SUNMARC 2024 PROGRAM & ABSTRACTS

The rooms are equipped with a PC connected to the internet. The speakers can use a USB drive or their personal computer for the presentations.
Espresso and Tea will be available in the lounge next to SMLC 356 on the 3rd floor.

1. Program

1.1. **FRIDAY, APRIL 5.**

Of interest: Department Colloquium, Nicola Garofalo (University of Padova & Arizona State University), *Heat asymptotics in sub-Riemannian geometry*, 3:00pm to 4:00pm, SMLC 356.

5:00-6:30 pm	SMLC Atrium	Registration/Walk around campus
6:30–7:15 pm	SMLC Atrium	Dinner
7:15–8:15 pm	SMLC 102	Plenary Talk: Sam Mundy, Princeton University, *Number theory, and a journey towards its research*
8:30–9:30 pm	SMLC 102	Math Game

1.2. **SATURDAY, APRIL 6.**

8:15–8:30 am	SMLC 102	Welcome
8:30–9:30 am	SMLC 102	Plenary Talk: Nicola Garofalo, University of Padova & Arizona State University, Title The restriction problem for the Fourier transform
9:30-10:00 am	SMLC Atrium	Poster Session

Nisa Aliyeva, University of Arizona, *Common Statistical Methods in Research Concerning Psychiatric Assistance Dogs for Veterans with PTSD.*
Amelia Edwards, Arizona State University, *Coherence-based Change Detection for Sea Ice Imagery*
Hugo Saavedra, University of New Mexico, *Extremal Problems for Chebyshev Polynomials*
Amari Stepanek, Colorado State University, *Exploring the "Base Prime" Number System*

10:00–10:30 am	SMLC Atrium	Coffee break

Session 1, Saturday Morning, SMLC 102. Chair: Sundar Tamang

10:30-10:50 am	John Hyde & Brennan Mai, Arizona State University, *Modeling, Fitting, and Predicting Population Dynamics in Tribolium Confusum*
10:50-11:10 am	CJ Chen, University of Arizona, *Fluorescence of Anthocyanins*
11:10-11:30 am	Giorgio Simoncioni, U.S. Air Force Academy, *3N+1: The Four Step Plan to Fame and Fortune*
11:30-11:50 am	Rachel Wissenbach, Arizona State University, *Coral Food Webs Under Stoichiometric Constraints*

Date: April 5, 2024.

Session 2, Saturday Morning, SMLC 356. Chair: Wenbo Tang

10:30-10:50 am	Stone Fields, Texas Tech University, *A New Variational Approach to Grim Reaper Curves*
10:50-11:10 am	Alexander Nez, Northern Arizona University, *Measles Meta-population Model Dynamics: Developing Realistic Movement Models to Assess Measles Spatial Spread Potential*
11:10-11:30 am	Marcus Cruz, Arizona State University, *The Effects of Advection on Heat Increase in a Growing Urban Area*
11:30-11:50 am	Nicolaas Koers, University of New Mexico, *Mathematical Inquiries of Minecraft Breeding*

12:00–1:30 pm	SMLC Atrium	Lunch
1:30–2:30 pm	SMLC 102	Plenary Talk: Katherine Kosaian, Iowa State University, *Formalizing mathematics, ft. Isabelle/HOL*
2:30–3:00 pm	SMLC Atrium	Poster Session Continued, See above for titles
3:00-3:30 pm	SMLC Atrium	Coffee break

Session 3, Saturday Afternoon, SMLC 102. Chairs: Patrick Shipman 3:30-4:30 pm;
Wenbo Tang 4:40-5:40 pm

3:30-3:50 pm	James Cash, Texas Tech University, *Concurrent CNN+ResNet Model for Signal Separation*
3:50-4:10 pm	Shambhavi Srivastava, University of Arizona, *Advancing Gravitational Wave Detection with Topological Data Analysis and CNNs*
4:10-4:30 pm	Delany Finley, U.S. Air Force Academy, *Modeling Bipolar Disorder: The Mathematics of Highs and Lows*
4:30-4:40 pm	Break
4:40-5:00 pm	Avery Drennan, Northern Arizona University, *Integrative Forecasting of Flu Transmission: Merging Statistical Regression and Compartmental Models through Advanced Particle Filtering*
5:00-5:20 pm	Zachary Turner, Arizona State University, *On the Uncertainty in Pulmonary Hemodynamics Due to Medical Imaging*
5:20-5:40 pm	Keerthana Kumar, Arizona State University, *The Keep in School Shape Program: How a Calculus KiSS a day may keep learning loss away*

Session 4, Saturday Afternoon, SMLC 356. Chair: Mychael Smith.

