

**Program for Evolutionary Dynamics (PED)
Activity Report**

prepared January 2010 by Martin Nowak and Lydia Liu

www.ped.fas.harvard.edu

PED people:

Director: Martin Nowak (Professor of Mathematics and of Biology)

Chief Administrative Officer: May Huang

Staff Assistant: Lydia Liu

Research scientists

Tibor Antal
Terence Burnham (Acadian Asset Management Boston)
Anna Dreber Almenberg (Harvard Kennedy School)
Thomas Pfeiffer (Branco Weiss Fellow)
David Rand
Corina Tarniță (Harvard Society of Fellows)
Christine Taylor (PED and Department of Mathematics)

Previous research scientists

Ramy Arnaout (HMS Pathology)
Niko Beerenwinkel (ETH Zurich)
David Dingli (Mayo Clinic)
Kevin Foster (Bauer Fellow, FAS Center for Systems Biology)
Stefano Ghirlanda (University of Bologna)
Christoph Hauert (University of British Columbia)
Akiko Iwanaga-Ohtsuki (Sokendai Graduate University)
Philipp Langer (Swiss federal research)
Hisashi Ohtsuki (Tokyo Institute of Technology)
Christina Pawlowitsch (University of Vienna)
Arne Traulsen (Max Planck Institute for Evolutionary Biology)

Graduate students

Ivana Božić (Mathematics)
Alison Hill (Biophysics)
Jeffrey Ishizuka (Harvard Medical School)
Erez Lieberman (School of Engineering and Applied Sciences & MIT)
Michael Manapat (MIT Mathematics)
Jean-Baptiste Michel (Systems Biology)
Daniel Rosenbloom (Organismic and Evolutionary Biology)

Previous graduate students

David Rand (Systems Biology, PhD '09)
Corina Tarniță (Mathematics, PhD '09)
Martin Willensdorfer (Molecular and Cellular Biology, PhD '07)

Erick Matsen (Mathematics, PhD '06)
Franziska Michor (Organismic and Evolutionary Biology, PhD '05)

Visiting scholars (in residence):

Hava Siegelmann (University of Massachusetts Amherst)

Previous visiting scholars:

Charles Chip Aquadro (Cornell University)
Reinhard Bürger (University of Vienna Austria)
Richard Frankham (Macquarie University Australia)
Loren Imhof (University of Bonn Germany)
Yoh Iwasa (Kyushu University Japan)
C. Randal Linder (University of Texas at Austin)
Jorge Pacheco (University of Lisbon Portugal)
Akira Sasaki (Sokendai Graduate University Japan)
Edward Stabler (UCLA)
Keiichiro Tokita (Osaka University Japan)
Robert Trivers (Rutgers University)
Tandy Warnow (University of Texas at Austin)
Claus Wedekind (University of Lausanne Switzerland)

Guest researchers (in residence)

Feng Fu (Peking University)

Previous guests

2009

Matthijs van Veelen (University of Amsterdam).

2008

Immanuel Bomze (University of Vienna)
Tore Ellingsen (Stockholm School of Economics)
Moshe Hoffman (University of Chicago)

2007

Rebecca Asquith (Imperial College London)
Pat Barclay (Cornell University)
Manfred Milinski (Max Planck Institute for Evolutionary Biology)
Samuel Ojosnegros (ETH Zurich Switzerland)
Tobias Reichenbach (Rockefeller University New York)
Karl Sigmund (University of Vienna)
Eric Smith (Santa Fe Institute)
Masanori Sugiura (Osaka University)
Peter Taylor (Queens University Canada)
Joe Yuichiro Wakano (Meiji University)
Benno Wolfing (Max Planck Institute for Evolutionary Biology)

2006

Timothy Killingback (College of William and Mary)

Simon Levin (Princeton University)
Peter Michor (University of Vienna)
Sébastien Roch (UCLA)
Mary Molly Rorick (Yale University)
Jorge Zubelli (IMPA Brazil)

