

## SPECIAL REPORT



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## Science in the meltdown

The research enterprise faces many uncertainties in the looming global recession — but it also has many strengths that may help it weather the storm. *Nature* investigates.

The crisis that swept across the world's financial markets this autumn is widely regarded as the worst since the 1930s. The global economic downturn that helped precipitate the crash, and will be duly amplified by it, is widely expected to be the worst in a generation, at least. The effect this will have on the research enterprise will depend crucially on how the world's governments respond to the crisis — on what stimulus they think is necessary, and on what long-term commitments they may be willing to cut to deal with present pain (see page 141).

Whatever those responses, there are likely to be adverse consequences for many research undertakings, from university departments to corporate laboratories. The cost of capital, and the timescales of return expected on investment, will change the outlook for industry. Changed economic expectations may have an impact on the way investments in education are seen. In this special report, *Nature* looks at the current impacts and future trends in academia, industry and government — and at the particular problems and opportunities in energy research.

### Industry

If history is any guide, the worldwide research enterprise could survive this downturn comparatively well. Total research and development (R&D) spending by both government and industry rose at a fairly steady rate through major recessions in the early 1980s and 1990s, as well as through the 'dot-com' bust in the early 2000s (see graph, page 156). So did the total number of researchers (see graph, top of page 158). Certainly these trends

are far less volatile than those seen in the stock markets (see graph, page 157).

However, it remains to be seen whether that pattern will persist. And in any case, such aggregate figures can hide a great deal of turmoil and uncertainty felt by those living through the crisis. Nowhere is this more obvious than in the pharmaceutical and biotechnology industries. Large companies with well-established product lines seem to be in relatively good shape for the moment; sales may well drop during the downturn, but will not go to zero. Most major pharmaceutical companies have fairly copious cash — enough to be looking for acquisitions among the less fortunate. Meanwhile, the few larger biotech companies that already have products in the market — such as Amgen in Thousand Oaks, California, which reported strong earnings last month — are weathering the storm well.

But, the financial crisis has been brutal for the biotechnology industry. Falling stock prices — the Amex Biotechnology Index has lost about 25% of its value since mid August — and the global credit crunch have hit companies around the world. For example, Bavarian Nordic of Kvistgaard, Denmark, which supplies smallpox vaccines to the US biodefence stockpile, said last month that it is shoring up its defences against a hostile takeover based on its low share price. The gloom is not universal. At least some of the firms involved with personal genomics are optimistic, as investors see it as an area poised for quick market growth. And the sequencing business is not in crisis either.

"We're in a pretty fortunate position" and relatively immune from the economic crisis,

says Jay Flatley, chief executive of Illumina in San Diego, California, which makes microarrays and high-speed sequencing machines.

But, says Cliff Reid, chief executive of Complete Genomics, a sequencing company in Mountain View, California, "we're a really nice home in a really bad neighbourhood".

Moreover, venture capital is becoming scarce, as venture-capital firms shift more towards 'feeding their older children': reinvesting in established companies that promise near-term payoffs, while turning away from riskier prospects that promise only long-term results. "It's going to be tough sledding for companies needing to raise capital in the next 6 to 12 months," says Glen Giovannetti, global biotech leader at Ernst & Young in Boston, Massachusetts. So the smaller biotech companies are tightening their belts and turning to the more established firms as likely saviours. "Clearly there will be a lot of companies knocking on the doors of Pfizer, Lilly and Merck to see if they want to collaborate," says Alan Lewis, chief executive of Novocell, a stem-cell engineering company in San Diego.

It's not all one-way traffic. Drug companies are looking more and more to biotechnology companies to help replenish their dwindling pipelines. So one likely outcome of the downturn is a flurry of alliances and acquisitions, as companies combine forces.

A similar story is seen in the emerging clean-energy industries. Companies could flourish in some potentially high-growth areas. For example, Michael Holman, an analyst for Lux Research, a market-research firm in New York, foresees continued growth in the

development of batteries for hybrid vehicles. And recent years have been highly profitable for solar-energy firms — a fact that has led Wacker, an international chemical giant based in Munich, Germany, to announce a plan to build a €760-million (US\$977-million) polysilicon plant at its Nünchritz site. The company remains bullish despite the downturn, pointing out that the growth of photovoltaics has led to a shortage of polysilicon in the market.

