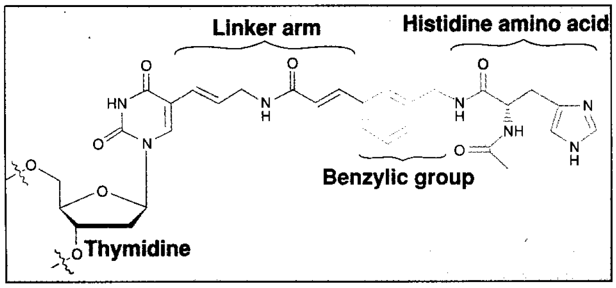


Armed and ready. An amino acid linked to a DNA building block could enable the double helix to catalyze chemical reactions.

plementary strand of the DNA—it might not affect the pairing and duplication.

The scheme worked. After only three tries, they devised a rigid hydrocarbon arm that projected from the back end of a thymidine nucleotide without affecting its ability to be incorporated into DNA chains and duplicated by DNA polymerases. The arm proved to be quite versatile. Barbas and Sakthivel initially found that they could hook numerous functional groups to the end, including a complete histidine amino acid—a common constituent of proteins—and they have added other amino acids since then.

Meanwhile, Benner's team—which included colleagues at Florida and at GenEra Inc., in Alachua, Florida—took a different route: They modified both the DNA and the polymerases. They had spent years designing novel nucleotides that could be incorporated into a DNA strand alongside the four standard building blocks, including one with a hydrocarbon linker and an amino group tacked onto the back of the molecule. They then engineered mutations into a small family of polymerases and tested them all until they found one that would tolerate the odd DNA.

Benner's group used its combination of modified DNA and tolerant polymerase to go a step further and evolve a DNA that could bind to a specific target. Using a polymerase prone to making occasional random errors, they copied a DNA chain containing the modified nucleotide many times over to produce a library of chains, all slightly different. Benner's team then ran the chains through a column containing a molecular target for the DNA: immobilized adenosine triphosphate (ATP) molecules. Most chains passed the target by, but a few stuck. Those that did were later removed and used as the starting material for a new round of replication. After about 12 rounds of this evolution and selection, they found a DNA hybrid that stuck to ATP 100 times more strongly than a similarly evolved but natural DNA strand.

Both groups say they are now working hard to isolate DNA hybrids that catalyze actual reactions. If that works, Benner says, it will confirm that DNA, like RNA and proteins, can carry out the two key functions of life. The prospect that DNA hybrids can do this, says Benner, raises the question of whether such hybrid molecules might have played a role in early evolution, taking care of both genetics and chemistry, before proteins and DNA went their separate ways. For now, there's more evidence to suggest that RNA was the original single biopolymer, notes Gerald Joyce of Scripps. But he adds that the new work underscores the notion that the chemistry of life may have changed over time. Says Joyce: "The paints on the palette [for life's beginnings] don't have to be the same ones we see in biology today." –ROBERT F. SERVICE

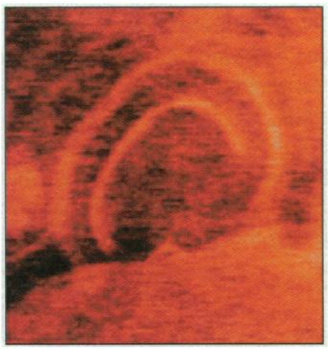
SOURCE: (TOP) CARLOS BARBAS III; (PHOTO CREDIT) RAYMOND ASHOORI

IMAGING

Technique Probes Electrons' Secret Lives

Electrons on the surface of a material can no longer hide from probing instruments, which can track virtually their every move. But physicists can't spy so easily on electrons that lurk below the surface and have only been able to guess at how they behave. Now, however, two groups of researchers have found a way to peer beneath an insulating surface and image intricate patterns formed by the electrons trapped in a thin, two-dimensional semiconductor layer.

At a meeting sponsored by the National High Magnetic Field Laboratory in Tallahassee, Florida, last week, the leader of one group, Raymond Ashoori of the Massachusetts Institute of Technology, showed the latest fruits of the technique, which maps subsurface charges by scanning the semiconductor with a sharp probe. The images, which show enigmatic rings and filaments of electrons, only deepen the puzzle of how electrons behave when they are trapped in a two-dimensional layer. "The experiments contain an incredible amount of information," says Sankar Das Sarma of the University of Maryland, College Park, "but it is still not clear how to absorb that information to make sense of it."