2005

Alain Jacob (University of Lausanne Switzerland)
Anirvan Sengupta (Rutgers University)
Davnah Urbach (University of Lausanne Switzerland)
Beat Von Siebenthal (University of Lausanne Switzerland)

2004

Lee Segel (Weizmann Institute of Science Israel)
Michael Turelli (University of California Davis)

2003

Steven Frank (University of California Irvine)
Partha Niyogi (University of Chicago)

Current research projects:

Evolution of eusociality – Martin Nowak, Corina Tarnita, Edward O. Wilson

Origin of Life – Martin Nowak and Michael Manapat [various projects; some of them in collaboration with Reinhard Buerger (University of Vienna), Hisashi Ohtsuki (Tokyo Institute of Technology), Irene Chen (FAS Center for Systems Biology) and George Church (HMS)]

Evolutionary set theory – Corina Tarnita

Driver and passenger mutations in cancer progression – Ivana Bozic, Tibor Antal, Martin Nowak, Bert Vogelstein

Indirect Speech – Martin Nowak [with Steven Pinker (Psychology)]

Facilitated Evolution – Martin Nowak [with Marc Kirschner and Walter Fontana (both in Systems Biology)]

Evolution of Brain Modules – Martin Nowak [with Steve Kosslyn (Psychology)]

Evolution and Theology of Cooperation – Martin Nowak [with Sarah Coakley (Cambridge University)]

Evolutionary Dynamics of HIV Infection – Martin Nowak [with Niko Beerenwinkel (ETH Zurich), Zabrina Brumme and Bruce Walker (both at the Partners AIDS Research Center)]

Punishment and Indirect Reciprocity – Martin Nowak [with Hisashi Ohtsuki (Tokyo Institute of Technology) and Yoh Iwasa (Kyushu University)]

Evolutionary Dynamics in Structured Populations – Martin Nowak [with Arne Traulsen (Max Planck Institute for Evolutionary Biology), Hisashi Ohtsuki (Tokyo Institute of Technology) and Jorge Pacheco (University of Lisbon)]

Group Selection Models and Their Relation to Kin Selection – Martin Nowak [with Arne Traulsen (Max Planck Institute for Evolutionary Biology)]

Analysis of the Luria-Delbruck Distribution with Applications to Drug Resistance Development during Tumor Growth – Martin Nowak and Tibor Antal [with P.L. Krapivsky (Boston University)]

Evolutionary Set Theory – Martin Nowak, Tibor Antal, Corina Tarnita and David Rand [with Arne Traulsen (Max Planck Institute for Evolutionary Biology) and Hisashi Ohtsuki (Tokyo Institute of Technology)]

Games in Phenotype Space – Martin Nowak and Tibor Antal [with John Wakeley (Department of Organismic and Evolutionary Biology), Peter Taylor (Queens University), and Hisashi Ohtsuki (Tokyo Institute of Technology)]

Tumor Progression via Clonal Expansions: Discrete and Continuous Time Models – Martin Nowak, Tibor Antal and Ivana Bozic [with Hisashi Ohtsuki (Tokyo Institute of Technology) and Bert Vogelstein (Johns Hopkins University)]

A Theoretical Investigation of the Role of Costly Punishment in the Repeated Prisoner's Dilemma, Using Adaptive Dynamics – David Rand and Martin Nowak [with Hisashi Ohtsuki (Tokyo Institute of Technology)]

A Theoretical Investigation of the Evolution of Anti-Social Behavior – David Rand [with Hisashi Ohtsuki and Mayuko Nakamaru (both at Tokyo Institute of Technology)]

A Theoretical Investigation of the Evolution of Irrational Cooperation in Fixed Length Centipede Games – David Rand, Corina Tarnita, Tibor Antal, and Martin Nowak [with Arne Traulsen (Max Planck Institute for Evolutionary Biology) and Hisashi Ohtsuki (Tokyo Institute of Technology)]

An Experimental Investigation of the Genetic Basis of Financial Risk-Taking – Anna Dreber and David Rand [with Richard Zeckhauser (Government)]

