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

University of Puget Sound
Tacoma, Washington
April 1-2, 2005

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

Sponsored by

Mathematical Association of America
University of Puget Sound
Lind-VanEnkevort Fund

University of Puget Sound
Department of Mathematics and Computer Science
Tacoma, Washington
April 1-2, 2005

Friday, April 1

7:45	**Packet Pickup for NExT Participants** *Wheelock Center, Ground Floor, Board Room*	
8:00 2:30	**Project NExT Meeting** *Wheelock Center, Ground Floor, Board Room*	
2:45 5:15	**Minicourse** **Combinatorics** *Thompson 318*	**Minicourse** **Linear Algebra** *Thompson 120*
5:30	**Project NExT Dinner** *Engine House No. 9* *611 North Pine Street*	
7:30 8:00	**Packet Pickup, Late Registration** *Kilworth Chapel Lobby*	
8:00	**UPS-MAA Presentation, Keith Devlin** (1) "How Much Mathematics Can Be For All?" *Kilworth Chapel*	
9:00	**Reception** *Kilworth Chapel Lounge*	

Saturday, April 2

<table>
<tr><td>7:30</td><td></td><td colspan="2" rowspan="2">Section Executive Committee Meeting
Wheelock Center Board Room</td></tr>
<tr><td>8:00</td><td rowspan="2">Coffee
Packet Pickup
Late Registration
Wheelock Student Center Lobby</td></tr>
<tr><td>8:30</td><td colspan="2"></td></tr>
<tr><td>9:00</td><td colspan="3">Welcome, Dean of the University Kris Bartanen
Wheelock Student Center, The Rotunda</td></tr>
<tr><td>9:05</td><td colspan="3">Invited Talk, Jenny Quinn (2)
“Proofs that Really Count”
Wheelock Student Center, The Rotunda</td></tr>
<tr><td>10:30
12:25</td><td colspan="2">Contributed Talks
Thompson Hall
Second and Third Floors</td><td>MAA Books & Gear
Thompson Foyer</td></tr>
<tr><td>12:30</td><td rowspan="2">Lunch
Wyatt Hall Atrium</td><td></td><td rowspan="2">Student Problem Solving Session
Wyatt 109</td></tr>
<tr><td>1:15
2:00</td><td>Business Meeting
Wyatt 307</td></tr>
<tr><td>2:10
3:10</td><td colspan="3">Invited Talk, Frank Farris (3)
“Forbidden Symmetry —
Relaxing the Crystallographic Restriction”
Wheelock Student Center, The Rotunda</td></tr>
<tr><td>3:30
5:25</td><td colspan="2">Contributed Talks
Thompson Hall
Second Floor</td><td>MAA Books & Gear
Th 319</td></tr>
<tr><td>

5:45
6:30
7:15
7:45</td><td colspan="3">Banquet
Marshall Hall, Wheelock Student Center

Social Hour
Buffet Dinner
Section Awards
Video Presentation, Keith Devlin (4)
“Using Math To Beat The Casino”</td></tr>
</table>

Contributed Talks — Morning

	Teaching Math Th 126	**Modeling Contest** Th 322	**Junior Faculty** Th 130	**Student Papers** Th 222	**Research Topics** Th 124	**Student Papers** Th 228
10:30 10:45	Vector Calculus 20 *Dray*	Toll Plaza Simulation 34 *Helmandollar*	Difference Equations 52 *Overdeep*	Convolution Sieve 11 *Buttcane*	Cantor Function 31 *Harper*	Linear Functional 15 *Case*
10:50 11:05	Differential Equations 29 *Hallstrom*	Toll Plaza Optimization 40 *Kranak*	Concepts of Variation 12 *Canada*	Genetic Algorithms 25 *Fitzgerald*	Catalanian Forests 58 *Smiley*	Metric Spaces 51 *Osborne*
11:10 11:25	Friendly Limits 55 *Scott*	Prints Beat DNA 48 *Mixon*	Homotopy Theory 36 *Johnson*	Quadratic Residues 56 *See*	Probabilistic Identities 37 *Kayll*	Conservation Laws 65 *Ventura*
11:30 11:45	Undergrad Matroids 60 *Starr*	Optimal Toll Plazas 14 *Carmichael*	Monge-Ampere Equation 32 *Hartenstine*	Trig of Square Matrices 39 *Kling*	The Fall Factor 17 *Curtis*	Bessel Functions 46 *Martinich*
11:50 12:05	Root Test 44 *Lum*	Modeling Toll Plazas 59 *Smith*	Extra Edge Paradox 41 *Kruczek*	Primitive Tourneys 49 *Morehouse*	Vibrating Beam 6 *Bardsley*	Free Modules 21 *Ellis*
12:10 12:25	Exotic Equations 45 *Lynch*	Queue and A 50 *Musselman*	Graph Algebras 67 *Walter*		Archimedean Globes 19 *DeTemple*	Food Chain Model 53 *Ranola*

Contributed Talks — Afternoon

	Teaching Math	**Student Papers**		**Student Papers**	**Research Topics**	**Student Papers**
	Th 126	Th 130	Th 322	Th 222	Th 124	Th 228
3:30–3:45	Group Exams 35 *Johnson*	Cauchy vs. Convergence 22 *Elmer*		Quintic Insolvability 64 *Tempel*	Graph of a Group 61 *Starr*	DeBono's L-Game 16 *Coblentz*
3:50–4:05	River Crossing Game 13 *Canada*	Cognitive Math 23 *Farnsworth*		Math Service Project 10 *Bittner*	Euler Flows 30 *Hallstrom*	Signal Processing 28 *Green*
4:10–4:25	Math Across Curriculum 43 *Leoni*	Mathlete Project 62 *Stoops*		Sphere Packing 24 *Fisher*	Allen Brain Atlas 33 *Hawrylycz*	Hyperbolic Geometry 47 *McCleary*
4:30–4:45	Differential Forms 9 *Bernhard*	Population Growth 66 *Wahrenbrock*		Combinatorial Flagpoles 54 *Reynolds*	Convex Polyhedra 68 *Williams*	Electrochemistry 26 *Gadd*
4:50–5:05	Active Assessment 5 *Averbeck*	Quantum Mechanics 57 *Shartel*		Matroids, Finite Groups 42 *LeCrone*	Teaching Quaternions 38 *Klassen*	Classifying Knots 8 *Berg*
5:10–5:25	Ill-Conditioning 63 *Stuart*	Grid Robots 18 *Davis*		Tribonacci Sequence 7 *Benim*		Algebra and Symbols 27 *Gelsinger*

Student Problem-Solving Session

This year's MAA Pacific Northwest Section meeting at the University of Puget Sound will include a Student Problem-Solving session. We will have several problems from various sources for students to consider, plus paper and pencils to work with. The session is strictly for fun; we hope to bring together students from different schools to work together on interesting problems.

In addition, problems from the American Mathematical Monthly will also be available; interested students can write up solutions for submission and publication in the Monthly as part of the Pacific Northwest Section Problem-Solving Group.

Here are a couple of sample problems; there will be many more at the meeting.

