

# MARTIN A. NOWAK

## Curriculum Vitae

### Personal Information

Name: Martin Andreas Nowak

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Degrees: M.Sc. Vienna, Ph.D. Vienna, M.A. (honoris causa) Oxford, A.M. (honoris causa) Harvard,  
Ph.D. (honoris causa) Cuza University of Iasi, Ph.D. (honoris causa) Dominican School of Philosophy  
and Theology

### Current position

Professor of Mathematics and Biology, Harvard University

Director, Program for Evolutionary Dynamics, Harvard University

### Education

1975-1983 Albertus Magnus Gymnasium in Vienna

1983-1989 University of Vienna, studying Biochemistry and Mathematics

1985 First Diploma: Biochemistry (first class honors)

1987 Diploma thesis: Theoretical Chemistry

1987 Second Diploma: Biochemistry (first class honors; finished one year faster)

1987-1989 Doctoral thesis: Mathematics

1989 Final exams for degree *Doctor rerum naturalium* (with highest honors)

### Scientific career

#### *Vienna:*

1987-1988 Institute for Theoretical Chemistry, Peter Schuster

1987-1989 Institute for Mathematics, Karl Sigmund

1988 Max Planck Institute for Biophysical Chemistry, Göttingen, Manfred Eigen

1993 "Habilitation" at the Institute of Mathematics, University of Vienna

#### *Oxford:*

1989-1990 Erwin Schrödinger Scholarship to work with Robert May (Lord May of Oxford)

1990-1992 Guy Newton Junior Research Fellow, Wolfson College

1991 Royal Society Research Grant

1992-1998 Wellcome Trust Senior Research Fellow in Biomedical Sciences

1993-1996 E. P. Abraham Junior Research Fellow, Keble College

1995-1998 Head of Mathematical Biology Group

1996-1998 Senior Research Fellow, Keble College

1997-1998 Professor of Mathematical Biology

#### *Princeton:*

1998-2003 Head, Program in Theoretical Biology, Institute for Advanced Study

1999-2003 Associated Faculty, Princeton University, Ecology and Evolutionary Biology

2000-2003 Associated Faculty, Princeton University, Program in Applied and  
Computational Mathematics

#### *Harvard:*

2003- Professor of Biology and Mathematics,  
Director, Program for Evolutionary Dynamics

### **Prizes, Named Lectures, Memberships**

- 1990 *Promotion sub auspiciis praesidentis rei publicae* (a distinction given to those who have passed all major exams during school and university with the best mark)
- 1990 Prize from the Austrian Science Minister
- 1995 Richardson Lecture, Keble College
- 1996 Weldon Memorial Prize (given every 2-3 years for outstanding contributions to Biometric Science; previous winners include: Ronald Fisher, JBS Haldane, Sewall Wright, Motoo Kimura, Robert May, David Cox)
- 1997 Shanks Lecture, Vanderbilt University, Nashville, Tennessee
- 1998 Albert Wander Prize and Memorial Lecture, University of Bern, Switzerland
- 1999 Porter Lecture, Rice University, Houston, Texas
- 1999 Erwin Schroedinger Lecture, University of Vienna, Austria
- 1999 Akira Okubo Prize, International and Japanese Society for Mathematical Biology
- 1999 Roger F. Murray Prize, Institute for Quantitative Research in Finance
- 2000 Gergen Lecture, Duke University
- 2001 Benjamin Pinkel Lecture, University of Pennsylvania
- 2001 Corresponding Member, Austrian Academy of Sciences
- 2001 Rainich Lectures, University of Michigan, Ann Arbor
- 2001 David Starr Jordan Prize, Stanford University, Cornell University, Indiana University
- 2003 Henry Dale Prize, The Royal Institution, London
- 2006 Invited Lecture, Congress for Mathematics, Madrid
- 2006 R.R. Hawkins Award for *Evolutionary Dynamics*, Professional and Scholarly Publishing Division of the American Association of Publishers
- 2007 Radon Lecture, Austrian Academy of Sciences
- 2008 Coxeter Lectures, Fields Institute, Toronto
- 2010 Templeton Lectures, Johns Hopkins University
- 2010 Doctor Honoris Causa, Alexandru Ioan Cuza University of Iasi, Romania
- 2011 Max Planck Lecture, Stuttgart, Germany
- 2012 MBI 10th Anniversary Keynote talk, Ohio State University
- 2012 Plenary speaker, Canadian Mathematical Society
- 2013 Plenary speaker, International Congress of Ecology, London, England
- 2013 Simons Lecture, Institute for Mathematics and its Applications, The Simons Foundation, Minneapolis
- 2013 Andre-Aisenstadt Chair, Centre de Recherches Mathématiques, Montreal
- 2014 Plenary Opening Talk, Nephrology Conference, Baden, Austria
- 2014 Keynote Lecture, 11th Austrian Research and Innovation Talk (ARIT), MIT Media Lab
- 2015 Plenary speaker, Collins Lecture Series, Massachusetts General Hospital
- 2015 Plenary speaker, Drug Discovery and World Therapy Congress, Boston
- 2016 Invited Lecture, Fermilab, Illinois
- 2016 Sewall Wright Speaker, University of Chicago
- 2016 Fannie Cox Prize for Excellence in Science Teaching
- 2017 AACR Team Science Award
- 2018 The Edmund R. Michalik Distinguished Lecture Series, University of Pittsburgh

