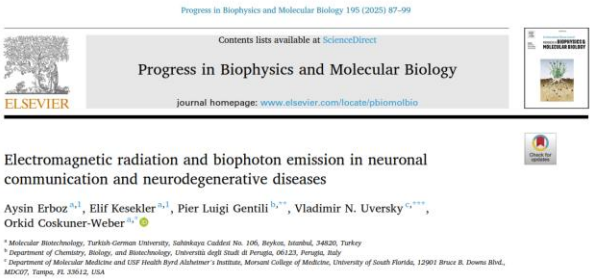
# FACING COMPLEXITY:

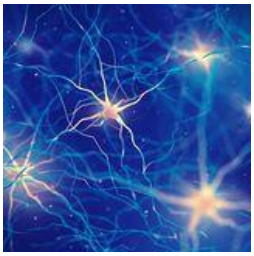
# NATURAL COMPUTING AND THE DEVELOPMENT OF CHEMICAL ARTIFICIAL INTELLIGENCE.

## ***Papers in Journals***

(56) A. Erboz, E. Kesekler, P. L. Gentili, V. N. Uversky, O. Coskuner-Weber.
"*Electromagnetic radiation and biophoton emission in neuronal communication and neurodegenerative diseases*."
Progress in Biophysics and Molecular Biology, **2025**, *195*, 87–99.
https://doi.org/10.1016/j.pbiomolbio.2024.12.004


Progress in Biophysics and Molecular Biology 195 (2025) 87–99
Contents lists available at ScienceDirect
Progress in Biophysics and Molecular Biology
journal homepage: www.elsevier.com/locate/pbiomolbio
Electromagnetic radiation and biophoton emission in neuronal communication and neurodegenerative diseases
Aysin Erboz [a,1], Elif Kesekler [a,1], Pier Luigi Gentili [b,**], Vladimir N. Uversky [c,***], Orkid Coskuner-Weber [a,*]

(55) Pier Luigi Gentili*, Siegfried Karg, Gyorgy Csaba, Konrad Szaciłowski
"*Editorial: Reviews and perspectives in neuromorphic engineering: novel neuromorphic computing approaches.*"
Front. Neurosci. 2024, 18, 1498684.
https://doi.org/10.3389/fnins.2024.1498684



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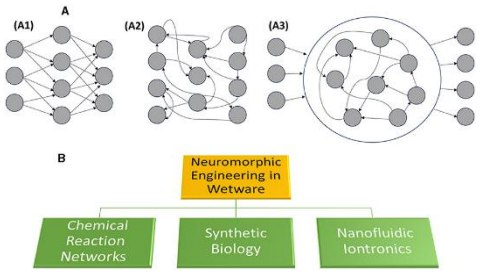


(53) Pier Luigi Gentili*, Pasquale Stano
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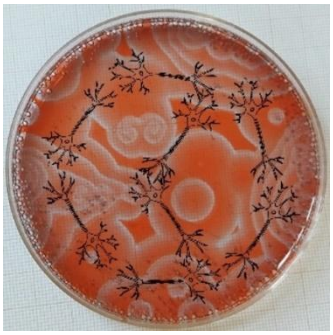
https://doi.org/10.1002/syst.202400054



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"*Determining Chemical Microheterogeneity from the Analysis of Absorption and Luminescence Transient Signals*."

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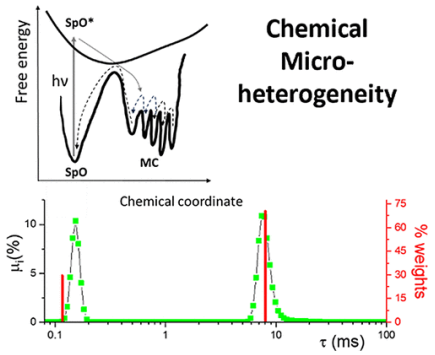


(51) Pier Luigi Gentili*, Pasquale Stano*

"*Living cells and biological mechanisms as prototypes for developing chemical artificial intelligence*."

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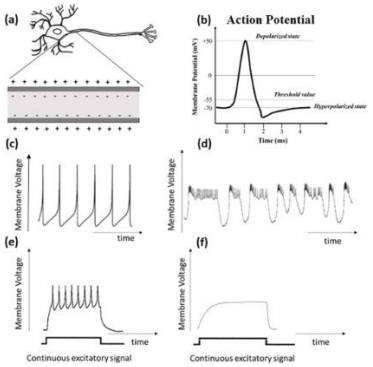


(50) Pier Luigi Gentili*

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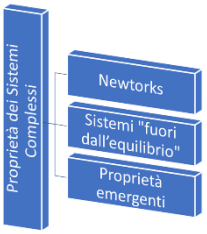


(49) Pier Luigi Gentili*

*The Conformational Contribution to Molecular Complexity and Its Implications for Information Processing in Living Beings and Chemical Artificial Intelligence*.

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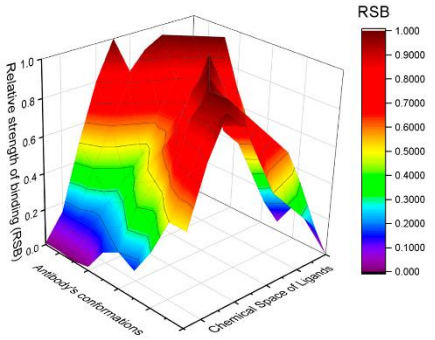


(48) Laura Tomassoli, Leonardo Silva-Dias, Milos Dolnik, Irving R. Epstein, Raimondo Germani, Pier Luigi Gentili*

*Neuromorphic Engineering in Wetware: Discriminating Acoustic Frequencies through Their Effects on Chemical Waves.*

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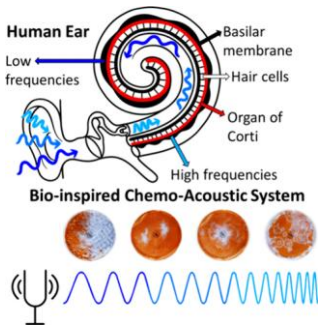

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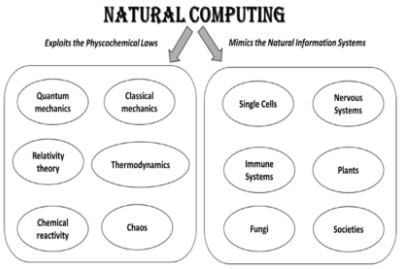


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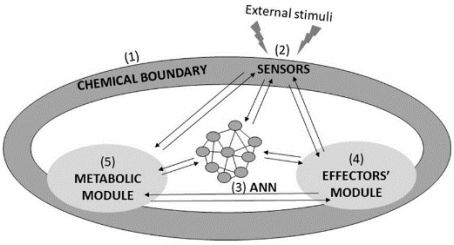


(44) Pier Luigi Gentili*, Pasquale Stano

*Tracing a new path in the field of AI and robotics: mimicking human intelligence through chemistry. Part I: Molecular and supramolecular chemistry.*

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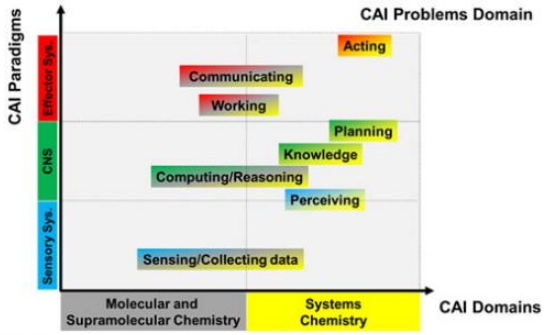


(43) Pasquale Stano*, Pier Luigi Gentili, Luisa Damiano, Maurizio Magarini

*A Role for Bottom-Up Synthetic Cells in the Internet of Bio-Nano Things?*

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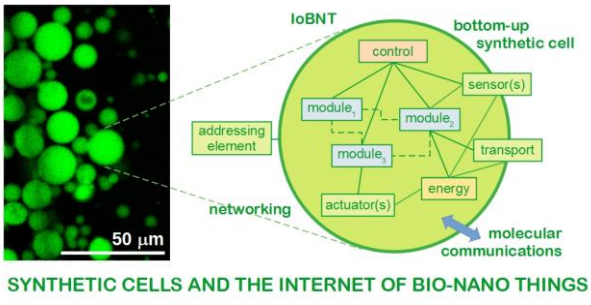
https://doi.org/10.3390/molecules28145564



(42) Pier Luigi Gentili*, Pasquale Stano*.
*"Monitoring the advancements in the technology of artificial cells by determining their complexity degree: Hints from complex systems descriptors*."
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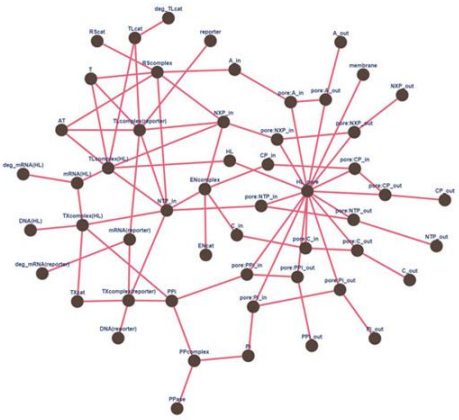

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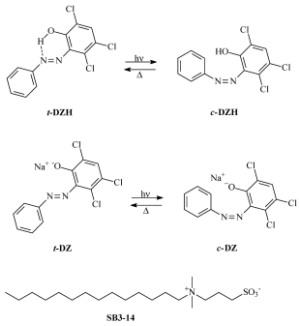


(40) Pier Luigi Gentili*, Juan Perez-Mercader
"*Quantitative Estimation of Chemical Microheterogeneity through the Determination of Fuzzy Entropy*."
Frontiers in Chemistry, 2022, 10, 950769.
https://doi.org/10.3389/fchem.2022.950769

Quantitative estimation of chemical microheterogeneity through the determination of fuzzy entropy

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(39) Pier Luigi Gentili
"*Photochromic and luminescent materials for the development of Chemical Artificial Intelligence.*"
Dyes and Pigments, 2022, 205, 110547
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Dyes and Pigments 205 (2022) 110547

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journal homepage: www.elsevier.com/locate/dyepig

Photochromic and luminescent materials for the development of Chemical Artificial Intelligence

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ABSTRACT

Artificial Intelligence (AI) is an interdisciplinary research line that aims to devise intelligent machines. Chemical Artificial Intelligence (CAI) focuses on designing intelligent chemical systems, primarily in wetware. This work shows that intelligent chemical systems can be implemented by devising neural surrogates that, by interplaying, can give rise to synchronization phenomena analogous to those of real neurons in the brain. When the signals employed in the communication are UV-visible radiations, the artificial neuron models can be implemented through photochromic and luminescent compounds, as this work demonstrates. Furthermore, this article describes how photochromic and luminescent materials contribute to processing Fuzzy logic, which is a good model of human power to compute by using words. Perspectives on how photoswitchable materials will be employed in further developments of CAI are outlined.

