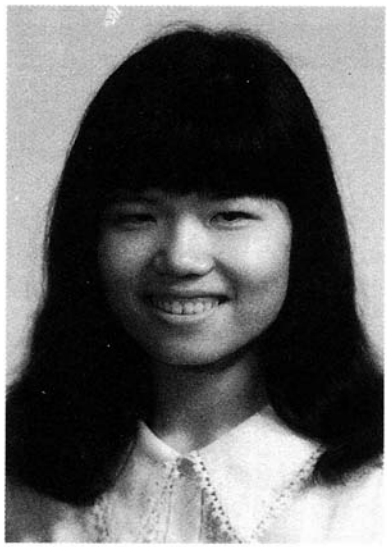

Fan Chung

Fan Chung

(1949–)

Fan Chung is the only woman interviewed for this book who was born in another country—she grew up in Taiwan and received her early mathematical training at Taiwan University. Chung came to the United States to do graduate work at the University of Pennsylvania and continued as a research mathematician in industry, first at Bell Labs, and later at Bellcore. Most recently she became a professor of both mathematics and computer science at the University of Pennsylvania. Chung's training in Taiwan, as well as her work in industry, provides an interesting contrast to the other stories included here.[37]

Though it is rather unusual for women to be mathematicians in either China or Taiwan, Fan's class in mathematics at Taiwan University was one-third female. The camaraderie with her female classmates, most of whom continued on in mathematics in the United States, played an important role in her identity as a woman mathematician. Fan has been an extremely productive mathematician; she has published more than 170 papers, with more than 90 different co-authors. For Fan, collaboration is a powerful mode of doing mathematics, one that she actively cultivates not only in her own work, but also in her role as a manager of a team of researchers at Bellcore.

Fan's life as a woman in mathematics has been a fairly smooth one. She was able to integrate marriage and motherhood with being a mathematician. Like so many women mathematicians, she is married to a mathematician, Ron Graham. Their relationship exemplifies one way to integrate personal and professional life and illustrates some of the advantages as well as potential disadvantages of such an arrangement.

From Taiwan to America

Fan Chung's family was from mainland China, but they moved to Taiwan the year Fan was born. Fan stayed in Taiwan until she finished college, at which point she came to the United States to begin graduate studies in mathematics. Her family was unusual because her mother worked full-time; she was a high school teacher who was respected and loved by her students. Though her mother taught what sounds like a very traditional subject for women—home economics—in Taiwan she represented a modern and non-traditional woman, both in her lifestyle (having a full-time career) and in what she taught. Home economics signified not so much the traditions of the past as the technology of the future, including the use of sewing machines and kitchen appliances, which radically redefined domestic roles. Fan's mother passed on to her daughter the lessons and advantages of economic independence, strongly encouraging her to pursue a career and "not just to be an attachment to a man."

It was clear to Fan, however, that she could not follow in her mother's footsteps by pursuing home economics. Though she much admired some of the craft traditions, including the very old art of knot design, she was not particularly good with her hands, so she decided early on to pursue a life of the mind instead. By the time she was in high school, she had decided on mathematics. "My father sort of directed me to mathematics. He said mathematics is a foundation and you can always switch to other fields later on. Also, since I'm not so good with my hands, it seemed good to go into a science that didn't require experiments, just a pencil and paper." Because Fan excelled on the standardized aptitude tests that were given to all students, her path into mathematics was relatively easy. She was the top math student in her high school on these tests, and was admitted to one of the best colleges, Taiwan University. Fan is humble about this accomplishment, for she believes it is really "small cleverness" to do well on exams. The real challenges in becoming a mathematician were yet to come.

As an undergraduate at Taiwan University, Fan received an extremely rigorous education. After her first year, *all* of her courses were in mathematics, a degree of specialization almost unheard of in American undergraduate education. The courses were intensive, many equivalent to graduate-level courses in the United States. Fan enjoyed this immersion in mathematics. Her positive experience was partly due to the unusual demographics of her class—out of thirty students, ten were women, a strikingly high percentage for Taiwan University. And the women were by far the strongest students; each had been either first or second in her

high school. This community of women created a supportive environment within which to learn mathematics. "When we were all in the same class, we would help each other a lot. It's not competition at all." As Fan elaborates:

> I was quite fortunate because it's good to be able to have mathematical discussions with other people. It's an important part of education. But in Taiwan, it's quite conservative; there were only male professors, no female professors. And the boys mingled together socially, but the girls were out! Girls were not in their circle at all. Fortunately there were several of us so we could discuss things among ourselves. In general women graduate students are at a disadvantage. They cannot mingle as much because it's a social situation.

