

# The Indian Girl's Guide to Science, Technology, Engineering and Math (STEM)

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*Intro: As children and young adults, women in India enjoy and excel at science. But as studies progress to careers, fewer and fewer women stay on. How can we change the complex factors that keep women out of STEM? And just as importantly, why does Indian science need women?*

On October 14 this year — Ada Lovelace Day — a handful of people assembled in a café near Bangalore's Ulsoor lake, typing away on their laptops to add material on Indian women scientists to what is possibly the world's most read encyclopedia: Wikipedia. Three days before, a much larger group had gathered at the Lotka-Volterra computer teaching lab at the Indian Institute of Science's Centre for Ecological Studies with the same purpose. A handful of organisers, 15 participants from the institute, and around 10 more participants — online, but elsewhere — proceeded to enter names, dates, career achievements and biographical details. It may sound like a mundane activity, but the organisers, who included the all-women team of a non-profit science outreach initiative, had been working for two months to organise this Wikipedia edit-a-thon. And at the end of Ada Lovelace Day, material on around 40 Indian women had been added — names we have not grown up with but should have. Anandibai Joshee, who in 1886 became the first Indian woman to get a degree in Western medicine; Janaki Ammal, a path-breaking botanist during the Second World War and Anna Mani, a pioneering physicist who published five single-authored papers while working in CV Raman's lab between 1942 and 1945.

Last month, this trio joined the women whose profiles were freshly created or updated on Wikipedia — their place made firm on the Internet, while they continue to be absent from history textbooks. Read the carefully composed but Wiki-standard "objective" profiles and you get the beginnings, the barest glimpse into the enormous endurance, intelligence and suffering of these early scientists. Hear about the love and energy poured into the edit-a-thon and you get a sense of the

search contemporary Indian women scientists are on both for their place in the present and for their forgotten ancestors.

Delhi-based non-profit *Feminist Approach to Technology* published a study in 2014 which examined the performance of middle and senior schoolgirls and boys in science subjects in classes 8 and 9. They found that as the children moved from middle to senior school, girls tended to outperform boys in science and maths, but were less likely to pursue those subjects for higher studies. According to the Department of Science and Technology, in 2005, only 37 percent of PhDs in science were held by women. And a 2004 report by the Indian National Science Academy concluded from the little data it could gather that the percentage of women occupying faculty positions in most research institutions and prestigious universities was less than 15 percent. Why are so many women slipping out of science along the way?

The scientific establishment's inability to attract enough women and keep them in the workforce is a large enough problem for it to feature in interactions between nations' governments. Women in science has been identified as "a priority area for engagement" between the US and India — in July 2014, the two countries organised an exchange on "Evidence-Based Techniques to Advance Gender Equality in Science, Technology, Engineering, and Mathematics". And at the huge Indo-US Technology Summit in Noida, a workshop has been organised to promote women in science.

## Throwing Like A Girl, Experimenting Like A Boy

Here's a question. Why is it important to have women in science at all?

The range of scientific research can only be as varied as the interests of its researchers, what heats of the curiosity of the individual scientist and in turn the establishment she/he becomes part of. The highly

respected experimental physicist Athene Donald began her career around 40 years ago as one of eight women in a class of 100 at Cambridge. When she began her research into soft matter physics and its application to living organisms, her peers laughed at her and told her that it was not physics, but today the work she kick-started might lead to a cure for Alzheimer's. Primatologist Alison Jolly — among the first generation of women primatologists in the 1960s like Jane Goodall — is said to have changed evolutionary biology forever. Through her work in the forests of Madagascar, she shattered the faith held until then that males are dominant in all primate species. She was also able to prove that social ties and environment, rather than ecological factors, led to the evolution of higher intelligence among primates.

The continued underrepresentation of women, Dalits and minorities in sciences is not “only” a social justice problem. It leads to a homogeneous, stagnant approach to problem solving, when science itself says, “groups of diverse problem-solvers can beat groups of high-ability problem solvers”.

Some months ago, the poster-covered stairway of the Bangalore bookshop Blossom featured a small flyer asking for volunteers for a National Centre for Biological Sciences (NCBS) study in the human throwing motion. The study asked unselfconsciously and specifically for men. And why would the flyer be self-conscious when this until very recently has been the norm for science?

The gendered language of science and technology (where mechanical or electrical parts are assigned genders — for example, a bolt is ‘male’ while a nut is ‘female’) is often a reflection of cultural gender stereotypes. Biology once saw female eggs as “passive” agents and sperm as “active” ones. Right up to the 1990s, even. Johns Hopkins researcher Emily Martin's study was the first to do major damage to the “warrior sperm and damsel-in-distress egg” trope. A developmental biologist who came around early to Martin's theory said, “If you don't have an interpretation of fertilisation that allows you to look at the egg as active, you won't look for the molecules that can prove it. You simply won't find activities that you don't visualise.”

