The Twenty-Second Annual Nebraska Conference for Undergraduate Women in Mathematics

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POSTER ABSTRACTS

Posters by Undergraduate Students

Cristina Alegria, Washburn University
"Spot it!" Can We Make Any Size Deck Work?

Inspired by the game "Spot it!" we explore aspects of divisibility within the integers, composition of one integer into the sum of two products, and some aspects of combinatorics and graph theory to create arithmetic tools with which to analyze the general case of these decompositions. A list of ranges of values split across a parameter starts the cataloguing process. A collection of arrangements grouped into families appears, and this leads to our catalogue of viable solutions. In part this exploration is motivated by an interest in understanding the mathematical mechanics of a deck of cards.

Hope Anderson, Davidson College
Parameter Estimation Within an SIR Model of Chestnut Blight in North America

Populations of the American chestnut (*Castanea dentata*), which once dominated eastern deciduous forests, have declined rapidly since the arrival of chestnut blight (*Cryphonectria parasitica*) in the early 20th century. The blight is deadly, but its virulence can be reduced by infection with Cryphonectria hypovirus (CHV). We expanded upon existing SIR models of chestnut blight and used data from several stands of C. dentata to estimate parameters within the model. By treating the parameters as proportions and comparing parameters between stands, we concluded that the death rates and sprouting rates in the model can be assumed equal across all stands. However, we hypothesize that transmission rates vary continuously with stage of infection. For simplicity, we devised three categories, with common parameters within each category, into which new stands can be sorted. This procedure allows the model to be used without estimating parameters specific to each stand. Our estimates of parameters for all categories differ from those found in the literature, better match known data from infected stands, and can be used to predict long term trends of a given stand.

Anabelle Arns, Augsburg University
Adapting the Searle Pedestrian Throw Formula for Use in a Calculus Course

In 1983 at the Stapp Car Crash Conference, Searle and Searle presented their Pedestrian Throw Formula. We learned about this formula from a Minnesota State Trooper. After learning about the formula we know we could adapt it for our Calculus I course at Augsburg University. The Pedestrian Throw formula was formed into a lab activity for the students to work out together in a one-hour-long session. This is one of the many ways our calculus students get to apply calculus to real-world scenarios.

Madeline Baillie, Slippery Rock University
Maximum Likelihood Estimation for Location and Scale Parameters of Burr Type III Distribution

In 1942, Burr type III distribution was first introduced by I. W. Burr for modeling lifetime data or survival data. In 1996, S. R. Lindsay introduced Burr type III distribution with location and scale parameters. In this project, we want to estimate location and scale parameters of Burr type III distribution by maximum likelihood estimation.

Andrea Barton, Brigham Young University
Defining Invariants from Petal Diagrams of Knots

Petal diagrams give us a convenient way to identify knots with full-length cycles in the symmetric group. In particular, a petal permutation is related to a knot projection with a single multi-crossing by describing the order in which the strands cross through the multi-crossing point. It has been shown that any two cycles that represent the same knot type can be related by a sequence of Reidemeister-type moves, which we refer to as trivial petal insertions and crossing exchanges. With these moves, we can attempt to define invariants from petal diagrams by showing that the given quantity is invariant under trivial petal additions and crossing exchanges.

Paige Beyer, Dordt University
Hannah Fields, Dordt University
Directed Graphs of Finite Rings

The directed graph of a ring, first introduced by Lipkovski, is a graphical representation of its additive and multiplicative structure. Using the relationship $(a, b) \to (a + b, ab)$, we can construct a unique directed graph for every ring. This work builds on the work completed by Hausken and Skinner as well as Ang and Shulte on directed graphs of commutative rings. We determine the possible incoming degrees of vertices in the directed graphs of certain classes of finite rings.

Katie Bird, William Jewell College
Seat Biases in the Delegate Allocation Methods of the Republican Presidential Primary

Apportionment methods used by state Republican Parties to apportion delegates in the 2012 and 2016 state presidential primaries varied from state to state, resulting in the implementation of many different methods. Of the seven methods that are proportional, all are quota-based and all but one are new. These new methods were introduced to make the delegate apportionment process more proportional. Through Monte Carlo simulation, we calculated the seat bias of each apportionment method (seat bias is a measure of how much an apportionment method favors leading candidates or punishes bottom candidates) using several different delegate and candidate sizes. Using these bias comparisons, we discuss how effective these new methods were in making the delegate process more proportional.

Emma Boven, Dordt University
Reliability and Validity of the STHS in Heart Disease Patients with Moderate to Severe Hopelessness

To confirm the reliability and validity of the State-Trait Hopelessness Scale (STHS) in patients with ischemic heart disease (IHD) who report moderate to severe hopelessness, a descriptive cross-sectional design was used. Hopelessness screening was done with 156 patients hospitalized for IHD. Data were then collected from 20 patients who reported moderate to severe levels of state hopelessness and who sustained hopelessness one week after hospital discharge. The state and trait subscales of the STHS were examined. Internal reliability (Cronbach's alpha) was high for the state (0.81) and trait (0.79) subscales. Concurrent validity of the subscales was confirmed using the Patient Health Questionnaire-9 and Snyder State and Trait Hope Scales. Convergent validity was confirmed using the EQ-5D-5LTM and PROMIS-29. Findings support future use of the scale in clinical settings and with intervention research focused on hopelessness. This work is joint with Sue Dunn and Nathan Tintle.

Courtney Brown, Furman University
British Square: An Analysis in Recreational Math

British Square is a two-player board game from the 1970s made by the publisher Gabriel. The game is composed of a square 5×5 game board and eleven pieces of each color, red and blue. Each player takes turns placing a piece on the board. The only rules are that the first player may not begin on the center square of the board, and no two pieces of opposing colors may be adjacent to each other. The game mechanics are simple, but playing a few rounds of the game brought up many questions about the mathematics behind the game. We explored the least and greatest number of turns to complete a game, whether there is a winning strategy, and the significance of the center square. In addition to proving some of our conjectures by hand, we created a computer program using Python. We used our program to help us prove our conjectures and to investigate strategies behind the game.

