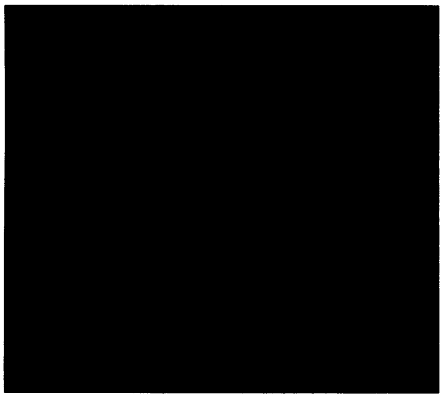
Other researchers are impressed, saying the technique could capture cells and tissues in three dimensions and give depth to machine vision. Kelvin Wagner, an electrical engineer at the University of Colorado, Boulder, who is familiar with the work, calls the group's method "an amazingly elegant way of turning the problem from something very messy into something far simpler."



**3D dino.** A (2D) rendering of the 7-centimeter dinosaur used to test the imaging system.

The technique grew out of a mathematical insight that joined two traditionally separate imaging tools. One, widely practiced in radio astronomy, is interferometry, in which radio waves collected by separate dishes from the same point in the sky are allowed to interfere. The waves' interference can be translated into the position and intensity of their source, and combining interference data from many different points yields precise 2D maps of quasars, supernovae, or galaxies. The other mathematical tool is tomography—the T in x-ray CT scans, which pinpoint the body's internal structures by analyzing x-rays sent through the body along many different paths.

The mathematical match was made when Daniel Marks, an Illinois graduate student, noticed that applying a mathematical tool called a Fourier transform to interference measurements would yield a data set ready-made for a particular type of tomographic analysis. By dovetailing the tomographic and interferometric algorithms and applying both of them to visible light, the group came up with its 3D lensless camera.

The imaging begins as the object—in this case a small plastic dinosaur—is rotated in front of an interferometer. For each viewing angle, the interferometer collects light that follows many different paths from each point on the object, filters it, and allows it all to interfere. The result is a pattern of light and dark spots, captured by an array of detectors. Then the algorithms kick in. First comes the analysis of the interference data, which transforms it into a two-dimensional projection—something like a shadow of the object. Next is the tomographic algorithm. It analyzes the two-dimensional projections, each one analogous to the x-rays collected along a single viewing direction in CT scanning, to build up a set of image slices representing the three-dimensional object.

The tomographic algorithm was designed for x-rays, which pass virtually unhindered through most tissues, but the Urbana-Champaign team has found that it also works surprisingly well for light reflected from opaque objects, allowing them to map the surface of their dinosaur with a resolution better than 1 millimeter. And the result is far richer than a hologram, which is made by recording the interference patterns of laser light, says David Brady, an electrical engineer with the Illinois group. Holography, which generally does not scan all viewing angles, "is not really a 3D imaging technique; it's a 3D perspective preserver," explains Brady.

Thomas Cathey, an electrical engineer and colleague of Wagner's at Boulder, cautions that the technique may be too slow for use in real-time applications such as robotic vision or automated quality control in manufacturing. But George Barbastathis, an electrical engineer at the Massachusetts Institute of Technology, thinks that for imaging biological samples, the new system could ultimately surpass techniques such as confocal microscopy, which builds up 3D images by illuminating and imaging samples point by point.

"Confocal systems acquire intensity data one point at a time," notes Barbastathis. "With Brady's method you scan in parallel. If they can manage to make the resolution comparable to confocal microscopy—and I believe that with their method it's actually possible to make the resolution better—then in that case it wins hands down." **–DANIEL RADOV**

Daniel Radov is a free-lance writer in Brookline, Massachusetts.

BIOPATENTS

## Legal Fight Over Patents on Life

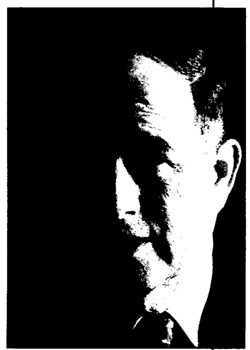
Biologist Stuart Newman of the New York Medical College in Valhalla is trying to get a patent on a "humanzee"—a chimeric animal made from human and chimpanzee embryos. Not because he really wants to create one, but because he wants to prevent other people from making one, and to challenge the rules for patenting life. Together with Jeremy Rifkin, president of the Founda-

**Provoking a debate.** Jeremy Rifkin.

CREDIT: (TOP TO BOTTOM) MARKS ET AL.; CATHALEEN CURTISS; CARL COX

## ScienceScope

**Change of Heart** When it comes to evaluating the effectiveness of federal R&D programs, you can't have too much input. At least that's what Neal Lane (below), the president's science adviser, has decided in lifting his objections to a congressional suggestion that the National Academy of Sciences (NAS) examine how well federal science agencies are complying with a 1993 law that calls for annual reviews of their research portfolios.



