CURRICULUM VITÆ
February 8, 2018

Giuseppe LONGO
Directeur de Recherches,
http://www.di.ens.fr/users/longo
CNRS – École Normale Supérieure, Paris
Former "Professore Ordinario" (Full Professor) di Informatica, Università di Pisa, Italy

Studies

1971	"Laurea" cum laude en Mathematics, University of Pisa Thesis: *Complessità di calcolo delle funzioni ricorsive.*

Principal Fields of Interest

Logic and Theory of Computation; denotational semantics and lambda-calculus; Type Theory, Category Theory and their applications to Computer Science. Philosophy of Mathematics and the Cognitive foundations of Mathematics.

Current Interests: Interfaces between Mathematics, Physics, Biology. Theoretical Biology and Epistemology: Theories and their relation to experimental biology (randomness vs determination; default states and enablement in ontogenesis and phylogenesis).

Experience in France

1989/Oct - 90/May	**École Normale Supérieure**, Paris (Dept. of Mathematics and Computer Science): Invited Professor (teaching: *I sem.*: Functional Programming Languages ; *II sem.*: courses of D.E.A. (now Master 2) in Mathematical Logic)
1990/Jun - 90/Sept	**École Normale Supérieure**, Paris (Laboratory of Computer Science): Associate (temporary) Director of Research (Directeur de Recherches Associé) **CNRS**
1990 — 2011	**École Normale Supérieure**, Paris (Laboratory of Computer Science): Director of Research (Directeur de Recherches, CNRS) **CNRS**, 2de cl. since Nov. 1990; **1st cl.** since 1994.
2011 — 2012	**École Polytechnique**, Paris (Centre de recherche en épistémologie appliquée, CREA)): Director of Research **CNRS**.
2012 — now	**École Normale Supérieure**, Paris (Centre Cavaillès): Emeritus Director of Research **CNRS**.
1991 — 1993	**Dec-Prl** (Digital, Paris Research Lab): Consultant.

Positions at the University of Pisa

1971/11 — 1973/03 Assistant Prof. of Applied Mathematics

1973/03 — 1980/08 Assistant Prof. (tenured, Optimization Methods)

1976/11 — 1980/08 Professor "Incaricato" (associate) of Mathematical Methods in Computer Science

1980/08 — 1987/10 Associate Professor (tenured) of Mathematical Logic (on leave January 1980 - October 1981: Oxford, Berkeley and M.I.T., see below)

1987/11 — 1990/10 Full Professor of Computer Science (on leave 1987/88 (Carnegie Mellon Univ.) and 1989/90 (E.N.S., Paris), see below)

More Teaching and Research Experiences

1 − Other Than Italy and France
(three years and four months total)

1979/09 — 1979/10 Utrecht University (Math. Dept.): Visiting Scientist, Nederlandse Z.W.O. grant, December 1978; Visiting Professor, guest of the dept.

1980/01 — 1980/02 Oxford University (Math. Inst.): Visiting Scholar, British Council grant.

1980/03 — 1980/12 U. C. Berkeley (Math. Dept.): Research Associate, grant of the Italian CNR.

1981/01 — 1981/10 M.I.T. (Lab. for Computer Science (LCS)): Research Associate, CNR grant and LCS - M.I.T. grant.

1982/10 **E.T.H.** Zurich (Math. Forshungsinst.): Visiting Scientist, host of Forshungsinst.

1987 — 1988 **Carnegie Mellon Univ., Pittsburg** (Computer Science): Invited Professor (teaching: *I sem.*: Formal Lang. and Comp.; *II sem.*: graduate course on Recursion, Categories and Polymorphism). June and August 1988, "research summer salary".

1988/07 **Dec-Src** (Digital, System Research Center, Palo Alto, California): consultant.

2012 — now **Tufts University, Boston** (Department of Anatomy and Cellular Biology, School of Medicine): Adjunct Professor.

2 – In Italy

1970 — 1971   **University of Pisa and CNR** (Dept. Math. et Ist. Elaborazione dell'Informazione, Pisa): scholarship of C.N.R.

1971 — 1975   **C.N.R.** (Ist. Applicazioni del Calcolo, Roma): research collab., (assistant professor in Pisa).

1975 — 1976   **University of Genova** (Dept. Math.): "Prof. Incaricato" (Lecturer) of Mathematical Logic, (assistant professor in Pisa).

Awards

1974   Unione Matematica Italiana, National Award for young mathematicians.

1992 — now   Member of **Academia Europaea**.

Editor of Scientific Journals

1990 — now   Founder and Editor-in-chief, **Mathematical Structures in Computer Science**, Cambridge University Press, 1990 — 2015; currently editor.

1982 — now   Editor, **Information and Computation**.

1985 — now   Editor, **Theoretical Computer Science and Applications** (previously: **R.A.I.R.O.**).

1994 — now   Editor, **The Journal of Universal Computer Science**, a Springer electronically available journal.

2010 — now   Editor, **European Review**, the interdisciplinary journal of the Academia Europaea.

1993 — now   Editor, **La Nuova Critica**: rivista di Filosofia della Scienza.

2010 — now   Editor, **Journal of Mind Theory**, UPM.

2012 — now   Editor, **Biophysics** (American Inst. Math. Sci.).

2011 — now   Editor, **Biology Forum** (former "Rivista di biologia", since 1919).

2011 — now   Editor, **Philosophical Enquires**, Philosophy of Science.

2012 — now   Editor, **Advances in Historical Studies (AHS)**, History of Sciences.

2013 — now   Editor, **Epistemologica**, Mimesis, Milano.

2015 — now   Editor, **Organisms. Journal of Biological Sciences**, Roma.

Editor, book series

2006 — 2016 Co-founder and director of the book series, **Visions des Sciences**, Hermann, Paris.

2017 — now Founder and director of the book series, **Nouvelles Visions des Sciences**, Spartacus IDH, Paris.

2011 — now Editor, **Studies in Applied Philosophy, Epistemology and Rational Ethics**, Springer.

Editor, Individual Volumes

1984 **Logic Colloquium '82**. G. Lolli, G. Longo, and A. Marcja (Editors), Studies in Logic and the Foundations of Mathematics n. 112 (pp. 1 - 358), North-Holland, 1984.

1995 **Selected papers of the 5$^{\text{th}}$ biennial meeting on Category Theory and Computer Science '93**. G. Longo and A. Pitts (Editors), MSCS 5 (4), Cambridge University Press, 1995.

1999 **Lambda-calculus and Logic**. M. Dezani, G. Longo, and J. Seldin (Editors), Volume in honor of Roger Hindley, MSCS 9 (4), Cambridge University Press, 1999.

1999 **On Computer Science**. G. Longo (editor), Special issue of the Monist, Journal in Philosophy of Science, vol. 82, n. 1, 1999.

2003 **The Difference between Concurrent and Sequential Computations**, Special issue of Mathematical Structures in Computer Science, L. Aceto, G. Longo, B. Victor (Editors), MSCS 13, n.4 and 5, Cambridge University Press, 2003.

2003 **New Programs and open problems in the Foundations of Mathematics**, Special issue of The Bulletin of Symbolic Logic, G. Longo and P. Scott (Editors), ASL, vol. 9, n. 2, June 2003.

2004 **Geometry and Cognition**, G. Longo (Editeur), special issue, Revue de Synthèse, Editions de la rue d'Ulm, tome 124, 2004.

2005 **Images and Reasoning**, P. Grialou, G. Longo, M. Okada (Eds), Keio University Press, Tokio, 2005.

2014 **Developments of the Concepts of Randomness, Statistic, and Probability**, Special issue of Mathematical Structures in Computer Science, G. Longo, M. Mugur-Schachter (Editors), Cambridge University Press, vol. 24, n. 3, 2014.

2016   **From the century of the genome to the century of the organism: New theoretical approaches**, Special issue of Progress in Biophysics and Molecular Biology, A.M. Soto, G. Longo (Guest Editors), Volume 122, Issue 1, October 2016.

Interviews

2007/09/13   **Radio, France Culture**, La place de la Toile: "Au tour de la notion de modèle, mathématique vs. informatique", Radiofrance, Paris.

2010/3/12   **Radio, France Culture**, La place de la Toile (only speaker): "Internet, logique et finance".

2010/04   **Bulletin of European Assoc. Theoretical Computer Science**, April 2010: Interview by Cristian Calude.

2010/12/26   **Radio, France Culture**, La place de la Toile : "Alan M. Turing".

2011/13/06   **National Public Radios**, U. S. A.: Science and Philosophy, posting of June 13, 2011: "Are Financial and Scientific Views of the World Related?".

2017/15/06   **France Culture**, La Méthode scientifique: "Alan Turing : l'homme derrière la machine ?".

Research Evaluation Committees

1996 — 2000   Member of Scientific Committee of the Centre d'analyse et de mathématique sociales (CAMS) of EHESS.

1997 — 1998   Regional Coordination Council for Cogniscience Activities (CogniSeine, chaired by A. Berthoz of Collège of France).

1998 — 1999   Member, International Panel for the evaluation of Research in Mathematics and Computer Science in Portugal, Ministry of Science and Technology, Lisbon.

2003 — 2004   ACI New Interfaces of Mathematics, CNRS.

2004 — 2010   Member of Coordination Committee of Jumelage, CNRS - Russian Academy of Science.

2004 — now   Advisory Committee, Center for Logic and Computation, Lisbon, Portugal.

2009 — now   FET - Open, European Com. research projects.

2012 — now   KAIST (Korean Advanced Institute for Science and Technology), Member of Academic Peer Review Survey.

2015 — now   Russian Science Foundation, expert.

Referee and reviewer for the Projects ESPRIT, U.S. NSF and NSERC of Canada (Computer Science Grant Selection Committee); for Ministry of Universities, Italy.

Author of reviews for Math. Reviews, for the Journal of Symbolic Logic, Philosophy of Science and other international journals.

Conference Program Committees

1979   Member, Program Committee, **Lambda Calculus Conference**, Swansea (G.B.) 1979.

1984   Member, Program Committee, **Logic Colloquium 82**, Florence 1982 and Editor, **Proceedings**, North Holland (Studies in Logic, vol. 112), 1984.

1986   Member, Program Committee, **Symposium on Theoretical Aspects of Computer Science (STACS 86)**, Paris 1986.

1987   Member, Program Committee, **2nd IEEE Conference on Logic in Computer Science (LICS 87)** , Cornell (Ithaca, N.Y.), June 1987.

1990   Member, Program Committee, **CAAP'90**, Copenhagen, March 1990.

1991   Member, Program Committee, **Category Theory and Computer Science (CT&CS 91)**, Paris, September 1991.

1991   Member, Program Committee, **6th IEEE Conference on Logic in Computer Science (LICS 91)**, Amsterdam, June 1991.

1992   Co-organizer, **La nouvelle vie de la Logique Mathématique** (Logique entre fondements et *Computer Science*), Paris, April 1992.

1993   Member, Program Committee, **Category Theory and Computer Science (CT&CS 93)**, Amsterdam, September 1993.

1994   Member, Program Committee, **Rationalité Logique et Intuition Géométrique**, Paris, June 1994.

1995   Organizer, **Constructivité, en Mathématique et en Vision**, ENS, Paris, March 1995.

1995   Member, Program Committee, **Typed Lambda Calculus and Applications**, Edinburgh, April, 1995.

1995	Member, Program Committee, **World Conference on Foundamentals of A. I.**, Paris, July, 1995.
1995	Member, Program Committee, **Category Theory and Computer Science** (**CT&CS 95**), Cambridge, August, 1995.
1995	Member, Program Committee, **Logic Methodology and Philosophy of Science**, Florence, August, 1995.
1996	Organizer, **Mathematics, Machines and Brain**, ENS, Paris, May 1996.
1996	Member, Program Committee, **Functional and Objet-Oriented Programming Languages**, Rutgers University, N.Y., USA, July 1996.
1997	Member, Steering Committee, **Functional and Objet-Oriented Programming Languages**, Paris, January 1997.
1997	Co-organizer, **Construction de objectivité : entre intuition et raisonnement**, ENS, Paris, January 1997.
1997	Member, Organizing Committee, **HCM meeting on Denotational Semantics**, Siena, March, 1997.
1997	Member, Program Committee, **Logical Foundations of Computer Science** (LFCS97), Yaroslavl, Russie, July 1997.
1997	Member, Program Committee, **Category Theory and Computer Science** (**CT&CS 97**), S. Margherita Ligure, September 1997.
1998	Co-organizer, **Wittgenstein et les fondements des Mathématique**, ENS, Paris, April 1998.
1998	Member, Program Committee, **13th IEEE conference on Logic in Computer Science**, Indianapolis (In., USA), June 1998.
1998	Member, Program Committee, **Computer Science Logic**, Brno, Czech Republic, September 1998.
1998	Member, Program Committee, **Journées Francophones des Langages Applicatifs, JFLA'98**, October 1998.
1999	Member, Organizing Committee, **Workshop on Realizability Semantics**, Trento, Italie, June 1999.
1999	Chairman of the Program Committee, **15th IEEE Conference on Logic in Computer Science, LICS'99**, Trento, Italie, July 1999.

2000   Member, Program Committee, **Foundations of Software Science and Computation Structures, FOSSACS'00**, Berlin, D., March 2000.

2000   Program Organizer, **New programs and open problems in the foundation of mathematics and of its applications**, Paris, November 13-14, 2000.

2001   Co-organizer local, **Genesis of perception and the notion of space in machines and humans**, Paris, ENS, October 18-19, 2001.

2002   Co-organizer local, **Is the dynamics of forms at the core of cognition?**, Paris, April 5 - 6, 2002.

2002   Member, Program Committee, **Forme et objet du logique**, Rome, May 2 - 4, 2002.

2002   Member, Organizing Committee of the **IEEE Conference on Logic in Computer Science, LICS**, from 1997 till 2001 (2000: Santa Barbara, Ca.; 2001: Boston, Mass.; 2002: Copenhagen (DK)).

2002   Member, Program Committee, **Isomorphisms of Types**, International workshop at IRIT, Toulouse (Fr.), November 8-9, 2002.

2003   Organizer, Colloquium: **Géométrie, continu et théorie de la connaissance / Workshop on Geometry, continuum and theory of knowledge**, École Normale Supérieure, June 2, 2003.

2004   Organizer, Colloquium: **Images, reason and reasoning / Images, raison et raisonnement**, École normale supérieure, March 15, 2004.

2004   Member, Program Committee, Workshop: **Logique et Interaction: vers une Géométrie de la Cognition**, Aix-en-Provence , May 9 - 11, 2004.

2004   Member, comm. de Program, Colloquium: **3 corps, classique-quantique et discret-continu mathématiques**, École normale supérieure, Paris, September 28-29, 2004.

2005   Member, Program Committee, Colloquium **Qu'est-ce qui est réel?** , École normale supérieure, Paris, September 27, 2005.

2005   Member, Program Committee, Conference **The impact of categories**, École normale supérieure, Paris, October 10-14, 2005.

2005 Member, Program Committee, International Workshop on **Invertibility of Lambda-Terms**, Toulouse (France), October 28-29, 2005.

2005 Co-organizer, **Géométrie et complexité : la logique et ses images**, Salle des Conférences au 46, École normale supérieure, Paris, November 18 - 19, 2005. annual group meeting: "Logique and Intéraction: vers une Géométrie de la Cognition".

2006 Organizer, Conference **Continuous Dynamics and Computability**, Salle Weil, 45 Rue d'Ulm, École normale supérieure, Paris, May 3, 2006.

2006 Member, Program Committee, École **Constructivisme et Enaction. Un nouveau paradigme pour les sciences cognitives**, Ile d'Oléron, May 29 - June 3, 2006.

2006 Member, Program Committee, Conference **Computability in Europe, CiE, 2006: New Computational Paradigms**, Swansea, GB, June 30 - July 5, 2006

2006 Co-organizer, Colloquium **Ouvrir la logique au monde**, Salle Dussane, 45 Rue d'Ulm, École normale supérieure, Paris, September 29, 2006.

2006 Co-organizer, **Giornate di studio, Continuo e discreto: dall'esperienza percettiva alle costruzioni di razionalita**, Villa Feltrinelli, Gargnano (It.), October 5-7, 2006.

2007 Co-organizer, Second annual meeting "More Geometrico": "**Changement d'échelle - changement de niveau**", Paris, May 2 - 4, 2007.

2007 Member, Program Committee, 4th annual Conference on **Theory and Applications of Models of Computation (TAMC07)**, Shanghai, China, May 22-25, 2007.

2007 Member, Program Committee, Conference **Computability in Europe, CiE, 2007: Computation and Logic in the Real World**, Siena, Italy, June 18-23, 2007.

2008 Member, Program Committee, 5th annual Conference on **Theory and Applications of Models of Computation (TAMC08)**, Shanghai, China, April, 2008.

2008 Member, Program Committee, Worshop, **Logic, Language, Information and Computation**, Edinburgh, June 1-4, 2008.

2008 Member, Program Committee, study days, **Le dinamiche del vivente**, Villa Feltrinelli, Gargano (It.), September 28-30, 2008.

2008	Member, Program Committee, Colloquium **Négation, Dualité, Polarité** of the Group LIGC, Carry le Rouet (Marseille), October 16-19, 2008.
2009	Workshop: **The physical singularity of life phenomena. Extending concepts and techniques from Physics to Life Science**, ENS, Paris, April 10 , 2009.
2009	6th annual Conference on **Theory and Applications of Models of Computation (TAMC09)**, Changsha, China, May 26-30, 2009.
2009	Colloquium **Quelque part : entre biologie et philosophie**, ENS, Paris, June 12 - 13, 2009.
2009	Workshop: **Games, Dialog and Interaction**, University Paris VII, Paris, September 28-29, 2009.
2010	Conference **Computability in Europe, CiE, 2010: Programs, Proofs, Processes**, Ponta Delgada (Azores), Portugal, June 2010.
2010	Workshop, **Logic, Language, Information and Computation**, Brasilia (Br), July 6-9, 2010.
2010	Colloquium, **Les fondements à l'ère post-fondationnelle**, Groupe LIGC, Paris, November 18-20, 2010.
2011	Workshop, **Physics and Computation**, Turku, Finland, June 6-10, 2011.
2011	Conference, **Engineering of Complex Computer Systems**, Las Vegas, USA, April 27-29, 2011.
2011	Workshop, **The present phase of development of the concept of probability and randomness**, based on a special issue of MSCS, ENS, Paris, October 28, 2011.
2012	Study day: **La biologie de synthèse**, CREA, Paris, April 12, 2012.
2012	9th annual Conference on **Theory and Applications of Models of Computation (TAMC12), part of the Turing Year in China**, Beijing, China, May 16th - 21st, 2012.
2012	Conference on **Model based reasoning in science and technology: Theoretical and Cognitive issue**, Sestri Levante, Italy, June 21-23, 2012.
2012	International Workshop on **Statistical Physics and Mathematics for Complex Systems** (SPMCS2012), Kazan University (Kazan, Russia) from 25th to 30th of August, 2012.

2013	International Conference on **Computation Tools 2013** May 27 - June 1, 2013 - Valencia, Spain.
2013	International Conference on **Science and Information**, London, October, 2013.
2013	International Conference on **History And Philosophy of Computing** (HAPOC 2013), Paris, at École Normale Sup., from 28th to 31th of October 2013.
2015	**Pascal Conference: Biology and organisms: revisiting the systemic approach.** Paris, May 5 and 6, 2015, co-organizer.
2015	International Conference on **Model-Based Reasoning**, Sestri Levante on June 25-27, 2015.
2015	Colloquium **Lois des dieux, des hommes et de la nature**, October 15-16, 2015, Institut des Études Avancées de Nantes.
2017	Colloquium **Mathematical models and previsions, use and abuse in natural and human sciences**, February 15-16, 2017, Institut des Études Avancées de Nantes.
2017	Colloquium **Lancement de l'association Girolamo Cardano: science contre scientisme**, ENS, Paris, December 14, 2017.

Main Research Grants

1976 — 1990	Member, CNR (It) Gruppo Nazionale Strutture Algebriche e Geometriche.
1982 — 1986	NSF (USA) - CNR: joint grant (with K. Bruce, Albert R. Meyer (M.I.T.)).
1988 — 1991	European Community (CE-Science): project "Lambda-calcul" (J.Y. Girard (Paris VII, in charge of the European project).
1989 — 1990	BRA-Esprit project n. 3020: *Integration.*
1989 — 1992	CNR: Italian Universities /Stanford University (with S. Feferman and J. Mitchell (Stanford)).
1991 — 1997	Research Group *Programmation* (GDR 690 du CNRS).
1993 — 1996	NSF (USA) - Esprit (CE): Workshop on *Functional and Object Oriented Programming Languages* (in charge USA: K. Bruce).
1993 — 1997	CHM, CE: Responsible for the Paris region of the European Network for Fundamental Research in "Computer Science" (EUROFOCS), main center in Edinburgh (G. Plotkin).

1993 — 1997 European community research training project:*European institute in the logical Foundations of Computer Science* (EURO-FOCS).

1993 — 1998 Esprit working group 21900: *Types for Proofs and Programs* (TYPES).

1993 — 1998 Human Capital and Mobility (CHM): in charge for the group ENS-INRIA-PARIS VII de projet "TYPES" (J.Y. Girard, Marseille, in charge at European level).

1995 — 1997 Polish Academy of Sciences/French Embassy research exchange contract.

1995 — 1998 INTAS: contract CE/Russie.

1998 — 2001 Esprit Working Group 26142: *Applied Semantics* (APPSEM).

1999 — 2000 Franco-Italian Action of Scientific and Technical Collaboration, Ministries of Foreign Affairs and National Education.

2000 — 2002 Action "Cognitique" of MENRST: Head of the interdisciplinary workshop *Géométrie et Cognition: le problème mathématique de l'espace physique et du vivant*, (14 participants: maths, biology, physics and philosophy).

2002 — 2003 Program MATH/STIC CNRS (OSV BS): Project *Isomorphism of types: nouveaux développements.* In charge at national level: S. Soloviev (Univ. Toulouse).

1999 — 2004 ECOS-Sud (Cooperation with l'Uruguay): project *Types and programming (multi paradigms).* in charge.

2002 — 2004 Project MyThS: *Modèles and Types pour la Sécurité dans le systèmes distribués with mobilité*, IST action of the European Union as part of FET Global Computing. Contract IST-2001-32617. (Total allocation 4.9MF, including 1.5MF for the team ; in charge locally: G. Castagna).

2004 — 2005 Project *Invertibilité des termes and Programs en Théorie des Types and applications*, funded by CNRS, (in charge: S. Soloviev).

2004 — 2007 Project *Neurogeometry of the visual cortex*, funded by ACINIM (in charge: B. Teissier).

2004 — 2011 Part-time researcher (20/100) at **CREA** (Centre de Recherche en Epistémologie Appliquée), École Polytechnique, Paris.

2006 — 2009 Responsible of the ANR project: *Singularités physiques et calculabilité effective* (États critiques, singularités et calcul digital : théorie et applications).

2008 Bonus Qualité Recherche, ENS.

2011 — 2012 Annual funding, Réseau Nat. Systèmes Complexes, RNSC: *Biological time and rythms*, with J. Champagnat, biology, CNRS at Paris Sud, and M. Buiatti, Biology, Univ. Firenze.

2011—2014 IRSES, CE-FP7, European consortium extra CE, with K. Svozil, Physics, U. Vienna, and C. Calude, Maths, U. Aukland, NZ.

2015 — 2017 Participant, Project *Stability and variability*, Univ. Paris I.

2014 — 2018 Participant, European "Cost" Project, *The Origin of Life.*

2014 — 2020 Proponent and in charge of the project, *Lois des dieux, des hommes et de la nature*, at Institut des Etudes Avancées de Nantes (one post-doc is affected to the project), `http://www.iea-nantes.fr/rtefiles/File/projet-giuseppe-longo-2014.pdf`.

Setting Up and Direction

1993 — 2008 **CENECC**: "CENtre D' Etudes" of Complex systems and of Cognition, inter-Departements Unity of ENS, with J.-P. Nadal (Physics), B. Victorri (Linguistics).

1998 — 2002 **LTL**: New team "Langages, Types et Logique", Dépts. Mathématiques et Informatique, Ecole Normale Sup..