3:30-3:50 pm	Franklin Pezzuti Dyer, University of New Mexico, *Algebraic structure of asymptotic growth orders*
3:50-4:10 pm	Cannon Turner, U.S. Air Force Academy, *Reflecting on Coxeter Groups*
4:10-4:30 pm	Ben Kussmann, Mesa Community College, *Getting to the Root of It – Measuring Polygons with Pure Algebra*
4:30-4:40 pm	Break
4:40-5:00 pm	Ian Kilty, Colorado State University, *Open Source Computational Number Theory*
5:00-5:20 pm	John Rafael Munoz-Grenier, University of Arizona, *Formalizing Mathematics in Lean*
5:20-5:40 pm	Judah Towery, University of New Mexico, *Formal Mathematics and the Lean Proof Assistant*

5:40-7:00 pm	SMLC Atrium	Dinner
7:00-9:00 pm	SMLC 102	Movie Night

1.3. **SUNDAY, APRIL 7.**

Session 5, Sunday Morning, SMLC 102. Chair: Janet Vassilev.

8:30-8:50 am	Taylor Daack, U.S. Air Force Academy, *Analytic number theory and the circle method*
8:50-9:10 am	Emerald Davis, Mario Ochoa-Dominguez and Daniel Zieske, Doña Ana Community College, *Finding explicit generators in the homology of clique complexes*
9:10-9:30 am	Jacob Cooper & Ethan Leventhal, Arizona State University, *Binomial Edge Ideals: Graph Theory Meets Abstract Algebra!*
9:30-9:50 am	Isa Chou, University of New Mexico, *Mathematical beauty, as told by Euclid, Erdős and Furstenberg*

Session 6, Sunday Morning, SMLC 356. Chair: Kurt Herzinger

8:30-8:50 am	Tara Zurick, Northern Arizona University, *New Results on Sylver Coinage When 4 Has Been Played, Part I*
8:50-9:10 am	James Warner, Northern Arizona University, *New Results on Sylver Coinage When 4 Has Been Played, Part II*
9:10-9:30 am	Natalie Burton, Northern Arizona University, *New Results on Sylver Coinage When 4 Has Been Played, Part III*
9:30-9:50 am	Morgan Boyers, Northern Arizona University, *New Results on Sylver Coinage When 4 Has Been Played, Part IV*

10:00-10:30 am	SMLC Atrium	Coffee Break
10:30-11:30 am	SMLC 102	Plenary Talk: John N. Shadid, Sandia National Labs, *On Scalable Simulation Methods for MHD Modeling of Magnetic Confinement Fusion (MCF) Energy Systems*

Session 7, Sunday Morning, SMLC 102. Chair: Sundar Tamang

11:30-11:50 am	Juniper Neff, Arizona State University, *Fostering Belonging in the Math Classroom*
11:50-12:10 am	Jake Kerby, Mesa Community College, *Squigonometric Functions, a Superset of Trigonometric Functions*

Session 8, Sunday Morning, SMLC 356. Chair: Dimiter Vassilev.

11:30-11:50 am	Harold Margeta-Cacace, Texas Tech University, *A Numerical Comparison of Deep Ritz Networks and Physics-Informed Neural Networks for Modeling High-Frequency and Multiscale Differential Equations*
11:50-12:10 am	Eric Dudebout, Arizona State University, *Mathematical Model for TRPM8 Dynamics in Cold Sensory Neurons*

12:10-1:30 pm	SMLC Atrium	Lunch and Conference Closure

END OF CONFERENCE. HAVE A SAFE TRAVEL BACK HOME!

ABSTRACTS

2. Abstracts - Planary Talks

2.1. **Nicola Garofalo, University of Padova & Arizona State University, *The restriction problem for the Fourier transform.***

2.2. **Katherine Kosaian, Iowa State University, *Formalizing mathematics, ft. Isabelle/HOL.***
Abstract: Many mathematical algorithms are used in safety-critical contexts. Correctness of these algorithms, and the mathematical results underlying them, is crucial. In formal methods, a piece of software called a theorem prover can be used to formally verify algorithms. In this approach, code for an algorithm is accompanied by a rigorous proof of correctness that only depends on the logical foundations of the theorem prover. Algorithms that have been verified in this way are highly trustworthy and thus safe for use in safety-critical applications. The theorem prover Isabelle/HOL is well-suited for formalizing mathematics. This talk will motivate formalized mathematics, exhibit how mathematics is formalized in Isabelle/HOL, and discuss the challenges that may arise, with a focus on three different use cases: 1) verifying algorithms for real quantifier elimination, 2) verifying Coppersmith's method, 3) verifying Pick's theorem.

2.3. **Sam Mundy, Princeton University, *Number theory, and a journey towards its research.***
Abstract: Number theory is, at least in its history, concerned with properties of integers and the equations they satisfy. It is a beautiful area of pure mathematics, though some like to say that "number theory is applied math!" This is, of course, a joke, but it has a kernel of truth which is reflected in the following fact: From a modern standpoint, research in number theory receives a remarkable amount of input from a whole host of other diverse areas of mathematics. I will describe some of the first problems in the history of modern number theory whose solutions received significant input from other areas of math, both analytic and algebraic. At the same time, I will describe how these problems, as well as the people around me, helped motivate me to pursue research in number theory.

