time with Karen) and her colleagues both professionally and personally provide an example of academic excellence.

I will never forget my first birthday away from home when Karen organized a surprise party at her own place as well as the warm and welcoming dinner for my father visiting from Italy.

Although the path of graduate work in the history of mathematics Karen had envisioned and designed for me sometimes felt burdensome, I always recognized her genuine goal of training her students to become knowledgeable and successful professionals.

I have often treasured the rigor and the dedication that Karen required from me as her student: these qualities have proved fundamental in the development of my professional career also outside of the academic world.

Laura Martini

Credits

Photo of Della Dumbaugh is courtesy of the University of Richmond.
Photo of Patti Hunter is courtesy of Patti Hunter.
Photo of Sloan Despeaux is courtesy of Sloan Despeaux.
Photo of Deborah Kent is courtesy of Radina Droumeva.
Photo of Laura Martini is courtesy of Laura Martini.

Interview with Jennifer Chayes[2]

Anthony Bonato

I first met Jennifer Chayes at the 2012 Workshop on Algorithms and Models for the Web Graph conference in Halifax. She gave a keynote talk, and I chatted with her as she set up her presentation. My first impression was of her cool confidence and the force of her intellect.

Jennifer is one of the leading researchers in network science, working at the interface of mathematics, physics, computational science, and biology. She is the Managing

Figure 2. Jennifer Chayes.

Director of Microsoft Research New England and New York City. She is highly awarded, being a Fellow of the American Mathematical Society, a Fellow of the Association for Computing Machinery, recipient of the Anita Borg Institute Women of Vision Leadership Award, and winner of the Society for Industrial and Applied Mathematics John von Neumann Lecture Prize. She was also recently made Microsoft Technical Fellow.

This interview was conducted in September 2017.

AB: *What was your first mathematical memory as a child?*

JC: I was four years old or so. I used to visit a neighbor—I started going there because a very nice woman gave cookies to my brothers and me. When we were choosing cookies, I heard her husband and daughter, who was a high-school math teacher, doing math problems. I thought it sounded cool, so I started asking them if they could give me puzzles. They probably thought I was weird, but they gave me puzzles, and I loved doing them.

There hadn't been any math in my household; my father was a pharmacist, and my mom couldn't add fractions (although she's very smart). But my neighbors sounded like they were having so much fun. They then started making up little word problems for me. I didn't know algebra or anything, although I did know how to count.

I liked it, and I found it very fun. They loved projective geometry, and they would give me things to work on at my level.

AB: *Was there a person or teacher who influenced your early scientific career before university?*

JC: In seventh grade, I took Euclidean geometry, and our teacher taught us how to prove things. It was an honors class for kids good in math. He taught us about logic: statements,

Anthony Bonato is a professor of mathematics at Ryerson University. His email address is abonato@ryerson.ca.

[2]*Chapter 3 of* Limitless Minds: Interviews with Mathematicians *by Anthony Bonato,* https://bookstore.ams.org/mbk-118.

DOI: https://dx.doi.org/10.1090/noti2442

converses, contrapositives, how to properly conclude things, and so on. I loved it, and for me it was magic.

This sometimes happens with great teachers. He obviously understood a lot—not all of my teachers were like that. In eighth grade, I asked my teacher why I couldn't put a square root in the denominator. My teacher said to me, "You can't put radicals in the denominator, just like you can't put bananas in the refrigerator!" While the year before I had someone teaching me formal logic. They were a huge variance in the quality, enthusiasm, and understanding that my math teachers had.

My seventh grade teacher was very passionate, and he would get excited when there were kids in the class like me who fell in love with the subject.

AB: *Your undergraduate was in biology and physics, and then you completed a doctorate in mathematical physics at Princeton. What led you to Princeton, and how did you end up working with your supervisor?*

JC: Theoretical physics was more stylish at the time than mathematical physics. People said mathematical physics wouldn't get me a job. But things have changed, with mathematicians now caring a lot about that topic, which is at the forefront of mathematics. I liked proving theorems, and I liked physics.

I thought I was going to be a particle physicist first, but it wasn't nearly as mathematical as it is now. Then I took a class from Elliott Lieb who was doing beautiful work on atomic physics. I liked the class, but I wasn't as wild about atomic physics. I asked him if he would do statistical physics with me as his student and he agreed.

I also worked with the supervisor of my ex-husband Lincoln Chayes, who was Michael Aizenman. I was co-advised by Elliott and Michael. The work with Elliott was more analytical, and the things with Michael were more probabilistic.

