

CURRICULUM VITAE

January 22, 2016

Giuseppe Longo

Directeur de Recherches,

<http://www.di.ens.fr/users/longo>

CNRS - Ecole Normale Supérieure, Paris

et CREA Ecole Polytechnique, Paris

Former “Professore Ordinario di Informatica”, Università di Pisa, Italy

STUDIES: “Laurea” (cum laude) en Mathematics, University of Pisa, February 1971. *Thesis: Complessita’ 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 Mathematics, Physics, Biology. Theoretical Biology: epistemology, theories (randomness vs determination) and their relation to experimental biology (from default states to theory of biological measurement).

EXPERIENCE IN FRANCE

- **École Normale Supérieure**, Paris (Dept. of Mathematics and Computer Science): Invited Professor (teaching: *I sem.*: Langages Fonctionnels ; *II sem.*: cours of D.E.A.), Octobre 1989 - Mai 1990.
- **École Normale Supérieure**, Paris (Laboratoire of Computer Science): Directeur de Recherches Associé **CNRS**, Juin - August 1990.
- **École Normale Supérieure**, Paris (Laboratoire of Computer Science): Directeur de Recherches **CNRS**, 2ème cl. since Nov. 1990; 1ère cl. since Nov. 1994.
- **École Polytechnique**, Paris (Centre d’épistémologie appliquée, CREA)): Directeur de Recherches **CNRS**, Oct. 2011 - July 2012.
- **École Normale Supérieure**, Paris (Centre Cavallés): Directeur de Recherches Emérite **CNRS**, since August 2012.
- **Dec-Prl** (Digital, Paris Research Laboratory): Consultant, from 1991 to 1993.

POSITIONS AT THE UNIVERSITY OF PISA:

- Assistant Prof. of Applied Mathematics, Nov. 1971 - March 1973
- Assistant Prof. (tenured), Mars 1973 - August 1980
- Professor “Incaricato” (associate) of Mathematical Methods in Computer Science , Novembre 1976 - August 1980

- Associate Professor (tenured) of Mathematical Logic, August 1980 - Octobre 1987 (on leave January 1980 - Octobre 1981: Oxford, Berkeley and M.I.T., see below)
- Full Professor of Computer Science , Nov. 1987 - Oct. 1990 (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):

- **Utrecht University** (Math. Dept.): Visiting Scientist, Nederlandse Z.W.O. grant, Decembre 1978; Visiting Professor, guest of the dept., Septembre and Octobre 1979.
- **Oxford University** (Math. Inst.): Visiting Scholar, British Council grant, January and February 1980.
- **U.C.Berkeley** (Math. Dept.): Research Associate, grant of the italien CNR, March - Decembre 1980.
- **M.I.T.** (Lab. for Computer Science (LCS)): Research Associate, CNR grant and LCS - M.I.T. grant, January - Octobre 1981.
- **E.T.H.** Zurich (Math. Forshungsinst.): Visiting Scientist, host of Forshungsinst., Octobre 1982.
- **Carnegie Mellon Univ** (Computer Science): Invited Professor (teaching: *I sem.*: Formal Lang. and Comp.; *II sem.*: graduate course on Recursion, Categories and Polymorphism), academic year 1987/88. June and August 1988, "research summer salary".
- **Dec-Src** (Digital, System Research Center, Palo Alto, California): July 1988, consultant.

2. IN ITALY:

- **University of Pisa and CNR** (Dept. Math. et Ist. Elaborazione dell'Informazione, Pisa): scholarship of C.N.R., 1970/71.
- **C.N.R.** (Ist. Applicazioni del Calcolo, Roma): collabor. of research, 1971- 1975 (MdC á Pise).
- **University of Genova** (Dept. Math.): "Prof. Incaricato" of Mathematical Logic, 1975/76 (assistant prof in Pisa).

AWARDS:

- Unione Matematica Italiana, National Award for young mathematicians, 1974.
- Member of l'**Accademia Europaea**, since 1992.

EDITOR OF SCIENTIFIC JOURNALS:

- Editor - in - chief, **Mathematical Structures in Computer Science**, Cambridge University Press, founder and editor since 1990. (*far away the main editorial activity*).
- Editor, **Information and Computation**, since 1982.
- Editor, **Theoretical Computer Science and Applications** (previously: **R.A.I.R.O.**), since 1985.
- Editor, **The Journal of Universal Computer Science**, a Springer electronically available journal, since 1994.
- Editor, **European Review**, the interdisciplinary journal of the Academia Europaea, since 2010.
- Editor, **La Nuova Critica**: rivista di Filosofia della Scienza, since 1993.
- Editor, **Journal of Mind Theory**, UPM, since 2010.
- Editor, **Biophysics** (American Inst. Math. Sci.), since 2012.
- Editor, **Biology Forum**, since 2011 (former “Rivista di biologia”, since 1919).
- Editor, **Philosophical Enquires**, Philosophy of Science, since 2011.
- Editor, **Advances in Historical Studies (AHS)**, History of Sciences, since 2012.
- Editor, **Epistemologica**, Mimesis, Milano, since 2013.

EDITOR, BOOK SERIES:

- Co-founder and current director of the book series, **Vision des Sciences**, Hermann, Paris, since 2006.
- Editor, **Studies in Applied Philosophy, Epistemology and Rational Ethics**, Springer, since 2011.

EDITOR, INDIVIDUAL VOLUMES:

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

- **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.
- **On Computer Science.** G. Longo (editor), Special issue of the *Monist, Journal in Philosophy of Science*, vol. 82, n. 1, 1999.
- **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.
- **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.
- **Geometry and Cognition,** G. Longo (Editeur), special issue, *Revue de Synthèse*, Editions de la rue of Ulm, tome 124, 2004.
- **Images and Reasoning,** P. Grialou, G. Longo, M. Okada (Eds), Keio University Press, Tokio, 2005.
- **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.

INTERVIEWS:

- 1 - **Radio, France Culture**, La place de la Toile: “Au tour de la notion de modèle, mathématique vs. informatique”, Radiofrance, Paris: 14h, 13 septembre, 2007.
- 2 - **Radio, France Culture**, La place de la Toile: le 12/3/10, de 11h à 12h (seul intervenant) : “Internet, logique et finance” (audio téléchargeable de la page de l’auteur).
- 3 - **Bulletin of European Assoc. Theoretical Computer Science**, April 2010: Interview by Cristian Calude.
- 4 - **Radio, France Culture**, La place de la Toile : 17h : “Alan M. Turing”, 26 décembre, 2010.
- 5 - **National Public Radios**, U. S. A. : Science and Philosophy, posting of June 13, 2011 : “Are Financial and Scientific Views of the World Related?”.

RESEARCH EVALUATION COMMITTEES

- Member of Committee Scientifique of Centre Applications and Mathematics Sociales (CAMS) of l’EHESS, 1997.
- Member of conseil of coordination régional des activités en Cogniscience (CogniSeine, présidé par A. Berthoz of Collège of France), 1997 and 1998.
- Member, International Panel for the evaluation of Research in Mathematics and Computer Science in Portugal, Ministry of Science and Technology (réunions: February 1998 and January 1999, Lisboa.)

- Member of Coordination Committee of Jumelage, CNRS - Académie des Sciences of Russie.
- ACI Nouvelles Interfaces des Mathematics, CNRS, 2003 and 2004.
- Advisory Committee, Center for Logic and Computation, Lisbon, Portugal, since 2004.
- FET - Open, European Com. research projects, since 2009.
- KAIST (Korean Advanced Institute for Science and Technology), Member of Academic Peer Review Survey, since 2012.
- Russian Science Foundation, expert, since 2015.

Referee and reviewer for the Projets ESPRIT, U.S. NSF and NSERC of Canada (Computer Science Grant Selection Commettee); 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:

1. Member, Program Committee, **Lambda Calculus Conference**, Swansea (G.B.) 1979.
2. Member, Program Committee, **Logic Colloquium 82**, Florence 1982 and Editor, **Proceedings**, North Holland (Studies in Logic, vol. 112), 1984.
3. Member, Program Committee, **Symposium on Theoretical Aspects of Computer Science (STACS 86)**, Paris 1986.
4. Member, Program Committee, **2nd IEEE Conference on Logic in Computer Science (LICS 87)**, Cornell (Ithaca, N.Y.), Juin 1987.
5. Member, Program Committee, **CAAP '90**, Copenhagen, Mars 1990.
6. Member, Program Committee, **Category Theory and Computer Science (CT&CS 91)**, Paris, Septembre 1991.
7. Member, Program Committee, **6th IEEE Conference on Logic in Computer Science (LICS 91)**, Amsterdam, Juin 1991.
8. Co-organizer, **La nouvelle vie de la Logique Mathematics** (Logique entre fondement and Computer Science), Paris, Avril 1992.
9. Member, Program Committee, **Category Theory and Computer Science (CT&CS 93)**, Amsterdam, Septembre 1993.
10. Member, Comittée de Programme, **Rationalité Logique and Intuition Géométrique**, Paris, Juin 1994.
11. Organizer, **Constructivité, en Mathematics and en Vision**, ENS, Paris, Mars 1995.

12. Member, Program Committee, **Typed Lambda Calculus and Applications**, Edinburgh, Avril, 1995.
13. Member, Program Committee, **World Conference on Fundamentals of A. I.**, Paris, Juillet, 1995.
14. Member, Program Committee, **Category Theory and Computer Science (CT&CS 95)**, Cambridge, August, 1995.
15. Member, Program Committee, **Logic Methodology and Philosophy of Science**, Florence, August, 1995.
16. Organizer, **Mathematics, Machines and Cerveau**, ENS, Paris, Mai 1996.
17. Member, Program Committee, **Functional and Object-Oriented Programming Languages**, Rutgers University, N.Y., USA, Juillet 1996.
18. Member, Steering Committee, **Functional and Object-Oriented Programming Languages**, Paris, January 1997.
19. Co-organizer, **Construction de objectivité : entre intuition and raisonnement**, ENS, Paris, January 1997.
20. Member, Organizing Committee, **HCM meeting on Denotational Semantics**, Siena, Mars, 1997.
21. Member, Program Committee, **Logical Foundations of Computer Science (LFCS97)**, Yaroslavl, Russie, Juillet 1997.
22. Member, Program Committee, **Category Theory and Computer Science (CT&CS 97)**, S. Margherita Ligure, Septembre 1997.
23. Co-organizer, **Wittgenstein and les fondements des Mathematics**, ENS, Paris, Avril 1998.
24. Member, Program Committee, **13th IEEE conference on Logic in Computer Science**, Indianapolis (In., USA), Juin 1998.
25. Member, Program Committee, **Computer Science Logic**, Brno, Czech Republic, Septembre 1998.
26. Member, Comitté de Programme, **Journées Francophones des Langues Applicatifs, JFLA'98**, Octobre 1998.
27. Member, Organizing Committee, **Workshop on Realizability Semantics**, Trento, Italie, June 1999.
28. Chairman of the Program Committee, **15th IEEE Conference on Logic in Computer Science, LICS'99**, Trento, Italie, Juillet 1999.
29. Member, Committee of Programme, **Foundations of Software Science and Computation Structures, FOSSACS'00**, Berlin, D., Mars 2000.
30. Organizer of Programme, **New programs and open problems in the foundation of mathematics and of its applications**, Paris, November 13-14, 2000.

31. Co-organizer local, **Genesis of perception and the notion of space in machines and humans**, Paris, ENS, Octobre 18-19, 2001.
32. Co-organizer local, **Is the dynamics of forms at the core of cognition?**, Paris, 5 - 6 Avril, 2002.
33. Member, comm. of programme, **Forme et objet du logique**, Rome, 2 - 4 mai, 2002.
34. 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)).
35. Member, comm. of programme, **Isomorphisms of Types**, International workshop at IRIT, Toulouse (Fr.), 8-9 November, 2002.
36. Organizer, Colloque: **Geometry, continu et théorie de la connaissance / Workshop on Geometry, continuum and theory of knowledge**, Ecole normale supérieure, 2 juin 2003.
37. Organizer, Colloque: **Images, reason and reasoning / Images, raison et raisonnement**, Ecole normale supérieure, 15 mars, 2004.
38. Member, comm. programme, Workshop: **Logique et Interaction: vers une Geometry de la Cognition**, Aix-en-Provence , 9 - 11 Mai, 2004.
39. Member, comm. de programme, Colloque: **3 corps, classique-quantique et discret-continu mathématiques**, Ecole normale supérieure, Paris, 28-29 septembre, 2004.
40. Member, comm. de programme, Colloque **Qu'est-ce qui est réel?** , Ecole normale supérieure, Paris, 27 septembre, 2005.
41. Member, comm. de programme, Conference **The impact of categories**, Ecole normale supérieure, Paris, 10 -14 October, 2005.
42. Member, comm. of programme, International Workshop on **Invertibility of Lambda-Terms**, Toulouse (France), October 28-29, 2005
43. Co-organizer, **Geometrie et complexité : la logique and ses images**, Salle des Conférences au 46, Ecole normale supérieure, Paris, 18 - 19 novembre, 2005. Réunion annuelle de groupe : "Logique and Intéraction: vers une Geometry de la Cognition".
44. Organizer, Conference **Continuous Dynamics and Computability**, Salle Weil, 45 Rue de Ulm, Ecole normale supérieure, Paris, May 3, 2006.
45. Member, comm. of programme, Ecole **Constructivisme and énaction. Un nouveau paradigme for sciences cognitives**, Ile de Oléron, 29 mai - 3 juin, 2006.
46. Member, comm. of programme, Conference **Computability in Europe, CiE, 2006: New Computational Paradigms**, Swansea, GB, June 30 - July 5, 2006.