### **Research Interests**

Evolutionary dynamics  
Cancer evolution and treatment  
Infection dynamics  
Quasispecies theory  
Genetic redundancy  
Evolutionary game theory  
Adaptive dynamics

Finite populations  
Evolutionary graph theory  
Evolutionary set theory  
Evolution of language  
Cooperation, fairness, reputation  
Indirect reciprocity  
Group selection  
Experimental games  
Origin of evolution, prolife  
Evolution of eusociality

### **Books**

Nowak M, RM May (2000). *Virus Dynamics: Mathematical Principles of Immunology and Virology*. Oxford: Oxford University Press.  
Nowak MA (2006). *Evolutionary Dynamics: Exploring the Equations of Life*. Cambridge, MA: Harvard University Press.  
Nowak MA, R Highfield (2011). *SuperCooperators: Why We Need Each Other to Succeed*. Simon & Schuster.  
Coakley S, MA Nowak, eds (2013). *Evolution, Games, and God: The Principle of Cooperation*. Harvard University Press.

### **Selected Publications**

Hilbe, C., Chatterjee, K., & Nowak, M. A. (2018). Partners and rivals in direct reciprocity. *Nature Human Behaviour*, 1. DOI: 10.1038/s41562-018-0320-9  
Noble C, J Olejarz, K Esvelt, G Church, MA Nowak (2017). Evolutionary dynamics of CRISPR gene drives. *Science Advances* Vol. 3, no. 4, e1601964. DOI: 10.1126/sciadv.1601964  
Allen B, G Lippner, Y-T Chen, B Fotouhi, N Momeni, S-T Yau, MA Nowak (2017). Evolutionary dynamics on any population structure. *Nature* 544: 227–230. DOI: 10.1038/nature21723  
Waclaw B, I Bozic, ME Pittman, RH Rhuban, B Vogelstein, MA Nowak (2015). A spatial model predicts that dispersal and cell turnover limit intratumour heterogeneity. *Nature*. DOI: 10.1038/nature14971  
Hauser OP, DG Rand, A Peysakhovich, MA Nowak (2014). Cooperating with the future. *Nature* DOI: 10.1038/nature13530  
Diaz LA Jr., RT Williams, J Wu, I Kinde, JR Hecht, J Berlin, B Allen, I Bozic, JG Reiter, MA Nowak, KW Kinzler, KS Oliner, B Vogelstein (2012). The molecular evolution of acquired resistance to targeted EGFR blockade in colorectal cancers. *Nature* 486 (7404): 537-540. DOI: 10.1038/nature11219  
Nowak MA (2012). Evolving cooperation. *J theor Biol* 299: 1-8. DOI: 10.1016/j.jtbi.2012.01.014  
Rand DG, JD Greene, MA Nowak (2012). Spontaneous giving and calculated greed. *Nature* 489 (7416): 427-430. DOI: 10.1038/nature11467  
Rosenbloom DIS, AL Hill, SA Rabi, RF Siliciano, MA Nowak (2012). Antiretroviral dynamics determines HIV evolution and predicts therapy outcome. *Nat Med* 18 (9): 1378-1385. DOI: 10.1038/nm.2892  
