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WARMING IN NORTH DISRUPTS ECOLOGY

NYT 11/16/90

Ontario Study Links a Rise in Temperatures to Threats to Forests and Fauna

By WILLIAM K. STEVENS

In what is described as a preview of some of the effects of global warming, Canadian researchers have documented a profound and pervasive disruption of ecosystems that they attribute to a rise in the temperature of northwestern Ontario in the last two decades.

The study, being published today in the journal Science, found that from the late 1960's to the mid-1980's, the average annual temperature rose by about 3.5 degrees Fahrenheit in a region of Ontario that has been set aside for longterm ecological research.

Scientists say they do not know whether the rise is part of a natural variation in climate or is a result of a climatic warming brought about by increasing levels of heat-trapping chemicals produced by human activity. The chemicals include carbon dioxide, methane and chlorofluorocarbons.

The effect of the warming has hardly been wholly benign, contrary to what might be expected in northern climes, the study found. The researchers say the warmer temperatures have made droughts and forest fires more frequent, diminished soil moisture and disrupted the ability of the forests to renew themselves.

Other Harmful Effects

They also discovered that the warmth has decreased the flow of water into the region's myriad freshwater lakes, changed their chemistry and warmed them so that the future of a wide variety of aquatic fauna is threatened. These include lake trout and supporting species that make up one of the world's most valuable fisheries.

If forecasts of future worldwide warming are correct, the report said, the north-woods ecosystems "should be severely affected." Scientists generally expect the average global climate to warm by about 2 degrees by the year 2025 and by about 5.5 degrees by the end of the next century, if the current output of heat-trapping chemicals continues. By comparison, the average global temperature is about 9 degrees higher now than it was in the last ice age.

But climate forecasters generally expect the warming to be greatest in northern regions of the Northern Hemisphere, with forecasts calling for average temperature increases of as much as 10 to 15 degrees and losses in soil moisture of more than 50 percent in northwestern Ontario in summer.

The findings in Science were reported by a team of 10 researchers headed by Dr. David W. Schindler, an ecologist at the University of Alberta in Edmonton. Other members of the team were associated with the Canadian Government's Freshwater Institute in Winnipeg, Manitoba.

The study concentrated on a lake called simply Lake 239 and its watershed. This is one of many lakes set aside in the 1960's for long-term ecosystem studies in what is called the Experimental Lakes Area of northern Ontario. Since the late 1960's, the researchers have been collecting a wide variety of data for many purposes.

Some Benign Effects

"The record was not collected with the intention of analyzing climate and climatic effects," Dr. Schindler said.

As might be expected, the study did find some benign effects: in the spring, ice disappears from the lakes about three weeks earlier than it did before. Snow has become sparser, with midwinter melting occurring in most years. And in one of the biggest effects, the warming stimulated a long-term increase of nitrogen, a powerful fertilizer, in the lakes. One result was an enrichment of microscopic plant life, with a proliferation of diverse algae species.

But decreased rainfall and soil moisture also caused less water to run into the lakes. One effect was to increase the time it takes the lakes to replenish their waters to 20 years from 4 or 5, increasing the concentration of many chemicals in the lakes. Dr. Schindler said this meant that the lakes were far less able to flush out pollutants.

Less water flowing into the lakes also means that fewer organic particles flow into them, the study found. This means that they are clearer, and that sunlight penetrates farther and warms them to a greater depth. At the same time, higher winds are allowed to develop because wide areas of forest have been denuded by forest fires.

The winds, Dr. Schindler said, have driven cold, oxygen-rich layers of the lakes where lake trout and many other cold-water species seek summertime refuge deeper into the lake, squeezing, compressing and in some cases eliminating the refuges. Much more climatic warming would destroy the refuges altogether, the study says, leading to the destruction of the lake trout, which can survive only in cold water.

Dr. Schindler noted that many large lakes 200 or so miles north of the study area were so shallow that they had no refuge layers. Cold-water fish there would be totally at the mercy of higher temperatures.

Any significant further warming would probably mean the extermination of the lake trout and other cold-water species on which they depend, Dr. Schindler said. It is not clear that fisheries of comparable value or ecosystems of comparable diversity would be quickly re-established, the study said. Bass could replace trout, Dr. Schindler said, but they would have to be stocked.

Noting that the effects of climatic change on fresh waters have been "largely disregarded" in efforts to deal with climate change, the report said, "they are already scarce in many regions of the world, and they are a key element in the maintenance of non-marine organisms, including man."

Bush Signs Major Revision of Anti-Pollution Law

WASHINGTON, Nov. 15 (AP) — Saying every American "deserves to breathe clean air," President Bush today signed an extensive overhaul of the nation's anti-pollution law to curb acid rain, urban smog and toxic chemicals.

Mr. Bush said the Clean Air Act of 1990, which updates and tightens Federal air pollution standards for the first time since 1977, was "simply the most significant air pollution legislation in our nation's history."

"This bill means cleaner cars, cleaner power plants, cleaner factories, and cleaner fuels," he said at a packed White House ceremony. "And it means a cleaner America."

Susan Merrow, president of the Sierra Club, described the law as "a breath of fresh air after a 10-year smog alert."

The goal of the law is to cut acid rain pollutants by half, sharply reduce urban smog and eliminate most of the toxic chemical emissions from industrial plants by the turn of the century.

The cost of adhering to the regulations is expected to be up to $25 billion a year.

Environmental groups temporarily put aside their differences with the President on other issues to praise his effort on clean air. But they said the effectiveness of the legislation would require aggressive enforcement by the Federal Government.

Richard Ayers, chairman of the National Clean Air Coalition, called the legislation "cause for celebration and hope."

Remember Cost, Business Says

But Ruth Caplan, executive director of Environmental Action, said Mr. Bush's signature marked "only the first step toward cleaning up our air," adding, "There are dozens of provisions that must be implemented through regulation."

Industry representatives were more muted in their approval.

"While business supports the act's clean air objectives, its costs to American consumers and workers cannot be sugarcoated," said William D. Fay, administrator of the Clean Air Working Group, a coalition of 2,000 businesses and trade associations.

The President's signature ended a decade-long debate over anti-pollution rules. The legislation was the product of 16 months of wrangling among Administration and Congressional negotiators over the many technical provisions.

The new law requires tougher emission controls on cars and requires service stations to sell cleaner-burning gas. It mandates new equipment in thousands of businesses and factories to capture smog-causing pollutants and toxic chemicals.

It also requires coal-burning power plants to halve sulfur dioxide emissions, which cause acid rain.

Some of the new requirements will be phased in within a few years, but most will not fully be in place until the end of the decade. Cities with the worst smog problems have up to 15 to 20 years to meet the Federal rules.

Mr. Bush, fulfilling a campaign promise, proposed a broad rewrite of the clean air laws in July 1989. Earlier efforts to revise the laws had been blocked by economic and regional interests and the Reagan Administration.

"Every city in America should have clean air," Mr. Bush said. "With this legislation I firmly believe we will. Every American expects and deserves to breathe clean air."

New Scientist 27 April 1991

Left-handers don't die young after all

Dan Charles, Washington DC

A STUDY claiming to show that left-handed people die nine years earlier than right-handed people relied on faulty statistical methods, according to scientists who have reviewed the research. The study was published in the *New England Journal of Medicine* two weeks ago, and received wide press coverage.

Stanley Coren of the University of British Columbia and Diane Halpern of the California State University in San Bernardino relied on death records for their study. They obtained records of 987 people who died in two counties of southern California. Family members told Coren and Halpern whether the deceased people were right or left-handed.

Coren and Halpern then calculated the average age at which the right and left-handers died. Right-handers, it turned out, died at the ripe old average age of 75. Those who preferred their left hand died at an average age of 66.