Or you could ask Sarah S Richardson why science needs diversity. Richardson's 2013 book *Sex Itself: The Search for Male and Female in the Human Genome* shows that the X and Y are not “sex chromosomes” after all. But once they were so named, around 30 years after they were discovered, it put blinkers on the way researchers approached chromosomes, bringing

cultural gender stereotypes into the way scientists looked at the science of sex. And in some cases, it resulted in some rather poor science — for instance, all the decades in which people wrongly believed that the XYY chromosome syndrome made men dangerous, violent and criminally inclined.

We are only just beginning to understand the impact of gender bias in research in areas such as women's health. Until very recently, there was little medical research into women and cardiac disease because it was assumed that women did not have heart attacks. But the medical establishment has now admitted that the signs we think are the classic symptoms of a heart attack (the pain in the left arm, etc.) are all signs men have. Women experience heart attacks very differently and are often under-diagnosed, misdiagnosed and likely to die. Similarly, one-third of all osteoporotic fractures are said to occur in men. Since the disease continues to be seen as the problem of post-menopausal women, men are very rarely tested for it.

Why do we have so little information on cardiac disease in women? Because science, medicine, drug trials most often use male subjects, whether rodent or human, even to test drugs that are not gender-specific. Hormone fluctuations in women and potential harm to foetuses during trials — privileging women's child-bearing ability over contributions to trials — have been seen as good reason to exclude women from studies in biology and medicine.

Because a male subject, in the minds of a male scientific establishment, is the neutral and the normal. It is an argument that is increasingly being seen as a flawed one, calling into question the very evidence basis of medicine. What this means is that in some cases, the medical treatment that women get, including drug dosage, may be far from right.

The US National Institutes of Health (NIH) on May 2014 announced that it would roll out policies beginning in October that would require applicants for funding to report their plans for the balance of male and female cells and animals in preclinical studies. Amidst increasing recognition that men experience hormone fluctuations too, the NIH pointed out in its announcement that “[t]ypically, reasons for male focus in animal-model selection centre on concerns about confounding contributions from the oestrous cycle. But for most applications, female mice tested throughout their hormone cycles display no more variability than males do, as confirmed in a meta-analysis”. But this skew has led to what is known as the drug-dose gap, where insufficient tests mean that women are receiving

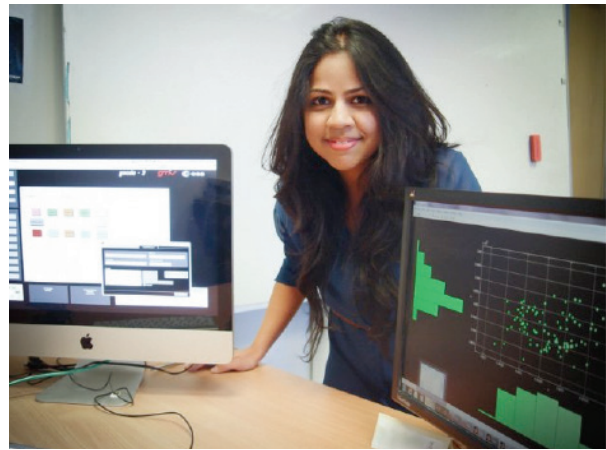
the wrong doses of medicine, and while it may drive up the cost of studies, it does not make financial sense in the long term — in 2005, it emerged that a male bias in drug efficacy and side-effect research led to the withdrawal of 8 out of 10 prescription drugs from the US market, because they affected women's health. Taking sex differences into account can have a widespread impact on science, and the instinct to control for variation needs to be examined.

Back to Bangalore and ball throwing. The NCBS scientist behind the study, Madhusudhan Venkadesan, responded as unselfconsciously as his flyer to my enquiry about the throwing study: "The current study in my lab is focused on understanding how humans achieve throwing accuracy at the same time as speed. [...] Those who throw often in early childhood develop an arm morphology that aids in throwing at very high speeds. There is then a strong possibility that social and cultural factors that sometimes preclude girl children from outdoor play could in turn affect the throwing ability in women. This conjecture is plausible, but not yet scientifically proven. Nevertheless, because it is important for our study to control for such variation in morphology, we are looking primarily for men. The goal of our study is not to differentiate between motor function in men versus women, but simply to find consistently fast throwers, particularly those who have been throwing since early childhood."

