

Gregory Henselman-Petrusek

Pacific Northwest National Laboratory
gregory.rock@pnnl.gov

Revised: June 2022

Education

Ph.D. Electrical and Systems Engineering, University of Pennsylvania, Philadelphia, PA, May 2017

Dissertation: *Matroids and Canonical Forms: Theory and Applications*

Adviser: Robert W. Ghrist

M.S. Mathematics, University of Oregon, Eugene, OR, May 2011

B.A. Mathematics and Classical Studies, *magna cum laude*, Willamette University, Salem, OR, May 2010

Appointments

Research

Senior Research Scientist, Pacific Northwest National Laboratory. 2022-Present

Postdoctoral Research Associate, Mathematical Institute, University of Oxford. 2020–2022

Supervisors: Heather Harrington, Ulrike Tillman

Associate Research Scholar and Swartz Fellow, Princeton University. 2019–2020

Postdoctoral Research Associate and Swartz Fellow, Princeton University. 2017–2019

Supervisor: Jonathan D. Cohen

Visiting Student Collaborator, Princeton Neuroscience Institute. 2016–2017

Intern, United Technologies Research Center. 2012

Graduate Fellow, University of Pennsylvania, 2011-2017

Teaching

Instructor, Princeton Neuroscience Institute Summer Internship Program. 2020

Instructor, US Air Force Research Laboratories. 2018

Instructor, Summer at ICERM. 2017

Instructor, Center for Teaching and Learning, University of Pennsylvania. 2015

Graduate Teaching Fellow, University of Oregon. 2010–2011

Research

Mathematics

exact categories - order theoretic foundations of homological persistence

homological algebra - sparse matrix algebra, algebraic Morse theory, discrete Morse-Witten theory

matroids - combinatorial invariants of monoidal categories.

Applications

cognition - deep network architectures, brain imaging, semantics, cognitive control

modeling - quantitative and qualitative interpretation of topological statistics

computation - performant algorithms for homological algebra

Teaching

Methods

Universal design, adaptive methods for attentional disorders, active learning

Courses

Introduction to matroid theory, *Short course*, University of Oxford. 2021

Introduction to data science, *Instructor*, Princeton Neuroscience Institute Summer Internship. 2020

Decision Models, *Teaching Assistant*, University of Pennsylvania. 2015

Calculus: Single Variable, *Teaching Assistant*, Coursera. 2014

Introduction to Calculus, *Instructor of Record*, University of Oregon. 2011

Precalculus, *Instructor of Record*, University of Oregon. 2011

Precalculus, *Instructor of Record*, University of Oregon. 2010

Mentorship and advising

Haibin Hang, *Postdoc, Mathematics*, 2019-2021

NSF CDS&E-MSS: High performance computing in homological algebra.

Emily Russell, *Graduate student, Mathematics*, 2020-2021

Research methods in research computing.

Thomas Chaplin, *Graduate student, Mathematics*, 2021-2022

Path homology of directed graphs.

Jacob Leygone, *Graduate student, Mathematics*, 2020-2022

Computing the homotopy type of the persistence fibers.

Tyler Giallanza, *Graduate student, Neuroscience*, 2019-2021

Neural coding and feature representations in cognitive control.

Simon Segert, *Graduate student, Neuroscience*, 2018-2019

Geometry of shared representations.

Zhaoheng Li and Qingru Zhang, *Undergraduate REU, Mathematics*, 2021-2022

NSF CDS&E-MSS: Algorithm design and implementation for minimal cycle representatives in persistent homology.

Lu Li, *Undergraduate REU, Mathematics*, 2020-2021

NSF CDS&E-MSS: Minimal Cycle Representatives in Persistent Homology using Linear Programming: an Empirical Study with User's Guide.

Connor Thompson, *Undergraduate REU, Mathematics*, 2020-2021

NSF CDS&E-MSS: Acceleration and statistical analysis of persistent cycle representatives.

Robert Angarone, *Undergraduate REU, Mathematics*, 2020-2021

NSF CDS&E-MSS: Combinatorial foundations in persistent homology computation.

Sophia Wiedmann, *Undergraduate REU, Mathematics*, 2020-2021

NSF CDS&E-MSS: Combinatorial foundations in persistent homology computation.