But Coren and Halpern never found out how many left and right-handers there were in those two counties of California to start with, much less how old they were. As a result, their results "mean absolutely nothing", says Tricia Hartge, an epidemiologist at the National Institutes of Health.

The American Academy of Actuaries also issued a statement calling Coren and Halpern's methods "faulty". Richard Labombarde, an actuary with the private firm of Milliman and Robertson in Washington, says that Coren and Halpern's research reminded him of methods used by actuaries 200 or 300 years ago.

Coren and Halpern's result, says Hartge, may simply reflect a well-known fact: the average left-handed person in the US is significantly younger than the average right-handed person. This may have nothing to do with the life expectancy of left-handed people. It is probably due to the practice, common until recent decades, of forcing left-handed people to write with their right hands in school. Because the population of left-handers is younger, the left-handed people who die will, on average, be younger than right-handed people who die, says Hartge.

Coren denies that historical practices of forcing left-handers to change could have produced his data. He says that it is very difficult to persuade people to switch hands, and even then, the people may write with the right hand and do most other things as they did before.

But Coren's own studies sh[illegible] and schoolteachers did succeed in [illegible] many small children write with their right hands. It seemed to work best with girls. Among children younger than nine who were subjected to these pressures, 60 per cent of the girls switched, but only 20 per cent of the boys.

Coren has also collected studies showing that the overall proportion of left and right-handed people has not changed in the US during this century. He has even surveyed art work in galleries and on the walls of caves to see how many people are shown holding tools or weapons in their left hands. Based on all these data, he concludes that the percentage of left-handers has stayed almost constant through history. The reason there is such a striking absence of elderly left-handers, Coren says, is because they must die early.

But both Hartge and the Academy of Actuaries dismissed the significance of Coren's historical studies, saying that only a valid study of life expectancy could resolve the question. This would require taking two matched groups, one of left-handed people and the other other of right-handed people, and keeping track of how many die as they get older. Apparently, no such study has been done. □

Mild winters blamed for dolphin deaths

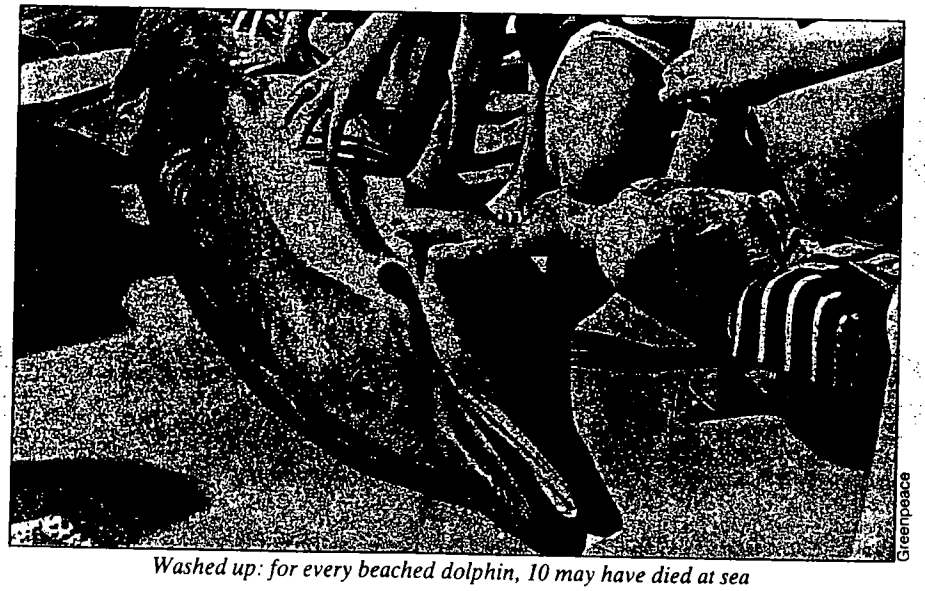
SPANISH biologists are blaming recent warm winters for the epidemic that killed hundreds, perhaps thousands, of striped dolphins in the Mediterranean last summer.

According to Alex Aguilar of Barcelona University, who is president of the European Cetacean Society, two successive mild winters with relatively little rain dramatically reduced food stocks in the Mediterranean, leaving the dolphins with weakened immune systems that lowered their defences against two deadly viruses: distemper and herpes.

"What struck us immediately on examining some of the 550 corpses washed up on beaches along the southeastern coast of Spain, was their inordinate lack of blubber," says Aguilar. His team of marine biologists now believes that as the dolphins were starved of food they mobilised their fat reserves. This released toxic polychlorinated biphenyls (PCBs) that had accumulated in their fat, freeing them to enter the bloodstream. "The PCBs further weakened the hungry dolphins and from what we have seen of liver samples taken from the dead animals, herpes and then distemper did the rest," Aguilar concludes.

After several attempts to explain what caused the deaths last summer, Aguilar's investigations revealed the presence of parasites, PCBs and the two viruses. But he said the fifth factor — the meteorological one — baffled him for months. Under normal conditions, healthy dolphins would not succumb to the viruses or PCB poisoning.

Reviewing weather patterns over the past two winters, Aguilar found that the production of nutrients in the sea which were normally stimulated by cold weather had been reduced, and because of the shortage of rain, little organic matter from land was flushed into the sea. Winds that usually drive local currents also failed to blow. "There was nothing to stir up what nutrients there were from the lower, more productive depths of the sea," he said.



Greenpeace

Washed up: for every beached dolphin, 10 may have died at sea

Aguilar thinks a sixth, unidentified factor was also at work. Most of the dolphins that washed up on the Spanish coast came ashore within a triangle formed by Valencia, Alicante and the Balearic Isles, where the greatest concentration of tourists are. "The epidemic here was particularly virulent," Aguilar says, "but we have yet to determine whether this was due to pollution, the total collapse of nutrients production, the massive presence of the viruses or what."

No one will ever know how many dolphins died. Some biologists suggest that for every corpse washed ashore, 10 more probably died at sea. After discussions with fishermen and the crews of research ships, who have spotted dozens of dead dolphins at sea, Aguilar agrees that the corpses found on beaches must be only a small percentage of the total.

According to Aguilar, the epidemic is now waning although several dolphins have been swept ashore on Spain's Atlantic shoreline this year. **Anthony Luke, Madrid**

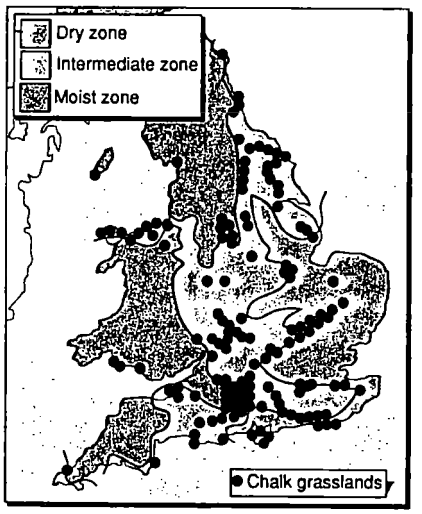
2: Looking for the first signs of climate change

AMONG the grasslands likely to be most affected by climate change in southern Britain is a community dominated by rich mixtures of small basiphilous tussock grasses, dicotyledonous herbs and mosses. The community occurs on sharply draining rendzina soils on a wide variety of limestones

If the climate of southern Britain becomes warmer and drier, as predictions suggest, this kind of grassland will change. It is likely to become more like a related community that is at present largely restricted to the chalk of East Anglia, where the climate is already quite continental.

So we will be looking for an opening up of the sward at our monitoring locations, with the loss of less drought-tolerant perennial plants; a spread of xerophytic mat plants able to capitalise on increased light, and an abundance of ephemeral plants germinating on patches of bare ground in the autumn, which are able to complete their life cycle before the soils become parched again in the summer. We will concentrate our observations on plots located close to the boundary between the two grassland communities, where we might expect responses to occur first.

