Physics grapples with its image problem

Fewer young people are wanting to study physics but universities are fighting back by designing more relevant courses. Graduates in the subject find plenty of openings in industry but a shortage of posts in the academic world.

Helen Gavaghan

Newspapers are awash with stories of cloning, biotechnology and genetic modification. Medical breakthroughs are reported daily. Governments, arguing that the biological sciences are an important basis for future economic well-being, and for people's health, have no difficulty justifying the decision to hand large chunks of taxpayers' money to biological research. In the United States, for example, the National Institutes of Health won an astonishing 15 per cent increase in its budget for 1999. In industry, the picture is equally rosy, with biotechnology growing and pharmaceutical company shares holding their own.

In short, it's cool to be a biologist, and the justification for a biology career choice is clear to anyone who can read. You can talk about biology at parties, and people will look you in the eye and say, "That must be really interesting."

What of physics? Here is an endeavour tackling the deepest mysteries of matter and energy as well as providing the underpinning for much of science, including biology. The discipline plumbs imaginative depths, its practitioners never knowing what greater depths may lie below. It brushes the fringes of philosophy and the unknown. Yet when the UK Institute of Physics asked academically bright teenagers why they were not studying physics after the age of 16, some gave the unbelievable response that they were interested in ideas and so would rather not study physics, thank you very much.

This perception of physics as dull and irrelevant may partly explain why fewer UK students are studying it after the age of 16 and why applications for undergraduate courses are falling. Around 12,000 fewer students took A-level physics (an exam that students sit when they are 18 and preparing for university) in 1998 than the nearly 47,000 who sat the exam in 1989.

In the United States, by contrast, the number studying physics at school has risen from 20 to 28 per cent over the past decade. Yet all is not rosy in the United States. In 1997, US institutions granted 3,826 bachelors degrees in physics, the lowest number in 40 years and a 24 per cent decrease since 1989. The decrease, mirrored in other physical sciences and in engineering, is partly attributable to the fact that there are fewer 18- to 24-year-olds now than 10 years ago.

Demographics is not the whole story, however. Students who have prepared to study physics at university often change subjects in their first year, says Alvin Saperstein, a physics professor at Wayne State University in Michigan. It is as though US students do not become as disillusioned about physics as their British counterparts until their first year at university.

Saperstein thinks falling numbers of physics students is the universities' fault for not paying enough attention to teaching. The consequences of that attitude, he argues, are now coming home to roost because, if there is less teaching to do, retiring members of staff may not be replaced. Top-heavy departments such as Saperstein's — 30 faculty members for a department turning out two or three physics majors per year — will be particularly vulnerable.

There are more faculty members in the United States over the age of 60 than under the age of 40, so the issue of what happens as staff retire will come to a head during the next five years or so. "If the decline in enrolments bottoms out at 1997 levels, it will be OK," says Roman Czujko of the American Institute of Physics (AIP). "But if it continues there will be pressure on faculty." What happens at the undergraduate level will set the stage for academic physics for the next decade.

A decline in the number of faculty positions for physics would make the task of finding a full-time, permanent job in academic research even more crushingly difficult than it is today. The current difficulty arises because the number of new physics PhDs has risen sharply in recent years. Although the number of postdocs on the market has risen, the number of faculty positions becoming vacant each year has stayed the same.

In the early 1990s, the competition increased further when corporate mergers and downsizing put many mid-career physicists on the market. The end of the Cold War also made internationally renowned eastern European physicists available for work. For the US postdoc class of 1993, the situation was abysmal, and remained that way up to about 1996, easing off now to merely 'pretty bad'.

Bright prospects and high salaries

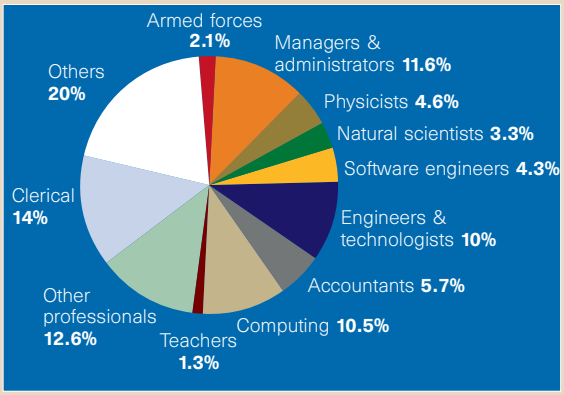
One of the most visited pages at the American Association of Science's website is called salary survey. Actually it is about more than salaries, showing how PhDs from 14 disciplines compare in the job market. Physicists come out well in the survey, having nearly the lowest unemployment level at 2 per cent, as well as comparatively high salaries.

