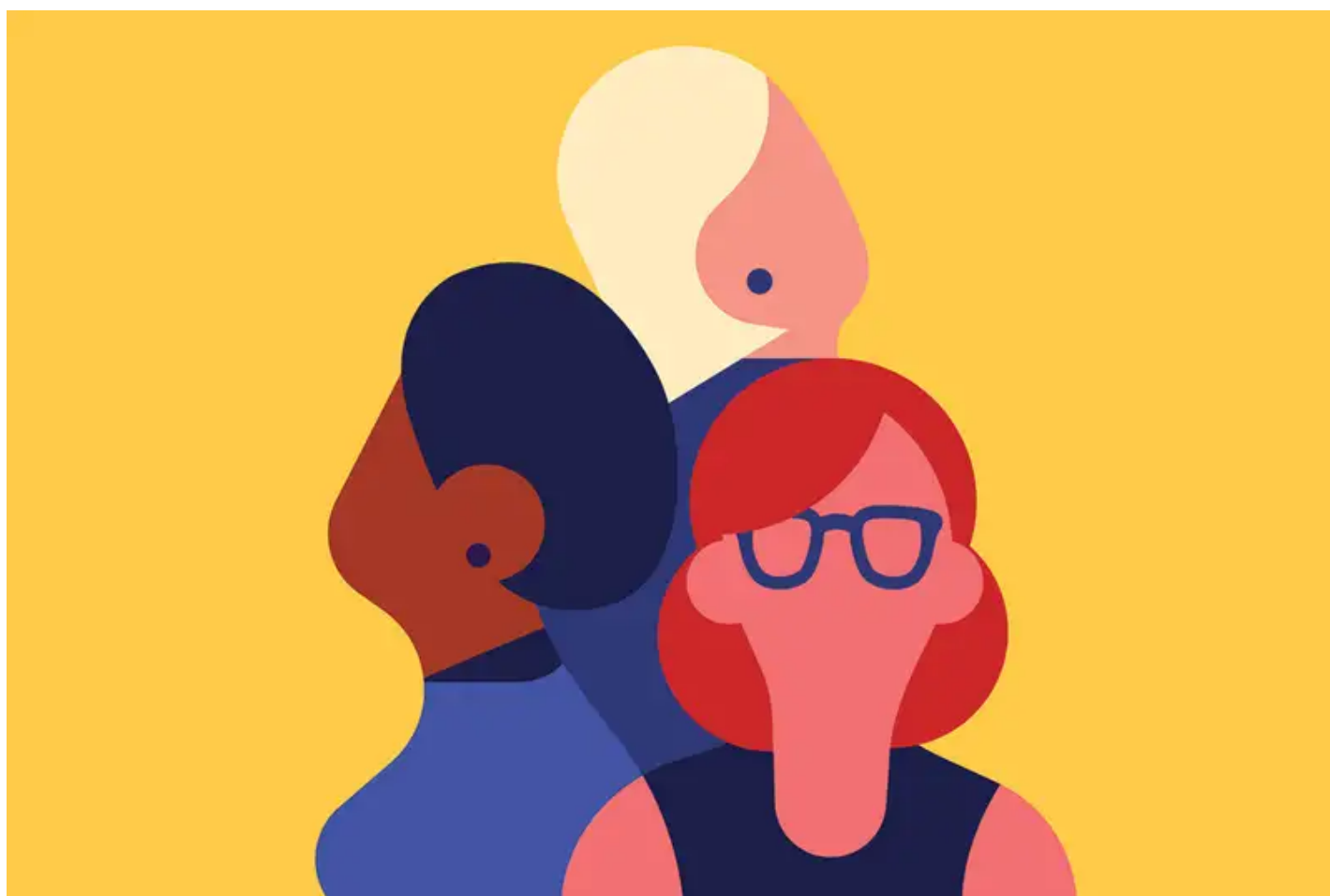




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Women in physics: Why there's a problem and how we can solve it

Women are still wildly under-represented in physics – but it doesn't have to be like that. Our special report looks at the steps we can take to improve things



Miguel Montaner

By **Valerie Jamieson**

WHEN we were 16 years old, my friend Karen and I were interviewed for an educational video. With our hair thick with styling mousse, pale blue eyeliner and misplaced teen swagger, we explained why we had chosen to study physics. We were the only two girls in our school that year who had. Our video was going to inspire other girls to do the same. We were going to change the world.

taking the subject. It is a similar picture across much of the world. Despite all the initiatives to attract more girls into physics, the proportion remains stubbornly low.

