

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
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LIGHT RARE-EARTH ELEMENTS are generally considered to be those ranging from lanthanum to promethium. The remainder are known as heavy rare earths.

dependent on China for metal making and magnet production.

"There are several chicken and egg situations for this industry," says Castilloux. "Having oxides-processing capacity in the US will bolster the business case for establishing metal-making capacity and magnet capacity." MP, for one, says it plans to manufacture NdFeB magnets by 2025.

Separating concentrated ores to individual RE oxides is the most capital-intensive part of the process, says King. China has heavily invested in plants that may not be the most efficient, he notes. "If we start today with all the research that has gone into separations and reduction, we should be able to build more efficient plants and compete with China on a free-market basis."

Ucore, which declined an interview request, plans to build a separation plant at its Alaska prospect and hopes that sales of oxides will help pay to develop the mine. "With the ability to refine raw materials into high-purity RE oxides, the significant capital costs to build an RE mine can then be justified," company chairman and interim CEO Pat

Ryan said in an October 2020 statement. In the meantime, Ucore says its Alaska plant will separate REs from unspecified non-Chinese sources. But helping others process their material could undermine Ucore's own mining project, says Castilloux, who views the Alaskan deposit as one of the more economically challenging.

An alternative source

Growing demand and prolonged high prices may stimulate the extraction of REs from monazite, an RE-rich component of mineral sands. Last August, the Saskatchewan provincial government provided Can\$31 million (\$24 million) to build an RE processing facility. It will have a capacity to produce 500 tons a year of individual RE oxides from monazite when it begins operation in late 2022.

Energy Fuels, the largest US uranium miner, announced in December an agreement to acquire monazite sands from the Chemours Co's Georgia mine. Energy Fuels says it can recover enough mixed REs to meet 10% of US demand when it begins processing in the first quarter

of this year. But while it considers whether to build its own separation facility, the company will ship its RE-rich concentrated ore to Europe or Asia for that purpose.

Medallion Resources in Vancouver, British Columbia, is completing a technical and economic feasibility study of a monazite-processing plant that would produce 3500 tons of REs annually, including 500 tons of NdPr.

Other nations with abundant monazite deposits include Australia, India, Indonesia, Madagascar, and the Philippines. Iluka Resources, an Australian mineral-sands mining company, has committed AU\$35 million (\$26.8 million) to upgrade its monazite-processing operation to produce RE enriched ores.

"Developing a US-based integrated RE magnet supply chain is a significant challenge requiring cooperative efforts from the mine to the magnet original equipment manufacturer," Ormerod sums up. "A close private-public sector coordinated effort is essential if the capital, economic, and technical hurdles are to be overcome."

David Kramer

Guiding inventions from lab to market

A career in technology transfer requires skills in multitasking, communicating, and negotiating; one reward is seeing scientific advances benefit society.

"What can I do with a physics degree?" In 2014, nearing the end of his PhD at the University of Texas at Dallas, Chris Wohlgamuth typed that question into a search engine. The prospect of applying for grant money had soured him on the idea of pursuing a tenure-track academic position, and nothing had panned out in industry. Through his online search, Wohlgamuth stumbled onto technology transfer. "I read that the field needs technically sound people that have some understanding of patent law

and business acumen," he recalls. He landed an entry-level position as a technology licensing analyst at the Ohio State University, where he got on-the-job training for the business and law know-how he lacked. He is now a senior licensing specialist for the physical sciences at the University of Texas at Austin. The job involves guiding inventions—and inventors—from early stages through commercialization.

Dipika Singh got her first taste of commercialization in 2012–13 when she

and her supervisor at the University of Nebraska Medical Center developed a proprietary medium for freezing neurons. Freshly extracted neurons are especially "finicky," she says, and without a method to cryopreserve them, researchers discarded valuable neuronal cells after harvesting what they needed from animals. Their medium is now commercially available, and she gets an annual royalty check from its sales.

At the time of her invention, Singh was 25 and deciding whether to pursue a PhD or explore the business side of biotech. "I am an instant-gratification type of person, so science was not kind to me at times," she says. She earned an MBA at the University of Colorado Boulder. While there, she did an internship at the university's tech transfer office. Seven

years later she is a senior licensing officer at the university.

As a freshly minted physics PhD in 1991, Margaret Wilkinson went to work for Shell as a researcher. She tested fuel formulations and then moved into a policy position where she focused on recycling plastics. After a decade at the company, she joined the tech transfer office at the University of Cambridge. There were 6 people in the office; two decades later, there are 80. "Our mission is to help researchers use commercial avenues to develop ideas for the benefit of society, the economy, themselves, and the university," she says.

Cultural shift

The rapid growth of tech transfer in the US can be traced to the Patent and Trademark Law Amendments Act of 1980—known as the Bayh–Dole Act—which gave universities, nonprofits, and small businesses first dibs on inventions resulting from federally funded research. Previously, the government owned the intel-

lectual property rights, says Rick Smith, director of Lehigh University's office of technology transfer. "Little was happening with those inventions." The hurdles were high and the incentives were low. "Allowing universities to own the intellectual property rights was a huge catalyst for tech transfer," he says.

