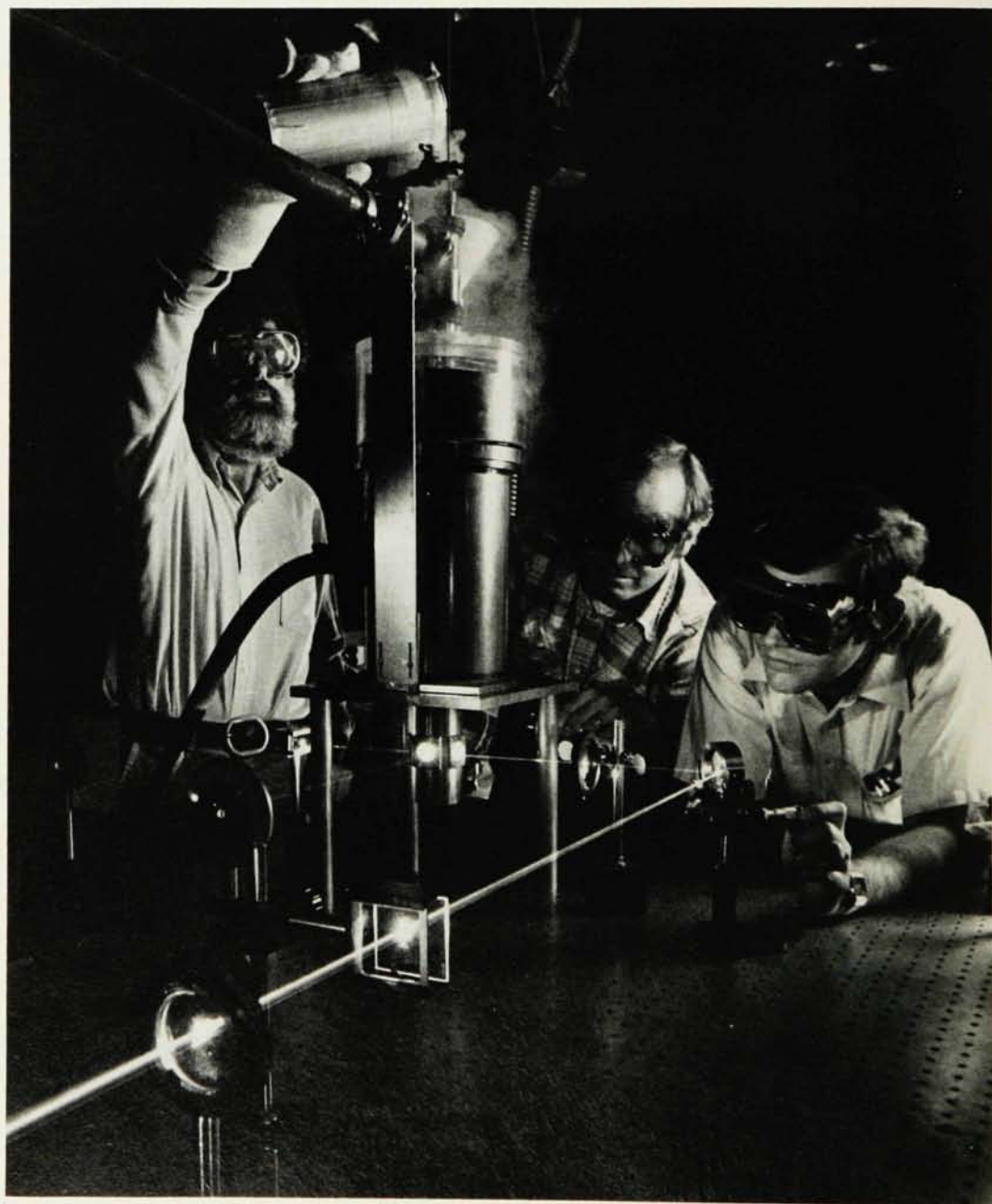


Beyond the ivory tower

New materials. At the IBM Almaden Research Center, Roger Macfarlane (left), Robert Shelby and W. E. Moerner are working on materials to be used in frequency-domain optical storage, which promises to provide extremely high-density storage of information.