2.4. **John N. Shadid, Sandia National Laboratories, & University of New Mexico, *On Scalable Simulation Methods for MHD Modeling of Magnetic Confinement Fusion (MCF) Energy Systems*.***
Abstract: Continuum plasma physics models are used to study important phenomena in astrophysics and in technology applications such as magnetic confinement (e.g. tokamak), and pulsed inertial confinement (e.g. NIF, Z-pinch) fusion devices. The computational simulation of these systems requires solution of the governing PDEs for conservation of mass, momentum, and energy, along with various approximations to Maxwell's equations. The resulting systems are characterized by strong nonlinear coupling of fluid and electromagnetic phenomena, as well as the significant range of time- and length-scales that these interactions produce. For effective long-time-scale integration of these systems some aspect of implicit time integration is required. These characteristics make scalable and efficient parallel iterative solution, of the resulting poorly conditioned discrete systems, extremely difficult.

In this talk I will begin with a brief discussion of plasmas and magnetic confinement fusion (MCF) energy from a very high-level perspective. I will then briefly discuss an implicit resistive magnetohydrodynamics (MHD) formulation based on a variational multiscale (VMS) finite-element (FE) approach. The solution of the strongly coupled highly nonlinear discretized system is achieved with a fully-coupled Newton nonlinear iterative method. The resulting large-scale sparse linear algebraic systems are iteratively solved by a GMRES Krylov method, preconditioned by approximate block factorization (ABF) and physics-based preconditioning approaches. To demonstrate the flexibility and performance of these methods we consider application of these techniques to various forms of resistive MHD models for challenging prototype plasma problems. These include computational results relevant to aspects of magnetic confinement fusion applications. Results are presented on robustness, efficiency, and the parallel and algorithmic scaling of the solution methods. This work is collaborative with Jesus Bonilla, Edward Phillips, Peter Ohm, Michael Crockatt, Roger P. Pawlowski, R. Tuminaro, Jonathan Hu, Xinazhu-Tang, and Luis Chacon.

* This work was partially supported by the U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research, Applied Mathematics Program. It has also been partially supported by the U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research and Office of Fusion Energy Sciences, Scientific Discovery through Advanced Computing (SciDAC) program.

3. Abstracts - Posters

3.1. **Nisa Aliyeva, University of Arizona, *Common Statistical Methods in Research Concerning Psychiatric Assistance Dogs for Veterans with PTSD*.**
Abstract: In 2019, 6,261 US veterans died by suicide – nearly double the rate among US civilian adults. Existing evidence-based treatments for posttraumatic stress disorder (PTSD), although effective for some, have dropout rates up to 54 % and nonresponse rates up to 50 %. Thus, there is a critical need to identify and evaluate additional effective interventions for PTSD. One of which is a partnership with a psychiatric assistance dog. Although early research has found that assistance dog partnership may be associated with reduced PTSD symptom severity, further evidence is still needed. The goal of this project will be to assess data analytic procedures, statistical evaluation methods, and limitations of research regarding psychiatric assistance dogs for veterans with PTSD. Papers on Psychiatric Assistance Dogs for Veterans with PTSD were selected from a meta-analysis of assistance dogs for military veterans with PTSD and sorted by design into 3 major categories: qualitative, quantitative, and mixed-method studies. We reviewed 25 studies with psychiatric assistance dogs for veterans with PTSD (total of 1564 participants). Measures from a study in "Current Practices in Data Analysis Procedures in Psychology" were used to identify DAPs (Data Analysis Procedures) in each study to calculate the frequency of the methods utilized across all publications. Finally, we calculated the frequency of each DAP, as well as the PTSD Severity Quantifier, and Software package used. We displayed our final computations as a bar-chart plot made using R. Further research will look into the limitation, conclusion, and discussion sections of each study, which were analyzed to find overarching themes that challenged the generalizability of outcomes obtained by the research.

3.2. **Amelia Edwards, Arizona State University, *Coherence-based Change Detection for Sea Ice Imagery*.**
Abstract: This study focuses on images of sea ice obtained using optical photographs or radar images from aircraft or satellites. The goal is to develop foundational understanding on detection and localization of changes in the ice surface using a sequence of two or more images of the same place taken at different times. It begins with a review of a statistical method, magnitude-squared coherence (MSC) estimation, for comparing two signals or images that is well established in connection with applications in multi-channel radar.

3.3. **Hugo Saavedra, University of New Mexico, *Extremal Problems for Chebyshev Polynomials*.**
Abstract: We will discuss problems for which classical Chebyshev polynomials are extremal, and extensions to a multi-interval setting.