An Experimental Investigation of the Role of Costly Punishment in the Prisoner's Dilemma – Anna Dreber, David Rand, and Martin Nowak [with Drew Fudenberg (Economics)]

An Experimental Investigation of the Scientific Process, Choice of What to Study and What to Publish – Thomas Pfeiffer, David Rand and Anna Dreber

Gameome Project – Anna Dreber, David Rand, Erez Lieberman and Martin Nowak [with Tina Tang (GSAS), Rob Miller and Lydia Chilton (both at MIT)]

Biological Foundations of Decision Making and Risk Taking – Anna Dreber [with Coren Apicella (Anthropology), Ben Campbell (University of Wisconsin-Milwaukee), Peter Gray (University of Nevada-Las Vegas), Dan Eisenberg (Northwestern University), Moshe Hoffman (University of Chicago), Anthony Little (University of Sterling), Justin R. Garcia and J. Koji Lum (both at Binghamton University)]

An Experimental Investigation of the Effect of Reputation Markets on Indirect Reciprocity – Thomas Pfeiffer, David Rand, and Anna Dreber

An Experimental Investigation of the Role of Targeted Interactions in the Public Goods Game – David Rand, Anna Dreber and Martin Nowak [with Drew Fudenberg (Economics)]

An Experimental Investigation of Altruism, Social Image and Framing – Anna Dreber, David Rand and Martin Nowak [with Tore Ellingsen and Magnus Johannesson (both at the Stockholm School of Economics)]

An Experimental Investigation of Group Identity – Anna Dreber and David Rand [with Yochai Benkler (HLS)]

An Experimental Study on Charitable Giving Among Church-Goers – Anna Dreber, David Rand and Martin Nowak [with Sarah Coakley (Cambridge University)]

An Experimental Study of Altruism in Children – David Rand [with Peter Blake (HGSE)]

A Theoretical and Experimental Study of the Role of Punishment as a Form of Operant Conditioning in the Evolution of Cooperation – David Rand [with Fiery Cushman (Psychology)]

A Data Analysis Study of Emotion as Infectious Disease – David Rand [with Nicholas Christakis (Department of Health Care Policy)]

Five Mechanisms for the Evolution of Cooperation in the Prisoner's Dilemma and Snowdrift Game – Christine Taylor and Martin Nowak

A New Approach for Group Selection – Christine Taylor and Martin Nowak [with Yoh Iwasa (Kyushu University)]

A Model of Consensus Formation – Christine Taylor and Feng Fu [with Yoh Iwasa (Kyushu University)]

Evolutionary Dynamics of Multiplayer Games – Christine Taylor and Martin Nowak

Finding the Optimal Level of Punishment for the Evolution of Cooperation in a Public Goods Game – Christine Taylor [with Janet Chen (Mathematics) and Yoh Iwasa (Kyushu University)]

Evolution of Cooperation in Spatial Public Goods Games – Martin Nowak [with Christoph Hauert (University of British Columbia) and Joe Yuichiro Wakano (University of Tokyo)]

Evolution of Punishment and Volunteering – Martin Nowak [with Christoph Hauert (University of British Columbia), Arne Traulsen (Max Planck Institute for Evolutionary Biology), Hannalore Brandt and Karl Sigmund (both at the University of Vienna)]

Evolutionary Dynamics on Degree Heterogeneous Graphs – Feng Fu and Martin Nowak [with Christoph Hauert (University of British Columbia)]

Vaccination games – Feng Fu and Martin Nowak [with Long Wang (Peking University) and Jorge Pacheco (University of Lisbon)]

Invasion and Expansion of Cooperators in Lattice Populations: Prisoner's Dilemma vs. Snowdrift Games - Feng Fu [with Christoph Hauert (University of British Columbia)]

Reciprocal Altruism and the Use of Social Information – Thomas Pfeiffer

Evolution of Complex Biochemical Networks – Thomas Pfeiffer

Language Regularization – Erez Lieberman, Jean-Baptiste Michel and Martin Nowak [with Tina Tang (GSAS)]

