BULLETIN

INTERNATIONAL CENTER FOR MATHEMATICS

June 2007

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Contents

Coming Events

June 23, 2007: 10th Annual Workshop on Applications and Generalizations of Complex Analysis

Organizers

J. Carvalho e Silva (Univ. of Coimbra), Ana Foulquié and Isabel Cação (Univ. of Aveiro).

Aims

This workshop is intended to give an opportunity for discussions between junior and senior researchers from several European countries in various fields of mathematics related to Complex, Quaternionic and Clifford Analysis (like Algebra, Geometry, Numerical Analysis, Differential Equations, etc.)

It is a satellite event of the 13th European Intensive Course on "Complex Analysis and its Generalizations", that takes place in Coimbra and Aveiro.

For more information about the event, see

www.mat.uc.pt/~jaimecs/ac/10thw.htm

June 27-29, 2007: EPSA 2007 - Workshop and Advanced School on Eigenvalue Problems, Software and Applications

Organizers

Paulo B. Vasconcelos and Maria J. Rodrigues (Univ. of Porto), Osni Marques (Lawrence Berkeley National Lab., USA), José Roman (Technical Univ. of Valencia, Spain).

Aims

The goal of the Workshop and Advanced School is to bring together leading researchers in the numerical solution of eigenvalue problems to survey the state-of-the-art methods and computational tools to solve large eigenvalue problems.

It aims to encourage the interchange of new ideas, to create a suitable environment for the participants to get acquainted and involved in today's computational mathematics, in particular research and applications that involve eigenproblems and spectral analysis.

Specific objectives are

(i) to survey and present recent developments in both theoretical and computational aspects of matrix eigenvalue problems,

(ii) to report on important practical applications and on challenging problems using high performance computing and

(iii) to foster new collaborations between the participants.

This event comes as a follow up of successful events, such as the Advanced Summer School on Recent Development on Large Scale Scientific Computing (a CIM event organized in 2001) and six Workshops on ACTS - Advanced CompuTational Software Collection (organized by DOE/LBNL). It will include a range of tutorials on methods and tools for the solution of eigenvalue problems and hands-on practices using the high performing clusters from the new Grid Computing infrastructure available at the University of Porto.

The target attendees are researchers and post-graduate students on Mathematics, Biomathematics, Engineering, Computer Science, Computational Economics and Finance, and other branches of Social Sciences. The course in the Advanced School will interest also graduate students and computational scientists whose research require the use of robust numerical algorithms, novel techniques, large amounts of eigenvalue calculations, or combinations of these.

The event is a Satellite Conference of ICIAM 07 and will take place at the Faculty of Science of the University of Porto.

Invited speakers

James Demmel (Univ. of California at Berkeley, USA)

Peter Arbenz (ETH, Zürich, Switzerland)

Filomena Dias d'Almeida (Univ. of Porto)

Tony Drummond (Lawrence Berkeley National Lab., USA)

Rui Ralha (Univ. of Minho)

Other speakers

Osni Marques (Lawrence Berkeley National Lab., USA)

José Roman (Technical Univ. of Valencia, Spain)

Paulo Vasconcelos (Univ. of Porto)

For more information about the event, see

www.fep.up.pt/epsa2007

July 18-20, 2007: LQCIL'07 Workshop on Quantum Cryptography

Organizers

Pedro Adão, Paulo Mateus (Chair), Cláudia Nunes and Yasser Omar (all Technical University of Lisbon).

Aims

This workshop will inaugurate the biannual Lisbon Quantum Computation, Information and Logic Meetings Series. It will be devoted to quantum cryptography and security, bringing together researchers from both classical and quantum information security to exchange ideas and discuss the latest results and future directions of the field. The workshop will be constituted by 7 invited lectures and 15 contributed talks. It is organized within the scope of the QuantLog project of SQIG - Security and Quantum Information Group, IT (formerly CLC - Center for Logic and Computation).

The event will take place at the Instituto Superior Técnico, Lisbon.

Invited speakers

Claude Crépeau (McGill Univ., Canada)

Artur Ekert (Cambridge Univ., U.K.)

Virgil Gligor (Univ. of Maryland, U.S.A.)

Hoi-Kwong Lo (Univ. of Toronto, Canada)

Mike Mosca (Univ. of Waterloo, Canada)

Andre Scedrov (Univ. of Pennsylvania, U.S.A.)

Umesh Vazirani (Univ. of California, Berkeley, U.S.A.)

For more information about the event, see

wslc.math.ist.utl.pt/lqcil07

July 22-27, 2007: CIM/UC Summer School "Topics in Nonlinear PDEs"

Scientific Coordinators

José Francisco Rodrigues (CMUC and Univ. Lisbon), José Miguel Urbano (CMUC and Univ. Coimbra).

Aims

Nonlinear Partial Differential Equations (PDEs) are central in modern Applied Mathematics, both in view of the importance of the concrete problems they model and the novel techniques that their analysis generates. The subject has developed immensely in recent years, in many unexpected and challenging directions, and a new range of applications emerged with the advent of Biomathematics.

The Summer School is a joint venture of the CIM and the University of Coimbra (UC), and is sponsored by the Gulbenkian Foundation. It will gather a group of leading specialists working on Partial Differential Equations and its main applications to Biology, Engineering and Physics, and will highlight emerging trends and issues of this fascinating research topic.

The School will consist of four short courses of six hours each, and of short communications by PhD students and Post-Docs. It will be held at the University of Coimbra.

Short courses

Luis Caffarelli (Univ. of Texas at Austin, USA)
Problems and methods involving free boundaries

Charlie Elliott (Univ. of Sussex, UK)
Critical state models in superconductivity

Felix Otto (Univ. of Bonn, Germany)
Analysis of pattern formation in physical models

Benoit Perthame (École Normale Supérieure, France)
Nonlinear PDEs in Biology

For more information about the event, see

www.cim.pt/pdes07

September 17-19, 2007: ROBOMAT 2007 - Workshop on Robotics and Mathematics

Organizers (Chairpersons)

Hélder Araújo (University of Coimbra), Maria Isabel Ribeiro (Technical University of Lisbon).

Aims

This workshop will aim at discussing several problems from Robotics from the perspective of the mathematical problems that they raise. It will be a forum where specialists with backgrounds both in Engineering and Mathematics will have an opportunity to discuss relevant research issues not from the point of view of the application but essentially from the point of view of the mathematical models and principles required to solve them.

This workshop will be relevant for:

PhD and MSc students working in Robotics and in relevant mathematical aspects;

Established researchers in Robotics and in Mathematics interested in strengthening the domains of their research work that are relevant for both Robotics and Mathematics;

The following mathematical disciplines are likely to have strong relevance for robotics: Algebraic and differential topology, Dynamic systems theory, Optimization algorithms, Combinatorics, Differential algebraic inequalities, Statistical learning theory.

The workshop will be held at Hotel D. Luís, Santa Clara, Coimbra.

Invited speakers

Henrik Christensen
(Director of the Centre for Autonomous Systems at the Royal Institute of Technology, Stockholm, Sweden, and a chaired professor of computer science specialising in autonomous systems, in the Department of Computer Science and Numerical Analysis.)

David Mumford
(Professor at the Division of Applied Mathematics of the Brown University, USA; in 1974 he was awarded the Fields Medal at the International Congress of Mathematics; his main topic of current research is Pattern Theory.)

Raja Chatila
(*Directeur de Recherche CNRS*, he is the Head of the Robotics and Artificial Intelligence Group, of the LAAS, Toulouse, France; he has numerous contributions in Mobile Robotics, Intervention Robots and Planetary Rovers, Service Robots, Personal Robots,

Cognitive Robots; he has an extensive number of publications in all these fields and he has been responsible for several important European projects.)

For more information about the event, see

http://labvis.isr.uc.pt/robomat

October 26-27, 2007: Follow-up Workshop on Optimization in Finance

ORGANIZERS

A. M. Monteiro (Fac. of Economics, Univ. of Coimbra), R. H. Tütüncü (Goldman Sachs, Asset Management, Quantitative Equity, New York, USA) and L. N. Vicente (Dep. of Mathematics, Univ. of Coimbra).

AIMS

The Workshop on Optimization in Finance was held in Coimbra, Portugal, in July 5-8, 2005 Coimbra, Portugal. The quality of the meeting was considered high and the participation surpassed the best expectations. The conference program is still available at the web site www.mat.uc.pt/tt2005/of/program.htm. The workshop was organized under the auspices of CIM, and was one of the events of the CIM Thematic Term on Optimization 2005.

As in the 2005 workshop, the targeted audience for the Follow-up Workshop on Optimization in Finance includes graduate students and faculty members working in applied mathematics, operations research, and economics, who have been or plan to be interested in optimization methods in finance. The event will also be attractive for those doing quantitative modelling in the financial market. The Follow-up Workshop topics include, among others, asset allocation, risk management, and derivative pricing.

The Follow-up Workshop will be held in Coimbra (Hotel Quinta das Lágrimas). It will consist of a limited number of invited lectures. Those interested in contributing can submit a title and an abstract for a poster session.