The assumption is that among all the humans who learn to throw balls as children, the small subgroup of gifted, consistently fast throwers are most likely male — and that the human throwing motion is equal to the male throwing motion. Even if, to borrow the scientist's phrase, it is not scientifically proven.

### Who Knows Where the Men Are? We Are Going to Mars

Anusha Mujumdar is a 27-year-old aerospace engineer from Bangalore. She is one of only 35 women across the globe this year who have been awarded the Zonta International Amelia Earhart fellowship for research into aerospace, science and engineering. Mujumdar is a part of the European Space Agency's Mars Sample Return Mission, which will retrieve soil samples so scientists can study them to determine, among other things, whether there really is life on Mars. And she is a third-year PhD student at Exeter in the UK, working in the Department of Applied Mathematics on verification and validation of spacecraft controllers. Her friends teasingly refer to her as a rocket scientist.



Aerospace engineer Anusha Mujumdar.  
[Photo courtesy University of Exeter]

Around two and a half weeks ago, Mujumdar got married and moved to her in-laws' home in a Bangalore suburb — when I visited her, I could still see the mehendi on her hands and her feet. Mujumdar grew up on the Indian Institute of Science campus. She says she was never "very good at science and math, but in the 8th and 9th standard, I had good science teachers and that was what motivated me to go into science, when I was around 13 or 14". At some point she was struck by the discovery that she could find patterns in any system that can be expressed mathematically. "That really excites me," she says. "The coolest thing I have done so far is work on the special controllers for the Airbus launch vehicle Ariane 5ME. I used some of my fellowship money to go to Airbus [an aircraft manufacturer] in Bremen, Germany, to work on it. The Ariane 5ME launches multiple satellites at a time, and to do that it has to stay in orbit for really long. One side of it faces the sun, so it has to keep rotating — the special controllers keep it evenly heated, preventing damage from thermal stress. And I worked on that."

Most female PhD students in India learn to answer grotesque questions about marriage in informal situations at work and during formal, career-changing, life-changing interviews. Mujumdar had to deal with enough of them, but I throw in one of my own: Why did she choose to get married before she finished her PhD? "It felt like the right time," she tells me. But for now, she still has a year of her PhD left to complete, and her sights are set firmly on her career — in December, she will be back at Exeter to make sure spacecraft stay in the sky.

Marriage and families remain recurrent motifs in the daily drama of women in the scientific establishment, in their leaving of the scientific establishment. In the last decade and a half, the Indian government

has made several efforts to encourage more girls and women to take up (and stay in) science. In 2003, the Council of the Indian Academy of Sciences constituted a committee on women in science, and later set up the Women in Science (WiS) panel, now chaired by particle physicist Rohini Godbole, the author of important work in the hadronic structure of high-energy photons. “The WiS panel’s main initiatives included publishing books to inspire more women to take up science, and a report [an Indian Academy of Sciences and National Institute of Advanced Studies (IAS-NIAS) study in 2010, titled “Trained scientific women power: How much are we losing and why?”] which was not appreciated as much as I think it should have been — I haven’t known any other study of that variety”. The panel also holds lectures and workshops on careers in science, and in February, the panel intends to organise its first conference with international collaborators.

In October 2004 came the Indian National Science Academy’s “Science Career for Indian Women” — one of the first reports to attempt to examine why Indian women were dropping out of science. In 2008, a report by the Task Force on women in science set up by the Department of Science and Technology looked into the subject with greater depth, having conducted meetings with scientists across India and having sought information from a range of institutions. Both reports identified family pressure — to get married, or have children, or care for dependent relatives — as a significant reason for women failing to continue in science despite being qualified to do so.

In 2010, the IAS-NIAS study examined the reasons for women with PhDs in science dropping out of their fields after doing a PhD. It surveyed 568 women scientists and 226 men scientists with PhDs in Science, Engineering or Medicine. Women were classified in three groups: women in research (WIR), women not in research (WNR) and women not working (WNW). Although the majority of women in all three groups were married, 14 percent of WIR between 30 and 70 — the highest in all groups — answered that they had “never married”. The corresponding figure for men in research (MIR) was 2.5 percent. When it came to children, 74.4 percent of WIR had children, a lower proportion than women in the other groups, including MIR — 86.3 percent of whom had children.

“Of course women have to choose,” says Anupama Surenjan, a third-year PhD student at IIT Chennai, with some heat. She tells me about a match that was arranged for her while she was studying for her MTech degree, where the boy did not want her to do a PhD. He

expected that she would relocate after marriage to an area near his workplace, and find an engineering job that would bring in money while causing the least disruption in his life. Surenjan chose her PhD.