Last fall Lane complained to legislators that an NAS study, recommended in a bill funding the National Science Foundation, would be redundant and out of step with the Government Performance and Results Act. But now he has given NAS president Bruce Alberts the green light for such an "independent assessment," suggesting in a letter that the academy write up case studies of a half-dozen federal programs. The House and Senate science panels have chimed in too, stating in separate letters that they "look forward to seeing the results."

Academy staffers hope that the support from Lane and Congress will persuade agencies to pony up the needed $300,000 for the study. If funded, they say, the project would take about a year.

**Sounding Out** The U.S. Office of Naval Research (ONR) wants to continue the once-controversial Acoustic Thermometry of Ocean Climate (ATOC) project, which measures sea temperatures by clocking underwater sound pulses.

In 1994, activists stalled the installation of ATOC emitters off California and Hawaii, worrying that the pulses would deafen whales; that fear proved unfounded (*Science*, 27 February 1998, p. 1302). But ATOC's $40 million seed grant ran out last year and the California station is being dismantled. Last week, however, ONR signaled its desire to keep the Hawaii source running for at least a few more years, saying it will sponsor an environmental study necessary for obtaining new operating permits. ATOC researchers are thrilled by the move, which could take a year to complete, because it will allow them to collect valuable long-term data.

**Contributors: Robert Koenig, Elizabeth Pennisi, Jeffrey Mervis, David Malakoff**

tion on Economic Trends in Washington, D.C., Newman is embroiled in a strange legal contest with the government that entered a new phase last week as the duo announced that—to their delight—the Patent and Trademark Office (PTO) had turned down their patent application.

Newman and Rifkin have never seen a humanzee, much less created one. But on 16 June, they put out a press release saying that they had applied for U.S. patents on many types of chimeras. The government actually rejected this application 3 months ago, says Rifkin, but he kept the information quiet until now because he wanted to avoid publicity while drafting an appeal. That appeal was completed last week, and Rifkin's attorney submitted it to the PTO.

"If we win," Rifkin claims, "we'll hold the patent in trust for 20 years" to prevent others from commercializing human-animal combinations. But he seems equally enthusiastic about losing: "We will appeal all the way," he says, even to the Supreme Court if possible. Rifkin wants to provoke a debate about what it means to be "human" and to undermine the legal basis for patenting organisms—particularly those containing human genes.

The first round of the contest shows that the PTO has begun the debate right where the duo wants it, says Rifkin: on the question of whether it is acceptable to patent human tissue. In its rejection letter, the PTO says that Newman's claimed invention—which relies on the use of human embryos—"includes within its scope a human being, and as such falls outside the scope" of what the PTO regards as legally patentable.

Some patent attorneys suspect, however, that government lawyers may sidestep the big issues in future proceedings. For example, says Paul Clark of the Clark and Elbing law firm in Boston, lead attorney on Harvard's "oncomouse" patent, the courts could simply dismiss Newman's claims because he has never created the exotic chimeras he aims to patent. —**ELIOT MARSHALL**

**CLIMATOLOGY**

## The Little Ice Age—Only the Latest Big Chill

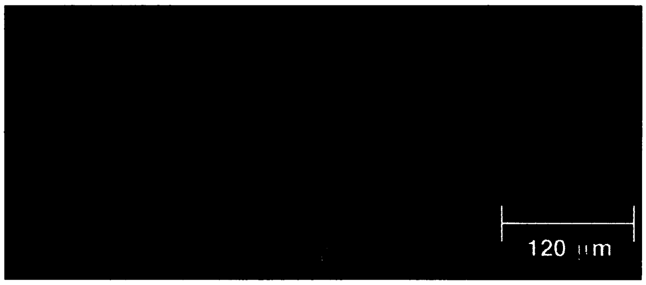
**BOSTON**—George Washington's winter at Valley Forge in 1777–78, when temperatures fell as low as −15°C, was relatively mild for those days; some years, New York Harbor froze solid. Indeed, so bitter were the centuries from about 1400 until 1900 that they have been dubbed "The Little Ice Age." But new evidence appears to confirm that the long cold snap was nothing exceptional. Instead, it was only the most recent swing in a climate oscillation that has been alternately warming and cooling the North Atlantic region, if not the globe, for ages upon ages.

