TECTONIC MOVEMENTS

How cultural shifts can lift up women in science

For Women in Science

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FOREWORD

The world needs science and science needs women

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These past few months will be recorded in history as a time when the global liberation of women's voices accelerated in the worlds of cinema, politics, the not-for-profit sector and even business. Yet, there is one sector where women's voices have remained astonishingly silent: science. This despite the fact that science faces the kind of disparity about which we should all, as a society, be concerned.

The proportion of women engaged in scientific careers has grown, albeit too slowly. Many still come up against obstacles to accomplishing long and flourishing careers, achieving positions of responsibility or gaining access to funding. As a result, in the European Union, for example, only 11% of senior roles in academic institutions are currently held by women. Less than 30% of researchers are women and only 3% of Nobel Prizes for Science have ever been awarded to women scientists. How can we explain that after years of fighting for gender equality, the under-representation of women in science should still be so glaring, and above all, what are the consequences for our world?

They are numerous and we must collectively seek to understand them, as much for the society that we want to build, as for the advance of scientific progress and knowledge, which is critical to solving the great challenges of our time.

The absence of women has had and will have major consequences. Let's take two fields of scientific application.

First, in the area of health care, there are many examples of the consequences of under-representation. Have we finally gotten over, for example, the idea that cardiovascular illnesses are a masculine issue? As recently as 1999, doctors examined half as many women for cardiac illness as men. What's more, many clinical trials on reducing risk factors have been led exclusively by men. The result? The landmark study on aspirin as a means of reducing the risk of cardiac arrest included more than 22,000 men and not a single woman[1]. Sadly, this led to inappropriate treatment for women.

Second, and just as concerning, is the digital revolution. Men's control over key technologies has implications for women. In the early stages of voice recognition, for example, men dominated software development. Consequently, the number of transcription errors when women used voice recognition applications was considerably higher than amongst their male counterparts. Now, along comes artificial intelligence (AI), which will have a profound effect on our future. We haven't learnt from our mistakes. Sure enough, studies have shown that AI-powered image banks, developed mostly by men, associate women with domestic tasks and men with sport[2]. Indeed, image recognition software not only reproduces these prejudices; it amplifies them. Unlike a person, an algorithm cannot fight consciously against acquired prejudices. As AI gradually pervades our lives, the issues will only become more acute. If we use robots to shape our world in the near future, it is vital that they should be programmed by men and women.

The takeaway is not that women would be better scientists than men, but rather that we have to be conscious of our need for a more gender balanced scientific community. The decision is between depriving ourselves of valuable creativity and talent, or designing a more inclusive society through scientific progress. The choice is clear.

We commissioned this report with that choice in mind, to inform the future focus of the L'Oréal Foundation's work. We reached out to over a dozen experts around the world to inform this report in the spirit of building coalitions. We owe a debt of gratitude to all of them. Creating coalitions for a more inclusive science is urgent, in order to best address the challenges facing the world, while advancing knowledge for the benefit of all.

The world needs science, and science, more than ever, needs women.

Alexandra Palt

Executive Vice President of the L'Oréal Foundation.

For 20 years, the L'Oréal Foundation has worked to empower women in science, through a programme of recognition for brilliant women scientists called 'For Women in Science'. The programme is implemented globally in partnership with UNESCO. The Foundation also raises awareness of scientific careers amongst school pupils in France. In March 2018, the L'Oréal Foundation is launching an initiative called 'Men for Women in Science', calling male scientists to take action to empower women in their institutions by signing a charter. More than 25 male scientists occupying key positions within the scientific world have already joined the initiative.

INTRODUCTION

How cultural shifts can lift up women in science

This report, commissioned by the L'Oréal Foundation, examines the state of gender balance in science, taking stock of emerging solutions and promising areas of further investigation. It supports with empirical research the programmes of the L'Oréal Foundation, including the L'Oréal-UNESCO FWIS scheme.

The Age of Enlightenment brought a scientific revolution that led to our modern practice of science. It was accompanied by the important notion that humanity could improve itself by responding to rational thought.

Lately, however, our scientific output has begun to flag, at a time when the stakes for humanity grow larger. We're relying on the scientific community to help solve existential crises. For example, anti-microbial resistance threatens modern medicine. And the climate change we've effected through our industrial economies may surpass humanity's capacity to cope, as the atmosphere warms to levels never experienced by modern civilisations. It is a moral imperative for us to raise the effectiveness of our scientific research and spark a new scientific revolution to help humanity improve itself once again through rational thought.

That revolution will require us to unleash all of human potential on scientific endeavour. And yet, we are currently struggling to resolve one of the more obvious imbalances in science: the gender gap. Girls and women are entering scientific study at rates similar to their brothers, but they systematically leave at critical junctures of the education and scientific careers pipeline at higher rates. How can we hope to spark a scientific revolution if we continue to push away half of humanity?

Research on gender imbalance in science has tended to focus on those critical junctures and on important issues of bias. But despite the best intentions of leaders and scientists, the imbalances of our scientific research institutions have persisted. Cultures are slow to change.

Addressing culture change is the key to addressing gender imbalances in science. Our own research revealed that, rather than focusing on cultural biases at critical junctures, change is more likely to occur when scientific institutions take a systems view of the imbalances. It's not enough to point to self-confidence issues, harassment or bias at discrete parts of the career track. Academia's gender imbalances stem from the interaction of many factors: some unique to science, such as highly structured and closed career paths; others specific to academia, like rigid hierarchies; and still others, like unconscious bias, found across society.

The interactions amongst cultural biases need to be addressed simultaneously. Strategies and initiatives that have been successful, to a degree, can be combined in the right measures within an institution. Initiatives designed to combat combinations of cultural factors, some of which we outline here, can be successful in re-balancing the gender equation in science.

Why the world needs More women in science

Science and technology, and in particular basic research, are part of the foundation for economic development and societal well-being. Recent evidence suggests however, that innovation and technological progress are becoming more expensive and labour-intensive, requiring more researchers to achieve the same degree of breakthroughs than in the past. Research productivity is falling by half every 13 years[3]. Put differently, we need to double the number of researchers every dozen years if we are to improve our scientific output.

Scientific research doesn't occur in a vacuum. It's directed not only to advance our basic understanding of how the universe operates, but also to achieve normative outcomes that benefit society and humanity. The challenges facing society and humanity are enormous in the life sciences, in physical sciences and in other disciplines.

Research also drives the economy. The OECD found that the long-term elasticity of government and university-performed research on multi-factor productivity is 17%, even higher than for business R&D[4]. In the United States, as in many other countries, science and technology-related employment is growing faster than the overall job market. The U.S. Bureau of Labor Statistics projects that 853,600 new science and technology jobs will be added between 2016 and 2026, a growth rate roughly 1.5 times faster than that of the overall workforce[5].

To boost their research and meet their employment goals, countries can't afford to neglect the talents of half their population. In India, for instance, women make up only 14% of researchers[6]. Research done by BCG and the L'Oréal Foundation finds that there are 300,000 'missing' doctoral degree holders a year across 14 developed and developing countries studied. If women began to earn doctorates at the same rate as men, within 15-20 years there would be 3 million more PhD holders contributing their skills to progress.

How gender diversity leads to better science & stronger institutions

Neglecting talent has real consequences for scientific innovation and economic productivity[7] For example, women held fewer than one in five patents – a measure of scientific output – in 2010 according to a 2016 report from the Institute for Women's Policy Research. And they made up just 8% of primary inventors[8]. Globally, women make up less than 30% of workers in STEM fields[9].

This imbalance of women as researchers and innovators represents more than a loss of talent and skilled labour. There's also evidence that gender diversity tends to coincide with better science. Peer-reviewed ecology publications with gender-diverse teams of co-authors received 34% more citations than publications by more gender-homogenous teams, suggesting that scientists judged the former papers were higher quality[10]. That effect could come down to diversity in the teams. Or, it could be due to underlying causes; academic institutions that do well on representation and fairness may be likely to perform strongly elsewhere too. In R&D, too, gender-diverse teams are more innovative: a Spanish study of 4,277 companies found that those with more gender-diverse R&D teams were more likely to put radical new innovations on the market in a two-year period[11]. The overall evidence for a business case for diversity in STEM is mixed, a 2014 Royal Society report finds; the impacts of increasing diversity are contextual, and research quality may improve not by increasing diversity per se, but through the changes in culture, leadership, behaviour, norms and values that underpin successful diversity initiatives[12]. Gender imbalances also perpetuate the gender biases built into research and testing. For example, US and European automobile crash tests do not require the use of pregnant crash test dummies, even when 82% of US foetal deaths with known causes result from motor vehicle collisions[13]. Medical science failed to realise until the last few decades that heart disease in women looks different from that in men, leading to misdiagnosis or under-diagnosis[15]. And because clinical trials do not always include equal numbers of men and women, the effects of new drugs on women may not be adequately studied. Between 1997 and 2001, eight of the 10 prescription drugs released in the US had to be recalled because they posed greater health risks for women than men[15].

Of course, there's nothing stopping male-dominated research teams from considering gender in their design of scientific studies, products or services. But this has historically not been true. And there is a clear link between increased women's authorship on studies and the integration of gender and sex analysis into medical research. When researchers examined more than 1.5 million medical research papers, they found that papers with women authors were more likely to include gender and sex-related factors in their analysis[16].

Finally, even though plenty of evidence supports the merits of bringing more women in science, programmes that overtly support women are often perceived – by both men and women – as tokenism, diffusing or sacrificing scientific excellence for diversity. However, we argue that supporting women in science simply levels a playing field that has long been greatly skewed, and correcting this imbalance helps drive scientific excellence.

> *“More visibility and representation may lead to greater diversity in public support as more people see themselves represented in science.”*
>
> – Dr Maryam Zaringhalam
> of the US grassroots network 500 Women Scientists, which is dedicated to training diverse leaders in science

THE STATE OF WOMEN IN SCIENCE

THE GENDER GAP GROWS BY LEVEL OF SENIORITY:

GAPS BEYOND THE NUMBERS:

Beyond a lack of representation, women in science have less stable employment, less pay and less power than men.