2002 — 2010 **CIM**: New team at the LIENS: Morphological Complexity and information.

2000 — now Direction of regular seminars at ENS: "Geometry and Cognition" (2000-2002) and "Philosophie et mathématiques" (2000 - 2016). At Crea: "Biologie théorique" (with M. Mossio and N. Perret, 2007 - 2012). At Centre Cavaillès, ENS: continuing **CIM** (2012 - now).

Anniversary Conference

2007/06/28-29 **From Type Theory to Morphologic Complexity: A Colloquium in Honor of Giuseppe Longo's 60**[th] **birthday**, Paris (*cf.* `http://www.pps.jussieu.fr/~gc/other/rdp/talks.html`)

Scientific Activity

1   Mathematical Logic and Theory of Computation

The first part of my research activities have focused on the study of the syntactic and semantic properties of "basic" functional programming languages (Combinational Logic, Lambda Calculus and their extensions). However, I have always integrated these studies into a broader perspective on the relationships between various mathematical theories which are at the core of such languages serving as logical and computer science tools. It is in this view that I have devoted myself to works spanning from Axiomatic Recursion Theories (for example, papers such as [91], [92]), to Recursion in Higher Types ([150], [97], [101]), and to Category Theory ([1], [104], [49], [141]). Outside of this framework, there are also papers such as [90] and [137], in which we assess various measures of computational complexity, as well as [96], which provides a semantic demonstration of the Paris- Harrington Independence Theorem for Arithmetics (a subject which I explored at Berkeley, in 1980, before my research experience at M.I.T., in 1981, steered me back towards the Theory of Programming Languages).

In short, in my papers, I tried to explain how the fallouts of the aforementioned mathematical theories, with respect to Computer Science, come in great part from the relationships between these various disciplines, in particular through the study of the mathematical semantics of programming languages. The purpose of this is to contribute to the construction of a rigorous mathematical framework for the theory of programming. These researches gave rise on the one hand to results which relate syntax to semantics (see [94] and [93] on the general notion of model and of full abstractness) and, on the other hand, to a deepening of the structural properties of the models (e.g. [98] and [100]). They have also allowed to establish new links with a very rich and important field of Logic which is that of Recursion in Higher Types, in particular, thanks to papers such as [97] and [100].

The [101] and [102] papers are the most representative of the latter topic. They are based on notions presented in [152] and give an original characterization of calculability in higher types, which enabled to relate Scott domains to computability in the higher types of Kleene and Kreisel. The discussions in Zuerich, in 1982, and the correspondence with Georg Kreisel (see `http://www.di.ens.fr/users/longo/files/FourLettersKreisel.pdf`) opened the way to this work. On this matter, a relevant paper (J. R. Cockett, P.J. Hofstra, Introduction to Turing categories, Annals of Pure and Applied Logic 12; 156(2-3):183-209, 2008), where " a convenient setting for the categorical study of abstract notions of computability" is presented, acknowledges that "Longo and Moggi, in [101] and [104], made significant contributions to this programme. While their main motivation seems to have been the development of categorical settings for the study of computability at higher types (as opposed to elementary recursion theory), they formulated the appropriate categorical concepts corresponding to Gödel numberings and parametrization."

The mathematical methods studied (Recursion in Higher Types, Semantics of Typeless Lambda Calculus) provided the technical tools for the following works (as well as for those by my students) concerning the categorical structures for the semantics of very current constructions in the Theory of Functional Languages:

- Typing and Type checking (see [102] and [140], which demonstrate, among other things, the completeness of certain typing systems).

- Polymorphism (see [1], [103], [106], [105], [143], [144]).

The importance of polymorphism in programming comes from its ability to capture a part of the notion of "modularity" in programming (see the Edinburgh ML language or the systems applications F by J.Y. Girard). In the study of polymorphism, the power of the logical methods such as those mentioned above becomes essential. My work in this field has established new links between notions which are very often used in Computer Science (types as parameters, records, inheritance, etc.) and the mathematical structures which come from Generalized Recursion, Demonstration Theory and Category Theory.

Papers such as [104], [49] and [141], to name but a few, use the traditional tools of Category Theory, as well as new concepts (spaces of partial morphisms, complete objects) for the semantic analysis of the "functional completeness" of typeless languages and of divergence. Following these researches, I felt the need to contribute to a systemization of certain aspects of Category Theory which I found interesting in terms of computer science applications. This systematization is what drives the book [1], published by M.I.T. Press, which serves as both an introduction to categories for computer scientists and as a tool for researchers interested in advanced fields dealing with the interaction between categories and Programming Theory. The book presents, for example:

- The notion of Cartesian Closure in the framework of Denotational Semantics

- Monoidal Categories and their relationships with Linear Logic

- Internal Categories as tools for the Semantics of Polymorphism (and of second order λ-calculus).

As regards applications, we should mention that these studies have had some influence, not only in terms of semantic investigation but also in the design of prototypical programming languages. The Quest language, for example, implemented at Digital (Dec-src, Palo Alto), is based on a very rich field of types and on a very strong use of polymorphism, formalized by higher order systems enriched with a notion of sub-type (essentially, the notion of inheritance in object-oriented languages). The extension of the language's type kernel, with records and sub-types, was inspired by the semantics of polymorphism and by inheritance in terms of "internal categories" in a constructive categorical framework (described in [105], written while visiting the Digital Research center in Palo Alto). The influence of the year I spent teaching and conducting research at the University of Carnegie Mellon in addition to my work as a Consultant for Digital at Palo-Alto, in 1987 and 1988, have had a great impact on my subsequent work in the functional analysis of object-oriented languages.

Returning to work as a Consultant for Digital in Paris (Dec-prl), from 1991 to 1993, gave me the opportunity to better appreciate the practical significance of an aspect of polymorphism which has not benefited from sufficient theoretical attention: "ad hoc" polymorphism. On the one hand, the study of this problem lead me to demonstrate the characteristics of "parametricity" of second order systems, widely used in programming ([16], [17]) and, on the other hand, I developed with former and current students an extension of classical functional systems which enriches such systems with uniform and mathematically coherent forms of ad hoc polymorphism ([107], [145]). In the first case, the Genericity Theorem ([16]) is considered to be an important result with respect

to the Theory of Proof of λ-calculus. In the second case ([145]), we proposed an original solution to the relationships between Functional Programming and "Object-Oriented Programming", thanks to the functional treatment of notions such as the "passing of messages" and "overloading".

The study of the links between parametricity, subtyping and inheritance is at the basis of the collaboration with S. Soloviev and K. Milsted (Digital Research, Paris, and, later on, CNET, France Télécom), which continued until 1999. Within this framework, we proposed a simple computation of "perfectly expressive" sequences of points, that is, sequences which are complete with respect to the properties of subtypes in functional languages (see the preliminary version [146]). Recent developments of these systems are found in [109] and [59].

An original analysis of the "invariance levels" of proofs is proposed with the notion of Prototype Proofs, in Type Theory. It is a question of understanding what is the "skeleton" of a proof or that which makes it invariant with respect to the genericity of its arguments/variables (see [147] and [108]). This tool for the analysis of proof as a term or as a program (prototype) is applied to the study of certain ("concrete") incompleteness theorems in [116]. The first version of this paper, written in 2000, all the while remaining within the framework of Logic (Type Theory and Proof Theory) and of its applications, opens up new avenues which will be at the core of the thematic change which will follow. It has been reprinted (and revised) upon invitation.

Thematic Change: From "Geometry and Cognition" to the "Complexity and Morphological Information" Team, CIM

From 1993 to 1999, I coordinated the interdisciplinary meetings of the Cogni-science Group at ENS, created upon the initiative of J.-P. Nadal (Physics), D. Lestel (Psychology) and myself (see above the interdepartmental "Center for the Study of Complex Systems and Cognition", CenECC, which has picked up the group's work, since 2000).

The group's activities, as well as invitations to Philosophy of Mathematics or to Cognitive Science Conferences and seminars (see for example [64], [60], [168], [61]), reflect the engagement in reflections of an interdisciplinary nature; although this was done at first on a part-time basis, this work became increasingly important. It was about elaborating a "foundation of mathematical knowledge", relating cognitive phenomena to the foundations of mathematics. One of the motivations of this new direction (which is not the first "thematic change" to occur during my career as a researcher) is the "crisis" undergone today by the relationships between Mathematical Logic and Computer Science: Computer Science, born during the 30s and 40s out of the formal (sequential!) computability systems (Herbrand, Gödel, Church, Kleene, Turing ...), today introduces problems mainly relative to space and time. Distributed, concurrent and asynchronous systems must first be analyzed in "spatio-temporal" terms. The investigation of our phenomenal relationship to space and to time is part, in my opinion, of a discussion concerning these very principles which enabled the birth of our logical and computational systems that were then expanded thanks to new principles. My engagement in this direction was first epistemological (and mathematical), as part of the analysis of correlations between the foundations of mathematics and (spatial) cognition.

The first papers regarding these matters constitute a reflection on mathematical continuity and infinity and their logical and computational formalizations [20], [21], as well as on the role of action and of movement in the constitution of the geometric intelligibility of sensible space, [18]. It continued by further insights into the role of order and symmetries in the cognitive foundations of Mathematics, [33], and on the relation of the invention of the perspective in painting vs. the foundation of geometry and of the concept of infinity in Mathematics, [34].

From cognition, a dialog with biologists soon became part of this project (see the presentations at the Collège de France and at the Vatican, in 1998, as well as [166], [167], [171], [63]), but also with physicists. Indeed, two working groups, one in the field of the Epistemology of Mathematics and of Physics, the other in the field of Geometry and Cognition, have constituted an important component of my scientific activity: the results produced by the first group have appeared in a volume (see [22]), and the other served as a starting point for a research project, "Geometry and Cognition"
(see http://www.di.ens.fr/users/longo/geocogni.html). This project under my responsibility was funded at the level of our request by MENRST (there was also the organization of eleven seminars on these topics, between 1994 and 2003, and of joint seminars with colleagues in the fields of Biology, Physics and Philosophy). The volumes edited as part of this project ([8], [10], [11]), and the thesis by A. Viarouge, co-directed by S. Dehaene (Collège de France), defended in October 2008, contains the most important results among our work on these topics.   In short, we believe, on the one hand, that the geometric intelligibility of space poses a fundamental problem which is independent from (adds itself to) those addressed by Logic, and, on the other hand, that any "informational content" also depends on the geometric structure which encodes the information as well as on its context (measurement, scale). One of the objectives of the "Geometry and Cognition" working group consisted, in particular, in a preliminary analytical work regarding the functional structure of the primary visual cortex and of its geometry, as the locus of the elaboration of information (under the direction of J. Petitot, Director of CREA, and B. Teissier, CNRS-Maths, Paris VII). Some of the most interesting advances in understanding perception concern the way in which the processing of a signal can produce morphological structuring, that is, an organization into forms (these topics are part of the objectives of the "Neurogeometry" project, directed by B. Teissier, and funded by ACINIM '04, 2004-7).

In general, we can note that, traditionally, the theory of computability and of information are based on the analysis of sequences of 0s and 1s. From Turing to Shannon, information has been encoded in binary sequences and their transformations constitute the material support and the mathematical structure at the center of these two theories which have changed our world (and I have devoted a great deal of work to the first of them). A critique on the use of these notions in Biology may be found in [111].

Now, the processing of information in biological entities can follow other schemas, which also include "changes in form". From proteins to neural networks, it increasingly seems evident that modifications in form (in the three-dimensional folding of amino acids or in network structures) form an integral part of the process, that some continue to consider an "elaboration of information". Our new viewpoint corresponds to an approach which integrates the mathematical organization of space with causality in Physics and in Natural Science (see [25]

and [29], [72]). All the while developing this framework, the thesis of Boris Saulnier (Computer Science), under my direction and an important culmination of the CIM team's work (in conjunction with the thesis of M. Mossio, Cognition, see below), provides a synthesis and an original framework for a "morphological" analysis of information by its various entropic correlates and their scale invariants, in Physics and in Biology.

On the basis of the remarkable work which has already been done in the analysis of two traditional aspects of computation (digital), but by taking new paths, if possible, we are thus developing a mathematical theory of "complexity and of information in geometric structures" or, in the case of life phenomena, in the geometry of levels of organization (see [68]). The general quality of the approach should enable us to grasp other aspects of this problem, beyond the two examples we mentioned, which may very well refer to both the physics of dynamical systems as well as to the analysis of intracellular communication. The essential incompleteness of the purely formal approaches in Mathematics, their correlations with the incertitude of physical measurements (see [67]), as well as the "impossible geometry" of certain computational modelizations (see [29], [66]) motivate our approach. These reflections, of the "exploratory-interdisciplinary" type, enabled us to launch the activities of the new team at LIENS called "Complexity and Morphological Information" (CIM, October 2002).

As part of the funding received but regarding one of the themes which were the original motivation for this long term project (Geometrization in Computability and Programming), a special issue of the MSCS journal published by Cambridge Univ. Press, which I directed, was published in 2000: "Geometry and Concurrency", vol. 10, n. 4. Advances regarding the foundational aspects of the project are presented in [65]; other papers, by numerous authors, can be found in the three volumes / special issues edited from 2003 to 2005 (see the collective publications [8], [9], [10], [11]); the papers in this latter volume summarize, from various standpoints, the work initiated with "Geometry and Cognition" and carried on by the new CIM team.

A Few of the Research Areas of the New "Complexity and Morphological Information" Team (CIM, October 2002)

To present a synthetic framework, we can place a physico-mathematical notion at the center of the team's activity, that of *critical transition*, a particular form of physical singularity. This notion is elaborated throughout various projects and correlates the work undertaken regarding the computational structure of certain physical dynamics with the analysis we develop concerning life phenomena, seen as "extended critical transition".

The project "Physical singularities and effective computability".

Singularities and critical transitions play a key role in modern physics. By a project, supported by the french ANR, a collaboration with a mathematician from the University of Pisa, S. Galatolo, a physicist of CNRS, A. Lesnes, and two PhD theses have been made possible (M. Hoyrup and C. Rojas, whose theses have been defended in 2008). Beyond some stability theorems in numerical analysis, we investigated the effectiveness of renormalization methods, compared various forms of randomness (Birkhoff vs Martin-Loef), in physics and in Algorithmic

Information Theory; we analyzed divergence and undecidability. Besides the work in the two theses (in Mathematics and Informatics), some results are in [28], [70]. A more recent survey may be found in [77].

2 Towards Biology: the physical singularity of the living state of matter.

In our perspective, the methods of physics should be directly borrowed in biology, in particular as for the key role they had in constructing new "objectivities", such as new pertinent observables (consider thermodynamics, with its P, V, T as observables and the trajectories in their phase space or quantum physics, whose objects are co-constituted in the experience, thus as a result of a theoretical construction.) In no way, by the concepts we hint to, we intend to define or characterize life. We just try to focus on some phenomenalities which seem particularly preeminent and try to treat them in a possibly conceptually robust fashion, with some mathematics when this may help. The three points below briefly outline the work developed over several articles, to which we refer when appropriate.

2.1 Extended Criticality.

The biological interest of physical theories of criticality is due first to the fact that, in physics, *critical phase transitions* are processes of change of state where, by the sudden change (a singularity w. r. to a control parameter), the global structure is involved in the behavior of its elements: the local situation depends upon (is correlated to) the global situation. Mathematically, this may be expressed by the fact that the correlation length formally tends towards infinity (the case with second order transitions, such as para-/ferromagnetic transition); physically, this means that the determination is global and not local. In other words, a critical transition is related to a change of phase and to the appearing of critical behaviors of some magnitudes of the system's states — magnetization, density, for example — or of some of its particular characteristics — such as correlation length. It is likely to appear at equilibrium (null fluxes) or far from equilibrium (non-null fluxes). In the first case, the physico-mathematical aspects are rather well-understood (renormalization as for the mathematics, see [120], thermodynamics for the bridge between microscopic and macroscopic description), while, in the second case, we are far from having theories as satisfactory.

Some specific cases, without particular emphasis on the far from equilibrium situation, have been extensively developed and publicized by Bak, Kauffman and others (see [112]). The sand hips, whose criticality reduces to the angle of formation of avalanches in all scales, percolation or even the formation of a snowflake are interesting physical examples. The perspective assumed is, in part, complementary to Prigogine's: it is not fluctuations within a weakly ordered situation that matter in the formation of coherence structures, but the "order that stems from chaos". Yet, in both cases potential correlations are suddenly made possible by a change in one or more control parameters for a specific (point-wise) value of this parameter. For example, the forces attracting water molecules towards each other, as ice, are potentially there: the passage below a precise temperature, as decreasing Brownian motion, at a certain value of

pressure and humidity, allows these forces to apply and, thus, the formation of a snow flake, typically.

The critical transitions must be also understood as sudden symmetry changes (symmetry breakings and formation of new symmetries), and a transition between two different macroscopic physical objects (two different states), with a conservation of the symmetries of the components. The specific, local and global symmetry breakings give the variety of organized forms and their regularities (the new symmetries) as these transitions are (very) sensitive to fluctuations in the vicinity of criticality. In physics, the point-wise nature of the "critical value" of the control parameter is an essential mathematical issue, as for the treatment by the relevant mathematics of "renormalization" in theories of criticality, see [120].

Along the lines of the physical approaches to criticality, but within the frame of far from equilibrium thermodynamics, we consider living systems as "coherent structures" in a continual (extended) critical transition. The permanent state of transition is maintained, at each level of organization, by the integration/regulation activities of the organism.

In short, in recent work [112], [120] and [2], we propose to analyze the organization of living matter as "extended critical transitions". These transitions are extended in spacetime and with respect to all pertinent control parameters (pressure, temperature etc.), their unity being ensured through global causal relations between levels of organization (integration/regulation). More precisely, our main physical paradigm is provided by the analysis of critical phase transitions, as this peculiar form of critical state presents two particularly interesting aspects for biological situation: the formation of extended correlation lengths and coherence structures, as mentioned above, by the divergence of some observables with respect to the control parameter(s) and the change of symmetry associated to potentially swift organizational changes. However, the "coherent critical structures" which are the main focus of our work cannot be reduced to existing physical approaches, since phase transitions, in physics, are treated as "singular events", corresponding to a specific well-defined value of the control parameter, just one (critical!) point as we said. Whereas our claim is that in the case of living systems, these coherent critical transitions are "extended" and maintained in such a way that they persist in the many dimensional space of analysis. A living object is not only a dynamics or a process, in the various possible senses analyzed by physical theories, but it is permanent *critical transition*: it is always on the border of a change, of symmetries changes in particular, as analyzed in [120]. One then has an extended, permanently reconstructed and transforming *global* organization in an interaction with *local* structures, as the global/local interplay is proper to critical transitions (by singularities). Some radical consequences of our approach are derived in [82]. The a priori unpredictability of the pertinent phase space (of phenotypes) radically changes the theoretical framework needed for biology: the very space of possibilities undergoes an unpredictable (random) evolution, in contrast to the ordinary approaches to physical (both quantum and classical) indetermination or randomness.

So far, our analysis, in the papers quoted above, has been only in part mathematical and largely conceptual, since, by the loss of the mathematics of renormalization, there seem to be little known Mathematical Physics that applies to this physically singular, far from equilibrium situation. The second major conceptual and technical difficulty is also clearly the instability of the symmetries

involved. The question is then how to objectivize them, since, in contradiction with the physical situations they do not not seem to be theoretically determined to be in a specific, pre-given set, [82].

2.2 Anti-entropy

.

In [113] our systemic perspective for biological complexity in both phylogenesis and ontogenesis is developed by an analysis of organization in terms of "anti-entropy", a notion we defined and which conceptually differs from the common use of "negative entropy". Note that both the formation and maintenance of organization (a permanent reconstruction of the coherent structure) go in the opposite direction of entropy increase. This is also Schrödinger's concern in the second part of his 1944 book, where he considers the possible decrease of entropy by the construction of "order from order", that he informally calls negative entropy. In our approach, anti-entropy is mathematically presented as a new observable, not just entropy with a negative sign (negative entropy, as more rigorously presented in Shannon and in Brillouin). Typically, when added, equal entropy and negative entropy give 0: in our approach, entropy and anti-entropy are found simultaneously only in the non-void (extended) interval of criticality, inherent to the living state of matter. A purely conceptual analogy may be done with anti-matter in Quantum Physics: this is a new observable, relative to new particles, whose properties (charge, energy) have opposite sign. Along our wild analogy, matter and anti-matter never give 0, but a new energy state (double energy production as gamma rays).

To this purpose, we introduced two principles ("existence and maintenance of anti-entropy"), in addition to the thermodynamic ones, which are (mathematically) compatible with traditional principles but which have no meaning with regard to inert matter. A traditional balance equation for the metabolism is then been extended to the new notion as specified by these principles. This equation is inspired by Gibbs analysis of free energy, which is hinted as a possible tool for the analysis of biological organization in Schrödinger's classic "What is Life?". We examined far from equilibrium systems and we focused in particular on the production of global entropy associated to the irreversible character of the processes. In [113], a close analysis of anti-entropy has been performed from the perspective of a diffusion equation of biomass over phenotypic complexity along evolution. That is, we could reconstruct, on the grounds of general principles, Gould's complexity curve of biomass over complexity in evolution (see his "Full House", 1989 book). Moreover, a quantitative evaluation of phenotypic complexity in embryogenensis is proposed, in relation to some empirical data (Caenorhabditis elegans). Once more, Quantum Mechanics indirectly inspired our mathematical approach: we borrowed Schrödinger's operatorial approach in his famous equation but in a classical framework. Classically, that equation may be understood as a diffusion equation (as a matter of fact, we used real coefficients instead of complex ones, thus outside of the mathematical framework of quantum theories): we used to analyze the growth of phenotypic complexity along species evolution, [113], [81].

2.3 Biological time.

The usual physical (linear) representation of time is insufficient, in our view, for the understanding of some phenomena of life. An extended form of present seems more adequate for the understanding of memory, since this is an essential component of learning, for the purposes of future action (based on "protention", as pre-conscious expectation). In particular, while memory, as retention, is treated in some physical theories (relaxation phenomena), protention seems outside the scope of Physics. We then suggested some simple functional representation of biological rentention and protention [117].

Similarly, the role of biological rhythms does not seem to have any counterpart in mathematical formalizations of physical clocks, which are based on frequencies along the usual (possibly thermodynamical) time. By this, in [115] a two-dimensional manifold as a "mathematical frame" for accommodating autonomous biological rhythms is presented: the second dimension is "compactified", that is, it is a circular fiber orthogonal to the oriented representation of physical time. The addition of a new (compactified) dimension for biological time is justified by the peculiar dimensional status of *internal* biological rhythms. Life is temporally scanned by both external (physical) rhythms (cicardian, typically), which are frequencies, and internal ones (metablism, respiration, cardiac rhythms). These are pure numbers, not frequencies: they become frequencies and produce the time of life span, when used as coefficient in scaling laws.

The two new aspects of biological time allowed us to introduce the abstract notion of "biological inertia", as a component of the conceptual time analysis of extended criticality.

Another aspect of biological time, introduced in [120], is the time constituted by the cascade of symmetry changes which takes place in extended critical transitions. In other terms, this time is defined by the ubiquitous organizational transformations occurring in biological matter. This time corresponds therefore to the *historicity* of biological objects and to the process of biological individuation (both ontogenetic and phylogenetic). Thus, on top of the physical irreversibility of thermodynamical time, of course proper also to biological phenomena, one has to consider another form of irreversible time (another observable in the same dimension of time, like the dimension of energy has more than one observable in physics, potential, kinetic . . .). This form of time better corresponds to our view of the increasing complexity in phylo (and onto-)genesis.

3   Synthesis, from 2002 to 2012

Broadly speaking, except for the consideration in terms of extended criticality and symmetry changes, the laws which we propose while addressing the peculiar observables and quantities, specific to life phenomena, constitute a simple *extension* of existing physical laws: they preserve the same formal mathematical structure and, if we set the value of the considered observables or parameters to 0 (protention, second temporal dimension, value of anti-entropy), they return the theories of inert. Our theoretical propositions are thus compatible, although irreducible, to "existing physical theories". That is, they are reducible to these laws *only* if, but *as soon as* we are outside of the extended critical zone having its own temporality and its own anti-entropy, or as soon as these specific quantities

go to 0.

