

Artemy Kolchinsky

Universal Biology Institute, University of Tokyo

- CONTACT** E-mail: artemyk@gmail.com Google Scholar: [link](#)
Web: <https://artemyk.github.io> GitHub: [@artemyk](#)
- EDUCATION** **Indiana University** (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
New York University (New York, NY, USA), 2004
B.A. Magna Cum Laude, Individualized Study (concentration in Complex Systems)
- ACADEMIC POSITIONS** **Universitat Pompeu Fabra** (Barcelona, Spain), June 2023-
Marie Curie postdoctoral fellow
University of Tokyo (Tokyo, Japan), Jan 2022-May 2023
Project researcher at the Universal Biology Institute
Santa Fe Institute (Santa Fe, NM, USA), Dec 2015-Dec 2021
Postdoctoral fellow with postdoctoral advisor David H. Wolpert
Instituto Gulbenkian de Ciência (Oeiras, Portugal), 2009-2010 and Summer 2008/2011/2012
Visiting researcher at FLAD Computational Biology Collaboratorium
Indiana University (Bloomington, IN, USA), Sep 2011-May 2015
Research assistant with Ph.D. advisor Luis M. Rocha
- INDUSTRY** **LinkedIn Corporation** (Mountain View, CA, USA), Summer 2014
Data science internship. Supervisor: Mathieu Bastian
- PUBLICATIONS** J. Piñero, R. Solé, **A. Kolchinsky**, “Optimization of nonequilibrium free energy harvesting illustrated on bacteriorhodopsin”, *Physical Review Research*, 2024. [pdf link](#)
A. Kolchinsky, N. Ohga, S. Ito, “Thermodynamic bound on spectral perturbations, with applications to oscillations and relaxation dynamics”, *Physical Review Research*, 2024. [pdf link](#)
D.R. Sowinski, J. Carroll-Nellenback, R.N. Markwick, J. Piñero, M. Gleiser, **A. Kolchinsky**, G. Ghoshal, A. Frank, “Semantic Information in a model of resource gathering agents”, *PRX Life*, 2023. [pdf link](#)
A. Kolchinsky, “Generalized Zurek’s bound on the cost of an individual classical or quantum computation”, *Physical Review E*, 2023. [pdf link](#)
M. Aguilera and **A. Kolchinsky**, “Quantifying higher-order entropy production in organized nonequilibrium states”, *Proceedings of the ALIFE 2023*, 2023. [pdf link](#)
N. Ohga, S. Ito, **A. Kolchinsky**, “Thermodynamic bound on the asymmetry of cross-correlations”, *Physical Review Letters*, 2023. (*Editors’ Suggestion; Featured in Physics*) [pdf link](#)
K. Yoshimura, **A. Kolchinsky**, A. Dechant, S. Ito, “Housekeeping and excess entropy production for general nonlinear dynamics”, *Physical Review Research*, 2023. [pdf link](#)
F.C. Sheldon, **A. Kolchinsky**, F. Caravelli, “Computational capacity of LRC, memristive, and hybrid reservoirs”, *Physical Review E*, 2022. [pdf link](#)
A. Kolchinsky, “A Novel Approach to the Partial Information Decomposition”, *Entropy*, 2022. [pdf code link](#)
A. Kolchinsky and D.H. Wolpert, “Dependence of integrated, instantaneous, and fluctuating entropy production on the initial state in quantum and classical processes”, *Physical Review E*, 2021. [pdf link](#)

A. Kolchinsky and D.H. Wolpert, “Work, entropy production, and thermodynamics of information under protocol constraints”, *Physical Review X*, 2021. [pdf link](#)

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 pharma-

cokinetic 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

R. Solé, C. P. Kempes, B. Corominas-Murtra, M. De Domenico, **A. Kolchinsky**, M. Lachmann, E. Libby, S. Saavedra, E., D. Wolpert, “Fundamental Constraints to the Logic of Living Systems”, 2024. [preprint](#)

A. Kolchinsky, “Partial information decomposition as information bottleneck”, arXiv:2405.07665, 2024. [arxiv](#)

K. R. Thomsen, **A. Kolchinsky**, S. Rasmussen, “Metabolism, information, and viability in a simulated physically-plausible protocell”, arXiv:2405.04654, 2024. [arxiv](#)

A. Kolchinsky, “Thermodynamic dissipation does not bound replicator growth and decay rates”, arXiv:2404.01130, 2024. [arxiv](#)

A. Kolchinsky, “Thermodynamics of Darwinian evolution in molecular replicators”, arXiv:2112.02809, 2024. [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](#)

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*, Biofisika 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 2nd 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