Electric arcs. A 2-micrometer-square region of an electron layer in a magnetic field shows mysterious rings of compressible charge.

Ashoori and his colleagues, along with a group led by Amir Yacoby of the Weizmann Institute of Science in Rehovot, Israel, have been studying the phenomenon that earned a trio of other physicists the Nobel Prize this year: the quantum Hall effect. Under exacting conditions—temperatures within a fraction of a degree of absolute zero and strong magnetic fields—the current flowing through a two-dimensional "electron gas" (2DEG) exhibits a series of plateaus where it no longer increases as the voltage is cranked up. The quantum Hall effect has intrigued physicists since its discovery in 1980, and this year's Nobel Prize is the second to be awarded for studies of it (*Science*, 23 October, p. 613). But physicists don't have a clear view of how the electrons behave as they stack up in quantum energy levels—the source of the plateaus. "There are a lot of data on how a two-dimensional sheet conducts electricity," says Ashoori, "and a lot of guessing as to what's going on inside. But nobody has ever looked."

To see what's happening in the 2DEG, Ashoori adapted a technique called scanning probe microscopy, a standard way to map atoms on surfaces. A sharp tip probes the semiconductor surface, but instead of tracing its atom-scale undulations, it picks up tiny charge variations with the help of an ultrasensitive charge detector. To distinguish the subsurface charges from ones sitting on the surface, the team pumps charge in and out of the semiconductor at a frequency of about 100 kilohertz. The tip locks onto a signal of just that frequency, indicating charges moving in the 2DEG, and ignores the unmoving charge at the surface. Yacoby's probe detects static charges instead and relies on other techniques that don't depend on frequency to tease out the subsurface signal.

Both groups are using their techniques to study the current plateaus seen in the quantum Hall effect. Physicists speculate that "incompressible" regions in the 2DEG—places where the electrons are already squashed together as tightly as the laws of quantum mechanics allow—are responsible. These incompressible regions can't accommodate any additional electrons, and so they block increased current flow. In between the plateaus, current flows more freely because "compressible" regions open up in the 2DEG.

What Ashoori's team has seen so far confirms that general picture but adds puzzling details. "Imagine dumping charge in [the material] and waiting to see how it spreads," says Ashoori. "To our shock, it goes into these patterns that are enormously sensitive to field." Ashoori interprets the patterns, which range from long filaments to small droplets to large islands, as variations in the compressibility of electrons. They appear only at the current plateaus, and they change when the field is changed by just 1%. Yacoby's group also sees an odd mosaic of compressibility variations.

The images Ashoori showed in Florida only deepened the puzzle. "We see objects that look like perfect rings," he says. "Now why would electrons form circles like that?"

Some physicists caution that the technique itself—in particular, the presence of the tip and the charge pumping—might be creating these patterns. Still, most physicists are enthusiastic about the technique's potential. Allan MacDonald of Indiana University in Bloomington thinks it might also be useful for revealing other exotic electron configurations that can form in a 2DEG, such as a Wigner crystal, where the electrons don't slosh around like a liquid but remain in fixed positions to form a lattice. Even when they are buried in a semiconductor, electrons can't hope for much privacy anymore. —MEHER ANTIA

Meher Antia is a science writer in Vancouver.

ASTROPHYSICS

Powerful Cosmic Rays Tied to Far-Off Galaxies

Catching mystery rays. A prototype detector at the Fly's Eye in Utah, which is searching for the highest energy cosmic rays.

CREDIT: FERMILAB

A pair of astronomers may have solved a long-standing puzzle about the source of ultrahigh-energy cosmic rays, particles that slam into the atmosphere with 100 million times the energies reached in the largest particle accelerators. They have traced a handful of these particles back to highly energetic active galactic nuclei, the turbulent centers of distant galaxies that may harbor massive black holes. The finding, reported in the 26 October issue of *Physical Review Letters*, could upset current notions about the nature of ultrahigh-energy cosmic rays.