Women in scientific research are more likely to be on fixed-term contracts of one year or less, or no contract at all

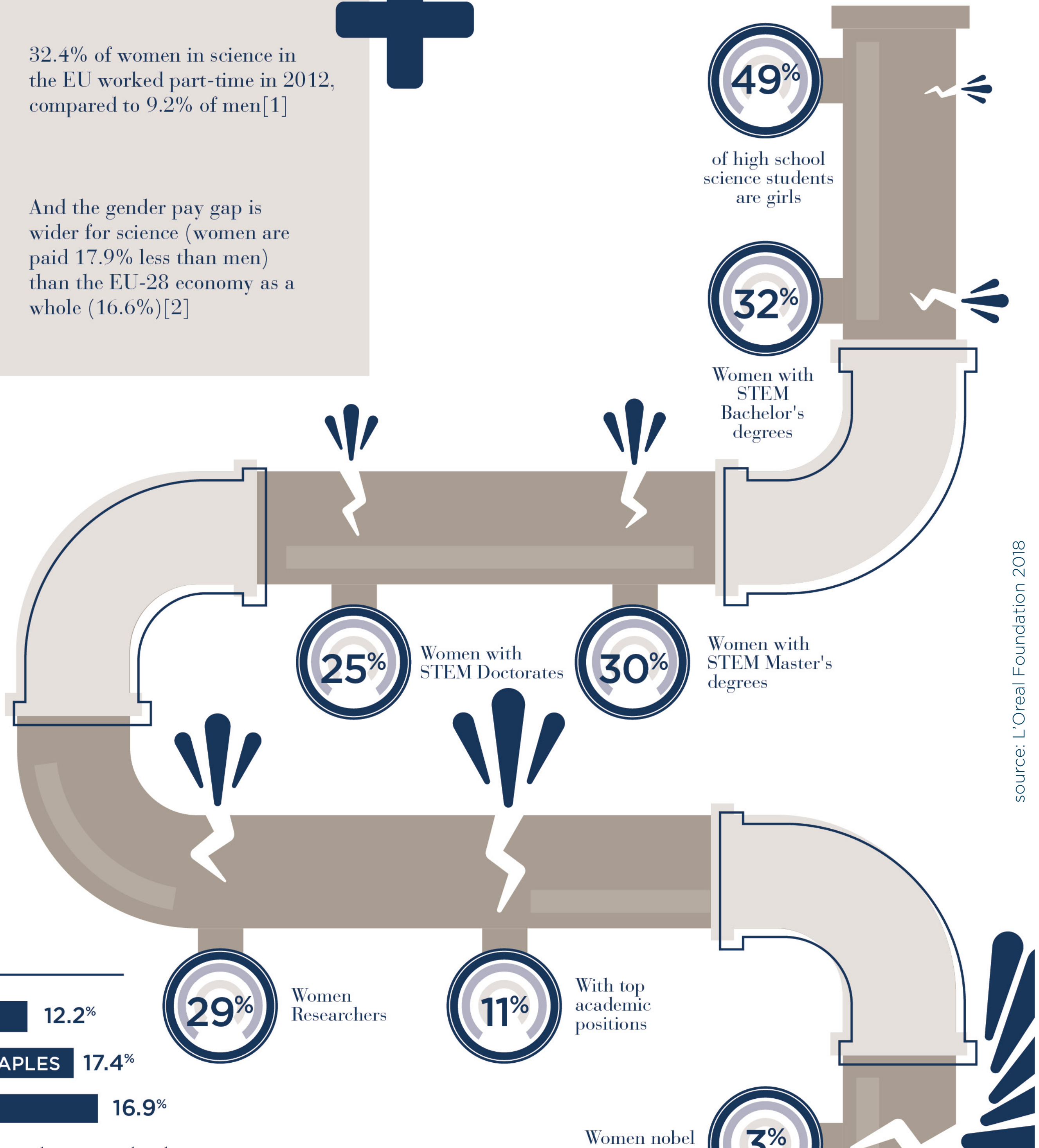
32.4% of women in science in the EU worked part-time in 2012, compared to 9.2% of men[1]

And the gender pay gap is wider for science (women are paid 17.9% less than men) than the EU-28 economy as a whole (16.6%)[2]

SCIENCE CULTURE
- Closed hiring & promotion systems
- Linear, path-dependent pipeline
- Keen competition
- Long training with little security

ACADEMIC CULTURE
- Gendered organisational norms
- Funding & power
- Lack of transparency

SOCIETAL CULTURE
- Stereotype threat
- Unconscious bias
- Harassment
- Gendered workplace expectations
- Outdated expectations about career & family



IT INDUSTRY	12.2%
CONSUMER STAPLES	17.4%
FINANCIALS	16.9%

Women are less well represented on corporate boards in STEM sectors[3]. In 2015, they made up only 12.2% of corporate boards in the information technology industry, lower than industries such as consumer staples and financials.

Sources:
[1] SHE Figures, 2015
[2] SHE Figures, 2015
[3] Renee B. Adams and Tom Kirchmaier, "Women on Boards in Finance and STEM Industries," American Economic Review, vol. 106, no. 5 (2016).

source: L'Oreal Foundation 2018

Is the leaky pipeline a useful visual construct?

The image of a pipeline with 'leaks' at various points along the way is often used to describe the problem of achieving gender equality in STEM. The pipeline metaphor has long been used to describe STEM careers, implying that a certain quantity of entering students is needed at one end to produce sufficient graduates or researchers at the other. Girls and women are thought to drop out at various stages of an academic science career, pushed out by a buffet of challenges, from internalised stereotypes about scientists, to unconscious bias in hiring or publishing, to the opacity of the tenure process itself.

The pipeline model is a useful construct to allow us to visualise the critical junctures in a career at which women tend to leave:

- **At the secondary education level:** In secondary school, by the OECD's PISA (Programme for International Student Assessment) test results, girls and boys are equally prepared and qualified in STEM subjects. Indeed, they outperformed boys in 22 of 72 countries where the PISA tests were administered. However, an OECD study found girls and boys had different expectations about their future careers; girls were more than three times as likely as boys to expect to work in health professions, while boys were twice as likely to expect to become engineers, scientists or architects[17].

- **Entering higher education**: Women receive 32% of STEM Bachelor's degrees around the world, according to a BCG-L'Oréal study. That figure differs across disciplines; in many biological and medical subjects, women outnumber men. Just a quarter of STEM PhDs are awarded to women. That research also found that the gap between men and women studying STEM subjects begins roughly when students transition to university, depending on the discipline.

- **Entering a research career:** Women are also more likely to leave STEM after receiving their doctorates. Globally, women make up less than 30% of those in research careers.

- **After postdoctoral training:** In the biomedical sciences, women constitute approximately 45% of postdoctoral fellows at universities and research institutions in the United States, but only 29% of tenure-track principal investigators[18].

- **Tenure and beyond:** Women may not drop out of science while and after they get tenure, but they may not thrive, either. In US universities, women make up 43% of doctorates working in science, engineering and health roles 10-14 years after receiving their degrees. That figure drops to 29% for those 15 years after their doctorate[19].

The pipeline model has its uses, in helping to imagine the points where women leave the traditional scientific career track and to be able to measure progress. However, the pipeline construct also has its limits. First, it assumes that career paths are linear and one-directional, and that individual scientists seek to remain on these career paths. Such a model posits only two types of solutions; increasing capacity at the front end and plugging the leaks along the way.

Yet today's career paths are not necessarily linear; they may be more of a 'jungle gym' than a 'ladder'[20]. To be sure, almost all academic STEM leadership is path-dependent: it's nearly impossible to become the dean of a faculty or chair of an academic department without a PhD in the relevant subject, tenure and years of service. But referring to a 'leaky pipeline' implicitly devalues anyone who elects to leave. It does not acknowledge the necessary and valuable contributions of women and men scientists who bring their skills to other contexts; government, industry, entrepreneurship and elsewhere. Policymakers set the tone for research nationally and regionally, and much high-impact innovation stems from industry and its symbiotic relationships with academic research. While we focus in this paper on gender equality in academic STEM, a broader question might be: how might women scientists in academia, as well as those who have 'leaked' from the academic pipeline into other sectors, strengthen conditions for women in academia and contribute in valuable ways to the state of scientific knowledge?

"It's important that we don't just define success in science as success in academia," Nature editor Helen Pearson told us. "If you train to a very high academic level, like a PhD, you can take that knowledge and skills and use that in many important and valuable ways in society. It might be science-related, it might be politics – you mustn't devalue those contributions to society." She also suggested STEM academia could learn from diversity practices and women's leadership experiences in other sectors, such as the corporate world.

What's more, the metaphor of the linear pipeline does not fully explain the impact of underlying, external factors. It shows where and when women leave academic science careers, but fails to explain why – and the why is as important, or more important, as when. Are they victims of harassment? Or are the reasons less malignant, such as a desire to apply one's skills to policy or communications, or getting a job offer from industry that is more attractive than a short-term postdoctoral contract? The pipeline model doesn't show, either, how addressing those underlying external factors may address leaks at multiple points simultaneously. A dedicated university initiative to reduce bias in hiring and leadership promotion halts leaks at multiple stages, and also creates conditions that are conducive to retaining younger women scientists.

> *"It's important that we don't just define success in science as being just success in academia. If you train to a very high academic level, like a PhD, you can take that knowledge and skills and use that in many important and valuable ways in society. It might be science related, it might be politics – you mustn't devalue those contributions to society."*
>
> – Helen Pearson, chief magazine editor for Nature

Rather, we could consider careers as part of an ecosystem, in which changes to some parts have an impact on other parts. To provide effective solutions we need to understand how different ecosystem forces and factors interact to put pressure on scientists throughout their careers. These include factors unique to the culture of science or academia, such as tenure and promotion metrics, and other societal and cultural forces, such as unconscious bias or harassment.

Culture creates pipeline stresses

We asked a series of STEM academics, STEM diversity practitioners, gender diversity experts and others to talk about the systemic factors that influence why women leave, as well as potential solutions that take a systemic view. It's not enough to say 'the system is sexist' and provide a list of examples from discrete points in the career pipeline. Rather, an understanding of the ecosystem – of how cultural factors in science, academia and society combine to discourage women – will be important for establishing how to retain them in greater numbers. Some factors do involve inherent gender biases; others are not gendered, but they interact with others to produce gender-unequal results.

Science culture: the one-track mind

Academic science careers are **linear paths**; without a PhD, you can't go on to do a postdoctoral fellowship. Without a postdoc (or several) you can't secure a tenure-track job. Without tenure, forget about a leadership position in a university department. And they're path-dependent; if you begin your career studying a specific topic like Arctic climate or a specific organism such as yeast, expect to continue in the same vein for at least some time.

STEM's **closed hiring and promotion** are a related factor. Though they are employed by universities, faculty members are essentially self-employed in that they must source their own grants and sustain a record of publications, making career breaks difficult. Meanwhile, there are lots of off-ramps, but no on-ramps for people who wish to return to science after leaving.

Closed systems lead to **ongoing gender disparities**. The largest gender gaps were in the labs of the 22 male Nobel Prize winners included in one study. Male postdocs outnumbered women three to one. This can create gender disparities in future hiring, because where a candidate is trained and by whom has enormous influence on his or her hiring potential[21].

Additionally, a survey by the UK's Royal Society of Chemistry found that women saw academic science careers as **too all-consuming and solitary**, and not collaborative enough[22]. During their doctoral studies, they were also more likely than male counterparts to have had little pastoral care or have had to cope with a supervisor who lacked interpersonal or management skills. Moreover, they were more likely to experience a lack of integration with their research group, isolation and exclusion (and more rarely, bullying), or to have been been uncomfortable with their research group's working patterns, time, level of competition and expectations.

Keen competition for academic jobs – there are too many PhDs and not enough academic positions – is limiting. In the US, for instance, only about 26% of PhD students eventually move into tenured or tenure-track positions. Yet many PhD students harbour unrealistic expectations. A 2015 Nature survey of more than 3,400 science graduate students around the world suggested that many were overly optimistic about their chances in academia. About 78% of respondents said that they were 'likely' or 'very likely' to follow an academic career, and 51% thought that they would land some type of permanent job in one to three years[23].

