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"There are really many great female mathematicians doing great things" Maryam Mirzakhani (1977-2017)

In the next pages, we will publish two interviews with Mirzakhani about her life and her vision of mathematics. One of them is written by Saeed Kamali Dehghan for The Guardian in 2017 and the other one appeared on the Clay Mathematical Institute Annual Report in 2008. This short introduction has been written by our editorial staff by selecting excerpts from the article "A Tenacious Explorer of Abstract Surfaces" by Erica Klarreich in Quanta Magazine, 2014.

Maryam Mirzakhani is the first woman to win a Fields Medal. The gender imbalance in mathematics is long-standing and pervasive, and the Fields Medal, in particular, is ill-suited to the career arcs of many female mathematicians. It is restricted to mathematicians younger than 40, focusing on the very years during which many women dial back their careers to raise children.

Mirzakhani liked to describe herself as slow. Unlike some mathematicians who solve problems with quicksilver brilliance, she gravitated toward deep problems that she could chew on for years. "Months or years later, you see very different aspects" of a problem, she said. There are problems she has been thinking about for more than a decade. "And still there's not much I can do about them," she said. Asked to describe her contribution to a particular research problem, she laughed, hesitated and finally said: "To be honest, I don't think I've had a very huge contribution." And when an email arrived in February saying that she would receive what is widely regarded as the highest honor in mathematics, she assumed that the account from which the email was sent had been hacked.

As an 8-year-old, she used to tell herself stories about the exploits of a remarkable girl. Every night at bedtime, her heroine would become mayor, travel the world or fulfill some other grand destiny. In her life, she wrote many other elaborate stories in her mind. In a way, she said, mathematics research feels like writing a novel. "There are different characters, and you are getting to know them better," she said. "Things evolve, and then you look back at a character, and it's completely different from your first impression."

She finished elementary school just as the Iran-Iraq war was drawing to a close and opportunities were opening up for motivated students. She took a placement test that secured her a spot at the Farzanegan middle school for girls in Tehran, which is administered by Iran's National Organization for Development of Exceptional Talents.

In her first week at the new school, she made a lifelong friend, Roya Beheshti, who is now a mathematics professor at Washington University in St. Louis. To her dismay, she did poorly in her mathematics class that year. Her math teacher didn't think she was particularly talented, which undermined her confidence. At that age, "it's so important what others see in you," she said. "I lost my interest in math." The following year, Mirzakhani had a more encouraging teacher, however, and her performance improved enormously. "Starting from the second year, she was a star," Beheshti said.

Mirzakhani went on to the Farzanegan high school for girls. There, she and Beheshti got hold of the questions from that year's national competition to determine which high school students would go to the International Olympiad in Informatics, an annual programming competition for high school students. Mirzakhani and Beheshti worked on the problems for several days and managed to solve three out of six. Mirzakhani went on to the Farzanegan high school for girls. There, she and Beheshti got hold of the questions from that year's national competition to determine which high school students would go to the International Olympiad in Informatics, an annual programming competition for high school students. Mirzakhani and Beheshti worked on the problems for several days and mana-

Maryam Mirzakhani is awarded the Fields Medal in Seoul on 16 August 2014.

ged to solve three out of six. Even though students at the competition must complete the exam in three hours, Mirzakhani was excited to be able to do any problems at all.

In 1994, when Mirzakhani was 17, she and Beheshti made the Iranian math Olympiad team. Mirzakhani's score on the Olympiad test earned her a gold medal. The following year, she returned and achieved a perfect score. Having entered the competitions to discover what she could do, Mirzakhani emerged with a deep love of mathematics. "You have to spend some energy and effort to see the beauty of math," she said.

Gold medals at the mathematical Olympiad don't always translate into success in mathematics research. "In these contests, someone has carefully crafted a problem with a clever solution, but in research, maybe the problem doesn't have a solution at all." Unlike many Olympiad high-scorers, Curtis McMullen said, Mirzakhani "has the ability to generate her own vision." And so she did until last year when she died before she turned 40.

Maryam Mirzakhani: Iranian newspapers break hijab taboo in tributes

Tehran front pages run photographs of mathematician without head covering, showing her prominence overrode rules

Fig. 1. – Maryam Mirzakhani was the first woman to win the Fields medal. Photograph: Maryam Mirzakhani /Stanford University/EPA.

Iran's state-run newspapers on Sunday broke with the country's strict rules on female dress to show the mathematician Maryam Mirzakhani with her head uncovered, as the country mourned the death at the age of 40 of the woman known as the queen of mathematics.