INVITED SPEAKERS

Alexandre d'Aspremont (Princeton Univ., USA)
Covariance Selection with Applications in Finance

Victor DeMiguel (London Business School, UK)
Portfolio Optimization and Estimation Error

Jacek Gondzio (Univ. of Edinburgh, UK)
Parallel Solution Techniques in Very Large Scale Financial Planning Problems

Peter Laurence (Univ. di Roma "La Sapienza", Italy)
Hedging Spread Options

Ioana Popescu (INSEAD, France)
Robust Mean-Covariance Solutions for Portfolio Optimization

Ekkehard Sachs (University of Trier, Germany)
Optimization Methods in Calibration and Hedging

Ralf Werner (Technische Universität München & Hypo Real Estate Holding, Germany)
Consistency of Robust Portfolio Estimators

December 13-15, 2007: CIM Iberian Workshop on Partial Differential Equations, Numerical Solutions and Applications

The Workshop will bring together leading specialists in different aspects of the analysis of Partial Differential Equations. The program will include invited talks, mainly by Spanish and Portuguese mathematicians, as well as a few contributed talks. There will be ample room for discussion and interaction between the participants.

OTHER CIM EVENTS IN 2007:

WORKING AFTERNOONS SPM/CIM

CIM, Coimbra

A joint initiative of the Portuguese Mathematical Society and CIM.

September 29, 2007: Calculus of Variations

Organizer: Luísa Mascarenhas (New Univ. of Lisbon)

November 24, 2007: Algebraic Topology

Organizer: Margarida Mendes Lopes (Tech. Univ. of Lisbon)

For more information, see

www.spm.pt/investigacao/spmcim/spmcim.phtml

CIM short courses

Hotel Quinta das Lágrimas, Coimbra

October 13, 2007: ***Mathematics and Games***

Lecturer: Jorge Nuno Silva (Univ. of Lisbon)

Abstract: We explore the relation between mathematics and boardgames. Some classical examples: early strategy games (Ur, Senet), pedagogical games from the Middle Ages (Rithmomachia, Metromachia, Goose), Combinatorial Games of Conway. Sim and the Pigeonhole principle, Hex and Brower's Fixed Point Theorem, Dots & Boxes and Euler's Theorem, Hamilton's game and graphs.

Schedule:

- 9:30 - 11:00 : Session 1
- 11:00 - 11:30 : Coffee-Break
- 11:30 - 13:00 : Session 2
- 13:00 - 15:00 : Lunch
- 15:00 - 17:00 : Session 3

Registration:

www.cim.pt/?q=short_course_math_and_games_2007

Meetings SPE/CIM

Hotel Quinta das Lágrimas, Coimbra

A joint initiative of CIM and the Portuguese Society of Statistics (SPE) with the support of the National Institute for Statistics (INE).

November 17, 2007: Methodological Issues in Official Statistics

Coordinator: Pedro Corte-Real (INE).

CIM Events for 2008

The CIM Scientific Council, in a meeting held in Coimbra on February 10, approved the CIM scientific programme for 2008.

The list of events is the following:

International Conference on Mathematics and Continuum Mechanics

February 19-22, University of Porto

Organizers

António Joaquim Mendes Ferreira (Univ. of Porto), Isabel Maria Narra de Figueiredo (Univ. of Coimbra) and Juha Videman (IST, Lisbon).

Aims

The event focuses on a selected range of interdisciplinary topics handled from both a mathematical and an engineering applications point of view. Despite the apparent heterogeneity of the topics, they are certain to prompt interesting dialogue among the conveners.

The target audience is, besides engineers, physicists and mathematicians, graduate and PhD students interested in doing research on problems related to Mathematics, Solid and Fluid Mechanics and Geophysics.

The conference will feature six thematic mini-symposia:

Computational Methods for Advanced Composites

Contact Mechanics

Mathematics and the Atmospheric Sciences

Modelling of Industrial Processes

Numerical Analysis of Thin Structures

Ocean Dynamics.

Each symposium consists of one forty-five minute plenary session and two to four invited half-hour addresses. Some contributed papers will be selected for fifteen to twenty minute presentations and others to be on display in a poster session.

For more information about the event, see

paginas.fe.up.pt/~cim2008

CIM/CRM Workshop on Financial Time-Series

June 12-14, CIM, Coimbra

GAP VI: Joint CRM/CIM Workshop on Geometry and Physics – Integrable Systems

June 16-21, CRM, Barcelona (Spain)

Workshop on Nonparametric Inference WNI2008

June 26-28, University of Coimbra

Workshop on Estimating Animal Abundance

July 7-9, University of Évora

CIM/UC Summer School on Dynamical Systems

July 21-26, University of Coimbra

International Meeting on Calculus of Variations and Applications

September, New University of Lisbon

For updated information on these events, see

www.cim.pt/?q=events

CIM News

Meeting of the General Assembly of CIM

The General Assembly of CIM met on May 26, 2007, during the morning, in the CIM premises at the Astronomical Observatory of the University of Coimbra. In the afternoon of the same day, the members of the General Assembly had the opportunity to attend a talk by Gabriela Gomes (Gulbenkian Institute of Science), titled "*The SIRI Model in Epidemiology: Pertussis and Malaria*".

During the Assembly two new associates were welcomed: the Group of Mathematical Physics of the University of Lisbon (gfm.cii.fc.ul.pt) and the Centre of Mathematical Sciences of the University of Madeira (www.uma.pt/Investigacao/Ccm).

The next Meeting of the General Assembly of CIM will be held in Coimbra on April 5, 2008.

Annual Meeting of the ERCOM

March 7-8, 2008, Coimbra

The forthcoming ERCOM meeting will take place at the Centro Internacional de Matemática, Coimbra, Portugal, on March 7 and 8, 2008.

Research in Pairs at CIM

The programme is suspended until January 2008.

CIM on the Web

For updated information about CIM and its activities, see

www.cim.pt

News from our Associates

- **Announcement and first Call for Papers for the International Journal for Computation Vision and Biomechanics**

  The main goal of the International Journal for Computational Vision and Biomechanics consists in the provision of a comprehensive forum for discussion on the current state-of-the-art in these fields.

  Webpage: www.fe.up.pt/~ijcvb

- **CT2007 - International Category Theory Conference**

  June 17-23, 2007, Carvoeiro, Portugal

  The Annual Conference on Category Theory will bring together leading experts on category theory and its applications. It is organized by the Category Theory Group of the Centre for Mathematics of the University of Coimbra and will celebrate the 70th birthday of F. William Lawvere.

  Webpage: www.mat.uc.pt/~categ/ct2007

- **Nonuniformly Hyperbolic Dynamics and Smooth Ergodic Theory**

  June 25-29, 2007, Instituto Superior Técnico, Lisbon, Portugal

  Conference dedicated to Yakov Pesin on the occasion of his 60th birthday. Topics will include the subjects of his landmark works and those on which he exerted the strongest influence, including: nonuniform hyperbolicity, smooth ergodic theory, partial hyperbolicity, thermodynamic formalism, dimension theory in dynamics, and related subjects.

  Webpage: www.math.ist.utl.pt/camgsd/pesin

- **ICDEA2007 - International Conference on Difference Equations and Applications**

  July 22-28, 2007, Lisbon, Portugal

  The purpose of the conference is to bring together both experts and novices in the theory and application of difference equations and discrete dynamical systems. The main theme of the meeting will be "Discrete Dynamical Systems and Nonlinear Science".

  Webpage: www.math.ist.utl.pt/icdea2007

- **56th Session of the ISI - International Statistical Institute**

  August 22-29, 2007, Lisbon, Portugal

  This is the most important world meeting in Statistics, gathering usually more than 2000 participants. So as to allow for a large participation in this event, the Portuguese Statistical Society has scheduled its XV Annual Conference to August the 19th-21st in Lisbon (a combined registration is available at www.spestatistica.pt).

  Webpage: www.isi2007.com.pt

- **ORP^3 - Operations Research Peripatetic Postgraduate Programme**

  September 12-15, 2007, Guimarães, Portugal

  ORP^3 is a new instrument of EURO designed for young OR researchers and practitioners. ORP^3 aims at being a forum promoting scientific and social exchanges between the members of the future generation of OR in academic research and industry. ORP^3 is a European peripatetic conference each edition of which is hosted by a renowned European centre in OR.

  Webpage: www.norg.uminho.pt/orp3

- **17th International Workshop on Matrices and Statistics**

  July 23-26, 2008, Tomar, Portugal

  The 17th International Workshop on Matrices and Statistics will honour Professor Theodore Wilbur Anderson on the occasion of his 90th birthday. Call for contributed papers and registration will be online soon.

  Webpage: www.ipt.pt/iwms08

For updated news, see www.cim.pt/?q=newsassoc

Feature Article

Towards an Evolutionary Epistemology

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Abstract

This work concerns a non-traditional approach to logic and epistemology, based on a challenging, albeit conjectural, articulation of views proceeding from Evolutionary Psychology and Biology, Non-Monotonic and Decision Logics, and Artificial Intelligence. The hinges to the latter inevitably suggest the emergence of an innovative symbiotic form of evolutionary epistemology.

1. Evolution and the Brain

The first bipedal primates establish the separation between the human species and the other simians. To fathom the abilities of the human brain it is necessary to understand what exactly the problems our ancestor primates were trying to solve that led them to develop such an extraordinarily intricate brain. We cannot look at the modern human brain, and its ability to create science, as if the millions of evolution-years which attuned it to its present configuration had never taken place. Among the eventual problems we certainly have those of status, territorialism, mating, gregariousness, altruism versus opportunism, the building of artifacts, and the mappings of the external world.

To *Homo Sapiens Sapiens*' brain, considered indistinguishable from our current one, we assign an estimated age of one or two hundred thousand years. The Palaeolithic started at about 60 or 30 thousand years before that, the period in which language, and much later writing, began to develop. By the Upper Palaeolithic times however, from 40,000 to 10,000 before the present, the tempo of cultural evolution quickened dramatically. According to the theory of population genetics, most of the change was far too fast to be tracked closely by genetic evolution.