That level of competition also pushes early-career researchers to do multiple postdoctoral fellowships to bolster their resumes before applying for faculty positions, said Weill-Cornell Medicine Qatar associate dean of research Dr Khaled Machaca, which adds to the length of their training. **Long training with little security** may be a turnoff for scientists who don't wish to move themselves and their families around the globe, or who watch non-academic peers climb the career ladder much earlier, particularly in an economic climate where job security is valued. "Most scientists in the biomedical field don't get their first 'real' job until they are in their late 30's" added Dr Machaca.

Finally, science assumes it is a gender-neutral meritocracy, and its leaders and practitioners may assume that outstanding scientists are already being identified and rising to the top, said Professor Abigail Stewart, the Sandra Schwartz Tangri Distinguished University Professor of Psychology and Women's Studies and former director of the University of Michigan ADVANCE/STRIDE programme to improve campus environment and faculty diversity from 2001-2016. However, that **complacency** causes leaders and practitioners to doubt the value of efforts to boost diversity. "We stress [to faculty] that we endorse the goal of excellence, and that we don't see diversity and excellence as opposed; we agree that of course every department is searching for the best scientists but up till now, we have been populating our departments with bias that has led us to an unequal situation," she said.

Academic culture: inside the ivory tower

Academic organisations often fall into familiar gendered patterns. Ethnographic studies in the US point to **gendered academic norms**: professors and institutions assume the 'ideal' or default math or physics student is a young, middle-class, white male, one with no financial constraints or caregiving responsibilities[24]. That's not what today's classroom looks like[25]. Likewise, university departments may fall into gendered assumptions about labour, making early-career women faculty teach more introductory courses, which takes time away from their research[26]. Similarly, women spend more time on service work in their departments than their male counterparts; they are also appointed to multiple administrative-leadership positions earlier in their careers than male counterparts. That detracts from their research and hampers progression as administrative roles are not rewarded[27]. There's also **funding – and its relationship to power**. In some disciplines, the funding that pays for graduate stipends is controlled by a student's supervisor, concentrating power in the supervisor's hands. In others, graduate students get funding from multiple sources, including teaching assistantships and other grants, which empowers them and gives them more flexibility to leave or switch supervisors if they face harassment or bullying.

Finally, our interviewees agreed that academic institutions could have **more transparent and swifter complaint investigations**, such as in cases of harassment or assault. When it comes to investigating and addressing harassment, "In some ways, corporate environments do this better than academia," said Dr Kathryn Clancy of the University of Illinois at Urbana-Champaign. "They have much faster turn-around." At the same time, she added, due process is still necessary, and universities should not necessarily be fully corporatized either. The tenure system may also make it difficult to remove harassers[28]. Some suggest there are lessons from the corporate sector here; women in flatter, less-hierarchical biotech firms are eight times more likely to hold supervisor positions than those in more traditional organisation structures – and paths to progression based on business outcomes, like the creation of new intellectual property, are less susceptible to biased evaluation[29].

Science doesn't exist in a vacuum: milieu matters

Bias in society is not limited to science, of course. Societal norms also colour women's experiences in STEM.

To begin with, girls in school (and beyond) may face **stereotype threat** in which they conform, subconsciously and unwillingly, to prevailing stereotypes when reminded of their identity as female. Stereotype threat occurs when negative stereotypes about a group, such as 'girls can't do mathematics', raise doubts and anxieties that subconsciously affect group members' ability to perform. So, for example, when test-takers are told a mathematics test shows gender differences, women perform worse than men. This manifests later in careers as 'imposter syndrome', in which a lack of confidence inhibits the pursuit of key career enhancers, such as speaking engagements.

Early-stage pipeline measures often take aim at stereotypes, enlisting role models and girls-only STEM programmes to boost girls' confidence and increase the number of girls who view science and engineering as a viable career path. That may work in some subjects or fields where the pipeline narrows at an early stage. But at UK universities, the women enrolled in some science subjects outnumber the men, yet disparities persist at the top[30], so early-stage steps to boost pipeline capacity may not be enough.

Later in careers, **workplace expectations** and demands implicitly cater to men with stay-at-home spouses. Workers in many professional jobs work longer hours than ever; a third of college-educated American men work 50 or more hours a week[31].

At the same time, **outdated attitudes persist about work and family**. A Harvard Business School study found that while its female graduates expected their careers would take equal priority as their spouses', the majority of the men still assumed their careers would take precedence, and that their spouses would do most of the child-rearing[32]. It's not known if such disparities in beliefs are as prevalent amongst men and women in science, but such attitudes certainly play out in practice in the US, where women more than men adjust their careers for family life[33].

And widely prevalent **sexual harassment** has been revealed in industries from media to government; science is no exception. In many STEM fields, field research is an integral component of scholarship, but women face sexual harassment and assault in hostile field environments. A 2014 survey of 666 scientists found that 70% of women and 40% of men had experienced harassment in the field, while 26% of women and 6% of men had been assaulted[34].

Finally, the **gender biases in hiring** found elsewhere are also found in science. Those biases perniciously include unconscious biases that are unrecognised by those making decisions. In an experiment, researchers submitted fictitious student resumes for a lab manager position with the name changed – on half the applications, the candidate was 'John', on the other half, 'Jennifer'. Both male and female science faculty rated the male student as more competent and hireable, offered a higher starting salary, and offered more career mentoring. Another qualitative study uncovered persistent biases in junior faculty hiring, such as factoring in (illegally, in the US) the relationship status of women candidates but not men[35]. In hiring interviews, faculty members may think asking about family plans is small talk that makes candidates feel more comfortable, but instead it pushes them away.

Indeed, biologist Nancy Hopkins of MIT outlined the extent to which prevailing norms, stereotypes and biases can be internalised by even women scientists themselves in this anecdote about her advisor, James Watson:

> *“The science drew me to Jim's lab every available moment. I lived in a state of euphoric scientific excitement. Jim told me repeatedly I should be a scientist. I knew I couldn't live without this science, but how could I be like these men? Even postdocs had wives who stayed home to care for their children while the men put in 70-hour weeks at the lab. Who would care for my children? I knew I would have to give up science before I had children: in the era before amniocentesis, that meant before the age of 30. So I made a plan: do the most exciting science possible as fast as you can, hope you do a Nobel Prize-winning experiment before the age of 30, then retire and be a wife and mother... ”*

> *Given such an auspicious start, no wonder I didn't see any gender discrimination in science. But looking back, it's hard to understand how I could have been quite so slow to recognize that a profession in which half the population can't participate equally and also have children is by definition discriminatory. I saw the family–work problem as a biological one – a woman's choice, unfixable. It would be years before my colleague, Professor Lotte Bailyn, helped me see that the way science careers and institutions are structured is an artificial and hence changeable system designed by men, for men, in an era when men had full-time wives to care for their families.*

—Nancy Hopkins '50 years of progress for women in STEM',DNA and Cell Biology (2015).

Developing and non-Western economies: the picture for women in science

Addressing the challenges for women in science is context-dependent; programmes and interventions must take into account different cultures and varying levels of geopolitical support both for women and for science in general. Some countries invest heavily in science training as part of a knowledge-based economic strategy, producing many women PhD graduates but lacking programmes specifically targeted at retaining them. Others may be woefully under-resourced, with few resources to devote to research at all.

Even in Western countries, the argument arises that funding and resources should be devoted to areas that are integral to science overall, rather than gender-equality programmes[36]. On the other hand, retaining women in science is necessary to ensure that investments in basic science training are well-spent.

IN FOCUS: KENYA: RESEARCH IN UNDER-RESOURCED ENVIRONMENTS

Research on Africa is typically done by those from outside Africa, said Dr Rose Mutiso, co-founder of the Mawazo Institute, a non-profit supporting women's academic research and thought leadership in Kenya. Data on women's career paths in science is sparse, but Kenya produces roughly 300 PhDs a year across all disciplines out of a population of 48 million. 26% of its researchers are female. Male-dominated Kenyan culture also poses extra constraints for women; for example, women may be less able to move freely or leave the country for further education and training due to family commitments, and they may face open bias and hostility in the culture of universities and science departments.

In such an under-resourced environment, laboratory-based science fields may not get the resources and equipment they need, and getting training in these fields is challenging for both men and women, Dr Mutiso said. Less resource-intensive fields such as mathematics and computer science may provide more opportunities for aspiring scientists.

Challenges which confront women in science also vary across and within African countries, where science uptake is generally low, said Dr. Peggy Oti-Boateng, senior programme specialist for science and technology at UNESCO's Office for Southern Africa and Coordinator for the African Network of Scientific and Technological Institutions (ANSTI). Some regions don't have adequate systems to train or support scientists at all, and aspiring scientists must travel abroad to study. For those who cannot afford to leave, or who have family care or other obligations, this is a major barrier. For others, relocating takes away systems of social support which would be crucial to achieving their goal.

In addition, attitudes about women in science even from teaching staff can be negative. Dr Oti-Boateng has encountered many teaching staff who think women are incapable of doing well in science; in that context, she believes it's essential for women to have strong social support to stand a chance of ascending to professorship.

How cultural clashes magnify inequity

None of these cultural factors alone – not closed systems of hiring, nor outdated attitudes about work and family, nor harassment, nor anything else specific to one geography or another – is responsible for the departure of women from science. Long hours and lengthy training have not deterred women from becoming doctors or pharmacists, nor has fierce competition deterred them from seeking careers in biomedical sciences where they outnumber men at entry level. Much paid employment remains implicitly structured for people with stay-at-home spouses, yet this does not deter women from remaining in the labour force; in the US, 70% of women with children under 18 are in paid employment and three-quarters of those work full time[37].

These cultural stresses and their interactions help explain why some interventions to boost gender parity in science, as well-intended as they are, fail. Measures that operate at only one point in the pipeline are not effective if they fail to take into account how culture influences earlier or later stages. For instance, early-stage pipeline interventions such as increasing girls' interest in science, are useful and sustainable only if the deep and structural patterns of discrimination that exist in science and academia at later stages are properly addressed. Meanwhile, career coaching workshops that try to help women succeed may be less effective in environments where hiring and funding bias persist. And universities may provide well-intentioned policies to pause the tenure clock for parental leave, but when men continue to assume their spouses will make concessions for them, that leads to unequal outcomes: men simply use this extra time to write more[38].

However, broader societal mores - the culture of academic institutions and the culture of science - appear to interact in ways that are especially damaging to gender equality. Here are some examples that may force girls and women out at various stages of a scientific career.

Example 1: **Gendered academic norms** interact with **outdated attitudes to work and family** and **gender biases in hiring**

Women constitute approximately 45% of the postdoctoral fellows in the biomedical sciences at universities and research institutions in the US, but a much lower percentage of women hold faculty positions. In the US National Institutes of Health Intramural Research Program, for example, women make up only 29% of the tenure-track investigators and hold just 19% of the tenured senior investigator appointments. Research chalked this discrepancy up to family demands and self-confidence and found that 30% of male respondents expected their spouse to make concessions for their career paths, compared with just 15% of women[39].