Staci Brown, Metropolitan State University of Denver
Determining Cascade Probabilities for Thermal Neutron Calibration of Dark Matter Detectors

One aspect of thermal neutron calibration of CMDS (Cryogenic Dark Matter Search) detectors is modeling thermal neutron capture. When a thermal neutron is captured by a nucleus, it is initially captured by some energy level of that isotope that is lower than the separation energy for that isotope. It will then quickly cascade back down to ground level. Each transition from one energy level to another releases a photon with energy equal to the difference in energy levels minus the recoil energy of the nucleus. The sum of these transitions is what the detector measures. Our goal is to build a model that includes neutron capture and then use it to calibrate the detector. Part of modeling these transitions involves knowing the probability of various cascades and their expected lifetimes. Using experimental data on the various commonly used isotopes of Si and Ge, the probability of all possible cascades was determined. These were then weighted by the percentage of each isotope present in the sample. Using the spin and parity of each energy level and the Weisskopf estimates, the lifetime in femtoseconds of each transition was estimated. Next steps will be to account for what happens when a nucleus decays in flight and how the transition lifetimes affect the model.

Olivia Calvin, Coe College
Nitrate in Iowa Watersheds

Using mathematical modeling and statistical analysis, our research aimed to discover if the amount of precipitation within a given time and location caused an increase of nitrate in the surrounding watersheds. The watersheds that we analyzed were all within the vicinity of farmland. Nitrate is a highly soluble polyatomic ion that is the key ingredient for many fertilizers. Its high solubility coupled with proximity to watersheds means that they were all highly susceptible to fertilizer runoff. We were able to investigate this relationship by gathering and analyzing data from the Iowa Department of Public Health and the Coe College Department of Chemistry.

Elaina Chapnell, Westminster College
Exploring Retinal Blood Vessels Through Fractal Dimension

Diabetic retinopathy is a vascular disease in the retina that can cause vision loss. Severe cases of this disease are characterized by neovascularization of blood vessels in the eye. In this study, we will use fractal dimension to attempt to determine a difference in the complexity of retinal blood vessels between individuals who have diabetic retinopathy and those without the disease.

Mary Collins, Cedarville University
Algebra of ROC Functions

Label fusion rules are used to combine multiple detection systems into a single detection system with improved performance. Receiver operating characteristic (ROC) curves are used to visually display the performance of both individual and combined detection systems and ROC functions mathematically describe the ROC curves. A very prevalent set of label rules are the AND and the OR rules. Previously, ROC functions and the Boolean rules were incorrectly considered as a Boolean algebra. In this poster, we show that ROC functions and the Boolean rules do not form a Boolean algebra, but instead form what we call a near-lattice and in certain cases form a semilattice.

Elsie Cortes, University of California, Merced
Python Implementation of Boundary Integral Methods for Optical Cloaking

In this poster we present an optimized python simulation of the light scattering in layered media using boundary integral equation methods, in order to perform optical cloaking. Optical cloaking refers to light propagating in various layered media coated on an object leading to (almost) no light scattering (the object is difficult to detect). We consider concentric layers and use the periodic trapezoid rule to discretize the problem. Because boundary integral equation methods use full, dense matrices, a careful implementation is necessary to limit computational time. We will present results in the case of two layers and further investigate multiple layers.

Liliaokeawawa Cothren, Arizona State University
Proving Stable Distributions Have Smooth Density Functions

Broadly, a distribution is said to be stable if a linear combination of independent, random variables with similar distributions reflects the distribution up to location and parameter specifications. Perhaps the most well-known and arguably the most common stable distribution is the normal distribution. While the normal distribution does have an analytically expressible probability density function and an analytically expressible cumulative distribution function, most stable distributions don't. Because of this odd flaw, stable distributions are often only characterized through certain parameters found using Fourier Transforms, or as more commonly referred to in probability theory, characteristic equations. Moreover, an exploration into proving all stable distributions have smooth density functions leads to larger results. Famously, the Central Limit Theorem establishes that the convolution or summation of any independent, random variables with differing distributions approaches a limit of the normal curve. Interestingly, after asserting that all stable distributions have smooth density functions, we can re-examine the Central Limit Theorem more generally: the proper summation of independent, random variables is a stable distribution.

Natasha Crepeau, Harvey Mudd College
On (t, r) Broadcast Domination of Certain Grid Graphs

If $G = \langle V(G), E(G) \rangle$ is a connected graph, then a set $D \subset V(G)$ is dominating if every vertex of $V - D$ has at least one neighbor in D. A generalization of this concept is (t, r) broadcast domination. In this setting certain vertices are designated as towers of signal strength t, which send out a signal to neighboring vertices decaying linearly as the signal traverses the edges of the graph. We let $\mathbb{T}$ be the set of all towers, and we define the signal received by a vertex $v \in V(G)$ as $f(v) = \sum_{w \in \mathbb{T}} \max(0, t - d(v, w))$, where w is a tower and $d(v, w)$ denotes the distance between v and w. Blessing, Insko, Johnson, and Mauretour (2014) defined a (t, r) *broadcast dominating set*, or a (t, r) *broadcast*, on G as a set $\mathbb{T} \subseteq V(G)$ such that $f(v) \geq r$ for all $v \in V(G)$. The minimal cardinality of a (t, r) broadcast on G is called the (t, r) *broadcast domination number* of G. In this poster, we present our research on the (t, r) broadcast domination number for graphs including paths, grid graphs, and different lattices.

Erin Dahl, Pacific University
Single Cell Analysis of Pancreatic Tumor Cells and Disseminated Liver Cells

During pancreatic tumor progression, tumor cells typically disseminate from the primary site to other organs including the liver. These disseminated tumor cells may remain dormant for months, years, or decades before entering metastasis. Single cell research on dormant tumor cells and tumor cells can uncover how gene expression and copy numbers vary within these cell populations. Seurat Single Cell bioinformatics software was used to analyze gene expression in both pancreatic tumor and dormant liver cells. The computational analysis revealed a graph with two distinct clusters and cell types. One cluster consisted of tumor cells, and some dormant tumor cells mixed in. It is probable that these dormant tumor cells are tumor-like cells. The other cluster identified only consisted of dormant tumor cells which means it may be a group of normal cells or a subpopulation of tumor cells. In addition, copy number analysis software, HoneyBadger, calculated copy number variations in comparison to a reference genome. Resulting heatmaps demonstrate that the tumor and dormant tumor cells did not have many differences in copy numbers. Additional analysis is needed on the small changes in gene expression that account for these differences. Furthermore, if specific genes expressed are responsible for the dormancy of a tumor, anti-cancer drugs can be developed that regulate the gene expression of a tumor cell to look like that of a dormant cell.