Summer cohort, *University of Pennsylvania Center for Teaching and Learning*, 2015

Teaching practicum: problem-based methods for classroom instruction in STEM

Certifications

Teaching Certificate, Center for Teaching and Learning, University of Pennsylvania, 2015

Publications

Doctoral Thesis

G. Henselman-Petrusek *Matroids and Canonical Forms: Theory and Applications* (2017)

ArXiv preprint: <https://arxiv.org/abs/1710.06084>

Preprints

J. Leygonie & G. Henselman-Petrusek, *Algorithmic reconstruction of the fiber of persistent homology on cell complexes* (2021)

Under review, Journal of Applied and Computational Topology Available at : <https://arxiv.org/abs/2110.14676>

- H. Hang, C. Giusti, L. Ziegelmeier, G. Henselman-Petrusek, *U-match factorization: sparse homological algebra, lazy cycle representatives, and dualities in persistent (co)homology* (2021)
Under review, *Journal of Applied and Computational Topology* Available at : <https://arxiv.org/abs/2108.08831>
- G. Henselman-Petrusek, T. Giallanza, S. Musslick, J. D. Cohen, *Multitasking networks use multi-affine representations to direct flow of feature data* (2020)
Available at: <https://gregoryhenselman.org>
- G. Henselman-Petrusek, *Semitopological coproducts and free objects on N totally ordered sets in some categories of complete, distributive, modular, and algebraic lattices* (2019)
Available at: <https://gregoryhenselman.org>
- G. Henselman-Petrusek & R. Ghrist, *Saecular persistence* (2021)
Available at: <https://gregoryhenselman.org>
- G. Henselman & R. Ghrist, *Matroid Filtrations and Computational Persistent Homology* (2017)
Available at : <https://arxiv.org/abs/arXiv:1606.00199v2>

Articles

- L. Li, C. Thompson, G. Henselman-Petrusek, C. Giusti, L. Ziegelmeier, *Minimal Cycle Representatives in Persistent Homology using Linear Programming: an Empirical Study with User's Guide*.
Frontiers in Artificial Intelligence (accepted) 2021
- M. Kumar, et al., *BrainIAK: The Brain Imaging Analysis Kit* (2021) *Aperture Neuro*, 1(4), 19. Available at <https://apertureneuro.pub.cloud68.co/articles/42/index.html>
- A. Hylton, G. Henselman-Petrusek, J. Sang, & R. Short, *Tuning the Performance of a Computational Persistent Homology Package*, *Software: Practice and Experience* (Feb 2019)
Available at <https://onlinelibrary.wiley.com/doi/abs/10.1002/spe.2678>
- C. T. Ellis, M. Lesnick, G. Henselman-Petrusek, B. Keller, & J. D. Cohen, *Feasibility of topological data analysis for event-related fMRI*, *Network neuroscience* 3(3), 695-706. (2019)
Available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6663178/>

Conference Proceedings

- G. Henselman-Petrusek, T. Giallanza, S. Musslick, J.D. Cohen. *Regression, encoding, control: an integrated approach to shared representations with distributed coding*, Proceedings of the 43rd Annual Conference of the Cognitive Science Society. Cognitive Science Society (2021)
- Y. Urano, A. Kurosu, G. Henselman-Petrusek, & A. Todorov *Good visual hierarchy is good design*, ACM Conference on Human Factors in Computing Systems (2021).
Preprint available at <https://psyarxiv.com/hksf9/>.
- G. Henselman-Petrusek, S. Segert, B. Keller, M. Tepper, & J. D. Cohen *Geometry of Shared Representations*, Conference on Cognitive Computational Neuroscience (2019)
- S. Musslick, A. Saxe, K. Özcimder, B. Dey, G. Henselman, & J.D. Cohen, *Multitasking Capability Versus Learning Efficiency in Neural Network Architectures*, Cognitive Science Society (2017)
- A. Hylton, J. Sang, G. Henselman-Petrusek, & R. Short, *Performance enhancement of a computational persistent homology package*, IEEE 36th International Performance Computing and Communications Conference (IPCCC) (2017): 1-8.
- G. Henselman & P. Dlotko, *Combinatorial invariants of multidimensional topological network data*, IEEE Global Conference on Signal and Information Processing (GlobalSIP) (2014): 828-832.

Software

- Exact Homological Algebra for Computational Topology (ExHACT)* (2019 - Present)
- Eirene Library for Computational Persistent Homology* (2016 - Present)
Available at <https://github.com/Eetion/Eirene.jl>
- PNI-Intel Collaboration for Brain Image Analysis: Repository for topological analysis of parallel distributed processing in neural network architectures* (2017 - Present)
Available at <https://github.com/IntelPNI>

Funding

MSRVP/ECRVP *Mathematical Sciences Institute, Australian National University*. Research collaboration with Prof. Katharine Turner. Awarded for August 2020, deferred during COVID-19 pandemic. Award: 6,000 USD.

