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Fan Chung Graham

Many times, moving to a different country can be a difficult transition for an individual. For many the "culture shock" involved can be too much to handle. As a young woman moving to America from Taiwan to further her studies, Fan Chung experienced some degree of this culture shock first hand. However, she overcame these obstacles to become one of the world's top mathematicians with a highly successful career in industry and academia (Notable, p. 29).

Fan Chung was born in Taiwan in 1949. Her family was from Mainland China, but moved to Kaochiung, Taiwan.
Her father was an engineer, and her

mother was a home economics teacher. As a home economics teacher in Taiwan, her mother instilled in her daughter the advantages to being economically independent by encouraging Fan to have a career and "not just to be an attachment to a man."

Although Fan respected her mother because she was a modern woman, having a full time job, and teaching home economics, which was a respected subject in Taiwan at the time, she knew she did not want to pursue home economics as a career. Fan was not good with her hands, and chose to pursue a "life of the mind" instead (Henrion, p. 98).

As a high school student in an all girls high school in Kaoshiung, Taiwan, Fan decided to pursue mathematics (Notable). Her father guided Fan into the field, saying mathematics is a good foundation that allows you to switch to other fields later on in life (Henrion, p. 98). He also said, "In math all you need is pencil and paper (Albers)." Fan had no problems in her early pursuit of mathematics, as she excelled on the standardized aptitude tests that were given to all students. She also scored the highest math score on these tests of all the students in her high school (Henrion, p. 98).

Because of Fan's excellence in the field of mathematics, she was admitted to Taiwan University, which was known as one of the best colleges in the country. During Fan's duration at Taiwan University, her course load was extremely demanding. Her last three years of college consisted of Fan having all mathematics courses on her schedule. These courses were quite advanced, most being of the same level of difficulty as graduate-level mathematics courses in the United States (Henrion, p. 98).

Despite the rigorous course load, Fan Chung enjoyed the challenge and saw herself as being luckier than many mathematicians. In a profile of her life she commented, "As an undergraduate in Taiwan, I was surrounded by good friends and many women mathematicians (Albers)." In fact, the demographics of her class were very unique. Of the thirty students in her class, ten were women, which was very unusual for Taiwan University. The university had only male professors, and the presence of these women was quite exceptional, especially since they were the top students in the class. In fact, in her graduating class of 1970, the top six graduates were women even though men outnumbered women two to one in the university (Notable, p. 31). Many of her female classmates, like Fan, went to universities in the United States to continue their education at a higher level (Henrion, p. 98). Finally, after much hard work, Fan received her Bachelors of Science degree in Mathematics in 1970.

Fan chose the University of Pennsylvania as the institution from which she would pursue graduate studies. Her research area was in combinatorics and discrete mathematics. The transition to America was quite difficult. "Culture shock" such as differences in language, customs, and values made it difficult for a young woman from Taiwan to adjust to the United States. Perhaps to better adjust to the change, Fan decided to get married early on in her graduate career (Henrion p. 99).

At the University of Pennsylvania, Fan worked in a very different environment than what she had been used to in Taiwan. She worked mostly alone on research and class work, with the exception of consulting her advisor, Herbert Wilf, and a fellow student, Joanne Hutchinson at times. In addition to her studies, Fan was busy balancing her life as a student with her life as a wife (Henrion, p. 99). During her last year of graduate school, Fan gave birth to her first child. She thinks this was a wonderful time for her to have her first child, as she was on a pretty flexible schedule with only her thesis to finish before graduation (Albers). Chung balanced all her roles perfectly, and in

1974 she earned her PhD in mathematics from the University of Pennsylvania (Agnesscott).

During the latter stages of her pregnancy and prior to finishing up her graduate studies, Fan began searching for a job. At first, she felt looking for a job was going to be difficult because she was a woman from a foreign country and to top it all off, she was going to have to miss work to have a baby (Henrion, p. 100). Despite her worries, in 1974 Chung was offered and accepted a job with Bell Labs. Bell Labs was a mathematical research center that employed some of the nation's top scientists and mathematicians.

She soon learned at her new job that "if you just put your hands out in the hallway, you'd catch a problem (Albers)." During her twenty years of work at Bell Labs, Fan developed a "nose" for problems, as she learned to collaborate with her colleagues in order to achieve success (Albers). She found that her research went hand in hand with problems in areas such as communication and computation. As a result, she collaborated with engineers, computer scientists, chemists, physicists, and other mathematicians (SIAM).

