21 The *Physical Review* and Electronic Publishing

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The scientific journal *Physical Review*, which was founded in 1893, started out very slowly. The United States was a backwater of physics at that time and distribution of scientific knowledge was slow. Scientists needed a journal that would be used in the United States for the distribution of physics results.

A number of significant papers appeared in that journal even in the early days. Ultimately *Physical Review* became, and still is, one of the premier physics journals in the world. The number of significant scientific results published in this journal has increased significantly, but the percentage of papers that are significant has probably not changed from the beginning. This is pointed out very frequently. Today we publish close to 100,000 pages every year using paper technology.

We are now in a period of centennials. *Physical Review* had its centennial in 1993, X-rays in 1995, radioactivity in 1996, the electron in 1997, and radium in 1998. The American Physical Society, which published subsequently to the founding of *Physical Review*, celebrated its centennial in 1999.

The publishers of *Physical Review* celebrated its centennial by putting out a collection of significant articles that appeared in the journal over the years. The book was about seven centimeters thick. It contained a number of summaries of the different fields of physics, as well as a selection of papers in each of those fields chosen by a panel of experts. The difficulty arose when the experts could not confine themselves to 200 papers. In fact, they had 1,000 papers. It sounds strange to talk about 1993 as the distant past, but electronically it is. In 1993, they put

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Martin Blume is the editor-in-chief of Physical Review, *published by the American Physical Society.* *This article is based on remarks delivered at the 24th Annual AAAS Colloquium on Science and Technology Policy, held April 14–16, 1999, in Washington, DC.*

in the back of the book a CD that contained all 200 papers published in the book itself, plus the other 800, plus all the ancillary material.

The founders of *Physical Review* would have been astonished at the physics that had been done in those 100 years, but they would have been quite comfortable with the journal as it was published in 1993. It was still a paper journal, but with a slightly different color. There were many more papers, but overall the format and the way of distributing the information would have been completely comfortable for the founders 100 years ago. The CD, however, would have astonished them.

What information was contained in that 100th anniversary volume? The papers that appeared there have, in fact, changed our view of the universe and the way we live. Some of the early papers discussed the Millikan oil drop experiment, the Compton effect and Compton scattering, and the Davidson-Germer effect, which showed that electrons are waves. A paper that appeared in the 1980s on the Higgs mechanism was one of the reasons that physicists wanted to build the supercollider here and why we are participating in the Large Hadron Collider elsewhere. A paper by J. Robert Oppenheimer and Hartland Snyder was the first place where the idea of black holes was announced. A famous paper by Einstein, Podalsky, and Rosen discussed whether quantum mechanics is a complete theory. And the invention of the transistor was announced in *Physical Review*. Some papers have led to Nobel Prizes.

All scientists need places where they can talk to one another in detail. *Physical Review* was described a few years ago in the *New York Times* as one of the most opaque and unreadable journals in the world. My predecessor, Editor-in-Chief Ben Bederson, wrote a very nice letter to the *Times*, which was published, pointing out that every technical journal is opaque, but it has to be understandable to other scientists. For example, Richard Feynman had a reputation, correctly, as a fine communicator. Yet it astonishes people to look at the density of equations in his papers in *Physical Review*. This density is necessary because it has to be boiled down later on. If you explain only in words it will not work. So we say proudly that our journal is opaque, but it is understandable to other physicists.

The distribution of this knowledge and of the journals is very important. Scientists want to distribute their knowledge as quickly as possible. Early on the idea of the preprint came about.

As the electronic era dawned, the preprint evolved into E-prints. E-prints are now very much with us and are very important. Scientists can distribute their papers by submitting them to various E-print servers, the

most famous of which is Paul Ginsparg's at Los Alamos. In this way they can distribute the knowledge very, very quickly. E-prints also provide something of a relief valve because people sometimes want to put out very controversial ideas. These ideas can be distributed through E-prints. The difficulty with E-prints is the same difficulty with preprints. They are not peer-reviewed and they are not edited.

Of course, peer review is not an absolute certification. It does not say that something is right. It always disturbs me when I hear reporters stating that this was published in a peer-reviewed journal. They say it as if this were a mark of honor, indicating that this is something that is, therefore, absolutely correct. The only thing we can say for peer review is that it states that this paper is worthy of other scientists' attention. It may well be wrong; it may well be erroneous. After all, peer review cannot be an absolute. Verification has to be done in the marketplace of scientific ideas.