Principal Investigator *NSF CDS&E-MSS Exact Homological Algebra for Computational Topology (EXHACT)*. Period: 2019-2023. Agency: National Science Foundation Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences. Award: 510,000 USD.

Swartz Fellow *Theoretical and computational neuroscience*, Neuroscience of Cognitive Control Lab, Princeton Neuroscience Institute 2017-2020.

Keynote Talks and Panels

- 2022 April: SIAM International Conference on Data Mining (*Panel*) *Computational Tools in TDA*
- 2021 December: Topology in distinct flavors, Warwick University *Optimal cycle representatives in persistent homology*
- 2021 June: IEEE International Conference on Big Data, Workshop on applications of topological data analysis *How to make sense of a barcode: practical steps to cleaning the picture*

Invited Talks and Trainings

- 2022 May: University of Albany, *Saecular persistence*
- 2022 April: SIAM International Conference on Data Mining, *Panel on computational topology*
- 2022 April: Joint Mathematics Meetings, *How to analyze a persistence module of abelian groups into simple parts, with applications*
- 2021 January: Oregon State University, *Toward Order-Theoretic Foundations of TDA: Morse-Witten Theory for Real Operators*
- 2020 November: Quarterly meeting of the EPSRC Centre for Topological Data Analysis, *Matroids in TDA*
- 2020 July: Computational & Algorithmic Topology, Sydney
- 2020 April: Princeton University P-6, *M-PHATE visualization of control representations in deep network architectures*
- 2019 December: Intel Labs, *A mechanistic account of abstraction in networks that perform multiple tasks*
- 2019 April: Intel Labs, *Geometry of network feature representations*
- 2019 March: CUNY College of Staten Island, *Morse-Witten Theory for Real Operators*
- 2018 October: Intel Labs, *Topological Structure in Hidden Activations in Neural Network Architectures*
- 2018 October: Category Theory Octoberfest, *Functoriality in Topological Data Analysis*
- 2018 September: Ursinus College, *The Spectral Theorem*
- 2018 August: Institute for Mathematics and its Applications, *Morse Theory and Persistent Homology Computation*
- 2018 June: University of Colorado, *Toward Single Parameter Persistence with Nonlinear Coefficients*
- 2018 April: Mathematical Institute, University of Oxford, *Combinatorial Foundations in TDA*
- 2018 April: Swansea University, *Convex Algorithms in Single-Parameter Persistence*
- 2018 March: Max Plank Leipzig, *The Eirene Library*
- 2018 February: Technical University of Munich, Workshop on Multiparameter Persistence, *Semimodular Lattices in TDA*

- 2018 January: Joint Math Meetings, *Morse-Witten Theory for Real Operators*
- 2017 October-November: Institute for Advanced Study, *Lecture Series: Modularity, an Ancient Language of Classification for Abelian Categories.*
- 2017 August: SIAM Conference on Applied Algebraic Geometry, *Matroids, Morse Theory, and Fast Persistent Homology Computations*
- 2017 June: Campus Biotech, *Canonical Forms and Persistence Modules: Toward Combinatorial Foundations in TDA*
- 2017 June: Penn State University, *Morse Theory and Computational Persistent Homology*
- 2017 May: Banff International Research Station, *Circuits, Filtrations, and Matrix Factorization: The Role of Matroids in Fast Persistent Homology Computation*
- 2017 April: Brown University, *Canonical Forms in TDA*
- 2017 April: Applied Algebraic Topology Network, *Matroids and Canonical Forms: Theory and Applications*
- 2017 March: Alan Turing Institute, *Combinatorial Homology: A Simplified Approach to Persistence and Computation, via Matroids*
- 2017 January: Joint Math Meetings, *The Combinatorial Linear Chain Complex*
- 2016 June: Institute for Advanced Study, *Möbius Inversion, Morse Theory, and Homological Persistence*, Institute for Advanced Study
- 2016 January: Joint Math Meetings, *Matroids, Morse Theory, and Fast Persistent Homology Computations*
- 2015 November: Rutgers University, *A Morse-Theoretic Algorithm to Compute Persistent Homology, with Generators*
- 2015 October: Lehigh University, *Cellular Matroids & Applications*
- 2015 September: Columbia University, *Data, Algorithms, and Problems on Graphs, A novel algorithm for persistent homology, with applications to neuroscience*
- 2015 September: University of Oxford, Computational Algebraic Topology School, *Based Persistence: Matroids and Morse Theory for Spaces with Big Cliques*
- 2014 December: IEEE Global Signal & Information Processing Symposium, *Combinatorial Invariants of Multidimensional Topological Network Data (poster).*
- 2014 February: University Pennsylvania ESE Seminar, *Duality for Nonlinear Flows: Maxwell's Equations and Beyond.*
- 2012 July: United Technologies Research Center, *Sheaves & Applications.*
- 2008 May: Willamette University, Presidential Thesis Defense. *Deterministic Generation of Three-Regular Graph Representations for One-Face Maps.*