Many of the women in her class went on to do graduate work in the U.S., and to have successful careers in mathematics. Though they don't get to see each other a lot, they still stay in touch and know what is going on in each other's lives.

Having support in making the transition to the United States was important because it was quite a difficult change. For some, the culture shock was unbearable. The smartest of the group, Fan's closest friend, ended up committing suicide. She was doing fine mathematically, but the foreignness was extreme: the language, the customs, the values. It is impossible to know what actually led to the tragedy, or whether the same thing would have happened had she stayed in Taiwan. As Fan says, "There is often a very thin line between being talented and being crazy."

One way Fan was able to cope with the transition to America was to marry early. In this way she was protected from having to deal with the most radical differences in culture, particularly in the social sphere:

> For us, holding hands with a boyfriend was a serious thing. But the first thing I learned when I came to this country was that couples who were not even married were living together. According to my teachings, that was absolutely a no-no. It was a difficult change. My solution was to get married, so I wouldn't have to deal with all that confusion.

Graduate School and Early Professional Life

Fan went to graduate school at the University of Pennsylvania in Philadelphia. In contrast to undergraduate school, where she did most of her work with her fellow students, in graduate school she worked primarily alone

or with her advisor, Herbert Wilf.[38] There was one other female graduate student, Joanne Hutchinson, whom she really liked and who would talk with her about both mathematics and social issues. The latter was particularly helpful for Fan.

From the start, it was not difficult for Fan to integrate mathematics and motherhood. She had her first child during her last year of graduate school. She believes that this is in fact a good time for women to have children. In Fan's case, it was made easier by the fact that her schedule was quite flexible. She had done so well during her first years as a graduate student that she received a research fellowship, which precluded the need to teach. Hence, she was able to work at home whenever she needed to, both throughout her pregnancy and during the first few months after her child was born. The only problematic part was that she was also applying for jobs, and she thought it would hurt her professionally to go to interviews so obviously pregnant. The job market was tight, she was a woman, and she was from a foreign country to boot. Being pregnant did not seem like an asset. Fortunately, she received two job offers without an interview. One was a short-term position at the University of Hawaii. The other was a position at Bell Labs, a major center for mathematical research. She chose Bell Labs. She had done a joint paper with Ron Graham, a highly respected mathematician there. Based on that work and word-of-mouth recommendations, she was hired.

Fan's research has been in combinatorics and discrete mathematics—areas that could have potentially important applications in the communications industry and beyond. Combinatorics is an unusual field; the problems are often simply stated, and in that way very accessible, though they can still taken tremendous creativity and ingenuity to solve.

> Combinatorics was really interesting and fun for me. Some people with infinite training in mathematics, or too much theoretical buildup, sometimes have a hard time dealing with these simply stated problems. They don't know where to start. There's no clear, well-defined path. You have to just look at it. Of course, that's not completely true. There are some standard kinds of techniques. And there are some well-developed theories, but often you have to use everything you know, and just dig in with your hands. I like this problem-solving kind of thing. There are two kinds of mathematicians, theory developers and problem solvers, I think I have a good part of the problem solver in me.

Fan stayed at Bell Labs from 1974 to 1983, until the AT&T antitrust lawsuit. After the breakup, an offshoot, Bellcore, was formed, where Fan is now a division manager and continues to be actively involved in research.

Being active in research did not, however, preclude her having a second child. When she got pregnant during her second year at Bell Labs, her manager wondered whether she planned to quit once the child was born. Fan never discussed her home life with her professional colleagues, so her manager was not even aware that she already had one child, and that that had clearly not interfered with her work.

> I just said that I would work until the last day. It's a lot of trouble in this country to take maternity leave. They have to change benefit plans, etc. So I said I would just take vacation. It was not even in my record that I was leaving for a second child. In fact, I actually wrote a paper during the four weeks I was out. I was in the hospital and then home, and Ron mentioned a nice problem to me—a graph decomposition problem. I heard the problem and immediately thought I could do something about it. So I solved the problem and wrote up a paper during that month.

Once again, Fan found having a child relatively easy to integrate into her work life. She had a private office, so she could close the door and take a nap when she needed to. Her schedule was again quite flexible—she did not have students knocking at her door or courses to teach. She could work any time, day or night. But perhaps most important, she had tremendous support at home. She was able to hire excellent women to help with the children and domestic responsibilities.