Overall, however, the falling price of oil since last summer has taken some of the fizz out of green energy, as has the recognition that some earlier expectations were unrealistic. The return on investment for most non-solar-energy companies — especially biofuels — has ranged from poor to abysmal. According to New Energy Finance, a consultancy based in London, the prices of green-energy stocks worldwide have fallen 61% since the beginning of 2008. Just as in the biotech industry, there is less capital available for start-ups, says Jonathan Kestenbaum, chief executive of the UK National Endowment for Science, Technology and the Arts. And small start-ups are more likely to get a buy-out than to raise money in an initial public offering.

This story is repeated in industry after industry. The online business and technology news provider Xconomy in Cambridge, Massachusetts, reports that there is less venture capital everywhere — and energy and biotech are actually two of the bright spots. Xconomy predicts that there could be trouble ahead for Internet-start-up deals and capital-intensive technology operations such as telecommunications and semiconductor companies.

### Universities and government

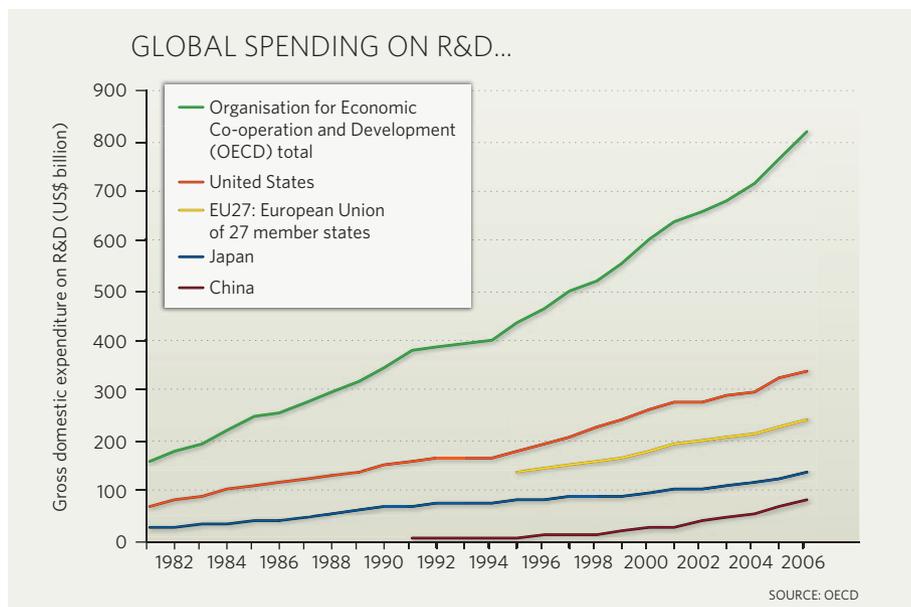
In the United States, unlike in most other countries, the great research universities are often private, not public — and those that are public are funded by individual US states. In either case, they face a unique set of challenges from the downturn.

On the one hand, they are somewhat buffered by an almost guaranteed set of customers: unless the economy melts down catastrophically, a new crop of undergraduates will show up every year. And the science- and technology-related graduate schools might even flourish. US National Science Foundation data show that enrolments have typically gone up (see graph, bottom of page 158) during previous economic downturns, when the forbiddingly tight job market led students to continue their education, or caused laid-off older workers to go back to school.

On the other hand, private universities are in

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— Janez Potočnik



much the same position as research foundations such as the Wellcome Trust. They depend heavily on investment returns from their endowments, which can drop precipitously during downturns (see *Nature* 455, 712–703; 2008). All universities also face a reduction in charitable donations and falling income for corporate-sponsored research. At the same time, students' need for financial aid is increasing.

“All of these factors contribute to perhaps the tightest financial outlook we have seen in decades,” wrote John Hennessy, the president, and John Etchemendy, the provost, at Stanford University in Palo Alto, California, in an e-mail circulated to the faculty members and staff on 30 October. They warned faculty members and staff to plan for roughly a 5% reduction in the \$800 million general-funds budget for each of the next two years, and a “quite modest” salary programme.

Long-term planning becomes very difficult in a volatile environment, and institutions become

reluctant to take on large new programmes — or new faculty members. Instead, many universities besides Stanford have been taking pre-emptive action to conserve resources in the near term. On 30 September, Robert Brown, president of Boston University, called for an immediate hiring freeze and a moratorium on new construction projects. In early November, Brown University in Providence, Rhode Island, and Cornell University in Ithaca, New York, imposed similar measures. Drew Faust, president of Harvard University, has said that the planning and development of the university's Allston campus will be reassessed (see *Nature* 454, 686–689; 2008).