van Veelen M, J García, DG Rand, MA Nowak (2012). Direct reciprocity in structured populations. *Proc Natl Acad Sci USA* 109 (25): 9929-9934. DOI: 10.1073/pnas.1206694109  
Michel JB, YK Shen, A Presser Aiden, A Veres, MK Gray, The Google Books Team, JP Pickett, D Hoiberg, D Clancy, P Norvig, J Orwant, S Pinker, MA Nowak, E Lieberman Aiden (2011). Quantitative analysis of culture using millions of digitized books. *Science* 331 (6014): 176-182. DOI: 10.1126/science.1199644  
Nowak MA, R Highfield (2011). *SuperCooperators: Why We Need Each Other to Succeed*. Simon & Schuster. ISBN: 9781451626636  
Bozic I, T Antal, H Ohtsuki, H Carter, D Kim, S Chen, R Karchin, KW Kinzler, B Vogelstein, MA Nowak (2010). Accumulation of driver and passenger mutations during tumor progression. *Proc Natl Acad Sci USA* 107: 18545–18550. DOI: 10.1073/pnas.1010978107

Nowak MA, CE Tarnita, EO Wilson (2010). The evolution of eusociality. *Nature* 466: 1057-1062. DOI: 10.1038/nature09205

Yachida S, S Jones, I Bozic, T Antal, R Leary, B Fu, M Kamiyama, RH Hruban, JR Eshleman, MA Nowak, VE Velculescu, KW Kinzler, B Vogelstein, CA Iacobuzio-Donahue (2010). Distant metastasis occurs late during the genetic evolution of pancreatic cancer. *Nature* 467: 1114–1117. DOI: 10.1038/nature09515

Antal T, H Ohtsuki, J Wakeley, PD Taylor, MA Nowak (2009). Evolution of cooperation by phenotypic similarity. *Proc Natl Acad Sci USA* 106: 8597-8600. DOI: 10.1016/j.jtbi.2008.11.023

Ohtsuki H, Y Iwasa, MA Nowak (2009). Indirect reciprocity provides only a narrow margin of efficiency for costly punishment. *Nature* 457: 79-82. DOI: 10.1038/nature07601

Rand DG, A Dreber, T Ellingsen, D Fudenberg, MA Nowak (2009). Positive interactions promote public cooperation. *Science* 325: 1272-1275. DOI: 10.1126/science.1177418

Tarnita CE, T Antal, H Ohtsuki, MA Nowak (2009). Evolutionary dynamics in set structured populations. *Proc Natl Acad Sci USA* 106: 8601-8604. DOI: 10.1073/pnas.0903019106

Dreber A, DG Rand, D Fudenberg, MA Nowak (2008). Winners don't punish. *Nature* 452: 348-351. DOI: 10.1038/nature06723

Nowak MA, H Ohtsuki (2008). Prevolutionary dynamics and the origin of evolution. *Proc Natl Acad Sci USA* 105: 14924-14927. DOI: 10.1073/pnas.0806714105

Hauert C, A Traulsen, H Brandt, MA Nowak, K Sigmund (2007). Via freedom to coercion: The emergence of costly punishment. *Science* 316: 1905-1907. DOI: 10.1126/science.1141588