Staci Davis, United States Air Force Academy
Sylver Coinage Game

My professor proposed a research project to me concerning a game based on the concept of numerical semigroups. In this two-player game, all positive integers are in play. The players take turn naming numbers, and after a number is named, the number and all other numbers that can be expressed as linear combinations (with non-negative coefficients) of it and any numbers already named are eliminated from play. Eventually, using a theorem by JJ Sylvester, the set of playable numbers becomes finite. The player who is forced to choose the number 1 loses the game. The research proposed is finding out what characteristics "winning positions" share, and what characteristics "losing positions" share, so as to always guarantee yourself a win. A "winning position" is classified as the situation when the player to play next can win the game starting in that position, and a "losing position" is exactly the opposite. There have been a few patterns noticed concerning winning and losing positions, but there is still more research to be done before the secrets for winning the game every time are discovered.

Montana Ferita, Westminster College
An Agent-based Model of Pollen Competition in Arabidopsis thaliana

In 2016, Swanson et al. showed that when an Arabidopsis thaliana stigma is pollinated with equal amounts of pollen by two accessions, Columbia and Landsberg, Columbia pollen sire disproportionately more seeds. This phenomenon is known as nonrandom mating. Previous experiments have investigated nonrandom mating by examining how pollen performance traits such as proportion of pollen germinated, time to germination, and pollen tube growth rates differ between these two accessions. In addition, bioenergetics, such as the energy supplied to pollen tubes from the pistil during fertilization, likely also magnify competition. While plant fertilization is well studied, the exact mechanics of pollen competition remain unknown. Using an agent-based model, we aim to identify the traits that cause pollen from one accession to sire more offspring than pollen from another accession and to what extent these traits contribute to this process. We calibrate our model against a number of parameters from empirical data to observe the output of seed siring proportions from mixed pollinations; we compare these values to those found in the literature. Our model can also be extended to predict seed siring proportions for other accessions of Arabidopsis thaliana given data on their pollen performance traits.

Tayler Fernandes Nunez, Northeastern University
Kayla Gibson, University of Iowa
Towards a Database of Belyi Maps

A Belyi map $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ is a rational function with at most three critical values; we may assume these are $\{0, 1, \infty\}$. A Dessin d'Enfant is a planar bipartite graph on the sphere obtained by considering the preimage of a path between two of these critical values, usually taken to be the line segment from 0 to 1. Such graphs can be drawn on the sphere by composing with stereographic projection: $\beta^{-1}\big([0,1]\big) \subseteq \mathbb{P}^1(\mathbb{C}) \simeq S^2(\mathbb{R})$. This project sought to expand on a database of such Belyi pairs, their corresponding Dessins d'Enfant, and their monodromy groups. We did so for up to degree N = 5 in the hopes of generating an algorithm to generate Dessins from monodromy triples.

Hannah Fields, Dordt University
see **Paige Beyer**

Chloe Frechette, Northern Arizona University
Sylver Coinage Digraph Analysis

Sylver Coinage is a two-person game, created by John Conway, played on the natural numbers. The two players take turns naming positive integers greater than 1 that are not the sum of nonnegative multiples of previously named integers. The player who cannot name such a number loses. Despite its simplicity, Sylver Coinage has not been fully analyzed; in particular, although some winning positions are classified, strategies to maintain those winning positions are in general unknown. When the remaining set of plays is finite, game states can be represented using digraphs. We will analyze familiar families of digraphs and present new results in determining winning and losing positions, along with the resulting strategies applied to Sylver Coinage.

Marlena Giannone, Colorado State University
Isomorphisms and Counting Problems Related to Graphs and Trees

Graphs are sets of vertices connected by edges, which are used to represent mathematical problems in discrete mathematics and combinatorics, as well as practical problems in biology, computer science, information systems, and a variety of other sciences/topics. Trees are undirected graphs, without cycles and are also important in computer science to represent problems or to explain the way a program works through inheritance. They are used in chemistry to represent molecules and can be used to find the minimum cost of things represented by graphs, among other applications. An isomorphism is another version of a graph or tree. Isomorphisms are important to distinguish because although isomorphic graphs may not look the same, they have the same properties, and therefore should not be counted again in certain calculations. In this poster, I will give the inductive formula of the number of rooted, non-isomorphic trees on n vertices and explain the proof both visually and arithmetically.

Kayla Gibson, University of Iowa
see **Tayler Fernandes Nunez**

Ashlynd Heatherington, University of Central Oklahoma
Markov Chains, Games, and Beyond

Markov chains serve many purposes and can be utilized in various mathematical disciplines. For this poster, we'll begin by considering Markov chains in Linear Algebra as they relate to games, like Candy Land. Markov chains can be witnessed in Queuing Theory, Monte Carlo simulations, and simulated annealing, some of which also will be explored in the poster.

Faith Hensley, Marshall University
Ashley Peper, University of Wisconsin–Stevens Point
Extremal Numbrix Puzzles

Numbrix is a puzzle in Parade magazine. The player is given a 9×9 grid with some integers between 1 and 81 filled in. The player then needs to fill in the rest of the integers between 1 and 81 so that consecutive integers appear in adjacent cells of the grid. Generalizing this puzzle we consider $m \times n$ grids with the entries being the integers between 1 and mn. We say that a set of clues defines a puzzle if there exists a unique solution given those clues. In 2018, Hanson and Nash found the maximum number of clues that fail to define an $m \times n$ puzzle for all m and n. We present our work on their conjecture concerning the minimum number of clues necessary to define a puzzle. We also discuss what happens when diagonal moves are allowed. This research was conducted as part of the 2019 REU program at Grand Valley State University.