3.4. **Amari Stepanek, Colorado State University, *Exploring the "Base Prime" Number System*.**
Abstract: We present a unique system for representing numbers, termed "base prime," which expresses prime factorization. We explore the relationship between a written representation of a number and its actual value through different bases, including base prime. This results in numbers that have the same representation in both base prime and another base. We term these numbers "equivalent." We present several restrictions that equivalent numbers must follow as well as algorithms for discovering them.

4. Abstracts - Student Talks

4.1. **Morgan Boyers, Natalie Burton, James Warner and Tara Zurick, Northern Arizona University, *New results on Sylver coinage when 4 has been played I-IV*.**

Abstract: In the game of Sylver coinage, two players alternate choosing positive integers. On each turn, all positive integers which can be expressed as a linear combination, with non-negative integer coefficients, of all previously chosen integers are removed from play. The player that must choose the number 1 loses the game. In this talk, the second in a series of 4 consecutive talks on Sylver coinage, we will discuss known strategies and explain the four research problems that our group is investigating.

4.2. **James Cash, Texas Tech University, *Concurrent CNN+ResNet Model for Signal Separation.***
Abstract: It is a common problem in the field of signal analysis to pinpoint overlapping waves, called signal separation. 1D convolutional neural networks are a popular approach for analyzing photon pulse signals, as they effectively capture the inherent one-dimensional 'image' structure of the data. If additional 'vector' information about the overlapping pulse is available, it can be beneficial to combine this knowledge with the convolutional processing for improved analysis. Therefore, I introduce a concurrent CNN+ResNet model which processes image+vector data (respectively) in separate streams, and strategically integrates the vector processing into the CNN channels for enhanced performance.

4.3. **CJ Chen, University of Arizona, *Fluorescence of Anthocyanins.***
Abstract: Anthocyanins are a type of water-soluble plant cell pigment. They are principally responsible for the beautiful pink, red, purple, and blue colors found in flowers, fruits, leaves, and stems throughout the plant world. These pigments undergo a series of pH-sensitive structural transformations that may be observed via color changes, which can be modeled using a system of nonlinear ODEs. In this talk, we discuss extending the model to include fluorescence.

4.4. **Isa Chou, University of New Mexico, *Mathematical beauty, as told by Euclid, Erdős and Furstenberg.***
Abstract: What is a proof? The answer might seem obvious: a chain of formal implications towards a result, verifying its absolute truth. But this rarely matches the handwavy, dynamic proofs we see in the classroom. These are appeals to intuition and understanding; rarely ever is a mathematical theory formally derived from a set of axioms. Leaps in an argument are expected and used tastefully by researchers and educators. Moreover, if proofs were an exercise in verification, there would be no incentive to prove something twice. There is nothing lacking about Euclid's proof, given in 300BC. Not only is it logically sound, it is concise, versatile, and appeals to intuition. It is so beautiful it is featured first in Erdős' theoretical collection of proofs approved by God. Yet there was incentive for Erdős to prove the result differently in 1938, for Furstenberg to do it again in 1955, for Gilchrist to do it again in 2007, and so on. There is aesthetic value in proofs. Mathematicians scorn ugly proofs as by "brute force," and describe exciting ones as "elegant" or "deep." To me, proofs are best characterized as jokes; there is some amount of shared context, a buildup, and a punchline. Thus, though they provide no new results, the value of Furstenberg's and Erdős' proofs come directly from their novelty. The depiction of a mountain by one impressionist painter does not prevent another from portraying it in a distinct, equally captivating manner.

4.5. **Jacob Cooper and Ethan Leventhal, Arizona State University, *Binomial Edge Ideals: Graph Theory Meets Abstract Algebra!***
Abstract: Binomial edge ideals are the perfect introduction to the connection between graph theory and algebraic geometry. We study the multidegree of these ideals, which for an expert is a powerful geometric invariant with wide-reaching applications in algebraic geometry, but for the curious is just a surprisingly interesting and accessible list of numbers! We introduce some basic concepts in graph theory and demonstrate how they can help us compute the multidegrees of graphs, then finish with a show-and-tell of our favorite graphs with the most interesting multidegrees!

4.6. **Marcus Cruz, Arizona State University, *The Effects of Advection on Heat Increase in a Growing Urban Area.***
Abstract: The urban heat island effect is a phenomenon where cities experience higher temperatures than those observed in surrounding rural areas. It is caused by the differences in building material and the