US states have also been cutting back on university support. On 21 October, the Regents of the University of California approved a 2008–09 operating budget that incorporated an effective 5% drop in the state's \$3-billion contribution to the university — and the university's president, Mark Yudof, warned that more cuts were possible.

Elsewhere, the effect on universities — and research in general — will depend on the attitude of each national government: will they see money spent on research and education as an expense to be cut, or as a strategic investment for long-term economic growth?

So far, at least, most governments around the world have embraced the latter view, and pledged to keep their investment steady. For example, on 17 October, at the opening of an ultra-modern technology hub named Fusionopolis, Singapore Prime Minister Lee Hsien Loong noted concerns about his country's already well-advanced recession — and then declared: “The government remains fully committed to investing in R&D, in order to develop a key capability that will keep our economy competitive in the long term.”

“What we need is more research and more collaboration,” says Janez Potočnik, the European Union research commissioner. “Less investment in science and innovation would only turn this hopefully manageable crisis into a long-term structural problem for Europe.”

Depending on the severity of the coming recession, however, those ambitions could soon be diminished by reality. Many countries are already deferring new initiatives, and proposing flat or decreasing budgets. “If there is less money available, there will only be losers, no winners,” says Dieter

Imboden, president of the Research Council of the Swiss National Science Foundation.

In the United Kingdom, for example, research funding was generally flat last year, even before the downturn, so scientists are expecting hard cuts in the 2009 budget. "The only unknown is how deep and for how long," says Marjorie Wilson, a member of the Natural Environment Research Council, who is also pro-dean for research in the faculty of environment at the University of Leeds, UK. However, Paul Drayson, the newly appointed minister for science and innovation, has declared that he will "vigorously" defend the science budget against cuts; it remains to be seen how effectively he can do that.

Elsewhere in Europe, experts think it is unlikely that the downturn will lead to any immediate major cuts in public science budgets. Most notably, says Potočník, the European Union's €50-billion Seventh Framework Programme, the largest single research funding programme in the world, is expected to continue unscathed to its planned completion in 2013.

And in some European countries, including Germany, Switzerland, Sweden and the Netherlands, research budgets are buffered by multi-year science plans that call for annual rises in the budgets of national funding agencies, as well as for research organizations such as the German Max Planck Society. Indeed, Germany and Sweden recently announced that they would invest more in science and education despite the cloudy economic outlook.

Nonetheless, a deep and long-lasting economic recession could leave its mark on science throughout Europe, most likely through the effects of cuts or budget freezes on individual grants for basic research. Countries such as Iceland and Hungary, which have been hit hard, are thought to be particularly vulnerable

in that respect. Russia, for its part, is taking the official view that the financial crisis is largely a problem for others. Expecting large economic growth to continue despite falling oil and gas prices, government officials said last month that all public budgets, including science, are safe.

In Asia, most of the R&D powerhouses are following Singapore's path by sticking to mid or long-term strategies, often laid out in five-year plans. Indeed, if continued support for science in Asia is coupled with cutbacks elsewhere, it might further accelerate a trend in which

accomplished Asian scientists find better opportunities back home than in the West.

Japan, for example, has dipped in and out of recession since an asset bubble burst in the late 1980s. But Hayashi Towatari,

the head of the science ministry's science and technology policy bureau, points out that Japan has maintained one of the highest rates of R&D investment as a proportion of gross domestic product (GDP) in the world — 3.62% in 2007. The science budget is currently flat, he says, and seems unlikely to grow anytime soon given the economic turmoil. But even so, he says, Japan is committed to the idea that science will build the economy (see *Nature* 455, 1030–1031; 2008).

China has little exposure to the securities that have poisoned global financial institutions, although it has begun to see declining growth rates as economic turmoil around the world spoils its export markets. On 9 November, the government unveiled an economic stimulus programme totalling four trillion yuan (US\$586 billion). Among other things, it will feature a tax deduction for corporate spending. But the Chinese government is still intent on bolstering its R&D spending as laid out in the current five-year plan for science and technology, which covers the period from 2006 to 2010.

