

MARTIN A. NOWAK

Curriculum Vitae

Personal Information

Name: Martin Andreas Nowak

Address: Program for Evolutionary Dynamics, Harvard University

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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

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 people 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 Schrodinger 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

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

Publications

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.

Selected Publications

Beale N, DG Rand, H Battey, K Croxson, RM May, MA Nowak (2011). Individual versus systemic risk and the Regulator's Dilemma. *Proc Natl Acad Sci USA* 108 (31): 12647-12652. DOI: 10.1073/pnas.1105882108

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.

Nowak MA, CE Tarnita, EO Wilson (2011). Nowak et al. reply. *Nature* 471 (7339): E9-E10. DOI: 10.1038/nature09836

Rand DG, MA Nowak (2011). The evolution of antisocial punishment in optional public goods games. *Nat Commun* 2: 434. DOI: 10.1038/ncomms1442

Tarnita CE, N Wage, MA Nowak (2011). Multiple strategies in structured populations. *Proc Natl Acad Sci USA* 108 (6): 2334-2337.

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.

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

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.

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.

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

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

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

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

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

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

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

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

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

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.

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

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

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

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

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

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

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.

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

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.

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

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

Nowak MA, KM Page, K Sigmund (2000). Fairness versus reason in the ultimatum game. *Science* 289:

1773-1775.

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

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

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

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

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

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

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.

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.

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.

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

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

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.

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

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

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.

Articles in Scientific American and Natural History

Nowak MA, RM May, K Sigmund (1995). The arithmetics of mutual help. *Sci Am* 272: 76-81.

Nowak MA, AJ McMichael (1995). How HIV defeats the immune system. *Sci Am* 273: 58-65.

Nowak MA (2000). Homo Grammaticus. *Nat Hist* 109: 36-44.

Sigmund K, K Fehr, MA Nowak (2002). The economics of fair play. *Sci Am* 286: 82-87.

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.
2. Nowak M, K Sigmund (1989). Game-dynamical aspects of the prisoner's dilemma. *Appl Math Comp* 30: 191-213.
3. Nowak M, K Sigmund (1989). Oscillations in the evolution of reciprocity. *J theor Biol* 137: 21-26.

1990

4. Nowak MA (1990). An evolutionarily stable strategy may be inaccessible. *J theor Biol* 142: 237-241.
5. Nowak M (1990). HIV mutation rate. *Nature* 347: 522.
6. Nowak M (1990). Stochastic strategies in the prisoner's dilemma. *Theor Pop Biol* 38: 93-112.
7. Nowak MA, RM May, RM Anderson (1990). The evolutionary dynamics of HIV quasispecies and the development of immunodeficiency disease. *AIDS* 4: 1095-1103.
8. Nowak M, K Sigmund (1990). The evolution of stochastic strategies in the prisoner's dilemma. *Acta Appl Math* 20: 247-265.

1991

9. Kwiatkowski D, M Nowak (1991). Periodic and chaotic host-parasite interactions in human malaria. *Proc Natl Acad Sci USA* 88: 5111-5113.
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.
11. Nowak M (1991). The evolution of viruses. Competition between horizontal and vertical transmission of mobile genes. *J theor Biol* 150: 339-347.
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.
13. Nowak MA, RM May (1991). Mathematical biology of HIV infections: Antigenic variation and diversity threshold. *Math Biosci* 106: 1-21.
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.

1992

15. McLean AR, MA Nowak (1992). Competition between zidovudine sensitive and resistant strains of HIV. *AIDS* 6: 71-79.
16. McLean AR, MA Nowak (1992). Models of interactions between HIV and other pathogens. *J theor*

Biol 155: 69-86.

17. Nowak MA (1992). Variability in HIV infections. *J theor Biol* 155: 1-20.
18. Nowak MA (1992). What is a quasispecies? *Trends Ecol Evol* 7: 118-121.
19. Nowak MA, RM May (1992). Coexistence and competition in HIV infections. *J theor Biol* 159: 329-342.
20. Nowak MA, RM May (1992). Evolutionary games and spatial chaos. *Nature* 359: 826-829.
21. Nowak MA, K Sigmund (1992). Tit for tat in heterogeneous populations. *Nature* 355: 250-253.
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
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.
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.

1993

25. Nowak MA, RM May (1993). AIDS pathogenesis: Mathematical models of HIV and SIV infections. *AIDS* 7: S3-S18.
26. Nowak MA, RM May (1993). The spatial dilemmas of evolution. *Int J Bifurcat Chaos* 3: 35-78.
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: Wuert 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.
29. Nowak M, K Sigmund (1993). Chaos and the evolution of cooperation. *Proc Natl Acad Sci USA* 90: 5091-5094.