1. Observe that
$$9^3 + 15^3 + 12^3 = 18^3$$
$$28^3 + 53^3 + 75^3 = 84^3$$
$$65^3 + 127^3 + 248^3 = 260^3$$
Find a generalization. [Source: Five Hundred Mathematical Challenges, Barbeau, Klamkin, Moser, 1995, MAA]

2. Each of the four faces of a regular tetrahedron is divided into four equilateral triangles. You have four colors with which to paint this solid, subject to the following rules: (a) You may only use two colors on each face (b) Each color must be used exactly four times (c) If two triangles share a side, they must be different colors.

   In how many different ways can you paint this tetrahedron according to the rules? [Source: My Best Puzzles in Mathematics, Hubert Phillips ("Caliban"), 1961, Dover]

Be sure to let your students know about this opportunity to get to know students from other schools in a fun, informal setting!

Social Events

Friday Evening Reception
Kilworth Chapel Lounge
Sponsored by the MAA and UPS

Saturday Morning Registration
Wheelock Student Center Lobby
Coffee and Baked Goods

Morning Coffee
Thompson Hall Foyer
Coffee and Baked Goods

Lunch
Wyatt Hall Atrium
Italian Focaccia Sandwich
Tarragon Chicken Salad on Croissant
Roasted Vegetable Focaccia

Afternoon Snack
Thompson Hall Foyer
Cookies and Soft Drinks

Social Hour, Banquet Dinner, Awards Ceremony
Marshall Hall, Wheelock Student Center
Mixed Green Salad
Caesar Salad
Poached Salmon with Red Pepper Sauce
Prime Rib of Beef with Au Jus
Broiled Polenta with Herb and Wild Mushrooms
Baby Carrots with Butter & Dill
Broccoli & Cauliflower Polonaise
Wild Rice Pilaf Blend
Assorted Rolls
Beer, Wine and Soft Drinks
Chocolate Blackout Torte
Colossal Carrot Cake

Abstracts of Invited Talks

(in chronological order)

1 How Much Mathematics Can Be For All?
Keith Devlin, Stanford University

In his book The Math Gene [Basic Books, 2000], Devlin presented an evolutionary argument to show that the basic capacity for mathematical thinking is present in everyone as part of our genetic inheritance. But how much mathematics comes in this way? he now asks. Is there a point beyond which most people will simply never get it? Devlin believes there is sufficient evidence to suggest that the answer may be yes, and that among those parts of mathematics that can possibly be mastered only by a few is at least one topic taught in the middle school.

2 Proofs that Really Count
Jenny Quinn, Occidental College

Every proof in this talk reduces to a counting problem—typically enumerated in two different ways. Counting leads to beautiful, often elementary, and very concrete proofs. While not necessarily the simplest approach, it offers another method to gain understanding of mathematical truths. To a combinatorialist, this kind of proof is the only right one. I have selected some favorite identities using Fibonacci numbers, binomial coefficients, Stirling numbers, and more. Hopefully when you encounter identities in the future, the first question to pop into your mind will not be “Why is this true?” but “What does this count?”

3 Forbidden Symmetry — Relaxing the Crystallographic Restriction
Frank Farris, Santa Clara University

If you look at enough swatches of wallpaper, you will see centers of 2-fold, 3-fold, 4-fold, and 6-fold rotation. Why not 5-fold centers? They cannot occur, according to the Crystallographic Restriction, a fundamental result about wallpaper patterns, which are defined to be invariant under two linearly independent translations. Even so, we offer convincing pictures of wallpapers with 5-fold symmetry and ask “Who is lying?”. The talk is intended to be accessible to students who know something about level curves in the plane and linear algebra.

4 Using Math To Beat The Casino
Keith Devlin, Stanford University

In the mid-1990s, a team of MIT students took mathematics into the Las Vegas casinos and came home with millions of dollars. They were playing blackjack, using a method based on a mathematical discovery made 40 years earlier by professor Edward Thorp. Keith Devlin will introduce a recent BBC television documentary, ”Making Millions the Easy Way”, that chronicles the 50-year war between generations of mathematically savvy players and the might of the casinos, that culminated in the MIT assault. Afterwards Devlin will comment briefly on the program and lead a short discussion.

Abstracts of Contributed Talks

(in alphabetical order, by presenter)

5 Getting Students Active in Assessment
Pat Averbeck, Edmonds Community College

A grading method will be discussed that transforms the process of returning tests into a learning experience. This method engages students through a petitioning process, where students identify their mistakes and explain their work. By encouraging the students to focus on the test content rather than their score, the negative student-teacher interactions are reduced in intensity and number.

To explore whether the grading method was effective, a student survey was given to 234 students in two classes that utilized the method. An interview with an instructor and a survey with teaching assistants who implemented the grading method were conducted. Finally, a comparison between two classes that used the method and two classes that did not use the method will be completed Winter Term 2005.

The initial results have indicated that this grading method has been effective for student learning. One student wrote, “This [method] was a very effective way to actually make the student ‘care’ or learn from their mistakes and sit down and figure out the error in calculations.” Another wrote, “Rather than throw our tests away, it gave us an opportunity to look over what we did wrong and learn from it.” An instructor using this method stated, “I can get the students to look at their mistakes without the grade inflation from other methods that I’ve used.”

6 What Do a Vibrating Beam and Spring/Mass System Have in Common?: An Algorithm for the Estimation of Parameters in Differential Equation Models
John Bardsley, The University of Montana

We will begin the talk by presenting a simple parameter estimation problem. This problem can be posed as the following question: Can the basic ODE

$$u'' + cu' + ku = 0, \quad u(t_0) = u_0,\, u'(t_0) = 0,$$

be used to model the motion of a vibrating beam. In order to answer this question, a nonlinear least squares problem is formulated, and a trust region implementation of the Levenburg-Marquardt (LM) algorithm is presented for its solution. A straightforward extension of this LM algorithm is then presented that can be used on problems in which the parameters of interest are subject to bound constraints.

7 An Introduction to the Tribonacci Sequence
Robert Benim, University of Portland

The Tribonacci sequence is a simple extension of the Fibonacci sequence, where each member of the sequence is the sum of the previous three members. A few properties of the sequence will be examined, and these will be extended into further sequences of this type.

8 Classifying Knots Using Fundamental Groups
Chelsea Berg, Pacific Lutheran University

Fundamental group theory is often used to determine whether two surfaces are the same or different in topology. Often times it is easy to physically see the differences between surfaces such as a torus and a sphere. However, it is not always as easy to see the differences between knots. Thus fundamental groups provide a nice technique to prove one knot is different than or the same as another knot. This technique will be put to use to prove a very important fact known to knot theorists: a trefoil knot is different than a trivial knot. The trefoil knot and the trivial knot are fairly simple knots, however they are also important. These two knots are the building blocks of many other knots, and their difference is thus fundamental to knot theory.