The median salary for a PhD physicist in business/industry is US$62,000; the median for government work is $63,000. This compares with $72,500 and nearly $55,000, respectively, for computer scientists in business/industry and government.

Nevertheless, economists beat both physicists and computer scientists, with a median starting salary of $73,500 in business/industry, a figure which might explain the attraction some physicists feel for Wall Street and the City of London (see page 267).

In the United Kingdom, the Institute of Physics carries out a salary survey every two years. In 1998, the median salary across all sectors and levels of qualification was £27,850 ($45,000), an increase of 5 per cent compared with 1996. The highest-paid jobs were in industry. The median salary in the chemical and petrochemical industry, for example, was £37,500. In telecommunications and electronics, the median was £35,500.

Academic physicists, however, will have to find the intellectual challenge enough in itself – their salaries being below those in industry and other fields. Median salaries for those in universities were £28,000 and for those in research laboratories £26,173.



SOURCE: HESA

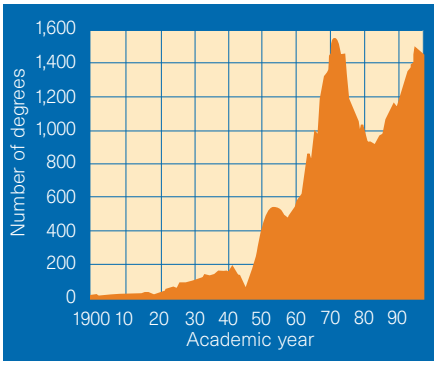
Options: areas of work of UK physics graduates surveyed in 1996.

Rick Moyer, a research physicist at the University of California, San Diego, believes it is unethical for institutions to continue to churn out new PhDs trained for academic research, most of whom will be hoping for a tenure-track position, when such positions are like gold dust. Moyer argues that PhD training could perhaps include business studies to prepare physicists for jobs in industry.

Worldwide problem

In France too, where 2,200 physics PhDs were awarded last year, there is a need for training to reflect the reality that most PhDs have to find work in industry, says Marc Joucla, director of the Association Barnard Gregory. ABG is a non-profit group offering seminars to doctoral students from different disciplines to help them to acquire a wider professional perspective than academic research alone.

Helmut Krauth of the German Physical Society, an industrialist with a metals company, Vacuum Schmelze, says that German industry is in general happy with the quality of physicists with PhD and diploma education. Nevertheless, he says, "professors should encourage students to get work experience during the summer". Such training will set them up for work in industry, he says.



SOURCE: AIP

Education peaks: US physics PhDs rose in the 1980s, outstripping the number of faculty posts.

Moyer's argument for commercially based training had more force a few years ago than it does today, because companies used to be leaner and more focused. They did not want the expense of taking on PhD physicists who would need training for the job. In those stringent times, the much vaunted ability of the physicist to be flexible and apply skills to a variety of problems was not attractive when a company could employ someone with just the specialist skills they were looking for. Now that the US economy is booming, industry is once again being creative and expanding, and is attracted by the generalist skills of physicists. Software and telecommunications are particular growth areas.

Even though physicists are once again in demand, there is still a need to prepare PhDs for the reality of their future careers rather than the dream of success in the academic sphere. Native US physicists with PhDs now have to compete against physicists from elsewhere lured to the United States by companies offering better salaries than available in their own countries but lower than paid to their US counterparts, says Moyer.

Industry beckons

The consequence of a strong economy and the difficulty of getting postdoc positions that could lead to tenure-track jobs are reflected in the latest figures from the AIP. These show that the numbers accepting jobs in US industry have risen during the past decade. Ten years ago, just under half of all PhDs who took permanent jobs went to industry. Now the number is 70 per cent.

Not all of those in industry are happy. "Some are disappointed to be in the private sector because they thought they wanted to be physicists when they grew up," says

Exciting times at the interface with other disciplines

Multidisciplinary research is of increasing importance, according to the US National Science Foundation. "We are seeing excitement at the interface," says Jack Lightbody, executive officer of the foundation's physics division. Lightbody says there is work to be had for physicists in areas such as modelling social and biological systems, and in medical physics.

The UK Engineering and Physical Sciences Research Council (EPSRC) is thinking along similar lines. Its policy document published this month, *Programme Landscape 1999–2000*, sees opportunities "for pioneering research across traditional boundaries". Helmut Krauth of the German Physical Society agrees: "There is a tendency to do more interdisciplinary research," he says.