> Having live-in help made a big difference. It takes away the worrying. Some women enjoy staying at home, and that's fine. But for those who like to have their own work, they have to get as much help as they can—from husbands, or someone else—and try not to put too much on themselves. I have seen some women try to do too much themselves, and they get too tired. It's not good for them or the kids.

Her husband was also quite helpful with their children, a somewhat unusual trait for a man from Taiwan. For some women, hiring full-time help to take over duties traditionally ascribed to women is a difficult step. They feel that they are abandoning their duties as mothers, and are inclined to try to do it all themselves. But this seems not to be an issue that Fan struggled with. In part, this was because she had clear signals from both her parents, even when she was young, that having a professional life is very important.

Although having hired help was essential, it did not eliminate all domestic responsibilities. One final factor she feels is critical for balancing personal and professional life is the ability to juggle these different roles simultaneously.

> You have to be able to juggle. When I was at home, I was cooking, thinking, working on my stuff, while the kids kept coming by and asking questions. You have to piece together small periods of time and accept interruptions. House things need to be done, kids need attention; husbands are almost like kids, they need attention too. If you really need uninterrupted, concentrated time, it's hard.

Thus, while for Fan integrating mathematics and motherhood was relatively easy, all of these factors were important: talent, a flexible schedule, smooth pregnancies, healthy children, excellent live-in help, a supportive spouse and parents, and the ability to juggle many things at once.

A Mathematical Marriage

Just as Fan was able to mix mathematics and motherhood, so too was she able to smoothly integrate marriage and professional life. While Fan's first marriage played an important role in her adjustment to the new world of the United States, and her husband was actively involved in raising the children, in the end it did not last. "The marriage was not so bad, but I think I went into it a little bit too fast. We had a few good years, but it was not the right foundation for a marriage. He was very nice to me, but I was never madly in love."

Her second marriage, to Ron Graham, a talented and eclectic mathematician who also worked at Bell Labs, is a striking example of how personal and professional life can become completely fused. Though many women mathematicians are married to other mathematicians, few have such an intensely collaborative relationship. As Fan says, "In terms of mathematics, we have almost our own language." Mathematics, to them, is not so much about work as it is about play. They love what they do; it is fun and interesting, and exactly what they want to be doing with their time—all of their time. As Fan says, they are both workaholics. It is not unusual for mathematics to be the first thing they talk about when they wake up in the morning. Even in the evening, when they arrive home from work, they do mathematics together. And on the rare occasion that they take a vacation, they do mathematics wherever they go.

Their house, too, is a perfect reflection of the bond that unites them. It is a lovely and spacious home, recently remodeled with an addition that Fan designed. One room is their mathematics library, filled with books and mathematics journals from floor to ceiling. Their living room has one

whole wall dedicated to their whiteboard—the kind with markers so they don't have chalk dust all over the room. Even their furniture was carefully chosen to add to the functional ambiance: a beanbag chair, a hanging chair, and other unusual chairs.

Their style of doing mathematics is casual and playful. They don't sit at a desk or a computer. "I usually work by holding a pad and pencil and sit in one of those chairs. In our bedroom there is a round glass table. Now and then I sit there and do things, but it's not like a desk; there are no drawers, it's just a clear surface." There are plenty of diversions around: Ron is an avid juggler and trampolinist, there are rooms full of video arcade games, and puzzles, Rubik's cubes, and electronic teasers are scattered throughout the house.

For many people, close collaboration is a difficult relationship to achieve. How do they manage, given how intimately intertwined their lives are? Fan acknowledges that she has had to learn how to work with Ron, since their styles are somewhat different. Occasionally she feels strongly and differently about something, for example how a paper should be written up, but for the most part their collaboration is easy. She has learned how to work with their differences:

> Ron is a very smart man, so it takes a relatively smart person to understand him. He definitely has many ideas, ranging from new and interesting to outrageous. Sometimes if you push him to the north, he goes to the south, so if I want to get him to go to the south, I push to the north! After understanding that theory a little bit, I found that he is really very easygoing and considerate.
>
> *You know him well.*
>
> Yes, actually we even joke often about that. That's probably part of the reason that some couples don't work together—it could cause too much friction. But in our case we really enjoy working together a lot. I do notice that the work gets much better, not just with Ron but also with other co-authors. With another person pushing in a different direction it goes faster and further.
>
> *Two halves make more than a whole.*
>
> Right.