Lieberman E, JB Michel, J Jackson, T Tang, MA Nowak (2007). Quantifying the evolutionary dynamics of language. *Nature* 449: 713-716. DOI: 10.1038/nature06137

Nowak MA (2006). *Evolutionary Dynamics: Exploring the Equations of Life*. Cambridge, MA: Harvard University Press. (Excerpt, Nature review, Science review, R.R. Hawkins Award). ISBN: 9780674023383

Nowak MA (2006). Five rules for the evolution of cooperation. *Science* 314: 1560-1563. DOI: 10.1126/science.1133755

Ohtsuki H, C Hauert, E Lieberman, MA Nowak (2006). A simple rule for the evolution of cooperation on graphs and social networks. *Nature* 441: 502-505. DOI: 10.1016/j.jtbi.2005.11.012

Lieberman E, C Hauert, MA Nowak (2005). Evolutionary dynamics on graphs. *Nature* 433: 312-316. DOI: 10.1038/nature03204

Michor F, TP Hughes, Y Iwasa, S Branford, NP Shah, CL Sawyers, MA Nowak (2005). Dynamics of chronic myeloid leukemia. *Nature* 435: 1267-1270. DOI: 10.1038/nature03669

Nowak MA, K Sigmund (2005). Evolution of indirect reciprocity. *Nature* 437: 1291-1298. DOI: 10.1038/nature04131

Nowak MA, F Michor, Y Iwasa (2004). Evolutionary dynamics of tumor suppressor gene inactivation. *Proc Natl Acad Sci USA* 101: 10635-10638. DOI: 10.1073/pnas.0400747101

Nowak MA, A Sasaki, C Taylor, D Fudenberg (2004). Emergence of cooperation and evolutionary stability in finite populations. *Nature* 428: 646-650. DOI: 10.1038/nature02414

Nowak MA, K Sigmund (2004). Evolutionary dynamics of biological games. *Science* 303: 793-799. DOI: 10.1126/science.1093411

Wei X, JM Decker, S Wang, H Hui, JC Kappes, W Xiaoyun, JF Salazar, MG Salazar, JM Kilby, MS Saag, NL Komarova, MA Nowak, BH Hahn, PD Kwong, GM Shaw (2003). Antibody neutralization and escape by HIV-1. *Nature* 422: 307-312. DOI: 10.1038/nature01470

Nowak MA, NL Komarova, P Niyogi (2002). Computational and evolutionary aspects of language. *Nature* 417: 611-617. DOI: 10.1038/nature00771

Nowak MA, NL Komarova, A Sengupta, PF Jallepalli, IM Shih, B Vogelstein, C Lengauer (2002). The role of chromosomal instability in tumor initiation. *Proc Natl Acad Sci USA* 99: 16226-16231. DOI: 10.1073/pnas.202617399

Nowak MA, NL Komarova, P Niyogi (2001). Evolution of universal grammar. *Science* 291: 114-118. DOI: 10.1126/science.291.5501.114

Nowak M, RM May (2000). *Virus Dynamics: Mathematical Principles of Immunology and Virology*. Oxford University Press. ISBN: 9780198504177

Nowak MA, KM Page, K Sigmund (2000). Fairness versus reason in the ultimatum game. *Science* 289: 1773-1775. DOI: 10.1126/science.289.5485.1773

Nowak MA, JB Plotkin, VAA Jansen (2000). The evolution of syntactic communication. *Nature* 404: 495-498. DOI: 10.1038/35006635

Nowak MA, D Krakauer (1999). The evolution of language. *Proc Natl Acad Sci USA* 96: 8028-8033. DOI: 10.1073/pnas.96.14.8028

Nowak MA, K Sigmund (1998). Evolution of indirect reciprocity by image scoring. *Nature* 393: 573-577. DOI: 10.1038/31225

Bonhoeffer S, RM May, GM Shaw, MA Nowak (1997). Virus dynamics and drug therapy. *Proc Natl Acad Sci USA* 94: 6971-6976. DOI: 10.1073/pnas.94.13.6971

