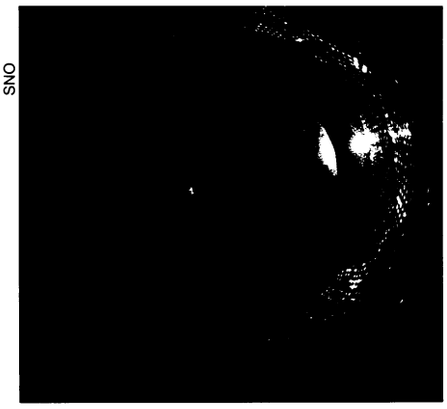
tists see Canada's SNO as the best bet for quick proof of neutrino oscillations.

The great promise of SNO lies in its detector's unique use of deuterium, an isotope of hydrogen with an extra neutron, which reacts with neutrinos in two ways. One reaction takes place only with electron neutrinos, the sole type that the sun emits. The other occurs equally for all three neutrino flavors. Comparison of the rates of the two reactions should allow scientists to know with unprecedented certainty whether electron neutrinos are transforming into muon or tau neutrinos.

Escaping the vagaries of using natural neutrino sources, K2K is the first of a new generation of accelerator-based experiments. These so-called long-baseline experiments will fire neutrinos hundreds of kilometers to verify independently the Super-Kamiokande results. Fermilab is building a detector, and physicists have proposed another similar experiment for Europe. The neutrino flight paths of each would extend about three times the distance of K2K. Because these experiments use accelerators to make their neutrinos, researchers expect to gain much greater control over what is headed for their detectors.

Aside from SNO and long-baseline


SNO

An acrylic sphere 12 meters across hangs inside a shell of photomultiplier tubes in Canada's Sudbury (Ottawa) Neutrino Observatory. Shown empty, the sphere will hold 1,000 tons of heavy water. When neutrinos hit the water, buried more than two kilometers deep, the tubes will detect faint flashes.

projects, many other experiments of various types are expected to contribute pieces to the puzzle. Some researchers use nuclear reactors to fire neutrinos over relatively short distances. Others are studying the decay of neutrons, which release the antimatter partners of neutrinos, to more deeply probe the nature of neutrinos.

Data from astronomical observations may also shed some light. Two upcoming satellite studies of the cosmic background radiation could yield evidence for or against a fourth neutrino's existence. Also, a recently inaugurated telescope survey of the distribution of galaxies in space could provide a new estimate of neutrino mass. "It looks like astronomers will actually be able to say something about neutrino physics," says Subir Sarkar of the University of Oxford in England.

With so many voices expected to chime in during the next few years, Albright predicts a rapid denouement to the hunt for neutrino mass. "We'll have the mystery pretty much unraveled in a 5-to-7–year period," he predicts.

Langacker senses that neutrino oscillations may be the first step toward an even bigger prize, a theory of everything, which could unite all the forces in the universe, including gravity, in a single framework—perhaps within the next 20 years.

"We will have the new ideas, the new probes, the neutrino masses, and the new accelerators," he says. "It's a very, very exciting time for understanding nature at the most fundamental level." The promise of his utopian vision hints that more than just the uncertainty of the '60s is back. □

Biology

Night life discovered for bumblebees

Bumblebees, supposedly your basic daylight travelers, can navigate outside their nests in the dark, researchers have accidentally discovered.

One night last year, someone left on an infrared monitoring system in a bumblebee colony in the darkened lab of James D. Thomson at the State University of New York at Stony Brook. The next morning, researchers were startled to realize that the bees had slipped out of their nest to visit a feeding station after hours.

Bees must be able to get around in the dark since they live in underground nests, Thomson points out. Yet researchers know little about the dark side of navigation.

Outdoors, some bees will fly in bright moonlight, but they don't buzz over the landscape in pitch blackness. The lab bees didn't fly, either. They walked.

Subsequent studies of their late-night hikes suggest they use odor and perhaps some kind of magnetic compass, report Lars Chittka of the University of Würzburg in Germany, Thomson, and their colleagues. The analysis appears in the Jan. 7 PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON B.

Bees respond to scents once they reach a flower, but previous studies had not turned up evidence that scent guided foragers. The researchers let bees troop out to the feeder, then removed it and reoriented the surface they walked on. In the next forays, bees headed in the wrong direction, as if still following the scent trails laid down on earlier treks.

When researchers cleaned the surface, the bees headed in the compass direction of the feeder's original location. Other research has suggested that honeybees and a few other arthropods have internal magnetic compasses, but this evidence is new for bumblebees.

In another novel finding, the lab bees going out to forage showed two rush-hour peaks: one in full light at midday and one in the dark at midnight. —*S.M.*

Do parasites explain female promiscuity?

An experiment with bumblebees provides the most direct evidence yet for a theory explaining why females of so many species go to the trouble of mating with more than one male.

Such behavior has puzzled biologists because of "the obvious costs of time, energy, and exposure to predation," as Boris Baer and Paul Schmid-Hempel put it in the Jan. 14 NATURE. The researchers, from ETH Zurich in Switzerland, point out that some social insects "carry this behavior to extremes." Virgin honeybee queens mate with 10 to 20 males during a once-in-a-lifetime round of midair sex.

Female insects can give birth to broods with multiple fathers, and theorists have proposed that boosting the genetic diversity of a brood should make the colony better able to withstand parasites.

Baer and Schmid-Hempel artificially inseminated bumblebee queens with either low- or high-diversity sperm. The colonies that the queens founded foraged outdoors, where workers encounter all sorts of menaces. The seven high-diversity colonies ended up with fewer parasites and greater reproductive success, on average, than the low-diversity colonies.

William D. Hamilton of the University of Oxford in England, one of the theorists who proposed the parasite idea, greeted the work warmly. Besides helping explain the forces behind insect orgies, he says, the paper may also help resolve another mystery, "perhaps the very greatest of the subject—that of why sexual reproduction so often prevails over its obviously far more efficient alternative, female-female parthenogenesis."

Would female animals be more likely just to give birth without male input if it weren't for the risks of parasites? The new study, Hamilton muses, "reflects on a lot that we all care about—on love, for example, and all its troubles, and on all the rest of the wonderful, yet confusing, patterns that sex creates." —*S.M.*