Morgan Holt, Liberty University
Modeling Seasonal Dynamics of Swimmer's Itch and the Efficacy of Potential Treatment Options

Swimmer's itch is a skin condition that results when people come in contact with water containing parasitic worms that are released from snails and typically infect waterfowl. Due to both the health and financial concerns associated with this interaction, swimmer's itch is now considered an emerging, neglected disease. Based on the migratory patterns of waterfowl hosts, we created connected differential equation models for lakes that serve as stop-over (transient) sites and those that are utilized by birds as summer resident locations. Furthermore, we explored the possibility of controlling swimmer itch by giving waterfowl anti-parasite drugs at both transient and resident lakes. We found that treating birds at a transient lake during the spring migration significantly lowered the likelihood of swimmer's itch cases at the resident lake and was a more efficient control strategy than treating waterfowl at the resident lake itself. These findings could be used by both state agencies such as the Department of Natural Resources and/or lake managers as a tool for optimizing treatment plans to best manage future outbreaks of swimmer's itch.

Savannah Howard, University of Nebraska–Lincoln
Analysis of the Rate of Epidermal Skin Cell Proliferation, Differentiation, and Death

The skin is one of the most, if not the most, important organs that organisms possess because of the functions it provides for the survival of their bodies. Such functions include a protective barrier and divide between the internal and external environments, a body temperature regulator, a sensory information detector. It also plays a role in the immune system. Gaining more information about the stratification, differentiation, and death of skin cells will allow us to gain more knowledge about the skin that can be used in biological and medical research to better benefit the medical industry and science, therefore advancing the community. I propose to utilize differential equations and the linear algebra technique of Jacobian stability analysis to determine its steady states. The variables within each differential equation will represent a component that affects the rate during either the process of reproduction, transition into a new skin cell type, or the deterioration of these skin cells. The relationships and interactions amongst these components will be shown within the differential equations, and determining the steady state of each equation will provide insight into what concentration, speed, external and internal elements, and environmental factors are necessary to maintain a constant existence state. Deviations from or disruptions to what is defined as the normal process will change these relationships and ultimately the steady state, resulting in phenotypic abnormalities and/or differences such as rashes, cancer, dry skin, etc.

Carlyn Johannigman, Rose-Hulman Institute of Technology
Introducing Inhibitory Levels into a Boolean Network of Carcinogenesis

1.7 million people per year in the US are diagnosed with cancer. Because of this, researchers are exploring how mutations in different genes and proteins affect those cells. Pathways involved in carcinogenesis are described via protein-protein interaction networks. This network can be modeled as a discrete dynamical system. In previous research, Fumia and Martins investigated the effects of multiple simultaneous cancer therapies that entirely inhibit the production of proteins on this Boolean system. We extend a portion of their work by considering these therapies as either entirely inhibitory or only moderately inhibitory of the proteins involved.

Aubrey Kimmel, Pacific University
Using Fractal Dimensions and 2D Discrete Fourier Transforms to Analyze Interfaces with Surfactants

The motivation for this research was to see how the broadening and roughness of the surface of water affects surface tension, and how a surfactant's structure affects an oil/water interface. We want to reduce surface tension by making better surfactants, which make better detergents and emulsifiers for oil clean-ups. The method used to investigate this was computational molecular dynamics. Our previous research has shown that the density profile is broadened by the presence of surfactants. The remaining questions are what is the length scale of roughness parallel to the interface, and if different surfactants cause this broadening at different length scales. This would help characterize the degree of aggregation vs. dispersion of surfactant molecules at the interface. The first step was to develop an efficient algorithm to identify the water surface for multiple frames of a molecular dynamic system. We resolved the interface at a subatomic length-scale. Since the interface was dynamic, it was not possible to average the interfacial positions. Instead, we employed two analysis methods that probe the characteristic lengths of interfacial structures: 2D Discrete Fourier Transformation (FFT) and Fractal Dimensional Analysis. The FFT transforms the spatial dimension to an inverse 2D-space, which is then averaged over multiple frames of a simulation. Similarly, Fractal Dimensions, using the Triangular Prism Method, calculates the surface area of a 3D surface as a function of a length-scale.

Jessica Kisner, Central Washington University
Prions: The Good, the Bad, and the Computational

The word prion stands for proteinaceous infectious particle, and is most infamous with respect to the Mad Cow Disease scare of the 1990s. Prions are typically concentrated in the brain and are responsible for most fatal neurodegenerative diseases, including Alzheimer's, Jakob-Creutzfeldt Disease, and Huntingtons. Recent research shows that prions are also fundamental to how connections are made within the brain, playing a role in growth cone guidance and in the formation of memories. The central goal of this research project is to computationally investigate this schism in prion behavior. To explore the infectious nature of prions, a cell environment was modeled in which prions were free to undergo Brownian motion, while stochastically transitioning to an infected state, governed by a set of differential equations. Simulations demonstrated that the time scale for total cell infection is sensitive to the threshold for nucleation. To explore the beneficial side of prions, a model for prion stimulation of axonal outgrowth was developed, based on the hypothesis that prions stimulate movement of growth cones, which are structures at the tips of axons that guide axonal growth during nervous system development. Two distinct mechanisms for the interactions between prions and growth cones were simulated, making testable predictions that can be compared against experimental data.

Anna Kucherova, University of California, Merced
Kayla Quinones, University of California, Merced
Genetic Algorithm, Simulated Annealing, and their Hybrid for University Timetabling

Course timetabling lies within a class of NP hard problems faced by various industries. In our work we develop a hybrid algorithm that combines the genetic algorithm and simulated annealing to solve a scheduling problem for the Merritt Writing Program at the University of California, Merced. Our methods consider faculty preferences and a compendium of hard and soft administrative constraints used to quantify and minimize faculty dissatisfaction with their assigned course schedule. We present the advantages of our hybrid method over the individual application of each method.

Natalie Larsen, Brigham Young University
A Numerical Rootfinder for Solving Systems of Multivariable Functions

We present a multivariate numerical rootfinding algorithm to find all the common zeros in a given compact region in $\mathbb{R}^n$ of a system of functions. The method builds on ideas of Nakatsukasa, Noferini, and Townsend to subdivide the original search interval and approximate the functions with Chebyshev polynomials. It then uses a variant of Telen and Van Barel's method to find the roots in each subdomain by computing eigenvectors or eigenvalues of the Chebyshev form of certain Möller-Stetter matrices constructed with a well-chosen basis. We compare the algorithm, in terms of accuracy and speed, to other popular numerical rootfinding algorithms, such as Bertini and Chebfun2. In many instances, this algorithm outperforms all known competitors.

