PRIME BITS

Fall 2015   **Volume 17**

Chair's Communiqué

It has been a great year of transformation for the CU Math Department (and just a great year overall!) There has been a transformation in personnel: Professor Don Monk, who was the builder of and standard-bearer for our world-famous Logic and Foundations group retired after 54 years at CU, and we hired an excellent new Foundations faculty member Peter Mayr, whose specialty is Universal Algebra.

There was also transformation of our physical space. When our beautiful Mathematics Building was built in 1992, much office space was set aside to store various types of paper. In the digital world, this space was underutilized, so we remodeled our office suite to create a new room where faculty can meet with students for informal mentoring. The room will be lined with math books (donated by alumni and retired faculty — we can always use more!) so students can expand their knowledge outside of coursework. But the main transformation is ongoing as we revise our courses to use the latest pedagogy to better meet the mathematical needs of our majors and all CU students. It is now our pleasure and privilege to teach more "student-credit-hours" than any other department on campus.

David Grant

This effort began years ago when Professors Robert Tubbs and Eric Stade redesigned our first-year calculus sequence to make use of active-learning and group work facilitated by undergraduate Learning Assistants. A CU Presidential Teaching Scholar, Professor Stade was named this year a "Best Should Teach" Gold faculty awardee via an initiative managed by the CU Graduate Teacher Program.)

Two years ago our Calculus sequence was named one of four national models for how calculus should be taught by the Mathematics Teacher Education Partnership, and the Helmsley Trust gave CU a grant to develop and disseminate materials for the calculus courses. Two years ago we hired Dr. Faan Tone Liu to coordinate our calculus courses, and through her work with Tubbs and Stade, those materials are now publicly available to teachers everywhere.

Our efforts to bring the best mathematics education to all CU students are now expanding. There is a national movement geared to designing mathematics curriculum to provide pathways for success. Colorado is part of that effort, and Tubbs is representing CU in that statewide effort.

William B. Jones to retire after 28 years as *Prime Bits* editor

I began writing and publishing *Prime Bits* in 1987 when serving as the Mathematics Department Chair and realizing the need to communicate with campus faculty and students and more than 3000 Math alums around the world. Due to limitations of age (84), I will retire as the writer and editor of *Prime Bits* after the publication of the 2015 issue. I have enjoyed my 28 years as editor (10 years as a faculty member and 18 as a volunteer emeritus professor). It has enabled me to stay in touch with our alumnae/alumni and also with an evolving Mathematics Department.

Prime Bits has attempted to give news about our alums, current students and many of the service activities performed by our faculty such as teaching and student advising, research and scholarly work. During the past 28 years there have been many faculty retirements, replacements and a number of deaths. All but four members of the current faculty were hired after 1987. The department moved into the new Mathematics Building in 1992, after being housed in the Engineering Center for a quarter of a century and before that

Department Chair Communiqué, (continued from p. 1)

Towards that end we are redesigning our precalculus course for STEM students, building a new course for students in CU's new College of Media Communications and Information, and we have already rolled out a new course, "Mathematical Analysis in Business" for CU Leeds School of Business Students. The course was jointly developed by CU Mathematics Instructor Dr. Dee Dee Shaulis and Leeds Professor Laura Kornish. This is a model for all our new efforts -— working hand-in-hand with constituent departments to meet the mathematical needs of their students. We have reached out to several Social Science departments in our efforts to build an innovative course to get their students prepared for statistics courses. It will be a course on modeling of functions based on data, which will replace our traditional algebra course. We are also building bridges to the Arts by hosting a MoSAIC (Mathematics of Science, Art, Industry, Culture) conference this spring.

For our best majors, two summers ago we started a Summer Research Program, headed by Professor Nat Thiem, which pairs undergraduates with faculty who guide them on research projects. This summer, we included first-year graduate students on these projects, which helps both the graduate students and the undergraduates. This improvement to our graduate program was possible because funds that were once needed for other expenses are now available because of generous donations of our alumni. But this is only one example of where this generosity makes improvements possible.

