Annual Meeting
of the
Pacific Northwest Section
of the

MATHEMATICAL ASSOCIATION OF AMERICA

University of Montana
Missoula, Montana

June 26–28, 2014

Annual Meeting
of the
Pacific Northwest Section
of the
Mathematical Association of America

Sponsored & Hosted by

University of Montana
Department of Mathematical Sciences
College of Humanities and Sciences
Missoula, Montana

June 26–28, 2014

Thursday, June 26

8:00	**Project NExT Meeting** *PFNAC 202*	
2:00 – 2:45	**Registration & Book Exhibit** *PFNAC Gathering Space*	(Project NExT Meeting continues)
3:00 – 5:30	**Minicourse: Jennifer Halfpap** *Exploring, Conjecturing, and Proving: Using Python in Transition and Analysis Courses* **[1]** *PFNAC 103*	**Minicourse: Jennifer Quinn** *Combinatorially Thinking: Connecting Digraphs and Determinants* **[2]** *PFNAC 105*

8:00 – 8:50	**Public Invited Lecture: Robert L. Devaney** *Chaos Games and Fractal Images* **[3]** *ISB 110*
8:50	**Reception** *ISB Lobby*

Friday, June 27

Time			
7:30		**Executive Committee Meeting** *PFNAC 211 (Kyi-Yo Club Room)*	
8:00	**Registration & Book Exhibit** *PFNAC Gathering Space*		
9:00 9:15 10:05		**Introduction and Welcome: Chris Comer** Dean, College of Humanities & Sciences, University of Montana **Pólya Lecture: Ravi Vakil** *The Mathematics of Doodling* **[4]** *ISB 110*	
10:30 11:45		**Contributed Talks** *PFNAC 103, 105, 201, and 202*	
11:50		**Lunch (provided)** *PFNAC Gathering Space*	
12:30 1:10			**Business Meeting** *PFNAC 103*
1:20 2:10	**Invited Lecture: Robert L. Devaney** *The Fractal Geometry of the Mandelbrot Set* **[5]** *ISB 110*		
2:25 4:00	**Contributed Talks** *PFNAC 103, 105, 201, 202, and 011*		
4:10 5:00	**Panel:** *Community College Math Major/Minor Transfer Students* [8] *PFNAC 105*	**Panel:** *Outreach in Mathematics: Feeding the Pipeline* [9] *PFNAC 103*	**Hike to the M** *Meet in PFNAC Gathering Space*
5:30 7:00	**Social Hour** *Canyon Club* (use the South Gate of *Washington Grizzly Stadium*)		
7:00 8:30	**Banquet Dinner - Section Awards** *Canyon Club* (use the South Gate of *Washington Grizzly Stadium*)		
8:30 9:20	**Invited Lecture: Skip Garibaldi** *Math and the Lottery:* *Answers to Good Questions from Students and Reporters* **[6]** *Canyon Club* (use the South Gate of *Washington Grizzly Stadium*)		

Saturday, June 28

8:30	**Registration & Book Exhibit** *PFNAC Gathering Space*	
8:55 – 10:30		**Contributed Talks** *PFNAC 103, 105, 201, and 202*
10:45 – 11:35	**Invited Lecture: Ravi Vakil** *Murphy's Law in Geometry* **[7]** *ISB 110*	

Program of Contributed Papers

The program of contributed papers appears on the following pages. In some cases, titles or other information are abbreviated for reasons of space; please see the full abstract for more information.

A dagger (†) indicates which contributor(s) will present when multiple contributors are listed and fewer are presenting the work. An asterisk (*) indicates the contributor is an undergraduate student. Double asterisks (**) indicate the contributor is a graduate student.

Session Organizers

- *Inverse Problems and Biofilms*: John Bardsley, University of Montana
- *Mathematical Modeling in Biology*: Andrew Oster and Frank Lynch, Eastern Washington University, and Bonni Dichone, Gonzaga University
- *Neat Theorems or Problems, Intuitively Explained ...mostly correctly*: Jim Bisgard, Central Washington University
- *Research and Pedagogical Trends in Discrete Mathematics*: Nancy Ann Neudauer, Pacific University, and Mark Kayll and Jenny McNulty, University of Montana
- *Junior Faculty Research*: Matt Roscoe, University of Montana
- *Student Papers*: Dominic Klyve, Central Washington University
- *General Contributed Papers*: Emily Stone and Nikolaus Vonessen, University of Montana

Please contact the session organizers with any questions about a session.

Moderators: Please start each talk on time, but **not** early. Meeting participants often move between sessions and will want to be there when the talks are scheduled to begin.

Contributed Talks – Friday Morning

	Neat Theorems	**Discrete Mathematics I**
	PFNAC 103	*PFNAC 105*
10:30–10:45	*Defining Elementary Functions using Differential Equations* [32] **Christopher Hallstrom, University of Portland**	*Visualizing Large Scale Behaviour of Combinatorial Families* [46] **Marni Mishna, Simon Fraser University**
10:50–11:05	*Two-Dimensional Rigidity Percolation: Not Your Regular Cup-O-Joe* [37] **Filip Jagodzinski, Central Washington University**	*Orienting Representable Matroids* [55] **Jakayla Robbins, Vanderbilt University**† **Daniel Slilaty, Wright State University**
11:10–11:25	*Computing Mountain Passes* [13] **Garret Bolton, Central Washington University**	*Fixing Numbers for Matroids* [31] **Gary Gordon, Lafayette College**
11:30–11:45	*Searching for Saddles and Mountain Peaks* [12] **Jim Bisgard, Central Washington University**	*Towards a Flow Theory for the Dichromatic Number* [34] **Winfried Hochstättler, FernUniversität in Hagen, Germany**

Contributed Talks – Friday Morning

	Inverse Problems and Biofilms I *PFNAC 201*	Student Papers *PFNAC 202*
10:30–10:45	*Randomize-then-Optimize: a Method for Sampling from Posterior Distributions in Nonlinear Inverse Problems* [11] **Johnathan Bardsley, UM**	*Lake Mead Temperature Modeling* [44] **Kelsey Marcinko, Whitworth University***† **Catherine Schepp, Haverford College*** **Lisa Driskell, Colorado Mesa University**
10:50–11:05	*Point Spread Reconstruction from the Image of a Sharp Edge* [38] **Kevin Joyce, UM****† **John Bardsley, UM** **Peter Golubstov, Moscow State University** **Aaron Luttman, National Securities Technologies**	*Traffic Flow and Safety Analysis Using a Discrete Particle Model* [61] **Benjamin Squire, Central Washington University***† **Nathan Minor, CWU***† **John-Paul Mann, CWU***
11:10–11:25	*Analysis and Implementation of Besov Norm Regularization* [50] **Cody Palmer, UM****	*Emergent Reducibility in Iterates of Cubic Polynomials* [49] **Amrei Oswald, University of Puget Sound***† **Jason Preszler, University of Puget Sound**
11:30–11:45	*Constructing Optimal Convolution Kernel for Image Processing with Imperfect Information on Original Distortion* [30] **Peter Golubtsov, Moscow State University**† **Kevin Joyce, UM**** **Johnathan Bardsley, UM**	*Polya's Enumeration Theorem and Book Embeddings* [20] **Chauncy Cullitan, Gonzaga University***

Contributed Talks – Friday Afternoon		
	Math Modeling in Biology I	**Discrete Mathematics II**
	PFNAC 103	*PFNAC 105*
2:25–2:40	*Optimal Prediction of Moving Sound Source Direction in the Owl* [27] **Brian J. Fischer, Seattle University†** **Weston Cox, Seattle University***	*From Zero to Research in 18 Days* [59] **Tyler Seacrest, The University of Montana Western**
2:45–3:00	*Mathematical Modeling of Cerebral Lactate Homeostatis Across Sleep/Wake Cycles* [54] **Michael J Rempe, Whitworth University†** **William Clegern, WSU** **Michelle Schmidt, WSU**** **Jonathan Wisor, WSU**	*Prime Distance Graphs, 2-odd Graphs, and Prime Factor Graphs* [62] **Colin Starr, Willamette University**
3:05–3:20	*Neural Development of the Visual System: a laminar approach* [48] **Andrew M. Oster, EWU†** **Paul C. Bressloff, University of Utah**	*Secrecy Coverage* [57] **Amites Sarkar, Western Washington University**
3:25–3:40	*Bistability and the Emergence of Oscillations in Repressilator Models with Quorum Sensing* [52] **M. Pernarowski, MSU†** **T. Gedeon, MSU** **S. Zhao, MSU*** **A. Wilander, MSU****	*Chessboard Tilings, Number Sequences, and Continued Fractions* [10] **Barry Balof, Whitman College†** **Helen Jenne, University of Oregon*, ****
3:45–4:00		*Graph Tilings and Tiling Polynomials* [35] **Matt Hudelson, Washington State University**