47. Co-organizer, Colloque **Ouvrir la logique au monde**, Salle Dussane, 45 Rue de Ulm, Ecole normale supérieure, Paris, 29 septembre, 2006.
48. Co-organizer, **Giornate di studio, Continuo e discreto: dall'esperienza percettiva alle costruzioni di razionalità**, Villa Feltrinelli, Gargnano (It.), 5-7 Ottobre, 2006.
49. Co-organizer, Deuxième rencontre annuelle "More Geometrico": "**Changement de échelle - changement de niveau**", Paris, 2 - 4 mai, 2007.
50. Member, comm. of programme, 4th annual Conference on **Theory and Applications of Models of Computation (TAMC07)**, Shanghai, China, May 22-25, 2007.
51. Member, comm. of programme, Conference **Computability in Europe, CiE, 2007: Computation and Logic in the Real World**, Siena, Italy, June 18-23, 2007.
52. Member, comm. of programme, 5th annual Conference on **Theory and Applications of Models of Computation (TAMC08)**, Shanghai, China, April, 2008.
53. Member, comm. of programme, Workshop, **Logic, Language, Information and Computation**, Edinburgh, June 1-4, 2008.
54. Member, comm. de programme, Giornate di studio, **Le dinamiche del vivente**, Villa Feltrinelli, Gargano (It.), 28-30 settembre, 2008.
55. Member, comm. de programme, Colloque **Négation, Dualité, Polarité** du Groupe LIGC, Carry le Rouet (Marseille), 16-19 octobre 2008.
56. Workshop : **The physical singularity of life phenomena. Extending concepts and techniques from Physics to Life Science**, Ens, Paris, 10 avril, 2009.
57. 6th annual Conference on **Theory and Applications of Models of Computation (TAMC09)**, Changsha, China, May 26-30, 2009.
58. Colloque **Quelque part : entre biologie and philosophie**, Ens, Paris, 12 - 13 juin, 2009.
59. Workshop : **Games, Dialogue and Interaction**, University Paris VII, Paris, September 28-29, 2009.
60. Conference **Computability in Europe, CiE, 2010: Programs, Proofs, Processes**, Ponta Delgada (Acores), Portugal, June 2010.
61. Workshop, **Logic, Language, Information and Computation**, Brasilia (Br), July 6-9, 2010.
62. Colloque, **Les fondements à l'ère post-fondationnelle**, Groupe LIGC, Paris, 18-20 novembre, 2010.
63. Workshop, **Physics and Computation**, Turku, Finland, 6-10 June 2011.

64. Conference, **Engineering of Complex Computer Systems**, Las Vegas, USA, 27-29 April, 2011.
65. Workshop, **The present phase of development of the concept of probability and randomness**, based on a special issue of MSCS, ENS, Paris, 28 October, 2011.
66. Journee sur la **La biologie de synthèse**, CREA, Paris, 12 Avril 2012.
67. 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.
68. Conference on **Model based reasoning in science and technology: Theoretical and Cognitive issue**, Sestri Levante, Italy, June 21-23, 2012.
69. International Workshop on **Statistical Physics and Mathematics for Complex Systems (SPMCS2012)**, Kazan University (Kazan, Russia) from 25th to 30th of August, 2012.
70. International Conference on **COMPUTATION TOOLS 2013** May 27 - June 1, 2013 - Valencia, Spain.
71. International Conference on **Science and Information**, London, October, 2013.
72. International Conference on **History And Philosophy of Computing (HAPOC 2013)**, Paris, at Ecole Normale Sup., from 28th to 31th of october 2013.
73. **Pascal Conference: Biology and organisms: revisiting the systemic approach**. Paris, 5 et 6 mai 2015, co-organizer.
74. International Conference on **Model-Based Reasoning**, Sestri Levante on June 25-27, 2015.
75. Colloque **Lois des dieux, des hommes et de la nature**, Les 15 et 16 octobre 2015, Institut Etudes Avancées de Nantes.

MAIN RESEARCH GRANTS:

- Member, CNR (It) Gruppo Nazionale Strutture Algebriche e Geometriche, 1976-90.
- NSF (USA) - CNR: joint grant (with K. Bruce, Albert R. Meyer (M.I.T.)), 1982-86.
- Communauté Européenne (CE-Science): projet "Lambda-calcul" (J.Y. Girard (Paris VII, in charge européen of projet), 1988 - 91.
- BRA-Esprit project n. 3020: *Integration*, 1989 - 1990.

- CNR: Italian Universities /Stanford University (with S. Feferman and J. Mitchell (Stanford)), 1989 - 92.
- Groupe De Recherche *Programmation* (GDR 690 du CNRS), 1991-1997.
- NSF (USA) - Esprit (CE): Workshop on *Functional and Object Oriented Programming Languages* (in charge USA: K. Bruce), 1993 - 96.
- CHM, CE: Responsable pour la region parisienne de Reseau Européen pour la research fondamentale en Computer Science (EUROFOCS), with centre principal à Edinburg (G. Plotkin), 1993 - 97.
- European community research training project:*European institute in the logical Foundations of Computer Science* (EUROFOCS), 1993-1997.
- Esprit working group 21900: *Types for Proofs and Programs* (TYPES), 1993-1998.
- Academie des Sciences Polonaise/Ambassade de France: research exchange contract, 1995 - 97.
- INTAS: contract CE/Russie, 1995 - 98.
- Human Capital and Mobility (CHM): in charge for the group ENS-INRIA-PARIS VII de projet "TYPES" 1993 - 98 (J.Y. Girard, Marseille, in charge européen).
- Esprit Working Group 26142: *Applied Semantics* (APPSEM), 1998-2001.
- Action of scientific and technical collaboration franco-italian, Ministères des affaires étrangères and éducation nationale, 1999-2000.
- Action "Cognitive" de MENRST: in charge de l'atelier interdisciplinaire *Geometry and Cognition: le problème mathématique de l'espace physique et du vivant*, 2000-02 (14 participants: maths., biology, physics and philosophy).
- Programme MATH/STIC CNRS (OSV BS): Projet *Isomorphism of types: nouveaux developpements*. Responsable national : S. Soloviev (Univ. Toulouse), 2002 - 2003.
- ECOS-Sud (Cooperation with l'Uruguay): projet *Types and programming (multi paradigmes)*. in charge, 1999 - 2004.
- Projet MyThS: *Modèles and Types pour la Sécurité dans le systèmes distribués with mobilité*, action IST de l'Union Européenne dans le cadre de FET Global Computing. Contrat IST-2001-32617, 2002-2004. (Dotation globale 4.9MF, dont 1.5MF pour l'équipe; in charge locally: G. Castagna).
- Projet *Invertibilité des termes and programmes en Théorie des Types and applications*, financement CNRS, 2004-5 (in charge: S. Soloviev).
- Projet *Neurogeometry of the visual cortex*, financement ACINIM, 2004-7 (in charge: B. Teissier).

- Responsable de projet ANR (2006-2009) : *Singularités physiques et calculabilité effective* (Etats critiques, singularités and calcul digital : théorie and applications).
- Bonus Qualite' Recherche, ENS, 2008.
- Financement annuel, Réseau Nat. Systmes Complexes, RNSC: *Biological time and rythms*, with J. Champagnat, biology, CNRS Paris Sud, and M. Buiatti, Biology, Univ. Firenze, 2011-12.
- IRSES, CE-FP7, European consortium extra CE, with K. Svozil, Physics, U. Vienna, and C. Calude, Maths, U. Aukland, NZ, 2011-14.
- Participant, Project *Stability and variability*, Univ. Paris I, 2015 - 2017.
- Responsable du projet, *Lois des dieux, des hommes et de la nature*, at Institut Etudes Avancées de Nantes (one post-doc is affected to the project), <http://www.iea-nantes.fr/rtefiles/File/projet-giuseppe-longo-2014.pdf>, 2014 - 2018.
- Participant, European "Cost" Project, *The Origin of Life*, 2014 - 2018.

From 2004 to 2011, part time researcher (20/100) at **CREA** (Centre of Epistémologie Appliquée), Ecole Polytechnique, Paris.

SETTING UP AND DIRECTION OF:

CENECC: "CENTre D' Etudes" of Complex systems and of Cognition, inter-Departements Unity de l'ENS, with J.-P. Nadal (Physics), B. Victorri (Linguistics), since 2000.

CIM: Nouvelle équipe au LIENS: Morphological Complexity and information (octobre 2002).

Direction of regular seminars at ENS : "Geometry and Cognition" (2000-2002) and "Philosophie and mathématiques" (2000 - present). At Crea : "Biologie théorique" (with M. Mossio and N. Perret, 2007 - 2012).

ANNIVERSAIRE CONFERENCE: Paris, 28-29 June 2007: **From Type Theory to Morphologic Complexity: A Colloquium in Honor of Giuseppe Longo's 60th birthday**

(voir <http://www.pps.jussieu.fr/~gc/other/rdp/talks.html>)

1 Scientific Activity

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 [84], [85]), to Recursion in Higher Types ([135], [90], [94]), and to Category Theory ([1], [97], [44], [126]). Outside of this framework, there are also papers such as [83] and [122], in which we assess various measures of computational complexity, as well as [89], 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 [87] and [86] 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. [91] and [93]). 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 [90] and [93].

The [94] and [95] papers are the most representative of the latter topic. They are based on notions presented in [137] 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 mathematical methods studied in more detail (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 [95] and [125], which demonstrate, among other things, the completeness of certain typing systems).
- Polymorphism (see [1], [96], [99], [98], [128], [129]).

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 [97], [44] and [126], 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 [98], 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 ([14], [15]) 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 ([100], [130]). In the first case, the Genericity Theorem ([14]) is considered to be an important result with respect to the Theory of Proof of λ -calculus. In the second case ([130]), 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 [131]). Recent developments of these systems are found in [102] and [54].

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 [132] and [101]). 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 [109]. 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 Cogniscience 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 [59], [55], [153], [56]), 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 [18], [19], as well as on the role of action and of movement in the constitution of the geometric intelligibility of sensible space, [16]. It continued by further insights into the role of order and symmetries in the cognitive foundations of Mathematics, [31], 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, [32].

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 [151], [152], [156], [58]), 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 [20]), 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 [104].

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 *citeSpaceTime* and [27], [67]). 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 [63]). The general quality of the approach should enable 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 [62]), as well as the “impossible geometry” of certain computational modelizations (see [27], [61]) motivate our approach. These reflections, of the “exploratory-interdisciplinary” type, enabled 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 [60]; 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 [26], [65]. A more recent survey may be found in [72].

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 phenomenologies 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 [112], 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 [105]). The sand dunes, 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 flakes, 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 [112].

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 [105], [112] 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 [112]. 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 [77]. 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 seem to be theoretically determined

to be in a specific, pre-given set, [77].

2.2 Anti-entropy

In [106] 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, proper 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 [106], 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 *Caenorhabditis elegans* is proposed, in relation to some empirical data. 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, [106], [76].

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 retention and protention [110].

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 [108] 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 (circadian, typically), which are frequencies, and internal ones (metabolism, 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 [112], 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 From 2002 to 2012: Conclusion and Opening.

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 organi-

zation, 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 centered 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 [106], [35] 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 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

¹This 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.

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 ongoing work with two biologists, 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 - 2015: Epistemology of 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 Habilitations in Philosophy.

In a sense, all 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 [38]. 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 [76]. The stress on the role of randomness in biology is first made in [113], a collaboration with a geneticist which surveys and frames the abundant 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 [111]. In [114], 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 [118]. As a matter of fact, the approach to cancer by Sonnenschein and Soto, has found in our collaboration a way to be correlated to a view of the organism that gives to their approach a novel sense. These biologists of cancer since long understand this disease as an organismal 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 paper, we extensively motivate our approach by empirical evidence. The role of history in the formation of present biological structures and the intrinsic unpredictability of future is stressed in [82]. In particular, to the properties of synchronic measurement in physics, the relevance of diachronic measurement in biology is evidenced, 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),

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 1: 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).

which is a co-constitutive of the dynamic. In this framework, we understand the Darwinian principle of inheritance, inheritance 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 histor-

ical 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, [114], that was further developed with Montévil ([37]) 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 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, [32].

