Science Journals Go Wired

This Special News Report examines a trend that is transforming scientific communication, turning journals into electronic seminars and weaving them into a single linked database

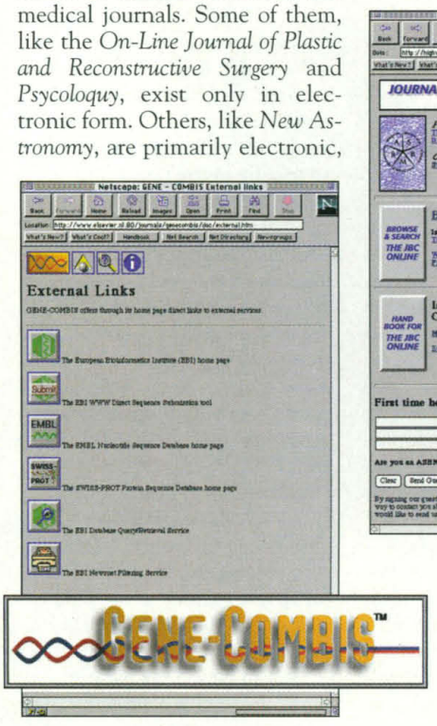
In the cost-plagued world of print journals, showy debuts are a rare thing. But on the World Wide Web, they have become so common as to be almost routine. Take Elsevier Science's effort to establish its presence in astronomy. When the Amsterdam-based publishing company's journal *New Astronomy* goes on line this spring, it will do so with a small but undeniable bang. In a video simulation accompanying one paper on binary pulsars, says Elsevier editor Michiel Kolman, "You will see how two stars rotate around each other: They evolve; one star sucks up matter from the other, explodes in a supernova explosion, and so on. It is a very beautiful way to illustrate a theoretical model." And to David Schramm of the University of Chicago, who will be one of *New Astronomy*'s editors, the stellar fireworks are also an indication that Elsevier has recognized that the electronic journal "is clearly the way to go, the wave of the future."

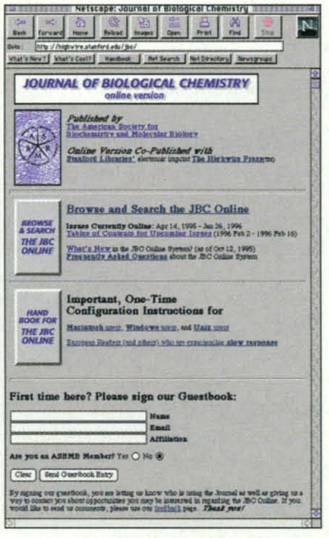
It might be more accurately described as a tidal wave. As of the end of 1995, the Internet was already home to over 100 peer-reviewed science, technical, and medical journals. Some of them, like the *On-Line Journal of Plastic and Reconstructive Surgery* and *Psycoloquy*, exist only in electronic form. Others, like *New Astronomy*, are primarily electronic, with a paper edition published solely for archival purposes. Still others are the electronic versions of paper journals, such as *Applied Physics Letters* or the *Journal of Biological Chemistry* (*JBC*), publishing hundreds of pages of articles on-line weekly. Most common are electronic adjuncts of paper journals such as *Science*, *Nature*, the *Journal of the American Medical Association*, and others, which offer tables of contents, abstracts, selected articles, and other features, but not yet the full text of all their published articles. By the end of 1996, the number of electronic peer-reviewed journals may increase by another order of magnitude, as publisher after publisher announces on-line offerings (see table on p. 766).

But this electronic wave isn't just a change in medium; it is also a force that is transforming the nature of scientific communication. Publishers talk about using the interactive powers of the Internet to turn journals into perpetual electronic conferences, where articles take the place of lectures and sprout on-line discussion groups and commentary. The World Wide Web—the network of linked Internet sites that is the home of nearly all these publications—also opens the way to weaving electronic journals and scientific libraries into a single interconnected database. Already a mouse click can take a subscriber from one article to related articles in the same journal, other journals, and resources such as databases of DNA sequences, protein structures, or galaxy images. By offering authors' raw data or the software used in the analysis, some of the journals will even allow readers to double-check an author's work. All this may sound like hype, says David Lipman, head of the National Center for Biostatistics Information at the National Institutes of Health, but "in this case, this really is substance. It really is doable, and can be done very soon. It will really happen."

Still, there is a tentative aspect to this revolution. "Everyone is realizing there's some advantage to being hooked up electronically to the rest of the world," says Nobel laureate molecular biologist Rich Roberts, who is head of New England Biolabs and editor of *Nucleic Acids Research*, which officially went on-line on 1 January. "But most [journal publishers] don't really know what they want to do, or how it will all shake out."