Indeed, we also hired two new Meyer Postdoctoral Fellows this year, Jakub Bulin in Foundations and Jordan Watts in Geometry, who are contributing to the research life of the Departments, with proceeds of an endowment established by the late Math Department Professor Burnett Meyer. This summer we awarded our first Richard Laver Graduate Fellowship to Clifford Bridges, which was partially funded by an endowment started by friends and family of the late Emeritus Professor Richard Laver, our beloved colleague who passed away three years ago. We are still collecting for this endowment so that it can fully support the summer research of a deserving graduate student.

I'm pleased to announce that CU Alumnus Jim Marshall and his wife Laura are donating money over the next ten years to fund both undergraduate scholarships (so needed now as more and more of our hard-working majors are saddled with debt or heavy in-term work commitments to pay for college) and to send graduate students to conferences, which is crucial to launching them in their careers.

I'm also pleased to announce that CU Alumnus George Moreno and his wife Clara are giving money over the next five years for undergraduate scholarships and to fund

undergraduate events which build community for our majors and enrich their undergraduate experience.

On behalf of our students, our Department is so grateful to them and everyone who helps this and future generations of students, through donations, or by providing jobs or mentorships to our students and graduates.

Thanks and best wishes,
David Grant
Professor of Mathematics and Department Chair

Math Department awards first Richard Laver graduate fellowship

The Richard Laver Graduate Fellowship, now 60 percent fully funded, is currently the department's top fundraising priority. Our colleague Rich Laver was a wonderful set theorist and a wonderful man, who succumbed to Parkinson's Disease in 2012, after spending his career in the Mathematics Department at CU Boulder, enriching the lives of his students and coworkers.

Richard Laver

Last year, his family and friends endowed a graduate mathematics fellowship in Rich's honor at CU, and through their generosity, we have now raised more than 60% of the amount needed to fund an annual summer graduate fellowship of $4500.

The Department's number one fundraising goal is to raise the remaining $45,000 needed to completely fund this endowment.

In the meantime, the Department last year supplemented the annual proceeds of the endowment to award the first ever Richard Laver Graduate Fellowship to the advanced Graduate Student Clifford Bridges, whose thesis is on "classifying solutions to some Galois embedding problems," a foundational question in algebra.

Rich Laver joined the faculty in 1974 and retired in 2008. He earned a Ph.D. from Berkeley in 1969 under the direction of Ralph McKenzie, making him the "academic brother" of CU Professor Keith Kearnes and the "academic grandson" of retired CU Professor Don Monk. Besides being a celebrated set theorist, Rich was an expert chess player, bridge player, and cruciverbalist, and a life-long athlete, hiking and walking until the end of his life.

Meet Our New Faculty

Dr. Jakub Bulín received his Ph.D. in Mathematics in 2014 from Charles University in Prague, Czech Republic, under supervision of Dr. Libor Barto. He joined the CU Boulder Mathematics Department as a Burnett Meyer Postdoctoral Fellow in August 2015 after a postdoctoral position at Jagiellonian University in Kraków, Poland.

Dr. Bulín's research interests include universal algebra and its connections to theoretical computer science. In particular, he is interested in the Constraint Satisfaction Problem and related structural properties of finite algebras and relational structures. Other interests include hiking in the mountains, traveling and meeting interesting people.

Dr. Peter Mayr submitted the following brief bio in response to a request by *Prime Bits*: "I grew up in Austria and developed a love for Math at competitions in high school. There I realized that Mathematics is not about learning and applying formulas, but about problem solving and creativity. I studied at the Johannes Kepler University Linz (Austria) and finally received my PhD there for a thesis on polynomial functions on groups under the direction of G. Pilz. Since then I had visiting research positions at UW Madison, CU Boulder (2006/07), and the University of Lisbon, Portugal, and worked as assistant professor at JKU Linz. For the previous three years I have been conducting a project on computational algebra there.

"My main research area is Universal Algebra with connections to Logic and Computer Science. General algebraic structures come up for example in connection with Constraint Satisfaction Problems (CSP) which generalize Boolean satisfiability, graph coloring, and scheduling problems. A typical question is then how to classify and represent these structures and how to compute with them efficiently.

"I am very happy to join the vibrant Logic group and work with faculty and students at CU Boulder. Moreover I enjoy the great possibilities for hiking, climbing and skiing in the area."