Abigail Loe, Carleton College
Minimal Discriminants of Rational Elliptic Curves with Specified Isogeny

By a rational elliptic curve, we mean a projective variety of genus 1 that admits a Weierstrass model of the form $y^2 = x^2 + Ax + B$ where A and B are integers. For a rational elliptic curve E, there is a unique quantity known as the minimal discriminant, which has the property that it is the smallest integer (in absolute value) occurring in the Q-isomorphism class of E. In 1975, Hellegouarch showed that the elliptic curve $y^2 = x(x + a)(x - b)$ for relatively prime integers a and b comes equipped with an easily computable minimal discriminant. Recently, Barrios extended this result to all rational elliptic curves with non-trivial torsion subgroup. This project gives a classification of minimal discriminant for rational elliptic curves that admit an isogeny of degree N greater than or equal to 2. This work is part of PRiME (Pomona Research in Mathematics Experience) with assistance by Alex Barrios and Timothy McEldowney. This work was sponsored by the National Science Foundation (DMS-1560394).

Marcella Manivel, Carleton College
Iterative Respacing of Polygonal Curves

Start with a list of points in the plane. Create a polygonal curve by drawing line segments connecting consecutive points in this list. Next, create a new list of points by sampling from the polygonal curve at evenly spaced intervals. Iterate this process using the new list of points produced as the starting point of a new iteration. We analyze how this iterative respacing smooths a polygonal curve and tends toward an evenly spaced curve as the number of iterations goes to infinity.

Miah Masvero, Grand Valley State University
Vertex Distinguishing Edge Colorings of Chorded Cycles

A Vertex Distinguishing Edge Coloring (VDEC) of a graph is an edge coloring such that no two vertices have the same color set of edges incident to them. A strong coloring is a VDEC in which no adjacent edges share a color. We investigate the minimum number of colors necessary to generate a strong VDEC of a graph. Specifically, we explored this for the graph obtained by taking a cycle graph and adding a chord between two vertices separated by one vertex. We give exact values for the minimum number of colors necessary to assign a strong VDEC to this type of graph. Coauthored with Sam Koch and Michael Baas (neither attending).

Carly Middleton, The Ohio State University
Josey Sorenson, University of Wisconsin-La Crosse
Improving Parasite Transmission Parameters for a Mathematical Model of Swimmer's Itch

Swimmer's itch is a skin condition caused by avian parasitic schistosome worms that attempt to invade human skin within infested water bodies. Although the parasites fail to develop in people, infection does result in extreme itching and discomfort that can last for days to months. Because of this, there is growing interest in developing strategies that can help better predict outbreaks of Swimmer's Itch and, ultimately, reduce the number of human cases. One novel approach is to develop mathematical models that adequately capture the biology of the system; however, establishing relevant parameters can be difficult due to the complex nature of host-parasite interactions. We developed a seasonal model for swimmer's itch which initially contained a number of unresolved parameters (such as parasite transmission rates and death rates in infected birds). To rectify this issue, we employed field collections, literature searches, and mathematical techniques (e.g. specifically, genetic algorithm approaches) to better estimate biologically relevant parameters for the model. Through this process we have enhanced the predictive capacity of our swimmer's itch model which, in turn, could serve as an important tool for managing outbreaks of the disease throughout the Midwest.

Daisy Montalvo, Humboldt State University
Dragon Ecology

In the fictional television series Game of Thrones, based on the series of epic fantasy novels A Song of Ice and Fire, three dragons are raised by Daenerys Targaryen, the "Mother of Dragons." Our team is assigned to analyze dragon characteristics, behavior, habits, diet, and interaction with their environment. The main question is: What is the ecological impact and requirements of the dragon? Based on the details provided by the author, we fit a logistic model to predict the final length of a dragon. We compared the logistic model of the dragon with two other existing organisms in order to estimate the mass of a full-grown dragon. The calculated mass is 3,0218 kg. To estimate the foraging area, we used the dragon's mass used proportionality with A. condor. We found the area required to be 3,300 m $\times$ 4,500 m. We used Google maps to display a visual representation of that space. The dragon's mass was also an essential component to calculate the required calorie intake based on proportionality in comparison with the saltwater crocodile. We estimate the number of calories to be 4,602.74 kCal , which is equivalent to 75 buffalos per year. Finally, the energy exp. Is assumed to be the same as the Indian elephant. The energy expenditure for Indian elephant is $5.4 \cdot 10^5$ kJ/d weighing at 3.67 t (McNab, 2012).

Vanessa Montano, Central Washington University
Mathematically Modeling US Asylum Facilities: Social-Economic Observations and SIR Variations

As of July 2019, the United States reported a 124% increase in people traveling to the US and requesting asylum, on the basis of political and social conditions. This increase in migration is causing a crisis for the processing facilities along the United States-Mexico border. The Department of Homeland Security has acknowledged that the conditions the migrants are held in at these facilities is below the standard for basic care. Knowing this, my team became interested in modeling the spread of disease in these facilities using variations of SIR models, a compartmentalized model that demonstrates the extent of disease spread in a population, to see what impact the influenza and mumps could have on this population. We also investigated the social-economic impact of holding children in these conditions for long periods of time. Using data from a migrant shelter, a contracted facility, and comparisons to child welfare, we were able to make conclusions that justify our recommendations on changes to future policy.

Rachel Morris, University of Richmond
Yifei Tao, Hobart and William Smith Colleges
Constructing Semi-Directed Level-1 Phylogenetic Networks from Quarnets

We introduce two algorithms for reconstructing semi-directed level-1 phylogenetic networks from their complete set of 4-leaf subnetworks, known as quarnets. The first algorithm, the sequential method, begins with a single quarnet and adds on one leaf at a time until all leaves have been placed. The second algorithm, the cherry-blob method, functions similarly to cherry-picking algorithms for phylogenetic trees by identifying exterior network structures from the quarnets.