The EPSRC, which funds university physics research (excluding particle physics and astronomy), plans a series of meetings to help physics cross interdisciplinary boundaries. One example will focus on modelling and simulation for physicists, people in industry and other academics. Interdisciplinary studies involving physics and environmental science and physics for healthcare will continue to be encouraged.

One new activity should help future job hunters interested in biophysics. The EPSRC plans to explore the opportunities in this area, believing that physics has much to offer the study of protein signalling networks, protein folding, biopolymers and colloids.

The physics and astronomy board of the US National Research Council also recognizes the value of links with biology in these days of shrinking physics budgets and blossoming biology funding (see *Nature* **397**, 89; 1999). Explaining its current study into the future of physics, the board says: "To attract ambitious people in the future, it is necessary that physics concern itself with rapidly developing areas such as medicine and biology."

Several US universities have already spotted the intellectual value of promoting collaboration between physics and biology (see *Nature* **397**, 3; 1999). Stanford University is investing in a new institute with 50 faculty members (including 10 new posts) that will draw together disciplines as disparate as applied physics and clinical medicine.

A survey conducted last year for the United Kingdom's higher education funding bodies confirmed the pervasiveness of interdisciplinary research in higher education. Three-quarters of researchers are doing interdisciplinary work. The funding agencies commissioned the study as part of their consultation on the quality of the country's methods of assessing university research and apportioning funding. They wanted to know whether the research assessment method inhibits interdisciplinary research.

Preliminary findings are that most researchers are involved in both single discipline and interdisciplinary research. Of these, 23 per cent believe that the research assessment exercise strongly inhibits interdisciplinary research. Those who spend most of their time on interdisciplinary research have the greatest concern. Heads of academic departments for the most part thought that the assessment exercise had little effect on interdisciplinary research. The survey also found that research assessment panels are less interdisciplinary than the scientists whose work they are evaluating.

The full analyis, by Evaluation Associates, is due to be published soon. It is likely to extend the preliminary recommendations that more scientists with knowledge of interdisciplinary work should be included in research assessment panels. If physics is to continue reaching into new areas, implementation of these recommendations will be important.

The preliminary findings can be found at:
http://www.evaluation.co.uk

Czujko. He hopes to follow up some of these PhDs to discover their views in a few years' time. "My guess is they will be real happy. These people are earning entry-level salaries of $60,000 to $70,000 per year. I want to feel their emotional pain, but..."

Perhaps sympathy should be reserved for the 43 per cent of 1997 physics PhDs who took postdoc positions. A study by the Commission on Professionals in Science and Technology published 18 months ago found that many new PhDs are forced to spend increasing lengths of time in low-paid, temporary, postdoc positions. The survey showed that of PhDs who took postdoc positions in all subjects (not just physics) in 1993, only 13 per cent had achieved tenure-track positions two years later. By 1995, the figure in tenure-track posts was only 16 per cent.

The AIP survey of 1997 PhDs shows that, of those in temporary postdoc positions, three-quarters were in those positions only because they could not find a full-time, permanent post. Because physics faculties are unlikely to increase in size, the best that can be done to minimize the waste of highly trained postdocs in low-paid temporary posts is to try to keep faculties with the same staffing levels, which means attracting physics majors and holding their interest.

Tailor-made courses

One institution with an imaginative response to the problem is Rutgers University in New Jersey, which draws from a blue-collar population. The students are often the first in their family to go to university and are people who are likely to want to get a job after their first degree rather than going on to do a PhD. This is not because they are not smart enough, but is the result of economic reality. Rutgers is teaching a physics course deliberately structured to this reality. About 800 US institutions offer bachelors degrees in physics, and many are seeking ways to change the curriculum to attract more students.

At masters level, too, there is a need to tailor education to students' realistic job prospects. Surprisingly few masters courses include options of obvious value to business. In the United States there is the additional problem that holders of masters degrees tend to be perceived as failed PhDs rather than as bona-fide holders of a higher degree.

Those who want to study physics to bachelors, masters or doctoral level would be well-advised to question whether the course

Modelling makes the money go round

The esoteric and intriguing world of derivatives trading is attracting increasing numbers of physicists. As yet only a trickle of some tens of people each year are joining the business in the United States and United Kingdom, but nevertheless the financial sector is an emerging job market for physicists.

Derivatives trading can be speculative and purely for profit, even to the extreme of becoming a gambling addiction. Equally, however, this field can satisfy a socially responsible and economically meaningful function by, for example, minimizing the risk of financial institutions. Banks shelter from the unpredictable winds of economic fortune by buying or selling derivatives. This allows banks to sell mortgages to individual customers at affordable levels and stay in business, despite fluctuations in interest rates.