Collaboration occasionally extends to teaching as well as research. She and Ron recently co-taught a course at Princeton based on a book Ron co-authored called *Concrete Mathematics*.[39]

Being married to Ron has other advantages as well. His reputation gives him the flexibility to accommodate Fan's career. At one point she was

offered, and seriously considered taking, a position at a major research university. Ron was very supportive since it would have been relatively easy for him to find a job in the new location. Though she declined the offer in the end, such options continue to be a possibility in their lives.

Mathematics is a passion they can share not only with each other, but with their children as well. At the time of this interview, Fan's son was at a math training camp where future math Olympiad team members are selected. Both Fan and Ron had spent weeks coaching him, and Ron had developed a wonderful series of lessons to teach him mathematics. Though Fan felt that her son's chances of being selected for the team were slim because this was his first year at the camp, the whole family was very involved in the excitement and training.

Of course, there are certain disadvantages in being married to a mathematician as well. Fan is keenly aware of the potential danger of living in the shadow of such a prominent mathematician. She has been careful, therefore, to do plenty of research on her own and with other mathematicians. Her work with Ron is only about one-third of her published research.

Another disadvantage arose when Fan was considered for a political office in a major mathematics association. She was turned down because she was married to Ron, who had a formal position in the association. It was seen as a conflict of interest for her to have such a post. She was somewhat disappointed. "In that sense it hurts me to be married to such a big name. It hurts my identity. As a woman mathematician, it's relatively hard not to marry another mathematician, just because most people I run into are also mathematicians. We share more in common and we work on problems together. It's wonderful to have a spouse who can appreciate what's been done and who can say, 'Oh, this is nice.'" It is rare that a man is denied a position because his wife is a member of the same professional organization.

Mathematical Research

One reason Fan has so thoroughly enjoyed her field of research—combinatorics—is that it has connections to many other fields within mathematics, as well as to other sciences and technology. These interdisciplinary connections contribute to the rapid growth of the field, continuously stimulating new ideas and problems. At times she works with engineers, at other times with computer scientists, and at still other times with number theorists. And because the field is quite young, there are plenty of

problems to work on. In fact, as she says, "there are too many problems and not enough ideas. I can just stretch my arm in the hole and pick one out."[40]

In the beginning she would work on any problem she came across that looked interesting and fun, but over time she has come to have a larger vision of combinatorics research, and she now tries to work on problems that seem important or central. She has developed a "taste" for problems as she sees how things fit together into "sort of a bigger tree." The question of what constitutes an important problem is of central concern to her in her role as editor of a major mathematical journal. And it is a topic she discussed recently on a trip to China, for she feels that one of the major difficulties for the Chinese is that they are relatively isolated mathematically and hence cannot always discriminate between dead-end problems and those that are more central.

So what criteria does Fan use in determining important questions? First, she argues that it is good to work on "mainstream" problems, i.e., central problems in a field that may relate to many other problems. When you work on mainstream problems, even partial results can be important. Furthermore, even if you don't solve them, you will learn a lot of important mathematics by working on them. Second, she recommends working on problems that other (prominent) people have asked, and worked on, but have not been able to solve. The underlying assumption is that major researchers in the field have developed a taste for important problems, and so one can rely on their judgment. A third guide is to find problems that have a lot of impact either within the field of combinatorics or on other fields in math (pure or applied) and science. Often the impact of a problem is not recognized until after it has been solved, however, so this is only partially helpful. Finally, Fan says, it certainly helps if a problem has "a natural beauty."

Fan recognizes that even though all of these factors are important, often people choose to work on a problem because it captures their imagination and stimulates their curiosity. A "natural curiosity" is something she refers to often and believes is very important for a mathematician.

One of the advantages of working in industry is the tremendous amount of collaboration among colleagues. Communication between mathematicians is actively cultivated, and there is a great deal of flexibility in schedules to allow for travel and interaction with other mathematicians around the world. "When you think about it, all you need [for research] is a computer, travel money, help typing up papers, etc. But that's about all." And a library as well. But what is clear is that communication with colleagues is at the core of research. And research labs such

as Bell Labs and Bellcore have done a good job at creating that. Indeed, they provide a fascinating contrast to the model that has evolved in academia, which tends to be focused more on the individual. The whole system of tenure and promotion tends to cultivate competition rather than collaboration. Clearly, however, research in industry is effective—most labs would not survive if they did not prove to be worthwhile. Though research in this context is inevitably more closely tied to utilitarian ends, there is no reason to assume that a similar model might not be effective in research that was not driven by such clear practical goals.

Thus, Fan's story raises provocative questions about how mathematics is practiced. Certainly for Fan, collaboration has been central to her research. As she says, "My co-authors are my best teachers. You learn a lot of proven theorems, known results, and how to actually use them to do things. You really see the action when you collaborate with other people. . . . It's a wonderful relationship—it's a little more than just friends."

