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AMERICA'S SCIENCE TEST

The Real Science Crisis: Bleak Prospects for Young Researchers

Tight budgets, scarce jobs, and stalled reforms push students away from scientific careers

By RICHARD MONASTERSKY

It is the best of times and worst of times to start a science career in the United States.

Researchers today have access to powerful new tools and techniques — such as rapid gene sequencers and giant telescopes — that have accelerated the pace of discovery beyond the imagination of previous generations.

But for many of today's graduate students, the future could not look much bleaker.

They see long periods of training, a shortage of academic jobs, and intense competition for research grants looming ahead of them. "They get a sense that this is a really frustrating career path," says Thomas R. Insel, director of the National Institute of Mental Health.

So although the operating assumption among many academic leaders is that the nation needs more scientists, some of brightest students in the country are demoralized and bypassing scientific careers.

The problem stems from the way the United States nurtures its developing brainpower — the way it trains, employs, and provides grants for young scientists. For decades, blue-ribbon panels have called for universities to revise graduate doctoral programs, which produced a record-high 27,974 Ph.D.'s in science and engineering in 2005. No less a body than the National Academy of Sciences has, in several reports, urged doctoral programs to train science students more broadly for jobs inside and outside academe, to shorten Ph.D. programs, and even to limit the number of degrees they grant in some fields.

Despite such repeated calls for reform, resistance to change has been strong. Major problems persist, and some are worsening. Recent data, for example, reveal that:

- Averaged across the sciences, it takes graduate students a half-year longer now to complete their doctorates than it did in 1987.
- In physics nearly 70 percent of newly minted Ph.D.'s go into temporary postdoctoral positions, whereas only 43 percent did so in 2000.
- The number of tenured and tenure-track scientists in biomedicine has not increased in the past two decades even as the number of doctorates granted has nearly doubled.
- Despite a doubling in the budg-et of the National Institutes of Health since 1998, the chances that a young scientist might win a major research grant actually dropped over the same period.

The job market in science is now shifting faster than graduate programs can keep up, leading often unhappy Ph.D.'s to hunt for careers far from the academic homes where they hoped their degrees would lead.

Academic and government leaders acknowledge some of these problems and are attempting to correct them. Major sponsors of science — the National Science Foundation, the NIH, and the Howard Hughes Medical Institute — have started programs to help young scientists weather the rough climate. And a five-year study led by the Carnegie Foundation for the Advancement of Teaching has assessed reform programs to try to improve doctoral education across all of academe.

But given the inertia of academic departments and the spotty results from past reform attempts, widespread success may be elusive. Paula E. Stephan, a professor of economics at Georgia State University who studies the scientific work force, says, "We've known about these problems for a long time, but we're very slow to address them."

Against All Odds

Stephen D.H. Hsu is just the type of scientist America hopes to produce. A professor of physics at the University of Oregon, Mr. Hsu is at the forefront of scholarship on dark energy and quantum chromodynamics. At the same time, he has founded two successful software companies — one of which was bought for $26-million by Symantec — that provide the sorts of jobs and products that the nation's economy needs to thrive.

Despite his successes, Mr. Hsu sees trouble ahead for prospective scientists. He has trained four graduate students so far, and none of them have ended up securing their desired jobs in theoretical physics. After fruitless attempts trying to find academic posts, they took positions in finance and in the software industry, where Mr. Hsu has connections. "They often ask themselves," he says, "Why did I wait so long to leave? Why did I do that second or third postdoc?" By and large, he says, the students are doing pretty well but are behind their peers in terms of establishing careers and families.

The job crunch makes science less appealing for bright Americans, and physics departments often find their applications for graduate slots dominated by foreign students who are in many cases more talented than the homegrown ones. "In the long run, I think it's bad for the nation," he says. "It will become a peripheral thought in the minds of Americans, that science is a career path."

Melinda Maris also sees hints of that dark future at the Johns Hopkins University. Ms. Maris, assistant director of the office of preprofessional programs and advising, says the brightest undergrads often work in labs where they can spot the warning signs: Professors can't get grants, and postdocs can't get tenure-track jobs.

Such undergraduates, she says, "are really weighing their professional options and realize that they're not going to be in a strong financial position until really their mid-30s." In particular, those dim prospects drive away Americans with fewer financial resources, including many minority students.

