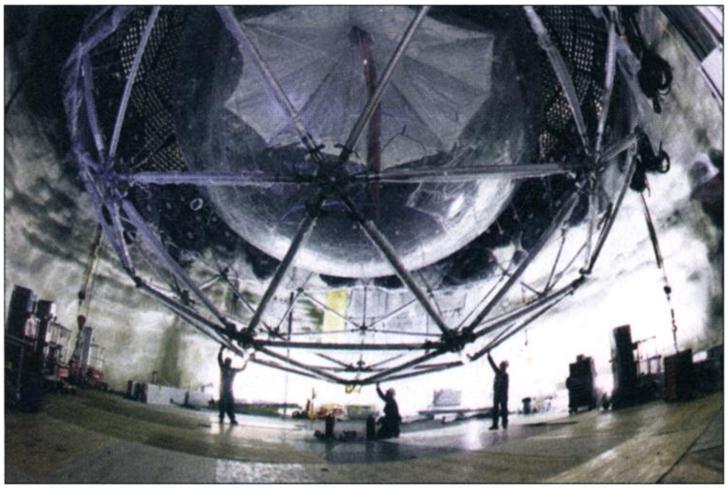
about a key property of the particles.

Neutrinos are incredibly hard to detect because they seldom interact with matter; they can zip through Earth without noticing it. Occasionally, one will trigger a physicist's detector, but not all neutrinos are equally easy (or difficult) to catch. Neutrinos come in three "flavors," named after the subatomic particle that each is associated with: the electron neutrino, the muon neutrino, and the tau neutrino. Electron neutrinos are the easiest to detect, because they participate in reactions involving the very common electron; tau and muon neutrinos are hard to spot. That reticence seemed to explain a puzzling deficit of electron neutrinos created in the sun's nuclear furnace: If electron neutrinos changed flavors into muon or tau neutrinos, they could escape detection.



Key ingredient. Heavy water in globe at the heart of the Sudbury Neutrino Observatory traps flavors of neutrinos that other detectors miss.

The raison d'être for SNO—a 1000-ton sphere 2 kilometers under Earth's surface—is to spot all three flavors. Unlike other big neutrino detectors, such as the Super-Kamiokande facility in Kamioka, Japan, SNO's sphere is filled with heavy water—water made with deuterium, a heavy isotope of hydrogen—rather than ordinary water. The deuterium in the detector allows SNO scientists to see neutrino reactions that others can't.

Last year, scientists first revealed their measurements of one of these reactions: the charged-current reaction, in which an electron neutrino strikes a deuterium nucleus and converts its neutron into a proton and an electron. This enabled scientists to measure the number of electron neutrinos and compare it with the total number of neutrinos that were scattering off matter (*Science*, 22 June 2001, p. 2227). The results set neutrino physicists abuzz. Not only did they give strong evidence that neutrinos were changing flavor, but they matched up well with the models of solar neutrino production. The solar neutrino deficit seemed to be accounted for.

On 21 April, SNO scientists revealed their measurements of another deuterium-specific reaction, called the neutral current, in which a neutrino of any flavor slams into deuterium and breaks it apart into a neutron and a proton. Only electron neutrinos can trigger the charged-current reaction, but the neutral current is equally sensitive to electron, muon, and tau neutrinos. By measuring the relative ratios of electron, muon, and tau neutrinos coming from the sun, SNO scientists saw that solar neutrinos, which began their journey to Earth as electron neutrinos, had changed into muon or tau neutrinos by the time they reached the detector. "This is strong evidence for flavor change," says team member Andre Hamer of Los Alamos National Laboratory in New Mexico. "And the total number of neutrinos agrees with the standard solar model prediction."

Not only is the evidence for flavor change much stronger than before—in statistics-speak, a 5.3-sigma result rather than a 3.3-sigma one—but the new measurements pin down the properties of neutrinos with unprecedented precision. "They have a significant impact on our understanding of the relative masses of neutrinos," says team member Art McDonald of Queens University in Kingston, Ontario. The results also show that another property of neutrinos related to how they interact with matter, known as the "mixing angle," must be large rather than small, contrary to what physicists believed until quite recently (*Science*, 2 November 2001, p. 987). "The small-mixing-angle solution is out," says Hamer.

