

# Artemy Kolchinsky

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<b>EDUCATION</b>	<b>Indiana University</b> (Bloomington, IN, USA), 2015 Ph.D. in Informatics (focus in Complex Systems), Minor in Cognitive Science Thesis: “Measuring Scales: Integration and Modularity in Complex Systems” Committee: Luis M. Rocha (chair), Yong-Yeol Ahn, Randall Beer, Alessandro Flammini, Olaf Sporns <b>New York University</b> (New York, NY, USA), 2004 B.A. Magna Cum Laude, Individualized Study (concentration in Complex Systems)
<b>ACADEMIC POSITIONS</b>	<b>Universitat Pompeu Fabra</b> (Barcelona, Spain), June 2023- Marie Curie postdoctoral fellow <b>University of Tokyo</b> (Tokyo, Japan), Jan 2022-May 2023 Project researcher at the Universal Biology Institute <b>Santa Fe Institute</b> (Santa Fe, NM, USA), Dec 2015-Dec 2021 Postdoctoral fellow with postdoctoral advisor David H. Wolpert <b>Instituto Gulbenkian de Ciência</b> (Oeiras, Portugal), 2009-2010 and Summer 2008/2011/2012 Visiting researcher at FLAD Computational Biology Collaboratorium <b>Indiana University</b> (Bloomington, IN, USA), Sep 2011-May 2015 Research assistant with Ph.D. advisor Luis M. Rocha
<b>INDUSTRY</b>	<b>LinkedIn Corporation</b> (Mountain View, CA, USA), Summer 2014 Data science internship. Supervisor: Mathieu Bastian
<b>PUBLICATIONS</b>	<b>A. Kolchinsky</b> , N. Ohga, S. Ito, “Thermodynamic bound on spectral perturbations, with applications to oscillations and relaxation dynamics”, <i>Physical Review Research</i> , 2024. <a href="#">pdf link</a> D.R. Sowinski, J. Carroll-Nellenback, R.N. Markwick, J. Piñero, M. Gleiser, <b>A. Kolchinsky</b> , G. Ghoshal, A. Frank, “Semantic Information in a model of resource gathering agents”, <i>PRX Life</i> , 2023. <a href="#">pdf link</a> <b>A. Kolchinsky</b> , “Generalized Zurek’s bound on the cost of an individual classical or quantum computation”, <i>Physical Review E</i> , 2023. <a href="#">pdf link</a> M. Aguilera and <b>A. Kolchinsky</b> , “Quantifying higher-order entropy production in organized nonequilibrium states”, <i>Proceedings of the ALIFE 2023</i> , 2023. <a href="#">pdf link</a> N. Ohga, S. Ito, <b>A. Kolchinsky</b> , “Thermodynamic bound on the asymmetry of cross-correlations”, <i>Physical Review Letters</i> , 2023. ( <i>Editors’ Suggestion; Featured in Physics</i> ) <a href="#">pdf link</a> K. Yoshimura, <b>A. Kolchinsky</b> , A. Dechant, S. Ito, “Housekeeping and excess entropy production for general nonlinear dynamics”, <i>Physical Review Research</i> , 2023. <a href="#">pdf link</a> F.C. Sheldon, <b>A. Kolchinsky</b> , F. Caravelli, “Computational capacity of LRC, memristive, and hybrid reservoirs”, <i>Physical Review E</i> , 2022. <a href="#">pdf link</a> <b>A. Kolchinsky</b> , “A Novel Approach to the Partial Information Decomposition”, <i>Entropy</i> , 2022. <a href="#">pdf code link</a> <b>A. Kolchinsky</b> and D.H. Wolpert, “Dependence of integrated, instantaneous, and fluctuating entropy production on the initial state in quantum and classical processes”, <i>Physical Review E</i> , 2021. <a href="#">pdf link</a> <b>A. Kolchinsky</b> and D.H. Wolpert, “Work, entropy production, and thermodynamics of information under protocol constraints”, <i>Physical Review X</i> , 2021. <a href="#">pdf link</a>