In 1988, Val Fitch of Princeton was president of the American Physical Society. He commissioned a report on the possibilities of distributing scientific results electronically. This was before the E-print archives were established. Stewart Loken of the Lawrence Berkeley Laboratory chaired that committee. In 1991, he put out a very prescient report, which was given with a title that is very common right now, 20/20. Obviously you want to have good vision for the future. The 20/20 report gave a number of possibilities for electronic distribution, which were supposed to be implemented by the year 2020. At the time of the report some of the relevant technology was bitnet, e-mail, anonymous FTP, and the gopher distribution of the results of scientific research. The report considered these and also had a glimmer of using the Internet in other ways, but the World Wide Web did not really exist then. (The browsers were just coming into play at that time and they have made a significant change). We have seen that everything predicted for 2020, amazingly, has already taken place. (Because of the prescience of that report I have asked Stewart Locan to form another committee to reconsider the situation. I want that committee to think about future developments and to predict where we may end up going).

How did we start with electronic publication and distribution? The first thing you think of is taking what you were going to put out in print and putting it online. This has been called "shovelware" by one wag. You just take whatever is there, shovel it online, and that is it. It is a very smart way to start electronic distribution, but it is a very dumb way

to proceed. When you do this, consider the problems of *Physical Review*. We received 23,000 submitted articles for submission last year. And we have to put out our journals on a timely basis. We, therefore, have to do two things at once. We have to continue to put out the journal on paper (paper will not go away for a long time) and, at the same time, we have to move very rapidly. This is particularly true for physics journals because physicists are very comfortable with electronic media. The members of the American Physical Society will simply push the publications to the limit and make sure that we are as close to the forefront as possible. Otherwise they will go elsewhere. They will take their very good work and publish it elsewhere. We do not want that to happen.

We also believe in the importance of peer review in putting out the journals. That has to be worked into the electronic distribution as well.

You can do many other things besides just putting an article online and letting that take the place of the paper article. You have to consider the additional information that can be included electronically, including multimedia and movies. Mathematical physicists can put up a program that is actually executable so results can be duplicated and tested. There has been significant expansion of what you can do.

In addition to putting the current issues online we have also put online all of our journals back to 1985. This totals 100,000 articles. An important policy question here has to do with intellectual property. Scientists are now being pressured to hold on to the copyright and to give a license to publish to the publishers. If we had been doing this and had only a limited license that made no mention of new technologies, we would have been faced with getting 100,000 permissions in order to put all of these articles online. We probably would not have done this simply because of the effort. We could not have possibly have tracked everyone down. As a consequence, I believe the scientific community would have been that much poorer. This is one example of how intellectual property questions come in.

We also see the possibility of keeping a license that says we can do whatever we want with the articles we publish in the future as if we have the copyright, with any technology now known or to be invented. One of the difficulties with this is that it is not, according to the lawyers we have consulted, necessarily enforceable abroad. Only one-third of the society's papers come from the United States; two-thirds come from elsewhere in the world. In fact, more papers come from Western Europe than from the United States, and it is there that some of these copyright laws might come into play.

One of the things that also would have astonished the first editors of *Physical Review* is that our online archive goes back only to 1985. All we have to do now is fill in the gap between 1893 and 1985 and we will have a complete collection. In total shelf space we are more than halfway there. But the journal continues to grow very rapidly. (A story variously attributed to different famous physicists says that if they extrapolate the growth of the journal *Physical Review* to the middle of the next century, the speed of expansion on the shelves of libraries would, in fact, exceed the speed of light. But this would not violate relativity because no information would be exchanged).

Many things will happen as a result of having all of the journals online. In looking ahead to the future we also have to consider other scientific journals. We want to have a seamless web of scientific journals. If you have a reference in one journal you should be able to click on that and go to the other journal where the reference is. This is already a possibility. The Physical Society established a link manager where all you have to know is the reference. When you put the reference in, it goes to our program, which calculates where the article is now and takes you to the abstract of that article. If you have a subscription it also gives you the article itself. The European Physical Society and the French-German journal *European Physical Journal* have started linking to us in this way.

It is very important to be able to move rapidly around the world. There are two ways in which you can do this. One is to establish mirror sites of your journals in other parts of the world. This has certain advantages. It is very easy to do if it is not something for which you need access controls. But it raises taxation questions. A value-added tax can be put on electronic subscriptions in some countries in Europe. At the same time, the print is not taxed. Therefore our journals are distributed with electronic access given along with the print to avoid the value-added tax.

