But some primatologists say the results may not mean much for conservation. "It's an interesting exercise, but it doesn't get us that far in practical terms," says Ian Tattersall, a primatologist at the American Museum of Natural History in New York City, who notes that knowing the ecological effects of extinctions doesn't help much in staving them off.

Still, ecologist Stuart Pimm of the University of Tennessee, Knoxville, thinks this kind of study is quite valuable, because it helps "bridge the gap" between studies of extinction and of ecosystem productivity. "Most of what we do in terms of documenting species loss tends to look at the species as completely independent of each other," says Pimm. "In fact, the better analysis would be that you're tinkering with a complex piece of machinery."

–JOCELYN KAISER

QUANTUM COMPUTING

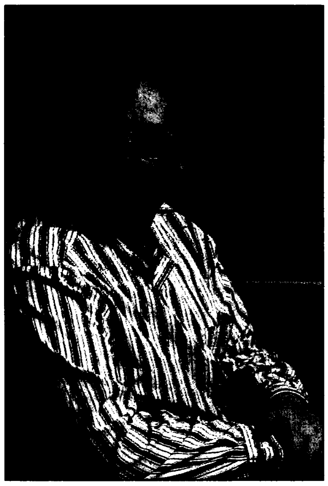
Fighting Corruption in The Quantum World

If there is one sure thing in the computer industry, it is that sooner or later, engineers will not be able to squeeze any more circuits onto chips. But an enthusiastic group of researchers is speculating about a whole new realm of miniaturization: devices so small that they operate according to the unfamiliar quantum laws of the atomic world. Quantum computers could remain a dream unless physicists can find a way around the vexing tendency of quantum information to leak away and degrade. But now a team of Los Alamos theorists and East Coast experimenters has shown that quantum computers could identify errors and fix them.

"What we have done is demonstrated in an experiment for the first time that we can make quantum information more robust, that we can protect it against corruption," says Raymond Laflamme, a member of the team at Los Alamos National Laboratory in New Mexico. According to David Deutsch of the Centre for Quantum Computation at the University of Oxford in England, "it's an important step toward the goal of building a useful quantum computer."

Current "classical" computers process information, or bits, as digital 0's and 1's. In quantum computers the element of information, the qubit, is a blend of both a 0 and a 1, their relationship expressed by the qubit's "phase." This mingling allows an array of qubits to carry a whole swath of numbers simultaneously, even though actually reading the array will yield just one value as the quantum states "collapse." By working on entire sets of numbers all at once, a quantum computer can in principle solve certain types of problems incredibly efficiently. Factoring big numbers, for example—a taxing task for today's computers—would be a cinch for quantum computers and would render obsolete today's most secure encryption systems, which are based on the difficulty of this task.

Unfortunately, a passing atom can interact with a qubit, causing some of its information to leak away and introducing errors. Skeptics say that the fragility of quantum information threatens the whole idea of a practical quantum computer. Because there is no way to avoid the errors, the next best thing is to correct them. This is not easy for quantum information, because reading it out to check for errors or correct them instantly collapses the qubit array, spoiling its number-juggling capacity. "The whole trick of the quantum error correcting code was to find a way to know what the error was without knowing what the message is," says Laflamme.



AT&T LABS

Error buster. Peter Shor's quantum error correction code has been shown to work.

In 1996 Peter Shor of AT&T Bell Labs and, independently, Andrew Steane at Oxford devised a theoretical scheme for doing so. The basic idea is to spread the information of one qubit into a family of linked qubits so that, should any be corrupted, the information can still be recovered from its partners. Now Laflamme and his Los Alamos colleagues have teamed up with a group of Massachusetts-based specialists in nuclear magnetic resonance (NMR) to demonstrate the scheme with atomic nuclei that encode qubits in their magnetic orientations.

A nucleus can behave like a small magnet and point either up or down relative to a strong magnetic field. Thus a molecule could be used as an array of qubits, with the nuclear orientations encoding 0's (up) and 1's (down). To control such an array, the researchers used NMR to manipulate the orientation of nuclear magnets by tweaking the nuclei with radio-frequency waves.