Victoria Morado, California State University, Stanislaus
Mathematical Image Analysis on Galaxies

Powerful telescopes and various methods of measuring distance allow astronomers to discover billions of galaxies. The Hubble Telescope alone has revealed an estimated 100 billion galaxies over the years. As telescope technology improves, this number is expected to keep growing. The vast discovery of galaxies and their respective distances away from us is arguably a scientific accomplishment like no other; however, there is very little known about the distances between points within these galaxies. In our research, we attempt to gain more knowledge about these intergalactic distances. There are several types of galaxies, but we are interested in galaxies that are elliptically shaped. We are also focused on galaxies that are brightest at their centers. For these reasons, we work with images of the galaxies IC2006, NGC3610, and IC1101. Furthermore, we use MATLAB to develop a code that locates the centers of each of our galaxies and can calculate the distance between any point in a galaxy and its respective center.

Leah Mork, Concordia College
Exploration of Julia Sets Arising from Centered Polygonal Lacunary Functions

Centered polygonal lacunary functions are a particular type of lacunary function that exhibit properties that set them apart from other lacunary functions. Primarily, centered polygonal lacunary functions have true rotational symmetry. This rotational symmetry is visually seen in the corresponding Julia and Mandelbrot sets. The features and characteristics of these related Julia and Mandelbrot sets are discussed, and the parameter space, made with a phase rotation and offset shift, is intricately explored.

Sarah Nash, New College of Florida
Connectivity in Origami Flip Graphs for Flat-foldable Vertices

Given a flat-foldable origami crease pattern C, we can describe how we fold it flat with a mountain-valley (MV) assignment, where each crease is described as bending convexly (mountain) or concavely (valley) when viewed from one side of the folding material. A MV assignment is called valid if it can be used to fold the crease pattern flat along all of its creases (i.e., it can be pressed in a book without crumpling or self-intersecting). We construct the *origami flip graph*, $OFG(C)$, from C as follows: the vertices are all valid MV assignments of C, and two vertices u and v are connected by an edge if and only if the MV assignment u can be turned into that of v by "flipping" one face F of C (reversing the MV parity of the creases bordering F). In this poster we examine origami flip graphs of single-vertex crease patterns. We describe, for a single-vertex crease pattern C, when $OFG(C)$ is connected and prove that if the number of valid MV assignments of C is 2^n then $OFG(C)$ is a subgraph of the n-cube.

Vanessa Newsome-Slade, California Polytechnic State University, San Luis Obispo
Tracking Contaminant Transport in an Aquifer with Nonuniform Data

Radial Basis Functions (RBFs) have proven to be a versatile tool for generating approximate solutions to systems described by partial differential equations. Traditional approaches such as the finite difference method or finite element method rely upon a regular mesh and a robust collection of boundary or initial conditions. In the field, however, natural or human structures can be an obstacle to collecting a complete set of data. This also poses computational challenges by requiring large processing effort to generate the domain mesh. RBFs have proven to be a reliable meshfree method to address both restrictions. This project explores the role of data collection on the generation of a reliable model for contaminant flow in a groundwater system within the context of improving access to safe drinking water.

Haylee Nguyen, Earlham College
Kinetics of a Gierer-Meinhardt System with Inhibition via Activator Destruction and Inhibitor Autoca

In this research, we study the local nonnegative, constant solutions of a modified Gierer-Meinhardt system, and use properties of ordinary differential equations to ascertain the existence, boundedness, and convergence of equilibrium solutions. Numerical simulations have been carried out to correlate our analytic findings.

Erica Papke, Mercer University
Unfolding Monodromy

In this talk, we will examine integral affine structures on spheres and cylinders. For a sphere to have an integral affine structure, it must have singularities. We are interested in a particular kind of singularity, called a node, which arises in mirror symmetry and symplectic geometry. To better understand integral affine surfaces with nodes, we would like planar models. By cutting at the nodes, unfolding the surface, and stitching it back together, we obtain something similar to the net one gets when unfolding a prism in grade school. However, monodromy (like the flip in a Möbius band) makes things a lot more complicated.

Ashley Peper, University of Wisconsin-Stevens Point
see **Faith Hensley**

Jasmine Philipoom, Case Western Reserve University
Hemimethylation Patterns in Lung Cancer Patients

For each chromosome, tumorous and normal cell samples were collected from eighteen patients and processed with bisulfite sequencing methods to reflect methylation attributes of both the forward and reverse strands for each cell sample. The data included the methylation level of each CpG site, ranging from zero to one, and the coverage level, denoting the proportion of sample reads per each CpG site. Thus, each chromosome has eight raw data files used to analyze and compare hemimethylation patterns in tumor and normal cells. These data were then analyzed using mean-difference testing, and the Wilcoxon Signed-Rank Test to determine if there were statistically significant differences in hemimethylation in tumor cells as opposed to normal cells.

Ashlea Posey, University of Alabama at Birmingham
Solving Differential Equations in High Dimensions

We will solve several differential equations in high dimensions. These equations are ubiquitous in mathematical biology and physics. We are going to use state-of-the art tensor computation techniques in solving these equations numerically. Specifically, we will tensor decompositions in the Galerkin approximation formulation.

Hannah Potgieter, Seattle University
Accuracy of Equations Modeling Higher Harmonics in Surface Water Waves

We study the evolution of the higher harmonics in surface water wave experiments. We compare numerical predictions from asymptotic reductions of the Euler equations and its dissipative generalizations with measurements from water wave experiments conducted at Penn State University. Our models include the (i) nonlinear Schrödinger equation (NLS), (ii) dissipative NLS equation, (iii) Dysthe equation, (iv) viscous Dysthe equation, and (v) the dissipative Gramstad-Trulsen equation. We find the predictions from these models are not always consistent with the experimental data.

Kayla Quinones, University of California, Merced
see **Anna Kucherova**

Akshara Ramaseshan, Colgate University
Maps Preserving Multiplicativity of the Euler Characteristic

The Euler characteristic is a topological invariant: a value $\chi(X)$ that contains information about the structure of a topological space, X. This value may often be straightforward to compute for simple spaces in 1, 2 or 3 dimensions, but can be hard to compute for more abstract spaces. Because of this, topologists seek to exploit relationships between complicated spaces and more familiar spaces whose Euler characteristics are known. In 1980 Albrecht Dold asked the following open question: For which classes of maps is it true that if $f : X \to Y$ has the property that the pre-image of every point has Euler characteristic k, the multiplicative formula $\chi(X) = k \cdot \chi(Y)$ holds? We examine piece-wise linear and simplical maps for which this multiplicative Euler characteristic formula holds. Of specific interest are maps preserving this multiplicativity, but for which the pre-images of points are not all topologically equivalent.