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"*Chemical Neural Networks Inside Synthetic Cells? A Proposal for Their Realization and Modeling.*"

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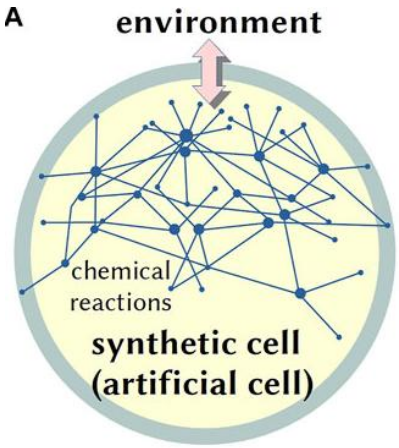


(37) Giulia Quaglia, Beatrice Bartolomei, Pier Luigi Gentili, Loredana Latterini.

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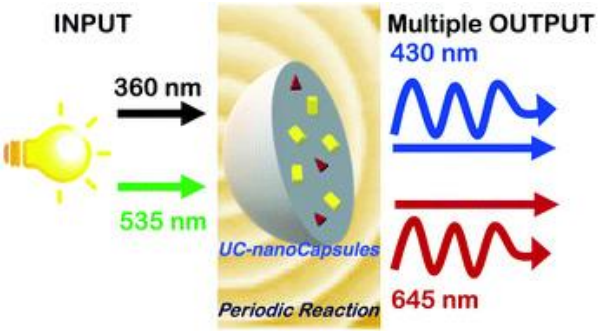


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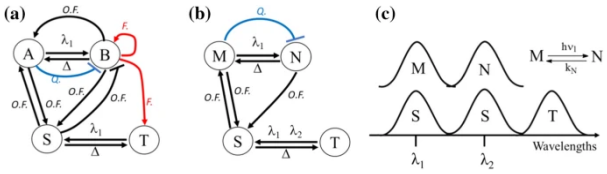


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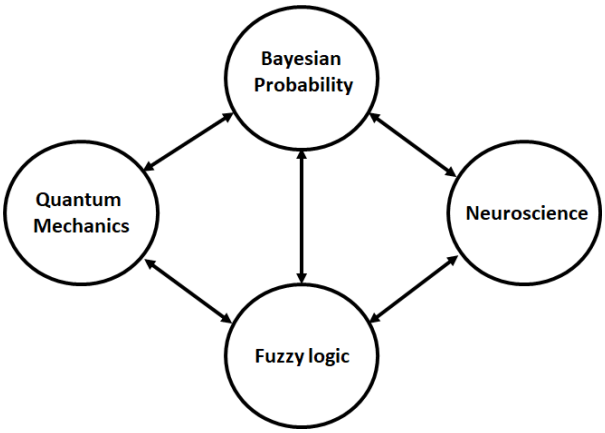

(34) Pier Luigi Gentili*

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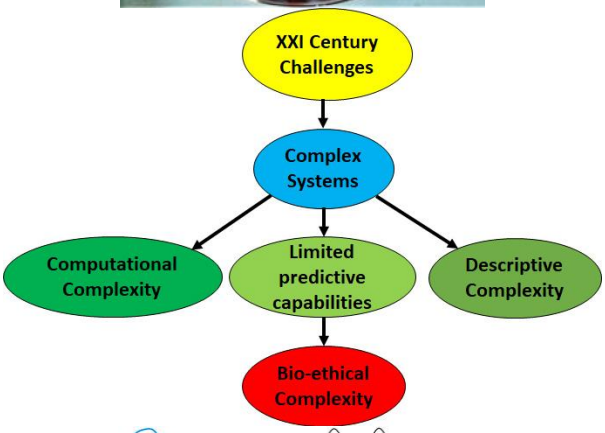


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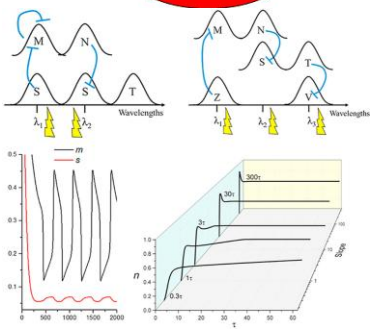

(31) Pier Luigi Gentili

*"The Fuzziness in Molecular, Supramolecular, and Systems Chemistry"*

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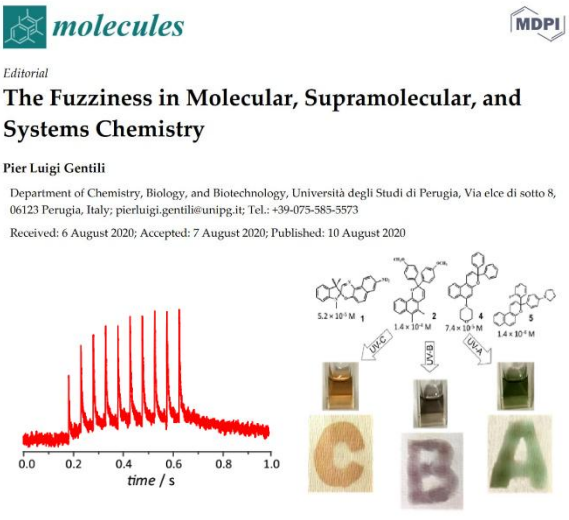
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*Editorial*

**The Fuzziness in Molecular, Supramolecular, and Systems Chemistry**

**Pier Luigi Gentili**

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(30) Dawid Przyczyna, Piotr Zawal, Tomasz Mazur, Marcin Strzelecki, Pier Luigi Gentili,* Konrad Szaciłowski*

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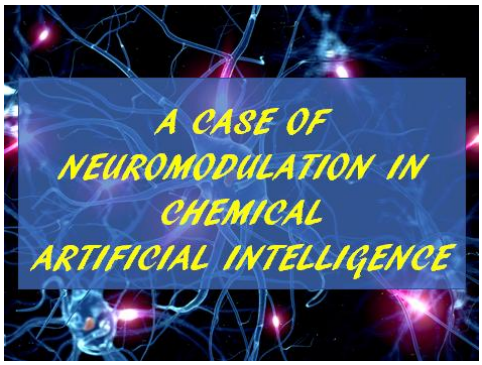


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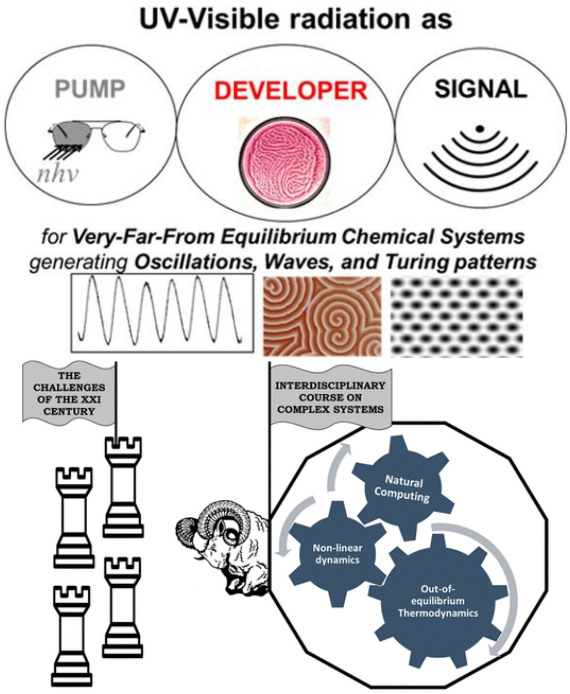


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**Interview**


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*Mimicking the Secretory Action of a Gland by a Composite System Made of a pH-Responsive Surfactant-Based Hydrogel and a Dialysis Membrane.*

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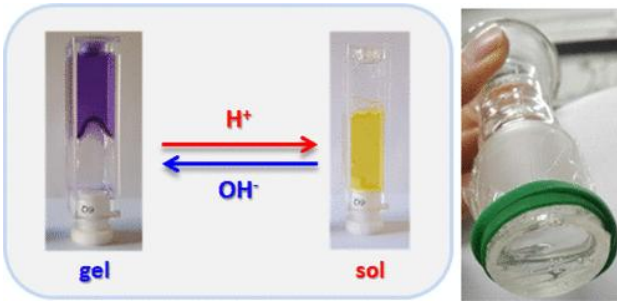