As the psychiatrist must look at a patient's past in order to better understand him in the present, so must we look also at our species' past in order to understand our modern peculiarities. This stance is called Evolutionary Psychology - a fascinating field of study - born some 40 years ago. It is a consummate example of successful ongoing scientific unification, engendered by a deeply significant combination of Psychology, Anthropology, Archaeology, Evolutionary Biology, Linguistics, Neurosciences, and Artificial Intelligence (David M. Buss, 2005). Evolutionary Psychology has been studying the brain from the evolutionary perspective, thereby originating some extremely relevant contributions. In that perspective, it has been strongly supported by Anthropological Archaeology in its empirical study of the cultural evolution of mankind (Stephen Shennan, 2002).

2. Evolutionary Psychology: Genes and Memes

In human life, we have two reproductive mechanisms: one is sexual reproduction, in which the replication unit is the gene; the other is mental reproduction. Some authors from Evolutionary Psychology have construed the notion of "meme", in complement and contrast to that of gene. A meme is that which substantiates a second reproductive system executed in the brain. It is the mental unit corresponding to the gene. Memes gather in assemblies, in patterns, similar to the way genes gather in chromosomes. Memes are patterned by ideologies, religions, and common sense ideas. Indeed, certain memes work well together, mutually reinforcing each other, others not, so that correcting (and correctional) mechanisms may be triggered.

We have a genetic reproduction system and, on top of it, Nature - through evolution - has created a second one, which we employ in pedagogy. We reproduce ideas: generally, good ideas propagate and replicate, being selected over the bad ones, although no one is around to guarantee it. Genes persist because they reproduce, and memes are the reproduction units associated with the brain - the brain being a reproductive organ. What we are doing, in schools and universities, is to reproduce knowledge. Educational systems consist of a means for "infecting" students with good memes, ideas having proven themselves able enough to self-reproduce and persist, while despising others that fail to survive. There are many educational systems variants, for instance madrasas.

When people interact they communicate ideas, and those which are infectiously good tend to reproduce. There are assemblies of ideas, sets of beliefs, which reproduce together. The memes in such memeplexes - like the genes in chromosomes - are in competition amongst themselves and also with the gene base. They exist because they are part of a reproductive mechanism which is necessary to achieve faster local adaptations, as genes take too long to reproduce with respect to the time scale of the individual bearing the memes. Thus the individual phenotype may be given more of a chance to reproduce its genotype. This leads directly to the meme-gene co-evolution.

Memes however could not spread but for the biologically valuable tendency of individuals to imitate, something afforded by the brain. There are plenty of good reasons why imitation should have been favoured by conventional natural selection working on genes. Individuals that are genetically predisposed to imitate enjoy a fast track to skills that may have taken others a long time to build.

Consequently, the brain and its accompanying mind are the result of a deep symbiosis, a genetic product influenced by the mechanism of memetic reproduction. In this faster system of adaptation we have reached the point of being able to predict our own memetic (and genetic) mutations, as necessary changes to prepare for the future by anticipating it. That is why we imagine the future - we create hypothetical scenarios, predict the possible futures, and choose to pursue some of them.

However, beyond simple reproductive success there are also pressing concerns in regard to social interaction. As communal beings, we need to develop some sort of status in order to be respected, copied, or obeyed. We must worry about territorial expansion and its defence, if we are to have descendants and, moreover, descendents with descendents. We need to sign contractual agreements with those who share our social and cultural ecology. There is also the important requisite of personal expression opportunity. If we do not express ourselves, no one will copy even our dearest memes, let alone our scientific theory memeplexes.

In this view, scientific thought emerges from distributed personal interaction, albeit it at a special and temporal distance, and never in an isolated way. It must be erected from several confluences, or in teams, as is the case in science. In truth, knowledge is not constructed in an autonomous way; rather it is engendered by networks of people. In science it is important to work as a team. The stereotype of the isolated and enlightened aristocratic scientist has been defeated for quite some time: science is institutionalized, organized and has proper methodologies, conferences. It is processed in appropriate environments, one being the educational one, in which we carry out *memetic* proliferation.

3. Specific Modules versus General Intelligence

Theoretical and field archaeologists, like Steven Mithen in *The Prehistory of Mind* (1996), are bringing in historical and pre-historical evidence that our ancestors began with a generic intelligence, such as we find in apes. There has been a broad discussion - in fact reproduced within the Artificial Intelligence (AI) community - about whether intelligence is a general functionality or else best envisaged as divided into specific ability modules or components. When it first appeared, Evolutionary Psychology developed a trend, which Chomsky had begun in insisting on innate specialized areas for language processing in the brain, and it was generally accepted that a plethora of specific modules for a diversity of certain brain functions do exist. Indeed, in the beginnings of Evolutionary Psychology, the likes of Steven Pinker, Leda Cosmides, John Tooby, and David Buss, in consonance with AI's own vision of specific modules, believed all brain function to be founded on such modules - for language, for mating, religion, etc.

Meanwhile, archaeologists have demonstrated, via historical record, that human species went from a first phase of general intelligence to a second phase of three major specialized modules: one for natural history and naive physics (knowledge of Nature); the one for knowledge and manufacture of instruments; and one for cultural artifacts, i.e. the rules of living in society and the very politics of coexistence.

These three specialized intelligences were separated, and it is only at a newer stage - corresponding to *Homo Sapiens*, with the appearance of spoken language - that it becomes necessary to have a cupola module, articulating the other ones. How else do the different specialized modules connect, and how can people communicate among themselves? That need gave birth to the generic cupola module, a more sophisticated form of general intelligence, the cognitive glue bringing the specialized modules to communicate and cooperate.

4. The Evolution of Reason: Logic

The formal systems of logic have ordinarily been regarded as independent of biology, but recent developments in evolutionary theory suggest that biology and logic may be intimately interrelated. William S. Cooper (2001) outlines a theory of rationality in which logical law emerges as an intrinsic aspect of evolutionary biology. This biological perspective on logic, though at present unorthodox, could change traditional ideas about the reasoning process (Robert Hanna 2006).

Cooper examines the connections between logic and evolutionary biology and illustrates how logical rules are derived directly from evolutionary principles, and therefore have no independent status of their own. Laws of decision theory, utility theory, induction, and deduction are reinterpreted as natural consequences of evolutionary processes. Cooper's connection of logical law to evolutionary theory ultimately results in a unified foundation for an evolutionary science of reason. According to Cooper, today, in the general drift of scientific thought, *logic* is treated as though it were a central stillness. For the most part, the laws of logic are taken as fixed and absolute. Contemporary theories of scientific methodology are logico-centric. Logic is seen commonly as an immutable, universal, meta-scientific framework for the sciences, as for personal knowledge. Biological evolution is acknowledged, but it is accorded only an ancillary role, as a sort of biospheric police force, whose duty is to enforce the logical law among the recalcitrant. Logical obedience is rewarded and disobedience punished by natural selection, it is thought. All organisms with cognitive ability had better comply with the universal laws of logic on pain of being selected against!

Comfortable as that mind set may be, Cooper believes he is not alone in suspecting it has things backward. There is a different, more biocentric, perspective to be considered. In the alternative scheme of things, logic is not the central stillness. The principles of reasoning are neither fixed, absolute, independent, nor elemental. If anything, it is the evolutionary dynamic itself that is elemental. Evolution is not the law enforcer but the law giver - not so much a police force but a legislature. The laws of logic are not independent of biology but implicit in the very evolutionary processes that enforce them. The processes determine the laws.

If the latter understanding is correct, logical rules have no separate status of their own but are theoretical constructs of evolutionary biology. Logical theory ought then in some sense to be deducible entirely from biological considerations. To paraphrase, the hypothesis is that the commonly accepted systems of logic are branches of evolutionary biology. Indeed, evolution has provided humans with symbolic thought, and symbolic language communication abilities. Objective common knowledge requires thought to follow abstract, content independent rules of reasoning and argumentation, which must not be entirely subjective, on pain of making precise communication and collective rational endeavour impossible. Such rules have become ingrained in human thought, and hold an enormous joint survival value. In human cognitive evolution, both mimetic knowledge (such as that inherent in reality-simulating maps and models), and imitation knowledge (such as that present in ritual observation, or in artefact reproduction), were essential first steps towards socially situated, joint rule following behaviour, required by, say, hunting plans.

Decision theory is the branch of logic that comes into most immediate contact with the concerns of evolutionary biology. They are bound together by virtue of their mutual involvement in behaviour. The logic of decision is concerned with choices regarding the most reasonable courses of action, or behavioural patterns. Behaviour is observable, it is amenable to scientific prediction and explanation, and there is the possibility of explaining it in evolutionary terms. This makes behaviour an interdisciplinary bridge approachable from both the biological and the logical sides. Ultimately, behaviour is the fulcrum over which evolutionary forces extend their leverage into the realm of logic. Viewed through the lenses of biology, favoured behaviour is evolutionary fit. Through the lens of logic it is rational decision behaviour (Cooper, 2001), according to rules for reasoning and rules for action.

On the heels of rational group behaviour, throughout human cultures there emerged abstract rule following social games. Game rules encapsulate concrete situation defining patterns, and concrete situation-action-situation causal sequencing, which mirrors causality-obeying physical reality. From games, further abstraction ensued, and there finally emerged the notions of situation-defining concepts, of general rules of thought and their chaining, and of legitimate argument and counter-argument moves. Together they compose a cognitive meta-game (John Holland, 1998).