Physics and sexism has been thrust into the spotlight in recent weeks by the incendiary comments made by theoretical physicist Alessandro Strumia. At a workshop on gender in physics, of all places, at CERN near Geneva in Switzerland, he claimed that women were less capable than men at physics research. The day after he was suspended by CERN, Donna Strickland became only the third woman to receive the Nobel prize in physics in its 117-year history, sharing this year's award for her pioneering work on lasers.

All this paints a picture of physics as a career that is unwelcoming to women to start with and isolating for many of those who do make it. But why is this still the case in 2018 – and what can we do about it?



Left: Félicie Albert, Laser physicist, Lawrence Livermore National Laboratory, California: "I think physics is traditionally seen as a field dominated by men, and so we need to rebalance things. This year's Nobel prize is definitely a step in the right direction, and let's hope we don't have to wait 55 years for the next one!"

Right: Carole Mundell, Observational astrophysicist, University of Bath, UK: "In countries like the UK, it has been a relatively short time since women were admitted to university, awarded degrees, allowed to continue to work after marriage and to return after starting a family. It takes time and conscious effort to ensure these changes feed through to traditionally male-dominated fields like physics. Now is an exciting time to make that happen."

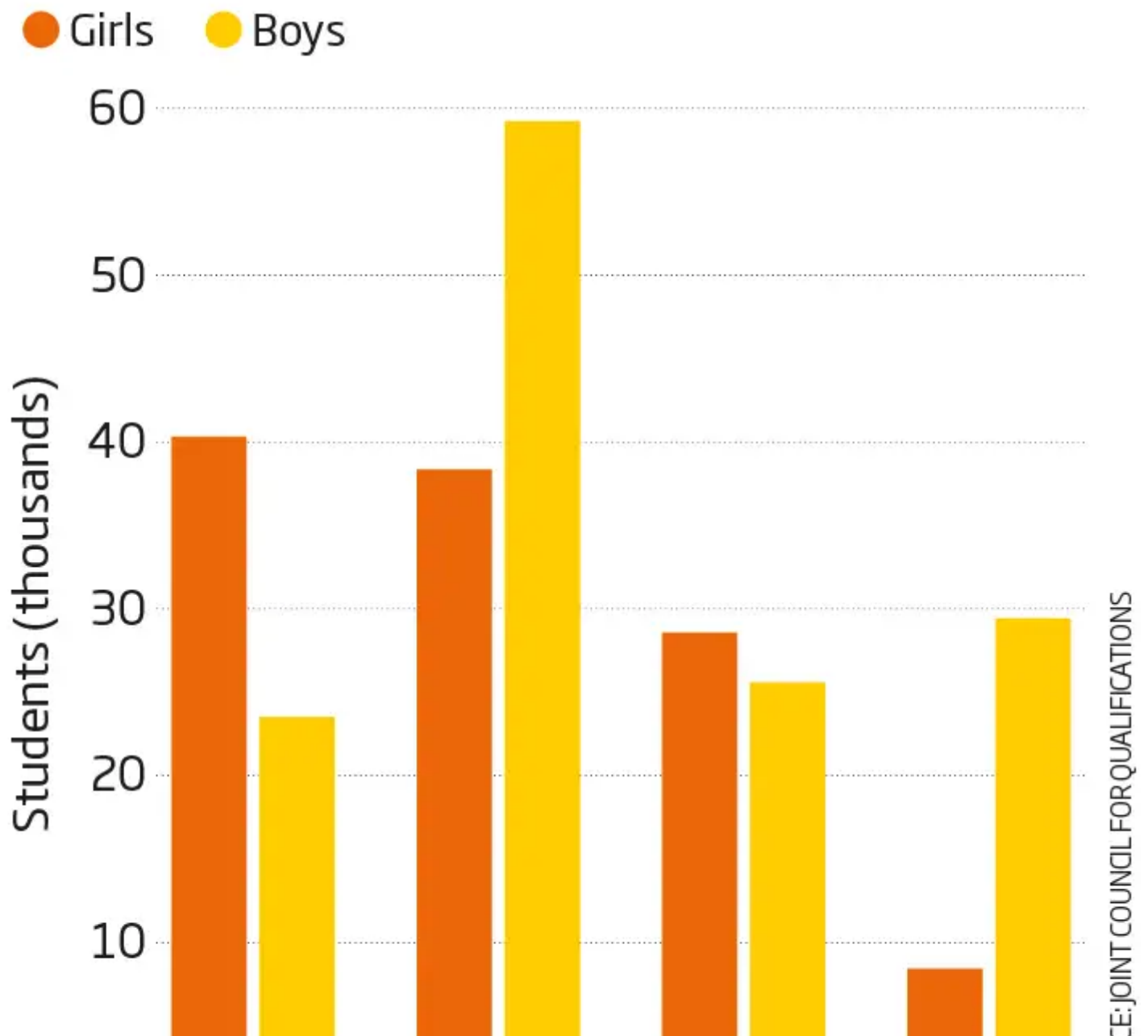
Left: Julie Russell Right: Nic Delves-Broughton/ IDPS, University of Bath 2016