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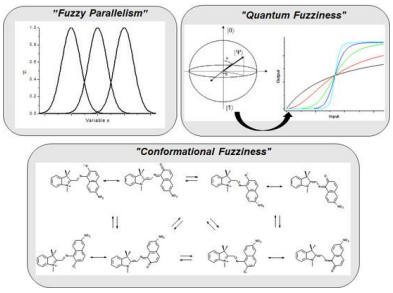
**Perspective paper**

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*Photochromic and luminescent compounds as artificial neuron models.*

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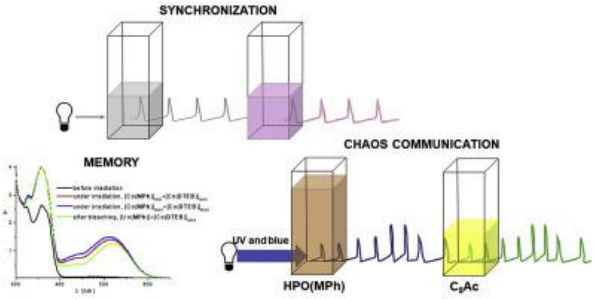


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*Optical Communication among Oscillatory Reactions and Photo-Excitable Systems: UV and Visible Radiation Can Synchronize Artificial Neuron Models*

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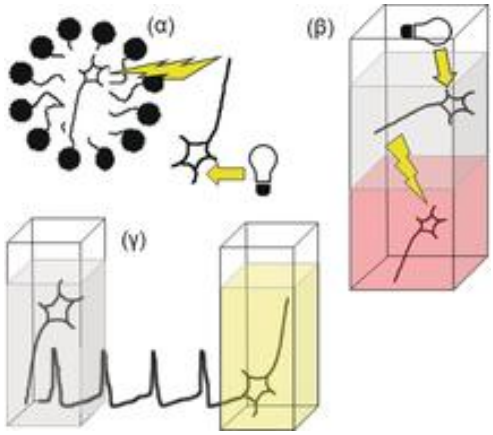


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*Processing Binary and Fuzzy Logic by Chaotic Time Series Generated by a Hydrodynamic Photochemical Oscillator*

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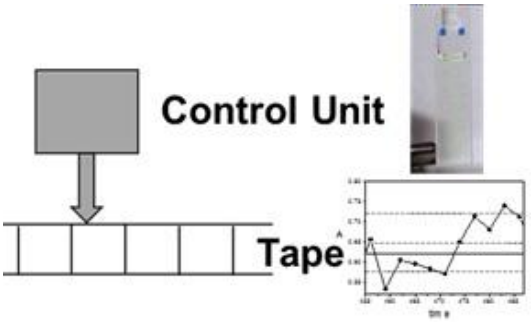
**Invited contribution**




(19) Pier Luigi Gentili

*A Contribution to the Development of Chemical Artificial Intelligence: The Implementation of Biologically Inspired Photochromic Fuzzy Logic (BIPFUL) Systems that Extend Human Vision to UV.*

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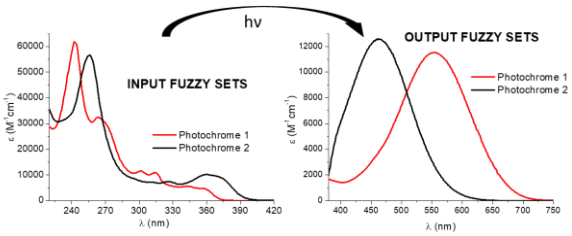


**Invited contribution.**

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*Discriminating between the UV-A, UV-B and UV-C regions by novel Biologically Inspired Photochromic Fuzzy Logic (BIPFUL) systems: A detailed comparative study.*

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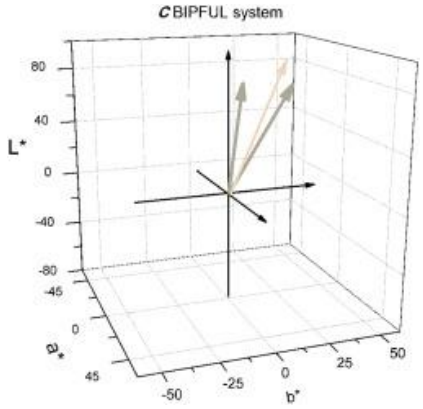
https://www.sciencedirect.com/science/article/abs/pii/S0143720816300523

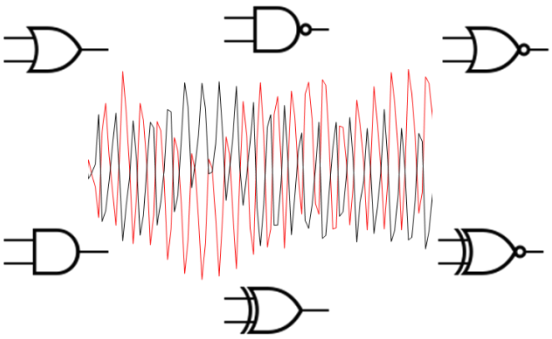



(17) Kenta Hayashi, Hiroshi Gotoda, Pier Luigi Gentili

*Probing and exploiting the chaotic dynamics of a hydrodynamic photochemical oscillator to implement all the basic binary logic functions.*

Chaos, 2016, 26, 053102 (1-8)

https://aip.scitation.org/doi/10.1063/1.4948590

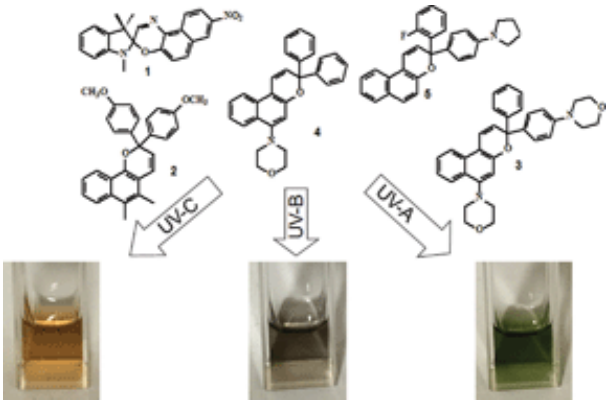


(16) Pier Luigi Gentili, Amanda L. Rightler, B. Mark Heron, Christopher D. Gabbutt

*Extending human perception of electromagnetic radiation to the UV region through biologically inspired photochromic fuzzy logic (BIPFUL) systems.*

Chem. Comm., 2016, 52, 1474-1477

https://pubs.rsc.org/en/Content/ArticleLanding/CC/2016/C5CC09290F#!divAbstract

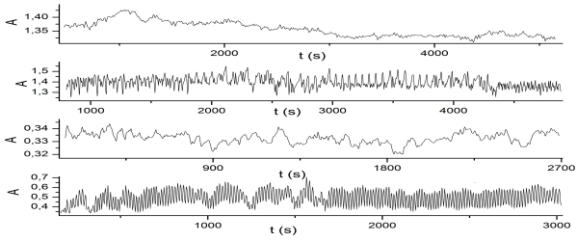



(15) Pier Luigi Gentili, Hiroshi Gotoda, Milos Dolnik, Irving R. Epstein

*Analysis and prediction of aperiodic hydrodynamic oscillatory time series by feed-forward neural networks, fuzzy logic, and a local nonlinear predictor.*

Chaos, 2015, 25, 13104 (1-14)

https://aip.scitation.org/doi/10.1063/1.4905458

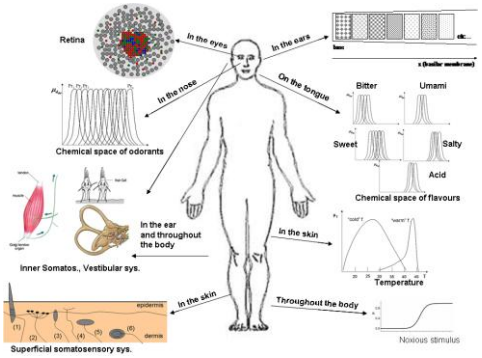



(14) Pier Luigi Gentili

*"The human sensory system as a collection of specialized fuzzifiers: A conceptual framework to inspire new artificial intelligent systems computing with words."*

J. of Intel. & Fuzzy Sys., 2014, 27, 2137-2151

https://content.iospress.com/articles/journal-of-intelligent-and-fuzzy-systems/ifs1179

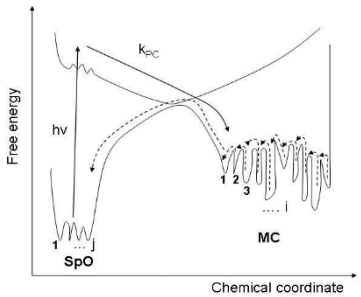



(13) Pier Luigi Gentili

*"The Fuzziness of a Chromogenic Spirooxazine."*

Dyes and Pigments, 2014, 110, 235-248.

https://www.sciencedirect.com/science/article/abs/pii/S0143720814001041




(12) Pier Luigi Gentili

*"Le sfide della complessità e il contributo dell'intelligenza artificiale chimica"*

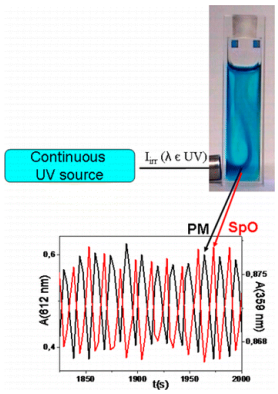
100news-Scienza, raccolta del 15 gennaio 2014, 3-4.

