oratory Astrophysics—in Boulder, Colorado. He's confident that can be done. Whether the promise of great science is enough to convince Congress is another matter: DOE's budget is already feeling the strain of another major project, the $1.3 billion Spallation Neutron Source, which is expected to be completed in 2005. **–ROBERT F. SERVICE**

QUANTUM MECHANICS

Entangled Trio to Put Nonlocality to the Test

One of the strangest claims of quantum mechanics is that two particles can be "entangled"—inextricably linked at birth. In theory, a measurement on one entangled particle is linked to a degree that defies common sense to a measurement on the other, even though the pair may have traveled to opposite sides of the cosmos. Now physicists at the University of Innsbruck in Austria have created the same eerie link among a trio of photons, so detecting two of the photons preordains the result of the third measurement.

Photon tangle. Beam-splitting apparatus which muddles the identity of photons from two entangled pairs.

CREDIT: HARALD WEINFURTER

The feat, which the Innsbruck group reported in the 15 February issue of *Physical Review Letters*, allows researchers to close some loopholes in tests of the strange predictions of quantum mechanics. By studying pairs of entangled photons, physicists have already tested the quantum prediction that a measurement on one of the pair will instantly affect the outcome of a measurement on the other, even if they have traveled great distances apart since being created. But these tests have to be run over and over to be sure these "nonlocal" effects aren't due to chance, and purists find such statistical evidence dissatisfying. The entangled trio opens the way to a single measurement that will give one result if nonlocality is true and another if it is not. "This could be like a single shot test of quantum mechanics," says Vlatko Vedral of Britain's University of Oxford.

Because of these stakes, says Daniel Greenberger of the City University of New York, City College, a "race" was on to create such three-photon states. The winning Innsbruck team "did a phenomenal job," he says. "I think it's very significant," agrees Vedral. Besides allowing a yes-no test of quantum nonlocality, three-photon entanglement should also offer more efficient quantum communications, says senior team member Harald Weinfurter. Quantum communications, which promises to be more efficient and secure than normal optical signals, uses entangled states to pass information between participants using carefully prepared sets of photons shared among them in advance. "We are moving toward quantum communications," says Vedral. "It's got implications for quantum computing and all kinds of fundamental experiments," adds Greenberger.

The Innsbruck experiment begins with the same kind of crystal that spawns entangled photons in pairs. When a photon is fired into it, the crystal can split the photon into two daughters that each have half the frequency of the parent. Their common parentage means that the photons' properties are linked. For example, if the first one is horizontally polarized, the other has to be vertical. However, according to quantum mechanics, such properties remain indeterminate until they are actually measured, so if a measurement on one photon finds that it has vertical polarization, its sibling instantly "knows" that its own polarization is horizontal.

To entangle three photons, Weinfurter and his colleagues direct a high-frequency laser beam onto the photon-splitting crystal and wait for two photons to cleave simultaneously, giving two entangled pairs. Each time this happens, three of the four photons pass through a system of polarization-sensitive beam splitters and other optical elements, which tangle together the photons in such a way that it is impossible to tell them apart. "We interfere the particles in such a way that in the end you cannot decide any more which of the particles belongs to which pair," says Weinfurter.

Each entangled trio then heads toward three single-photon counters, each with a polarization filter in front of it. These are primed to look out for the trio, amongst other photons, by the detection at a fourth detector of the fourth, unentangled photon of the two pairs. The orientation of the polarization filters is set so that, if the photons are entangled, the counts in two of the detectors are correlated with those in the third—so simultaneous detection in all four detectors flags three-photon entanglement. Three independent photons would show no such correlation.

Recent theoretical work by the University of Calgary's Richard Cleve and others suggests that entangled trios could make quantum communication systems more efficient, reducing by a third the amount of communication required to share information. Equally tantalizing for quantum purists is the possibility of a simple yes-no test of nonlocality. Three-photon entanglement means that the experiment in effect registers a photon in one detector if nonlocality is operating, but in a different one if it isn't. "It's no longer a statement about probabilities, but it's really a statement about one event," says Weinfurter. The team has already made a first stab at the measurements and is analyzing the results, he says. The early news: "Quantum mechanics is correct." **–ANDREW WATSON**

INDIA BUDGET

Big Increase Seen as Answer to Sanctions

NEW DELHI—Indian researchers are feeling buoyed by a new budget unveiled last weekend that hands science its largest increase of the decade. A 20% hike that would benefit both civilian and defense sectors is seen as a shot in the arm for domestic efforts to overcome foreign sanctions imposed in the wake of last spring's nuclear tests. These large increments "reflect India's determination to fight ... the sanctions and denial of technology," says Raghunath A. Mashelkar, director-general of the Council of Scientific and Industrial Research (CSIR).