Neutrino physicist Bruce Berger of Lawrence Berkeley National Laboratory in Berkeley, California, agrees. Although the case isn't closed, Berger says, "it's extremely unlikely, given current measurements, that it's a small mixing angle." Little by little, the ethereal neutrino is assuming a tangible form.

—CHARLES SEIFE

CREDITS: (TOP TO BOTTOM) SNO; JOSEPH W. DOUGHERTY

EVOLUTIONARY BIOLOGY

Darwin's Avian Muses Continue to Evolve

Charles Darwin spent just over a month on the Galápagos Islands in 1835. The peculiar finches he collected there, each species with a distinctive beak shape, helped inspire his theory of evolution by natural selection. In 1973, Peter and Rosemary Grant, a husband-and-wife team of Princeton University biologists, returned to the Galápagos to observe the evolution of Darwin's finches up close. On the volcanic island of Daphne Major, they and their students have been keeping track of every single finch from birth to death, allowing them to quantify the effects of natural selection on the birds. The ongoing study is "one of the true classics of evolutionary biology," says biologist John Burke of Indiana University, Bloomington.

Evolutionary beacon. Medium ground finch beaks wax and wane with climate shifts.

On page 707 of this issue, the Grants review 30 years of evolution among Darwin's finches. Evolution has proven predictable in the short term but unpredictable over the course of decades, they report. Climate change has been a powerful influence guiding the evolution of the finches—and its effects turn out to be surprisingly complex. Natural selection is not the only force altering the birds: So is their promiscuous sex life. The two species on Daphne Major can and sometimes do interbreed, and their hybrids—far from being mulelike reproductive dead ends—are a source of fresh genetic variability. Interbreeding may be one of the secrets to the fast evolution of Darwin's finches, the Grants suggest, adding that hybrids may be an unrecognized factor in the evolution of many other animals.

On Daphne Major the two most common species of Darwin's finches are the medium ground finch (*Geospiza fortis*) and the cactus finch (*G. scandens*). Ground finches have blunt beaks that are well suited for cracking small seeds of perennials, and larger individuals can break open the harder, larger seeds of a plant called the caltrop. The cactus finches have pointier beaks that they use to devour the fruits and pollen of cactus.

Changes in the food supply have made natural selection favor birds with beaks of certain sizes and shapes at different times, the Grants have demonstrated—just as Darwin theorized. In 1977 a La Niña–related drought wiped out the plants that produce small seeds, and most of the ground finches died. But some big-beaked birds survived because they could feed on caltrop seeds. Within a few generations, the average ground finch beak evolved to be 4% bigger. But in 1983 the island was clobbered by La Niña's soggy twin, El Niño, whose rains triggered a frenzy of small-seed plant growth. Ground finches with small beaks were more efficient at eating the new seeds and had more offspring, shrinking the average beak by 2.5% within a few years.

Cactus finches have evolved as well, although natural selection has acted more weakly on them. When the 1983 El Niño swamped the birds' favored cactuses, birds with slightly blunter beaks could eat the small seeds of other plants. But the Grants found a paradox: Cactus finch beaks have been getting significantly blunter year after year, even though selection pressures from the birds' food source have diminished.

The reason, the Grants found, is that cactus finches have been fraternizing with ground finches—and the latter's genes are shaping the former's beaks. After the 1983 floods, female cactus finches starved as the larger males drove them away from the few remaining fruits. That left as many as five male cactus finches for every female. A few desperate males mated with female ground finches, which then produced perfectly healthy and fertile hybrids. These hybrids only mate with cactus finches, because they imprinted on the songs of their cactus-finch fathers. "The sons will sing the same song as the fathers sing, and the daughters, having paid attention to the songs of their father, will pick a cactus finch male when they grow up," Peter Grant explains. As a result, ground finch genes are flowing into the cactus finch gene pool—a process called introgression—making their beaks blunter.