Chromatin Epigenetics – Erez Lieberman [with Eric Lander (MIT), Brad Bernstein and Tarjei Mikkelsen (both at the Broad Institute)]

HIV Diversity Analysis – Erez Lieberman [with Eric Lander (MIT), Mathew Henn and Bruce Birren (both at the Broad Institute)]

Nanowell DNA Amplification – Erez Lieberman [with Chris Love (MIT) and Fan Liang (HST)]

Complexity Theory of Evolution on Graphs – Erez Lieberman [with Robert Hearn (Dartmouth), Erik Demaine and Scott Aaronson (both at MIT)]

Assembly of a Massive Corpus of Blogs – Erez Lieberman, Jean-Baptiste Michel, and Michael Manapat [with Sep Kamvar (Stanford University)]

Assembly of a Large Corpus of Historical Texts - Jean-Baptiste Michel, Erez Lieberman, and Martin Nowak [with Steven Pinker (Psychology) and Yuan Shen (MIT)]

Neuroimaging of Grammatical Rules Using fMRI - Erez Lieberman and Jean-Baptiste Michel [with Joe Fruchter (New York)]

Quantifying the Population-Wide Variability of Linguistic Rules - Jean-Baptiste Michel, Erez Lieberman, and Martin Nowak [with Steven Pinker (Psychology)]

Impact of Cognitive Constraints on the Evolution of Languages: Preposition Stranding and Case Markers - Jean-Baptiste Michel and Christina Pawlowitsch [with Andrew Nevins (Linguistics)]

Emergence of Cooperation Between Countries: The Dynamics of International Law - Jean-Baptiste Michel

Bounded Rationality of Players in Online Gaming Data - Anna Dreber and Jean-Baptiste Michel [with Pedro Bordalo (HMS)]

Next Generation HLA Typing – Erez Lieberman [with Zabrina Brumme, Bruce Walker (both at the Partners AIDS Research Center), Abha Chopra, and Simon Mallal (both at Murdoch University)]

Development of Wearable Diagnostics for Poor Balance – Erez Lieberman [with William Paloski (NASA), Laurence Young (MIT), Katey Forth, Qian Yang and Ricardo Piedrahita (all at iShoe)]

Complexity Theory of Neural Networks – Erez Lieberman and Hava Siegelmann

Complexity Theory in Biological Computing – Erez Lieberman and Hava Siegelmann [with Robert Hearn (Dartmouth)]

Emotion Epidemics – Erez Lieberman and Michael Manapat [with Aviva Presser (Broad Institute) and Sep Kamvar (Stanford)]

Life Detection – Martin Nowak and Hava Siegelmann [with Oscar Loureiro (UMass-Amherst)]

Asynchronous Computation – Erez Lieberman, Hava Siegelmann and Martin Nowak

Teaching:

Courses

Math 153: Mathematical Biology – Evolutionary Dynamics (fall terms 2004, 2005, 2006, 2008, 2009)
Math 243 (formerly Math 234): Evolutionary Dynamics (spring terms 2005, 2006, 2007, 2008, 2009, 2010)
Mathematics 388: Topics in Mathematics and Biology (every term)
OEB 275r: A Survey of Evolutionary Biology (spring term 2008)
OEB 361: Somatic Evolution of Cancer (every term)
Systems Biology 300hf: Introduction to Systems Biology Research (spring terms 2007, 2009)
Systems Biology 350: Systems Biology Research (every term)

ROME (Research Opportunities in Mathematical Evolution)

The following undergraduate (and graduate) students have performed research projects at PED from 2003 until now. Some students have published their first paper in this program or given their first talk.