Contributed Talks – Friday Afternoon

	Inverse Problems and Biofilms II	Junior Faculty Research I	General Papers I
	PFNAC 201	*PFNAC 202*	*PFNAC 011*
2:25–2:40	*Using Polynomials to Sample from Large Gaussians Used to Model 3-D Confocal Microscope Images of Biofilms* [51] **Al Parker, MSU**	*Data Streaming Algorithms as an Experimental Discovery of Probabilities* [42] **Jérémie Lumbroso, Simon Fraser University**	*A New Twist: Finiteness of Topologically Minimal Surfaces in 3-Manifolds* [22] **David Bachman, Pitzer College** **Ryan Derby-Talbot, Quest University Canada**† **Eric Sedgwick, DePaul University**
2:45–3:00	*Transport and Productivity in Microbial Biofilms* [40] **Isaac Klapper, Temple University**	*Using Transparent Representations to Promote Prospective Teachers' Re-Conceptualization of Factors* [56] **Matt Roscoe, UM**	*Orbifolds: V-Manifolds to Groupoids* [19] **Vesta Coufal, Gonzaga University**
3:05–3:20	*A Mathematical Model for Cyanobacterial Mat.* [25] **Fadoua El Moustaid, Temple University**† **Isaac Klapper, Temple University**	*Introductory Statistics Students' Understanding of Variability* [16] **Rachel Chaphalkar, UM**	*Fun Applications of Abstract Algebra: The 15 Puzzle* [21] **Dibyajyoti Deb, Oregon Institute of Technology**
3:25–3:40	*Image-Based Modeling and Parameter Estimation in Bacterial Biomineralization* [18] **James Connolly, MSU**† **Benjamin Jackson, MSU**** **Johannes Hommel, University of Stuttgart**** **Isaac Klapper, Temple University** **Robin Gerlach, MSU**	*The Limit of Humanly Knowable Mathematical Truth, Gödel's Incompleteness Theorems, and Artificial Intelligence* [45] **Tim Melvin, Carroll College**	*Magic Squares of Lie Groups* [23] **Tevian Dray, OSU**† **John Huerta, Instituto Superior Técnico, Lisbon** **Joshua Kincaid, OSU**** **Corinne A. Manogue, OSU (physics)** **Robert A. Wilson, Queen Mary, Univ. of London**
3:45–4:00	*Using Inverse Methods to Estimate Biomineralization Parameters in a Biofilm* [36] **Benjamin Jackson, MSU**† **James Connolly, MSU**** **Al Parker, MSU** **Isaac Klapper, Temple University** **Robin Gerlach, MSU**		

Contributed Talks – Saturday Morning

	Math Modeling in Biology II *PFNAC 103*	Discrete Mathematics III *PFNAC 105*
8:55–9:10	*Traveling Waves in Pancreatic Islets* [47] **Heather Moreland, Southwest Minnesota State University**† **Jack Dockery, MSU**	*Venn Diagrams are Hamiltonian* [53] **Gara Pruesse, Vancouver Island University**† **Frank Ruskey, University of Victoria**
9:15–9:30	*Leaves are not Rectangular – Contribution of Leaf Geometry to Water Uptake* [43] **Frank Lynch, EWU**† **Gretchen North, Occidental College** **C.J. Faulwell, OC*** **Franklin Maharaj, OC***	*Building Breakfree Barrycades* [60] **Richard K. Guy, University of Calgary** **Karen Seyffarth, University of Calgary**†
9:35–9:50	*A Model for Soil-Plant-Surface Water Relationships in Arid Flat Environments* [64] **David J. Wollkind, WSU**† **Bonni Dichone, Gonzaga University**	*Edge Nim on Graphs: Variations on a Theme* [26] **Lindsay Erickson, Augustana College, Sioux Falls, SD**
9:55–10:10		*From Tennis Balls to Mountains of Numbers of Mountains* [63] **Evan B. Wantland, Warren Wilson College**
10:15–10:30	*Nonlinear Stability Analyses of Turing Patterns for a Mussel-Algae Model System* [15] **Richard Cangelosi, Gonzaga University**† **David Wollkind, WSU** **Bonni Dichone, Gonzaga University** **Inthira Chaiya, Mahidol University**	*Hilbert bases of cocircuits* [29] **Tanmay Deshpande, Simon Fraser University**** **Luis Goddyn, Simon Fraser University**† **Tony Huynh, Simon Fraser University** **Marko Mitrovic, Simon Fraser Universtiy***

Contributed Talks – Saturday Morning

	General Papers II *PFNAC 201*	Junior Faculty Research II *PFNAC 202*
8:55–9:10		
9:15:-9:30	*Extending Hall's Marriage Theorem to Certain Tripartite Graphs* [14] **Wayne Broughton, University of British Columbia, Okanagan campus, Kelowna, B.C.**	*Totienomial Coefficients* [24] **Tom Edgar, Pacific Lutheran University**
9:35–9:50	*Boundary Splitting for the Laplacian Inside a Circular Annulus* [28] **Tiernan Fogarty, Oregon Institute of Technology**	*The Stable Concordance Genus* [39] **M. Kate Kearney, Gonzaga University**
9:55–10:10	*On Proofs Without Words and Beyond* [58] **Tim Doyle, Whitman College** **Lauren Kutler, WC*** **Robin Miller, WC*** **Albert Schueller, WC†**	*Stretching Linear Optimization Until it Breaks* [17] **Tien Chih, UM**
10:15–10:30	*Flipped University Math Courses, A Discussion and Guide* [41] **Paul Krouss, Washington State University, Vancouver**	*Connecting Numerical Oscillations to Eigenvalues in Solving Partial Differential Equations* [33] **Corban Harwood, George Fox University**

Social Events

Thursday Project NExT Dinner
(For Project NExT Participants Only, No Host)
5:45

Thursday Evening Invited Public Lecture
Chaos Game and Fractal Images
Robert L. Devaney [3]
8:00 ISB 110

Thursday Evening Reception
8:50 ISB Lobby

Friday Morning: Coffee, Pastries, & Fruit
Sponsored by Wiley Publishing
8:00–11:00 PFNAC Gathering Space

Friday Lunch
11:50 PFNAC Gathering Space

Friday Afternoon: Coffee
2:00–5:00 PFNAC Gathering Space

Friday Evening Social Hour
5:30 Canyon Club

Friday Evening Awards Ceremony and Banquet Dinner
7:00 Canyon Club

MC: Kelly McKinnie

Introduction of new Section Project NExT Fellows

Presentation of 25- and 50-year MAA membership certificates

PNW MAA Distinguished Teaching Award

Friday Evening Invited Lecture
Math and the Lottery: Answers to Good Questions from Students and Reporters
Skip Garibaldi [6]
8:30 Canyon Club

Saturday Morning: Coffee, Pastries, & Fruit
8:30–10:45 PFNAC Gathering Space

Campus Information

Campus Map:

`http://cas.umt.edu/math/pnwmaa/documents/UM-campus-map-annotated.pdf`

Building Codes:	PFNAC	Payne Family Native American Center
	ISB	Interdisciplinary Science Building
	MATH	Mathematics

WiFi is widely available on campus; select the “grizzlyguest” network (no password is necessary).