The increases stand in sharp contrast to last year's budget, which favored the atomic, space, and defense R&D sectors but didn't provide enough for other departments to even keep pace with inflation (*Science*, 5 June 1998, p. 1520). Science and Technology Minister M. M. Joshi told *Science* that this year's planned outlay of $2.56 billion is proof that the prime minister's slogan of "hail science," coined after the blasts, "was not a hollow promise." Still, not everyone is pleased. M. G. K. Menon, a physicist and former science and technology minister, says that the overall budget "lacks any bold new initiatives," such as downsizing the general bureaucracy, and that it fails to invest sufficiently in civilian R&D. "The government has its priorities all wrong" through its emphasis on strategic research related to national security, he says.

To be sure, defense research still receives the lion's share of the government's science and technology investment, rising

by 20% to $696 million. That figure constitutes 6% of the country's overall defense budget, its highest share ever, and reflects the government's attempt to beef up indigenous military technologies.

Two related sectors also fare well. Space research is scheduled to rise by 16%, to $439 million. The increase will fuel a program to develop a booster for the country's new geosynchronous communications satellites and to create a second launch site. Atomic energy programs will receive a 32% boost, to $384 million, and funding for nuclear power plants, including a prototype fast breeder reactor, will also rise. The Bhabha Atomic Research Center in Mumbai, India's leading laboratory for nuclear weapons research as well as for civilian-related projects, gets a 33% hike, to $134 million. In addition, the Department of Atomic Energy announced a new National Center for Applied Mathematics and Radiophysics at the Tata Institute for Fundamental Research in Mumbai, although no details were available at press time.

On the civilian side, the department of science and technology, which funds academic research, is receiving an 18% hike, to $164 million, and the department of biotechnology's budget will rise by 9%, to $30 million. Civilian electronics garnered a 33% increase, to $52 million, reflecting India's push to compete in world markets. The budget for agricultural research and education is slated to rise by 26%, to $303 million, with the largest increases going for research on wheat, rice, and pulses.

Some of the loudest applause is coming from CSIR, which runs a chain of 40 laboratories catering to the needs of industry. Its 30% boost, to $199 million, is the largest in its 50-year history. "For the first time, our R&D budget is looking healthy," says Mashelkar, who singled out for praise a tripling of its $1.25 million program to find commercial applications for biologically active agents in plants.

The new budget also contains new initiatives in grassroots innovations, vaccines, and biodiversity. A $5 million foundation is being set up to encourage small inventors to pursue commercialization of their ideas, along with a national registry to recognize the achievements of those without the means to apply for patents. The vaccine initiative is most likely to benefit efforts to develop vaccines against rotavirus and cholera, which are already undergoing clinical tests. A new National Bioresources Board is expected to consolidate under one roof all research related to bioresources and to expand survey and taxonomic activities. "This would put India in a very strong position to exploit the age of biology in the next century," says Manju Sharma, secretary of the department of biotechnology.