Despite the realities on the ground, leaders at the top of government, academe, and industry insist that the nation needs *more* scientists. In a high-profile report in 2005 called "Rising Above the Gathering Storm," a panel convened by the National Academy of Sciences argued for enlarging "the pipeline" of students studying science. The report acknowledged that "the recommendations for additional support for thousands of undergraduates and graduates could be setting those students up for jobs that might not exist." But it dismissed such fears with the vague proclamation that the number of doctorates "has not kept pace with the increasing importance of science and technology to the nation's prosperity."

The influential report also called for increasing support for the physical sciences, which have been relatively neglected in recent decades. Congress took those recommendations to heart and last month enacted a law that calls for doubling the budgets of the National Science Foundation, the Energy Department's office of science, and other divisions that support physical sciences.

But the act represents a broad promise, similar in many ways to other failed pledges of money for science that Congress has made in the past. With discretionary dollars in tight supply, supporters of science are not holding their collective breath for the extra funds.

Double Trouble

In a perverse way, such surges in financial support could actually exacerbate problems for young scientists. Biomedicine learned that lesson the hard way after Congress doubled the NIH budget from $13.6-billion to $27.3-billion between 1998 and 2003. Since then, the agency's appropriations have not kept pace with inflation, which has eroded the actual amount available for research.

The doubling had sweeping effects, spurring universities to go on a building and training spree that in some cases defied budgetary realities. One survey of 84 medical schools found that they expected to expand their research space by 26 percent between 2003 and 2008, and that they would need to increase the amount of NIH support they receive, despite the tightening of that agency's budget. (See article.) The universities added graduate students and postdocs in biomedical departments, but the number of permanent jobs available did not significantly increase, says Michael S. Teitelbaum, a demographer and vice president of the Alfred P. Sloan Foundation. "What's happening in the biomedical sciences — it's a crisis," he says.

Last month the Federation of American Societies for Experimental Biology, or FASEB, released a report showing that the number of doctorates in the biomedical sciences had risen from just over 4,000 in the mid-1980s to more than 7,000 in 2004, with no increase in the number of tenured and tenure-track positions.

Many of the younger scientists are parked in temporary positions, which almost doubled in number between 1985 and 2003, according to an analysis by Susan A. Gerbi, a professor of biology at Brown University, and Howard Garrison, of FASEB.

"I've never seen a time like the current one," says Ms. Gerbi, who pays close attention to graduate career issues and served as chairwoman of the Association of American Medical Colleges' group on graduate research, education, and training. Ms. Gerbi, in fact, has felt the financial pinch herself, having recently spent a year without grants for her own research. After nearly 20 years of getting NIH support, she failed in attempts to win new grants there and had to look elsewhere. She now keeps her lab afloat with money from the Defense Department and the National Science Foundation.

This money crunch is hurting established scientists, who are spending far more of their time writing grants than they had in the past, says Glen N. Gaulton, executive vice dean at the University of Pennsylvania medical school. Even successful researchers often have applications turned down once or twice before getting accepted, which means they can go without a grant for a year or more. Penn now spends between $5-million to $10-million a year in "bridge funds" to keep labs from getting shuttered. Many older scientists are just giving up and deciding to retire early, says Mr. Gaulton.

And the situation is even more desperate for younger scientists. In a talk at Harvard earlier this year, Ms. Stephan of Georgia State presented data concerning NIH's premier grants, including the R01 grants that usually provide four to five years of support at levels of more than $350,000 a year. Young faculty members must win those types of awards to support a lab and to gain tenure. In fact, many schools are now requiring that investigators show a track record of having garnered two or three such grants to get tenure.

Scientists say that many of the most creative advances come from younger researchers, but their slice of the research pie has shrunk considerably in recent years. In 1995, 25 percent of the R01 and similar grants went to scientists age 40 and younger. By 2005, the fraction going to that group dropped to 15 percent, while researchers older than 51 were gobbling up almost half of the big grants.

Recognizing that problem, the NIH created smaller grants for new investigators, but those awards are not sufficient, says Ms. Stephan. "It's hard to start a lab off of those," she says. "It's hard to get your first foot in the door permanently with those kinds of funds." And they won't earn a young professor tenure, she

says.

Last month that gloomy FASEB data moved the journal *Nature* to run an editorial titled "Indentured Servitude," which argues that "too many graduate schools may be preparing too many students, so that too few young scientists have a real prospect of making a career in academic science."