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, [40]. 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 substantiated in [40], 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 ([113]), Bravi, a physicist ([78]) and Calude, a mathematician ([117], [119]), and is also central to Abbotts 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, [119], revitalized

some early work done in Berkeley in 1980, [89]: Ramsey Theorem provided then a concrete example of incompleteness (at the time analyzed 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 ([115], [116]). 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 Villoutreixs 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 - 2015

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 his 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 Hermann, 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 twenty-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/exposetous.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.
- **Ecole Normale Supérieure, Paris** (Invited Professor, Dept. Math. and Computer Science): Languages Fonctionnels et un cours de D.E.A., Octobre 1989 - Mai 1990.
- **ENS-ParisVII- Polytechnique:** cours **D.E.A.** 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) in Computer Science, from 1995/96 to 2006.
- **ENS-ParisVI/VII-Polytechnique: DEA, Master** en Science Cognitives : cours en 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**, cours introductif à la logique: “Eléments de Théorie de la démonstration” for élèves en maths and en philosophie, janvier et février 1996.
- **ENS**, cours libres: “Six leçons sur l’incomplétude : logique, mécanique quantique”, en collaboration avec T. Paul, mathématiques, CNRS-ENS, janvier et février, de 2008 à 2011.
- **Univ. Roma III:** cours de doctorat, avril-mai 2009.
- **ENS**, cours libre : “Indécidabilité logique, et aléatoire physique”, février and mars 2010 (vidéo-enregistré à l’ENS, Savoirs en multimedia).
- Ecoles de Printemps, GDR de programmation: cours à Nice (Mars 1991), Bordeaux (Avril 1992), St. Malo (Avril 1993) and Toulouse (Mars 1994).
- Intensive Course of Doctorate (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’Universita’ di Catania (10 hours in a week) Avril, 2000.
- Exposés à l’**ENS** (research and teaching): “Logique and Calculabilité” (Journée introductive à la Cognition, Nov. 1992); “Les irrationalités de la Logique” (Séminaire de Philosophie des Mathematics, organisé par P. Cartier, F. Loi, R. Thom, February 1993);

“Mémoire et systèmes déductifs” (Exposé faisant partie d’un cycle sur la Mémoire en Biologie, Computer Science et Philosophie, February 1994); “Pour un fondement de la connaissance mathématique” (Séminaires d’Histoire and Epistémologie des Mathematics, Mars 1996); “Les Fondements de l’Arithmétiques et ‘la teneur de phosphore dans le Cerveaux’ (Frege)” Journée de l’ELSAP, Jourdan, January 1997; “Sur les démonstrations des Théorèmes indémonstrables” (Séminaire de Philosophie des Mathematics, Mai 1997); “L’infini mathématique, les machines and les méthaphores” (Groupe “La Pensée des Sciences”), 27 Mai, 1998; “Mathematics and Cognition: since l’intelligibilité géométrique de l’espace sensible” (with B. Teissier), 17 February , 1999 (voir web Longo: Geometry and Cognition); “Mémoire and objectivité en mathématiques” (Séminaire de Philosophie des Mathematics, Mars, 2000); “Expressivité and incomplétude logique” (Cours bref, 2 ou 4 heures, dans le cadre de l’Option Intermagistère ENS en *Science Cognitives*, Novembre ’96, ’97 and ’99, February ’00, Novembre ’00, January ’02); “Les fondements des Maths and la metaphore for cerveau” (Séminaire de Philosophie des Mathematics, Juin 2002).

Les exposés suivants sont enregistrés (audio et video) et téléchargeables de site de l’ENS (Savoirs en multimedia): La philosophie des mathématiques, le 24 October 2003; Table-ronde autour de la notion de Trois corps, classique-quantique, discret-continu, le 29 September 2004; Dynamiques de pensée en mathématiques : principes de preuves vs. principes de construction, le 29 April 2006; Continuum vs. discrete: Physics, Mathematics, Computing, le 3 May 2006; Présentation de la version française du livre [2], 20 novembre 2006 ; le cours de 2010.

- Member du Conseil Pédagogique du **DEA** en Science Cognitives (2000-04).

6 Theses Supervised

6.1 “Tesi di Laurea”, University of Pisa (*only research theses are mentioned (cum laude)*):

- P.Giannini “Calcolabilità’ su strutture astratte” Dip. di Informatica, Pisa, 1979. (*Enseign.-chercheur, Univ. Torino*)
- A.Bosisio “Operatori di enumerazione e topologie deboli” Dip. di Matematica, 1979 (*Chercheur dans l’industrie*).
- B.Mugnani “Metodi deduttivi per l’assegnamento di tipi” Dip. di Informatica, Pisa, 1982 (*Chercheur dans l’industrie*).
- S.Martini “I funzionali di Kleene e Kreisel e gli operatori ricorsivi” Dip. di Informatica, Pisa, 1983. (*Ph. D., Informatica Pisa; Prof. Ordinario, Udine et 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; chercheur Olivetti, 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; Chargé de Rech. INRIA, 90-92; Prof. Associato puis Ordinario, Bologna, since 1993*)
- G. Monteleoni “Alcuni aspetti semantici della programmazione funzionale” Dip. di Informatica, Pisa, 1985. (1987/88: *bourse CNR, Computer Sci., CMU; chercheur IRI, Pisa*)
- R. Amadio “Semantica dei tipi parametrici” Dip. di Informatica, Pisa, 1985. (*Ph. D., Informatica Pisa; Chargé de Rech., CNRS, Nancy, puis, Professor, U. Marseille, puis 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 esplicito” Dip. di Informatica and Scuola Normale Superiore, Pisa, 1986. (*Ph. D., Informatica Pisa; I.B.M. award for Computer Science Thesis; Enseign.-chercheur, Univ. Udine, since 1991*).
- F. Barbanera “Intuizionismo e la nozione di formula come proposizione” Dip. di Informatica, Pisa, 1987. (*Ph. D., Informatica, Torino; Enseign.-chercheur, 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; bourse CHM, E.N.S.; Enseign.-chercheur à Rome, puis Paris VII, 1999*)
- D. Lepore “Convergenze non topologiche, stabilità, sequenzialità” Dip. di Informatica, Pisa, 1987. (*chercheur dans l'industrie*).
- G. Castagna “Teoria dei tipi per ‘Object Oriented Programming’” Dip. di Informatica, Pisa, 1990. (*CR, puis DR, CNRS, LIENS, since 1994*).

6.2 Mémoires de DEA ou Master II

- G. Santini **Domaines and systèmes dynamiques**. DEA Sémantique Preuves Programmation. Année 1996-1997.
- C. Truchet (ENS) **Contuinité non-topologique**. DEA Sémantique Preuves Programmation. Année 1997-1998.
- S. Vacca **La forme finie du theoreme de Kruskal**. DEA Sémantique Preuves Programmation. Année 1996-1997.
- P.-S. Graillou, **Aspects cognitifs des preuves visuelles**. DEA Sciences Cognitives. Année 1998-1999.
- G. Halimi, (ENS) **Sémantique de polymorphisme**. DEA Philosophie. Année 1999-2000.
- M. Mossio, **Constitution d’invariants spatiaux**. DEA Sciences Cognitives. Année 2001-2002.
- P. Bucholc (co-direction de stage), **Les suites de Godstein and la prouvabilité**. DEA Sciences Cognitives. Année 2001-2002.

- E. Tendero, **Démontrabilité and indémontrabilité : un théorème de Friedman**. DEA Logique Mathematics. Année 2001-2002.
- B. Saulnier, **Information and entropie topologique**. DEA d'Computer Science , SPP. Année 2001-2002.
- J. Narboux, **Généricité dans les systèmes polymorphes**. DEA d'Computer Science , SPP. Année 2001-2002.
- A. Viarouge, **Cognition Mathematics: nombres and espace**, DEA Sciences cognitives, Année 2003-2004.
- G. Hoyrup, **Calculabilité and systèmes dynamiques**, DEA Computer Science - SPP, Année 2003-2004.
- A. Kolcak **Indécidabilité computationnelle and imprédictibilité dynamique**, DEA Computer Science - SPP, Année 2004-2005.
- M. Montevil **Etats critiques étendus**, Master II en Sciences Cognitives, Année 2005-2006.
- G. Delalleau **Bifurcations of Hopf and dynamiques irrversibles**, Master II en Mathematics, Paris VII, Année 2007-2008.

6.3 Doctoral Thesis, dates of the Defense (*Le Doctorat de Recherche a été institué en 1982, en Italie*):

- S. Martini “**Modelli non estensionali del polimorfismo in programmazione funzionale**” Dip. di Informatica, Pisa, 1988 (*Ricercatore puis Professore 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 puis chercheur INRIA, 89-92; Professore ordinario, Bologna, 2001*)
- G. Ghelli “**Data types for an higher-order database language: semantics and type-checking**” Dip. di Informatica, Pisa, 1989. (*Ricercatore puis Professore ordinario, Pisa, 2002*)
- S. Berardi (suivi en collaboration with M. Dezani) “**Proof Theoretic aspects of system F**” Dip. di Matematica, Torino, 1989. (*Ricercatore puis Professore ordinario, Torino, 2002*).
- R. Amadio “**Recursion and subtyping in lambda calculi**” Dip. di Informatica, Pisa, 1991. (*post-doc LIENS, 90-91; chercheur CNRS, Nancy, puis Professor , U. Marseille, puis Paris VII*)
- R. DiCosmo “**Isomorphisms of types**” Dip. di Informatica, Pisa, 1993. (*Md-Conf., ENS; Prof. Paris VII, since 1999*).
- G. Castagna “**fondements fonctionnelles de la Programmation Orientée Objets**” Paris VII, January 1994. (*Cr, puis DR, CNRS, LIENS, since 1994*).
- A. Bucciarelli (suivi principalement par P.L. Curien) “**Coherence et Stabilité for langages sequentiels**” LRI, Orsay, Octobre 1994. (*bourse CE-CHM 1993-95; Enseign.-chercheur à Rome, puis Paris VII, 1999*).
- R. Bellucci “**Sistemi formali e Modelli per il Polimorfismo parametrico**” Università di Siena (et LIENS), January 1996 (*Chercheur chez Eurostat*).
- Chen Gang (suivi en collaboration with G. Castagna) “**Sous-typage et conversions de types**” University of Paris VII (et LIENS), Décembre 1998 (*Associate researcher, Univ. South Australia, puis Boston Univ.*).
- F. DeJaeger “**Calculabilité sur les réels**” University of Paris VII (etLIENS), novembre 2003 (*chercheur chez Apple*).

- B. Saulnier, “**Aspects multi-échelles de l’information : de la physique à la biologie**”, septembre 2006 (*post-doc, Univ. Leiden, puis “quant” chez Merryl Lynch*).
- M. Mossio, “**Adéquation théorique et maîtrise expérimentale : un enquête interdisciplinaire en sciences cognitives**”, octobre 2006 (*post-doc, CR, sect. 35 de CNRS*).
- M. Hoyrup “**Computability, randomness and ergodic theory on metric spaces**” juin 2008 (*CR-CNRS, INRIA, Nancy*).
- C. Rojas “**Computability and Information in models of randomness and chaos**” juin 2008 (*Bourse Ecole Polytechnique, Mathematics, puis post-doc 4 ans au Fields Institute, Canada; professor, U. Santiago, Chile*).
- P.-G. Sbrissa “**Simulations informatiques, histoire d’un constructivisme**” janvier 2011 (*en co-direction, Philosophie, EHESS; Journaliste*).
- G. Frezza “**The concept of Interaction: crossovers among biology, logic and philosophy**” April 2011 (*en co-direction, Philosophie, Univ. Roma III; post-doc Rome III*).
- M. Montévil “**Temps Biologique et Transitions Critiques Etendues**”, octobre 2011, *Ecole Doctorale Frontière du Vivant, Paris Descartes; post-doc, Biology Dept., Tufts University, Boston, and Paris VII, Paris, .*
- N. Perret “**Épistémologie constitutive pour les sciences du vivant; sur la catégorie de causalité en biologie**”, juin 2013, co-direction avec M. Bitbol, *Ecole Doctorale Lettre/Sciences - 540, Ens, Paris; post-docs Pascal Chair, ensuite IEA Nantes, jusqu’en 2016*.
- P. Villoutreix “**Aléatoire et variabilité dans l’embryogenèse animale ; une approche multi-échelle**”, Juillet 2015, co-direction avec N. Peyriéras, *Ecole Doctorale Frontière du Vivant, Paris Descartes; post-doc, Biology Princeton*.
- A. Abbott “**Value Indefiniteness, Randomness and Unpredictability in Quantum Foundations**”, November 2015, co-direction avec C. Calude, *Ecole Doctorale Lettre/Sciences - 540, Ens, Paris, et Mathematics/Computer Science Auckland University, NZ; post-doc, Institut Néel, Physique, Université de Grenoble .*

Thèses en cours : JM. Catherin (Thèse en codirection avec JM. Besnier, Ecole doctorale P. IV, à partir de octobre 2011: fondements des Mathématiques); S. Biondi (Thèse en codirection avec J. Lassègue, Ecole doctorale Lettre/Sciences - 540, Ens, Paris, à partir de octobre 2015 : épistémologie)

Direction de post-docs :

- G. Pulcini (bourse Ville de Paris), 2008-09 ;
 A. Marinucci (bourse Ville de Paris), 2012-13 ;
 E. Pagni (bourse Ville de Paris), 2013-14 ;
 N. Perret, IEA de Nantes, projet *Lois des dieux, des hommes et de la nature*, 2014-16.