A derivative is a contract whose value derives from the value of an underlying security such as a stock price, interest rate or foreign exchange level. The derivative might be an option to buy a stock at a given price in the future. In other words, the holder of an option can buy a stock for, say, $150 on a given day in the future. If the value of the stock on that date is $180, the individual will exercise his or her option and buy the stock at $150. If the value is lower, the individual will not buy. Either way, the individual will have paid the derivative trader for the option.

The financial institution selling the derivative must, of course, be able to provide the stock at the value agreed if the customer exercises his or her option, but it clearly does not want to lose money if the stock has soared in value beyond that anticipated. Myron Scholes and Fisher Black, an economist and an applied mathematician working together at the Massachusetts Institute of Technology, came up with a formula in the 1970s for pricing options.

Another class of derivatives is known as futures. The idea behind futures is easiest to grasp in the context of a commodity such as orange juice. The holder of a futures contract agrees to buy orange juice at a given price in the future, and thus the seller of the contract assumes the risk of a possible increase in the price. Unlike in the case of an option, the contract holder cannot walk away from the deal if the price of orange juice declines. The customer pays the dealer for the privilege of being protected from that risk.

Options are the simplest types of derivatives, says Andrew Lesniewski, a former Harvard physicist who made the move to Wall Street in preference to heading a mathematics department at a US university. Currently, Lesniewski trades exotic derivatives at the French investment bank Paribas.

More complex derivatives are contracts that protect the buyer from unfavourable variations in, say, interest rates or foreign exchange. The buyer could be a mortgage company worried about refinancing when interest rates decline, a US portfolio manager holding foreign stocks in his or her portfolio, or a European company whose balance sheet depends on the US dollar price of crude oil. The derivatives dealer decides how much he or she will charge to assume the risk of the unfavourable market movement in interest rates, foreign exchange, or oil price. "Derivatives can be as customized and as complex as you want," says Lesniewski.

To protect itself, the derivatives trader will have its own constantly changing portfolio of derivatives. The trader needs to hedge its portfolio against future movements of a range of commodities, stocks and financial indicators. It must price its derivatives so that they are good value to the company needing to off-load risk, while remaining viable itself despite the risk it is carrying. Risk management of a portfolio of derivatives held by a financial institution is the key role of a trader. In the case of interest-rate derivatives, this involves sophisticated mathematical models of the shape and dynamics of the yield curve, or term structure of interest rates.

Hence there is a need for people able to reduce complex systems to their essentials and to describe them mathematically. "The people we recruit must be smart," says Lesniewski. They need a sophisticated knowledge of probability theory, stochastic processes, partial differential equations and numerical analysis. It is a job that physicists, statisticians and mathematicians can do. "What I find challenging," he says, "is that it is a new, dynamic and growing area of the economy. You can do original work, make a significant contribution and see concrete results."

Yet there is a need for caution. Derivatives traders need a realistic knowledge of the role of money. "It's not just that money is the bottom line in this business," says Lesniewski. "Derivative trading is about buying, selling and managing money and predicting how economic factors will influence its behaviour. If you are not comfortable with money, it is not for you."

Further reading:

Hull, J. *Options, Futures, and Other Derivative Securities* (Prentice Hall).

offered suits their needs in the modern world, or is one that suits a faculty's traditional view of what physics should be about.

Declining interest

A similar story of declining interest in physics among university applicants is to be heard in the United Kingdom. The number graduating with a bachelors degree is holding steady at about 2,300 per year (an apparent dramatic dip in physics graduates in 1996 was an artefact resulting from the introduction three years earlier of four-year courses), but the percentage of applicants for physics degrees is down by 10 per cent compared with 1998. This compares with an average 2 per cent decline nationally in all subjects. The decline in the numbers taking up postgraduate positions has different reasons. The minimum stipend for a PhD is £6,500 ($10,000) per year, not enough to live on (*Nature* **397,** 640; 1999).

In an effort to reverse the decline in physics at school level, the UK Institute of Physics has devised a curriculum to make the subject more attractive to 16–18-year-olds. This programme goes beyond classical physics and introduces students to cosmology and particle physics. A few schools will take part in a pilot study starting this September to test the course. If successful, the course will be widely available in September 2000.