Dr. Jordan Watts is currently a Visiting Assistant Professor in the Math Department at the University of Colorado Boulder, working with Carla Farsi and Markus Pflaum. He is studying generalizations of smooth structures (e.g. diffeology, differential spaces, stacks), orbifolds, Lie groupoids, symplectic geometry, and Hamiltonian group actions.

Dr. Watts was born on Prince Edward Island, in Canada, where he grew up. After finishing high school, he moved to Calgary, Alberta, Canada, where he completed a BSc and MSc under the supervision of Jędrzej Śniatycki at the University of Calgary. Watts next moved to Toronto, Ontario, Canada, where he completed a PhD under the supervision of Yael Karshon at the University of Toronto. Following graduation, Watts worked as a J. J. Uhl Research Assistant Professor at the University of Illinois at Urbana-Champaign."

Delong Lectures 2014-2015

Professor Robert Bryant, the Phillip Griffiths Professor of Mathematics at Duke University presented the 51st annual DeLong Lectures during the week of Oct. 13, 2015.

For the first lecture Professor Bryant spoke on "The Idea of Holonomy." The topic of his second lecture was "Convex Billiards and Non-holonomic Systems."

Professor Bryant is currently the President-elect of the American Mathematical Society. He is a fellow of the American Academy of Arts and Sciences and a member of the National Academy of Sciences. His research interests center on exterior differential systems and the geometry of differential equations as well as their applications in Riemannian geometry, special holonomy, and related areas.

Faculty Spotlights

Sebastian Casalaina-Martin

Sebastian Casalaina-Martin currently has a Simons Foundation Collaboration Grant for Mathematicians and an NSA grant proposal was approved for funding starting in 2016.

Richard Green

Richard Green has been posting on social media about mathematics. The posts, which are aimed at a general audience, have received millions of views.

Incidentally, he posted about Katherine Stange's work last October, which resulted in her work being featured by John Baez in his AMS column "Visual Insight". Here's a link to Richard's original post:

https://plus.google.com/101584889282878921052/posts/eM3adto6nsj

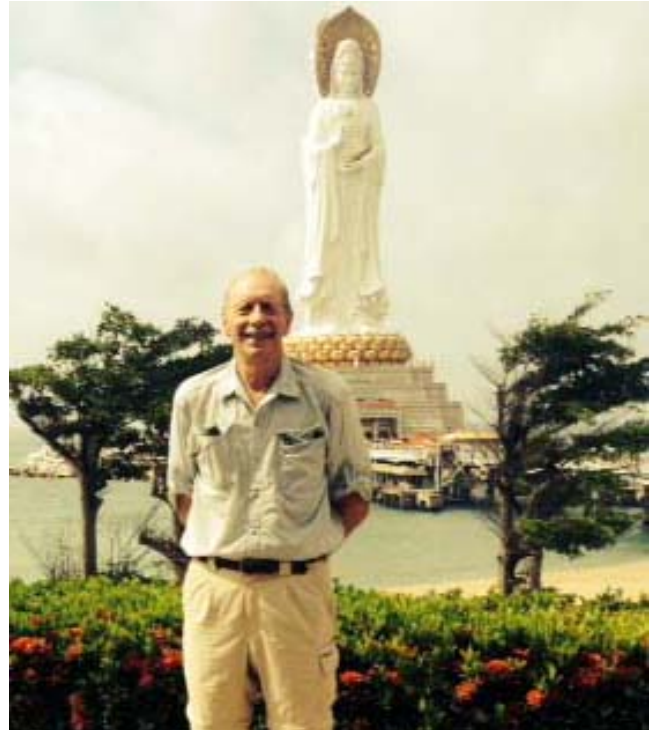**Karl Gustafson** gave four international keynote addresses.

In November 2014 at the 31st Annual Meeting of the Greek Mathematical Society he spoke on The Future of Mathematics: From the Pure-Applied Debate to Reality (see https://www.youtube.com/watch?v=XOv9SJ3Q-WI).

On March 9 2015 his opening keynote at the Quantum Probability and Decision Making conference at the Fields Institute in Canada was The Importance of Imagination (or lack thereof) in Artificial, Human, Quantum Cognition and Decision Making (see the Fields Institute Conferences online videos).