Clearly, many men's attitudes haven't caught up with the fact their wives work. But 72% of full-time faculty and 74% of full-time women faculty have employed partners, many of them fellow scientists[40]. When women (and indeed men) are hired, universities may need to raise the question of dual hiring and have clear dual-hiring policies. If women are forced to sacrifice their careers for their spouses', both they and their prospective employers lose out.

In addition, the structure and demands of the academic workplace, such as travel requirements or expectations that researchers be fully devoted to their work, weigh more heavily on women, who disproportionately bear the burden of household management and caring for dependents[41].

Example 2: **Gender bias in hiring interacts with the too all-consuming and solitary pressure to publish and shapes the output on which a researcher is judged for tenure**

Even after a woman is hired on the tenure or principal-investigator track, the effects of unconscious bias accumulate over time to hold them back. Women in science receive academic grants at a lower rate than men in science, compared to social science where funding patterns are more even[42]; women scientists receive on average less than half the startup funding of male scientists[43]. Women are also requested as journal reviewers less often than men[44]and are invited to speak at conferences less often[45] [46]while author gender has been shown to have an impact on the perceived quality of a paper[47].

Meanwhile, there seems to be a distinct 'baby penalty' for women academics. Women with children under age six were 15% less likely than childless counterparts to obtain tenure, and 25% less likely than male counterparts with children under age six[48]. Even where universities provide the option to stop the tenure clock for family reasons, women may opt not to take advantage of them for fear of hurting their careers[49].

Example 3: **Stereotype threats and gender bias in hiring influence women's promotion and leadership – and a lack of representation has repercussions for future generations**

While women don't necessarily leave their jobs at the stage when they might potentially transition to leadership, they find that pathways to promotion and leadership are unclear. They may also bear more teaching and service responsibilities than male colleagues, including serving as the sole female representative on a large number of committees[50]. The criteria for promotion to leadership may not be clear, which opens the door for promotion based on vague criteria (and influenced by stereotypes and unconscious bias) rather than straightforward expectations[51].

At the same time, a dearth of women in leadership has implications for women aspiring to successful careers in science, who see few role models. This also has implications for women leaders themselves, who unlike men bear the burden of having to represent their entire gender. For instance, science communicator Maryam Zaringhalam, of the US grassroots network 500 Women Scientists said: "When I get invited to speak on panels, the conversation often leads away from my science or policy interests towards the many struggles that women have in science. I'm excited to go and talk about my work or my interests, but end up being asked about all the different ways I've been abused or harassed in science while my male co-panellists are asked about their expertise. It's not a conversation I want to be obligated to have when I have my own expertise I'm excited to share."

Example 4: **Sexual harassment interacts with science culture's closed systems of hiring and promotion and linear career pipelines, as well as funding – and its relationship to power**

Sexual harassment is an issue throughout the pipeline; harassment in the field has been found to occur most often to female undergraduates, graduate students and those in other junior positions.

However, this may vary by field of study. Research on astronomy and physics found that women of all ranks, including faculty and senior positions face the same verbal and physical harassment, and were equally likely to avoid meetings, fieldwork or other professional events because they felt unsafe[52].

Dr Clancy notes that the unique dependence of STEM students on their advisors, for funding and elsewhere, can prevent them from feeling like they are able to report experiences of sexual or other harassment: "You have to make reporting mean something. It must lead to consequences." It also makes a difference whether the bulk of a PhD student's funding is controlled by her advisor, or whether she receives it through grants and teaching assistantships.

Harassment may be particularly devastating at early stages of women's careers, when women researchers are less likely to report issues due to fear of repercussions or lack of disciplinary action, and are thus most vulnerable.

Even when victims of harassment do report it, they may lose access to data or expensive shared equipment that a harasser controls, then leave science as the time and effort they've invested in their particular field amounts to little without that access.

IN FOCUS:

INTERVIEW WITH DR. KATHRYN CLANCY

We interviewed Dr Kathryn Clancy, associate professor of biological anthropology, University of Illinois at Urbana-Champaign. Dr Clancy also studies the prevalence of harassment in STEM. Note: This Q&A has been edited for length and clarity.

How did your research on harassment begin?

A friend of mine told me about her experiences with being sexually assaulted; she had flashbacks and trauma that inhibited her ability to finish her degree. When she told her advisor, she was believed, but her advisor discouraged her from pursuing action in case they lost collaborator data.

I was invited to give a talk on it at the American Association for Physical Anthropology meeting, but my abstract was rejected. I was told it wasn't acceptable because there was nothing empirical in it. I started reaching out to colleagues to collect data, and that's how the SAFE survey (Survey of Academic Field Experiences) was started.

What have you found so far?

In the field, unwanted sexual advances seem to occur more. Whereas in astronomy and undergraduate physics, what we've seen is more selective incivilities, put-downs and come-ons.

For the field survey, we found that women in junior positions reported more harassment, but our paper on astronomy and planetary science did not find rank effects. It didn't matter what your rank was, even women in faculty-level and senior positions reported harassment. And they faced it more from their peers than people further up the hierarchy fieldwork can be very hierarchical and linear. There may be a sexualisation of fieldwork: 'what happens in the field, stays in the field'. [In anthropology] there's an 'Indiana Jones' archetype of the adventurer who goes in and steals things from other cultures without sleeping or eating.

What aspects of science or academic culture present obstacles to addressing harassment?

From the organisational literature we find two things that contribute to workplace harassment. First, male domination: not just more men than women, but more men in leadership, or something that's typically considered to be a 'male' job. Next, organisational tolerance which signals sexual harassment is permitted. People don't bother reporting as they think nothing will happen or they'll be retaliated against.

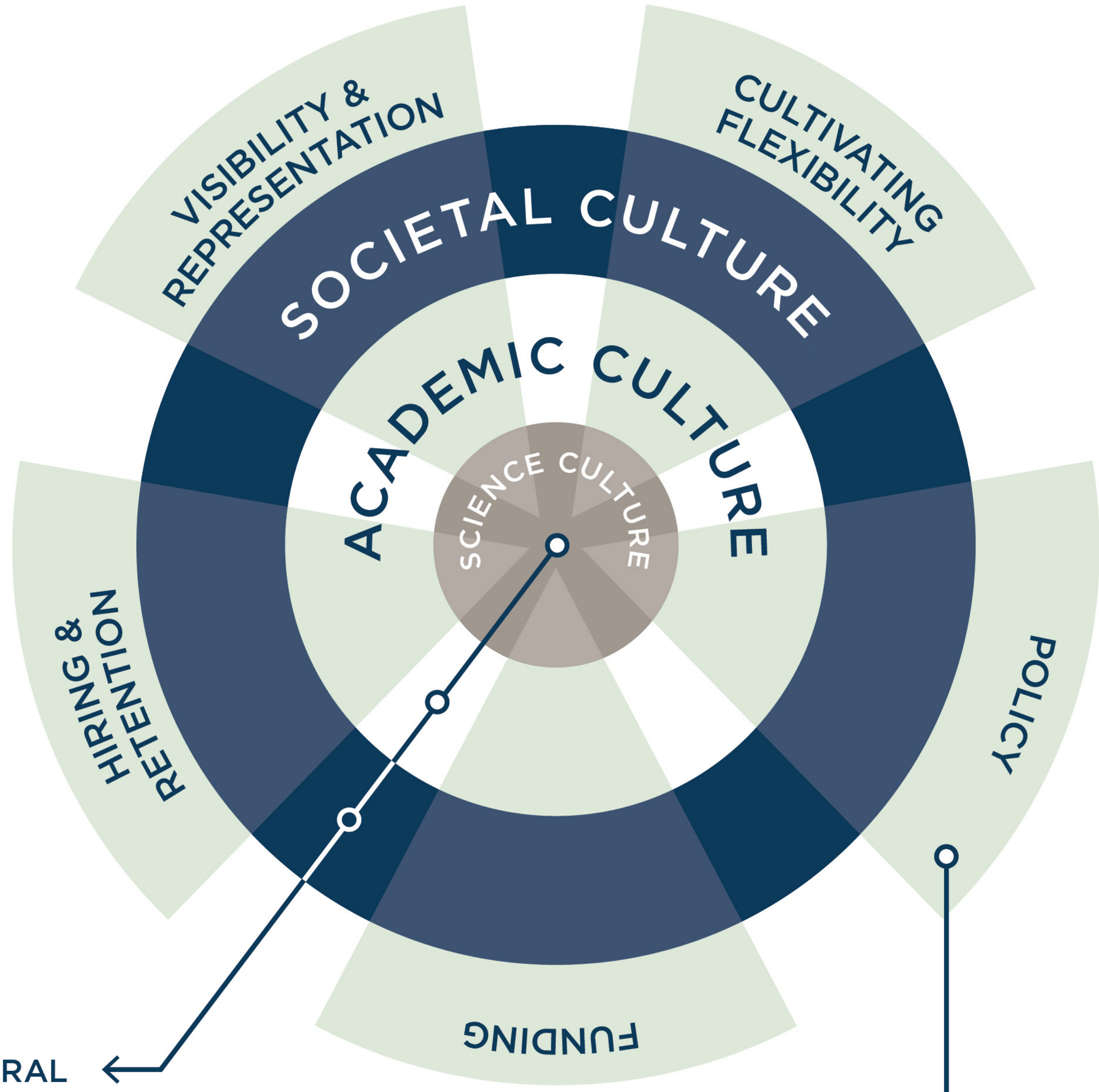
Science has both these features. Even in disciplines where women outnumber men, the expectations are structured for men. We're expected to work around the clock, as though we don't have bodies, as though we don't have children or elders to care for, or meals to make..

Positive antidotes: solving the gender equation

If the cultures of society, science and academia and their interactions are what's pushing women away from academic science careers, that suggests interventions need to address multiple aspects of scientific or academic culture at the same time to improve gender parity in science. None of the following interventions works in isolation. But taken together, they have the potential to move the needle to some degree. Experts cautioned, though, that interventions and initiatives to increase gender equality in the sciences must be routinely assessed to monitor their implementation and effectiveness.

TOWARDS A VIRTUOUS CYCLE FOR WOMEN IN SCIENCE

Just as the cultures in science, academia and society interact with one another to create a cycle that works against women's participation and advancement in science, key forms of intervention must work together across each of those cultures and create a virtuous system to deliver meaningful change.



source: L'Oreal Foundation 2018

CULTURAL FACTORS

SCIENCE CULTURE
- Closed hiring & promotion systems
- Linear, path-dependent pipeline
- Keen competition
- Long training with little security

ACADEMIC CULTURE
- Gendered organisational norms
- Funding & power
- Lack of transparency

SOCIETAL CULTURE
- Stereotype threat
- Unconscious bias
- Harassment
- Gendered workplace expectations
- Outdated expectations about career & family

FORMS OF INTERVENTION

POLICY
- Implement anti-harassment codes of conduct at scientific meetings

FUNDING
- Change funding systems for a better power balance between students/ postdoctoral associates/ junior scientists & advisors/ senior scientists

HIRING AND RETENTION
- Offer systematic training on unconscious bias in hiring
- Implement equal-opportunity & non-discrimination policies

VISIBILITY & REPRESENTATION
- Increase women's representation at conferences & in media
- Strengthen networks of women in science

CULTIVATING FLEXIBILITY
- Change curriculum & pedagogy to better support beginner students
- Value alternate career pathways

Visibility, advocacy and women's networks

Why it works: Grassroots and networking organisations for women in science may help combat the **too all-consuming and solitary** nature of research and the **stereotype threats,** including impostor syndrome. In addition, as more women gain visibility by speaking on conference panels, to media and to classrooms, that combats **gender bias in hiring** within and outside of the academy, by dispelling misconceptions about women's abilities compared to men's, belying the myth that there aren't enough excellent women candidates for open positions and diversifying perceptions of what scientists look like.