Being naturally poor in nutrients, the rendzina soils that support these swards are especially prone to enrichment by nitro-gen deposited in various forms from the atmosphere. Comparison with similar grasslands on rather more fertile calcareous earths suggests that we might see a spread of bulky mesophytic herbs through the basiphilous swards. Com-bined with a more drought-prone climate, though, an increased deposition of nitrogen might encourage the spread of rank nutrient-demanding weeds through many grasslands on limestone in southern Britain. □



Chalk grasslands: early warning sites?

▶ The survey is already being put through its paces in two studies for the Department of the Environment: the Critical Pollution Loads and Climate Change programmes. We have begun to locate monitoring plots in representive stands of 14 different types of grassland on lime-rich bedrocks throughout Britain (see Box 2 for further details). Being on sharply draining, nutrient-poor soils, these grasslands will be among the first to register the impact of a drier climate. Even though the soils are generally well buffered against the effects of acid rain by the underlying lime-rich rocks, we have identified some borderline swards where surface acidification is likely to have an early effect.

What contribution can our classification scheme make to the management of Britain's vegetation resources? Human activity has influenced most plant communities in this country. Grazing or mowing grass; the cutting or burning of heaths; coppicing and extraction of timber; reclamation for farming or forestry; draining and the management of rivers, lakes and reservoirs; trampling, or just plain neglect—all have left their mark on our plant communities and their distributions. Our survey should help assess the likely impact of such activities on different types of vegetation, making it easier to know when to intervene or leave well alone.

For example, on Shakespeare Cliff near the exit of the Channel Tunnel workings, maritime grasslands have been mapped by a team of difficult-terrain surveyors from the former Nature Conservancy Council. We know from our survey that the intricate patterns of different plant communities here can be related to the salt from sea spray. How will these be affected by the wide berm of tunnelling waste being deposited along the foot of the cliff? Judging by the earlier effects of a smaller berm nearby, the waste will be more than sufficient to push the wave-break zone too far from the cliffs for sea-spray to control the vegetation pattern. The diverse zones of plant communities on Shakespeare Cliff are likely to be lost.

The results of the National Vegetation Classification should help us restore derelict ground and identify sites which had other uses and might now be valuable for conservation. We should be better able to restore plant communities, too. The Forestry Commission, for example, can now select sites with the best combinations of climate and soil for particular kinds of broadleaf afforestation.

Specifically, the commission can target a fen or heath site which already has vegetation elements of the semi-natural woodland that would be most appropriate for the site, an approach that could speed the development of a suitable field layer. The survey could also be used as a guide to the proportions of the particular trees and shrubs in the plantation.

The goal of sensitive conservation of the landscape and its resources is elusive and costly. And our research does not provide the last word on the definition of British plant communities. There are types of vegetation for which our coverage is rather sketchy, and the detailed distribution and extent of the communities we have classified remains to be catalogued in many parts of the country. Some of our comments about the environmental relationships of the vegetation types are also of necessity educated guesswork. Despite this, the classification is, we feel, a reliable tool for describing and studying plant comunities. We hope the work will help us all look with new interest at Britain's vegetation, which, for its own sake, deserves understanding and care. □

OA Photos

Cliffhanger: will work on the Channel Tunnel (background) destroy the plant communities of Shakespeare Cliff?

John Rodwell was coordinator of the National Vegetation Classification project and is now Director of the Unit of Vegetation Science at the University of Lancaster. The survey, *British Plant Communities*, is published by Cambridge University Press.

From Rafe Pomerance 11/20/90

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NYT 11/20/90

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The effect of the warming has hardly been wholly benign, contrary to what might be expected in northern climes, the study found. The researchers say the warmer temperatures have made droughts and forest fires more frequent, diminished soil moisture and disrupted the ability of the forests to renew themselves.

Other Harmful Effects

They also discovered that the warmth has decreased the flow of water into the region's myriad freshwater lakes, changed their chemistry and warmed them so that the future of a wide variety of aquatic fauna is threatened. These include lake trout and supporting species that make up one of the world's most valuable fisheries.

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As might be expected, the study did find some benign effects: in the spring, ice disappears from the lakes about three weeks earlier than it did before. Snow has become sparser, with midwinter melting occurring in most years. And in one of the biggest effects, the warming stimulated a long-term increase of nitrogen, a powerful fertilizer, in the lakes. One result was an enrichment of microscopic plant life, with a proliferation of diverse algae species.

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Any significant further warming would probably mean the extermination of the lake trout and other cold-water species on which they depend, Dr. Schindler said. It is not clear that fisheries of comparable value or ecosystems of comparable diversity would be quickly re-established, the study said. Bass could replace trout, Dr. Schindler said, but they would have to be stocked.

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PHOTOCOPY PRESERVATION

this also found?

403-492-3111

Rafe - urged witness?

THE
INTERPARLIAMENTARY
CONFERENCE ON THE
GLOBAL ENVIRONMENT

* get in touch w/
Susan Fletcher (Fog)

& ~~NOI~~ Marine
Mammal Commission
(seals?).

Rise in Carbon Dioxide May Alter Plant Life

Continued From Page C1

doubt that the growth spurt induced by carbon dioxide affects some plant species much more than others, and some very little if at all. Some trees, grasses and other plants will flourish at the expense of others, they say, disrupting the ecological makeup of croplands, forests, marshes and grasslands with consequences that will reverberate through entire ecosystems.

And because the nitrogen content of unfertilized plants is diluted as carbon dioxide stimulates their growth, they say, many will be less nutritious. Experiments suggest that some insects that eat such plants do not develop properly and display higher mortality rates even if they eat much more plant material to compensate for the lower quality. This, scientists fear, could reduce insect populations and affect entire food chains.

Scientists are also turning up evidence that increased carbon dioxide may alter the timing of plants' flowering, disrupting the interaction between some plants and their pollinators to the detriment of both.

"The consequences are unbelievably complicated and there are so many of them," says Dr. Fakhri A. Bazzaz, a plant ecologist at Harvard University who is in the forefront of research on the question. Experimental work suggests there is "no reason to be sanguine" about the responses of both natural and human-made ecosystems to higher levels of carbon dioxide, he said.

The Dynamics

Carbon Dioxide And Plant Growth

Carbon dioxide is the primary raw material used by plants in manufacturing carbohydrates from which they build their tissues and enzymes. Using energy acquired from visible light in photosynthesis, plants "fix" or capture carbon dioxide molecules from the air.

In the last century, roughly the industrial age, atmospheric carbon dioxide has increased to about 350 parts per million from about 280 parts per million. In the latter half of the next century, many scientists say, it will reach 600 to 700 parts per million if the current rate of increase continues.

Scientists have established that doubled concentrations of the gas would have startling effects on the growth of many types of plants, greatly increasing rates of photosynthesis and agricultural yields. One survey of 700 agronomic studies by Dr. Bruce Kimball at the Phoenix laboratory found that crop yields improved by 34 percent where carbon dioxide was doubled.

Trees and plants usually grow taller, produce more and bigger branches, flowers and fruit, display more and thicker leaves with more chlorophyll and send out more extensive root systems to search out more nutrients in the soil. Scientists have also established that increased carbon dioxide causes small pores on the outside of leaves, called stomata, to close slightly. This reduces the amount of moisture lost from the leaf to the atmosphere, enabling the plants to withstand drought better.

A number of studies have suggested that the carbon dioxide increases of the last few years are stimulating a worldwide surge of plant growth. Some scientists say this is reflected in increased widths of tree rings and in changes in the number of stomata on plant leaves.

But the chief evidence comes from studies by a number of independent researchers in the late 1980's showing that terrestrial vegetation in the Northern Hemisphere is absorbing more and more carbon dioxide in the spring and early summer and releasing more to the atmosphere as plants die in the fall.