Academia is the traditional training ground for research in physics but only a minority of PhDs continue working there—does their academic training provide them with a good basis for a career in industry?

Bruce M. Schechter

The industrial research laboratory was arguably Thomas Alva Edison's greatest invention. With more ideas than time to pursue them, Edison built a laboratory in Menlo Park, New Jersey, and staffed it with the brightest young men he could find. They were, for the most part, self-taught like himself: He had little patience with universities, having once defined an academic scientist as "a man who would boil his watch while holding onto an egg." But if he was nothing else, Edison was an experimenter. From time to time he hired an academic scientist. The results were mixed. He said of one:

He knows a lot but he doesn't stick to the job. I set him at work developing details of a plan. But when he happens to note some phenomenon new to him, though easily seen to be of no importance in this apparatus, he gets sidetracked, follows it up and loses time. *We can't be spending time that way!* We have got to keep working up things of commercial value—that is what this laboratory is for. We can't be like the old German professor who as long as he can get his black bread and beer is content to spend his whole life studying the fuzz on a bee!

A hundred years after Menlo Park, industry has become the largest single employer of PhD physicists. For the most part, industrial research managers feel that the PhDs they hire today are as intelligent and well educated in the nuts, bolts and theories of physics as ever. This does not mean that academia turns out perfect industrial physicists—to some degree Edison's criticism still applies today. Many industrial managers and supervisors believe academic training can lead to difficulties in commercial settings that require scientists to be flexible generalists instead of narrowly focused specialists. In the largest industrial research

laboratories, such as Bell Laboratories and IBM, which are almost indistinguishable from academia, specialization is an affordable luxury. In most smaller labs, however, physicists have less leisure to pursue basic research wherever it leads in the hope that someday it will bear fruit—there researchers are supposed to be "working up things of commercial value."

Corporate culture

Success in industry is not entirely a matter of scientific competence. A new employee must adapt quickly to the so-called corporate culture. Some aspects of this adaptation are easily managed: Physicists in industry, especially those just starting out, spend less time on committees than they would at a university, and no time teaching. A more difficult problem is acquiring the communication and management skills needed to thrive in industry. An industrial physicist must be able to talk clearly and effectively to technicians, customers and upper-level management as well as to other physicists. These skills are now often acquired—sometimes painfully—on the job.

Whatever problems they may face when they begin their first industrial jobs, the simple truth is that given the small number of academic positions available and the enticements of larger industrial salaries, fresh PhDs are increasingly being drawn to industry. In 1984, according to a study by Susanne D. Ellis of the American Institute of Physics Manpower Statistics Division, over half of all new physics doctorates accepted jobs outside of the universities and colleges. Those who ended up in industry received a median salary of \$37 920, compared with \$20 100 for university postdocs. "Industry not only pays the highest salaries of all employers," Ellis writes, "but also recorded the largest increase in the proportion of new doctoral physicists

from the class of 1984; the 26% [of PhD recipients accepting potentially permanent positions in industry]...represents an increase from 21% in the previous year."

Why is industry apparently so fond of physicists? John Willison, who is head of research and development at Stanford Research Systems, a small Palo Alto-based company that designs and manufactures electronic laboratory instrumentation, gives one answer: "By choosing PhDs you get smart people."

Willison, who employs four PhD physicists, all culled from the graduates of Stanford University, does not believe that graduate education at the doctoral level is particularly relevant to the kind of work done at a small company like his. Still, he likes to hire PhDs because, he says, "smart people feel a kind of peer pressure to get a PhD" and what Willison most wants is smart people. The problem with graduate training, Willison says, is that it can result in "tunnel vision," a narrow focusing on the specifics of thesis research at the expense of more general skills. He concedes, however, that "graduate schools do relatively little damage."