(11) Pier Luigi Gentili, Milos Dolnik, Irving R. Epstein

*"Photochemical Oscillator": Colored Hydrodynamic Oscillations and Waves in a Photochromic System.*

J. Phys. Chem. C, 2014, 118, 598-608.

https://pubs.acs.org/doi/abs/10.1021/jp407393h




(10) P. L. Gentili

*Small steps towards the development of chemical artificial intelligent systems*

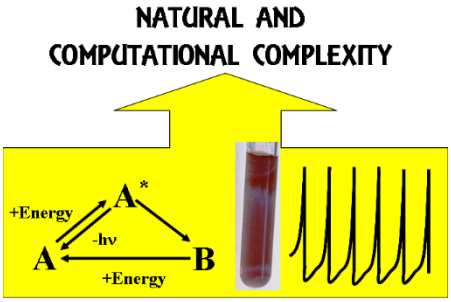
RSC Advances 3, 2013, 25523-25549

https://pubs.rsc.org/en/content/articlelanding/2013/ra/c3ra44657c#!divAbstract

**This article has been selected for the RSC Advances 10th Anniversary collection focusing on Machine learning and artificial neural networks in chemistry.** Link:

https://pubs.rsc.org/en/journals/articlecollectionlanding?sercode=ra&themeid=576ef2a3-f849-46d2-9be3-3e4bb6926b2e

Chemical Artificial Intelligent Systems to face the Challenges of Complexity.



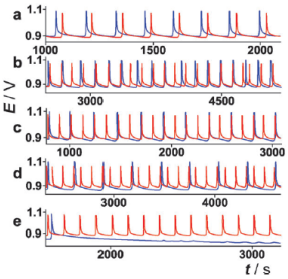

(9) **VIP: Very Important Paper**

V. Horvath, P. L. Gentili, V. K. Vanag, I. R. Epstein

*Pulse-Coupled Chemical Oscillators with Time Delay*

Angew. Chem. Int. Ed. 51, 2012, 6878-6881

https://onlinelibrary.wiley.com/doi/abs/10.1002/anie.201201962




**Finger on the pulse**: In a system of two pulse-coupled Belousov–Zhabotinsky oscillators, introducing a time delay or increasing the coupling strength brings about novel dynamic features (see picture, the two oscillators are shown in different colors), such as reversal of the roles of excitatory and inhibitory couplin or fast anti-phase oscillation. These features are not observed in diffusively coupled systems, and shed light on hov such pulse coupling occurs at synapses

(8) P. L. Gentili, V. Horvath, V. K. Vanag, I. R. Epstein

*Belousov-Zhabotinsky "chemical neuron" as a binary and fuzzy logic processor.*

Int. J. of Unconventional Computing, 8, 2012, 177-192.

https://www.oldcitypublishing.com/journals/ijuc-home/ijuc-issue-contents/ijuc-volume-8-number-2-2012/ijuc-8-2-p-177-192/

We demonstrate experimentally that the well-known oscillatory Belousov-Zhabotinsky (BZ) reaction can be exploited to process both Boolean and fuzzy logic if the input variables are either the volumes or the phase of addition of pulse-injected solutions of inhibitor (bromide) and activator (silver ion) and the output variable is the oscillation period. Analysis of the relations between the input and the output variables reveals that this oscillating chemical reaction is suitable to process infinite-valued fuzzy logic, and that all fundamental fuzzy logic operators (AND, OR, NOT) can be implemented with it. We discuss the possibility for biological oscillators such as neurons or pacemaker cells to process information using principles of fuzzy logic.

(7) P. L. Gentili

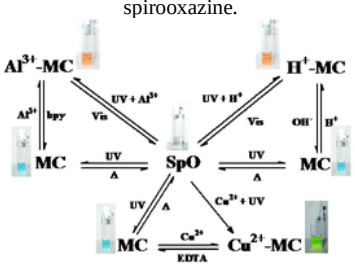
Complex Boolean logic circuits and the AND, OR, NOT operators of Fuzzy logic implemented by the chameleonic chromogenism of a

*The fundamental Fuzzy logic operators and some complex Boolean logic circuits implemented by the chromogenism of a spirooxazine.*

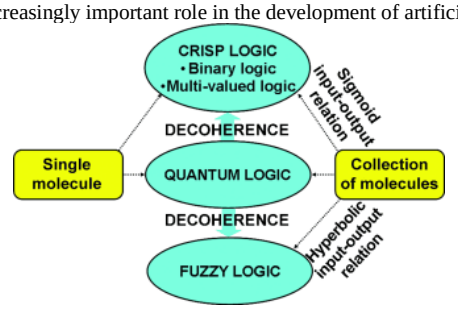
Phys. Chem. Chem. Phys., 13, (2011), 20335-20344.

https://pubs.rsc.org/en/content/articlelanding/2011/cp/c1cp21782h#!divAbstract

spirooxazine.




**Chemical intelligence:** Different types of logic can be implemented with molecules. In absence of decoherent effects, quantum logic can be carried out. Otherwise crisp logics can be processed (see flowchart). In case of collections of molecules, there are conditions favourable for building fuzzy logic systems which are playing an increasingly important role in the development of artificial




(6) P. L. Gentili

*Molecular Processors: From Qubits to Fuzzy Logic.*

ChemPhysChem, 12 (2011) 739-745.

https://onlinelibrary.wiley.com/doi/abs/10.1002/cphc.201000844

Future Information Technology Systems will hinge on logic gates implemented at the molecular level. To expand the intelligence quotient of next artificial machines, it is necessary to find out how to process Fuzzy logic at the molecular level. Fuzzy logic allows certain and uncertain information, objective and subjective knowledge to be dealt with.

(5) P. L. Gentili

*Fuzzy Logic Implemented at the Molecular Level*

La Chimica e l'Industria, 2 (2010) 132-138.

https://www.soc.chim.it/it/riviste/chimica_industria/rivista/2010/2

(4) P. L. Gentili

*Fuzzy Logic in Molecular Computing.*

International J. of Computer Research, 16 (2008) 283-292.

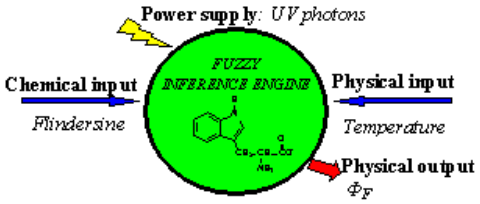
If the logic gates, sculpted from bulk semiconductors, are based exclusively on electrical signals, those based on single molecules can be extended to chemical, optical and other physical inputs and outputs. Purpose of the chemist is to find out always-new powerful molecular systems that can carry out the logic operations required for computer circuitry. If the compound behaves as a versatile molecular switch, it can be adopted to process Boolean binary logic. On the other hand, if a chemical species responds to external inputs with a continuously variable output signal and the relation between inputs and output can be rationalized in terms of IF-THEN statements, it can be employed to process Fuzzy logic.

(3) P. L. Gentili

*Boolean and Fuzzy Logic Gates Based on the Interaction of Flindersine with Bovine Serum Albumin and Tryptophan.*

J. Phys. Chem. A, 112 (2008), 11992-11997

https://pubs.acs.org/doi/abs/10.1021/jp806772m

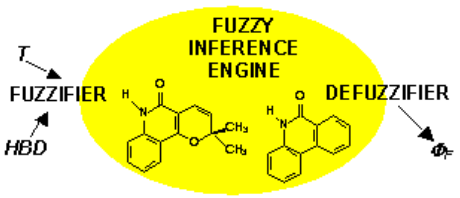



(2) P. L. Gentili

*Boolean and Fuzzy Logic Implemented at the Molecular Level*

Chem. Phys., 336 (2007) 64-73.

https://www.sciencedirect.com/science/article/abs/pii/S0301010407001760



(1) P. L. Gentili

*Fotorecettori Biologici. Il sole e la vita sul pianeta terra.*

La Chimica nella Scuola, 1 (2006) 41-49.

http://www.culturachimica.it/wp-content/uploads/2017/03/Fotorecettori.pdf

The Sun is an energy source of utmost importance for the Earth. Solar energy has been crucial for the emergence of Life and is still fundamental for its support.

In this paper, the role fulfilled by the Sun's energy toward the terrestrial evolutionary processes and the current action performed toward the living beings are presented. Life on Earth employs the solar radiation as both energy source and information spring for its spatial and temporal orientation.

## ***Books***

(1) Pier Luigi Gentili

*"Untangling Complex Systems: A Grand Challenge for Science"*

2018, Taylor and Francis Inc. (CRC Press),

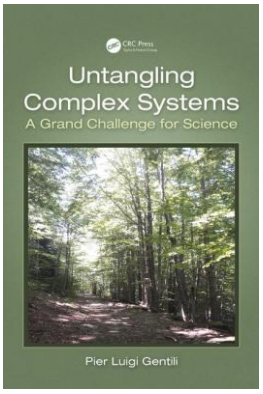
https://www.crcpress.com/Untangling-Complex-Systems-A-Grand-Challenge-for-Science/Gentili/p/book/9781466509429

**Invited book.**

ISBN: 9781466509429 (Hbk) Published August 10, 2018

ISBN 9780429455049 (eBook) Published September 2, 2018

ISBN 9780367485627 (Pbk) Published January 13, 2020




(2) Pier Luigi Gentili, **Editor**.

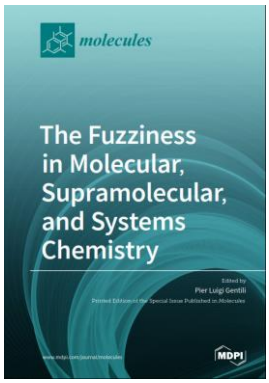
"*The Fuzziness in Molecular, Supramolecular, and Systems Chemistry*"

https://www.mdpi.com/books/pdfview/book/2920

Printed Edition of the Special Issue Published in "Molecules" di MDPI, Basel (Svizzera).

ISBN 978-3-03943-178-6 (Pbk) in print 2020

ISBN 978-3-03943-179-3 (PDF) in print 2020.




(3) Pier Luigi Gentili

"*The Winged Science to Face Bioethical Complexity*"

Gemma Edizioni , 2023.