Publishers are torn between the fear of losing print subscribers and topflight research papers if they don't move fast enough into the electronic world—and the fear of losing revenues if they move too fast. Reliable mechanisms for controlling and charging for access to an electronic publication have not yet been established, says John Sack, director of Stanford University's HighWire Press, which publishes and develops on-line publications (including *Science*'s on-line table of contents and other features). Moreover, the technology for putting full-text scientific articles on-line isn't simple, says Sack: "To do many articles and do it week after week after week, you need a real production process that doesn't require a lot of human intervention. And that takes a lot of solid programming."





Electronic newsstand. Screen displays from three full-text electronic journals.

Decisions, decisions

Then there's the question of which of the Web's strengths a publisher should exploit. The most obvious is its capacity to publish vast amounts of material fast and cheaply, as the success of electronic preprint servers like the e-print archives at Los Alamos National Laboratory shows (see p. 767). But while the electronic preprint servers are fast and free, they are low-budget operations with no peer review. In traditional, refereed journals, pub-

Speed of Publication: Stuck in First Gear

Publishers of electronic journals may debate how best to equip their offerings with search functions, interactive forums, supplementary material, and video displays (see main text). But they have no doubt about the need for another feature: speed. Cutting the lag from submission to publication could be electronic journals' biggest selling point, say publishers. So far, however, they are falling short. "In the future, [electronic journals] have to be faster," says Tim Ingoldsby, director of new product development at the American Institute of Physics.

By eliminating the production, printing, and mailing steps, electronic publication can cut several weeks from the process—but that can still leave a lag of months between a paper's submission and its appearance. Journal publishers are striving to shrink that gap, and reader and author expectations aren't the only spur. There's also the prospect of competition from electronic preprint archives—low-budget, non-peer-reviewed operations like the Los Alamos e-print archives, which every week publishes several hundred new preprints, all of them within minutes, if not seconds, of submission.

One stopgap for traditional publishers is to put articles online as soon as they've been accepted, rather than bundling them with others as an entire issue. In the case of one electronic journal, *Astrophysical Journal Letters*, this helps cut submission-to-publication time from 20 weeks to 17. But efforts to save even more time run up against a human factor. Most of the publication lag is due, says Ingoldsby, to "the peer-review step and the waiting for the author to return corrected galleys step." Or, as Elsevier Associate Publisher Nigel Fletcher-Jones says, "It's getting people to sit down, read the manuscript, and do something with it."

"We have to rethink how this whole process works," says Bob Kelly, director of journal information systems at the American Physical Society (APS). "And the first step would be put the whole thing on line"—from electronic submission of manuscripts, through refereeing, revising, and editing, to electronic publication of the finished copy.

To encourage authors to submit papers electronically, the APS is thinking of setting up publicly accessible preprint archives complementary to those run by Los Alamos, covering the physics disciplines not accommodated by the Los Alamos archives. That way, physicists will be able to submit papers to *Physical Review Letters* and other APS journals from either set of archives. With no need to rely on the mails for receiving manuscripts or sending out reviewers' copies, says Kelly, the manuscript handling process would accelerate "to the blink of an eye."

The APS is also considering shipping out interactive software to its referees. Not only would on-screen refereeing speed up the mechanical steps of receiving, marking up, and returning a manuscript, but it might also have a psychological effect, says Kelly. "Some recent studies have shown that some referees are responding quicker because they're receiving a manuscript electronically: It's there, they look at it, and get rid of it as opposed to having it disappear into a pile of paper on their desk."

With the submission-to-publication system completely "reengineered," he says, the APS may be able to cut the minimum publication time of an article from 3 months to one. Whether that will be fast enough for impatient Internet users remains to be seen, of course. If it isn't, says Ingoldsby, at least in physics, "these preprint servers like the Los Alamos operation are going to drive traditional publishers out of business."

–G.T.

lishers are discovering, the potential speed of electronic publication is difficult to exploit (see box).

But the Internet promises a lot more than speed. There are also the electronic bonuses that can be offered on-line—"imaginative ways," says Roberts, "that you can browse an article and get a lot more back that's simply not available on printed page." They can include:

■ *Video and audio.* The new electronic *Journal of Image Guided Surgery*, for instance, put out by John Wiley & Sons, has already published a video of the cervical spine rendered in three dimensions, which can be manipulated by surgeons to study the placement of the pins that must hold the neck still during neurosurgery. "You can show that placement much more accurately than in a two-dimensional picture," says Gregory St. John, director of new media development at Wiley. "You can also stop it, start it, rotate it, and change the speed."