C. Kumar N. Patel, executive director of physics and academic affairs for AT&T Bell Laboratories, values a graduate education, but he agrees that tunnel vision is a problem. Patel says that "the graduate education in physics doesn't seem to prepare individuals for attacking a broad class of problems in physics. By the time a person gets his PhD he has concentrated so much on his thesis that he loses view of other things that are going on in physics." And this, according to Patel, is true even though the general quality of training is better now than it has been in five years. Patel attributes that five-

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Dan Phelps of Kodak Research Laboratories, at work developing new compound semiconductor devices.

year slump to the effects of the Vietnam War.

Patel would like his new PhDs to recognize more often that there is more to physics than what is contained in their doctoral dissertations. One way to ensure this recognition, he believes, is through giving students more course work before they proceed with years of specialized thesis research. In Patel's estimation, the true goal of a graduate education should be to produce a "superior physicist," by which he means "a person who can attack and solve any problem that has a basis in physical science. Peripheral vision is something we have to instill in them here. Without it a person will not be able to identify important problems. And identifying important problems is at least as important as solving them."

'Street wisdom'

The Celanese Research Company, which employs a large staff of scientists that includes about a dozen PhD physicists, develops forefront technology for new ventures in areas such as biotechnology, liquid-crystalline polymers and ceramics. Paul Harget is a research supervisor at Celanese. He says that finding physicists who are technically well equipped and who are also able to thrive in industry is sometimes difficult. "A large part of my time is taken up with helping graduates develop the necessary skills to make them effective in the industrial environment," Harget says. "Unless they have a good boss who really cares, it can take them several years to get street wise."

"Street wisdom" in industry comprises several elements: One is the basic ability to work well and diplomatically with superiors, coworkers and support staff. Many new scientists fail to understand that technical problems are often intimately coupled to equally difficult—and in the world of the bottom line, equally important—human problems. "A researcher can be really enthusiastic about a scientific problem," Harget says, "but then some researchers will go and get the project technicians angry or annoyed," bringing everything to a grinding halt.

Another element of street wisdom is being able to find solutions to real-world problems without taking scientifically interesting, but industrially useless, detours. Today, as in Edison's time, industry has little need for—or patience with—the "old German professor." A street-wise researcher, according to Harget, knows the difference between the "textbook bottom line and the industrial bottom line."

Allen Krieger, who is senior vice-president in charge of space research at American Science and Engineering in Cambridge, Massachusetts, also keeps his eye on the bottom line. "It's not that new PhDs are narrow and specialized," he says; "it's that their training does not provide them with physical intuition. . . . AS&E is in the business of building x-ray and gamma-ray imaging systems for a wide range of applications. We want physicists who know how to solve problems."

Krieger does not blame the system of graduate education for the dearth of

problem-solving physicists. He points instead to the rapid expansion in the complexity of physics research, which often results in graduate students—especially the ones whose training matches AS&E's requirements—becoming attached to large groups. As a result, he says, "universities aren't training experimental physicists anymore. The people coming out now typically know a lot of physics, which is good. On the other hand, the majority of their experience comes from analyzing data other people have obtained."

Krieger recalls that twenty years ago, when he was a graduate student at MIT, they used to joke about the Berkeley bubble-chamber group, choosing Berkeley mainly because it was 3000 miles away. "We used to say that they had a PhD in charge of buying film. The point is that that guy doesn't do any physics. He may know an awful lot about film, he might even know a lot about cameras, but he doesn't do physics. The reason we would joke about it is that we were still doing experiments where our research supervisor would say, 'Here's what you have to measure,' and then you'd have to do everything pretty much all by yourself. That's also what you do in the real world." Unfortunately, according to Krieger, the large groups necessary for doing frontier physics make such individual initiative impossible. The result is a crop of physicists who can no longer solve problems. "But maybe," allows Krieger, "I'm just getting old."

