

# Gregory Henselman-Petrusek

Mathematical Institute, University of Oxford  
Andrew Wiles Building  
Radcliffe Observatory Quarter  
Woodstock Road, Oxford, OX2 6GG  
henselmanpet@maths.ox.ac.uk

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## 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

Postdoctoral Research Associate, University of Oxford. 2020–2021

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

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

Adviser: 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* - 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 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

### Mentoring

Supervisor, *Graduate research in control models of semantic cognition*, Neuroscience of Cognitive Control Lab, Princeton University. 2020

Mentor, *Linear methods in cycle analysis*, Macalaster College REU. Summer 2020

Mentor, *Homological generators in scientific computing*, Macalaster College REU. Summer 2019

Graduate TA Trainer, *Center for Teaching and Learning*, University of Pennsylvania. 2015

### 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

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, *Decomposition of nonlinear persistence modules* (2019)  
Available at: <https://gregoryhenselman.org>

G. Henselman & R. Ghrist, *Matroid Filtrations and Computational Persistent Homology* (2016)  
Available at : <https://arxiv.org/abs/arXiv:1606.00199v2>

### Articles

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/>

### Peer-Reviewed Conference Proceedings

G. Henselman & P. Dlotko, *Combinatorial invariants of multidimensional topological network data*, IEEE Global Conference on Signal and Information Processing (GlobalSIP) (2014): 828-832.

S. Musslick, A. Saxe, K. Özcimder, B. Dey, G. Henselman, & J.D. Cohen, *Multitasking Capability Versus Learning Efficiency in Neural Network Architectures*, CogSci (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.

### Conference Proceedings

G. Henselman-Petrusek, S. Segert, B. Keller, M. Tepper, & J. D. Cohen *Geometry of Shared Representations*, Conference in Cognitive Neuroscience (2019)

### 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>

*Nonstaff contributor: Ripser library for homological persistence.*

Available at <https://github.com/Ripser/ripser>

## 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.

## Invited Talks and Trainings

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 Mulltiparameter 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 Seminars

- 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

- 2021 Minisymposium “Emerging directions in computational topology,” SIAM conference on Computational Science and Engineering (CSE21), *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  
Chad Giusti, Department of Mathematics, University of Delaware  
Vidit Nanda, Mathematical Institute, University of Oxford