"This tells me the biosphere as a whole is being stimulated," said Dr. Idso. "More carbon dioxide is being taken out of the atmosphere and more is being put back in, the biosphere breathes once a year and is breathing deeper."

Although plants emit oxygen as part of photosynthesis, he said, the amount added to the atmosphere because of increased growth would not be enough to have a significant effect on the vast pool of oxygen that animals breathe.

The Caveats

Not All Plants Respond Alike

Not all plants are taking in carbon dioxide at the same rate. The difference shows up most broadly between two main classes of plants, C3 and C4, so named because of differences in the way they absorb carbon dioxide. In the first stage of absorption, C3 plants manufacture a molecule with three carbon atoms, while C4 plants manufacture a four-atom molecule. The C4 molecule is part of a chemical mechanism, or "pump," that enables the plant to assimilate carbon dioxide more efficiently.

Lacking the more efficient mechanism of the C4 plants, the C3's depend on simple diffusion of carbon dioxide through their tissues. Higher concentrations of the gas in the air aid this diffusion, but make less difference to a C4 plant. The result is that C3's benefit more than C4's from the higher concentrations.

In the salt marshes of Chesapeake Bay south of Annapolis, scientists led by Dr. Bert Drake of the Smithsonian Environmental Research Center at Edgewater, Md., have studied the effects of increased carbon dioxide on naturally growing C3 and C4 marsh grasses for the last four years. Surrounded by special chambers that allow the plants to be saturated with carbon dioxide, the C3 grasses showed increases in photosynthetic rates and mass of 60 to 80 percent. The C4 grasses showed no increase. Both species demonstrated greater efficiency in water use.

Other species of C4 plants show some increase in growth amid increased carbon dioxide, but generally the C3's outperform them. Among C3's are many important field crops, including wheat, rice and soybeans, although a few field crops, like sugar cane and corn, are C4's. Virtually all trees and most broadleaf plants are C3's, while grasses may be either.

Some scientists say that with increased carbon dioxide, C4 crops will find it more difficult to compete with C3 weeds and vice versa.

Even within each of these broad classes, species respond differently. In a study led by Dr. Boyd Strain, a plant ecologist and physiologist at Duke University, two common southern species of C3 trees, sweet gum and loblolly pine, were subjected to higher carbon dioxide levels. Loblolly is the South's most important timber crop, and sweet gum is a major competitor for resources in the ecosystem they share. The study found that sweet gum seedlings, largely because of their broad leaves, responded more dramatically than the pines.

Many scientists believe differences in species' response to enhanced carbon dioxide, and other problems some attribute to the enhancement, can be satisfactorily managed and minimized in agricultural settings where one crop predominates, and that higher carbon dioxide levels will be an agricultural boon.

"Agriculture has survived so many catastrophic events," said Dr. David T. Patterson, a plant physiologist for the Department of Agriculture associated with Dr. Strain's laboratory. "It's likely that this change will also be weathered."

But the price of this might be high, says Dr. Bazzaz, since crops do not benefit from higher carbon dioxide levels unless more fertilizer is applied and more pesticides are used to kill insects and, in the case of C4 crops, competitive C3 weeds. This would increase costs, and farmers in some development countries might not be able to afford it, he said.

Tim Koors for The New York Times

Dr. Sherwood B. Idso with a three-year-old orange tree grown in high carbon dioxide levels at Agriculture Department laboratory, Phoenix. Such trees were found to be hardier in some respects.

Natural Ecosystems

The Impact On the Wild

Natural ecosystems cannot be managed like agricultural fields, Dr. Bazzaz said. Both Dr. Strain and Dr. Bazzaz, whose work deals mainly with natural ecosystems, say shifts in competitive advantage among plant species could produce far-reaching changes in the wild and even reduce the number of species.

In his laboratory at Harvard, Dr. Bazzaz has found that some annual plants do not do as well as others amid increased carbon dioxide. This, he said, suggests that annuals will leave fewer seeds when they die and that other species that do better in elevated carbon dioxide will become dominant the following year. Other experiments at Harvard have found that increased carbon dioxide altered the relative strength of five species of tropical trees.

While there is cause for concern on this score, Dr. Idso wrote in a 1989 review of research on the subject, it is possible that ecosystems could adjust much as forests did in the remote past, when carbon dioxide levels were higher than now.

Humans also have little or no control over what Dr. Bazzaz and Dr. Strain say is a drop in the nutritional quality of natural vegetation that accompanies its jump in quantity at higher levels of carbon dioxide.

"Without fertilizing the soil," said Dr. Strain, "you pump more carbon into the plant and the ratio of carbon to nitrogen or phosphorus goes way up." He said this means insects and other plant-eaters have to eat more plant material to get enough protein.

In an experiment at Dr. Bazzaz's laboratory, Dr. Eric D. Fajer found that larvae of the buckeye butterfly ate 20 to 30 percent more vegetation from plants when they were grown in an atmosphere of doubled carbon dioxide, but that even so they developed more slowly and had higher mortality rates. Dr. Bazzaz suggests such effects could "cascade down the food chain" as fewer insects survive to provide food for predators. Dr. Idso, in his recent review, wrote that while some studies have found harmful repercussions for a number of insect species, they have not done so for others.

Reduced nitrogen in plants could slow the decay of leaves and other plant litter, said Dr. Bazzaz, reducing soil fertility and producing a thick carpet of undecayed leaves and twigs that could hinder seed germination and, ultimately, the regeneration of forests. Dr. Idso says this could be offset by higher populations of litter-eating microorganisms that would be attracted to the larger root networks, and by an increase in earthworms.

While scientists struggle to learn how all these factors play out in nature, another question looms: If the global climate does warm substantially, how will this change the picture? Dr. Idso says the stress of high temperatures can be mitigated by carbon-dioxide enrichment. But studies at the University of Florida found that at both present and higher levels of carbon dioxide, grain yields decrease as temperature rises. A world 5 to 6 degrees warmer than now, as climatologists now predict by the end of the next century, "may not overpower the carbon dioxide effect, but we haven't run the numbers," said Dr. Hartwell Allen, a plant physiologist with the university and the Agriculture Department.

With the Arts
And Entertainment

Science Times

The New York Times

Carbon Dioxide Rise May Alter Plant Life, Researchers Say

Studies suggest the gas could feed a burst of vegetation.

By WILLIAM K. STEVENS

EVEN if rising concentrations of carbon dioxide in the atmosphere do not cause the earth's climate to warm, they will probably work dramatic changes in natural and agricultural ecosystems, plant physiologists and ecologists say.

In a research effort that has been accelerating over the last five years, scientists are uncovering intricate patterns of plant responses to higher levels of carbon dioxide. But they are a considerable distance from understanding the full range of responses or achieving a consensus on how the positive and negative effects add up on balance.

Carbon dioxide is accumulating in the atmosphere so rapidly, largely because of the burning of fossil fuels, that the global concentration will double by the end of the next century if the present rate of buildup continues, experts say. While scientists are still uncertain about the ultimate impact of the gas's heat-trapping properties on global climate, some believe that they can already detect the early stage of a worldwide explosion of vegetation stimulated by carbon dioxide, and their latest experiments suggest that astonishing developments may lie ahead.

In a controlled experiment at a Federal laboratory in Phoenix, for instance, orange trees raised from seedlings have been exposed to nearly doubled levels of carbon dioxide for the last three years. The combined volume of their trunks and branches is almost triple that of orange trees grown in normal air.

For some experts, this eye-opening growth portends major improvements in agricultural productivity, promises a lusher and more robust natural world, and suggests that burgeoning trees and other vegetation might remove enough carbon dioxide from the air to stabilize atmospheric concentrations, although at higher levels than now.

Scientists have found that plants growing amid higher carbon dioxide levels also are hardier in some respects. They use water more efficiently and because of their greater mass, they can better resist stress in general.