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...RISES FAR MORE STEADILY THAN THE STOCK MARKET



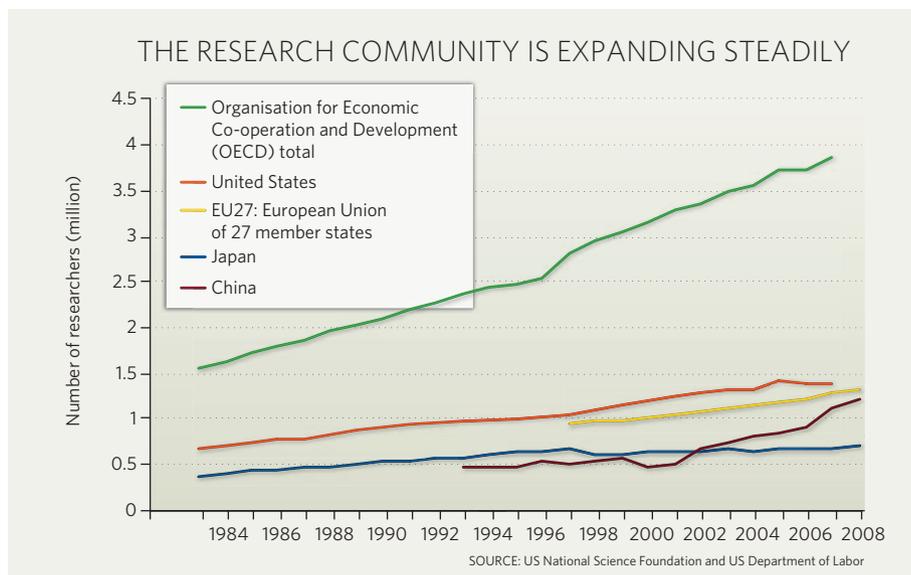
SOURCE: NASDAQ

In particular, says Xian-En Zhang, who is in charge of basic research at the science and technology ministry, an economic slowdown is unlikely to affect any large projects, such as the recently announced 'megaprojects'. These projects, in areas such as drug innovation, infectious diseases, information technology and environmental technology, have significant political weight behind them (see *Nature* 455, 142; 2008). Effects on other R&D spending are tougher to judge. But it is possible that the government will invest more than it is already, says Lan Xue, a science-policy specialist at Tsinghua University in Beijing. In 1998, following the 1997 Asian financial crisis, the government invested in infrastructure projects. It also expanded funding for higher education, which had a dramatic impact: enrolment in China's colleges and universities climbed by more than 40% within a year.

In Latin America, national science programmes and budgets haven't been cut back or harmed so far, say officials who attended the 27–28 October Organization of American States (OAS) Meeting of Ministers and High Authorities on Science and Technology. Held in Mexico City, the meeting included representatives from member nations, including most Latin countries. Because these nations have such small science budgets, less than 1% of their GDP, they are particularly sensitive to reductions. Nonetheless, says Lino Baranao, Argentina's minister for science and technology, "we all decided the way to exit from this crisis is through investment in innovation".

Indeed, many of the OAS nations, from Chile to Trinidad and Tobago in the Caribbean, are on a path to try to push their investment in science and technology towards 1% of their GDP by 2010, says Clovis Baptista Neto, the director of the Inter-American Telecommunications Commission. Only his native Brazil is now near that mark.

In the United States, President-elect Barack Obama's campaign featured an ambitious economic stimulus scheme that would emphasize federal investments in new green-energy technology, advanced infrastructure, improved health care, education and research. It remains to be seen how big those investments will actually be. "With an economic downturn coming, discretionary federal spending is by definition going to be tight," says Charles Vest, president of the National Academy of Engineering and president emeritus of the Massachusetts Institute of Technology in Cambridge. But if any



elements of Obama's R&D plans do materialize, they will clearly provide a significant boost to many areas of science.

In the meantime, the United States is still living with the aftermath of partisan deadlock that has long made it impossible for Congress to pass a timely budget. Among other things, this has blocked implementation of the 2007 America Competes Act — which called for a doubling of federal funding in basic physical-sciences research — leading to essentially flat funding for the major research agencies for the past few years. If an Obama administration isn't able to break that deadlock, or must keep science investment

flat to cope with looming budget deficits, some projects may find their funding cut. Those most at risk are likely to be new initiatives such as US involvement in the future International Linear Collider, or a deep underground laboratory planned for South Dakota, or the Large Synoptic Survey Telescope.