Let's get one thing straight. Girls are just as capable as boys at physics. You don't need brain scans to tell you, just look at the exam results. "Girls perform at least as well, if not better," says Charles Tracy, head of education at the Institute of Physics in the UK. This year, 30 per cent of girls achieved the highest two grades at A level – typically taken by 16 to 18-year-olds – compared with 29.5 per cent of boys. And it isn't

The problem is that this is minuscule compared with the 29,400 boys who chose it (see “Graph”). Physics was the second most popular subject for boys at A level, yet the 18th most popular for girls. “Many girls who could have had careers in physics are dropping out. It’s a terrible shame that we’re losing that amount of talent,” says Julia Higgins, president of the Institute of Physics.

Girls opt out

Three times as many boys as girls took physics A level in the UK in 2018



Biology

Mathematics

Chemistry

Physics

Something seems to be happening around the age of 16. Up until this point, most girls who have studied science have physics in their top four grades. But then they quit. Why?

For almost 20 years, the Institute of Physics has been trying to find out. “When we started looking for reasons why, we found that there was little evidence,” says Higgins.

At first, the institute thought it was to do with sexism and stereotypes within physics teaching. Initiatives to address these issues had some success, pushing the ratio of girls choosing physics at A level from 17 to 23 per cent. But then the improvements shuddered to a halt. The institute began to suspect that the problem wasn't with physics teachers or even science departments, but a problem with the entire school.

What followed was the closest thing to a controlled experiment exploring the issues. Starting in 2014, 26 schools took part in a two-year study that took four different approaches. The first group of schools worked on improving the confidence of 13 and 14-year-old girls. A second group focused on working with physics teachers. A third worked on tackling the culture of the schools as a whole by involving teachers, governors and students from every subject, not just science. The final group of six schools took part in a pilot project funded by the Drayson Foundation that blended these three approaches and tailored them to fit an individual school's needs.

The results were positive in all cases, but what really stood out were the outcomes from the Drayson schools. The number of girls starting A level physics more than trebled in two years, soaring from 16 to 52. “We looked at physics and it's not the physics, it's the environment,” says Higgins. The Institute of Physics now plans to roll out a larger version of the Drayson pilot to 100 schools in England, starting in March 2019.