Emeline Root, Grand Valley State University
Total Prime Labelings of Graphs

A graph is a set of vertices, typically drawn as dots, connected by edges, typically drawn as line segments that connect the dots. To numerically label a graph, each vertex and edge is assigned a natural number. We are interested in total prime labelings of graphs. A total prime labeling of a graph is a labeling of each vertex and each edge with natural numbers from 1 to the number of edges plus the number of vertices, such that:

1. the labels of every pair of adjacent vertices are relatively prime, and
2. for each vertex of degree at least 2, the labels of every pair of incident edges are relatively prime.

Previous results have proven that all paths, all comb graphs, all even cycles, all stars, all complete bipartite graphs with one partition having two vertices, and all wheels have a total prime labeling. We explore whether other graph families have total prime labelings.

Karie Schmitz, Truman State University
Exploring Preference Orderings Through Discrete Geometry

Consider $n+1$ points in the plane: a set S consisting of n points along with a distinguished vantage point v. By measuring the distance from v to each of the points in S, we generate a preference ordering of S. The maximum number of orderings possible is given by a fourth-degree polynomial (related to Stirling numbers of the first kind), found by Good and Tideman (1977), while the minimum is given by a linear function. We investigate intermediate numbers of orderings achievable by special configurations S. This work is motivated by a voting theory application, where an ordering corresponds to a preference list. We also consider this problem for points on the sphere, where our results are similar to what we found for the plane. Other variants of the original problem inspired by voting theory are developed. These include using a weighted distance function and also using two vantage points.

Nicole Schneider, Wartburg College
Effects of Edge Subdivision on the Cop Number of a Graph

Cops and Robber is a two-player complete information game played on a discrete graph. A given number of cops are assigned to vertices of the graph and then one robber is assigned to a vertex. The cops and robber then move in alternate turns, where a move consists of sliding any number of the player's pawns along an edge to an adjacent vertex. The cops win if they can occupy the same vertex as the robber, thus capturing the robber. The robber wins if he can escape capture indefinitely. We investigate how the cop number is affected by subdividing edges. In particular, for each positive integer k, we construct a graph with cop number one that becomes cop number at least k after edge subdivision.

Natalie Schurman, State University of New York at Geneseo
Estimating the Minimum Eigenvalue of a Connected Threshold Graph

A threshold graph is a graph that can be constructed by starting with a single vertex and then recursively adding an isolated or dominating vertex. The recursive process can be represented by a sequence of 0's and 1's, where a 1 represents a dominating vertex and a 0 represents an isolated vertex. A graph can be represented by a binary matrix called the adjacency matrix whose eigenvalues can be used to reveal structure in the graph. In this project, we consider threshold graphs of the form $(0^{s_1}, 1^{t_1}, 0^{s_2}, 1^{t_2}, ..., 0^{s_k}, 1^{t_k})$ where the s_i and t_i values represent runs of 0's and 1's. Our focus is to find estimates to the minimum eigenvalue of a general, connected threshold graph. We do this by finding eigenvalues of all subgraphs of a very special form and applying Cauchy eigenvalue interlacing.

Ana Shaw, University of Florida
Can Persistent Homology Detect the Shape of a Drum?

Given a region X in the plane, one can solve the eigenvalue problem for Laplace's equation $\Delta u + \lambda u = 0$, yielding a sequence of eigenvalues $\lambda_1 \leq \lambda_2 \leq \ldots$ and corresponding eigenfunctions $u_1, u_2, \ldots$. In this project, we use finite element methods to approximate the first few of these for parallelograms X_n having one side along the x-axis and adjacent side forming an angle of π/n. We then take their sum to obtain a real-valued function f_n on X_n and compute the persistent homology of the sublevel set filtration for this function. The resulting barcodes vary accordingly and allow us to deduce information about the region X_n.

Josey Sorenson, University of Wisconsin-La Crosse
see **Carly Middleton**

Yifei Tao, Hobart and William Smith Colleges
see **Rachel Morris**

Evelina Teran, University of Montevallo
Imaging Algorithms for Small Radar Seekers

The purpose of this study was to implement and understand the performance of the Polar Format and Phase Gradient Autofocus algorithms for use in small radar seeker signal processing chains. Original software was written in MATLAB and tested on a data set collected under the Air Force Research Laboratory (AFRL) GOTCHA program. After editing and testing, the code was deemed capable of executing both algorithms resulting in high resolution radar images that can be used to detect fixed and mobile stationary targets. Both algorithms were then used to process a different data set from a radar owned by AFRL/RWWS known as the Smart Submunition Radar Seeker developed by L-3 Mustang. The data collected with the Smart Submunition Radar Seeker consisted of trajectories that were very atypical from those in the GOTCHA data, however, the Polar Format and Phase Gradient Autofocus algorithms were still effective ways of processing the data.

Lam Tran, Denison University
A Statistical Analysis of Drug Seizures and Opioid Overdose Deaths in Ohio from 2014 to 2018

Deaths due to unintentional drug overdose have quadrupled in the past twenty years, and more people now die annually from drug overdoses than from car accidents. In 2017, Ohio had the second-highest rate of drug overdose deaths despite having average drug use patterns. In this presentation, I will explain the association between drug seizures by law enforcement in Ohio and the number of opioid overdose deaths, and what factors we should consider while trying to improve the opioid epidemic in Ohio.

Hollee Trent, Rose-Hulman Institute of Technology
Structure of Number Theoretic Graphs

Questions about the structure imposed on a set of objects by the relationships between them can be reframed as graph theory questions. In particular, one considers the graph whose vertices are elements of that set and whose edges indicate the relationship of interest, and investigates properties of that graph, such as its hamiltonicity. In Matt Parker's "Things to Make and Do in the Fourth Dimension," the question of whether the integers 1 through n can be ordered linearly so that the sum of each pair of adjacent elements is a square is investigated briefly. For n up to and including 14, n from 18 to 22, and $n = 24$, it can't be done. For all other n less than 200, it can be done, as shown by example. It's suspected but not proved that it can be done for all n greater than 25. This presentation will further discuss relevant properties of the graphs underlying this problem, as well as graphs generated by other number theoretic properties.

