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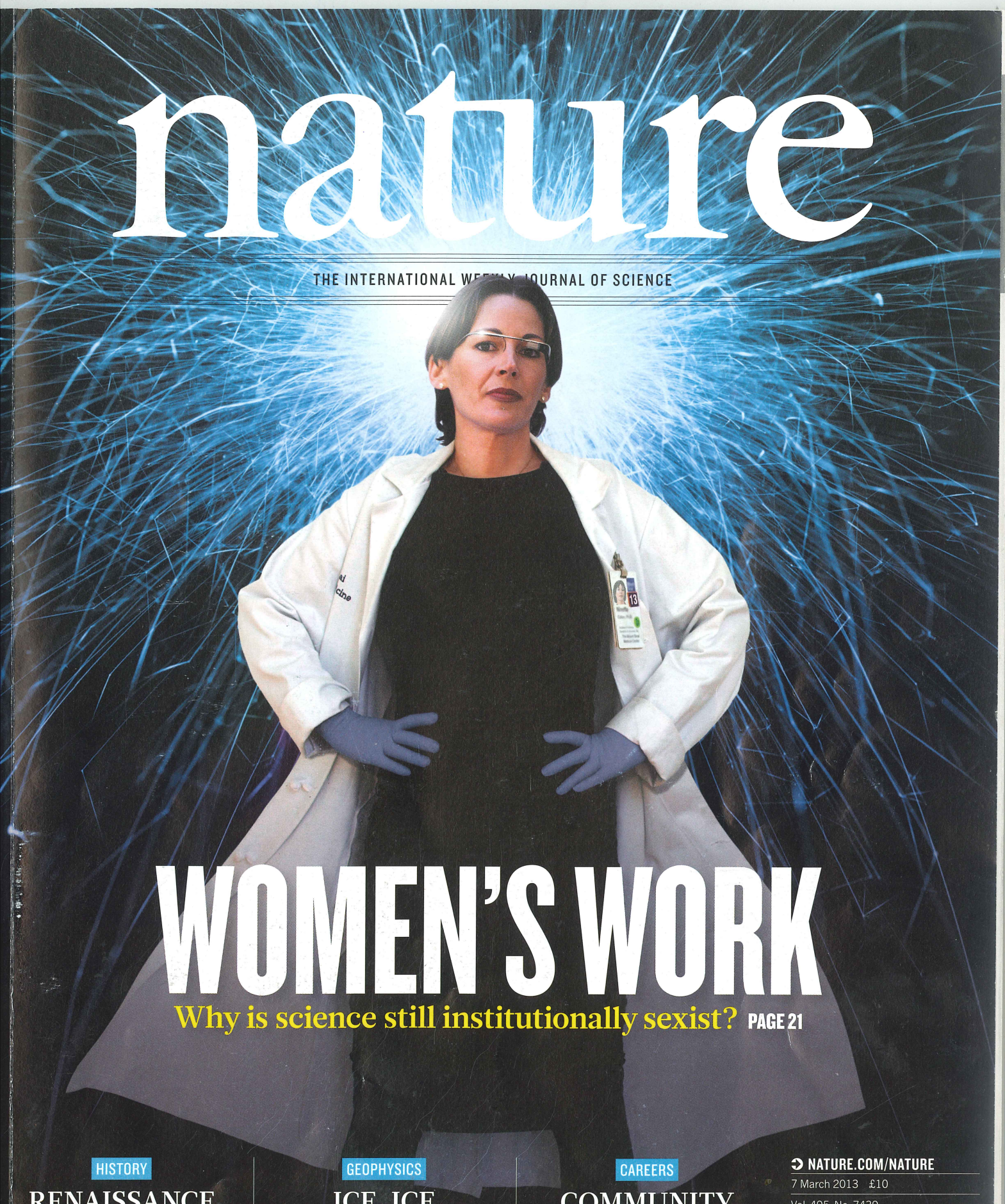

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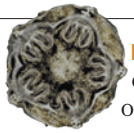

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Science for all

Many women are deterred from pursuing a career in science at the highest levels. Much more must be done to address the reasons behind this potential waste of human talent.

WOMEN IN SCIENCE
The gender gap and how to close it
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Whether female scientists will want to celebrate International Women's Day on 8 March may depend on how far they look back in time. Things have changed, and if you talk in terms of decades, there are considerable victories to cheer about. But despite those victories, progress now seems to have stalled.

That is clear from the package of articles in this week's *Nature* (see page 21) that exposes the dismaying extent to which sexism still exists in science. In the United States and Europe, around half of those who gain doctoral degrees in science and engineering are female — but barely one-fifth of full professors are women. Women are not invited in significant numbers to sit on the scientific advisory boards of start-up companies. A scientific conference at which half of the keynote speakers are women stands out simply because of that.

Why has progress stalled? Childcare is one major factor that blocks the career of many women. But that is a practical issue, theoretically easy to fix given political will. Even the most enlightened childcare policies will not fix a second, more insidious major problem: overt or unconscious gender bias. It can be detected even in female scientists, and even, according to neurobiologist Jennifer Raymond (see page 33), in those who actively promote women within science.

POLITICS

The fate of women in science can be influenced for good and bad by political systems. In communist China, women and men had a fairly equal presence in science until recently, when its tottering attempts to open up to the capitalist world led to a disproportionate recruitment of young men returning from research training abroad. This sets the stage for gender imbalance in the future. At the other end of the political spectrum, Portugal's twentieth-century dictatorship similarly managed to secure a healthy balance of female professors. That may have been for the wrong reasons, such as that those jobs were of low salary and prestige, or because a bellicose foreign policy sent male graduates to fight in colonial wars. Most of those men chose to stay abroad, leaving the academic field open for women. The role models were therefore in place when Portugal became a democracy in 1974 and began to invest in research in the 1990s. A healthy gender balance continues there.

The worrying gender bias in mature democracies won't be resolved by the flick of a master switch. As in most professions, it is locked in place by male dominance at all the levels of decision-making that affect academic careers — from journal editorial boards, to grant-reviewing boards, to academic selection committees. Women are barely visible at these levels, fixing the subconscious idea that science belongs to men. There are many ways to chip away at this invisibility and they should all be tried, with the results published so that others can learn from them.

One serious proposal is the imposition of quotas. In certain contexts, such as academic promotions, this would be a good way to ensure that young female scientists have female role models. Some argue that setting a quota for women in leading academic positions such as professorships will result in mediocre female candidates being promoted. But there is a gap in reasoning here. Women and men are equally talented, so if men occupy a large majority of high-level posts, there must be an awful lot of mediocrity among their number. Is mediocrity more acceptable in men? Quotas on decision-making committees, however, do come with the inbuilt problem of overburdening the few women who already hold top positions. The solution here would be to keep the quota realistically low for now.

PROFILE RAISING

Individuals — from Nobel prizewinners to lowly postdocs — have a part to play. Some laureates have contributed with foundations. The Rita Levi-Montalcini Foundation supports young women in Africa who wish to become scientists. The Christiane NüsseleinVolhard Foundation supports young female scientists with children. And other scientists engage in various consciousness-raising activities.

At the institutional level, several European research agencies and institutions have special funding programmes for women, allowing them to establish their own labs. Last November, *Nature* made a public challenge to itself by reporting that only 14% of its reviewers and 19% of its invited Comment and World View authors were female (see *Nature* **491,** 495; 2012). We vowed to improve, and have asked our editors to try harder to engage with women. In time, we will make our progress public.

One useful tool is the online platform AcademiaNet (http://academianet.info), created by the Stuttgart-based Robert Bosch Foundation in Germany in cooperation with *Spektrum der Wissenschaft*, the German edition of *Scientific American* (which is owned by the Nature Publishing Group). AcademiaNet gives a web presence to high-achieving female scientists, making them visible to conference-programme committees seeking female speakers, journalists seeking experts to quote, head-hunters seeking board members and the like. The network will become even more important as work to address gender imbalance accelerates. With successful women being both fewer and less likely to push themselves forward than their male counterparts, they can be hard to find for even the most enthusiastic gender-balancer.

AcademiaNet was opened in 2010 by German chancellor Angela Merkel, a former physicist, who stressed how important it is to preserve half of a country's scientific potential. She recalled her own difficulties training with men who would rush impulsively to try to solve practical-class problems. Her style was to think and then try out, by which time the equipment was occupied or broken. Might an option for separate training in some areas be useful for women, she pondered? Merkel knows a thing or two about being a successful woman, so let's add her idea to that list of things to try. It's a long list. It's time to get started. What are you waiting for? ■

SPECIAL ISSUE

Science remains institutionally sexist. Despite some progress, women scientists are still paid less, promoted less, win fewer grants and are more likely to leave research than similarly qualified men. The reasons range from overt and covert discrimination to the unavoidable coincidence of the productive and reproductive years.

In this special issue, *Nature* takes a hard look at the gender gap and at what is being done to close it. A survey of the data (see page 22 and go.nature.com/ytmyhf) reveals where progress has been made and where inequalities still lie, from salary to tenure. A News Feature (see page 25) reveals a particular dearth of women in some commercial spheres, such as on the scientific advisory boards of biotechnology firms, and an article by historian Patricia Fara (see page 43) traces the wearying stereotypes perpetuated by the biographers of women scientists.

A series of Comment articles looks at possible solutions. Neuroscientist Jennifer Raymond (see page 33) calls on both sexes to recognize and reduce their biases against women in science, and eight researchers from around the world offer their prescriptions (see page 35), from equalizing the retirement age in China, to liberalizing travel restrictions in Saudi Arabia, to boycotting conferences that lack female speakers. We catalogue some of the ambitious moves being made in Europe to get more women into top positions (see page 40) and explore some surprising statistics about mandatory quotas (see page 39). Finally, profiles of four successful 30-something women (see page 28) show how ambition and talent can trump obstacles.

This special issue is dedicated to the memory of Maxine Clarke. In the 28 years that Maxine spent championing the highest scientific standards as an editor at *Nature*, she was all too often the only one to ask, "Where are the women?" ■

WOMEN'S WORK

A special section of *Nature* finds that there is still much to do to achieve gender equality in science.

WOMEN IN SCIENCE
The gender gap and how to close it
nature.com/women

IMAGE: VIKTOR KOEN

MIND THE GENDER GAP

Despite improvements, female scientists continue to face discrimination, unequal pay and funding disparities.

BY HELEN SHEN

As an aspiring engineer in the early 1970s, Lynne Kiorpes was easy to spot in her undergraduate classes. Among a sea of men, she and a handful of other women made easy targets for a particular professor at Northeastern University in Boston, Massachusetts. On the first day of class, "he looked around and said 'I see women in the classroom. I don't believe women have any business in engineering, and I'm going to personally see to it that you all fail."

He wasn't bluffing. All but one of the women in the class ultimately left engineering; Kiorpes went on to major in psychology.

Such blatant sexism is almost unthinkable today, says Kiorpes, now a neuroscientist at New York University. But Kiorpes, who runs several mentoring programmes for female students and postdoctoral fellows, says that subtle bias persists at most universities. And it drives some women out of science careers.

By almost any metric, women have made great gains in closing the scientific gender gap, but female scientists around the world continue to face major challenges. According to the US National Science Foundation, women earn about half the doctorates in science and engineering in the United States but comprise only 21% of full science professors and 5% of full engineering professors. And on average, they earn just 82% of what male scientists make in the United States — even less in Europe.

Scientific leaders say that they continue to struggle with ways to level the playing field and entice more women to enter and stay in science. "We are not drawing from our entire intellectual capital," says Hannah Valantine, dean of leadership and diversity at the Stanford School of Medicine in California. "We've got to put on the accelerator to evoke social change."

One of the most persistent problems is that a disproportionate fraction of qualified women drop out of science careers in the very early stages (see 'Women in science'). A 2006 survey of chemistry doctoral students by the Royal Society of Chemistry in London, for example, found that more than 70% of first-year female students said that they planned a career in research; by their third year, only 37% had that goal, compared with 59% of males[1].

Many experts say that a big factor driving this trend is the lack of role models in the upper divisions of academia, which have been slow to change. The Royal Society of Chemistry has found, for instance, that female chemistry students are more likely than males to express low self-confidence and to report dissatisfaction with mentorship[2]. Female students "conclude consciously and unconsciously that these careers are not for them because they don't see people like them", suggests Valantine. "That effect is very, very powerful — this sense of not belonging."

The attrition continues at later stages. In biology, for example, women comprised 36% of assistant professors and only 27% of tenure candidates in a 2010 study by the US National Research Council[3]. "We're not talking about a lack of talent here. Part of the story is that women leave earlier. In a sense, they give up on an academic career," says Curt Rice, vice-president of research and development at the University of Tromsø in Norway, who has studied gender equality in US and European universities.

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FAMILY VALUES

Many of the UK chemistry students viewed research as an all-consuming endeavour that was incompatible with raising a family. Meeting the demanding schedule of academic research can seem daunting for both mothers and fathers. But family choices seem to weigh more heavily on the career goals of women.

Law professor Mary Ann Mason at the University of California, Berkeley, and her colleagues have found[4] that male and female postdocs without children are equally likely to decide against research careers, each leaving at a rate of about 20%. But female postdocs who become parents or plan to have children abandon research careers up to twice as often as men in similar circumstances.

"The plan to have children in the future, or already having them, is responsible for an enormous drop-off in the women who apply for tenure-track jobs," says Wendy Williams, a psychologist at Cornell University in Ithaca, New York. Furthermore, women who do become faculty members in astronomy, physics and biology tend to have fewer children than their male colleagues — 1.2 versus 1.5, on average — and also have fewer children than they desire[5].

In response to these concerns, many universities have taken steps to establish family-friendly policies such as providing child-care assistance and extending tenure clocks for new

WOMEN IN SCIENCE: MANY HURDLES AHEAD

The number of women studying and practising science has risen sharply, but women are disproportionately driven away from scientific careers.

KEY

MEN | WOMEN

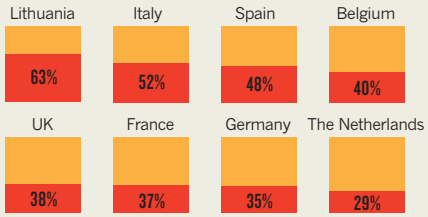
GRADUATE SCHOOL

The fraction of women gaining doctorates in science has more than doubled in the United States since 1980 and is now nearing equity. In some European countries, women outnumber men in science degrees but there is significant variation between nations and fields.