The pervasiveness of informal logic for capturing knowledge and for reasoning, a veritable *lingua franca* across human languages and cultures rests on its ability to actually foster rational understanding and common objectivity. Crucially, objective knowledge evolution dynamics, whether individual or plural, follows ratiocination patterns and laws. Furthermore, and more recently, the very same rules of reasoning can and are employed to reason about reasoning. Moreover, new reasoning methods can and have been invented and perfected throughout human history. Examples of these are transfinite induction, *reductio ad absurdum* (proof by contradiction), recursion, abduction, and contradiction removal, to name but a few.

Though some reasoning methods are well known, some are still unconscious but, like the rules of grammar, can be discovered through research. Indeed, humans can use language without learning grammar. However, if we are to understand linguistics, knowing the logic of grammar, syntax and semantics is vital. Humans do use grammar without any explicit knowledge of it, but that doesn't mean it cannot be described. Similarly, when talking about the movement of electrons we surely do not mean that a particular electron knows the laws it follows, but we are certainly using symbolic language to describe the process, and it is even possible to use that description to implement a model and simulation which exhibits precisely the same behaviour.

New purported reasoning methods may be disputed, just like any specific train of reasoning can. But reasoning can only be disputed by further reasoning, if any consensus is to be found! (Thomas Nagel, 1997). Some argue that scientific and philosophical discussion is necessarily a tantamount to a culture sensitive, and culturally relative, persuasive informal *ad hoc* argumentation, allied to anything goes rhetoric (criticized by Paul Gross, Norman Levitt, 1994). They ignore that argumentation is just another form of reasoning which has itself been made the subject of logical formalization, and are oblivious to the fact that rhetoric may be fine for preachers, but is not conducive to the two-sided communication required to reach common agreement in the all rigorous scientific praxis that lead to cumulative knowledge.

Logic, we sustain, provides the overall conceptual cupola that, as a generic module, fluidly articulates together the specific modules identified by evolutionary psychology. In that respect, it is mirrored by the computational universality of computing machines, which can execute any program, compute any computable function.

The relationship of this argument to logic is ensured by the philosophical perspective of functionalism: logic itself can be implemented on top of a symbol processing system, independently of the particular physical substrate supporting it. Once a process is described in logic, we can use the description to synthesize an artefact with those very same properties. As long as it is a computational model, any attempt to escape logic will not prove itself to be inherently more powerful.

On the other hand, there is an obvious human capacity for understanding logical reasoning, a capacity developed during the course of brain evolution. Its most powerful expression today is science itself, and the knowledge amassed from numerous disciplines, each of which with their own logic nuances dedicated to reasoning within their domain. All that has been learned empirically about evolution in general, and mental processes in particular, suggests that the brain is a machine assembled not to understand itself, but to survive. Understanding the mind at work, then, needs to be brought about by the methods of science.

5. Epistemic Tools

The canonical definition of objective scientific knowledge avidly sought by the logical positivists is not a philosophical problem nor can it be attained, as they hoped, simply by logical and semantical analysis. It is an empirical question too, that can be answered only by a continuing probe of the possible functionality of the thought process itself and its physical basis. In some cases, the cognitive tools and instruments of rationality will be found hardware independent. Even then, the appropriateness of their use in specific real circumstances and goals will need to be empirically determined. There is no universal one-size-fits-all epistemological recipe, but agreement can be had on the relative success of any given tool kit.

In any case, partial understanding may also be sought by building intelligent machines, functionalism coming to the rescue when positing that the material substrate is often not of the essence, that it suffices to realize equivalent functionality albeit over different hardware. Moreover, distinct functioning roads to the same behaviour may be had, thereby accruing to our understanding of what general intelligence means, toward their symbiotic entwining, the most recent step in evolutionary epistemology. Functionalism can only make that more adroit.

The most fruitful procedures will almost certainly include the use of Artificial Intelligence, theory and technique, aided in due course by the still embryonic field of artificial emotion, to simulate complex mental operations. This modelling system will be joined to an already swiftly maturing neurobiology of the brain, including the high-resolution scanning of computational networks active in various forms of thought.

With this background in mind, and namely the discussion about specialized modules and general intelligence, I would like to introduce at this point the informal notion of *cognome*, by analogy with genome, standing for an individual's particular structural combination of cognitive memes.

When consider scientific knowledge, if the computer processing of the human genome is what leads us to Bio-informatics then, by analogy, we may state that the cognome will be the basis of a future "Cognotechnology", applicable in any science. This way, the future of AI is connected to the characteristic of it being an epistemological instrument, not only for an autonomous agent, but a symbiotic one which will help humans in performing science itself.

And I'm not just talking about data mining, pattern recognition, ontology building, although in those fields we can approach more structured aspects of epistemology. I'm thinking about that which every scientist does, which is to abduce, invent and prophesy theories, put them to the test, create experiments, draw conclusions to support additional observations, discuss those observations and his conjectures with other scientists.

Veritably, the capacity for cognition is what allows us to anticipate the future, to pre-adapt and imagine scenarios of possible evolutions - of the world and of ourselves as cognitive agents - to make choices, to use preferences about some hypothetical worlds and their futures, and meta-preferences - preferences on which preferences to employ and how to make them evolve. The activity of prospecting the future is vital and characteristic of our species and its capacity to understand the real world and ourselves, living in society, where distributed cognition is the normal and regular way to do science. Prospective consciousness allows us to pre adapt to what will happen. For that, a capacity to simulate, to imagine "what would happen if", i.e. is hypothetical thinking, becomes necessary. Such thinking is indispensable in science; for it gives us the rules to predict and explain what will or can happen, without which technology would not be possible.

How does natural selection anticipate our future needs? Well, by creating a cognitive machine called brain that can create models of the world, and even of itself, and process hypotheticals much like a Universal Turing Machine can mimic any other Turing machine, and just like any given computer can run any program. This plasticity provides for its universal versatility (cf. Martin Davis, 2000).

Lately, I've been working towards automating this capacity, by implementing programs which can imagine their futures, making informed choices about them, and then modify themselves to enact those choices - the inklings free will. We call it prospective computing (Gonçalo Lopes, Luís Moniz Pereira, 2006).

There is an ongoing meta-argumentation about what is good reasoning, what are the conclusions we can draw from a discussion (i.e. a semantics), which is inherent to all scientific activity. The computer will be used more and more as a research aide, not just to automate but also propose experiences and hypotheses and, in the end, by making our own conceptions on epistemology application repeatable and externalized it will make them more objective too.

Epistemology will eventually have the ability to be shared, be it with robots, aliens or any other entity who must needs perform cognition to go on existing and program their future. Creating situated computers and robots means carrying out our own cognitive evolution by new means. With the virtue of engendering symbiotic, co-evolving, and self-accelerating loops. Computerized robots reify our scientific theories, making them objective, repeatable, and part of a commonly constructed extended reality, built upon multi-disciplinary unified science. Artificial Intelligence and the Cognitive Sciences, by building such entities, provide a huge and stimulating step towards furthering that construction. To this end, the functionalist stance is most helpful.

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Curvature and the growth of cells.

A mathematics article was published, April 26, 2007, in the general science journal *Nature*. This unusual occurrence is due to the prominence and wide applicability of the result. Robert MacPherson and David Srolovitz solved the 50-year old problem of generalizing to three dimensions John von Neumann's work on the growth of cells in planar tesselations. The hypotheses in both cases are that *cell walls move with a velocity proportional to their mean curvature*, and that domain walls meet at 120°, hypotheses which are realized in many physical and biological contexts.

Von Neumann showed that the rate of change dA/dt of the area A of such a cell can be expressed in terms of γ the surface tension of a domain wall, M a kinetic coefficient describing the walls' mobility and n the number of vertices where distinct walls intersect, by

$$dA/dt = -2\pi M\gamma(1-n/6).$$

So for example in the tessellation portion shown in Fig. 1, the 8-vertex regions A and B will grow at the expense of the 2-vertex region C.

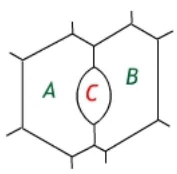


Fig. 1. With the common factor $2\pi M\gamma$ set to 1, von Neumann's formula tells us that $dA/dt = dB/dt = 1/3$, while $dC/dt = -2/3$.

MacPherson and Srolovitz's formula for the rate of change of the volume of a domain D in a 3-dimensional tessellation is formally analogous but requires the new and ingeniously defined *mean width* $\mathscr{L}(D)$, which they describe as "a natural measure of the linear size" of D. In terms of $\mathscr{L}(D)$, their formula reads

$$\frac{dV}{dt} = -2\pi M\gamma\Big(\mathscr{L}(D) - \frac{1}{6}\sum_i e_i\Big),$$

where e_i is the length of the i-th 1-dimensional edge of D, and the sum is taken over all the edges. Note that following our initial requirement, faces meet 3 by 3 along an edge with dihedral angles 120°.

The mean width $\mathscr{L}(D)$ is computed in two steps. First, for each line ℓ through the origin, the *Euler width* $\omega(D,\ell)$ of D along ℓ is the integral along ℓ of the Euler characteristic $\chi(\ell_p^\perp \cap D)$ of the intersection of D with the plane perpendicular to ℓ (see Fig. 2):

$$\omega(D,\ell) = \int_\ell \chi(\ell_p^\perp \cap D)\, dp.$$

So if D is convex (χ always $= 1$), $\omega(D,\ell)$ is exactly the length of the projection of D on ℓ.