Contributed Talks and Trainings

- 2022 May: Topological Data Visualization Workshop, University of Iowa, *Optimal cycle representatives for visualization and feature localization: empirical insights for the practitioner*
- 2020 November: DeepMath, *A nonparametric model of independence for cognitive feature representations*
- 2019 December: Princeton Neuroscience Institute, *Parallelism in deep network architectures*
- 2019 September: Conference in Cognitive Computational Neuroscience (CCN), *Geometry of shared representations*
- 2019 September: Princeton Neuroscience Institute, *Generalization geometry in deep network architectures*
- 2015 February: University Pennsylvania Applied Topology Seminar, *Cellular matroids & Topological Data Analysis.*
- 2011 June: University Oregon, WETSK. *Euler Integration and the Euler-Bessel/Euler-Fourier Transforms.*
- 2011 May: University Oregon, Homotopy Seminar. *Persistent Homology and Data Analysis.*

2011 April: Willamette University, Colloquium. *Topological Robotics: Theorems & Examples.*

2010 January: University Oregon, Homotopy Seminar. *Homological Approachs to Network Coverage.*

Service

Outreach, inclusion

2020 Princeton Neuroscience Institute Summer Internship Program, *Instructor*

2019-2020 Princeton Neuroscience Institute Climate and Inclusion Committee, *Secretary*

2018-2020 ADHD Connections: Princeton University focus group for students with attentional challenges,
Program Coordinator

2019 Princeton Neuroscience Institute Code of Conduct Committee, *Drafting member*

2015 FIRST LEGO League Championship, *Volunteer Coordinator*

Scholarship

2023 AIMS workshop on emerging methods in computational topology, *Organizer*

2022 ICLR, *Reviewer*

2022 Journal of Applied and Computational Topology, *Reviewer*

2021 Frontiers in Artificial Intelligence, *Reviewer*

2021 Minisymposium “Emerging directions in computational topology,” SIAM conference on Computational Science and Engineering (CSE21), *Organizer*

2021 TDA Seminar, Centre for TDA, University of Oxford, *Organizer*

2020 Applicable Analysis and Discrete Mathematics (AADM), *Reviewer*

2019-2020 Workshop on Topology in Complex Systems, Institute for Advanced Study, *Organizer*

2019 IEEE ICMLA Special Session for Topological Data Analysis, *Organizing committee*

2018-2019 Journal of Applied and Computational Geometry, *Reviewer*

2018 Special Session on Applied Algebraic Topology, AMS Fall Eastern Sectional Meeting Newark, DE
Organizer

2018 Institute for Mathematics and Applications Workshop of Multiparameter Persistence, *Instructor*

2018 Air Force Research Laboratory Summer of TDA, *Instructor*

2017 Symposium on Computational Geometry, *Reviewer*

2017 Summer at ICERM, *Instructor*

2016 Graduate Teaching Assistant Training, Center for Teaching and Learning, University of Pennsylvania,
Workshop Leader

2015 Graduate Student Seminar, Department of Electrical and Systems Engineering, University of Pennsylvania,
Founder, Coordinator

Awards and Certifications

2020 MSRVP/ECRVP Visiting Researcher, Mathematical Sciences Institute, Australian National University

2017-2020 Swartz Foundation Fellowship for Theoretical Neuroscience, Princeton University

2015 Teaching Certificate, Center for Teaching and Learning, University of Pennsylvania

2009 Charles W. & Elizabeth H. Curtis Award for Mathematics

2009 M. Glockers Garner Award

2008 Phi Beta Kappa

2007 Presidential Research Grant in Mathematics, Willamette University

2006 Willamette University Class of 1965 Scholarship

2004 Honors at Entrance, Willamette University

Professional and Honor Societies

Association for Women in Mathematics
American Mathematical Society
Institute of Electrical and Electronics Engineers
Phi Beta Kappa

References

Robert W. Ghrist, Department of Mathematics, University of Pennsylvania
Jonathan D. Cohen, Princeton Neuroscience Institute, Princeton University
Ulrike Tillmann, FRS, Mathematical Institute, University of Oxford
Heather Harrington, Mathematical Institute, University of Oxford
Chad Giusti, Department of Mathematics, Oregon State University
Vidit Nanda, Mathematical Institute, University of Oxford