Even if we tackle the problem of getting girls to opt for physics at school, they still face issues as they progress further through their careers. Karen and I parted ways when we left school. She studied geology and I went to study physics at the University of Glasgow. While men outnumbered women, I certainly wasn't alone. About 20 per cent of the undergraduates were female, a number that is typical in other countries, including the US.

One exception is Iran, where 60 per cent of physics undergraduates are women. “Some of the Middle Eastern countries provide well-balanced opportunities with segregated education,” says Gillian Butcher, who chairs the International Union of Pure and Applied Physics's working group on women. “But the opportunities post-education are then limited, restricting women to be the educators for the next generation of women.”



Left: Ágnes Mócsy, Theoretical physicist, Pratt Institute, New York: We bring to work our subconscious beliefs about others and about ourselves as well. We then end up treating, evaluating, judging people who are different than us differently. Some of us have multiple minority identities, and thus the barriers may be even more complex." Right: Chanda Prescod-Weinstein, Cosmologist and theoretical physicist, University of Washington, Seattle: "Here in the US, we live in an anti-indigenous, white supremacist and patriarchal society, and physics as a community has inherited society's problems."

Left: Anjali Chandrashekar, Right: Lisa Longstaff

Most countries have issues somewhere along the line, says Butcher. These can include limited career prospects or a hostile environment at work. "Women face a massive set of obstacles at every stage of their career," says Emma Chapman, a Royal Astronomical Society fellow at Imperial College London.

For instance, research shows that women in science are more likely than men to have their emails ignored when requesting information about potential PhD positions. And, on average, they need to have published three more papers in top-tier journals than men to get the same academic job. And they are more likely to leave their career due to harassment and bullying. These issues aren't unique to physics: women face them across science.

To find out more about physicists' everyday experiences, the American Institute of Physics surveyed 15,000 people from 130 countries. It was the first survey of its kind to explore whether men and women have equal access to the resources they need to carry out research and present their results. Without adequate funding, lab space, travel budget and students to help with research, for example, a researchers' career can stall. Meanwhile, experiences, such as being invited to speak at a conference or serving as editor of a journal, can help to advance a career.

The survey revealed that women were worse off than men on every single measure. And while there were differences between highly developed countries and those lower down the scale, the brakes are being put

women.



Left: Jessie Christiansen, Astrophysicist, NASA Exoplanet Archive: "Children learn about the accomplishments of historical male physicists, male physicists win the prizes and chair the panels and appear in the media. They are seen as the authority figures of physics." Right: Athene Donald, Experimental physicist, University of Cambridge: "In the UK, our society, culture and schools convey the message that physics is not for girls through attitudes, toys and education. Additionally, unlike most other countries, we require decisions about subject choice to be made early, around age 14. This is an age when children are particularly susceptible to external pressures and messages, be they from peers or adults."

Left: Caltech Right: Keith Morris/Alamy

This adds up to a constant battle for women trying to forge a career in the field. "It's the isolation women feel, it's the unconscious biases, being made to feel you're inadequate," says physicist Jess Wade at Imperial College London. "Fighting diversity battles on top of your research, it's exhausting."

In September, Wade spoke at a workshop held at CERN for women at the start of their physics careers. The event focused on recent developments in theoretical high-energy physics and cosmology, such as dark matter, black holes and neutrinos. There were also talks dedicated to research on gender in academia with the aim of developing an action plan to support women in physics.

However, the workshop was overshadowed by the talk by Alessandro Strumia, who argued that the main reason there are more men in theoretical physics is that women are inherently less capable of physics research than men. What's more, he claimed that the biases in physics worked in the favour of women, and against men.

His arguments have been branded “morally reprehensible” in an open letter signed by more than 4000 particle physicists. The letter debunks each of Strumia’s claims. For example, he argued that men are intrinsically better at physics because they have written the papers that are most frequently referred to in work by other researchers. This is an absurd proxy for quality, particularly in particle physics where the number of authors on a paper can easily reach into the thousands due to the practice of listing every member of a collaboration. The paper that detailed the discovery of the Higgs boson in 2012, for example, lists more than 5000 authors. Many of them will have contributed little towards that particular analysis.