Nowak MA, MC Boerlijst, J Cooke, J Maynard Smith (1997). Evolution of genetic redundancy. *Nature* 388: 167-171. DOI: 10.1038/40618

Nowak MA, CRM Bangham (1996). Population dynamics of immune responses to persistent viruses. *Science* 272: 74-79. DOI: 10.1126/science.272.5258.74

Nowak MA, S Bonhoeffer, AM Hill, R Boehme, HC Thomas, H McDade (1996). Viral dynamics in hepatitis B virus infection. *Proc Natl Acad Sci USA* 93: 4398-4402. DOI: 10.1073/pnas.93.9.4398

Nowak MA, RM May, RE Phillips, S Rowland-Jones, DG Laloo, S McAdam, P Klenerman, B Köppe, K Sigmund, CRM Bangham, AJ McMichael (1995). Antigenic oscillations and shifting immunodominance in HIV-1 infections. *Nature* 375: 606-611. DOI: 10.1038/375606a0

Wei X, SK Ghosh, ME Taylor, VA Johnson, EA Emini, P Deutsch, JD Lifson, S Bonhoeffer, MA Nowak, BH Hahn, MS Saag, GM Shaw (1995). Viral dynamics in human immunodeficiency virus type 1 infection. *Nature* 373: 117-122. DOI: 10.1038/373117a0

Nowak MA, RM May (1994). Superinfection and the evolution of parasite virulence. *Proc R Soc B* 255: 81-89. DOI: 10.1098/rspb.1994.0012

Tilman D, RM May, CL Lehman, MA Nowak (1994). Habitat destruction and the extinction debt. *Nature* 371: 65-66. DOI: 10.1038/371065a0

Nowak MA, K Sigmund (1993). A strategy of win-stay, lose-shift that outperforms tit for tat in the Prisoner's Dilemma game. *Nature* 364: 56-58. DOI: 10.1038/364056a0

Nowak MA, RM May (1992). Evolutionary games and spatial chaos. *Nature* 359: 826-829. DOI: 10.1038/359826a0

Nowak MA, K Sigmund (1992). Tit for tat in heterogeneous populations. *Nature* 355: 250-253. DOI: 10.1038/355250a0

Nowak MA, RM Anderson, AR McLean, TFW Wolfs, J Goudsmit, RM May (1991). Antigenic diversity thresholds and the development of AIDS. *Science* 254: 963-969. DOI: 10.1126/science.1683006.

## All Publications

### 1989

1. Nowak M, P Schuster (1989). Error thresholds of replication in finite populations: Mutation frequencies and the onset of Muller's ratchet. *J theor Biol* 137: 375-395. DOI: 1
2. Nowak M, K Sigmund (1989). Game-dynamical aspects of the prisoner's dilemma. *Appl Math Comp* 30: 191-213. DOI: 10.1016/0096-3003(89)90052-0
3. Nowak M, K Sigmund (1989). Oscillations in the evolution of reciprocity. *J theor Biol* 137: 21-26. DOI: 10.1016/S0022-5193(89)80146-8

### 1990

4. Nowak MA (1990). An evolutionarily stable strategy may be inaccessible. *J theor Biol* 142: 237-241. DOI: 10.1016/S0022-5193(05)80224-3
5. Nowak M (1990). HIV mutation rate. *Nature* 347: 522. DOI: 10.1038/347522a0
6. Nowak M (1990). Stochastic strategies in the prisoner's dilemma. *Theor Pop Biol* 38: 93-112. DOI: 10.1016/0040-5809(90)90005-G

7. Nowak MA, RM May, RM Anderson (1990). The evolutionary dynamics of HIV quasispecies and the development of immunodeficiency disease. *AIDS* 4: 1095-1103. DOI: 10.1097/00002030-199011000-00007
8. Nowak M, K Sigmund (1990). The evolution of stochastic strategies in the prisoner's dilemma. *Acta Appl Math* 20: 247-265. DOI: 10.1007/BF00049570