When first conceived, the Internet belonged to academia and to researchers. One of the problems that we see now is the heavy use, as people go online to shop, play video games, etc. Academic use is very much on the back burner. It is very important for intellectual discourse that there be some sort of dedicated links that would work strictly for academia.

With the Physical Society we have gone to another way besides mirror sites. We also have pipelines. We work with a company called Digital Island based in Honolulu that has links to different parts of the world. We can go from Honolulu to Paris in one hop. We use this to distribute our work.

You can also do searches on articles. Searching will be very important in the future. I often look through the online archive, simply typing my name into the references part of the link and finding all of the articles that refer to my papers. This is a very interesting exercise. A new search engine that we are working on will have special capabilities. It will, in fact, enable us to distribute the journals free, since the money we make on its sales will pay for everything we need. That search engine will find every paper that does not refer to you but which you should have. That is not too farfetched with a little artificial intelligence.

The implications of globalization are also very great. The development taking place right now in the electronic world parallels in many ways the revolution in personal transportation that occurred in the 50 or 60 years after the 1893 founding of *Physical Review*. The horse and buggy, which was the main form of personal transportation in 1893, was gradually replaced with the automobile. At the same time the highway system was developed, with pavement, four lanes, and, ultimately, limited access. Our publishing situation right now is at the stage where the horse and buggy is being replaced with an automobile that looks like a buggy but has an internal combustion engine. After all, that is what the first cars looked like. Only when the automobile was designed from the ground up did it reach its full potential.

As far as the roads are concerned, we are looking at a paved but not limited-access highway in many parts of the world. In other parts of the world we see either dirt paths or no roads at all. We have to take significant care to make sure that our colleague physicists in electronically remote parts of the world are served, and that they have access to the journals on the same rapid basis that other people do.

We are in the process of removing some of the horse manure left over from the horse and buggy era. We hope that this will not be replaced with the air pollution that has come with the cars.

Coming from Long Island, I have a particular fear. We have a nice limited-access highway, the Long Island Expressway, known affectionately as the world's longest parking lot. In fact, we can imagine the electronic super highway becoming a toll version of the Long Island Expressway, something to be seriously avoided.

I chair a committee of the International Union of Pure and Applied Physics. Its purpose is to address a number of international issues. One of the issues is international Internet availability and reliability for scientific publications. Every time you build a new highway the traffic increases disproportionately and you run into difficulties. We are going

to have to work on that to ensure that scientists can continue to work on the Internet. Another issue is linking, mirroring, and cross-publication searching for journals of different publishers. A third issue is the availability of publications in electronically remote areas. Long-term availability and archiving of electronic publications are two particularly significant parts of this issue. I mentioned the CD that we put out in the back of the 100th anniversary volume just five years ago. That CD consisted of TIF images and some special software that enabled you to read them. It was readable only on a PC. It was not readable on a UNIX machine or on a Macintosh. I recently got a new PC with Windows98. I installed that special software and my PC promptly crashed. I tried again and it crashed again. It does not crash on all versions of Windows98 but it certainly did on that one.

We have to keep our electronic archives readable in the future. A few of us have been around long enough to have IBM punch cards with a particular computer program that we ran 25 or 30 years ago. It is very hard to get them read now. A few museums have punch card readers, and you could do it there, or perhaps some remote places still use punch card readers in one way or another. I would not have a problem if I had simply translated the punch cards and put them on tape and put that into a computer. The program was FORTRAN, which would probably run somewhere (but even that might have to be updated). We had to update the CD because of all the noise we made about our promise to keep things update-able.

The same thing is going to have to be done by publishers in the future to maintain the important elements of the archive. Paper is paper. It is there and that is what you have. But things can become unreadable electronically. They translate into something illegible. Long-term availability issues are very important.

Another issue is peer review and E-print archives. We want to maintain peer review, but the E-print archives are important. People can submit their articles to *Physical Review* from the E-print archive at Los Alamos. We will actually link to Los Alamos if there is a paper that is referred to and appears only in the E-print archive. People can download it and see it.

Finally, we have international intellectual property questions, which have been touched on. All of that is significant to us. The most important priority, of course, is that we want the scientific enterprise to continue to prosper. I personally want to see the most important papers published and distributed through *Physical Review*. I hope that will continue to be the case.