"I'm really sold on carbon dioxide; I think it's very beneficial," said Dr. Sherwood B. Idso of the Agriculture Department's water conservation laboratory in Phoenix, where the orange-tree experiment is under way.

But other scientists, urging caution, are not so sure, and some say it is possible that greater carbon dioxide levels may be harmful on balance. They say the growth can be limited or even canceled out by a number of offsetting factors, particularly shortages of soil nutrients. They also say a growing body of research leaves no

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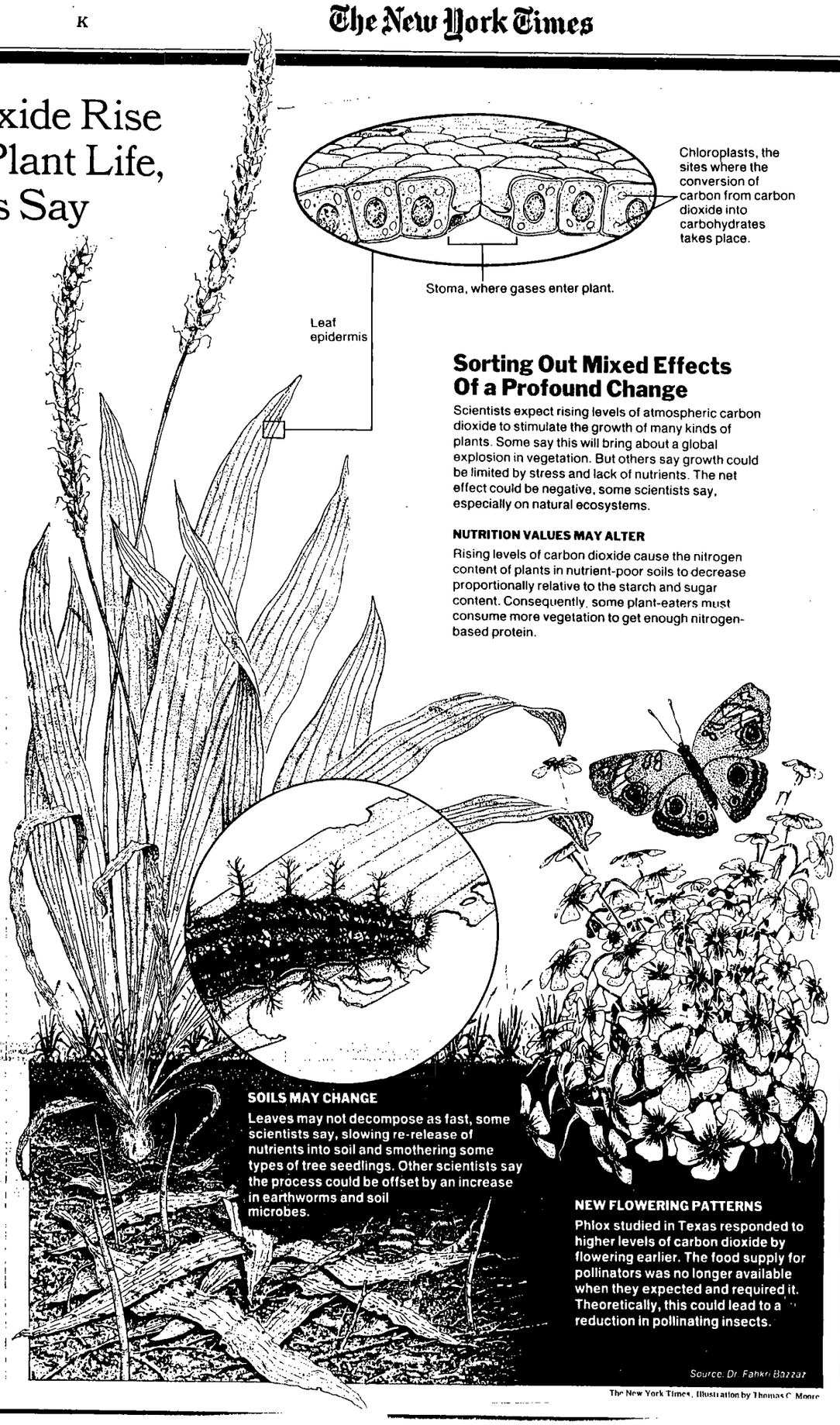

Sorting Out Mixed Effects Of a Profound Change

Scientists expect rising levels of atmospheric carbon dioxide to stimulate the growth of many kinds of plants. Some say this will bring about a global explosion in vegetation. But others say growth could be limited by stress and lack of nutrients. The net effect could be negative, some scientists say, especially on natural ecosystems.

NUTRITION VALUES MAY ALTER

Rising levels of carbon dioxide cause the nitrogen content of plants in nutrient-poor soils to decrease proportionally relative to the starch and sugar content. Consequently, some plant-eaters must consume more vegetation to get enough nitrogen-based protein.

The New York Times, Illustration by Thomas C. Moore

...of skull reconstruction surgery. ...allow surgeons to plan and even simulate ...complicated reconstructive operations of the ... Continued on Page C6

Plants May Teach How to Make Fuel From Sunbeams

By WILLIAM K. STEVENS

SCIENTISTS believe they are on the verge of constructing test-tube versions of photosynthesis, the basic life process in which plants tap the sun's energy. Their aim is to open the way to new sources of usable energy based on the cheapest and most abundant of raw materials: sunlight, water and carbon dioxide.

In principle, the effort could eventually enable chemists to mount a new two-front attack on the threat of global warming posed by the buildup of carbon dioxide from burning fossil fuels. Artificial assemblies of photosynthetic molecules that converted the sun's energy into liquid fuels like hydrogen would both cut demand for oil, and remove carbon dioxide from the atmosphere.

"That's the dream," said Dr. Mark Wrighton, a chemist at the Massachusetts Institute of Technology who is in the forefront of photosynthesis research.

"We can see how to do it and we're embarking at this point on a faithful reproduction of the biological system," he said in an interview. "We hope we'll be able to make inexpensive molecules, make them efficiently and make them durable."

Dr. Wrighton was the main speaker on the subject at the Second Annual Frontiers of Science Symposium conducted recently by the National Academy of Sciences at Irvine, Calif., where many of the latest advances were described.

> Scientists hope artificial photosynthesis will be a clean and abundant source of liquid fuels.

"Understanding has been developing very, very fast," and the close circle of scientists working on the problem has become "a very excited group of people," said Dr. George L. McLendon of the University of Rochester, another speaker.

In a critical step, chemists have already put together elegant artificial versions of the basic molecular mechanism that is at the heart of photosynthesis. In this mechanism, solar energy strikes molecules of chlorophyll inside the leaves of green plants. The energy infuses electrons with new force, sending them leaping and cascading from molecule to molecule, transferring energy as they go.

The chain of reactions ultimately results in the conversion of atmospheric carbon dioxide to the carbohydrates that sustain almost all life. Oxygen is released to the atmosphere as a byproduct.

Scientists believe they will be able in time to manipulate the process to produce not only carbohydrates, but also hydrogen, methane and other forms of chemical energy. Methane is the essential ingredient of natural gas, the burning of which emits less carbon dioxide than either coal or oil. The burning of hydrogen emits no carbon dioxide. It could be used to power motor vehicles or, combined with oxygen in a fuel cell, to make electricity.

Plants convert solar energy to chemical energy inside organs called chloroplasts, tiny components of plant cells. The parts of the chloroplast that capture solar energy and set off the cascade of electrons are known as photochemical reaction centers. These are complexes of proteins and the green-colored chlorophyll molecules that give plants their distinctive color.