IN FOCUS: 500 WOMEN SCIENTISTS

The US grassroots network 500 Women Scientists was formed in 2016 as a platform for women scientists to connect and use their skills for public good, as well as to promote diverse leadership in science. Today, it has more than 200 'pods' or chapters around the world. We spoke with several members of their National Leadership Team.

What do you gain from being part of a network of women scientists?

Dr Maryam Zaringhalam, 500 Women Scientists National Leadership Team: It helps combat isolation or low confidence. As you grow a network, you feel less like it's you that's weak and more like it's the system that's broken. Networks of women in science also help us envision something better, like more equitable policies and institutions.

What other effective solutions have you implemented?

Dr Jane Zelikova, co-founder and National Leadership Team: In January 2018, 500 Women Scientists launched the Request a Woman Scientist web platform to enable conference organisers, journalists and other members of the public to search for women scientists by geography and area of expertise. Before the site launched, 500 women volunteered to be listed; today, there are more than 5,000 women scientists from close to 100 countries who have signed up. People are already using it to find speakers for panels and conferences, sources for media articles and speakers for classroom outreach. 500 Women Scientists also offers or plans to offer media training, training in op-ed writing, and training in how to give public talks to the women who have volunteered to be on the site.

How do you reconcile that need for visibility with the fact that women in science already carry the burden of service labour and representation?

Dr Zelikova: The benefit of speaking about your science or your expertise in a public venue is greater visibility for yourself and your research and potentially the students in your lab. Today, we see the same people speaking on science topics in multiple venues, which reinforces their credibility and expertise. We need to spread that expertise and credibility to more people than just a few men.

Women-in-science groups such as 500 Women Scientists in the United States provide networking opportunities and advocate for representation. Outside the US, the non-profit Singapore Women in Science organisation and other Singapore groups for women scientists, technologists and clinician-scientists include women from undergraduate level to executive leadership and enable them to mix in informal settings, said Dr Vandana Ramachandran, a committee member at Singapore Women in Science and head of administration at Singapore's Institute of Medical Biology (the Institute of Medical Biology is part of the country's Agency for Science, Technology and Research, or A*Star, which carries out industry-oriented research).

Besides informal or grassroots groups, institutions themselves can take steps to increase women's representation. The Institute of Medical Biology's (IMB's) goal for instance is proportional representation at the conferences it organises and at the larger conferences it chairs. Why? Across higher education and private and public research institutes in Singapore, roughly 36% of researchers with PhDs overall are women. However, women's numbers fall at later pipeline stages, such as principal investigator, full professor and other leadership levels. That poor representation may dent the confidence of early-career women scientists and worsen impostor syndrome, said Dr Ramachandran. IMB and other institutions can take concrete steps to change that.In some countries, national programmes and historical trends have interacted with culture to achieve unexpectedly gender-equal results, finds the UNESCO Science Report 2015[53]. Middle-income Malaysia has close to gender parity in science - 49% of its researchers are women, by UNESCO statistics. In Malaysia, the information technology sector especially employs a large number of women as university professors and in the private sector. This is a product of two historical trends; the predominance of women in the Malaysian electronics industry (a precursor to the IT industry) and a national push for a 'pan-Malaysian' culture. The Malaysian government has quotas for educational support for its three main ethnic groups, Malay, Indian and Chinese, and the take-up rate of IT education by Malay men is low, leaving more room for women.

Several experts also validated the impact of the L'Oréal-UNESCO For Women in Science programme for representation. For instance, Dr Machaca, who sits on the committee that selects the laureates, said the awardees have tremendous potential to shift public perceptions of women's career paths in science, and to serve as role models in their communities.

However, women in STEM shouldn't have to be outstanding at everything they do; no one expects the same of men, argues Stanford University student Amy Nguyen in an essay. That's why sheer numbers and at least proportional representation are key to shifting unconscious bias in science and academia. The more women are visible in science, the more acceptance there will be of varying levels of accomplishment, Nguyen writes:

> *“ More than women who are at the top of their fields, I need women who suck at programming. I need women who are okay at their jobs. I need women who sometimes have to ask questions and admit weakness…the way we keep promoting only the exceptional isn't going to create more acceptance for women in tech as a whole. It's going to reject all the women who don't meet those impossible standards.”*[54] ”

Hiring and retention

Why it works: Policies to address bias in hiring and retention, such as the University of Michigan's ADVANCE programme, help break the self-perpetuating **gender disparities** in science hiring, in which the labs of elite scientists, mostly male, employ more junior men than women. The University of Michigan provides hiring faculty with information about **gender bias in hiring**, including unconscious bias and how to combat its prevalence, which may also shift faculty beliefs about **gendered academic norms.** Working in concert, policies that support caregivers and other family needs signal that employers don't expect work to be **too all-consuming and solitary**, while clear policies to address **sexual harassment** and other grievances signal that an employer is prepared to act on reports and complaints.

IN FOCUS: THE UNIVERSITY OF MICHIGAN ADVANCE PROGRAM

In 2001, the US National Science Foundation (NSF) began giving out grants to institutions and organisations to help recruit, retain and advance women in STEM in a programme called ADVANCE. The University of Michigan's programme grew out of an initial NSF ADVANCE grant and at the time focused on hiring in STEM. Today, it is permanently supported by the institution and covers various types of diversity across all departments.
Under the STRIDE portion, which focuses on faculty recruitment, scholars on campus are trained to provide their colleagues with compelling evidence on how bias can operate within hiring-committee deliberation, and practical steps to limit its impact. For instance, practical steps include discussing and defining candidate evaluation criteria in advance, and avoiding global evaluations and summary rankings which can be coloured by bias.

Within two years of the programme's launch, the rate of women hires had more than doubled from 15% of all STEM hires across campus to 32%, a rate that has been sustained since. STRIDE does not appear to have had an effect on tenure rates or time to tenure, as there was no apparent evidence for disparate tenure rates at the programme's start. There are more women students in departments with more women faculty. However, STEM hiring has plateaued at roughly one-third of new hires, for reasons that are unclear.

Today, more than half the faculty on campus have attended a STRIDE workshop and they must refresh their training every three years. Faculty also report that they apply STRIDE workshop skills to other practices, such as annual salary reviews and tenure reviews. We spoke to Professor Abigail Stewart, the Sandra Schwartz Tangri Distinguished University Professor of Psychology and Women's Studies and former director of the University of Michigan ADVANCE/ STRIDE programme (from 2001-2016).

Note: this Q&A has been edited for length and clarity

What kind of pushback did you get? How did you overcome it?

The first kind was this issue of excellence. We stress that we endorse the goal of excellence, and that we don't see diversity and excellence as opposed; we agree that of course every department is searching for the best scientists but up 'til now we have been populating our departments with bias which has led us to unequal situation.

Next, we heard, "Our field has no pipeline." We provide data about the actual pipeline in their field and the reasons to believe that women over-perform compared to men, and therefore that 10 or 15 or 20% of the pool are actually more qualified than some of the men. Some people grasp that – that's persuasive.

A lot of people talk about how women make all their decisions based on family, and we talked about the pernicious effect of assuming that's the case. We did exit interviews of people who turned down offers and asked them why – women found questions about family plans obnoxious, and they went elsewhere where they didn't get asked those questions. That's powerful evidence.

The most important thing is to get people to understand we're not attacking them. They mean well, but good intentions can have bad effects.

How does the University of Michigan transfer its knowledge to other institutions?

The NSF provides ADVANCE funding to partnerships for sharing expertise, and we consult for other institutions that have received their own ADVANCE grants and want to construct their own STRIDE programmes. These universities include Northeastern University and Florida International University.

STRIDE faculty members also go to other institutions when asked and conduct workshops; we've been doing this for 12 to 14 years now. Last year, ADVANCE offered an onsite STRIDE training programme for the first time, and that went very well.

After women are hired, what helps retain them?

We're looking at the connection between the rate of faculty from a department participating in a STRIDE committee, and the departmental climate (things like how often one hears offensive comments, sexual harassment, do you feel you have a voice or influence on the direction of the department). We believe there's likely to be a relationship.

We look at separate indicators as well as overall positivity of climate. Some of it has to do with gender, some of it is overall department climate, such as whether it's contentious or collaborative for everyone. It turns out that improving climate predicts in the same direction for everyone: male, female and people of colour.

It's very gratifying to have the data because it answers the question: if we make it better for women will it be worse for men? And there is absolutely no evidence of that in our data.

More resources for institutions that wish to learn from the University of Michigan can be found at: http://advance.umich.edu/strideResources.php.

Amongst other notable efforts to improve hiring and retention are those by CERN, the European Organization for Nuclear Research. For more than two decades, CERN has had concerted gender-equality policies based on equal-opportunity and non-discrimination principles such as work-life balance and family friendly measures, gender-diverse hiring committees and so on.

CERN's equality policies work along three axes: encouraging women to take up scientific careers and employing them using equitable HR processes; career development which integrates diversity principles into staff learning programmes and leadership development; and creating an inclusive and respectful work environment with work-life balance and family-friendly policies. Some years ago, CERN introduced a competency model for hiring to try and contain bias in recruitment. More recently, they brought unconscious bias concepts into their training process.

Initially, there was a sharp rise in female hires. Women made up 3% of scientists, engineers and technicians in the 1990s, and this rose to 14% by the start of the 2000s. However, since 2009 CERN has seen those numbers plateau and even dip slightly to 12% today. At the organisational level for all professions including administrative roles, numbers of women have plateaued at roughly 21%.

This is due largely to a small proportion of female applicants, comprising 10-11% of the total pool for scientific and engineering positions, said CERN diversity head Genevieve Guinot. That figure is disproportionately low, compared to the overall pool of women PhD graduates in Europe: women made up 42% of science, mathematics and computing PhDs in 2012, and 28% of engineering, manufacturing and construction PhDs[55].

Currently, CERN is studying why its female applicant pool is disproportionately small.

"Once women are in the system they seem to do well. They don't leave CERN; they don't leave science to go to administration any more than men do," Guinot said. Women make up 25% of management, up from 5% in the late 90s, and are in 3 of the 15 highest positions, including CERN's director-general, Fabiola Giannotti.

Funding & power

Why it works: Linking research funding to gender equality or addressing harassment can be a powerful external incentive for institutions and organisations to address gendered academic norms and be more transparent and swifter about complaint investigations. Once they do so, the effect may be sustained. Meanwhile, changing the structure of individual students' or researchers' funding can also alter the power dynamic between students and advisors, or principal investigators and postdoctoral fellows, which has a protective effect from sexual harassment and bullying.

