LAUDATIO

on the occasion of the investiture of Professor

Martin Andreas NOWAK,

of Harvard University, USA, with the degree of *Doctor Honoris Causa* of Alexandru Ioan Cuza University of Iaşi

9th June 2010

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Laudatio

In honor of
Professor **Martin Andreas NOWAK**,
Harvard University, USA

"Science is organised knowledge. Wisdom is organised life."

The words of Immanuel Kant quoted above provide us with the appropriate background against which we can speak of a scholar who, by means of science, produces wisdom. Our attempt today - at mentioning the merits which entitle us to confer Professor Nowak the highest distinction an academic institution can offer – is a delicate one, since, unfair as it may be, we can only select from the multitude of his discoveries and accomplishments.

Born in 1965 in Vienna, Martin Nowak begins his studies in the fields of Biochemistry and Mathematics at the University of Vienna. He graduates in 1987, a year earlier than normally scheduled and with the highest marks, having had the privilege to work under the supervision of Peter Schuster – the current president of the Austrian Academy of Sciences. Together, they continued the quasispecies theory (a theory on which Professor Schuster had worked with the German Professor Manfred Eigen, the Nobel Prize laureate for Chemistry in 1967). Martin Nowak himself cooperated with Professor

Eigen in 1988 at the Max Planck Institute for Biophysical Chemistry, Göttingen. Two years later, at the age of 24, Martin Nowak is awarded the title of "*Doctor rerum naturalium sub auspiciis praesidentis*" – by the same university - with a thesis in Mathematics about the evolution of cooperation. The thesis was written under the guidance of Professor Karl Sigmund, one of the pioneers of the evolutionary game theory. After being awarded the PhD degree, he receives an Erwin Schrödinger Scholarship which – for a year - enables him to work at Oxford, the fief of Biochemistry, with Professor Robert May, the later Lord May of Oxford. Through computational and mathematical methods, the two proved that AIDS is not caused by HIV through the progressive degradation of the immune system; on the contrary, it is a catastrophic event triggered when HIV has so many different strains that the immune system is overwhelmed. The cooperation of the two scholars will continue and, along with many papers, in 2000 Professor Nowak publishes *Virus Dynamics: Mathematical Principles of Immunology and Virology* (Oxford University Press). Until 1998, he continues his activity at Oxford: he is Guy Newton Junior Research Fellow at Wolfson College for two years and then, between 1992 and 1998, he is Wellcome Trust Senior Research Fellow in Biomedical Sciences; in the meantime, he became the head of the Mathematical Biology Group at Oxford and, in 1997, he was appointed a professor in the same field. The period Professor Nowak spent at Oxford is highly prolific, each year bringing with it an important discovery; in 1991, he offers the mathematical base for the mechanism of HIV disease progression. The methodological idea behind this mathematical approach had been induced to him when he was a student; in 1988, after a lecture he attended on the human immunodeficiency virus, at the University of Vienna, Martin Nowak conjectured that biology alone could not show the dynamic interactions between the viruses populations and that Mathematics held the key to it. The mathematical model that Professor Nowak introduced for HIV was to revolutionise the study of other viruses as well. The series of Martin Nowak's challenging new and fundamental insights continues: spatial game dynamics (1992), *generous tit-for-tat* and *win-stay, lose shift* (1993) - strategies that can also be applied to the dynamics of the self-replicating populations, be they molecules or patterns of individual behaviour. To the basic strategy of "the iterated prisoner's dilemma" – namely cooperation in the first round and reproducing the opponent's previous behaviour in the subsequent ones – Professor Nowak added, in 2004, the "1/3 rule": "If you cooperate, then I shall cooperate. If you defect, then I shall cooperate with probability 1/3." ("Tit-for-tat is too unforgiving"; hence "generous tit-for-tat"). Another remarkable result (1995) concerns the evolution of drug resistance in HIV infection. During the next three years, Professor Nowak makes three more breakthroughs regarding the quantification of the dynamics of HBV infection, the mechanisms for the evolution of genetic redundancy and, on a different horizon, the evolution of cooperation by indirect reciprocity based on reputation.

In 1998, Martin Nowak moves to Princeton where he establishes the first programme in theoretical biology at The Institute for Advanced Study – whose head he is until 2003, when he takes his present position at Harvard University. During those five years, out of the multiple aspects concerning the application of mathematics to biology, Professor Nowak is particularly interested in a better understanding of the evolution of human language and cooperation and of genetic systems (cancer genetics and the dynamics of infectious diseases). Since 1999, he has been an Associate Professor at Princeton University for two programmes: Ecology and Evolutionary Biology (during the first five years) and Applied and Computational Mathematics (from 2004 onwards). Between 1999 and 2002, he is the first to mathematically substantiate the study of language evolution. By means of illustration, we vulgarise the findings of the complex study published in *Nature* by reminding a simple mathematical rule that governs the evolution of language: the inverse proportionality between the frequency of use and the speed of verb regularisation.