Tributes were led by the president, Hassan Rouhani, who posted a recent picture of Mirzakhani on Instagram without a hijab. "The grievous passing of Maryam Mirzakhani, the eminent Iranian and world-renowned mathematician, is very much heartrending," he wrote.

Mirzakhani, a Stanford University professor, died in hospital in California on Saturday after cancer in her breast spread to her bone marrow. The university president, Marc Tessier-Lavigne, said Mirzakhani's influence would live on in the "thousands of women she inspired" to pursue maths and science.

When in 2014 she became the first woman to win the Fields medal, often described as maths' Nobel prize, Iranian newspapers digitally retouched Mirzakhani's photograph to put a scarf over her head while others published a sketch showing only her face. Iran's strict laws on female dress require all women to be covered in public.

Fig. 2. – Sunday's front pages of Iranian newspapers bearing portraits of the scientist Maryam Mirzakhani, who died of cancer. Photograph: Atta Kenare/AFP/Getty Images.

The front page of Hamshahri, a state newspaper, particularly stood out, winning praise for portraying her as she had lived. "Maths genius yielded to algebra of death", read its headline over a picture of Mirzakhani without a hijab. "The queen of mathematics' eternal departure", read the headline of Donya-e-Eqtesad's headline.

The Fields medal, first given in 1936, is awarded to exceptional talents under the age of 40 once every four years. Mirzakhani won the prize in 2014 for her "outstanding contributions to the dynamics and geometry of Riemann surfaces and their moduli spaces".

Christiane Rousseau, vice-president of the International Mathematics Union, said at the time it was "an extraordinary moment" and compared it to Marie Curie's Nobel prizes in physics and chemistry at the beginning of the 20th century.

In another sign that Mirzakhani was breaking more taboos even after her death, a group of parliamentarians in Iran on Sunday urged the speeding up of an amendment to a law that would allow children of Iranian mothers married to foreigners to be given Iranian nationality.

Mirzakhani is survived by her Czech scientist husband and her daughter but a marriage between an Iranian woman and a non-Muslim man was previously not recognised, complicating visits to Iran by their children. Fars news agency reported on Sunday that 60 MPs were pressing for the

amendments so that Mirzakhani's daughter could visit Iran.

Fig. 3. – Iranian president Hassan Rouhani's tribute to Maryam Mirzakhani.

Mirzakhani was born and raised in Iran. She studied at Tehran's prestigious Sharif university and later finished a PhD at Harvard in 2004.

She had survived a bus crash in February 1998 when a vehicle carrying the mathematical elite of Tehran's Sharif University back from a competition in the western city of Ahwaz skidded out of control and crashed into a ravine. Seven award-winning mathematicians and two drivers lost their lives in the crash.

Mirzakhani and at least two other survivors later left their country, underlying Iran's long-standing brain drain difficulties.

"A light was turned off today, it breaks my heart ... Gone far too soon," said Firouz Naderi, an Iranian Nasa scientist. "A genius? Yes. But also a daughter, a mother and a wife."

Tessier-Lavigne, the Stanford president, described Mirzakhanai as "a brilliant mathematical theorist, and also a humble person who accepted honours only with the hope that it might encourage others to follow her path."

Edward Frenkel, University of California Berkeley professor and the author of the New York Times bestseller Love and Math, tweeted: "RIP #MaryamMirzakhani – a great mathematician and wonderful human being who broke a glass ceiling and inspired many, men and women alike."

Mirzakhani predominantly worked on geometric structures on surfaces and their deformations.

A statement from Stanford said she "specialised in theoretical mathematics that read like a foreign language by those outside of mathematics: moduli spaces, Teichmüller theory, hyperbolic geometry, Ergodic theory and symplectic geometry."

In a rare 2008 interview, with the Clay Mathematics Institute, Mirzakhani said as a child she dreamt of becoming a writer and did poorly at maths at school.

"I never thought I would pursue mathematics until my last year in high school," she said, crediting her older brother for getting her interested in maths and science.

"My older brother was the person who got me interested in science in general. He used to tell me what he learned in school. My first memory of mathematics is probably the time that he told me about the problem of adding numbers from 1 to 100." (The answer is 5,050 and the trick is to look at pairs that add up to 101.)

Interview with Research Fellow Maryam Mirzakhani

Maryam Mirzakhani, a native of Iran, is currently a professor of mathematics at Stanford. She completed her Ph.D. at Harvard in 2004 under the direction of Curtis T. McMullen. In her thesis she showed how to compute the Weil-Petersson volume of the moduli space of bordered Riemann surfaces. Her research interests include Teichmüller theory, hyperbolic geometry, ergodic theory, and symplectic geometry.