9 Differential forms: bridging the gap

James Bernhard, University of Puget Sound

While differential forms provide a unified description of many aspects of multivariable calculus, they are so abstract that it is often difficult to understand even what it means to integrate them. In ordinary single-variable calculus, the way an integral is set up is usually by means of a Riemann sum. In the literature, however, the connection between differential forms and Riemann sums seems to have been obscured, if not lost. In this talk, we show how differential forms relate to Riemann sums and consequently how they can be described to students encountering them for the first time, thus bridging the traditional gap between calculus and differential geometry. Our focus here will be primarily on differential 1-forms.

10 A Service Project in Mathematics
Rachel C. Bittner, Gonzaga University

In this presentation, I will discuss my experiences creating curriculum for and implementing a zero hour algebra-skills course at St. Aloysius School. The zero hour program is a nine-week course designed to improve student performance on high school entrance exams and solidify a foundation for further advanced study in mathematics.

11 A Convolution Sieve
Jack Buttcane, Southern Oregon University

The presentation will be on the student's personal work on the Twin Primes Conjecture. A sieve relying on the structure of periodic waveforms under a Fourier transform will be presented. A simple example of the use of the sieve will be given and the talk will conclude with possible methods for applying it to the conjecture

12 Conceptions of Variation: The Case of Preservice Math Teachers
Daniel L. Canada, Eastern Washington University

Recent research has been aimed at finding out how precollege students think about variation, but very little research has been done with the prospective teachers of those students. My current research addresses how preservice teachers think about variation in the three contexts of sampling, data and graphs, and probability situations.

In this session I'll share some of the tasks that I created or modified which proved useful in examining preservice teachers' conceptions of variation in different contexts. Also, some sample responses from my subjects will be given to illustrate the kinds of conceptions that have arisen. I'll also emphasize the use of technology as a direction for future research in this area, and I'll be sharing how the use of Fathom offers possible avenues of new exploration.

13 Deep Thoughts About the River Crossing Game
Daniel L. Canada, Eastern Washington University

In an ongoing attempt to stimulate appreciation for the underlying variation behind seemingly innocuous probabilistic situations, this talk provides a fresh look at a familiar game. Played in undergraduate math classes for preservice teachers as well as in elementary and middle schools, the River Crossing Game essentially depends on the sum of tosses of two fair dice. However, even with a grasp of the overall distribution for the sum of two dice, the strategies for this game are not always as simple as they might seem at first glance.

After motivating the talk by explaining the game and profiling some students' initial strategies, I'll invoke the use of the Fathom software in illustrating a simulation to gain some experimental data for different strategies. The experimental data suggests some counter-intuitive results which are then backed up via an explication of the mathematical principles behind the strategies for the game.

In the end, the River Crossing Game provides a lively and stimulating avenue for developing an appreciation for the key characteristic in stochastical thinking, that of variation.

14 The Optimal Toll Plaza Configuration: Western Oregon University's Solution to the Modeling Contest
*Jennifer Carmichael*and Brian Davis, Western Oregon University*

Often when commuters encounter a toll plaza, they are required to wait in a long queue until they can reach a tollbooth and pay their toll. When the plaza configuration consists of more toll booths than incoming (and outgoing) lanes, the cars must also wait in a queue as they merge and depart the toll plaza. After a discussion of what it means to have an optimal configuration, Western Oregon University's 2005 MCM team will present their model for determining under what conditions it is optimal to have exactly the number of booths as lanes, and when it is optimal to open more booths than lanes.

15 On Determining the Norm of a Linear Functional
J. F. Case, The University of Montana - Missoula

During this talk we will examine bounded linear functionals of the type

$$f(x) = \int_a^b g(t)\,x(t)\,dt$$

where x may be any continuous function on $[a, b]$ and g any may be any given continuous function, and determine $\|f\|$, the norm of f. There are a number of proofs which determine $\|f\|$ in a rather long and technical way. We will show how to determine $\|f\|$ through an elementary method which also holds for any Riemann integrable function. This will be accomplished through the proof of a theorem and three separate extensions.

16 Some Generalizations of de Bono's L-Game
Bayley Coblentz, Linfield College

The combinatorial game known as de Bono's L-Game was designed by Edward de Bono in 1967 as a method to "practice" strategic thinking. His goal was to create a two player game that could be played by anyone because of its simple concept, but that still required a high degree of skill to master. The result was an indeterminate game where two players with perfect ability could play forever. The game consists of two "L-pieces," one for each player, and two neutral pieces that can be used by either player on their turn. Our research focused on the known strategy for playing de Bono's L-Game and how we could apply that knowledge to variations on the game's initial conditions. Specifically, we looked at how the winning strategy would change when we varied the number of neutral pieces.

17 Rock climbing and Differential Equations - The Fall Factor
Wendell D. Curtis, Central Washington University

Rock climbers tie themselves to one end of a rope which is attached to protection devices placed in the rock and held at the other end by a "belayer", whose job it is to stop the rope in the event of a fall. If a climber falls, he will sustain a jolt when the rope stops the fall. It seems reasonable that this jolt will be larger for a longer fall than for a shorter fall. It is, however, well known to climbers that this is not so. The size of the impact felt by the climber depends not on the length of the fall but rather, on the ratio of the length of the fall to the length of rope between the belayer and the climber. This ratio is called the fall factor. In this talk we will show, using elementary differential equations and simple physics, why this is so. We will also discuss implications of this fact for climbing technique and for the testing of climbing equipment.

18 The Effect of Hybridization and Representation on the Evolution of Grid Robots
Adam Brian Davis, Western Oregon University

Grid robots, virtual robots living on a rectilinear grid, are capable of performing a wide range of tasks. These tasks vary widely in difficulty and complexity in an unintuitive fashion. This study seeks to find generic improvements in the performance of grid robots by comparing two representations, GP-Automata and ISAc lists, on a multi-agent version of the Tartarus task. In addition to testing these two representations on the task, the worth of a generic technique called genetic hybridization is assessed.

19 Pyramids and Archimedean Globes
Duane DeTemple, Washington State University

Archimedean globes are a remarkable family of solids recently introduced by Apostol and Mnatsakanian [Amer Math. Monthly 111 (2004) 496 - 508]. An Archimedean globe is easily described by its cross-sections made by the planes parallel to the equator of the sphere circumscribed by the globe. These planes intersect the surface of the globe in a system of similar polygons, all with the same orientation, that circumscribe the corresponding circle of latitude cut by the plane. In this presentation, I will consider the volume and surface areas of pyramids associated with Archimedean globes. I will also consider prolate Archimedean globes, obtained by dilations along the polar axis.

20 The Vector Calculus Bridge Project
*Tevian Dray*and Corinne A. Manogue, Oregon State University*

For the last several several years, we have led an NSF-supported effort to "bridge the gap" between the way mathematicians teach vector calculus and the way other scientists use it. In a nutshell, mathematics is about functions, but science is about things. The unifying theme we have discovered is to emphasize geometric reasoning, not (just) algebraic computation. We have developed guided small group activities for this purpose as well as an accompanying instructor’s guide, and we offer annual workshops on their use. In this talk, we summarize the current status of the Bridge Project, including efforts to disseminate our materials, which are currently in use at several schools around the country, and in both mathematics and physics classrooms at OSU. Further information about the Bridge Project is available at http://www.math.oregonstate.edu/bridge

21 Matrix representations of free module homomorphisms
Karen Ellis, Southern Oregon University

A module is a generalization of a vector space in which the field of scalars is replaced by a commutative ring with unity. This talk is an investigation of how a homomorphism between free modules can be represented by a matrix of scalars from the ring over which the modules are defined. It will begin with an explanation of what a module is, what it means for a module to be free, and conclude with the implications of such a fascinating way to express free-module homomorphisms.