According to Krieger the emergence of big science has caused another prob-



lem. "One area that everybody is absolutely in the dark about is how to get money. Because of the large budgets, graduate students have not participated in writing proposals. They think the Easter bunny brings the money."

Of course, few graduate students are totally unaware of the realities of funding. Nevertheless their lack of experience in seeking funds and selling ideas can hinder them in industry. Arthur H. Muir Jr., a program manager at the Rockwell International Science Center in Thousand Oaks, California, emphasizes the importance of strong communication abilities in an industrial setting. "Anything you do involves selling yourself or selling your project. In industry we are involved in contract research, where it is important to make a clear presentation to customers." Presentations, both oral and written, are the way projects get sold and money gets allocated in industry. "If you want to have any kind of upward mobility," Muir says, it is essential to be able to "go over the results of your work with people from entirely different cultures," that is, with managers and customers who do not have technical backgrounds. The lack of this ability can prevent a good scientist from scaling the higher rungs of the industrial ladder. As Muir puts it, "Sometimes we'll say, 'Let's not bring this guy to the customer: He can only talk in formulas.'"

To find the kind of people they need, laboratory directors concentrate on the interview. "The interview is the most

important factor in determining if there is a match between us and an individual," says Bell's Patel. Recruiters invite about one out of three people they see on campus to visit Bell Labs. The candidate spends several days talking to a number of researchers at Bell. "This is the time we see what kind of broad-based knowledge he has," Patel explains. About half of those interviewed are made offers, and about 70%—most of them new PhDs—accept.

Krieger also stresses the importance of an interview. "There is one specific question I always ask," he says. "That is 'What did YOU do?' The 'you' is capitalized. The guy we're looking for did it all—or at least did part of it all. And it's getting absolutely harder to find these people."

Survival of the adaptable

Dan Abbas, a research supervisor at Eastman Kodak Research Laboratories, agrees that talented industrial researchers are hard to find. Candidates are invited to Kodak to give a talk on their thesis work, but Abbas is not interested primarily in finding out if the candidate's thesis exactly fits in with research done at Kodak. "When hiring, the most important thing I look for is a good person." A "good" person, he explains, "is somebody who can go into the lab and make things happen. . . . Given a choice between a good person who doesn't have the experience and a mediocre person with experience, I'll take the good person."

Research directors naturally lead when it comes to hiring, but it still

takes two to tango. Their partners in this dance are the graduate students themselves. And while industrial employers say good graduates with a broad education are a somewhat scarce commodity, the graduates themselves are apparently fairly satisfied that their education is equal to the challenges of industry.

After receiving his PhD in experimental solid-state physics from MIT, David Cooper, a scientist at SRI, decided to leave academic physics. His main reason was money. His professor at MIT had offered him a postdoc but "the postdoc salary was \$13 000. My first job paid twice that."

The basic research skills Cooper acquired in academia have served him well in the outside world. "Most of the tools that I learned as a graduate student, all the basic optics and electronics, are things I've used ever since. On a day-to-day basis there is no difference between what I'm doing now and what I did as a graduate student. It's just that the end result is a paper in *Applied Physics Letters* rather than in the *Physical Review*."

Harris Goldberg, a senior research physicist at Celanese, is also happy with his education, although he admits that "what I am doing now is different from anything I ever dreamed of doing." He received his PhD seven years ago from the University of Massachusetts in theoretical solid-state physics, but soon after joining Celanese began to do experiments, mainly, he says, because a company like Celanese cannot justify employing a full-time theo-



Testing materials. Harris Goldberg (left) and Jim Kuder measure the properties of a new optical storage medium at the Celanese Research Company.

rist. In his years at Celanese he has done work on carbon fibers, intercalated graphite, gas-separation membranes, microwave properties of materials and, most recently, optical storage media. For Goldberg the constant shifting is part of the fun of working in industry. But, he says, not everyone feels this way—and those are the ones who do not survive. “Projects change so quickly that you can’t be an expert in a narrow field and expect to have a 20-year career in a company like Celanese,” he says. Success in industry, in Goldberg’s experience, is not as much a matter of training and background as it is one of personality. The lesson is straight from Darwin: In a rapidly changing environment, the adaptable survive.