ISBN: 978-88-31318-93-8

https://www.gemmaedizioni.it/prodotto/the-winged-science-to-face-bioethical-complexity/

4 Pier Luigi Gentili, Konrad Szaciłowski, Andrew Adamatzky, **Editors**


"Approaching human intelligence through chemical systems: Development of unconventional chemical artificial intelligence."

e-Book of the Research Topic published in "*Frontiers in Chemistry*", "*Frontiers in Robotics and AI*", and "*Frontiers in Bioengineering and Biotechnology*".

ISBN: 978-2-8325-3994-1

DOI 10.3389/978-2-8325-3994-1

file:///C:/Users/pierl/Downloads/9782832539941%20(1).PDF

## ***Chapters in Books***

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|---|---|---|
| (14) | Lorenzo Del Moro; Beatrice Ruzzante; Maurizio Magarini; Pier Luigi Gentili; Giordano Rampioni; Andrea Roli; Luisa Damiano; Pasquale Stano. "*Chemical Neural Networks and Semantic Information investigated through Synthetic Cells*" In: "Proceeding of the XVI International Workshop on Artificial Life and Evolutionary Computation (WIVACE 2022); Gaeta (LT), Italy, 14-16 September 2022; C. Di Stefano, F. Fontanella (Eds.)". Springer book series: Communications in Computer and Information Science (CCIS), 2023, 1780 CCIS, pp. 27–39. | *In a previous contribution we briefly sketched novel topics that lie at the interface between synthetic biology (SB) and artificial intelligence (AI). In particular, we discussed (a) the possibility of engrafting chemical AI-like tools in bottom-up synthetic cell systems, and (b) the investigation of fundamental concepts of information theory – such as the "semantic" information – by means of synthetic cells. Here we intend to report on the progress done by our groups in these fields and shortly devise future steps for theoretical and experimental approaches.* |
| (13) | Piero Dominici, Pier Luigi Gentili "*Ripensare educazione e didattica nell'era dell'obsolescenza dei saperi e delle competenze*" in "*Unipg pensa il post-Covid*" edited by D. Parbuono, Collana Culture Territori Linguaggi, Perugia, 2021. | What we consider today to be the limits of the fields of knowledge, to be the borders between knowledge and skills, between rationality and creativity, can and must become openings, passageways, pathways, opportunities. Because it is the complexity of the ongoing changes, its ambivalence, velocity and unpredictability – a complexity that is increasingly marked by the co-existence of order and chaos – to have shown us, in no uncertain terms, the inadequacy of the current educational and formative processes, as well as the inconsistency of reductionist explanations and of traditional linear interpretative models. These are profound criticalities and anomalies which, alongside with our (ontological) incompleteness, have accelerated the obsolescence of knowledge and skills even more sharply. |

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|---|---|---|
| (12) | Pier Luigi Gentili, Apostolos Syropoulos. "Vagueness in chemistry" in "*Vagueness in the Exact Sciences: Impacts in Mathematics, Physics, Chemistry, Biology, Medicine, Engineering and Computing*" edited by A. Syropoulos, B. K. Papadopoulos. De Gruyter, Berlin, Boston: 2021." https://doi.org/10.1515/9783110704303-006 | Chemistry is intrinsically vague mainly because life is in a way a chemical phenomenon. However, vagueness emerges unexpectedly in other areas of chemistry and this is why molecules can be described by mathematical models of vagueness. Naturally, this means that we must revise the way people understand the discipline and work in it. |
| (11) | Maria Lis, Shu Onuma, Dawid Przyczyna, Piotr Zawal, Tomasz Mazur, Kacper Pilarczyk, Pier Luigi Gentili, Seiya Kasai, Konrad Szacilowski. "*From Oscillatory Reactions to Robotics: A Serendipitous Journey Through Chemistry, Physics and Computation*" in "*Handbook of Unconventional Computing*" Volume 2, edited by A. Adamatzky. World Scientific, Singapore, 2021. Pag. 1-79. https://doi.org/10.1142/9789811235740_0001 | The continuous search for more efficient and energy-effective computing technologies drives researchers into various fields, seemingly not related to computing at all. It turns out, however, that system dynamics is the powerful computational medium, irrespectively of the physical nature of the system itself. This review presents a potpourri of systems and devices which share the common feature — they evolve in time, respond to the external signals and are thus suitable for information processing. It makes them useful for computational purposes and even for such demanding applications as autonomous robotics. |
| (10) | Pier Luigi Gentili*<br>"*How to face the Complexity of the 21st Century Challenges? The contribution of Natural Computing.*"<br>Unconventional Computing edited by A. Adamatzky and L.-J. Lestocart.<br>Luniver Press 2021, Bristol (UK). Pag. 79-83. | The XXI Century Challenges are Complexity Challenges because they regard Complex Systems, and hence other types of Complexities, such as Bio-ethical, Computational, and Descriptive Complexities. This article proposes some strategies to tackle the compelling challenges of this century. A promising strategy is the interdisciplinary research line of Natural Computing that includes Artificial Intelligence. |
| (9) | Pier Luigi Gentili*<br>"*Astrochemistry and the theory of Complex Systems.*"<br>Rendiconti della Accademia Nazionale delle Scienze detta dei XL<br>Memorie e Rendiconti di Chimica, Fisica, Matematica e Scienze Naturali<br>138° (2020), Vol. I, fasc. 1, pp. 31-34<br>ISSN 0392-4130 • ISBN 978-88-98075-38-6 | This paper wants to highlight some of the links between the science of Complex Systems and Astrochemistry. First, the driving forces that lead the two research fields are presented. Then, it is demonstrated that Astrochemistry investigates Complex Systems. Hence, the features of Complex Systems and the strategies to deal with them are described. An open question concludes this paper. |
| | | L'umanità è chiamata a vincere le sfide della Complessità. Vi sono tre tipi di Complessità e quindi vi sono tre tipi di sfide. Vi sono le sfide della Complessità Naturale che coinvolgono tutto il sapere |

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|---|---|---|
| (8) | Pier Luigi Gentili<br>*Le sfide della Complessità Naturale e Computazionale: come vincerle? Il contributo della Chimica.*<br>In "Fare scienza oggi", pag. 539-548, Morlacchi Editore U. P., Perugia 2018. | scientifico. Vi sono, poi, le sfide della Complessità Computazionale che coinvolgono, in primo luogo, le scienze matematiche ed informatiche. Tuttavia per poter affrontate le sfide della Complessità Computazionale in maniera efficace, è necessario anche il contributo delle altre discipline scientifiche. Infine esistono le sfide della Complessità Etica e Bioetica. Quest'ultime richiedono il contributo di tutto il sapere umano; non solo quello scientifico, ma anche quello umanistico. Ho già proposto una strategia per poter affrontare le sfide della Complessità Bioetica nel volume dedicato al I Convegno Interdipartimentale dell'Ateneo perugino. La strategia proposta prevede l'uso del messaggio cristiano come chiave di lettura e codice morale per trovare risposte ai complessi interrogativi bioetici (cfr. Gentili, 2017). In questo capitolo intendo parlare di come la chimica può contri-<br>buire a vincere le sfide della Complessità Naturale e Computazionale. |
| (7) | Pier Luigi Gentili<br>*I complessi interrogativi bioetici: dove cercare risposte?*<br>In "Bioetica. Un approccio interdisciplinare", pag. 37-55, Morlacchi Editore U. P., Perugia 2017. | Questo contributo si pone due obiettivi. Il primo consiste nel far capire perché è giusto definire complessi gli interrogativi bioetici. A tale scopo, si presentano le sfide della Complessità Naturale e quelle della Complessità Computazionale che la scienza contemporanea è chiamata ad affrontare. Il secondo obiettivo consiste nel proporre degli ambiti disciplinari dove cercare risposte ai complessi interrogativi bioetici. Secondo l'autore non è sufficiente un approccio puramente scientifico, ma è necessario coinvolgere il sapere giuridico, umanistico ed anche teologico. In particolare la teologia è l'unica disciplina che può fornire risposte cariche di speranza agli interrogativi esistenziali che sono coinvolti nelle questioni bioetiche. |
| (6) | Pier Luigi Gentili<br>*A strategy to face complexity: The development of chemical artificial intelligence*<br>Communications in Computer and Information Science<br>Volume 708, 2017, Pages 151-160<br>11th Italian Workshop on Artificial Life and Evolutionary Computation, WIVACE 2016; Fisciano; Italy; 4 October 2016 through 6 October 2016; Code 191279 | Nowadays, science is spurred to win the Complexity Challenges. There are challenges regarding Natural Complexity. But there are also challenges regarding Computational Complexity. A strategy to face both of them consists in developing Chemical Artificial Intelligence. Its development requires an analysis of the Human Nervous System and Human Intelligence at three levels; at the (i) Computational, (ii) Algorithmic, and (iii) Implementation levels, respectively. The effectiveness of this approach is demonstrated by showing three ways for implementing Fuzzy logic at the molecular level |

