versity of Illinois microbial ecologist Lutgarde Raskin and her colleagues, for example, are using fluorescent probes to study the associations between organisms that break down nutrients in waste-water treatment plants. In such plants, as in many more-natural environments such as soils and sediments, numerous types of microbes work in close association. In waste-water plants, microbes often clump together to form granules about 1 millimeter across, says Raskin, and with their probes, she and her colleagues have shown that these granules have a consistent structure, with organisms that get their food from the nutrient-rich water located on the outside and species that feed on each others' waste products lying in successive rings toward the center.

By all accounts, such studies are causing a fundamental shift in the discipline of microbiology. By giving researchers the means to study specific organisms in the environment, "molecular methods are creating a wonderful bridge" between molecular biologists and environmental scientists, says Sayler. Many researchers believe that this type of cooperation will be critical to deepening researchers' understanding of how microbial species control broad biogeochemical processes, such as the cycling of carbon, nitrogen, and sulfur. "The biosphere is dominated by microbial processes," says Olsen, and global change, ranging from the buildup of greenhouse gases to new land uses, may be altering these processes.

"We don't yet know a lot [about the effect of such changes on microbial processes] ... although the field is progressing rapidly," says Woese. And for many researchers, that progress spells excitement. "No one could have convinced me 10 years ago that [microbiology] would be this exciting today," says Staley. "The next decade is likely to be one of the best yet."

–Robert F. Service

PHYSICS

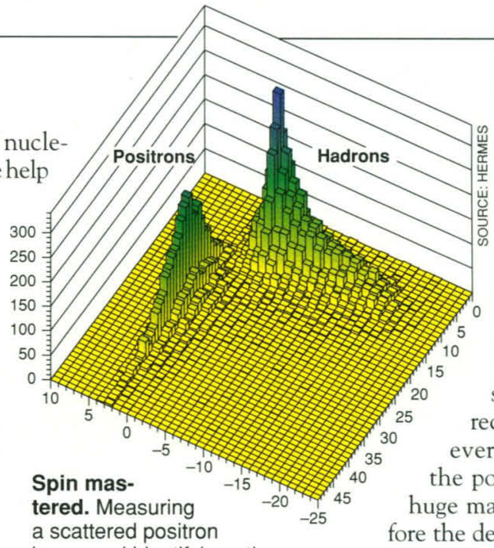
Subatomic Spin Still in Crisis

A new detector on the HERA positron-proton collider in Hamburg, Germany, has confirmed that there really is a crisis in particle physics—and physicists are delighted. The crisis is a decade-old conundrum about the toplike spin of protons and neutrons. These particles are composed of quarks, which themselves spin, but the quarks don't contribute nearly enough spin to explain the total. Results announced last week from the new detector, called HERMES, have confirmed the shortfall—and thus shown that HERMES's new spin-probing technology is working properly. That's welcome news, say physicists, because HERMES, as the most advanced experiment in the field, could eventually track down the missing spin.

"People will mainly be excited by the fact that the experiment is working," says physicist Richard Milner, spokesperson for the HERMES collaboration. HERMES replaces the solid targets of past experiments with a gas of simple atoms, polarized so that their nuclei spin in the same direction. The arrangement allows polarized positrons (antimatter counterparts of electrons) from HERA's circular beam to pass through the target time after time, yielding plenty of clean data on the spinning innards of nucleons—protons and neutrons. "They made a major accomplishment in proving this new technique works," says Yale University physicist Vernon Hughes.

With HERMES, physicists should eventually be able to probe how much spin is carried by elusive components of nucleons such as gluons (force particles exchanged by quarks) and so-called strange quarks, which don't normally inhabit nucleons but can briefly pop into existence and then vanish. A resolution to the spin crisis could also open new insights into the theory that describes how quarks and gluons behave, called quantum chromodynamics (QCD). The surgical precision of QCD's equations is difficult to translate into ironclad predictions about the interiors of nucleons, so "we need all the help we can get from experiments," says Massachusetts Institute of Technology theorist Robert Jaffe.

To tease out the sources of spin, physicists make two measurements, one with the spins of the target nucleons aligned with those of the probing particles, and the other with the target spins reversed. Differences in the numbers of particles scattered hold clues to how spin is distributed in the nucleon. Several major experiments, including the Spin Muon Collaboration at CERN, the European center for particle physics, and projects at the Stanford Linear Accelerator Center (SLAC), have fired polarized probe beams at targets such as solid ammonia or butanol. Solid targets yield more collisions—but also a lot of "noise" from unpolarized nucleons, says HERMES team member Klaus Rith.



Spin mastered. Measuring a scattered positron beam and identifying other debris (hadrons) reveal the neutron's spinning interior.

A decade of studies at SLAC and CERN has shown that instead of carrying about 60% of a nucleon's spin, as QCD implies, the quarks account for just half that amount. Now, analyses of the early HERMES data confirm that quarks carry about 25% to 30% of a neutron's spin, estimates Milner—"about a factor of 2 lower than you would expect" from theory.

Physicists now hope that HERMES's innovative technology will allow it to show where the extra spin is coming from. The gas target—a cloud of spin-polarized hydrogen or helium—yields a cleaner signal than the solid targets of past experiments, and a clever polarization scheme exploits the natural alignment of HERMES's high-energy positron beam.

As Milner explains, the spin axes of the positrons end up pointing across their flight path as they are accelerated in HERA's 6.4-kilometer ring. Spin studies need probe particles that spin along their direction of travel, however, so HERMES twists the positrons' spin with a huge magnet placed just before the detector. After the detector, a second magnet restores the positrons to their original orientation for experiments on HERA's two other detectors.

Next week, HERMES physicists will start building a new detector element that will identify particles dislodged from nucleons in the gas by the impinging positron. "The [structure of] those residues ... reflects important information about the spin of the original proton and neutron and the way it was put together," says Jaffe. Particles called kaons, for example, betray the presence of strange quarks inside the nucleon. To identify and analyze these fragments, whose low energy makes them hard to detect, the new instrument will record the Čerenkov light (the optical equivalent of a bow wave) generated when charged particles enter the counter moving faster than the speed of light in the material.

HERMES won't rule the spin field for long. CERN and SLAC both plan new experiments that will also be able to identify emitted particles. But HERMES, true to its name, may bring the first news that could end the spin crisis.

–Andrew Watson

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