Parking:

- Thursday and Friday 7 am — 5 pm: Parking permits are required to park on campus. Daily Parking Passes ($3) are sold during registration times in the PFNAC Gathering Space (and are also available during regular business hours at the Office of Public Safety, University Center Bookstore and Info Desk, and Griz Center in the Lommasson Center). You can park in a Quick Stop parking spot free for twenty minutes while you get the daily parking pass.
- After 5 pm and on Saturday: Parking is free on campus.
- Overnight Parking is possible in Lot H (behind Pantzer Hall). (Note that a Daily Parking Pass is required for this lot Thursday and Friday 7 am — 5 pm.)
- The most convenient parking lots for all conference activities (except Friday evening) are the two parking lots at the corner of E. Beckwith Ave. with Maurice Ave (Lots G and H).
- Weekdays during the day, parking is not permitted in the residential neighborhoods right next to campus. But if you don’t mind walking a few blocks, you can park for free West of Hilda Ave., which is two blocks from the West end of campus (Arthur Ave.).

Emergency Information:

- Police/Fire/Medical Emergency: 911
- UM Public Safety/Police: Emergency (406) 243-4000; Non-Emergency (406) 243-6131

Acknowledgments

A big THANK YOU! (in no particular order) to those that made this meeting possible:

- Program Co-Chairs for Contributed Talks Nikolaus Vonessen and Emily Stone for organizing the contributed sessions.
- Nikolaus Vonessen for editing this program, organizing the general papers talks and taking care of many other tasks.
- Dominic Klyve for organizing the student talks and Matt Roscoe for organizing the Junior Faculty Research talks.
- John Bardsley, Jim Bisgard, Paul Casillas, Bonni Dichone, Donald Hickethier, Mark Kayll, Frank Lynch, Jenny McNulty, Nancy Ann Neudauer and Andrew Oster for organizing panels and special sessions.
- Project NExT Coordinator Jenny McNulty and Project NExT Local Arrangements Chair Eric Chesebro for organizing the Section NExT meeting.
- Thomas Tonev for organizing the book sale.
- Amy Stout for designing and supporting the conference website and implementing the online registration form.
- Matt Roscoe for organizing and coordinating with the hotels.
- Students and recent graduates Eli Bayat-Mokhtari, Rachel Chaphalkar, Tien Chih, Jessica Hurd, Lyric Liu, Nhan Nguyen and Mike Severino for helping with many conference aspects.
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- Dean Harshbarger with Wiley Publishing, the UM Mathematics Graduate Program, the UM Department of Mathematical Sciences, the College of Humanities and Sciences Dean's office and an anonymous donor for providing support for the meeting.
- Jenny McNulty, Nancy Ann Neudauer, Brian Blitz, Colin Starr and Josh Laison for thoughtful advice and moral support.
- All the conference speakers and participants for making the conference an awesome one!

– Thanks everyone! Kelly McKinnie, Local Arrangements Chair

Minicourse Descriptions

Thursday, June 26

1 *Exploring, Conjecturing, and Proving: Using Python in Transition and Analysis Courses*

Jennifer Halfpap, University of Montana

Transition to proof courses and analysis courses are notoriously hard for students. Part of the reason is that students see a proof as an end in itself rather than as the last step in a process that begins with an interesting question, proceeds through exploration and conjecture, and only then produces a proof as a way of communicating the explanation to the community. Students thus often approach a proofs course as yet one more template-matching course in which they learn to classify problems as “induction problems”, “divisibility problems”, or “delta-epsilon problems.”

It is, of course, hard to teach students to explore, conjecture, and prove (rather than just to prove) because it requires us to pose interesting open-ended problems that are nonetheless accessible to students. In this workshop, we discuss these sorts of problems and illustrate how teaching students basic Python programming may give them some of the tools they need to explore and conjecture before trying to prove.

2 *Combinatorially Thinking: Connecting Digraphs and Determinants*

Jennifer Quinn, University of Washington-Tacoma

Most mathematicians appreciate clever combinatorial proofs. But faced with an identity — in particular a determinantal identity — can you create one? This workshop will provide you with some useful combinatorial interpretations, lots of examples, and the challenge of finding your own combinatorial proofs. We will work to connect digraphs and determinants using two approaches:

- Given a “pretty” matrix, can we design a (possibly weighted) digraph that clearly visualizes its determinant?
- Given a “nice” directed graph, can we find an associated matrix and its determinant?

Previous knowledge of determinants is an advantage but not a necessity. This will be a hands-on session, so bring your colored pencils, your creativity, and be prepared to explore the mathematical connections.

Abstracts of Invited Lectures

(in chronological order)

3 *Chaos Games and Fractal Images*

Robert L. Devaney, Boston University

In this lecture we will describe some of the beautiful images that arise from the “Chaos Game.” We will show how the simple steps of this game produce, when iterated millions of times, the intricate images known as fractals. We will describe some of the applications of this technique used in data compression as well as in Hollywood. We will also challenge students present to “Beat the Professor” at the chaos game and maybe win his computer.

4 *The Mathematics of Doodling*

Ravi Vakil, Stanford University

Doodling has many mathematical aspects: patterns, shapes, numbers, and more. Not surprisingly, there is often some sophisticated and fun mathematics buried inside common doodles. I’ll begin by doodling, and see where it takes us. It looks like play, but it reflects what mathematics is really about: finding patterns in nature, explaining them, and extending them. By the end, we’ll have seen some important notions in geometry, topology, physics, and elsewhere; some fundamental ideas guiding the development of mathematics over the course of the last century; and ongoing work continuing today.

5 *The Fractal Geometry of the Mandelbrot Set*

Robert L. Devaney, Boston University

In this lecture we describe several folk theorems concerning the Mandelbrot set. While this set is extremely complicated from a geometric point of view, we will show that, as long as you know how to add and how to count, you can understand this geometry completely. We will encounter many famous mathematical objects in the Mandelbrot set, like the Farey tree and the Fibonacci sequence. And we will find many soon-to-be-famous objects as well, like the “Devaney” sequence. There might even be a joke or two in the talk.

6 *Math and the Lottery: Answers to Good Questions from Students and Reporters*

Skip Garibaldi, Emory University

I never thought much about the lottery until I taught a course on finite probability and the students asked me: “Why shouldn’t we buy lottery tickets?” That is a much more complicated question than it first appears. Answering it led to more conversations with students and to interviews with reporters, and more good questions. In this talk, I will describe some of the more interesting questions and their answers.

7 *Murphy’s Law in Geometry*

Ravi Vakil, Stanford University

When mathematicians consider their favorite kind of object, the set of such objects often has a richer structure than just a set — often some sort of geometric structure. For example, it may make sense to say that one object is “close to” another. As another example, solutions to equations (or differential equations) may form manifolds. These “moduli spaces” often are hoped to behave well (for example be smooth). I’ll explain how many ones algebraic geometers work with are unexpectedly as far from smooth as they possibly can be.

Panel Descriptions

Friday, June 27

8 *Community College Math Major/Minor Transfer Students*

Organizers: **Paul Casillas, Clark College**
Don Hickethier, Flathead Valley Community College
Other Panelists: **Mike Kenyon, Green River Community College**
Tom McKenzie, Gonzaga University
Hilary Risser, Montana Tech

We will discuss how community colleges and four-year colleges and universities can encourage community college students to pursue a mathematics minor or major at a transfer institution. The panel will focus on the experiences and course background students have after two years of math at a community college, the course work and “habits of mind” transfer institutions expect from incoming transfer students, and what all mathematics departments can do to promote their major/minor programs to transfer and non-transfer students.

9 *Outreach in Mathematics: Feeding the Pipeline*

Organizer: **Nancy Ann Neudauer, Pacific University,**
MAA Dolciani Mathematics Enrichment Grant Program Director
Panelists: **Robert Devaney, Boston University**
Kelly McKinnie, University of Montana
Elizabeth McMahon, Lafayette College

Increasing communication between those teaching in secondary and college education might be the key to building a pipeline, or feeding the existing pipeline, of talented students into mathematics, advancing mathematics education at both levels. How do we keep talented youngsters interested and engaged in mathematics and bring mathematics from outside the standard curriculum, fun investigations, and interesting problems to students and their teachers? With all the talk of preparing students for STEM fields, what can we as college faculty do?

The panelists have had experience with different types of outreach to diverse audiences. Learn what they have done and bring questions and your own experience.