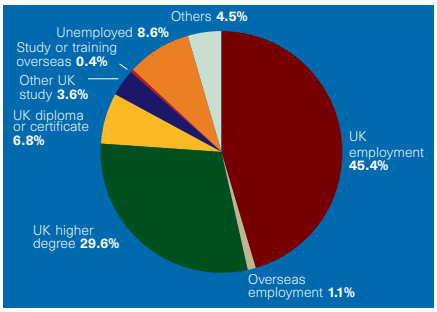
Cold wind blows

Although there are few hard numbers to back up the perception, it seems that the coolness towards physics seen in the United States and the United Kingdom is also being felt across northern Europe. "It's largely hearsay, but throughout northern Europe there are anecdotal stories of declining numbers enrolling to study physics," says John Lewis, treasurer of the European Physical Society. So concerned is the society that in September it is bringing together 50 influential physicists from across Europe, including presidents of 16 national societies, to thrash out a strategy for discovering how much of a problem there is and how it can be dealt with.

Germany is likely to feel the pinch soon. In 1998 for the first time more physics PhDs were awarded than physics diplomas (a degree that is more than a masters but less than a doctorate), says Krauth. In Germany a diploma is a highly regarded qualification awarded after five years of higher education and essential for anyone wishing to earn a doctorate. The decline in diplomas, which has taken everyone by surprise, will mean that Germany's production of PhD physicists will fall in a few years, says Alex Bradshaw, head of the German Physical Society.

Social conscience

The factors causing the declining interest in school or undergraduate physics are complex. In the United States and the United Kingdom, one reason is the unimaginative quality of curricula and teaching methods in first-year university courses or at 16-plus. But there are bigger issues at stake. Krauth says: "In Germany, young people are questioning whether physics and technology have served humanity well."



First destinations: work or further study chosen by recent UK physics graduates surveyed in 1996.

SOURCE: HESA

In the United States, the physics and astronomy board of the National Research Council (the research arm of the National Academy of Sciences) began a decade-long series of studies in 1991 to confront head on the issue of the relevance to society of all branches of physics. Central questions being addressed include: 'How can the intellectual vitality of physics be continued into the next millennium?' and 'What contribution does physics make to the national need?'

In these post-Cold War days the answer to the second question is less obvious to the public, and hence to prospective students, than it used to be. One problem is that there is no physics industry, says Czujko. Chemistry has the chemical industry, biology has biotechnology and pharmaceuticals, geology has mining and oil exploration, but the path from basic physics to industrial usefulness and jobs is not obvious.

Conscious of this low visibility of physics, the physics and astronomy board's first study of a branch of physics, published in 1994, pointed out that atomic, molecular and optical physics is the underpinning science for 9 per cent of US gross domestic product. During 1999, the board will publish studies of elementary particle physics, condensed matter and materials physics, nuclear physics and gravitational physics. Then will come the third and most difficult stage, an overview of physics, to be published in 2000 and making recommendations about education and attempting to define the place of physics in today's society.

The low profile of physics leaves students with the false impression that job options are limited. Yet, providing that they do not aspire to a full-time, permanent academic research post, this is a false perception. In 1997, only two per cent of US PhD physicists were unemployed after six months. But of the 48 per cent in permanent positions, only 43 per cent were employed in physics. The rest had jobs in engineering, computing, other sciences, business and finance. At Vacuum Schmelze in Germany, Krauth says that 60 physicists out of a total workforce of 2,000 do a full range of jobs from research and development to sales and marketing.

A UK survey by the Higher Education Statistics Agency shows that people with a bachelors degree in physics found jobs in 1996 in business analysis, as test engineers, in sales, data research, the armed services, as systems engineers, analysts and programmers, as teachers and as production, telecommunications and safety engineers. Just under 30 per cent were studying for PhDs or masters degrees.

Perhaps then, despite the gloom in the academic sphere, there is some justification for Czujko's assertion: "I don't think physics is dead. I'm bullish on physics." □

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Job search starts here

The American Institute of Physics website is the most relevant site for US physicists, containing forums, links and a wealth of statistics, survey data and job advertisements, as well as a section in which to post your resumé. Other useful URLs are those of the American Physical Society and the American Association for the Advancement of Science.

In Europe, start with the European Physical Society site. This connects you with the physics societies in Europe and gives access to sites like that of the non-profit group Association Barnard Gregory in France, a resource for job-hunting scientists. The UK Institute of Physics is the best funded European organization, and offers the most extensive resources and information about education and careers of the European sites.

For electronic searches, remember the bulletin boards and USENET. If you send unsolicited CVs, remember that they may be scanned into a database. Make sure the layout is clean and unfussy with no fancy typefaces. Make sure the CV contains the crucial search words that you would want to be identified to pull your CV to the fore. Good luck!

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