Some institutions already had tech transfer offices—Stanford University opened its in 1970—but as a result of Bayh–Dole, nearly every research university and national lab in the country now has one. And many other countries have aligned their patent ownership rules with the US model.

According to the technology transfer association AUTM, from 2013 to 2018 the number of tech transfer jobs rose from 2353 to 2600 at the 187 US institutions that reported data. AUTM's latest salary survey, from 2017, reports that the median salary for entry-level licensing agents at US universities was \$65 000 (standard deviation \$12 000). A PhD would typically start at the associate

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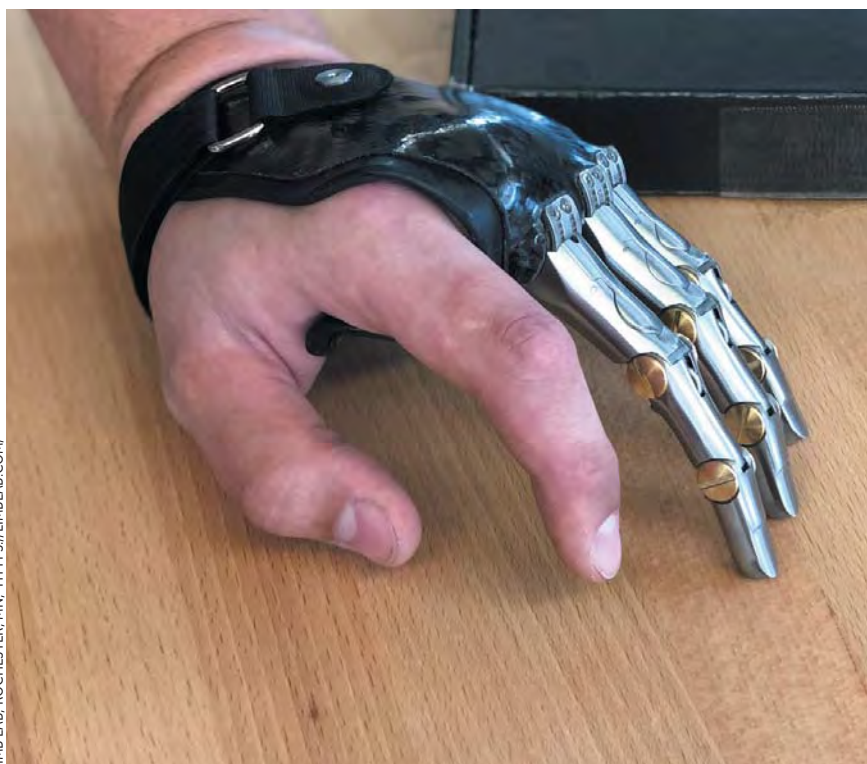
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PROSTHETIC FINGERS made by Point Designs in Colorado. Founded in 2016, the company grew out of prosthetic design research that cofounder Jacob Segil conducted as a graduate student in mechanical engineering. The company produces prosthetics for machinists, woodworkers, and others who have lost fingers. The company is now fundraising to create a prosthetic thumb. Segil is managing director of a new initiative at the University of Colorado Boulder to help researchers win funding to create startups.

level, for which the median starting salary was \$75 000 (standard deviation \$26 000). For that level, the average bonus was \$7000 for men and \$5700 for women. Those salaries are higher than for new faculty and lower than median starting salaries for physics PhDs in the private sector, according to data from the Statistical Research Center of the American Institute of Physics (which publishes this magazine). Compensation can exceed \$200 000 for directors of tech transfer offices.

Scott Elrod became an associate director for licensing in Stanford's tech transfer office in 2017 after more than three decades at Xerox's Palo Alto Research Center. The job is "intellectually very engaging because of the technical content," he says. "Elements like drafting agreements can be learned quickly, but instincts about business and value—being able to sense what has the potential to be realized commercially—can take years to develop.

"If you like multitasking and working

on a diversity of projects, then tech transfer may be for you," Elrod says. Learning new things and seeing success "is the biggest buzz," says Cambridge's Wilkinson. Over the past 20 years, she says, academia's appetite to spin out companies has grown. Her office used to help create one or two a year; now it's more than 10.

"When I started out 35 years ago, I had to convince faculty it was in their interest to commercialize their work," says Jon Soderstrom, managing director of technology commercialization and faculty innovation at Yale University. "Nowadays, faculty are tuned in to the idea that for their technology to go anywhere, industry has to be engaged. It's become part of the culture."

No market, no patent

Tech transfer officers do a lot of outreach: They meet with new faculty and visit departments to describe the services they offer, give talks about tech transfer, post signs around campus, host workshops,

and offer internships to students. The ball gets rolling on a new invention when a researcher fills out a disclosure form online or calls the tech transfer office. Informal conversations are also a common starting point. Benjamin Frisch is a physicist who works in knowledge transfer at CERN. "A lot happens around coffee," he says. "Many of the opportunities I have become aware of came up in conversations in CERN's main restaurant."