Abstracts of Contributed Talks

(in alphabetical order, by presenter)

10 *Chessboard Tilings, Number Sequences, and Continued Fractions*

Barry Balof, Whitman College†
Helen Jenne, University of Oregon*, **

(*Session:* Research and Pedagogical Trends in Discrete Mathematics II)

In this talk, we will look at two recent results in Enumerative Combinatorics that use proofs by direct counting, chessboard tilings, and number sequences. In the first result, the number sequence has ties various disciplines outside of mathematics. In the second we give a combinatorial proof of a lesser known identity of Euler involving a continued fraction for e.

11 *Randomize-then-Optimize: a Method for Sampling from Posterior Distributions in Nonlinear Inverse Problems*

Johnathan M. Bardsley, University of Montana

(*Session:* Inverse Problems and Biofilms I)

Many solution methods for inverse problems compute the maximum a posterior (MAP) estimator via the solution of an optimization problem. Uncertainty quantification (UQ), on the other hand, is typically performed using simulation techniques such as Markov chain Monte Carlo. In this talk, we present a Monte Carlo method for UQ, which we call randomize-then-optimize, that makes use of the optimization algorithm used in the MAP estimation step to sample from the posterior density function, even in nonlinear cases.

12 *Searching for Saddles and Mountain Peaks*

Jim Bisgard, Central Washington University

(*Session:* Neat Theorems or Problems, Intuitively Explained . . . mostly correctly)

We discuss a saddle point theorem, and provide a constructive method to find such points. In addition, we present an interesting problem: if there are two saddles found by the constructive method, must there exist a third critical point?

13 *Computing Mountain Passes*

Garret Bolton, Central Washington University**

(*Session:* Neat Theorems or Problems, Intuitively Explained . . . mostly correctly)

If two valleys are separated by a ridge, is there a mountain pass point between the valleys? If there is a pass, how can we find it? The mountain pass theorem of Ambrosetti and Rabinowitz provides conditions guaranteeing the existence of a mountain pass point. In this presentation we look at a series of illustrations that intuitively explain how the mountain pass theorem works to locate these points.

14 *Extending Hall's Marriage Theorem to Certain Tripartite Graphs*

Wayne Broughton, University of British Columbia, Okanagan campus, Kelowna, B.C.

(*Session:* General Papers II)

A complete matching from one part of a bipartite graph to the other is a set of non-adjacent edges that "pairs off" every vertex in the first part with a vertex in the second part. Hall's Marriage Theorem shows that a rather obvious necessary condition for such a complete matching to exist is in fact also sufficient. This is also equivalent to the Kőnig-Egerváry Theorem, which says that in any bipartite graph the minimum size of a vertex cover equals the maximum size of a matching.

In this talk, I will describe the problem of extending Hall's Theorem to a certain type of tripartite graph. We now want a Hall-type condition that guarantees the existence of a set of non-adjacent triangles that completely covers all of the vertices of the tripartite graph. I will also present current progress on this problem.

15 *Nonlinear Stability Analyses of Turing Patterns for a Mussel-Algae Model System*

Richard Cangelosi, Gonzaga University†
David Wollkind, Washington State University
Bonni Dichone, Gonzaga University
Inthira Chaiya, Mahidol University
(*Session:* Mathematical Modeling in Biology II)

In this talk we introduce a particular interaction-diffusion mussel-algae model system for the development of spontaneous stationary mussel bed patterning on a homogeneous substrate covered by a quiescent marine layer containing algae as a food source is investigated employing weakly nonlinear diffusive (Turing) instability analyses. Model pattern predictions are compared with both relevant field and laboratory experimental evidence and existing numerical simulations for the associated interaction-dispersion-advection mussel-algae model system.

16 *Introductory Statistics Students' Understanding of Variability*

Rachel Chaphalkar, The University of Montana
(*Session:* Junior Faculty Research I)

Variability is one of the most important concepts in statistics. Students in a college-level introductory statistics course do not all understand variability to the same level. This presentation will briefly review research literature on variability and present/discuss different ways students comprehend variability in dot plots and histograms. Data were collected from over 100 college students who enrolled in an introductory statistics course at a Northwestern public doctoral degree granting institution.

17 *Stretching Linear Optimization Until it Breaks*

Tien Chih, University of Montana
(*Session:* Junior Faculty Research II)

The traditional study of the theory and applications of primal-dual, max-min affine optimization problems have been well studied over the last hundred years. Central to this study is a beautiful duality theory, and several theorems concerning the existence of forms of optimal solutions. The traditional setting is finite dimensional real vector-space, and the traditional approach has been basis and coordinate dependent, as is natural for the applications to real world settings. Generalizations include integer programming, and some variations of infinite dimensional real programming. However, in these more general settings, not all of the results from the classical setting can be realized. In this work, we discuss some ways that the classical affine programming setting can be extended, and then determine what conditions are necessary for each of the classical results to hold in a more abstract setting.

18 *Image-Based Modeling and Parameter Estimation in Bacterial Biomineralization*
James Connolly, Montana State University†
Benjamin Jackson, Montana State University∗∗
Johannes Hommel, University of Stuttgart∗∗
Isaac Klapper, Temple University
Robin Gerlach, Montana State University
(*Session:* Inverse Problems and Biofilms II)

Under certain conditions some bacteria induce carbonate mineral precipitation. These bacteria and the minerals that they form can be employed in the subsurface for engineered purposes such as permeability reduction, increasing soil strength and coprecipitation of contaminants. The work that will be presented concentrates on the quantification of pore-scale physical and chemical environments where bacterially induced calcium carbonate precipitation takes place. A combination of time-lapse confocal microscopy, traditional microscopy and finite element modeling was used to calculate reaction rates and develop relationships that are useful in refining continuum models that are utilized to predict behavior in the field.

19 *Orbifolds: V-Manifolds to Groupoids*
Vesta Coufal, Gonzaga University
(*Session:* General Papers I)

Orbifolds are a generalization of manifolds and, as such, were originally defined using charts and atlases. It turns out that there is a better way of thinking about them, one that leads to a category of orbifolds. These ideas will be presented and examples will be explored. This is an introductory talk, and should be accessible to undergraduates.

20 *Polya's Enumeration Theorem and Book Embeddings*
Chauncy Cullitan, Gonzaga University∗
(*Session:* Student Papers)

A standard n-book is a line in 3-space (called the spine), together with n half-planes (the pages), joined together at the spine. A graph is embedded in a book by ordering the vertices along the spine and placing the edges within the pages of the book so that no two edges cross each other or the spine. The book-thickness of a graph G is the smallest number of pages needed to embed G in a book. For certain graphs, such as the complete bipartite graph$K_{m,n}$, the optimal book-thickness is unknown. We use Polya's Enumeration Theorem to greatly reduce the space of possible vertex orderings in hopes of improving bounds for the book-thickness of $K_{m,n}$.

21 *Fun Applications of Abstract Algebra: The 15 Puzzle*
Dibyajyoti Deb, Oregon Institute of Technology
(*Session:* General Papers I)

Abstract Algebra, at first glance seem to have very few applications in the real world, which deters undergraduate students from taking the class unless it is mandatory. In this talk we will look at ways in which we can make Abstract Algebra fun and interesting for students. I will talk specifically about the 15 puzzle.

22 *A New Twist: Finiteness of Topologically Minimal Surfaces in 3-Manifolds*
David Bachman, Pitzer College
Ryan Derby-Talbot, Quest University Canada†
Eric Sedgwick, DePaul University
(*Session:* General Papers I)

Topologically minimal surfaces are a broad class of surfaces in 3-manifolds whose compressing disks — disks embedded in their complements — form a complex with a particular topological structure. Analogous in many ways to geometrically minimal surfaces, topologically minimal surfaces provide an approach to a variety of computational questions about surfaces in 3-manifolds. Using lots of pictures, we will highlight several such results, including why the number of "twists" in such surfaces must be limited.

23 *Magic Squares of Lie Groups*
Tevian Dray, Oregon State University†
John Huerta, CAMGSD, Instituto Superior Técnico (Lisbon)
Joshua Kincaid, Oregon State University**
Corinne A. Manogue, Oregon State University (physics)
Robert A. Wilson, Queen Mary, University of London
(*Session:* General Papers I)

The Freudenthal-Tits magic square uses a pair of division algebras to label certain Lie algebras, among them the exceptional Lie algebras, all of which are associated with the octonions. We summarize here two different descriptions of the magic square at the group level, leading in one case to a unified treatment of a closely-related but simpler magic square, and in the other to new insight into some of the exceptional groups.
This work has been supported by FQXi and the John Templeton Foundation.