SOURCE: NSF/REF. 12

US FEMALE DOCTORAL RECIPIENTS IN SCIENCE AND ENGINEERING

FEMALE DOCTORAL RECIPIENTS IN SCIENCE IN EUROPE (2006)

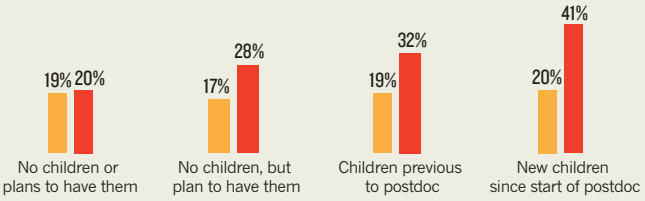


POSTGRADUATE POSITIONS

A 2009 survey of postdoctoral fellows at the University of California showed that women who had children or planned to have them were more likely to consider leaving research.

SOURCE: REF. 4

POSTDOCS WHO DECIDED AGAINST CAREERS AS RESEARCH FACULTY MEMBERS (2009)



"The plan to have children in the future, or already having them, is responsible for an enormous drop-off in the women who apply for tenure-track jobs."

Wendy Williams, Cornell University

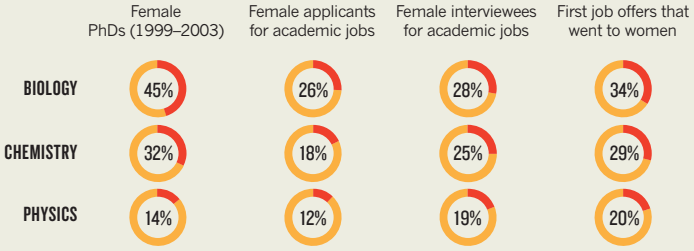
EARLY CAREER

Female representation among science and engineering faculty members in the United States has lagged behind gains in graduate education, in part because many women do not apply for tenure-track jobs. But women who do apply are more likely than men to receive interviews and offers.

SOURCE: NSF/WEBCASPAR

"At least part of the lack of applications is due to the fact that women look at these careers and don't see people like themselves."

Hannah Valantine, Stanford University

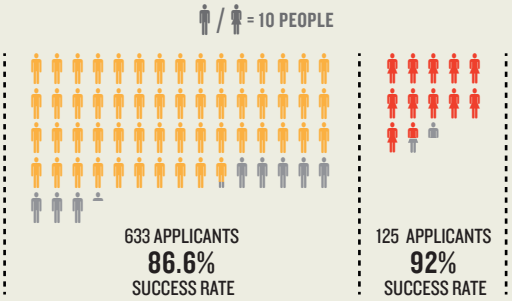


RISING IN THE RANKS

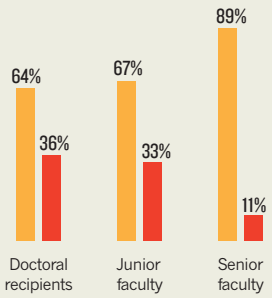
A study of US science departments showed that women were more successful than men in gaining tenure between 2002 and 2004. In Europe as in the United States, the gender gap is greater among senior than among junior faculty members.

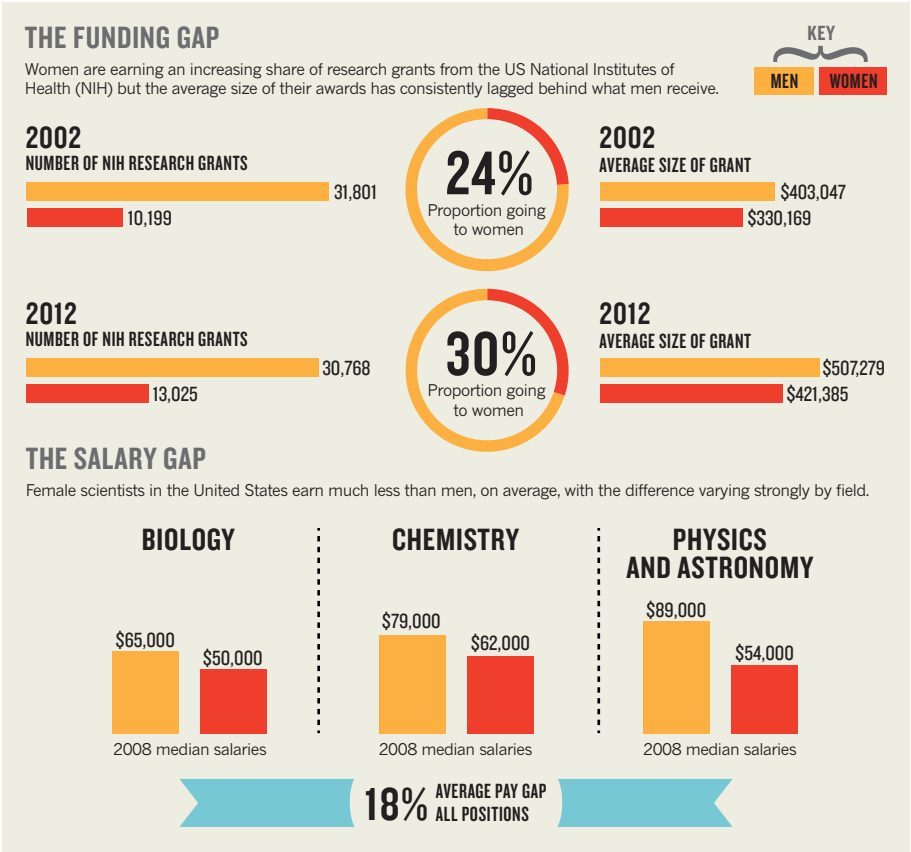
SOURCE: REF. 3/REF. 12

US TENURE DECISIONS 2002–04



GENDER GAP AMONG SCIENTISTS IN EUROPEAN UNIVERSITIES (2006)





SOURCE: NIH

SOURCE: NSF/SESTAT

parents. Shirley Tilghman, president of Princeton University in New Jersey, believes that such initiatives provide crucial support for women, but that other solutions are still needed. "I don't think there's a single obstacle," she says. "I think there's a whole series of phenomena that add up."

LIVE ISSUE

At Yale University in New Haven, Connecticut, microbiologist Jo Handelsman is one of many researchers who think that gender discrimination continues to be a significant part of the problem. In a much-talked-about experiment last year[6], her team showed that science faculty members of both sexes exhibit unconscious biases against women. Handelsman's group asked 127 professors of biology, chemistry and physics at 6 US universities to evaluate the CVs of two fictitious college students for a job as a laboratory manager. The professors said they would offer the student named Jennifer US$3,730 less per year than the one named John, even though the CVs were identical. The scientists also reported a greater willingness to mentor John than Jennifer. "If you extrapolate that to all the interactions that faculty have with students, it becomes very frightening," says Handelsman.

Her findings match well with the results of a survey[7] done in 2010 by the American Association for the Advancement of Science. Of the 1,300 or so people who responded, 52% of women said that they had encountered gender bias during their careers, compared with just 2% of men.

Still, other concrete evidence of bias is hard to find. Some measures show female scientists outperforming male rivals in landing interviews and job offers early in their careers. The National Research Council study[3] showed that women accounted for 19% of the interview pool and received 32% of job offers for tenure-track electrical-engineering positions. Women fared just as well as men in tenure evaluations, but female assistant professors in many disciplines seemed less likely to reach tenure consideration compared with men.

Women face even more daunting odds in Spain. Men are 2.5 times more likely to rise to the rank of full professor than female colleagues with comparable age, experience and publication records[8].

Disparities can also be found in grant funding in some countries. In one frequently cited study[9], Christine Wennerås and Agnes Wold at the University of Gothenburg in Sweden found in 1997 that female applicants for postdoctoral fellowships had to score 2.5 times higher on an index of publication impact to be judged the same as men.

Several groups, such as the UK Medical Research Council and biomedical research charity the Wellcome Trust, have since investigated their grant programmes and found negligible or very subtle effects of gender[10]. The Canadian Medical Research Council found no differences in success rate in most of its research grant programmes, but reported lower success rates for women in some training grants[11]. In the United States, women are slightly more successful than men in obtaining grants from the National Science Foundation, but the trend is reversed for the National Institutes of Health (NIH). The NIH also gives women smaller awards on average (see 'The funding gap').

Information provided to *Nature* by the NIH through a Freedom of Information Act request indicates that the percentage of women on review panels has improved marginally over the past decade, from 25% in 2003 to 30% in 2012. Those figures roughly parallel the percentage of women applying for and receiving grants in that time.

PAY PROBLEMS

The inequalities also extend to salaries. In the European Union, female scientists earned on average between 25% and 40% less than male scientists in the public sector in 2006 (ref. 12). Although the average pay gap is smaller in the United States, the disparity is particularly large in physics and astronomy, where women earn 40% less than men.

For young academic scientists, however, those differences may be fading. The National Research Council found an 8% pay gap at the level of full science and engineering professors but no significant differences among junior faculty members[3]. Some experts argue, however, that the salary gap may reflect other continued trends, such as the fact that a disproportionate share of women move into non-tenure positions or faculty jobs at lower-status universities.

Tilghman says that Princeton and many other universities have grown increasingly conscious of the need to track and rectify gender gaps in salary and other institutional support. "Absolutely, it needs eternal vigilance," she says. "But we're in a much better place." ■

Helen Shen *is an intern with* Nature *in Washington DC.*

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2. Newsome, J. L. *The Chemistry PhD: The Impact on Women's Retention* (RSC, 2008).
3. National Research Council *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty* (National Academies, 2010).
4. Goulden, M., Frasch, K. & Mason, M. A. *Staying Competitive* (Center for American Progress, 2009).
5. Ecklund, E. H. & Lincoln, A. E. *PLoS ONE* **6,** e22590 (2011).
6. Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J. & Handelsman, J. *Proc. Natl Acad. Sci. USA* **109,** 16474–16479 (2012).
7. Cell Associates *Barriers for Women Scientists Survey Report* (AAAS, 2010).
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10. Grant, J., Burden, S. & Breen, G. *Nature* **390,** 438 (1997).
11. Friesen, H. G. *Nature* **391,** 326 (1998).
12. European Commission. *She Figures 2009* (European Communities, 2009).

BARRED FROM THE BOARDROOM

The number of women in scientific research is going up — but where academia crosses into industry, men still rule.

VIKTOR KOEN

BY ALISON MCCOOK

Nancy Hopkins started Googling her colleagues in spring 2012. She mentally scanned the hallways of her institution at the Massachusetts Institute of Technology (MIT) in Cambridge — along with the campuses of other elite institutions — for the offices of men she knew who had founded companies. Then she clicked on the websites of their firms, and counted the number of men and women serving on their scientific advisory boards (SABs), a prestigious position for researchers who steer the company's scientific direction.

It was an informal exercise, rather than a systematic survey. But Hopkins, a molecular biologist at MIT and a long-time campaigner for women in science, found the results shocking. A sample of 12 of the companies she examined had a

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total of 129 SAB members; only 6 were women. "I was completely stunned," says Hopkins. "And it made me sad. I thought, 'gee, why don't these men want to work with [MIT] women?' We have such incredible women faculty."

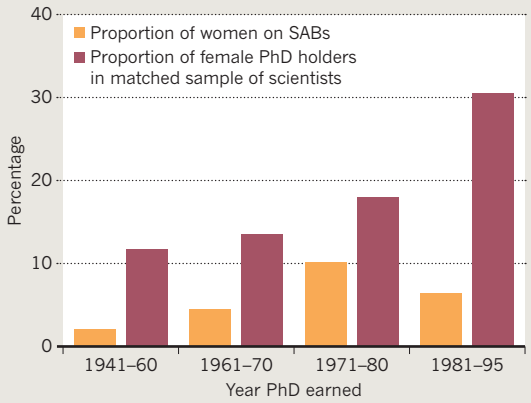
The proportion of women in industrial and academic science has shot up over the past 20 years. According to the US National Science Foundation, women make up 25% of tenured academics in science and engineering and more than 25% of industry scientists in research and development. But when it comes to academics engaging in commercial work — patenting their discoveries, starting biotech companies or serving on SABs — the picture is less progressive. Studies have confirmed Hopkins' impression that even leading female scientists are often absent from these roles. "The secret club [of men] used to be going to the lab and conferences," says Fiona Murray, who studies life-sciences entrepreneurship at MIT. "That world has changed a lot, but we have a new venue where it is still difficult for women to play a similar role."

Experts in industry and academia speculate that the disparity could reflect the small numbers of women in certain specialized fields; the demands of family life; or a residual male clubbiness. Whatever the reasons, this stubborn gender gap hurts everyone, says Bonnie Bassler, a molecular biologist at Princeton University in New Jersey. "I think the companies would do better science by having the best people on their board. And I think these women, who are great scientists, would do better science in their labs by having access to these ideas."

"Everybody's losing," says Bassler.

INEQUALITY ON BOARD

The proportion of women on biotech scientific advisory boards (SABs) lags behind the proportion of eligible female candidates.



SOURCE: REF. 1

HIDDEN PROBLEM

For much of the 1980s and 1990s, there were more than 11 men for every one woman in the science faculty at MIT. Things started to change 20 years ago, when Hopkins, as the first chair of MIT's Committee on Women Faculty in the School of Science, and her team drove through major increases in the hiring of women. By 2006, one out of every five biology faculty members on the MIT campus was a woman.

At a dinner last April to honour these achievements and mark her retirement from the lab, Hopkins spoke about the work still to be done. She talked about a list she had been given by a graduate of Harvard Business School in Boston, Massachusetts, showing the names of scientists in the area who had received funding from a local venture-capitalist firm. Among 100 names, only one was a woman. The list would not have surprised Hopkins more than 30 years ago, when she had been told by a colleague that "women aren't allowed" to found biotech companies. But to see such a dearth of academic women in modern biotechnology was upsetting.

Around that time, Hopkins embarked on her Google search. She was particularly interested in SABs because they consist mainly of working scientists who are often invited by the company's academic founders — a social process that could reveal conscious or unconscious biases against female academics. And membership in advisory boards comes with advantages: it can tip members off to promising tools and areas of research, and lead to other lucrative prospects, such as consulting. Plus, for a few meetings per year, board members are paid a sometimes-substantial fee, given stock options, or both.

