coral its color, through an imperfectly understood mechanism. But severe bleaching, a result of an excessive loss of zooxanthellae, can kill the coral. Record-high sea surface temperatures in tropical regions during the 1997–98 El Niño–Southern Oscillation led to the most extensive coral bleaching event ever seen. And because coral reefs host a disproportionate share of marine life, their loss represents a serious blow to the ecosystem.

Done studies a reef outside one of the Lakshadweep Islands off India's west coast that, like many Indian Ocean reefs, looked "like a graveyard" after the 1998 bleaching. But in a March survey of the reef, Done found a surprising amount of new coral, of a size that indicates it must have settled and begun growing at just about the time of the bleaching. Their presence poses a mystery. "If they drifted in after the bleaching, it isn't clear where they would have come from," Done says, as several species of adult coral were virtually wiped out in the bleaching. But if they arrived before the bleaching, as he suspects, "how did they survive?"

One bleaching hypothesis holds that the high water temperatures disrupt enzymes in the zooxanthellae, which then create toxic byproducts during photosynthesis. Done speculates that the new coral had minimal zooxanthellae in their tissue, which would have spared them these toxic effects. And by lodging in cracks and fissures, the coral were shielded from the sun's normal ultraviolet radiation that would have accelerated production of the toxins.

Other scientists are seeing similar recoveries, although they say the recovery mechanism is not clear. William Allison, a marine biologist with Sea Explorers Association in the Maldives, also reports seeing "survival of corals that must have settled during or shortly before or after the bleaching event." And Robert Richmond, a marine biologist at the University of Guam in Mangilao, says that recent surveys of reefs near Palau have turned up "some very nice [coral] recruits in areas that had been hit by the bleaching events." Although these corals likely have arrived since the bleaching, he says that any recovery is "good news."

However, not all reports are so upbeat. In a February survey of reefs near Belize in the Caribbean that virtually collapsed during the El Niño bleaching, Richard Ransom of Dauphin Island Sea Lab in Alabama found "no signs of recovery." Even the recovery events in the Pacific and Indian oceans, he notes, are patchy and seem to depend on the absence of other stress factors.

That connection puts the fate of the coral reefs in the hands of any future global warming trend. Coral have a good chance to recover from a one-time, short-term disturbance like bleaching if water and substrata quality are sufficiently high and there is a viable adult population within a reasonable distance, says Richmond. "But if you then kick it and stomp on it, there is a limit to the stress it can take," he adds.

Done notes that it may become harder for coral reefs to enjoy the decade or more of undisturbed growth needed for a full recovery if global warming triggers more episodes of severe bleaching. Under such a scenario, he says, "this recovery won't do the reefs much good. They'll no sooner get 1 or 2 years old before they'll be wiped out again."

–DENNIS NORMILE

CLIMATE CHANGE

Panel Estimates Possible Carbon 'Sinks'

The December 1997 Kyoto Protocol was a major milestone on the road to addressing human-induced climate change, but it left unanswered many questions that have stalled the treaty's ratification. One of the most vexing: Just how much carbon can a forest or farmland hold, and how easy is it to measure? The reason it's an issue is that the protocol allows developed countries to meet tough carbon emissions targets—5% below 1990 levels, between 2008 and 2012—both by reducing emissions from fossil fuels and, in a controversial option, by "sequestering" carbon in forests or other types of land. A new report* attempts to answer the question scientifically, but it is unlikely to make the option more palatable politically.

Some European countries and environmental groups object to allowing developed countries to get too much credit for carbon sinks because they think it will let energy-guzzling countries such as the United States off the hook. Storing carbon in forests and fields won't stave off the need to find renewable energy sources, and it's too difficult to accurately track how much carbon they hold, say such groups as the World Wildlife Fund. Leery that countries won't cut emissions and that sequestration won't work, these critics want to limit how much of a country's emissions can be reduced this way.

Leaving the political issues aside, the new report—written by a scientific panel of the United Nations–sponsored Intergovernmental Panel on Climate Change (IPCC) and approved by delegates from over 100 countries this week at a meeting in Montreal—adds long-awaited numbers and a how-to manual to what has, until now, been a murky academic debate. "There was a lot of mystery for the delegates. Now the scientists have really aired it out, and there's a good source of information," says Mike Coda, a climate change analyst with The Nature Conservancy in Arlington, Virginia.