IN FOCUS:

ATHENA SWAN

Several interviewees cited the Athena SWAN programme as one that has been effective on a national level.

The UK's Equality Challenge Unit (ECU), a registered charity, supports various forms of equality in higher education, and its Athena SWAN charter framework was launched in 2005 to promote gender equality in STEM. The framework enables universities and research institutions to voluntarily measure and assess their performance on gender representation, career progression, positive work environment and other measures. Institutions can apply for three additive levels of awards: bronze, silver and gold.

In 2011, Dame Sally Davies, the chief medical officer for England, announced that academic applicants for National Institute for Health Research (NIHR) Biomedical Research Centre funding must be Athena SWAN silver award holders. Within six months, Athena SWAN applications from medical and biomedical-related departments had increased fourfold. Today, Athena SWAN applications and membership have expanded to the United Kingdom, Ireland and Australia, with interest from India, Canada, the United States and Japan.

However, the actual impact of Athena SWAN adoption on women's employment, satisfaction and career paths in science seems to be mixed. An independently commissioned ECU survey finds that institutions did make conscious decisions to increase the number of women employed, and more visible representation of women in key positions and senior roles[56]. However, while the number of women employed in academic medicine has increased since the introduction of the Athena SWAN Awards, reports did not find that this increase was due to Athena SWAN itself[57].

On one hand, women felt Athena SWAN had a positive impact on their career development, such as being encouraged to apply for grants, fellowships and promotions. They also felt the programme increased awareness of gender and other diversity issues in their departments and institutions, and adoption of tangible measures to support those with caregiving responsibilities, such as holding meetings only during core hours, subsidising nursery places, and supporting flexible and part-time work. On the other hand, women remained less satisfied with career performance and promotion criteria, and less likely to agree that they had been encouraged to apply for promotion than men.

But surveys and studies also raised questions about funding-linked Athena SWAN adoption: was it a mere box-checking exercise paying lip service to diversity? Would it be sustainable in the longer term? However, evidence suggests that the changes implemented as a result of

Athena SWAN were sustainable, and that practices introduced as a result of Athena SWAN had been incorporated at both strategic and operational levels within participating institutions[58].

Finally, survey respondents raised other concerns: that Athena SWAN did not support women from minority backgrounds, that some of its initiatives remained inaccessible to certain members of staff, and that women bore a disproportionate burden of the Athena SWAN administrative work for their institutions and departments. (The ECU acknowledged these limitations, and in 2015 expanded the scheme to include non-academic support staff and to require that applicant institutions consider intersectionality – ethnicity as well as gender – in their efforts.) A number of reports also highlighted that Athena SWAN was significantly limited by factors beyond its programme design, such as institutional practices, national policies and societal norms about women as primary care providers [59] [60].

Today, in the UK, National Institute for Health Research (NIHR) Biomedical Research Centre funding requires academic applicants to have at least an Athena SWAN Silver award, while in Nordic countries, the use of public funding requires a gender equality plan. In the same vein, the US National Science Foundation earlier this year (2018) announced it would require institutions to report sexual harassment by people working on the projects it funds, and that it might suspend or remove research grants after institutions find that a grantee committed harassment. Previously, the agency had had to rely on media reports to uncover harassment by grantees[61].

When students or postdoctoral associates rely on a single source of funding from their advisors or principal investigators, they are effectively beholden to them, and thus vulnerable to harassment, bullying, or other abuse, notes Dr Clancy. In some institutions and disciplines, a student's advisor funds her research, while in others, such as in the social sciences, students receive their funding and support from teaching assistantships (effectively serving as teachers for undergraduate classes). Some STEM departments have implemented co-advisor models so that students are not advised by a lone advisor, and thus less vulnerable to abuses of power.

IN FOCUS:

DONOR FUNDING AS A LEVER ?

In some contexts, donor funding is the prevalent form of funding for science, and thus can have a significant impact on gender equality. The Mawazo Institute's Dr Rose Mutiso mentioned the prevalence of donor funding in the Kenyan context: when donor funding from development agencies and other sources is allocated for research activities, for instance, it may bear gender-based stipulations, which may serve as the only incentive for principal investigators to include women researchers or carry out gender-focused research. "It's a blunt tool, but one of the only ones we have," Dr Mutiso said.

Moreover, though the donor agenda is broadly aligned with women's interests and issues in the developing-economy context, such research may still be ghettoised and dismissed as 'women's issues', Dr Mutiso added. What's more, if the underlying climate for women in science does not shift, women in science may remain in positions subordinate to male researchers and their pace of advancement may remain slow. In addition, a focus on development-related research is valuable, but a thriving knowledge economy needs scientists to formulate and propose their own original questions on a variety of topics.

To that end, the Mawazo Institute set up a PhD scholarship for African women under 40 who are enrolled at Kenyan universities; research is not limited to specific questions, such as health or agriculture, but any development-focused research is considered. (The institute and its programmes are funded by private donors, typically family foundations, using no-strings-attached funding. The scholarship's generous age cap is based on Mawazo's research, which found women often did not enter PhD programmes until after they had started families, unlike in the West). In 2017-2018, its pilot year, "we expected maybe 30 applications for 5 to 10 places, but we received nearly 200 applications," Dr Mutiso said.

IN FOCUS:

WOMEN IN SCIENCE IN QATAR: FUNDING VERSUS SOCIAL NORMS

In the past one to two decades, the relatively wealthy Qatari government has invested heavily in science education and research to build a knowledge-based economy. Today, according to UNESCO statistics, Qatar spends roughly US$ 1.28 billion or 0.5% of GDP on research each year, and 22% of its researchers are women, with a higher proportion of women in the biomedical and life sciences.

The numbers alone don't necessarily translate into a supportive environment for women in science, however. Dr Machaca of Weill-Cornell Qatar noted that social norms and constraints, such as acceptance of science as a viable career path for women, remain. And the preponderance of women in life sciences may be due to the availability of more career options for men, such as oil and gas or military careers.

At the same time, he added, "Some of the Qatari institutions are even more flexible and more generous than their US counterparts in supporting family and flexibility". Due to the country's energy wealth, financial concerns are also less of an obstacle for Qatari women who are more likely to follow their own choices to pursue a science career. Given that Qatar's science investments date back only about a decade, most Qatari women scientists are relatively junior; it remains to be seen how many will move up the pipeline to tenured, principal investigator or other leadership positions.

Scientific professional societies: policy changes

Why it works: Besides linking science funding to diversity initiatives, another category of policies is those by scientific societies and conference organisers, which due to their broad reach have an influence on the culture of science. Scientific meetings can implement codes of conduct which take aim at sexual harassment. While this is their primary cultural influence, addressing harassment at meetings empowers women scientists to network and interact more freely, which combats a sense of too all-consuming and solitary research environments and enables them to embark on more valuable collaborations.

IN FOCUS:

HOW SCIENTIFIC SOCIETIES AND MEETINGS CAN CHANGE THE FUTURE OF SCIENCE

In 2017, the American Geophysical Union adopted a new ethics policy defining sexual harassment as a form of scientific misconduct, following a year-long effort to rethink its ethical guidelines[62]. That has a direct impact on the culture of science and people's behaviour at scientific conferences and meetings, said Dr Sherry Marts, who consults for employers and scientific societies to prevent harassment of all kinds at meetings. In a report, 'Open Secrets and Missing Stairs', she finds that harassment at conferences is similar to street harassment due to the transient nature of conferences, the anonymity of a relatively public space, and the fact that victims may have little recourse and are unlikely to take action against the harasser[63].

Professional scientific societies are academic communities that convene scientists and enable them to network and discuss their research; scientists view these major conferences and meetings as a useful tool to enrich their research, and for networking and collaboration. Societies such as AGU and the American Astronomical Society are well placed to influence harassment, Dr Marts said, as they can set standards for behaviour at conferences and act quickly by warning, removing or even banning a harasser. "They are in a solid position to have an influence on the culture – it's one thing to do science, but you need to publish your data and present at meetings. What do scientific societies do? They publish journals and they hold meetings. So, they have a chance to have a pretty significant impact on changing the culture." Even scientific societies based in the US are influential globally, she adds: they are often the largest in their field, with international memberships and international coalitions.

What's the impact of societies' codes of conduct? Many societies who have adopted codes[64] that outline a clear policy for addressing harassment find that the number of incident reports increases over the first two or three meetings, followed by a steep drop-off after that – a pattern common to meetings which introduce codes of conduct, signifying that victims of harassment are empowered to report incidents. However, the code of conduct needs to be publicised and communicated, Dr Marts says. "You have to make sure everyone at your meeting is made aware of it; this puts harassers on notice and encourages victims to report."

Cultivating Flexibility

For some fields where the pipeline narrows early, at high school or undergraduate level, gender-neutral interventions that disarm stereotype threat at the same time as they encourage girls and women to enter science can be effective in increasing pipeline capacity. However, there's no doubt that the model of the pipeline needs to be reconfigured with more on- and off-ramps and greater flexibility to tackle science's linear career pipelines, the long training with little security scientists face, and the keen competition for a small number of jobs. By offering more information and greater flexibility about parallel career paths, a re-envisioned model can reframe narratives about what success and failure in science look like.

In some disciplines such as computer science and engineering, the pipeline starts to narrow from the beginning, when women select their undergraduate fields of study. By changing their curricula and instructional methods, some universities have made strides in the proportion of women opting for these majors. For example, when Harvey Mudd College changed its introductory computer science courses to be more welcoming of beginner students, its proportion of computer science graduates rose to more than 50% women; furthermore, 64% of women computer science graduates took jobs in the technology industry[65]. And by introducing project-based introductory design classes and hands-on skills sessions that welcome beginners, Dartmouth College in 2016 graduated its first majority-female class of undergraduate engineering students[66]. Research finds that such changes are a powerful way to increase women's participation and take-up rate of STEM courses[67].

The 'pipeline' construct, however, assumes that academic science career paths are and should be linear and one-directional, and also that individual scientists seek to stay on these tracks. Moreover, the model implicitly devalues scientists – women and men – who choose to take their skills to other contexts such as policy, communications, industry and entrepreneurship.

While academic STEM is genuinely path-dependent, and greater and greater specialisation is required at some stage for today's highly-specific fields of study, it may be time to ask: how might the pipeline be reconfigured or reimagined such that there is greater mobility between sectors; how might this better serve women in academia and better use the talents of women scientists who currently leave science completely; and how might doing so serve science itself? On a rigid, path-dependent career track, the further along you get, the higher the risk of women's talents and perspectives being lost, since it becomes increasingly difficult to find equivalent roles elsewhere. If pathways are less linear or rigid, the risks of entering academic science is tempered, and more women might be willing to give academic science a shot.
Interviewees agreed that a new, reimagined model was necessary. "You need these on-ramps and off-ramps and so forth," said Nature's Helen Pearson.

But what might such a reimagined and reconfigured model look like? Interviewees had difficulty envisioning how this might be feasible under the current system of academic science. "You're always being judged on how many papers you've published and how much grant funding you've won, so if you're behind it's hard to keep up," Pearson added.

