and *in vitro* fertilization. I have relied on the generosity of colleagues who have helped to educate me — about how experiments involving human subjects or tissues are regulated in different countries, for example, and how ethical difficulties stemming from *in vitro* fertilization have been handled historically.

This year has been intense — and intensely fascinating. At times I have wished that I could step off the merry-go-round, just for a few minutes, to process everything. Ensuring that my travel and other commitments do not disrupt the progress of my lab members has been a priority, but working with them has increasingly involved meeting at night or on weekends, or conferring by e-mail or Skype. For now, time for my beloved vegetable garden and for hikes into the wilds of California with my 13-year-old son is gone.

Almost three years after a colleague warned me that a "tidal wave" of research, discussion and debate involving CRISPR–Cas9 was coming, I still don't know when the wave will crest. But as the year ends, there are some things of which I am sure.

BROADENING THE CONVERSATION

With only 18 attendees — all from the United States and most of whom were scientists — the Napa meeting could only ever be a starting point for a broader conversation. But the meeting, and the commentary that resulted, were important on two fronts.

By mid-2014, I was concerned that CRISPR–Cas9 would be used in a way that was either dangerous, or perceived to be dangerous, before scientists had communicated enough about it to the wider world. I wouldn't have blamed my neighbours or friends for saying, "All this was going on and you didn't tell us about it?" The *Science* perspective, and a related Comment published in *Nature* the week before[9], helped to convey the message that those leading the work recognized that they had a responsibility to voice concerns.

The discussion initiated by these articles — which grew more urgent when a study was published in April in which CRISPR–Cas9 was used to modify the genomes of non-viable human embryos[10] — also helped to set in motion the multitude of hearings and summits that have happened around the world since. The most prominent of these occurred in Washington DC earlier this month when the Chinese, US and UK science academies co-hosted a meeting on gene editing in humans.

> **"These discussions have pushed me far outside my scientific comfort zone."**

With science now so influenced by international collaboration, scientists can in principle shape the direction of the global scientific enterprise to some extent through self-censorship. It seems obvious to me now that engendering more trust in science is best achieved by encouraging the people involved in the genesis of a technology to actively participate in discussions about its uses. This is especially important in a world where science is global, where materials and reagents are distributed by central suppliers and where it is easier than ever to access published data.

I am excited about the potential for genome engineering to have a positive impact on human life, and on our basic understanding of biological systems. Colleagues continue to e-mail me regularly about their work using CRISPR–Cas9 in different organisms — whether they are trying to create pest-resistant lettuce, fungal strains that have reduced pathogenicity or all sorts of human cell modifications that could one day eliminate diseases such as muscular dystrophy, cystic fibrosis or sickle-cell anaemia.

But I also think that today's scientists could be better prepared to think about and shape the societal, ethical and ecological consequences of their work. Providing biology students with some training about how to discuss science with non-scientists — an education that I have never formally been given — could be transformative. At the very least, it would make future researchers feel better equipped for the task. Knowing how to craft a compelling 'elevator pitch' to describe a study's aims or how to gauge the motives of reporters and ensure that they convey accurate information in a news story could prove enormously valuable at some unexpected point in every researcher's life. ■ SEE NEWS REVIEW P.449

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Scientists must work harder on equality

Astronomer **Meg Urry** reflects on a turbulent year for women in science.

Gender equality in science made headlines repeatedly this year. Nobel-prizewinning biochemist Tim Hunt made his ill-advised quip about women in labs; Shrinivas Kulkarni, an astrophysicist at the California Institute of Technology, called astronomers and their telescopes "boys with toys"; and in a much more serious matter, astronomer Geoff Marcy resigned from his post at the University of California, Berkeley, after public disclosure that he had sexually harassed female students. More quietly, there were rumours that at least three astronomers had been dismissed, and in some cases scrubbed from institutional websites.

None of these incidents were in any way related to motherhood, which was — and is — too often invoked to explain the dearth of women in science. (Gender is of course neither binary nor necessarily stationary; that I talk about 'women' and 'men' in this piece is not meant to obscure that point.)

As the mother of two amazing women, I would say that family issues are the least of the problem. It is unquestionably true that employers must improve support of families, with progressive policies on paid parental leave, care of the elderly, high-quality on-site child care, and tenure 'clock stops'.

But if inequality were all about family issues, why has women's participation in the life sciences grown so much faster over the past three decades than in physics or engineering? (see 'Running the gauntlet'). Why, in the United States, where I have worked in the scientific enterprise for nearly four decades, does astronomy have twice the percentage of women that physics does, despite requiring a very similar skill set? And if fixing the disproportionate burden of family care on women is all that matters, countries that have strong family-support systems — such as Sweden and Denmark — would have greater participation of women in science than in the United States, which languishes near the bottom of parental pay and leave leagues.