In the 7 September *Physical Review Letters*, the team describes tests on two molecules: alanine, an amino acid, and trichloroethylene. Both provide a suitable set of three neighboring nuclear magnets: a single information qubit plus two control qubits to provide error correction. The researchers first used a radio-frequency pulse to twist the linked nuclear magnets into a particular position, then left them to the mercy of their surroundings. Errors caused the three magnets to drift out of alignment before a further radio-frequency pulse reversed the initial twisting. Because the three magnets are linked magnetically, enough information was contained in the misalignment of the two control qubits to allow the team to figure out the error on the information qubit without having to measure it directly. The experimenters then showed that they could correct the error with another pulse. "We've demonstrated in the smallest and simplest code that we had enough control to do the right operation and preserve the quantum information," says Laflamme.

Although enthusiastic about this demonstration of principle, other researchers emphasize that this is just the first step toward full quantum error correction. "It's a long way from three qubits to a quantum computer powerful enough to solve significant problems," says Shor. A future "significant step" would be to demonstrate error correction in a five-qubit system, enough to guard both the phase information and correct another type of error that flips the 0's and 1's, explains Shor. "We hope to do this in the next few months," says Laflamme.

–ANDREW WATSON

Andrew Watson is a writer in Norwich, U.K.

CANADIAN FUNDING

NRC Seeks Boost for Base, Special Projects

OTTAWA—Canada's oldest and most revered scientific institution, reeling from 3 years of budget cuts, is pleading with the government for more money to shore up its scientific base and to launch projects in five areas. The National Research Council (NRC) makes its case in a still-secret report, which has been obtained by *Science*, that has been presented to government officials in a series of briefings. Insiders say that the NRC stands a good chance of regaining much of its core funding and winning approval for at least some of the special initiatives.

Established in 1916, the NRC holds a premier place in Canada's science establishment as a supporter of basic and applied research in industrial sectors or technologies seen as critical to the nation's economic development. But a $58 million cut in its budget, now at $242 million, has forced NRC's own labs to seek out contract services and short-term R&D projects. "As NRC's capacity to maintain projects and facilities at the leading edge diminishes, key staff and top scientists may be lost," officials write in the report, dated 31 August.

To recoup its losses, the NRC is asking for annual increases of $16 million in federal funds in each of the next three fiscal years, beginning on 1 April 1999. It is also requesting $165 million for new "strategic initiatives" in five areas: aerospace, genomics, optoelectronics, fuel cells, and information networking. "NRC has been successful in the past because it has been willing to invest for the long term," says president Arthur Carty. "Our strength is medium- to long-term R&D in strategic areas that are absolutely crucial to Canada." Government officials declined to comment on the details of the plan.

The fate of the initiatives, say observers, depends on the NRC's ability to make them stand out in a crowd. The proposal to build an optoelectronics prototyping foundry for small- and medium-sized businesses within the information and telecommunications sectors, for example, is being touted as "unique in the world." But the plan to develop a national genomics program conflicts with a similar initiative from the Medical Research Council (MRC) that has been slow to get off the mark (*Science*, 3 July, p. 20), and with a separate proposal from the Canadian Institutes of Health Research (*Science*, 8 May, p. 821) for a network of centers that could include work in genomics. In fact, the MRC and NRC recently struck a preliminary agreement to develop a joint genomics initiative that would stand a better chance of winning support.

One point in the NRC's favor is the promise of matching funding from industrial and university partners for each of the five proposed initiatives. That commitment is particularly strong for the aerospace proposal, which includes building a center for more energy-efficient generation of gas turbines in Ottawa and an advanced aerospace manufacturing technology facility in Montreal. Some industrial partners have long been urging the government to do more. Last month, in announcing a planned 25% cut over the next 18 months in its R&D workforce, Pratt & Whitney Canada said the government's "commitment to support future R&D is insufficient to allow us to stay fully competitive in the global aerospace market."

–WAYNE KONDRO

Wayne Kondro writes from Ottawa.