Such indictments have a familiar ring. In 1998, Shirley M. Tilghman, now president of Princeton University, chaired a National Research Council committee that looked at young careers in the life sciences. That panel noted that an oversupply of graduate students and postdoctoral fellows did provide some benefits. "To the established investigator and the overseers of life-science research, the availability of large numbers of bright young scientists willing to work very hard for relatively little financial compensation is an asset that contributes to a remarkably successful enterprise."

But the committee argued that the oversupply was untenable. The report stated that "the committee recognizes that the number of PhD's awarded each year might already be too high."

Ms. Tilghman's committee urged "restraint of the rate of growth." But even that mild recommendation drew strong criticism from America's scientific establishment. One professional society, for example, said the research council's report was based on old data. With no prescience, the society challenged the idea that job shortages would continue. Graduate programs, for their part, largely ignored the calls for restraint, and the number of doctorates surged, as recent data shows.

Some administrators have finally decided enough is enough with respect to doctoral students. Brown cut its incoming class of biomedical Ph.D. students by 20 percent this year, and Penn slimmed its class by about 12 percent. The National Institute of Mental Health has trimmed its budget for graduate training in an effort to preserve the money available for research grants.

One other study, called Re-envisioning the Ph.D., was sponsored by the Pew Charitable Trusts, which interviewed over 450 people involved in training doctoral students and in hiring graduates of Ph.D. programs. In 2003 the Pew-supported team issued its own list of recommendations, many of which overlapped with previous reform efforts. Among its proposals, the project called on schools to enhance communication with graduate students, expose students to a wide variety of career options, better prepare them to teach, and expand participation by underrepresented minorities.

More recently, the Carnegie Initiative on the Doctorate tried to put many of those recommendations into practice through a program that involved 84 departments in the fields of chemistry, education, English, history, mathematics, and neuroscience. George Walker, vice president for research and graduate dean at Florida International University, oversaw that program, which will publish its findings later this year. Departments in the program identified their own weaknesses and developed fixes, which they shared with others involved in the program.

When he recounts the lessons learned from the five-year project, Mr. Walker raises many of the themes that have emerged from past studies. "There are many fine reports sitting on bookshelves," he says. "Many recommendations going back 50 or 60 years are still relevant."

Behind Closed Lab Doors

In fact, the American Chemical Society made suggestions in 1947 that largely mirror the most recent studies, including proposals to improve mentoring, to avoid narrow specialization, and to prepare students for careers in industry.

Mr. Walker says that American graduate programs train students to be superb researchers. But they need to do more, he argues. Departments and students must recognize that the majority of science doctorate recipients no longer become professors, and that realization should cause a shift in the culture and practice of graduate education. "There's a mismatch between the opportunities available to students as they complete their work and their expectations and the nature of their training along the way."

Graduate programs, he says, need to help students learn how to be nimble — to work at the junctions of disciplines, to collaborate as part of a team, and to be able to move from one topic to another. All of these skills, he says, are becoming increasingly important as careers evolve, both within and outside academe.

And programs will have to shake up the traditional model of doctoral education, in which a student apprentices with one faculty member who oversees the research training. "Only the American bedroom has more privacy associated with it than the relationship between the faculty member and the Ph.D. student," says Mr. Walker. "That's not good." He calls for a more open process, for multiple mentors, and for more involvement by the department in the care of students.

Some programs have made significant strides, such as the neuroscience department at Georgetown University, the chemistry department at the University of Michigan, the mathematics department at the University of Nebraska. (See box.) And Mr. Walker says the effort by departments in the Carnegie project has impressed him. "I'm more optimistic than I've been," he says.

He is also a realist. While some programs are making progress, departments have done a poor job of sustaining reforms in the past and of matching rhetoric with action. "I have seen so many departments where if you look at their handbook of their graduate program, it sounds terrific," says Mr. Walker. "But if you get into the program, it doesn't work."

Debra W. Stewart, president of the Council of Graduate Schools, says that graduate deans in the United States are acutely aware of the difficulties faced by young scientists and that schools are trying to help graduate students succeed in careers. "There is a quiet revolution on campuses that is directly responsive to student concerns," she says.

Universities have strived to better prepare graduate students for teaching and for work outside of academe, she says. They have tried to lower "career angst" by providing more professional development for doctoral students and postdocs and by giving them opportunities to develop skills and experience that will help them make a transition into the job market.