ways they absorb, store, and emit heat. While this phenomenon explains the increase in the minimum temperatures in cities compared to nearby rural areas, it does not explain why these minimums continue to rise in already-developed areas such as Phoenix. Our team's objective was to explain this continued increase in temperatures. We simulated the minimum temperature increase at locations in cities surrounded by urbanization. The simulations were conducted over the time period June 1, 2018 at 12 UTC to June 7, 2018 at 0 UTC. They were configured with five scenarios: real urbanization, no urbanization, and urbanization removed outside a disk centered on Sky Harbor Airport with a radius of 16-, 8- and 4-kilometers. The domains use resolutions with grid spacing of 18, 6, and 2 kilometers. The outermost WRF domain is forced by initial and time-dependent boundary conditions extracted from the European Center for Medium-Range Weather Forecast (ECMWF) reanalysis. The other nested domains were driven by initial and boundary conditions interpolated from the parent WRF domain. The external time-dependent forcing data included relevant surface and upper air meteorological variables such as temperature, pressure, relative humidity, and wind velocities among other variables. The WRF simulations showed that the nighttime minimum temperature was increasing as the amount of urbanization surrounding the airport increased. Our hypothesis is that the continuing heat increase is caused by advection of air originating from rural regions and traveling over larger urbanized areas before reaching locations at the center of cities. (Joint with Vani Segura Fuentes, Faith Hsia, Kevin Lopez, and Dr. Mohamed Moustaoui)

4.7. **Taylor Daack, U.S. Air Force Academy,** ***Analytic number theory and the circle method.***
Abstract: We will explore the roots of number theory and its connection to analysis, motivated by some problems. We will then discuss techniques pioneered in the early twentieth century, and ties to applications today.

4.8. **Emerald Davis, Mario Ochoa-Dominguez and Daniel Zieske, Doña Ana Community College,** ***Finding explicit generators in the homology of clique complexes.***
Abstract: We are studying various topological properties of graph complexes, which are simplicial complexes derived from undirected graphs. Specifically, we're using the Smith normal form of matrices to find explicit generators in the ordinary homology with integer coefficients. By investigating the topology of these complexes, we gain insights into the structure of two distinct classes of graph complexes: namely, clique complexes and neighborhood complexes. This allows us to obtain information about their homotopy types.

4.9. **Avery Drennan, Northern Arizona University,** ***Integrative Forecasting of Flu Transmission: Merging Statistical Regression and Compartmental Models through Advanced Particle Filtering.***
Abstract: Disease surveillance is essential for proactive public health measures, and it plays a crucial role in shaping health decisions by detecting disease trends. In this study, we developed a novel forecasting framework by combining the strengths of two commonly used approaches: statistical regression model and compartmental model, enabling us to capture both real-time changes and long-term trends in disease transmission. We first revised the particle filter algorithm and used it to infer the time dependent transmission rate. As the numerical round-off of the likelihood could cause sample degeneracy and impoverishment, it necessitates a new weight computation and resampling scheme in the particle filter algorithm. Our scheme simultaneously infers both time-dependent and static parameters from hospitalization data. With the inferred time-dependent transmission rate, we then used a penalized likelihood framework integrated with a Genetic Algorithm, ensuring accurate forecasting by capturing multiple change points in the transmission rate. By reincorporating the forecasted transmission rates into the SIR model, we achieved enhanced precision in our predictions for flu progression.

4.10. **Eric Dudabout, Arizona State University,** ***Mathematical Model for TRPM8 Dynamics in Cold Sensory Neurons.***
Abstract: Cold sensory neurons (CSNs) are a subset of the somatosensory system that encode cold temperature via electrochemical firing patterns. Exhibiting oscillatory bursting at lower temperatures, tonic firing at higher temperatures, and dynamic responses to changing temperatures, CSNs exhibit complex

behavior that is dependent on the activation of cold-sensitive ion channels. The primary channel responsible for this cold thermo-transduction in mammals is the transient receptor potential melastatin 8 (TRPM8) channel. TRPM8 is a polymodal, nonselective cation channel with an activation that is dependent on a variety of signals, including the membrane potential, calcium concentration, temperature, and ligands such as menthol. Mathematical modeling provides valuable insight into biochemical phenomena such as the dynamics of these channels during complex firing patterns, which is difficult to observe experimentally. Here, we propose a conductance-based model of a CSN consisting of a system of ordinary differential equations, specifically including equations that characterize the dynamics of the TRPM8 ion channel. We fit the parameters of the TRPM8 ion channel model to replicate experimental TRPM8 transfected HEK293 cell electrophysiology data using a genetic algorithm. Using KMeans clustering, we note eight clusters consisting of parameter sets that provide a good fit to these data sets. By integrating our TRPM8 channel model into a two-compartment CSN model, we are able to replicate responses to temperature, including hysteresis seen during temperature ramp simulations, and make predictions about the dynamics of CSN firing patterns in response to multiple stimuli.

4.11. **Stone Fields, Texas Tech University, *A New Variational Approach to Grim Reaper Curves*.**
Abstract: The classical grim reaper curves are known in differential geometry as the only translating solitons to the mean curvature flow in the plane, but have also recently been discovered to be critical points of an entropy-like energy functional, and have also gained attention for their unexpected connections to thermodynamics, information theory and Hamilton-type entropy. We introduce a novel variational approach to studying these solitary translating curves using the concept of p-elasticae, the first variation formula and properties of the Riemann curvature tensor. We show that these solitary translating curves are periodic solutions to the Euler-Lagrange equations associated with this functional in certain Riemannian and Pseudo-Riemannian 2-space forms, and obtain closed periodic solutions when they exist.