The first name Hopkins looked up was Eric Lander, founding director of the Broad Institute of MIT and Harvard. She typed "Eric Lander companies" into the search engine. Scrolling through the results, she came upon Verastem, a cancer stem-cell company founded in 2010 by Lander and others, including Robert Weinberg, a cancer researcher at the Whitehead Institute in Cambridge. She counted 14 people on Verastem's SAB; all were men.

Entering "Phil Sharp companies" brought up Alnylam Pharmaceuticals, a Cambridge-based firm co-founded by the Nobel prize-winning molecular biologist at MIT in 2002. The company, which is developing therapies based on RNA interference, had one woman on its 11-person SAB. "Bob Langer companies" yielded a handful of the 20-plus firms that the MIT bioengineer has helped to launch, including Taris Biomedical in Lexington, Massachusetts, which focuses on genitourinary conditions, and the biopharmaceutical company Blend Therapeutics in Watertown, Massachusetts. Neither SAB included any women. (Weinberg and Lander say that they were not involved in selecting the SABs at Verastem, and Langer that he was not involved with the process at Blend or Taris. Sharp says that at Alnylam, choosing the SAB required "agreement between" the founders, chief executive, venture capitalists and other people already brought into the company.)

Hopkins included in her search a few scientists from other institutions, such as Harvard University in Cambridge and Memorial Sloan-Kettering Cancer Center in New York. Overall, among the full-time professors affiliated with a sample of 14 companies she reviewed, only 5% of founders or SAB members were women. Although boards change over time, that fraction was much the same as of last month.

Last July, Hopkins began circulating her results to a handful of faculty members at MIT and to scientists further afield. Vicki Sato, a professor of biology and management at Harvard with a long career in the biotechnology industry, says she could not believe what she was seeing. "I was stunned by the sampling she had done, and told her she had to be wrong," says Sato. "But I knew deep down she was right."

GLOBAL CONCERN

More rigorous studies have reached similar conclusions. In a paper published last October[1], Murray, Toby Stuart at the University of California, Berkeley, and Waverly Ding at the University of Maryland in College Park reviewed all publicly available lists of US biotech SABs, starting in the 1970s and including about 500 companies. Although women represented between 12% and 30% of academically active PhD holders over that time period, the percentage of women on SABs never exceeded 10.2% (see 'Inequality on board'). Even when the researchers compared male and female faculty members with similar levels of achievement, measured by factors such as publication and citation counts, male scientists were roughly twice as likely to join SABs as female ones.

SABs are not the only commercial forum in which academic women seem to be disadvantaged. US women also receive patents about 40% as often as men[2], start businesses half as often[1] and receive significantly less funding for the start-ups that they do launch[3]. This is not just a US problem: a study released in April 2012 by the Royal Society of Edinburgh found that women

are underrepresented on the boards of UK science, technology, engineering and mathematics companies[4]. That is despite the fact that including women seems to be beneficial: a 2012 report from Credit Suisse in Zurich, Switzerland, found that worldwide, companies with women on the board have higher share prices than those with all-male boards[5].

INVITATION ONLY

So what is going on? For SABs, Hopkins thinks that the answer is simple: women are not asked. When she noticed the stark patterns in board memberships, Hopkins asked some of her female colleagues — including one she believed was an "absolute star" — if they had ever been invited to serve on boards. All of them said no. "In the end, these stories are very sad," says Hopkins. "People know they're excluded, and it's costly professionally. They're embarrassed to talk about it. It's like not being asked to dance."

But the picture is not so simple, says Paul Schimmel, a former colleague of Hopkins who is now based at the Scripps Research Institute in La Jolla, California, and is a co-founder of Alnylam. He says that he has tried to ensure equal gender participation in his lab and his companies for the past 20 years. "There's no lack of effort, I tell you," says Schimmel. But serving on a board "can be a lot of work" — conference calls, e-mails, travel several times a year and thick documents to review — and women often bear the majority of domestic work and child care. At least one woman has turned down Schimmel's invitation to serve on an SAB because of family responsibilities, he says. Indeed, research has shown that female academics with children are less likely than those without to patent their discoveries[6].

> "People know they're excluded. They're embarrassed to talk about it. It's like not being asked to dance."

Some prominent female scientists disagree. Carolyn Bertozzi, a chemical biologist at the University of California, Berkeley, who has two young children and one on the way, says that she is always willing to make time to serve on the research advisory board at GlaxoSmithKline, which entails attending two-day meetings twice a year for "generous" compensation. The meetings teach her about what it takes to make a drug, including medicinal chemistry, regulatory issues and intellectual property; that helps with her start-up, Redwood Bioscience in Emeryville, California, which has two female SAB members out of four. Bertozzi acknowledges that her situation is unusual: her female partner is a stay-at-home mother. But Bassler, too, says that the work involved in SABs is worth the sacrifices. "If I were asked to serve on a board, I wouldn't do something else," she says. Bassler has been invited to serve on two SABs in her career, but "of course" would accept another invitation if it arose.

Research seems to support the idea that it is a lack of invitations — not a lack of time — that reduces female membership in biotech SABs. Murray, Stuart and Ding found that both men and women tend to join SABs on average around the 20th year after completing their PhDs[1] — often a time when the major strain of child rearing is over. This suggests that family obligations are not holding back women more than men. And in interviews at a leading institution that Murray declined to name, women consistently reported they had rarely been invited to serve on their colleagues' SABs — which was not the case in a matched sample of men[7].

Stuart says that the disparity is most likely to be a result of social connections and unconscious bias among men. "If you're male, you're slightly more comfortable shooting the shit with your male colleagues, and they're who come first to mind when you're putting these boards together. You may assume — 'oh, she's got two kids, she's not going to be interested' — and then not invite her."

But companies say that they can have difficulty finding women with the right experience, because there are fewer women than men in academia overall. At Alnylam, says Schimmel, the type of science and the diseases it hopes to treat "considerably narrow the size of the pool of highly qualified senior investigators, regardless of gender". (A statement from the company notes that women represent "nearly 30%" of Alnylam's management team.) At Taris, says Langer, the SAB had to include mostly clinical experts in urology, who are generally men. And Verastem found that there were few prominent female biologists who focus on cancer stem cells, says chief medical officer Joanna Horobin. At least one woman declined the offer to join the SAB, Horobin says, because she was already working with a competing company.

The academics and biotech companies interviewed for this story say that they hope the situation will change. At Alnylam, people have "discussed openly the issue of gender and the SAB", says Schimmel. "All of us support strongly the idea of addressing the 'gender problem' in a thoughtful way and are actively working on it." In Lander's opinion, more important than the make-up of the SAB is the selection of the company's board of directors — who "control the entire company". Two out of seven directors at Verastem are women.

Women can also make the first move, says Helen Blau, a stem-cell biologist at Stanford University in California, who has served on the advisory boards for several start-ups. She broke into commercialization by patenting discoveries and talking to companies at conferences about her work. The effort paid off: companies have licensed at least a dozen of her patents, which helped Blau to get consulting jobs, board invitations and now her own start-up, Didimi in Berkeley, California.

Hopkins, meanwhile, has not let the issue lie. After she discussed her data with MIT colleagues, the group decided to forward the findings to the university's provost, Chris Kaiser. It turned out that Lydia Snover, director of institutional research at MIT, had already started mining faculty CVs across the entire institution for information about activities such as patenting, technology licensing and participation in SABs. If MIT finds gender differences and can help to do something about them, it will, says Snover. "We want all [faculty members] to be involved in the same way."

Hopkins wants to see all institutions follow MIT's example. In academia, people used to believe that "time would fix things naturally", and that women would eventually move up the ranks, she says — and this attitude may still exist when it comes to academics moving into industry. "I think [the gender disparity in SABs] is what universities would look like if we hadn't stopped, analysed what was going on, and changed it. If you don't put attention to it, it doesn't happen." ■

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30 something science

What's being female got to do with anything, ask the scientists who are starting labs and having kids.

DANA SMITH

KAY TYE: POWER MOVER

The neuroscientist break-dancing down the tenure track.

BY HEIDI LEDFORD

Being five months pregnant comes with a series of concessions: no booze, no sushi, no double-shot espressos. Less appreciated, perhaps, is the havoc it can wreak on a break-dancer's moves. "My dancing is definitely limited now," says Kay Tye, neurobiologist, award-winning b-girl and assistant professor at the Picower Institute for Learning and Memory at the Massachusetts Institute of Technology (MIT) in Cambridge. "I can't do windmills — I can't do anything that might cause me to fall. Which is, like, everything."

It is one of the few limitations that Tye, 31, has been willing to accept. Striving to make her mark in optogenetics, one of the hottest fields in neuroscience, Tye thought nothing of working past midnight, getting by on four or five hours sleep a night and maintaining a constant, transcontinental travel schedule. She has had to dial back a little in recent weeks, and she knows that life may change further once her daughter is born. But she is ready. "I've been preparing for this my entire life," she says. "I chose a career path that's family friendly."

An assistant professorship at MIT, where the tenure rate hovers at around 50% and the faculty is still about 80% male, may not strike many as particularly family friendly. But Tye, the daughter of a theoretical-physicist father and a biochemist mother, grew up in her mother's lab, where she was paid 25 cents per box to rack pipette tips. With her mother as a role model, Tye says that she was in her teens before it occurred to her that her gender could hold back her career. "And by then, my brain was already fully formed," she says with a smile.

Even so, Tye wasn't sure that science was for her. After graduating from MIT, where she first took up break-dancing, she travelled to

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Australia to live on a cattle farm, in a yoga ashram and finally in a beach tent in an art commune. Her goal was to live moment-to-moment and write a novel based on her experiences. But Tye found her new lifestyle unfulfilling — and, she adds, the novel wasn't very good. She flew back home and started graduate school at the University of California, San Francisco. After rotating through the usual three labs without finding a suitable home, she begged neurobiologist Patricia Janak for the chance to do one last placement in her lab. "If you don't let me rotate, I'm going to drop out," Tye tearfully told her.

Tye got the place and a new mentor: Janak, a successful female scientist with two children. And Janak watched Tye bloom. "Her insecurities rapidly disappeared," she says. "She started to get amazing results." In Janak's lab, Tye published her first *Nature* paper after finding that in rats learning to associate a cue with a reward, there was a boost in the activity and synaptic strength of neurons in the amygdala, a brain region that in humans is associated with processing emotions (K. M. Tye *et al. Nature* **453,** 1253–1257; 2008). But Tye wasn't satisfied: she wanted to be able to switch neurons on or off directly. That led her to optogenetics, a way to activate or inhibit specific neurons in rodent brains using light.

After a two-year postdoc learning the technique in Karl Deisseroth's lab at Stanford University in California, Tye landed at the Picower. She plans to use the approach to map the neural circuits that govern whether an animal forms a positive or a negative association with a given environmental cue. Ultimately, she hopes that her studies can be used to devise ways to treat disorders such as anxiety, depression and addiction.

Over the past five years, the Picower has recruited a number of young female faculty members, several of whom have since started families. (MIT opened a day-care facility across the street from Tye's office in 2004 and uses it as a recruitment tool.) It definitely helps to know they have paved the way, says Tye.

Since her return to MIT a year ago, Tye has recruited four graduate students and four postdocs, applied for 13 grants, extended her list of top-tier papers and begun to prepare herself for the impact of motherhood. Some decisions are easy: the exercise bike in her office will be replaced with "a crib, or playpen, or whatever" for the times that her daughter accompanies her to work. Some are more difficult, like a trip to Tokyo to speak at a conference a month after the baby is due. Tye can't say no, not yet.

And tenure remains near the top of her list. "I never thought that my life had to be limited to anything," she says. "And I want to set that example for my daughter." ■

JOHNNY TANG

"I NEVER THOUGHT THAT MY LIFE HAD TO BE LIMITED TO ANYTHING, AND I WANT TO SET THAT EXAMPLE FOR MY DAUGHTER."

KARINE MARAFIGO DE AMICIS

KEITY SOUZA SANTOS: VENOM DETECTIVE

An immunologist who studies allergic shock receives a shock of her own.

BY ANNA PETHERICK

What should have been an ordinary Thursday for Keity Souza Santos turned out to be anything but. It was 4 a.m. when she woke up on 22 November 2012, tired but alert. She had been meaning to take a pregnancy test for days; now she decided she couldn't put it off any longer, and headed to the bathroom. Later, at work at the University of São Paulo Medical School's allergy and immunology department in Brazil, Santos, 33, told none of her colleagues why she had felt like screaming for joy hours earlier. She kept her secret even when one of them called to tell Santos that she had won the prestigious Young Investigator Award from the São Paulo Research Foundation. That meant that she would be starting her own lab at about the same time as her baby was due. Only it will not be just one baby; Santos is expecting twins.

Santos studies life-threatening allergens in foods and insects, a serious threat in Brazil. Well known for its stunning biodiversity, the country ▶

has more than 400 species of wasp compared with the Northern Hemisphere's 30-odd. One species, *Polybia paulista*, causes hundreds of hospitalizations in Brazil every year. But doctors often have trouble pinpointing the cause of the allergic reactions. "Sometimes patients even bring the wasp to the hospital, but even then we cannot treat them properly because we don't know what allergens are in the sting," Santos says.

During a PhD at the University of São Paulo, Santos worked on an antivenom against the sting of the Africanized honeybee or 'killer bee' (*Apis mellifera* L.). As a postdoc, she studied the proteins responsible for anaphylactic reactions to cassava (*Manihot esculenta*), a staple food in north Brazil, and to the sting of several wasps. From *P. Paulista* alone, she and her colleagues separated out and identified 84 venom proteins — including some that had previously been found only in snake venom — and showed how they can trigger devastating tissue damage (L. D. dos Santos *et al. J. Proteome Res.* **9,** 3867–3877; 2010). Now she is trying to identify the offending proteins in other insect venoms.

To learn the mass spectrometry and other molecular techniques required for the task, Santos spent months in labs in the United States and Austria. While abroad, she heard tales of sexism, something she says she did not encounter when growing up in Brazil. Santos says that her family was shocked when she announced (after reading about the cloning of Dolly the sheep) that she wanted to become a biologist, but not because of her gender. No one in her family was a scientist, and such a career was different from the world they knew.