Nandini Nagarajan, a 64-year-old retired geophysicist, was once the only woman in her class at IIT Kharagpur. In 1977, the Oil and Natural Gas Corporation (ONGC) wanted the Indian Institute of Geomagnetism to install a continuously running magnetometer in Port Blair in the Andaman and Nicobar islands. “I was given the task. I did everything from scratch — including passports to fly through Burma, permission letters from the Commissioner of the Andamans to buy a ticket to fly to the Andamans, instrument packing — in 4 days. I set up the instrument in a wooden hut and left soon after, and we managed to give ONGC four months’ data.” In 1988, she was the joint lead for a team to Ladakh — again, it involved permissions, instrument testing and deployment. “We camped outside Leh town for a month and bathed in streams. I brought a team of 3 vehicles and 4 colleagues back by the long route — through Srinagar, long before daily flights, cell phones, or even telephones were around.”



Geophysicist Nandini Nagarajan with colleagues on a field trip to Ladakh, 1988. [Photo courtesy Nandini Nagarajan]

Nagarajan believes that one of the main reasons women are forced to drop out of science is “relocation, relocation, relocation.” Her husband, who works as a chemical engineer, had to move cities every two years for the first decade of their marriage. “Well, the only solution to that,” she says dryly, “is divorce.” “I’d have been far more senior without those interruptions. My contemporaries who didn’t have those problems went on to get promotions, and head groups and institutions.”

The IAS-NIAS study points out that a significantly lower proportion of men have reported breaks in career compared to women. “While personal factors such as health, further studies and voluntary retirement have led to breaks for men, for women, domestic

responsibilities of childcare and care for elders have been the primary reason for the breaks in career,” it says.

Interestingly, the report found that the spouses of 41 percent of WIR were scientists too. “They all tend to pair off in the end,” senior wildlife biologist Rauf Ali chuckled over the phone from Pondicherry about the ecology students he has had over the years. Swapna Neraballi, a 34-year-old wildlife scientist currently studying vegetation patterns in the Andaman Islands, agrees that it is common for scientists in her field to pair up. “The couples I know tend to pick similar research interests and work locations so that they get to spend time with one another,” she says of her former classmates and colleagues. But Neraballi is married to a photographer who travels often for work, like she does. My long-distance phone conversation with her takes place at 6 am on a weekday, before she heads out into the field with her assistants from Wandoor (South Andaman) to examine a plot of land in Alexandria for changes in vegetation, on which she has been collecting data for a month. “The bottom line is, we spend a lot of time apart,” she says.

Anusha Mujumdar grew up on the Indian Institute of Science campus, where her father works as a scientist, and she grew up surrounded by men and women in science. Many of the women, she knows, had to take up less demanding jobs than their husbands after marriage or stop working entirely (significantly, the IAS-NIAS report points out that the largest proportion of women with PhDs who had spouses who worked in the same field or organisations were not working, indicating that having a partner doing similar work did not necessarily mean they would be more supportive of a woman’s career in science). Mujumdar tells me she has been lucky so far about not having to make a choice between a career in science and having a family. But later in our conversation, she mentions that she is clear she wants to have children. “And when I do that, I want to do it well...” she trails off. “I want to be a good mother...” For a moment, I see her confidence waver and wished I had not asked the question. I had just contributed to the death by a thousand cuts on young women who are pushed to “leave before they leave.” In *Lean In*, Facebook COO Sheryl Sandberg wrote, “From an early age, girls get the message that they will likely have to choose between succeeding at work and being a good wife and mother. By the time they are in college, women are already thinking about the trade-offs. In a survey of Princeton’s class of 2006, 62 percent of women said they anticipated work/family conflict, compared

with 33 percent of men — and of the men who expected a conflict, 46 percent expected that their wives would step away from their career track. These expectations yield predictable results: among professional women who take time off for family, only 40 percent return to work full time. But women rarely make one big decision to leave the workforce. Instead, they make a lot of small decisions along the way.”

### Feeling At Home In the Lab

In 2004, Vineeta Bal of the National Institute of Immunology (NII), New Delhi, found that 85.7 percent of the papers from India in 38 high-impact journals in biological sciences had men as the corresponding/senior authors and only 14.3 percent had women, despite the higher representation of women in these fields.

For the science-loving woman who fights her own sense of dutifulness to the family (real or imagined), the establishment often raises new obstacle courses. Only these obstacles are ones that the female scientist cannot talk about without raising suspicions that she is too “sensitive” or feeling that it is her own fault.