4.12. **Delaney Finley, U.S. Air Force Academy, *Modeling Bipolar Disorder: The Mathematics of Highs and Lows*.**
Abstract: Bipolar disorder is a mental disorder defined by both episodes of low depression and mania, and is classified into two categories: type one and type two. This paper focuses specifically on type two bipolar, which is unique in the fact that a person who is diagnosed with type two is one who swings back and forth between the periods of depression and mania on a regular basis, in an oscillating manner. Through the use of three different, second order nonlinear ordinary differential equations, the Van Der Pol, Lienard, and Rayleigh oscillators, we can seek to model Bipolar behavior and analyze the effects that the parameters play on both the solution and its respective limit cycles. Through the use of varied equations and parameters, we can demonstrate certain patient cases and outcomes, find equilibrium points, and analyze the stability or instability of the amplitude of a patient through the use of limit cycles.

4.13. **John Hyde and Brennan Mai, Arizona State University, *Modeling, Fitting, and Predicting Population Dynamics in Tribolium Confusum*.**
Abstract: In this study, we seek to model the relationships between the larvae, pupae, and adult stages of a lab population of Tribolium Confusum using MatLab modeling software. Tribolium Confusum is a species of beetle that has been used in population analysis since the 1920s, and the species has been critical in furthering our understanding of modern population analysis. In our research, we created more granular models, dividing the adult populations into age groups as we predict different behavior between these demographics. However, when fitting our models to the data, we found that a simpler model gave us a comparable level of accuracy. Our goal with this research is to lay the groundwork for the future development of a universal population model.

4.14. **Jake Kerby, Mesa Community College, *Squigonometric Functions, a Superset of Trigonometric Functions*.**
Abstract: The equation of a circle can be defined as $1 = x^n + y^n$ when $n = 2$. But what happens when

n is any natural number besides two? Are there differences when n is even or odd? As long as n is an even power, the standard circle starts shape-shifting, gradually turning into a square. The shapes between a circle and a square are broadly known as squircles. There exists a superset of functions that trigonometric functions belong to that describe these squircles as long as n is an even natural number.

4.15. **Ian Kilty, Colorado State University,** ***Open Source Computational Number Theory.***
Abstract: I will talk about a project on open source software in computational number theory and the relation between high performance computing and readability within programming languages in terms of computing "hard" number theory problems.

4.16. **Nicolaas Koers, University of New Mexico,** ***Mathematical Inquiries of Minecraft Breeding.***
Abstract: Minecraft animal breeding takes every unique pair of animals and produces a third animal. I call the sequence populations growing in this fashion the Minecraft Breeding Sequences, and their growth is exponential save for a slight error, which is the Minecraft Breeding Constant. In this talk I motivate and define breeding sequences and breeding constants. Results on these sequences provide, on the surface level, a way to determine the asymptotic efficiency of breeding a particular population of cows, but on a deeper level are a peculiar number theoretic construction. I will cover results on sequences such as root sequences, the sequences which include all other sequences; parity sequences, which are the breeding sequences reduced modulo 2, and generation of breeding sequences based on finite parity sequences; aperiodicity and difficulties in determining irrationality of breeding constants; relations between sequences; and other properties. To conclude I will introduce some open questions, particularly about breeding constants.

4.17. **Keerthana Kumar, Arizona State University,** ***The Keep in School Shape Program: How a Calculus KiSS a day may keep learning loss away.***
Abstract: If you don't use it, you lose it! It's true for physical skills, but cognitive skills – especially math - also need to be regularly rehearsed to stay fresh, or pronounced learning loss may occur. The Keep in School Shape (KiSS) Program delivers daily review opportunities via text or email to students enrolled in an introductory calculus course sequence over academic breaks so that they maintain foundational skills for future coursework. In this interactive session, I will demonstrate how the KiSS Program works, present data showing how students engage with the KiSS Program, and discuss the potential of programs like this to reach students beyond the ASU Mathematics community.

4.18. **Ben Kussmann, Mesa Community College,** ***Getting to the Root of It – Measuring Polygons with Pure Algebra.***
Abstract: We provide a construction for functions whose zeros correspond to side lengths and diagonals of regular polygons. These functions resemble sine in their range, local extrema, and derivatives. In showing that certain expressions of the form sin(pi/n) are algebraic, polynomial factors of members of this group of functions can serve as an alternative to the commonly used approach involving the roots of unity.