In our perspective, closely developed in the book [3], the phenomenality of life deserves some new observables (extended critical transition, biological organization, proper time, in our attempts). The point we treated is the pertinence of these treatments, "*per se*". Those who claim that all these concepts should be reduced to physical (existing?) theories are welcome to try. But they should first look at the history of Physics itself, where novel theoretical frames are marked by the invention of new concepts and new perspectives. Their pertinence had to be judged "as such", not on the grounds of their reducibility to existing, thus "safe", explanatory grounds: the unity in Physics and, a fortiori, in natural sciences is a difficult conquest, not a metaphysical a priori. The point of view of extended critical transitions, in association with ubiquitous symmetry changes, may, however, lead to more radical methodological changes, as associated to the specificity of objects and genericity of trajectories. This epistemological critique and positive proposal is in [3].

3.1   Remarks Concerning the Method: From Information to Organization

The ambition of this part of our work is not only to reconstruct the physico-mathematical complexity of certain aspects of Biology, but to first and foremost propose a change of perspective. We believe that the theoretical differentiation between the theory of inertia and those of the *living state of matter* requires, among other things, a change in the relevant parameters and observables. Now, the mathematization of physics has been centred around invariants, among which the great constants (g, c, h), but also those of the "objective determinations" which we address in length in the book [2][1]. In our view, we must base ourselves on the rare invariants, including constants and rhythms, for example, which we find in time in Biology, because beyond the physico-chemical, the structural stability of life phenomena is not so invariant, physically speaking: it is deeply riddled with variability. In order to grasp this state, extended criticality, which is difficult to mathematize, we started with these invariants, these rhythmic constants, and we constructed the outline of a non-trivial geometry of biological time, even if it does not make physical sense.
To this was added a quantitative analysis of the structural invariant which is organization, quantified as anti-entropy, with its own balance equations, a very recent approach, albeit a preliminary one, which we believe to be novel (also see [113], [37] for references and comparisons).

To conclude, over the last years, we have compared dynamic randomness with algorithmic randomness (which is at the center of algorithmic theories of information); we have modified criticality (which becomes extended, for Biology); we have added anti-entropy to fundamental (in)equalities and thermodynamic balance equations; we have started to produce models of biological rhythms and time in two-dimensional manifolds. The basic idea was that the notion of information, in Biology, must be enriched by that of organization, as a proper biological observable. This new observable, which we grasp in particular with the "intertwining and coupling of levels of organization", is at the center of our

---

[1]This book was first published in French by Hermann, in 2006; incidentally, when this book was sent to the publisher for its possible publication, I was invited to co-direct a new collection, "Visions des Sciences", of which this book was the first.

formal analyses.

We therefore aimed to enrich the widespread notions of "information", "complexity", etc., so as to more closely account for the phenomenology of the living state of matter. The risk taken by the establishment of the CIM team consisted in the title itself, of which the challenge was to propose scientific ideas which were different from Shannon's as well as from Kolmogorof's computational complexity and information. These are highly important notions, but, in our opinion, they are insufficient for the study of biological phenomena, just to mention their abuse in Molecular Biology (about what "information" are we talking about? They differ or are in contraposition as regards "complexity", see the work with A. Soto, C. Sonnenshein, Tufts U., Boston. The notion of anti-entropy formalizes phenotypic complexity (morphology) in phylogenesis and in ontogenesis and constitutes a strong point of our work (and a firm one, we think).

From the methodological standpoint, our undertaking in Biology consists in developing elements for a theory which is specific to life phenomena, even if it does not find any correspondence or make sense in current physical theories. The proposed reversal which makes an operator of time and a parameter of energy, for example (the dual of that which is done in Physics, in Quantum Physics in particular), is one of the propelling elements of this change of observables and of parameters we are pursuing. In a very general way, the laws we use when addressing these particular quantities and which were introduced specifically for purposes of analyzing life phenomena constitute extensions of usual physical theories (thermodynamic theory, in particular): they preserve the same formal mathematical structure and, if we set the value of the considered observables or parameters to 0 (extension of the critical interval, second temporal dimension, value of anti-entropy), they return the theories of inertia. As a true extension, our theoretical propositions are therefore compatible with, albeit irreducible to, "existing physical theories".

4   Introduction to the work 2012 - 2016: Theory and Epistemology at new scientific interfaces

The epistemological commitment of our scientific work is very strong and has been made explicit in several papers. It is at the root of several invitations to co-edit epistemology journals and collections as well as to speak in Philosophy of Science Conferences and seminars (see below). It motivated the co-direction of two PhD Thesis in Philosophy (Frezza and Perret), the invitation as referee and/or jury member of several Thesis and Habiltations in Philosophy.

As a matter of fact, everal papers, including those published in scientific journals are "conceptual" analyses, that focus on the epistemological frame as a "conditions of possibility" also as for the technical developments. This frame mostly focuses on the interfaces of Computing, Physics and Biology, always in collaboration with colleagues from these disciplines. Yet, in view of the collaboration with biologists and philosophers of biology, a relevant component of the work is within biology and of a theoretical nature.

4.1 Theoretical Biology

The evolutionary history of life produces occasionally "simple" structures through complex paths, the "simplexity" analysed in [41]. Yet, it also produces increasing organismal complexity as the result of an asymmetric random diffusion from a "wall" of minimal complexity (conventionally considered to be bacteria), as discussed in [81]. The stress on the role of randomness in biology is first made in [121], a collaboration with a genetician which surveys and frames the abbundant evidence of the various sorts of physical randomness in cellular activities (classical and quantum) and insist on the functional role of it. Randomness is not "noise" in biology, but a fundamental component of variability, thus of diversity, which contributes to the "stability" of populations and species, as well as of organisms (see below). This is one of the motivations for the critique of the use of the notion of information in biology, addressed in [118]. In [122], we argue that one major aspect of biological evolution is the continual change of the pertinent phase space (the space of the observables and parameters) and the unpredictability of these changes. This analysis is based on the theoretical symmetries in biology and on their critical instability along evolution. We discuss two notions to the purposes of this analysis: differential causality and *enablement* (see below). A turning point of our many years investigation, is the synthesis of two converging life research histories presented in [127]. As a matter of fact, the approach to cancer by Sonneschein and Soto, has found in our collaboration a way to be correlated to a view of the organism that gives to their approach even further sense. These biologists since long understand cancer as a tissue problem in the organism's relation to the ecosystem. By our joint work, we could propose some new strong principles that allow to see development as part of phylogenesis ("descent with modification", a Darwinian principle that we apply also to ontogenesis), under the idea that there is "never identical iteration of a morphogenetic process", both at the level of organs and of organisms (which include cells in multicellular organisms). In our papers, we extensively motivate our approach by empirical evidence. A recent synthesis of the work on these themes by our Boston-Paris team is in [13], a volume that collects nine papers by eighth authors. The role of history in the formation of present biological structures and the intrinsic unpredictability of future is stressed in [135]. In particular, to the properties of synchronic measurement in physics, the relevance of diachronic measurement in biology is evidentiated, as well as the way this contributes to the very formation of the biological phase space.

4.2 Interfaces of Physics, Biology and Computing

From an epistemological point of view, the focus of my work (mostly in collaboration with biologists and physicists, but also with a mathematician of Computing, C. Calude) on the historicity of the biological object (the organism) as well as on indeterminacy, in the timing of evolution, of its phase space (the pertinent observables and parameters – the phenotypes and the ecosystem), poses a challenge to the "a priori" spaces that has been at the heart of the very fruitful interaction between physics and mathematics. Note first that both the mathematical and the physical object are generic (they are invariant w.r. to the theory and experiments), and that the physical trajectories are specific, that is they are geodetics in suitable and pre-given phase spaces. Dually, in biology, on

the one hand, the objects are specific, inasmuch as they are historical, in that (for us) their theoretical symmetries (the analogues of the conservation properties in physics) are constituted over time in the process of individuation (phylogenesis, ontogenesis). On the other hand, their trajectories are generic in the sense that they cannot be deduced mathematically from stable symmetries, since these form a possible and changing space (in fact, the ecosystem), which is a co-constitutive of the dynamic. In this framework, we understand the Darwinian principle of inheritance, "reproduction with modification", as a principle of non-conservation of the phenotype. We may summarize our comparison between what is at the heart of biological theory (of organisms) in relation to what is specific to physics in the following table:

This table is an example of how we have proceeded and will proceed, from a methodological point; this is, by engaging in an intense dialogue between the foundations of both mathematical physics and theoretical biology, where the crosscurrents take place by analogies and passageways, but also by dualities, as in this case.

We have introduced this play of analogies and dualities in many articles, most recently thanks to a critical review of empirical results on symmetries in biology, specifically symmetries of scale (including allometry, the variability of biological rhythms and in the form of certain structures, [3]). We have remarked on their descriptive interest but also on the omnipresent and important gap within the current biological understanding, where for example the fractal dimensions involved are not invariant. This hypothesis has major epistemological consequences, since the instability of theoretical symmetries does not permit recourse to the same method of objectification of phenomena as it does in the mathematics of physics. Hence it is a matter of establishing other modes of objectivation by starting with this difficulty, which I have done in the method hinted in the table above, in particular in my book with Montévil. 2014. The philosophical interest of this approach has also been evaluated from an historical perspective in Perret's thesis (see below). One of the consequences of my approach, which maintains that theoretical symmetries of biology are unstable, is that the phase space (or space of description) of an object must change over time. This is our way of apprehending biological (evolutionary) novelty. By contrast, in physics, the phase space is always stable in the sense that it is described by a finite number of theoretical symmetries. This corresponds in terms of mathematical logic with mathematical incompressibility (in the sense of Kolmogorov) of the description of phenotypes in evolution: it is impossible to enumerate them before their occurrence.

This idea of the instability of the phase space was independently proposed by Stuart Kauffman (USA), on different bases, and so we have worked to mutually enrich our approaches in a collaborative article, [122], that was further developed with Montévil ([40]) and taken up in the 2014 book. In a theoretical framework in which symmetries are unstable, a trajectory can no longer be determined as a consequence of a combination of factors that can be formally stated. Thus, it is the causal regime that has changed here by adding the notion of enablement to the field of physical causality. For example, the appearance of swim bladders enables specific bacteria, which colonize it, and the formation of novel interactions between these bacteria and the fish, if not a new microbiome, but it does not cause these interactions in the sense that one cannot deduce their structures before they are established. Note that a notion of differential causality of a

PHYSICS	BIOLOGY
randomness is **non deterministic** or deterministic non predictability **within a pre-given phase space**	**randomness** is **intrinsic** **indetermination** given also by changing phase spaces (ontogenesis and phylogenesis)
specific trajectories (geodetics) and **generic objects**	**generic trajectories** (possible/compatible with ecosystem) and **specific objects**
point-wise criticality	**extended criticality**
reversible time (or irreversible for degradation - *e.g.* thermodynamics)	**double irreversibility of time** (thermodynamics plus phenotypic complexity constitution)

Table 16: A possible theoretical differentiation between inert and living state of matter is described through some conceptual dualities, based on the work in Longo and Montévil (the 2014 book and several papers).

physical type does remain valid, in the sense that the introduction of a difference leads to one or more differences. In relation to the role of phase spaces, in natural sciences, an epistemological and historical reflection on the origin of the infinite mathematical space of modern physics may be found in the article on "perspective" in Italian painting" that was inspired by the work of D. Arasse, an historian of Art, [34].

This work, lying between science and epistemology, also led us to a comparative discussion of the practices of computational simulation and modeling. In particular, we investigate the relation between simulations and mathematized theoretical frameworks by examining several case studies, [45]. In fact, it is remarkable that some types of simulation do not correspond to predefined spaces of description (in particular in object-oriented programming - around 1990, I was the co-author, with K. Bruce and L. Cardelli, of its mathematical foundation in Type Theory, still very cited today).

My epistemological claim, technically substanciated in [45], is that randomness in physics may be understood theoretically as a change of symmetry, usually in pre-defined spaces (in particular, the breaking of symmetry). In effect the breaking of symmetry presupposes a prior and given equivalence between possibilities that are not present in the final result. In contrast to the various forms of randomness encountered in physics, the originality of biology in our framework is due to the fact that the implied theoretical symmetries themselves have a random component – hence the unpredictable character of the phase space and of the theoretical description, typically, of the ecosystem to come about. The mathematical analysis – conceptual and epistemological – of randomness in both physics and biology lies at the heart of many articles I have written in collaboration with Buiatti, a biologist ([121]), Bravi, a physicist ([85]) and Calude, a mathematician ([126], [134]), and is also central to Abbott's doctoral thesis (defended in 2015), as well as featured in the volume edited in 2014, [12]. The second paper with Calude, a critique of the abuses of Big Data, [134], revitalized some early work done in Berkeley in 1980, [96]: Ramsey Theorem provided then a concrete example of incompleteness (at the time analized in model theoretic terms), it now helped us to show the presence of spurious correlations in all sufficiently large data bases.

To our great surprise, our work on the unpredictability of the space of possibilities in the historical sciences, as in evolutionary biology, has interested two economists (T. Felin of Oxford, R. Koppl of Syracuse University), with whom Kauffman and I have collaborated on two articles ([124], [125]). Our analysis of evolutionary dynamics as co-constitutive of the space of possibilities indeed appears well adapted to an innovative epistemology of economics. The second of these articles is among the five finalists for a prize in economics that will be awarded in Boston in September 2016.

Almost all the articles of this period are conceptual analyses starting from original scientific propositions, on the basis of which I always try to make explicit an epistemology constructed from direct contact with biological practice (see in particular articles written in collaboration with biologists Buiatti, Sonnenschein, Soto and Villoutreix's dissertation). This followed long years of collaboration up to 2012 that were first centered on epistemological analyses in physics with physicists Bailly and Paul.

4.3 Team and Main International Activities, 2012 - 2016

Leading a team (CIM, see my web page) has enabled a permanent exchange with three post-docs and three PhD students mentioned below (plus two more current ones), with former doctoral students (Mossio and Montévil) and at least four other older and younger scholars, including V. Thomas-Vaslin (biology of the immune system), A. Soto and C. Sonnenschein (biology of cancer at Tufts, Boston). At my suggestion, A. Soto was appointed to the Blaise Pascal chair at ENS, for twelve months spread between 2014 and 2016. A. Soto is the director of the Boston laboratory at which I have been Adjunct Professor since 2012. Before her regular stays at ENS, I spent long work periods there, which will resume starting in the autumn of 2016.

After a stay of three very stimulating months at the IEA in Nantes in 2014, the director of this institute (S. Jubé) proposed that I launch a three-year renewable project. This project, under the rather ambitious title "Laws of gods, humans, and nature", started by a dialogue between disciplines and cultures, which got underway in the course of these stays, with a Chinese jurist (A. Zheng), an historian of Muslim law (Y. Aykan), and an Indian historian (A. Bhalla). On the bases of a colloquium I organized in Nantes in October 2015, I will edit a volume to be published by Spartacus IDH, which will compare the various meanings and different histories of the delicate and central notion of "law" in the natural and the social sciences. Each year a post-doc is assigned by the IEA to this project (see N. Perret below).

Leadership of the MSCS (Cambridge U.P.) and participation in ten editorial teams of international journals are only one component of my activity at the international level. In fact, since July 2012, I have been invited to give fourthy-some lectures (seminars or colloquia) abroad, particularly in the USA, Great Britain, Sweden ... and during a trip "around the world in 40 days", from west to east as a result of linking three invitations, to China, New Zealand, and Chile (2014-15) (see: `http://www.di.ens.fr/users/longo/exposes-tous.html#INTRODUCTION14`)

The most important international exchange, however, is the one made possible by my commitment as adjunct professor at Tufts University in Boston. On the occasion of these visits, I accepted invitations to give talks at M.I.T. (September 2012) and in New York (CUNY, September 2013). The influence of our theoretical explorations in biology for the epistemology of economy, in Great Britain and the USA, is a novelty that I may decide to pursue.

5 Teaching activity

- **University of Pisa, from 1971 to 1989** (about four years leave, GB, USA, Holland): "Teoria e Metodi di Ottimizzazione", "Metodi Matematici per l'Informatica", "Logica Matematica", from assistant to Full Professor.

- **Carnegie Mellon Univ**: "Formal Languages and Computability" (undergraduate) and "Recursion, Categories and Polymorphism" (graduate course), academic year 1987/88.

- **École Normale Supérieure**, Paris (Invited Professor, Dept. Math. and Computer Science): Functional Languages and a course of D.E.A. (Master 2), October 1989 - May 1990.

- **ENS-ParisVII- Polytechnique**: **D.E.A.** (Master 2) courses in Computer Science, with P.-L. Curien, from 1990/91 to 1993/94.

- **ENS-ParisVII-Polytechnique-ParisXI-CNAM**: an introductory and an advanced course "Types et calculabilité" of **D.E.A.** (later Master 2) in Computer Science, from 1995/96 to 2006.

- **ENS-ParisVI/VII-Polytechnique**: **DEA, Master** in Cognitive Science: courses in Théorie de la Démonstration et des Types, from 1998 to 2004, on different aspects of modelization and of calculability (discrete vs. continua) to 2007.

- **ENS**, Introductory course to logic : "Éléments de Théorie de la démonstration" students in maths and philosophy, January and February 1996.

- **ENS**, free courses: "Six leçons sur l'incomplétude : logique, mécanique quantique", in collaboration with T. Paul, mathematics, CNRS-ENS, January and February, from 2008 to 2011.

- **Univ. Roma III**: PhD Classes, April-May 2009.

- **ENS**, free courses: "Indécidabilité logique, et aléatoire physique", February and March 2010 video-recorded at the ENS, Savoirs en multimedia (Knowledge in multimedia)).

- Spring Schools, research group (GDR) for programming: courses in Nice (March 1991), Bordeaux (April 1992), St. Malo (April 1993) and Toulouse (March 1994).

- Intensive Doctoral Courses (10 hours in a week); Turin (June 1993) and Rome (February 1994).

- Summer School, Logic, Language and Computation (10 hours in a week), Copenhagen, August 1994.

- Scuola Superiore dell'Università di Catania (10 hours in a week) April, 2000.

- Exposés at the **ENS** (research and teaching):
  "Logic and Calculability" (introductory day in Cognition, Nov. 1992); "Irrationalities of Logic" (Seminar of Philosophy of Mathematics, organized by P. Cartier, F. Loi, R. Thom, February 1993); "Memory and Deductive Systems" (Lecture part of a cycle on Memory in Biology, Computer Science and Philosophy, February 1994); "For a foundation of mathematical knowledge" (Seminars on History and Epistemology of Mathematics, March 1996); "The Foundations of Arithmetic and the 'Phosphorus Content in the Brain' (Frege)" ELSAP Day, Jourdan, January 1997; "On demonstrations of indemonstrable theorems" (Seminar of Philosophy of Mathematics, May 1997); "Mathematical Infinity, Machines and Methaphores" (Group "La Pensée des Sciences" ("The Thought of Science"))), May 27, 1998;
  "Mathematics and Cognition: since the geometric intelligibility of the sensitive space" (with B. Teissier), 17 February, 1999 (see Longo's website:

Geometry and Cognition); "Memory and objectivity in mathematics" (Seminar of Philosophy of Mathematics, March, 2000); "Expressiveness and logical incompleteness" (short course, 2 or 4 hours, within the framework of the Intermediate Option ENS in *Science Cognitives* (Cognitive Science), November '96, '97 and '99, February '00, November '00, January '02); "The Foundations of Maths and the Metaphor for Brain" (Seminar of Philosophy of Mathematics, June 2002).

The following presentations are recorded (audio and video) and can be downloaded from the ENS (Savoirs en multimedia (Knowledge in Multimedia)): website: The Philosophy of Mathematics, October 24, 2003; Panel discussion around the notion of Three bodies, classical-quantum, discrete-continuous, September 29, 2004; Dynamics of Thinking in Mathematics: Proof principles vs. principles of construction, April 29, 2006; Continuum vs. discrete: Physics, Mathematics, Computing, May 3, 2006; Presentation of the French version of the book [2], November 20, 2006; the Master course of 2010. More videos are accessible from my web page, till 2018.

- Member of the Pedagogical Council of the **DEA** (Master 2) in Cognitive Science (2000-04).

6 Theses Supervised

6.1 "Master Degree", University of Pisa *(only research theses are mentioned (cum laude)):*

- P. Giannini "Calcolabilità su strutture astratte" Dip. di Informatica, Pisa, 1979. *(teaching and research, Univ. Torino)*

- A. Bosisio "Operatori di enumerazione e topologie deboli" Dip. di Matematica, 1979 *(Researcher in industry).*

- B. Mugnani "Metodi deduttivi per l'assegnamento di tipi" Dip. di Informatica, Pisa, 1982 *(Researcher in industry).*

- S. Martini "I funzionali di Kleene e Kreisel e gli operatori ricorsivi" Dip. di Informatica, Pisa, 1983. *(Ph. D., Informatica Pisa; Prof. Ordinario, Udine and Bologna, since 1996)*

- E. Moggi "Categorie cartesiane chiuse in teoria dell'enumerazione" Dip. di Informatica and Scuola Normale Superiore, Pisa, 1983. *(Ph. D., Computer Sci. Edinburgh Univ.; lecturer, Edinburgh Univ.; Professore Ordinario, Genova, since 1992)*

- F. Ruggeri "Convergenza in spazi di filtri ed operatori di Turing" Dip. di Matematica, Pisa, 1984. *(1985-88: Ph. D., Computer Sci. Univ. of Chicago; Olivetti Researcher, Pisa)*

- E. Paglia "Il secondo ordine nel polimorfismo dei tipi di dato" Dip. di Informatica, Pisa, 1984.

- A. Asperti "Strutture categoriali per la semantica denotazionale" Dip. di Informatica, Pisa, 1985. *(Ph. D., Informatica Pisa; Researcher (Chargé de Rech.) at INRIA, 90-92; Prof. Associato then Ordinario, Bologna, since 1993)*

- G. Monteleoni "Alcuni aspetti semantici della programmazione funzionale" Dip. di Informatica, Pisa, 1985. *(1987/88: CNR grant, Computer Sci., CMU; Researcher at IRI , Pisa)*

- R. Amadio "Semantica dei tipi parametrici" Dip. di Informatica, Pisa, 1985. *(Ph. D., Informatica Pisa; Researcher (Chargé de Rech.), CNRS, Nancy, then Professor , U. Marseille, then Paris VII)*

- R. Di Cosmo "Isomorfismo fra tipi e type-checking" Dip. di Informatica and Scuola Normale Superiore, Pisa, 1986. *(Ph. D., Informatica Pisa; Maître de Conf., Computer Science , E.N.S., Prof. Paris VII)*

- P. Di Gianantonio "La semantica degli intervalli per il polimorfismo espilcito" Dip. di Informatica and Scuola Normale Superiore, Pisa, 1986. *(Ph. D., Informatica Pisa; I.B.M. award for Computer Science Thesis; teaching and research, Univ. Udine, since 1991).*

- F. Barbanera "Intuizionismo e la nozione di formula come proposizione" Dip. di Informatica, Pisa, 1987. *(Ph. D., Informatica, Torino; teaching and research, Univ. Torino, since 1991)*

- A. Bucciarelli "Teoria generalizzata della ricorsività in alcuni modelli del lambda-calcolo" Dip. di Informatica, Pisa, 1987. *(Ph. D., Informatica Pisa; CHM grant, E.N.S.; teaching and research at Rome, then Paris VII, 1999)*

- D. Lepore "Convergenze non topologiche, stabilità, sequenzialità" Dip. di Informatica, Pisa, 1987. *(Researcher in industry).*

- G. Castagna "Teoria dei tipi per 'Object Oriented Programming'" Dip. di Informatica, Pisa, 1990. *(CR, then DR, CNRS, LIENS, since 1994).*

6.2   DEA or Master II

- G. Santini **Domaines et systèmes dynamiques**. DEA Semantics, Proofs, Programming. 1996-1997.

- C. Truchet (ENS) **Continuité non-topologique**. DEA SSemantics, Proofs, Programming. 1997-1998.

- S. Vacca **La forme finie du theoreme de Kruskal**. DEA Semantics, Proofs, Programming. 1996-1997.