- A. Kolchinsky** and D.H. Wolpert, “Entropy production given constraints on the energy functions”, *Physical Review E*, 2021. [pdf link](#)
- A. Kolchinsky** and D.H. Wolpert, “Thermodynamic costs of Turing Machines”, *Physical Review Research*, 2020. [pdf link](#)
- D.H. Wolpert and **A. Kolchinsky**, “The thermodynamics of computing with circuits”, *New Journal of Physics*, 2020. [pdf link](#)
- A. Kolchinsky** and B. Corominas-Murtra, “Decomposing information into copying versus transformation”, *Royal Society Interface*, 2020. [pdf link](#)
- A.M. Saxe, Y. Bansal, J. Dapello, M. Advani, **A. Kolchinsky**, B.D. Tracey, D.D. Cox, “On the information bottleneck theory of deep learning”, *Journal of Statistical Mechanics*, 2019. [pdf code link](#)
- A. Kolchinsky**, B.D. Tracey, D.H. Wolpert, “Nonlinear information bottleneck”, *Entropy*, 2019. (*Entropy* 2021 Best Paper Award) [pdf link](#)
- A. Berdahl, C. Brelsford, C. De Bacco, M. Dumas, V. Ferdinand, J.A. Grochow, L. Hébert-Dufresne, Y. Kallus, C.P. Kempes, **A. Kolchinsky**, D. B. Larremore, E. Libby, E.A. Power, C.A. Stern, B.D. Tracey, “Dynamics of beneficial epidemics”, *Scientific Reports*, 2019. [pdf link](#)
- E.A. Hobson, V. Ferdinand, **A. Kolchinsky**, J. Garland, “Rethinking animal social complexity measures with the help of complex systems concepts”, *Animal Behaviour*, 2019. [pdf link](#)
- A. Kolchinsky**, B.D. Tracey, S. Van Kuyk, “Caveats for information bottleneck in deterministic scenarios”, *International Conf on Learning Representations (ICLR)*, 2019. [pdf code link](#)
- D.H. Wolpert, **A. Kolchinsky**, J.A. Owen, “A space–time tradeoff for implementing a function with master equation dynamics”, *Nature Communications*, 2019. [pdf link](#)
- A. Avena-Koenigsberger, X. Yan, **A. Kolchinsky**, M. van den Heuvel, P. Hagmann, O. Sporns, “A spectrum of routing strategies for brain networks”, *PLoS Computational Biology*, 2019. [pdf link](#)
- J.A. Owen, **A. Kolchinsky**, D.H. Wolpert, “Number of hidden states needed to physically implement a given conditional distribution”, *New Journal of Physics*, 2019. (*correction*) [pdf link](#)
- A. Kolchinsky** and D.H. Wolpert, “Semantic information, autonomous agency, and nonequilibrium statistical physics”, *Royal Society Interface Focus*, 2018. [pdf code link](#)
- A.M. Saxe, Y. Bansal, J. Dapello, M. Advani, **A. Kolchinsky**, B.D. Tracey, D.D. Cox, “On the information bottleneck theory of deep learning”, *International Conf on Learning Representations (ICLR)*, 2018. [pdf code link](#)
- A. Kolchinsky**, N. Dhande, K. Park, Y.Y. Ahn, “The Minor Fall, the Major Lift: Inferring emotional valence of musical chords through lyrics”, *Royal Society Open Science*, 2017. [pdf data code link](#)
- A. Kolchinsky**, D.H. Wolpert, “Dependence of dissipation on the initial distribution over states”, *Journal of Statistical Mechanics*, 2017. [pdf link](#)
- A. Kolchinsky**, B.D. Tracey, “Estimating mixture entropy with pairwise distances”, *Entropy*, 2017. (*correction*) [pdf code link](#)
- A. Kolchinsky**, A.J. Gates, L.M. Rocha, “Modularity and the spread of perturbations in complex dynamical systems,” *Physical Review E*, 2015. [pdf code link](#)
- A. Kolchinsky**, A. Lourenço, H. Wu, L. Li, L.M. Rocha, “Extraction of pharmacokinetic evidence of drug-drug interactions from the literature,” *PLOS One*, 2015. [pdf link](#)
- A. Kolchinsky**, M.P. van den Heuvel, A. Griffa, P. Hagmann, L.M. Rocha, O. Sporns, J. Goñi, “Multi-scale integration and predictability in resting state brain activity,” *Frontiers in Neuroinformatics*, 2014. [pdf link](#)
- A. Rossi, F.J. Parada, **A. Kolchinsky**, A. Puce, “Neural correlates of apparent motion perception of impoverished facial stimuli I: A comparison of ERP and ERSP activity,” *NeuroImage*, 2014. [pdf link](#)
- A. Kolchinsky**, A. Lourenço, L. Li, L.M. Rocha, “Evaluation of linear classifiers on articles containing pharmacokinetic evidence of drug-drug interactions,” *Proc Pacific Symposium on Biocomputing*, 2013. [pdf link](#)
- A. Kolchinsky** and L.M. Rocha, “Prediction and modularity in dynamical systems,” *Proc of European Conf. on*