22 Cauchy vs. Convergence
Ambra Elmer, Southern Oregon University

A general understanding of sequences is intuitive; everyone understands that a sequence of events is a set of events that occur in a given order. This talk will begin with a formal review of sequences and convergence in R. From there I will look at Cauchy sequences and present a proof of the Cauchy Criterion in R.

23 Cognitive Mathematics: Using the Brain’s Innate Abilities for Mathematical Understanding
Suzanne Farnsworth, Southern Oregon University

Cognitive mathematics is a relatively new discipline that suggests that mathematics is a cognitive process utilizing such cognitive mechanisms as image schemas and conceptual metaphors. This view is in contrast with the popular notion that mathematics is objective and exists externally. Recent research in the teaching of mathematics to grade school children suggests that using a cognitive approach hastens mathematical understanding. This talk will present an original experiment conducted by the author on the cognitive nature of mathematics. The current study involved thirty-eight college students (16 experimental, 15 control). The participants were given a pretest that contained concepts from set theory in both classical and cognitive format. The participants were then randomly assigned to either a classical (control) or cognitive (experimental) lecture group, after which they were given a similar posttest. The results of the experiment were reliable, and supported the view that cognitive mathematics is an effective tool for teaching mathematical concepts. The results also supported the principle that mathematics is innate to human understanding.

24 Lattice Sphere Packing in $\mathbb{R}^2$
Bethany Fisher, University of Puget Sound

The pursuit of the densest arrangement of equal sized spheres dates back at least to 1611, when Sir Walter Raleigh asked his friend and mathematician, Thomas Harriot, how to calculate the number of cannonballs in a pile. After creating a formual for counting cannonballs, Harriot took the idea a step further and searched for the densest way to pack balls in general. He posed this question to his collegue, Johannes Kepler, who quickly made his famous conjecture that the densest way to pack cannonballs was just as the fruit vendors stacked their apples and oranges. Over three hundred years would pass before his conjecture would be proven correct.

In this talk, we will discuss the history of the sphere packing problem and investigate some of the mathematics involved by looking at the analogous two-dimensional question. In particular, we will outline methods for finding the maximal two-dimensional lattice disk packing densities and describe the extent to which these methods translate to higher dimensions. We will also discuss some general problems delaying the total completion of finding the densest sphere packing in all dimensions.

This talk will be accessible to students who have had linear algebra.

25 Natural Selection as a Means of Problem Solving
Sean Fitzgerald, Aaron Brown, Andrew Burton, and Peter Stackle, Gonzaga University*

This talk introduces genetic algorithms, a concept based on the process of natural selection, and shows how they can be used in structural engineering and mathematics. In particular, genetic algorithms will be applied to the traveling salesperson problem, providing "good enough" solutions to this famous problem in graph theory. This work is part of an ongoing study at Gonzaga University to design and implement genetic algorithms that generate reasonable solutions to difficult problems in mathematics and engineering.

26 Mathematics in Electrochemistry
Jennifer Gadd, Pacific University

In a classical paper by Schwarz and Shain, Laplace Transform methods are used to solve partial differential equations modeling electro-chemical reactions. This presentation will discuss my senior project involving understanding these methods and exploring alternative solution methods.

27 What Are Symbols? Teaching Algebra Using Symbolic Representations
Christine Gelsinger, Southern Oregon University

It seems that many students become frightened when they see mathematical symbols. In this presentation I will address the meaning of symbols and why they are so important in mathematics. Also, I will introduce some techniques and approaches for teaching algebra using symbolic representations.

28 Basic Signal Processing with Fourier Analysis & Sampling Theorem
Joe Green, Pacific University

A basic demonstration of how the Sampling theorem and Fourier transforms are used in the decomposition of waveforms into spectral components and reconstruction of the original signal. A discussion of how these tools apply to the analysis of acoustical sound waves will conclude the session.

29 Using Current Research in Differential Equations Courses
Chris Hallstrom, University of Portland

Recently, a simplified model to describe braiding patterns in a stream of fluid flowing down an inclined plane was used to shed considerable light on our understanding of this interesting problem. Although a full description of the fluid dynamics involves a difficult system of partial differential equations, this new model uses a relatively simple system of ordinary differential equations. The development and subsequent analysis of this system touches on many of the topics found in a standard undergraduate differential equations course and therefore this research can be used to provide a link between these standard topics and current research topics;

as well as provide interesting and stimulating examples of these topics. In addition, this application can help provide a link between a standard first course in differential equations and a more advanced course in partial differential equations.

30 Instability in Euler Flows
Chris Hallstrom, University of Portland

The connection between a nonlinear partial differential equation and its linearization is not always well understood. For example, if a solution to the linearized equation is unstable, is the corresponding solution to the original nonlinear problem also unstable? In contrast to ordinary differential equation, there is no general answer to this question. However, for certain examples of interface dynamics in ideal fluid flows, such as the dynamics of a two-dimensional vortex sheet with surface tension, we can use information about the growth rate of the unstable linear solution to characterize the nonlinear dynamics.

31 A Few Moments with the Cantor Function
James D. Harper, Central Washington University

Recall that the Cantor function or Devil's Staircase is constant on each of the Cantor middle third intervals, in particular, $f(x) = 1/2$ on $[1/3, 2/3]$, $f(x) = 1/4$ on $[1/9, 2/9]$, $f(x) = 3/4$ on $[7/9, 8/9]$ etc. It is well known that its derivative is zero almost everywhere despite the fact that its values rise from 0 to 1 on the unit interval. From here it is natural to ask what is the integral of the Cantor function? This definite integral is not difficult to compute or visualize. However, computing its moments (that is, the integral of x^n times the function) is a little trickier.

32 The Monge-Ampere Equation and Applications
David Hartenstine, Western Washington University

The Monge-Ampere equation is one of the most studied and most important fully nonlinear partial differential equations. Applications of Monge-Ampere type equations to differential geometry are well-known. More recently, these equations have appeared in the study of optimal transport problems. In this talk, I will discuss weak solutions (both viscosity and Aleksandrov solutions) for these equations, extensions of Caffarelli's regularity theory, applications and directions for future work.

33 Mathematics of the Allen Brain Atlas
Mike Hawrylycz, Allen Institute for Brain Science

The Allen Brain Atlas (ABA) is an in-situ gene hybridization map of the approximately 20,000 gene transcripts of the adult mouse brain. The goal of our bioinformatics and image processing groups is the design and implementation of quantitative and analytic components of the atlas data pipeline including:

- Construction of informatics tools to manipulate an anatomically correct mouse brain reference atlas and its annotation,
- Registration of image data to the reference atlas and validation of the registration process, and
- Quantification and measurement of expression patterns on gene expression data, and strategies for how to approach mining this database.

