise steeply.

China probably already has a larger number of women practising birth control than any other country. The present demand for contraceptive materials also seems well within the country's productive capacity—in contrast to those many developing countries which must import huge amounts of hardware. While the Chinese countenance the notion "Take care of the people and the population will take care of itself", they recognise that birth control facilities must be immediately available to whomever wishes to avail himself/herself of them. Birth control services are virtually free.

Other inducements to reducing family size stem from a series of social factors. Ninety per cent of China's women of reproductive age are literate and employed—both factors which strongly correlate with readiness to undertake birth control. Late marriage also reduces family size. Marriage is socially acceptable in urban areas only when a man is 28 and a woman 25, and in rural zones 25 and 23. Thereafter a five-year interval between children is becoming de rigueur.

The birth rate in 1953 was 43 per 1000 persons in the populace. It rose higher for a while, but by 1960 it dropped to around 38 per 1000. Present figures are 10-19 per 1000 of the populace for cities, 14-23 for medium-sized towns, and 20-35 for rural areas. The overall figure is 29, or perhaps a little less, per 1000 (Table 1).

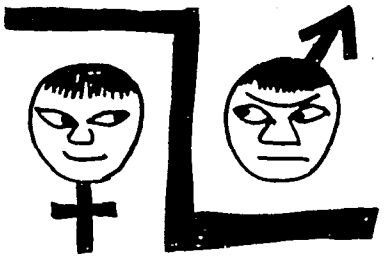
Before the communist revolution, China's death rate was at least 40 per 1000. By 1960 it had dropped to around 25, by the late 1960's to 17. Now it is only 13 (5-6 in cities, 9-12 in towns and 14-18 in rural areas). A major share of this decline is due to exten-

Table 1 Population statistics for China and other countries — 1974 PGCP1 (China statistics)

Country	Present population (in millions)	Birth rate (per 1000 persons per year)	Death rate (per 1000 persons per year)	Infant mortality rate (per 1000 live births per year)	Population growth rate (per cent per year)	Population under 15 Years (per cent)	Per Capita GNP (US $)	Population projection for 1985 (in millions)
China	800 (plus 20 or minus 30)	29 (objective "as soon as possible": 18)	13 (objective "as soon as possible": 8)	20–30 (according to region)	1·6 (objective "as soon as possible": 1)	"at least 40"	approx. 185	910 (plus 20 or minus 30)
Rest of Eastern Asia	182	26	10	16	1·7	(without Japan) 40	(without Japan) 325	218
Hong Kong	4·6	20	5	19	2·4 (some immigration)	38	970	6
Outer Mongolia	1·5	42	11	—	3·1	31	460	2
Japan	109	19	7	13	1·2	24	1920	121
Southern and SE Asia	1171	44	17	110	2·7	43	115	1571
India	616	42	17	139	2·5	42	110	808
Pakistan	70·4	51	18	142	3·3	45	100	110
United Kingdom	58	14·9	11·9	18	0·3	24	2270	62

Sources: For China, author's findings and other visitors' records; for other countries, data from Population Reference Bureau, International Planned Parenthood Federation, Population Council, UN Demographic Yearbook.

PGCP 2 (people's heads)



BRG sive cut-backs in infant mortality, or death before the first birthday. This now runs between 20 and 30 per 1000 live births according to locality. Pre-school mortality ranges from 2 to 5 per 1000. This achievement is a world away from the experience of India and other parts of impoverished regions, where infant and pre-school mortality often counts for half the total mortality. So long as infants die in hundreds of thousands each year, exhortations about birth control are not convincing.

EVN

BRG The figures for birth and death rates indicate a 1·6 per cent growth rate in China. The declared aim ten years ago was to achieve a growth rate of 1 per cent by the end of the century. Now the policy is to reach that level as soon as possible—perhaps shortly after 1980 if, say, the birth rate can be brought down to 18 per 1000 and the death rate to 8 per 1000. Urban areas should immediately aim for a rate of natural increase, ie discounting immigration (in any case marginal), of 1 per cent, and rural areas of 1·5 per cent.