- P.-S. Graillou, **Aspects cognitifs des preuves visuelles**. DEA Cognitive Sciences. 1998-1999.

- G. Halimi, (ENS) **Sémantique de polymorphisme**. DEA Philosophy. 1999-2000.

- M. Mossio, **Constitution d'invariants spatiaux**. DEA Cognitive Sciences. 2001-2002.

- P. Bucholc (co-direction de stage), **Les suites de Godstein et la prouvabilité**. DEA Cognitive Sciences. 2001-2002.

- E. Tendero, **Démontrabilité et indémontrabilité : un théorème de Friedman**. DEA Mathematical Logic. 2001-2002.

- B. Saulnier, **Information et entropie topologique**. DEA of Computer Science, SPP. 2001-2002.

- J. Narboux, **Généricité dans les systèmes polymorphes**. DEA of Computer Science, SPP. 2001-2002.

- A. Viarouge, **Cognition in Mathematics: numbers and space**, DEA Cognitive Sciences, 2003-2004.

- G. Hoyrup, **Calculabilité et systèmes dynamiques**, DEA Computer Science - SPP, 2003-2004.

- A. Kolcak **Indécidabilité computationnelle et imprédictibilité dynamique**, DEA Computer Science - SPP, 2004-2005.

- M. Montevil **Etats critiques étendus**, Master II in Cognitive Sciences, 2005-2006.

- G. Delalleau **Bifurcations of Hopf and irreversible dynamics**, Master II in Mathematics, Paris VII, 2007-2008.

6.3 Doctoral Thesis, *(dates of the Defense, since 1982, in Italy)*

- S. Martini **"Modelli non estensionali del polimorfismo in programmazione funzionale"** Dip. di Informatica, Pisa, 1988 *(Researcher then Prof. Ordinario, Udine, 1996; Bologna 2002)*

- A. Asperti **"Categorical methods in the theory of functional, logic and parallel languages"** Dip. di Informatica, Pisa, 1989. *(post-doc then researcher INRIA, 89-92; Prof. ordinario, Bologna, 2001)*

- G. Ghelli **"Data types for a higher-order database language: semantics and type-checking"** Dip. di Informatica, Pisa, 1989. *(Researcher then Prof. ordinario, Pisa, 2002)*

- S. Berardi (supervised in collaboration with M. Dezani) **"Proof Theoretic aspects of system F"** Dip. di Matematica, Torino, 1989. *(Researcher then Prof. ordinario, Torino, 2002).*

- R. Amadio **"Recursion and subtyping in lambda calculi"** Dip. di Informatica, Pisa, 1991. *(post-doc LIENS, 90-91; researcher CNRS, Nancy, then Professor, U. Marseille, then Paris VII)*

- R. Di Cosmo **"Isomorphisms of types"** Dip. di Informatica, Pisa, 1993. *(assistant professor, ENS; Prof. Paris VII, since 1999).*

- G. Castagna "**fondements fonctionnelles de la Programmation Orientée Objets**" Paris VII, January 1994. *(CR (researcher), then DR (research director), CNRS, LIENS, since 1994).*

- A. Bucciarelli (supervised mainly by P.L. Curien) "**Cohérence et Stabilité pour les langages sequentiels**" LRI, Orsay, October 1994. *(grant CE-CHM 1993-95; teaching and research at Rome, then Paris VII, 1999).*

- R. Bellucci "**Sistemi formali e Modelli per il Polimorfismo parametrico**" Università di Siena (and LIENS), January 1996 *(Researcher at Eurosat).*

- Chen Gang (supervised in collaboration with G. Castagna) "**Sous-typage et conversions de types**" University of Paris VII (and LIENS), December 1998 *(Associate researcher, Univ. South Australia, then Boston Univ.).*

- F. DeJaeger "**Calculabilité sur les réels**" University of Paris VII (and LIENS), November 2003 *(Researcher at Apple).*

- B. Saulnier, "**Aspects multi-chelles de l'information : de la physique à la biologie**", September 2006 *(post-doc, Univ. Leiden, then "quant" at Merryl Lynch).*

- M. Mossio, "**Adéquation théorique et maîtrise expérimentale : un enquête intersciplinaire en sciences cognitives**", October 2006 *(post-doc, CR, sect. 35 of the CNRS).*

- M. Hoyrup "**Computability, randomness and ergodic theory on metric spaces**" June 2008 *(CR-CNRS, INRIA, Nancy).*

- C. Rojas "**Computability and Information in models of randomness and chaos**" June 2008 *(École Polytechnique Scholarship, Mathematics, then a 4 years post-doc at the Fields Institute, Canada; professor, U. Santiago, Chile).*

- P.-G. Sbrissa "**Simulations informatiques, histoire d'un constructivisme**" January 2011 *(co-directed, Philosophy, EHESS; Journalist)*

- G. Frezza "**The concept of Interaction: crossovers among biology, logic and philosophy**" April 2011 *(o-directed, Philosophy, Univ. Roma III; post-doc Rome III).*

- M. Montévil "**Temps Biologique et Transitions Critiques Etendues**", October 2011, *École Doctorale Frontière du Vivant, Paris Descartes; post-doc, Biology Dept., Tufts University, Boston, and Paris VII, Paris.*

- N. Perret "**Epistémologie constitutive pour les sciences du vivant ; sur la catégorie de causalité en biologie**", June 2013, co-directed with M. Bitbol, *École Doctorale Lettre/Sciences - 540, ENS, Paris; post-docs Pascal Chair, then IEA Nantes, until 2016.*

- P. Villoutreix "**Aléatoire et variabilité dans l'embryogenèse animale ; une approche multi-échelle**", July 2015, co-directed with N. Peyriéras, *École Doctorale Frontière du Vivant, Paris Descartes; post-doc, Biology Princeton.*

- A. Abbott "**Value Indefiniteness, Randomness and Unpredictability in Quantum Foundations**", November 2015, co-directed with C. Calude, *École Doctorale Lettre/Sciences - 540, ENS, Paris, et Mathematics/Computer Science Auckland University, NZ; post-doc, Institut Néel, Physics, University of Grenoble, France.*

Ongoing Thesis:

- J. M. Catherin (Thesis in co-direction with JM. Besnier, Doctoral School P. IV, from October 2012: foundations of Mathematics; deceased in December 2017); S. Biasoni (Thesis in co-direction with J. Lassègue, Doctoral School in Litterature/Sciences - 540, ENS, Paris, from October 2015: Epistemology)

Direction of post-docs

- G. Pulcini (scholarship from the City of Paris), 2008-09 ;

- A. Marinucci (scholarship from the City of Paris), 2012-13 ;

- E. Pagni (scholarship from the City of Paris), 2013-14 ;

- N. Perret, IEA of Nantes, project *Lois des dieux, des hommes et de la nature*, 2014-16.

Referee and/or jury member for Thesis/Habilitation

R. Amadio (June 94), S. Soloviev (September 94), L. Boi (December 1997), R. Di Cosmo (March 1998), A. Carbone (January 1999), L. Colson (January 1999), M. Fernandez (September 2000), G. Castagna (January, 2002), O. Bournez (December 2006), O. Michel (December 2007), J.B. Joinet (December 2007), A. Bucciarelli (November 2009). J. Lassègue (October 2010, Paris 5), P. Uzam (November 2013, Paris 7).

Theses referee or examiner, since 1990

Couronné (December 1990), Fouda (December 1992), Jiang (June 1993), Chillan (September 1993), Monsuez (January 1994), Compagnoni (Nijmegen NL, January 1995), Boldini (February 1995), Jacquet (September 1995), Xavier Gouy (December 1995, Paris VII), Crolard (December 1996, Paris VII), Bastonero (December 1996, Paris VII), Pravato (February 1997, Torino), Pocholczyk (April 1997, Paris VI), Lenzi (June 1997, SNS, Pisa), Macjik (May 1998, Roma), Saibi (March 1999, INRIA-Paris VII), Thiénot (June 1999, Paris VI), V. Schachter (December 1999, Paris-Orsay), D. Chemouil (Toulouse, September 2004), D. Hainri (December 2006, Nancy), A. Hazan (December 2007, Paris XIII), G. Giannini (April 2008, Urbino), M. Caponigro (April 2008, Camerino), M. Toscano (March 2009, Bergamo), C. Chalons (September 2014, Paris 7), M. Pistone (July 2015, Philosophie, Roma III, and Institut de Mathématiques de Marseille (I2M)), I. Wilkins (January 2016, Goldsmiths Univ., London).

Director of several Thesis minors at ENS (Magistère, in Mathematics and Computer Science).

7 Invited lectures and seminars

University College of Swansea, G.B. (Mini Lambda-Conference, Mathematics Dept.; host: R. Hindley), September 1974: "Non-strict functions and their representation in Axiomatic Recursion Theories",
February 1980: "The countable functionals and lambda calculus models".

Scuola Normale Superiore, Pisa: series of seminars:
(A.A. 74/75): "Ricorsività generale e la gerarchia aritmetica",
(A.A. 75/76): "Introduzione al lambda-calcolo ed alla sua semantica",
(A.A. 76/77): "I teoremi di incompletezza di Gödel e Gödel-Rosser",
(A.A. 81/82): "Strutture di tipi e senza tipi per la calcolabilità".
January 1990: "Strumenti logico-matematici per i linguaggi di programmazione".
January 1992: "Realismo matematico ed immagini mentali, discussione in scienze della conoscenza".

C.N.R., Roma (I.A.C.; host: M. Venturini-Zilli),
June 1978: "Verso una Teoria dei Modelli del Lambda-calcolo"
October 1981: 1) "Il teorema di Paris-Harrington e le incompletezze matematiche dell'Aritmetica";
2) "Alberi di Böhm e la caratterizzazione semantica di proprietà del lambda-calcolo".

Utrecht University, Holand (Mathematisches Instituut; host: H. Barendregt), December 1978: "Plotkin's models of lambda calculus and type two Recursion Theory"
October 1982: "The hereditary partial recursive functionals".

Università di Torino (Dip. Informatica; host: M. Dezani), January 1979: "Un'introduzione alla Ricorsività nei tipi superiori";
December 1981: "Semantica operazionale vs denotazionale in lambda-calcolo".
June 1993: "Il Teorema di Genericità "
June 1993 (Dip. di Fisica; host: F. Pegoraro): "Poincaré e Weyl fra Fisica e fondaz. della matem.: oggi".

Amsterdam University, Holand (Mathematisches Instituut, Intercity Seminar; host: D. Van Dalen), Septembre 1979: "Effectiveness in some Ershov spaces for the partial continuous functionals".

Oxford University, G.B. (Mathematical Institute; host: R. Gandy), February 1980: "Generalized Myhill-Shepherdson theorem and its applications to lambda-calculus models".

University of Chicago, U.S.A. (Mathematics Dept.; host: R. Soare), March 1980: "An overview of recent results in lambda-calculus syntax and semantics".

Universidad Aut. Nac. de Mexico, C. de Mexico (dept. de Matematica; host: F. Bracho), December 1980: "Set-theoretical lambda-models and their applications".

M.I.T., U.S.A. (Lab. for Computer Science; host: A. Meyer), February 1981: "Recursion Theory in higher types: relating Ershov and Hyland approaches",
October 1984: "Categories of partial morphisms and the semantics of types".
October 1985: "The semantics of types and terms for (higher-order) λ-calculi".

January 1987: "Lambda-calculus: *the* Theory of Conputable Functions"

July 1987: "The denotational meaning of impredicative Type Theories".

University of Indiana, Bloomington, U.S.A. (Computer Sci. Dept.; host: M. Wand),

September 1981: "The Lambda-calculus: its syntax, its semantics and how they relate".

Yale University, New Haven, U.S.A. (Mathematics Dept.; host: A. Macintyre), September 1981: "An introduction to the model-theory of lambda calculus".

E.T.H., Zurich, C.H. (Math.-Comp. Sci.; host: E. Engeler), October 1982: "Some connections between lambda-calculus models and computability in abstract structures".

Oberwolfach Forschungsinstitut, R.F.T. (Organizers: Felscher, Schwichtemberg), April 1983: "Relative gödel-numberings and recursion theory in higher types".

Università di Padova (Ist. Matematico; host: R. Ferro), May 1983: "Informatica e Matematica: metodi di indipendenza in problemi combinatori".

Universitat Dortmund, R.F.T. (Leh. Informatik; host: E. Börger), April 1984: "Analytic methods in Computer Science".

University of Maryland, U.S.A. (Workshop on Semantics, Special Year in Logic and Computer Science; organizers: K. Lopez-Escobar, C. Smith), October 1984: "Provable isomorphisms, invertible terms and continuous models".

Imperial College, London, G.B. (Computer Sci. Dept.; host: S. Abramski), April 1985: "Solvable domain equations in all models of typed and second order lambda-calculus".

University of Edinburgh, G.B. (Computer Sci. Dept.; host: G. Plotkin), April 1985: *same as at the Imperial College.*

Carnegie Mellon University, U.S.A. (Computer Sci. Dept.; host: D.S. Scott), November 1985: "Categories and models of various lambda-calculi"; June 1986 (host: R. Statman): "From Gödel-numberings to higher types and higher order".

October 1987 (host: D.S. Scott): "Some aspects of impredicativity".

Stanford University, U.S.A. (CSLI; host: J. Meseguer), November 1985: *same as at M.I.T. (October 1985);*

January 1988 (Mathematics Dept.; host: S. Feferman): "Modest Models and Motivations of impredicative Type Theories".

Banach Mathematical Center, Warsaw (host: H. Rasiowa), December 1985: 1)*see article [49];*

2) "The higher-type Banach-Mazur functionals in recursion theory".

Paris VII, Paris (L.T.I.P.; host: P.L. Curien), January 1986: 1) *same as at M.I.T. (October 1985)* ; 2) "Modèles sans types pour les calculs d'ordre supérieur".

(Logic group; host: J.Y. Girard) January 1987: "Calculabilié sur les domaines de Scott et sur les espaces coherents".

(Logic group; host: C. Berline) January 1995: "Paramétricité, Théorème de Généricité et Soustypage".

Chalmers University, Göteborg (Programming Methodology Group; host: B. Nordstrom), September 1986: "Models for explicit polymorphism in Functional Languages"

June 1987 (delivered in Mastrand, *Workshop on Logic of Programming*)**:** *same as at M.I.T. (July 1987)***.**

Pennsylvania State University (Math. Dept.; *Mid-Atlantic Mathematical Logic Seminar*; host: S. Simpson), December 1987: "The Curry-Howard 'Types-as-Formulas' analogy and the Models of Combinatory Logic".

University of Pennsylvania, Philadelphia (Computer Sci.; host: V. B.-Tannen), May 1988: *same as Stanford, January 1988.*

Université de Marseille (Fac. Science Luminy; host: G. Blanc and A. Preller), April 1990: "The categorical meaning of various lambda-calculi: from type-free to higher order".

I.N.R.I.A., Rocquencourt -Paris (host: J.J. Levy), December 1989: "Quest: polymorphism and subtyping";
February - May 1990 Weekly seminars organized (and sometimes presented) by J.Y. Girard, G. Huet and G. Longo.

DEC-PRL, Digital - Paris Research Lab., Rueil-Malmaison (host: H. Aitkaci), June 1990: "An introduction to Quest: its types and its semantics".

III Reunion CE - Twinning"Typed lambda-calculus", Paris, Jan. 1991: "Type Theory and Object Oriented Programming".

Università di Milano (Department of Computer Science; host: N. Sabadini), January 1992: "Tipi, categorie e calcoli".

Università di Napoli (Department of Theoretical Physics; host: G. Trotteur), April 1993: "Logica, rappresentazioni mentali ed Informatica".

Stanford Research Institute (SRI, Computer Science; host: Workshop of the American Twinning "Lambda"), October 1993: "Invariant and Effective Polymorphism".

IReunion, NSF - Esprit Workshop on **"Functional and Object Oriented Programming"**, Stanford University, October 1993: "Overloading as Message passing".

I Reunion "Lambda-calcul" CHM (CE) Project **"Typed lambda-calculus"**, Univers. of Rome, November 1993: "Computations in Theories and Models".

Chinese Academy of Sciences, Pekin (Dept. of Comp. Sci.; host: Wong Ju), April 1994: "Types, Categories and Functional Languages" + "Overloading in a functional frame".

JiaoTong University Shanghai, Chine (Dept. of Comp. Sci.; host: Sun Yong), April 1994: "Recent advances in Type Theories".

CNRS et I.N.R.I.A. Lorraine, Nancy (CRIN; host: R. Amadio), June 1994: "Théories équationnelles du lambda-calcul et leur sémantique".

LMD, CNRS, Marseille (host: J.Y. Girard; réunion CHM, Typed Lambda), November 1994: "A (linear) Logic for Subtyping".

Institut Henri Poincaré, Paris (host: J. Petitot), January 1995: "De la théorie de la Démonstrations aux Programmes et aux Morphismes".

Informatika, Katholic Universitaat, Nijmegen (host: H. Barendregt), January 1995: "Polymorphism and the functional behaviour of terms applied to types: universality properties and subtyping".

CNR, Roma (Istituto di Psicologia, host: D. Parisi), February 1995: "Memoria e Matematica".

Università di Rome I (Dip. di Informatica, host: R. DeNicola), February 1995: "Impredicativita': teorie, semantica e risultati recenti in Teoria dei Tipi".

November 1995 (Dip. di Matematica, host: M. Fattorosi): "Sulle dimostrazioni di Teoremi indimostrabili".
(Dip. di Informatica, host: C. Boehm), April 1996: "Applicazioni ed osservazioni sul Cut-elimination".

Universidad de Vina del Mar, Chile (Escuela de Ingenieria, host: E. Perez Santi), April 1995: I. "Logic and Computer Science: from cloks to Proof Theory" and II. "Impredicativity: the general notion and some recent consequences in Type-Theory".

Universidad de Chile, Santiago (Depto. de Ciencias de la Computacion, host: R. Baeza-Yates), April 1995: "Proofs and programs: an introductory survey".

City University of N.Y., New York (Dept. of Computer Sci.; host: R. Parikh), June 1995: I. "Categories, programs and impredicative definitions" and II. "Reflections on Logic and Cognition".

University of Warsaw, Warsaw (Dept. of Computer Sci.; host: J. Tiuryn), July 1995: "Recent results in constructive proofs and categories".

ENST, Paris, September 1995: "Types et Objets pour le polymorphisme".

Università di Torino (HCM meeting, host: S. Ronchi), November 1995: "On the regularity of generic proofs".

ENS of Lyon (host: C. Paulin-Mohring), March 1996: "Le Polymorphisme dans les langages fonctionnels".

ENS, Jourdan, Paris (host: D. Dubois), May 1996: "Invariants et Notations en Mathématiques".

Centro Fiorentino per la Filosofia della Scienza, Florence (host: A. Cantini), October 1996: "Logica e Tempo in Informatica" (voir [170]).

EHESS, Paris (CAMS; host: J.-P. Desclés), June 1996: "Types Intuitionnistes et Structures Géometriques".
May 1997 (host: J. Petitot): "Imprédicativité et Théorie des Types: enjeu logique et résultats récents".

Instituto Superior Tecnico, Lisboa, Portugal (Department of Mathematics; host: A. Sernadas): "Proofs, morphisms and programs: a survey", February 12, 1998.

Università di Bologna (Department of Computer Science; host: A. Asperti): "Circoli vizioni: dalla logica ai sistemi dinamici", February 20, 1998.

Collège de France, Paris (LPPA; host: A. Berthoz): "Réflexions sur les fondements cognitifs de la géométrie", March 24, 1998.

Laboratoire des Maths Discrètes, CNRS, Marseille (Colloquium HCM "Types"; coordinator: I.Y. Girard): "From Logical circularities to Mathematical expressiveness. Impredicativity and dynamical systems", April 10, 1998.

Università di Roma I, Roma (Computer Sciences, Science; host: C. Boehm): "Circolarità ed Impredicatività in Logica ed in Matematica: dalla Teoria dei Domini a quella dei Sistemi Dinamici. April 21, 1998.

Università di Roma II, Roma (Department of Philosophy: host: A. Carsetti): "Logica e tempo in Informatica", May 19; "Infinito e dimostrazioni in Aritmetica", May 21, 1998.

Brandeis University, Boston (Department of Computer Science; host: H. Mairson): "Computability in Dynamical Systems via Domain Theory", June 25, 1998.

Conference on "Operations, Sets and Types". Invited lecture: "Vicious circles: in Logic and in Mathematics", Castiglioncello (It.), October 3-6,

1998.

Università di Pisa, Pisa (Department of Computer Science; host: G. Levi):
"Topologie e geometria in Informatica", October 26, 1998.

Pontificia Universitas Lateranensis, (Center for Phenomenological Studies;
host: A. Ales Bello): "Formalismi ed incompletezza, oggi, dopo Friedman e
Girard: riflessioni di un matematico applicato, a partire delle osservazioni
di Weyl (Il Continuo, 1918; La Simmetria, 1953), Wittgenstein (1928-36)
ed Husserl (Le Origini della Geometria, 1936)", November 28, 1998.

Workshop on "Methodology in Cognitive Sciences", lecture on "Mathe-
matical invariance and coding-dependence in Logic and Computer Science,
an issue in knowledge representation", Fondation des Treilles, Nice, Decem-
ber 7 - 13, 1998.

**First Annual Meeting of the Cofinanced Project "Tecniche formali per
la specifica, l'analisi, la verifica, la sintesi e la trasformazione di
sistemi software"**. Invited foreign lecturer: "Circolarità ed equazioni, in-
varianza e geometria, dalla Teoria dei Tipi ad altri aspetti dell'Informatica",
Roma, December 21 - 23, 1998.

Università di Genova, Genova (Department of Mathematics; host: P. Boero):
"Assiomatica e deduzione: dalla lettura degli assiomi di Euclide al teorema
di Kruskal-Friedman (FFF)"; Comune: "La resistibile ascesa della metafora:
il cervello è un calcolatore digitale", March 11 and 12, 1999.

Colloquium "L'existence en Mathématiques". Guest Conference: "Exis-
tence, coherence et constructions mathématiques possibles", Paris, March
27, 1999.

EHESS, Paris, Seminar "Histoires des Géométries" (host: D. Flement). Exposé:
"Les limites du formalisme: l'intelligibilité géométrique de l'espace", May
10, 1999.

University of Kyoto, Japan (Computer Sci. Dept., Workshop on Proof-
checking; host: S. Hayashi): "Impredicativity: the general notion and
some recent consequences in Type-Theory", May 15, 1999.

University of Keio, Tokyo, Japan (Philosophy Dept., host: M. Okada): "Cat-
egories, types and programs, in the context of mathematical knowledge"
and "Some remarks of Husserl's and Wittgenstein's and the understanding
of recent incompleteness results in Proof-Theory.", May 18 and 19, 1999.

Tokyo Inst. of Technology, Japan (Computer Sci. Dept, host: M. Takahashi):
"On the proofs of unprovable theorems.", May 20, 1999.

Scuola "Matematica e Musica": "Costruzioni di mondi sonori". Guest Con-
ference: "Costruzioni nello spazio e nel tempo, in Logica ed in Informatica",
Maratea, August 29 - 31, 1999.

Colloquium "Le réel en Mathématiques". Guest Conference: "Objectivité
et construction en Mathématiques", Cérisy, September 3 - 10, 1999.

The **1999 meeting of the British Logic Colloquium**. Invited lecture: "Proto-
type Proofs and Genericity in Type Theories", Swansea, Wales, September
23-25, 1999.

Università di Bologna, Bologna (Dipartimento di Matematica ed Informat-
ica; host: A. Asperti): "Sulle dimostrazioni dei teoremi indimostrabili",
September 27, 1999.

III scuola estiva di Logica, AILA-SILFS: "Circolarità logiche ed espressività
matematica" Cesena, Italy, September 28-30, 1999.

Centro di Filososfia della Scienza, Firenze: "I fondamenti della matematica e la metafora: il cervello è un calcolatore digitale (II)", November 5, 1999.

Colloquium "Le rationnalisme: science et philosophie en France et en Italie", Istituto Italiano per gli Studi Filosofici, Napoli: "Il costituirsi del "piano fenomenale" in Matematica, con la Matematica", December 10 - 11, 1999.

Università di Torino, Torino (Department of Informatics; host: M. Dezani): "Riflessioni sull'incompletezza: risultati recenti", 20 December, 1999.