It has been shown that women without children generally do not advance any faster or further than women with families. In their ground-breaking 2002 paper[1], 'Do Babies Matter', researchers Mary Ann Mason and Marc Goulden showed that women with children who remain in full-time academia are no worse off than women without children. Both groups lag well behind men — especially men with children, who lead everyone else.

Clearly, strong family-support policies are not the whole story.

CHAMPIONS AND CRITICS

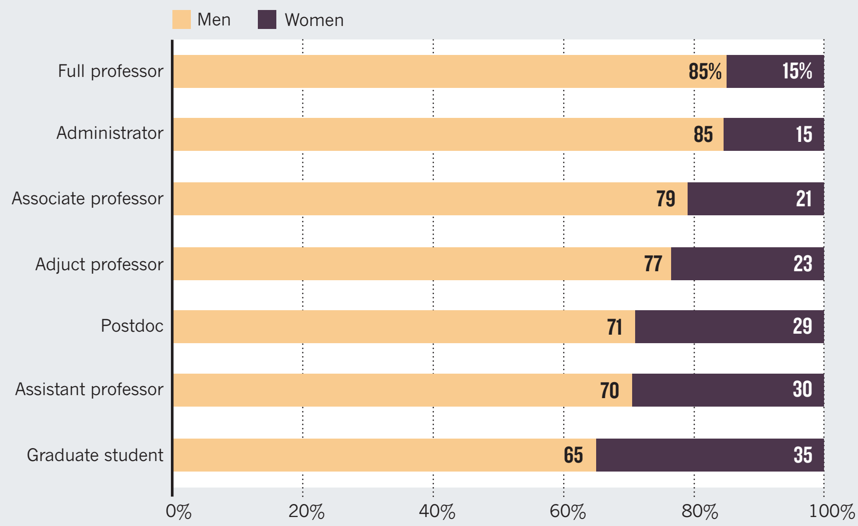
Every major criterion on which scientists are evaluated, for hiring, promotion, talk invitations or prizes, has been shown to be biased in favour of (white) men. These include authorship credit[2], paper citations[3], funding[4], recruitment[5], mentoring and tenure. For example, although women publish fewer papers than men, there is some evidence that on average they are longer and more complete, and that this difference vanishes if one corrects for funding level and research-group size.

Women in male-dominated careers face obstacles that are often invisible and usually unacknowledged (just read Virginia Valian's 1998 book, *Why So Slow? The Advancement of Women* (MIT Press) and the papers described in her annotated bibliography). I have experienced many of these obstacles. People often have a just a little more certainty that the man is a genius and a little more doubt that the woman will make the grade. Her contribution to the paper — was it her student's brilliance or her husband's work? Her work is risky and unlikely to succeed whereas his is revolutionary; hers is pedestrian while his is reliable. Men have champions; women have critics.

Letters of recommendation for women are shorter than letters for men. They are less detailed and are filled with 'grindstone' adjectives (such as 'hard-working', 'determined' and 'dependable') rather than superlatives ('brilliant', 'creative', 'outstanding'). They are more likely to mention personal characteristics ('likeable', 'friendly', 'helpful') and more likely to mention gender and parenting issues (for instance, "she did all this

RUNNING THE GAUNTLET

Just 15% of full professors are women in this snapshot of the gender balance in US astronomy in 2013.



SOURCE: AAS

work while having two children"). These differences hold true whether the writer is male or female[6]. Women are invited to give fewer talks and asked to sit on fewer scientific organizing committees and prestigious committees — yet they do much of the everyday committee work.

As a senior female astrophysicist, my proposals to use the Hubble Space Telescope — equivalent to winning funding of US$100,000 if granted — are less likely to succeed than those of my male colleagues (or my junior female colleagues)[7]. The difference is not statistically significant in any one review cycle, but after 25 years, it is clear that senior women are systematically less successful than their male counterparts, at a level of a few per cent per cycle. This is striking because almost all Hubble proposals are written by large teams that include both men and women, so the quality of the text does not depend on the gender of the principal investigator.

I am less likely to be nominated for a prize or honour[8]. I am more likely to be paid less (and was, for many years). In my experience, women are more likely to report having received gratuitously rude referee reports on their papers. (Whether the criticism is nastier or the sting is felt more acutely is not clear.)

Meanwhile, in my experience, women spend much more time teaching, mentoring and doing outreach than do their male colleagues. And this work is often not valued. One woman I know was described as having succeeded in her research "despite all the time she spent on outreach", as though her choice to attract girls to science was misguided. I would have described her as a superstar, who accomplished a very difficult (what some might call a 'highly risky') scientific measurement while creating an innovative new course and investing time in the future of her discipline.