PRE Whatever happens before the year 2000, China will presumably by then have passed the one billion mark. This means that the population will have doubled since the 1949 revolution, following 150 years in which the population is reputed to have increased by only 50 per cent. Prospects for further socio-economic advancement must be considered so favourable that China could shortly be selling large quantities of grain to the developing world (and oil to the developed world). So much for thoughts that this crowded mass of humanity might one day seek new lands to absorb its population increase. The one eighth of national territory which is now cultivated could readily be persuaded to produce twice as much food when China's green revolution gets underway.

SGN

Peking and Shanghai

BRG Peking and Shanghai illustrate some of the more exceptional trends. According to Ministry of Health personnel who, like other officials, had stacks of population statistics to give me, Peking's populace was growing at 3·5 per cent in the late 1950s, but the present total of 7·8 million is expanding at only 1·17 per cent. Peking's birth rate is now 18·8 per 1000 (15 in the main metropolitan zone, 20 or more in the rural communities within the city limits). The death rate is 6·4 per 1000. The natural rate of increase is thus 1·24 per cent per year. In contrast to major cities of other developing countries, where immigration often pushes the urban growth rates over 10 per cent and represents one of the more disruptive manifestations of population increase, Peking actually exports more citizens than it accepts from outside. This is due to the Cultural Revolution, which sends thousands of city dwellers each year into the countryside to accentuate political and social solidarity.

BRG Shanghai's record is even more remarkable, according to recent visitors. Inner city birth rates average 6·4, with some districts actually down to 4 or below. The suburbs average 15·6, making a figure of 10·75 for the whole city. These are among the lowest birth rates ever recorded—on a par with West Berlin's rate today of 9·7 and Vienna during the troubled 1930s of 9·6. The death rate is 5·6 per 1000. These figures produce a rate of natural increase of 0·5 per cent for the city of 10·7 million.

So avid are some big city communities in their wish to achieve low birth rates that they deliberately stress population planning as the approach to family planning, instead of the other way round as is usual. They decide how many births will be desirable during the coming year, then allocate the privilege to "deserving" couples. One neighbourhood committee in Peking, according to a frequent traveller to China, Dr Han Suyin, decided that its population of 47 000 should produce no more than 360 babies in order to achieve a birth rate of 7·5. This strategy of collective consent, or "birth by turn", has been attempted in Shanghai as well.

PRE The extraordinarily depressed birth rates for Peking and Shanghai can be partly explained by the age distribution of the populaces in question. Since a large proportion is in the young age brackets, over two fifths under 15 years old, a smaller percentage makes up the reproductive categories. This skews the birth rates. Similarly, death rates inevitably plunge in a young and healthy population, with implications for growth rates. In a few years' time these cities may have difficulty in holding their low levels, let alone reducing them still more. Steadily the cohorts of babies born before the plunge in birth rates will move upwards through the populace's age structure, to produce a bulge in the population pyramid. What happens when all those citizens reach marriage age? Will they not produce a flood of children? This would skew the distribution once again through an upsurge in population growth rates. These children could eventually produce a further bulge in turn, through an oscillatory process before population growth stability is reached several generations hence. On the other hand, the people in reproductive categories will, from now on, be entirely those who have been educated through the communist system. The indoctrination process should leave them all the more amenable to population planning.

BRG In any event, zero population growth is not the avowed aim. China rejects any notion of over-population as anti-Marxist (like the other measure which is often used in absolutist sense, GNP). The long-term objective is to achieve a balance between population, resources, and welfare levels. This approach

BRG

allows room for Mao's dictum, "Of all things people are the most precious". At the same time, the Chinese recognise that while God sends with every mouth a pair of hands and a brain, he does not send a seat in school, a bed in hospital, and a kit of production tools.

