

# Back to the Future

PHYSICISTS GAZE INTO THE CRYSTAL BALL BY GRAHAM P. COLLINS

**“P**redictions are hard to make, especially about the future,” said Nobel physicist Niels Bohr, many years ahead of Yogi Berra. But from October 7 to 9, more than 150 leading physicists gathered at the University of California at Santa Barbara to engage in just that daunting task. Commemorating the 25th anniversary of the school’s Kavli Institute for Theoretical Physics, they looked back at the past quarter of a century of physics and ahead to what will happen in the next.

The speakers leaned heavily toward the theory side of the aisle, but an experimental device figured prominently in several talks: the Large Hadron Collider (LHC)

at CERN, the European center for particle physics near Geneva. It will start scientific operations around 2007. A few speakers looked forward to the LHC answering outstanding questions related to the Standard Model of particle physics and what comes beyond it.

Nima Arkani-Hamed of Harvard University suggested that the LHC could reveal evidence of far stranger physics, such as that of the string theory “landscape” in which our universe is one small patch of a much larger multiverse with different physical constants holding sway in each patch [see “The String Theory Landscape,” by Raphael Bousso and Joseph Polchinski; *SCIENTIFIC AMERICAN*, September]. Arkani-Hamed described a new theoretical model concerning the Higgs particle, thought to be responsible for the masses of the other elementary particles and a prime target of LHC experiments. The model suggests that the Higgs mass is strongly fine-tuned within our patch of the multiverse, which will allow predicted effects of supersymmetry to take place at much higher energies than is currently expected. That change eliminates all the phenomenological problems of conventional supersymmetry models, he claimed, and makes detailed predictions of what the LHC will see.

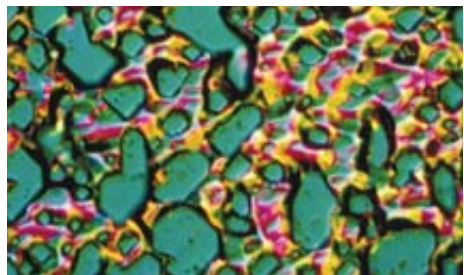
Steven Weinberg of the University of Texas at Austin shared a “nightmare” that

he has: the LHC will uncover the simplest possible variant of the Higgs particle and nothing that disagrees with the Standard Model. That would leave many questions unanswered and provide very few clues for how to extend the Standard Model.

On the lower-energy side of physics, Steven Kivelson of the University of California at Los Angeles, among others, discussed condensed-matter physics, which is primarily the science of electrons in matter. He said the most pressing problem is understanding so-called bad metals. Those materials exhibit phenomena that are simple to describe yet cannot be explained by any known metal physics. Philip Anderson of Princeton University focused on the particular case of high-temperature superconductors doped with a moderate level of impurities and warmer than their transition temperature. “We ought to be terribly ashamed,” he said, that the theory behind that state remains absolutely unsolved.

The meeting covered many other areas, such as nanophysics, astrophysics (particularly gravitational waves), and quantum computing and gravity. It also served as an impromptu celebration of the Nobel Prize awards, one of this year’s winners being the institute’s director, David Gross. In wrapping things up, Gross presented 25 forward-looking questions that ran the gamut of topics, culled from suggestions by the meeting’s attendees. Several concerned the application of physics to life sciences. How can one tell the shape of an organism by looking at its genome? Can the theory of evolution be quantitative and predictive? To understand biology, is new mathematics required, the way that string theory requires new mathematics?

The questions reflect a trend pointed out earlier in the conference by biophysicist William Bialek of Princeton. According to Bialek, 25 years ago biophysics involved the application of physics methods to problems posed by biologists, whereas today it is characterized by physicists asking new and different research questions about living matter. Perhaps at the institute’s 50th anniversary, sessions will cover a new kind of theoretical biology modeled on theoretical physics.



**“STRANGE METAL” STATE** that defies explanation exists in high-temperature superconductors, such as this praseodymium-based copper oxide, imaged through special photomicrography techniques.

## QUESTIONS FOR ANOTHER TIME

To wrap up the Kavli Institute for Theoretical Physics meeting, which explored the future of physics research, David Gross presented 25 questions, selected from suggestions submitted by the meeting’s attendees (the talk is available at <http://online.itp.ucsb.edu/online/kitp25/gross/>). Somewhat paraphrased, the queries included:

- How did the universe begin?
- What is the nature of dark matter and dark energy?
- Is quantum mechanics really the ultimate description of nature?
- Could space and time be emergent concepts?
- When will computers become creative theoretical physicists?
- Could it be that the behavior of a big thing is not entirely determined by the behavior of the little things that make it up?