Rapporteur ou examinateur d’Habilitation:

- R. Amadio (Juin 94), S. Soloviev (Sept. 94), L. Boi (Décembre 97), R. Di Cosmo (Mars 98), A. Carbone (January 99), L. Colson (January 99), M. Fernandez (Septembre 2000), G. Castagna (January , 2002), O. Bournez (décembre 2006), O. Michel (décembre 2007), J.B. Joinet (décembre 2007),

A. Bucciarelli (novembre 2009). J. Lassègue (octobre 2010, Paris 5), P. Uzam (novembre 2013, Paris 7).

Theses referee or examiner, since 1990:

Couronné (Déc. 90), Fouda (Déc. 92), Jiang (Juin 93), Chillan (Sept. 93), Monsuez (Janv. 94), Compagnoni (Nijmegen NL, Janv. 95), Boldini (Fév. 95), Jacquet (Sept. 95), Xavier Gouy (Dec. 95, Paris VII), Crolard (Déc. 96, Paris VII), Bastonero ((Déc. 96, Paris VII), Pravato (Fév. 97, Torino), Pocholczyk (Avril 97, Paris VI), Lenzi (Juin 97, SNS, Pisa), Macjik (Mai 98, Roma), Saibi (Mars 99, INRIA-Paris VII), Thiénot (Juin 99, Paris VI), V. Schachter (Décembre 99, Paris-Orsay), D. Chemouil (Toulouse, Septembre 2004), D. Hainri (décembre 2006, Nancy), A. Hazan (décembre 2007, Paris XIII), G. Giannini (avril 2008, Urbino), M. Caponigro (avril 2008, Camerino), M. Toscano (mars 2009, Bergamo), C. Chalons (septembre 2014, Paris 7), M. Pistone (juillet 2015, Philosophie, Roma III, et Institut de Mathématiques de Marseille (I2M)), I. Wilkins (janvier 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.; hôte: R. Hindley), Septembre 1974: “Non-strict functions and their representation in Axiomatic Recursion Theories”,
 February 1980: “The countable functionals and lambda calculus models”.
- Scuola Normale Superiore, Pisa** : cycles de séminaires:
 (A.A. 74/75): “Ricorsivita’ 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”.
 Gennaio 1990: “Strumenti logico-matematici per i linguaggi di programmazione”.
 Gennaio 1992: “Realismo matematico ed immagini mentali, discussione in scienze della conoscenza”.
- C.N.R., Roma** (I.A.C.; hôte: M. Venturini-Zilli),
 Juin 1978: “Verso una Teoria dei Modelli del Lambda-calcolo”
 Octobre 1981: 1) “Il teorema di Paris-Harrington e le incompletezze matematiche dell’Aritmetica”;
 2) “Alberi di Böhm e la caratterizzazione semantica di proprieta’ del lambda-calcolo”.
- Utrecht University**, Holand (Mathematisches Instituut; hôte: H. Barendregt), Dicembre 1978: “Plotkin’s models of lambda calculus and type two Recursion Theory”
 Octobre 1982: “The hereditary partial recursive functionals”.
- Universita’ di Torino** (Dip. Informatica; hôte: M. Dezani), Gennaio 1979: “Un’introduzione alla Ricorsivita’ nei tipi superiori”;
 Dicembre 1981: “Semantica operativa vs denotazionale in lambda-calcolo”.
 Juin 1993: “Il Teorema di Genericita’ ”
 Juin 1993 (Dip. di Fisica; hôte: F. Pegoraro): “Poincare’ e Weyl fra Fisica e fondaz. della matem.: oggi”.
- Amsterdam University**, Holand (Mathematisches Instituut, Intercity Seminar; hôte: D. Van Dalen), Septembre 1979: “Effectiveness in some Ershov spaces for the partial continuous functionals”.
- Oxford University**, G.B. (Mathematical Institute; hôte: R. Gandy), February 1980: “Generalized Myhill-Shepherdson theorem and its applications to lambda-calculus models”.
- University of Chicago**, U.S.A. (Mathematics Dept.; hôte: R. Soare), Mars 1980: “An overview of recent results in lambda-calculus syntax and semantics”.
- Universidad Aut. Nac. de Mexico**, C. de Mexico (dept. de Matematica; hôte: F. Bracho), Dicembre 1980: “Set-theoretical lambda-models and their applications”.
- M.I.T.**, U.S.A. (Lab. for Computer Science; hôte: A. Meyer), February 1981: “Recursion Theory in higher types: relating Ershov and Hyland approaches”,
 Octobre 1984: “Categories of partial morphisms and the semantics of types”.

- Octobre 1985: “The semantics of types and terms for (higher-order) λ -calculi”.
- Janvier 1987: “Lambda-calculus: *the* Theory of Computable Functions”
- Juillet 1987: “The denotational meaning of impredicative Type Theories”.
- University of Indiana**, Bloomington, U.S.A. (Computer Sci. Dept.; hôte: M. Wand),
- Septembre 1981: “The Lambda-calculus : its syntax, its semantics and how they relate”.
- Yale University**, New Haven, U.S.A. (Mathematics Dept.; hôte: A. Macintyre), Septembre 1981: “An introduction to the model-theory of lambda calculus”.
- E.T.H.**, Zurich, C.H. (Math.-Comp. Sci.; hôte: E. Engeler), Octobre 1982: “Some connections between lambda-calculus models and computability in abstract structures”.
- Oberwolfach Forschungsinstitut**, R.F.T. (Organizers: Felscher, Schwichtenberg), Avril 1983: “Relative gödel-numberings and recursion theory in higher types”.
- Universita’ di Padova** (Ist. Matematico; hôte: R. Ferro), Mai 1983: “Informatica e Matematica: metodi di indipendenza in problemi combinatori”.
- Universität Dortmund**, R.F.T. (Leh. Informatik; hôte: E. Börger), Avril 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), Octobre 1984: “Provable isomorphisms, invertible terms and continuous models”.
- Imperial College**, London, G.B. (Computer Sci. Dept.; hôte: S. Abramski), Avril 1985: “Solvable domain equations in all models of typed and second order lambda-calculus”.
- University of Edinburgh**, G.B. (Computer Sci. Dept.; hôte: G. Plotkin), Avril 1985: *same as at the Imperial College*.
- Carnegie Mellon University**, U.S.A. (Computer Sci. Dept.; hôte: D.S. Scott), Novembre 1985: “Categories and models of various lambda-calculi”;
- Juin 1986 (hôte: R. Statman): “From Gödel-numberings to higher types and higher order”.
- Octobre 1987 (hôte: D.S. Scott): “Some aspects of impredicativity”.
- Stanford University**, U.S.A. (CSLI; hôte: J. Meseguer), Novembre 1985: *same as at M.I.T. (Octobre 1985)*;
- Janvier 1988 (Mathematics Dept.; hôte: S. Feferman): “Modest Models and Motivations of impredicative Type Theories”.
- Banach Mathematical Center**, Warsaw (hôte: H. Rasiowa), Decembre 1985: 1) *voir article [44]*;
- 2) “The higher-type Banach-Mazur functionals in recursion theory”.
- Paris VII**, Paris (L.T.I.P.; hôte: P.L. Curien), Janvier 1986: 1) *same as at M.I.T. (Octobre 1985)* ; 2) “Modèles sans types pour les calculs d’ordre supérieur”.
- (Equipe de Logique; hôte: J.Y. Girard) Janvier 1987: “Calculabilité sur les domaines de Scott et sur les espaces cohérents”.
- (Equipe de Logique; hôte: C. Berline) Janvier 1995: “Paramétrie, Théorème de Généricité et Soustypage”.

- Chalmers University**, Göteborg (Programming Methodology Group; hôte: B. Nordstrom), Septembre 1986: “Models for explicit polymorphism in Functional Languages”
 Juin 1987 (delivered in Mastrand, *Workshop on Logic of Programming*): *same as at M.I.T. (Juillet 1987)* .
- Pennsylvania State University** (Math. Dept.; *Mid-Atlantic Mathematical Logic Seminar*; hôte: S. Simpson), Decembre 1987: “The Curry-Howard ‘Types-as-Formulas’ analogy and the Models of Combinatory Logic”.
- University of Pennsylvania**, Philadelphia (Computer Sci.; hôte: V. B.-Tannen), Mai 1988: *same as Stanford, Janvier 1988* .
- Université de Marseille** (Fac. Science Luminy; hôte: G. Blanc and A. Preller), Avril 1990: “The categorical meaning of various lambda-calculi: from type-free to higher order”.
- I.N.R.I.A.**, Rocquencourt -Paris (hôte: J.J. Levy), Decembre 1989: “Quest: polymorphism and subtyping”;
 Février - Mai 1990 seminaires ébdomadaires organizés (et parfois présentés) par J.Y. Girard, G. Huet and G. Longo.
- DEC-PRL**, Digital - Paris Research Lab., Rueil-Malmaison (hôte: H. Aitkaci), Juin 1990: “An introduction to Quest: its types and its semantics”.
- IIIème Réunion CE - Jumelage** ”Typed lambda-calculus”, Paris, Jan. 1991: “Type Theory and Object Oriented Programming”.
- Universita’ di Milano** (dip. di Informatica; hôte: N. Sabadini), Janvier 1992: “Tipi, categorie e calcoli”.
- Universita’ di Napoli** (dip. di Fisica Teorica; hôte: G. Trotteur), Avril 1993: “Logica, rappresentazioni mentali ed Informatica”.
- Stanford Research Institute** (SRI, Computer Science; hôte: Workshop of the American Jumelage “Lambda”), Octobre 1993: “Invariant and Effective Polymorphism”.
- Ière Réunion, NSF - Esprit Workshop on “Functional and Object Oriented Programming”**, Stanford University, Octobre 1993: “Overloading as Message passing”.
- Ière Réunion “Lambda-calcul” CHM (CE) Projet “Typed lambda-calculus”**, Univers. de Rome, Novembre 1993: “Computations in Theories and Models”.
- Académie des Sciences de Chine**, Pekin (Dept. of Comp. Sci.; hôte: Wong Ju), Avril 1994: “Types, Categories and Functional Languages” + “Overloading in a functional frame”.
- JiaoTong University** Shanghai, Chine (Dept. of Comp. Sci.; hôte: Sun Yong), Avril 1994: “Recent advances in Type Theories”.
- CNRS et I.N.R.I.A. Lorraine**, Nancy (CRIN; hôte: R. Amadio), Juin 1994: “Théories équationnelles du lambda-calcul et leur sémantique”.
- LMD, CNRS**, Marseille (hôte: J.Y. Girard; réunion CHM, Typed Lambda), Novembre 1994: “A (linear) Logic for Subtyping”.
- Institut Henri Poincaré**, Paris (hôte: J. Petitot), Janvier 1995: “De la théorie de la Démonstrations aux Programmes et aux Morphismes”.
- Informatika, Katholic Universitaat**, Nijmegen (hôte: H. Barendregt), Janvier 1995: “Polymorphism and the functional behaviour of terms applied to types: universality properties and subtyping”.
- CNR, Roma** (Istituto di Psicologia, hôte: D. Parisi), Février 1995: “Memoria e Matematica” .

- Universita' di Rome I** (Dip. di Informatica, hôte: R. DeNicola), Février 1995: "Impredicativita': teorie, semantica e risultati recenti in Teoria dei Tipi".
 Novembre 1995 (Dip. di Matematica, hôte: M. Fattorosi): "Sulle dimostrazioni di Teoremi indimostrabili".
 (Dip. di Informatica, hôte: C. Boehm), Avril 1996: "Applicazioni ed osservazioni sul Cut-elimination".
- Universidad de Vina del Mar, Chile** (Escuela de Ingenieria, hôte: E. Perez Santi), Avril 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, hôte: R. Baeza-Yates), Avril 1995: "Proofs and programs: an introductory survey".
- City University of N.Y.**, New York (Dept of Computer Sci.; hôte: R. Parikh), Juin 1995: I. "Categories, programs and impredicative definitions" and II. "Reflections on Logic and Cognition".
- University of Warsaw**, Warsaw (Dept of Computer Sci.; hôte: J. Tiuryn), Juillet 1995: "Recent results in constructive proofs and categories".
- ENST**, Paris, Septembre 1995: "Types et Objets pour le polymorphisme".
- Universita' di Torino** (HCM meeting, hôte: S. Ronchi), Novembre 1995: "On the regularity of generic proofs".
- ENS de Lyon** (hôte: C. Paulin-Mohring), Mars 1996: "Le Polymorphisme dans les langages fonctionnels".
- ENS, Jourdan**, Paris (hôte: D. Dubois), Mai 1996: "Invariants et Notations en Mathématiques".
- Centro Fiorentino per la Filosofia della Scienza**, Florence (hôte: A. Cantini), Octobre 1996: "Logica e Tempo in Informatica" (voir [155]).
- EHESS**, Paris (CAMS; hôte: J.-P. Desclés), Juin 1996: "Types Intuitionnistes et Structures Géométriques".
 Mai 1997 (hôte: J. Petitot): "Impredicativité et Théorie des Types: enjeu logique et résultats récents".
- Instituto Superior Tecnico**, Lisboa, PORTUGAL (Dep. de Matematica; hôte: A. Sernadas): "Proofs, morphisms and programs: a survey", 12 February, 1998.
- Universita' di Bologna** (Dip. di Informatica; hôte: A. Asperti): "Circoli vizioni: dalla logica ai sistemi dinamici", 20 Febbraio, 1998.
- Collège de France**, Paris (LPPA; hôte: A. Berthoz): "Réflexions sur les fondements cognitifs de la géométrie", 24 Mars, 1998.
- Laboratoire des Maths Discrètes**, CNRS, Marseille (Colloque HCM "Types"; coordinateur: I.Y. Girard): "From Logical circularities to Mathematical expressiveness. Impredicativity and dynamical systems", 10 Avril, 1998.
- Universita di Roma I**, Roma (Informatica, Scienze; hôte: C. Boehm): "Circularita' ed Impredicativita' in Logica ed in Matematica: dalla Teoria dei Domini a quella dei Sistemi Dinamici. 21 Aprile, 1998.
- Universita' di Roma II**, Roma (Dip. di Filosofia; hôte: A. Carsetti): "Logica e tempo in Informatica", 19 Maggio; "Infinito e dimostrazioni in Aritmetica", 21 Maggio 1998.
- Brandeis University**, Boston (Department of Computer Science; hôte: 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.), 3-6 Octobre, 1998.