*the Synthesis and Simulation of Living Systems (ECAL)*, 2011. [pdf link](#)

**A. Kolchinsky**, A. Abi-Haidar, J. Kaur, A.A. Hamed, L.M. Rocha, “Classification of protein-protein interaction full-text documents using text and citation network features,” *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, 2010. [pdf link](#)

**POPULAR  
SCIENCE**

**A. Kolchinsky**, “The cost of sending a bit across a living cell”, *Physics Magazine*, 2023. [link](#)

**PREPRINTS**

**A. Kolchinsky**, “Thermodynamics of Darwinian evolution in molecular replicators”, arXiv:2112.02809, 2021. [arxiv](#)

R. Nagayama, K. Yoshimura, **A. Kolchinsky**, S. Ito, “Geometric thermodynamics of reaction-diffusion systems: Thermodynamic trade-off relations and optimal transport for pattern formation”, arXiv:2311.16569, 2023. [arxiv](#)

P.M. Riechers, C. Gupta, **A. Kolchinsky**, M. Gu, “Thermodynamically ideal quantum-state inputs to any device”, arXiv:2305.00616, 2023. [arxiv](#)

J. Piñero, R. Solé, **A. Kolchinsky**, “Universal bounds on optimization of free energy harvesting”, arXiv:2303.04975, 2023. [arxiv](#)

**A. Kolchinsky**, A. Dechant, K. Yoshimura, S. Ito, “Information geometry of excess and housekeeping entropy production”, arXiv:2206.14599, 2022. [arxiv](#)

C. Gokler, **A. Kolchinsky**, Z. Liu, I. Marvian, P. Shor, O. Shtanko, K. Thompson, D. Wolpert, S. Lloyd, “When is a bit worth much more than  $kT \ln 2$ ?”, arXiv:1705.09598, 2017. [arxiv](#)

**A. Kolchinsky**, I. Marvian, C. Gokler, Z. Liu, P. Shor, O. Shtanko, K. Thompson, D. Wolpert, S. Lloyd, “Maximizing free energy gain”, arXiv:1705.00041, 2017. [arxiv](#)

**INVITED  
TALKS**

2/2024 - *Seminar at Barcelona Collaboratorium for Modelling and Predictive Biology*, Barcelona, Spain  
“Stochastic thermodynamics: promises and challenges for studying living systems”

11/2023 - *Mini-workshop: Non-equilibrium thermodynamics and biology*, Biofiska Institute, Bilbao, Spain  
“Stochastic thermodynamics: promises and limitations for studying living matter”

11/2023 - *Seminar*, Basque Center for Applied Mathematics, Bilbao, Spain  
“Nonequilibrium thermodynamics, cross-correlations, and the isoperimetric inequality”

7/2023 - *Information Engines at the Frontiers of Nanoscale Thermodynamics*, Telluride, CO, USA  
“Information geometry for nonequilibrium processes”