In this talk we will survey the methods and challenges of constructing the ABA and briefly touch on some of its applications in neuroscience.

34 Optimizing Toll Plazas with Computer Simulations
Heather Helmandollar, Jeremy Lecrone, and Chris Ventura, Pacific University*

In an attempt to maximize revenue and minimize delay time from toll plazas, we sought an optimal configuration of tollbooths within the plazas. To test various possibilities for the optimum number of toll booths to handle the amount of traffic common to the roadway, we generated computer simulation software to emulate the flow of traffic through one direction of the proposed toll plaza. For the delay associated with paying the toll, two methods were used in our simulations, one method in which every car took the same amount of time to complete the transaction and a second method where minor fluctuations were allowed in transaction time.

35 Group Exams in Calculus
Inga Johnson, Willamette University

Over the past seven years I have assigned in-class group exams in my calculus and linear algebra classes. The exams are designed to ensure that (i) students come to class prepared to participate in a group activity, (ii) students in a group contribute equally to the exam/quiz, (iii) students discuss, question, and help each other to solve the questions on the exam. I will discuss the design, implementation, and grading of group exams.

36 An introduction to homotopy theory and the degree 2 map for a sphere
Inga Johnson, Willamette University

We will introduce a few of the fundamental unsolved questions in classical homotopy theory, as well as some of the algebraic tools used to study these questions. Special attention will be paid to examples, in particular the example of the degree two map for the sphere and current research with regards to this map.

37 Two proofs of a probabilistic identity
Mark Kayll, University of Montana

Our investigation of a chip-firing game on complete graphs led to

$$\frac{n-1}{n+1} + \sum_{\ell=1}^{n} \binom{n}{\ell} \frac{\ell^{\ell-1}(n+1-\ell)^{n-1-\ell}}{n(n+1)^{n-1}} = 1, \tag{$*$}$$

since this sum's terms give the probabilities of a game experiencing firing sequences of each possible length. I'll present two proofs of $(*)$. The combinatorial one is new, but the algebraic one recognizes $(*)$ as a special case of a well-known identity dating back to 1826. The new approach ties $(*)$ to tree enumeration, while the algebraic view leans lightly on the theory of 'binomial-type' polynomials, which I'll discuss. The bijective proof arose in joint work with David Perkins from Houghton College.

38 Teaching Quaternions at DigiPen
Matt Klassen, DigiPen Institute of Technology

Thanks to a Theorem of Hamilton, it is possible to represent rotation operators in 3 and 4 dimensions elegantly and efficiently with quaternion multiplication. But why would computer science students and game programmers buy into such an abstraction (other than as an exercise for their developing linear algebra muscles) ?? The answer lies in the problem of interpolation. The unit quaternion sphere provides a context for smooth interpolation of rotation operators, yielding applications in computer graphics and animation. We will present some of the main theorems and applications of quaternions, as well as indicate how this course fits into the standard math curriculum.

39 Trigonometric Functions of Square Matrices
Jennifer Kling, Seattle University

Everyone knows that there are power series representations for functions of real numbers. Well-known ones are the exponential, sine, and cosine functions. Now consider those power series representations of the exponential, sine and cosine function as function of matrices instead of real numbers. This leads to the following questions: What is the sine of a matrix? How can the sine of a matrix be found? How can the sine of a matrix be analyzed? Does the sine and cosine of a matrix hold the same trigonometric identities as the sine and cosine of real numbers? Is the sine of a matrix always less then or equal to one like it is for real numbers? In this talk these questions will be addressed.

40 Toll Plaza Optimization: a Mathematical Contest in Modeling project
Verina Kranak, Kelly Sable and Fayaz Seifuddin*, Linfield College*

Tollbooths are necessary to fund and maintain the quality of frequently used highways and freeways. However, to the everyday commuter tollbooths are a nuisance and create even more congestion during heavy traffic hours. If the number of commuters decreases, so will the funding to maintain these roads. Our goal is to minimize the time it takes for one vehicle to travel through an entire toll plaza during these peak traffic hours. This achievement will help sustain the cycle of finances and quality of roads. In our project we identified the time as a function of total number of vehicles arriving, leaving and within the system over a given quantity of time.

41 A Uniform Example of the Extra Edge Paradox
Klay Kruczek, Western Oregon University

We first introduce strong positional games, which can be thought of as generalized versions of Tic-Tac-Toe. They are 2-player games where the players alternate selecting vertices of a given hypergraph $\mathcal{H}$. The play ends when either a player has completely occupied all vertices of a hyperedge of $\mathcal{H}$, or all vertices have been occupied. A very interesting phenomenon can happen in strong positional games. There are hypergraphs $\mathcal{H}$ where Player 1 has a winning strategy for the game played on $\mathcal{H}$, but if a particular hyperedge A is added to $\mathcal{H}$, then Player 2 can force a draw on $\mathcal{H}' = \mathcal{H} \cup \mathcal{A}$. We call this phenomenon the **Extra Edge Paradox**. First, we give two ***non-uniform*** examples of the Extra Edge Paradox, created by

Schroeppel. We then show a ***uniform*** example, which had been conjectured not to exist.

42 Matroids and Finite Groups
Jeremy LeCrone, Pacific University

Using a standard defintion of a matroid I will show how to define a matroid on a finite group. Making use of this example, I will then introduce further concepts from matroid theory, including the bases, circuits and rank of a matroid. Consequences of these ideas and how they apply to classical group concepts, as well as other possible matroid definitions on a group, are explored.

43 Mathematics Across the Curriculum
Deann Leoni, Edmonds Community College

The presenter, Deann Leoni, is one of the coordinators of a curriculum reform project called Mathematics Across the Curriculum (MAC). The project's goal is to improve the mathematical and quantitative skills of students by integrating mathematics and/or quantitative reasoning into courses across the disciplines. The presenter will share a brief overview of the history of the project, including some results of the project's assessment, and she will provide information on how to become involved in the project in the future.

Over the past five years, with the support of the National Science Foundation, the MAC project has helped faculty create and implement curricula integrating mathematics into other disciplines, including many typically not associated with mathematics such as art, art history, political science, anthropology, or gerontology. Examples and drafts of curriculum can be found on the MAC website at http://mac.edcc.edu.

44 How does one apply the root test?
Lewis Lum, University of Portland

According to my real analysis text to test the series $\sum_{k=1}^{\infty} a_k$ for absolute convergence using the root test one computes $\limsup_{k\to\infty} |a_k|^{1/k}$. It recently occurred to the author that the k^{th} root of the "k^{th} term" is ambiguous. Does one test $\sum_{k=101}^{\infty} 2^{-k} = \sum_{n=1}^{\infty} 2^{-(n+100)}$ by computing $\limsup_{k\to\infty} \left|2^{-k}\right|^{1/k}$ or $\limsup_{n\to\infty} \left|2^{-(n+100)}\right|^{1/n}$? Does it matter? In this brief talk I will discuss this and another example and then generalize.

