Computer Tools for Thinking in Tandem

"Groupware" can erase geography; it may supplant printed journals and link researchers in "virtual laboratories"

AFTER A DECADE OF EXCHANGING TEXT AND data overnight, Bethesda-based virologist Andrew Lewis and Denver-based immunologist James Cook were positively delighted to graduate to fax machines a couple of years ago for their cross-country collaborations. But even with transit times reduced from hours to minutes, "there was always a time lag between expressing the ideas and sharing them," recalls Cook, an associate professor of medicine, microbiology, and immunology at National Jewish Hospital in Denver.

Today, Lewis, who heads the viral pathogenesis section of the laboratory for immunopathology at the National Institutes of Health, and Cook have digitally erased their time lags by collaborating in real-time on a direct Macintosh-to-Macintosh computer link, using new "desktop conferencing" software developed by Group Technologies of Arlington, Virginia—a "groupware" company run by Lewis' son. This new environment has transformed both the speed and quality of their relationship; the editing process is now more like a dialogue than a set of soliloquies. The two can simultaneously work on the same passage, look over each other's shoulder, and chat onscreen as the work proceeds. "It gives us the ability to mold the text more easily," Cook notes. "If nothing else, it reduces some of the frustration level."

Lewis and Cook are in the vanguard of a wave of computer-mediated collaboration now sweeping across science. These technologies are designed to go far beyond electronic mail. Much as Watson and Crick depended on metal models as key collaborative tools in their effort to puzzle out the structure of DNA, research scientists are beginning to rely on computers to facilitate their own creative interactions. Lewis and Cook's collaborative software set-up represents just the first generation of technologies expressly designed to manage relationships as well as information. Such one-on-one collaboration may soon be joined by electronic "journals" in which networked investigators could share and critique results and "virtual laboratories" that would enable far flung investigators to participate in global experiments. Many observers believe that future high-speed, high-capacity networks such as the National Science Foundation's (NSF) proposed National Research and Education Network (NREN) will provide the high-bandwidth base needed for these "collaboratories."

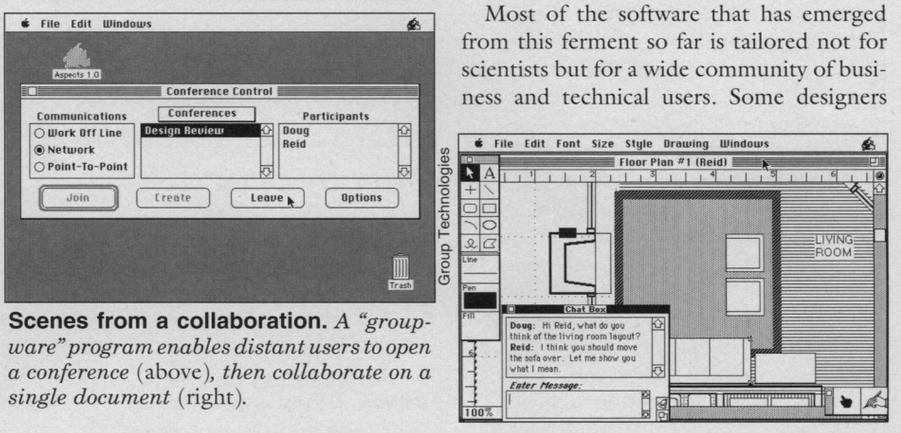
Such collaborative technology "is just beginning to catch on," says Nobel laureate Joshua Lederberg, the president emeritus of Rockefeller University, who ran a 1989 NSF workshop to explore possible architectures for nationwide collaboratories. If Lederberg is correct, then the next decade will see profound effects on the way science is done. These new forms of collaboration, proponents argue, will force major social readjustments within science. An electronic journal, for example, would reshape traditional relationships among authors, reviewers, and readers. Indeed, some of the researchers now pioneering digital collaborations are convinced that such social readjustments could prove to be a greater obstacle to the acceptance of the new form of idea-sharing than any technological barrier. "The challenge now," asserts Tom Malone, director of the Massachusetts Institute of Technology's Center for Coordination Science, "is to create technological infrastructures and environments that enable new sorts of social structures to emerge."