24 *Totienomial Coefficients*
Tom Edgar, Pacific Lutheran University
(*Session:* Junior Faculty Research II)

We discuss a construction, due to Knuth and Wilf, of generalized binomial coefficients that is valid for any nonzero integer sequence. We apply this process to the Euler totient function (and generalizations) and prove that these coefficients are integers themselves. We finish by initiating the search for a class of combinatorial objects enumerated by these coefficients and discussing a related family of matrices.

25 *A Mathematical Model for Cyanobacterial Mat.*
Fadoua El Moustaid, Temple University†
Isaac Klapper, Temple University
(*Session:* Inverse Problems and Biofilms II)

Biofilm-forming cyanobacteria perform photosynthesis in order to produce organic carbon. Natural light is used as a source of energy, along with water as a source of electrons to form the biomass. We present a one dimensional mathematical model describing the photosynthesis and growth. The model is initially given in terms of bacterial density, then modified to represent the bacterial cells in terms of carbon moles. The conversion is made to verify the conservation of mass within the system. A stability and numerical analysis are also performed.

26 *Edge Nim on Graphs: Variations on a Theme*
Lindsay Erickson, Augustana College, Sioux Falls, SD
(*Session:* Research and Pedagogical Trends in Discrete Mathematics III)

The two-player game of Nim on graphs is played on a regular graph with positively weighted edges by moving alternately from a fixed starting vertex to an adjacent vertex, decreasing the weight of the incident edge to a strictly smaller non-negative integer. The game ends when a player is unable to move since all edges incident with the vertex from which the player is to move have weight zero. Within the past few years, considerable work has been done in the area of edge Nim on graphs. Some such results include finding winning strategies on various graphs, defining new methods of game play, and determining computing complexity of the game. First we will look at how to play Nim on regular graphs and hypergraphs. We will see some of the work done on different varieties of Nim on graphs and how modified rules change strategies. Finally, we suggest new variations to Nim on graphs inspired by recent research on hypergraphs and discuss possible areas of continued study.

27 *Optimal Prediction of Moving Sound Source Direction in the Owl*
Brian J. Fischer, Seattle University[†]
Weston Cox, Seattle University[*]
(*Session:* Mathematical Modeling in Biology I)

Capturing nature's statistical structure in behavioral responses is at the core of the ability to function adaptively in the environment. Sound localization is a critical skill for many species, involving both the localization of stationary sound sources as well as predicting the future location of a moving sound source. An outstanding open question in neural coding for sound localization includes how sensory cues are integrated over time to optimally guide behavior. We address this issue using the system that underlies sound localization in barn owls. The barn owl displays localizing behaviors consistent with the prediction of the location of a moving source. Furthermore, it has been shown that the owl's sound localization for brief sounds is consistent with a Bayesian model. Here we address how a neural system can perform Bayesian prediction given sensory information and prior assumptions.

We developed a Bayesian model of predictive localization of moving sound sources. The form of the model is determined by the dynamics of the moving target and the statistical relationship between the direction of the target and the auditory input. Next, we determined conditions on the neural representation of moving sources that allow the population vector to decode the prediction.

The work here shows that the population vector decoder will perform Bayesian prediction when the preferred direction of each neuron shifts in response to the target trajectory. Specifically, the model predicts that the magnitude of shift is proportional to target velocity, with faster speeds requiring greater shifts. The predicted shifts of preferred direction are shown to match the shifts observed in the owl's midbrain.

We find that the owl's localization behavior for moving sounds may be described as Bayesian inference. This work provides a theoretical description of optimal coding of sound localization for moving sources that may be tested in other systems. More generally, we show that neural populations can be specialized to represent the statistics of dynamic stimuli to allow for a vector read-out of Bayes-optimal predictions.

28 *Boundary Splitting for the Laplacian Inside a Circular Annulus*
Tiernan Fogarty, Oregon Institute of Technology
(*Session:* General Papers II)

In this talk a solution technique for Laplace's equation inside a circular annulus with non-zero boundary conditions will be presented. The traditional Fourier series solution will be compared to an equivalent solution via a system of two problems with semi-homogenous boundary conditions. The split-boundary technique will be used to solve physically similar yet analytically dissimilar examples.

29 *Hilbert bases of cocircuits*
Tanmay Deshpande, Simon Fraser University**
Luis Goddyn, Simon Fraser University†
Tony Huynh, Simon Fraser University
Marko Mitrovic, Simon Fraser Universtiy*
(*Session:* Research and Pedagogical Trends in Discrete Mathematics III)

Several "covering" problems can be phrased in terms of the additive semigroup $\mathbb{Z}_+(M) \subseteq \mathbb{R}^{E(M)}$ generated by the cocircuits of a matroid M. Every vector in $\mathbb{Z}_+(M)$ lies in both the cone and the lattice generated by these vectors. We say that M is *cut-Hilbert* if the converse statement is true: i.e. $\mathbb{Z}_+(M) = \mathbb{Q}_+(M) \cap \mathbb{Z}(M)$.

For example it is known [AZG] that a cographic matroid is cut-Hilbert if and only if the graph has no Petersen-minor; thus these graphs satisfy the Cycle Double Cover conjecture. We investigate the cut-Hilbert property for other matroids. For example, we show that for graphic matroids, the cut-Hilbert property is not closed under minors. On the positive side, every H_6-minor free graph is cut-Hilbert, where H_6 is the unique 3-connected graphic coextension of K_5.

30 *Constructing Optimal Convolution Kernel for Image Processing with Imperfect Information on Original Distortion*
Peter Golubtsov, Lomonosov Moscow State University, currently: University of Montana†
Kevin Joyce, University of Montana**
Johnathan Bardsley, University of Montana
(*Session:* Inverse Problems and Biofilms I)

We study a problem of designing a two-dimensional Point Spread Function (PSF) with a given radius R. Such a function will be optimal for estimating an unknown signal f from an observation $g = a * f + \nu$. Here the PSF a represents a convolution-type distortion and ν is random noise. It is shown that if the additive noise is uncorrelated, then the optimization problem reduces to a one-dimensional Fredholm equation of the second kind on $[0, R]$. There are many ways to solve such problems numerically. However, it might be more natural to construct the PSF r in a certain finite-dimensional class of functions from the very beginning. Such a problem reduces to a set of linear equations. This technique is then generalized to the case when the PSF a is not known precisely.

31 *Fixing Numbers for Matroids*
Gary Gordon, Lafayette College
(*Session:* Research and Pedagogical Trends in Discrete Mathematics I)

The fixing number for a matroid is the smallest number of points that must be fixed in order to destroy all non-trivial automorphisms of the matroid. Fixing numbers have been explored for

graphs (where the vertices are fixed), and have a history in the permutation group literature that dates to the late 19th century. We give bounds and examples, and connect the fixing numbers for the cycle and bicircular matroids associated with a graph. This is joint work with Jenny McNulty and Nancy Neudauer.

32 *Defining Elementary Functions using Differential Equations*
Christopher Hallstrom, University of Portland
(*Session:* Neat Theorems or Problems, Intuitively Explained . . . mostly correctly)

If we define the exponential, sine, and cosine functions as solutions to certain initial value problems, then most of their properties follow simply and elegantly. The catch is that such a definition relies on existence and uniqueness theorems which are seldom proven in a typical differential equations course. For these particular functions, however, an almost-proof is certainly accessible to students with a calculus background.

33 *Connecting Numerical Oscillations to Eigenvalues in Solving Partial Differential Equations*
Corban Harwood, George Fox University
(*Session:* Junior Faculty Research II)

Numerical oscillations create infeasible results and are more difficult to predict than instabilities. Von Neumann stability analysis uses Fourier error growth factors which behave like the eigenvalues defining the numerical method. Using this relationship, we explore several ways of tracking numerical oscillations in order to use the growth factors to determine oscillation-free conditions. This talk will present results for linear parabolic partial differential equations and discuss early findings for other partial differential equations.