The other issue is that Strumia ignored research showing that there is a bias in the way that authors reference other researchers’ work. Papers by female authors are routinely ignored in favour of ones written by men, either consciously or unconsciously.



Left: Catherine Heymans, Astrophysicist, University of Edinburgh, UK: “Mothers, grandmothers, aunts and cousins, the most important female role models in the lives of young girls, are telling them from a very early age that science is too hard and not for them, just as they were told when they were young.” Right: Sabine Hossenfelder, Theoretical physicist, Frankfurt Institute for Advanced Studies, Germany: “Generally, the organisation of academia offers little job security at a time when people want to start families, a factor that discourages women more than men.”

Left: BBVA Foundation Right: Joerg Steinmetz

In the spotlight

Women who called out Strumia’s talk, such as Wade, found themselves the target of online abuse. A common call was for women to provide evidence that Strumia was wrong.

of Sciences, Engineering and Medicine this year. Several cases have come to light recently of male physicists sexually harassing their female students, and of universities being atrociously slow to act. The review also found that more than 50 per cent of female lecturers and staff at academic institutions have been sexually harassed.

Despite the grim headlines, particle physicist Jo Cole at Brunel University in London believes that the problems in physics are no worse than in any other male-dominated subject.

And times are changing for the better, says Cole. Spotlights are being shone on issues that were once covered up and these issues are now being dealt with. "These days, people are more aware of diversity issues in physics. People are taking it more seriously." All of the collaborations working on the four experiments at the Large Hadron Collider in CERN have a diversity committee, and in 2010 CERN introduced its first code of conduct that all staff, including visiting scientists, are expected to follow.

Funding organisations are starting to take bullying and harassment seriously, too. In the biomedical sciences, the Wellcome Trust, for example, requires the organisations it supports to have clear policies in place and will withdraw funding from organisations and individuals found guilty of bullying.



Left: Sau Lan Wu, Particle physicist, University of Wisconsin-Madison: "In my field, the most important experiments can be carried out only in a few laboratories in the world. I worked for more than 30 years to discover the Higgs particle, a discovery that involved 6000 physicists and could happen only at CERN. Long absences from the home institution and frequent travel are unavoidable. This makes life virtually impossible for a woman with small children." Right: Samaya Nissanke, Astrophysicist and theoretical physicist, University of Amsterdam, the Netherlands: "Women in physics appear to experience much more subconscious bias in the academic setting, sexual harassment – especially when there are power differentials at play – as well as straightforward bullying."

Left: Jeff Miller/University of Wisconsin-Madison University Communications Right: Hikaru Nissanke

that you are not alone and that you can discuss the challenges that you face on a day-to-day level has made the world of difference to me,” she says. Men too can make powerful advocates.

“My own success would not have been possible without my fantastic mentors, most of whom have been men,” says theoretical physicist Tracy Slayter at the Massachusetts Institute of Technology. She encourages male colleagues to speak up when women are treated or discussed in ways they disagree with. “Your voice has power, in part because of your gender,” she says.

We also need to shake off the idea that physics is a place for the lone genius, says Ágnes Mócsy, at the Pratt Institute in New York.

Given the challenges, why would girls thinking about a career in physics stick it out? Simply because the rewards can be huge. “I often get feedback from young people saying that meeting me and hearing about my job made them realise that this subject could be for them too – to be part of something big that will improve our future, to travel the world, to make a difference,” says Ceri Brenner, a laser physicist at the Science and Technology Facilities Council, UK. “You can have a fulfilling life. Of course this comes with a little bit of compromise, but which career doesn’t?”