HOW MUCH CARBON COULD THEY HOLD? (Megatons C/year)

Newly planted and regrowing forests*	197 to 584
Deforestation	–1788
Better management of:	
Croplands (no-till, erosion control, etc.)	125
Grazing land	240
Forests (fertilization, species choices, etc.)	170
Changes in land use:	
Agroforestry (grow crop trees, such as orange or apple, on unproductive grassland and cropland)	390
Cropland to grassland	38
Other	42

* At rate of current activities using IPCC definitions.

SOURCE: IPCC

The 460-page report runs through a dozen types of land uses, such as regenerating forests or converting cropland to grassland, spelling out just how much carbon might be socked away in each. The answer is, a lot. The report, informally known as the "sinks" report, suggests that, at first glance, the 41 developed countries could meet their Kyoto goals of cutting 200 megatons of carbon emissions per year entirely through land use changes rather than by reducing emissions from fossil fuels (see table). But following this route could be tricky, cautions the report, which offers a plethora of caveats concerning the difficulty of measuring how much these lands store.

For forests, however, the tally is mandatory: Countries will get credit for the forests they have grown or be docked for the trees they have lost since 1990. With so much at stake, just defining what a forest is has been controversial. For example, define a forest as 70% canopy cover, and countries with savanna forests, which have sparse canopies, might feel free to mow them down. Also crucial, the report notes, is whether forests that are harvested commercially and replanted should be counted.

But answering those questions is far simpler than estimating how much carbon might be stored by changing the use of other types of land, such as farmland. The protocol

* IPCC Special Report: Land Use, Land-Use Change, and Forestry. Available in June; contact: ipcc-sec@gateway.umo.ch

makes a vague reference to sequestering carbon through these "additional activities"; the IPCC panel ended up with the tough task of clarifying this option. First, scientists had to agree on how much of a particular land type exists globally, and then how much carbon it might hold if its management changed. Improving agricultural practices over the 1300 megahectares now in use, for instance, could save 125 megatons of carbon a year, the panel estimated. But experts caution that such estimates are optimistic and difficult to verify. Compared to forests, which "are pretty easy to see from space," tracking carbon soaked up by fields is "a lot harder," says panelist Richard Houghton of the Woods Hole Research Center in Massachusetts.

The report also discusses the feasibility of allowing developed countries to offset emissions by planting, protecting, or managing forests in developing countries (*Science*, 24 July 1998, p. 504). Such mechanisms can have "benefits," says the report, but there are risks, for instance, that displaced people will deforest lands elsewhere. Some European countries want to limit such offsets, maintaining that developed countries should reduce their own use of fossil fuels instead.

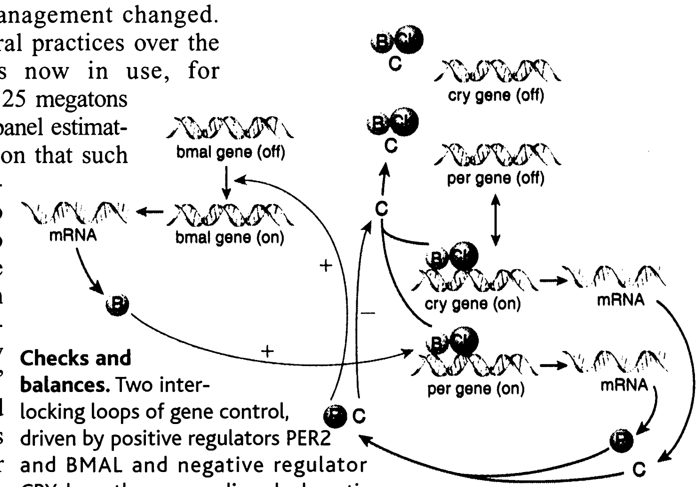
Now that this report has laid out carbon accounting options, countries must decide which ones to pursue before the next major meeting of Kyoto parties in November to finalize the treaty. —**JOCELYN KAISER**

CIRCADIAN RHYTHMS

Two Feedback Loops Run Mammalian Clock

As a grandfather clock keeps time with an oscillating pendulum, the 24-hour rhythm of the biological clock is also maintained by oscillations—in this case by oscillating levels of proteins. But the biological clock has two oscillations moving in counterpoint; the levels of one set of proteins cresting while the others are low, and vice versa. Results described on page 1013 now show how the mammalian form of the biological clock keeps those opposed oscillations in sync.