45 A strategy for computing complex solutions of Exotic equations
Samuel Lynch, Central Washington University

Approximations for real and complex solutions of the equation: $x^{10} - 2x = 0$ Using fixed point theory and programs for the TI-83 graphing calculator. Content includes iteration techniques for finding Real solutions of Exotic equations which have been used in High School and College Algebra and Precalculus, and finding Complex solutions via a program for the TI-83 graphing calculator, based on: $(a + bi) = r(\cos\theta + i\sin\theta) = re^{i\theta}$

46 An Introduction to Bessel Functions
Stephen Martinich, Southern Oregon University

As solutions to the second-order linear differential equation known as Bessel's equation, Bessel functions have numerous applications to engineering and the sciences. They represent a useful extension of the power series method for finding solutions to differential equations, and possess many interesting properties. This talk will explore several of these properties, including the ability to derive a Bessel function of one order by differentiating a function of another order, their relationship to the elementary functions sine and cosine, and the interlacing zeros of functions of consecutive order.

47 Distances in Hyperbolic Geometry
Katy McCleary, Southern Oregon University

After introducing the basic concepts of hyperbolic geometry and some of its models, I will dive into the idea of distance in H2. Specifically, I will introduce formulae for calculating distance in the Poincare disk model of H2, and discuss some properties that such formulae must obey.

48 Rule of Thumb: Prints Beat DNA
Dustin Mixon and Seth Miller, Central Washington University

We will present our solution from last year's Mathematical Contest in Modeling. We will (1) develop two models that estimate the probability that every thumbprint is unique, and (2) use the estimation to determine whether thumbprint- or DNA-testing has a higher rate of misidentification.

In our first model, we focus on the thumbprints' global features (those easily examined by the naked eye). We observe thumbprint pattern, ridge count, and type lines. With this model we determine the probability that two given thumbprints have the same global characteristics is at least 5.02×10^{-4}.

Our second model focuses on local features (those not easily examined by the naked eye). The local feature we observe is the thumbprints' minutiae. We look at the quantity of minutiae, their location, and the direction at which their corresponding furrow endings point. With this stronger model we determine the probability that two given thumbprints have the same local characteristics is approximately 6.41×10^{-143}.

We tackle the second part of our problem knowing identical twins share the same DNA. With this, we establish the probability that two given DNA strands are similar is approximately 8.29×10^{-14}. Since this probability is significantly more than the analogous probability for local thumbprint features, we conclude that DNA-testing has a higher rate of misidentification.

49 Witty Banter about Primitive Tournaments
Jerod Morehouse, University of Alaska Anchorage

Let T_n be the set of all tournaments with $n \geq 4$ vertices with in-degree$(u) > 0$ and out-degree$(u) > 0$ for all $u \in T_n$. Let τ be the element of T_6 with the out-degree set of $\{4, 4, 4, 1, 1, 1\}$. Let P_n be the subset of T_n, such that every P_n is primitive. I conjecture P_n consists of all elements of T_n except those containing τ as a subgraph. In this talk I will present evidence of this conjecture and discuss directions for possible proofs.

50 Queue and A
Andrew Musselman, Amy Eglin, and Nicholas Stanford, Central Washington University

We present our solution to the tollbooths problem posed in the recent Mathematical Contest in Modeling. Our purpose is to determine, for a given number of lanes in each direction, how many tollbooths are needed to minimize the average customer wait time.

To form our recommendation we investigated the scenario by developing a computer simulation in Mathematica. We emulated key characteristics of a hypothetical toll plaza including the flow of traffic into the plaza, the approach of cars toward the tollbooths, the time spent paying, the process of merging toward the exit, and the process of exiting the plaza.

51 An Introduction to Metric Spaces
John Osborne, Southern Oregon University

Metric spaces are a topic that not all mathematics undergraduates explore. This presentation will examine some basic ideas in metric spaces and explain why metric spaces are important to calculus and analysis.

52 On the Trichotomy Behavior of the Difference Equation

$$x_{n+1} = \frac{q_n x_n + r_n x_{n-1}}{1 + x_n}$$

C. H. Gibbons, S. Kalabušić, and Carol Overdeep, Western Oregon University*

We extend the known results of the nonautonomous solutions of the difference equation in the title to the situation where any of the parameters are a period-two sequence with non-negative values and the initial conditions are positive. In particular, we find regions of local stability and regions where unbounded solutions exist.

53 Four species food chain model
John Michael O. Ranola, University of Portland

Population studies have been commonplace for many years now. Information obtained through these studies, such as birth rates, death rates, and growth rates, seem to beg for models involving differential equations. In a recent REU experience in Mathematical Biology, I aided in the characterization of the qualitative behavior of a four species food chain modeled by the classic, non-logistic, Lotka-Volterra type equations. In this presentation I will summarize our findings.

54 Combinatorial Flagpole Arrangements
H. David Reynolds, Washington State University

Proofs of combinatorial identities will be given by asking for the number of arrangements of a flagpole, guy wires, and a row of blocks, where each block supports either the pole or a wire or remains unused. Various sets of conditions are imposed on the allowable arrangements. The goal is to count the number of arrangements in two ways, obtaining two different expressions that can be equated to prove an identity. In particular, we prove several identities involving binomial coefficients. The model can also be adapted to generate the recursion relations for the Fibonacci and Lucas sequences.

55 A More Student Friendly Definition of Limit
David Scott, University of Puget Sound

The traditional epsilon-delta definition of limit is difficult for calculus students to understand. This talk will introduce an equivalent definition that is easier for students to grasp, and will explore why this slight modification of the traditional one easier for them to use.

56 Quadratic residues and Related Solutions
Karley See, Western Oregon University

In this talk we investigate the necessary and sufficient conditions for -1 to be a quadratic residue of m, where m is a positive integer. For m an odd prime, the necessary and sufficient condition is determined. Furthermore, we showed that for a finite number of odd primes, each satisfying this condition, -1 is a quadratic residue of their product. This result also holds when the product is multiplied by two. We also investigate the methods of finding these solutions in the group of integers modulo m.

57 Speaking of Quanta: Development of Mathematics for Use in Quantum Mechanics
Anne Shartel, St. Martin's College

As science advances toward understanding of physical processes at microcosmic and macrocosmic levels, different techniques of analysis have been developed and used by scientists to help them understand their observations. When steps are taken and analyzed, the implications of what has been learned points the way to proceed. Following some tracks in the development of Quantum Mechanics during the 20^{th} century along with normal scientific contention that results in innovation, some techniques used by various scientists to explain quantum phenomena will be examined. In particular, the derivation of Schrödinger's Wave Equation and a review of Heisenberg's Matrix Mechanics will demonstrate some of the paths followed.

58 Catalanian Forests (and their paths)
Len Smiley, University of Alaska Anchorage

By the time of the Tacoma meeting, the size of the list of definitions of the Catalan sequence kept by R. Stanley will have exceeded 2^7. By viewing forests instead of trees, we will suggest projects (addressable by undergraduates) for moving the list into two more indicial dimensions.