University of Lisbon, Lisbon (Department of Informatics; host: V. Vasconcelos): "Continuous Structures in Computer Science: from domain equations to computations in dynamical systems", January 9, 2000.

Università di Roma III, Roma (Departments of Philosophy and Mathematics; host: M. Abrusci): "L'intelligibilità geometrica dello spazio ed i fondamenti della conoscenza (matematica)", February 7, 2000.

Università di Roma I, Roma (Department of Informatics ; host: A. Labella): "Incompletezze "concrete" in Aritmetica: dall'induzione formale al problema del carico induttivo", March 7, 2000.

Colloquium "Epistemologia aperta e filosofia della mente", Catania (Istituto di Studi Filosofici ed Epistemologici): "L'epistemologia della matematica e la filosofia della mente, fra geometria e linguaggi.", April 3 and 4, 2000.

Istituto Italiano di Cultura, Paris: "Il costituirsi dei concetti di numero e di spazio nella prassi della matematica", April 12, 2000.

Collège de France, Paris (Atelier Espace, host: M. Denis): "Les fondements cognitifs des mathématiques, entre espace et langage", April 17, 2000.

Olimpiadi Nazionali di Matematica, Cesenatico, It.: "Concetti e Deduzioni in Matematica", May 6, 2000.

Imperial College, London (Department of Computing; host: A. Edalat) "The geometric intelligibility of space and the foundation of mathematical knowledge", May 10, 2000.

Université de Paris VII, Paris (Equipe de Logique; host: P. Ressayre): "Le problème mathématique de l'espace et les fondements des mathématiques", May 15, 2000.

Colloquium "Mathématiques 2000: Mathématiques, calcul, ordinateurs", Paris (ENS): "The Difference between Diderot's clocks, Turing machines and concurrent systems", may 24, 2000.

Université de Paris VII, Paris (Labo. Preuves, Programmes et Systèmes; host: P.L. Curien, A Bucciarelli): "Réflexions sur les incomplétudes "concrètes" de l'Arithmétique et les preuves prototypes", June 8, 2000.

Colloquium "Conoscenza e cognizione", Firenze (It.): "Sulla natura della logica", November 7, 2000.

Colloquium "Geometria, intuizione ed esperienza", Castiglioncello (It.): "Concetti matematici ed oggetti della fisica", December 1 and 2, 2000.

Journées d'épistémologie (physique, logique, mathématiques), IHP, Paris : "Principes de preuve et principes de construction: la notion de preuve, en mathématiques, est-elle récursive?", December 5 and 6, 2000.

Annual Conference TYPES'2000. Invited lecture: "Formal unprovability of provable properties of numbers and prototype proofs in Type Theory", Durham, UK, December 8 - 12, 2000.

INRIA, Roquencourt (Colloquium; host: M. Kern): "Des fondements mathématiques possibles pour la prochaine machine", January 16, 2001.

Colloquium Mathematics and Cognition, University of Rome II: "Mathematics, intentionality and meaning", February 9 and 10, 2001.

Università di Roma I, Rome (Departments of Philosophy , host: C. Cellucci):"I fondamenti della Matematica, le macchine, il cervello", February 15, 2001.

Séminaire Heidelberg-Nancy-Strasbourg, Nancy (host: P. Nabonnand): "Le problème de l'espace, les fondements des mathématiques et l'informatique", March 30, 2001.

Università dell'Aquila, Aquila, It. (Department of Computer Science, host: B. Intrigila):"Codifiche e calcoli: alcune differenze fra gli "orologi" di Diderot, le Macchine di Turing ed il cervello", April 9, 2001.

Colloquium "The categorial researches: Husserl's Logic", (Archives Husserl, ENS, Paris): "From the "genealogy of concepts" (Riemann) to the "epistemological elucidation" (Husserl) in the foundations of Mathematics, today", April 27 - 28, 2001.

Cambridge University, Cambridge, GB (Computer Science Dept., host: A. Pitts): "On the formal unprovability of some provable properties of numbers", May 17, 2001.

Journée "Le concept de modèle interne en neurosciences", Collège de France, Paris : "Représentations de l'espace et du temps en mathématiques et en physique, leur rôle en cognition", June 15, 2001.

Colloquium "En honneur de Gilles CHATELET", Paris : "La métaphore et le geste dans la preuve: relire l'incomplétude mathématique des formalismes avec Gilles Châtelet, au-dela de la Gödélite", June 27-29, 2001.

AMS/SMF Meeting *(American Mathematical Society / Societé Mathématique de France)*, Lyon: "Foundations of mathematics: some challenges in the interaction with other sciences", July 17-20, 2001.

International Colloquium "Géométrie au vingtième siècle : 1930-2000", Institut Henri Poincaré, Paris: "Les fondements géométriques du calcul et de la logique; les fondements cognitifs de la géométrie", September 24 - 29, 2001.

International Colloquium "The Mathematics of Ennio De Giorgi", Scuola Normale Superiore, Pisa: "Concepts and conjectures vs axioms and proofs: reflections and results on and from De Giorgi's foundational approach". October 24 - 27, 2001.

Queen Mary and Westfield College, London (Computer Science Dept., host: E. Robinson): "Unprovability and Prototype Proofs in Type Theory", January 18, 2002.

Università di Pisa, Pisa (Department of Informatics, host: G. Ghelli): "Indimostrabilità "concreta" in Aritmetica e "giudizi geometrici"", February 19, 2002.

International Colloquium **Cognition, Meaning and Complexity. Self-Organization in Cognitive Systems**, Université de Rome II, Rome: "Complexity as the nesting and interaction of levels of organization", June 14-15, 2002.

International Colloquium **The cognitive foundations of mathematics** (Epistemology and Cognition as foundational issues in Mathematics), Villa Mirafiori, Univ. Roma I, Rome: "Naturalizing Mathematics: the cognitive roots of Mathematics' constructed effectiveness", September 9 - 10, 2002.

Colloquium **Giulio Preti a trent'anni dalla scomparsa**, Castello Pasquini, Castiglioncello (LI): "Rationality, computations and forms: a critique of a scientific experience/ Razionalita', calcoli e forme: riflessioni su una esperienza scientifica", October 17-19, 2002.

University of Nijmegen, Nijmegen, The Netherlands (Mathematics and Computer Science Depts., host: H. Barendregt): "Forms, Complexity and Information in some Natural Phenomena", December 9, 2002.

ENS, Paris (Seminar "Formes Symboliques"; host: J. Lassègue): "Abstraction, symbolisme et rigueur : l'objectivité construite des Mathématiques", Salle des Actes 16h - 19h, December 17, 2002.

Annual Meeting of the bf Cofinanced Project "CoMeta - Computational Metamodels". Invited foreign lecturer: "Al di là della codifica: un quadro concettuale per l'informazione e la complessità nei fenomeni naturali", Venezia, December 19 - 21, 2002.

Università di Milano, Milano, (Departments of Philosophy, host: R. Fabbrichesi-Leo): "Fondamenti delle Matematica e filosofia delle scienze naturali", January 27, 2003.

Tata Institute of Fundamental Research, Bombay, INDIA (School of Tech and Computer Science, host: R. Shyamasundar): Lecture I: "Reflections on concrete incompleteness". Lecture II: "Foundations of Mathematics and Philosophy of Natural Sciences", February 20 and 21, 2003.

International Conference on Theoretical Neurobiology, National Brain Research Centre, New Delhi, INDIA, invited lecture: "A conceptual frame for Complexity, Information and Causality", February 24-26, 2003.

Indian Institute of Technology, Delhi, INDIA (Dept. of Computer Science, host: S. Prasad): Lecture I: "Some topologies for computations." Lecture II: "Physical Space and Time and the Foundations of Mathematics", February 27, 2003.

Ministry of Foreign Affairs and CNR: conference of Italian scientists abroad, Roma: "Riflessioni sulla diaspora scientifica italiana", March 10-12, 2003.

ENS, Paris (Laboratoire "La Pensée des Sciences"; host: C. Alunni): "Catégories et dynamiques de la pensée : l'importance d'un cadre conceptuel ouvert et quelques applications spécifiques", March 26, 2003.

Centro Enriques ed Università di Pisa, Livorno, "Matematica e scienze della natura, a partire da Enriques", April 4, 2003.

Workshop: **Mathématique, Informatique, Philosophie**, Univ. Paris VII and Paris I, Paris : "Discret vs. continu mathématiques et causalité physique", April 24 - 26, 2003.

Università di Pisa, International School of Graduate Studies, Pisa: "Intelligibility of Space, the Continuum and Theories of Knowledge", May 9, 2003.

Université de Marne la Vallée, (Departments of Mathematics and Informatics; host: M. Cannone) , Marne la Vallée: "Le rôle de l'espace dans les fondements des mathématiques et de l'informatique", May 27, 2003.

Conference on **Cognition, Meaning and Reality**, Rome, invited lecture: "Mathematical structuring of causality", June 6-7, 2003.

European Software Engineering Conference and ACM SIGSOFT Symposium, Helsinki, Finland, invited lecture: "Complexity as nesting and

interaction of organization levels in some natural phenomena", September 1-5, 2003.

Journée **Intrications philosophie - sciences de la nature**, ENS, Paris: "La philosophie des mathématiques : de la scolastique platonisme/formalisme une composante d'une philosophie de la nature", October 24, 2003.

University of Sao Paulo, Brasil, (Dept. of Computer Science, host: M. Finger): "A cognitive investigation of concrete incompleteness", November 3, 2004.

University of Campinas, Brasil, (Center for Logic and Cognition, host: W. Carnielli): "Some aspects of information and complexity in natural phenomena", November 5, 2004.

University of Rio de Janeiro, Brasil, (Dept. of Computer Science, host: I. de Castro Dutra): "On the formal unprovability of some provable properties of numbers", November 10, 2004.

Ramifications of Category Theory, a Workshop in honour of W. Lawvere, Università di Firenze: "Categories against the absolute: relitivising constructions and "l'esprit de géométrie"", November 18-23, 2003.

Annual Meeting of the Cofinanced Project **CoMeta - Computational Metamodels**. Invited foreign lecturer: "Computer Modelling and Imitation in Natural Sciences", Udine, December 15 - 18, 2003.

King's College, London, (Computer Science Dept., host: T. Maibaum): "Computational vs continuous models and causal relations", January 28, 2004.

Annual Meeting **Didattica della Matematica**. Invited lecturer: "Linguaggio e gesto: dai fondamenti alla cognizione", Pisa, 5 - February 6, 2004.

Università di Milano, Milano, (Departments of Philosophy, host: C. Sini): 1 - "L'incompletezza concreta dei formalismi logici ed il senso nel segno (matematico)"; 2- "Determinazione fisica e formalismi logici: da Laplace a Turing, passando per Poincaré (cenni ad una artificialità incompleta)", March 10 - 11, 2004.

Journée **Intérêt de la notion de symétrie : comme paradigme interdisplinaire** , Guest Conference: "Symétries et structures causales", Paris, March 18, 2004.

Università di Roma I, Roma, (Departments of Mathematics, host: C. Berardi): "Fondamenti della matematica, fra processi cognitivi e filosofia della natura", May 4, 2004.

Journées sur la **Philosophie de la Nature : les mathématiques, la physique et la biologie en question** , conférence invitée: "Niveaux d'organisation et relations causales en science de la nature", Paris, May 13-14, 2004.

Conference on **Computing and Philosophy**, invited lecture: "Computer imitation and mathematical understanding", Pavia, Italie, June 3 - 5, 2004.

Colloquium **Détermination et compléxité**: "Aléas, déterminisme et Programs: les enjeux du continu vs. le discret mathématique", Cérisy, Fr., June 22 - 29, 2004.

Conference on **Dynamic Ontology: an enquire into systems, levels of reality and causality**, invited lecture: "The structures of causality and computer vs. mathematical modelling", Trento, Italie, September 8 - 12, 2004.

Colloquium **Non-linéarité, irréversibilité et complexité**, conférence invitée: "Complexité structurelle: le continu vs. le discret", Paris EHESS, October 7-8, 2004.

Conference **Alan M. Turing, pour le cinquantenaire de sa mort**, invited Conference : "De la difficulté de se mettre dans la peau d'un ordinateur: la Machine et le Vivant", Metz, October 15, 2004.

Conference **Alan Mathison Turing. L'uomo, la macchina, l'enigma**, invited Conference : "Dalla catastrofe della scrittura alla "Discrete State Machine": espressività e limiti del tagliare il mondo con l'accetta", Milano, November 3 - 4, 2004.

Imperial College, London, (Computer Science Dept., host: A. Edalat): "Continuous vs discrete dynamics; some history, some concepts, one theorem", January 26, 2005.

XXII meeting of the **Associazione Italiana di Logica e sue Applicazioni (AILA)**, conferenza di apertura: "Dai fondamenti della matematica alle scienze della natura: l'importanza dei risultati negativi." Pisa, February 10 - 13, 2005.

Workshop on "**Theoretical Biology**", at the National Brain Research Centre, New Delhi, INDIA, invited lecture: "From local physical criticality to the extended criticality of life", February 14 - 15, 2005.

Journée sur **La preuve et le raisonnement : visualization et structures**, REHSEIS - CNRS, Paris, (organizer: M. Panza): "Intuition et construction en mathématique", March 14, 2005.

Università La Sapienza, Roma, (Department of Informatics, host: S. Guerrini): "Calcolabilità e dinamiche: predittibilità vs. decidibilità", March 18, 2005.

Colloquium **Le logique et le biologique**, Paris, invited Conference: "L'originalité de nos formalismes laplaciens vs. la criticité dynamique du vivant", April 22, 2005.

Colloquium **À partir de l'origine de la géométrie de Husserl**, Paris, invited Conference: "Fondements des mathématiques: arithmétique vs géométrie, les enjeux pour une philosophie des sciences de la nature", may 14, 2005.

Colloquium **La preuve mathématique : logique, histoire, philosophie**, Lille, invitation to the debate: "L'incomplétude mathématique des formalismes et la complexité intrinsèque de la preuve", may 24 - 28, 2005.

École **Mathématiques et cerveau**, Paris, coordination and introductory speech to the debate: "Mathématiques, cognition et espace", June 14, 2005.

Colloquium **Intelligence de la complexité : science et pragmatique**, Cerisy, invited Conference: "Complexité critique : le discret vs. le continu mathématiques", June 23 - 30, 2005.

Laboratoire de Génomique Fonctionnelle (CNRS et Université Pierre et Marie Curie, host: C. Auffray), Villejuif : "L'incomplétude causale du paradigme du Program génétique et la singularité physique du vivant", September 29, 2005.

Colloquium **Turing, Goedel et Von Neumann: entre logique et biologie**, Nice, invited Conference: "Turing et Goedel au milieu du gué : de la détermination laplacienne vers la morphogénèse et le sens", November 9 - 10, 2005.

Laboratoire de Neurosciences Cognitives (LENA, CNRS et la Salpétrière, host: S. Baillet), Paris : "Imitations et modèles : le cerveau à la Turing et la situation critique du vivant", November 28, 2005.

Leiden University, Leiden (NL), (Biology Dept., host: H. van Mill): "Extended critical situations: physical causality vs. singularity and autonomy of life", January 10, 2006.

Universita di Siena, Siena, (Department of Mathematics, host: A. Ursini): "Da Poincaré a Turing: l'impredittibilità dei sistemi dinamici e l'indeicidiblita' computazionale sono nozioni correlate?", February 20, 2006.

Conference on **Rilievo culturale della Matematica**, Accademia di Livorno e centro F. Enriques, Livorno, conferenza su: "Fondamenti della matematica, fra processi cognitivi e filosofia della natura, a partire da Enriques", March 23 - 25, 2006.

Conference **Logic, Models and Computer Science**, Camerino, invited lecture: "Physical Determination, Unpredictability and Undecidability in Critical Processes", April 20 - 22, 2006.

ENS, Paris, **Séminaire interdisplinaire: La passerelle des Arts** : "Dynamiques de pensée en mathématiques: principes de preuve vs. principes de construction", Salle des Actes, 10h, April 29, 2006.

ENS, Paris **Séminaire "Formes Symboliques**; host: J. Lassègue : "Mathématiques et sciences de la nature. La singularité physique du vivant", au 45, salle des Résistants, 14h - 17h, may 2, 2006.

EHESS, Paris, Journée **Interfaces géométrie, physique et biologie** : "Géométrie du temps biologique", June 8, 2006.

Università di Torino, Torino, (Department of Informatics, host: M. Dezani): "Correlazioni fra impredittibilità dinamica ed indeicidiblita': alcuni concetti, a partire da Poincaré, ed alcuni risultati recenti su dinamiche unidimensionali", June 23, 2006.

Colloquium/École **Logique et Interaction: vers une géométrie du cognitif**, Cerisy-la-salle : "Structures causales et géométrie du temps biologique", September 19-26, 2006.

Neurofenomenologia Conference, Milano: "Processi cognitivi e la ragionevole efficacia della Matematica", October 4, 2006.

Franco-italian Conference: **Continuo e discreto**, Gargnano (Milano, It.) : "La determinazione fisica ed il continuo matematico (discussione)", October 5 - 7, 2006.

Université de Orsay, Orsay, (Department of Informatics, Grand Séminaire): "Que nous dit l'ordinateur du monde : entre informatique et sciences de la nature", October 11, 2006.

Università di Pisa, Pisa, (Lezione Galileana): "Dall'informatica alla biologia: la singolarità fisica del vivente", October 25, 2006.

Colloquium: **Federico Enriques et la science européenne**, Paris : "Principes de construction entre arithmétique et géométrie", December 8, 2006.

Theoretical Biology Colloquium: **À quoi sert la modélisation ?**, Centre Cavallès, Paris : "Imitations, modèles, schèmes", January 23, 2007.

Université de Nice, Nice, (Séminaire interdept., host: J. Kouneiher): "La question de la modélisation et la singularité physique du vivant", February 6, 2007.

Athens University, Athens, (Graduate Program in Logic, host: C. Dimitracopoulos): "Undecidability in Logic vs dynamical unpredictability", February 19, 2007.

Conference: **Mathematics and Truth: Fundamental Issues in Logical Research**, Pisa: "From Logic to the Natural Sciences: knowledge constructions and mathematical models", March 28, 2007.

Conference: **Deduction, Computation, Experiment. Exploring the notion of proof and model**, Bologna: "Processes as Deductions and Pro-

grams, a successful paradigm for Computing, a misleading metaphor in Molecular Biology", April 3-4, 2007.

Journée : **Schématiser la constitution de l'espace (et du temps)**, Collège de France, Paris: "Schèmes spatiaux du temps, continuité temporelle de l'espace", April 5, 2007.

Journée : "Epistémologie et mathématiques des systèmes complexes", CREA, Paris : "De la critique des principes physico-mathématiques aux changements de regard et d'espace des phases en biologie", June 5, 2007.

Colloquium : **La question des enchevêtrements hiérarchiques, en mathématiques et en biologie.**, Nice : "Différences et analogies entre autoréférences logiques et enchevêtrements-bouclages causaux chez le vivant", June 7-8, 2007.

France Culture: **Présentation du livre avec Francis Bailly**, Radiofrance, Paris: "Mathématiques et sciences de la nature. La singularité physique du vivant", June 14, 2007.

Conference: **From Type Theory to Morphological Complexity: A Colloquium in Honor of Giuseppe Longo**, CNAM, Paris: "From exact sciences to life phenomena: a few concluding remarks on Bohr and Schrï¿œinger", June 28-29, 2007.

The 2007 meeting: **ISHPS Studies in Biology**, Exeter (GB): "From the "DNA is a Program" paradigm towards the role of randomness and extended criticality in Biology", July 25 - 29, 2007.

Symposium: **Fondamenti delle Scienze: settorializzazione e unitarietà della conoscenza**, Arcidosso: "Critica dei principi delle scienze esatte e riflessioni teoriche in biologia", September 6-8, 2007.

Conference: **Types and Computations**, Roma: "Symmetries in Foundations", October 3, 2007.

Public Meeting: **La révolution numérique : écriture, monnaie, information**, Palazzo Farnese, Ambassade de France, Roma : "L'ordinateur et les sciences de la nature/La macchina digitale e le scienze della Natura", October 5, 2007.

Conference: **Logica e...**, Pisa: "La Logica, i Programmi ed il DNA", October 19, 2007.

Conference: **Neurophysiological memory: time and space**, Strasbourg: "Geometric schemes for retension, protension and biological rhythms over physical time", October 23, 2007.

Department of Informatics, Univ. Firenze, (Séminaire interdept., host: R. De Nicola): "Il DNA è un programma?", 11h 30, October 25, 2007.

Conference: **Logica e...**, Pisa: "La Logica, i Programmi ed il DNA", October 26, 2007.

Rehseis, Paris, : "Poincaré, Goedel et l'ADN : questions de détermination et de formalismes", 17h, November 20, 2007.

Centre Cavaillès, ENS, Paris, : "Critique de la raison physico-mathématique en sciences du vivant. Quelques extensions théoriques du physico-mathématique", 13h 30, November 21, 2007.

Conference: **Il filosofo e le pratiche scientifiche**, Milano: "L'elementare complesso e l'etica della conoscenza", December 5, 2007.

Colloquium 2007 of the **Group "Logique et Interaction: vers une géométrie du cognitif**, Roma: "Poincaré, Goedel et l'ADN", December 13-16, 2007.

Conference: **Type Theory, Lambda Calculus and Life**, Neijmegen (NL): "DNA, differential methods and the Boehm-out technique". (Personal attendance cancelled, but text in the proceedings).

Centre de Mathématiques Appliquées, EHESS (host: H. Berestycki), Paris: "Quelques résultats négatifs, l'incomplétude et la modélisation " (avec T. Paul), salle 214, 15-18h, January 22, 2008.

Conference: **La vita come fenomeno globale multilivello: origini, emergenze, evoluzioni**, Bergamo (It.): "La singolarità fisica del vivente, entropia negativa e criticità estesa ", February 27, 2008.

Dipartimento di Filosofia, Università di Pavia (host: L. Magnani), Pavia: "L'importanza dei risultati negativi. Comparazioni inter-teoriche di grandi programmi scientifici errati.", April 3, 2008.

Colloquium: **La thèse de Church hier, aujourd'hui, demain**, Paris : "L'arithmétique vs. l'enjeu du mobile et de la mesure", April 11, 2008.

Dipartimento di Filosofia, Università di Roma I (host: E. Gagliasso), Roma: "I miti alfabetici della logica e del programma, in cognizione e biologia", 14h, April 21, 2008.

Colloquium: **Enchevêtrements et action du temps dans les systèmes vivants**, Nice : "L'organisation comme anti-entropie et la double irréversibilité du temps biologique", June 4-6, 2008.

Workshop: **XXVIIIème Séminaire de la Société Francophone de Biologie Théorique** , Saint-Flour (Cantal, France): "Géométrie du temps biologique", June 8-11, 2008.

Conference: **Values and Logic in I. Royce**, Opole (Poland): "The role of order, relational invariants and infinity in modern foundations of Mathematics: some reflections following Royce", June 24-28, 2008.

Colloquium: **Temps Long. De la physique aux sciences humaines**, ENS, Paris : "L'aléatoire à temps court, long et infini", September 25-26, 2008.

Colloquium: **Négation, Dualité, Polarité** du Groupe LIGC, Carry le Rouet (Marseille) : "Antinomies et polarités dans les analyses de l'état vivant de la matière", October 16-19, 2008.

International Colloquium: **Science, épistémologie, société**, Venezia: "L'activité du vivant dans l'espace: des fondements cognitifs des mathématiques aux dynamiques biologiques", October 29-31, 2008.

Colloquium: **Maladies multifactorielles et état de santé qui les précède : comprendre l'interface, challenge de la médecine préventive du 21e siècle**, Paris : "Organisme / organes : schèmes abstraits d'intégration / régulation dans un état critique étendu", November 15-16, 2008.

Conference: **Metafore del vivente**, Roma: "L'informazione in Biologia: dal modello matematico al fascino discreto della metafora", November 27-29, 2008.

35th International Conference on: **Current Trends in Theory and Practice of Computer Science**, Spindleruv mlyn (Czech Republic): "Randomness and determination in Computing and Physics. Some reflections on Biology.", January 24-30, 2009.