### 1991

9. Kwiatkowski D, M Nowak (1991). Periodic and chaotic host-parasite interactions in human malaria. *Proc Natl Acad Sci USA* 88: 5111-5113. DOI: 10.1073/pnas.88.12.5111
10. Magurran AE, MA Nowak (1991). Another battle of the sexes: the consequences of sexual asymmetry in mating costs and predation risk in the guppy, *Poecilia reticulata*. *Proc R Soc B* 246: 31-38. DOI: 10.1098/rspb.1991.0121
11. Nowak M (1991). The evolution of viruses. Competition between horizontal and vertical transmission of mobile genes. *J theor Biol* 150: 339-347. DOI: 10.1016/S0022-5193(05)80433-3
12. Nowak MA, RM Anderson, AR McLean, TFW Wolfs, J Goudsmit, RM May (1991). Antigenic diversity thresholds and the development of AIDS. *Science* 254: 963-969. DOI: 10.1126/science.1683006
13. Nowak MA, RM May (1991). Mathematical biology of HIV infections: Antigenic variation and diversity threshold. *Math Biosci* 106: 1-21. DOI: 10.1016/0025-5564(91)90037-J
14. Nowak MA, AR McLean (1991). A mathematical model of vaccination against HIV to prevent development of AIDS. *Proc R Soc B* 246: 141-146. DOI: 10.1098/rspb.1991.0136

### 1992

15. McLean AR, MA Nowak (1992). Competition between zidovudine sensitive and resistant strains of HIV. *AIDS* 6: 71-79. DOI: 10.1097/00002030-199201000-00009
16. McLean AR, MA Nowak (1992). Models of interactions between HIV and other pathogens. *J theor Biol* 155: 69-86. DOI: 10.1016/S0022-5193(05)80549-1
17. Nowak MA (1992). Variability in HIV infections. *J theor Biol* 155: 1-20. DOI: 10.1016/S0022-5193(05)80545-4
18. Nowak MA (1992). What is a quasispecies? *Trends Ecol Evol* 7: 118-121. DOI: 10.1016/0169-5347(92)90145-2
19. Nowak MA, RM May (1992). Coexistence and competition in HIV infections. *J theor Biol* 159: 329-342. DOI: 10.1016/S0022-5193(05)80728-3
20. Nowak MA, RM May (1992). Evolutionary games and spatial chaos. *Nature* 359: 826-829. DOI: 10.1038/359826a0
21. Nowak MA, K Sigmund (1992). Tit for tat in heterogeneous populations. *Nature* 355: 250-253. DOI: 10.1038/355250a0
22. Nowak MA, K Tarczy-Hornoch, JM Austyn (1992). The optimal number of major histocompatibility complex molecules in an individual. *Proc Natl Acad Sci USA* 89: 10896-10899. DOI: 10.1073/pnas.89.22.10896
23. Payne RJH, MA Nowak, BS Blumberg (1992). Analysis of a cellular model to account for the natural history of infection by the hepatitis B virus and its role in the development of primary hepatocellular carcinoma. *J theor Biol* 159: 215-240. DOI: 10.1016/S0022-5193(05)80703-9
24. Sherratt JA, MA Nowak (1992). Oncogenes, anti-oncogenes and the immune response to cancer: A mathematical model. *Proc R Soc B* 248: 261-271. DOI: 10.1098/rspb.1992.0071

### 1993

25. Nowak MA, RM May (1993). AIDS pathogenesis: Mathematical models of HIV and SIV infections. *AIDS* 7: S3-S18. DOI: 10.1097/00002030-199201001-00002
26. Nowak MA, RM May (1993). The spatial dilemmas of evolution. *Int J Bifurcat Chaos* 3: 35-78. DOI: 10.1142/S0218127493000040