1994

30. Berry RM, MA Nowak (1994). Defective escape mutants of HIV. *J theor Biol* 171: 387-395.
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.
32. Bonhoeffer S, MA Nowak (1994). Mutation and the evolution of virulence. *Proc R Soc B* 258: 133-140.
33. May RM, MA Nowak (1994). Superinfection, metapopulation dynamics, and the evolution of diversity. *J theor Biol* 170: 95-114.
34. Moxon ER, PB Rainey, MA Nowak, RE Lenski (1994). Adaptive evolution of highly mutable loci in pathogenic bacteria. *Curr Biol* 4: 24-33.
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.
37. Nowak MA, S Bonhoeffer, RM May (1994). Spatial games and the maintenance of cooperation. *Proc Natl Acad Sci USA* 91: 4877-4881.
38. Nowak MA, RM May (1994). Superinfection and the evolution of parasite virulence. *Proc R Soc B* 255: 81-89.
39. Nowak MA, K Sigmund (1994). The alternating Prisoner's Dilemma. *J theor Biol* 168: 219-226.
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.
41. Tilman D, RM May, CL Lehman, MA Nowak (1994). Habitat destruction and the extinction debt. *Nature* 371: 65-66.

1995

42. Bonhoeffer S, EC Holmes, MA Nowak (1995). Causes of HIV diversity. *Nature* 376: 125.
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.
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.
46. Lipsitch M, MA Nowak (1995). The evolution of virulence in sexually transmitted HIV/AIDS. *J theor Biol* 174: 427-440.
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.
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.
50. McMichael AJ, S Rowland-Jones, P Klenerman, et al (1995). Epitope variation and t-cell recognition. *J Cell Biochem Suppl* S21A: 60.
51. Nowak MA (1995). AIDS pathogenesis: From models to viral dynamics in patients. *J Acq Immun Def Syn* 10: S1-S5.
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.
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

55. Nowak MA, RM May, K Sigmund (1995). Immune responses against multiple epitopes. *J theor Biol* 175: 325-353.
56. Nowak M A, RM May, K Sigmund (1995). The arithmetics of mutual help. *Sci Am* 272: 76-81.
57. Nowak MA, AJ McMichael (1995). How HIV defeats the immune system. *Sci Am* 273: 58-65.
58. Nowak MA, K Sigmund (1995). Invasion dynamics of the finitely repeated Prisoner's Dilemma. *Game Econ Behav* 11: 364-390.
59. Nowak MA, K Sigmund, E El-Sedy (1995). Automata, repeated games and noise. *J Math Biol* 33: 703-722.
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.

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.
62. Boerlijst MC, S Bonhoeffer, MA Nowak (1996). Viral quasi-species and recombination. *Proc R Soc B* 263: 1577-1584.
63. Bonhoeffer S, AVM Herz, MC Boerlijst, S Nee, MA Nowak, RM May (1996). Explaining "linguistic features" of noncoding DNA. *Science* 271: 14-15.
64. Bonhoeffer S, AVM Herz, MC Boerlijst, S Nee, MA Nowak, RM May (1996). No signs of hidden language in noncoding DNA. *Phys Rev Lett* 76: 1977.
65. Herz AVM, S Bonhoeffer, RM Anderson, RM May, MA Nowak (1996). Viral dynamics in vivo: Limitations on estimates of intracellular delay and virus decay. *Proc Natl Acad Sci USA* 93: 7247-7251.
66. Klenerman P, RE Phillips, CR Rinaldo, LM Wahl, G Ogg, RM May, AJ McMichael, MA Nowak (1996). Cytotoxic T lymphocytes and viral turnover in HIV type 1 infection. *Proc Natl Acad Sci USA* 93: 15323-15328.
67. Lipsitch M, S Siller, MA Nowak (1996). The evolution of virulence in pathogens with vertical and horizontal transmission. *Evolution* 50: 1729-1741.
68. McMichael AJ, P Goulder, S Rowland-Jones, MA Nowak, R Philips (1996). HIV escapes from cytotoxic lymphocytes. *Immunology* 89: 111.
69. Nowak MA (1996). Immune responses against multiple epitopes: A theory for immunodominance and antigenic variation. *Semin Virol* 7: 83-92.
70. Nowak MA, RM Anderson, MC Boerlijst, S Bonhoeffer, RM May, AJ McMichael (1996). HIV-1 evolution and disease progression. *Science* 274: 1008-1011.
71. Nowak MA, CRM Bangham (1996). Population dynamics of immune responses to persistent viruses. *Science* 272: 74-79.
72. 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.

73. Nowak MA, S Bonhoeffer, RM May (1996). Reply to Robustness of cooperation, A Mukherji, V Rajan, J Slagle. *Nature* 379: 126.
74. Payne RJH, MA Nowak, BS Blumberg (1996). The dynamics of hepatitis B virus infection. *Proc Natl Acad Sci USA* 93: 6542-6546.
75. Stekel DJ, MA Nowak, TRE Southwood (1996). Prediction of future BSE spread. *Nature* 381: 119.
76. Tilman D, C Lehman, R May, M Nowak (1996). Reply to Species fragmentation or area loss? S Budiansky. *Nature* 382: 216.

