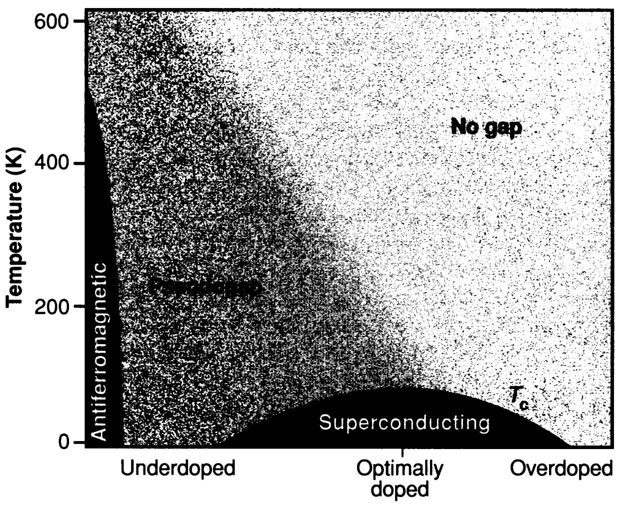
scattering is a technique whereby researchers fire photons at a material and watch how the light scatters off. The difference in energy between the fired and scattered photons reveals the energy levels of the electrons in the material.

When Blumberg and his colleagues fired photons at a cuprate made from bismuth, strontium, calcium, copper, and oxygen above the T_c, instead of producing the sharp peaks of discrete energy levels, the scattered photons showed a flat, smeared-out spectrum from low to high energies. This, says Blumberg, suggests that electrons in the cuprates interact with each other strongly, so that when incoming photons scatter from the material they excite not just one electron, but a whole group of electrons collectively.



Persistent gap. The gap signature of superconductivity hangs around in underdoped cuprates as a pseudogap above T_c.

The researchers found a different picture when they jacked the photons' energy up to 75 milli–electron volts: A large single scattering peak now appeared. "There are different interpretations of what this means," says Blumberg. "But my favorite is that superconducting [electron pairs] get established well above T_c, and their binding energy is 75 milli–electron volts." Hence, the higher energy photons are absorbed as they split the pairs apart.

If so, this suggests that somehow electrons in the cuprates manage to pair up at temperatures well above the superconducting temperature, maybe even as high as room temperature. Pairing is essential, but not enough, for electrons to superconduct. For this they also need "coherence," whereby they all travel together in step. But the extra heat present in the normal state probably causes the pairs to break apart almost as soon as they form. Thus, the pairs never get a chance to travel long distances, and superconductivity never arises.

That explanation agrees well with theoretical ideas advanced by Vic Emory of Brookhaven National Laboratory in Upton, New York, and Steven Kivelson of the University of California, Los Angeles, who argue that the pseudogap in HTS ceramics arises because the holes in doped cuprates are not distributed uniformly through the material. Neutron scattering experiments suggest cuprates have alternating striped regions with and without holes. And Emory and Kivelson suggest that interactions between these regions cause electrons to pair up. But at temperatures above the T_c, energy from heat prevents these pairs from becoming coherent. And although the notion is still by no means proven, "it is the simplest idea out there," says Timusk.

It's certainly not the only one. Another theoretical camp, led by Philip Anderson of Princeton University and MIT's Lee, argues that the architecture of the cuprates forces the two fundamental properties of electrons—their charge and spin—to separate. Spins on neighboring electrons then pair up, even as charges go their own way. The pseudogap, says Lee, is essentially a signature of this spin pairing, which takes energy to split apart.

Others propose that the behavior of the cuprates is tied to atomic-level magnetic fluctuations in the materials or a mixing of electronic excitations between oxygen and copper atoms. "The problem is not that there's no theory of high-temperature superconductivity," says Boebinger. "There's too damn many of them." And at this point, none of the theories is sophisticated enough to predict falsifiable properties of the materials. But Lee, Mook, and others believe that the host of new experiments on the normal-state properties of the cuprates is already beginning to put welcome constraints on theorists. "The challenge is to fit all those results together," says Mook. "We're not there yet. But I think we'll make it eventually."