Furthermore, the feasibility of on-ramping after leaving is highly field-dependent, pointed out Dr Ramachandran. It's one thing to be a bioinformatician and require only data and a computer; it's another to be a lab scientist whose research is done at the bench. "Currently, onboarding again after leaving from a postdoc is a rarity even for men. It's too competitive." In fact, only a small minority of postdoctoral associates achieve principal investigator rank annually – both men and women.

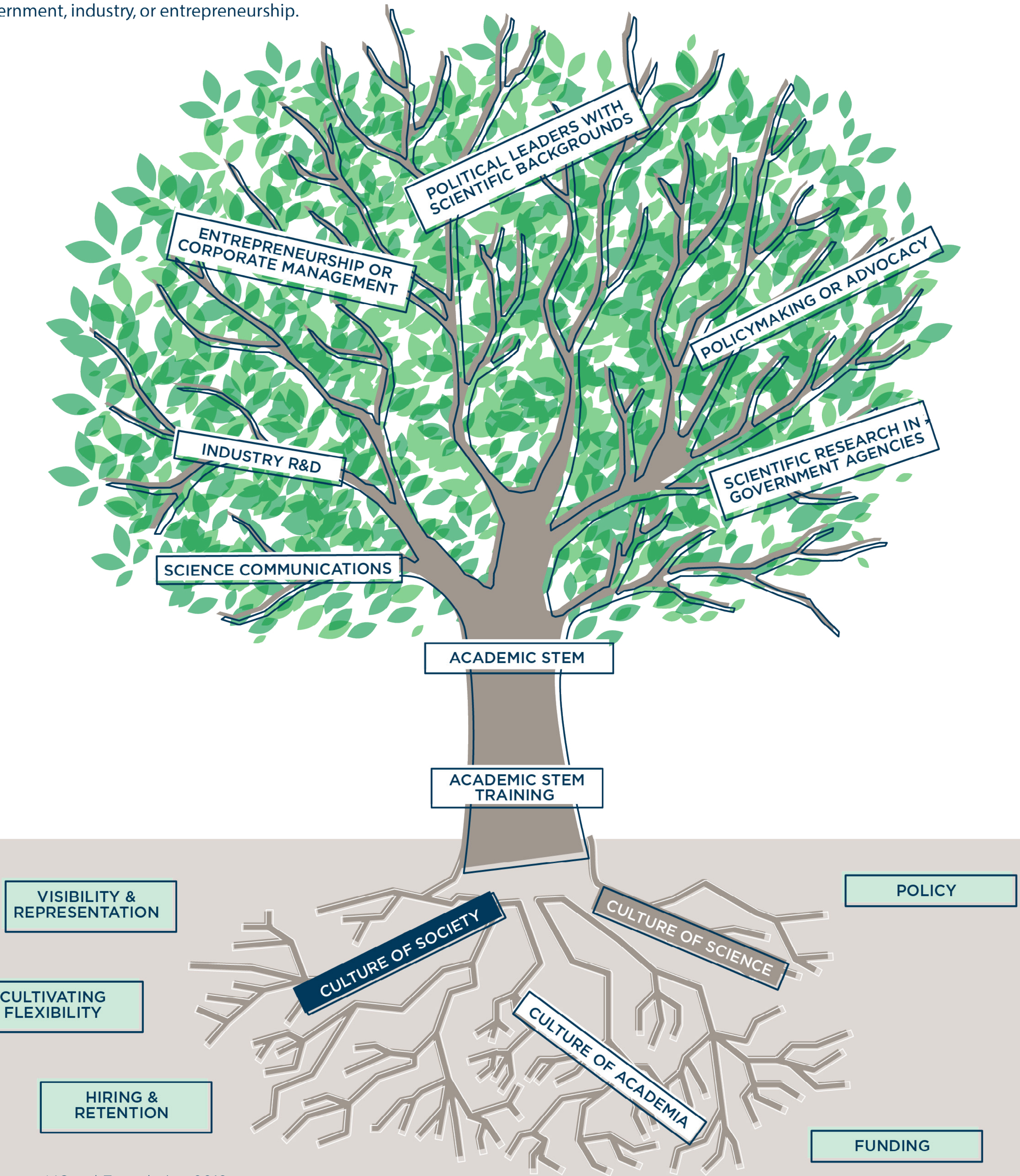
However, that's not to say women scientists aren't already trying to build their own on-ramps. Dr Wendy Bohon, who coordinates social media for 500 Women Scientists, is a geoscientist by training, but left research for science communications. Before leaving, she built a network of academic collaborators and allies willing to take her on as a kind of consulting scientist. "I'm still co-authoring papers and still named on research grants, but in a secondary position. That way if I decide I want to go back into research I still have a fighting chance…It's out of the box, but there's no reason that can't happen more often. I know other women working as part-time postdocs until children are old enough. So, we're slowly building those on-ramps" Bohon said.

Going in the reverse direction – from academic science to administration, policy, industry or elsewhere – is easier, but ways to do so systemically are not often discussed, meaning that early-career scientists often have to stumble upon alternate career paths on their own, interviewees said. "Well-established scientists ought to be more willing to talk about alternative, productive and valuable career paths," said Pearson. "It's a shared responsibility: it's also up to the institutions recruiting young scientists for PhDs and postdocs to inform them of their career options, and you have a duty as an individual to go in with your eyes open." Parallel pathways are not a consolation prize; rather, being informed about career options enables young scientists to fully consider what they hope to achieve in a science career and how they can best contribute to science.

Moreover, more women in visible STEM roles, whether in academia or in government, industry or other sectors, will help address impostor syndrome. And when academia has to compete with other sectors for the same pool of talent, that ought to improve conditions for all.

FROM ROOT TO BLOOM: A NEW VISUAL CONSTRUCT TO DESIGN INITIATIVES THAT WORK FOR ALL

A tree, which draws its resources from the ground and sky and has many branches, could be a new model for women's careers in science. Its trunk (the supply of women in academic STEM training) feeds several branches; from academia to government, industry, or entrepreneurship.



source: L'Oreal Foundation 2018

CONCLUSION

The ideas we've collected here are just a start. Clearly, more research is needed to understand which combinations of initiatives will be most effective in the presence of the most pernicious cultural factors that discourage women from participating in science.

Culture depends on context. A scientific institution's culture – its beliefs, behaviours and norms – is shaped as much by the culture of science, as it is by the culture of the broader institution and of the nation in which it sits. Interactions amongst these cultures can produce situations and environments that push women out of academic science, be especially unappealing to women, or factor into their departure in other ways. Thus, more research and more granular data on cultural factors and interactions are needed about the current picture for women not only in science, in general, but in different scientific disciplines, in particular institutions and in different parts of the world.

Why, for example, do countries with high gender equality, such as Finland and Norway, actually have lower rates of women's participation in STEM? Questions like this demand that we also consider cultural factors that encourage women to participate. Up to now, we've focused on plugging holes in the leaky pipeline. Surely there are other factors that make women scientists want to stay in the pipeline, even if there are cracks that would allow them to escape. In the Nordic countries, the ready availability of attractive alternatives to STEM careers is apparently pulling women away from science, rather than the culture of science pushing them out[68].

Ultimately, culture and cultural interactions need not be discouraging to women in science, and they are not set in stone. Culture is the system of shared assumptions and values that guide behaviour. Because the science environment is mostly male, the shared assumptions and values are dominated by male influence. Thus, changing the culture will require male participation. To enable women to thrive and achieve STEM leadership at the highest levels, we believe it's time for non-female allies in the scientific community to help accelerate change – to commit to improving conditions for women scientists as they progress in their careers.

The male leaders who occupy the majority of key positions in science fields have tremendous capacity to influence the culture, practices and barriers that prevent women from rising to the top of their chosen field. Other male allies in science, such as a new generation of scientists, are also subject to some of the same pressures that hold back would-be scientific innovators and leaders. Working together with female colleagues for systemic change helps harness the potential of women and achieve equity in science for the benefit of all.

This will be a daunting task, to say the least. Yet it's a task we must embrace as a moral imperative, to unleash all of human potential on scientific endeavour and enable humanity to improve itself again through rational thought.

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ABOUT THE L'ORÉAL FOUNDATION

The L'Oréal Foundation is committed to two main causes, that of science and that of beauty care as a means to helping the most vulnerable members of society. Based on values of excellence, generosity and creativity, science is at the core of the Foundation's commitments, most particularly its commitment to supporting women researchers through its For Women in Science program, a worldwide initiative in partnership with UNESCO. As well, rooted in the belief that beauty care is an essential need met by passionate professionals skilled in creating human relationships, the Foundation has launched several programs anchored by a vision of beauty as a path towards a fairer and more generous society. The Foundation is committed to assisting the economically disadvantaged and those suffering from physical and mental ailments in regaining their sense of self-esteem through beauty care and training in beauty care professions.

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FOOTNOTES

1 Doshi, V. (2015) 'Why Doctors Still Misunderstand Heart Disease In Women', The Atlantic, October 26, Accessed at https://www.theatlantic.com/health/archive/2015/10/heart-disease-women/412495/

2 Simonite, T. (2017) 'Machines taught by photos learn a sexist view of women', WIRED, August, Accessed at: https://www.wired.com/story/machines-taught-by-photos-learn-a-sexist-view-of-women/

3 Bloom et al. (2017) 'Ideas aren't running out, but they are getting more expensive to find', VOX, CEPR's Policy Portal, 20 September, Accessed at: https://voxeu.org/article/ideas-aren-t-running-out-they-are-getting-more-expensive-find

4 Guellec, D. and Bruno, P. (2001) 'R&D and productivity growth: panel data analysis of 16 OECD countries', OECD, Accessed at: https://www.oecd.org/eco/growth/ 1958639.pdf

5 Sargent, J. F. Jr (2017) 'The U.S. science and engineering workforce: recent, current, and projected employment, wages, and unemployment', Congressional Research Service, November, Accessed at: https://fas.org/sgp/crs/misc/r43061.pdf

6 Mehta, N. (2016) 'Gender gap remains wide in STEM', LiveMint, March, Accessed at: http://www.livemint.com/Politics/l3wd61aRHtcj7AKuVqOBAP/Gender-gap-remains-wide-in-STEM.html

7 Shambaugh, J and Portman, B. (2018) 'How many Grace Hoppers have been lost from the innovation pipeline?' Brookings Institution, January

8 Accessed at https://www.brookings.edu/blog/up-front/2018/01/08/how-many-grace-hoppers-have-been-lost-from-the-innovation-pipeline/

9 (2017) 'Women in science', UNESCO Institute for Statistics, Accessed at: http://uis.unesco.org/en/topic/women-science

10 Campbell, L.G. et al. (2013). 'Gender-Heterogeneous Working Groups Produce Higher Quality Science', PLOS One, October 30. Accessed at https://doi.org/10.1371/journal.pone.0079147

11 Díaz-García C. et. al (2014) 'Gender diversity within R&D teams: Its impact on radicalness of innovation', Innovation: Organization & Management, December 17. https://doi.org/10.5172/impp.2013.15.2.149

12 Wright, A. et al. (2014) 'Diversity in STEMM: establishing a business case', University of Westminster for the Royal Society's diversity programme, Report of research in 'Leading the way: increasing diversity in the scientific workforce', June