Ms. Stewart also cautions against seeing Ph.D.'s in isolation from the rest of society. While young scientists face intense career stress these days, so do people in medicine, law, and most other professions that have changed markedly in recent decades, she says. "It is unfair to somehow identify this as a problem of academic science," she says.

The Clock Is Ticking

Critics of doctoral programs say that one persistent problem is the time it takes American students to obtain a Ph.D.

In England, for example, chemistry students generally obtain their doctorates in 3.5 years, whereas Americans take almost double that, says Alvin Kwiram, a professor emeritus of chemistry and former vice provost for research at the University of Washington.

Mr. Kwiram recently spent a year at the University of Oxford studying the English graduate system. The comparison is not exact, he says, because English students get more specialized undergraduate training. But he adds that that difference should add only a year to American programs, not three or four.

"The time to degree," says Mr. Kwiram, "has gotten out of control, and the community has to face up to that. They don't want to because the incentives are all in the opposite direction." Professors prefer to keep graduate students for longer, he says, because their work grows more productive over time.

The long training weighed on Steven D. Miller when he was considering doctoral programs. A magna cum laude graduate from the University of Maryland in 2006, Mr. Miller had planned on pursuing a Ph.D. in entomology but gave up that goal after conducting research as an undergraduate.

"The life of a lot of doctoral students I saw was pretty dreary," he says. "It's easy to get yourself in a

situation where instead of taking the planned five years it takes seven, and that's a real bummer."

Instead of spending hundreds of hours studying a minute body part on a fly, he chose to go to medical school, which offers more variety and a chance to work directly with people, he says.

Beyond the length of doctoral education, reformers repeatedly point to another concern: the attitude within graduate programs to jobs outside the ivory tower. Although most Ph.D.'s in science find nonacademic positions, many mentors still look down on students who do not land a tenure-track job, say students and professors.

Almost every project aimed at improving graduate education suggests that departments should expose students to the breadth of jobs beyond academe, but faculty members still resist. When Mr. Hsu, the University of Oregon physicist, brings his former students back to talk about their jobs in finance or the software industry, it rankles some other professors.

Doctoral students pick up on that bias. "It was kind of a taboo topic," says Ms. Maris, the career adviser at Johns Hopkins, who recently earned a Ph.D. in genetics at Emory University and did one year of a postdoc at Hopkins before she decided to leave research.

Bruce Alberts, a former president of the National Academy of Sciences, says universities and the nation must take better care of young scientists. Now a professor of biochemistry at the University of California at San Francisco, Mr. Alberts says the current system of demoralized and underemployed Ph.D.'s cannot be sustained. "We need to wake up to what the true situation is."

Students may be quietly starting to lead the way — to recognize that they need to look beyond traditional ways of using their Ph.D.'s. When Mr. Alberts's colleagues polled second-year doctoral students last year, a full quarter of them expressed interest in jobs such as patent law, journalism, and government — jobs that their professors would not consider "science."

Of course, students might not be willing to share those desires yet with their mentors. The poll was anonymous.

SNAPSHOT OF A DEPARTMENT IN TRANSITION

Problem: Hyperspecialization
Industry and academe increasingly require scientists who can jump the fences between fields, whereas traditional Ph.D. programs encouraged students to spend years focusing on one topic.

Solution: Research rotations
The University of Michigan at Ann Arbor's chemistry department now requires first-year graduate students to complete two three-month rotations in different research groups before submitting their preferences for the one they would like to join. The department encourages students to try groups with different specialties.

Results: Broader experiences
In the first three years of the rotations program, 75 percent of students changed the plans they had had when they arrived at school. Some decided to work in an entirely different subdiscipline, while others picked a professor different from the one they had originally hoped to work with.

Some faculty members resisted the rotations. "The faculty is not a bunch of naïve cheerleaders," says Brian P. Coppola, a professor of chemistry at Michigan. "There was controversy about doing this from Day 1. There continues to be controversy."

But students have reaped the benefits, he says. They report feeling better connected to the department, and 85 percent said they felt comfortable collaborating with another faculty member or walking into another research group to get advice. Five percent of students now have multiple mentors for their dissertation work.