19 World Conference on: **Proof and Proving in Mathematics Education**, Taipei (Taiwan): "The constructed objectivity of Mathematics and its cognitive roots", May 10-15, 2009.

Conference: **Naturalismo e antinaturalismo**, Firenze (It): "Dall'alfabeto al

senso: verso i fondamenti cognitivi della matematica e verso una matematica dello stato vivente della materia", May 28-29, 2009.

Conference: **Quale scienza per quale societa'**, Palazzo Ducale, Lucca (It), sezione Pensare la scienza: "La scienza di fronte al limite: l'importanza scientifica, etica e politica dei risultati negativi", June 25-26, 2009.

The 2009 meeting: **ISHPS Studies in Biology**, Brisbane (Australia): "Complexity and Evolution, an analysis in terms of Entropy production", July 12 - 16, 2009.

Second Workshop on: **Informatic Phenomena**, *Information beyond Informatics*, New Orleans (USA): "Information in Biology: metaphor or model? Anti-entropy and a model of phenotypic complexity along Evolution", October 5 - 9, 2009.

School of Engineering and Applied Sciences, Harvard University, Boston, USA (host: D. Weitz): "Building bridges: from the Mathematics of Information to Biological Organization", at 14h, October 14, 2009.

Baxter Lectures 2006-2009: **1809-2009. Il futuro di Darwin**, Pisa, It.: "Complessità degli organismi, Evoluzione delle specie ed ... equazione di Schroedinger", November 27 and 28, 2009.

Conférence: **Visualisation et mathématisation**, Université de Liège, Be.: "*Voir* les mathématiques, des fondements aux applications", December 3 and 4, 2009.

Conference: **Nature, Selection and Biology**, Firenze, It.: "La singolarità fisica dello stato vivente della materia", December 4-8, 2009.

Ceperc, CNRS, Aix en Provence (host: P.-A. Miquel): "Criticité étendue et cycles biologiques", December 16, 2009.

Institut d'Etudes Avancées, Nantes (host: A. Supiot): "Penser et prouver en mathématiques et en physique. Et en biologie?", February 9, 2010.

Conference in **memoria di: Aldo Gargani**, Pisa: "La critica dei fondamenti e le correlazioni fra saperi scientifici", 2 march, 2010.

Conference in **honor of: Erwin Engeler's 80th birthday**, the Swiss Logic Society, Berne, Switzerland: "From Logic to Randomness and Organization, as Anti-entropy, in Darwin's Evolution", March 4-5, 2010.

École Interdisciplinaire de biologie, Berder, Fr.: "L'information et ses théories, de Turing à Chaitin. Et en biologie?", 29 March 29 - April 2, 2010.

Conference: **Models of Cognition**, Roma, It.: "Protension and biological rhythms", May 14 - 15, 2010.

Philmath Intersem 2010, Paris (host: M. Detlefsen): "Symmetries and principles of constructions, from Mathematics towards Biology", March 11, 2010.

Summer School: **Biology and Cognition**, San Sebastian, Spain: "Biological and Cognitive Times", June 22 - 26, 2010.

Conference: **Computability in Europe**, Ponta Delgada (Azores), Portugal: "Incomputability in Physics and in Biology", June 30 - July 5, 2010.

Conference: **11th International Symposium on Frontiers of Fundamental Physics**, Paris: "Some Mathematics for Biological Theories: Randomness and Organisation, as Anti-entropy, in Darwin's Evolution", July 6-9, 2010.

Journée: **Simplicité – complexité du vivant** (au tour du livre de A. Berthoz), Collège de France, Paris: "La complexité du temps et la simplicité de l'action protensive du vivant", September 28, 2010.

Seoul National University, Seoul, Korea (host: Sh. Kim): "The physical singularity of life phenomena", November 2, 2010.

KAIST (Korea Advanced Institute of Science and Technology), Daedeok Science Town, Daejeon, South Korea (host: Woosuk Park); "Foundational analyses in science and conceptual crossing-over", November 5, 2010.

Université Paris XIII, Paris (Department of Informatics, host: S. Guerrini); "Une critique de la notion d'information en biologie et un modèle de la complexité phénotypique au cours de l'évolution", November 29, 2010.

Conference: **Filosofia e Biologia**, Università di Bologna, Forli' ; "Dai fondamenti della matematica ai fondamenti teorici della biologia", December 3 - 4, 2010.

Second Meeting: **PhénoMath: Concepts purs / Concepts appliqués**, Nice : "Le geste, la trajectoire et l'infini dans la constitution de l'objet mathématique", December 9 - 10, 2010.

Interview, **France Culture**, La place de la Toile : à 17h : " Alan M. Turing", December 26, 2010.

Espace Mendès France, Poitiers (host: A. Bonnefoy): "Brève histoire de l'infini, du continu et du discret", January 11, 2011.

Université Montpellier 2, Montpellier (Department of mathematics ; host: V. Durand-Guerrier): "La preuve et le sens dans les fondements des mathématiques", February, 17; meeting with PhD students and discussion around the **video-taped Lecture** "Six leçons sur l'indécidabilité logique et l'aléatoire physique", February 18 , 2011.

Università di Verona, Verona (It.), Manifestazione pubblica: Infinita ... mente: "Sapere dire 'no' in scienza, o l'importanza dei risultati negativi", March 19, 2011.

École normale supérieure, Paris (Centre Cavaillès) : "Symétries et dualités : de la physique à la biologie par extensions théoriques", April 6, 2011.

Workshop: **The concept of Interaction: Biology, Logic and Philosophy**, Univ. Roma III, Roma: "Ever since Darwin: conceptual oppositions in Biology", April 27, 2011.

Conference: **Il benevolo disordine delle stato vivente della materia**, Pisa: "Simmetrie ed aleatorio in biologia", April 29, 2011.

Workshop: **Information et stochasticité en biologie**, Paris : "Codages, codages, codages ... les mythes du signal alphabétique et de l'information sans forme", May 4 - 6, 2011.

Workshop: **Self-Organization in Biology: Scope and Limits**, Aix-en-Provence: "Symmetries and symmetry-breakings in extended criticality", May 24 - 25, 2011.

Tufts University School of Medicine, Boston (Department of Anatomy and Cell Biology; host: A. Soto): "Information in Biology ?", June 7, 2011.

Brown University, Providence, RI, USA (Department of Computer Science; host: C. Kenyon): "Asymptotic (algorithmic/ergodic) Randomness vs. Randomness in Natural Sciences", June 9, 2011.

Interview, **National Public Radios**, U. S. A. : Science and Philosophy, posting of June 13, 2011 : "Are Financial And Scientific Views Of the World Related?".

Journée: **Concepts**, Paris : "Symétries, entre mathématiques et sciences de la nature: un concept? une Gestalt?", June 29, 2011.

Conference: **Possibilità e determinazione**, Pisa: "Dalla determinazione dei sistemi di riferimento in fisica all'aleatorio biologico: quali evoluzioni possibili dell'eco-sistema?", September 19, 2011.

Meeting with: **M. Buiatti e G. Longo**, Università La Sapienza, Villa Mirafiori, Roma: "Ripensare la logica del vivente", September 21, 2011.

Workshop: **The poised realm, between Physics and Biology**, Burlington, (Vermont, USA): "Biology and the undefiniteness of the space of possibilities", October 1 - 2, 2011.

McGill University, Montréal, Canada (Department of Mathematics; host: R. Seely): "From Algorithmic Randomness to Randomness in Natural Sciences", October 4, 2011.

Colloquium: **Le hasard au coeur de la cellule**, Lyon : "Aléatoire et irreversibilité du temps, physique/biologique", November 21 - 23, 2011.

Conference: **Theoretical Computer Science and Applications**, Auckland, New Zealand: "Interfaces of Randomness", February 21 - 24, 2012.

Colloquium, **La temporalité en biologie**, Paris: "L' irreversibilité propre du temps biologique : protension et rythmes comme organizateurs de l'action, face à l'aléatoire", March 29 - 30, 2012.

Atelier Morphologie, **ENSAD**, rue d'Ulm, Paris: "A. M. Turing: les calculs et les formes", April 2 - 3, 2012.

Università di Firenze, Dipart. Filosofia (host: R. Lanfredini), Firenze: "Il vivente è sempre "in transizione critica" ed in non-predefinibile spazio dei possibili. Quale teoria allora per la singolarità fisica dello stato vivente della materia ?", April 24, 2012.

Conferenze pubbliche, 100 anni di A. M. Turing, 10 anni di S.J. Gould, La Limonaia, Pisa: alle 11: "A. M. Turing: la macchina a stati discreti, le dinamiche continue delle forme ed il caso"; dalle 15 alle 17, con M. Buiatti: "A partire da S.J. Gould: l'evoluzione del vivente, fra salti e caso", April 27, 2012.

Conference, **Stephen J. Gould heritage: Nature, History, Society**, Venezia, It.: "Randomness increases biological organization: a mathematical understanding of Gould's critique of evolutionary progress", May 10 - 12, 2012.

Workshop, **La Simplexité**, Paris: "Un grand enjeu de l' évolution: la simplification des bauplan, la complexification du phénotype", May 23 - 24 , 2012.

Institut d'Etudes Avancées, Nantes, workshop: "Epistémologie, biologie, medecine", May 30 and 31, 2012.

Workshop of **The Turing year: The Incomputable**, Isaac Newton Institute Program - "Semantics and Syntax: A Legacy of Alan Turing" (SAS), Chicheley Hall, GB: "Turing, from the "Discrete State Machine" to the "exponential drift" in continuous dynamics", June 12 - 15, 2012

King's College, London (Department of Computer Science; host: M. Fernandez): "A. M. Turing: from the "coding" of the human computer to the "genesis" of forms", June 18, 2012.

The Turing Centenary Conference (CiE 2012), Computational Models After Turing: The Church-Turing Thesis and Beyond, Isaac Newton Institute Program - "Semantics and Syntax: A Legacy of Alan Turing" (SAS), Cambridge: "Computing? a machine imitating a man who is playing an alpha-numeric game", June 19 - 23, 2012

Conférence grand public (organisée par l'ENS de Lyon), Turing: 100 ans, L' héritage de Alan Turing, ou comment la machine universelle a bouleversé notre société, Lyon: "A. M. Turing: de la machine à états discrets au modèle des dynamiques continues des formes", July 2, 2012.

Conférence grand public, Il Limite, Università e Comune di Torino: "La matematica, come scienza "al limite"", 3 July, 2012.

Meeting "PhénoMath": **Les mathématiques et la philosophie du presque**, Paris ; "Les fondements des mathématiques, entre le Scylla du "presque" dans la mesure physique et le Charybdis de l'indécidabilité logique", July 5 - 6, 2012.

European Logic Colloquium 2012, Manchester, GB: "Schroedinger (1944) and Turing (1952) on the Logic of Life: from the "coding" to the "genesis" of organization and forms.", July 12 - 18, 2012

Conférence grand public (organisée par le LORIA), La naissance de la Machine, Nancy: " De Goedel à Turing ou l'importance des résultats négatifs", September 13, 2012.

Tufts University School of Medicine, Boston (Department of Anatomy and Cell Biology; host: A. Soto): "Biological observables and "default states"", September 19, 2012.

NECSI - MIT, Cambridge, USA (host: Yanner Bar-Yam): "The Physical Singularity of the living state of matter: Symmetries and symmetry breakings, in Physics vs. Biology", September 20, 2012.

Scuola Normale Sup., Pisa, It. (host: M. Mugnai): "Turing: dalla Macchina alla morfogenesi o l'importanza dei risultati negativi", October 2, 2012.

Università di Roma III, Roma, It. (host: T. Numerico): "Turing: la macchina, l'imitazione della donna ed i modelli del vivente, ", October 11, ed incontro con M. Buiatti "Biologia fra scienza e metafore sociali" Registrazione Video, October 15, 2012.

Seminario Enriques, Milano, It. (Dipartimento di Matematica, host: U. Bottazzini): "Turing, fra l'artificiale ed il vivente: dal formalismo alla dinamica delle forme, la ricchezza dei punti di vista di un matematico molto originale", October 22, 2012.

Universita', Verona, It. (Conferenza pubblica, host: R. Giacobazzi): "I fondamenti della matematica, fra fisica e biologia", December 6, 2012.

ENS, Centre Cavaillès, Paris: "Aléatoire, irréversibilité du temps et imprédictibilité", 13h 30 - 15h, January 30, 2013.

CNAM, Centre des systèmes complexes, Paris: "Echanges autour de "L'espace-temps en physique et en biologie", chapitre 3 du livre Bailly-Longo", 14h30-16h30, February 18, 2013.

Workshop, Origin of Life, CERN, Geneva, CH: "The Necessity of Contingency", February 26-28, 2013.

ENS, Séminaire Philosophie et Mathématiques, Paris: "Croisements aléatoire physique / incomplétude mathématique: Poincaré, Gödel, Monod", March 11, 2013. Texte de référence: Interfaces de l'incomplétude.

University College London, Bartlett International Lecture Series, London, GB: "Modelling: randomness makes the difference", March 15, 2013.

Conference, Poincaré (1854-1912) a centouno anni dalla scomparsa, Università Roma 2, Roma, It.: "Aleatorietà e determinazione, necessità e contingenza. L'insegnamento di Poincaré e la sua difficile assimilazione", March 21, 2013.

École de Berder, Corrélation, causalité et régulation en biologie, Berder, Fr.: "Les causes et les possibles, entre physique et biologie", April 9 - 12 2013.

Group, Evolution, Museum Nat. Histoire Naturelle, Paris: "Une critique de l'information: évolution de la complexité et de l'organisation biologique", April 23-25, 2013.

Symposium, Academia Europaea, Wenner-Gren Center, Stockholm, Sweden: "Science in our relational humanity: critical insights and knowledge construction", May 23 - 25, 2013.

Istituto Studi Avanzati (ISA), Bologna, It., (host: S. Martini) May and June 2013, cycles of Seminar: - Informatica: "Schroedinger (1944) e Turing (1952) sulla logica del vivente: dalla "codifica" alla "genesi" dell'organizzazione e delle forme", May 8; - Filosofia: "Simmetrie e rotture di simmetrie: per una epistemologia all'interfaccia delle discipline", May 16; - ISA: "The Relevance of Negative Results: Incomputability and Undecidability in Physics and in Biology", May 21; - Istituto Ramazzini per i tumori e le malattie ambientali: "Caso e diversità in biologia: raffrontando complessità e organizzazione funzionale", June 5; - Matematica (host: G. Citti): G. Longo (CNRS-ENS, Paris) e A. Sarti (CNRS-EHESS, Paris): "Discussione a piu voci: Rotture di simmetrie, dinamica di forme e singolarità fisica del vivente", June 11; - Filosofia (host: G. Pancaldi): M. Buiatti (Biologia, Firenze) e G. Longo (CNRS-ENS, Paris), intorno al loro articolo: "Randomness and Multi-level Interactions in Biology", June 18.

4th International Workshop on Interactions between Computer Science and Biology (CS2Bio), Firenze, It.: "Randomness, variability and diversity in biological dynamics", June 6, 2013.

Conference, Thinking Shadows (Philosophy of Memory and Morphogenesis), Bologna, It.: "The shadows of lines and the dynamics of forms", June 13-14, 2013.

Group, Evolution, Arcachon: "Information, biologie, evolution", July 1-3, 2013.

Conference, PROTO/E/CO/LOGICS 2013, Srebreno, Croatia: "The architecture of biological time", August 24-25, 2013.

A scientific meeting In honor of Pierre-Louis Curien, Venezia, It.: "Is the Full Grace of the Madonna an actual infinity? Perspectives in Mathematics and in Biology", September 9 - 11, 2013.

City University New York (Computer Science Dept., host: R. Parikh), New York: "Schroedinger and Turing on the logic of life: from the "coding" to the genesis of forms", September 24, 2013.

Miguel Abreu Gallery, (Sequence Press: Lecture and discussion introduced by R. Mackay), New York: "The Invention of Space: from Metaphysics to Human and Biological Spaces, via Paintings", paper, video recording, September 26, 2013.

Tufts University (Anatomy and Cellular Biology Dept., host: A. Soto), Boston: "Contingency and diversity in biology: from anatomical complexity to functional organization", October 2013.

Colloquium, Naturaliser le modèle, Chambord, Fr.: "Le modèle comme regard organisateur du réel", October 25 2013.

Group, Evolution, Paris: "Diversification, hasard, évolution", November 5 - 8, 2013.

Berlin Doctoral School of Mind and Brain, Berlin, D. (host: M. Chaumon): "Modelling in natural sciences: continua vs discrete or the necessity of

contingency", November 14, 2013.

Department of Philosophy, Università di Roma I (host: E. Gagliasso), Roma: "Le simmetrie come principi di costruzione e di intelligibilita', in matematica ed in fisica ... ed in biologia?", November 18 and 19 , 2013.

Department of Philosophy and of Mathematics and Physics, Università di Roma III (ospiti: T. Numerico, M. Abrusci), Roma: "La memoria ed la costruzione del "senso" in matematica", 20 November, e "Cambiamenti di simmetrie ed aleatorio: dalla fisica alla biologia", November 22, 2013.

Workshop, Epistemologia della matematica, Faenza: "Interfacce fondazionali e risultati negativi: il ruolo del sapere critico", November 23 - 24, 2013.

Institut d'Etudes Avancées, Nantes, exposés et projet de recherche : "La construction du sens et de l'objectivité scientifique: entre histoire et épistémologie" (présentation video, 15 min), January to March, 2014.

Université de Nantes - INRIA, LINA, (hôte: N. Tabareau) Nantes: "L'aléatoire: physique, biologique, computationnel" (enregistrement video), March 26, 2014.

Conference, A plea for balance in Philosophy: essays in Honour of Paolo Parrini, Firenze: "Towards an epistemology of new interfaces: mathematics, physics, biology", April 15, 2014.

Università di Firenze (Department of Philosophy) e Scuola nazionale COOP, Firenze: "Teoria e filosofia del tempo biologico" e "Il senso dell'organicità", April 14 16, 2014.

Meeting, Dalla malattia alla "grande salute", Centro espositivo museale, S. Michele degli Scalzi, Pisa: "Organismo ed evoluzione biologica: come uscire da metafore fuorvianti ed integrare una teoria dell'organismo in quella dell'evoluzione?", April 23, 2014.

Université de Nice, Séminaire de philosophie des sciences, Nice: "La théorie, le modèle, le réel", May 19, 2014.

Spring School, Le Vivant Critique et Chaotique, Société Francophone de Biologie Théorique (SFBT), Saint Flour, (Fr.) : "Changements critiques de symétrie et aléatoire : quelques aspects biologiques", May 21 - 25, 2014.

Colloquium, Epistémologie de l'informatique et de la numérisation, les conséquences en science de l'homme et de la nature, Paris: "La machine, sa logique, sa physique: du dualisme informationnel à un nouveau monisme sans matière", June 30 - July 2, 2014.

Conference, Luca Cardelli Fest (Informatics and Bio-informatics), Cambridge: "What happened after LUCA?", September 8-9, 2014.

ENS, Séminaire de la Chaire B. Pascal, Paris : "Logique et épistémologie de l'espace: de la "prospettiva" aux espaces théoriques de la biologie", September 30, 2014.

Meetings Glass Bead (`www.glass-bead.org`), Paris : "La constitution du sens: des structures des mathématiques aux organismes (e ritorno)", October 3 and 4, 2014.

École d'architecture Paris-Malaquais (hôte : P. Morel), Paris : "Modèles et simulations : le jeu continu discret et les brisures de symétries", October 9, 2014.

Colloquium, L'évaluation face aux enjeux globaux: biologie, techniques et vulnérabilités, Paris: "Aléatoire, historicité et complexité biologique", October 14, 2014.

Università di Roma 2 ed 1, Dipartimenti di Filosofia e Centro Cognizione-Linguaggio-Conoscenzza, Roma 2 (ospiti: Perilli, Gagliasso), Roma, 23 - 29 ottobre : 23 "La Macchina a Stati Discreti: conseguenze scientifiche della "metafora digitale"" (CLaC), 28 "Il ruolo della storia nella determinazione del futuro in biologia" (Roma 1), 29 "Lo spazio e gli a priori, in fisica, in biologia", October 2014.

Università di Pisa, Department of Mathematics (host: Maffei), Pisa : "L'invenzione dello spazio", October 30, 2014.

University of Fribourg, École Doctorale Suisse Occidentale, Fribourg : Série de séminaires "Modèles et méthodes : du computationnel au vivant", November 19 - 21, 2014.

Colloquium, Entretiens du nouveau monde industriel, Centre Pompidou, Paris : "La machine à états discrets, sa logique, sa physique: du dualisme informationnel à un nouveau monisme sans matière", December 5 and 6, 2014.

University of Macau, Macau (China): Three lectures: "From computational formalisms, to bio-physics and to the relevance of history in biological evolution", December 9 - 12, 2014.

Auckland University, Auckland, New Zealand (Dept. Informatics: C. Calude, host): "Classical, quantum and biological randomness", January 7, 2015.

Universidad Andres Bello, Santiago, Chili (Departmento de Matematicas: C. Rojas, host): "From physical to biological randomness: its role in enhancing life diversity and stability", January 13, 2015.

Series Digital Studies, Salle Triangle (Centre Georges Pompidou, Paris): "A partir de "L'origine de la géométrie" de Husserl", January 27, 2015.

Colloquium, Le vivant et sa représentation: usages de l'image dans les sciences de la vie, Liège, Belgique: "Des dynamiques évolutives aux diagrammes de contraintes pour l'ontogenèse à la Montévil et Mossio", April 1, 2015.

Conference, Blaise Pascal Chair, Paris: "Conceptual dualities at the interfaces Mathematics/Physics/Biology", May 6-7, 2015.

Université Paris I, IHPST, Paris : "Modèles vs. simulations: cadres philosophiques et comparaisons techniques - le rôle des symétries", May 11, 2015.

Conference *in onore di Marco Forti, Pisa*: "Il "senso delle strutture", dalla matematica agli organismi", May 22 - 23, 2015.

Goldsmiths University, London (host: L. Parisi): "What do equations and computations do?", June 2, 2015.

Conference, Model Based Reasoning, Sestri Levante, Italy: "Models vs. Simulations: a comparison by their Theoretical Symmetries", June 25 - 27, 2015.

Conference, Unconventional Computation and Natural Computation 2015, Auckland, New Zealand: "The unconventionality of nature: Biology from Noise to Functional Randomness", August 31 - September 4, 2015. (Video recording)

European Conference on Pragmatism on "Gesture, reasoning, mathematics", Paris: "The use of "geometric judgments" as meaningfull gestures in space and time in the proofs of recent unprovable propositions of Arithmetic", September 9 - 11, 2015.

Colloquium, Diversité biologique et résilience dynamique des systèmes complexes organisés multi-échelles : du système immunitaire aux macro-écosystèmes,

ISC, Paris: "Comment le futur dépend du passé dans les systèmes du vivant", October 12 - 14, 2015.

Colloquium, "Lois des dieux, des hommes et de la nature", IEA, Nantes: "Introduction au colloque : Le rôle de l'histoire: biologie vs. sciences humaines et l'idéologie des Big Data", October 15 - 16, 2015.

Università di Firenze, Department of Philosophy (host: R. Lanfredini), Firenze: "Costruzioni di conoscenza: fenomenologia dell'interazione matematica / fisica / biologia", October 26, 2015.

CAPHES, ENS, Paris, "L'espace comme carrefour épistémologique et phénoménologique": "Symétries et mesures en sciences de la nature, à partir de H. Weyl", November 13, 2015.

Colloquium, "Du web sémantique au web herméneutique", Centre Pompidou, Paris : "De la mesure physique au dénombrement : les très grandes bases de données et les régularités sans sens", December 14 - 15, 2015.

Colloquium, "La liberté de l'improbable", Collège de France, Paris : "Histoire et créativité ou l'aléatoire sans probabilités", 15 December 15, 2015.

Goldsmiths University, London (host: L. Parisi): "Classical, Quantum and Biological Randomness: on causality and continua", January 14, 2016.

Workshop, "Morphology at the crossroads of the empirical, the formal and the logical", Lisboa, Portugal: "Le " "savoir-être" qualitatif dans les phénomènes" comme a priori de la modélisation quantitative des formes", February 10 - 12, 2016.