A team led by Steven Reppert of Harvard Medical School in Boston reports that the key to this regulation seems to be a pair of proteins that enter the cell nucleus together but then apparently split their duties. One, called CRYPTOCHROME (CRY), turns off a set of genes, while the other, PERIOD2 (PER2), turns on a key gene. The work "explains how genes can be activated in two opposite phases," says clock researcher Paul Hardin of the University of Houston, whose group recently made a similar discovery about the clock of fruit flies.



Checks and balances. Two interlocking loops of gene control, driven by positive regulators PER2 and BMAL and negative regulator CRY, keep the mammalian clock on time.

Researchers are excited by the way the new work clarifies the role of CRY in the mammalian clock. In fruit flies, CRY, which absorbs light, helps reset the clock in response to light (*Science*, 23 July 1999, p. 506). But the mammalian clock, deep in the brain, doesn't receive direct light input, so researchers wondered what function CRY could be serving there. Reppert's team has now "firmly established" that CRY is a central component of the clockworks, where it turns off key clock genes, says circadian rhythm researcher Steve Kay of the Scripps Research Institute in La Jolla, California. What's more, it seems able to do this alone, without the aid of PER2, the protein previously thought to do the job.

The Reppert team's findings build on work on the fruit fly clock, which features a negative feedback loop similar to the one in which CRY participates. In flies, the feedback is accomplished by PER together with a protein called TIMELESS (TIM). The *per* and *tim* genes turn on in the morning, and the two proteins accumulate in the cytoplasm during the day. By evening, when they reach a critical concentration, they pair up and go to the nucleus to shut down their own genes. This feedback helps keep PER and TIM protein levels oscillating up and down every 24 hours.

But that is only half of the story. A protein called CLK oscillates in counterpoint with PER and TIM; its levels rise as theirs fall and vice versa. CLK is a positive regulator that pairs with a protein called CYC to turn the *per* and *tim* genes on. Indeed, PER and TIM shut their genes off by binding to and inactivating CLK and CYC.

Mammalian clocks use many of these same proteins, although mammals have three

ScienceScope

Not-So-Small Doubts The National Science Foundation (NSF) is looking for a giant-sized, 124% increase in nanotechnology research to lead the Administration's half-billion-dollar initiative (*Science*, 11 February, p. 952). But even legislators impressed with nanoscience's potential aren't sure that NSF is up to the job of overseeing five other agency efforts.

"Powerful bureaucracies usually win out over science," Senator Barbara Mikulski (D–MD) said last week during a hearing on NSF's 2001 budget request, worrying that the foundation could be pushed around by the program's bigger partners. "NSF may be trying to take on more than it can handle," added Senator Kit Bond (R–MO), the panel's chair, noting that it is already responsible for directing the Administration's information technology initiative.

No problem, responded presidential science adviser Neal Lane. A small coordinating office housed at NSF, he said, will help keep the troops in line and marching smoothly. But an army must also be fed. "We can't do it without the money," says NSF engineering chief Eugene Wong.

Chimpanzee Transfer The National Institutes of Health (NIH) has assumed ownership of 288 chimpanzees at the New Mexico–based Coulston Foundation. Details were still being worked out as *Science* went to press, but the arrangement "establishes a permanent home for the chimpanzees, with guaranteed support," says Coulston spokesperson Don McKinney. The animals have all been exposed to either HIV or hepatitis B as part of research protocols, and they will continue to be available for research.

Coulston has been under fire from animal rights groups and is the subject of an ongoing investigation by the U.S. Department of Agriculture's (USDA's) of animal welfare office (*Science*, 12 November 1999, p. 1269). As part of a 1999 settlement with the USDA, Coulston agreed to surrender up to 300 of its chimpanzees by January 2002, and McKinney says the 288 chimps, plus 21 animals slated to move elsewhere, would bring Coulston into compliance with that agreement.

For now, Coulston will continue to care for the chimps at Holloman Air Force base near Alamogordo, New Mexico, with funds from NIH. But NIH deputy director Wendy Baldwin says it is not yet clear where the animals will live for the long term. Holloman isn't an ideal spot for a research lab, she says, but its chimp facilities are the best available quarters.

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