34 *Towards a Flow Theory for the Dichromatic Number*
Winfried Hochstättler, FernUniversität in Hagen, Germany†
(*Session:* Research and Pedagogical Trends in Discrete Mathematics I)

In an attempt to tackle the 4-Color-Conjecture William T. Tutte developed the theory of Nowhere-Zero-Flows which can be considered as a concept dual to colorings. His famous 5-flow- and 4-flow-conjecture are still unsettled, while the 4-Color-Conjecture has become a theorem.

Victor Neumann-Lara defined the dichromatic number of a digraph as the smallest number of colors needed to color the vertices without introducing a monochromatic dicycle. He conjectured that any orientation of a simple planar graph has dichromatic number at most 2. Dual to this we introduce the concept of Neumann-Lara flows. We discuss the possibility that every three edge connected digraph admits a Neumann-Lara 2-flow.

35 *Graph Tilings and Tiling Polynomials*
Matt Hudelson, Washington State University
(*Session:* Research and Pedagogical Trends in Discrete Mathematics II)

We consider tilings (a tiling is a set of tiles covering the vertices and edges without repetition) of a graph G using three types of tiles. A tile is an edge together with any of its endpoints that are vertices. An a-tile is an edge with both endpoints in V, a b-tile is an edge with exactly one of its endpoints in V, and a c-tile is an edge with neither endpoint in V. To each graph G we associate a polynomial $\tau(G)$ in a, b, c whose coefficients enumerate the tilings of G with a given number of each tile. In this talk, we explore the properties of such "tiling polynomials" and the interplay between these polynomials and the graphs they represent, with a special emphasis for the case where G is a tree.

36 *Using Inverse Methods to Estimate Biomineralization Parameters in a Biofilm*
Benjamin Jackson, Montana State University†
James Connolly, Montana State University**
Al Parker, Montana State University
Isaac Klapper, Temple University
Robin Gerlach, Montana State University
(*Session:* Inverse Problems and Biofilms II)

Microbially induced calcite precipitation (MICP) has potential applications in subsurface engineering. MICP takes place in complex systems which often contain communities of bacteria adhering to surfaces, called biofilms, in which mineralization rates are not well known. We seek to characterize these rates in a biofilm system by parameterizing a mathematical model using data from tube reactor experiments conducted at Montana State University's Center for Biofilm Engineering. We formulate a forward ODE model and then solve the inverse problem using basic Bayesian methods. Careful use of synthetic data demonstrates the validity of this approach which we then apply to lab data.

37 *Two-Dimensional Rigidity Percolation: Not Your Regular Cup-O-Joe*
Filip Jagodzinski, Central Washington University
(*Session:* Neat Theorems or Problems, Intuitively Explained . . . mostly correctly)

Inferring the number of internal degrees of freedom in a two-dimensional network using a numerical approach is a computationally intensive task. A purely combinatorial pebble-game algorithm developed in the late 1990s has made that endeavor much more tractable. The algorithm by Jacobs and Hendrickson runs in $O(n^2)$ time, where n is the number of nodes in a 2-d graph. The algorithm has been applied to the study of glass-like networks, and to the study of the flexibility of macromolecular structures, both of which will be briefly – and intuitively – explained with visualizations and physical models.

38 *Point Spread Reconstruction from the Image of a Sharp Edge*
Kevin Joyce, University of Montana**†
John Bardsley, University of Montana
Peter Golubstov, Moscow State University
Aaron Luttman, National Securities Technologies
(*Session:* Inverse Problems and Biofilms I)

The blurring of a two dimensional image is often modeled as convolution with a point spread function specific to the imaging instrument. In certain applications, (e.g. high energy radiography) standard techniques to reconstruct the point spread function that involve imaging a bright point source are not feasible. In this work, we will present an alternative method for point spread reconstruction that is suitable for applications where it is possible to image a sharp edge. The reconstruction is given as a solution to a Fredholm integral equation of the first kind. We model the problem stochastically and use Bayesian techniques for providing stable estimates of the solution as well as quantifying uncertainty in the estimate.

39 *The Stable Concordance Genus*
M. Kate Kearney, Gonzaga University
(*Session:* Junior Faculty Research II)

The concordance genus of a knot is the least genus of any knot in its concordance class. Although difficult to compute, it is a useful invariant that highlights the distinction between the three-genus and four-genus. In this talk we will define and discuss the stable concordance genus of a knot, which describes the behavior of the concordance genus under connected sum.

40 *Transport and Productivity in Microbial Biofilms*
Isaac Klapper, Temple University
(*Session:* Inverse Problems and Biofilms II)

Some of the most fundamental questions about biofilms concern productivity: given available supplies of certain nutrients, at what rate can these nutrients be turned into product (e.g. new biomass)? Models of productivity are best first constructed in one dimension where diffusive transport limitations and issues of spatial competition are more easily isolated and understood. This talk will present some simple results and bounds on productivity in 1D continuum biofilm models as well as possible consequences for the microbial ecology of biofilm communities.

41 *Flipped University Math Courses, A Discussion and Guide*
Paul Krouss, Washington State University, Vancouver
(*Session:* General Papers II)

Have you considered "flipping" a class? Would you like to know more about what this entails?

Flipping a course is more than just making a lot of online content for students. After all, students have access to many resources (including their textbooks).

In this talk, I will discuss conducting my first fully flipped math course *Introduction to Algebraic Methods* Math 103, and comment on the anecdotal advantages and disadvantages of this method. I will present the course structure I used, tasks to do before, during, and after the semester is over, and what I will do for my next flipped course.

42 *Data Streaming Algorithms as an Experimental Discovery of Probabilities*
Jérémie Lumbroso, Simon Fraser University
(*Session:* Junior Faculty Research I)

Elementary notions in probability have long perplexed high schoolers and first year university students. It is well known that simulations are an effective vehicle to illustrate and communicate concentration notions such as mean and standard deviation. In this talk we will show how simple probabilistic results — such as the distribution of a minimum — can yield simple and amazing algorithms to extract statistics from Big Data; and how these are potentially colorful applications to be presented to learning students.

43 *Leaves are not Rectangular – Contribution of Leaf Geometry to Water Uptake*
Frank Lynch, Eastern Washington University†
Gretchen North, Occidental College
C.J. Faulwell, Occidental College∗
Franklin Maharaj, Occidental College∗
(*Session:* Mathematical Modeling in Biology II)

A measured value of total hydraulic conductance in the tank bromeliad *Guzmania lingulata* is decomposed into separate conductances in the axial and radial directions. This decomposition uses the numerical solution of a second order initial value problem where an unknown parameter is selected to satisfy a third boundary condition. The unknown parameter, representing radial conductance, is used to characterize the ability *G. lingulata* to conduct water through its axial and radial pathways.

44 *Lake Mead Temperature Modeling*
Kelsey Marcinko, Whitworth University*†
Catherine Schepp, Haverford College*
Lisa Driskell, Colorado Mesa University
(*Session:* Student Papers)

The largest reservoir in the Colorado River system, Lake Mead, is a vital water source for many of the agricultural, industrial, and domestic needs of southwestern communities. As drought persists and demand continues to rise, there is much interest in protecting this resource and considering options to address scarcity. A model of temperature and energy flow within the lake has the potential to provide valuable information for studies of evaporation, water quality, biological communities, and hydrological systems. We discuss a parabolic PDE used to model temperature change with respect to depth and time based on numerous meteorological and physical processes and parameters. We compare the results of the PDE to empirical data from a site in Lake Mead and find that the model reflects magnitude and seasonal variation of the water temperatures. We investigate applications of the model and the effects of varying meteorological components representative of various climate and weather scenarios.

45 *The Limit of Humanly Knowable Mathematical Truth, Gödel's Incompleteness Theorems, and Artificial Intelligence*
Tim Melvin, Carroll College
(*Session:* Junior Faculty Research I)

We show that the set of humanly known mathematical truth at any given time is finite and thus recursive and axiomatizable. Thus, humanly known mathematics can be the output of a Turing machine, and given Gödel's Incompleteness Theorem, then set of humanly known mathematics must be either inconsistent or incomplete. These arguments can be applied to all "human symbolic output", so we can show that the Lucas-Penrose anti-mechanism argument cannot be valid.