Winter School, "Scienza e società", Rivarolo (To), Italie : "Considerazioni scientifiche contro lo scientismo, oggi", February 26 - 28, 2016.

INS HEA, Strasbourg: Séminaire: Images des savoirs pratiques: "Informatique: origines logiques et images du monde ", April 25, 2016.

Thematic trimester, "Current Issues in the Philosophy of Practice of Mathematics and Informatics", Toulouse, France : "Counting vs. measuring: the foundational turn and some of its scientific consequences", May 25 - 27, 2016.

IMERA, Université Aix-Marseille: Séminaire : "Modèles et théories : du physique au biologique", May 31, 2016.

Conference, "Building Theories, Sciences and Hypotheses", Roma: "Theoretical challenges in biology: from cancer to organisms", June 16-18, 2016.

Colloquium, "Sciences de la vie, sciences de l'information", Cerisy-la-Salle : "L'information sans sens ni structures", September 19-26 2016.

Giornata di studi, "Esperienze della continuità", Verona: "La misura e la questione dell'"accesso" ai fenomeni: il discreto e la frattura cognitiva con il reale", November 3-4, 2016.

Colloquium, "La liberté de l'improbable", Collège de France, Paris : "Histoire et créativité ou l'aléatoire sans probabilités", November 29, 2016.

Universita' di Firenze, Philosophy Dept. (host: R. Lanfredini), Firenze: "L'importanza del qualitativo nell'era del digitale", November 30, 2016.

Conference, "Revisting Nature: a dialogue among forms of knowledge", Firenze: "Conceptual dualities in physics vs biology and their role in relating phylogenesis and ontogenesis", December 1-3, 2016.

Centre Pompidou, Les entretiens du nouveau monde industriel, Paris : "La machine à états discrets et les images du monde", December 13, 2016.

EHESS, Paris: Seminar: Morphodynamiques : "Comment le futur dépend du passé et des événements rares dans les systèmes du vivant", January 9,

2017.

Conference, "Sliding Doors: Prediction and Contingency in bio-sciences. 20th Res Viva's anniversary", Roma: "Historicity in Biology. The peculiarity of "Principles" and of Randomness from Darwin to a possible Theory of Organism", February 2-4, 2017.

Conference, "Mathematical models and previsions, use and abuse in natural and human sciences", Vidéo de la "Table ronde de présentation du colloque" (38 minutes), IEA (G. Longo, organizer), Nantes: "L'importance des résultats négatifs ... pour des théories solides. Les théories floues de l'information biologique: le cas du cancer", February 14-16, 2017.

Arizona State University, Phoenix (AZ, USA): Seminar: Emergence, Ontogenesis, Individuation: "Phylogenesis, ontogenesis and the formation of 'sense'", series of six lectures, February 27 - March 19, 2017.

Chapman University, Philosophy Dept, Claremont (CA), USA: "The invention of physico-mathematical spaces and the italian "prospettiva"", March 7, 2017.

U.C. Berkeley, Philosophy Dept, Berkeley (CA), USA: "Discussion on phylo-ontogenesis", T. Deacon's team, March 22, 2017.

Università la Sapienza, Philosophy Dept, Roma: "Cosa è oggi "What is life?" di Schrödinger?", April 12, 2017.

Palais Malaquais, Dép. de Architecture, Paris: "Le geste continu qui découpe et organise le monde vs. les Big Data qui le désarticulent", May 11, 2017.

ENS, Seminar "Philosophie et Mathématiques", Paris: "Irréversibilité du temps, brisures de symétries, aléatoire : une relation triangulaire qui marque l'imprédictibilité, physique et biologique", May 15, 2017.

Centre Pompidou, Seminar "Intelligence artificielle et épistémologie des 'boites noires'", Paris: "L'intelligence de et dans l'espace et le calcul sans espace", June 29 - 30, 2017.

Summer School Praxis, "Il possibile ed il reale", Forli': "Il ruolo del passato e degli eventi rari nella costruzione del possibile evolutivo del vivente", "Considerazioni matematiche sulla causalità in biologia: il continuo vs il discreto e la biologia del cancro", intervention July the 29th, 2017.

Workshop "Digital Culture and the Limits of Computation", British Academy/University of Sussex: "A major use and a major abuse of Information Sciences", September 21, 2017.

Colloquium "Corrélation et causalité dans l'univers des big data", Neurospin, Paris: "Aléatoire et grandes bases de données", October 18, 2017.

Conference "Dai fattori di rischio ai Big Data: Prevedere per Prevenire", XVIII edizione, Giornate della Scuola Medica Salernitana, Fac. di Medicina: "Usi ed abusi matematici dei Big Data, in biologia e medicina", October 20 - 21, 2017.

Conference "Organisms: a journal, a project", Univ. Sapienza, Roma: "Biological variation and stability in an organismal perspective", October 25 - 27, 2017.

Conference "Scienza aperta e integrità della ricerca", Milano: "Scienza e senso: deformazioni scientiste del rapporto al reale", November 9 - 10, 2017.

Seventh Conference on Systems Sciences, Università Cattolica, Milano, opening lecture: "The difficult interplay between theory, modeling and simulation. The relevance of negative results", November 16 - 17, 2017.

Presentation of the Book "La singularité du vivant", by M. Benasayag (afterword by G. Longo), Maison de l'Amérique Latine, Paris, 21h, November 17, 2017.

Conference "1948: Technosphere", Haus der Kulturen der Welt (HKW), Berlin: "TBA", November 30 - December 2, 2017.

Technical University (host: V. Buhlmann), Vienna: "The different ways discrete vs continuous mathematics organize reality", December 8 - 9, 2017.

Colloquium "Les mathématiques entre normativité et imagination : historicité, finance et sémiogenèse", Ens, Paris: "La friction difficile entre mathématiques et sciences historiques, à partir de la biologie", December 14, 2017.

Centre Pompidou, LES ENTRETIENS DU NOUVEAU MONDE INDUSTRIEL, "La "bêtise et l'intelligence artificielle"", Grande Salle, Paris: "Elaboration et transmission de l'information : deux sciences plaquées abusivement sur le réel. Dualisme et perte de sens", 19-20 December, 2017.

Universita' di Firenze, Dipart. Filosofia (host: R. Lanfredini), Firenze: "L'invenzione scientifica vs l'occupazione scientista del reale", January 18, 2018.

Centro Scientifico San Raffaele, Auditorium (host: M. Russo), Roma: "How Future Depends on Past Histories and Rare Events in Systems of Life", January 24, 2018.

Scuola di didattica e fondamenti della matematica, "Corpo e movimento in matematica: Incontri, intrecci e sviluppi", Rimini: "Gesti e senso in matematica", January 25-28, 2018.

8 Publications (most papers below and others not yet listed may be downloaded from Longo's web page)

Books

[1] Andrea Asperti and Giuseppe Longo. *Categories, Types and Structures.* M.I.T.- Press, 1991. (pp. 1-300).

[2] Francis Bailly and Giuseppe Longo. *Mathematics and the Natural Sciences. The Physical Singularity of Life.* Imperial College Press, London, 2011. (pp. 1-310). Version préliminaire en français, Hermann, Paris, 2006.

[3] G. Longo and M. Montévil. *Perspectives on Organisms: Biological time, symmetries and singularities.* Lecture Notes in Morphogenesis. Springer, Dordrecht, 2014. (pp. 1-280).

Editor

[4] Gabriele Lolli, Giuseppe Longo, and Annalisa Marcja, editors. *Logic Colloquium '82.* North-Holland, 1984. Studies in Logic and the Foundations of Mathematics n. 112 (pp. 1-358).

[5] Giuseppe Longo and Andy Pitts, editors. *Selected papers of the 5th biennial meeting on Category Theory and Computer Science '93.* Cambridge University Press, 1995. MSCS 5 (4).

[6] Mariangiola Dezani, Giuseppe Longo, and John Seldin, editors. *Lambda-calculus and Logic.* Cambridge University Press, 1999. Volume in honour of Roger Hindley, MSCS 9 (4).

[7] Giuseppe Longo, editor. *On Computer Science.* 1999. Special issue of the Monist, Journal in Philosophy of Science, vol. 82, n. 1.

[8] Luca Aceto, Giuseppe Longo, and Bjorn Victor, editors. *The difference between Sequential and Concurrent Computations.* Cambridge University Press, 2003. Two special issues of MSCS, 13 (4 and 5).

[9] Giuseppe Longo and Phil Scott, editors. *New Programs and open problems in the Foundations of Mathematics.* ASL, 2003. Special issue of the Bulletin of Symbolic Logic, ASL, vol. 9, n. 2.

[10] Giuseppe Longo, editor. *Géométrie et Cognition.* Albin-Michel, 2004. Numéro spécial de la Revue de Synthèse, n.1.

[11] G. Longo, M. Okada, and P. Grialou, editors. *Images and Reasoning.* Keio University Press, Keio, Japan, 2005.

[12] Giuseppe Longo and Mioara Mugur-Schachter, editors. *Developments of the Concepts of Randomness, Statistic, and Probability.* Cambridge University Press, 2014. A special issue of MSCS, 24, 3.

[13] Ana M. Soto and Giuseppe Longo (guest editors), editors. *From the century of the genome to the century of the organism: New theoretical approaches*, volume 122. Cambridge University Press, 2016. A special issue of Progress in Biophysics and Molecular Biology, 122, 1.

[14] Giuseppe Longo, editor. *Lois des dieux, des hommes et de la nature*. IEA, Nantes: "Introduction au colloque : Le rôle de l'histoire: biologie vs. sciences humaines et l'idéologie des Big Data" (Colloquium, October 15 - 16, 2015), Spartacus-Idh, 2017.

Invited Papers

[15] Giuseppe Longo. The new role of mathematical logic as a tool for computer science. *Information Sciences*, 57-58:23–29, 1991. Invited paper. (Version préliminaire: Conférence invitée, "International Conference on Problems of Logic and Philosophy of Science, today", Viareggio, Jan. 1990).

[16] Giuseppe Longo, Kathleen Milsted, and Sergei Soloviev. The Genericity Theorem and effective Parametricity in Polymorphic lambda-calculus. *Theoretical Computer Science*, 121:323–349, 1993. Invited Paper, special issue of T.C.S. "A Collection of contributions in honour of C. Böhm" (Version préliminaire: IEEE Conference on Logic in Computer Science (LICS 93), pp. 1-6, Montreal, Jan. 1993).

[17] Giuseppe Longo. Parametric and type-dependent polymorphism. *Fundamenta Informaticae*, 22(1-2):69–92, 1995. Invited paper, special issue on "Categorical Methods in C.S.".

[18] Giuseppe Longo. Géométrie, Mouvement et Espace. *Intellectica*, 25:195–218, 1997. Article invité, à partir du livre "Le sens du mouvement", par A. Berthoz, Odile-Jacob, 1997.

[19] Giuseppe Longo. Logique et Informatique. In *Encyclopédie de Philosophie et Histoire des Sciences*, pages 586–590. Press Universitaire de France, 1999.

[20] Giuseppe Longo. The Mathematical Continuum, from Intuition to Logic. In *Naturalizing Phenomenology: issues in contemporary Phenomenology and Cognitive Science (section on Mathematics and Formal Methods)*, 1999. Invited Paper, (Petitot et al eds.) Stanford University Press.

[21] Giuseppe Longo. Mathematical intelligence, infinity and machines: beyond the Goedelitis. *Journal of Consciousness Studies*, 6(11-12):191–214, 1999. Invited paper, special issue on Cognition. A preliminary french version of this paper appeared in Řevue de Synthèse, n. 1 (pp. 111-138), January 1999.

[22] Giuseppe Longo. The Constructed Objectivity of Mathematics and the Cognitive Subject. In M. Mugur Schacter et al., editor, *Proposals in Epistemology. On Quantum Mechanics, Mathematics and Cognition*, pages 433–463. Kluwer, 2002. Invited Paper.

[23] Giuseppe Longo. The reasonable effectiveness of Mathematics and its Cognitive roots. In *New Interactions of Mathematics with Natural Sciences*. Springer, 2002. Invited paper (L. Boi, editor).

[24] Giuseppe Longo. Proofs and Programs. *Synthese, Kluwer*, 134(1-2):85–117, January-February 2003. Invited paper.

[25] Francis Bailly and Giuseppe Longo. Space, time and cognition. from the standpoint of mathematics and natural science. In *Causality and Mind*, pages 149–199. Benjamins, 2004. Invited Paper, (A. Peruzzi ed.); version francaise: Revue de Synt èse, Paris, n. 1, 2004.

[26] Giuseppe Longo. Discreto e continuo, fra matematica ed informatica. In C. Cappuccio, editor, *Discreto e continuo*, pages 16–19, 2007. Dedalus, vol. speciale 2, n.2, rivista di Filosofia delle Scienza.

[27] Francis Bailly and Giuseppe Longo. Phenomenology of incompleteness: from formal deductions to Mathematics and Physics. In R. Lupacchini et al., editor, *Deduction, Computation, Experiment*, pages 243–272. Springer, 2008.

[28] Mathieu Hoyrup, Arda Kolcak, and Giuseppe Longo. Computability and the morphological complexity of some dynamics on continuous domains. *Theoretical Computer Science*, 398(1-3):170–182, 2008.

[29] Giuseppe Longo. Laplace, Turing and the "imitation game" impossible geometry: randomness, determinism and programs in Turing's test. In G. Roberts R. Epstein, editor, *Parsing the Turing Test*, pages 377–413. Springer, 2008.

[30] Giuseppe Longo. Critique of computational reason in the natural sciences. In E. Gelenbe, editor, *Fundamental Concepts in Computer Science*. Imperial College Press, 43-70, 2009.

[31] Giulia Frezza and Giuseppe Longo. Variations on the theme of invariants: conceptual and mathematical dualities in physics vs biology. *Human Evolution*, 25(3-4):167 – 172, 2010. Versione preliminare in italiano in "Metafore del vivente", (a cura di Gagliasso E. e Frezza G.), FrancoAngeli, Milano 2010.

[32] Giuseppe Longo. Incompletezza. In C. Bartocci, editor, *La Matematica*. Einaudi, 2010. Downloadable in English.

[33] Giuseppe Longo and Arnaud Viarouge. Mathematical intuition and the cognitive roots of mathematical concepts. In I. Starikova L. Horsten, editor, *Special issue of Topoi*, chapter "Mathematical knowledge: Intuition, visualization, and understanding", pages 15–27, vol. 29, n. 1. 2010.

[34] Giuseppe Longo. Mathematical infinity "in prospettiva" and the spaces of possibilities. *Visible, a Semiotics Journal*, 9, 2011. Original version in French, in "Le formalisme en action : aspects mathématiques et philosophiques", (J. Benoist, T. Paul eds) Hermann, 2012.

[35] Giuseppe Longo, Catuscia Palamidessi, and Thierry Paul. Some bridging results and challenges in classical, quantum and computational randomness. In H. Zenil, editor, *Randomness through Computation*, pages 73–92. World Scientific, 2011.

[36] Giuseppe Longo and Thierry Paul. The mathematics of computing between Logic and Physics. In B. Cooper et al., editor, *Computability in Context: Computation and Logic in the Real World*, pages 243 – 274. Imperial College Press, 2011.

[37] G. Longo and M. Montévil. The inert vs. the living state of matter: Extended criticality, time geometry, anti-entropy – an overview. *Frontiers in Physiology*, 3(00039), 2012. Invited paper, special issue.

[38] G. Longo and M. Montévil. The inert vs. the living state of matter: Extended criticality, time geometry, anti-entropy — an overview. *Frontiers in Physiology*, 3(00039), 2012.

[39] G. Longo and M. Montévil. Randomness increases order in biological evolution. In M. Dinneen, B. Khoussainov, and A. Nies, editors, *Computation, Physics and Beyond*, volume 7160 of *Lecture Notes in Computer Science*, pages 289 – 308. Springer Berlin / Heidelberg, 2012. DOI: 10.1007/978-3-642-27654-5_22.

[40] G. Longo and M. Montévil. Extended criticality, phase spaces and enablement in biology. *Chaos, Solitons & Fractals*, 55(0):64 – 79, 2013. Special Issue.

[41] G. Longo, M. Montévil, and A. Pocheville. L'incompressible complexité du réel et la construction évolutive du simple. In A. Berthoz and J.-L. Petit, editors, *Autour de la simplexité*. Odile Jacob, 2013. Article invité.

[42] G. Longo and M. Montévil. Introduction to new perspectives in biology. In Martin Abadi, Philippa Gardner, Andrew D. Gordon, and Radu Mardare, editors, *Essays for the Luca Cardelli Fest*, number MSR-TR-2014-104. Microsoft Research, September 2014.

[43] Giuseppe Longo. Synthetic philosophy of mathematics and natural sciences, conceptual analyses from a grothendieckian perspective. *Speculations: Journal of Speculative Realism*, 2015. (Web Journal).

[44] Arezoo Islami and Giuseppe Longo. Marriages of mathematics and physics: a challenge for biology. *Progress in Biophysics and Molecular Biology*, 131:179–192, 2017. Special Issue.

[45] G. Longo and M. Montévil. Comparing symmetries in models and simulations. In L. Magnani and T. Bertolotti, editors, *Springer Handbook of Model-Based Science*. Springer, 2017. DOI: 10.1007/978-3-319-30526-4.

[46] M. Montévil, G. Longo, and A. Soto. Du siècle du gène à celui de l'organisme : introduction à de nouvelles perspectives théoriques. In T. Gaudin, D. Lacroix, M.-C. Maurel, and J.-C. Pomerol, editors, *Sciences de la vie, sciences de l'information*, pages 76–90. ISTE-Editions., Paris, 2017.

Invited Lectures

[47] Giuseppe Longo. Continous structures and analytic methods in computer science. In Courcelle, editor, *Ninth Colloquium on Trees in Algebra and Programming (CAAP 84)*, pages 1–22. Cambridge University Press, 1984. Invited Lecture.

[48] Giuseppe Longo. Limits, higher type computability and type free languages. In Chytil and Koubek, editors, *Mathematical Foundation of Computer Science (MFCS 84), LNCS 176*, pages 96–114. Spriger-Verlag, 1984. Invited Lecture.

[49] Andrea Asperti and Giuseppe Longo. Categories of partial morphisms and the relation between type-structures. In *Mathematical Problems in Computation Theory*, pages 21–45. Banach Center Publications, 1987. Longo's Invited Lecture. (Version préliminaire: Proceedings of CAAP 86, LNCS 214, Springer-Verlag,1986 (pp.266-287)).

[50] Giuseppe Longo. From Numbered Sets to Type Theories. *Rendiconti del Seminario matematico di Torino*, Fasc. speciale:41–73, 1987. Invited Lecture at "Logic and Computer Science: new trends and applications", Torino, October 1986.

[51] Giuseppe Longo. On Church's formal theory of functions and functionals. *Annals of Pure and Applied Logic*, 40:93–133, 1988. Invited Lecture at "Church's Thesis after 50 years", Zeiss (NL), Juin 1986.

[52] Giuseppe Longo. Coherence and valid isomorphisms in closed categories, abstract. In Pitt et al., editor, *Category Theory and Computer Science (CT&CS 89), LNCS 389*, pages 1–4. Springer-Verlag, 1989. Invited Lecture.

[53] Giuseppe Longo. Some aspects of impredicativity: Weyl's philosophy of mathematics and today's Type Theory. In Ebbinghaus et al., editor, *Logic Colloquium 87 (European Summer Meeting of the A.S.L.)*, pages 241–274. North-Holland, 1989. Invited Lecture.

[54] Roberto DiCosmo and Giuseppe Longo. Constructively equivalent propositions and isomorphisms of objects (or terms as natural transformations). In Moschovakis, editor, *Logic from Computer Science at M.S.R.I., Berkeley, November 1989*, pages 73–94. Springer-Verlag, 1991. Longo's Invited Lecture.

[55] Kim Bruce, Roberto Di Cosmo, and Giuseppe Longo. Provable isomorphisms of types. *Mathematical Structures in Computer Science*, 2(2):231–247, 1992. Special issue: Proceedings of the "Symposium on Symbolic Computation", E.T.H. Zuerich, March 1990. Longo's Invited Lecture.

[56] Giuseppe Longo, Giuseppe Castagna, and Giorgio Ghelli. Overloaded functions with subtyping. In Winskell, editor, *Categorical Logic in Computer Science*, pages 139–160. DAIMI, Arhus, 1992. Invited Lecture. (Version définitive: les deux articles avec Castagna et Ghelli).

[57] Giuseppe Longo. Types as Parameters. In Gaudel and Jouannaud, editors, *TAPSOFT '93: Theory and Practice of Software development, LNCS 668*, pages 658–671. Springer-Verlag, 1993. Invited Lecture.

[58] Giuseppe Longo. Reflections on formalism and reductionism in logic and computer science. In A. Joseph et al., editor, *European Conference of Mathematics 92*, pages 202–209. Birkhauser, 1994. Invited Lecture, ECM 1992, Paris.

[59] Gang Chen and Giuseppe Longo. Subtyping parametric and dependent types. 1999. Longo's Invited Lecture, School on "Type Theory and Term Rewriting", September, 1996, Glasgow.

[60] Giuseppe Longo. The difference between Clocks and Turing Machines. In A. Carsetti, editor, *Functional Models of Cognition*, pages 211–232. Reidel, 1999. Conférence invitée au Congrès "Models of Cognition and Complexity Theory", Roma.

[61] Giuseppe Longo. Principes de construction et principes de preuve: au sujet du théorème de Kruskal-Friedman. In Carsetti, editor, *Logiche e Metodi di rappresentazione*, pages 25–46. La Nuova Critica, 33, 1999. Invited Lecture, Conference on "Mathematical constructions, inductive procedures and semantics", Rome.

[62] Giuseppe Longo. Cercles vicieux, Mathématiques et formalisations logiques. *Mathématiques, Informatique et Sciences Humaines*, 152:5–26, 2000. Texte revu d'une Conférence invitée, Colloque "Logiques et sciences humaines - nouveaux aspects", Paris, Juin 1997.

[63] Giuseppe Longo. Mathematics and the biological phenomena. In Basti et al., editor, *Foundations in Mathematical and Natural Sciences*, pages 330–354. Pontificia Universitas Lateranensis, Mursia, 2001. Invited Lecture, Vatican City, November, 1998.

[64] Giuseppe Longo. Mémoire et objectivité en Mathématique. 2001. Conférence invitée aux actes du Colloque "Le réel en mathématiques", Septembre 1999, Cérisy.

[65] Giuseppe Longo. Space and Time in the foundations of Mathematics, or some challenges in the interactions with other sciences. 2001. Invited Lecture, First American Mathematical Society/SMF Conference, Lyon, July 2001. Revised and submitted for publication. (Version francaise : Intellectica, 2003/1-2, n 36-37,).

[66] Giuseppe Longo. Computer Modelling and Natural Phenomena. In P. Inverard, editor, *European Software Engineering Conference and ACM SIGSOFT Symposium*, pages 1–5, New York, 2003. ACM Proceedings. Invited Lecture, Helsinki, Finland, September 1-5 , 2003.

[67] Francis Bailly and Giuseppe Longo. Incomplétude et incertitude en mathématiques et en physique. In Scarantino Parrini, editor, *Il pensiero filosofico di Giulio Preti*, pages 305–340. Guerrini ed associati, 2004.

[68] Francis Bailly and Giuseppe Longo. Objective and Epistemic Complexity in Biology. In N. D. Singh, editor, *International Conference on Theoretical Neurobiology*, pages 62–79, 2004. Invited Lecture, National Brain Research Centre, New Delhi, INDIA , 2003.

[69] Giuseppe Longo. Some Topologies for Computations. In Flament et al., editor, *Actes de "Géométrie au XX siècle"*, pages 377–399. Hermann, 2005.

[70] Francis Bailly and Giuseppe Longo. Randomness and determination in the interplay between the continuum and the discrete. In T. Paul, editor, *3-bodies, classical-quantum, discrete-continuum*, pages 289–307. Special issue, MSCS vol. 17, n.2, Cambridge U. Press, 2007.

[71] Boris Saulnier and Giuseppe Longo. Complexité et structures conceptuelles. In J. Le Moigne, editor, *Intelligence de la complexité*. Colloque de Cerisy, Editions de l'aube, Paris, 2007.