27. Nowak MA, AR McLean (1993). Mathematical models for the pathogenesis of AIDS. In *Mathematics Applied to Biology and Medicine*, eds. J Demongeot, V Capasso. Winnipeg: Wuertz Publishing, 275-284.
28. Nowak MA, K Sigmund (1993). A strategy of win-stay, lose-shift that outperforms tit-for-tat in the Prisoner's Dilemma game. *Nature* 364: 56-58. DOI: 10.1038/364056a0
29. Nowak M, K Sigmund (1993). Chaos and the evolution of cooperation. *Proc Natl Acad Sci USA* 90: 5091-5094. DOI: 10.1073/pnas.90.11.5091

#### 1994

30. Berry RM, MA Nowak (1994). Defective escape mutants of HIV. *J theor Biol* 171: 387-395. DOI: 10.1006/jtbi.1994.1242
31. Bonhoeffer S, MA Nowak (1994). Intra-host versus inter-host selection: Viral strategies of immune function impairment. *Proc Natl Acad Sci USA* 91: 8062-8066. DOI: 10.1073/pnas.91.17.8062
32. Bonhoeffer S, MA Nowak (1994). Mutation and the evolution of virulence. *Proc R Soc B* 258: 133-140. DOI: 10.1098/rspb.1994.0153
33. May RM, MA Nowak (1994). Superinfection, metapopulation dynamics, and the evolution of diversity. *J theor Biol* 170: 95-114. DOI: 10.1006/jtbi.1994.1171
34. Moxon ER, PB Rainey, MA Nowak, RE Lenski (1994). Adaptive evolution of highly mutable loci in pathogenic bacteria. *Curr Biol* 4: 24-33. DOI: 10.1016/S0960-9822(00)00005-1
35. Nowak MA (1994). The evolutionary dynamics of HIV infections. In *First European Congress of Mathematics: Paris, July 6-10, 1992, Vol. II*, eds. A Joseph, F Mignot, F Murat, B Prum, R Rentschler. Basel: Birkhauser, 311-326.
36. Nowak MA, S Bonhoeffer, RM May (1994). More spatial games. *Int J Bifurcat Chaos* 4: 33-56. DOI: 10.1142/S0218127494000046
37. Nowak MA, S Bonhoeffer, RM May (1994). Spatial games and the maintenance of cooperation. *Proc Natl Acad Sci USA* 91: 4877-4881. DOI: 10.1073/pnas.91.11.4877
38. Nowak MA, RM May (1994). Superinfection and the evolution of parasite virulence. *Proc R Soc B* 255: 81-89. DOI: 10.1098/rspb.1994.0012
39. Nowak MA, K Sigmund (1994). The alternating Prisoner's Dilemma. *J theor Biol* 168: 219-226. DOI: 10.1006/jtbi.1994.1101
40. Payne RJH, MA Nowak, BS Blumberg (1994). A cellular model to explain the pathogenesis of infection by the hepatitis B virus. *Math Biosci* 123: 25-58. DOI: 10.1016/0025-5564(94)90017-5
41. Tilman D, RM May, CL Lehman, MA Nowak (1994). Habitat destruction and the extinction debt. *Nature* 371: 65-66. DOI: 10.1038/371065a0

