MODERN MATH WORKSHOP 2024

PHOENIX CONVENTION CENTER

WEDNESDAY, OCTOBER 30TH

12:00 – 12:40 **Check-in** **Outside 222BC**

12:45 – 12:55 **Welcome Remarks** **222BC**
Selenne Bañuelos
Institute of Pure and Applied Mathematics

CONCURRENT SESSIONS

1:00 – 2:30 **Undergraduate Mini Course I (Part 1)** **222A**
Malena Español
Arizona State University
The Matrix Revolution: Data, Images, and Beyond

1:00 – 2:30 **Undergraduate Mini Course II (Part1)** **223**
Nancy Rodriguez
University of Colorado Boulder
Reaction Diffusion Models on a Network

1:00 – 1:45 **Research Talk – SLMath** **222BC**
Sandra Sandoval Gomez
University of Notre Dame & Vienna University of Technology
DG-algebras and their uses in determinantal rings

1:45 – 2:30 **Research Talk – ICERM** **222BC**
Gretchen Matthews
Virginia Tech
Matrices over Finite Fields, Hulls, and Applications

2:30 – 3:00 **Break** **Outside 222BC**

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CONCURRENT SESSIONS

3:00 – 4:30	**Undergraduate Mini Course I (Part 2)** **Malena Español** Arizona State University **The Matrix Revolution: Data, Images, and Beyond**	**222A**
3:00 – 4:30	**Undergraduate Mini Course II (Part 2)** **Nancy Rodriguez** University of Colorado Boulder **Reaction Diffusion Models on a Network**	**223**
3:00 – 3:45	**Research Talk – AIM** **Noelle Sawyer** Southwestern University **Unique Equilibrium States for Geodesic Flows**	**222BC**
3:45 – 4:30	**Panel Discussion** **RB McGee - Moderator** Haverford College	**222BC**
4:30 – 4:45	**Break**	**Outside 222BC**
4:45 – 5:45	**Plenary Talk** **Omayra Ortega** Sonoma State University **Equations of Equality: Rethinking Representation in AI and Math**	**222BC**
5:45 – 6:00	**Opportunities at the Math Institutes** **Christian Ratsch** Institute of Pure and Applied Mathematics	**222BC**
6:00 – 7:30	**Modern Math Workshop Reception**	**221ABC**

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THURSDAY, OCTOBER 31st

8:30 – 9:00	**Coffee and Pastries**	**222ABC**
9:00 – 9:45	**Research Talk – IMSI** **Lorin Crawford** Microsoft Research New England **Rewards and Consequences of Training Data Composition for Deep Generative Models in Single Cell Biology**	**222ABC**
9:45 – 10:30	**Research Talk – IPAM** **Anastasia Chavez** Saint Mary's College of California **The Matroids Among Us**	**222ABC**
10:30 – 10:45	**Break**	**222ABC**
10:45 – 11:45	**Panel Discussion**	**222ABC**

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Titles and Abstracts

The Matrix Revolution: Data, Images, and Beyond
Malena Español (Arizona State University)

What is a matrix, and how can it be used to create cutting-edge technologies? This mini-course will explore matrices' fundamental role in data science and digital imaging. You'll discover how matrices model complex imaging systems and learn robust, efficient, and effective methods for reconstructing images from data. This comprehensive course is ideal for anyone curious about the mathematics behind data or eager to apply these concepts to real-world imaging challenges.

Reaction-Diffusion Models on a Network
Nancy Rodriguez (University of Colorado Boulder)

With over two-thirds of the population using social network platforms, ideas and information spread rapidly. In this course, we will introduce fundamental concepts from network theory to help us model and analyze the spread of information and opinions. We will use software to create and visualize basic networks. Additionally, we will explore how to model reaction-diffusion equations on networks and determine key concepts like spreading speeds. We will also highlight the differences between the spread of information on networks and in physical space.

DG-algebras and their uses in determinantal rings
Sandra Sandoval Gomez (University of Notre Dame & Vienna University of Technology)

There is a relation between calculus and commutative algebra induced by derivatives. From this relationship arise new algebras called graded differential algebras or DG-algebras. We can find DG-algebras in many areas of mathematics such as commutative algebra, homological algebra, algebraic topology, representation theory, and rational homotopy theory.