[72] Francis Bailly and Giuseppe Longo. Causes and symmetries. the continuum and the discrete in mathematical modelling. In G. Giorello, editor, *More Geometrico*. Elsevier, 2008. A preliminary french version was a conférence invitée, aux Actes du Colloque "Logique et intéraction: pour une géométrie de la cognition" (J. B. Joinet ed.), Presses Universitaires de la Sorbonne, 2008.

[73] Francis Bailly and Giuseppe Longo. Geometric schemes for biological time. In J. Boniface, editor, *Logique du vivant*. Vrin, Paris, 2008. version en français, texte d'une conférence invitée au colloque international "Episodic memory and time in neurophysiology", Strasbourg, October, 2007.

[74] Giuseppe Longo. From exact sciences to life phenomena: following Schrödinger on Programs, Life and Causality. In *Information and Computation, Longo's conference special issue, 207*, pages 545–558, 2009. Concluding lecture at "From Type Theory to Morphological Complexity: A Colloquium in Honor of Giuseppe Longo's 60th birthday". Version préliminaire, en français, dans "Explication, modélisation et simulation en Biologie" (Barberousse et al. dir.) n. spécial de "Matière première", n. 3/2008, éd. Syllepse, Paris.

[75] Giuseppe Longo. Randomness and determination, from physics and computing towards biology. In M. Nielsen, editor, *International Conference on Current Trends in Theory and Practice of Computer Science*, pages 49–61. Spindleruv mlyn (Czech Republic), January 24-30, 2009, LNCS 5404, Springer, 2009.

[76] G. Longo. Interfaces de l'incomplétude. In *La Matematica*. Einaudi, 2010.

[77] Giuseppe Longo. Incomputability in physics and in biology. In B. Lowe et al., editor, *Computability in Europe*. Azorres, Portugal, June 2010, LNCS 6158, Springer, 2010. (Extended and revised journal version, MSCS, 2012).

[78] Giuseppe Longo. Theorems as constructive visions. In de Villiers G. Hanna, editor, *ICMI 19 conference on Proof and Proving*. Taipei, Taiwan, May 10 - 15, 2009, Springer, 2011.

[79] Jean Lassègue and Giuseppe Longo. What is TuringÕs comparison between mechanism and writing worth? In S.B. Cooper et al., editor, *The Turing Centenary Conference*, pages 451 – 462. Computability in Europe, LNCS 7318, Springer, 2012. Longo's invited lecture.

[80] G. Longo. On the relevance of negative results. In *Conference on Negation, duality, polarity, Marseille 2008*, November 2012. (proceedings in Influxus, electronic journal, `http://www.influxus.eu/article474.html`).

[81] G. Longo and M. Montévil. Randomness increases order in biological evolution. In M. Dinneen, B. Khoussainov, and A. Nies, editors, *Computation, Physics and Beyond*, volume 7160 of *Lecture Notes in Computer Science*, pages 289 – 308. Springer Berlin / Heidelberg, 2012. Invited paper, Auckland, New Zealand, February 21-24, 2012 (also an invited lecture at the S.-J. Gould conference, Venice, May 10-12, 2012).

[82] Giuseppe Longo, Maël Montévil, and Stuart Kauffman. No entailing laws, but enablement in the evolution of the biosphere. In *Genetic and Evolutionary Computation Conference*. ACM, ACM series, 2012. Invited Paper, GECCOŌ12, July 7-11, 2012, Philadelphia (PA, USA).

[83] G. Longo, M. Montévil, and A. Pocheville. L'incompressible complexité du réel et la construction évolutive du simple. In A. Berthoz and J.-L. Petit, editors, *Autour de la simplexité*. Odile Jacob, 2013.

[84] G. Longo and M. Montévil. Introduction to new perspectives in biology. In Martin Abadi, Philippa Gardner, Andrew D. Gordon, and Radu Mardare, editors, *Essays for the Luca Cardelli Fest*, number MSR-TR-2014-104. Microsoft Research, September 2014.

[85] Barbara Bravi and Giuseppe Longo. The unconventionality of nature: Biology, from noise to functional randomness. In C. S. Calude and M. J. Dinneen, editors, *Unconventional Computation and Natural Computation Conference (UCNC)*, pages 3–34. Springer LNCS 9252, 2015. Invited Lecture, Auckland, August, 2015.

[86] G. Longo and N. Perret. Anticipation, protension et inertie biologique. In A. Berthoz C. Debru, editor, *Anticipation et Prédiction*. Collège de France, 2015.

[87] Giuseppe Longo. Le conseguenze della filosofia. In *A Plea for Balance in Philosophy*. ETS, Pisa, 2015. Conferenza invitata, Firenze, aprile 2014.

[88] G. Longo and M. Montévil. From logic to biology via physics: a survey. volume Volume 13, Issue 4, 2016. Special issue, Scientific meeting in honor of Pierre-Louis Curien.

[89] G. Longo and M. Montévil. Big data et connaissance biologique. In T. Gaudin, D. Lacroix, M.-C. Maurel, and J.-C. Pomerol, editors, *Sciences de la vie, sciences de l'information*, pages 233–238. ISTE-Editions., Paris, 2017.

Refereed Journals

[90] Giuseppe Longo and Marisa Venturini-Zilli. Complexity of theorem-proving procedures: some general properties. *Revue francaise d'Automatique Informatique et Recherche Operationelle (R.A.I.R.O.) (serie rouge de Math.: Informatique Théorique)*, (3):5–18, 1974.

[91] Giuseppe Longo. On the problem of deciding equalities in Theories of Objects and in a formal system. *Studia Logica*, 35(4):335–348, 1976.

[92] Piero Ferrari and Giuseppe Longo. Axiomatic Theory of Enumeration: a note on the axiom of extensionality. *Studia Logica*, 37(3):261–268, 1978.

[93] Henk Barendregt and Giuseppe Longo. Equality of lambda-terms in the model T-omega. *To H.B. Curry: essays in Combinatory Logic, Lambda Calculus and Formalism*, pages 303–337, 1980. Volume of essays, refereed as for a journal.

[94] Roger Hindley and Giuseppe Longo. Lambda-calculus models and extensionality. *Zeitschrift für Mathemathische Logik und Grundlagen der Mathematik*, 26(2):289–310, 1980. Abstract: Journal of Symbolic Logic n. 2, vol. 45, 1980 (p. 392), Proceedings of the Logic Colloquium 78, Mons,1978.

[95] Giuseppe Longo and Marisa Venturini-Zilli. A lambda-delta-calculus with an algorithmic delta. *Zeitschrift für Mathemathische Logik und Grundlagen der Mathematik*, 26(2):289–310, 1980. Abstract: Journal of Symbolic Logic n. 2, vol. 42, 1977 (pp. 458-459), Proceedings of the Logic Colloquium 76, Oxford, 1976.

[96] Susana Berestovoy and Giuseppe Longo. Il risultato di Paris-Harrington per l' aritmetica di Peano: una dimostrazione con il metodo degli indicatori. *Modelli del Lambda-calcolo e della Aritmetica di Peano (Quaderni dei Gruppi di Ricerca in Matematica del CNR)*, pages 75–95, 1981. Monograph, refereed as for a journal.

[97] Henk Barendregt and Giuseppe Longo. Recursion theoretic operators and morphisms of numbered sets. *Fundamenta Mathematicae*, (119):49–62, 1982. (Version préliminaire: M.I.T. report, Lab. for Computer Science Tech. Mon. 194).

[98] Giuseppe Longo. Set-theoretical models of lambda-calculus: Theories, expansions, isomorphisms. *Annals of Pure and Applied Logic*, 24:153–188, 1983.

[99] Kim Bruce and Giuseppe Longo. On combinatory algebras and their expansions. *Theoretical Computer Science*, 31(1-2):31–40, 1984.

[100] Paola Giannini and Giuseppe Longo. Effectively given domains and lambda-calculus semantics. *Information and Control*, 62(1):36–63, 1984.

[101] Giuseppe Longo and Eugenio Moggi. The Hereditary Partial Recursive Functionals and recursion theory in higher types. *Journal of Symbolic Logic*, 49(4):1319–1332, 1984.

[102] Giuseppe Longo and Simone Martini. Computability in higher types, P-omega and the completeness of type assignment. *Theoretical Computer Science*, 2-3(46):197–218, 1986. (Version préliminaire: Symposium on "Theoretical Aspects of Computer Science" (STACS 84), Paris 1984 (Fontet, Mehlhorn eds.) LNCS 166 , Springer-Verlag, 1984 (pp. 186- 197)).

[103] Kim Bruce and Giuseppe Longo. A modest model of records, inheritance and bounded quantification. *Information and Computation*, 87(1-2):196–240, 1990. (Version préliminaire: 3rd IEEE Conference on Logic in Computer Science (LICS 88), Edinburgh, July 1988, (pp. 38 - 50)).

[104] Giuseppe Longo and Eugenio Moggi. A category-theoretic characterization of functional completeness. *Theoretical Computer Science*, 70(2):193–211, 1990.

[105] Luca Cardelli and Giuseppe Longo. A semantic basis for Quest. *Journal of Functional Programming*, 1(4):417–458, 1991. (Version préliminaire: ACM Conference on LISP and Functional Programming, pp. 30-44, Nice, Juin 1990).

[106] Giuseppe Longo and Eugenio Moggi. Constructive natural deduction and its "omega-set" interpretation. *Mathematical Structures in Computer Science*, 1(2):215–253, 1991.

[107] Giuseppe Castagna, Giorgio Ghelli, and Giuseppe Longo. A calculus for overloaded functions with subtyping. *Information and Computation*, 117(1):115–135, February 1995. (Version prélim.: ACM Conference on LISP and Functional Programming, pp.182-192, San Francisco, 1993).

[108] Giuseppe Longo. Prototype Proofs in Type Theory. *Mathematical Logic Quaterly (formely: Zeitscrift f. Math. Logik und Grundlagen der Math.).*, 46(3), 2000.

[109] Giuseppe Longo, Kathleen Milsted, and Sergei Soloviev. Coherence and Transitivity of Subtyping as Entailment. *Journal of Logic and Computation*, 10(4):493–526, 2000.

[110] Giuseppe Longo. Savoir critique et savoir positif: l'importance des réultats négatifs. *Intellectica*, 40(1):15–26, February 2005.

[111] Giuseppe Longo and P.-E. Tendero. The differential method and the causal incompleteness of Programming Theory in Molecular Biology. *Foundations of Science*, 12:337–366, 2007. Version française dans "Evolution des concepts fondateurs de la biologie du XXIe siècle" (P. A. Miquel ed.), DeBoeck, Paris, 2007.

[112] Francis Bailly and Giuseppe Longo. Extended Critical Situations. *Journal of Biological Systems*, 16(2):309–336, 2008. Version préliminaire en français dans Détermination et complexité (Bourgine ed.), La Découverte, Paris, 2007.

[113] Francis Bailly and Giuseppe Longo. Biological Organization and Anti-entropy. *Journal of Biological Systems*, 17(1):63–96, 2009.

[114] M. Mossio, G. Longo, and J. Stewart. Computability of closure to efficient causation. *Journal of Theoretical Biology*, 257(3):489–498, 2009.

[115] Francis Bailly, Giuseppe Longo, and Maël Montévil. A 2-dimensional geometry for biological time. *Progress in Biophysics and Molecular Biology*, 106(3):474 – 484, 2011.

[116] Giuseppe Longo. Reflections on (concrete) incompleteness. *Philosophia Mathematica*, 19(3):255–280, 2011. Preliminary version, Invited Lecture at the Type Theory Conference, Durham (G.B.), LNCS vol. 2277, pp. 160-180, Springer, 2002.

[117] Giuseppe Longo and Maël Montévil. Protention and retention in biological systems. *Theory in Biosciences*, 130(2):107 – 117, 2011.

[118] G. Longo, P.-A. Miquel, C. Sonnenschein, and A. M. Soto. Is information a proper observable for biological organization? *Progress in Biophysics and Molecular biology*, 109(3):108 – 114, 2012.

[119] G. Longo, M. Montévil, and A. Pocheville. From bottom-up approaches to levels of organization and extended critical transitions. *Frontiers in Physiology*, 3(232), july 2012.

[120] Giuseppe Longo and Maël Montévil. From physics to biology by extending criticality and symmetry breakings. *Progress in Biophysics and Molecular Biology*, 106(2):340 – 347, 2012.

[121] Marcello Buiatti and Giuseppe Longo. Randomness and multilevel interactions in biology. *Theory in Biosciences*, 132(3):139–158, 2013.

[122] G. Longo and M Montévil. Extended criticality, phase spaces and enablement in biology. *Chaos, Solitons & Fractals*, 55:64–79, 2013.

[123] G. Longo and M. Montévil. Extended criticality, phase spaces and enablement in biology. *Chaos, Solitons & Fractals*, 55(0):64 – 79, 2013.

[124] T. Felin, S. Kauffman, R. Koppl, and G. Longo. Economic opportunity and evolution: Beyond bounded rationality and phase space. *Strategic Entrepreneurship Journal*, 8(4):269–282, 2014.

[125] R. Koppl, S. Kauffman, T. Felin, and G. Longo. Economy for a creative world (target article). *Journal of Institutional Economics*, 11(1):1–31, March 2014.

[126] Cristian Calude and Giuseppe Longo. Classical, quantum and biological randomness as relative unpredictability. *Natural Computing*, 2015. in print.

[127] Giuseppe Longo, Maël Montévil, Carlos Sonnenschein, and Ana M Soto. In search of principles for a theory of organisms. *Journal of Biosciences*, pages 1–14, 2015.

[128] G. Longo and A. M. Soto. Why do we need theories? *Progress in Biophysics and Molecular Biology*, 122(1):1 – 14, 2016.

[129] Maël Montévil, Giuseppe Longo, and Matteo Mossio. Theoretical principles for biology (ii): Principle of variation. *Progress in Biophysics and Molecular Biology, to appear*, 2016.

[130] Matteo Mossio, Maël Montévil, and Giuseppe Longo. Theoretical principles for biology (i): Principle of organization. *Progress in Biophysics and Molecular Biology, to appear*, 2016.

[131] N. Perret and G. Longo. Reductionist perspectives and the notion of information. *Progress in Biophysics and Molecular Biology*, 122(1):27 – 44, 2016.

[132] A. M. Soto, G. Longo, P.-A. Miquel, M. Montevil, M. Mossio, N. Perret, A. Pocheville, and C. Sonnenschein. Toward a theory of organisms: Three founding principles in search of a useful integration. *Progress in Biophysics and Molecular Biology*, 122(1):77 – 82, 2016.

[133] A. M. Soto, G. Longo, M. Montévil, and C. Sonnenschein. The biological default state of cell proliferation with variation and motility, a fundamental principle for a theory of organisms. *Progress in Biophysics and Molecular Biology*, 122(1):16 – 23, 2016.

[134] Cristian Calude and Giuseppe Longo. The deluge of spurious correlations in big data. *Foundations of Science*, 22(3):595–612, 2017. First DOI online, March 2016.

[135] Giuseppe Longo. How future depends on past histories and rare events in systems of life. *Foundations of Science*, 2017. First DOI Online, June 2017; Révision à paraître en français dans La liberté de l'improbable (Berthoz, Ossola cur.), Collège de France, 2018, Odile Jacob, à paraître.

[136] Giuseppe Longo. The biological consequences of the computational world: Mathematical reflections on cancer biology. *Organisms. Journal of Biological Sciences*, 2(1), April 2018.

International conference communications with lecture committee (Perliminary versions of [15], [16], [49], [94], [95], [102], [103], [105], [107] are not included in this list)

[137] Giuseppe Longo. Towards an abstract analysis of time progression during computation. In *International Computing Symposium*, pages 496–504, 1972. (Partly also in: SIGACT News of A.C.M. , n. 12, 1971 (pp. 14-24)).

[138] Giuseppe Longo and Marisa Venturini-Zilli. Theory of computation with an identity disciminator. In Michelson and Milner, editors, *Automata Languages and Programming (ICALP 76)*, pages 147–167. Edinburgh University Press, 1976.

[139] Mario Coppo, Mariangiola Dezani, and Giuseppe Longo. Applicative information systems and recursive domain equations. In Ausiello and Protasi, editors, *Colloquium on Trees in Algebra and Programming (CAAP 83) LNCS 159*, pages 35–64. Springer-Verlag, 1983.

[140] Mario Coppo, Mariangiola Dezani, Furio Honsell, and Giuseppe Longo. Extended type structures and filter lambda models. In Lolli, Longo, and Marcja, editors, *Logic Colloquium 82*, pages 241–262. North-Holland, 1984. Studies in Logic 112, Amsterdam.

[141] Giuseppe Longo and Eugenio Moggi. Cartesian closed categories of enumerations for effective type structures. In Khan, MacQueen, and Plotkin, editors, *Semantics of Data Types LNCS 173*, pages 235–247. Springer-Verlag, 1984.

[142] Kim Bruce and Giuseppe Longo. Provable isomorphisms and domain equations in models of typed languages. In *Proceedings, 1985 A.C.M. Symposium on Theory of Computing (STOC 85) Providence*, pages 263–272. ACM, 1985.

[143] Roberto Amadio, Kim Bruce, and Giuseppe Longo. The finitary projection model for second order lambda calculus and the solutions to higher order domain equations. In *First IEEE Conference on Logic in Computer Science (LICS 86) Boston*, pages 122–130. IEEE, 1986.

[144] Roberto Amadio and Giuseppe Longo. Type-free compiling of types as parameters. In Wirsing, editor, *IFIP Conference on Formal Description of Programming Concepts III*, pages 377–398. North-Holland, 1987.

[145] Giuseppe Castagna, Giorgio Ghelli, and Giuseppe Longo. A semantics for lambda&-early: a calculus with overloading and early binding. In *Typed Lambda-calculus and Applications, LNCS 664*, pages 107–123. Springer-Verlag, 1993.

[146] Giuseppe Longo, Kathleen Milsted, and Sergei Soloviev. A Logic of Subtyping. In *Logic in Computer Science (LICS)*, pages 292–300. IEEE, 1995. San Diego, June 1995 (very preliminary version of [109]).

[147] Thomas Fruchart and Giuseppe Longo. Carnap's remarks on Impredicative Definitions and the Genericity Theorem. In Cantini et al., editor, *X International Conf. in Logic, Methodology and Philosophy of Science*, pages 41–56. Kluwer Academic Publishers, 1999.

Miscellanea

[148] Giuseppe Longo. Semantica dei sistemi formali: i modelli di Scott per il lambda-calcolo, seminari di informatica teorica. Pubblicazione I.A.C. - C.N.R., 1973. Roma (pp. 41-82).

[149] Giuseppe Longo. I problemi di decisione e la loro complessitá seminari di informatica teorica 2. Pubblicazione I.A.C. - C.N.R., 1974. Roma(pp. 87-108).

[150] Giuseppe Longo. Ricorsività nei tipi superiori: un'introduzione alle caratterizzazioni di Ershov ed Hyland. Rendiconti del Seminario Matematico di Torino, vol. 37, 2, pages 1-29., 1979.

[151] Giuseppe Longo. Prefazione a "Modelli del lambda-calcolo e dell'Aritmetica di Peano". Quaderno dei Gruppi di Ricerca in Matematica del CNR, 1981.

[152] Giuseppe Longo. Hereditary partial effective operators in any finite type. Forshungsinstitut für Mathematik E.T.H. Zuerich, 1982.

[153] Giuseppe Longo. Ricorsività e continuità: un'introduzione. Atti degli Incontri di Logica Matematica, 1982.

[154] Kim Bruce and Giuseppe Longo. An elementary approach to the solution of recursive domain equations, 1983. Williams College.

[155] Mario Coppo, Mariangiola Dezani, Furio Honsell, and Giuseppe Longo. Applicative information systems. Nota Scientifica S-83-5, Universitá di Torino, 1983.

[156] Giuseppe Longo. Logica ed Informatica: metodi di indipendenza in Informatica matematica. *Teoria*, 3(2):39–51, 1983.

[157] Giuseppe Longo, Simone Martini, and Eugenio Moggi. Two results on recursive operators and hereditary partial functionals in any finite type. Recursive Function Theory Newsletter, 1983. n. 29 (April), #281.

[158] Giuseppe Longo and Eugenio Moggi. Types, computations and categories. International Congress on Logic and Philosophy of Science, San Geminiano, 1983.

[159] Kim Bruce and Giuseppe Longo. Domain equations and valid isomorphisms in all models of (higher order) languages. Atti degli Incontri di Logica Matematica, Siena, 1986.

[160] Giuseppe Longo. The denotational meaning of impredicative type theories. Proceedings of the Workshop on Logic of Programming, Mastrand (Sweden), 1987. Invited Lecture.

[161] Giuseppe Longo. Remarks on logic in mathematics and in computer science. Logic Colloquium '88, Ferro et al. (eds.), North Holland., 1988.

[162] Giuseppe Longo. Review of Feferman's paper "Weyl vindicated, Das Continuum 70 years later". Journal of Symbolic Logic, vol 58, n. 3, 1993.

[163] Giuseppe Longo. La dette publique et le système fiscal italien. Alternatives Economiques, n. 115, Mars 1994. pp. 14 - 18.

[164] Giuseppe Longo. Review of Trakhtenbrot's paper "Comparing the Church and Turing approaches: two prophetical messages". Journal of Symbolic Logic, 1994. vol. 59, n. 4.

[165] Giuseppe Longo. Sur l'Emergence de l'Objectivité et de l'Universalité en Mathématiques. *Intellectica*, 20(1), 1995.

[166] Giuseppe Longo. Cerveau, nombres et bon ordre: à partir du livre "La Bosse des Maths", par S. Dehaene. Revue de l'Association Henri Poincaré, n. 6, pp. 6-16, juin, 1997.

[167] Giuseppe Longo. Logica e modelli teorici della Biologia. *Sistemi Intelligenti*, (1):150–155, 1997.

[168] Giuseppe Longo. Rigueur mathématique, Logique et Machines, 1997. Conférence invitée, actes du Colloque "Voir, Entendre, Calculer, Raisonner", La Villette, Paris.

[169] Giuseppe Longo. La Razionalitá e le Macchine, prefazione al libro "Logica ed Informatica" di A. Asperti e S. Ciabattoni, North-Holland, 1998.

[170] Giuseppe Longo. Logica e Tempo in Informatica. Atti del ciclo di seminari "La realtá ed i linguaggi: nuove frontiere della scienza", pages 63-93, 1999. Conférence invitée, Centro Fiorentino per la Filosofia della Scienza, Octobre 1996.

[171] Giuseppe Longo. Est-ce que les calamars font de la géométrie? compte-rendu du livre "Les anatomies de la pensée", par A. Prochiantz, Odile Jacob, 1997. Ecrit pour Les Archives de Philosophie, 2001.

[172] Giuseppe Longo. Laplace (a note on incompleteness). MSCS, Cambridge U.P., 2001. An item of J-Y. Girard's dictionnary , at the end of "Locus Solum", vol.11, n.3.

[173] Giuseppe Longo. Lo spazio, i fondamenti della matematica e la resistibile ascesa della metafora: il cervello è un calcolatore digitale. In "L'uomo e le macchine", a cura di M. Bresciani Califano, Leo S. Olschki, Firenze, 2002. Conférence invitée, ciclo "Nuove frontiere della scienza", Centro Fiorentino per la Filosofia della Scienza.

[174] Giuseppe Longo. Symmetries and symmetry-breakings: the fabric of physical interactions and the flow of time. *Foundations of Science*, 2011. A review article,Vol. 16, Issue 4, pp. 331-333.

[175] Giuseppe Longo. L'informatique aux interfaces des savoirs, 2012. Actes du colloque *Quelques interactions logique/monde* (JB. Joinet, editor).

Lecture Notes

[176] Giuseppe Longo. Teorie del primo ordine e calcolabilità effettiva. *Centro Stampa dell'Università di Pisa*, 1978. Appunti per il Corso di Logica Matematica (pp. 1 - 323).

[177] Giuseppe Longo. From type structures to type theories. *Carnegie Mellon University*, 1988. Lecture Notes, Graduate Cours, AA 1987/88, Computer Sci. Dept. (pp.1 - 200).