Now working largely independently, Santos's goal is to create kits that will help doctors to quickly identify the allergens to which a person has been exposed and how to detoxify them. But first she is focused on the challenges that this summer will bring. "My boss is a little bit worried," she says. "But I already have a PhD student and a technician. We can Skype a lot [during my maternity leave]."

"I think she will manage," says immunologist Jorge Kalil, Santos's head of department, before adding after a pause, "but they are twins". Santos has no such qualms. "I want to increase my group of students and collaborators," she says. "Why would I give up my scientific career now?" ■

MÓNICA BETTENCOURT-DIAS: CELL MECHANIC

A biologist who explores and shares the intricacies of the cell.

BY ALISON ABBOTT

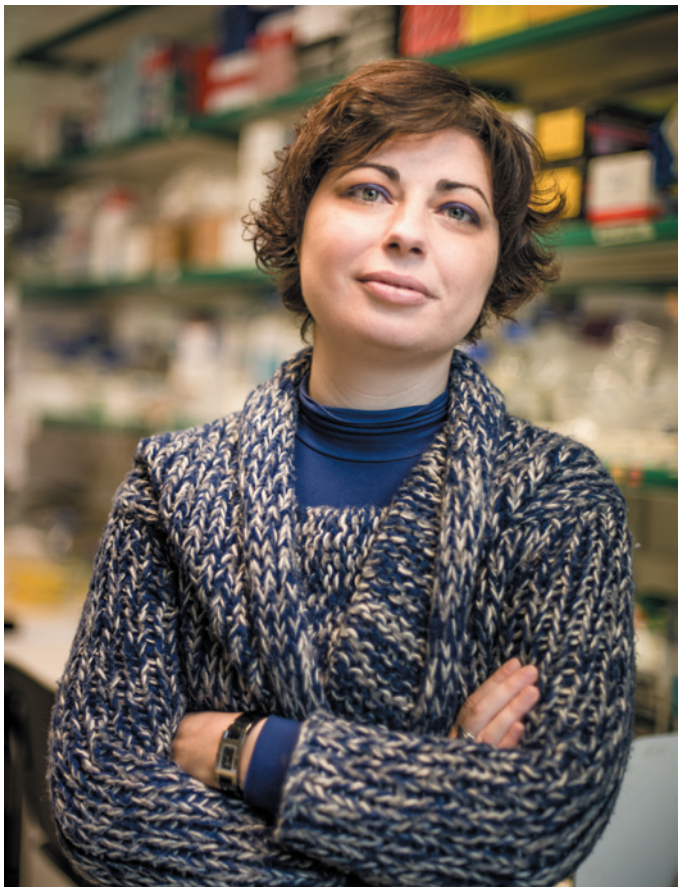
Mónica Bettencourt-Dias grew up surrounded by role models. Despite being relatively poor, Portugal has an excellent record within Europe for appointing women to top positions in academia and other professions. Some think that the situation traces back to the 1960s and 1970s, when educated young men were sent to fight in Angola and Mozambique, leaving room to promote women and spawning a gender blindness in academia. On top of that, Bettencourt-Dias was raised by a supportive mathematician father and social-scientist mother, and she came of scientific age just as her country was introducing an innovative, government-paid doctoral programme, for which she was selected in 1996. "We had some of the world's best scientists teaching us," she recalls, "and I was able to learn that my destiny was cell biology and development."

Bettencourt-Dias travelled to University College London to study the regenerative properties of salamanders as part of her PhD. Later, as a postdoc at the University of Cambridge, UK, she discovered a master regulator of the centrosome, an organelle that organizes some of the key structures and machinery involved in the cell cycle, bagging her first *Nature* paper (M. Bettencourt-Dias *et al. Nature* **432,** 980–987; 2004). She returned to Portugal in 2006 to start her own laboratory at the Gulbenkian Institute of Science in Oeiras and the money has flowed generously ever since — including a prestigious €1.5-million (US$2-million) Starting Grant from the European Research Council.

Now 39, Bettencourt-Dias's life changed a few months ago with the long-awaited arrival of her adopted one-year-old daughter. But Portugal has abundant professional child-care places, and family members tend to be close by to help out. Bettencourt-Dias's husband, also a scientist, does his share of the child-raising, and the couple has hired help for their domestic chores.

In the lab, Bettencourt-Dias still focuses on the tight communication and organization imposed by cellular-signalling pathways and centrosomes. There are parallels in her own life. Being well-organized has been essential to her career, she says, and she developed a drive for communicating science to the public that has led to regular participation in workshops in Portugal's former colonies. Last year, she organized a molecular biology workshop in the west African island nation of Cape Verde, which in 2008 became the first country in Africa to have a government comprising a majority of women. The workshop had a similar number of men and women, Bettencourt-Dias says, and the attendees "told me they wanted to learn science to help their country — you don't hear this in Western countries".

Sharing is a life philosophy for Bettencourt-Dias; her discoveries are recalled in those terms. One of her first such moments came in Cambridge when she and her first PhD student showed that an enzyme called PLK4 is important for the structure of fly centrosomes (M. Bettencourt-Dias *et al. Curr. Biol.* **15,** 2199–2207; 2005). Together, they watched scores of tiny centrosomes forming under the microscope. "It is beautiful to share that moment with someone you are teaching," she says. ■



ROBERTO KELLER-PÉREZ

TONY MARKS

AMANDA WELTMAN: DRIVING FORCE

A cosmologist who probes dark energy and ignores stereotypes.

BY LINDA NORDLING

When Amanda Weltman discovered physics as an undergraduate at the University of Cape Town in South Africa, she thought that "understanding the way the Universe worked was just about the coolest job anyone could have".

Weltman was just 24 when she shot to fame with a proposal about how the Universe works at the grandest scales. Her breakthrough paper, '*Chameleon Cosmology*' (J. Khoury and A. Weltman *Phys. Rev. D* **69,** 044026; 2004), published when she was graduate student at Columbia University in New York, gave rise to a popular theory to explain the phenomenon of dark energy — the mysterious force that is hypothesized to be speeding up the expansion of the Universe.

Weltman and her colleague Justin Khoury suggested that a new force that changes according to its environment could explain many observations about the Universe's expansion. This 'chameleon' force would be weak when particles are packed together, such as on Earth or in the early Universe. But as galaxies fly apart the force would grow, and accelerate the growth. What makes their theory popular is its testability: it predicts that a photon will sometimes decay into a chameleon 'particle' when travelling through a strong magnetic field. Experimental physicists have begun looking for this effect, but haven't yet found anything conclusive (see *Nature* http://doi.org/b96z3f; 2009).

In 2009, after finishing her PhD at Columbia and a postdoc at the University of Cambridge, UK, Weltman moved back to South Africa. This enabled her to start a life with her husband, string theorist Jeff Murugan, whom she had met a decade earlier. Until that point, their courtship had been a typical case of academia's 'two-body problem' — mostly conducted at great distances. Their return to South Africa was also driven by idealism. After years learning from the best in their disciplines, they wanted to bring that expertise home. "We thought we could be better put to use here to grow the country's science and knowledge," Weltman says.

Back at the University of Cape Town, she is part of a large research group, but is also building her own — she has one student and one postdoc so far — to extend and test the chameleon theory. Last year she received a 'P' rating from the country's National Research Foundation, a distinction given to a handful of young researchers who are on their way to becoming international leaders in their field.

Weltman thinks that early barriers for women — the expectations that girls are better at soft sciences than hard ones, or that mathematics is more for boys than girls — are the most harmful. She was raised in a family in which such stereotypes did not exist, she says, and is grateful to have had role models, many of whom were men. "I don't think girls necessarily need girl role models, but I think they need good role models," she says.

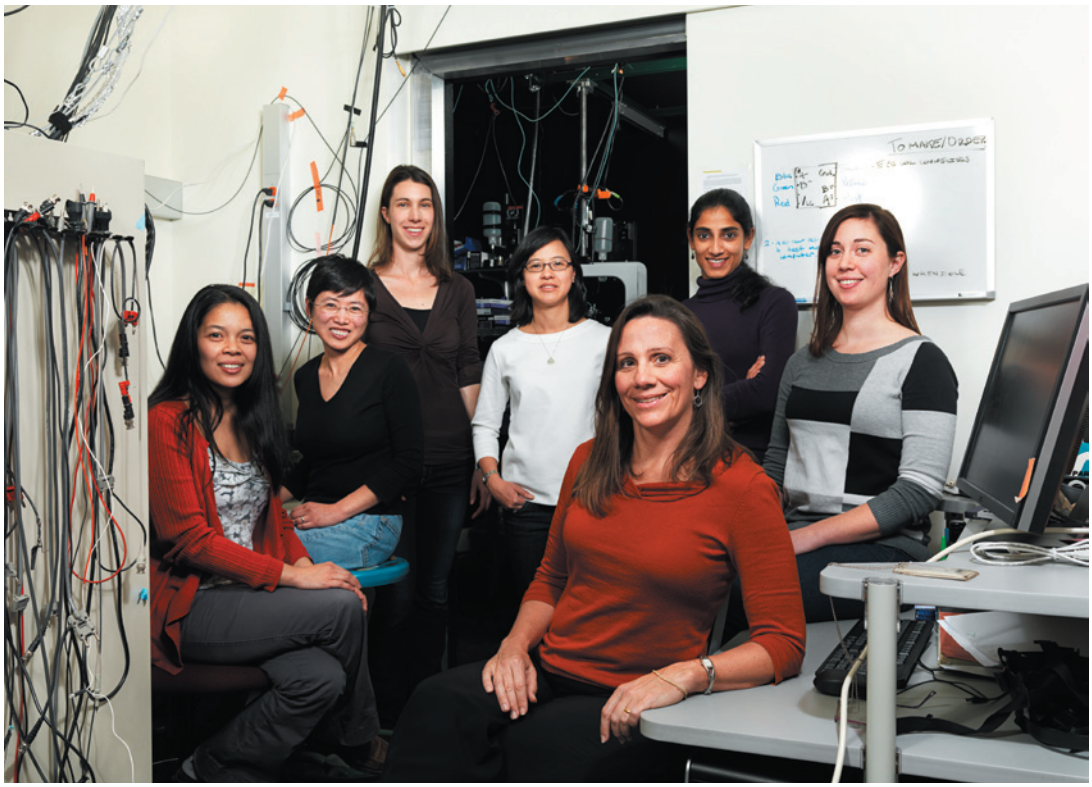
"I DON'T THINK GIRLS NECESSARILY NEED GIRL ROLE MODELS, BUT I THINK THEY NEED GOOD ROLE MODELS."

Having her husband down the hall was handy after the arrival of their two children, now 2 years old and 8 months old. Weltman, who is now 33, kept her research going through her four-month bouts of maternity leave, which in practice were only a leave from teaching. She admits that it was tough at times. Her husband, she says, "looked after the children as much as possible, so I could work. Together we make it work by finding the cracks in the day". They go to conferences as a family and take turns looking after the children.

Academia offers flexibility, but it can still be a daunting place to start a family, Weltman says. "When I was pregnant, I felt a little bit defensive and guilty, like I was admitting that my personal life was important to me by having a child," she says. "In physics, you are supposed to be life, blood, flesh, dedicated 100% to your research." ■

COMMENT

CODY PICKENS



Neurobiologist Jennifer Raymond (front) and her colleagues in their lab at Stanford University in California.

Most of us are biased

Let's move beyond denial, own up to our prejudices against women and retrain our brains to overcome them, says **Jennifer Raymond**.

I have a bias against women in science. Please don't hold this against me. I am a woman scientist, mentor and advocate for women in science, and an associate dean in my school's Office of Diversity, with a budding field biologist as a daughter. Yet my performance on the Implicit Association Test (https://implicit.harvard.edu/implicit/demo), which measures unconscious associations between concepts, revealed that I have a tendency to associate men with science and career, and women with liberal arts and family. I didn't even need to wait for my score; I could feel that my responses were slower and that I made more mistakes when I had to group science words such as 'astronomy' with female words such as 'wife' rather than male words such as 'uncle'.

The results from hundreds of thousands of people indicate that I am not an outlier — 70% of men and women across 34 countries view science as more male than female[1].

Gender bias is not just a problem in science. A host of studies shows that people tend to rate women as less competent than men across many domains, from musical abilities to leadership[2], and that many individuals hold biases about competency on the basis of other irrelevant attributes, such as skin colour, body weight, religion, sexual orientation and parental status.

Such biases have important consequences in the workplace. One study showed that mothers are 79% less likely to be hired and are offered US$11,000 less salary than women with no children[3]. By contrast, the same study shows that parenthood confers an advantage to men in the workplace.

A 2012 study by Jo Handelsman of Yale University in New Haven, Connecticut, and her colleagues shook the scientific community by reporting that science faculty members have a pervasive bias against female ▶

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BIAS BUSTERS

Ways to conquer gender assumptions

- **Raise awareness of gender bias as a first step to overcoming it.** Call for transparency in salaries, hiring, leadership and editorial decisions. Organize a discussion of implicit bias in science, and what can be done locally to address it. At Stanford University, we have a Gender Issues in Neuroscience discussion group that brainstorms ways to overcome challenges such as competition, response to failure, networking and speech and body language. We include men in these discussions because they are also affected by gender stereotypes and are an essential part of the solution.
- **Use gender-blind review[5] or other processes to mitigate bias** when reviewing applicants for a job, award, speaking engagement, grant or manuscript. Define measurable review criteria in advance to avoid a gut response, which is most vulnerable to bias. Be vigilant for rationalizations that could reflect an unconscious bias, such as "she's great, but seems awfully young/is not a good fit/is working in such a competitive area". Create an environment in which it is acceptable to question colleagues when bias might be influencing their behaviour. It is easier to detect bias in others than ourselves[8], so we need to help each other without judgement. It is especially helpful if men initiate conversations about gender bias so that women don't bear the full responsibility.
- **Make a conscious effort to offer women mentoring and other support**, including an equal salary to male peers, to overcome the documented tendency to offer women less[4]. Trumpet the achievements of female colleagues, because biases have the greatest influence when there is a dearth of specific information[9].
- **Women should overcome their own gender bias** because it could make them less likely to compete for prestigious jobs or awards[10]. Be proactive in seeking mentorship, and negotiate for salary and other resources. Offer your talent to employers who have programmes to help level the playing field for women. Join or start a women-in-science group, especially within your own scientific subspeciality, because such groups can provide speaking invitations, tenure letters, advice about the key issues and players in the field, and reviews of papers and grants. For about 15 years, women in my subspeciality have got together at our national neuroscience meeting for an annual event that we irreverently call the Babes of the Vestibular/Oculomotor System Dinner.
- **Fund pilot projects** to test innovative interventions to mitigate the effects of bias, and create a central repository for sharing strategies. These programmes will more than pay for themselves if they help to retain the best talent. Considerable resources are being invested in training each young scientist — if we want to be good stewards of that investment, we need to provide everyone, male and female, with a fair shot at success. Institutions should provide incentives, such as salary support or alleviation of other duties, to individuals who spearhead efforts to address implicit bias.

scientists[4]. This prevents us from doing our job of promoting the best scientists, and society is paying a price in terms of the advancement of science.