46 *Visualizing Large Scale Behaviour of Combinatorial Families*
Marni Mishna, Simon Fraser University
(*Session:* Research and Pedagogical Trends in Discrete Mathematics I)

Uniform random generation of large objects is a very natural way to illustrate key properties of, and differences between, combinatorial families. We will demonstrate some recent research on Boltzmann generation schemes by generating and visualizing a variety of different objects. We will briefly address some applications of this random generation to combinatorial models that arise in the physical sciences.

47 *Traveling Waves in Pancreatic Islets*
Heather Moreland, Southwest Minnesota State University†
Jack Dockery, Montana State University
(*Session:* Mathematical Modeling in Biology II)

In response to an increase in blood glucose levels, insulin is released into the bloodstream by the pancreatic islets of Langerhans. As a result of this influx of glucose, the islets start what are called bursting oscillations of the membrane potential and the intracellular calcium concentration. Time delays of several seconds in the activity of distant cells in the islets have been observed, indicating the presence of traveling waves through the islets.

By considering a robust model of a pancreatic islet in one dimension, we study the relationship between the wave speed and the model parameters for the existence of traveling wave fronts and traveling wave pulses. After a systematic reduction of the model equations, the wave fronts (or heteroclinic connection) are studied. Using the bi-stable equation, for which an exact expression of the heteroclinic connection can be computed, we use a homotopy parameter to move from this equation to an islet model. A relationship between the wave speed and the conductance of the ATP-modulated potassium channel is constructed. Upon the inclusion of the slow gating variable back into the model equations, we observe the presence of a traveling wave pulse (or homoclinic connection). Using a high period periodic orbit to approximate the homoclinic orbit, a similar relationship between the these two parameters is constructed. We observe that the heteroclinic connection is a good approximation for a portion of the homoclinic connection. Comparisons of the speed of the wave traveling through the islet in the partial differential equation model and the model in traveling coordinates is carried out.

48 *Neural Development of the Visual System: a laminar approach*
Andrew M. Oster, Eastern Washington University†
Paul C. Bressloff, University of Utah
(*Session:* Mathematical Modeling in Biology I)

In this talk, we will introduce the architecture of the visual system in higher order primates and cats. Through activity-dependent plasticity mechanisms, the left and right eye streams segregate in the cortex in a stripe-like manner, resulting in a pattern called an ocular dominance map. We introduce a mathematical model to study how such a neural wiring pattern emerges. We go on to consider the joint development of the ocular dominance map with another feature of the visual system, the cytochrome oxidase blobs, which appear in the center of the ocular dominance stripes. Since cortex is in fact comprised of layers, we introduce a simple laminar model and perform a stability analysis of the wiring pattern. This intricate biological structure (ocular dominance stripes with 'blobs' periodically distributed in their centers) can be understood as occurring due to two Turing instabilities combined with the first-order dynamics of the system.

49 *Emergent Reducibility in Iterates of Cubic Polynomials*
Amrei Oswald, University of Puget Sound∗†
Jason Preszler, University of Puget Sound
(*Session:* Student Papers)

We study a class of recursive sequences where the kth term is the k-fold composition of a polynomial f with itself. Our goal is to determine when a term f^k is irreducible over $\mathbb{Q}$ but f^{k+1} is reducible over $\mathbb{Q}$, i.e. emergent reducibility. In Chamberlin et al., elliptic curves are used to identify emergent reducibility for quadratic f. We wish to extend this approach to cubic polynomials and ultimately generalize it to polynomials of any degree. To this end, we have determined that if f is a polynomial of degree n, f^k is irreducible over $\mathbb{Q}$ and f^{k+1} is reducible over $\mathbb{Q}$, then f^{k+1} factors into irreducible polynomials whose degrees are integer multiples of n^k. In this talk, we will summarize the results of Chamberlin, et al. and present our progress in generalizing their work.

50 *Analysis and Implementation of Besov Norm Regularization*
Cody Palmer, University of Montana∗∗
(*Session:* Inverse Problems and Biofilms I)

Suppose we have a linear operator equation $Au = z$ on L^p that is ill posed. Then any small perturbations in z can lead to very inaccurate least squares estimates. One way of regularizing this problem is to consider u that minimizes a functional of the form

$$T(u) := \|Au - z\|_p^2 - \alpha J(u)$$

where J is a so-called penalty functional. In a typical Tikhonov regularization scheme the penalty functional $J(u) = \|u\|_p$ is added so that approximate solutions with large L^p norms are eliminated. Using a different functional those solutions that contain high frequency wavelets are eliminated. For example, given the right wavelet basis of L^p, approximate solutions can be found that better fit true solutions with discontinuities. The natural space to work in, then, is a Besov space, which is equipped with a norm that is based on the wavelet representation of the solution. In this talk we will be doing an abstract analysis on such a regularization scheme, seeing whether it can agree with an abstract definition of a regularization scheme and also discussing implementation.

51 *Using Polynomials to Sample from Large Gaussians Used to Model 3-D Confocal Microscope Images of Biofilms*

Al Parker, Montana State University

(*Session:* Inverse Problems and Biofilms II)

Multivariate Gaussians and systems of linear equations are both specified by a quadratic form. This similarity can be exploited to produce samples from Gaussians using well established iterative techniques from numerical linear algebra. This talk will make clear how to apply Chebyshev polynomials to Gibbs samplers to speed up the geometric convergence of this class of samplers. This sampler is applied to quantify the uncertainty of parameter estimates calculated from videos of 3-D confocol microscope images of biofilms before and after application of anti-microbial treatments.

52 *Bistability and the Emergence of Oscillations in Repressilator Models with Quorum Sensing*

M. Pernarowski, Montana State University†
T. Gedeon, Montana State University
S. Zhao, Montana State University*
A. Wilander, Montana State University**

(*Session:* Mathematical Modeling in Biology I)

Metabolic pathways of E. Coli have been genetically engineered to exhibit cyclic expression patterns (Ellowitz et al 2000). Repressillator models for such networks include mRNA and transcribed protein concentrations as well as (extracellular) autoinducer concentrations which drive the various quorum sensing behaviors. We present a unified analytical approach for predicting monostability and bistability within the networks. The type of stability depends largely on which protein the autoinducer positively feeds back to. When one can prove monostability, synchronous network stability is independent of the number of cells and can only change via Hopf bifurcations. In the bistable case, equilibria existence is explicit but more complex.

53 *Venn Diagrams are Hamiltonian*

Gara Pruesse, Vancouver Island University†
Frank Ruskey, University of Victoria

(*Session:* Research and Pedagogical Trends in Discrete Mathematics III)

In 1984, Peter Winkler famously conjectured that every Venn diagram is extendible – that is, to any n-Venn diagram can be added a new curve so that the result is a $n+1$-Venn diagram. This is equivalent to conjecturing that the planar dual of any Venn diagram is Hamiltonian. Much work on the problem followed, with notable results, but the conjecture remains open.

We consider the dual to that much-studied problem: that is, is the Venn diagram itself Hamiltonian? Here the intersection points of the curves are the vertices of the graph, and the curve segments that connect intersection points are the edges. In this talk, we present a proof that all Venn diagrams are Hamiltonian, by proving that a larger class of closed curve graphs all admit a Hamilton cycle.

54 *Mathematical Modeling of Cerebral Lactate Homeostatis Across Sleep/Wake Cycles*
Michael J Rempe, Whitworth University†
William Clegern, Washington State University, Spokane
Michelle Schmidt, Washington State University, Spokane**
Jonathan Wisor, Washington State University, Spokane
(*Session:* Mathematical Modeling in Biology I)

It is known that brain metabolism is lower during slow wave sleep (SWA) compared to wakefulness and REM sleep. One marker of changes in metabolism is lactate concentration, which rises during wakefulness and REM sleep and falls during SWA. Although there have been several mathematical models of lactate and glucose dynamics, so far none of them take into account the effect of sleep state.

Working closely with experimentalists who measure the concentration of lactate in the mouse cerebral cortex I have applied a simple homeostatic model for lactate dynamics as a function of sleep state. Using the values of the parameters that ensure the best fit of the model to the data, we determine differences in lactate dynamics across genetic strains and we make comparisons between lactate and EEG delta power as sleep markers.