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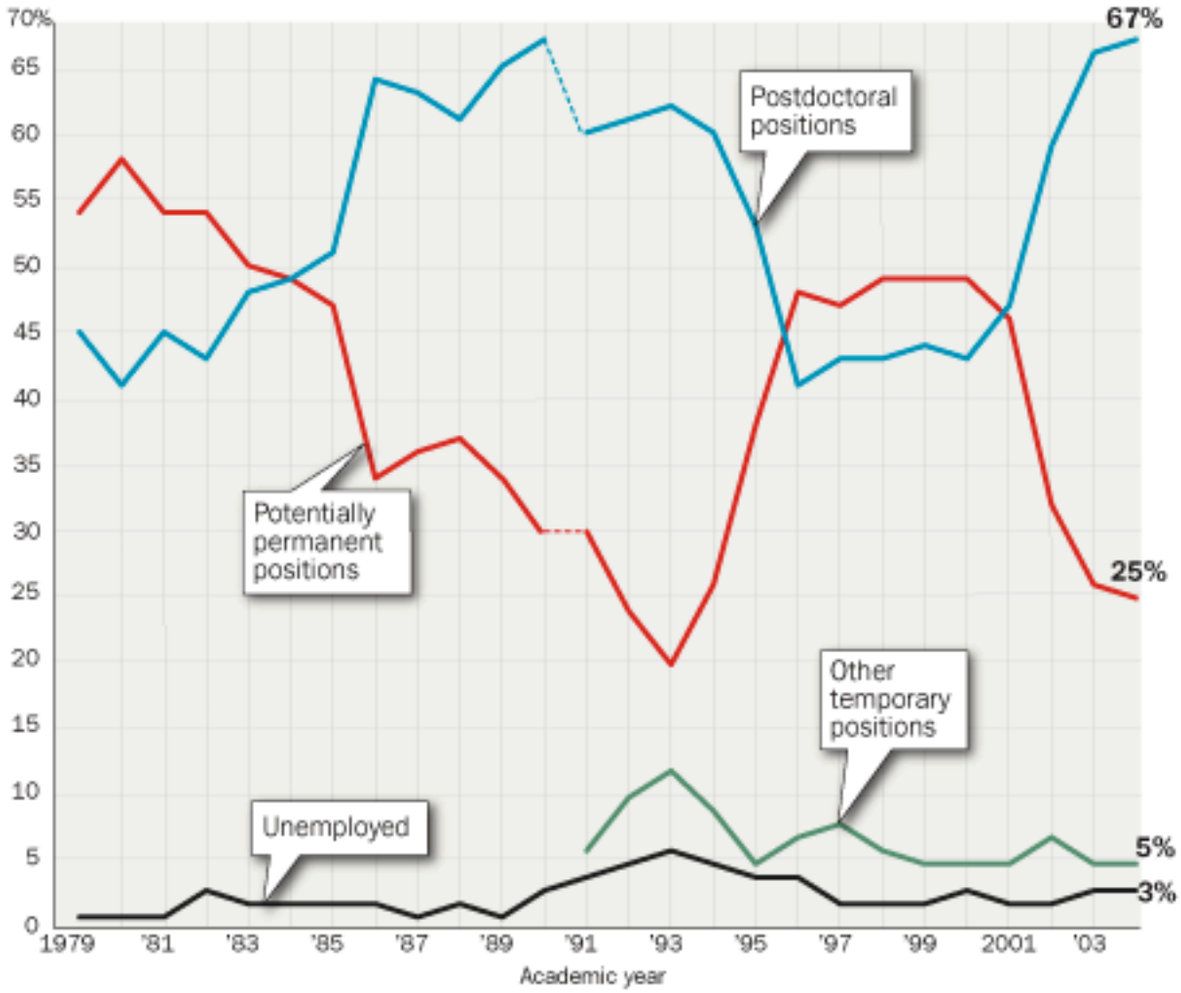
AGE OF SCIENTISTS WITH MAJOR NIH GRANTS

	1970	2005
Average age of people winning their first grant	35.2	42.9
Average age of all researchers	40.9	51.7

SOURCE: National Institutes of Health

INITIAL EMPLOYMENT OF PHYSICS PH.D.'S, 1979-2004

With the tight job market, most physics Ph.D.'s now take postdoctoral positions, according to a survey of recent graduates.



NOTE: In 1991 the survey added a new category for temporary positions.

SOURCE: American Institute of Physics