■ *Search functions.* Most electronic journals allow users to search for particular key words—within or across past and present issues.

■ *Discussion forums.* Nigel Fletcher-Jones, the designer of the new Elsevier molecular biology journal *Gene-COMBIS*, calls these "virtual coffee breaks," likening them to the informal information exchange that occurs at scientific conferences. Readers of articles can e-mail responses to the editors, who edit interesting and constructive letters and attach them to the articles.

■ *Links to related articles.* In the case of electronic journals published by the On-line Computer Library Center (OCLC) in Dublin, Ohio, this is known as the "see also" feature. "It allows you to look at related articles immediately on the screen," says Andrea Keyhani, manager of electronic publishing for OCLC.

■ *Automatic notification and alerting service.* This feature allows readers to indicate which authors and topics interest them and then be notified by e-mail when such articles appear in the journal. "So if a doctor is interested only in certain aspects of dermatology, for example," says Keyhani, "the doctor can put in those terms and then receive notification of those articles in that area on a weekly basis."

But perhaps the most revolutionary change brought by the new medium is the capacity to publish supplemental resources that would be difficult or impossible to present in print. References at the end of each article in *JBC*, for example, are hotlinked to the National Library of Medicine's MedLine service. Click on a reference, and the system will pluck the abstract of the article from MedLine. And any genes in *JBC* articles are linked to GenBank, a service provided by the National Center for Biostatistics Information. Click on the gene, and you can go directly to the DNA sequence, if it exists. From GenBank, the NLM's own database structure allows users to jump in turn to other publications relevant to that sequence.

Individual articles will also start "sprouting databases"—additional information that could not fit in a print version but "will be fully refereed and dealt with the same as if it was printed," says Vitek Tracz, chair of the Current Science Group, a consortium of print and electronic publishing companies that publish the *Current Opinion* journals, among others. The American Institute of Physics's (AIP's) journal *Applied Physics Letters*, for instance, which has been on-line since the end of 1994, is providing an electronic version of a service called the Physics Auxiliary Publishing Service, or PAPS.

"What we've used it for in the past," says Tim Ingoldsby, director of new product development at the AIP, "is if an astronomer, for instance, has a massive data table related to an article he's writing, but it's entirely too large to

ELECTRONIC JOURNALS: THE COMING EXPLOSION

The table below gives a sampling of the plans that major commercial publishers are laying for electronic journals.

Elsevier Science. A program called Elsevier Electronic Subscriptions makes all 1100 Elsevier journals available electronically to subscribing institutions through their local servers. Elsevier also plans to offer a handful of new, fully electronic journals through the World Wide Web, including *Gene-COMBIS* and *New Astronomy*.
URL: http://www.elsevier.nl

Springer Verlag. Eight journals are available on the Web now, two as fully electronic journals, including the *Journal of Molecular Modeling*. Through an experimental program with AT&T Bell Laboratories and the University of California, San Francisco, Springer is delivering 24 of its 350 journals on-line to researchers at UCSF and plans to make its remaining journals available electronically within the next few years.
URL: http://www.springer.de

John Wiley & Sons. Wiley's fully electronic *Journal of Image Guided Surgery* went on-line last April. It plans to develop Web sites for all 326 of the journals it publishes worldwide. Only a few will be available full-text to subscribers; most will offer tables of contents, abstracts, or other additional services. URL: http://www.wiley.com

Blackwell Science Limited. Blackwell hopes to have 125 of the 200 journals it publishes worldwide available in full text on the Web by September through a system called Steamline. URL: http://www.blacksci.co.uk/

Academic Press. By the end of March, Academic hopes to make 174 of the 175 journals it publishes worldwide available on the Web in full text through a program called IDEAL, for International Digital Electronic Access Library. URL: http://www.idealibrary.com

Taylor & Francis. This British publisher is experimenting with full-text, Web versions of 16 out of its 125 journals. URL: http://www.catchword.co.uk

reproduce in full, we allow that to be deposited in PAPS." Until recently the material would simply be mailed to a reader on request, Ingoldsby says, "but now we're establishing an electronic version of this, with a small fee for deposit but no fee for retrieval. In the on-line version, all that stuff will be hot-linked to the appropriate spot in the article."