Can the Chinese model be exported?

EVN

China's achievement cannot readily be replicated in other developing countries. It reflects the present ethos of society in China: if the economy is to be planned, so should population. People are ready for birth control, people practise it. Moreover, although the population campaign is centrally planned, birth control is very much a grass-roots affair. It is the subject of extensive discussion by local groups, which partially explains the varying degree of success between one city and another, between one region and another. Minority groups, such as the Tibetans, are not encouraged to practise family planning at all if they do not wish to.

Certain aspects of China's experience could, to be sure, be transferred to other countries. The barefoot doctors, for example, are an excellent means for accomplishing wide distribution of health benefits. A similar strategy could be adopted in Southern Asia, Africa and Central America without a dose of socialist ideology—provided young medical practitioners could be persuaded to leave the bright lights of the city for the countryside. Rural populations of the Third World are where the action is: they are the communities most deprived of minimum living conditions, and they are the ones most responsible for the sudden upsurge in population growth rates.

SGN

CON

In many ways, China's success is an intrinsically Chinese affair. As the Chinese constantly insist, other countries should work their own salvation in accord with their socio-economic and politico-cultural capacities. Meantime, it is encouraging to reflect that one third of the developing world is in good shape, and seems to be squeezing through its demographic transition in record time.

New Scientist 8 January 1976

TTL

Population patterns in the mid 1970s

GLM

If we can achieve a new vision of history, the eventual prognosis for the human race need not be viewed with undue reserve

Dr John Loraine, of the MRC External Scientific Staff, is Chairman of the Doctors and Overpopulation Group

PRB

As 1976 opens, the world population will have topped the 4000 million mark. This compares with figures of 1500 million in 1900, 2500 million in 1950. During 1976 more than 70 million people will be added to the planet. This is 14 million more than the current population of the UK, and approximately equal to that of Pakistan and Bangladesh.

PRB

Vis-à-vis population, the world of 1976 will remain dramatically divided. Indeed, what might be termed an "iron curtain of demography" is interposed between the rich and the poor nations; between the haves and the have nots.