HEAVY ELEMENTS

Fast Chemistry Snares Stray Plutonium Isotope

Since it was first used to produce nuclear weapons in 1945, plutonium has inspired its share of fear. But the element has inspired mysteries as well, notably the case of its missing isotope. Over the past 50 years, researchers have isolated a total of 17 plutonium isotopes, all with different numbers of neutrons in their nuclei. But one predicted isotope—plutonium-231—remained at large. Now at last the search for plutonium-231 is over. At the American Chemical Society meeting in Boston late last month, a team from the University of California, Berkeley, and the Lawrence Berkeley National Lab (LBNL) reported using some fleet-footed chemistry to pin it down.

"People have been saying all along that it should be there. But it wasn't easy to find," says Alice Mignerey, a nuclear chemist at the University of Maryland, College Park. The challenge came in spotting plutonium-231's characteristic pattern of radioactive decay amid those of other nuclides. "It's really quite a coup these days to measure anything new," says Mignerey. The new isotope isn't likely to find much practical use: It has a half-life of just 8.5 minutes. Still, other nuclear chemists are hailing the discovery for filling in a long-sought piece of the nuclide table and confirming models of nuclide stability.

"It's really quite a coup these days to measure anything new."

—Alice Mignerey

Making the isotope was the easy part for the Berkeley team, led by postdoc Carola Laue and chemistry professor Darleane Hoffman. The group used LBNL's cyclotron to bombard a stack of uranium targets with helium-3 ions. As the helium ions—each containing two protons and a neutron—collide with the targets, some or all of their protons and neutrons fuse with the uranium nuclei to produce new nuclides, in this case plutonium, neptunium, uranium, and thorium.

Isotope hunters track their targets by looking for the characteristic chain of decays as an unstable nucleus splits apart or spits out various particles, yielding daughter nuclides that decay further until they reach a stable nuclide. Plutonium-231 is hard to identify, however, because its decay chain includes uranium and neptunium isotopes that can be produced in the same cyclotron reaction, mimicking the plutonium-231 signal. Hence the researchers had to do some rapid chemistry to sift the plutonium isotopes from the other elements in time to watch for the plutonium-231's signature decay chain.

To do so, the researchers gathered the nuclides blasted out of the target into a gas stream flowing into a thin capillary tube. They had spiked the gas with ultrafine potassium chloride particles that bound to the radioactive elements. At the end of the capillary tube the particles, now laced with nuclides, were deposited on a collection plate. To extract the plutonium isotopes, Laue dissolved the potassium chloride in nitric acid, which then passed through a tiny separation column. The column contained an ammonium-based resin, which binds to heavy elements with four positive charges, snagging the plutonium and thorium isotopes. After washing everything else out of the column, Laue flushed out the thorium with hydrochloric acid, then added hydrogen iodide to free the plutonium so it too could be washed out. A quick dry-out left a residue of pure plutonium.

The final challenge came in picking out plutonium-231's decay signal. Calculations suggested that plutonium-231 would either emit an alpha particle to create uranium-227 or snag an electron, converting a proton to a neutron and creating neptunium-231. Plutonium-232, which the cyclotron reaction also produced, emits an alpha to create uranium-228. The decay chains of all three of these daughter nuclides are well known. And because the researchers had previously removed any uranium or neptunium, they could now be sure that if their sensitive detector registered uranium-227 or neptunium-231, these chains originated from plutonium-231. Once they had placed their pure plutonium sample in the detector, "we just watched the [uranium-227 and neptunium-231] signatures grow back in," says Hoffman, confirming the presence of plutonium-231.

Laue and Hoffman note that several other isotopes, such as americium-231, remain to be found. Flushed with solving one mystery, the Berkeley detectives are now off to tackle another.

–ROBERT F. SERVICE

BROOKHAVEN NATIONAL LAB

Plutonium	Pu228	Pu229	Pu230	Pu231	Pu232	Pu233	Pu234	Pu235	Pu236	Pu237	Pu238	Pu239	Pu240	Pu241	Pu242	Pu243	Pu244	Pu245	Pu246
Neptunium		Np228	Np229	Np230	Np231	Np232	Np233	Np234	Np235	Np236	Np237	Np238	Np239	Np240	Np241				
Uranium	U226	U227	U228	U229	U230	U231	U232	U233	U234	U235	U236	U237	U238	U239	U240				

Isotope unmasked. Nuclide table showing the possible decay routes of "missing" isotope plutonium-231.