Universita’ di Pisa, Pisa (Dip. di Informatica; hôte: G. Levi): “Topologie e geometria in Informatica”, 26 Ottobre, 1998.

Pontificia Universitas Lateranensis, (Centro di Studi Fenomenologici; hôte: 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)”, 28 Novembre, 1998.

Workshop on “Methodology in Cognitive Sciences”, lecture on “Mathematical invariance and coding-dependence in Logic and Computer Science, an issue in knowledge representation”, Fondation des Treilles, Nice, 7 - 13 Decembre, 1998.

Primo Incontro Annuale del Progetto Cofinanziato “Tecniche formali per la specifica, l’analisi, la verifica, la sintesi e la trasformazione di sistemi software”. Conferenziere straniero invitato: “Circolarita’ ed equazioni, invarianza e geometria, dalla Teoria dei Tipi ad altri aspetti dell’Informatica”, Roma, 21 - 23 Dicembre 1998.

Universita’ di Genova, Genova (Dipartimento di Matematica; hôte: P. Boero): “Assiomatizza e deduzione: dalla lettura degli assiomi di Euclide al teorema di Kruskal-Friedman (FFF)”; Comune: “La resistibile ascesa della metafora: il cervello e’ un calcolatore digitale”, 11 et 12 Mars, 1999.

Colloque “L’existence en Mathématiques”. Conférence invitée: “Existence, coherence et constructions mathématiques possibles”, Paris, 27 Mars 1999.

EHESS, Paris, Seminaire “Histoires des Géometries” (hôte: D. Flement). Exposé: “Les limites du formalisme: l’intelligibilité géométrique de l’espace”, 10 Mai 1999.

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

University of Keio, Tokyo, Japan (Philosophy Dept., hôte: M. Okada): “Categories, 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.”, 18 and 19 May 1999.

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

Scuola “Matematica e Musica”: “Costruzioni di mondi sonori”. Conferenza invitata: “Costruzioni nello spazio e nel tempo, in Logica ed in Informatica”, Maratea, 29 - 31 Agosto 1999.

Colloque “Le réel en Mathématiques”. Conférence invitée: “Objectivité et construction en Mathématiques”, Cérisy, 3 - 10 Septembre 1999.

The 1999 meeting of the British Logic Colloquium. Invited lecture: “Prototype Proofs and Genericity in Type Theories”, Swansea, Wales, September 23-25, 1999.

Universita’ di Bologna, Bologna (Dipartimento di Matematica ed Informatica; hôte: A. Asperti): “Sulle dimostrazioni dei teoremi indimostrabili”,

27 Settembre, 1999.

III scuola estiva di Logica, AILA-SILFS: “Circolarità logiche ed espressività matematica” Cesena, Italia, 28-30 Settembre, 1999.

Centro di Filosofia della Scienza, Firenze: “I fondamenti della matematica e la metafora: il cervello e’ un calcolatore digitale (II)”, 5 Novembre, 1999.

Colloque “Le rationalisme: 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”, 10 - 11 Dicembre, 1999.

Università di Torino, Torino (Dipartimento di Informatica; hôte: M. Dezani): “Riflessioni sull’incompletezza: risultati recenti”, 20 Dicembre, 1999.

University of Lisbon, Lisboa (Department of Informatics; hôte: V. Vasconcelos): “Continuous Structures in Computer Science: from domain equations to computations in dynamical systems”, Jan. 9, 2000.

Università di Roma III, Roma (Dipartimenti di Filosofia e di Matematica; hôte: M. Abrusci): “L’intelligibilità geometrica dello spazio ed i fondamenti della conoscenza (matematica)”, 7 Febbraio, 2000.

Università di Roma I, Roma (Dipartimento di Informatica; hôte: A. Labella): “Incompletezze “concrete” in Aritmetica: dall’induzione formale al problema del carico induttivo”, 7 Marzo, 2000.

Colloque “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.”, 3 e 4 Aprile, 2000.

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

Collège de France, Paris (Atelier Espace, hôte: M. Denis): “Les fondements cognitifs des mathématiques, entre espace et langage”, 17 Avril, 2000.

Olimpiadi Nazionali di Matematica, Cesenatico, It.: “Concetti e Deduzioni in Matematica”, 6 Maggio, 2000.

Imperial College, London (Departement of Computing; hôte: A. Edalat) “The geometric intelligibility of space and the foundation of mathematical knowledge”, May 10, 2000.

Université de Paris VII, Paris (Equipe de Logique; hôte: P. Ressayre): “Le problème mathématique de l’espace et les fondements des mathématiques”, 15 Mai, 2000.

Colloque “Mathématiques 2000: Mathématiques, calcul, ordinateurs”, Paris (ENS): “The Difference between Diderot’s clocks, Turing machines and concurrent systems”, 24 mai, 2000.

Université de Paris VII, Paris (Labo. Preuves, Programmes et Systèmes; hôte: P.L. Curien, A Bucciarelli): “Réflexions sur les incomplétudes “concrètes” de l’Arithmétique et les preuves prototypes”, 8 Juin, 2000.

Colloque “Conoscenza e cognizione”, Firenze (It.): “Sulla natura della logica”, 7 Novembre, 2000.

Colloque “Geometria, intuizione ed esperienza”, Castiglioncello (It.): “Concetti matematici ed oggetti della fisica”, 1 e 2 Dicembre, 2000.

Journées d’épistémologie (physique, logique, mathématiques), I H P, Paris : “Principes de preuve et principes de construction: la notion de preuve, en mathématiques, est-elle recursive?”, 5 et 6 Décembre, 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; hôte: M. Kern): "Des fondements mathématiques possibles pour la prochaine machine", 16 Janvier, 2001.
- Colloque Mathematics and Cognition**, University of Rome II: "Mathematics, intentionality and meaning", February 9 and 10, 2001.
- Universita' di Rome I**, Rome (Dip. di Filosofia, hôte: C. Cellucci): "I fondamenti della Matematica, le macchine, il cervello", 15 Febbraio, 2001.
- Séminaire Heidelberg-Nancy-Strasbourg**, Nancy (hôte: P. Nabonnand): "Le problème de l'espace, les fondements des mathématiques et l'informatique", 30 Mars, 2001.
- Universita' dell'Aquila**, Aquila, It. (Dip. di Informatica, hôte: B. Intrigila): "Codifiche e calcoli: alcune differenze fra gli "orologi" di Diderot, le Macchine di Turing ed il cervello", 9 Aprile 2001.
- Colloque "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., hôte: 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", 15 Juin, 2001.
- Colloque "En honneur de Gilles CHATELET"**, Paris: "La métaphore et le geste dans la preuve: relire l'incomplétude mathématique des formalismes avec Gilles Chatelet, au-delà de la Gödelite", 27-29 June, 2001.
- AMS/SMF Meeting** (*American Mathematical Society / Société Mathématique de France*), Lyon: "Foundations of mathematics: some challenges in the interaction with other sciences", July 17-20, 2001.
- Colloque international "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", 24 - 29 septembre 2001.
- Colloque international "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., hôte: E. Robinson): "Unprovability and Prototype Proofs in Type Theory", January 18, 2002.
- Universita' di Pisa**, Pisa (Dip. di Informatica., hôte: G. Ghelli): "Indimostrabilità "concreta" in Aritmetica e "giudizi geometrici"", 19 Febbraio, 2002.
- Colloque international Cognition, Meaning and Complexity. Self-Organization in Cognitive Systems**, Université de Rome II, Rome: "Complexity as the nesting and interaction of levels of organization", 14-15 June, 2002.
- Colloque international 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", 9 - 10 September, 2002.
- Colloque **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", 17-19 ottobre 2002.
- University of Nijmegen**, Nijmegen, The Netherlands (Mathematics and Computer Science Depts., hôte : H. Barendregt): "Forms, Complexity and Information in some Natural Phenomena", December 9, 2002.
- ENS**, Paris (Séminaire "Formes Symboliques"; hôte: J. Lass 'egue): "Abstraction, symbolisme et rigueur : l'objectivité construite des Mathématiques", Salle des Actes 16h - 19h, 17 Décembre, 2002.
- Incontro Annuale del **Progetto Cofinanziato "CoMeta - Computational Metamodels"**. Conferenziere straniero invitato: "Al di là della codifica: un quadro concettuale per l'informazione e la complessità nei fenomeni naturali", Venezia, 19 - 21 Dicembre 2002.
- Università di Milano**, Milano, (Dip. di Filosofia, hôte : R. Fabbrichesi-Leo): "Fondamenti della Matematica e filosofia delle scienze naturali", 27 Gennaio 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.
- Ministero degli Affari Esteri e CNR: convegno degli scienziati italiani all'estero**, Roma, : "Riflessioni sulla diaspora scientifica italiana", 10-12 Marzo 2003.
- ENS**, Paris (Laboratoire "La Pensée des Sciences"; hôte: C. Alunni): "Catégories et dynamiques de la pensée : l'importance d'un cadre conceptuel ouvert et quelques applications spécifiques", 26 Mars, 2003.
- Centro Enriques ed Università di Pisa**, Livorno, "Matematica e scienze della natura, a partire da Enriques", 4 Aprile 2003.
- Workshop: **Mathématique, Informatique, Philosophie**, Univ. Paris VII et Paris I, Paris : "Discret vs. continu mathématiques et causalité physique", 24 - 26 Avril, 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**, (Dépts. de Mathématiques et d'Informatique; hôte: 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 scholastique platonisme/formalisme une composante d’une philosophie de la nature”, 24 octobre, 2003.
- University of Sao Paulo**, Brasil, (Dept. of Computer Science, hôte : M. Finger): “A cognitive investigation of concrete incompleteness”, 3 November 2004.
- University of Campinas**, Brasil, (Center for Logic and Cognition, hôte : W. Carnielli): “Some aspects of information and complexity in natural phenomena”, 5 November 2004.
- University of Rio de Janeiro**, Brasil, (Dept. of Computer Science, hôte : I. de Castro Dutra): “On the formal unprovability of some provable properties of numbers”, 10 November 2004.
- Ramifications of Category Theory**, a Workshop in honour of W. Lawvere, Università di Firenze: “Categories against the absolute: relativising constructions and ‘l’esprit de géométrie’”, 18-23 November, 2003.
- Incontro Annuale del Progetto Cofinanziato **CoMeta - Computational Meta-models**. Conferenziere straniero invitato: “Computer Modelling and Imitation in Natural Sciences”, Udine, 15 - 18 Dicembre 2003.
- King’s College, London**, (Computer Science Dept., hôte : T. Maibaum): ”Computational vs continuous models and causal relations”, January 28, 2004.
- Incontro Annuale di **Didattica della Matematica**. Conferenziere invitato: ”Linguaggio e gesto: dai fondamenti alla cognizione”, Pisa, 5 - 6 Febbraio, 2004.
- Università di Milano**, Milano, (Dipartimento di Filosofia, hôte : 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)”, 10 - 11 Marzo, 2004.
- Journée **Intérêt de la notion de symétrie : comme paradigme interdisciplinaire**, conférence invitée: “Symétries et structures causales”, Paris, 18 Mars, 2004.
- Università di Roma I**, Roma, (Dipartimento di Matematica, hôte : C. Bernardi): “Fondamenti della matematica, fra processi cognitivi e filosofia della natura”, 4 Maggio, 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, 13-14 Mai, 2004.
- Conference on **Computing and Philosophy**, invited lecture: “Computer imitation and mathematical understanding”, Pavia, Italie, 3 - 5 June, 2004.
- Colloque **Détermination et complexité**: “Aléas, déterminisme et programmes: les enjeux du continu vs. le discret mathématique”, Cérisy, Fr., 22 - 29 Juin, 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, 8 - 12 September, 2004.
- Colloque **Non-linéarité, irréversibilité et complexité**, conférence invitée: “Complexité structurelle: le continu vs. le discret”, Paris EHESS, 7-8 octobre, 2004.
- Conférence **Alan M. Turing, pour le cinquantième de sa mort**, conférence invitée : “De la difficulté de se mettre dans la peau d’un ordinateur: la Machine et le Vivant”, Metz, 15 octobre, 2004.
- Convegno **Alan Mathison Turing. L’uomo, la macchina, l’enigma**, conférence invitée : “Dalla catastrofe della scrittura alla “Discrete State Machine”: espressività e limiti del tagliare il mondo con l’accetta”, Milano, 3 - 4 Novembre, 2004.
- Imperial College**, London, (Computer Science Dept., host : A. Edalat): “Continuous vs discrete dynamics; some history, some concepts, one theorem”, January 26, 2005.
- XXII incontro della **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, 10 - 13 Febbraio, 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, (organisateur : M. Panza): “Intuition et construction en mathématique”, 14 Mars, 2005.
- Università’ La Sapienza**, Roma, (Dip. di Informatica, ospite: S. Guerrini): “Calcolabilità e dinamiche: predittibilità vs. decidibilità”, 18 Marzo, 2005.
- Colloque **Le logique et le biologique**, Paris, conférence invitée : “L’originalité de nos formalismes laplaciens vs. la criticité dynamique du vivant”, 22 avril 2005.
- Colloque **A partir de l’Origine de la géométrie de Husserl**, Paris, conférence invitée : “Fondements des mathématiques: arithmétique vs géométrie, les enjeux pour une philosophie des sciences de la nature”, 14 mai 2005.
- Colloque **La preuve mathématique : logique, histoire, philosophie**, Lille, invitation au débat: “L’incomplétude mathématique des formalismes et la complexité intrinsèque de la preuve”, 24 - 28 mai 2005.
- Ecole **Mathématiques et cerveau**, Paris, coordination et introduction au débat: “Mathématiques, cognition et espace”, 14 juin 2005.
- Colloque **Intelligence de la complexité : science et pragmatique**, Cerisy, conférence invitée : “Complexité critique : le discret vs. le continu mathématiques”, 23 - 30 juin 2005.
- Laboratoire de Génomique Fonctionnelle** (CNRS et Université Pierre et Marie Curie, hôte: C. Auffray), Villejuif : “L’incomplétude causale du paradigme du programme génétique et la singularité physique du vivant”, 29 septembre, 2005.
- Colloque **Turing, Goedel et Von Neumann: entre logique et biologie**, Nice, conférence invitée : “Turing et Goedel au milieu du gué : de la détermination laplacienne vers la morphogénèse et le sens”, 9 - 10 novembre 2005.