The conceptual roots of network-mediated collaboration reach back roughly 25 years—in particular, to computer pioneer Douglas Engelbart's research in man/machine interface design at the Stanford Research Institute. As the inventor of the mouse and dozens of other interface innovations, Engelbart was intrigued by the prospect of using computers to "augment" relationships rather than just to "automate" them—an idea he tested by developing computer networks for conferencing. He felt that "interpersonal computing" was at least as important as personal computing.

According to Irene Greif, a former MIT computer science professor now with Lotus Development Corp., the field took form under the name computer-supported cooperative work (CSCW) at MIT workshops in 1984. Two years later, at the MCC research consortium in Austin, a few software engineers and network designers launched the first CSCW conference—an event that had grown to 500 researchers by last year, when it was held in Los Angeles. Topics ranged from Japanese designs for collaboration technology to communications protocols for emergency vehicle dispatchers.

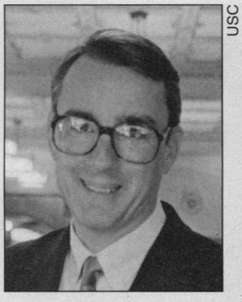
Most of the software that has emerged from this ferment so far is tailored not for scientists but for a wide community of business and technical users. Some designers take a bottom-up approach, aiming their products at one-on-one collaborations like Lewis and Cook's. Others want to foster enterprise-wide collaboration. Lotus Development Corp., best known for its 1-2-3 electronic spreadsheet, now markets Lotus Notes, a "social spreadsheet" that lets users both create and coordinate information-based relationships across the company. Lotus founder Mitchell Kapor's new company, On Technology, in Cambridge, Massachusetts, offers software that supports intense small-group collaborations. Researchers at Baylor College of Medicine have recently announced a Virtual Notebook System that would enable scientists thousands of miles apart to "open up" the notebook and add an entry or an image that would be instantly visible to every other one of the networked researchers. Its designers think the notebook could become a central, unifying element in far-flung research collaborations.

But others believe that collaborative tools and technologies should be designed with an eye toward creating collaborative "environments" for larger communities, whether they are scattered or physically on scene. In



Scenes from a collaboration. *A "groupware" program enables distant users to open a conference* (above)*, then collaborate on a single document* (right).

a 1980s project called CoLab, for example, Xerox Palo Alto Research Center networked a clutch of machines to what Xerox PARCers called a "liveboard"—a community screen to which all participants had access. People could work privately on their own screens or display their work on the liveboard for group consumption. The liveboard became the shared space where participants—generally white-collar managers—collaboratively created spreadsheets, diagrams, charts, and documents. The productivity boost was eye-opening, says Mark Stefik, a senior Xerox PARC researcher. "People come out of a CoLab session saying, 'We've just done 10 hours' work in 90 minutes,' and they can't believe it."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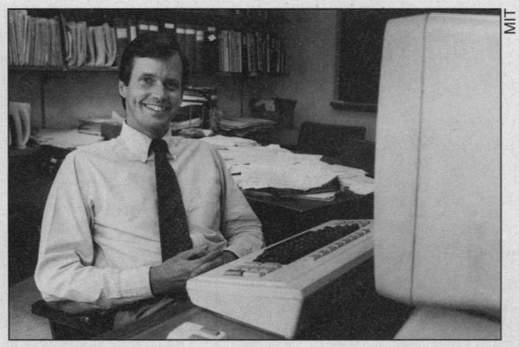
Although Xerox didn't commercialize the CoLab, it became the model for several internal Xerox product development centers that enjoy limited use. Other companies have followed suit. General Motors/Electronic Data Systems in Ann Arbor, Michigan, for example, developed a similar environment called the Capture Lab that features eight Macintoshes around an oval table with a large screen at the end of the room. To an observer, a Capture Lab session feels less like a meeting than like being in a TV van directing coverage of a football game. There is a sense of multiple perspectives, multiple players, and the feeling that everything is moving just a little faster than normal. Phrases and concepts seem to be tangible things—in reach on a screen, where they can be moved around, edited, blown up or filed away.