4.19. **Harold Margeta-Cacace, Texas Tech University,** ***A Numerical Comparison of Deep Ritz Networks and Physics-Informed Neural Networks for Modeling High-Frequency and Multiscale Differential Equations.***
Abstract: Neural networks have proven quite effective in the context of numerical solutions to differential equations, particularly through the use of physics-informed neural networks (PINNs). However, PINNs encounter significant challenges when modeling multiscale and high-frequency solutions, even with mitigating strategies like Fourier-feature mappings. Thus, alternative network architectures are needed. In this work, we numerically compare the performance of the one such architecture, the Deep Ritz Network (DRN), with that of the PINN for ODEs and PDEs whose solution is multiscale or high-frequency, and observe superior errors for the DRN in such cases. Additionally, we show how hard constraints and Fourier-features universally improve the suitability and fidelity of the eigenvectors of the neural tangent kernel (NTK) matrix, which in turn allows for faster and more accurate convergence.

4.20. **John Rafael Munoz-Grenier, University of Arizona,** ***Formalizing Mathematics in Lean.***
Abstract: A discussion of how the Lean theorem prover encodes proofs as functions, and the tradeoffs encountered using machine-assisted proof instead of human language proofs.

4.21. **Juniper Neff, Arizona State University,** ***Fostering Belonging in the Math Classroom.***
Abstract: The compelling question is "How can a sense of belonging be brought to the Math classroom?" This topic centers at the intersection of mathematics, history, and education. The mathematics field is overwhelmingly portrayed as antiquated, white, and male. There is a lack of history taught in the math classroom. As such, adding history that counters the perceptions of who belongs in mathematics will engage students who had not previously felt represented in the field. In addition, students who lack interest in mathematics may find themselves interested in the historical aspects, leading to more retention in the classroom. The main goals of this project are to create an addition to the mathematical curriculum that can be added as a starter to classroom discussions or a warm up before a lecture. The ideal form is a laminated flip book consisting of photos, descriptions, and fun facts about 52 mathematicians (one per week) from diverse time periods, countries, and backgrounds.

4.22. **Alexander Nez, Northern Arizona University,** ***Measles Meta-population Model Dynamics: Developing Realistic Movement Models to Assess Measles Spatial Spread Potential.***
Abstract: This study develops a stochastic compartmental model to understand measles transmission dynamics among individuals aged 0 to 18 years, utilizing 2019 Census data. The population was divided into seven compartments: Susceptible (S), Exposed (E), Infected (I), Recovered (R), First Vaccine-Prone (V_{P1}), First Vaccine-Responsive (V_{R1}), and Second Vaccine (V_2). We assess the impact of gravity and school commuter movement models on disease spread within the population. The gravity model, influenced by gravity weight ϕ, predicts movement between census block groups. Conversely, the school commuter matrix, structured around student populations in census block groups and school enrollment data in Maricopa County, uses a Voronoi diagram to create an $n \times n$ commuter matrix. Incorporating school vaccine data, we identify areas of susceptibility, improving our understanding of at-risk populations.

To model measles spread, we use a tau-leaping algorithm that divides the day into parts: 1/3 for school, 1/2 for post-school movement and interaction, and the remaining time at home. This method provides insight into how susceptible individuals, exposed in various locations, can spread the virus within their census block group upon returning home. Our modeling captures the dynamics of disease transmission, offering insights into its trajectory and behavior.

4.23. **Franklin Pezzuti Dyer, University of New Mexico,** ***Algebraic structure of asymptotic growth orders.***
Abstract: Asymptotic growth orders are often used in theoretical computer science, number theory and combinatorics to compare the growth rates of sequences of numbers. In his undergrad honors thesis, UNM student Franklin Pezzuti Dyer has been exploring a framework that treats growth orders as "first class citizens" comprising their own kind of number system. This talk will describe, at a high level, some of the operations that can be defined on growth orders, and the curious properties of the algebraic structures that they give rise to.

4.24. **Giorgio Simoncioni, U.S. Air Force Academy,** ***3N+1: The Four Step Plan to Fame and Fortune.***
Abstract: The Collatz conjecture is deceptively simple to explain but has remained mere conjecture since 1937. In this talk, we will delve into the difficulties that arise in attempting to prove or disprove the conjecture using traditional methods. Additionally, novel statistical and analytical approaches to the problem are introduced, providing intriguing new angles to this century-old problem and leading the audience to further ponder the conjecture. The intended audience includes everyone from grade-school mathematicians to experienced Collatz enthusiasts.