- Laboratoire de Neurosciences Cognitives** (LENA, CNRS et la Salpêtrière, hôte: S. Baillet), Paris : “Imitations et modèles : le cerveau à la Turing et la situation critique du vivant”, 28 novembre, 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.
- Università di Siena**, Siena, (Dip di Matematica, host : A. Ursini): “Da Poincaré a Turing: l’impredittibilità dei sistemi dinamici e l’indecidibilità computazionale sono nozioni correlate?”, 20 Febbraio, 2006.
- Convegno sul **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”, 23 - 25 Marzo 2006.
- Conference **Logic, Models and Computer Science**, Camerino, invited lecture: “Physical Determination, Unpredictability and Undecidability in Critical Processes”, 20 - 22 April 2006.
- ENS**, Paris, **Séminaire interdisciplinaire: La passerelle des Arts** : “Dynamiques de pensée en mathématiques: principes de preuve vs. principes de construction”, Salle des Actes, 10h, le 29 avril 2006.
- ENS**, Paris **Séminaire “Formes Symboliques**; hôte: J. Lassègue : “Mathématiques et sciences de la nature. La singularité physique du vivant”, au 45, salle des Résistants, 14h - 17h, 2 mai 2006.
- EHESS, Paris, Journée **Interfaces géométrie, physique et biologie** : “Géométrie du temps biologique”, 8 juin 2006.
- Università’ di Torino**, Torino, (Dip di Informatica, host : M. Dezani): “Correlazioni fra impredittibilità dinamica ed indecidibilità: alcuni concetti, a partire da Poincaré, ed alcuni risultati recenti su dinamiche unidimensionali”, 23 Giugno, 2006.
- Colloque/Ecole **Logique et Interaction: vers une géométrie du cognitif**, Cerisy-la-salle : “Structures causales et géométrie du temps biologique”, 19-26 septembre 2006.
- Convegno di **Neurofenomenologia**, Milano: “Processi cognitivi e la ragionevole efficacia della Matematica”, 4 Ottobre, 2006.
- Convegno franco-italiano: **Continuo e discreto**, Gargnano (Milano, It.) : “La determinazione fisica ed il continuo matematico (discussione)”, 5 - 7 Ottobre, 2006.
- Université de Orsay**, Orsay, (Dept d’Informatique, Grand Séminaire): “Que nous dit l’ordinateur du monde : entre informatique et sciences de la nature”, 11 Octobre, 2006.
- Università di Pisa**, Pisa, (Lezione Galileana): “Dall’informatica alla biologia: la singolarità fisica del vivente”, 25 Octobre, 2006.
- Colloque : **Federico Enriques et la science européenne**, Paris : “Principes de construction entre arithmétique et géométrie”, 8 décembre 2006.
- Colloque de biologie théorique : **A quoi sert la modélisation ?**, Centre Cavallès, Paris : “Imitations, modèles, schèmes”, 23 janvier, 2007.
- Université de Nice**, Nice, (Séminaire interdept., hôte : J. Kounieher): “La question de la modélisation et la singularité physique du vivant”, 6 février, 2007.
- Athens University**, Athens, (Graduate Program in Logic, host : C. Dimitracopoulos): “Undecidability in Logic vs dynamical unpredictability”, 19

- February, 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 Programs, 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”, 5 Avril 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”, 5 juin, 2007.
- Colloque : **La question des enchevêtrements hiérarchiques, en mathématiques et en biologie.**, Nice : “Différences et analogies entre autoréférences logiques et enchevêtrements-bouclages causaux chez le vivant”, 7-8 juin, 2007.
- France Culture: **Présentation du livre avec Francis Bailly**, Radiofrance, Paris: “Mathématiques et sciences de la nature. La singularité physique du vivant”, 14 juin, 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 Schringer”, 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.
- Simposio: **Fondamenti delle Scienze: settorializzazione e unitarietà della conoscenza**, Arcidosso: “Critica dei principi delle scienze esatte e riflessioni teoriche in biologia”, 6-8 settembre, 2007.
- Conference: **Types and Computations**, Roma: “Symmetries in Foundations”, October 3, 2007.
- Rencontre publique: **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”, 5 octobre, 2007.
- Conference: **Logica e...**, Pisa: “La Logica, i Programmi ed il DNA”, 19 Ottobre, 2007.
- Conference: **Neurophysiological memory: time and space**, Strasbourg: “Geometric schemes for retension, protension and biological rhythms over physical time”, October 23, 2007.
- Dipartimento di Informatica**, Univ. Firenze, (Séminaire interdept., hôte : R. De Nicola): “Il DNA e’ un programma?”, 11h 30, il 25 Ottobre, 2007.
- Conference: **Logica e...**, Pisa: “La Logica, i Programmi ed il DNA”, 26 Ottobre, 2007.
- Rehseis**, Paris, : “Poincaré, Goedel et l’ADN : questions de détermination et de formalismes”, 17h, le 20 novembre, 2007.
- Centre Cavallès**, ENS, Paris, : “Critique de la raison physico-mathématique en sciences du vivant. Quelques extensions théoriques du physico-mathématique”,

- 13h 30, le 21 novembre, 2007.
- Convegno: **Il filosofo e le pratiche scientifiche**, Milano: “L’elementare complesso e l’etica della conoscenza”, 5 Dicembre, 2007.
- Colloque 2007 du **Groupe “Logique et Interaction: vers une géométrie du cognitif**, Roma: “Poincaré, Goedel et l’ADN”, 13-16 Dicembre, 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 (hôte : H. Berestycki), Paris, : “Quelques résultats négatifs, l’incomplétude et la modélisation ” (avec T. Paul), salle 214, 15-18h, le 22 janvier, 2008.
- Convegno: **La vita come fenomeno globale multilivello: origini, emergenze, evoluzioni**, Bergamo (It.): “La singolarità fisica del vivente, entropia negativa e criticità estesa “, 27 febbraio, 2008.
- Dipartimento di Filosofia**, Università di Pavia (hôte : L. Magnani), Pavia, : “L’importanza dei risultati negativi. Comparazioni inter-teoriche di grandi programmi scientifici errati.”, 3 Aprile, 2008.
- Colloque: **La thèse de Church hier, aujourd’hui, demain**, Paris : ”L’arithmétique vs. l’enjeu du mobile et de la mesure”, 11 avril, 2008.
- Dipartimento di Filosofia**, Università di Roma I (hôte : E. Gagliasso), Roma, : “I miti alfabetici della logica e del programma, in cognizione e biologia”, 14h, 21 Aprile, 2008.
- Colloque: **Enchevêtrements et action du temps dans les systèmes vivants**, Nice : “L’organisation comme anti-entropie et la double irréversibilité du temps biologique”, 4-6 juin, 2008.
- Workshop : **XXVIIIème Séminaire de la Société Francophone de Biologie Théorique**, Saint-Flour (Cantal, France) : “Géométrie du temps biologique”, 8-11 juin, 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.
- Colloque: **Temps Long. De la physique aux sciences humaines**, ENS, Paris : ”L’aléatoire à temps court, long et infini”, 25-26 septembre, 2008.
- Colloque: **Négation, Dualité, Polarité** du Groupe LIGC, Carry le Rouet (Marseille) : “Antinomies et polarités dans les analyses de l’état vivant de la matière”, 16-19 octobre 2008.
- Colloque international: **Science, épistémologie, société**, Venezia : ”L’activité du vivant dans l’espace: des fondements cognitifs des mathématiques aux dynamiques biologiques”, 29-31 octobre, 2008.
- Colloque : **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”, 15-16 novembre, 2008.
- Convegno : **Metafore del vivente**, Roma : “L’informazione in Biologia: dal modello matematico al fascino discreto della metafora”, 27-29 novembre, 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.
- Convegno sul: **Naturalismo e antinaturalismo**, Firenze (It): “Dall’alfabeto al senso: verso i fondamenti cognitivi della matematica e verso una matematica dello stato vivente della materia”, 28-29 Maggio, 2009.
- Convegno: **Quale scienza per quale società**, Palazzo Ducale, Lucca (It), sezione Pensare la scienza: “La scienza di fronte al limite: l’importanza scientifica, etica e politica dei risultati negativi”, 25-26 giugno 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”, 27 e 28 Novembre, 2009.
- Conférence: **Visualisation et mathématisation**, Université de Liège, Be.: “*Voir* les mathématiques, des fondements aux applications”, 3 et 4 décembre, 2009.
- Convegno: **Nature, Selection and Biology**, Firenze, It.: “La singolarità fisica dello stato vivente della materia”, 4-8 dicembre, 2009.
- Ceperc, CNRS, Aix en Provence** (host: P.-A. Miquel): “Criticit     tendue et cycles biologiques”, 16 d  cembre, 2009.
- Institut d’Etudes Avanc  es**, Nantes (host: A. Supiot): “Penser et prouver en math  matiques et en physique. Et en biologie?”, 9 f  vrier, 2010.
- Convegno in **memoria di: Aldo Gargani**, Pisa: “La critica dei fondamenti e le correlazioni fra saperi scientifici”, 2 marzo, 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.
- Ecole Interdisciplinaire de biologie**, Berder, Fr.: “L’information et ses th  ories, de Turing    Chaitin. Et en biologie?”, 29 mars - 2 avril, 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: Ran-

