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# Obituary
# John Forbes Nash (1928–2015)



*Vito Fragnelli and Gianfranco Gambarelli*

## Life

John Forbes Nash was born on 13 June 1928 in Bluefield (West Virginia); in 1948, he graduated from Carnegie Institute of Technology (now Carnegie Mellon University) with both BS and MS degrees in mathematics; Nash then accepted a scholarship to Princeton University, where he pursued graduate studies in mathematics. It is worthwhile noting that Nash's adviser, Prof. Richard Duffin, wrote a letter recommending Nash to Princeton that consisted of only five words: "He is a mathematical genius." In Princeton, John Nash started work on game theory with John von Neumann, Lloyd Shapley, and Harold Kuhn. Kuhn, who died on 2 July 2014, was close to Nash during the worst periods of his life, but was also the person who informed him of the award of the Swedish Riksbank Prize in the Memory of Alfred Nobel and made the official presentation in Stockholm. Nash mainly worked on game theory, but also covered other fields of mathematics, as indicated by the statement accompanying the award of the Abel Prize in 2015 (see later). His research on manifolds was anticipated by the Italian mathematician Ennio De Giorgi. Nash wrote: "It happened that I was working in parallel with Ennio De Giorgi of Pisa, Italy. And De Giorgi was first actually to achieve the ascent of the summit (of the figuratively described problem), at least for the particularly interesting case of elliptic equations" (see Nasar 1998, p. 64).

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Nash hoped that he would be awarded the Fields Medal for this work, the most important prize for young mathematicians, but this did not happen. It is possible that this was among the precipitating causes of his illness. During the later 1950s, Nash went from hospital to hospital searching for therapy suitable to his schizophrenia. It was only at the beginning of the 1990s that new drugs allowed him to recover a partial mental equilibrium. In 1994, he won the Nobel Prize for his work during the 1950s on game theory, and he once more became active in the scientific community.

In 1998, Sylvia Nasar published *A Beautiful Mind,* which was nominated for the Pulitzer Prize and inspired the film of the same title directed by Ron Howard, with Russell Crowe in the role of John Nash and Jennifer Connelly in the role of Alicia. The film was a resounding success, receiving two Golden Globe and four Academy Awards. Sylvia Nasar (1998: Prologue) wrote: "While Nash the man remained frozen in a dreamlike state, a phantom who haunted Princeton in the 1970s and 1980s scribbling on blackboards and studying religious texts, his name began to surface everywhere – in economics textbooks, articles on evolutionary biology, political science treatises, mathematics journals." The title of the book and of the film echoes the remark made by Shapley in *The Essential John Nash*: "'What redeemed him was a clear, logical, beautiful mind' reported in the book *The Essential John Nash.*" (Kuhn and Nasar 2002).

When the illness went into remission, Nash had a period of inner calm, also receiving several expressions of affection and scientific acknowledgements testifying to the relevance of his studies and the moral lesson that he offered those that met him, justifying Russell Crowe's remark: "A Beautiful Mind, a beautiful heart."

## John Nash and the theory of games

The managers of two neighbourly supermarkets change the prices according to changes made by the other; a country considers the possibilities in the supply of energy to another technologically developed country; an anti-missile system is designed to intercept an enemy missile before the target is reached; the managers of two soccer teams have to fix the sealed offer for a player; a citizen has to decide whether to evade a tax, and if so, the amount to withhold, while the tax office has to establish a review procedure; a political party has to decide whether a proposal to form a governing majority can be improved.

All these problems may be represented as *mathematical models of strategic interaction* and they are examples of real-world applications of g*ame theory.* Princeton is the place where the most outstanding scholars congregated, from Albert Einstein to Hermann Weyl; in Princeton, the Hungarian mathematician John von Neumann met the German economist Oskar Morgenstern, and in 1944, their collaboration led to the publication of the *Theory of Games and Economic Behavior*, which represents a turning point in economic studies and the starting date of the newborn discipline, Theory of Games or simply Game Theory. We may remark that, in 1928, von Neumann[1] published his "Minimax Theorem," the basis of some future game theoretical results, and applied it to military situations.

Up until 1944, classical economics accounted for a single decision-maker, while a game theoretical model allows considering different interacting agents: producers, consumers, retailers, and so on, with a better representation of the real situations, in which the agents may subscribe to binding agreements (cooperative games) or not (non-cooperative games). On the one hand, game theory profits from the mathematical tools it uses; economic journals move towards a different and more symbolic language. On the other hand, mathematical scholars need new instruments and research fields; for instance, the simplex method, the duality theory, and the characteristic function due to George Dantzig, Harold Kuhn, and Albert W. Tucker.

Game theorists have been awarded 11 Nobel Prizes in 21 years: John Nash, John Harsanyi, and Reinhard Selten in 1994; Robert Aumann and Thomas Schelling in 2005; Roger Myerson, Leonid Hurwicz, and Eric Maskin in 2007; Alvin Roth and Lloyd Shapley in 2012; and Jean Tirole in 2014.

The solution of two-person constant sum games, i.e., when the sum of the pay-offs of the two players is constant whatever the final outcome, can be found in the paper by von Neumann (1928); in the book by von Neumann and Morgenstern (1944), there are some improvements but a general solution is still not defined.

The problem was solved by Nash with two papers; the first (1950a) presents a non-cooperative (or competitive) solution for *n*-person variable sum games, the well-known Nash equilibrium that corresponds to a set of strategies, one for each agent, which provides no incentives to anybody for unilaterally changing the proposed strategy; the second (1950b) deals with a cooperative solution for two-person variable sum games that satisfies a suitable set of axioms. In 1953, Nash presented another cooperative solution, the *threatening solution*, when cooperation among the agents is brought about by coercion.

Profiting from Nash's work, game theory is now used not only in economics, political sciences, and defence, but also in the social sciences, finance,

1 For further information on the origin of game theory, we refer to Gambarelli and Owen (2004).

medicine, biology, sports, and so on.[2] The Nash Program, i.e., the interrelation of cooperative and non-cooperative game theory and their solutions, still attracts the interest of several scholars; we just mention Binmore, Rubinstein and Wolinsky (1986), Serrano (1997), and Dagan and Serrano (1998).

## The curse of the second "Nobel"

In 2015, Nash was awarded the Abel Prize (a kind of Nobel Prize for mathematicians) jointly with Louis Nirenberg "for striking and seminal contributions to the theory of nonlinear partial differential equations and its applications to geometric analysis." He received the prize in Oslo, presented to him by the King of Norway. On his return to Princeton on Saturday 23 May 2015, he and his wife Alicia took a taxi to their house. At 4.30 p.m., the taxi hit the guardrail on the highway near Monroe Township (New Jersey) and overturned, causing the death of both.

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2 For a recent survey, see Fragnelli and Gambarelli (eds.) (2013a, 2013b).