Alexandra Veliche, Northeastern University
Nonlocality in Shallow Quantum Circuits

For the past two decades, there has been a considerable amount of research in determining how quantum computers may be more powerful than classical ones. Since the physical implementation of quantum computers is difficult due to the nature of qubits, there has been increasing interest in Noisy Intermediate-Scale Quantum technology: quantum computers that use only 50-100 qubits. As part of this effort, Bravyi, Gosset, and König proved – without any complexity theory assumptions – that constant-depth circuits with bounded fan-in can solve instances of the 2D-Hidden Linear Function problem, while a classical circuit would require logarithmic depth. In other words, they separated the complexity classes NC^0 and QNC^0. I will illustrate the importance of quantum nonlocality in shallow quantum circuits by proving some of their results for small examples.

Stephanie Walker, University of Central Oklahoma
Using Fixed Point Theory to Determine Existence for a Class of Difference Equations

This poster spotlights a process for determining the existence of at least three positive solutions for a particular class of even order nonhomogeneous boundary value problems on a discrete domain using Fixed Point Theory. The method takes advantage of reducing the even order difference equation into a system of simpler second order equations and then transforming this new system so that it is subject to homogeneous boundary conditions. We then create a specific operator and cone that meet the criteria of the Guo-Krasnosel'skii Fixed Point Theorem. This allows us to apply the theorem multiple times, guaranteeing a minimum of at least three distinct solutions. As a result, we conclude that although solutions to this type of boundary value problem exist, they are not unique.

Alyssa Watson, Pacific University
Graph Pebbling

Graph Pebbling is an area of study in graph theory in which pebbles are placed in a variety of configurations on the vertices of a given simple connected graph. An interesting application is using graph pebbling to distribute troops or fuel, making sure that you have enough to spare in order to make it. A pebbling move takes two pebbles from one vertex and adds one to an adjacent vertex, and a vertex is reachable if we can move a pebble to it through a series of pebbling moves. We say the pebbling number of a graph is the minimal number of pebbles required such that for any configuration of the pebbles, any vertex could be reached using pebbling moves. There are extensions to the pebbling number, such as the optimal pebbling number, the cover pebbling number, and the two-pebbling property; and there known results for many classes of graphs. We investigate some of the properties of this seemingly simple game and the applications and extensions of it.

Madeline Weinstein, Northeastern University
The Security of Key Exchanges in Polycyclic Group-Based Cryptography

When two parties wish to communicate private information via an insecure channel, they have two options: they can either use a public key cryptosystem in order to transmit their messages, or execute a protocol to create a secret key to be used together with a symmetric key cipher. In this project, we will explore the security of protocols for the key exchange featured in the latter option, specifically those which rely on polycyclic groups.

While cryptanalysis has revealed that several types of group-based cryptosystems are not secure against attacks, certain classes of polycyclic groups appear to be suitable. Polycyclic groups are finitely presented and feature solvable word, conjugacy, and isomorphism decision problems, which builds a case for their resilience against many algorithms. This project focuses on the complexity of the conjugacy problem in one class of polycyclic groups.

Ella White, Coe College
Diamond Sampling: A Girl's Best Friend

While diamonds are said to be a girl's best friend, women in mathematics can find a friend in diamond sampling. Diamond sampling is a method that helps determine the maximal entries of a large network matrix after multiplication with itself. The goal of this project is to find a similar algorithm that determines the maximal entries of a large matrix after repeated multiplication with itself k times. Part of our investigation involved analyzing the accuracy of the diamond sampling algorithm to identify the largest entries of the squared matrix. We then applied the algorithm to a real-world network and evaluated the accuracy.

Shannon Yeakley, University of Central Oklahoma
A Spatial and Longitudinal Analysis of Firearms Casework in Texas

Project SCHOLAR is an undergraduate student statistical consulting program in the Department of Mathematics and Statistics at the University of Central Oklahoma, where students are split into teams to work on projects along with an advisor. One of these groups was asked to assist a Firearm and Tool Mark Examiner from the Plano Police Department (PD) in Texas. The provided data is from a seven-year period during which the Plano PD was contracted by other PDs and some Federal agencies in the surrounding counties to assist with ballistic analysis. The SCHOLAR group has been asked to clean the data, and calculate percentages of cases from agencies outside of the Plano PD. They have also been asked to analyze changes in case completion times over time, and identify significant differences in case completion times (if they exist) by submitting agency.This presentation will detail the results of this analysis.

Amber Young, University of Central Oklahoma
Modeling Measles Vaccination and Outbreak

Measles is a highly contagious infectious disease with symptoms such as cough, fever, and a characteristic rash, with the possibility of more severe complications such as pneumonia, brain damage, deafness, and even death. Although measles was declared eliminated from the United States in 2000, there are over 1,000 cases this year alone. This research aims to use mathematics to better understand the transmission of measles. Differential equations are used to model the transmission of measles in a population. Model variables include susceptible, vaccinated, infectious, and recovered individuals. The model is solved numerically, producing plots of the variables as functions of time. Steady state and bifurcation analysis are used to provide more insight into the effect two model parameters (the rate of vaccination and the rate of infection) have on the number of individuals with measles. This set of differential equations can be used to determine the fraction of the population that needs to be vaccinated to achieve herd immunity and prevent the spread of measles in a population. The cost of a measles outbreak is also modeled, and results are presented for both open and closed populations.

Camille Zaug, Seattle University
Comparisons of Generalizations of the NLS to Ocean Data

The nonlinear Schrödinger equation (NLS) describes the evolution of small-amplitude waves on deep water. Previous work has shown that dissipative generalizations of the NLS are effective models at wave tank scales. Extending this work, we examine the efficacy of these equations at modeling waves at oceanic scales. In 1966, Snodgrass et al. collected wave spectra at six great-circle locations from storm-generated Pacific Ocean swell propagating northwards. Using the data at the southernmost station as an initial condition, we use NLS, the dissipative NLS, the Dysthe equation, the viscous Dysthe equation, the dissipative Gramstad-Trulsen equation, and the Islas-Schober equation to numerically evolve the data via a sixth-order operator splitting algorithm. In this talk, we introduce NLS and its generalizations, discuss our methods of processing ocean data, and show that dissipative models much more accurately model the ocean waves.