Still, the global economic woes could actually bolster the position of those who argue for increased basic research funding. "The optimist in me thinks this may be an opportunity

to drive home the message that if we want to turn the economy around, we must invest in the long-term basic research that ultimately drives our economy," says Vest.

## Energy and climate

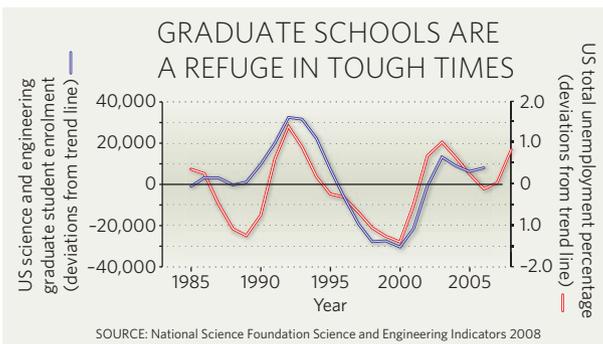
How a global recession might affect efforts to address climate change is another unknown. There is now a widespread acceptance that climate change is a major threat, and that carbon emissions will have to be controlled through some sort of tax or cap-and-trade system. The European Union has operated such a carbon-trading system since 2005, and Obama campaigned on a promise to put a similar system at the centre of US energy policy — the goal being to limit emissions while encouraging both conservation and research into green-energy technologies. Indeed, Obama's platform set a target of an 80% reduction in greenhouse-gas emissions by 2050, and called for a \$150-billion investment in clean energy — with the money to come from auctioning off emissions permits.

Whatever the benefits of carbon-control efforts in the long term, however, the economic crisis has raised concerns that financially hobbled governments and businesses will not have the will — or capacity — to make the necessary hard choices in the short term. Overhauling the energy sector, and thus the entire economy, won't be cheap. And for a time, at least, it is bound to push up energy prices as cleaner technologies are brought on line.

Those fears seemed to play out last month as the European Union delayed a decision on its climate policy after opposition from Poland and other coal-dependent nations, which

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feared additional burdens for their domestic industries (see *Nature* 455, 1008; 2008). And the crisis may have had a role in the Canadian elections as voters backed the incumbent Conservative Steven Harper over Liberal opposition leader Stephane Dion, who had been pushing for carbon taxes to put Canada's economy on a greener path.

But the news isn't all bad. The United Kingdom recently adopted the world's first law mandating substantial long-term emissions cuts. The bill, which would cut emissions by 80% from 1990 levels by 2050, passed only after being strengthened to include a provision on emissions from aviation.

Moreover, the United States — the largest sticking point in the global-climate negotiations — seems to have resoundingly reversed course with the election win of Obama and the strengthening of the Democratic Party. Few expect a congressional passage of a carbon-trading scheme to be easy, even with larger Democratic majorities; there are too many interests to be reconciled. But Capitol Hill is very aware of the potential pay-off. Greenhouse-gas regulations could create a vast new revenue

stream that could be tapped to pay for clean technology or raided for other priorities.

And, Democrats (and many Republicans) have long been sympathetic to the argument that clean energy could generate millions of new jobs, serving as a boost to the ailing economy, and have not backed away from funding such measures. Last month, Congress tacked \$17 billion in tax incentives for clean energy onto the \$700-billion Wall Street bailout bill; they also enacted a \$25-billion loan-guarantee programme to help car makers to retool their facilities for the production of fuel-efficient vehicles.

Of course, declining tax revenues and a growing national deficit could make such investments increasingly difficult. The financial sector's problems could also make it tougher for wind, solar and other green-energy companies to find financing for major projects. In addition, the price of carbon credits on the European Union's carbon trading scheme has fallen by roughly 40% since July — which translates into less investment in reducing emissions. And the plunge in oil prices — from \$147 per barrel in July to just over \$60 per barrel this week — is

adding a whole new set of uncertainties.

Cheaper energy will put more money in the hands of consumers, and might well soften the looming recession. But it will also reduce demand for alternatives and could threaten investments in advanced-energy technology — particularly if wary investors want a faster pay-off. In some respects, this is exactly what happened after the price of oil collapsed in the 1980s.

Still, the difference this time is the concern over global warming, which isn't going away. Alden Meyer, director of strategy and policy for the Union of Concerned Scientists in Washington DC, points out that policy-makers will eventually have their hands forced by problems associated with global warming if they don't make the difficult choices now. "The reality is that there is no cost-free future." ■

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**See Editorial, page 141.**