Life on the cutting edge

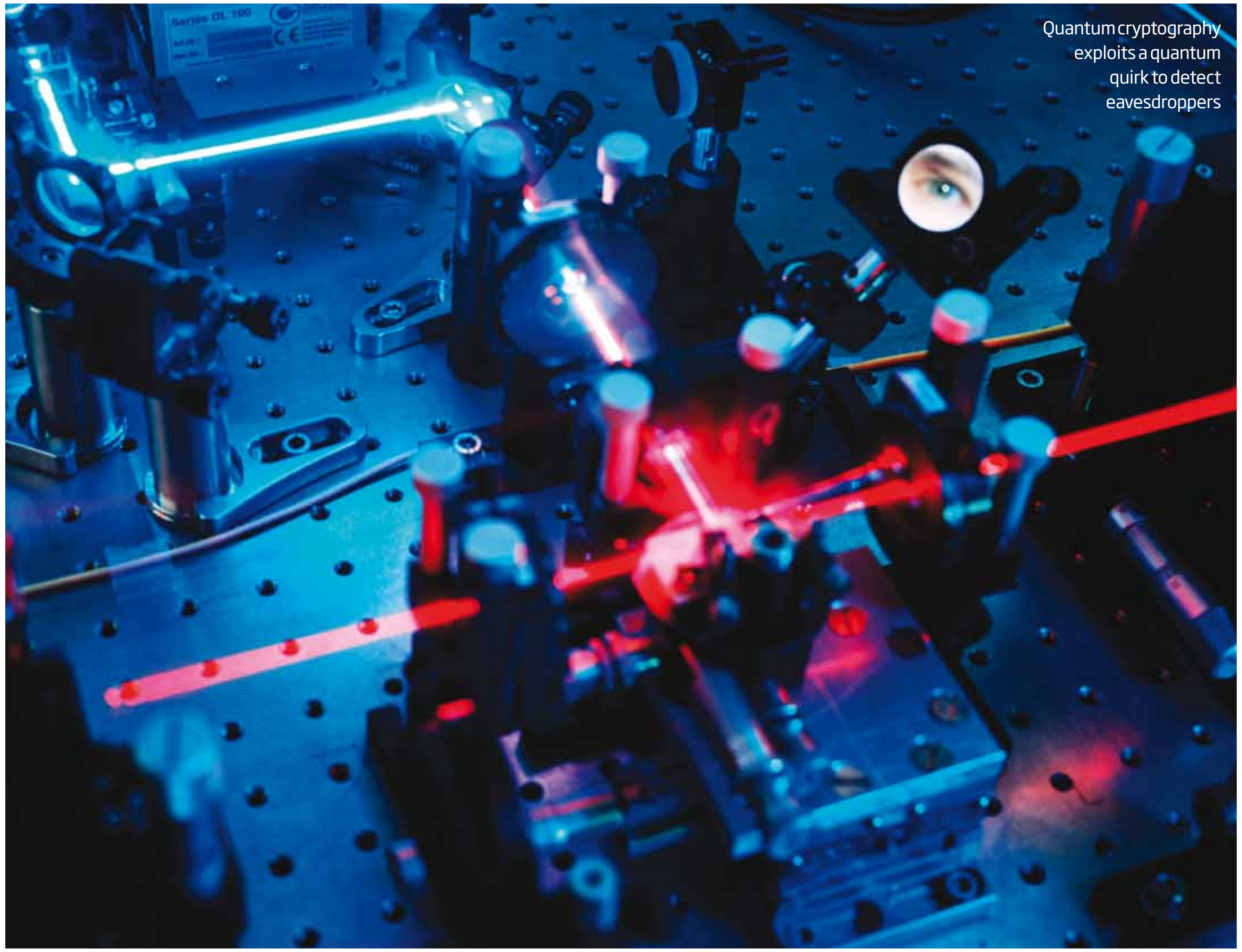
Fields that were once seen as akin to science fiction are now a reality – and offer plenty of opportunities for researchers. **Becky Oskin** talks to those working in some of science's hottest disciplines

WHAT'S IN a name? Quite a lot, if you ask Stanley Prusiner, the biochemist who coined the term 'prion' to describe the protein found in the brains of animals with diseases such as scrapie and BSE. Conventional wisdom said that these diseases were caused by viruses or bacteria – agents that could pass on their genetic information to the host. Prusiner, however, argued that the protein itself was infecting the animals.

The idea that a protein, with no genetic information, was causing the infection was tantamount to heresy, and the community ridiculed Prusiner. An article in this magazine in 1994 reported that many thought it "a brazen attempt to appropriate an entire area of research with a smart buzzword".

But Prusiner continued his work on the 'P word', developing a protein-misfolding mechanism to explain the infection. In 1997, he was awarded a Nobel prize for "a new biological principle of infection".

This is a perfect example of the fickle nature of research trends. Working at the cutting edge can be risky as well as exhilarating, but if you pick the right nascent field, the payoff could be great. Here, we look at three hot disciplines that have crossed into the mainstream, with entire university departments now dedicated to research that once felt more like sci-fi than real life.