–**Robert F. Service**

QUANTUM MECHANICS

Teleportation Beams Up a Photon's State

For "trekkies," being teleported from the bridge of the Starship Enterprise onto the surface of an alien world is still a dream. But at least in the quirky world of quantum mechanics, teleporting is now a reality. Anton Zeilinger and his team at the University of Innsbruck in Austria have shown that part of the spin orientation of a photon of light can be transferred instantaneously to another photon, irrespective of distance.

Zeilinger says his team's work is "the first experimental demonstration of quantum teleportation"—the transfer of a quantum state from one particle to another, first proposed by IBM's Charles Bennett and his collaborators in 1993 (*Science*, 25 October 1996, p. 504). "The real interest of this is [that] it represents a new kind of information transfer," says Bennett, of the Thomas J. Watson Research Center in Yorktown Heights, New York. Quantum teleportation could have applications in quantum computing, says Tony Sudbery of Britain's University of York: "constructing stable memories, protecting delicate quantum states, [and] communicating between quantum computers."

In today's computers, it is a simple matter to read off the digital 1s and 0s that are the two possible states of a computer circuit. In the quantum world, however, where 1 and 0 are labels for, say, the two spin states of a photon, taking the reading is a more interventionist act: It forces the system to adopt one of the two quantum states. Until then, it is some mixture of the two. If Alice—in quantum-speak, the person or circuit at one end of a quantum communication channel—wants to tell Bob (at the other end) about her photon, she has to take a measurement of it. The measurement forces it to be either a 1 or a 0, when what she really wants to tell Bob is about the mixed quantum state. But if computers based on quantum principles are ever to become a reality, they must be capable of moving quantum information around without ruining it by either having to read it before sending it or by sending photons through noisy, disruptive circuits.

Enter quantum teleportation. The key to the Austrian experiment, reported in this week's issue of *Nature*, is to create a pair of photon twins that are intimately related to each other. When photons from a laser are fired into certain crystals, a single photon can split into two identical twins. The quantum state of the parent photon must be conserved, so the sum of the two offspring photons must make up that original quantum state. In the language of modern quantum mechanics, the pair are "entangled," linked through some invisible quantum web. If a measurement on one indicates, say, that its spin is up, the entangled twin is forced into the opposite state—spin down.

Bennett and his collaborators realized that an entangled pair can serve as a vehicle for teleporting the state of a third photon, the "message" photon. In their scheme, Alice makes a combined measurement on one member of an entangled pair together with her message photon. This measurement does not tell her the state of her message photon, but it does entangle her two photons in such a way that they end up with opposite states. As a result of her measurement, Bob's photon becomes instantly primed so that when Alice tells Bob what to do to his photon, he will find that it is identical to the original message photon.

Although the process destroys the original state of the message photon, that state lives on in Bob's photon, the second entangled photon, irrespective of his distance from Alice. There is no transport of actual photons from Alice to Bob—only a flow of quantum information. "It is more like faxing than teleportation," says Sudbery.

Although the setup sounds simple, the team's apparatus is a bewildering tangle of lasers, mirrors, and optical instruments, and the work "required a great deal of experimental finesse," says Bennett. One key was the development over the past 2 years of pure and bright sources of entangled photons, explains Zeilinger. Another, he says, was learning how to take measurements like Alice's, which register information about the joint properties of two photons that lose their individual identities in the process.

A separate group, headed by Francesco De Martini at Italy's National Institute of Nuclear Physics in Rome, has performed a similar experiment, which the researchers will report in *Physical Review Letters*. The Rome group's experiment departs from Bennett's original vision but is optically simpler than the Innsbruck work. It relies on a single pair of entangled photons, with one twin forced to play the role of Alice's message photon in addition to its teleporting role.

"I think one of the main uses to which teleportation will be put is moving data around inside a quantum computer," says Bennett. In quantum computation, "there's the very serious problem that quantum information is very delicate. If it leaks out of the computer at all in the course of the calculation, the result will be spoiled." Teleportation can help beat this kind of problem. "This is a way of sending quantum information reliably through a noisy channel," he adds.

Sadly for *Star Trek* fans, however, quantum teleportation cannot be scaled up to move Captain Kirk from place to place. It is more akin to teleporting "states" of Captain Kirk around the universe. One could imagine the captain's amorous mood being teleported to a far-off clone, a prospect sure to strike fear into the hearts of all female aliens. One consolation: The original amorous state of the captain would be destroyed in the process.