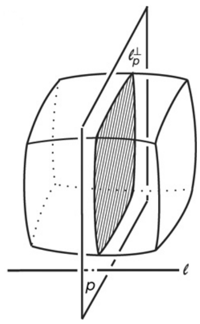


Fig. 2. For D a 3-dimensional domain, and ℓ a line through the origin, the Euler width $\omega(D,\ell)$ of D along ℓ is calculated by measuring, for each point p on ℓ, the Euler characteristic $\chi(\ell_p^\perp \cap D)$ of the intersection of D with the plane through p perpendicular to ℓ, and integrating along ℓ. Image reprinted by permission from Macmillan Publishers Ltd: *Nature* (Vol. **446**, 26 April 2007, p. 1054), copyright (2007).

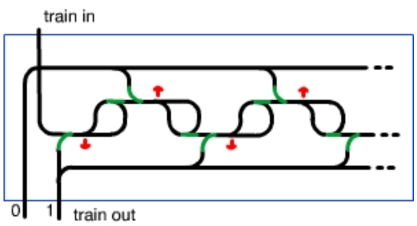
Then $\mathscr{L}(D)$ is computed as twice $\omega(D,\ell)$, averaged over the space RP^2 of lines through the origin:

$$\mathscr{L}(D) = 2\int_{RP^2} \omega(D,\ell)\, d\ell,$$

where $d\ell$ is normalized to have total integral 1.

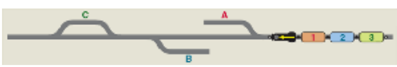
The authors state that their formula and von Neumann's are both special cases of a general n-dimensional formula, which they give. The Supplementary Information (see www.nature.com/nature/journal/v446/n7139/supp info/nature05745.html) for their article (entitled "The von Neumann relation generalized to coarsening of three-dimensional microstructures") gives the proof of their 3-dimensional formula and rules for computing $\mathscr{L}(D)$; for example the cube of side length a has mean width $3a$.

Computing with locomotives. "Trains of thought" is a piece by Brian Hayes in the March-April 2007 *American Scientist* (available online — www.americanscientist.org/AssetDetail/assetid/54774). He takes us to a "hump yard," where boxcars are sorted into trains by rolling through a series of switches: "... I can't shake the impression that the hump yard itself is a kind of computer–that the railroad cars are executing some secret algorithm." In fact *any* algorithm can be so executed. In 1994 Adam Chalcraft and Michael Greene, then Cambridge undergraduates, showed how to use a track layout to implement a given Turing machine (paper available online — www.monochrom.at/turingtrainterminal/Chalcraft.pdf). As Hayes explains it: "The machine is programmed by setting switch points in a specific initial pattern; then a locomotive running over the tracks resets some of the switches as it passes; the result of the computation is read from the final configuration of the switches." One of the trickier parts is what they call a *distributor*: it routes trains alternatively onto track 0 and onto track 1. They prove that this cannot be accomplished with a finite configuration, and exhibit the following open-ended layout to do the distribution.



Chalcraft and Greene's *Distributor* has two kinds of switches: *spring switches* which always direct an incoming car to the green track, and *lazy switches* which are reset by the last train through. The red arrow shows the current setting of each lazy switch. The first train through resets the leftmost lazy switch to "up" on its second pass and exits on track 1.

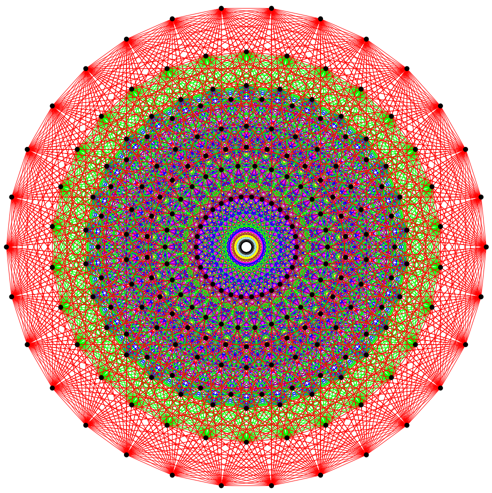
Train-track layouts turn out to have fascinated puzzle makers and computer scientists for quite some time. Hayes' illustrations include one of Sam Loyd's puzzles and Donald Knuth's "railroading interpretations of three important data structures: the stack, the queue and the double-ended queue, or deque." Hayes even gives us a puzzle of his own:



"The task is simply to deliver cars 1, 2 and 3 to destinations A , B and C. The cars are already in delivery order." The solution is given at www.ams.org/mathmedia/archive/05-2007-media.html#four.

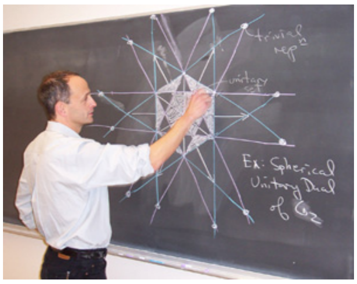
Chalcraft and Greene's work was picked up by Ian Stewart for his Mathematical Recreations column in the September 1994 *Scientific American*. That column ("A Subway Named Turing") is available online (www.fortunecity.com/emachines/e11/86/subway.html).

E_8 in the *New York Times*.



The *Times* printed a black and white version of this image, giving a glimpse of the size and complexity of the Lie group E_8. The configuration (projected here into 2 dimensions) shows part of the arrangement of closest packed balls in 8-dimensional space; the vertices represent a ball's 240 nearest neighbors in 8-space, with bonds drawn between nearest neighbors among the neighbors. E_8 contains a discrete subgroup mapping 256-to-one *onto* the 696,729,000-element symmetry group of this configuration. The image given here was made by John Stembridge, who explains it in www.math.lsa.umich.edu/~jrs/coxplane.html.

The most straightforward Lie groups are groups of n by n matrices characterized by some linear algebraic condition preserved in products, e.g. determinant nonzero, determinant $= 1$. The product of two matrices is a matrix whose entries are analytic functions (actually sums of products) of the entries in the factors. That's all it takes to make a Lie group. The building blocks of Lie theory, the simple Lie groups, fall into four infinite families of larger and larger matrices, plus five *exceptional* groups F_4, G_2, E_6, E_7, E_8. The last, largest (248-dimensional) and gnarliest of the exceptionals, E_8, has been in the news recently. Kenneth Chang reported, in the March 20 2007 *New York Times*, the culmination of a four-year effort by a team of 18 mathematicians, led by Jeffrey Adams (Maryland), to work out the details of its algebraic structure. His description of exactly what they were calculating is very vague, perhaps inevitably, but he clearly conveys the message that the task was enormous. "To understand using E_8 in all its possibilities requires calculation of 200 billion numbers," Chang tells us. "Possibilities" presumably refers to the set of unitary representations of E_8: the main way a group can be analyzed is through *representations* (projections which preserve multiplication) onto finite or infinite-dimensional matrix groups. The many episodes of the huge computation are laid out in David Vogan's narrative (atlas.math.umd.edu/kle8.narrative.html), a good story well told.



"Jeffrey D. Adams and a Lie group," as seen in the *Times*. Photo by Mark Tilmes, used with permission.

Intel silver and bronze for math projects. Second and third place in this year's Intel Science Talent Search went to mathematics projects, as reported by Aimee Cunningham in *Science Online* (www.sciencenews.org/articles/20070317/fob7.asp) for March 17, 2007. "Second place and a $75,000 scholarship went to John Vincent Pardon, a 17-year-old from Durham Academy in Chapel Hill, N.C. In his mathematical project, Pardon proved that a closed curve can be made convex without permitting any two points on the curve to get closer to one another.

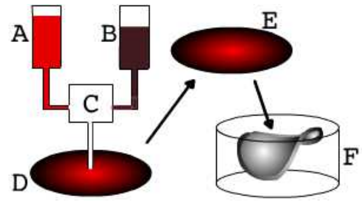
Mathematics research also won the third-place prize, which comes with a $50,000 scholarship. Eighteen-year-old Dmitry Vaintrob of South Eugene High School in Eugene, Ore., found a connection between different descriptions of certain mathematical shapes."

Vaintrob's project was reported on the Intel site in more detail: the award was "for his sophisticated investigation of ways to associate algebraic structures to topological spaces. Dmitry proved that loop homology and Hochschild cohomology coincide for an important class of spaces." Pardon's Intel citation also mentioned that his project had "solved a classical open problem in differential geometry."]

Pardon and Vaintrob's scholarship awards were also reported in the March 14 2007 *New York Times.*

"Journeys to the Distant Fields of Prime". Kenneth Chang's article took up the top of the first page in the *New York Times* Science section for March 13, 2007. It is a "Scientist at Work" profile of Terence Tao (UCLA), one of this year's Fields Medal winners. Don't be put off by the absurd title; Chang gives us a balanced and sympathetic look at this mathematical star. He takes us to Tao's public lecture on prime numbers (slides available in www.math.ucla.edu/~tao/preprints/Slides/primes.pdf, video in http://164.67.141.39:8080/ramgen/specialevents/math/tao/tao-20070117.smil), but then focuses on a "real-world" area of Tao's research, his work on compressed sensing. In a digital camera millions of sensors record an image which then gets compressed. Tao: "Compressed sensing is a different strategy. You also compress the data, but you try to do it in a very dumb way, one that doesn't require much computer power at the sensor end." In fact, Chang tells us, Tao and Caltech professor Emmanuel Candès have shown that "even if most of the information were immediately discarded, the use of powerful algorithms could still reconstruct the original image."