Other biologists are surprised that two distantly related species can produce healthy hybrids that go on to play an important evolutionary role. Introgression is "something that's invisible unless you do work like the Grants have been doing for so long," says David Reznick, a biologist at the University of California, Riverside. "It may turn out to be much more important than people think."

This new source of genetic diversity makes it easier for a species with donated genes to adapt to a changing environment, the Grants claim. At the same time, introgression of the finch genes demonstrates just how leaky the barriers are between species. "It forces people to think of species much more as open genetic systems rather than closed ones with an impermeable membrane," says Peter Grant.

As for the finches' future, the Grants can say only that it promises to be as unpredictable as the past. Will *G. scandens* disappear as it acquires more and more *G. fortis* genes? "I think the fusion is taking place right now," says Peter Grant. As evolution unfolds on Daphne Major, the Grants and their students will be watching.

–CARL ZIMMER

Carl Zimmer is the author of *Evolution: The Triumph of an Idea.*

CREDIT: SAM KITTNER

DEFENSE SCIENCE

Jason Hooks Up With New Sponsor

An exclusive group of academic scientists is moving up the Pentagon food chain and will soon resume a 40-year flow of unvarnished technical advice to the U.S. government.

One month after the Defense Advanced Research Projects Agency (DARPA) acknowledged dropping its support of Jason (*Science*, 29 March, p. 2340), the group is nearing completion of a similar arrangement with the higher ranking Director of Defense Research and Engineering (DDR&E). The new relationship comes just in time for the next planning meeting of the self-selected group of scientists, who produce often-classified studies on a variety of issues. "It's important to have academics helping [the defense department] address tough problems," says Delores Etter, a former acting head of DDR&E who is now at the U.S. Naval Academy in Annapolis, Maryland. "Even more so since 9/11."

The ties between Jason and the military, formed in the wake of Sputnik, were severed last December after DARPA officials concluded that Jason had not kept up with the times and that its studies focused too heavily on physics. Jason disputed that assessment, noting that a third of its members were not physicists and citing recent studies ranging from modeling biological systems to building computers with molecular electronics. The

ScienceScope

De-Celeration Biotechnology's enfant terrible—Celera Genomics in Rockville, Maryland—is mellowing with age. Last week, it formally disavowed its youthful aim of becoming a worldwide purveyor of genome news and data, a goal once proclaimed by founder and former president J. Craig Venter, who left the outfit abruptly in January. Instead, Celera is morphing into a drug R&D firm and will operate primarily as a data provider to its parent organization, Applera Corp. of Norwalk, Connecticut.

Applera CEO Tony White announced on 22 April that an executive from within the company, Kathy Ordoñez, is being promoted to serve as president of both Celera Genomics and a subsidiary called Celera Diagnostics. White explained that an internal study concluded that the company could not profit in the long term by selling only data. So Celera's services will be combined with an online reagent and equipment supply operation to be known jointly as the Applied Biosystems Knowledge Business. White called it "a complete transformation."

Wilson Resigns Prominent gene therapy researcher James Wilson (below) will resign as director of the University of Pennsylvania's Institute for Human Gene Therapy in Philadelphia. The decision, announced last week by Penn officials, comes 31 months after the death of an institute research subject sparked intense scrutiny of the institute's procedures and widespread debate about the adequacy of human subject protections.

The September 1999 death of patient Jesse Gelsinger prompted federal officials to shut down eight gene-therapy trials at the institute and to consider stripping Wilson of authority to oversee research involving human subjects (*Science*, 12 May 2000, p. 951). Wilson's troubles—and gene therapy's dimming promise—prompted an internal Penn committee to conclude that the $13 million institute should "broaden its scientific focus to include cell-based therapies, as well as stem cell biology and molecular virology," according to an e-mail sent to faculty members last week by medical school dean Arthur H. Rubenstein. The memo's contents were first reported by *The Philadelphia Inquirer*.

Wilson could not be reached for comment. In his e-mail, Rubenstein said Wilson will resign 1 July but will remain at Penn as a researcher and professor.