didn't know what they were doing and expectations were unrealistic."

To take an example, since MIT reorganized its office of technology transfer in 1985 the income of the office has increased more than fivefold and the staff has increased about fourfold. The income received in 1997 was a record $21.2 million, up from $2 million or so in 1985. Overall, MIT consummated 59 new licences (now totalling 455 active licensees), and eight new companies were started in 1997.

Further, about 115 start-up companies have been created by MIT's technology licensing office, now one of the top technology transfer institutions. According to CED, there are more than 1,000 MIT-related companies in Massachusetts, with about 125,000 workers in Massachusetts alone and worldwide sales of more than $53 billion. Similar developments have taken place in California's Silicon Valley and in Research Triangle, North Carolina.

Recent makes and models

Vehicles for commercialization are coming in different shapes and sizes. With institutions like MIT and Stanford setting the precedent, others would surely like to emulate their success. OSU, for example, has adopted new mechanisms to develop more efficient technology transfer, and to create some of the entrepreneurial, business and financial infrastructure found in places like Boston or San Francisco's bay area.

Balanced properly, such endeavours should benefit the companies that use university research, the university itself, its students and the local economy. "We are more likely to evolve relationships with them to do sponsored research, experiential learning opportunities and internships for students, as part of a whole realm of activities that are partnership oriented," says Allen.

Because the university's first research park was not successful, OSU set up a 40-member task force four years ago to try to make technology transfer more effective. One of the problems, says Allen, "is that as a unit the university was imbued with all of the consensus decision-making and deliberation that occurs at a pretty glacial pace for technology transfer". The task force has created a corporation outside the university to produce entrepreneurial activity quickly and help build the infrastructure which is underdeveloped in the Columbus area. This result is the Science Technology Campus Corp., which houses 14 companies, half of which owe their existence to university technology.

Also separate from the university is the business technology centre where prospective businesses can come to have their ideas developed. According to Allen, start-up companies must be based on a relatively new technology that has a good market trajectory — that is, it must be more than just a research finding. Also, the company should have some of its leadership in place.

One of the things that the business technology centre offers is a really strong board of trustees; these are entrepreneurs, business people and financial people, says Allen. Success depends on effective teamwork with the board, he adds.

Faculty members seldom leave their positions at the university, but often stay involved on the research side "by pushing the technology in the laboratory forward", he says. However, they often have colleagues, friends or graduate students who want to capitalize on the technology through a corporate venture. The business technology centre then adds to this initial team by filling out the business structure. Funding comes from risk capital sources, often 'business angels' — wealthy friends or associates of entrepreneurs. Allen would like this source of capital to be organized into a formalized mechanism. □

Partnerships and the critical mass

Academic faculties today may have insufficient openings to accommodate all prospective candidates, but industry partnerships are generating opportunities for basic and applied researchers to help make up the difference. Funding indicators reported by the US National Science Foundation confirm that collaborations between the academic and industrial sectors are on the rise. In the United States, investment by industry in basic research performed at universities and colleges increased in real terms between 1991 and 1997, rising to a total of $1.05 billion. An even longer term trend is indicated by the fact that co-authorship of journal articles by US industrial researchers with their colleagues in academic and government labs has been increasing steadily across all fields since 1981.

The trend towards industry collaborations has been most pronounced in the United States, thanks to the great depth of its scientific establishment, and a well-developed infrastructure of venture capital and technology transfer. But, as the worldwide force of scientific creativity strains to find expression, industrial–academic partnerships, either on the US or some comparable model, are flourishing elsewhere. In Europe, for example, the member states of the European Molecular Biology Laboratory (EMBL) have authorized the lab to accept shares in companies in exchange for releasing technology, and to establish a technology-transfer company fully owned by EMBL.

The European Bioinformatics Institute (EBI), an outstation of EMBL at Hinxton Hall, in Cambridge, has an active outreach programme to foster company-funded research. This has led to important advances in development of CORBA, a set of standards which allows databases and software applications to communicate. Once developed by the company/institute consortium, the standards can be used to develop fully commercial products.

One collaboration between EMBL and the private sector is Lion Biosciences, based in Heidelberg, Germany, which is focused on high-throughput expression profiling and bioinformatics. Supported by private and state funding, it has formed relationships not only with EMBL/EBI, but also with the German Cancer Research Centre, the University of Heidelberg, Hoechst, and other companies. Since its foundation 15 months ago, Lion has doubled its staff numbers to 55, and expects to double again within a year.

Christian Marcazzo, a product development manager of Lion's sequence retrieval system, an indexing and retrieval tool for molecular biology data libraries, which was developed at EMBL/EBI over the past six years or so, says he expects hiring in his department to triple in the year ahead. The new staff will include not only scientists but people who are not usually in strictly academic development projects: quality assurance, documentation, customer support and marketing. "The goal of the activity," he says, "is to turn good technology into good products for the pharmaceutical, biotech and agriculture research communities."


Marcazzo: expects hiring to triple.