1997

77. Bittner B, S Bonhoeffer, MA Nowak (1997). Virus load and antigenic diversity. *B Math Biol* 59: 881-896.
78. Boerlijst MC, MA Nowak, K Sigmund (1997). Equal pay for all prisoners. *Am Math Mon* 104: 303-305.
79. Boerlijst MC, MA Nowak, K Sigmund (1997). The logic of contrition. *J theor Biol* 185: 281-293.
80. Bonhoeffer S, JM Coffin, MA Nowak (1997). Human immunodeficiency virus drug therapy and virus load. *J Virol* 71: 3275-3278.
81. Bonhoeffer S, RM May, GM Shaw, MA Nowak (1997). Virus dynamics and drug therapy. *Proc Natl Acad Sci USA* 94: 6971-6976.
82. Bonhoeffer S, MA Nowak (1997). Pre-existence and emergence of drug resistance in HIV-1 infection. *Proc R Soc B* 264: 631-637.
83. Chun T-W, L Stuyver, SB Mizell, LA Ehler, JAM Mican, M Baseler, AL Lloyd, MA Nowak, AS Fauci (1997). Presence of an inducible HIV-1 latent reservoir during highly active antiretroviral therapy. *Proc Natl Acad Sci USA* 94: 13193-13197.
84. Cooke J, MA Nowak, MC Boerlijst, J Maynard-Smith (1997). Evolutionary origins and maintenance of redundant gene expression during metazoan development. *Trends Genet* 13: 360-364.
85. Goulder PJR, RE Phillips, RA Colbert, S McAdam, G Ogg, MA Nowak, P Giangrande, G Luzzi, B Morgan, A Edwards, AJ McMichael, S Rowland-Jones (1997) Late escape from an immunodominant cytotoxic T-lymphocyte response associated with progression to AIDS. *Nat Med* 3: 212-217.
86. Goulder P, D Price, M Nowak, S Rowland-Jones, R Phillips, A McMichael (1997). Co-evolution of human immunodeficiency virus and cytotoxic T-lymphocyte responses. *Immunol Rev* 159: 17-29.
87. Lifson JD, MA Nowak, S Goldstein, JL Rossio, A Kinter, G Vasquez, TA Wiltrout, C Brown, D Schneider, L Wahl, AL Lloyd, J Williams, WR Elkins, AS Fauci, VM Hirsch (1997). The extent of early viral replication is a critical determinant of the natural history of simian immunodeficiency virus infection. *J Virol* 71: 9508-9514.
88. May RM, DJ Stekel, MA Nowak (1997). Antigenic diversity thresholds and hazard functions. *Math Biosci* 139: 59-68.
89. Nowak MA, MC Boerlijst, J Cooke, J Maynard Smith (1997). Evolution of genetic redundancy. *Nature* 388: 167-171.

90. Nowak MA, S Bonhoeffer, GM Shaw, RM May (1997). Anti-viral drug treatment: Dynamics of resistance in free virus and infected cell populations. *J theor Biol* 184: 203-217.
91. Nowak MA, AL Lloyd, GM Vasquez, TA Wilttrout, LM Wahl, N Bischofberger, J Williams, A Kinter, AS Fauci, VM Hirsch, JD Lifson (1997). Viral dynamics of primary viremia and antiretroviral therapy in simian immunodeficiency virus infection. *J Virol* 71: 7518-7525.
92. Sigmund K, Nowak M A (1997) The natural history of mutual aid: An eye for an eye, and a meal for a meal. In *Wissenschaft als Kultur*, ed. F Stadler. New York: Springer, 259-272.
93. Stekel D, CE Parker, MA Nowak (1997). A model of lymphocyte recirculation. *Immunol Today* 18: 216-221.
94. Wein LM, SA Zenios, MA Nowak (1997). Dynamic multidrug therapies for HIV: A control theoretic approach. *J theor Biol* 185: 15-29.

1998

95. Goh WC, ME Rogel, CM Kinsey, SF Michael, PN Fultz, MA Nowak, BH Hahn, M Emerman (1998). HIV-1 Vpr increases viral expression by manipulation of the cell cycle: A mechanism for selection of Vpr in vivo. *Nat Med* 4: 65-71.
96. Kilby JM, S Hopkins, TM Venetta, B DiMassimo, GA Cloud, JY Lee, L Alldredge, E Hunter, D Lambert, D Bolognesi, T Matthews, MR Johnson, MA Nowak, GM Shaw, MS Saag (1998). Potent suppression of HIV-1 replication in humans by T-20, a peptide inhibitor of gp41-mediated virus entry. *Nat Med* 4: 1302-1307.
97. Levin BR, R Antia, E Berliner, P Bloland, S Bonhoeffer, M Cohen, T DeRouin, PI Fields, H Jafari , D Jernigan, M Lipsitch, JE McGowan, P Mead, M Nowak, T Porco, P Sykora, L Simonsen, J Spitznagel, R Tauxe, F Tenover (1998). Resistance to antimicrobial chemotherapy: A prescription for research and action. *Am J Med Sci* 315: 87-94.
98. Nowak MA, DC Krakauer, A Klug, RM May (1998). Prion infection dynamics. *Integr Biol* 1: 3-15.
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