Unlike the executives the Capture Lab was designed for, most scientists don't spend their time conversing around conference tables. But some of the same techniques for creating collaborative environments might form the basis of a virtual laboratory. As collaboration technologists picture it, members of a research team could be scattered geographically, wherever climate, family, or other circumstances take them, yet come together electronically around simulations and models for bouts of intensive collaboration. Tomorrow's research director, asserts MIT's Malone, may spend as much time managing network-mediated collaborations as ones going on down the hall. "Will there be scientific managers who make their name from creating electronic research centers?" he asks.

Some of the basic research that could fulfill his vision is already under way. At Bellcore, the research arm of the regional Bell telephone operating companies, and the University of Toronto, researchers use television cameras and high-bandwidth networks to create "virtual hallways" where people can digitally "bump into" each other and discuss ongoing projects. The goal isn't simply the transmission of presence—a telephone does that—but creating "copresence": a sense that all the parties involved are actually face-to-face. Currently, the researchers are the subjects of their own experiments.

But it is in the literature, not the laboratory, that Lederberg thinks electronic media will have the biggest impact on the practice and mores of science. "The most important mode of collaboration is the literature," he asserts. To be sure, many scientific publications now accept electronically transmitted articles, and there are already a few online journals; indeed, the American Association for the Advancement of Science plans to launch an all-electronic specialty journal next year, in collaboration with the Online Computer Library Center (OCLC) of Dublin, Ohio. But those journals are basically electronic analogues of print—more like databases or electronic bulletin boards than the dynamic community documents Lederberg envisions. "Molecular biologists have been sharing information on DNA sequencing over the GenBank at Los Alamos," Lederberg observes, "but it's not quite the organic collaboration that I'd prefer to see; it's really only an extension of electronic mail."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Seeing the future. *Lyman* (left) *and Malone.*

What Lederberg and many others would like to see are electronic forums in which scientists could do more than exchange equations and text. He imagines subscribers sharing full-motion video simulations online as smoothly as they now exchange equations and sequences. Molecular biologists could see their helixes animatedly writhe and twist instead of depending upon static representations. Software based on existing "hypercard" concepts could let a reader fashion his own version of a paper, one that provided extra detail in his areas of interest while glossing over other areas.

Indeed, would scientists participating in these interactive networks simply be "readers"? Lederberg wants readers and authors of these online journals to be able to interact "dynamically and dialectically." The presentation and content of a "paper" might be reshaped continually by readers' curiosity and critiques. "With these new media the concept of the author changes," says Peter Lyman, executive director of the Center for Scholarly Technology at the University of Southern California, who is investigating hypercard-based publications. "Now the reader can also structure the knowledge."

Proponents acknowledge that the prospect raises some troubling sociological questions (see box). "The main reason we cling to the published article isn't just tradition," says Lederberg, who's pushing colleagues to get the *Journal of the American Society for Microbiology* online. "It's that we haven't worked out the social mechanisms" like peer review. What happens to traditional notions of peer review when what the author submits is liable to change continuously after network "publication," as a result of the interplay between readers and authors?

"A scientific journal is more than paper going through the postal system," observes Malone. "It includes a whole set of social structures; structures about how you find the readers, the authors; what it means to be peer reviewed. Those are all social structures that are supported by the technology but go beyond the simple transportation of information."

The ultimate future of collaborative technologies, however, may lie not in electronic texts with their new sets of social protocols but in "virtual realities" demanding radically different models of interaction. Researchers at the University of North Carolina and elsewhere are building virtual "molecules" that researchers can actually "feel" with force-feedback mechanisms. Ultimately the molecular worlds they're creating will not be sequestered on a screen but will be available for researchers donning computerized goggles to "inhabit." Indeed, one of the first "virtual realities" designed by VPL's Jaron Lanier, a virtual reality entrepreneur, is called RB2—Reality Built for Two. According to Lanier, the future of scientific collaboration may lie in electronic simulacra of natural phenomena, tailored to allow researchers to explore them like reconnaissance teams probing new territory. ■ **MICHAEL SCHRAGE**

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