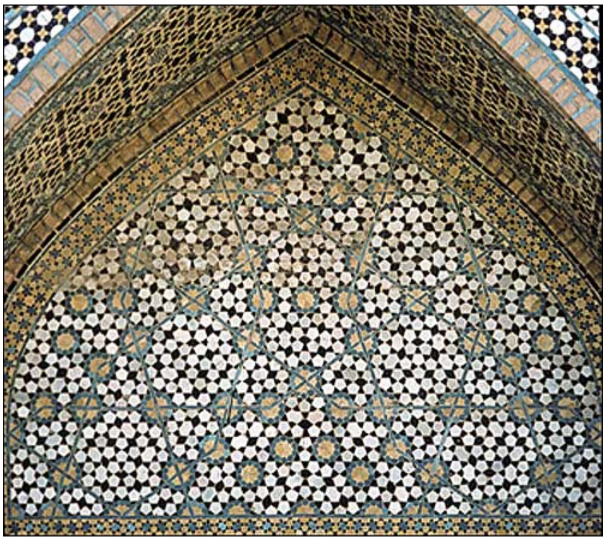
Cooking Gaussian curvature.



Gaussian cuisine. Low-concentration solution (A) and high-concentration solution (B) of N-isopropylacrylamide (NIPA) are mixed (C) in continuously varying proportion and extruded centrally between parallel plates (D) to form a gelatinous disc (E) with radially varying NIPA concentration, which is placed (F) in a hot bath; the heat makes the low-concentration areas shrink faster than the high, resulting in a non-Euclidean metric. Adapted from *Science* **315** 1117.

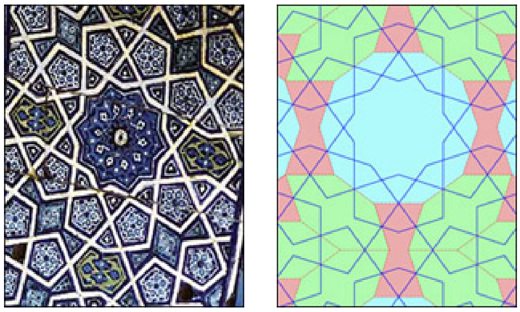
Anyone who has considered a potato chip mathematically has seen how Gaussian curvature can be produced by cooking. A team at the Hebrew University have found a way to control this process so as to produce (within a certain range) discs whose Gaussian curvature is a prescribed function of the radial coordinate. Their report, in the February 23 2007 *Science*, is entitled: "Shaping of Elastic Sheets by Prescription of Non-Euclidean Metrics." The authors (Yael Klein, Efi Efrati and Eran Sharon) present their project as a "novel shaping mechanism" for 2-dimensional objects. "Rather than aiming at a specific embedding, one prescribes on the sheet only a 2D metric, the 'target metric' g_{tar} ... . The free sheet will settle to a 3D configuration that minimizes its elastic energy. In this mechanism, the selected configuration is set by the competition between bending and stretching energies, and its metric will be close to (but different from) g_{tar}." Bending energy comes into the picture because the gel is not a 2-dimensional object: it has a finite thickness and resists bending. Nevertheless, "We show that the construction of elastic sheets with various target metrics is possible and results in spontaneous formation of 3D structures." The authors spend some time discussing the difference between the positive curvature case ("The surfaces of $K_{tar} > 0$ preserve the radial symmetry of g_{tar}, generating surfaces of revolution") and the negative ("The surfaces of $K_{tar} < 0$ break this symmetry, forming wavy structures"). They report: "A more surprising observation is the asymmetric distribution of the Gaussian curvature. Instead of the negative, rotationally symmetric K_{tar}, $K(\rho, \theta)$ varies periodically in θ, attaining positive and negative values." [It looks to me like they are measuring normal curvature here. -TP]

Medieval Islamic quasi-periodic tilings.



A quasi-periodic tiling from the Darb-i Imam shrine in Isfahan. Image courtesy K. Dudley and M. Elliff.

"... by the 15th century, the tessellation approach was combined with self-similar transformations to construct nearly perfect quasi-crystalline Penrose patterns, five centuries before their discovery in the West." This text appears in the abstract for "Decagonal and Quasi-Crystalline Tilings in Medieval Islamic Architecture," by Peter J. Lu and Paul J. Steinhardt, in the February 23 2007 *Science*. It is known that 5-fold rotational symmetry is incompatible with translational periodicity, but Peter Lu seems to have been the first one to notice that medieval Islamic artists went ahead, used motifs with 5-fold symmetry, and produced "quasi-periodic" patterns long before that concept was born. As he told NPR (*All Things Considered*, February 22 2007; transcript and images available online — www.npr.org/templates/story/story.php?storyId=7544360), he made this observation during a trip to Uzbekistan. When he got back to Harvard, where he is a graduate student in Physics, he did some investigation and discovered that Islamic geometers had devised a set of five polygonal building-blocks, each one decorated with polygonal lines; when the blocks were used to tile an area the lines fit together to give the intricate knot-like patterns called *girih*. One of these "girih blocks" is in fact identical to the "fat rhombus" we use in Penrose tilings.



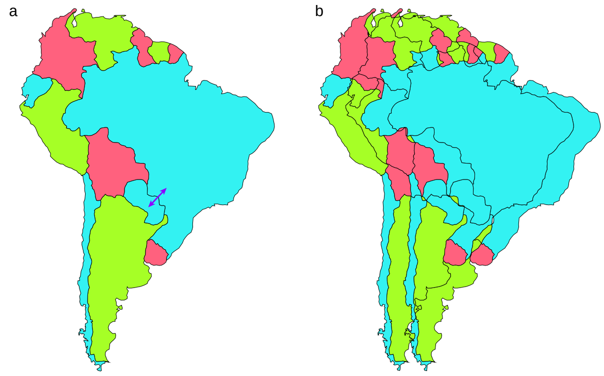
Part of a *girih*-pattern tiling from a Turkish mosque, with its analysis in terms of three of the decorated blocks (bowtie, decagon and flat hexagon) used by Islamic geometers. The other two are a pentagon and our "fat rhombus." Photographic image courtesy W. B. Denny, geometric analysis image courtesy Peter J. Lu.

Self-similarity is the one of the hallmarks of Penrose-type quasi-periodic tilings; this fact also seems not to have escaped the Islamic geometers: "Perhaps the most striking innovation arising from the application of girih tiles was the use of self-similarity transformation (the subdivision of large girih tiles into smaller ones) to create overlapping patterns at two different length scales, in which each pattern is generated by the same girih tile shapes." An example: the tiling from the Darb-i Imam shrine shown above.

Mathematical tools needed. "Bringing cartoons to life" is an essay by John J. Tyson under the "Connections" rubric in the February 22 2007 *Nature*. Abstract: "To understand cells as dynamic systems, mathematical tools are needed to fill the gap between molecular interactions and physiological consequences." Tyson, university distinguished professor of biological sciences at Virginia Tech, makes the point that "a network of interacting genes and proteins is a dynamic system evolving in space and time according to fundamental laws of reaction, diffusion and transport." He focuses on *programmed cell death* as an example of a a nonlinear system: "its molecular regulatory network is bistable (either off or on) at zero signal strength and monostable (on) for signals above the threshold." He posits a chemical feedback loop which "might generate" this kind of dynamic responses, and asks "But can we be sure our intuition is correct? ... How might the regulatory system fail? What are the most effective ways to intervene pharmaceutically to repair the cell-death pathway?" The answers, he proposes, will come from computer modeling. "The network of reactions ... can be cast into a set of kinetic [differential] equations. ... By following the arrows, a computer can simulate the temporal evolution of the control system under any specified experimental conditions." Tyson points to the existence of "a well-developed mathematical theory" with qualitative concepts such as bifurcation points, which "accord well with our intuitive notions," a theory which "forges a rigorous chain of deductions from molecular interactions to kinetic equations to vector fields to physiological consequences." He ends by predicting that in particular the uncertainties about "the molecular correlates of programmed cell death" will "be resolved largely by experiments driven by theoretical issues such as the importance of bistability, the roles of feedback and feed forward, and robustness in the face of noise."

"Proof at a roll of the dice." That's the title of a News and Views piece contributed by Bernard Chazelle (Computer Science, Princeton) to the December 28 2006 *Nature*. His subject is probabilistically checkable proof, or PCP: "the curious phenomenon that the mere ability to toss coins makes it possible to check the most complex of mathematical proofs at no more than a passing glance." The underlying theorem is about ten years old, and has recently been given an "elementary" proof ("the latest chapter in one of the most engrossing chronicles of computer science") by Irit Dinur (Hebrew University).

Here is Chazelle's statement of the PCP Theorem: "any statement S whose validity can be ascertained by a proof P written over n bits also admits an alternative proof, Q. This proof Q has two appealing features: it can be derived from P in a number of steps proportional to n^c, where c is some constant; and P can be verified by examining only three bits of Q picked at random. If S is true, a correct P will satisfy the verifier with a probability of 99%. If it is not true, any alleged proof P will trigger a rejection from Q with a probability higher than 50%." To suggest how P and Q are related, Chazelle has us imagine figure **a** below as P: a proof of the (false) statement that a map of South America can be colored with 3 colors so that no adjacent countries are colored the same. To check the validity of this proof one has to check all the boundaries of all the countries; eventually one finds that Brazil and Paraguay are colored the same. Q corresponds to the coloring **b** of the "smeared out" map on the right. Dinur's construction guarantees that if the first map is not 3-colorable, then **b** "will leave at least a fixed fraction of its edges monochromatic." And so a random probe has a good chance of detecting an error. Chazelle reminds us towards the end to "Keep in mind that this is all about verifying proofs, not about understanding them — with only three bits! — let alone discovering them. That must still be done the hard way."