Some Anonymous Real-Life Experiences from Women In Physics

- An influential colleague once tried to convince me that it’s OK to have fewer women in physics because our brains are just intrinsically different. He helpfully suggested I go read the literature on it
- I was greeted with wolf whistles and stamping feet when going into a physics lecture
- Colleagues tell me that I only got the promotion to professor because I was a woman
- I’m often mistaken for the group’s secretary
- I was talking to a group of male colleagues at a physics conference when one man walked past and groped me. None of my colleagues challenged him
- I was told not to change my name when I got married because it would affect my publication record when I got divorced
- When I make a mistake, I’m made to feel that it’s because women can’t do physics. I carry the responsibility of the entire gender
- I watch what I wear so that I’m taken more seriously

Best in Class

Girls turn away from physics around the age of 16 (see main story), but one school that is bucking the trend is Kendrick School in Reading, UK. This state-run girls' grammar school has 270 pupils in its final two years. Of them, 79 are studying physics. In comparison, 68 per cent of schools that admit girls in England, Wales and Northern Ireland have no more than one girl studying physics.

The motto at Kendrick is physics is fun. It might sound trite, but the school's head of physics, Theresa Conlon, aims to get pupils living and thinking about physics without feeling under pressure.

The pupils run their own weekly science clubs. They are a way for like-minded students to get together, exchange ideas and encourage each other's interests. "They don't feel geeky, or isolated," says Conlon. "There's no negativity about physics or engineering."

What can we do about it?

Some views from women in physics on how to tackle the problems facing the field

- We need more role models, and we need to support each other.
- I begin and end a lot of my outreach talks with a message that I borrowed from Albert Einstein – "imagination is more important than knowledge" – with the intention of raising discussions about the role of creativity and imagination in physics, as I really believe these are our core skills. And in highlighting these as being as important as technical skills and knowledge, then we will attract and retain a more diverse, proactive, progressive and effective physics community.
- There are various studies showing ways of increasing diversity in physics hires, including having objective criteria defined in advance, having a diverse hiring panel and hiring a group of people at once instead of one by one.
- It isn't enough to just increase the number of women and think that is the problem solved. We also need to change our unconscious attitudes. Bring the unconscious biases into the conscious. This process takes effort and it can be uncomfortable, but it is necessary.
- Talk to women about their science – not the biases they face. After all, they are in physics because they are good at it and enjoy it. Credit their work, amplify their voices and don't steal their ideas!
- We need to ensure that girls and boys are brought up in a gender neutral way all through their lives, so that girls are just as likely to be given toys that require them to think about shape and geometry (and boys given toys that bring out their interpersonal skills), and encourage them to build and create, to use their imagination.
- Addressing systemic problems such as sexual harassment is a must.

sex ratio in the lecture theatres. It is hardly surprising there aren't equal numbers at the top.

- How about we start steering away from advertising physics as the place for genius? Instead tell the true story: that we go through physics with hard work and effort, that we accomplish things through being in constant “work-in progress” mode.
- I think the question of salaries and power is much more urgent to tackle than the one about the interests of boys and girls. Today, more and more girls are encouraged to develop an interest in physics, but they will find the same career struggles as their grandmothers if we don't consider the role of women in society at large.
- Those of us with power and influence in our field – physicists of all genders, not only women – need to be willing to push back when our colleagues or institutions reinforce harmful messages, deliberately or not.
- One new strategy that several groups are working on at the moment is to talk science with young parents at baby and toddler groups. By reaching out to a new audience that wouldn't normally connect with science, we can explain that science and maths really aren't any harder than other subjects. Science is utterly awesome and absolutely for everyone, not just for boys. These parents can then become the role models, encouraging, not discouraging their own children from fulfilling careers in science.
- Women need mentors who are truly in their corner. Women of colour need mentors who look like them. Black and indigenous women and gender minorities are for the most part denied the opportunity to have a mentor who shares their gendered and racial identities.
- Senior figures should work hard to fix legacy problems so that the weight doesn't fall on junior scientists' shoulders. Both men and women need to do this – it isn't a women's problem for women to fix.
- More discussion about bullying and harassment, which are still not openly discussed in the physics community, is needed to increase awareness and develop official methods to tackle them, where the burden doesn't lie on women who are making the complaints.

This article appeared in print under the headline “Why are there so few women in physics?”

Leader: “Swelling the number of women in physics will require a broad alliance”

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