59 Modeling Toll Plaza Traffic Congestion During Peak Hour Traffic
Tedd Smith, Todd Curtis, and Jed Rembold, Linfield College*

In an attempt to alleviate the congestion of modern toll plazas, our team took on the challenge to find the optimal number of tollbooths for a variable lane road. To us, the optimal number of booths is the number of booths that minimize the length of time that it takes commuters to travel through the plaza, regardless of traffic congestion, speed limit, or monetary issues. These parameters were varied throughout the simulations but proved to have a negligible effect on our final results. In order to best model this data, we decided to use a complex simulation to model an hours worth of traffic flow through varying toll plaza setups. Starting with a setup of one booth for every inbound lane, we quickly moved on to multiple booths per lane. By then comparing graphs and averages between the variable booths for a set number of lanes, we were able to find the number of booths that minimizes the travel time. This data led us to develop a rough formula to calculate the optimal number of booths for a specified number of lanes. Further analysis revealed that this solution held up under rigorous parameter testing. We believe that implementation of the found toll plaza strategies would go great lengths towards easing traffic congestion on busy toll roads.

60 Undergraduates Can Do Matroids!
Colin Starr, Willamette University

The topic of the Senior Seminar at Willamette University rotates on a two-year basis. This year and last, the topic has been Matroid Theory. I will discuss my approach to the course in terms of both philosophy and mechanics. I will also discuss the effectiveness of the course and student reactions.

61 The Graph of a Group
Colin Starr, Willamette University

The problem of drawing subgroup lattices arises naturally whenever one teaches abstract algebra. In the interests of keeping the initial examples simple, it is desirable to have this lattice be planar. In this talk I will introduce the graph of a group (essentially the subgroup lattice) and characterize the abelian groups that have planar subgroup lattices. I will also discuss the progress my colleague, Dr. Galen Turner of Louisiana Tech, and I have made on the non-abelian case.

62 The Mathlete Project: College Student Coaches for Middle School Math Teams

Jen Stoops, Emily Zeigler and Laura Thompsen, Pacific Lutheran University

PLU students will describe their experience coaching middle school "Mathlete" teams from three local school districts to prepare for the Washington State Math Olympiad. The goal is to create a sense of community around mathematics by providing role models and mentors to middle school children and having fun with mathematics. Learn how you, as a student or faculty member, could create a similar program, and what the rewards are for you and your school!

63 A Simple Classroom Demonstration of Ill-Conditioning

Jeff Stuart, Pacific Lutheran University

Most students encounter the theory and practice of solving linear systems only once during their college careers: in their linear algebra course. Typically, one of the few things that students remember from that experience is that every invertible linear system behaves the same way: there is a unique solution; Gaussian elimination finds it; computers always do Gaussian elimination faster and better; and there is no more to be said. Unfortunately, what students remember, and what is true, are often at variance.

We will present a simple but surprisingly effective, tripartite classroom presentation on ill-conditioning. The presentation begins with a physical demonstration that requires little more than a couple of long sticks, a couple of chairs, and a chalk or white board.. This physical demonstration is followed by a short computational experiment in which each student computes a few data points for a pair of graphs. These graphs reveal that simple linear systems can have complex behavior. Finally, there is a brief, theoretical explanation of the algebra and geometry of what is actually happening Amazingly, all of this can be accomplished within a single class period.

64 The Insolvability of a Quintic

David Tempel, St. Martin's College

The quadratic formula is a well-known equation for finding the roots of any quadratic polynomial. There are also formulas for cubic and quarticpolynomials. No such formula exists for the general quintic polynomial. I will develop some of the ideas necessary for Galois theory and present a summary of the proof of the insolvability of the quintic using Galois theory. A basic understanding of groups and fields is helpful but not necessary.

65 Conservation Laws of the Nonlinear Schrödinger Equation
Chris Ventura, Pacific University

Particles snapping in and out of existence, appearing in two places at the same time, and measuring one particle instantaneously determines the position of a related particle even if it is a few light years away – this is the world of quantum mechanics. In contemporary physics, nonlinear versions of the Schrödinger equation are used to describe these phenomenon, but one might wonder with all of these seemingly wild results, are there any conserved quantities. Through the use of Nöther's Theorem, we shall find conservation laws governing energy, linear momentum, angular momentum, and the norm.

66 Systems of Differential Equations: Population Growth Models
Megan Wahrenbrock, Southern Oregon University

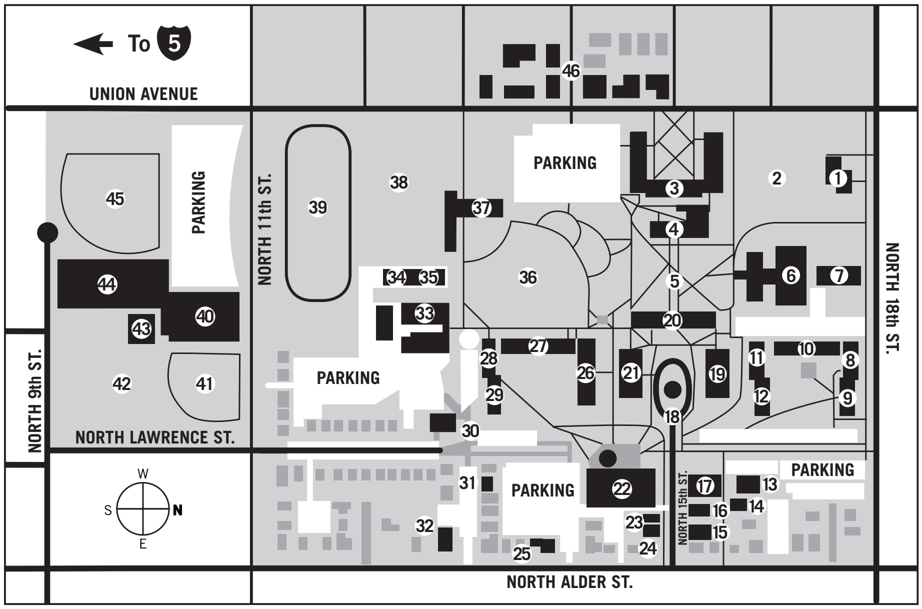
Ordinary differential equations are the key to modeling population growth. This talk focuses on their formulation, interpretation, and analysis in relation to population growth of microorganisms. A main emphasis is on how important assumptions simplify the problem, how important variables are identified, and how differential equations are tailored to describing essential features of a continuous process.

67 Some Finitely Based Varieties of Directed Graph Algebras
Brian L. Walter, The Evergreen State College

Shallon invented a means of deriving algebras from graphs, yielding numerous examples of so-called graph algebras with interesting equational properties. Our subject is directed graph algebras, derived from directed graphs in the same way that Shallon's graph algebras are derived from graphs. We present results characterizing several types of finitely based directed graph algebra varieties. We classify the finitely based looped directed graph algebras and find the five finitely based varieties generated by them, showing that every looped directed graph algebra is either finitely based or inherently nonfinitely based. We present further results about loop-free directed graph algebras and graph algebras in general. We also show a general two-part method for showing that varieties are finitely based; this method is developed further, into syntactic and semantic components, and applied in the specific case of varieties generated by directed graph algebras.