Photosynthesis begins when particles of light, known as photons, strike molecules of chlorophyll. Each photon boosts an electron

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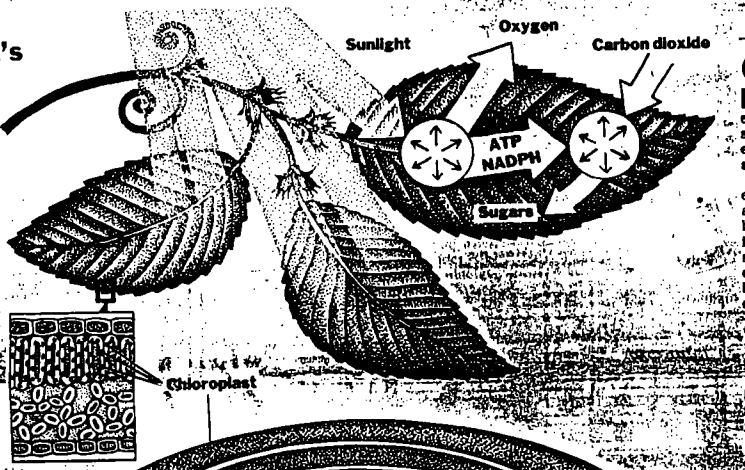
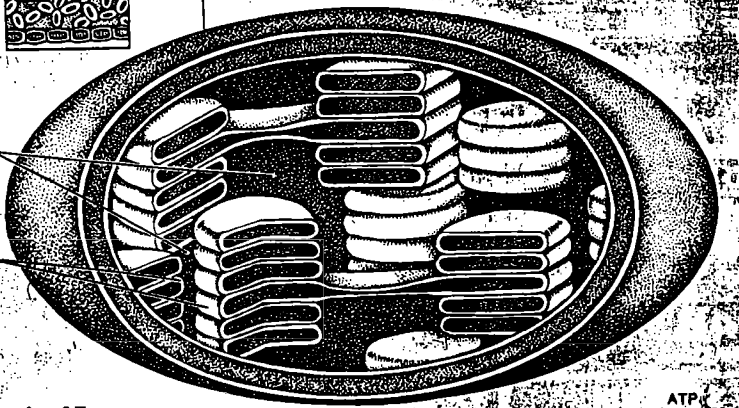
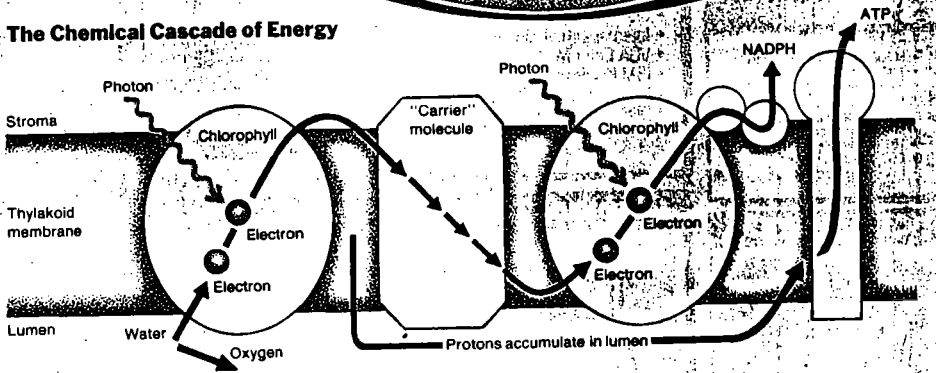
Green Power: Inside the Plant's Energy Factory

In photosynthesis, plants convert solar energy into the compounds ATP and NADPH, which play key roles in chemical reactions that create sugars out of atmospheric carbon dioxide. The sugars sustain almost all life, and the process releases oxygen to the atmosphere as a byproduct. All this takes place in tiny organs called chloroplasts within leaf cells. Scientists hope to open up new sources of energy by duplicating the process artificially.





The Chemical Cascade of Energy



Photosynthesis begins inside a complex of proteins and chorophyll, called a photochemical reaction center, when a photon, or particle of sunlight, strikes a chlorophyll molecule.

The photon boosts an electron to a higher energy state, and it jumps to a special "carrier" molecule. This is the first in a sequence of such electron leaps. At the same time, protons accumulate in the lumen, or cell interior.

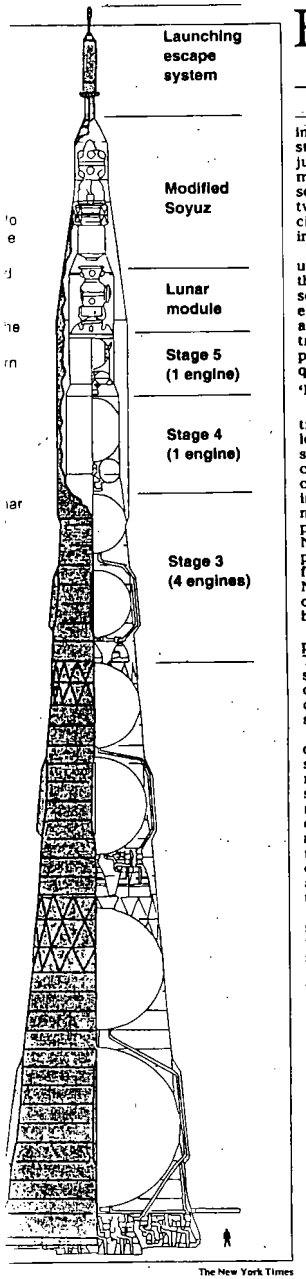
Electrons lose energy along the way. To regain it, they jump to a second chlorophyll molecule, where a second photon reboosts the energy level, and a second cascade of electrons begins. It ends with the synthesis of NADPH.

The protons that have accumulated in the lumen trigger the synthesis of ATP. Outside the photochemical reaction center, in the stroma, ATP and NADPH drive the manufacture of sugars from carbon dioxide.

To restore the system to its initial state, the electron that is lost from chlorophyll at the start must be replaced. It comes from water molecules which then react to release oxygen to the air.

Sources: Dr. Mark Wrighton; "Molecular Biology of the Cell" (Garland); "Molecular Cell Biology" (Scientific American Books)

The New York Times; Illustration by Patricia J. Wynne



The New York Times

Plants May Teach How to Get Fuel From Sun

Continued From Page C1

in the chlorophyll to a higher energy state. The excited electron then jumps across to a special "carrier" molecule nearby. This is the first in a sequence of leaps by electrons between molecules that are held in precise positions in a special membrane in the reaction center.

Along the way, the electrons give up some of the energy imparted to them by the photon. In a reaction separate from the chain of jumping electrons, this energy is harvested as a compound known as adenosine triphosphate, or ATP. This compound plays an important role in the subsequent manufacture of carbohydrates.

'Dark Photosynthesis'

Back in the main stream of electron flow, the energy level of the leaping electrons is reboosted by a second photon, and the electrons cascade down a second series of molecules. This chain of events culminates in the creation ofa molecule called nicotinamide adenine dinucleotide phosphate hydride, or NADPH. The NADPH molecule is a sort of special-purpose battery that stores electrons for the vital reaction in which NADPH teams with ATP to convert carbon dioxide from the air into carbohydratea, or sugars.

These sugars provide food for plants and hence for almost all life. The reactions that create them constitute a second phase of the process, called "dark photosynthesis" because it is not directly dependent on sunlight.

The electron that is lost at the start of photosynthesis, when a photon strikes the first chlorophyll molecule, must be replaced so as to restore the system to its initial state. Replacement electrons come from water molecules through a mechanism that is not yet completely understood. In surrendering electrons, the water molecules split apart into hydrogen atoms and oxygen. The oxygen is released to the atmosphere.

Despite their considerable understanding of this mechanism, scientists have only recently gained insight into what Dr. McLendon calls the "basic ground rules that nature is playing with." These involve, for instance, such critical details as the way in which the parts of the system are physically arranged in relation to each other, the distances electrons must travel and the speeds at which the action takes place.

