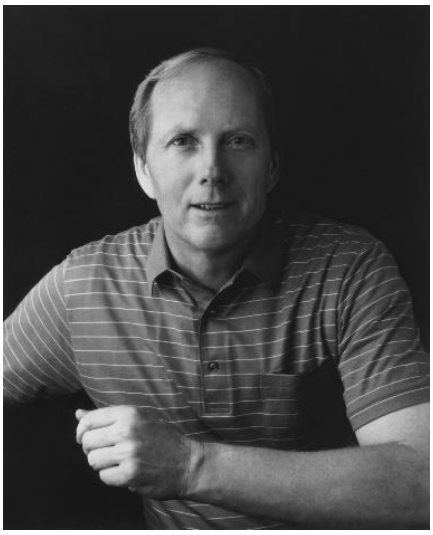
"American mathematician known for his leading role in the rapid growth of discrete mathematics in recent decades" (July 2020)

by Colm Mulcahy (a much shortened and edited version of this appeared in the *Guardian*)




Ron Graham, who has died aged 84, was one of the most prolific American mathematicians of the last half century, despite never finishing high school. The cause of death was bronchiectasis.

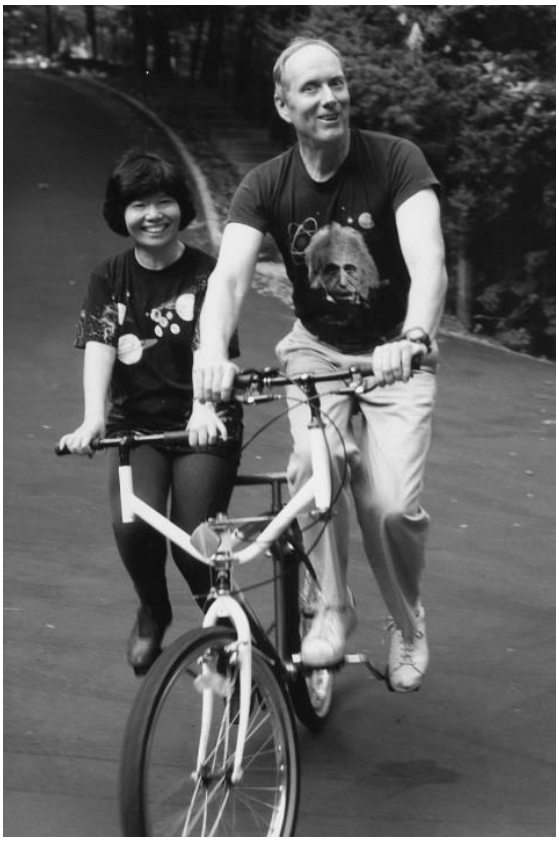
Ron worked in both applied and pure mathematics, often in the underpinnings of theoretical computer science and telecommunications. Two thirds of his long career was spent in industry, at Bell Labs in New Jersey, and the rest was at the University of California at San Diego.

He did pioneering research in discrete mathematics, or combinatorics, specifically in Ramsey theory, quasi-randomness, scheduling theory, and discrete and computational geometry, as well as in recreational mathematics and mathematical magic. He published about 400 papers, 100 of them with his wife Fan Chung; together they were a formidable mathematical team. He authored an influential book with her, and others with Paul Erdős, Don Knuth and Persi Diaconis. He was an engaging popularizer of mathematics through extensive expository talks and writings. He once said, "Some people think that mathematics is a serious business that must always be cold and dry; but we think mathematics is fun, and we aren't ashamed to admit the fact. Why should a strict boundary line be drawn between work and play?

Ramsey theory is named in honour of British mathematician Frank Ramsey, who died tragically young in 1930, and whose brother Michael was later the Archbishop of Canterbury. It concerns the certainly of having some order in a collection of random relationships. It starts with the surprising observation that if there are six or more bishops at afternoon tea, then it must be the case that either some three of them already know each other, or some three of them are mutual strangers. It applies to heathens as much as to bishops, but it wouldn't work for just five people.

Equivalently, if there are at least six points, all connected to each other with either red or blue lines, then there must be some three points which form a red triangle or a blue triangle. If we wish to make a similar statement replacing three by four, then we need at least eighteen points.

The answer to the corresponding question when three is upped to five is still unknown, despite exhaustive human and computer efforts.

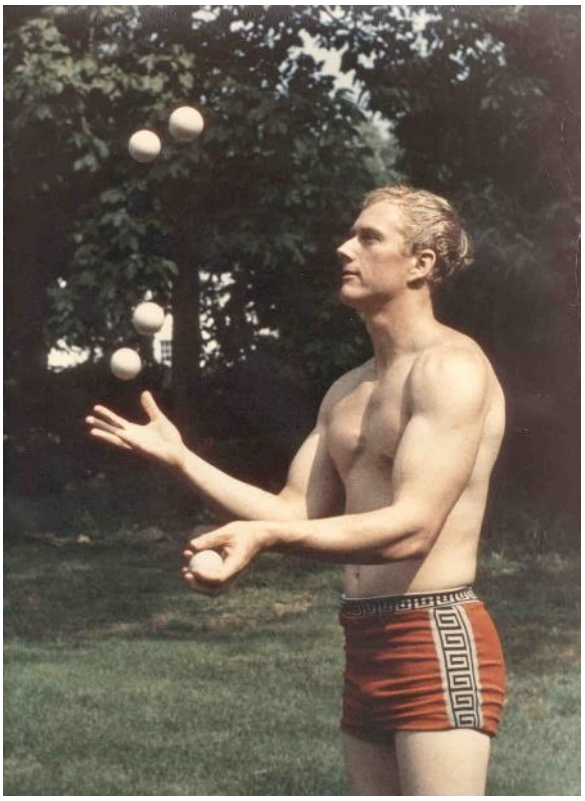


Ron also had considerable physical dexterity, and he saw many connections between athletic and intellectual endeavours. In his youth he was a competitive (and prize winning) trampolinist, and he was an accomplished acrobat, unicyclist and juggler. In 1972 he was elected president of the International Jugglers' Association, and over the years he published often about the mathematics of juggling. In his prime, he could juggle seven balls comfortably. In his own words, "Juggling is sometimes called the art of controlling patterns, controlling patterns in time and space."