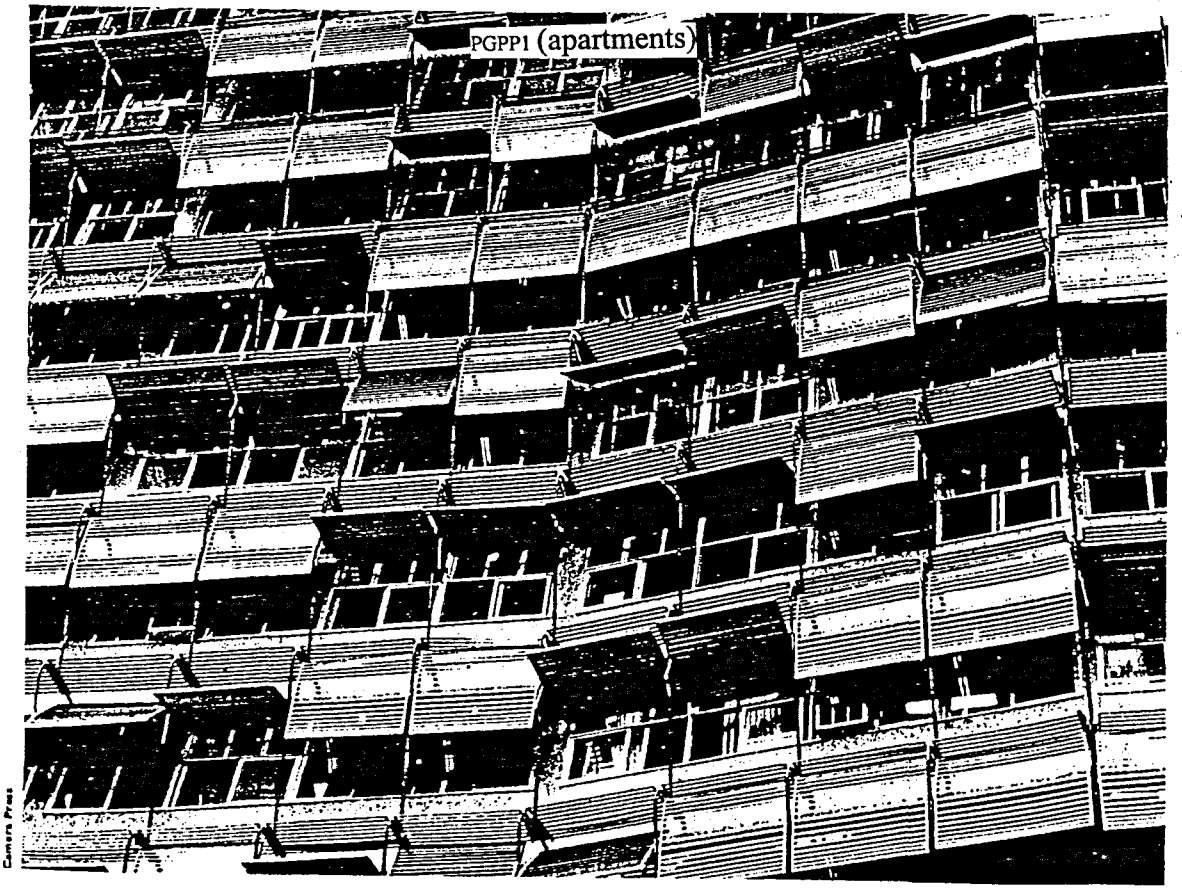
BRG

In the 30 odd countries throughout the world which are generally regarded as developed, fertility rates are now not far off replacement levels; some of these countries have reached, or are about to approach the state of, Zero Population Growth. Such nations have other characteristics in common. They are enjoying the material abundance associated with industrialisation; their literacy rate is high; their average life expectancy at birth is over 70 years; and they eat a rich and satisfying diet. Their health services are good; their infantile mortality rates low; educational facilities are rich and varied; and they offer a relative plethora of occupational opportunities.

BRG

The decline in fertility in the Western world has been in full swing since the mid 1960s; it is continuing with even greater speed in the 1970s. Britain is fairly typical in this respect. In England and Wales during the 12 months ending June 1975 the number of deaths and emigrants exceeded the number of births and immigrants by a figure of some 10 000. The average population growth rate in France during the period 1970 to 1975 was only 0·9 per cent per annum. In the Netherlands it was 0·8 per cent, in Belgium 0·4 per cent, in Luxembourg 0·2 per cent. In the countries of Central Europe the trend in birth rates from the mid 1960s onwards has been rapidly downhill. For the period 1970-1975 the lowest birth rate in the world (12·0 per 1000) was in the Federal Republic of Germany. Low figures, below 15 per 1000, were also recorded in Austria and Switzerland.

The nations of the Eastern bloc fall into the category of developed countries. Since the end of the Second World War they have shown a uniform decline in fertility. The



PGPP1 (apartments)

Camera Press

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ready availability of abortion, not only as a means of promoting maternal health and welfare but also as a method of birth control, has hastened this process. By the mid 1970s crude birth rates in countries such as Hungary, Poland, Bulgaria, and the German Democratic Republic were below 17 per 1000. In 1975 in the USSR there were approximately 2·5 births per woman. This is a somewhat higher fertility rate than that of other Eastern European countries barring Romania, which in 1966 repealed its permissive abortion law, made divorce less easy to obtain, and launched a pronatalist campaign *via* the media. European and Asiatic Russia differ in their fertility patterns. In the former the overall birth rate is similar to that of Western Europe; in the latter it is considerably higher.