"There is nothing magic about the molecules used in photosynthesis," said Dr. Thomas E. Mallouk of the University of Texas at Austin, another participant in the Frontiers of Science symposium. "What's special about it is that they're organized in a certain spatial arrangement that allows the electrons to go in one direction in the chain."

How the leap of electrons happens "is one of the big things that's been worked out in the past six years," said Dr. McLendon. "The distances that the electron has to jump are very big compared to the sizes of the molecules. It is clear that in photosynthesis, electrons can jump a lot farther than we used to think."

Building Molecules That Work

In the last few years, scientists in several laboratories have designed assemblies of molecules that mimic the photochemical reaction center in its ability to absorb photons and excite electrons. "We can make very complicated molecules now, and big ones," and they work, said Dr. Wrighton of M.I.T., whose laboratory is one of the makers.

> 'There is nothing magic about the molecules used in photosynthesis.'

The first such molecule was synthesized in 1983 by chemists at Arizona State University. It consisted of an electron-donating molecule, a light-absorbing molecule and an electron-accepting molecule, all linked in the right way to make the photochemical reaction possible.

Scientists say progress has been rapid since then, and several laboratories have produced synthetic molecules that duplicate the essence of photosynthesis.

One of the latest, reported last year, is a five-part molecule called the pentad system, produced by the Arizona State laboratory that first created the triad molecule. "We're basically using the same building blocks as nature, but we're controlling the structure differently," said Dr. Devens Gust, a leader of the Arizona team.

The pentad molecule is made of organic chemicals that absorb light and receive and donate electrons. The chemicals are porphyrins, quinones and sometimes materials derived from chlorophyll itself. But while nature embeds the molecules in protein, the Arizona State researchers hold them together through chemical bonds.

The salient advantage of the molecule, said Dr. Gust, is that it mimics the multistep cascading of electrons so as to maintain an energetic state long enough for useful products to be derived. If the chain is too short, the energy will simply dissipate before anything useful can happen.

'Microscopic Swiss Cheese'

Dr. Mallouk's group at the University of Texas is duplicating the light-induced cascade of electrons with a chain of nonbiological molecules containing the metal ruthenium. These molecules absorb light like chlorophyll. The molecule was devised by Michael Grätzel, a Swiss chemist.

The Texas team has strung five of these molecules together, embedding them in a matrix made from minerals called zeolites. The zeolites are full of empty spaces, "like microscopic Swiss cheese," says Dr. Mallouk, and the spaces can be strung together to make tunnels about the size of a molecule.

By choosing zeolites with the right pore size, the Texas team believes it will be possible to solve a major problem: how to hold the molecules in place at proper distances and angles from each other. This orientation "is going to be central to getting high efficiency whether we make electricity or, whether we make chemical fuel," said Dr. Wrighton.

In the first place, the molecule at one end of the electron-transfer chain must be kept away from the molecule at the other end; otherwise, the two molecules would exchange electrons and all the energy originally absorbed from the sun would be lost as heat. And even if they can be kept apart, molecules must be arranged in certain ways, relative to each other, for maximum efficiency of energy conversion from solar to chemical.

Most of the artificial assemblies of molecules until now have been suspended in an electrolyte solution. This means that although the early steps of photosynthesis can be carried out efficiently, the energy is ultimately dissipated. Apart from the Texas zeolite method, researchers are trying to embed the molecules in some sort of

> Scientists expect to make hydrogen and methane as well as carbohydrates.

biological material, as in nature, to bind them to films, and to suspend them chemically, as Dr. Wrighton's group is trying to do, between two electrodes.

Researchers face an even more difficult problem in the question of how water molecules yield up electrons to replace those lost by chlorophyll. They do not fully understand this process, although they know that a manganese compound plays a critical role.

'Like a Tinker Toy Box'

A group headed by Dr. Thomas J. Meyer of the University of North Carolina is approaching the problem by substituting a ruthenium compound for the manganese compound, which is hard to manipulate in an artificial system because it is so unstable. The more stable ruthenium mimics the action of manganese so well, said Dr. Meyer, that "we're beginning to get a good handle" on electron replacement.

Still another challenge is presented by "dark photosynthesis," the final part of the process in which NADPH and ATP are used to create carbohydrates from carbon dioxide. Duplicating this, says Dr. Meyer, "is difficult chemistry" and "no picnic."

How close are scientists to fashioning artificial photosynthetic systems that could produce usable energy?

"We could almost put all this together in a single device now, but we're not quite ready yet," said Dr. Meyer. "It's just like a Tinker Toy box. All the pieces are lying around, some of them assembled, but the complete assembly has yet to be done."

Dr. McLendon says that while "many people have done elegant synthesis and have made some lovely molecules," scientists understand the process "to about a 90 percent level.

"But that's like saying we understand engineering principles to within 90 percent of building a bridge," he said. "You wouldn't want to drive over it."

Economic Question Remains

And even if all these problems are solved, years of further development will be required before any operational devices can be produced.

A major question is how much of the energy carried by photons can be converted to practical use. Theoretically, said Dr. Wrighton, 20 to 25 percent could be converted. This efficiency would rival that of conventional photovoltaic systems.

With such efficiencies, scientists believe, artificial photosynthesis might be used to produce a variety of fuels. In theory, chemists could manipulate the photochemical reaction center so as to produce methane or hydrogen in place of NADPH.

Once the technical problems are solved, the question of economic feasibility remains. But the prospect of converting the sun's energy directly into liquid fuels, and of removing unwanted carbon dioxide from the atmosphere, is too important to ignore. So scientists are pressing ahead on the basic science of the problem in the hope of an eventual payoff.

Dr. McLendon calls it "the scientific field-of-dreams approach" to technological advance: "If you build the foundation, it will come."

which has increased by 400 percent in the past few years. Mayor Agnos speaking at a kickoff ceremony for the program: "Our solution is not going to be vacuuming up people like a toxic oil spill and shoving them into jails" (Jane Ganahl, S. F. EXAMINER, 7/19).

*23 FLORIDA: CRACKING DOWN ON ENVIRONMENTAL CRIMES

Dale J. Mills, a Gainesville engineer, was indicted on federal criminal charges that he knowingly concealed wetland and river pollution at a wastewater treatment plant in Zolfo Springs, FL. The charges say that Mills used incorrect site drawings to conceal underground pipes and a conduit which discharged "effluent and other pollutants" into area wetlands and rivers, reports Tom Lyons of the GAINESVILLE SUN.

For each count on the indictment Mills faces a possible five-year prison term and $250,000 fine. U.S. Attorney Robert Genzman in a recent statement: "Environmental crimes are a growing concern in this state, and we intend to pursue environmental offenders to the full extent of the law" (7/20).

*24 NORTH CAROLINA: UNIVERSITIES POOL RESOURCES TO SAVE THEM

Duke, North Carolina State and University of North Carolina at Chapel Hill have decided to unite to fight global environmental pollution. Organized under The Center for World Environment and Sustainable Development, the three universities plan to concentrate on tropical conservation and development, environmental problems in industrialized countries and worldwide environmental change. Initially, the universities funded the entire program but future funding will come from U.S. government agencies and private foundations and organizations (Kirstin A. Conover, C.S. MONITOR, 7/22).

*25 WISCONSIN: FISH KILL IN THE FOX RIVER

About 4,000 fish were killed in WI's Fox River near the Menasha marina and state fisheries officials blamed the die-off on a combination of low oxygen due to an algae buildup, and high temperatures (CHICAGO TRIBUNE). White bass, walleye, sheepshead, perch, bluegills and crappies were among those killed. Ron Bruch, state Department of Natural Resources: "There is virtually no oxygen [in the water] right now. They're dying in the marina and in the locks channel, both of which are man-made structures that were apparently poorly designed for water flow-through." Department biologist Art Techlow called the die-off substantial: "This type of thing is not uncommon, but it's usually on a much smaller scale" (7/24).