In May 2015 as the ILAS speaker at the 24th IWMS meeting in Haikou, Hainan, China, he spoke on Antieigenvalue Analysis, Further Applications: Continuum Mechanics, Economics, Number Theory (see arXiv:1505.03678).

In June 2015 at the 2nd Shanghai Forum on Trade and Financial Statistics, his opening keynote address presented his recent results New Financial Risk Ratios and Portfolio Growth Angles (see JSCS 85:13(2015) 2682-2692).

In a discussion period at the Shanghai forum Gustafson was asked his opinions of China's current economic situation. Having intensively studied our own 2008 crash, Gustafson said he warned of a potential similar housing bubble brewing there. Two weeks later the Shanghai stock market fell about 30 percent. Much of that loss hit the new Chinese middle class.

Professor Karl Gustafson near Sanye at the southern end of Hainan Island, China, May 30, 2015.

Carrie Muir

Carrie Muir has accepted, a tenure track position in the Math Department at Whatcom Community College in Bellingham, WA. She will be starting there this fall. Carrie has been an instructor and advisor for the department since 1999. She was promoted to Lead Advisor in 2013 and she recently received the Excellence in Advising Award. Carrie wrote: "It's been a great run here in Colorado. While I'm very excited for this next chapter, I'm going to miss my awesome Boulder colleagues and students."

Faculty Spotlights, (continued from page 4)

Eric Stade received a "Best Should Teach Initiative Award" in August 2015. Best Should Teach Initiative strives to acknowledge excellence in teaching and academic leadership. The initiative is managed by the Graduate Teacher Program in coordination with the School of Education, the College of Arts and Sciences, and the Graduate School at the University of Colorado at Boulder.

Eric Stade

Kate Stange was awarded a 2014 ASSETT Development Award to purchase a WACOM tablet to make math videos for Linear Algebra and other classes for flipping the linear algebra classroom. The videos that she has made so far explain core concepts for Discrete Math students. Stange uses a stylus pen to draw on the Autodesk Sketchbook. Stange's videos last between three and five minutes. They currently support Introduction to Discrete Mathematics. Stange also won a two-year Young Investigators' Grant from the NSA in July 2015. The National Security Agency Mathematical Sciences Program (MSP) was started at NSA in 1987 in response to an increasingly urgent need to support mathematics in the United States.

Kate Stange demonstrates use of a tablet to make math videos

Letter from Prime Bits Editor, (continued from p. 1)

in Hellems and Ketchum Halls. In 1987 the Math Department had only one endowment fund, the Ira M. DeLong Lectures; in 2015 the department has 13 Endowment Funds supporting student scholarships (8), lectureships (3), teaching awards for Graduate Student Teaching Assistants (2) and post-doctoral faculty appointments (1). These endowment funds are made possible by generous gifts from our alumnae/alumni family, former faculty members and friends of the university. They greatly expand the services that our faculty can perform. *Prime Bits* also provides a year-by-year brief history of the Mathematics Department, supplementing the 1979 publication: "A History of the Mathematics Department of the University of Colorado" by Burton W. Jones and Wolfgang J. Thron.

Martha and Bill Jones

I am grateful for the support and encouragement of the faculty, the office staff and particularly the department chairs, who have sometimes struggled to find the funds needed for printing and mailing *Prime Bits*. I am also grateful to my daughter Kathleen H. Jones (B.S. 1985 and M.A. 1996, Journalism, CU Boulder), a professional journalist, who has provided formatting for most of the issues of *Prime Bits*. I acknowledge with gratitude the assistance of my wife Martha Hadley Jones, an English teacher, for careful proof reading of every issue of *Prime Bits* and for her encouragement in this project.

With deep gratitude,
William B. Jones
Emeritus Professor

Student News

William Lowell Putnam Competition

The top three CU Boulder student competitors in the William Lowell Putnam Competition were: first place Michael Moy, second place Varodom Theplertboon, and third place Julia Young.

Pictured above, from left: Sergei Kuznetsov (faculty mentor), 1st place Michael Moy, 2nd place Varodom Theplertboon, Alexander Gorokhovsky (faculty mentor).