- domness 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", 28 septembre, 2010.
- Seul National University**, Seul, 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 (dépt d'Informatique, host: S. Guerrini); "Une critique de la notion d'information en biologie et un modèle de la complexité phénotypique au cours de l'évolution", 29 novembre, 2010.
- Convegno: **Filosofia e Biologia**, Università di Bologna, Forlì; "Dai fondamenti della matematica ai fondamenti teorici della biologia", 3 - 4 dicembre, 2010.
- Deuxième rencontre: **PhénoMath: Concepts purs / Concepts appliqués**, Nice: "Le geste, la trajectoire et l'infini dans la constitution de l'objet mathématique", 9 - 10 décembre, 2010.
- Interview, **France Culture**, La place de la Toile: 17h: "Alan M. Turing", 26 décembre, 2010.
- Espace Mendès France**, Poitiers (hôte: A. Bonnefoy): "Brève histoire de l'infini, du continu et du discret", 11 janvier, 2011.
- Université Montpellier 2**, Montpellier (Dépt. de mathématiques; hôte: V. Durand-Guerrier): "La preuve et le sens dans les fondements des mathématiques", le 17 février; une rencontre avec les doctorants et discussion au sujet du **cours vidéo-enregistré** "Six leçons sur l'indécidabilité logique et l'aléatoire physique", 18 février, 2011.
- Università di Verona**, Verona (It.), Manifestazione pubblica: Infinita ... mente: "Sapere dire 'no' in scienza, o l'importanza dei risultati negativi", 19 marzo, 2011.
- Ecole normale supérieure**, Paris (Centre Cavallès): "Symétries et dualités: de la physique la biologie par extensions théoriques", 6 avril, 2011.
- Workshop: **The concept of Interaction: Biology, Logic and Philosophy**, Univ. Roma III, Roma: "Ever since Darwin: conceptual oppositions in Biology", 27 aprile, 2011.
- Convegno: **Il benevolo disordine delle stato vivente della materia**, Pisa: "Simmetrie ed aleatorio in biologia", 29 aprile, 2011.
- Atelier: **Information et stochasticité en biologie**, Paris: "Codages, codages, codages ... les mythes du signal alphabétique et de l'information sans forme", 4 - 6 mai, 2011.
- Workshop: **Self-Organization in Biology: Scope and Limits**, Aix-en-Provence: "Symmetries and symmetry-breakings in extended criticality", 24 - 25 May, 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?”, 29 juin, 2011.
- Convegno: **Possibilita' e determinazione**, Pisa : “Dalla determinazione dei sistemi di riferimento in fisica all’aleatorio biologico: quali evoluzioni possibili dell’eco-sistema?”, 19 settembre, 2011.
- Incontro con: **M. Buiatti e G. Longo**, Università La Sapienza, Villa Mirafiori, Roma : “Ripensare la logica del vivente”, 21 settembre, 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.
- Colloque: **Le hasard au coeur de la cellule**, Lyon : “Aléatoire et irréversibilité du temps, physique/biologique”, 21 - 23 novembre, 2011.
- Conference: **Theoretical Computer Science and Applications**, Auckland, New Zealand: “Interfaces of Randomness”, February 21 - 24, 2012.
- Colloque, **La temporalité en biologie**, Paris: “L’irréversibilité propre du temps biologique : protension et rythmes comme organisateurs de l’action, face l’aléatoire”, 29 - 30 mars, 2012.
- Atelier Morphologie, **ENSAD**, rue d’Ulm, Paris: “A. M. Turing : les calculs et les formes”, 2 - 3 avril, 2012.
- Università di Firenze**, Dipart. Filosofia (ospite: R. Lanfredini), Firenze: “Il vivente e’ sempre “in transizione critica” ed in non-predefinibile spazio dei possibili. Quale teoria allora per la singolarita’ fisica dello stato vivente della materia ?”, 24 aprile 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”, 27 aprile, 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”, 10 - 12 maggio, 2012.
- Workshop, **La Simplexité**, Paris: “Un grand enjeu de l’ évolution: la simplification des bauplan, la complexification du phénotype”, 23 - 24 mai, 2012.
- Institut d’Etudes Avancées**, Nantes, workshop: “Epistémologie, biologie, médecine”, 30 et 31 mai, 2012.
- Workshop of **The Turing year: The Incomputable**, Isaac Newton Institute programme - “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 programme - “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 modle des dynamiques continues des formes”, 2 juillet, 2012.

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

Rencontre “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”, 5 - 6 juillet, 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”, 13 septembre, 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. (ospite: M. Mugnai): “Turing: dalla Macchina alla morfogenesi o l’importanza dei risultati negativi”, 2 ottobre 2012.

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

Seminario Enriques, Milano, It. (Dipartimento di Matematica, ospite: 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”, 22 ottobre 2012.

Università, Verona, It. (Conferenza pubblica, ospite: R. Giacobazzi): “I fondamenti della matematica, fra fisica e biologia”, 6 dicembre 2012.

Ens, Centre Cavallès, Paris: “Aléatoire, irréversibilité du temps et imprédictibilité”, 13h 30 - 15h, le 30 janvier 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, le 18 février 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, Gdel, Monod”, 11 mars 2013. Texte de référence: Interfaces de l’incomplétude.

- University College London, Bartlett International Lecture Series, London, GB:
"Modelling: randomness makes the difference", 15 March, 2013.
- Convegno, Poincaré (1854-1912) a centouno anni dalla scomparsa, Università Roma 2, Roma, It.: "Aleatorietà e determinazione, necessita' e contingenza. L'insegnamento di Poincaré e la sua difficile assimilazione", 21 marzo 2013.
- Ecole de Berder, Corrélation, causalité et régulation en biologie, Berder, Fr.:
"Les causes et les possibles, entre physique et biologie", 9 - 12 avril 2013.
- Groupe, Evolution, Museum Nat. Histoire Naturelle, Paris: "Une critique de l'information: évolution de la complexité et de l'organisation biologique", 23-25 avril, 2013.
- Symposium, Academia Europaea, Wenner-Gren Center, Stockholm, Sweden:
"Science in our relational humanity: critical insights and knowledge construction", 23 - 25 May, 2013.
- Istituto Studi Avanzati (ISA), Bologna, It., (host: S. Martini) maggio e giugno 2013, ciclo di seminari: - Informatica: "Schroedinger (1944) e Turing (1952) sulla logica del vivente: dalla "codifica" alla "genesi" dell'organizzazione e delle forme", 8 maggio; - Filosofia: "Simmetrie e rotture di simmetrie: per una epistemologia all'interfaccia delle discipline", 16 maggio; - ISA: "The Relevance of Negative Results: Incomputability and Undecidability in Physics and in Biology", 21 maggio; - Istituto Ramazzini per i tumori e le malattie ambientali: "Caso e diversità in biologia: raffrontando complessità e organizzazione funzionale", 5 giugno; - 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", 11 Giugno; - 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", 18 giugno.
- 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.
- Groupe, Evolution, Arcachon: "Information, biologie, evolution", 1-3, juillet, 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.
- Colloque, Naturaliser le modèle, Chambord, Fr.: "Le modèle comme regard organisateur du réel", 25 octobre 2013.
- Groupe, Evolution, Paris : "Diversification, hasard, evolution", 5 - 8 novembre, 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.
- Dipartimento di Filosofia, Università di Roma I (ospite: E. Gagliasso), Roma, : "Le simmetrie come principi di costruzione e di intelligibilità", in *matematica ed in fisica ed in biologia?*", 18 e 19 novembre, 2013.
- Dipartimenti di Filosofia e di Matematica e Fisica, Università di Roma III (ospiti: T. Numerico, M. Abrusci), Roma, : "La memoria ed la costruzione del "senso" in matematica", 20 novembre, e "Cambiamenti di simmetrie ed aleatorio: dalla fisica alla biologia", 22 novembre, 2013.
- Workshop, Epistemologia della matematica, Faenza: "Interfacce fondazionali e risultati negativi: il ruolo del sapere critico", 23 - 24 novembre, 2013.
- Institut d'Études Avancées, Nantes, exposés et projet de recherche : "La construction du sens et de l'objectivité scientifique: entre histoire et épistémologie" (présentation video, 15 min), séjour de janvier à mars, 2014.
- Université de Nantes - INRIA, LINA, (hte: N. Tabareau) Nantes: "L'aléatoire: physique, biologique, computationnel" (enregistrement video), 26 mars, 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 (Dipartimento di Filosofia) e Scuola nazionale COOP, Firenze: "Teoria e filosofia del tempo biologico" e "Il senso dell'organicità", 14 e 16 aprile, 2014.
- Incontri, 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?", 23 aprile, 2014.
- Université de Nice, Séminaire de philosophie des sciences, Nice: "La théorie, le modèle, le réel", 19 mai, 2014.
- Ecole de printemps, Le Vivant Critique et Chaotique, Société Francophone de Biologie Théorique (SFBT), Saint Flour, (Fr.) : "Changements critiques de symétrie et aléatoire : quelques aspects biologiques", du 21 au 25 mai 2014.
- Colloque, 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", 30 juin - 2 juillet, 2014.
- Conference, Luca Cardelli Fest (Informatics and Bio-informatics), Cambridge: "What happened after LUCA?", 8-9 september, 2014.
- Ens, Séminaire de la Chaire B. Pascal, Paris : "Logique et épistémologie de l'espace: de la "prospettiva" aux espaces théoriques de la biologie", 30

- septembre, 2014.
- Rencontres Glass Bead (www.glass-bead.org), Paris : La constitution du sens: des structures des mathématiques aux organismes (e ritorno), 3 et 4 octobre, 2014.
- Ecole d'architecture Paris-Malaquais (hte : P. Morel), Paris : Modèles et simulations : le jeu continu discret et les brisures de symétries, 9 octobre, 2014.
- Colloque, Lévaluation face aux enjeux globaux: biologie, techniques et vulnérabilités, Paris: "Aléatoire, historicité et complexité biologique", 14 octobre, 2014.
- Universita' di Roma 2 ed 1, Dipartimenti di Filosofia e Centro Cognizione-Linguaggio-Conoscenza, 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", ottobre 2014.
- Universita' di Pisa, Dipartimento di Matematica (ospite: Maffei), Pisa : L'invenzione dello spazio, 30 ottobre, 2014.
- Université de Fribourg, Ecole Doctorale Suisse Occidentale, Fribourg : Série de séminaires Modèles et méthodes : du computationnel au vivant, 19 - 21 novembre, 2014.
- Colloque, 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, 5 et 6 décembre, 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, 7 Janvier, 2015.
- Universidad Andres Bello, Santiago, Chili (Departamento de Matematicas: C. Rojas, host): From physical to biological randomness: its role in enhancing life diversity and stability, 13 Janvier, 2015.
- Series Digital Studies, Salle Triangle (Centre Georges Pompidou, Paris): A partir de "Lorigine de la géométrie" de Husserl, 27 Janvier, 2015.
- Colloque, 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, 1 avril, 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, 11 mai, 2015.
- Convegno in onore di Marco Forti, Pisa: Il "senso delle strutture", dalla matematica agli organismi", 22 - 23 maggio, 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, 25 - 27 June, 2015.
- Conference, Unconventional Computation and Natural Computation 2015, Auckland, New Zealand: The unconventionality of nature: Biology from Noise

- to Functional Randomness”, 31 August - 4 September, 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”, 9 - 11 September, 2015.
- Colloque, 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”, 12 - 14 octobre 2015.
- Colloque, ”Lois des dieux, des hommes et de la nature”, IEA, Nantes: Introduction au colloque : Le rle de l'histoire: biologie vs. sciences humaines et lidéologie des Big Data”, 15 - 16 octobre, 2015.
- Universita' di Firenze, Dipart. Filosofia (ospite: R. Lanfredini), Firenze: ”Costruzioni di conoscenza: fenomenologia dell'interazione matematica/fisica/biologia”, 26 ottobre 2015.
- CAPHES, Ens, Paris, “L’espace comme carrefour épistémologique et phénoménologique”: Symétries et mesures en sciences de la nature, à partir de H. Weyl, 13 novembre, 2015.
- Colloque, ”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”, 14 - 15 décembre, 2015.
- Colloque, ”La liberté de l'improbable”, Collège de France, Paris : Histoire et créativité ou l'aléatoire sans probabilités”, 15 décembre, 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-tre” qualitatif dans les phénomènes” comme a priori de la modélisation quantitative des formes”, 10 - 12 février, 2016.
- Scuola invernale, ”Scienza e società”, Rivarolo (To), Italie : Considerazioni scientifiche contro lo scientismo, oggi”, 26 - 28 febbraio, 2016.
- INS HEA, Strasbourg: Séminaire: Images des savoirs pratiques: Informatique: origines logiques et images du monde , 25 avril, 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”, 25 - 27 may, 2016.
- IMERA, Université Aix-Marseille: Séminaire : Modèles et théories : du physique au biologique, 31 mai, 2016.
- Conference, ”Building Theories, Sciences and Hypotheses”, Roma: Theoretical challenges in biology: from cancer to organisms”, 16 - 18 june, 2016.
- Colloque, ”Sciences de la vie, sciences de linformation”, Cerisy-la-Salle : L'information sans sens ni structures”, 19 - 26 septembre 2016.

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).

Édition d'ouvrages collectifs

- [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.

Invited Papers

- [13] 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).
- [14] 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).
- [15] 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.”.
- [16] 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.
- [17] Giuseppe Longo. Logique et Informatique. In *Encyclopédie de Philosophie et Histoire des Sciences*, pages 586–590. Press Universitaire de France, 1999.
- [18] 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.
- [19] 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 *Revue de Synthèse*, n. 1 (pp. 111-138), January 1999.
- [20] 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.
- [21] 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).
- [22] Giuseppe Longo. Proofs and Programs. *Synthese, Kluwer*, 134(1-2):85–117, January-February 2003. Invited paper.
- [23] 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 française: *Revue de Synthèse*, Paris, n. 1, 2004.

- [24] 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 Scienze.
- [25] 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.
- [26] 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.
- [27] 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.
- [28] 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.
- [29] 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.
- [30] Giuseppe Longo. Incompletezza. In C. Bartocci, editor, *La Matematica*. Einaudi, 2010. Downloadable in English.
- [31] 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.
- [32] 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.
- [33] 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.
- [34] 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.
- [35] 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.