6/2023 - *Mathematics, Physics & Machine Learning Webinar*, Instituto Superior Técnico, Lisbon, Portugal  
“Information geometry for nonequilibrium processes” (virtual)

6/2023 - *Conference on Decomposing Multivariate Information in Complex Systems*, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany  
“A Novel Approach to the Partial Information Decomposition”

9/2022 - *Seminar at Dutch Institute of Emergent Phenomena*, University of Amsterdam, Netherlands  
“Information geometry of fluxes and forces in nonequilibrium thermodynamics” (virtual)

8/2022 - *Seminar*, Earth-Life Science Institute (ELSI), Tokyo, Japan  
“Thermodynamics of Darwinian evolution in molecular replicators”

6/2022 - *Evolution of complexity from the statistical physics perspective*, Yerevan Physics Institute, Armenia  
“Thermodynamics of Darwinian evolution” (virtual)

6/2022 - *Yagami Statistical Physics Seminar*, Keio University, Japan  
“Thermodynamics under protocol constraints” (virtual)

5/2022 - *Workshop on Stochastic Thermodynamics III*, University of Tokyo, Japan  
“The algorithmic cost of a single classical or quantum computation” (virtual)

4/2022 - *Cross Labs Workshop: Is AI Extending the Mind?*, Cross Labs, Japan  
“Autonomous agents and semantic information” (virtual)

2/2022 - *Physics Department Colloquium Series*, University of Rochester, NY, USA  
 “A thermodynamic threshold for Darwinian evolution” (virtual)

12/2021 - *Universal Biology Institute Seminar Series*, University of Tokyo, Japan  
 “A thermodynamic threshold for Darwinian evolution” (virtual)

02/2021 - *Origins of Life: The Possible and the Actual* workshop, Santa Fe Institute, NM, USA  
 “Fundamental thermodynamic constraints and trade-offs in origin of life”

7/2020 - *ICTP Seminar Series*, Abdus Salam International Center for Theoretical Physics, Trieste, Italy  
 “Bounds on entropy production and thermodynamics of information under protocol constraints” (virtual)

2/2020 - *AI Seminar Series*, Information Sciences Institute, Los Angeles, CA, USA  
 “Machine Learning through the information bottleneck”

7/2019 - *ISTI Seminar Series*, Los Alamos National Lab, Los Alamos, NM, USA  
 “Machine Learning through the information bottleneck”

6/2018 - *Connectomics Lecture Series*, Universidad Diego Portales, Santiago, Chile  
 “Machine learning, deep neural networks, and the brain”

4/2018 - *Meeting of the Society for the Neural Control of Movement*, Santa Fe, NM, USA  
 “Machine learning, deep neural networks, and the brain”

4/2018 - *SITE Santa Fe* (contemporary art museum), Santa Fe, NM, USA  
 “Life, entropy, and the 2<sup>nd</sup> law of thermodynamics”

11/2017 - Seoul National University, South Korea  
 “Science at the Santa Fe Institute” (w/ V. Ferdinand)

8/2017 - *Thermodynamics & Computation: Towards a New Synthesis*, Santa Fe Institute, NM, USA  
 “Statistical physics of Turing Machines”

10/2016 - *Statistical Physics, Information Processing and Biology*, Santa Fe Institute, NM, USA  
 “Dependence of dissipation on the initial distribution”

2/2016 - Information Sciences Institute, Los Angeles, CA, USA  
 “Multi-scale integration & modularity in complex systems”

#### **AWARDS & FELLOWSHIPS**

2022 - Marie Curie Individual Fellowship (HORIZON-MSCA-2021-PF-01)  
 “NETOLIFE: Nonequilibrium thermodynamics of the origin of life”

2012 - 2013 - Lilly Graduate Fellowship, Biocomplexity Institute, Indiana University, Bloomington, IN

2007 - 2009 - Eli Lilly Fellowship, Indiana University, Bloomington, IN,

2004 - Dean’s List Gallatin School, New York University, NY

#### **GRANTS**

2023 - John Templeton Foundation (62828), \$947,926, Co-PI  
 “Goal-directed behavior and the origin of life”