And we wonder why the attrition of women remains greater than attrition of men at every level in the scientific hierarchy.

TIME FOR CHANGE

We should not forget that within living memory many Western democracies overtly — not just covertly — discriminated against women. Before 1969, some of the best US research universities did not admit women as undergraduates (two being Yale University in New Haven, Connecticut, and Johns Hopkins University in Baltimore, Maryland, where I was educated). Equal-pay acts were not passed until 1963 in the United States, 1970 in the United Kingdom, and decades later in other parts of Europe. As recently as 1990, there remained elements of voting that were open only to men in one part of Switzerland. When I first applied for assistant-professor positions about 25 years ago, some universities still had anti-nepotism rules, which were a real problem for scientific couples.

But gender inequality today is not about discrimination in the past. In the United States, institutes established since the 1980s are just as biased as the oldest in the land. California's Silicon Valley, which has flowered in the past few decades, has an abysmally low number of women in business leadership positions.

I have heard colleagues say, "women don't want faculty jobs — the work is too hard, it's incompatible with having a life". Apart from this being nonsense, the answer is not to ignore half of the brains. Rather, it is to create a more humane workplace, in which impact and quality of work have greater weight than monastic devotion and 100-hour work weeks.

What prompts people to conclude that women don't want faculty jobs? It is, in part, because the presence of women in the applicant pool for such jobs can be much lower than the fraction of women who are qualified for the positions — simply because men apply to many more jobs, on average, than women do. The low fraction of women has nothing to do with lack of interest.

Social-science research on confidence hints at why this might be the case (see, for example, ref. 9). Women tend to apply only to jobs for which they feel they have a fighting chance, either because the qualifications listed in the job advertisement match theirs or because the institution is one that they think they are good enough to join; men apply regardless. Recruiters should note that female applicants, being more selective in their attempts, are likely to be well suited to the position that they have applied for.

When I give a colloquium at a university whose physics department lacks female faculty members, I often ask: "Have you thought about hiring women?" The answer is usually earnest: "Oh yes, we definitely want to do that, but we want to hire the best." Do my hosts realize how insulting it is to imply those two goals are mutually exclusive?

Recently, a colleague worried openly about young men who, in the face of added competition from women, might not land that coveted assistant-professor position. If a woman of equal ability were hired affirmatively in place of a man, he suggested, the unsuccessful male applicant should be compensated with $100,000. My jaw dropped. By that reasoning, shouldn't we compensate the thousands of women or other underrepresented scientists who were preferentially not hired over the past 50 years, despite being as talented as — or substantially more so than — the men who got the jobs?

"What is missing is not ways to do better — but the recognition that we must change."

Rather than focusing on what young men are losing when they have to compete with talented women, we should be asking what research is losing by not having the full participation of women. Sometimes, science feels increasingly homogenous, with professors training graduate students to think like them, and sameness being valued.

As I (and many others) have pointed out several times, the failure to hire women and minorities in science is a guarantee that the best are not being hired. The old canard that there aren't any women or there aren't any people of colour does not hold up. When you look, they are there. And they bring talent that we desperately need, not to mention huge value as role models for students, who are so much more diverse a group than the faculty.

BEST PRACTICE

Many practical steps increase the likelihood of hiring and retaining women and other underrepresented scientists. For example, before evaluating applicants for a position, a search committee should agree on the set of desired qualities (subfield of research, teaching ability, publication record, contribution to diversity, ideas for student projects, research funding, and so on). When each candidate is evaluated in those categories, bias in the outcome is reduced.

Institutions can tone down elitist language in job advertisements without hurting their programme — status depends on quality, not adjectives. Women can be more likely to apply to institutions that describe themselves as 'collegial' and 'student-oriented' than 'top-rated' and 'world-class'.

Wherever possible, reviews should be done blind, so the reviewer does not know whom they are reviewing. A well-known example of the effectiveness of this technique is in orchestra auditions, where the proportion of women hired shot up when auditions were performed anonymously behind a curtain.

The literature abounds with other best practices for academia (see the United Kingdom's Athena SWAN Charter or the US National Science Foundation's ADVANCE programme).What is missing is not ways to do better — but the recognition that we must change.

Different ideas lead to scientific advances. Rome projected influence over a great empire, but did not foster a distinguished scientific enterprise: the greatest discoveries tended to come at the intersections of trade routes. Sameness leads to stagnation. We simply have to try. Harder. ■ SEE NEWS REVIEW P.451

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