What first drew you to mathematics? What are some of your earliest memories of mathematics?

As a kid, I dreamt of becoming a writer. My most exciting pastime was reading novels; in fact, I would read anything I could find. I never thought I would pursue mathematics before my last year in high school. I grew up in a family with three siblings. My parents were always very supportive and encouraging. It was important for them that we have meaningful and satisfying professions, but they didn't care as much about success and achievement. In many ways, it was a great environment for me, though these were hard times during the Iran-Iraq war. My older brother was the person who got me interested in science in general. He used to tell me what he learned in school. My first memory of mathematics is probably the time that he told me about the problem of adding numbers from 1 to 100. I think he had read in a popular science journal how Gauss solved this problem. The solution was quite fascinating for me. That was the first time I enjoyed a beautiful solution, though I couldn't find it myself.

Could you talk about your mathematical education? What experiences and people were especially influential?

I was very lucky in many ways. The war ended when I finished elementary school; I couldn't have had the great opportunities that I had if I had been born ten years earlier. I went to a great high school in Tehran, Farzanegan, and had very good teachers. I met my friend Roya Beheshti the first week after entering middle school. It is invaluable to have a friend who shares your interests, and helps you stay motivated. Our school was close to a street full of bookstores in Tehran. I remember how walking along this crowded street, and going to the bookstores, was so exciting for us. We couldn't skim through the books like people usually do here in a bookstore, so we would end up buying a lot of random books.

Also, our school principal was a strong-willed woman who was willing to go a long way to provide us with the same opportunities as the boys' school. Later, I got involved in Math Olympiads that made me think about harder problems. As a teenager, I enjoyed the challenge. But most importantly, I met many inspiring mathematicians and friends at Sharif University. The more I spent time on mathematics, the more excited I became.

At Sharif University, we had problem-solving sessions and informal reading groups with my classmates. The friendship and support of all the people I met there and later at Harvard helped me a lot in many different ways. I am grateful to all of them.

Did you have a mentor? Who helped you develop your interest in mathematics, and how?

Many people have had a great influence on my math education, from my family and teachers in high school to professors at Sharif University, and later at Harvard.

You were educated in Iran. Could you comment on the differences between mathematical education there and in the US?

It is hard for me to comment on this question since my experience here in the U.S. is limited to a few universities, and I know very little about the high school education here.

However, I should say that the education system in Iran is not the way people might imagine here. As a graduate student at Harvard, I had to explain quite a few times that I was allowed to attend a university as a woman in Iran. While it is true that boys and girls go to separate schools up to high school, this does not prevent them from participating say in the Olympiads or the summer camps.

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But there are many differences: in Iran you choose your major before going to college, and there is a national entrance exam for universities. Also, at least in my class in college, we were more focused on problem solving rather than taking advanced courses.

What attracted you to the particular problems you have studied?

When I entered Harvard, my background was mostly combinatorics and algebra. I had always enjoyed complex analysis, but I didn't know much about it. In retrospect, I see that I was completely clueless. I needed to learn many subjects which most undergraduate students from good universities here know. I started attending the informal seminar organized by Curt McMullen. Well, most of the time I couldn't understand a word of what the speaker was saying. But I could appreciate some of the comments by Curt. I was fascinated by how he could make things simple, and elegant. So I started asking him questions regularly, and thinking about problems that came out of these illuminating discussions. His encouragement was invaluable. Working with Curt had a great influence on me, though now I wish I had learned more from him! By the time I graduated I had a long list of raw ideas that I wanted to explore.

Most problems I work on are related to geometric structures on surfaces and their deformations. In particular, I am interested in understanding hyperbolic surfaces.

Can you describe your research in accessible terms? Does it have applications to other areas?

Most problems I work on are related to geometric structures on surfaces and their deformations. In particular, I am interested in understanding hyperbolic surfaces. Sometimes properties of a fixed hyperbolic surface can be better understood by studying the moduli space that parametrizes all hyperbolic structures on a given topological surface.

These moduli spaces have rich geometries themselves, and arise in natural and important ways in differential, hyperbolic, and algebraic geometry. There are also connections with theoretical physics, topology, and combinatorics. I find it fascinating that you can look at the same problem from different perspectives, and approach it using different methods.

What research problems and areas are you likely to explore in the future?

It's hard to predict. But I would prefer to follow the problems I start with wherever they lead me.