I knew Princeton had very good mathematical physics at the time. Even though I was not a mathematics undergraduate (I was one or two courses shy of such a degree), I loved mathematics. The summer before my senior year, I met Barry Simon at Princeton. Barry thought it was implausible that this couple coming from Wesleyan would go into mathematical physics at Princeton as they only accept one or two students in that area a year. He tried to have us apply to other graduate schools. I left feeling depressed, but I learned later that Barry was on the admissions committee and pushed to get us in.

Figure 3. Elliott Lieb.

AB: *Your work is in many areas, ranging from graph limits, to phase transitions, to modeling complex networks. How would you describe your research to a non-mathematician?*

JC: It might appear as if I am doing several different things, but I have a set of lenses through which I see the world. Many mathematicians have similar lenses, and, for many of us, the lenses are set early. In graduate school, I did work on random surfaces and percolation that helped set these lenses.

I try to see networks and geometric structures as representations of something going on in a certain system. Much of my early work was on percolation, which is like coffee percolating. A passageway is either open or closed to a liquid. Not everyone's grains of coffee are in the same configuration and yet there are some bulk properties similar to my espresso and yours. It's like taking draws from a distribution.

I tend to study systems with randomness, which is common in the real world. After I got to Microsoft about fifteen years ago, people were just starting to talk about the internet and the World Wide Web as structures that one could understand. I took insights from percolation and phase transitions, and I used that to model the internet and the web, and then later social networks. I also see networks in computational biology that I do. There are omic networks, where you have genomic or proteomic data, where many

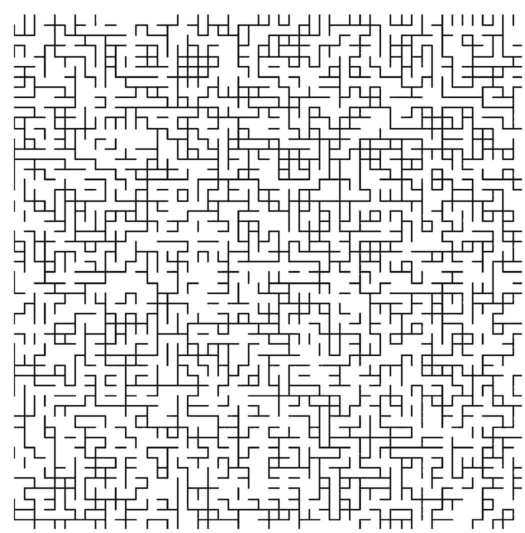

Figure 4. Percolation theory studies the connectivity of networks.

times you don't observe the whole network. For example, when you study an evolutionary tree, all you see are the leaves. In biological data, you don't see every gene that has been activated or every protein in a cell. You try to infer the missing parts of a network. These inference problems are often related to machine learning problems. There are nice implications there: if I recognize a protein as important that no one else has recognized, then that could be a drug target.

Phase transitions were things I also studied in graduate school, and, for me, these have become a metaphor for the world. We just underwent a phase transition in November 2016! In phase transitions, when you vary the system, you see both quantitative and qualitative changes. Examples are water boiling or freezing, or certain types of magnets, which are magnetized or not at certain temperatures. They also happen in graphical representations of other problems. This is how I went from a mathematics department to Microsoft. There were problems people studied in computer science that have graphical representations and that undergo phase transitions from tractable to intractable. There is a precise mathematical correspondence there, and I started to use equilibrium statistical physics to study things that were happening in theoretical computer science.

More recently, I've used non-equilibrium statistical physics methods, which happens in a system with a driving force of some sort. I am using this to provide insight into how deep neural nets work.

AB: *What research topics are you working on now? You can be more technical here if you like.*

JC: I am working on several different things. I am working on graph limits, which is something we invented twelve years ago with László Lovász, Christian Borgs, Vera Sós, and Katalin Vesztergombi. Christian and I have continued to work on the topic up to the present. We first did graph limits for dense graphs, where every node is connected to a positive fraction of all other nodes. Most networks in the real world are sparse, however. For example, Facebook keeps growing, but I'm not friends with a positive fraction of other nodes. So that's a sparse graph.

Figure 5. Jennifer Chayes with husband and collaborator Christian Borgs at Microsoft.

In the last five years or so, we've developed two very different theories for graph limits of sparse graphs, and in particular sparse graphs with long tails like the Facebook graph or power-law graphs. We have one that is a static theory, a kind of L_p theory, where things are integrable, but they may not have a second moment. We also have a time-dependent theory that the statisticians like that models the progression of these networks.