Pictured at left: Julia Young, 3rd place

William E. Briggs Teaching Excellence Award 2014
Noah Williams

Burton W. Jones Teaching Excellence Award 2015
Natalie Coston, Julie Linman, and Erica Shannon

John H. "Jack" Hodges Scholarship
Harold Hausman

Adele V. Leonhardy Scholarships, 2015-2016
Nicholas Boschert and Alaina Metivier

Sieglind Talbott Haller Scholarship
Clifford Blakestad
Matthew Krupa
Erica Shannon
Jeffrey Shriner
John Willis
Jonathan Lamar
Megan Ly
Matthew Grimes

Frances C. Stribic Scholarship
Krisztian Havasi
Ryan Rosenbaum
Julie Linman

Wolfgang J. Thron Fellowship
Shawn Burkett
Kathleen Smith

University Scholarships
Boramey Chhay
Jared Nishikawa
Pearce Washabaugh
Alexander Nita
Nicole Sanderson
Paul Lessard
Kevin Berg
Matthew Grimes

Richard Laver Graduate Fellowship
Clifford Bridges

Graduate School Summer Fellowship
Keli Parker

PhD Candidate Erica Shannon was selected by CU's United Government of Graduate Students (UGGS) to receive the Top TA/GPTI Award for 2015 in recognition of her demonstrated dedication to excellence in teaching. Award recipients were honored at UGGS's annual Roundtable Reception on April 21st.

Professor Eric Stade and Erica Shannon

Annual Fall Convocation Lecture by alumnus

Judge Morris Hoffman (B.A. Math 1974) presented the Sixth Annual Fall Convocation Lecture on December 9, 2014 in Math 100.

The title of his lecture was "Mathematics, Science and Law: Will This Ever Work." Questions Hoffman discussed in the lecture included: what does the n-body problem have to do with legal causation? What does the mind/body problem have to do with the criminal law? What has the United States Supreme Court said about testing the reliability of science in the courtroom?

Judge Hoffman received a B.A. in Mathematics from the University of Colorado in 1974. Please see related article in Alumnae/Alumni News on page 9.

Graduate Degrees

(Degrees are listed by student's name, degree and faculty thesis advisor/mentor. Thesis titles are given for Ph.D. degrees.)

December 2014

Ilias Gialampoukidis (Ph.D. Math, University of Thessaloniki, Greece), Karl Gustafson; The Time Operator and age of evolutionary processes

Kathleen Smith (MA Math), Sergei Kuznetsov

May 2015

Kevin Selker (Ph.D. Math), Donald Monk; On some min-max cardinals on Boolean Algebras

Joseph Migler (Ph.D. Math), Alexander Gorokhovsky; Determinants in K-theory and operator algebras

Trubee Davison (Ph.D. Math), Judith Packer; Generalizing the Kantorovich Metric to Projection-Valued Measures: With an Application to Iterated Function Systems

Liang Zhang (Ph.D. Math), Janos Englander; Problems concerning spatial branching particle systems with interaction

Dalton Jones (BA/MA Math, Markus Pflaum

Kevin Berg (MA Math), Keith Kearnes

Nicole Sanderson (MA Math), Stephen Preston

Jonathan Lamar (MA Math), Nathaniel Thiem

Megan Ly (MA Math), Nathaniel Thiem

Kevin Selker

Joseph Migler

Trubee Davison

Liang Zhang

Retired Faculty News

Kent Goodrich

Emeritus Professor Kent Goodrich in January marked the completion of 30 years as a mathematical consultant with NCAR (the National Center for Atmospheric Research) at the Research Applications Lab.

He started out doing wind shear analysis. The wind shear algorithms developed by his group are used in many airports around the world. There has not been a fatal wind shear accident at any airport that has implemented this system in the last 23 years.

His group then moved on to work on turbulence detection algorithms which have been implemented at the new Hong Kong Airport and at Juneau Alaska. His group at NCAR is now working on icing algorithms for aircraft. This work is covered by five US Patents and some European patents. The turbulence work uses a lot of interesting mathematics.

J. Donald Monk

Emeritus Professor J. Donald Monk began retirement from the university faculty in 2015. He joined the CU Boulder Mathematics Department faculty in fall 1962 after completing a Ph.D. from the University of California, Berkeley. During his long tenure at the university he founded a strong research/teaching faculty group in Foundations of Mathematics, Logic, Set Theory, Boolean Algebras and related areas.