Since July 2003, Martin Nowak is Professor of Mathematics and Biology at Harvard University and Head of the new programme he establishes, the Programme for Evolutionary Dynamics (PED). This new field, Evolutionary Dynamics, studies the mathematical models that describe the constitutive elements of evolutionary processes. At Harvard, Professor Nowak ideally illustrates the interdisciplinary approach of the University. His outstanding results during these seven years include those on evolutionary game dynamics in finite populations (2004). In 2005, he lays the foundation of the evolutionary graph theory; this new field – set at the frontier joining Graph theory, the theory of probabilities and mathematical biology - studies the relation between topology and the evolution of a population. In the same year, Professor Nowak offers the first quantification of the *in vivo* kinetics of human cancer. In a paper published in *Nature* in 2006, Professor Nowak enunciates and unifies the five mathematical laws that are the basis of the evolution of cooperation. In a nonmathematical presentation, these are: kin selection (cooperation depends on the genetic relation between donor and receiver: the closer this is, the more probable it becomes for the two to cooperate, since it is in the donor's own interest that genes similar to his, survive), direct reciprocity (the donor decides to cooperate because s/he hopes that, in the future, s/he will be helped by the receiver; the more the probability of a future encounter between the two increases, the more likely cooperation becomes), indirect reciprocity (by helping the receiver, the donor obtains a reputation from which s/he will benefit in the future, since it becomes more likely for others to help him/her), network reciprocity (since real populations are not well mixed, social networks imply that some individuals react more often than others; for cooperation to take place, the benefit-to-cost ratio must exceed the average number of individuals in a network) and group selection (in the long run, a group of cooperating individuals - willing to help the others or even to sacrifice themselves for the others - might be more successful than a group of defectors). Martin Nowak minutely presents the research concerning these five rules in his 2006 book, *Evolutionary Dynamics: Exploring the Equations of Life* (Harvard University Press). The mathematical equations of evolutionary dynamics provide a fruitful framework for studying evolutionary processes. The book presents a range of analytical tools that can be used to this end: mutation matrices, genomic sequence space, random drift, quasispecies, replicators, games in finite and infinite populations, evolutionary graph theory, evolutionary kaleidoscopes, spatial chaos, and fractals. The book details the way evolutionary dynamics can be applied to critical real-world problems, including the progression of viral diseases such as AIDS, the virulence of infectious agents, the mutations that lead to cancer, the evolution of altruism, and even the evolution of human language. Professor Nowak's book makes a clear and compelling case for the understanding of living systems in terms of evolutionary dynamics.

Professor Nowak is now working on 'pre-life' - a formal approach to study the origin of evolution – in which his goal is to provide mathematical models of the "transition from no life to life"; in his own words, "I don't know what the ultimate understanding of biology will look like, but one thing is clear: it's all about getting the equations right."

Professor Nowak's appetence to apply mathematical thinking to key theoretical issues in other disciplines has led to numerous discoveries and paved the way to new approaches; though his projects are apparently shared by such various fields as biology, medicine, theology, economics, chemistry and mathematics, actually they all have a common core, which is the understanding of cooperation.

Professor Nowak's findings were published until now in over 300 articles - in top-level scientific journals and magazines; tens of them were published in *Nature*, *Science* and *Proceedings of the National Academy of Sciences,* journals of which he is a referee as well. Professor Nowak is a member of the editorial board of *Proceedings of the Royal Society of London*, *Journal of Theoretical Biology*, *Journal of Theoretical Medicine*, *Journal of Difference Equations*, *International Journal of Bifurcation and Chaos.*

Professor Nowak's activity, diverse and prolific in all the directions he approached, has been acknowledged ever since the beginning of his career. In 1996, he is awarded Oxford's Weldon Memorial Prize. Since 1907, this prize has been offered annually to researchers who, during the previous ten years, have had the most noteworthy contribution to the development of mathematical or statistical methods applied in Biology. In 1998, Professor Nowak receives the Albert Wander Prize of the University of Bern, a prize awarded every two years since 1952. In 1999, Professor Nowak receives both the Roger E. Murray Prize awarded by the Institute for Quantitative Research in Finance (for his paper *The Evolution of Cooperation: Direct, Indirect and Spatial Reciprocity)* and the Akira Okubo Prize, offered by The Society for Mathematical Biology and The Japanese Association for Mathematical Biology (for outstanding and innovative theoretical work, for establishing extraordinary conceptual ideas, for solving tough theoretical problems and for uniting theory and empirical data to advance a biological subject). In 2002, Martin Nowak is the recipient of the David Starr Jordan Prize – awarded by Stanford, Indiana and Cornell Universities every three years - for his contribution to the evolution of epidemics, the theories on the evolution of language and the application of the game theory in the study of evolution. In 2006, as a result of the impressive success of his book *Evolutionary Dynamics* – to critics and the public alike -, he receives the R. R. Hawkins Award of the Professional and Scholarly Publishing Division of the American Association of Publishers. This prize is awarded to Professor Nowak for a book which "offers not just the basics, but also conveys the excitement and challenges of cuttingedge research, being valuable to readers at every level of sophistication in biology and related disciplines."

A sign of worldwide recognition is the impressive list of special conferences: Richardson Lecture at Keble College, Oxford in 1995, Shanks Lecture at Vanderbilt University in 1997, Erwin Schroedinger Lecture at the University of Vienna and Porter Lecture at Rice University in 1999, Radon Lecture at the Austrian Academy of Sciences in 2007 and Templeton Research Lectures at Johns Hopkins University, delivered this year.

Since 2001, Professor Martin Nowak has been a corresponding member of the Austrian Academy of Sciences.

What Professor Nowak illustrates in today's Science is the creative force able to trigger the Kuhnian paradigm shift characteristic of the scientific revolutions. We honour today a contemporary representative of the Renaissance–born encyclopaedic spirit. Professor Nowak is an erudite who offers mathematically profound answers to fundamental questions. He shows how Mathematics can be the source of encyclopaedic approaches covering an overwhelming diversity of fields. His profound understanding of life and the world propagates cooperation both as a theoretical model and as a life strategy.

On the occasion of its sesquicentennial jubilee, Alma Mater Iassiensis – Alexandru Ioan Cuza University of Iaşi has the joy and honour to solemnly confer the title of Doctor Honoris Causa to Professor Martin Andreas Nowak.

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Iaşi, 9th June 2010