- [36] 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.
- [37] G. Longo and M. Montévil. Extended criticality, phase spaces and enablement in biology. *Chaos, Solitons & Fractals*, 55(0):64 – 79, 2013. Special Issue.
- [38] 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 simplicité*. Odile Jacob, 2013. Article invité.
- [39] 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.
- [40] G. Longo and M. Montévil. Models vs. simulations: a comparison by their theoretical symmetries. In M. Dorato, L. Magnani, and T. Bertolotti, editors, *Springer Handbook of Model-Based Science*. Springer, 2015.
- [41] Giuseppe Longo. Synthetic philosophy of mathematics and natural sciences, conceptual analyses from a Grothendieckian perspective, reflections on “Synthetic philosophy of contemporary mathematics by F. Zalamea. *Speculations: Journal of Speculative Realism*, 2016. To appear.

Invited Lectures

- [42] Giuseppe Longo. Continuous 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.
- [43] 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. Springer-Verlag, 1984. Invited Lecture.
- [44] 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)).
- [45] 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.
- [46] 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.

- [47] 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.
- [48] 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.
- [49] 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.
- [50] 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.
- [51] Giuseppe Longo, Giuseppe Castagna, and Giorgio Ghelli. Overloaded functions with subtyping. In Winskell, editor, *Categorical Logic in Computer Science*, pages 139–160. DAIMI, Aarhus, 1992. Invited Lecture. (Version définitive: les deux articles avec Castagna et Ghelli).
- [52] 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.
- [53] 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.
- [54] 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.
- [55] 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.
- [56] 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.
- [57] 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.

- [58] 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.
- [59] Giuseppe Longo. Mémoire et objectivité en Mathématique. 2001. Conférence invitée aux actes du Colloque “Le réel en mathématiques”, Septembre 1999, Cérisy.
- [60] 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 française : *Intellectica*, 2003/1-2, n 36-37.).
- [61] Giuseppe Longo. Computer Modelling and Natural Phenomena. In P. Inverard, editor, *European Software Engineering Conference and ACM SIG-SOFT Symposium*, pages 1–5, New York, 2003. ACM Proceedings. Invited Lecture, Helsinki, Finland, September 1-5 , 2003.
- [62] 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.
- [63] 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.
- [64] Giuseppe Longo. Some Topologies for Computations. In Flament et al., editor, *Actes de “Géométrie au XX siècle”*, pages 377–399. Hermann, 2005.
- [65] 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.
- [66] 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.
- [67] 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 interaction: pour une géométrie de la cognition” (J. B. Joinet ed.), Presses Universitaires de la Sorbonne, 2008.
- [68] 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.

- [69] 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.
- [70] 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.
- [71] G. Longo. Interfaces de l'incomplétude. In *La Matematica*. Einaudi, 2010.
- [72] Giuseppe Longo. Incomputability in physics and in biology. In B. Lowe et al., editor, *Computability in Europe*. Azores, Portugal, June 2010, LNCS 6158, Springer, 2010. (Extended and revised journal version, MSCS, 2012).
- [73] 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.
- [74] Jean Lassègue and Giuseppe Longo. What is Turing's 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.
- [75] 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>).
- [76] G. Longo and M. Montévil. Randomness increases order in biological evolution. In M. Dinneen, B. Khossainov, 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).
- [77] 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, GECCO12, July 7-11, 2012, Philadelphia (PA, USA).
- [78] 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.
- [79] G. Longo and N. Perret. Anticipation, protension et inertie biologique. In A. Berthoz C. Debru, editor, *Anticipation et Prédiction*. Collège de France, 2015.

- [80] Giuseppe Longo. Le conseguenze della filosofia. In *A Plea for Balance in Philosophy*. ETS, Pisa, 2015. Conferenza invitata, Firenze, aprile 2014.
- [81] G. Longo and M. Montévil. From logic to biology via physics: a survey. 2016. Special issue, Scientific meeting in honor of Pierre-Louis Curien.
- [82] Giuseppe Longo. How future depends on past histories in systems of life. In V. Thomas-Vaslin, editor, *Approches théoriques et modélisation de la diversité biologique: du système immunitaire aux macro-écosystèmes*, 2016. Invited Lecture, ISC conference, octobre 2015, Paris (apparso in italiano in Paradigmi, n. speciale XXXIII, Maggio-Agosto, 2015, G. Gagliasso e F. Sterpetti, eds).

Refereed Journals

- [83] Giuseppe Longo and Marisa Venturini-Zilli. Complexity of theorem-proving procedures: some general properties. *Revue française d'Automatique Informatique et Recherche Operationelle (R.A.I.R.O.) (serie rouge de Math.: Informatique Théorique)*, (3):5–18, 1974.
- [84] Giuseppe Longo. On the problem of deciding equalities in Theories of Objects and in a formal system. *Studia Logica*, 35(4):335–348, 1976.
- [85] Piero Ferrari and Giuseppe Longo. Axiomatic Theory of Enumeration: a note on the axiom of extensionality. *Studia Logica*, 37(3):261–268, 1978.
- [86] 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.
- [87] Roger Hindley and Giuseppe Longo. Lambda-calculus models and extensionality. *Zeitschrift für Mathematische 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.
- [88] Giuseppe Longo and Marisa Venturini-Zilli. A lambda-delta-calculus with an algorithmic delta. *Zeitschrift für Mathematische 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.
- [89] 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.
- [90] 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).

- [91] Giuseppe Longo. Set-theoretical models of lambda-calculus: Theories, expansions, isomorphisms. *Annals of Pure and Applied Logic*, 24:153–188, 1983.
- [92] Kim Bruce and Giuseppe Longo. On combinatory algebras and their expansions. *Theoretical Computer Science*, 31(1-2):31–40, 1984.
- [93] Paola Giannini and Giuseppe Longo. Effectively given domains and lambda-calculus semantics. *Information and Control*, 62(1):36–63, 1984.
- [94] 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.
- [95] 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)).
- [96] 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)).
- [97] Giuseppe Longo and Eugenio Moggi. A category-theoretic characterization of functional completeness. *Theoretical Computer Science*, 70(2):193–211, 1990.
- [98] 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).
- [99] Giuseppe Longo and Eugenio Moggi. Constructive natural deduction and its “omega-set” interpretation. *Mathematical Structures in Computer Science*, 1(2):215–253, 1991.
- [100] 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).
- [101] Giuseppe Longo. Prototype Proofs in Type Theory. *Mathematical Logic Quarterly (formerly: Zeitschrift f. Math. Logik und Grundlagen der Math.)*, 46(3), 2000.
- [102] Giuseppe Longo, Kathleen Milsted, and Sergei Soloviev. Coherence and Transitivity of Subtyping as Entailment. *Journal of Logic and Computation*, 10(4):493–526, 2000.
- [103] Giuseppe Longo. Savoir critique et savoir positif: l’importance des résultats négatifs. *Intellectica*, 40(1):15–26, February 2005.

- [104] 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.), De-Boeck, Paris, 2007.
- [105] 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 (Bourguine ed.), La Découverte, Paris, 2007.
- [106] Francis Bailly and Giuseppe Longo. Biological Organization and Anti-entropy. *Journal of Biological Systems*, 17(1):63–96, 2009.
- [107] M. Mossio, G. Longo, and J. Stewart. Computability of closure to efficient causation. *Journal of Theoretical Biology*, 257(3):489–498, 2009.
- [108] 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.
- [109] 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.
- [110] Giuseppe Longo and Maël Montévil. Protention and retention in biological systems. *Theory in Biosciences*, 130(2):107 – 117, 2011.
- [111] 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.
- [112] 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.
- [113] Marcello Buiatti and Giuseppe Longo. Randomness and multilevel interactions in biology. *Theory in Biosciences*, 132(3):139–158, 2013.
- [114] G. Longo and M. Montévil. Extended criticality, phase spaces and enablement in biology. *Chaos, Solitons & Fractals*, 55:6479, 2013.
- [115] T. Felin, S. Kauffman, R. Koppl, and G. Longo. Economic opportunity and evolution: Beyond bounded rationality and phase space. *Strategic Entrepreneurship Journal*, 8(4):269282, 2014.
- [116] 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.
- [117] Cristian Calude and Giuseppe Longo. Classical, quantum and biological randomness as relative unpredictability. *Natural Computing*, 2015. in print.

- [118] 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.
- [119] Cristian Calude and Giuseppe Longo. The deluge of spurious correlations in big data. *Foundations of Science*, 2016. To appear.
- [120] Maël Montévil, Giuseppe Longo, and Matteo Mossio. Theoretical principles for biology (ii): Principle of variation. *Progress in Biophysics and Molecular Biology*, to appear, 2016.
- [121] Matteo Mossio, Maël Montévil, and Giuseppe Longo. Theoretical principles for biology (i): Principle of organization. *Progress in Biophysics and Molecular Biology*, to appear, 2016.

**Communication dans des conférences internationales avec
comité de lecture**

**(Les versions préliminaires de [13], [14], [44], [87], [88], [95], [96],
[98], [100], ne sont pas incluses dans cette liste)**

- [122] 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)).
- [123] Giuseppe Longo and Marisa Venturini-Zilli. Theory of computation with an identity discriminator. In Michelson and Milner, editors, *Automata Languages and Programming (ICALP 76)*, pages 147–167. Edinburgh University Press, 1976.
- [124] 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.
- [125] 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.
- [126] 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.
- [127] 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.
- [128] 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.

- [129] 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.
- [130] 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.
- [131] 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 [102]).
- [132] 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

- [133] 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).
- [134] Giuseppe Longo. I problemi di decisione e la loro complessità seminari di informatica teorica 2. Pubblicazione I.A.C. - C.N.R., 1974. Roma(pp. 87-108).
- [135] 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.
- [136] Giuseppe Longo. Prefazione a “Modelli del lambda-calcolo e dell’Aritmetica di Peano”. Quaderno dei Gruppi di Ricerca in Matematica del CNR, 1981.
- [137] Giuseppe Longo. Hereditary partial effective operators in any finite type. Forshungsinstitut für Mathematik E.T.H. Zuerich, 1982.
- [138] Giuseppe Longo. Ricorsività e continuità: un’introduzione. Atti degli Incontri di Logica Matematica, 1982.
- [139] Kim Bruce and Giuseppe Longo. An elementary approach to the solution of recursive domain equations, 1983. Williams College.
- [140] Mario Coppo, Mariangiola Dezani, Furio Honsell, and Giuseppe Longo. Applicative information systems. Nota Scientifica S-83-5, Università di Torino, 1983.
- [141] Giuseppe Longo. Logica ed Informatica: metodi di indipendenza in Informatica matematica. *Teoria*, 3(2):39–51, 1983.

- [142] 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.
- [143] Giuseppe Longo and Eugenio Moggi. Types, computations and categories. International Congress on Logic and Philosophy of Science, San Geminiano, 1983.
- [144] 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.
- [145] Giuseppe Longo. The denotational meaning of impredicative type theories. *Proceedings of the Workshop on Logic of Programming*, Mastrand (Sweden), 1987. Invited Lecture.
- [146] Giuseppe Longo. Remarks on logic in mathematics and in computer science. *Logic Colloquium '88*, Ferro et al. (eds.), North Holland., 1988.
- [147] Giuseppe Longo. Review of Feferman's paper "Weyl vindicated, Das Continuum 70 years later". *Journal of Symbolic Logic*, vol 58, n. 3, 1993.
- [148] Giuseppe Longo. La dette publique et le système fiscal italien. *Alternatives Economiques*, n. 115, Mars 1994. pp. 14 - 18.
- [149] Giuseppe Longo. Review of Trakhtenbrot's paper "Comparing the Church and Turing approaches: two prophetic messages". *Journal of Symbolic Logic*, 1994. vol. 59, n. 4.
- [150] Giuseppe Longo. Sur l'Emergence de l'Objectivite' et de l'Universalite' en Mathematiques. *Intellectica*, 20(1), 1995.
- [151] 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.
- [152] Giuseppe Longo. Logica e modelli teorici della Biologia. *Sistemi Intelligenti*, (1):150-155, 1997.
- [153] Giuseppe Longo. Rigueur mathématique, Logique et Machines, 1997. Conférence invitée, actes du Colloque "Voir, Entendre, Calculer, Raisonner", La Villette, Paris.
- [154] Giuseppe Longo. La Razionalità e le Macchine, prefazione al libro "Logica ed Informatica" di A. Asperti e S. Ciabattoni, North-Holland, 1998.
- [155] Giuseppe Longo. Logica e Tempo in Informatica. *Atti del ciclo di seminari "La realtà ed i linguaggi: nuove frontiere della scienza"*, pages 63-93, 1999. Conférence invitée, Centro Fiorentino per la Filosofia della Scienza, Octobre 1996.
- [156] 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.

- [157] Giuseppe Longo. Laplace (a note on incompleteness). MSCS, Cambridge U.P., 2001. An item of J-Y. Girard's dictionary , at the end of "Locus Solum", vol.11, n.3.
- [158] Giuseppe Longo. Lo spazio, i fondamenti della matematica e la resistibile ascesa della metafora: il cervello e' 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.
- [159] 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.
- [160] Giuseppe Longo. L'informatique aux interfaces des savoirs, 2012. Actes du colloque *Quelques interactions logique/monde* (JB. Joinet, editor).

Lecture Notes

- [161] 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).
- [162] 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).