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| (5) | Pier Luigi Gentili<br>*The Development of Chemical Artificial Intelligence Processing Fuzzy Logic*<br>ISCS 2014: Interdisciplinary Symposium on Complex Systems, Emergence, Complexity and Computation Vol. 14, 2015, pag. 37-46, Editors A. Sanayei, O. Rössler, I. Zelinka, Springer International Publishing, ISBN: 978-3-319-10758-5 | The Human Nervous System is an outstanding example of natural complex system. Its hierarchical architecture and its basic nonlinear working principles store the secrets of Complexity. Of course, a scrutiny of the Human Nervous System is going to have a profound impact on the challenges to Complexity. In this contribution, we present the first results in our analysis of the human nervous system at the "computational", "algorithmic" and "implementation" levels. Such analysis will probably bring to the development of a new generation of computing machines imitating the human intelligence that computes with words and solves quite easily computational problems like the recognition of variable patterns. |
| (4) | Pier Luigi Gentili<br>*Processing Fuzzy Logic by Molecules*<br>Fuzzy Logic: Applications, Systems and Technologies, Editor Dinko Vukadinovic<br>Nova Science Publishers, Inc. 2013,<br>pag. 133-152.<br>(ISBN: 978-1-62417-151-2) | Current computers process information based on transistors and electrical signals. The futuristic chemical computers will store, process, and convey information by using molecules, their assemblies, and physical-chemical signals. It is possible to compute by exploiting single molecules or large collections of them. Different kinds of logic can be processed. Since molecules obey the laws of quantum-mechanics, quantum logic can be implemented, as long as decoherent effects are avoided. If the collapse of superimposed or entangled wave-functions is inevitable, molecules can still be used to process either Boolean or discrete multi-valued or fuzzy logic. The conditions favourable to chemically process the infinite-valued fuzzy logic are presented in this text and few examples of its chemical implementation are reported. Fuzzy logic is particularly important for the development of artificial intelligence because it models pretty well human decision making. This property is due to the structural analogies existing between fuzzy logic systems and human nervous system. |
| (3)<br><br><br><br><br><br><br>(2) | Pier Luigi Gentili<br>*Fuzzy Logic in Molecular Computing*<br>Expert Commentary appeared in:<br>(a) "Fuzzy Logic: Theory, Programming and Applications", Editor R. E. Vargas, Nova Science Publishers, Inc. 2009, pag 3-12 (ISBN: 978-1-60456-915-5).<br>(b) "Computer Systems, Support and Technology", Editor N. E. Mastorakis, Nova Science Publishers, Inc. 2011, pag. 1-10 (ISBN: 978-1-61122-759-8). | There exists a worldwide race to make microprocessors of computers as much powerful as possible by shrinking electronic components and cramming logic gates onto smaller and smaller wafers of silicon. Over the past few years, some companies and several academic laboratories have started seriously entertaining the idea of constructing computers in which computations are performed by individual molecules. If the logic gates, sculpted from bulk semiconductors, are based exclusively on electrical signals, those based on single molecules can be extended to chemical, optical and other physical inputs and outputs. Purpose of the chemist is to find out always-new powerful molecular systems that can carry out the logic operations required for computer circuitry. If the compound behaves as a versatile molecular switch, it can be adopted to process Boolean binary |

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| (1) | (c) "Encyclopedia of Mathematics Research", Editors: J. D. Mathias and S. I. Cleaves, Nova Science Publishers, Inc. 2011 (ISBN: 978-1-61324-228-5). | logic. On the other hand, if a chemical species responds to external inputs with a continuously variable output signal and the relation between inputs and output can be rationalized in terms of IF-THEN statements, it can be employed to process Fuzzy logic. Organic compounds exhibiting "Proximity Effect" in their photophysics give an opportunity to implement Fuzzy Logic Engines at the molecular level. For these chemical species a quantum state, consisting of a superposition of two electronic levels, can be produced through excitation by UV-Visible radiation. The nature of the quantum state and its ability to emit light can be varied in a continuous manner by regulating environmental conditions such as temperature and hydrogen bonding donation ability of the solvent. This opens up a new avenue to implement Fuzzy logic at the molecular level. |

## ***Communications at Congresses and Seminars***

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|---|---|---|
| (79) | 1st Anglo-Italian Chemical Biology Bilateral Meeting. Perugia 15-17 December 2024. Proceedings: pag. OC5 | Pier Luigi Gentili "*Bio-inspired Chemical Systems in "Wetware" for Sensing.*" **Oral contribution presented on-site** |
| (78) | 5th International Caparica Christmas Conference on Translational Chemistry, Lisbon 8-12 December 2024. Proceedings pag. 55 e 79. | Pier Luigi Gentili "*A Novel Accomplishment of Chemical Artificial Intelligence: Using Chemical Waves to Discriminate Acoustic Frequencies.*" **Invited Keynote** |
| (77) | Workshop on "*Quantum Chemistry and Cheminformatics*" organized by the Accademia dei Lincei in Rome from 26 to 27 September 2024. | Pier Luigi Gentili "*An Unconventional Chemical Approach for the Development of Quantum Artificial Intelligence*." **Invited Talk delivered on-site** |
| (76) | XXVIII National Congress of Società Chimica Italiana, 26-30 August 2024, Milano (Italy). Proceedings pg. KN-066. | Pier Luigi Gentili "*Chemistry and Complexity Science allied together for a better future.*" **Invited Keynote delivered on-site** |
| (75) | Thermodynamics 2.0, August 5-7, 2024, Boone, NC (USA). Proceedings pg. 26. | Pier Luigi Gentili "*Characterizing the Micro-heterogeneity of Chemical Systems by Determining their Fuzzy Entropy*" **Oral contribution presented online.** |

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| (74) | VI Caparica Conference on Chromogenic and Emissive Materials 2024.<br>July 8 – 11, 2022 Lisbona (Portogallo).<br>Proceedings pag. 92. | Pier Luigi Gentili<br>*"Determining and Exploiting the Microheterogeneity of Photochromic and Luminescent Materials"*<br>**Invited Keynote delivered on-site** |
| (73) | Within the VITALITY-PNRR project, a national conference entitled "Between Material and Immaterial: An Interdisciplinary Dialogue" was organized in Perugia on April 23rd, 2024. | Pier Luigi Gentili<br>"*Can a chemist materialize the immaterial?*"<br>**Talk in Italian** |
| (72) | National conference entitled "*Having hope? Some thoughts about the ethics of science after the pandemic period*" organized by the professors of the PhD course on Ethics of Communication, Scientific Research, and Technological Innovation at the University of Perugia.<br>8-9 November 2023 | Pier Luigi Gentili<br>"*The Complexity of the XXI century challenges. How to face it?*"<br>**Invited Plenary Lecture** |
| (71) | Workshop on Unconventional Computing<br>Bristol (UK) 5-6 October 2023<br>Proceedings : pages 3-4. | Pier Luigi Gentili<br>"*Tracing a New Path in the Field of AI and Robotics: Attempts at Mimicking Human Intelligence through Chemistry in Wetware*."<br>**Invited Talk in English** |
| (70) | XLIX Congress of the Physical Chemistry Division of the Società Chimica Italiana.<br>Torino 4-7 Settembre 2023.<br>Proceedings: page T2K01 | Pier Luigi Gentili<br>"*Tracing a New Path in the Field of AI and Robotics: Mimicking Human Intelligence through Soft Matter*."<br>**Keynote delivered on site** |
| (69) | Workshop on Quantum Artificial Intelligence.<br>Naples 27-28 July 2023.<br>Proceedings: pages 25-27. | Pier Luigi Gentili<br>"*Unconventional Chemical Contributions to Quantum Artificial Intelligence.*"<br>**Oral contribution delivered on site by P. L. Gentili** |
| (68) | Talk presented at the Congress organized by the Didactic Division of the Italian Chemical Society.<br>Proceedings: page 16-17.<br>Salerno 15-17 June 2023. | Pier Luigi Gentili<br>"*An innovative course wherein Chemistry and Complexity Science prepare the new generation to face the Global Challenges of the XXI century.*"<br>**Oral contribution delivered on site by P. L. Gentili** |
| (67) | Invited lecture delivered at the Institute of Advanced Studies of the Aix-Marseille Université in France. | Pier Luigi Gentili<br>"*Interdisciplinary Investigation into Complex Systems*" |

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| | | **Invited Lecture** |
| (66) | Invited lecture delivered at the Rowland Institute of Harvard in the research group "Biologically Inspired Chemically Operated Synthetic Systems" lead by Juan Perez-Mercader. | Pier Luigi Gentili<br>"*How to face Complex Challenges? The role of Natural Computing and Chemical Artificial Intelligence*"<br>**Invited Lecture** |
| (65) | III Sympósio De Química Teórica E Estrutural De Anápolis<br>13-15 September 2022, Pirenópolis-Goiás | Pier Luigi Gentili<br>"*How to face Complex Challenges? The role of Natural Computing and Chemical Artificial Intelligence."*<br>**Invited Plenary Lecture delivered online by P. L. Gentili** |
| (64) | Thermodynamics 2.0/2022. July 18-20, 2022. Boone, North Carolina (hybrid conference).<br>Proceedings: T03.119 | Pier Luigi Gentili and Juan Perez-Mercader<br>"*Implementing Fuzzy Sets through Molecules and Determining their Entropy*."<br>**Invited Talk delivered online by P. L. Gentili.** |
| (63) | ALIFE 2022: The 2022 Conference on Artificial Life; Online, July 18-22, 2022.<br>Proceedings: pp. 465-467. S. Holler, R. Löffler, S. Bartlett (Eds.), Cambridge, MA: MIT Press, 2022DOI: https://doi.org/10.1162/isal_a_00557 | P. Stano, P. L. Gentili, G. Rampioni, A. Roli, L. Damiano<br>"*En route for implanting a minimal chemical perceptron into artificial cells*."<br>**Talk presented by P. Stano.** |
| (62) | 5th International Caparica Conference on Chromogenic and Emissive Materials 2022.<br>July 4 – 7, 2022 Lisbon (Portugal).<br>Proceedings pag. 104. | Pier Luigi Gentili<br>"*Photochromic and Luminescent Materials for the development of Chemical Artificial Intelligence*."<br>**Invited Keynote delivered on site by P. L. Gentili** |
| (61) | 8th International Conference on Higher Education Advances (HEAd'22)<br>June 15 – 17, 2022 · Valencia, Spain (hybrid conference).<br>Proceedings pag. 959-963.<br>http://dx.doi.org/10.4995/HEAd22.2022.14319 | Pier Luigi Gentili, Gianluigi Cardinali, Piero Dominici, David Grohmann, Maria Elena Menconi, Claudio Santi.<br>"*The Science of Complex Systems for Preparing the New Generation to Tackle Global Challenges*."<br>**Oral contribution delivered online by P. L. Gentili** |
| (60) | International conference titled "DCP22: Dynamics and Complexity".<br>Pisa, 26/28 May 2022. Hybrid form. | Pier Luigi Gentili<br>"*Complexity in Chemical Systems*."<br>**Invited talk.** |
| (59) | Seminar given online at the Academic Center for Materials and Nanotechnology of the AGH University of Science and Technology in Kraków (Poland).<br>21/04/2022 | Pier Luigi Gentili<br>*"Tracing a new path in the field of AI: the development of Chemical Artificial Intelligence (CAI)".*<br>**Invited Lecture** |