Bill Gallagher, who did a theoretical thesis on superconductivity at MIT, ended up at IBM Research Laboratories after working with Richard Garwin on a policy project. He performed his first assignment at IBM as part of the Josephson-computer group. Gallagher was given an extremely “applied” problem—that of determining the reliability of Josephson switches after repeated thermal cycling. After his years of theoretical work he found it “nice being part of a project that was ambitious and had a goal you could understand.”

Gallagher was surprised at the freedom he was given to pursue his interests at IBM. Without the burden of teaching he was able to pursue side projects that have since evolved into his primary research. And he says that at IBM it is possible to switch technical jobs without too much difficulty, provided, of course, that you are successful. “If I were in academia I couldn’t just say that next year I want to work on semiconductor devices.” Change in academia must be more incremental; at IBM leaps are possible.

Had it not been for his fortuitous

association with Garwin, Gallagher might never have ended up in industry at all, which he believes would have been unfortunate. “The only role model you had in graduate school was the academic physicist,” he says. “The only kind of job I thought was available for someone in physics was an academic job. The value system you’re exposed to in school seemed to put more weight on academic-type careers.” To solve this problem, he maintains, there should be better mechanisms to promote the free flow of physicists between academia and industry.

So far no industrial use has been found for magnetic monopoles or quantum-electrodynamics calculations of the self-energy of the electron, two of the interests of Joan Cartier, a recent graduate of the University of Florida with a PhD in quantum electrodynamics. After receiving her PhD and being a postdoc for a year she decided that she had had enough of “this postdoc-ing business.” Cartier started writing companies, all kinds of companies. “I said, ‘Here I am; I don’t have any background in what you want but I’m trainable.’” Evidently some of them subscribed to Willison’s theory that PhDs are basically smart people, and before long she had a job at the Texas Research Institute in Austin. Cartier works on improving the reliability of the sonar transducers on submarines. The skills she developed modeling the subnuclear world were easily adapted to the submarine problem.

A more difficult change for Cartier to adjust to was not being actively engaged in fundamental research. She had hoped that her industrial job would be 9-to-5, allowing her time enough in the evening to keep up with her particle-theory interests. But her job soon absorbed all of her attention, forcing her to abandon the rarefied world of pure research. Cartier does keep up with recent developments, however,

which she lampoons in cartoons drawn for PHYSICS TODAY.

Research for defense

Cartier, like many physicists in industry, is doing defense-related research. She says that she was surprised to find how “all roads lead to the Pentagon.” John Rigden of the University of Missouri, the editor of the *American Journal of Physics*, is concerned that students are not being informed of the high probability of their eventually having to do defense-related research. “Our students are in a precarious position,” he says. “In my experience students go to academe or else they work for Caspar Weinberger, either directly or indirectly.” He believes that students should be told of their job prospects as early as possible. “Maybe they’ll say that ‘if physics means making cruise missiles, I don’t want it.’”

SRI’s Cooper, who worked at Los Alamos characterizing the tiny targets used in laser fusion studies, eventually left when he found himself moving toward research with more defense applications. His qualms were not only moral: Much of the work he would be doing would be classified; he would not be able to publish any of his results. “If you’ve gone ten years without publishing... it is hard to convince people outside your field that you’ve been doing important work.” And so it is hard ever to get out of military research.

Industry’s appetite for PhD physicists will undoubtedly continue to increase. And in physics, as in most things, a good man will always be hard to find—and a good woman, given the current graduate enrollment, even harder. Things would become easier if communication between graduate students and their future industrial employers began long before they met across the interview table. □