Martin Gardner wrote in his memoirs about meeting Ron one day for lunch at Bell Labs, "His office was up a long flight of stairs. Ron greeted me by walking down the stairs on his hands!" It was Gardner, in a 1977 column for *Scientific American*, who introduced the world to Ron's biggest claim to fame, Graham's Number. It was at the time was the largest specific positive whole number to have been used in a mathematical proof, a fact acknowledged by the Guinness Book of Records in 1980.

Graham's number is a theoretical ceiling for the number of dimensions one must operate in when studying hypercubes to be 100% sure of the presence of certain all-red or all-blue configurations like the triangles mentioned earlier for six points. A square has dimension 2 (flat), a cube has dimension 3 (space), a hypercube can have dimension 4 or any higher number. Analysing the possible presence of all-one-colour configurations in higher dimensions quickly gets beyond what even computers can check, although we now know that these configurations can be avoided

in all dimensions up to 12. But, they might be inevitable in dimension 13, or 14. Regardless, they will arise by the time we get to Graham's number dimension. That leaves a vast gap in human knowledge, but that's the nature of progress in maths.



With his athletic Californian demeanour, Ron would not have looked out of place in the Beach Boys, but he also had a relentless drive and work ethic. When asked about his productivity, he liked to remind people that "there are 24 hours in every day. And if that's not enough, you've always got the nights!" He excelled in other realms too: his mastery of Chinese was enough to allow him to deliver an address to Chinese president Jiang Zemin in October 1997.

His collaborator and onetime Bell Labs colleague Pete Winkler recalls, "in many respects, Ron seemed like an overgrown boy, fun-loving and irreverent. But at meetings he was sometimes the only one acting like an adult."

Ron Graham was born in Taft, California, about 190 km NW of Los Angeles, the first of three children to Jane Anderson and Leo Graham. His father worked in the oil and shipbuilding industries in both California and Georgia, and changed jobs so often that Ron was hardly ever in the same school two years in a row. After his parents divorced, he lived in Florida with his mother. Although he never officially completed high school, a scholarship allowed him to attend the University of Chicago for 3 years at the start of the 1950s. There he mastered gymnastics, but not mathematics. He then spent a year at the University of California at Berkeley, ostensibly as an engineering student, before dropping out again and joining the US Air Force for a while. He finally earned a degree (in physics) from the University of Alaska Fairbanks in 1959. Returning to Berkeley, he received the PhD there in 1962 for research in number theory under advisor Dick Lehmer. By 1964 he was married for the third time, to Nancy Young; the couple had two children.

Over a period of 37 years at Bell Labs (later AT&T Labs), he rose to Chief Scientist, directing mathematical research in an era which saw the field transform how telecommunications was done. The efficient routing of telephone calls was a primary concern, as he himself observed "There are a lot of mathematical questions that come up when you're driving around, and you're leaving one cell site and connecting to another."

He also kept an eye on pure maths, befriending itinerant Hungarian Paul Erdős, the most prolific mathematician in history, who roamed the world doing maths without the hindrance of a proper job. Over time Ron effectively became his travel agent and banker, as well as a close research collaborator; they wrote about 30 papers together. In the decades since Erdős died, Ron continued to administer cash prizes which Erdős had offered for particularly challenging maths problems, including one recent one for $10,000.

Ron was generous with his time and talents, and had a reputation for always offering useful advice on any problem he was asked to help with, even if the requester was not previously known to him. Upon retirement from AT&T in 1999, he commented about his own priorities: "People first, discipline second, institution third. So, I wasn't as much of a company man as I might have been. To me some of the greatest pleasure is being able to see people develop." He mentored legions of aspiring students in maths and computer science, and also many in juggling and magic.

Ron was elected to the National Academy of Sciences in 1985, and was elected as president of both the American Mathematical Society (1993-1994) and the Mathematical Association of America (2003-2004). He was inducted as an Association of Computing Machinery Fellow in 1999 "for seminal contributions to the analysis of algorithms." He received the George Pólya Prize in 1971, the Euler Medal in 1993, the AMS Leroy Steele Prize for Lifetime Achievement in 2003. Upon receiving the last mentioned, he said, "I will happily continue to keep hammering pitons into the sides of the infinite mountain of mathematical truth, as we all slowly inch our way up its irresistible slopes."

He is survived by Fan Chung, whom he married in 1983, and stepchildren Dean Chung and Laura Bower; as well as daughter Cheryl (Ché) and son Marc from his marriage to Nancy Young; and daughters Laura Lindauer and Christy Newman from a relationship with Joann Quinlivan.

Colm Mulcahy

• Ronald Lewis Graham, mathematician, born 31 October 1935; died 6 July 2020