There has been a pronounced decline in fertility in the Scandinavian countries. This is especially so in Finland where the number of births per woman has fallen from an average of 3·5 in the years immediately after the Second World War to 1·8 in 1973. In Southern European countries —Italy, Spain, Portugal, and Greece—trends in procreation are similar to those in more northern climes. In Italy and Greece fertility is currently hovering at about two births per woman. In the Iberian peninsula fertility rates are somewhat higher, Spain notching 2·8 and Portugal 3·9 births per woman in 1973.

Boom in births

The "baby boom" after World War Two was unduly prolonged in the US, Canada, Australia and New Zealand. Yet over the past decade fertility in these countries has also declined in keeping with that of the developing world as a whole. By 1973 the fertility rate in the US and Canada was less than two births per woman; in Australia the figure was 2·5 and in New Zealand 2·9. Between 1970 and 1975 the average growth rate of population in the US was 0·9 per cent, in Canada 1·3 per cent, in New Zealand 1·4 per cent and in Australia 1·9 per cent. Birth rates in these countries are significantly higher than in Western and Central Europe, yet the figures scarcely suggest that another surge in fertility is in the offing.

The situation in the Third World countries of Asia, Africa and Latin America is totally different. Population changes in the Third World dominate the global scene. Three quarters of the world's people live there; 85 per cent of all births take place there; during the past quarter of this century 90 per cent of all new additions to the planet will be in these areas.

Population growth rates throughout most of the Third World remain extraordinarily high. For example, in the geographical area known as South Asia and comprising India, Pakistan, Bangladesh, and Sri Lanka, there is a total population of some 1300 million. This is increasing by over 40 000 every day; the growth rate as a whole is 2·4 per cent per annum, indicating that numbers could double in less than 30 years.

There are two main reasons why, for the foreseeable future, most Third World countries will continue to carry an immense burden of population. The first is concerned with the age structure of its inhabitants. Past population growth rates have already boosted the numbers of young people and these are, of course, parents of the next generation. In 1975 in countries such as India, Bangladesh, Pakistan, Indonesia, and many African and Latin American nations, over 40 per cent of the population is under 15 years of age. This is in marked contrast to the situation in developed countries where the corresponding percentage is between 20 and 30 and the average age of the population is therefore higher. The young of the Third World, in common with young people everywhere, tend to have a high sex drive. Birth control methods in these areas are being used to a very limited extent; it is therefore scarcely surprising that high fertility rates are the order of the day.

Camera Press

India: family planning clinic....

The second main reason for the population explosion in the Third World is that people are now living longer. Improved hygiene and advances in medicine have slain the "captains of the men of death" such as malaria, smallpox, cholera, and typhus. The average lifespan thoughout the Third World is increasing dramatically. In India in the 1920s it was 27 years; by 1945 it had risen to 32; now it is just over 50; by the end of the century it could be close to 70. Already in Latin America the average life-span is 60 years—not much lower than that in developed countries. In parts of equatorial Africa life expectancy is still low; but this is likely to change with the progress of the Medical Revolution, and by the end of the century most of the inhabitants of that area could be living to an age of 70 years of more.

Gloomy prognosis for India

The population giants of the world are India and China. By the year 2000, one in six of the Earth's inhabitants could be Indian, one in six Chinese. The history of mankind is likely to be shaped by the ability of these countries to control their growth of numbers.

The situation in India is gloomy. By mid 1975 the population of that country was over 600 million as compared with 370 million in the early 1950s. The Indian birth rate remains high; death rates are gradually falling. The overall population growth rate is 2·4 per cent per annum, and the "doubling time" is 29 years. India has based its population policy mainly on family planning. It has attempted to

.... *and relief clinic*

BRG conduct a vigorous campaign of persuasion under the symbol of the Red Triangle. The favoured method of contraception has been the intrauterine device; recently the oral contraceptive Pill and the condom have become increasingly popular; sterilisation in women by tubal ligation and in men by vasectomy are encouraged; a moderately liberal abortion law, based on its British counterpart, came into operation in the early 1970s.