Also while at Bell Labs, Fan Chung gave birth to a second child. She did not take a maternity leave. Rather she took a four-week vacation in which she spent time with her newborn baby and wrote a paper. It was also at Bell where Fan met her second husband, Ron Graham, who like Fan is also a mathematical genius (Albers). Fan and her husband enjoy "talking" mathematics, and she once said, "In terms of mathematics, we have almost our own language." The have a mathematics library in their home that is full of math journals and books from top to bottom. They also have an entire wall in their living room that is a dry erase board where they can sit and work out math problems in their free time (Henrion, p. 103).

In 1993, after spending seven years as a manager at Bellcore, a branch of Bell Labs with which she worked for twenty years, Fan accepted a job as a visiting professor at Harvard. During this time she continued to make connections with other mathematicians and "catching" problems, which is much of what she did at Bell. However, this experience in academics made Fan want to return to the field. So, in 1994 when the University of Pennsylvania offered her a job as a professor, she happily accepted (Albers).

Fan remained at the University of Pennsylvania from 1994-1998, when she joined the faculty of the University of California at San Diego. Her teaching is geared toward "bridging the gaps between mathematics in the classroom and mathematics that is actually being used in the real world (BIO)." She is also working toward establishing a generation of "dynamic students." She has also been described as being "broad-minded about the paths taken by her students (SIAM)."   She believes that mathematics is more important than ever in terms of the problems that arise from the many advances in technology (Albers).

A biography of Fan's life and work would not be complete without making mention of her many accomplishments and awards. Throughout her career as a distinguished mathematician, Fan has written about 200 papers, with over half of them being written collaboratively. She is the author of two books: <u>Erdös on Graphs</u> and <u>Spectral Graph Theory</u>. She is now the editor-in-chief of the <u>Electronic Journal of Combinatorics</u> and Advances in Applied Mathematics. Adding to her busy life is the fact that she also works on the editorial boards of more than a dozen journals (Bio). In 1990, Fan was awarded the Allendoefer Award from the Mathematical Association of America for her excellence in the article "Steiner Trees on a Checkerboard," which she co-authored with her husband Ron Graham (Agnessscott).

The mathematics of this paper will focus a topic on which Fan Chung Graham wrote one of her many papers. The paper is called “Mathematics and the Buckyball,” and Fan co-authored this paper with Shlomo Sternberg.

A buckyball is a molecule comprised of 60 carbon atoms arranged in a form similar to a soccer ball. Its properties, such as symmetry, have inspired interest in people throughout multiple fields of science. In their paper, "Mathematics and the Buckyball," Fan Chung and Shlomo Sternberg provide mathematical analysis of some of the buckyball's properties such as stability by combining topology, group theory, three-dimensional geometry and graph theory. The topology aspects of the buckyball will be the main focus of mathematical aspects of this paper (buckyball).

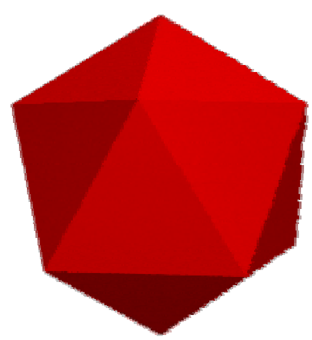


Fig. 1.1: Regular Icosahedron

Consider the formula, $f - e + v = 2$, given to us by Euler, where f is the number of two dimensional sides, e represents the number of lines or edges, v is the number of points that are vertices. A regular icosahedron consists of twelve vertices, twenty sides, and thirty edges (Refer to Fig. 1.1). One can see that the properties fit Euler's formula by observing, 20 - 30 + 12 does in fact equal 2. The sides of the icosahedron are triangular and there are 5 edges emerging from each of the twenty vertices. To obtain the shape of the buckyball, convert the sides of the regular icosahedron from triangle to pentagons and hexagons. To make this conversion, turn one vertex into a pentagon (See fig. 1.2-1.4).