At the spring meeting of the American Geophysical Union here earlier this month, paleoceanographers William Showers of North Carolina State University in Raleigh and Gerard Bond of Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York, reported that they had found tiny bits of ice-borne rock in North Atlantic sediments laid down during the Little Ice Age. Identical rock fragments show up in older sediments every millennium or two, beginning at least 130,000 years ago.

The finding implies that Earth has experienced a long string of Little Ice Ages, perhaps driven by variations in the sun or by changes in ocean currents. It also suggests that the world will be warming naturally, as part of this roughly 1500-year climate cycle, on top of any human-induced greenhouse effect. "It's intriguing," says paleoclimatologist Jonathan Overpeck of the National Geophysical Data Center in Boulder, Colorado. "It's not a plausible explanation of the rapid warming we're having today, [but] it's very important that we study these century- and millennial-scale phenomena" to predict accurately any future warming.

Historical records testify to the chill of the Little Ice Age—essential Dutch canals froze up all too regularly—and clues from the sea floor, lake beds, and glacial ice confirm that after 1400 temperatures in the Northern Hemisphere dropped 0.5° to 1°C below 20th century levels. Taking a longer view, Bond and his colleagues have spent the past few years assembling a 140,000-year record of climate cycles in the northern North Atlantic by counting microscopic bits of rock deposited during cold periods. The debris, picked up by ice on or around North America, Greenland, and Iceland, floated into the North Atlantic in icebergs and sank when they melted. During the ice age, Bond found, the debris jumped in abundance every 1500 years (give or take half a millennium) as the great ice sheets surged toward the sea. The oscillations continued after the ice age ended 10,000 years ago, although at greatly reduced levels.

The trace of the most recent cold pulse in this series had eluded Bond until now, however. The conventional coring method of dropping a long pipe end first into the bottom mud flushes away the soupy upper centimeters of sediment accumulated in the past thousand years or so. To capture the topmost part of a core, Bond gently pressed a set of short pipes into the sediment, then sealed them before bringing them to the surface.




**Sedimental journey.** Icelandic volcanic glass hitched a ride when ice floated as far south as Newfoundland during the Little Ice Age.

CREDIT: BOND *ET AL.*

Using both methods, Bond took cores near Newfoundland. After tallying the ice-rafted debris particles, he could see that the 1000- to 2000-year oscillation runs "through the Holocene and right into the Little Ice Age," says Bond. "The Little Ice Age was not an isolated event."

Bond has "a reasonable argument" that the ice-rafted debris corresponds to the Little Ice Age, agrees paleoceanographer Jerry F. McManus of the Woods Hole Oceanographic Institution (WHOI) in Massachusetts. "There are others who think they have something like this marching through the record," he adds. Lloyd Keigwin of WHOI found signs of a couple of cycles, including the Little Ice Age, off Bermuda. And earlier this year, Giancarlo Bianchi and Nicholas McCave of the University of Cambridge reported that the varying size of sediment grains down a core taken from south of Iceland reveals a rough 1500-year cycle in the speed of bottom currents during the past 7000 years, slower during the Little Ice Age and other cold phases.

Linking the Little Ice Age to a long-running climate cycle lets Bond and Showers eliminate possible mechanisms behind the cycle. Even though it coincides with periodic surges of the Northern Hemisphere ice sheets, ice can't be the driving force, because the oscillation continues in a milder form during interglacial periods, when those ice sheets disappear. And the sun-shielding debris of volcanic eruptions, often proposed as the cause of the Little Ice Age cooling, seems to be ruled out, says Bond; there is no known 1500-year cycle in volcanic activity or any good reason for one.

That leaves variations in solar activity—there were almost no sun spots during much of the Little Ice Age, implying that solar activity was at a low ebb—or some sort of oscillation in the ocean's operation, as hinted by Bianchi and McCave's deep-water flow record. Whatever the cause, says Bond, "the impact of this millennial-scale oscillation will have to be taken into account" as researchers plot the climatic future in hopes the world will fare better in the warming than Washington's army did in the chill at Valley Forge. —**RICHARD A. KERR**