Could you comment on collaboration versus solo work as a research style? Are certain kinds of problems better suited to collaboration?

I find collaboration quite exciting. I am grateful to my collaborators for all I have learned from them. But in some ways I would prefer to do both; I usually have some problems to think about on my own.

What do you find most rewarding or productive?

Of course, the most rewarding part is the "Aha" moment, the excitement of discovery and enjoyment of understanding something new, the feeling of being on top of a hill, and having a clear view. But most of the time, doing mathematics for me is like being on a long hike with no trail and no end in sight!

I find discussing mathematics with colleagues of different backgrounds one of the most productive ways of making progress.

How has the Clay Fellowship made a difference for you?

It was a great opportunity for me; I spent most of my time at Princeton which was a great experience. The Clay Fellowship gave me the freedom to think about harder problems, travel freely, and talk to other mathematicians. I am a slow thinker, and have to spend a lot of time before I can clean up my ideas and make progress. So I really appreciate that I didn't have to write up my work in a rush.

What advice would you give to young people starting out in math (i.e., high school students and young researchers)?

I am really not in a position to give advice; I usually use the career advice on Terry Tao's web page for myself! Also, everyone has a different style, and something that works for one person might not be so great for others.

What advice would you give lay persons who would like to know more about mathematics—what it is, what its role in our society has been and so on? What should they read? How should they proceed?

This is a difficult question. I don't think that everyone should become a mathematician, but I do believe that many students don't give mathematics a real chance. I did poorly in math for a couple of years in middle school; I was just not interested in thinking about it. I can see that without being excited mathematics can look pointless and cold. The beauty of mathematics only shows itself to more patient followers.

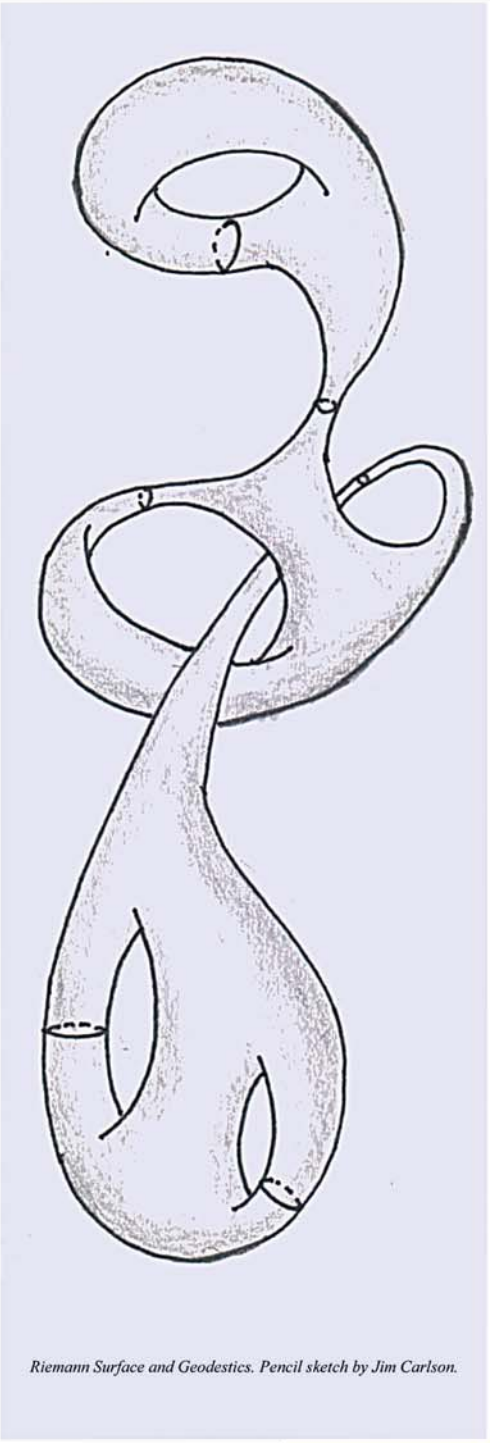
Please tell us about things you enjoy when not doing mathematics.

Mostly, I spend time with my family and husband. But for myself, I prefer solo activities; I enjoy reading and exercising in my free time.

Recent Research Articles

"Ergodic Theory of the Earthquake Flow." *Int Math Res Notices* (2008) Vol. 2008.

"Ergodic Theory of the Space of Measured Laminations," with Elon Lindenstrauss. *Int Math Res Notices* (2008) Vol. 2008.



Riemann Surface and Geodestics. Pencil sketch by Jim Carlson.