There is now sufficient evidence to move us beyond the denial phase of dealing with gender bias. Yet in talking to colleagues around the world, I find continued resistance to the idea that scientists, who take pride in being rational and objective, could be influenced by bias. One colleague was convinced that gender bias could affect the hiring of a lab manager, but he still doubted that it would affect a faculty-level hiring decision or the evaluation of a manuscript, even though the evidence suggests otherwise[5]. And I have seen junior colleagues shake their heads disapprovingly at the gender bias of older science faculty members, yet resist the idea that their generation might also have such bias.

Unfortunately, young people are not immune to gender bias. Many studies have been conducted on college-age subjects, and gender bias has even been reported in preschool children[6]. I tried to protect my own children from gender bias by doing things such as changing the gender of the characters in the children's books I read to them to reverse gender stereotypes, and using the feminine pronoun wherever possible — "Look at the elephant; she is so strong." Despite these efforts, my daughter had a bias against women in leadership positions by the age of three. One day in the park, she announced, "I am the captain; I'm a girl captain," suggesting that she knew she had to violate a gender stereotype to assume that leadership position. And although she has a scientist mum who runs a lab full of women, when my daughter took the implicit association test at age 8, it revealed a bias against women in science. My presence as a role model and other efforts at countering gender stereotypes were not enough to overcome the powerful cultural transmission of bias. Thus, it seems unlikely that unconscious gender bias will be eradicated any time soon, and the best we can do in the near term is to suppress its symptoms.

If we are vigilant, we can reduce the influence of bias on our decisions. Unconscious biases are mental habits that tend to dominate our gut reactions, but we also have more-rational decision processes, which compete with our biases for control of behaviour. Just as one can overcome physical habits such as biting one's fingernails or saying 'umm' when one speaks, one can suppress undesirable mental habits such as gender bias through deliberate, conscious strategies (see 'Ways to conquer gender assumptions'). By enabling more women to succeed, despite the existence of unconscious bias, this will gradually eliminate the stereotype of the successful scientist as male, which is the root of gender bias.

However, if left unrecognized and unchecked, bias can commandeer both our behaviour and our rational thought processes. Our brains are skilful at creating seemingly rational justifications for our behaviour, even when it is driven by bias. People who had to rate two 'applicants' for police chief — one who had more education and the other who had more experience — always chose the man over the woman, but justified their choice as arising from the value they placed on either education or experience, whichever factor was assigned to the man[7].

Denial that bias exists gives it more power. I am not proud of my unconscious bias against women in science. However, I know that I must first recognize my own bias to overcome it with deliberate practices that suppress its effects. I urge you to join me. ■

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Scientists of the world speak up for equality

Eight experts give their prescriptions for measures that will help to close the gender gap in nations from China to Sweden.

TOP TO BOTTOM: JIM SPENCER (FROM PHOTO BY ASHOK PRASAD); VIKTOR KOEN

LIHADH AL-GAZALI

Remove social barriers

Clinical geneticist at the United Arab Emirates University in Al-Ain

Just 1% of Saudi Arabia's researchers were women in 2011, according to the International Labour Organization. This low number is particularly surprising given that 65% of the nation's bachelor's science degrees go to women. Similar patterns are evident in the rest of the Arab Middle East. Women are clearly interested in science. But many cannot continue their careers because of limiting social attitudes in traditional Arab societies.

The expected role for women — graduates included — is housewifery. In some areas, women must ask the permission of the men of the household even to leave their house. Conservative families may not allow their daughters to work in mixed-gender workplaces. To pursue advanced training in research often requires postgraduate study elsewhere. If a woman wishes to do this, the household patriarch may mandate that a male family member accompanies her abroad.

Despite these restrictions, the pool of highly qualified women scientists continues to grow in some Arabic countries. According to the Organisation of Islamic Cooperation in Jeddah, Saudi Arabia, women now represent 19% of researchers in the occupied Palestinian territories and 22% in Libya. Few of these women are university presidents, ▶

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nature.com/women

directors or department heads.

Having more women in these positions would help to shift cultural expectations. Leading Arab women scientists should continue to get involved in the political life of their countries, where they can be strong advocates for other women scientists. Developments such as the inclusion of leading women academics in the Shura council, Saudi Arabia's highest advisory council (which is now 20% female), and in the Federal National Council of the United Arab Emirates (22% female), are steps in the right direction. Highlighting success stories will encourage qualified Arab women to pursue careers in science. Role model and mentoring initiatives are also important. Examples of such programmes include the Stars of Science initiative by the Qatar Foundation for Education, Science and Community Development, and the TechGirls Exchange Program of the US Department of State.

Universities and professional organizations must help to educate the public about what science entails by inviting families to join conferences, careers days or networking events that include presentations of the achievements of women scientists.

VIRGINIA VALIAN

Invite women to talk

Psychologist at Hunter College and the Graduate Center, City University of New York

In 2003, I was invited to give the keynote speech at an event held annually by the Sigma Xi scientific-research society to honour scientists' achievements. I was asked to speak about women in science. During dinner, I scanned a list of the event's previous speakers, from 1964 on, to count how many women had given the keynote. Most were listed only by surname and first initial, so between courses, I walked around the room asking people whether they knew anyone on the list. Eventually, I found an older scientist who reviewed the list, recognizing every name, then turned to me with a surprised, rueful smile: in nearly 40 years, I was the only woman to speak at this event. He had heard nearly every lecture but had never noticed that they were all given by men.

At the beginning of my talk, I used that story as an example of how hard it would be for organizers and attendees to detect such a pattern, given only one data point a year. The pattern isn't a product of discrimination or intentional exclusion of women. Rather, few people — men or women — think of women when they picture 'top' scientists who might headline an event.

Are men still disproportionately featured at conferences? Determining an expected number is hard, but it is still relatively rare to find women giving plenary or keynote speeches at conferences. At the American Chemical Society's upcoming spring meeting, for example, all four of the planned plenary speakers are male. That doesn't send an optimistic message to young female chemists. The blog Feminist Philosophers lists nearly 20 recent philosophy conferences — many of which focus on science — featuring only male speakers.

At a language-processing conference I attended recently, I went to 15 or so talks, making note of who asked questions in each one. Women were more likely to ask questions in sessions chaired by women, regardless of the speaker's gender. If that is a general pattern, bringing more women into prominent positions in conferences will increase women's overall participation in scientific discourse. Many organizations strive to include scientists who are from non-English-speaking countries — the same can be done for women.

To that end, my colleague Dan Sperber, a cognitive scientist at the Central European University (CEU) in Budapest, and I have created an online petition (go.nature.com/sj4yed) whose signatories commit to accepting talk invitations only from conferences that have made good-faith efforts to include women. So far, we have more than 450 signatures — but few of them are from senior male scientists, and even fewer are from scientists in the United States.

What counts as a good-faith effort? There is no single prescription, but Sperber and I have adopted a few suggestions from Feminist Philosophers. For one, organizers should seek out women in relevant fields to speak at conferences — and keep looking if the first woman they ask says no. Other examples include extending invitations early so that women have time to make arrangements, and offering child-care services at meeting sites.

But efforts should go beyond the individual. Conference funders should be mindful of gender equity for invited speakers. Similarly, universities should follow the example of the CEU, which now requires that organizers of university-funded events show good-faith efforts to include qualified female speakers (go.nature.com/ym81ws).

BEN BARRES

Allow time for postdoc babies

Neurobiologist at Stanford University in California

Three decades ago, when Nobel laureate Rosalyn Yalow spoke to a women in science group at a major university, her opening statement was: "The primary problem is childcare. Everything else is secondary." Fortunately, many universities now recognize the huge amount of time needed to raise children and help to offset this by providing an extension of 1 year to assistant professors who have a child while seeking tenure. Increasingly, however, scientists are having babies during graduate or postdoctoral training, which together can now total 10 years or more.

I propose that universities modify their tenure-clock extension rules to cover children born at any stage in a career. So even if people already have children when starting out as assistant professors, they should be offered an additional year per child (up to two children, perhaps) to obtain tenure. Even though women typically provide more of the child care than do men, it seems only fair to provide the same extension to men. In the modern world, both parents often work and like to eat dinner with their children (and so cannot write grant applications and papers until midnight).

LEFT TO RIGHT: JIM SPENCER (FROM PHOTO BY DAVID MELNIKOFF); JIM SPENCER

This change would remove a persistent, if unintentional, form of discrimination that deters many young scientists, particularly women, from choosing tenure-track jobs, and would increase the chance that those who do will make tenure. At Stanford, our provost routinely grants tenure-clock extensions when requested. Why not just make it the rule at every university?

The main argument against extending tenure clocks is that it might help men more than women, because men may use the extra time to amass papers whereas women use it to raise children. If so, one could argue that this is also true of the tenure-clock extensions already granted. Yet most agree that these have been beneficial to all involved. If universities wish to achieve a more diverse faculty, we must continue to remove obviously discriminatory policies.

LEFT TO RIGHT: JIM SPENCER; JIM SPENCER (FROM PHOTO BY NICK ROMANENKO)

LING-AN WU

Equalize the retirement age

Physicist at the Institute of Physics, Chinese Academy of Sciences, Beijing, China

There are two things that China can and should do to make it easier for women to succeed in science: enforce laws that grant equal opportunities to women in the workplace, and make the retirement age the same for men and women.

In some ways, it is harder to be a woman in science in China today than it was 50 years ago, before the Cultural Revolution. Then, under the socialist system, men and women were given jobs based purely on their performance, so sex ratios were relatively fair. Now that more-capitalist principles infiltrate job placement, it has become more difficult for women to find work. I benefited from the socialist system. After working on a farm for three years, I was assigned a job doing translations at Beijing's Institute of Physics, Chinese Academy of Sciences, because I was fluent in English. This enabled me to go to the United States and obtain a PhD in physics. On returning to the institute with my new skill set, I became a researcher.

Now, women face discriminatory practices that make it harder for them to succeed. For example, in most Chinese institutions, women who are not full professors are required to retire by age 55, 5 years before men. The earlier retirement age was originally established to protect women performing manual labour. In science it essentially prevents them from reaching the same career goals as men, particularly if they had to take time off to raise children. In the past, this practice was not compulsory for academia. It was put into effect at the turn of the twenty-first century to open up positions for young returnees from abroad, who were mostly men. This led to a fast drop in the proportion of women holding lab or department directorships — for example, at my institute, that percentage fell from around 20% before the 1990s to 6% in 2003. (The proportion of female associate scientists has risen to the original level of 27%, but they still make up only 13% of the full-scientist ranks.)

Furthermore, bias now plays a major part in job recruitment. Even in academia, I frequently hear faculty members — even women — saying that they would prefer to hire male students. Private companies advertise for men only, or decline to interview female candidates. Although a 1995 law prohibits discrimination by employers based on gender in China, this is often completely disregarded.

Still, the country has made progress. In 2011, the National Natural Science Foundation of China, which oversees the largest source of government funding for fundamental research, raised the age of its young investigators' awards from 35 to 40 for women, to give them time off to raise children. This allows women to compete more fairly with their male counterparts, especially important because the number of day-care centres has plummeted owing to rising costs. Today, Western and old feudal perceptions spread by the media have led to the saying: "It is more worthwhile to find a good husband than a good job." But no one says: "It is more worthwhile to find a good wife than a good job." This saddens me.

EVA Y. ANDREI

Inspire our daughters

Physicist at Rutgers University in New Jersey

As a female physicist I am a 'rare bird' — a member of a tiny minority, scarcer than in any other field of science and engineering. Women's representation in physics at major US research universities hovers at about 13%, for many reasons. In my view, these demographics alone make it hard to find female plenary speakers, conference organizers and journal reviewers.

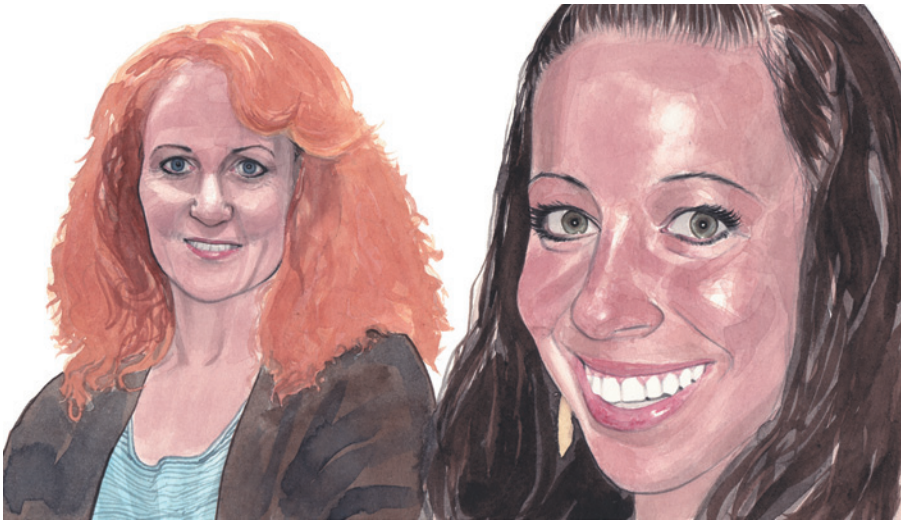
It would be counterproductive to restore the gender balance by burdening the 13% with more refereeing or committee work. Instead, the solution needs to be sought through inspiring and mentoring high-school girls and undergraduate students.