* copy of biological indicators

========== POLL UPDATE ==========

*26 ATI POLL: AMERICANS FAVOR U.S. LEADERSHIP ON GLOBAL ISSUES

recycles its own products and nips toxic spills in the bud." Reduced packaging and an $11 million waste-to-energy heating-and-cooling plant has cut the company's trash by 90 percent since 1982 in addition to saving the company $750,000 a year in fuel and landfill costs. By the end of this year, the plant will have paid for itself -- 10 years ahead of schedule. It has saved an additional $550,000 by eliminating excess packaging and utilizing reusable shipping wrap.

Joe Azzarello, an engineer who oversees the waste-to-energy plant is "among the company's best idea people. ... Azzarello's goal is to end trips to the dump by 1995." The company already recycles leather, vinyl, foam, office paper, phone books, and lubricating oil. Miller has also been involved in reconditioning used furniture and developing products with cradle-to-grave factors, such as recycled materials used to make re-recyclable objects, as part of the design. The company has also spent $800,000 on incinerators that burn toxic solvents escaping from booths in which furniture is stained and varnished.

Miller has decided not to advertise any of their efforts because Philip Mercorella, senior vp for sales, sees '"green marketing' as a ploy that will eventually wear thin with customers. And why advertise if you aren't perfect?" Woodruff writes. Miller recycles only 15% of its corrugated cardboard, choosing to burn most of it in the energy plant.

Another reason not to advertise is that plants outside MI tend to be less vigilant. Helikon Furniture Co., a former CT subsidiary, improperly stored solvents that seeped into the ground and cost $200,000 to clean up before Miller sold the plant (9/16 issue).

*10 MONT PELERIN: GREEN UNLIKE US

The same week communism was falling in the Soviet Union, at a meeting of the Mont Pelerin Society, "the world's leading group of free-market scholars," in Big Sky, MT, "members plunged into trying to build a free-market environmental movement. The transition was appropriate. As communism exits history's stage, the main threat to liberty may come from a utopian environmental movement that, like socialism, views the welfare of human beings as subordinate to 'higher' values," writes W.S. JOURNAL editorial writer John Fund.

Mont Pelerins fear that radical environmentalists, like the Green Party, threaten the free market. "True conservationists in Europe have no use for quasi-Marxist Greens," says Peter Stein of Sweden, where voters eliminated the green Party Sunday. "They call them watermelons -- green on the outside and red on the inside" (9/19).========== GLOBAL ISSUES ==========

*11 CLIMATE: CHANGE CAUSED MASS OCEAN EXTINCTIONS IN PALEOCENE

A period of relatively rapid global warming some 57 million years ago altered the chemical and biological composition in the waters of Antarctica and led to a mass extinction of marine life, according to a study by J. P. Kennett of the Marine Science Institute and L.D. Stott of the U. of Southern California's geology department.

Their report, carried in the current issue of NATURE magazine, found, however, that it was those organisms living on the ocean bottom or deep ocean that were wiped out by changing climate. Plankton floating in the upper ocean or in shallow water were relatively unaffected, according to the study, which examined rock strata taken from beneath the Weddell Sea. The differing fate of the sea organisms was apparently a result of a shifting distribution of oxygen and nitrogen in the layers of water as a result of the global warming trend (9/19).

The record of what happened to marine life 57 million years ago could offer a clue as to what to expect in the warming trend projected for the next century by many computer models.

*12 CLIMATE II: EL NINO READY TO BE A BAD BOY AGAIN

El Nino, the current of warm water that wanders around the central and southern Pacific Ocean, is preparing to do mischief again, reports a team of scientists in Australia.

The current, which in the past has produced damaging climate effects including droughts in Australia, famine in Africa and floods in South America, is building for a return according to a REUTERS report from Sydney carried by the MIAMI HERALD. "We're looking at a very bad period ahead," said Dr. Roger Stone of Australia's Queensland University.

Some strange climate effects have been occurring already which might be attributable to the return of El Nino. These include snow falling in Chile's normally bone-dry Atacama desert, mud slides that killed 116 people in the Chilean port of Antofagasta and August's torrential rains in Ecuador that killed crops. Large areas of Australia are experiencing severe drought (9/16).

========== WORLDVIEW ==========

*13 CHERNOBYL: MONITORING OF HEALTH EFFECTS STILL INADEQUATE

More than five years after the disastrous explosion of the nuclear power plant in the Ukraine, there still is no reliable system to monitor the health of the 280,000 people who continue to live in the contaminated area, writes Paul Taylor in the Toronto GLOBE AND MAIL.

Now, however, Ukrainian doctors are being brought to the U. of Toronto to learn more about monitoring and treating radiation-related illnesses. "The politics, the medical structure and

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University of Michigan
October 1991
Volume 1, No. 3

Global Change

Newsletter of the Project for the Integrated Study of Global Change

The Project for the Integrated Study of Global Change (GCP) began in February 1990 with funding provided by the University of Michigan. It was formed to develop inter-disciplinary research and curriculum to address the complex problems of global change. The objectives of the GCP are to stimulate awareness of the relationship between human behavior and the global environment, focus resources to increase the scientific understanding of global change, and provide research findings to individuals and policy makers. The GCP is comprised of a number of research programs, including the Population Environment Dynamics Project (PEDP) and the Project in Biodiversity Conservation, devoted to studying specific aspects of global change.

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IN THIS ISSUE:

EDITORS' NOTE

This second issue of the Global Change Newsletter for Fall 1991 continues the series on the relationship between global change and public policy by looking at the link between scientific integrity and effective communication. It also introduces some of the groundbreaking work being conducted at the University of Michigan regarding the relationship between global warming and the geographic distributions of wildlife.

Editors: Danielle Gordon, Matthew Wunder, Leslie Gray.

Biological & Ecological Consequences of Global Climate Change

If research conducted by University of Michigan scientists is correct, Kirtland's Warbler, which breeds in a narrow band of jackpine forests in Northern Michigan, could become the first recorded extinction in this state directly attributable to global warming. The forests, which are the only known breeding habitat for this small bird, could be forced northward by the increase in temperature. In a less sandy habitat, reproduction would suffer and the population could decline. Extinction is the most severe consequence of a disturbing trend in species range shifts that can be attributed to global warming. In essence, the climate is changing extremely fast and some of the plant and animal species existing today may not be able to respond rapidly enough to readjust.

A rise in the earth's temperature will occur over the next century due to increased concentrations of carbon dioxide, chloro-fluoro-carbons, methane and nitrogen oxides in the atmosphere which produce the greenhouse effect. Although this change may average only a few degrees C, it may have a dramatic effect on species distributions because of very specific physiological limitations. During the last ice age, some 18,000 years ago, temperatures were about 3 to 5 °C cooler than the current interglacial era. The gradual warming, which took five to ten thousand years to occur, has radically transformed natural ecosystems throughout the world, allowing whole assemblages of plants and animals to move towards the poles and trapping populations on islands as sea levels rose. The changing climate altered effective precipitation, temperature regimes and growing season length, which significantly influenced the distribution and lifestyles of humans around the globe.

Temperature is a key factor affecting the survival of individual plants and animals, and ultimately species distributions. The collective responses of individuals will determine a species' range. While most species have fluctuating core temperatures that reflect ambient conditions, birds and mammals must expend energy to maintain body temperatures within a very narrow band. In addition, plants must have an adequate frost free period to grow and reproduce. If the climate changes beyond the range of tolerance, the organism must either move, as some animals can, or die. Climate can influence organisms through the frequency, intensity, and duration of extreme temperatures which kill individuals. Overall temperature

Continued on next page