In the IAS-NIAS study, the researchers did something interesting. They asked both men and women in science what support they thought women scientists needed to stay in the game. The answers exhibited fascinating differences: “While a majority of WIR and MIR have reported flexibility in timings as an important provision, a larger percentage of responses by MIR indicated the need for refresher courses, fellowships, awareness and sensitisation campaigns to retain women in Science. In contrast, women perceive provisions such as accommodation and transportation as provisions that would help them balance their career and family.”

The researchers also pointed out that “family and societal pressures cannot explain completely why women drop out of Science”, cautioning against an overemphasis on women’s family roles. It pointed out that other organisational factors and infrastructure in the workplace also had a significant impact on whether women stayed on.

Hostile or unsafe work environments are a deterrent to women pursuing science careers. Whether it is within an institution or out in the field, women are often reluctant to talk about the harassment they face because their concerns can often be dismissed by male colleagues.

Rajaram Nityananda, a senior physicist who has worked at several scientific research institutions across

the country in the course of his career, served as the Centre Director of the National Centre for Radio Astrophysics in Pune, and is currently at the Azim Premji University, Bangalore. He says he had to deal with a couple of cases of sexual harassment. “In one instance, a complaint was lodged about the doctor of an institute who was reported to have made his female patients from the institute uncomfortable, by touching them unnecessarily. Once the case came up, more women began to speak up to the women’s cell about their experiences with the doctor. In that particular instance, the doctor’s contract was terminated.”

“In another instance, a woman student doing a project with a senior academic accused him of inappropriate behaviour. This person had developed a reputation for making his women students uncomfortable, many years earlier. The institute did take some immediate formal action based on the investigation and report of its Women’s Cell, and the student was given an alternative project and guide. However, it appears that this incident did not have any consequences for later decisions, which were examined purely based on the academic record. It appears that the prevailing attitude at the highest level was one of letting sleeping dogs lie.”

Shobhana Narasimhan, a theoretical physicist at JNCASR in Bangalore, says that when men tend to go for drinks after work, they are also creating informal but very significant spaces to network and share valuable information. “How to apply for grants, which journals to approach, which institutions to apply to — these are things that are otherwise hard to learn; no one teaches you these things. Women are typically excluded from these circles.”

Nandini Rajamani Robin, a wildlife biologist with IndiaBioScience, the non-profit that organised the Wikithon on women scientists, also identifies networking as being a major hindrance to career progression for women. “Appearing at conferences, which is one way to network, requires time and travel, and women with families aren’t always able to participate in this.” Another factor she points to is a sense of discomfort with self-promotion. “Networking also involves consciously putting yourself out there and talking about your work, which is something women have to learn to be comfortable doing.”

Listening to pioneering women scientists talk of their incredible achievements can be greatly invigorating but also disorienting. Some can believe that they controlled their lives and careers, but are hesitant when it comes to questions about gender. A common

tendency is to casually intersperse their sincere arguments that women just need to work hard instead of feeling like victims, with the stories of the shocking discrimination they faced.

Nandini Nagarajan was the first woman in her class, has four siblings who studied science (one of whom is Rajaram Nityananda), and her father was a mathematician. She sharply zeroes in on the “relocations” that disrupted her career, but when she talks about how she started in geophysics at IIT Kharagpur, she says, “The admissions committee was gender-blind.” Then, she says, “The teachers sat me down and asked me to consider going back to the physics department because there was fieldwork involved in the geophysics department, which they said would be hard for a woman. They neither coddled nor tried to marginalise me. After me there was someone who did her fieldwork in Bastar! For six months! Those were the good days. But it’s important to note that I was not a unique case. Just isolated because women were rare in some fields then. In that era, every discipline probably had a lone woman.”

A little later, Nagarajan points out that the Indian Institute of Chemical Technology, the institute next door to the National Geological Research Institute (NGRI), where she worked, got its first woman director in 60 years. The new director is in good company. Fabiola Gianotti, the first woman director-general of CERN in the 60-year existence of the particle physics lab was quoted as saying that she does not believe there is any intellectual discrimination against women in science. In the same profile where she was praised for her calm and ability to smile during stressful situations.

The feisty Anna Mani ragged Abha Sur, author of *Dispersed Radiance*, soon after meeting her, “What is this hoopla about women and science? It must be getting difficult for women to do science these days. We had no such problems in our time.” Sur wrote, “Yet, as I asked Anna Mani about the social environment and the support of her peers, a deep-seated hurt and anger surfaced. ‘He was an odious man’, she said, referring to a colleague who had done his best to make the women feel inept, both as scientists and as women. Any slight error the women made in handling instrumentation or in setting up an experiment was immediately broadcast by some men as a sign of female incompetence.” After she finished her PhD dissertation, Anna Mani was disqualified on a technicality and was never awarded her doctorate.