Don plans to continue active research and scholarly work during retirement. More information can be found on the department web site Colorado.edu/math.

Annual potluck picnic

Twenty-nine retired faculty and spouses/partners of the Mathematics Department gathered at the home of Bill and Martha Jones for the seventh annual potluck picnic on August 3, 2015. Co-hosting the event and providing great assistance were Richard and Frieda Holley. Pictured, sitting in front, from left: Pat Schmidt, Rebekka Struik, Richard Roth and Laura Fischer. Standing, from left: Bill Jones, Jerry Malitz, Kent Goodrich, Susan Malitz, Jan Mycielski, Anne and Jay Wolkowsky, Muriel Brigg (front), Homer Ellis (back), Arlan Ramsay, Walter Taylor, Doris Goodrich, Sally Ellis, Don and Dottie Monk, Virginia and Al Lundell, Wolfgang Schmidt, Larry Baggett, Frieda Holley, Christy Baggett, Dick Holley and Martha Jones.

Alumnae/Alumni News

Delilah Ball Blount (B.A. Math 1966) was a member of the Alpha Delta Pi Sorority, SPURS and Hesperic. At CU she enjoyed going to the football games and still has season tickets to CU football. She taught mathematics in junior high school for 16 years and in high school for 15. Ms. Blount has traveled in Germany and the Czech Republic. She now enjoys watching her grandchildren in athletic events. She remembers with love the CU Boulder Campus, Old Main, The Sink and Tulagis.
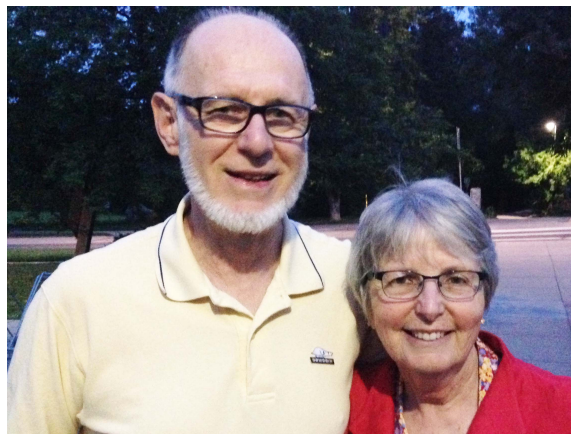

Drs. Cathy and Ed Bonan-Hamada & son Connor

Cathy Bonan-Hamada (Ph.D. Math 1994) and **Edward Bonan-Hamada** (Ph.D. Math 1996), Professors of Mathematics at Colorado Mesa University, visited Boulder recently to see friends including their respective thesis advisors William B. (Bill) Jones and Jerome (Jerry) Malitz. Cathy and Bill also discussed their joint (with Olav Njastad) work on a research paper, "Survey Article: Continued Fractions Associated with Wiener-Levinson Filters, Frequency Analysis, Moment Theory and Polynomials Orthogonal on the Unit Circle."

James Patrick Coughlin (Ph.D. Math 1973). Dr. James Coughlin had a career as a GS-13 Research Physicist at USNWL in Dahlgren, VA. He married Arlene Lawrence in July 1978. He traveled to Iran in 1980 to address the Iranian Mathematical Society. Dr. Coughlin had a faculty exchange with Oldenburg University, Oldenburg, Germany. Although most of the CU faculty that he remembers have gone, he remembers a class in Complex Variables with Professor William B. Jones.

David Anthony Field (A.B. Bowdoin College 1965, M.A. Oakland University 1966, Ph.D. CU Boulder 1971, Math) and **Maureen Bell Field** (M.A. CU Boulder, History) visited Boulder in July 2015 on their way to a family reunion at the YMCA of the Rockies in Estes Park, CO. Before

retiring David was a career employee at General Motors Research and Maureen at Ford Motor Company in Michigan.