13 Schiebinger, L. (2010) 'Keynote remarks: UN Expert Group Meeting on Gender, Science and Technology', United Nations, Paris, September

14 (2012) 'Heart disease in women: formulating research questions', Gendered Innovations: Stanford University, The European Commission, National Science Foundation, Accessed at: https://genderedinnovations.stanford.edu/case-studies/heart.html#tabs-2

15 (2001) 'Most drugs withdrawn in recent years had greater health risks for women', US Government Accountability Office, Accessed at: https://www.gao.gov/products/GAO-01-286R

16 Nielsen, M. W. et al. (2017) 'One and a half million medical papers reveal a link between author gender and attention to gender and sex analysis', Nature Human Behaviour, vol. 1, p. 791_796

17 (2015) 'Equity in education' OECD PISA, October, Accessed at: http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-i_9789264266490-en#.WjuKDFSFi1s

18 Martinez et al. (2007) 'Falling off the academic bandwagon: women are more likely to quit at the postdoc to principal investigator transition', EMBO Reports

19 (2017) 'SEH doctorates in the workforce, 1993-2013', National Science Foundation, Accessed at: https://www.nsf.gov/nsb/sei/infographic2/?yr=2013&fd=All%20SEH%20Fields&cs=ShowGender#main

20 Sandberg, S. (2013) 'Women, work and the will to lead', Alfred A. Knopf: New York

21 Sheltzer, J. M & Smith J. C. (2014) 'Elite male faculty in the life sciences employ fewer women', PNAS, July, Vol. 111, no. 28, p.10107-10112, Accessed at: https://doi.org/10.1073/pnas.1403334111

22 Newsome, J. L. (2008) 'The chemistry PhD: the impact on women's retention' UK Resource Centre for Women in SET & Royal Society of Chemistry, Accessed at: http://www.biochemistry.org/Portals/0/SciencePolicy/Docs/Chemistry%20Report%20For%20Web.pdf

23 Gould, J. (2015) 'How to build a better PhD', Nature News feature, December, Accessed at: https://www.nature.com/news/how-to-build-a-better-phd-1.18905

24 Parson, L. & Ozaki, C. C. (2017) 'Gendered student ideals in STEM in higher education' NASPA Journal About Women in Higher Education

25 Williams, J.P (2014) 'College of tomorrow: The changing demographics of the student body', US News and World Report, Accessed at: https://www.usnews.com/news/college-of-tomorrow/articles/2014/09/22/college-of-tomorrow-the-changing-demographics-of-the-student-body

26 Hart, J. (2016) 'Dissecting a gendered organization: implications for career trajectories for mid-career faculty women in STEM', The Journal of Higher Education, Vol. 87, No.5, September/October, p.605-634

27 Misra et al. (2011) 'The ivory ceiling of service work', American Association of University Professors

28 Ghorayshi, A. (2017) 'In unprecedented move, the University of Washington just fired a professor for sexual harassment', Buzzfeed News, August

29 Barnett, R. C. & Sabattini, L. (2009) 'A history of structural barriers to women in science: from stone walls to invisible walls', in The Science of Women in Science, ed Hoff Sommers,C

30 Gristock, J. (2016) 'Why aren't there more women in science? The industry structure is sexist', The Guardian, May, Accessed at: https://www.theguardian.com/commentisfree/2016/may/31/women-science-industry-structure-sexist-courses-careers

31 Avent, R. (2016) 'Why do we work so hard?' The Economist, Vol. 1843, April/ May, Accessed at: https://www.1843magazine.com/features/why-do-we-work-so-hard

32 Ely, R. J et al. (2014) 'Rethink what you know about high-achieving women', Harvard Business Review, December, Accessed at: https://hbr.org/2014/12/rethink-what-you-know-about-high-achieving-women

33 Parker, K. (2015) ;Women more than men adjust their careers for family life', Pew Research Center, October, Accessed at: http://www.pewresearch.org/fact-tank/2015/10/01/women-more-than-men-adjust-their-careers-for-family-life/

34 Clancy, K B H. et al (2015), 'Survey of academic field experiences (SAFE): trainees report harassment and assault', PLoS One, July, Accessed at: https://doi.org/10.1371/journal.pone.0102172

35 Rivera, L A. (2017) 'When two bodies are (not) a problem: gender and relationship status discrimination in academic hiring', American Sociological Review, vol.82, no. 6, p. 1111-1138

36 (2018) 'Sharing successful gender equality measures: Establishing GENERA Network for research organisations in physics and related fields', Gender Equality Network in the European Research Area (GENERA), Kings College London, Workshop: 22-23 Januar

37 DeWolf, M. (2017) '12 stats about working women', US Department of Labor Blog, March, Accessed at: https://blog.dol.gov/2017/03/01/12-stats-about-working-women

38 Antecol, H. et al. (2016) 'Equal but inequitable: who benefits from gender-neutral tenure clock stopping policies?', IZA Institute of Labor Economics, April, Accessed at: http://legacy.iza.org/en/web-content/publications/papers/viewAbstract?dp_id=9904

39 Martinez et al. (2007) 'Falling off the academic bandwagon: women are more likely to quit at the postdoc to principal investigator transition', EMBO reports, Vol.8, No.11, p.977-981, Accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2247379/

40 Schiebinger et al (2008) 'Dual-career academic couples: what universities need to know', Clayman Institute for Gender Research, Stanford University, Accessed at: http://gender.stanford.edu/sites/default/files/DualCareerFinal_0.pdf

41 Martinez et al. (2007) 'Falling off the academic bandwagon: women are more likely to quit at the postdoc to principal investigator transition', EMBO reports, Vol. 8, No. 11, p.977-981, Accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2247379/

42 Boyle, P. J et al. (2015) 'Gender balance: women are funded more fairly in social science', Nature, September, Accessed at: http://www.nature.com/news/gender-balance-women-are-funded-more-fairly-in-social-science-1.18310

43 Sege, R. et al. (2015) 'Sex differences in institutional support for junior biomedical researchers' JAMA, vol.314, no. 11, p. 1175-1177

44 Lerback, J. & Hanson, B. (2017) 'Journals invite too few women to referee', Nature, vol.541, p.455-457

45 Isbell et al. (2012) 'Stag parties linger: continued gender bias in a female-rich scientific discipline', PloS ONE, vol.7, no.11

46 Schroeder et al. (2013) 'Fewer invited talks by women in evolutionary biology synposia', Journal of Evolutionary Biology, vol.26, no.9

47 Knobloch-Westerwick, S. et al. (2017) 'The Matilda effect in science communication: an experiment in gender bias in publication quality perceptions and collaboration interest', Science Communication, vol.35, no.5, p.603-625

48 Connolly et al. (2015) 'Faculty hiring and tenure by

sex and race: new evidence from a national survey', presented at the Annual Meeting of the American Educational Research Association, April 16-20, Chicago, IL

49 Bhattacharjee, Y. (2004) 'Family matters: stopping tenure clock may not be enough', Science, December, Accessed at: http://science.sciencemag.org/content/306/5704/2031.full

50 Hart, J. (2016) 'Dissecting a gendered organization: implications for career trajectories for mid-career faculty women in STEM', The Journal of Higher Education, Vol.87, No.5, September/October,
p.605-634

51 Fox, M. F & Colatrella, C. (2006) 'Participation, performance, and advancement of women in academic science and engineering: what is at issue and why', Journal of Technology Transfer, vol.31, no.3, p.377-386

52 Clancy, K, B. H et al. (2017) 'Double jeopardy in astronomy and planetary science: women of color face greater risks of gendered and racial harassment', Journal of Geophysical Research: Planets, July, Accessed: http://onlinelibrary.wiley.com/doi/10.1002/2017JE005256/full

53 Huyer, S. (2015) 'Is the gender gap narrowing in science and engineering? UNESCO science report: towards 2030', UNESCO, Accessed at: https://en.unesco.org/sites/default/files/usr15_is_the_gender_gap_narrowing_in_science_and_engineering.pdf

54 Nguyen, A. (2015) 'Why we need terrible female engineers', Huffington Post, April, Accessed at: https://www.huffingtonpost.com/amy-nguyen/why-we-need-terrible-female-engineers_b_7129278.html

55 (2015) 'SHE figures 2015', European Commission, Accessed at: https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf
56 (2014) 'Advancing women's careers in STEMM: evaluating the effectiveness and impact of the Athena SWAN Charter', Equality Challenge Unit, May, Accessed at: https://www.ecu.ac.uk/publications/evaluating-athena-swan/

57 Caffrey L. et al. (2016) 'Gender equity programmes in academic medicine: a realist evaluation approach to Athena SWAN processes' BMJ Open, vol. 6, no.9

58 (2014) 'Advancing women's careers in STEMM: evaluating the effectiveness and impact of the Athena SWAN Charter', Equality Challenge Unit, May, Accessed at: https://www.ecu.ac.uk/publications/evaluating-athena-swan

59 Ovseiko P V. et al. (2017) 'Advancing gender equality through the Athena SWAN Charter for Women in Science: an exploratory study of women's and men's perceptions', Health Res Policy Syst, vol.21, no.15, February

60 Caffrey L. et al. (2016) 'Gender equity programmes in academic medicine: a realist evaluation approach to Athena SWAN processes' BMJ Open, vol.6, no.9

61 Kuo, M. (2018) 'NSF requires institutions to report sexual harassment findings', Science, February, Accessed at: http://www.sciencemag.org/news/2018/02/nsf-requires-institutions-report-sexual-harassment-findings

62 Kuo, M. (2017) 'Scientific society defines sexual harassment as scientific misconduct', Science, September, Accessed at: http://www.sciencemag.org/news/2017/09/scientific-society-defines-sexual-harassment-scientific-misconduct

63 Marts, S A. PhD (2016) 'Open Secrets and Missing Stairs: Sexual and Gender-Based Harassment at Scientific Meetings', S*Marts Consulting, Accessed at: https://static1.squarespace.com/static/51a662bde4b06440a1627b96/t/58b067e846c3c4cf659bd4e3/1487955946386/Open+Secrets+and+Missing+Stairs.pdf

64 Smarts Consulting. 'These Associations Have Codes of Conduct For Their Meetings'. S*Marts Consulting, Accessed at http://smartsconsulting.com/code-of-conduct-examples

65 Staley, O. (2016). 'Harvey Mudd College took on gender bias and now more than half its computer science majors are women'. Quartz, August 22, Accessed at https://qz.com/730290/harvey-mudd-college-took-on-gender-bias-and-now-more-than-half-its-computer-science-majors-are-women/

66 (2016) 'Dartmouth Makes History by Graduating a Majority-Female Engineering Class'. Thayer School of Engineering at Dartmouth. Accessed at https://engineering.dartmouth.edu/news/dartmouth-makes-history-by-graduating-a-majority-female-engineering-class/

67 Knight, D B. et al. (2012) 'An exploration of gender diversity in engineering programs: a curriculum and instruction-based perspective', Journal of Women and Minorities in Science and Engineering, vol.18, no.1, p.55-78, Accessed at: http://www.dl.begellhouse.com/download/article/732b48956eb95759/JWM-3702%20ww.pdf

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