We must also ask whether girls are less inclined towards physics than boys. Is there something in the discipline or its culture that turns them away? Can this be changed?

I am somewhat heartened to see that the fraction of physics PhDs earned by women has increased from 2% in 1966 to 18% in 2010. The percentage of women faculty members at every rank matches the numbers who graduated in the respective years. Still, we are not there yet, and the decline since 2002 in the number of women earning a bachelor's degree in physics is a further cause for concern.

When I polled my women colleagues, almost all agreed that a dearth of guidance and mentorship early on was the main reason for the lack of female physicists.

The rising tide of women joining the profession will encourage more young women into physics. In the meantime, we should showcase successful female physicists through lectures and prizes, and retain young scientists by offering travel bursaries and by stopping tenure clocks. But to really solve the problem, we must inspire our high-school daughters.



JO HANDELSMAN & CORINNE MOSS-RACUSIN

Institute training to reduce bias

Microbiologist, and social psychologist, Yale University, New Haven, Connecticut

In 2012, we published a study showing that scientists of all ranks and both genders are more likely to hire, mentor and pay more to a 'John' than a 'Jennifer'. Soon afterwards, we were contacted by the office of US congresswoman Louise Slaughter about ways that policy-makers might help to promote gender equity in science.

We proposed that the ethics training now required for students funded by grants from the US National Institutes of Health be expanded to include gender-bias training. Indeed, we feel that all scientists should go through such training. It has been shown that students who undergo diversity training score markedly lower on tests of implicit bias than students who do not (L. A. Rudman *et al. J. Pers. Soc. Psychol.* **81,** 856–868; 2001).

Other approaches can also make a difference — the board game Wages, designed by Stephanie Shields, a psychologist at Pennsylvania State University in University Park, and her colleagues, shows players how subtle disadvantages to women can have enormous cumulative impact on their careers.

Visual priming works too — for example, people who have viewed images of disliked white people and admired African Americans within the past 24 hours are less likely to show automatic pro-white attitudes (N. Dasgupta & A. G. Greenwald *J. Pers. Soc. Psychol.* **81,** 800–814; 2001).

For more sustained effects, we could paint murals of admired female scientists throughout the halls of universities. A large image of, say, Rosalind Franklin, viewed daily by students in an introductory molecular-biology class, might be even more powerful than explicit instruction on implicit bias. Scientists have agreed on standards and training to ensure proper treatment of animal and human research subjects. The people doing the research are just as important. Striving for equality should be a core aspect of being a scientist.

LIISA HUSU

Recognize hidden roadblocks

Professor of gender studies at the GEXcel Centre of Gender Excellence, Örebro University, Sweden

In researching women in science and academia, I have found that it is not only the things that happen to women — such as recruitment discrimination or belittling remarks — that affect them in pursuing a career in science or that slow their career development. It is also the things that do not happen: what I call 'non-events' (L. Husu *Adv. Gender Res.* **9,** 161–199; 2005).

Non-events are about not being seen, heard, supported, encouraged, taken into account, validated, invited, included, welcomed, greeted or simply asked along. They are a powerful way to subtly discourage, sideline or exclude women from science. A single non-event — for example, failing to cite a relevant report from a female colleague — might seem almost harmless. But the accumulation of such slights over time can have a deep impact.

Non-events can be manifold. Superiors or colleagues might ignore or bypass women's research and performance; fail to invite or welcome them to important informal and formal networks; bypass them for awards, prizes or invitations; fail to give them merit-advancing tasks such as representing the research group in public forums; not ask them to design or participate in scientific meetings, conferences, panels or as keynote speakers; or simply stay silent when it comes to career support, advice and mentoring. Even supposedly small non-events can send a powerful message, such as when a female postdoc publishes a high-profile article that generates no reaction from senior local colleagues, while her male counterpart's parallel article is celebrated with high-fives all round.

"Non-events are a powerful way to subtly discourage, sideline or exclude women from science."

Non-events are challenging to recognize and often difficult to respond to. Nothing happened, so why the fuss? Often, non-events are perceived only in hindsight or when comparing experiences with peers. Learning to recognize various non-events would help women scientists to respond to them, individually or collectively, with confidence and without embarrassment. Anonymous pooling of non-event experiences would be an eye-opener and a good start to understanding how non-events work in various scientific settings.

All scientists — leaders, gatekeepers, rank and file — need to be aware of how they might inadvertently exclude women from crucial collegiality. Monitoring the practices of support, encouragement, inclusion and exclusion in research groups, projects, networks, conferences and science institutions from a gender perspective would be a first step forward. Addressing this issue in management and supervisor training and early-career coaching is key. ■

LEFT TO RIGHT: JIM SPENCER (FROM PHOTO OF HANDELSMAN BY TIFFANY TSANG); JIM SPENCER (FROM PHOTO BY ULLA-CARIN EKBLOM)

Quotas are questionable

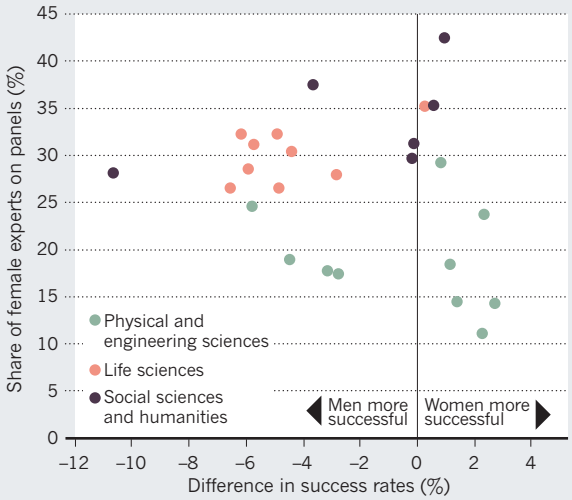
Measures to give women a fair chance in science should be based on evidence, warns **Isabelle Vernos**, or they could make matters worse.

In Europe, only 36% of mid-ranking professors, and 18% of full professors, are women, despite equal proportions of men and women at the undergraduate level[1]. To address the problem of gender imbalance, the European Commission (EC) has committed to reaching 40% female participation in its advisory structures for Horizon 2020, the European Union's research-funding programme for 2014–20. The EC has also proposed a mandatory quota of 40% for women on non-executive boards of public companies.

But statistics collected by the European Research Council (ERC) suggest that quotas are no magic wand to bring about gender equality in research and academia (despite tentative successes elsewhere, such as for company boards in Norway). Quotas might even make matters worse by overworking already-stretched female scientists. Instead, a range of bottom-up and top-down measures are needed to effect lasting change in the structures and culture of science.

GRANT GAP

Aggregating data for 2008–12, the European Research Council found no correlation between the percentage of women on its evaluation panels and the success rate of female applicants.



SOURCE: ERC

THE ERC EXPERIENCE

The ERC, launched in 2007, provides up to five years of funding for scientific-research projects chosen by peer reviewers through a transparent competition system. So far, women make up a disheartening 19% of the ERC's 3,500 grantees and account for just 25% of the nearly 35,000 applications received by the ERC to date; 29% of applicants for early-career grants, and only 15% of those for advanced grants, are female.

In 2010, the ERC implemented some recommendations — made by its gender-balance working group (GBWG) under the excellent leadership of outgoing chairwoman Teresa Lago — such as increasing the window of grant eligibility for applicants who have children (the US National Science Foundation adopted similar measures in 2011). The number of female applicants for ERC grants has increased, but so has the number of male applicants — the gap has not narrowed.

Another concern is the lower success rate of female applicants for ERC grants: 10% on average, versus 12% for men. This general trend has been observed in other funding schemes, including the European Molecular Biology Organization[2] and the international Human Frontier Science Program[3]. Despite several studies on the issue, the reasons for these disparities are still elusive[2,4]. The dearth of women in academia's upper ranks translates into their scarcity on committees, and it has been argued that this gender imbalance could be feeding back into the lower success rate of female applicants for funding schemes and positions.

I do not think this is so — at least not at the ERC. We have found no correlation between the success rates of female applicants and the gender balance of evaluation panels (see 'Grant gap'). Nor have we found that female applicants are more successful when the panels are chaired by women. Other studies have found that women fare worse than men in evaluations[4], even when applicant gender is undisclosed to evaluators[2]. These findings suggest that a quota system for staffing evaluation panels will not lead to more grants for women.

Worse, quotas would place greater demand on the small pool of female scientists who would serve on these panels — possibly enough to hamper their career progress. Scientists are evaluated on the basis of creativity and productivity, and scientific excellence requires steely focus and lots of time. Female scientists are more likely than males to bear domestic duties[2,5], making their time already stretched. My estimate, based on the proportion of ERC grantees who are women, is that the burden of panel participation would be three or more times higher for these women than for men in equivalent positions. That said, concerted efforts should be made to identify qualified women for all posts.

Given that measures taken to date have had limited impact, some argue that mandatory quotas are the best way to accelerate gender balance in research (see page 42). I disagree. There are many pockets of good practice — such as mentorship programmes, family-friendly policies and transparency in recruitment — and these should be expanded. Further solutions must also be sought. The GBWG has commissioned a study, called ERCAREER, to examine the career paths of young female and male scientists. Another study, to begin this year, will look into possible sources of gender bias in the ERC's evaluation processes.

Progress towards improving women's representation in science is too slow. More efforts are needed to understand the reasons for gender disparities and to recruit, retain and promote excellent female scientists — and thus increase the research talent pool and power scientific progress. Europe's future success requires a society that recognizes talent and offers equal opportunity to all — through evidence-based measures. ■

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YURI SOUSA/EPWS

At the European Parliament in Brussels, the European Platform of Women Scientists is calling for binding gender targets.

Only wholesale reform will bring equality

Providing equal opportunities for women in science requires change at every level, argue **Brigitte Mühlenbruch** and **Maren A. Jochimsen**.

Gender-equality policy in science at European regional and national level has come a long way, thanks to more than 20 years of efforts by women scientists and far-sighted politicians. Yet progress is slow. The pipeline is still leaking and female researchers still hit glass ceilings.

In 2007, in the 27 countries that comprise the European Union (EU), women scientists accounted for 38% of active researchers and only 19% of full professors, on average[1]. In 2009, 45% of doctorates were awarded to female students[2]. Although the number of women PhD graduates is growing — up by an average of 4.9% per year between 2004 and 2009, compared with 3.2% for men[2]— this is not enough to suggest that science's gender imbalance is self-correcting.

When it comes to women in decision-making positions in science and research, Europe is a long way from its 2001 target of 40%. With the exception of Sweden, Finland and Norway, women in Europe are still significantly under-represented on the boards of research institutions, funding organizations, scientific councils and academies, and are rarely found among the heads of higher-education institutions in the majority of European countries[2]. In short, Europe could do better.

The persistent gender gap has prompted great changes in equal-opportunities strategies at European and member-state level, particularly since the launch of the EU's Women and Science activities in 1998. At first, policy concentrated on individual programmes to equip women scientists with the necessary soft skills to advance, such as networking, mentoring, stipends, training and the provision of role models. These remain indispensable instruments for encouraging individuals.

However, impediments to women scientists have deep institutional roots. The lack of full female participation in academic careers is often a systemic consequence of the culture and organization of higher-

education institutions. Consequently, attention is shifting in the EU to encouraging structural changes in research organizations. Measures include increasing diversity in recruitment; introducing promotion and retention policies; updating management and research-assessment standards; developing course content to successfully attract women as well as men; policies for dual-career couples; and schemes that allow women to return to work after career breaks[3].

To achieve lasting equality, science needs a culture that is sensitive to gender and diversity in all its endeavours: individual and social, structural, institutional and political. We need transparency, accountability and monitoring in decision-making, evaluation, recruitment, attribution and funding. We need to secure the interest and collaboration of highly qualified women and men by offering predictable academic careers, attractive working places and conditions that enable work and life to be reconciled[4].

Furthermore, we need to agree that gender is indispensable to research itself. For example, given that there are important sex differences in responses to many drugs and therapies, the underrepresentation of women in clinical trials must be fixed. This applies to animal studies too: laboratory experiments in mice predominantly use male animals, limiting what can be inferred from findings. Gender should be addressed from proposals to papers and beyond[5].

BEST PRACTICE

Changing the academic culture will take a mixture of voluntary commitments and binding regulations — all backed up by funding. Here we describe some examples of measures that are having good effects and that should be replicated elsewhere.

In 2008, the member organizations of the German Research Foundation (DFG; Germany's largest research-funding body) committed to a set of structural and personal guidelines called Research-Oriented Standards on Gender Equality. These call on member institutions to make gender equality integral to management, human resources, organizational development, strategy and content, resource allocation and quality-assurance procedures. The standards also demand that institutions publish data on gender equality at all organizational levels and academic career stages. The guidelines require that institutions design procedures in a transparent, structured and formal manner, that they counter outdated gender stereotypes, accommodate individual life plans and empower men and women to combine family life and academic careers.

Responsibility for implementing the standards lies with each member institution, and the DFG uses incentives and evaluation reports to ensure adherence. To help, the foundation also provides an online toolbox of practical examples (see go.nature.com/dojcsz; in German). Implementing the standards is voluntary but is a condition of DFG funding.

These standards have led to progress. For example, most DFG member institutions now have flexible working schedules, childcare facilities and other family services. Most member universities have implemented transparent, structured and formalized procedures for the unbiased evaluation of scientific quality and the hiring of professors. Other positive developments include the endeavour to replace stipends, especially PhD grants, with employment contracts that include social-security benefits.

The University of Duisburg-Essen, where one of us (M.A.J.) manages the Essen College of Gender Studies, is particularly notable for its pro-women activities. These include a university-wide mentoring system; a nationwide network on university course development and teaching for sharing expertise in gender issues; and an online portal of gender information for staff. The institution even has a vice-rector for diversity management — the first post of its kind at a German university.

At European level, the European Research Council (ERC) published a gender-equality plan in 2011 (ref. 6). Each process within the ERC — from advertising to grant signing — is designed to give equal opportunities to men and women (see page 39). Among other measures, the ERC sets goals for and monitors the gender balance of its panels of peer reviewers on the basis of information from relevant scientific communities and its pool of applicants. If a goal is not reached this must be reported, with an analysis of how the situation can be improved[6]. The ERC also commits to challenging potential sources of gender bias in the evaluation process, for example by publishing men and women's submission rates, success rates and granted amounts. The council offers gender-equality training to ERC scientific officers and discusses gender awareness with evaluation panels, highlighting how they should evaluate career breaks and unconventional research career paths[6].

