High-powered discussions on high-temperature superconductivity

"Anything that is not forbidden is allowed" is how Soviet scientist Vitaly L. Ginzburg characterizes current efforts to describe the theory behind the recent high-temperature superconductivity phenomenon (see p. 356).

Ginzburg last month joined scientists from around the world to discuss the latest theoretical and experimental results of the compounds found to lose all electrical resistance at temperatures above liquid nitrogen (77 kelvins), making them cheaper to cool than previous superconductors that required more expensive liquid-helium (4.2 K) coolants (SN: 2/21/87, p.116). The Boston conference was sponsored by the British journal NATURE.

Much of the discussion at the meeting focused on what makes the new superconductors work. Conventional superconductors are explained through the Bardeen-Cooper-Schrieffer (BCS) theory, which was formulated some 40 years after the first superconductor was discovered by Heike Kamerlingh Onnes in 1911. In ordinary materials, electrons move about randomly, causing resistance to the flow of electricity. The BCS theory says that in superconductors, electrons travel in pairs, allowing electricity to flow freely throughout the material (SN: 3/14/87, p.164). But since electrons normally repel each other, they require a mediator to cause them to attract. In the BCS theory, that mediator is a phonon, which causes the electrons to attract through vibrations in the crystal lattice structure of the superconducting material.

But there is growing opinion that this theory fails to predict how the new, higher-temperature superconductors work. Most scientists agree that the electrons still pair in the new materials, but disagree on just how that mechanism is mediated.

One theory, developed by Philip W. Anderson of Princeton (N.J.) University, calls for some sort of magnetic excitation in the crystal lattice structure to act as an intermediary for the attraction of electron pairs. Called the resonating valence bond (RVB) theory, it relies on the magnetic spins of copper atoms to cause, under special circumstances, the attraction of electron pairs. "About half the job is done," Anderson says. "I have the theory of the new superconductors, but I don't have the theory of the new superconductivity complete." Other popular theories call for some kind of electronic motions, such as collective motion or local polarization of electrons, to mediate the exchange process.

Yet the only consensus at the meeting seemed to be on the elimination of the phonon-mediated mechanism (and even then there were a few holdouts). "The one thing that seems to finally be true is that the theorists believe that it's not electron-phonon coupling," Robert J. Cava of AT&T Bell Laboratories in Murray Hill, N.J., told SCIENCE NEWS. "In the beginning there were some people who wanted that to fit no matter what." Cava believes the physicists are fairly evenly divided between the magnetic and electronic excitation theories. Others believe the RVB theory is gaining momentum. "The tide is definitely turning in that direction," says T.M. Rice of the Institute of Theoretical Physics in Zurich.

When will the theory be ironed out? David Pines of the University of Illinois at Urbana-Champaign believes it will be two years from the original 1986 discovery of the 35 K materials before a mechanism is identified, and another five years before a microscopic theory is developed.

Experimentally, researchers are gaining ground in their study of the microscopic crystal structure of the new materials. One problem found is that the coherence length – the range over which the electrons are paired – is very small. "If the coherence length is very small, that essentially means you have a weak link at this point," says Praveen Chaudhari of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y. The problem comes in structural defects in the material that cause these weak links where the electrons have to tunnel to reach the next pair. In polycrystalline, or multicrystal, samples this prohibits a high enough critical current necessary for many potential large-scale applications (SN: 8/15/87, p.106). This has not been found to be an overriding problem in the single-crystal samples.

"I think one of the big challenges in this business will be the development of a tunnel junction between two superconductors," says John Clarke of the University of California at Berkeley. Such a junction would connect the coherence that occurs between superconductors. Currently, these junctions can be built for such materials as lead, tin and niobium, which have coherence lengths greater than about 1,000 angstroms. The new yttrium-based superconductors, however, have coherence lengths only a few angstroms in length, making the prospect of tunnel junctions a difficult one.

Scientists are also divided about where superconductivity actually takes place in the new materials. Some think it occurs in the chains of copper and oxygen found in the structure, citing experiments that show that if these chains are disordered, superconductivity drops. Others believe the key is in the planes of the structure, saying that there are high-temperature superconducting materials that don't exhibit these chains.

The furor over room-temperature superconductivity also appears to have been quelled. Although room-temperature superconductivity is still expected to be achieved someday, most groups are concentrating their efforts on the materials that superconduct in the 95 K range. Others also are studying materials that superconduct at lower temperatures.

Several researchers note the importance of looking for new examples of materials that superconduct, or of peering into the reasons why some of the rare earths apparently don't superconduct. "I think the question now is why *aren't* some of the rare earths superconducting, not why *are* some of them superconducting," Cava says, adding that a variety of materials should be studied. "It's a gigantic periodic table and there's a lot of stimulation here for people's minds."

– Karen Hartley

An antidrug malaria pump?

The drug resistance of malaria-causing parasites may be due to a highly effective "sump pump" that can expel a common antimalaria medication, scientists reported last week. But, say the scientists, this mechanism can be inhibited by other drugs that could be added to the therapy regimen for malaria.

Researchers at Washington University in St. Louis and Walter Reed Army Institute of Research in Washington, D.C., say that *Plasmodium falciparum* parasites resistant to the commonly used drug chloroquine apparently release the drug 40 to 50 times more rapidly than do *P. falciparum* killed by chloroquine. The scientists report in the Nov. 27 SCIENCE that this "rapid efflux phenomenon" can be found in drug-resistant malarial parasites from Africa, South America and Asia. But by adding other drugs – including two that block the entry of calcium into cells – to *P. falciparum* cultures, the researchers were able to significantly slow chloroquine release. They say that results suggest this chloroquine resistance may be similar to multidrug resistance in mammalian cells. This similarity was noted previously by researchers studying the response of resistant *P. falciparum* to the anticancer drug verapamil (SN: 3/7/87, p.148).

Other researchers are working on vaccines against *P. falciparum* (SN: 3/21/87, p.181), but results from the first clinical trials of an antimalaria vaccine have been disappointing. Made by the U.S. Army, the potential vaccine protected only one of the six subjects immunized and then exposed to the parasite, according to an Army spokesman. □