2022 - John Templeton Foundation (62417), \$627,227, Co-PI  
 “Information architectures that enable life: the emergence of meaning”

2019 - Foundational Questions Institute (FQXi-RFP-IPW-1912), \$118,100, Co-Investigator (PI: David Wolpert)  
 “The role of constraints in the thermodynamics of intelligence”

2016 - Foundational Questions Institute (FQXi-RFP-1622), \$128,319, Co-Investigator (PI: David Wolpert)  
 “Observers as self-maintaining non-equilibrium systems”

2016 - NSF INSPIRE (CHE-1648973), \$999,947, co-author (PI: David Wolpert)  
 “Tradeoffs in the Thermodynamics of Computation: A New Paradigm for Biological Information-Processing”

2016 - NSF (1620462), \$770,000, co-author (PI: David Wolpert)  
 “Information Networks and the Evolution of Social Organizations”

#### **TEACHING**

**Online courses**

2018 - “Fundamentals of machine learning” (w/ B.D. Tracey), Complexity Explorer from the Santa Fe Institute  
Designed and delivered a 12-part online course on basics of machine learning [\[link\]](#)

**Workshops, lectures, and tutorials**

6/2019 - Santa Fe Institute Complex Systems Summer School, NM, USA

Two lecture series on machine learning and its research frontiers

3/2019 - Santa Fe Institute, NM, USA

Tutorial on “Machine learning with TensorFlow”

6/2017, 6/2018 - Santa Fe Institute, NM, USA

Tutorial on introduction to programming and data analysis in Python (w/ V. Ferdinand)

11/2017 - Seoul National University, Seoul, South Korea

Week-long workshop on “Thermodynamics, evolution, and inference through the lens of information theory”  
(w/ V. Ferdinand)

11/2017 - ACTioN/Trustee Meeting, Santa Fe Institute, NM, USA

Lecture on “Machine learning: A guide for the perplexed” (w/ B. D. Tracey)

5/2010 - Instituto Gulbenkian de Ciência, Oeiras, Portugal

Assisted with week-long “Bayesian brain” educational module

**Teaching Assistant at Indiana University, Bloomington, IN**

Spring 2014 - “I400 Large-scale Social Phenomena” [\[link\]](#)

Spring 2011 - “I201 Math and logic foundations of Informatics”

Fall 2010 - “I485 Biologically Inspired Computing” [\[link\]](#)

Developed and implemented a 5-part computational lab series

Fall 2008-Spring 2009 - “I210 Information Infrastructure” (Python programming)

**ADVISING**

*Nicolas Freitas*, Santa Fe Institute REU Program, Santa Fe, NM, June-August, 2018

Project: “Scaling of information in biochemical systems”

*Francis Cavanna*, Santa Fe Institute REU Program, Santa Fe, NM, June-August, 2017

Project: “Investigating the relationship between criticality and Landauer costs using the Ising model”

**ACADEMIC  
SERVICE**

**Guest editor:** *Entropy* special issue on “Thermodynamics and Information Theory of Living Systems” [link](#)

**Reviewer**

Physics: *New J of Physics*, *PRL*, *PRR*, *PRE*, *Frontiers in Physics*, *J of Physics A*, *Physica A*

Biology: *J R Soc Proc B*, *PLoS Comp Bio*, *Theory in the Biosciences*

Information theory and machine learning: *Entropy*, *ICLR*, *IEEE Trans on Pattern Analysis and Machine Intelligence*, *Kybernetika*, *Applied Sciences*

**Other**

2008-2013 - Started and ran a weekly discussion group on complexity, dynamical systems, and embodiment in cognitive science, Indiana University, Bloomington, IN [link](#)

**SKILLS**

*Programming:* Python, MATLAB, C, C++, R, Java

machine learning with TensorFlow, web programming, databases/SQL, scalable computing

*Languages:* Fluency: English, Russian, Spanish / Basic: Portuguese