MEASURES OF MERIT

Other gratifying recent measures include a 2011 recommendation by the European Science Foundation (ESF) for its member organizations to attain a gender ratio of at least 40% women among grant reviewers. When selecting experts, the ESF also encourages the consideration of individual non-standard career paths affected by changes or interruptions caused by professional mobility or family reasons[7]. Among university associations at European level, the League of European Research Universities took the lead in mapping out what universities and their affiliated institutions can do to bring about change[8].

Germany's Programme for Women Professors, launched in 2007, is an exemplary blend of state prescription and voluntary institutional commitment. The programme funds universities for appointing women to the rank of full tenured professor. To be selected, a university must produce a coherent gender-equality plan. So far, the programme has led to more than 260 new female professorships at 109 universities

UNIV. DUISBURG-ESSEN

A chemistry student at Germany's University of Duisburg-Essen, notable for its pro-women activities.

(see go.nature.com/imunpf; in German). It has also funded measures such as increasing the number of women in decision-making positions, providing career development for young female researchers and boosting the proportion of women in disciplines that have low female participation, such as engineering, computer science and physics.

Although voluntary targets can achieve much, binding regulations are the only way to effect change in some cases. Quotas, as contested as they are, are another way to counter the under-representation of women scientists in decision-making positions in research organizations. In the Nordic countries and Austria, for example, quotas of at least 40% of each gender are mandated in the administrative parts of research organizations.

"Binding regulations are the only way to effect change in some cases."

From this year, the German Leibniz Association, a high-profile umbrella organization of 86 non-university research institutions, has become one of the first research organizations to introduce binding, merit-based quotas to encourage equal opportunities. The quotas use a 'cascade model': each level of university hierarchy in each discipline must, by 2017, reach at least the same proportion of women as is present at the level below. Such flexible quotas are sensitive to varying numbers of men and women in different scientific disciplines.

BEYOND ACADEMIA

The structural measures outlined above should be applied to other leading institutions, such as academic publishers, which should publicize the number of female editors and reviewers (see page 47). More women scientists should be invited to write editorials, reviews and survey articles. Journals and funding agencies should mandate that researchers account for gender in experiments and that they disaggregate gender data in all submitted and accepted papers where relevant, and in clinical trials and cohort studies as a matter of routine. The *Canadian Medical Association Journal* and the *Journal of the American College of Cardiology* already follow such good practice, and *Nature* and *The Lancet* are considering adopting similar policies[9,10].

Against this background, the European Platform of Women Scientists, which represents more than 12,000 female researchers in Europe and beyond, has urged the European Commission (EC) to do six things with respect to Horizon 2020, the upcoming EU Framework Programme for Research and Innovation[5].

First, the EC needs to introduce binding gender-evaluation criteria in EU research-funding programmes. Second, it should set targets for the participation of women in EU-funded research projects at all levels (young and senior scientists, project leaders, consortium managers) at the proposal stage, sanctioning missed targets and publishing results. Third, the EC needs to set indicators for gender sensitivity in the research design of proposed projects. Fourth, it should extend the 40% target for women's participation beyond advisory groups and evaluators' panels to all structures related to Horizon 2020 — including the ERC, Joint Research Centre, European Institute of Innovation and Technology, steering and expert groups and the like. Fifth, it needs to train evaluators in gender issues. Finally, the EC must increase funding for research into improving societal structures as part of its innovation strategy (see go.nature.com/y7vygb).

Motivation and participation are the basis of high-quality results in research — not biased evaluation criteria, job insecurity and glass ceilings. An academic culture that is transparent, democratic and sensitive to gender and diversity will benefit all scientists. Much has been achieved; a lot remains to be done. ■

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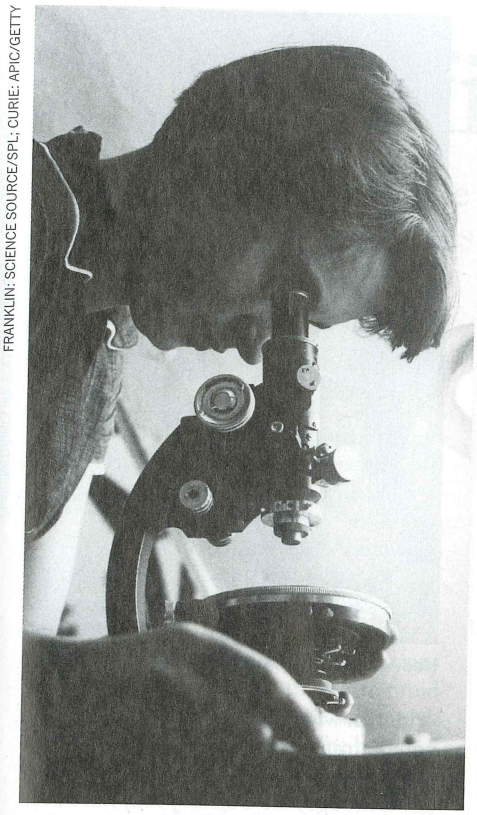
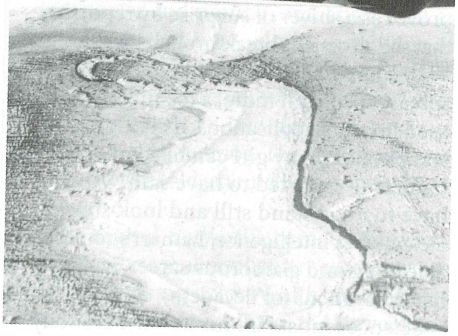




LAMONT-DOHERTY EARTH OBSERVATORY ARCHIVES

Rosalind Franklin, Marie Curie and Marie Tharp (from left to right).

WOMEN IN SCIENCE

Weird sisters?

Biographies of female scientists perpetuate stereotypes, laments **Patricia Fara**.

James Watson was thrilled to catch an illicit glimpse of Rosalind Franklin's X-ray photograph suggesting the double-helical structure of DNA. He was much less impressed by her personal appearance. "There was never lipstick to contrast with her straight black hair," he wrote in *The Double Helix*, "while at the age of thirty-one her dresses showed all the imagination of English blue-stocking adolescents." Had he been more aware of European fashion, he might have appreciated the care Franklin took to adopt designer Christian Dior's iconic 1947 New Look — although she presumably never revealed to him that her underwear was hand-made from parachute silk to her own specifications.

Watson was far from alone in believing that it is impossible for someone to be both a normal woman and a first-class scientist. To safeguard her reputation as a serious researcher, PhD student Jocelyn Bell — who discovered pulsars in 1967 — removed her engagement ring every morning before she went into the laboratory. Decades later, when president of Britain's Royal Astronomical Society, she complained that "As a woman in physics, you certainly need to be a superwoman".

In the past, biographers and their publishers routinely squeezed female scientists into stereotypical roles — the frump, the whore, the enchantress, the underdog or the power behind the throne. Even Brenda Maddox, who criticizes Watson for his chauvinistic attitudes, played on gender stereotypes in choosing the subtitle *The Dark Lady of DNA* for her biography of Franklin. Is it not sufficiently fascinating that Franklin's skilled research was crucial for Watson's fame?

Current writers, male and female, are keen to distance themselves from old-fashioned approaches. Still, to boost their book's appeal, they emphasize the singularity of their subjects. It seems that being an ordinary woman with a stellar scientific career is simply not enough: to be marketable, she must also be odd. Dust jackets entice purchasers by rebranding an overlooked character as a unique female individual — in other words, as a weird woman.

Converting female scientists into publishing opportunities may sell books, but it ▶

WOMEN IN SCIENCE
The gender gap and how to close it
nature.com/women

Marie Curie and her Daughters: The Private Lives of Science's First Family
SHELLEY EMLING
Palgrave Macmillan: 2012. 256 pp. $26.00

Soundings: The Story of the Remarkable Woman who Mapped the Ocean Floor
HALI FELT
Henry Holt: 2012. 352 pp. $30

Rosalind Franklin: The Dark Lady of DNA
BRENDA MADDOX
HarperCollins: 2002. 304 pp. $29.95

Hedy's Folly: The Life and Breakthrough Inventions of Hedy Lamarr, The Most Beautiful Woman in the World
RICHARD RHODES
Doubleday: 2011. 272 pp. $26.95

I Died For Beauty: Dorothy Wrinch and the Cultures of Science
MARJORIE SENECHAL
Oxford University Press: 2012. 312 pp. $34.95

does the cause of equality in science no favours. Take the recent biography of Marie Tharp, the American geologist and cartographer who, with colleague Bruce Heezen, produced the first systematic map of the ocean floor in 1977. In *Soundings*, author Hali Felt imagines Tharp walking along the streets of New York, her coat unbuttoned, shoes scuffed and frizzy hair unbrushed. "She does not look like the other women," Felt writes — reinforcing sweeping generalizations that female scientists are a race apart.

Even sympathetic authors perpetuate the prejudice that brains and beauty never go together. Describing the film star Hedy Lamarr as *The Most Beautiful Woman in the World*, Richard Rhodes deliberately provokes a shiver of surprise by reporting that she also made breakthrough inventions. With composer George Antheil, she devised spread-spectrum radio, a technology now used in many applications, including cordless phones. "Any girl can be glamorous," Lamarr is reported to have said. "All you have to do is stand still and look stupid." Despite her intelligence, Lamarr's remarkable looks and glamorous career occluded her innovations for decades.

Science's most famous heroine is surely Marie Curie. Over the decades, biographers have caricatured her as various unrealistic and undesirable ciphers, most notably the adulterous opportunist and the martyr to science. When her husband was killed — according to some such romances — she ensured her continuing success by latching on to his married colleague, Paul Langevin. Meanwhile, eulogies of the pioneer who dared to behave differently stress that she was often too absorbed in her work to eat, sacrificing her health as well as her appearance to the higher cause of research. Downplaying Curie's theoretical achievements, they portray her as a dedicated worker who spent months systematically sieving tonnes of pitchblende — a mindless, repetitive task with echoes of domestic drudgery.

Modern biographers may have abandoned such facile renderings, but they behave as if it were unthinkable to criticize an icon. Thus, in *Marie Curie and Her Daughters*, Shelley Emling presents the physicist as a doting mother to Eve and Irène, even though the evidence suggests otherwise. Birthday after birthday, Curie chose to be away, sending letters that overflowed with love and regrets, yet enclosed extra homework. Eve reported that her parents regarded radium as their third child, and they seem to have treated their human offspring as an experimental research project. Marie remained physically and emotionally remote, while meticulously recording the girls' clothes, diet and academic progress in her notebooks.

A less familiar name is that of mathematician Dorothy Wrinch, often labelled a harridan because of her forceful manner among her male peers. Like Curie, she was censored for behaving like a man — with ruthless ambition. The first woman to receive a doctor of science degree from the University of Oxford, UK, Wrinch developed a theory about the molecular structure of proteins that, although later discredited, ultimately contributed to genetics.

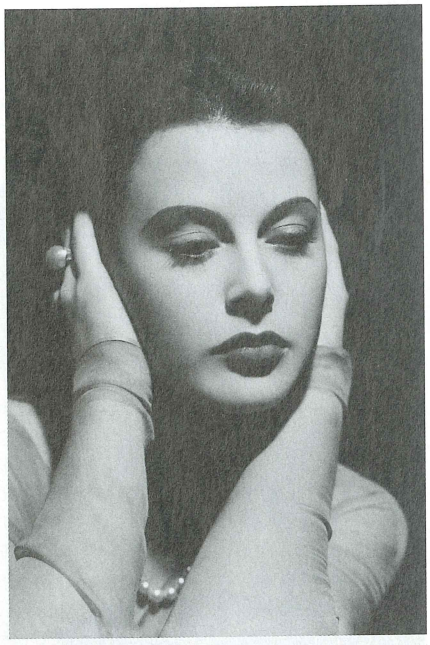
In contrast with Felt's book about Tharp, Wrinch's name does at least appear on the cover of Marjorie Senechal's biography, although relegated to the subtitle in favour of the eye-catching but misleading *I Died for Beauty*. Wrinch was indeed fascinated by the aesthetic appeal of mathematical truths, so the title and the pink cover motif implicitly trivialize her intellectual abilities.

Another infuriating feature of many biographies about women scientists is their use of first names and gushing prose. Senechal adopts the nickname 'Dot' for Wrinch — but presumably she would not have converted Michael Faraday into Mike, or Albert Einstein into Al. Similarly, although Maddox writes in an accessible yet dignified style, she insists on calling Franklin 'Rosalind'. So why does she use surnames for Watson and his male colleagues? Presumably, this patronizing practice is intended to foster an impression of cosy familiarity, but it signals once again that women who go into science are venturing into an alien male world.

In bids to restore women scientists' reputations, fulsomeness over their work's significance is as distorting as demeaning familiarity. True equality cannot be attained until women can accept criticism without taking the easy route of complaining about gender bias. Ideas are often rejected simply because they are not good enough: the US Navy may have been justified in dismissing Lamarr's projected guidance system as too bulky to be valuable. And failing to win a Nobel prize need not mean that a woman is a wronged genius: Franklin's X-ray photograph proved crucial in the race to find the structure of DNA, but Crick and Watson did get there before her.