Dr. David and Maureen Field

Morris Hoffman (B.A. Math, 1974) wrote to *Prime Bits*: "I graduated with an undergraduate math degree in 1974. My favorite math professors were Professors Monk, Goodrich and Gustafson. I was especially interested in number theory (though Professor Schmidt was on sabbatical and I never had a chance to study with him), and originally planned to go to graduate school in math to study number theory. But on a bit of a lark I applied to law school, and after considerable agonizing I decided to go the law route.

"After graduating from law school, I clerked for an appellate judge for two years, and then practiced law in Denver for another 11 years. I had a general civil practice, mostly representing individuals and companies in civil litigation, and creditors in bankruptcy. I was appointed to the state district court (trial) bench in Denver in 1990 by Governor Roy Romer, and have been here ever since. Like my colleagues, I hear general civil cases and felony criminal cases. I also preside over the Denver Grand Jury.

"I credit my early training in and love of math for opening some interesting doors for me since I've been appointed. I became interested in the intersection of law and science, especially law, evolutionary biology and neuroscience, and spent more than a decade reading, writing and teaching at that intersection. I have been lucky enough to be invited to belong to several groups dedicated to studying law and science, including the Gruter Institute for Law and Behavioral Research and the John D. and Catherine T. MacArthur Foundation's Research Network on Law and Neuroscience. I was nominated for a fellowship at Stanford's Center for the Advanced Study of Behavioral Science, but my day job, and our lack of any sabbatical program, prevented

In Memoriam

Jan and Emilia Mycielski

Emilia Mycielski passed away on March 3, 2015 in Boulder. Emilia was married to Emeritus Professor Jan Mycielski of the CU Boulder Mathematics Department.

Their daughter, Marysia Mycielski, was a member of the Math Department office staff for 6 years (2000-2006).

Emilia's passion was art and she painted landscapes using various techniques.

John Williamson

John Alexander Williamson died on March 30th 2015 in Boulder, following recent surgery and health problems including Parkinson's Disease. John Williamson was a faculty member of the CU Boulder Mathematics Department from 1967 until 1990, when he joined the newly formed CU Boulder Applied Mathematics Department. He retired as Professor of Applied Mathematics in 2005.

Most of his academic work focused on Probability and Statistics; his teaching was consistently rated very highly by students. In 1999, he received a Distinguished Citizen Award from Macalester College and in 1996 the Best Paper Award from the International Genetic Epidemiology Society.

One of his gifts was a sincere interest in whatever mattered most to the person he was speaking with. In spite of his immense knowledge about many things, he always wanted to learn more about what others were passionate about. John remained relentlessly positive, optimistic, and good natured, and his mind remained sharp. He was determined to overcome his latest medical challenge and achieve his goal of passing away peacefully at home after many more years of visits from friends and family.

Professor Williamson spent time on Friday afternoons helping students get ready for the national actuarial exams. This led to the founding of the Actuarial Studies Certificate Program in 1992. The three founders were Professors David Grant, Kent Goodrich and John Williamson. Many students have benefited from this program. The Applied Mathematics Department has set up a fund to honor John, a scholarship fund for students who are interested in statistics and/or probability theory.

A painting titled "Flowers," by Emilia Mycielski

Math Corner: Analysis versus topology

Professor Keith Kearnes describes a research area of CU Boulder Math Faculty member, Alexander (Sasha) Gorokhovsky.

High school students learn that the sum of the angles of a triangle is $180°$, while for a quadrilateral it is $360°$. These observations show that an easily computable numeric quantity can reflect properties of shapes. University students learn the Rank + Nullity Theorem of linear algebra: If A is an $n \times n$ matrix, then the sum of its rank and nullity is n. Here the *nullity* of A, also called the dimension of the kernel of A or $\mathbf{dim}(\ker(A))$, is the number of parameters needed to describe the solution space of $A\mathbf{x} = \mathbf{b}$ when this system is solvable. The number of parameters needed to define the restrictions on $\mathbf{b}$ required to make the system solvable is $\mathbf{dim}(\operatorname{coker}(A))$, which equals $n - \operatorname{rank}(A)$. Thus, the Rank + Nullity Theorem asserts that the *analytic index* of the operator A, $\mathbf{dim}(\ker(A)) - \mathbf{dim}(\operatorname{coker}(A))$, is zero. This number associated to A reflects something about its "shape", although it is not very interesting when A is an $n \times n$ matrix since it is always zero.