EVN Yet the Indian family planning programme has only touched a relatively small proportion of the fecund population. It has been operated to a disproportionate extent by Western trained doctors, and there is now good evidence from other Third World countries that when family planning is removed from the medical umbrella and is either put into the hands of para-medical staff such as nurses, midwives, health visitors and social workers, or provided as a community based service without constraints of any kind, the rate of acceptance of contraceptives is likely to be much higher.

Also in India the relationship between a population policy and development has been insufficiently appreciated. Development has been succinctly defined as a process of improvement in basic human needs. The New International Economic Order, enunciated by the Third World nations and trumpeted forth repeatedly at the UN General Assembly during 1975, has development as its lynch pin. To political leaders in most Third World nations, the main reason for the failure of family planning programmes to influence population growth has been the fact that they have been engrafted on an inappropriate political, social, economic, and religious context. Certainly too much is being asked of the Pill, the loop, the condom, sterilisation, and liberal abortion when poverty is rampant; where female emancipation is a dream rather than a reality; when the traditional religion has a pronatalist ethos; and where children, especially sons, represent the only stake of these people on the planet, their means of succour in sickness, their support in old age.

EVN Population and development are inextricably interwoven. Lord Caradon, former Permanent British Representative at the UN, summed up the position realistically at the World Population Conference in Bucharest in 1974 when he said that "to attempt to deal with population without at the same time dealing with development would be an insult. But to attempt to deal with development without at the same time dealing with population would be a deceit".

China: modified rapture

SLN The Chinese situation differs greatly from that in India. For some years China has operated one of the most eclectic birth control programmes in the world, featuring Pills, injectable contraceptives, spermicides, loops, vasectomy, female sterilisation, and liberal abortion. Paramedical staff, particularly the celebrated "barefoot doctors", are an integral part of the programme. They are much in evidence in the rural areas where they distribute contraceptives, ensure that they are used properly, and assist with and actually perform operations such as tubal ligation, abortion, and vasectomy.

Moreover, the Chinese government makes it clear that it is intimately involved in the reproductive habits of its citizens. Late marriage is advocated and women who postpone marriage to work for the fatherland are praised, as are couples who postpone childbearing after marriage. The psychological immaturity of those who marry young is stressed; the Commune system makes it less necessary for children to look after their parents in sickness and old age. The small family norm is lauded; two children are considered ideal; large families, although not penalised by fiscal measures, are generally regarded as evidence of social irresponsibility. No opprobrium attaches to spinsters or bachelors. Sex remains singularly non-commercialised; the incidence of premarital virginity is reputed to be high.

EVN The vital question is, of course, whether the Chinese experiment is succeeding. As of now the answer appears to be a qualified "yes". The population growth rate in China in the mid-1970s is reported to be less than 2 per cent per annum. This is, of course, still high by any historical standards, but it is a good deal lower than that of neighbouring countries such as India, Bangladesh, Pakistan, and Indonesia, which employ a much more *laissez-faire* approach to birth control.

CON Overpopulation is one of the dominant problems of the last quarter of the 20th century. Its ramifications are truly enormous. In the developed countries, continuing population growth is a major factor affecting the demand for resources and the deterioration of the environment. In the Third World it has numerous deleterious effects. It is speeding the drift of countrymen to cities and causing metropolitan areas such as Lima, Jakarta, Calcutta, Rio de Janeiro and many others to burst at the seams. Overpopulation is contributing to unemployment and underemployment, is swelling the tide of illiteracy and is a factor inimical to the emancipation of women. Worst of all, it has the propensity to predispose to armed conflict between nations.

COL We badly need a new vision of history. Instead of a state of sour desperation we have to dare to hope that the population problem can be tackled and resolved, If we can attain this goal the eventual prognosis for the human race need not be viewed with undue reserve. □