68 Label Assignment for Convex Polyhedra in $\mathbb{R}^2$
Anca Williams, Portland State University

The state-space isomorphism problem was first considered by E. Sontag and B. DasGupta in 1998. This problem has significant applications in the field of Control Theory, specifically to the class of piecewise linear control systems. The problem consists of determining if two piecewise linear sets are isomorphic. Piecewise linear sets (PL-sets) are given as finite unions and intersections of convex polyhedra in $\mathbb{R}^n$. Using the concept of a ***label***, it has been determined that there is a unique canonical label assignment to each PL-set. The main observation is that two sets have the same canonical label if and only if they are isomorphic in the category of piecewise linear sets. In addition, checking if two labels are reducible to the same canonical label can be performed efficiently in polynomial-time. The remaining question was how to assign a label to such a set efficiently. Using techniques from Geometry, Convexity Theory, and Complexity Theory, this talk will present an efficient technique that determines a label assignment for a PL-set in $\mathbb{R}^2$.

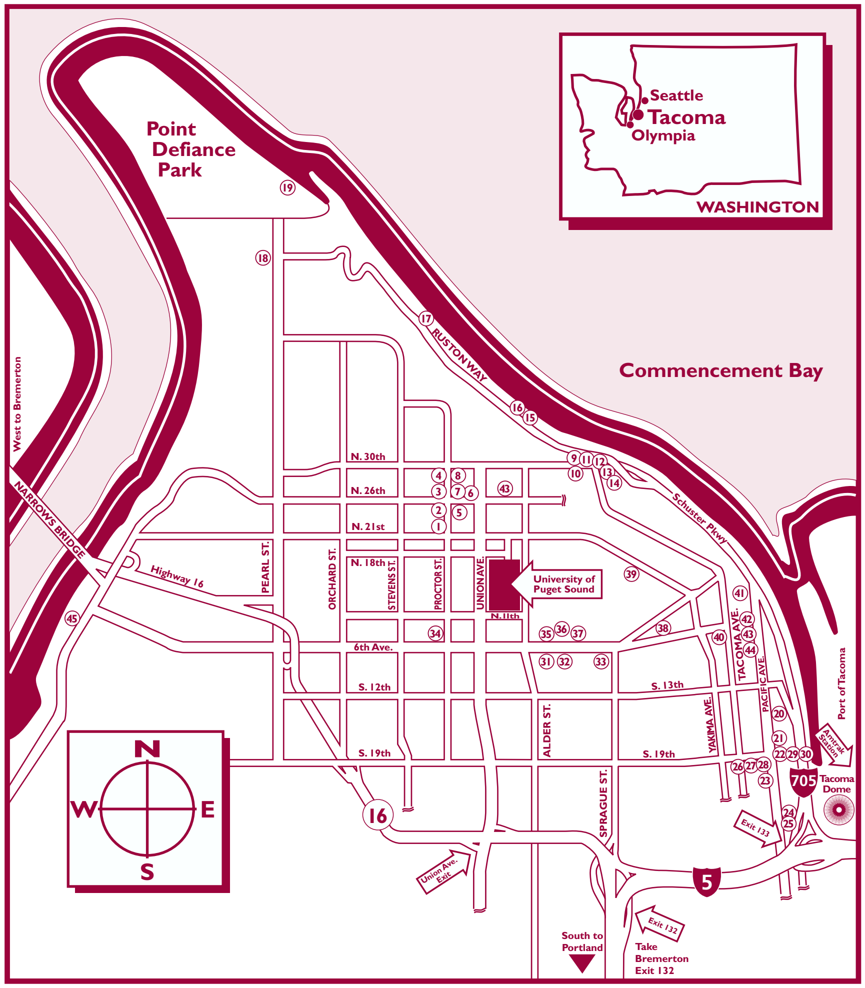


2 Alcorn Aboretum
10 Anderson/Langdon Residence Hall
39 Baker Stadium/Peyton Field/Shotwell Track
45 Baseball Diamond
13 Ceramics Building
6 Collins Memorial Library
25 Communications Office
31 Community Involvement & Action Center
23 Copy Center
42 East Athletic Field
40 Fieldhouse/Pamplin Sports Center
8 Harrington Residence Hall
21 Howarth Hall
30 Human Resources Office
18 Jones Circle
20 Jones Hall
5 Karlan Quad
7 Kilworth Chapel
17 Kittredge Art Gallery
32 Langlow House
38 Lower Baker Field
19 McIntyre Hall
4 Music Building/Schneebeck Concert Hall
1 President’s House
28 Regester Residence Hall
9 Schiff Residence Hall
14 Sculpture Building
24 Security Services
29 Seward Residence Hall
12 Smith Residence Hall
41 Softball Field
33 South Hall
15 Student Development Office
16 Student Diversity Center
44 Tennis Pavillion
3 Thompson Hall
36 Todd Field
27 Todd/Phibbs Residence Hall
26 Trimble Residence Hall
46 Union Avenue Residences
11 University Residence Hall
43 Volleyball Courts
34 Wallace Pool
35 Warner Gymnasium
22 Wheelock Student Center (WSC)
37 Wyatt Hall

Email: Thompson 120, login: uname = `acp_blue`, pword = `Blue123`

Wireless: Third Floor Thompson, network name is `CSMath`

Campus Security: 253-879-3311



North Tacoma Points of Interest

Proctor District
1. Metropolitan Market
2. May's Vietnamese Restaurant
3. Starbucks Coffee
4. La Fondita Mexican Restaurant
5. Europa Bistro
6. Pomodoro
7. Blue Mouse Theatre
8. Old House Cafe

Old Town
9. Trattoria Grazie
10. Tully's Coffee
11. The Spar Coffee Bar
12. The Spar
13. Starbucks Coffee
14. Café Divino

Waterfront
15. Ram Big Horn Brewing Company
16. C. I. Shenanigans
17. Lobster Shop
18. Antique Sandwich Co.
19. Anthony's at Pt. Defiance

Downtown
20. Tacoma Art Museum
21. Union Station/Federal Courthouse
22. Wash. State History Museum
23. Harmon Restaurant and Brewery
24. El Gaucho
25. The Melting Pot
26. The Swiss
27. The Old Spaghetti Factory
28. Rock Pasta Brick Oven Pizza
29. Bridge of Glass
30. Museum of Glass

6th Ave District
31. Primo Grill
32. Shakabrah Java
33. MSM Grocery & Deli
34. Sushi Tama
35. Jazzbones
36. Engine House No. 9 Restaurant & Brew
37. Gateway to India
38. It's Greek to Me

Other
39. Tacoma Little Thea
40. Grand Cinema
41. Over the Moon Ca
42. Pantages Theatre
43. Tully's Coffee
44. Rialto Theatre
45. Steamer's Seafood

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