Astrophysicists have figured that the highest energy cosmic rays have to originate near our galaxy. That's because any charged particle, like a proton, that has traveled farther would have been slowed to lower energy levels by the microwave background—the low-energy radiation that pervades the universe. But no one has been able to find a nearby source for the ultrahigh-energy rays.

Glennys Farrar, now at New York University, and Peter Biermann of the Max Planck Institute for Radioastronomy in Bonn suspected a more distant source: a highly energetic class of active galactic nuclei that have intense magnetic fields, which might be capable of accelerating particles to high energies. Because each incoming cosmic ray sets off a chain reaction in the atmosphere that ends in a detectable shower of electrons or positrons, Farrar and Biermann could figure out the approach angle of five cosmic rays. In each case, the path of the incoming ray could be traced back to a previously identified active galactic nucleus. The probability of the cosmic rays lining up with such galaxies by pure chance is only 0.5%, the researchers say.

"If the correlation is as good as they claim, then it's very, very suggestive that we may well have found the source of these extremely high-energy cosmic rays," says Raymond Protheroe, an astrophysicist at the University of Adelaide in Australia. But he adds that this would upset the current assumption that cosmic rays are made up of protons or atomic nuclei, because they could never retain such high energies over such long distances. If Farrar and Biermann are right, "whatever's getting to us cannot possibly be a proton," says Protheroe.

Farrar and Biermann hypothesize that the ultrahigh-energy cosmic ray particles could be new neutral particles or neutrinos, which would not interact with the microwave background. But given that the analysis rests on just a handful of events, they say, much more work will be needed to close the case.

—DENNIS NORMILE

RESEARCH MANAGEMENT

New Law Could Open Up Lab Books

Tucked into last month's giant spending bill is an unwelcome message to academic researchers: Their data may be fair game for anyone who asks.

A few words in the section funding the White House Office of Management and Budget (OMB) would extend the federal Freedom of Information Act (FOIA)—a 1966 law to make government more accountable to the public—to extramural grants. That opens the possibility that scientists at universities, hospitals, or nonprofit organizations might have to turn over the contents of their computer disks of data, or even their lab notebooks, in response to a request to the agency that funded their work. "We're all very troubled," says Wendy Baldwin, deputy director for extramural research at the National Institutes of Health.

The language, inserted by Senator Richard Shelby (R–AL), says OMB must revise its rules for administering federally funded research grants "to require Federal awarding agencies to ensure that all data produced under an award will be made available to the public through the procedures established under the Freedom of Information Act." Private parties requesting the data may be charged "a reasonable user fee." At present, only funding agencies themselves can ask grantees for data. The new language implies that federally funded researchers must turn over their data to anyone who files a FOIA request. "The taxpayers have a right to much of this information," says Shelby.

The roots of the provision go back to last year's controversy over new Environmental Protection Agency air pollution rules for fine soot. Industry groups and some legislators demanded that university researchers hand over their data on the health effects of the pollution, leading to an unsuccessful legislative proposal requiring public data release (*Science*, 8 August 1997, p. 758). This year, a separate funding bill containing a request for OMB to study the issue was vetoed by President Clinton for unrelated reasons, leading Shelby to insert more direct language in the massive spending bill passed before Congress adjourned (*Science*, 23 October, p. 598).

Some observers are outraged that this sweeping measure was passed with no hearings. "It is ironic that a provision described as a sunshine provision needed to be tucked into a 4000-page bill in the dead of night," says Representative George Brown (D–CA), ranking Democrat on the House Science Committee. And some health researchers are worried that the directive will give industry a new tool to stall health regulations. "If past history is any indication, vested interests will misuse [this provision] to discredit valid research results they don't like and to harass the researchers doing the work," says New York University environmental scientist George Thurston, whose studies helped form the basis for EPA's contested regulations.

Others worry that raw data will be requested before it has been analyzed and peer reviewed. "It's important that we have processes in place for data sharing, but this basically opens the door to anyone's data without any filters," Baldwin says. University researchers say that privacy and proprietary data might also be compromised.

The question facing OMB now is how to implement the new requirement. Agency officials say they hope to be consulted in a process likely to take many months.

—JOCELYN KAISER