55 *Orienting Representable Matroids*
Jakayla Robbins, Vanderbilt University†
Daniel Slilaty, Wright State University
(*Session:* Research and Pedagogical Trends in Discrete Mathematics I)

Matroid theory is an abstraction of the linear independence properties studied in linear algebra. Indeed many, but not all, matroids can be represented by some matrix over some field. An oriented matroid is the directed version of a matroid. Many, but not all, oriented matroids can be represented by some matrix over an ordered field. Orientations of matroids that can be represented by a matrix over the 2-element field or the 3-element field are well-understood. We present some preliminary results for orientations of matroids that can be represented over the 4-element field.

56 *Using Transparent Representations to Promote Prospective Teachers' Re-Conceptualization of Factors*
Matt Roscoe, University of Montana
(*Session:* Junior Faculty Research I)

In order to be effective, teachers must develop a deep understanding of the mathematics that they will teach their future students. Research has shown, however, that many prospective and in-service elementary teachers struggle to make sense of the mathematics that they are called to teach. One area of identified difficulty is that of elementary number theory. This talk will outline these documented difficulties and move on to describe an intervention designed to support prospective teachers' conceptual understanding of factors, prime factorization, and divisibility. Initial results obtained from classroom teaching experiments employing the intervention in the spring of 2014 will be shared.

57 *Secrecy Coverage*

Amites Sarkar, Western Washington University

(*Session:* Research and Pedagogical Trends in Discrete Mathematics II)

Place a billion black points and a million red points uniformly at random in a large disc D. Now grow a disc about each black point until it hits the nearest red point. What is the expected proportion of D that is covered by the small discs? What is the probability that D is entirely covered? These questions were inspired by the issue of security (or secrecy) in wireless networks; the black points represent nodes of the network, and the red points represent eavesdroppers. I'll present the best known (asymptotic) answers.

58 *On Proofs Without Words and Beyond*

Tim Doyle, Whitman College
Lauren Kutler, Whitman College*
Robin Miller, Whitman College*
Albert Schueller, Whitman College†

(*Session:* General Papers II)

We discuss the history of the Proofs Without Words feature of the MAA's Mathematics Magazine and The College Mathematics Journal periodicals. We provide a philosophical context for the consideration of these mathematical artifacts as "proof" through the lens of Gottlob Frege's "The Foundations of Arithmetic." We demonstrate several on-line, interactive, adaptations of selected Proofs Without Words that we have created. We argue that these on-line, interactive visual proofs are the next logical step in the evolution of Proofs Without Words.

59 *From Zero to Research in 18 Days*

Tyler Seacrest, The University of Montana Western

(*Session:* Research and Pedagogical Trends in Discrete Mathematics II)

Recently I taught a graph theory class using the block schedule system at the University of Montana Western. The goal was to start with an introduction to graph theory, and build to a short, original research paper during the three and a half weeks the course was in session. The topic we had success with was graph labeling, and in particular a variant we called edge-antimagic vertex labelings. We will cover my experience teaching the course and the results the students produced.

60 *Building Breakfree Barrycades*

Richard K. Guy, University of Calgary
Karen Seyffarth, University of Calgary†

(*Session:* Research and Pedagogical Trends in Discrete Mathematics III)

This problem originates with the observation that the partial sums of the integers $\{1,2,3,\ldots,n\}$ generate the triangular numbers $\{1,3,6,\ldots,\frac{1}{2}n(n+1)\}$. In an e-mail to Richard Guy in 2006, Barry Cipra asked if it would be possible, using a selection of permutations of 1 through n, to generate all the numbers from 1 to $\frac{1}{2}n(n+1)-1$ as partial sums, each in a unique way. When $n=4$, the sequence $(1,2,3,4)$ yields the partial sums $1,3$ and 6; the sequence $(2,3,4,1)$ yields the partial sums $2,5$ and 9; the sequence $(4,3,1,2)$ yields the partial sums $4,7$ and 8. Thus, when $n=4$, there is a positive answer to Cipra's question.

Richard Guy recast the problem in the following form. Using logs of lengths 1 through n in each layer, construct a *barrycade* of maximum height so that the joints between logs occur in all possible positions, but no two joints lie on the same vertical line (adding to the structural integrity). Such a structure is called a *breakfree barrycade*.

In 2007, Richard Guy presented this problem in the Discrete Mathematics Seminar at the University of Calgary, and (not for the first time in my life) I was hooked. In this talk, I will describe what we know and don't know about building breakfree barrycades, and mention some related problems.

61 *Traffic Flow and Safety Analysis Using a Discrete Particle Model*

Benjamin Squire, Central Washington University*†
Nathan Minor, Central Washington University*†
John-Paul Mann, Central Washington University*

(*Session:* Student Papers)

Extensive research has been done to model and simulate traffic flow in order to answer valuable questions regarding the implementation of different traffic policies. A major open question is whether or not the stay-right-except-to-pass rule is an efficient traffic policy in terms of traffic flow and safety. We developed a particle-interaction based model which stems from how cars react and make decisions using locally restricted knowledge, and observed how snap shots of these processes over a large, closed, continuous road affect the dynamics of the overall traffic. Through our computer simulation, we analyzed the difference between four different traffic policies, or passing rules, which determine how cars react to an impending accident. Specific reactions include passing on the left or right (free passing), passing strictly on the left and then returning to most right lane (single driving), passing on left and then returning to any open lane on the right (single passing), and finally not allowing any passing (no passing) in both low and high density traffic for 2 through 5 lanes. Our statistical analysis indicated that a free passing rule is both the safest and most efficient passing policy, but further research is needed to determine whether or not other passing policies are more efficient under other, untested, scenarios.

62 *Prime Distance Graphs, 2-odd Graphs, and Prime Factor Graphs*

Colin Starr, Willamette University

(*Session:* Research and Pedagogical Trends in Discrete Mathematics II)

A graph G is a prime distance graph (respectively, a 2-odd graph) if its vertices can be labeled with distinct integers such that for any two adjacent vertices, the difference between their labels is prime (either 2 or odd). We seek to characterize prime distance graphs as well as some generalizations of them. In this talk, I will generalize this problem and demonstrate connections between that and several famous problems and theorems in number theory.

63 *From Tennis Balls to Mountains of Numbers of Mountains*

Evan B. Wantland, Warren Wilson College

(*Session:* Research and Pedagogical Trends in Discrete Mathematics III)

In *Sweet Reason: A Field Guide to Modern Logic*, Tymoczko and Henle pose a simple and elegant problem about throwing labeled tennis balls in and out of a box to illustrate the tricky nature of infinite processes. Upon investigating this situation as a (finite) counting problem, in 1997, Grimaldi and Moser discovered another interesting occurrence of the Catalan numbers. Rethinking the problem by slightly altering the conditions reveals the Motzkin numbers, and generalizing these problems reveal generalizations of these closely related integer sequences.

Though I will introduce a few of these problems and their solutions, the focus of this presentation will be on how I have used these situations to tell a story about what mathematicians do and the nature of asking questions and describing answers. I have used this material (for years) as an instructor at the *DIMACS Young Scholars Program in Discrete Mathematics*, presented to high school and undergraduate math clubs, and given lectures in general college colloquia through upper level Math courses. I believe that tangible discrete math problems involving counting or drawing provide an excellent medium for introducing students to abstract (and beautiful) mathematical concepts, and I will describe how I work these concepts into the story at an appropriate level.

64 *A Model for Soil-Plant-Surface Water Relationships in Arid Flat Environments*

David J. Wollkind, Washington State University[†]
Bonni Dichone, Gonzaga University

(*Session:* Mathematical Modeling in Biology II)

A classification scheme for stationary vegetative patterned states along a rainfall gradient in an arid flat environment is developed by applying weakly nonlinear diffusive instability analyses to an interaction-diffusion plant-surface water model system. The main results of these analyses can be represented by closed-form plots in the rate of precipitation versus the specific rate of plant loss parameter space. From these plots regions corresponding to bare ground and vegetative patterns consisting of tiger bush, labyrinth-like mazes, pearled bush, irregular mosaics, and homogeneous distributions of vegetation, respectively, may be identified in this parameter space. Then that predicted sequence of stable states along a rainfall gradient is both compared with observational evidence and used to motivate an aridity classification scheme which sheds new light on desertification phenomena while suggesting potential recovery operations by human intervention.