COMMENT OBITUARY

John Forbes Nash

(1928–2015)

Master of games and equations.

John Forbes Nash, an exalted mathematician whose life took dramatic turns between genius, mental illness and celebrity status, made major contributions to game theory, geometry and the field of partial differential equations.

Nash, who died on 23 May, was born in Bluefield, West Virginia, in 1928. His father was an electrical engineer and his mother a schoolteacher. In 1945, after excelling in mathematics at high school, he attended the Carnegie Institute of Technology (now Carnegie Mellon University) in Pittsburgh, Pennsylvania. At first he studied chemical engineering, but soon after enrolling he switched to chemistry and then to maths.

In Nash's final year, one of his professors wrote a recommendation letter for the 19-year-old supporting his application to graduate school. It simply stated: "He is a mathematical genius." In 1948, Nash was accepted by Harvard University in Cambridge, Massachusetts, and by Princeton University in New Jersey. He chose Princeton.

As a PhD student, Nash proved the existence of the equilibrium that now carries his name. His 1950 paper 'Equilibrium points in *n*-person games', contains about 330 words, two references and not one equation (J. F. Nash Jr *Proc. Natl Acad. Sci. USA* **36,** 48–49; 1950). One of the citations is the 1944 book *Theory of Games and Economic Behavior* — in which mathematician John von Neumann and economist Oskar Morgenstern introduce game theory, a mathematical approach for studying strategic and economic decisions.

The Nash equilibrium is a position in a game from which none of the players can change their strategy to improve their pay-off. Imagine a game with two players (yourself and another person) and two strategies, A and B. If you both choose A, your pay-off is 2. If you choose A and your opponent chooses B, you score 0. If you choose B and the other player chooses A, your pay-off is 3. If you both choose B, you score 1. The same applies to your opponent.

In this example, the Nash equilibrium occurs when both players choose B. If both players choose B, their pay-off is 1; if either player switches to A, their pay-off falls to 0. In other words, neither player can independently switch their strategy and improve their pay-off. Observe that if both players select A, there is no Nash equilibrium because you could improve your pay-off by switching to B.

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Calculating the Nash equilibrium can be a formidable task in a complex game. There is also the uncertainty over whether the person you are playing against is sufficiently rational to play the equilibrium strategy. If both players are rational and their rationality is common knowledge, they would play it. But experiments often reveal that people are not rational. Regardless of whether people actually play the Nash equilibrium in social or economic interactions, working out what it is (or what the Nash equilibria are) is the first step to analysing any game.

Although dismissed at the time by von Neumann as a triviality, the Nash equilibrium has been used to analyse all sorts of competitive situations. As well as being key to decision-making in economics and politics, the idea is important in biology. Here, the nearly equivalent concept, formulated by evolutionary biologist John Maynard Smith in the 1970s is called an evolutionarily stable strategy (ESS). If all members of a population adopt an ESS, then natural selection prevents a rare mutant from spreading.

On completing his PhD, Nash joined the Massachusetts Institute of Technology (MIT) in Cambridge in 1951. He worked — first as an instructor and later as a professor — in the mathematics faculty until he resigned in 1959. It was while he was at MIT that Nash met and married Alicia Lopez-Harrison de Lardé, a physics student there.

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Among mathematicians, Nash is best known for his work in real algebraic geometry and nonlinear partial differential equations. He was not afraid to tackle the hardest problems in the field, and he succeeded. In 1957, he — in parallel with Italian mathematician Ennio de Giorgi — solved Hilbert's nineteenth problem involving partial differential equations.

It was during a talk in 1959 on what is seen to be one of the hardest problems in maths — the Riemann hypothesis — that the audience realized that there was something wrong with Nash. His talk was incomprehensible.

He was diagnosed with paranoid schizophrenia that year. Over the next two decades, Nash was in and out of hospitals. He underwent therapy, and for a while left the United States and sought asylum in Switzerland in an attempt to escape his imagined tormentors. For many years he wandered around the Princeton campus. Throughout this period, Alicia, who divorced Nash in 1963, oversaw much of his care.

In the late 1980s, Nash reappeared in academic circles, and in 1994 he was awarded the Nobel Memorial Prize in Economic Sciences for his work on game theory. The Nobel and the 2001 film *A Beautiful Mind*, based on journalist Sylvia Nasar's book of the same name, which recounted Nash's struggles, propelled him into the limelight.

In May this year, Nash received the Abel prize from the Norwegian Academy of Science and Letters for his work on partial differential equations. On the way back from the celebration in Norway, John and Alicia (who had remarried in 2001) were killed in a car accident in a taxi on the New Jersey turnpike. John was 86.

I met John in 1998 at the Institute for Advanced Study in Princeton. Over the years, I gave several talks there that he attended. One summer's day, when the usual sitting arrangements for lunch were disrupted by the closure of the main kitchen, I noticed John, the physicist Edward Witten and Andrew Wiles, the British mathematician who proved Fermat's last theorem, sitting down together at a small table. I wondered which of them would start the conversation. None of them did. I seem to remember that they ate their meal in silence. ■

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