Another thing I am working on is how to do A/B testing on networks. For example, we do A/B testing when the outcome of one group is getting a drug and another getting a placebo. Or the Microsoft homepage might roll out a different version to one percent of their traffic to see if they like that version more. But suppose I was studying people getting a flu shot with treated flu virus or a placebo flu shot. If your children got a real flu shot and you received a placebo shot, and none of you got the flu, it would not be sound to conclude the flu shot had no influence. There's interference in the network because members of your family are interacting with each other.

So how do you do an A/B test on a network? We have methods to draw correct inferences. We are excited about it since it has many practical applications for the experimental design of tests on networks of interacting entities.

Another big project we are starting is with Stand Up To Cancer. They are a wonderful foundation that has raised about six hundred million dollars. For our project, they raised about fourteen million dollars. They bring together groups of researchers to study certain classes of questions. Usually, they bring together biologists and oncologists. Recently, they've started what they call convergent projects, where they bring mathematicians, physicists, and computer scientists together with oncologists and biologists.

Our project is called Convergence 2.0, and we are studying cancer immunotherapy. We are applying machine learning and network analysis to try to understand why certain people respond favorably to cancer immunotherapy while others don't. These are very complex problems involving genomes and your T-cell profile. Everyone has a different T-cell profile; there is a neat combinatorial trick your body does to come up with a unique T-cell profile. We will work with people at about ten different institutions on problems around this. I also have a new physics-based theory of deep learning, which I mentioned earlier, although it's been non-rigorous up to this point. But in equilibrium statistical physics people are only now proving the results rigorously. There is little understanding of why these neural nets work, so I think it's worthwhile even to do non-rigorous work that gives us conjectures to attempt to prove.

AB: *Congratulations on becoming a Microsoft Technical Fellow.*

JC: In the industry, it's a big thing. It is the equivalent of a corporate vice president, but it is much more technical. Microsoft has over one hundred thousand employees, and under thirty Technical Fellows, so I am excited about it.

It wasn't just a promotion, but I have an additional responsibility. I have a lab in New York, one in Boston, and a small group in Israel, but I just got a new lab up in Montreal. It's a company that we acquired about eight months ago called Maluuba, which was roughly half research and half development, focusing on machine reading and comprehension, dialogue, reinforcement learning, and other topics in machine learning. I am also super excited about getting personally involved in the Montreal AI hub: Canada in general and Montreal, in particular, is at the forefront of AI, and I think this will continue. You have an amazing government, both federally and provincially in Quebec, which is supporting the Montreal region. We are going to be growing there, and I am thrilled to have a group there.

AB: *Maybe someday you will start something in Toronto?*

JC: Maybe. Like the investment in Montreal, the Canadian government is also making a big investment in Toronto with the Vector Institute. One of my postdocs is going there. There are three institutes in AI funded by the Canadian government. With these investments, instead of a brain drain, Canada is creating remarkable groups that can have an outsized influence on a dominant field.

AB: *What advice would you give to young people, especially young women, on pursuing a career in mathematics and STEM?*

JC: First, there is something I tell women even before they go to university: it's not sufficiently well publicized that STEM fields are creative and collaborative. We tend to see pictures of solitary guys sitting at computer terminals.

What I do is creative. I imagine worlds and prove theorems about them. Sometimes they have an impact on the real world; for example, they may help with cancer therapy. I have amazing collaborations, and I work in teams. And I have societal impact.

I think it is an easier life than being creative in other fields. I thought about becoming an artist when I was younger, but then I probably would have had to do a day job and come home exhausted trying to make art.

I would also say that for whatever reason, women tend to be less confident than men are. Part of that is not seeing as many role models. As a professor, I would interact with super talented women undergraduates, who didn't think they were good enough to go to graduate school. Women often don't realize that everyone is working hard; if you are doing well, it's also because of talent.

Women tend to take themselves out of the running before they should. Your self-assessment of your ability is not a reliable signal. If you like STEM, or if you had a teacher who tells you that you are good at it or you're passionate about it, then you should follow it. Reach out and network. STEM professions tend to lead to really satisfying careers.

Figure 6. "I imagine worlds and prove theorems about them." Jennifer Chayes.