Quantum cryptography exploits a quantum quirk to detect eavesdroppers

Artificial photosynthesis

"The biggest energy source known to mankind is the sun, and the best way to store that energy is in chemical bonds," says Nathan Lewis at the California Institute of Technology in Pasadena. "We should be able to figure out how to do it better, faster and cheaper than a plant does because we're smarter."

Taking a cue from plants, it should be possible to harness sunlight to produce hydrogen from water cleanly and cheaply. This can then be fed into a fuel cell, which can store the energy until it is needed. The concept dates back 30 years, but, until recently, the technology was not advanced enough to keep up with the theory. However, thanks to recent advances in materials and US government interest in the area, research into artificial photosynthesis now draws influential scientists and big money. "Thing have heated up as our planet has heated up," says Lewis.

Last year, Lewis received a $122 million grant from the US Department of Energy for the Joint Center for Artificial Photosynthesis (JCAP). This multidisciplinary energy hub, whose members include people from Caltech, the Lawrence Berkeley National Laboratory and a select group of universities, aims to build a commercially viable fuel generator from scratch.

JCAP will fund up to 200 jobs at Caltech and Berkeley. And opportunities elsewhere are plentiful for researchers with a background in artificial photosynthesis; the broad nature of the problem means that scientists can work in many areas.

Quantum cryptography

Like a parent cheering a baby's first ungainly steps, Michele Mosca was excited when he heard about the first hacking attempt on a quantum cryptography system last year.

"I see it as a great step, because this needed to happen for the technology to really mature," says Mosca, who is deputy director of the Institute for Quantum Computing at the University of Waterloo in Ontario. Luckily, the hacking attempts exposed hardware flaws, not problems with the underlying physics. "People are now looking at the physical security of actual devices," Mosca adds, "which in the beginning was an afterthought."

Quantum cryptography exploits the laws of quantum mechanics to thwart attempts to eavesdrop on messages. Data is encrypted into a series of entangled photons before being transmitted. Thanks to a quantum quirk, anyone trying to snoop on the message disturbs the photons' state, immediately revealing the eavesdropper's presence.

With companies such as BBN Technologies and MagiQ, both based in Boston, offering commercial systems to banks and other organizations, and tenure-track jobs available at most big physics departments, Mosca says quantum cryptography is "on the other side of the phase transition" as a research field.

Mosca sees a future in which everyone will use quantum security to keep their data safe. "At the Institute, we're working hard to make the technology widely deployable so we can communicate around the world with quantum bits," he says.

Brain-machine interfaces

Would housework be a little less tiresome if you could send your Roomba skittering after clumps of dirt with the power of your mind?

Justin Sanchez, associate professor of biomedical engineering at the University of Miami in Florida, thinks that a little Mary Poppins-style wizardry might help ease the tedium of daily life. "We want brain–machine interfaces [BMIs] to help people in everyday life," he explains. "That brings up a lot of interesting challenges. How do you make them robust in all the complexities of everyday life? If you can do that, I think people will indeed be able to control devices just by thinking about it."

With jobs available, quantum cryptography is "on the other side of the phase transition" as a research field

Sanchez's research focuses on BMIs that stimulate the brain's reward center. In his model, someone learning to use an artificial limb tries different actions to discover which is the most rewarding to perform, rather than simply being told what to do.

To make an impact in the field requires training in both neurology and engineering. "You can't innovate unless you're an expert in both," Sanchez says. He adds that researchers can choose to specialize in biology, implantable devices or applications – figuring out how to use the devices.

The field reached adolescence about six years ago, when departments started hiring neural engineers. Sanchez expects the growth to continue. "As the field develops and matures," he says, "I think the opportunity for jobs is going to increase." ■

Becky Oskin is a science writer based in California

Job-search smarts

"I went on the job market in 2009, and it was somewhat disastrous," recalls Douglas Densmore of his search for a tenure-track position. He wanted to work in synthetic biology – an expanding field that applies engineering principles to biological components to come up such oddities as an *E. coli* camera or a strain of yeast that churns out drugs. With a doctorate in electrical engineering and a postdoc in a well-regarded 'synbio' lab, Densmore marketed himself as a two-for-one deal. But the approach backfired. "I didn't get any job offers," he says. "They weren't sure what I was going to do, and I was already a risky bet."

Densmore may have raised eyebrows because he last took a biology class in high school. Rather than following a traditional route, he made the jump from electronic to genetic circuitry in 2007, having convinced a synthetic biologist at the University of California, Berkeley, that he could write software to stitch together biological components.

When Densmore next embarked on a job search in 2010, rather than emphasizing his broad credentials, he decided to focus on computational synthetic biology. This time, he landed an assistant professorship at Boston University, a synbio hotspot. His research centers on bio-design automation, a perfect fit for him as it takes techniques from electrical circuit design and applies them to biological systems. "I'm able to fill a niche most people can't provide," he says.

When it comes to switching careers, Densmore advises others to "make sure people know what they are getting, and don't be afraid to take a risk". He adds: "I knew I had a decent pedigree, so I knew if things fell apart, I could go back."

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