Marcazzo, who recently moved to Lion from a job in California's Silicon Valley, observes that the Europeans are eager to explore collaborations and to commercialize academic research. Nevertheless, the road for start-ups is not as well paved in Europe as in the United States. "There are fewer venture capitalists, and they are more conservative. The consultants you can find practically on every street corner in Silicon Valley are not here. And going public in Europe involves a lot more than merely satisfying minimum capital requirements to get a NASDAQ Stock Exchange listing, as in the States." He adds that employee stock options are unusual in

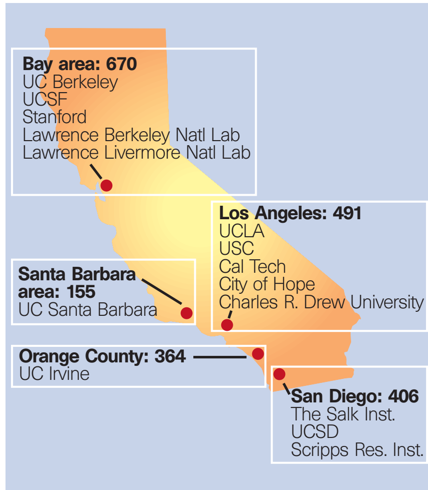
How to turn R into D and get paid for it

Diane Gershon

It is hard to find reliable and useful data on the economic benefits of academic research. One study by Edwin Mansfield[1] calculated the social rate of return from academic research during 1975–78 to be 28 per cent. Mansfield cautioned, however, that his estimate was "at best a very crude beginning". The Association of University Technology Managers (AUTM; see table) more recently estimated that, in 1996, technology transfer from academic institutions to industry contributed more than $24 billion to the US economy and supported about 212,500 primarily high-skilled, high-paying jobs. Comparable figures for the previous year were $21 billion and 180,000 jobs.

Although clearly not every licensed invention leads to a marketable product, much less a lucrative one, many have resulted in significant new products and technologies. Some have even formed the basis for new companies or entire industries.

Biotechnology is a good example of an area where public investment in basic research and evolution of the industry are inextricably linked. Small, entrepreneurial businesses in biotechnology and other areas of high technology were the engine for economic growth in California, which led to the dramatic turnaround in the state's economy.



Hotbed clusters of medical technology activity in California: companies are concentrated around major research institutions.

DATA FROM CHI/KPMG REPORT

Healthcare technology as a whole, of which biotechnology is a significant part, is now one of the fastest-growing, highest-paid industries in the state, second only to electronics in the high-technology arena, according to a report issued in July by the California Healthcare Institute and KPMG Peat Marwick (see table). In 1997, more than 200,000 people were employed in healthcare-related jobs in the state, with average annual earnings of $50,500 (compared with state-wide average of $32,800 for all industries). The highest-paid positions in the sector were in biotechnology, where the average salary was $67,000.

Perhaps the most compelling evidence of the vital link between academic institutions and the biotech industry is reflected in the results of a recent survey of biotech companies carried out by the University of California's (UC's) critical linkages project. It showed that one in three US biotech companies is within 35 miles of a UC campus; that one in five of California's biotech companies

Europe, and the start-up culture of "high-risk, high reward" is not a familiar idea to most young Europeans.

France, too, has tended to lag behind the United States in developing contacts between the academic community and industry. Daniel Louvard, research director of the Institut Curie in Paris, says: "A certain bias against applied research has existed in France. But this attitude is changing rapidly, driven in part by budgetary pressures." Already there has been an increase in the number of contracts between industry and the Curie, and ten patents have been granted so far this year to Curie researchers.

Elsewhere in the world the atmosphere may be less conducive for collaborative research ventures. Fred Dotzler, an investor with Medicus Ventures in Palo Alto, California, says: "We were recently involved with a venture in Korea and I got the feeling there was no vehicle whatever over there for technology transfer from the academic sector to start-up companies." But once a collaboration is in place its benefits — an accelerated pace of discovery and generation of science jobs and revenue — accrue not only to small ventures with rapidly evolving new technologies, but to mature, diversified establishments as well.

An example of the latter sort of partnership is the one between Novartis, the Swiss pharmaceutical giant, and the Scripps Institute, the graduate research university in La Jolla, California. Beginning last year, Scripps is receiving $20 million a year for five years from Novartis, with an option for a five-year renewal in 2002. The form of the funding is of particular value to Scripps, because 65 per cent of it is "unrestricted", meaning it can be used to pay for physical plant and equipment, expenditure that is excluded from the $70 million a year that Scripps receives from the US National Institutes of Health (NIH). Some $7 million a year of the Novartis funding is project-specific, and is allocated among the institute's labs by the Scripps scientific advisory board, on which Novartis has non-controlling representation.

Does the presence of industry money in a partnership change how science is done? Certainly the application of resources to a research venture advances the possibility of discovery and extends avenues of enquiry. But can the funding also — especially when concentrated and of long duration, as in the Scripps/Novartis partnership — exert some unwholesome influence on the conduct of science? Not in the least, asserts Arnold LaGuardia, Scripps senior vice-president. "We're basic researchers and we don't change over to applied research just because industry money comes in the door." To the contrary, he sees a salutary influence beyond the dollars, in that exposure to the industrial environment can give academic researchers a heightened appreciation of the difficulties faced by their colleagues in industry and applied science.

Nevertheless, it is pertinent to remember that a proposed agreement in the early 1990s between Scripps and Sandoz (a predecessor company of Novartis) caused a furore because of provisions that appeared to limit the autonomy of Scripps and its researchers. Objections by Congress and NIH officials caused that agreement to be renegotiated, giving rise to the one in place today.

The job-seeking researcher dismayed at the prospect of science defined by state and corporate policy-makers, subject to the stipulations of patent lawyers and venture capitalists, can be comforted by remembering that it is the individual idea that lies at the heart of science. Ernest Beutler, chair of molecular and experimental medicine at Scripps, says that the idea that large teams — the so-called 'critical mass' — are the key to success in science must be rejected. "Collaborations do play a role in exploiting new ideas, but the origin of an important new concept can usually be attributed to one person. As the Nobel laureate Charles Huggins once said, 'the critical mass in science is one scientist'." **Potter Wickware**

Potter Wickware is a science writer in Oakland, California, USA. e-mail: wick@netcom.com