There are some rings in which for any cyclic module there exists a DG-algebra structure in its minimal free resolution, for example Gorenstein rings of pdim=4. In particular, we want to determine this structure in the case of determinantal rings of submaximal minors.

Matrices over Finite Fields, Hulls, and Applications
Gretchen Matthews (Virginia Tech)

Linear algebra over finite fields is a rich area of mathematics with numerous applications in secure and reliable communications, distributed computing, machine learning, and more. Like linear algebra over infinite fields, linear algebra over finite fields deals with vector spaces, matrices, and linear transformations. However, some crucial differences have a significant impact on applications. One key difference is that the intersection of a vector space and its dual - known as the hull - can be nontrivial. The dimension of the hull plays a crucial role in quantum error correction, secret sharing, and protection against fault injection and side-channel attacks. Furthermore, it is relevant to code-based cryptography, which offers public-key cryptosystems believed to withstand attacks by a large-scale quantum computer, unlike the currently used RSA and elliptic curve cryptosystems. In this talk, we consider hulls and their relevance to these applications.

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The vibrant problem space surrounding linear algebra over finite fields and applications will be further explored at the Graduate Training Workshop on Linear Algebra over Finite Fields and Applications to be hosted at ICERM in August 2025.

Unique Equilibrium States for Geodesic Flows
Noelle Sawyer (Southwestern University)

In this talk I will give context and intuition about geodesics and equilibrium states of the geodesic flow in negative curvature, as well as introduce some known results. After, I will introduce some of the tools and techniques needed to show the uniqueness of equilibrium states in the setting of translation surfaces. If time allows, I will talk about some of our upcoming work about the Bernoulli property. This is joint work with Benjamin Call, Dave Constantine, Alena Erchenko, and Grace Work.

Equations of Equality: Rethinking Representation in AI and Math
Omayra Ortega (Sonoma State University)

As artificial intelligence (AI) continues to reshape our world, examples of the links between bias and representation in AI are becoming more and more apparent. For those of us in the mathematics community, understanding this connection is key. In this lecture, we'll dive into how AI algorithms work, how mathematics is essential to the success of AI, and why diverse representation matters in reducing bias in this field. We'll also explore how engaging in training in cultural literacy empowers us to create a more inclusive environment in our field.

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THURSDAY, OCTOBER 31TH

Titles and Abstracts

Rewards and Consequences of Training Data Composition for Deep Generative Models in Single Cell Biology

Lorin Crawford (Microsoft Research New England)

Foundation models for single-cell transcriptomics have the potential to augment or replace purpose-built tools for a variety of common analysis tasks, especially in cases where data is sparse. In the field of large language models, training data composition strongly shapes model performance; however, to date, single-cell foundation models have largely ignored this issue, opting instead to train on the largest possible corpus. Focusing on a tractable biological system (human hematopoiesis), we trained and analyzed deep generative models with a variety of training datasets, including cells from adult tissues, developing tissues, disease states, and perturbation atlases. From patterns of performance across these models, we infer that (1) deep generative models generalize poorly to unseen cell types, (2) addition of malignant cells to a healthy cell training corpus does not improve modelling of unseen malignant cells, and (3) inclusion of an embryonic stem cell transcription factor differentiation atlas in training data improves performance on out-of-distribution tasks. Integrating these results, we propose a strategy for designing training datasets that is organized by the developmental hierarchy of cell types. This strategy implies that there are potentially gains in model performance and training efficiency to be made by subsampling or reorganizing training data, in addition to increasing training data size.

The Matroids Among Us

Anastasia Chavez (Saint Mary's College of California)

Matroids are a fundamental combinatorial object with connections to many areas of mathematics: algebraic geometry, cluster algebra, coding theory, polytopes, physics ... just to name a few. Introduced in the 1930's, Whitney defined matroids with the desire to abstract linear and graphical dependence. In fact, every graph is associated with a matroid (called graphical) and from every vector configuration arises a representable matroid (over some field F). It has been shown that most matroids are neither graphical or representable, making these two matroid properties rare and highly desired. So then in what other ways do matroids arise? With just a few definitions and examples revealing their connections to a variety of fields, you too can begin searching for the matroids living among us.