Once a researcher has disclosed an invention, the tech transfer officer has to decide whether to file a patent. "We sit down with the faculty member—or post-doc or student—and ask them to explain their work," says Soderstrom. Why is the work unique? Why is it useful? Who cares? Can it lead to something that is better, faster, and cheaper than what's already available? How much will it cost to develop the technology? Patents are worthwhile only if there is a market for the invention, notes Lehigh's Smith. He presents a wacky example from a class he teaches: "Take the bird diaper, now-expired patent number 5,934,226."

A physicist at Lehigh recently emailed Smith about a graduate student who was defending her PhD dissertation. The work was in nonlinear optical materials. "I filed a patent application that day," he says. The researchers could still submit their work for publication, "and sometimes you have to file quickly to protect a valuable creation."

The officer weighs the value of the invention and its commercialization potential against the costs of applying for and maintaining a patent. Those costs may start at a few hundred dollars to file a placeholder and can climb to tens of thousands of dollars. Yale reviews 250–300 new inventions a year, says Soderstrom, and tech transfer officers may have up to 1000 cases in their portfolio. "You have to triage, to figure out which ones to spend time on."

A fraction of the inventions that arrive in tech transfer offices make it to market, and bringing in big money is rare. Estimates for patenting range from a quarter up to three-quarters of disclosures; only some of those are developed into products, and even fewer are commercialized. "We can't commercialize anything unless the researcher is enthusiastic," Wilkinson says. "They have to be keen to put in time and effort." Licenses can fail, for example, if a company changes

course or doesn't get funded; there may not be a market, or the invention may be immature and require significant further development. In her experience, a tenth to a hundredth of those that are commercialized bring in a "reasonable amount" of money, and she has seen two or three that have brought in "significant" revenue.

One of Cambridge's biggest earners came out of theoretical physics in the early 1990s: software to predict material properties from first principles. It's used by molecular modeling companies to develop drugs and novel materials. Another example out of Cambridge is Enval, a recycling company that uses microwave pyrolysis to separate materials in flexible plastic-aluminum laminate packaging such as food containers and toothpaste

tubes (see image on page 25). The company was spun out of a chemical engineering research group in 2005 by graduate student Carlos Ludlow-Palafox and his PhD adviser Howard Chase.

Most research at universities and national labs is early stage—far from ready for commercialization. Tech transfer officers evaluate inventions and possible uses; often companies want additional data. For example, Smith says he is working with a large chemical company to license a new fertilizer developed by an academic researcher at Lehigh. The researcher and the company are collaborating to test nitrogen levels and prove the fertilizer's efficacy and its scalability for manufacturing.

Many universities have funds for such directed research or for the researchers

to build a prototype. Companies tend to be risk averse, Smith says, and it's a challenge for new inventions to survive the "valley of death" between university research and commercialization.

Gains in translation

Olivia Nicoletti earned her PhD in materials science in 2012 and worked in tech transfer at Cambridge in 2015–20. "I worked with technologies from medical devices to quantum computers," she says. "You have to have a passion for technology. You have to be creative. You have to be a people person." A plus of tech transfer, she notes, is that the skills are transferable to other jobs. People move into innovation and intellectual property management, investment, negotiation, spinoff companies, and other areas; Nicoletti recently moved into venture capital.

A difficult aspect of working in tech transfer, Nicoletti says, is telling people things they don't want to hear. "I had to tell people they would not be a good CEO for their company," she says, "and that the best thing to do would be to bring in a professional CEO. These are not easy conversations to have." Kathleen McDonald, who leads the tech transfer division at Los Alamos National Laboratory, agrees. "Tact and nuance are essential," she says. "People get defensive if you call their baby ugly."

Another challenge can be the long time it often takes to see an invention make its way to market. The Lehigh fertilizer, for example, has been in the works for more than three years and will likely be under development for several more years before it reaches product readiness, says Smith. There is a lot of variability, he adds. "Software can be quick, and pharmaceutical products can take a decade or more to reach the market."

Part of the job is translating. For example, says CERN's Frisch, "quick" results for scientists may be different than for a company. And a tech transfer officer has to be able to translate from the technical language a researcher may use to explain to a nonscientist why they should care—without revealing confidential information. "It's a lot about communication," says Frisch. The job requires asking probing, intelligent questions, says Soderstrom. "Know-it-alls die in this business."

Toni Feder 



ACOUSTIC CYTOMETRY grew out of work at Los Alamos National Laboratory and was originally licensed in 2006. Sound waves manipulate the flow of cells, which are then interrogated with lasers. Because of its flexibility, from holding single cells in view to enabling high-throughput cell scanning and sorting, the approach has become the dominant technology in flow cytometry—also developed at Los Alamos, in the 1960s. This image shows a close-up of a DNA fragment-sizing flow cytometer. The current technology is sold by ThermoFisher as the Attune NxT acoustic cytometer.