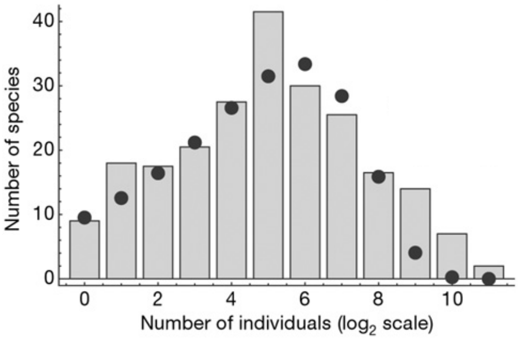


The putative proof **a** that South America is 3-colorable (false) has just one error. In the proof **b**, "smeared" in analogy to Dinur's PCP transformation, the error appears in many places. "Establishing the validity –or not– of the original map with high statistical certainty thus requires the checking of only a small, randomly chosen subregion of the smeared map." Image reprinted by permission from Macmillan Publishers Ltd: *Nature* (Vol. **444**, 21/28 December 2006, p. 1018), copyright (2007).

xe^{-x} in a tropical rainforest. "Dynamical evolution of ecosystems" ran in the December 14 2006 *Nature*. The authors, a team led by Jayanth Banavar (Penn State) and Amos Maritan (Padua), start their report with the sentence: "We present an analytical model that allows one to probe the characteristic timescales of evolving tropical forests and to evaluate the consequences of anthropogenic processes." In this and in a previous paper with a different team, Banavar and Maritan explore how *density dependence* (an effect that "disfavours the population growth of locally abundant species relative to uncommon species") impacts species diversity and relative species abundance (RSA). Here they show how a factor (b) representing density dependence fits into an analytic expression

$$P_{RSA}(x) = \frac{(D\tau)^{-b/D}}{\Gamma(b/D)} x^{b/D-1} e^{-x/D\tau}$$

for the probability distribution function giving relative species abundance, and match their calculation with a measured RSA distribution: that of trees in the stand of tropical rain-forest maintained by the Smithsonian Institution on Barro Colorado Island, Panama. The analytic expression is calculated using a symmetric model in which the species are interchangeable; they have birth and death rates $b(x) = b_1 x + p_0$, $d(x) = d_1 x - p_0$, where b_1 and d_1 are the per-capita rates and p_0 incorporates the density dependence. In the equation, $\tau = 1/(b_1 - d_1)$ is the characteristic timescale of the system (reflecting how fast the system returns to equilibrium after a perturbation); $D = (b_1+d_1)/2$ "accounts for demographic stochasticity" and $b = 2p_0$. The hairy coefficient is there to guarantee a total integral equal to 1.



Relative species abundance for trees in the Barro Colorado Island forest from the 1990 census, compared with predictions (dots) from the expression given above. Individuals of more than 1 cm in diameter were counted. Image reprinted by permission from Macmillan Publishers Ltd: *Nature* (Vol. **444**, 14 December 2006, p. 926), copyright (2007).

Mathematician becomes "Genome Sleuth". On December 12, 2006, the *New York Times* "Scientist at Work" series featured Nick Patterson, a mathematician. His PhD, from Cambridge, was in finite group theory. Patterson told the *Times*' Ingfei Chen: "I'm a data guy. What I know about is how to analyze big, complicated data sets." He honed this skill on code-breaking, first for the British, then for the U.S. Department of Defense. After some 20 years as a cryptographer, applying the Hidden Markov Model to "predict the next letter in a sequence of ... text" he turned this skill to predicting the next data point is a series of stock prices, working for the hedge fund managed by mathematician/financier Jim Simons. When he started, according to Chen, the fund was worth $200 million; seven years later, it was up to $4 billion. "Their methods apparently worked." But now the data guy is on to a third career: "Genome Sleuth Nick Patterson" was the caption for his photograph in the *Times*. And apparently the methods are still working. An article by him and four of his colleagues at the Broad Institute (Cambridge MA) ran in the June 29 2006 *Nature*. The title: "Genetic evidence for complex speciation of humans and chimpanzees." The team ran a comparison of the human, chimpanzee and related genomes on a much larger scale (by a factor of 800) than had ever been attempted. Chen: "Two strange patterns emerged. Some human DNA regions trace back to a much older common ancestor of humans and chimps than other regions do, with the ages varying by up to four million years. But on the X chromosome, people and chimps share a far younger common ancestor than on other chromosomes. ... the data appeared best explained if the human and chimp lineages split but later began mating again, producing a hybrid that could be a forebear of humans."

The math of swarms.

School of "silversides," Bonaire, N.A., March 2000. Image courtesy Kent Wenger.

"Math explains how group behavior is more than the sum of its parts" is the subtitle to Erica Klarreich's report "The Mind of the Swarm" (www.sciencenews.org/articles/20061125/bob10.asp) in the November 25 2006 *Science News*. Examples of the behavior in question: "a flock of birds swooping through the evening sky, ... a school of fish making a hairpin turn, an ant colony building giant highways, or locusts marching across the plains." One of Klarreich's sources is Iain Couzin (Oxford, Princeton) whose 2002 article (with several co-authors) "Collective Memory and Spatial Sorting in Animal Groups" (*J. theor. Biol.* **218**, 1-11) gave a simple mathematical Ising-type model (the "alignment zone" model) which duplicates some of the exotic behavior of schools of fish. Specifically, for a certain range of parameter values the simulated school would look like a torus, with all the fish swimming around a common axis. Klarreich quotes Couzin: "When we first saw [the doughnut] pattern in the simulations, I thought 'That's really weird!' But then we found in the literature that it really does appear in nature. ... There's nothing in the individual rules that says, 'Go in a circle,' but it happens spontaneously." The key to a general understanding of these collective phenomena, Klarreich tells us, seems to be "a trio of physics and engineering principles– nonlinearity, positive feedback, and phase transitions."

An Interview with Eduardo L. Ortiz

Professor Ortiz, please tell us a little bit about your early education. When did your interest in mathematics begin ? How did you go into mathematics ?

I was educated in Buenos Aires; through my secondary education I became interested in mathematics and also in physics; surface physics was my first interest, through it I had to learn more on advanced mathematics and found it quite interesting.

Were you directed towards mathematics by any immediate family influence ?

In a way yes. My father's main activity was in harbor design and management, an area of some engineering interest in a country with large exports as Argentina, but he was also a professor of Projective Geometry, probably the most abstract chapter of the mathematics engineers then studied. Besides being family related, my father and I were very good friends, his advise helped me enormously in my early readings on science, and also in other areas.

What are your recollections of your university studies ? Do you recall particular teachers or texts of seminal importance to you ?

In 1950 I joined a tiny contingent of mathematics and physics university students; since we were only very few, we enjoyed a very close contact with our teachers. However, this was a difficult time in Argentina; there was a considerable amount of political pressure on the universities and several hundreds of professors (including our then only Nobel Price in Science) were dismissed shortly before I entered university; my father was also dismissed. We were lucky three remarkable professors, Julio Rey Pastor, Luis A. Santaló (both also dismissed while I was still a student) and Alberto González Dominguez remained among advanced mathematics teachers. There is little to say about the first two but the third is, perhaps, less known outside Argentina. A student of Rey Pastor with further training in the United States, he was an inspired teacher with a deep understanding of mathematical analysis and full of interesting ideas. Alberto P. Calderón was González Dominguez best known student.

You obtained your PhD from the University of Buenos Aires in 1961, under the supervision of Misha Cotlar, the most distinguished functional analyst of Argentina, recently deceased, often associated with the Calderon-Zygmund Chicago school. What are your recollections of him ?

By the mid 1950s there was some change in the country and that was reflected at university level. A younger generation of mathematicians trained abroad joined the university then. One of them was Mischa Cotlar, who kindly agreed to supervise my doctoral research. Cotlar was not only an exceptional and generous teacher but a unique human being; his life revolved around mathematics, his students, and pacifism. He had been trained in Chicago, but was also well acquainted with contemporary Russian mathematics research; several of his students, including me, worked on topics closely related to the interests of that school. I worked on the theory of Sobolev's spaces; much later, in Paris and through Jacques-Louis Lions, I had the pleasure of becoming acquainted with Sobolev, a most interesting person. At the time I was a graduate student UNESCO opened a mathematics research center in Buenos Aires and several leading mathematicians visited us for long periods. One of them was Antoni Zygmund and I was privileged to do research under his guidance. I also benefited from inspiring lectures on abstract aspects of approximation theory given by Jean-Pierre Kahane.

Eduardo L. Ortiz (at the National Academy of Sciences of Argentina).

What did you do after you obtained your PhD ?

After I got my PhD I moved to the Institute for Advanced Studies, in Dublin, a research institute organized by Erwin Schröedinger after his exile from Germany. I went there because I had read some interesting work by Cornelius Lanczos (who had been one of Einstein's mathematicians in Berlin) in which he had developed an approach to treat differential equations which, I then thought, could be formulated in a far more abstract and general form. This work kept me busy for some years. These ideas were initially known as the Lanczos' Tau Method, today are better known as spectral techniques. After my scholarship ended I was offered a position in pure mathematics at Imperial College and moved to London; that was in 1963. After a few years I won a chair in Buenos Aires and decided to return, but after less than a year there was a new military coup and, together with Cotlar and many others, I was dismissed. After a short while I decided to return to Imperial College, where I have been since, except for visiting positions in the US or in France.