–Andrew Watson

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

DEVELOPMENTAL BIOLOGY

Possible New Roles for *HOX* Genes

MADRID, SPAIN—The best discoveries in the trendy field of "evo-devo" shed light on two processes simultaneously: how genes shape the bodies of today's organisms during embryonic development, and how those same genes may have guided the organisms' evolution (*Science*, 4 July, p. 34). New results from Peter Holland's team at the University of Reading in the United Kingdom seem to have achieved both objectives.

At a workshop on development and evolution held here last month by the Madrid-based Juan March Foundation, Holland reported that he and his colleagues found a putative second cluster of *HOX*-like genes in *Amphioxus*, a fishlike marine invertebrate that is seen as a crucial evolutionary link to vertebrates. A great deal of evidence has shown that the *HOX* genes—so-called because they carry a DNA sequence known as the homeobox—play important roles in laying down the head-to-tail patterns of embryos of organisms ranging from worms to flies to humans.

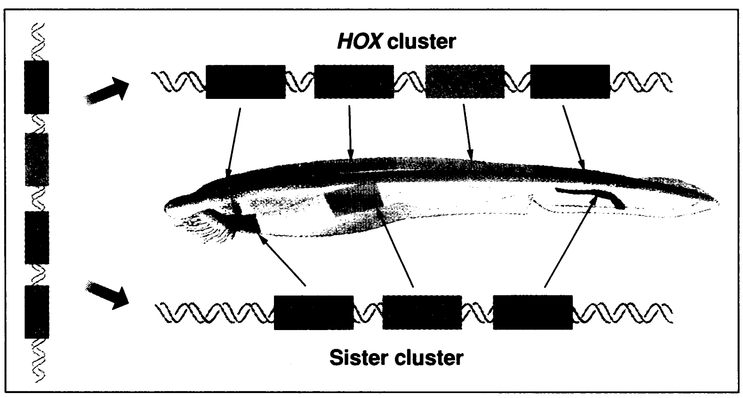


ILLUSTRATION: K. SUTLIFF

Division of labor. The descendants of a proto-*HOX* gene cluster (left) may help shape the *Amphioxus* ectoderm (above) and the gut (below).

In addition to providing a better understanding of the genes controlling *Amphioxus* development, the Holland team's result is intriguing because it may also help explain a key development in the rise of complex organisms like vertebrates during evolution: the creation of multiple "germ layers"—the primitive embryonic tissues that give rise to all of a creature's tissues and organs. *HOX* genes have long been known to be active in ectoderm, the outermost germ layer, but Holland found that the new "sister cluster" of *HOX*-like genes is expressed in the innermost layer, the endoderm. The results suggest, he said, that the appearance of the new cluster—presumably resulting from duplication of a primordial *HOX* gene cluster—is related to the creation of multiple germ layers in early evolution.

Although other researchers want more evidence before accepting that suggestion, it helped make Holland's presentation the most talked-about at the workshop. "These were the newest and best results at the meeting," says Andre Adoutte, an evolutionary biologist specializing in molecular phylogeny at the University of South Paris.

Holland made this discovery while studying a set of *HOX* genes that has long puzzled developmental biologists. Almost all *HOX* genes are arranged in clusters of roughly nine genes each. The expression patterns of these genes along the head-to-tail axis of the embryo typically follow their arrangement in the clusters, with those at one end tending to be expressed more anteriorly, while those at the other end are active farther back. But researchers have also identified three or four types of *HOX*-like genes that don't seem to fit this neat pattern.

While they carry a typical homeobox sequence, for example, they have never been shown to be part of a cluster. That presented a conundrum: If these "dispersed" or "orphan" *HOX* genes weren't in clusters, they could not have arisen the way true *HOX* genes supposedly did—by duplication of successive genes along a single chromosome. But their close similarity to true *HOX* genes makes it unlikely they arose by chance.

At the meeting, Holland described new data from his laboratory showing that three of these orphan *HOX* genes are in fact clustered in *Amphioxus* the way true *HOX* genes are. Using probes made from vertebrate *HOX* genes, he found that two dispersed *Amphioxus* genes were located in adjacent regions of a single chromosome. He then used the technique of "chromosome walking" to track down a third orphan *HOX* gene located close to the other two. Finding the genes close together means, Holland said,