She finds the four axioms of collaboration described by Hardy and Littlewood to be helpful guidelines for successful collaboration:

1. You don't have to be right or complete in what you say while collaborating.
2. When one person tries to communicate (e.g., by letter), the other has no obligation to respond because people have different paces. This is a way of protecting each other's freedom.
3. It is not necessary for both people to check all the details.
4. The proportion of contribution is totally irrelevant.

Fan thinks the last axiom is the most important, for she believes that the cause (i.e., getting results) and the relationship are much more important than quibbling about who contributed how much. Inevitably things balance out in the end, and the relationship is more important than a single paper because it often leads to future collaboration and results.

In moving from Bell Labs to Bellcore, Fan moved into administration. She is in charge of the research division in mathematics and theoretical computer science. In this capacity, one of her primary tasks is to create an atmosphere conducive to creativity, productivity, and collaboration. She is careful not to intimidate or take advantage of young researchers in her division. Thus she is sometimes less likely to do joint work with them. Instead, she encourages them to work with other peers, so they won't get lost behind her name.

Fan also believes it is important to recognize that different people have different mathematical paces: both in the short-term sense—how quickly they can solve a given problem—and also in the long-term sense—at what

point in their life they do their best work. In her own case, she feels fortunate to be fairly fast at doing math.

> I have had a chance to meet and work with many great mathematicians. Some people are just very, very fast. And that's good too. I've been able to work with them and you get a little faster. I think I'm faster than most people, but there are a few people who are just so much faster than I am. On the other hand, I know some great mathematicians who are very slow. So slow probably helps because it helps you think differently. I certainly admire those very fast people. That's one way of showing their intelligence. Some people are so fast they start to intimidate other people, and I think that's not very nice. I've been on both sides. There are people who are slower, especially young people. I always try to tell them that the speed is not the thing, it's the quality of research that matters. These two things are not always so perfectly correlated.

Fan is grateful that she ran into people who were faster than she late in life, for by then she had developed enough confidence in her own abilities that she was not easily intimidated. Instead, she just tries to learn from such colleagues and appreciate their speed for what it is.

Pace enters in not only in doing a given problem, but also in the timing of one's life and career. While there is the prevalent myth in math that one does one's best work early in life, Fan has found quite the opposite to be true. As she says, "Actually, I think I've proved my better theorems recently. I think my last year's work was my best. People have different paces."

Certainly being married to another mathematician and being in a highly stimulating research environment both contribute to her continued productivity. But in the end, what is perhaps most sustaining of all is that she continues to find mathematics both interesting and fun. "I think if we want to encourage more people into research, they should know the existence of such a great life. . . . Mathematics, especially research in mathematics, is wonderful. It's big puzzles and small puzzles. It's more than solving a puzzle. Like Hardy said, it's uncovering structures. In many senses it's like art work."

Epilogue
by Fan Chung

About five years ago, I was awarded a Bellcore Fellow and took a sabbatical as a visiting professor at Harvard. At the time, my choice was between a place with many people in my area or Harvard, where there was no one in combinatorics. I chose the latter, and it has worked out well. I ran into Shlomo Sternberg in the first week, and we started a series of collaborative works, including one article on the mathematics of the Buckyball which appeared in *American Scientist*. I have also collaborated with David Mumford and Persi Diaconis, repectively. Perhaps the most important collaboration is with S. T. Yau. We have worked on a series of ideas to develop spectral graph theory using powerful techniques in spectral geometry. The interplay between the discrete and the continuous has brought new approaches, deep insight, and many results in both areas. The work is still continuing since many new directions are being opened up. In the article, I talked about problem-solving and theory-developing. I guess that there is quite a bit of theory-developing in me also.

As you can see, the visit to Harvard was really good for my mathematics. At the time, the decision to leave our comfortable home to commute 250 miles away was not an easy one. It was possible only with the strong support of Ron, who understands and encourages the need for growth.

Two years ago I joined the faculty of the University of Pennsylvania as professor of mathematics and also the endowed Class of 1965 Professor. Recently, the Department of Computer Science at Penn gave me a secondary appointment as professor of computer science.

I have enjoyed the move to academic life. Some courses that I am teaching aim at bringing out the power and beauty of math by conveying the interaction of different mathematical areas and the connections of theory and practice. We have a number of guest speakers to address how mathematics is actually used as an integrated part of current technology in computing and in communication.