Reader replication

Gene-COMBIS, the new Elsevier journal, goes even further. The journal, which is a section of the existing journal *Gene*, went on-line last August as a loose collaborative effort with the European Bioinformatics Institute in Cambridge, England; its name, *COMBIS*, stands for Computing for Molecular Biology Information Service. "So much of molecular biology so far has been concerned with data gathering," says Fletcher-Jones. "We're just beginning the phase of data analysis, which is where *Gene-COMBIS* comes in."

Like *JBC*, *Gene-COMBIS* offers hot links to other databases, including Elsevier's own *Excerpta Medica* database, known as EMBASE, which includes pharmacological and biomedical information and abstracts, and the European Molecular Biology Laboratory's databases of nucleotide and protein sequences. But *Gene-COMBIS* also provides a service that Fletcher-Jones calls a "first in scientific communication." The journal makes it possible, while reading an article describing a software solution to a problem in molecular biology, to download the program that was used to analyze the data, and even the data themselves, if the authors agree to put them on-line. "So really for the first time anywhere in science you have the immediately reproducible experiment," says Fletcher-Jones.

The Current Science Group plans to initiate a similar system of reader replication with its new journal, *Folding and Design*, a protein structure journal that should go on-line this month. It will be both paper and electronic, and papers in the on-line version will be hot-linked, for instance, to a database of the reagents used in the work. Traditionally, explains Tracz, "researchers are supposed to provide reagents for an experiment if anybody else wants to repeat it." *Folding and Design* will formalize that tradition on-line. "This database of reagents will be available through the journal, and you will be able to order them directly."

Indeed, data and techniques that once would have remained in researchers' lab notes may become a staple of some on-line journals—if authors are willing. Current Science journals will encourage authors to submit their data, says Tracz, but will not demand that they do so: "It would be up to the authors who wish to do it." If the publication of raw data does become common, however, journals will face some difficult questions about how to handle the material. If the data are to reside on the author's computer, hot-linked from the journal, some mechanism will be needed to ensure it remains uncompromised. "For the same reason you can't allow people to change an article after it's accepted, you can't allow them to have arbitrary control over this other material," says Andrew Cohen, a Boston University physicist who is helping to create a new electronic physics journal.

Who pays?

That's not the toughest conundrum in the world of electronic journals, though. A more formidable one is how to make readers pay. Virtually all of the peer-reviewed journals on-line at present are free—for now. *JBC*, for instance, won't begin charging for access until this spring. And Elsevier expects to waive subscription fees for *Gene-COMBIS* for its first year of operation.

Once they begin charging, many of the publishers are currently planning to sell subscriptions to their on-line journals through so-called site licenses, which will allow unlimited and unrestricted access for users who log in from subscribing institutions. To set a price for these site licenses, publishers are contemplating one of two formulas: either offer them free to print subscribers or, as Bob Kelley of the American Physical Society describes it, "charge a little more for both paper and electronic, and a little less if electronic" or paper only.

In the case of *Applied Physics Letters*, for instance, published by the AIP, institutional subscribers to the journal get the on-line version for a little more than 10% extra. "Because we're going to make mistakes," says Ingoldsby, "and because the print journal is still driving our business, we've priced it so you can get on-line at a very small incremental cost in addition to retaining your print." And for primarily electronic journals like *New Astronomy*, publishers are setting prices conservatively. The *New Astronomy* site license, for instance, will cost less than $400 per year, and will cover electronic access and a paper edition.

But site licenses may not be a lasting solution. As journals become increasingly interconnected, researchers will find themselves hot-linking from one cited or related article to the next, regardless of who the original publisher happens to have been. If all the browsing is done in a single publisher's database, it could be covered by a single subscription to the database. But if the hot-links connect articles or databases of different publishers, then it will result in what Rich Wiklund refers to as buying by the glass rather than the bottle. Says Wiklund, who is director of on-line services for the electronic publisher E-DOC (which also produces electronic features for *Science*): "Based on people's travels as they jump from item to item through the Net, they will be buying parts from every single publisher."

How this will work in reality remains to be seen. "There are lots of financial issues that have to be worked out and some technical issues—for instance, pay per view, credit cards on the Internet, etc.," says Lipman of the National Center for Biostatistics Information. "Frankly, I don't know the answer to those questions, but I'm 100% confident they'll be solved."

–Gary Taubes

For a Web version of this article, complete with hot-links, see <http://science-mag.aaas.org/science/scripts/display/full/271/5250/764.htm>. For *Science*'s latest electronic offering—a set of full-text Perspectives with links to relevant papers, databases, and simulations—go to <http://science-mag.aaas.org/science/content/current/e-perspectives>.