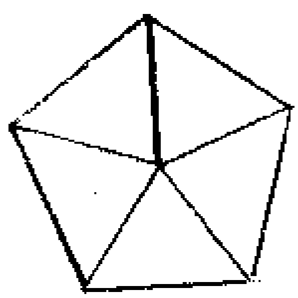


Fig. 1.2: Vertex of the Icosahedron

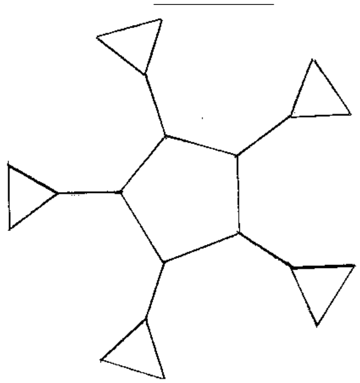


Fig. 1.3: Converted Vertex of the Icosahedron

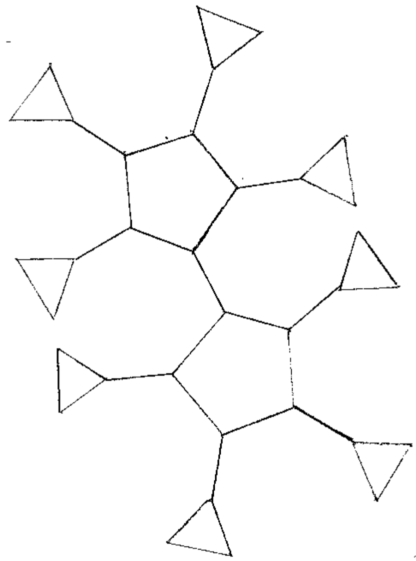
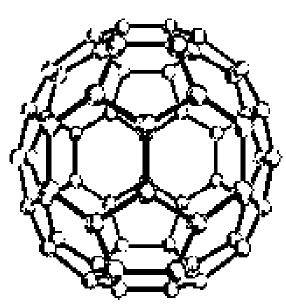


Fig. 1.4: Two Converted Vertices of the Icosahedron

What was a point is now a side with five sides and 5 vertices. Now the figure has 16 vertices, 21 sides and 35 edges. 21 - 35 + 16 = 2 so Euler's formula still holds. Repeat this process for the remaining vertices to obtain the buckyball. The buckyball has twelve sides in the shape of pentagons, twenty sides in the shape of hexagons, ninety edges, and sixty vertices. 32 - 90 + 60 = 2 therefore Euler's formula dimensions come about (buckyball).



Buckminsterfullerene

Having 12 vertices being converted into pentagons, which have 5 vertices, obviously explains how there are 60 vertices in the buckyball. The original five edges emerging from the vertices are now spread out by the new edges created from converting the vertices. Each pentagon is connected to another pentagon by one edge from the vertex of one pentagon to a vertex of another pentagon. Each vertex of a pentagon is connected to another pentagon by an edge. No pentagons share and edge nor do they have common vertices. The edges connecting the pentagon are the edges of the original regular icosahedron. Therefore there are the 30 connecting edges plus the 60 new edges, created by the pentagons, making a total of ninety edges.

The edges separating the pentagons combined with the edges of the pentagon form a hexagon. Therefore each pentagon is encased within hexagons and each hexagon shares an edge with three different pentagons and three different hexagons. From this we can determine that all sixty edges provided by the pentagons are also edges of hexagons and these edges form only half of the edges of the hexagons. Doubling this figure we can obtain that the sum of the edges of the hexagons is 120.   There are only 90 edges in the buckyball. However, half of the edges of hexagons are shared with other hexagons. If we separate the hexagons from their shared edges we could see that the sum of the edges of the hexagons is 120. Divide 120 by the number of edges in a single hexagon, 6, to obtain the number of hexagons within the buckyball, which are 20.

Using this mathematical derivation of the buckyball, Fan Chung and Shlomo Sternberg determine physical properties beyond the shape, such as symmetry, stability, and vibrational modes. These generalizations are beneficial to chemistry and physics. Fan Chung's contributions and significant findings have made her one of the more successful applied mathematicians of the modern day.

The road to becoming one of the world’s top mathematicians was not an easy one for Fan Chung. She had to work very hard to overcome many cultural barriers to get where she is today. When first living in America, Fan had to overcome “culture shock,” and learn to adapt to differing traditions, customs, and languages. She adapted to these changes beautifully and has never looked back. She has contributed to many papers, journals, and books. Fan truly is a leader in her field, and is quite involved in the field of mathematics.