4.25. **Shambhavi Srivastava, University of Arizona,** ***Advancing Gravitational Wave Detection with Topological Data Analysis and CNNs.***
Abstract: The detection of gravitational waves, as facilitated by the LIGO experiment, has opened new vistas in astrophysics, confirming key predictions of Einstein's general relativity. These waves, however, are incredibly faint and embedded within substantial noise, posing significant challenges for their identification and analysis. Traditional methods, like matched filtering, rely on pre-existing theoretical templates to sift through the noise, a technique that, while effective, has its limitations. My research introduces an innovative approach that incorporates Topological Data Analysis (TDA) and Convolutional Neural Networks (CNNs) to enhance the detection and analysis of gravitational wave signals. By applying TDA, we can extract robust geometric and topological features from the noisy data, revealing potential gravitational wave signatures undetectable by conventional means. Concurrently, CNNs are employed to classify these features, leveraging their superior pattern recognition capabilities. This methodology not only augments the detection sensitivity but also offers a new pathway for analyzing signals without precise templates. In this talk, I will present the pipeline, discuss its theoretical foundation, and share initial results showcasing the efficacy of combining TDA and CNNs in the realm of gravitational wave astronomy.

4.26. **Judah Towery, University of New Mexico,** ***Formal Mathematics and the Lean Proof Assistant.***
Abstract: The rise of formalized proofs in math has massive potential to shape the future of the field as we know it. Mathematics done in proof assistant languages such as Lean have been skyrocketing in popularity recently, and in this talk I will discuss what factors that could be contributing to this explosion. I will describe what the importance of formalization is and why we should bother spending time making formal proofs of our theorems in the first place. Further, I'll talk about the applications of proof assistants in math in terms of math education, AI, reasoning about the correctness of our math, and the de-centralization and crowd sourcing of mathematics. Lastly, I'll give a short demonstration of what it's like to write a formal proof using the Lean proof assistant.

4.27. **Cannon Turner, U.S. Air Force Academy,** ***Reflecting on Coxeter Groups.***
Abstract: I will give an overview on some of the basic principles of Coxeter Groups. Coxeter groups are a specific type of group in group theory with some interesting characteristics and properties. I will discuss some common presentations of Coxeter groups, some examples of Coxeter groups, and how these groups behave.

4.28. **Zachary Turner, Arizona State University,** ***On the Uncertainty in Pulmonary Hemodynamics Due to Medical Imaging.***
Abstract: Chronic thromboembolic pulmonary hypertension (CTEPH) is a fatal but curable disease, causing high blood pressure and unresolved lesions in the pulmonary arteries. One way to reduce lesions is via balloon pulmonary angioplasty (BPA), inserting micro-balloons into the arteries to reduce lesion size. Patients typically undergo several treatments each inserting three balloons. However, there is currently no objective way to identify which lesions to treat to minimize blood pressure and maximize perfusion of the lung. To inform this treatment, we develop a patient-specific fluid mechanics model predicting hemodynamics in geometries extracted from computed tomography (CT) images. Using 3D Slicer, we generate a three-dimensional (3D) volumetric surface from the CT image, and using the Vascular Modeling Toolkit, we extract centerlines and junctions creating a tree. However, obtaining a reliable representation of vascular networks is difficult. There is often significant uncertainty due to multiple overlapping networks and noise in clinical images. Tree labels including vessel radii and length and their uncertainty are obtained using a statistical change point algorithm. This algorithm identifies the segment along each vessel that best represents the vessel radius. We generate 1000 networks by sampling from the distribution of radii from each vessel. For each network configuration, we predict blood pressure and flow in each vessel by solving the one-dimensional Navier-Stokes equations. The microvasculature is represented by an asymmetric bifurcating structured tree in which daughter vessels are scaled relative to their parent. These microvascular trees are attached at the terminal branches of the imaged informed networks, and we solve a linearized wave equation

to predict hemodynamics. Perfusion is determined by projecting average flow and pressure at the end of each vessel onto the 3D lung volume. Results show segmentation quality, network size, and changes in radius and length significantly impact hemodynamics. Future work includes optimizing BPA strategies for CTEPH patients, simulating lesion reduction and its hemodynamic impact, as well as the comparison of different centerline extraction techniques.

4.29. **Rachel Wissenbach, Arizona State University, *Coral Food Webs Under Stoichiometric Constraints*.**

Abstract: Coral reefs are one of the most important and critical ecosystems on the planet which serve as a backbone to oceanic biodiversity. Coral reefs are among the ecosystems that are facing the greatest challenges to their survival. Perhaps the most critical species are the corals themselves. Corals depend on symbi- otic dinoflagellates called zooxanthellae which provide both carbon and essential nutrients to the coral. Using the framework of Ecological Stoichiometry, the study of the balance of essential elements in ecological interactions, we develop and ana- lyze a mathematical model of a coral food web. The model is an 11-dimensional system of ordinary differential equations that tracks the population dynamics of phytoplankton, zooplankton, zooxanthellae, coral, sponges, as well as the phos- phorus in the environment and live and dead biomass. Our model aims to better understand the relationship between a few key reef species and to discover criti- cal thresholds that determine the survival of the various species. We investigate how variations in light and nutrient levels affect population dynamics. The model explores key relationships, such as mutualism between zooxanthellae and coral and competition between coral and sponges. The model sheds light on critical factors influencing the biodiversity of coral reef food webs.