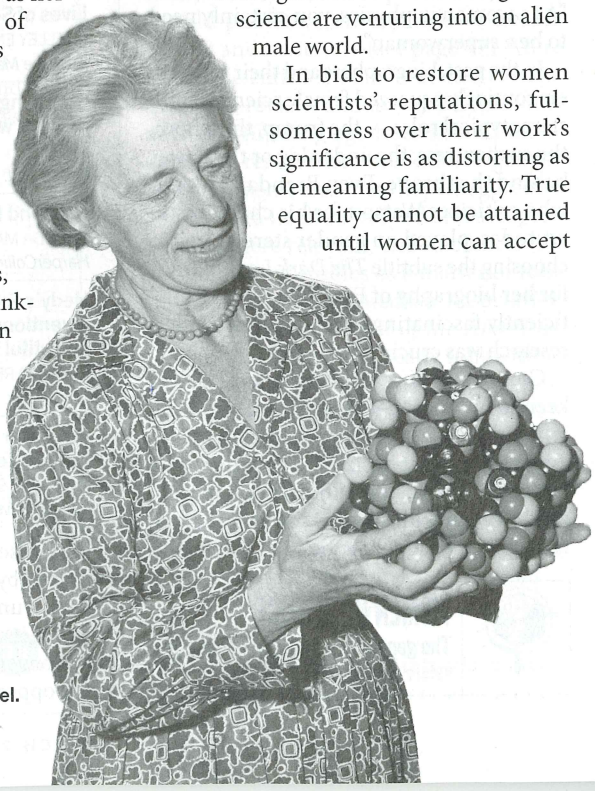
By perpetuating stereotypes, books affect how people think. When I was in my early twenties, I resolved never to confess that I had a degree in physics from the University of Oxford: I knew from experience that any potential suitor would immediately assume I slotted into one or other of the 'strange woman scientist' categories. And schoolgirls are still being steered, as I was, into mathematical and technical subjects by teachers serving the cause of political correctness. I migrated immediately after graduating not because I was incapable of tackling physics or because I was intimidated by being in an environment dominated by men, but because I was bored by the repetitive practical work.

Biographers can shift attitudes, but they need to celebrate their subjects for being special scientists, not marvel at them as weird women. Just like men, female scientists have individual personalities and idiosyncrasies, and they have weaknesses as well as extraordinary capabilities — not because they are women, but because they are human beings. ■



Hedy Lamarr co-invented spread-spectrum radio.

CLARENCE SINCLAIR BULL/JOHN KOBAL FOUNDATION/HULTON ARCHIVE/GETTY



Dorothy Wrinch with her protein model.

SOPHIA SMITH COLLECTION, SMITH COLLEGE

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TECHNOLOGY

Techno-fix troubles

Two analyses challenge the idea of the Internet as a panacea for social ills, finds **Nicholas Carr**.

To Save Everything Click Here: Technology, Solutionism and the Urge to Fix Problems That Don't Exist
EVGENY MOROZOV
Allen Lane: 2013. 432 pp. £20

Who Owns the Future?
JARON LANIER
Allen Lane: 2013. 384 pp. £20

In his introduction to the 1995 edition of *Engines of Culture* (Transaction), social scientist Daniel Fox lamented the rise of "technocratic solutionism". Frustrated by the messiness of politics, intellectuals were retreating to a simplistic view of social progress, predicated on a belief that "problems have technical solutions even if they are the result of conflicts about ideas, values and interests". In technology's promise of the quick fix, disheartened thinkers found comfort.

Some 20 years on, the appeal of solutionism is stronger than ever, thanks to rapid advances in the analytical and communicative powers of computers. The hopes of today's solutionists centre on the Internet. In its decentralized, 'peer-to-peer' architecture, they see a model for a more democratic polity. And in its bulging databases, they see a digital Rosetta Stone that, once decoded, will allow us to decipher the causes of social ills from obesity to government corruption. If we can just get the algorithms right, the thinking goes, we'll be able to solve our most intractable problems in an illuminating burst of statistical analysis.

The Internet has been around for long enough to put its curative powers to the critical test. Two authors — social theorist Evgeny Morozov and computer scientist Jaron Lanier — argue independently that the Net is too blunt an instrument to solve complex societal problems. Far from being a cure-all, the network actually aggravates some maladies, such as the concentration of economic power, that many assumed it would remedy.

In *To Save Everything, Click Here*, Morozov provides an astute, if sometimes shrill, critique of contemporary solutionists and their reductive assumptions. He describes the way in which "Internet centrism" has skewed our discussions of everything from law enforcement to public health. It may be tempting, he writes, to recast complicated cultural and political phenomena as "transparent and self-evident processes that can be easily optimized", but this usually culminates in simplistic prescriptions that do more harm than good. Painstaking analyses are replaced by vague bromides: embrace "openness", "sharing" and "virality", let information do its thing, and our problems will solve themselves.

NATURE.COM
For a review of Nicolas Carr's *The Shallows*, see:
go.nature.com/y9l1tw

Morozov points to the rise of 'crowd-funding' as an example. Online exchanges such as Kickstarter broaden the reach of venture capitalism by allowing people to make small investments in commercial and creative projects being undertaken by individuals and small businesses. The US singer Amanda Palmer, for example, raised more than a million dollars on Kickstarter to fund the recording of a solo album. The combination of automated transactions and an open marketplace is intoxicating to today's efficiency-minded technophiles, who have been quick to promote such sites as replacements for cash-strapped arts councils.

Wealth concentrates around those who control the servers and databases.

But, Morozov contends, crowd-funding is in thrall to the herd instinct. It funnels money towards endeavours that generate buzz rather than demonstrate merit, and it encourages artists to act as marketers and hucksters. He points to a recent study of documentary film-making in Britain that suggests that online contributors tend to concentrate their money in polemical features that promote a fashionable "activist agenda". They are much less likely to back documentaries that seek to explore contentious issues objectively and in depth. Crowd-funding is a solution only if you misjudge the problem.

Although Morozov is right to stress how technological determinism can warp political debates, he ends up going too far in the opposite direction. He claims that "the Internet" — his quotation marks — is largely a rhetorical construct, a sort of popular myth, and that it lacks any inherent qualities that might shape the behaviour of its users. Digital technologies, he asserts, "are not the causes of the world we live in but rather its consequences". This is a naive view of large-scale networks, and it lets Morozov sidestep difficult questions about the way the Net, like the highway system and the electric grid before it, moulds our economy and culture in its own image.

Lanier offers a more searching examination of the Internet's defects in *Who Owns the Future?*. The Net's workings, he argues, have been shaped by an ideology that, although well-intentioned, has deformed our commercial and social relationships. By mistaking free information for freedom, the network's designers and defenders have inadvertently created a system that centralizes power and profit. Companies such as Google and Facebook take in billions of dollars by hosting online exchanges, but the people who actually create whatever is being exchanged — words, ideas, works of art — often get nothing. The joy of participation, they're told, should be compensation enough.

As digital networks come to regulate more of the economy, Lanier sees a perverse dynamic taking hold. Wealth concentrates around those who control the servers and databases, whereas risk spreads outwards to the masses. He points to the banking crisis of 2008 as an example. By erasing local market boundaries and controls, computerized financial systems helped to funnel riches to a handful of bankers and traders — yet when the system collapsed, it was ordinary citizens who paid the bill.

The only way to change the dynamic is to redesign our computer networks to be a little less efficient and a little more egalitarian. Lanier imagines a "symmetrical" web, in which every piece of information is linked back to the person who created it. Copying the information triggers a "micropayment" to its creator. By placing a price on information, you constrain a company's ability to track and manipulate people and to reap windfalls by exploiting massive data stores.

Many of Lanier's proposals, including his call to assign everyone "a universal online identity", will be controversial. And some of them, such as the micropayments scheme — which would require the value of every Facebook update and blog comment to be calculated — seem far-fetched. But, like Morozov, Lanier does a service by challenging us to address societal problems as humanists, not engineers. ■

Nicholas Carr *writes on technology and culture. His book* The Shallows: What the Internet Is Doing to Our Brains *was a finalist for the 2011 Pulitzer Prize in General Nonfiction.*
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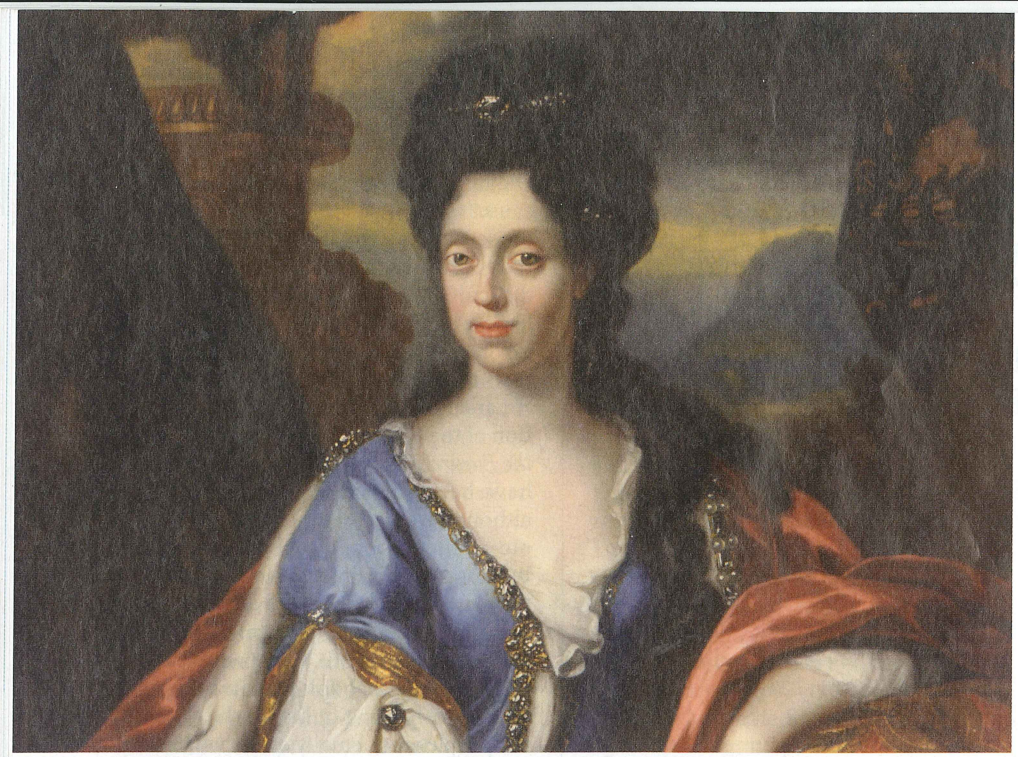

Anna Maria Luisa de Medici bequeathed her family's legacy to the city of Florence in Italy.

JEAN CHRISTEN/REM

HISTORY

Medicean secrets

Alison Abbott enjoys a scientific history of the family who ruled Florence during the Renaissance.

The Medici clan held sway over Florence and Tuscany during the Italian Renaissance and well beyond. They created one of Europe's most powerful banks, ruled Florence and produced four Popes. Today they are best remembered for their patronage of science, art and architecture. We have them to thank for Florence's enduring beauty — including the magnificent Basilica of San Lorenzo. Designed by the architect Filippo Brunelleschi, this is where most of the family were buried, several after violent deaths.

Tombs were shuffled around within San Lorenzo four times between the fifteenth and nineteenth centuries, as successive generations tried to improve the presentation of their dynasty. Some remains got jumbled; some labelling got lost. Then, in 1945, anthropologist Giuseppe Genna disinterred 23 skeletons to make measurements that he hoped would support fashionable 'anthropometric' theories of psychological traits. The research was scientifically misguided and damaging: Genna removed all traces of flesh from the bones before returning them to their graves. Today's molecular biologists could have made much of those scraps.

Now the exhibition *The Medici* at the Reiss-Engelhorn Museum in Mannheim, Germany, charts the family's rise and fall, from founding father Giovanni di Bicci (1360–1429) to Anna Maria Luisa de Medici, the last of the clan, who died in 1743. It is Anna Maria Luisa whose crowned skull graced international news media last month (see http://go.nature.com/gws6g3).

The Medici: People, Power and Passion
REISS-ENGELHORN MUSEUM, MANNHEIM, GERMANY.
Until 28 July 2013

The exhibition has the familiar round-up of formal portraits, many on loan from the Uffizi in Florence, the world-famous art museum built for the Medici. The family was known from contemporary documents to have been plagued by disfiguring illnesses such as psoriasis, syphilis and arthritis, which, unsurprisingly, the flattering portraits do not reflect.

But the paintings are complemented by casts of the skulls of each of those pictured. Some were made by Genna, others after more systematic exhumations — of both bones and the pots in which the Medici interred the entrails of the deceased — carried out since 2004, when the Medici Project was launched. This project was a collaboration of Italian scientists and the culture ministry to assess any damage caused by the catastrophic flooding of the city in 1966, to identify which remains belonged to whom and to try to work out, using molecular biology, what the various individuals died from.

The exhibition weaves stories about each Medici from these scientific results and from analyses of contemporaneous documents. A couple involve murder. Beautiful, flirtatious Isabella (1542–76) was strangled by her jealous husband, with the apparent encouragement of her brother. Her bones were thrown into a mixed grave. Researchers managed to identify which skull was likely to be hers, and used forensic techniques to make a facial reconstruction for the exhibition that closely matches a contemporaneous portrait. It stands startlingly apart from the other oil portraits in its modernity and humanity.

Project scientists also managed to tentatively identify the entrails pot of Bianca Cappello, long-term mistress and then second wife of Francesco I (1541–87), whose bones have disappeared. Bianca and Francesco died within hours of each other. Scientists found traces of arsenic in their remains, lending substance to the historical claim that they were poisoned rather than dying of malaria as autopsy doctors declared at the time.

But it is the exhibition's centrepiece — the exhumation of Anna Maria Luisa — that propelled it into the headlines recently. When project scientists at the University of Florence opened the wooden coffin of Anna Maria Luisa last October, they were startled. Her skeleton was almost undamaged by the floods and topped by a crown — not the expected Medici death crown, but that of her husband's principality of Palatinate, in what is now Germany's Rhineland, where the museum is located.

The scientists used a three-dimensional scanner to replicate the skull for palaeoforensics, one of the first such applications of the technology. They removed a small fragment of bone to analyse carbon and nitrogen isotopes that might illuminate how rich the Medicis' diets were in meat and fish, and for DNA analysis to determine her cause of death. Documents from the time suggest it could have been syphilis or breast cancer. Researchers also took samples for DNA testing from an unlabelled pot of entrails that they suspect belongs to her. The exhibition will be updated should results arrive.

A final thrill for scientists visiting the exhibition is a relic of Galileo Galilei (1564–1642), on display for the first time outside Italy. Galileo depended on Medici patronage. To keep things sweet, he named the moons of Jupiter, which he discovered in 1610, the Medicean Planets. The relic — the astronomer's fifth lumbar vertebra — has spent decades in a safe box at the University of Padua. It was brought out in 2010 when NASA requested a fragment for its Juno mission to Jupiter. The Italian Space Agency, apparently fearing Vatican disapproval, declined. After the Medici exhibition, the relic will go on permanent display at the university. ■

Alison Abbott *is* Nature*'s senior European correspondent.*