AB: *You were a child of Iranian immigrants to the US. What effects do you think the travel ban is doing to mathematical and scientific research in the US right now?*

JC: I'm thrilled that Microsoft brings in Iranian interns, going through the necessary steps hiring them. We don't think about nationality when we are hiring someone. Many Iranians have been my interns and postdocs, so I was concerned by the travel ban. I have a young colleague at Yale whose family was stuck outside of the country owing to the ban. His wife and child couldn't get back in, and he couldn't leave because he had to teach.

I also have DACA [Deferred Action for Childhood Arrivals] students in New York City who are very scared now. I think we are a country of immigrants, and our greatest talent and vibrancy comes from that. Embracing immigrants is so fundamental to what it is to be America. I am concerned.

AB: *I'd like to close with looking forward. What would you say are some of the major directions for mathematics in the future (or in your own program)?*

JC: Whenever there are things that work well with little understanding of why, then I believe that there is some mathematics to be formulated and proved. In my position, I'm witnessing much of what is happening in deep learning—from image recognition to speech recognition to machine reading and comprehension. We see all these unexpected breakthroughs. These are high-dimensional random problems.

What is it about the structure of deep neural net algorithms that is finding useful information in these sparse high-dimensional structures? Answering that will involve many areas of mathematics, and a great deal of new mathematics will be developed.

I believe that the problems the world brings us guide us in the development of new mathematics.

Credits

Figure 2 is licensed under Creative Commons Attribution-ShareAlike 4.0 International (CC BYSA 4.0).
Figure 3 is courtesy of the Archives of the Mathematisches Forschungsinstitut Oberwolfach.
Figure 4 is licensed under Creative Commons Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0).
Figure 5 is licensed under Creative Commons Attribution 2.0 Generic (CC BY 2.0).
Figure 6 is licensed under Creative Commons Attribution-ShareAlike 3.0 International (CC BYSA 3.0).

Interview with Maria Chudnovsky[3]

Anthony Bonato

Maria Chudnovsky is a leading mathematician working in the field of graph theory. She was born in St. Petersburg, Russia, in 1977, and moved to Israel with her family at the age of thirteen. Maria studied mathematics at Technion in Haifa. She completed her PhD at Princeton University in 2003, supervised by Paul Seymour, where she is now a professor.

Maria has the most famous PhD dissertation in the recent history of graph theory. She proved, in joint work with Neil Robertson, Paul Seymour, and Robin Thomas, the "Strong Perfect Graph Theorem" (SPGT), which was first posed by Claude Berge back in the 1960s. Research on SPGT and perfect graphs resulted in hundreds of papers and partial solutions before its resolution. There are about 700 citations on MathSciNet® for the search "perfect graphs" up to 2006 when the 178-page proof was published in the *Annals of Mathematics*. I vividly remember the excitement surrounding the announcement of the proof of SPGT, and how it sent ripples throughout the discrete mathematics community and beyond.

Maria is a giant in her field. For her work on SPGT, she won the Fulkerson Prize in 2009. She holds a MacArthur Foundation Fellowship (or "Genius" grant), and her research is funded by the National Science Foundation. Maria is also unique among mathematicians I know of for appearing in not one, but two television commercials: one for TurboTax and one for Comfortpedic.

This interview was conducted in May 2016.

[3]*Chapter 4 of* Limitless Minds: Interviews with Mathematicians *by Anthony Bonato*, `https://bookstore.ams.org/mbk-118`.

DOI: https://dx.doi.org/10.1090/noti2443

Figure 7. Maria Chudnovsky.

AB: *How did you first become interested in mathematics?*

MC: I don't remember a time when I wasn't. Math was always easy and fun, and everything else was hard. It was a very natural thing for me. It was always my favorite subject. I remember the pain of learning to read, and I don't remember the pain of learning to count.

AB: *Did anyone play a role in inspiring your interest in mathematics?*

MC: My dad loved math. He was an engineer, but as a kid he loved mathematics. Probably he said enough things to get me interested.

I was lucky as I had very good teachers. I went to a special mathematics school in St. Petersburg, Russia. I was born in Russia, and my family moved to Israel when I was thirteen. I went to this school from the ages seven to thirteen, where math was the most important thing in the world, and the best thing you could be was to be good at math. I also had many good teachers who made things beautiful and made things interesting. From everything I heard in school, I never doubted there was anything more interesting than math.

AB: *Can you tell us something about your experience at Technion? In particular, what was the environment like there, and how did it help lead you to Princeton?*

MC: I started at Technion in the eleventh grade, where I began going to a Math Circle that was led by a Masters student in applied mathematics. It was a fun experience. He would solve Math Olympiad problems with us. If he attended an advanced mathematics lecture, he would tell us