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| (58) | International Conference: New Perspectives in Science Education.<br>Florence (Italy), 17-18 March 2022. Hybrid form.<br>Proceedings: pages 315-320. | Pier Luigi Gentili, Gianluigi Cardinali, Piero Dominici, David Grohmann, Maria Elena Menconi, Claudio Santi.<br>*"Introducing Complexity Science in Higher Education for Preparing the New Generations to be Aware and Promote a Sustainable Future."*<br>**Oral contribution delivered online by P. L. Gentili.** |
| (57) | International Workshop on Molecular Cybernetics: Toward Chemical AI.<br>March 14 – 15, 2022. Online Workshop organized by the Japanese Molecular Cybernetics Research Group. Proceedings: page 6. | Pier Luigi Gentili<br>"*Stepping Stones to Chemical Artificial Intelligence (CAI)*"<br>**Invited Plenary Speaker** |
| (56) | The 4th International Caparica Christmas Conference on Translational Chemistry.<br>6-8 December 2021 in Lisbon and online.<br>Proceedings: page 102. | Pier Luigi Gentili<br>"*Processing Fuzzy Logic by Molecules*"<br>**Invited Keynote speech by P. L. Gentili** |
| (55) | "School of Complexity Management" organized by the Complexity Institute<br>02 October 2021<br>Online | Pier Luigi Gentili<br>"*Complexity Science in Chemistry*"<br>**Invited Lecture** |
| (54) | 4th Meeting of the International Panel of Mesoscience.<br>28 September 2021<br>Online | Pier Luigi Gentili<br>"*Complexity Science and Mesoscience allied together to promote Sustainability*"<br>**Invited talk given by P. L. Gentili** |
| (53) | Physical Chemistry 2021 organized online by the Society of Physical Chemists of Serbia.<br>20-24 September 2021.<br>Proceedings: 04-PL. | Pier Luigi Gentili, Lorenzo Baldinelli, Beatrice Bartolomei<br>"*Design of a photochromic oscillator to be used as dynamical model of pacemaker neurons*"<br>**Invited Plenary Talk given by P.L. Gentili** |
| (52) | XXVII National Congress of the Italian Chemical Society.<br>Online, 14-23 September 2021. | Pier Luigi Gentili<br>"*Establishing a link between Chemistry and Complexity Science to promote Sustainability*"<br>**Oral contribution by P. L. Gentili** |
| (51) | Theoretical and Foundational Problems (TFP) in Information Studies. Online 12-19 September 2021.<br>Proceedings: FIS OR038<br>Proceedings (MDPI) 2022, 81, 94.<br>https://doi.org/10.3390/proceedings2022081094 | Pier Luigi Gentili<br>"*Implementing Fuzzy Sets and Processing Fuzzy Logic Information by molecules.*"<br>**Invited talk.** |
| (50) | IUPAC CCCE 2021- 48th World Chemistry Congress & 104th Canadian Chemistry Conference and Exhibition.<br>Symposium: "Systems Chemistry in Chemistry Education" (Society)<br>19 August 2021 | Pier Luigi Gentili<br>"*How to prepare the new generations to tackle global challenges?*"<br>**Oral contribution by P. L. Gentili.** |
| (49) | Plenary Talk delivered to the Chemistry, Biology, and Biotechnology Department of the University of Perugia.<br>Perugia, 04/06/2021 | Pier Luigi Gentili<br>"*Merging Photochemistry and Complexity Science to promote Sustainability*"<br>**Invited Plenary Talk** |
| (48) | Webinar organized by the Social Cooperative DENSA: "DESIGN OUR SCHOOL: HOW TO INHABIT COMPLEXITY". | Pier Luigi Gentili<br>"*Complexity Science to prepare the new generations for Sustainable Development*"<br>**Invited Talk** |
| (47) | Webinar organized by the Complexity Institute,<br>29 Aprile 2021. | Pier Luigi Gentili<br>"*The Eco-Systemic Transformation*"<br>**Invited talk** |
| (46) | ACS Spring<br>5-16 April 2021. | Pier Luigi Gentili, Beatrice Bartolomei, B. Mark Heron, Jean-Claude Micheau |

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| | Virtual Event. PAPER ID: 3533970 | "*Photochromism in neuromorphic engineering*."<br>**Poster presented by P. L. Gentili** |
| (45) | DISEGNARE L'UNIVERSITA' DEL FUTURO. TERZO BRAINSTORMING DI ATENEO.<br>Webinar, 29 Marzo 2021. | Pier Luigi Gentili, Gianluigi Cardinali, Piero Dominici, David Grohmann, Maria Elena Menconi, Claudio Santi.<br>*"How to prepare the new generations to the global challenges of the XXI century?"*<br>**Oral contribution by P. L. Gentili.** |
| (44) | RSCTwitter<br>#RSCPoster Twitter Conference:<br>2-3 April 2021. | Pier Luigi Gentili<br>*"Chemical Artificial Intelligence and Chemical Robots."*<br>**Poster posted on Twitter** |
| (43) | WORKSHOP ORGANIZED BY THE PHYSICAL CHEMISTRY DIVISION OF THE ITALIAN CHEMICAL SOCIETY (14-15 December 2020). Online due to COVID-19. | Pier Luigi Gentili, Beatrice Bartolomei, B. Mark Heron, Jean-Claude Micheau.<br>"*The Photochromism in Neuromorphic Engineering*."<br>**Oral contribution by P. L. Gentili: in Italian.** |
| (42) | WORKSHOP ORGANIZED BY THE PHYSICAL CHEMISTRY DIVISION OF THE ITALIAN CHEMICAL SOCIETY (14-15 December 2020). Online due to COVID-19. | Giulia Quaglia, Pier Luigi Gentili, Loredana Latterini<br>"*Design of TTA-UC nanocapsules for the study of optical communication between oscillatory reaction and photo-excitable systems.*"<br>**Oral contribution by G. Quaglia: in Italian** |
| (41) | FOURTH INTERNATIONAL CAPARICA CONFERENCE ON CHROMOGENIC AND EMISSIVE MATERIALS, Lisbon (Portugal), 16-18 November 2020. Online due to COVID-19 | Pier Luigi Gentili, Beatrice Bartolomei, Antonio Capaccioni, Raimondo Germani, B. Mark Heron<br>"*Photochromic and Luminescent Compounds at the service of Artificial Intelligence*."<br>Proceedings, pages 79, 80, and 107.<br>**Invited Keynote presented by P. L. Gentili.** |
| (40) | THERMODYNAMICS 2.0<br>Massachusetts (USA), 22-24 June 2020, conducted online due to COVID-19. | Pier Luigi Gentili<br>*"The XXI Century Challenges and Complexity"*<br>Proceedings: page 37<br>**Oral contribution by P. L. Gentili** |
| (39) | UNIPG PENSA IL POST-COVID. 30 IDEE PER L'UMBRIA<br>Webinar, 25-28 May 2020. | Pier Luigi Gentili<br>"Re-thinking education and didactic in the era of knowledge and competences' obsolescence."<br>**Oral contribution by P. L. Gentili and P. Dominici** |
| (38) | UNIPG PENSA IL POST-COVID. PRIMO BRAINTORMING DI ATENEO.<br>Webinar, 4-5 May 2020. | Pier Luigi Gentili<br>"There is a trail to be blazed if we want to face pandemics"<br>**Oral contribution by P. L. Gentili** |
| (37) | Third International Caparica Christmas Conference on Translational Chemistry, 2-5 December 2019. | Pier Luigi Gentili<br>A Novel Interdisciplinary Course on Complex Systems.<br>Proceedings pag. 109<br>**Invited Talk presented by P. L. Gentili** |
| (36) | Third International Caparica Christmas Conference on Translational Chemistry, 2-5 December 2019 | Beatrice Bartolomei, Pier Luigi Gentili<br>Designing New Artificial Neuron Models for Neuromorphic Engineering.<br>Proceedings pag. 183.<br>**Poster presented by P. L. Gentili** |