–PALLAVA BAGLA

CREDITS: (TOP) MIKE ABBY/VISUALS UNLIMITED; (BOTTOM) TUFTS UNIVERSITY SCHOOL OF MEDICINE

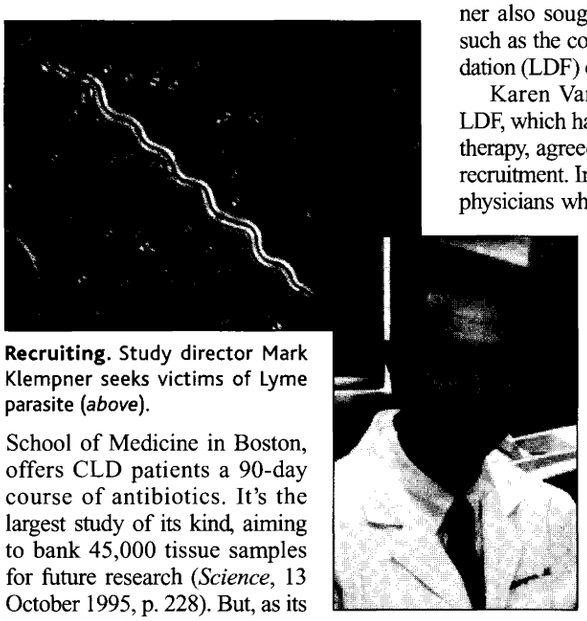
LYME DISEASE

Patients Scarce in Test Of Long-Term Therapy

Scientists are having trouble enrolling enough patients in a $4.2 million study to test whether long-term antibiotic treatment is effective against chronic symptoms of Lyme disease. Ironically, while researchers were discussing this problem in a suburb of Washington, D.C., last week, officials in Connecticut—ground zero for the disease—held a hearing to increase pressure on insurance companies to cover extended Lyme disease therapy.

About 13,000 U.S. citizens get tick bites each year that transmit a corkscrew-shaped parasite (*Borrelia burgdorferi*) that causes inflammation and joint pain—Lyme disease. But medical experts differ on how to treat very long bouts of arthritis, fatigue, and memory loss that some patients experience—a syndrome known as Chronic Lyme Disease (CLD), which is a controversial diagnosis.

The current study, run by a team led by Mark Klempner of the Tufts University School of Medicine in Boston, offers CLD patients a 90-day course of antibiotics. It's the largest study of its kind, aiming to bank 45,000 tissue samples for future research (*Science*, 13 October 1995, p. 228). But, as its leaders revealed in an interim review last week, patient recruitment is lagging.



Recruiting. Study director Mark Klempner seeks victims of Lyme parasite (*above*).

After a year of advertising, says Klempner, only 57 subjects had been enrolled. The goal is to get 260 by the time the study ends in 2 years. More than 1200 people have expressed interest, and 700 have come in for screening. But only one in 10 who appear in the clinic fits the study's strict criteria.

A patient is enrolled in the double-blind placebo study, funded by the National Institute of Allergy and Infectious Diseases (NIAID), only after testing positive in a blood antibody test for *Borrelia* or having evidence of a tick bite rash. Patients who have received extensive intravenous antibiotic treatment are excluded, as are, for ethical reasons, those who have never received any treatment. The criteria are designed to focus selectively on CLD. Once enrolled, patients are randomized into a placebo or treatment group. The treatment group gets 30 days of intravenous ceftriaxone followed by 60 days of oral doxycycline.

On 25 February, Klempner asked a gathering of NIAID project managers, members of an advisory panel, and patient advocates for ideas on how to speed up enrollment. But he also offered an encouraging note: Many CLD patients have a distinctive enzyme in their spinal fluid that's been seen before in patients with neuroborreliosis—when the organism invades the central nervous system. The enzyme, he suggested, might be useful as a disease marker.

After the meeting, Klempner and NIAID Lyme program director Philip Baker said they would not relax study criteria to get more patients. That would wreck the protocol, Baker said. Instead, at extra cost, NIAID will add a recruitment site in Connecticut to existing sites in Boston and New York, and possibly others in New Jersey and Maryland. Klempner also sought help from advocacy groups such as the controversial Lyme Disease Foundation (LDF) of Hartford, Connecticut.

Karen Vanderhoof-Forschner, chair of LDF, which has questioned conventional CLD therapy, agreed to open LDF's membership to recruitment. In addition, Klempner says, some physicians who specialize in CLD may cooperate. Vanderhoof-Forschner told *Science* that she thought some eligible candidates had not volunteered for the study because they are suspicious of the researchers. But it's also possible, Klempner concedes, that there aren't as many CLD patients as expected.

That possibility might surprise the attorney-general of Connecticut, Richard Blumenthal. One day before Klempner solicited ideas to enroll more patients, Blumenthal held a hearing in Hartford to help people seeking reimbursement for long-term antibiotic therapy for Lyme disease. "Most insurance companies will not cover treatment of longer than 4 weeks of intravenous antibiotics," Blumenthal says, "despite the judgment of treating physicians" that the drugs should be provided. Blumenthal is drafting a bill to "mandate" insurance coverage for what the doctor orders.

Meanwhile, Klempner says that his team will try to "remove barriers" to enrollment. Conducting free screening clinics "within the walls of advocacy organizations," he says, should provide access to a new cohort of patients.

–ELIOT MARSHALL