Current ROME students

Sarah Bakst '11 (Linguistics) – Comparative Adjective Morphology
Alexander D'Amour '08 SM '08 – Game Theory in Baseball
Arjun Manrai '08 (MIT PhD candidate) – Neural Networks
Yuan Shen (MIT PhD candidate) – The Google Million Book Research API
Nicholas Wage '10 (Mathematics) – Bounded Rationality and the Evolution of Intelligence

Previous ROME students

Ethan Abraham '04 – Evolutionary Game Dynamics
Joshua Segal '04 – Language Evolution
Gabriel Carroll '05 – Random Walks and the Voter Model, Computational Linguistics
Joseph Jackson '05 – Evolution of Irregular Verbs
Rita Loiotile '05 – Molecular Variable Reordering
Long Cai '01, AM '01, PhD '06 – Lymphoma Dynamics
Shaun Fitzgibbons '06 – The Agricultural Revolution
Brian Harrow JD '06 – Generalized Moran Process with Applications in Decision Making
Deniz Kural '06 – Institute for Virtual Economics
Vivek Rudrapatna '06 – Evolution of Protein Networks
Samuel Fraiberger SM '07 – The Judiciome
William Gaybrick '07 – Hypercomputation of the Faulty Automaton, LowLife
Andrew Laitman '07 – Hypercomputation on Neural Networks
Alexander Levin '07 – Evolutionary Dynamics
Mark Lipson '07 – Cancer Dynamics
Katherine Paur AM '03 PhD '07 – Modelling the effects of population structure and vaccination strategy on infectious diseases
Gouthram Seshadri '07 – Cascade Graphs, Consanguinity Clustering
Gerardo con Diaz '08 – Cooperation in Structured Populations
Joseph Armao '09 – Evolutionary Game Dynamics, Cooperation, and Costly Punishment
Charles Chen '09 – Consanguinity and the Matrix-Forest Theorem
William Chen '09 – Neural Networks
Kelley Harris '09 – Threshold Functions for Cascade Graphs
Da Lin '09 – Phylogeny of Germanic Languages
Charles Nathanson '09 – Evolution of Cooperation in Structured Populations under Weak Selection
Anupriya Singhal '09 – Neural Networks
Neal Wadhwa '09 – Update Rules in Graph-Structures Populations
Nils Wernerfelt '09 – Altruism, Group Identity, and the Infectiousness of Emotions
Qian Yang '09 – Math and Your Feet
Timothy Kim '10 – Consanguinity on Graphs
Joseph Barillari SM '07, PhD candidate – The Judiciome
David Broniatowski (MIT PhD candidate) – Quantifying Cooperative Behavior in Online Interactions
Celene Chang (PhD candidate) – Characterizing a Basic Stochastic Model of the Evolution of Cancer
Thomas Kolokotronis '00, MD '05, PhD candidate – Hysteresis in Evolutionary Graph Theory
Kaveri Rajaraman AM '06, PhD candidate – Clustering Methods Based on Google's Page Rank
Tina Tang '08, PhD candidate – Evolution of Irregular Verbs
Pedro Bordalo (HMS postdoc) – Dynamics of Neuron Growth
Joseph Fruchter – Frequency Effects on Neural Processing During Verb Conjugation

Funding:*

Gift from Jeffrey Epstein: 6.5 M (renewable, January 2003 – present).

John Templeton Foundation: Fundamental Questions in Evolutionary Biology (P.I. Martin Nowak). 10.0 M over 5 years (1 July 2009 – 30 June 2014).

John Templeton Foundation: Evolution and Theology of Cooperation (co-P.I.s Martin Nowak –FAS and Sarah Coakley - HDS). 2.0 M over 5 years (1 July 2005 – 30 June 2010).

NIH: Evolutionary graph theory and its applications (P.I. Martin Nowak). 1.25 M over 4 years (1 August 2006 – 31 July 2010).

Bill & Melinda Gates Foundation: Molecular analysis and modeling of HIV-1 transmission, containment, and escape (Harvard site P.I. Martin Nowak). 500 K over 5 years (1 July 2005 – 30 June 2010).

Harvard University Program on AIDS: Drug resistance as an impediment to long terms treatment for HIV/AIDS in Botswana (P.I. Max Essex). 50 K over 2 years (1 April 2006 – 31 March 2008).

FAS Start-up Fund of Martin Nowak. 500 K (January 2003 – open ended)

Total Funds received: 20.75M

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