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| (35) | Merck Young Chemists' Symposium, Rimini (Italy), 25-27 November 2019 | Francesco Nicoletti, Irene Di Guida, Matteo Tiecco, Raimondo Germani, Pier Luigi Gentili<br>Use of deep eutectic solvents for the Belousov-Zhabotinsky reaction.<br>Proceedings pag. 117. |
| (34) | Merck Young Chemists' Symposium, Rimini (Italy), 25-27 November 2019 | Beatrice Bartolomei, P. L. Gentili<br>Designing new artificial neuron models for neuromorphic engineering.<br>Proceedings pag. 121 |
| (33) | Chemistry meets Industry and Society, Salerno (Italy), 28-30 August 2019. | Pier Luigi Gentili<br>Smart Materials at the service of Artificial Intelligence.<br>Proceedings pag. WS8 OR02<br>**Talk presented by Gentili.** |
| (32) | Chemistry meets Industry and Society, Salerno (Italy), 28-30 August 2019. | Pier Luigi Gentili<br>Soft Robotics and the Chemical Artificial Intelligence.<br>Proceedings pag. BE PO05<br>**Short presentation in the Brokerage event and Poster by Gentili.** |
| (31) | 23rd Annual Conference of the International Society for the Philosophy of Chemistry (ISPC), Turin (Italy), July 15-17 July 2019. | Pier Luigi Gentili<br>The Complexity Challenges and the role of the Philosophy of Chemistry.<br>Proceedings pag. 27.<br>**Invited Talk presented by Gentili** |
| (30) | Observatory for Astrochemical Kinetics and Related Aspects at the Accademia delle Scienze in Rome (Italy), 27-28 June 2019. | Pier Luigi Gentili<br>Astrochemistry and the theory of Complex Systems.<br>Proceedings pag. 29.<br>**Invited Talk presented by Gentili.** |
| (29) | Statistical thermodynamics and chemical kinetics far away from equilibrium at the Accademia dei Lincei in Rome (Italy), 25-26 June 2019. | Pier Luigi Gentili<br>Out-of-equilibrium chemical reactions in neuromorphic engineering.<br>**Invited Talk presented by Gentili** |
| (28) | New Perspectives in Science Education,<br>Florence (Italy), 21-22 March 2019. | Pier Luigi Gentili<br>An Interdisciplinary Investigation into Complex Systems.<br>Proceedings, pages 29-33.<br>**Talk presented by Gentili** |
| (27) | Complexity Literacy Meeting,<br>Abano Terme (PD, Italy),<br>23-25 November 2018. | Pier Luigi Gentili<br>*Untangling Complex Systems:*<br>*A Grand Challenge for Science.*<br>**Talk presented by Gentili** |
| (26) | Third International Caparica Conference on Chromogenic and Emissive Materials, Lisbon (Portugal), 3-6 September 2018. | Pier Luigi Gentili<br>*Photochromic and Luminescent Compounds in Neuromorphic Engineering.*<br>Proceedings, pages XXVI, XXVII, and 49.<br>**Plenary talk** |
| (25) | Complexity Summer School organized by the Italian Complexity Institute, at the Abano Terme (Italy), the 28th of August 2018. | Pier Luigi Gentili<br>*The Physical-Chemical Mind*<br>**Invited Lecture** |
| (24) | Gordon Research Conference on "Oscillations and Dynamic Instabilities in Chemical Systems", Les Diablerets (Switzerland), 8-13 July 2018. | Pier Luigi Gentili<br>*Tracing a new path in the field of Neuromorphic Engineering.*<br>**Talk presented by Gentili** |
| (23) | Second International Caparica Christmas Conference on Translational Chemistry, Lisbon (Portugal), 4-7 December 2017 | Pier Luigi Gentili<br>*A step forward to the development of Chemical Artificial Intelligence*<br>Proceedings, O 02A, page 66.<br>**Invited speaker** |

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| (22) | Institut Català de Nanociència i Nanotecnologia, Barcelona (Spain), the 8th of September 2017. | Pier Luigi Gentili<br>*"Tracing a new path in the field of Neuromorphic Engineering"*<br>**(Invited speaker)** |
| (21) | Micro Energy 2017, International Conference, 3-7 July, Gubbio (Italy) | Pier Luigi Gentili<br>*A Clever Strategy for Computing by Micro-Energy: Exploiting the Emergent Properties of Out-of-Equilibrium Systems.*<br>Proceedings, page 22.<br>**Talk presented by Gentili** |
| (20) | XXXVII Dynamics Days Europe, 5-9 June 2017, Szeged (Hungary). | Pier Luigi Gentili<br>*Hydrodynamic Photochemical Oscillators Useful for Chaos Computing*<br>Proceedings, page 22. **(Invited speaker)** |
| (19) | 253rd American Chemical Society National Meeting & Exposition, 2-6 April 2017, San Francisco, CA (USA) | Naishka E. Caldero-Rodriguez, Pier Luigi Gentili<br>"*P-dodecyloxybenzyldimethylamine oxide (pDoAO) gel as pH sensitive artificial gland*"<br>Proceedings, CHED-1166. |
| (18) | II Convegno Interdipartimentale,<br>"Fare scienza oggi", 15-16 dicembre 2016,<br>Perugia (Italia) | Pier Luigi Gentili<br>"*The Challenges of Natural and Computational Complexities: how to win them? The contribution of Chemistry*".<br>**Talk presented by Gentili** |
| (17) | WIVACE/BIONAM 2016,<br>4-7 October 2016, Salerno (Italy) | Pier Luigi Gentili<br>"*A Strategy to Face Complexity: The Development of Chemical Artificial Intelligence.*"<br>Proceedings, page 5.<br>**(Invited Plenary)** |
| (16) | 2nd International Caparica Conference on Chromogenic and Emissive Materials held in Lisbon (Portugal), 5-8 September 2016. | Pier Luigi Gentili, Amanda L. Rightler, B. Mark<br>Heron, Christopher D. Gabbutt<br>*Implementation of Biologically Inspired*<br>*Photochromic Fuzzy Logic (BIPFUL) Systems that*<br>*extend human vision to UV.*<br>Proceedings, page KN14.<br>**(Invited Keynote speaker)** |
| (15) | 251st American Chemical Society National<br>Meeting & exposition, San Diego (CA, USA),<br>March 13-17, 2016. | Amanda Rightler, Pier Luigi Gentili<br>*Understanding research in Perugia, Italy: Extending*<br>*cultural horizons and human vision through fuzzy* |

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| | | *logic photochromic systems.*<br>Proceedings, page IAC-16. |
| (14) | 251st American Chemical Society National Meeting & exposition, San Diego (CA, USA), March 13-17, 2016. | Amanda Rightler, Pier Luigi Gentili<br>*Expanding human perception of electromagnetic*<br>*radiation to the ultraviolet region through fuzzy*<br>*logic photochromic systems*<br>Proceedings, page CHED-1102. |
| (13) | The 1st International Caparica Christmas Conference on Translational Chemistry, 7-10 December 2015, Lisbon (Portugal). | Pier Luigi Gentili<br>*"The Development of Chemical Artificial Intelligence to Tackle Complexity and Chaos"*<br>Proceedings, pag. O 31A<br>**(Invited speaker)** |
| (12) | 1st Interdepartmental Congress, 3-4 December 2015, Perugia (Italy) | Pier Luigi Gentili<br>*The Complex Bioethical Issues: Where Finding*<br>*Answers?*<br>**Talk presented by Gentili** |
| (11) | 1st International Caparica Conference on Chromogenic and Emissive Materials, 8-10 September 2014, Lisbon (Portugal). | Pier Luigi Gentili<br>*"The Fuzziness of a Chromogenic Spirooxazine"*<br>Proceedings, pag. 74<br>**(Invited Speaker).** |
| (10) | XLI Italian Congress of Physical Chemistry. 23-27 June 2013, Alessandria (Italy). | P. L. Gentili<br>*"The development of Chemical Artificial Intelligence to face the challenges of complexity."*<br>Proceedings, pag. 155.<br>**Poster presented by Gentili** |
| (9) | XLI Italian Congress of Physical Chemistry. 23-27 June 2013, Alessandria (Italy). | P. L. Gentili<br>*"Fuzzy logic to tame the chaos"*<br>Proceedings, pag. 154.<br>**Poster presented by Gentili** |
| (8) | Solvay Workshop on "Patterns and hydrodynamic instabilities in reactive systems"-15-17 May 2013, Brussels (Belgium). | P. L. Gentili, M. Dolnik, I. R. Epstein<br>*"Coloured Hydrodynamic Oscillations and waves in solutions of a photochromic compound."*<br>**Talk presented by Gentili** |
| (7) | Seminar taken at the Electrical and Information Engineering Department, University of Perugia, Perugia (PG).<br>19 December 2012. | P. L. Gentili<br>*"The Challenges of Complexity and Molecular Computation"* |

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| | | **Invited speaker** |
| (6) | Seminar taken at the Insitute of Complex Systems (CNR), Sesto Fiorentino (FI), the 18th October 2012. | P. L. Gentili<br>"*Small steps towards a Chemical Artificial Intelligence*"<br>**Invited speaker** |
| (5) | Gordon Conference on "Oscillations and Dynamic Instabilities in Chemical Systems", 15-20 July 2012, Colby College in Waterville, ME. | V. Horvath, P. L. Gentili, V. Vanag, I. R. Epstein<br>"*Dynamical Behavior of pulse-coupled chemical oscillators"* |
| (4) | ICAART 2011, 3rd International Conference on Agents and Artificial Intelligence, Rome 28 - 30 January 2011 | P. L. Gentili<br>"*Molecular Fuzzy Inference Engines. Development of Chemical Systems to Process Fuzzy Logic at the Molecular level.*"<br>Proceedings pages 205-210.<br>**Talk presented by Gentili** |
| (3) | XXIII IUPAC Symposium on Photochemistry, Ferrara 11 -16 July 2010 | P. L. Gentili<br>"*Molecular Processors for Fuzzy logic*".<br>Proceedings page 222.<br>**Poster presented by Gentili** |
| (2) | "Giacomo Ciamician, genio della chimica e profeta dell'energia solare", Bologna 16 - 18 September 2007 | P. L. Gentili<br>"*Il sole: sorgente di energia ed informazione."*<br>**Talk presented by Gentili** |
| (1) | Congresso Nazionale di Fotochimica, Salice Terme (PV) 14 -16 December 2006. | P. L. Gentili<br>"*Logica Booleana e Fuzzy elaborata a livello molecolare su sistemi fotosensibili."*<br>Proceedings page 12.<br>**Talk presented by Gentili** |