#### 1995

42. Bonhoeffer S, EC Holmes, MA Nowak (1995). Causes of HIV diversity. *Nature* 376: 125. DOI: 10.1038/376125a0
43. Bonhoeffer S, EC Holmes, MA Nowak (1995). Varying selection pressures in HIV -1 infection. *J Acq Immun Def Synd* 10: 85.
44. Bonhoeffer S, MA Nowak (1995). Can live attenuated virus work as post-exposure treatment? *Immunol Today* 16: 131-135. DOI: 10.1016/0167-5699(95)80129-4
45. Lipsitch M, EA Herre, MA Nowak (1995). Host population structure and the evolution of virulence: A "law of diminishing returns." *Evolution* 49: 743-748. DOI: 10.2307/2410327
46. Lipsitch M, MA Nowak (1995). The evolution of virulence in sexually transmitted HIV/AIDS. *J theor Biol* 174: 427-440. DOI: 10.1006/jtbi.1995.0109
47. Lipsitch M, MA Nowak, D Ebert, RM May (1995). The population dynamics of vertically and horizontally transmitted parasites. *Proc R Soc B* 260: 321-327. DOI: 10.1098/rspb.1995.0099
48. May RM, S Bonhoeffer, MA Nowak (1995). Spatial games and evolution of cooperation. In *Advances in Artificial Life: Third European Conference on Artificial Life, Granada, Spain, June 4-6, 1995*, eds. F Moran, A Moreno, JJ Merelo, P Chacon. Berlin: Springer, 749-759.

49. May RM, MA Nowak (1995). Coinfection and the evolution of parasite virulence. *Proc R Soc B* 261: 209-215. DOI: 10.1098/rspb.1995.0138
50. McMichael AJ, S Rowland-Jones, P Klenerman, et al (1995). Epitope variation and t-cell recognition. *J Cell Biochem Suppl* 59 (S21A): 60.
51. Nowak MA (1995). AIDS pathogenesis: From models to viral dynamics in patients. *J Acq Immun Def Syn* 10: S1-S5. DOI: 10.1097/00042560-199510001-00002
52. Nowak M (1995). Evolutionary dynamics of HIV infections. In *Models for Infectious Human Diseases: Their Structure and Relation to Data*, eds. V Isham, G Medley. Cambridge: Cambridge University Press.
53. Nowak MA, S Bonhoeffer, C Loveday, P Balfe, M Semple, S Kaye, M Tenant-Flowers, R Tedder (1995). HIV results in the frame: Results confirmed. *Nature* 375: 193. DOI: 10.1038/375193a0
54. Nowak MA, RM May, RE Phillips, S Rowland-Jones, DG Lalloo, S McAdam, P Klenerman, B Köppe, K Sigmund, CRM Bangham, AJ McMichael (1995). Antigenic oscillations and shifting immunodominance in HIV-1 infections. *Nature* 375: 606-611. DOI: 10.1038/375606a0
55. Nowak MA, RM May, K Sigmund (1995). Immune responses against multiple epitopes. *J theor Biol* 175: 325-353. DOI: 10.1006/jtbi.1995.0146
56. Nowak M A, RM May, K Sigmund (1995). The arithmetics of mutual help. *Sci Am* 272: 76-81. DOI: 10.1038/scientificamerican0695-76
57. Nowak MA, AJ McMichael (1995). How HIV defeats the immune system. *Sci Am* 273: 58-65. DOI: 10.1038/scientificamerican0895-58
58. Nowak MA, K Sigmund (1995). Invasion dynamics of the finitely repeated Prisoner's Dilemma. *Game Econ Behav* 11: 364-390. DOI: 10.1006/game.1995.1055
59. Nowak MA, K Sigmund, E El-Sedy (1995). Automata, repeated games and noise. *J Math Biol* 33: 703-722. DOI: 10.1007/BF00184645
60. Wei X, SK Ghosh, ME Taylor, VA Johnson, EA Emini, P Deutsch, JD Lifson, S Bonhoeffer, MA Nowak, BH Hahn, MS Saag, GM Shaw (1995). Viral dynamics in human immunodeficiency virus type 1 infection. *Nature* 373: 117-122. DOI: 10.1038/373117a0

## 1996

61. Antia R, MA Nowak, RM Anderson (1996). Antigenic variation and the within-host dynamics of parasites. *Proc Natl Acad Sci USA*. 93: 985-989. DOI: 10.1073/pnas.93.3.985
62. Boerlijst MC, S Bonhoeffer, MA Nowak (1996). Viral quasi-species and recombination. *Proc R Soc B* 263: 1577-1584. DOI: 10.1098/rspb.1996.0231
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