How did your research interests evolve over the years ?

In the 1960 and 70s I became interested in approximation theory and did some work with Theodore Rivlin and with other colleagues. I also became interested in the application of these ideas to problems directly related to the mathematics of numerical approximation. I also did some work on complex analysis with my old friend Walter Hayman, of Imperial College. In the 1970s Lions and his collaborators helped us at Imperial to set up a modern group oriented towards using advanced mathematics in problems of numerical mathematics.

How did you become interested in the history of mathematics ? Could you give us a brief idea of your work on the subject ?

I became interested in the history of mathematics in my university student's years, mainly through Rey Pastor's influence. Although the historical period I like best is the transition from the 18th to the 19th century, where mathematical ideas and philosophy were very closely intertwined, I have worked on other periods and have used my limited experience in the field to try to understand how mathematics was transmitted to our cultural area, something that always puzzled me. That led me to study the work of then little known nineteenth century mathematicians such as Henrique Manuel de Figueiredo in Portugal; Mendoza Ríos, Lanz and Durán Loriga, in Spain, Cáceres and Balbín in Argentina. This research connects directly with my work on Rey Pastor, Monteiro and other 20th century mathematicians.

Which mathematicians do you admire particularly ? Do you have a favourite mathematician from before the 20th century? And from the 20th century ?

My preferences on 20th century mathematicians are largely conditioned by my own interests; mathematics is today a big subject and I have only read on a very narrow area of mathematical analysis. Perhaps that is why among 20th century mathematicians I particularly admire Lions, Sobolev, and Laurent Schwartz. Of earlier periods my preferences go to Babbage in his younger years, and to the enigmatic Olinde Rodrigues.

You have published some articles on Portuguese mathematics and the work of some Portuguese mathematicians, notably António Aniceto Monteiro, who arrived to Argentina in December 1949 after a stay of five years in Brazil. When did you first meet him ? Did you have much interaction with him ?

I met Monteiro in the very early 1950s, when he lectured on the theory of filters at the Sociedad Científica Argentina, in Buenos Aires; I was introduced to him by Rey Pastor, who thought very highly of Monteiro. Later in that decade, for a short period and for family reasons, I visited Bahía Blanca often and I became more closely acquainted with him; since then we became good friends.

António Monteiro and Eduardo L. Ortiz. Picture taken during the sabbatical leave of António Monteiro (September 1969 - August 1970), in which he travelled in Europe. The child is the son of Eduardo Ortiz.

What are your recollections on the influence of Monteiro in the development of mathematics in Argentina ?

Monteiro brought to Argentina a new way of looking at modern mathematics, which he had acquired in France; however, he had also perceived very early in his career, when still in Paris, the importance of the work mathematicians such as G. Birkhoff and M. Stone were doing in the United States. This was the main influence he transmitted to Argentina: a very abstract view of mathematics without becoming excessively formal. Later he moved, quite naturally, to problems in algebraic logic and created a school on that subject.

How would you describe him as a person ?

Warm, cheerful, full on enthusiasm, hard working, madly in love with his work and always trying to engage others in what he was doing. However, it was his deep human dimension that dominated: although he had strongly held views on many topics, he was never dogmatic and was always prepared to listen and to examine things again. Rather unique.

Did his forced exile in Brazil and Argentina leave marks on him?

I don't think his forced exiles left a mark on him; he was above that. Of course he would have preferred to have a normal life in his own country, but in our times this has, some times, been rather difficult.

Prof. Eduardo Ortiz presenting a lecture at the public celebration of the 100th anniversary of Ruy Luís Gomes (December 2005, Porto, Portugal). Photo by Jorge Rezende, used with permission.

You have just participated in a colloquium in Lisbon, on the occasion of the centenary of his birth, with a talk about his connection with mathematics and mathematicians in France. What was the impact of that connection on Monteiro's life in Portugal, Brazil and Argentina?

Very significant, he was in direct touch with leading mathematicians in France and in the United States, later also in Poland. If you look at his papers you will find many instances in which he refers to results yet unpublished, communicated to him by very distinguished colleagues. His was mathematics in the making. Again, if you look at his extensive correspondence you will find that the list of mathematicians he was in personal contact with includes Fréchet, Dieudonné, Birkhoff, Stone, von Neumann, and many others who appreciated him highly. When necessary, some of them went out of their ways to try to help him. Rey Pastor, in particular, perceived clearly he was an outstanding man and a top mathematician and did his best to attract him to Argentina; he later placed him as head of a Mathematical Institute created at a new University in Bahía Blanca; in ten year he put that university in the map.

I know that you had been also a good friend of the renowned Spanish mathematician Julio Rey Pastor? When did you first meet him?

Yes, I was fortunate to have some contact with Rey Pastor; he was a main influence in my academic life. I met him soon after I entered university and later attended his courses on advanced mathematics and also contributed to edit some of his lecture-notes; much later I edited his collected works; this was a very rewarding job, it helped me to understand Rey Pastor's thought more closely. Rey Pastor had a deep philosophical view of the history of mathematics together with a unique technical command of several key chapters of mathematics. Today it would not be possible to cover, in such depth, so many different areas as he then did. As a person Rey Pastor was a true teacher, generous dedicated, and also very lively; great fun to be with, his anecdotes would fill a book.

Many people advocate using history in the teaching of mathematics. How do you think should history be used in the classroom?

I do believe the history of mathematics has a place in the classroom, it can tell students things that may take them a long time of doing mathematics to begin to realize; but not all good students are keen on the history of our subject; one has to be careful on that. I taught the history of mathematics at the Mathematics Department of Imperial College for many years; I insisted on having it in the last year, when students have some mathematical maturity and can choose, if they wish, to know more about the history of their subject. My courses tended to be highly specialized and on a narrow topic, which was discussed in depth, same as we do with other mathematics courses. Some became interested in it as a research subject.

You have also written a paper on the life and work of Henrique Manuel de Figueiredo, a Portuguese mathematician from the University of Coimbra, best remembered as a unique pioneer in the transmission of Riemann's work to Portugal. His work was remarkable regarding the slow process at the time of diffusion of mathematical ideas from leading to peripheral mathematical communities...

No doubt Henrique Manuel de Figueiredo showed mathematics of a much higher level could be done in Portugal at the time. His work is truly remarkable. It showed that having mathematicians is not sufficient to have mathematics in a given country.

What should be the role of societies and institutions in the peripheral world of mathematics ?

Mathematics is a difficult plant to cultivate, needs a lot of care over long periods of time. Societies, and institutions, as well as society, can contribute to make it live; in the long range it is society that benefits. Today is difficult to talk about the peripheral world of mathematics. No doubt people living in different areas of the world have different opportunities open to them, but mathematical talent seems to be randomly distributed. Are Sebastião e Silva, Calderón or Cafarelli periphery?

From your current position as Emeritus Professor of Mathematics and the History of Mathematics at Imperial College, London, how do you regard the changes that the Portuguese mathematics community experienced during the second half of the 20th century ?

The change is very significant, from a small group of 5 to 10 dedicated mathematicians in the 1940s to today's large and vibrant community of mathematicians there is a very long and successful way.

If you had to mention one or two great moments in 20th century mathematics which ones would you pick ?

Again, my perceptions are conditioned by my limited knowledge of a very narrow area and over relatively short period of time. As a student I would have said that the publication of van der Warden's book, that is the systematic introduction of structures, marked an important moment in the times of those who taught me. In my life time one of the most remarkable novelties has been a new concern with very large-scale problems in combinatorics, in numerical mathematics, in theoretical computing, in optimization, and also in areas of pure mathematics whose development have been inspired or affected by the consideration of that kind of problems.

How do you regard the near future? What can be done to attract new young students into mathematics ?

I don't think the future of our discipline is something to be concerned with. Mathematics is now a well established "profession", which almost did not exist as such in my student's years in Portugal, Spain, Argentina, or Brazil. But no doubt there are new problems to reckon with as mathematics is so widely used now in finance, banking and other similar activities. Nearly half of Imperial College's mathematics graduates are lured in that direction and some are among the best; the same is true in the United States. We will have to try much harder in future to be able to keep them in pure mathematics research.

During a visit to the University of Cantabria (Spain).

Interview by Jorge Picado (University of Coimbra)

Eduardo L. Ortiz is Emeritus Professor of Mathematics and the History of Mathematics at Imperial College, London.

Since his PhD in Mathematics obtained at the University of Buenos Aires in 1961, with a thesis titled *Continuity of potential operators in spaces with weighted measures*, Eduardo Ortiz has published approximately one hundred papers in Analysis, Numerical Mathematics, Complex Analysis and the History of Mathematics. He is co-editor of the Collected Works of António Monteiro (8 volumes), presented at the ICM 2006 (August, Madrid), and the Collected Works of J. Rey Pastor. He is also co-editor of the book *Mathematics and Social Utopias in France: Olinde Rodrigues and His Times*, published by the American Mathematical Society and the London Mathematical Society.

He was Professeur de la Première Classe, Universitè d'Orléans, France, 1992-1993, and John Simon Guggenheim Research Fellow in the Department of History at Harvard University from 1996 to 1998. He is Foreign Fellow, National Academy of Sciences, Buenos Aires 1998; Winner of J. Babini History of Science National Prize, Argentina, 1990; Chief Editor, The Humboldt Library, London.

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