The analytic index gets interesting in infinite dimensions, as was discovered by Fritz Noether.[1] He exhibited an operator D with $\mathbf{dim}(\ker(D))$ and $\mathbf{dim}(\operatorname{coker}(D))$ finite, but with analytic index $\mathbf{dim}(\ker(D)) - \mathbf{dim}(\operatorname{coker}(D))$ not equal to zero. Noether established the first *index theorem*, which started a chain of developments culminating in the Atiyah-Singer Index Theorem.[2] The Atiyah-Singer theorem states that the analytic index of certain operators equals the *topological index*, which is computed from the "shape" of the operator.

Following a different thread, Calderón proved that the analytic index of certain operators could be computed with a "trace", written $\operatorname{Trace}[T_f, T_{f^{-1}}]$. Then Berger and Shaw showed that the more general analytical quantity $\operatorname{Trace}[T_f, T_g]$ agreed with a topological quantity $\frac{1}{2\pi i} \int_{S^1} f \, dg$, where S^1 is the circle. Helton and Howe discovered that this was the 1-dimensional case of a link between a new analytical quantity and a corresponding topological quantity. The Helton-Howe higher-dimensional generalization is

$$(1) \qquad \operatorname{Trace}[T_{f_0}, \ldots, T_{f_{2n-1}}] = \frac{n!}{(2\pi i)^n} \int_{S^*(M)} f_0 \, df_1 \wedge \cdots \wedge df_{2n-1}$$

where the number of operators, $2n$, equals the dimension of M plus 1. Helton and Howe say that the quantities are zero when the number of operators exceeds $\mathbf{dim}(M) + 1$, and may not be well defined when the number falls short of $\mathbf{dim}(M) + 1$. But very recently Henri Moscovici and CU faculty member Alexander Gorokhovsky found a correspondence between the analytical and topological concepts in (1) for a small number of operators, $k \leq n$, namely

$$(2) \quad \operatorname{Trace} \Sigma_i[T_{f_0}^{(i)}, \ldots, T_{f_{2k-1}}^{(i)}] = \frac{k!}{(2\pi i)^k} \int_{S^*(M)} \operatorname{Td}(M) \wedge \mathbf{ch} \, \sigma(D) \wedge \Sigma_i(f_0^{(i)} \, df_1^{(i)} \wedge \cdots \wedge df_{2k-1}^{(i)}).$$

When asked how one might explain this equation to a layman, Sasha Gorokhovsky answered, "We don't understand it ourselves (yet)!"
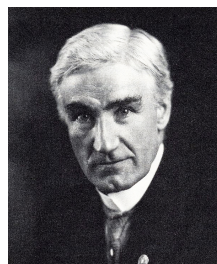
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[1] Fritz was the son of Max Noether and was the brother of Emmy Noether. Max has been called one of the finest mathematicians of the nineteenth century, while Albert Einstein called Emmy "the most significant creative mathematical genius thus far produced since the higher education of women began". The lesser-known Fritz had to leave Germany when the Nazis came to power, as he was Jewish, so he accepted a position in Siberia. He was arrested during Stalin's Great Purge, imprisoned, and executed a few years later.

[2] This theorem is to a great extent responsible for Atiyah winning the Fields Medal in 1966 and for Atiyah and Singer sharing the Abel Prize in 2004.

Mathematics Department Endowment Funds

It would be difficult to overstate the benefits of Endowment Funds which provide support for teaching, research and scholarship. The financial benefits continue in perpetuity in accordance with provisions determined by the donors. If you are interested in creating an Endowment Fund or contributing to an existing one please contact the Mathematics Department Chair, Professor David Grant, Department of Mathematics, University of Colorado, Boulder, CO 80309-0395 or by e-mail: David.Grant@Colorado.EDU. Following are brief descriptions of existing Endowment Funds.

Ira DeLong Lectures

Ira M. DeLong

Professor Ira M. DeLong was the Mathematics Department from 1888 until he retired in 1925. Upon his death in 1942 he gave $25,000 to the Mathematics Department which accumulated interest until 1963 when the Mathematics Department established the annual Ira DeLong

Lectures and undergraduate prizes for the Putnam Competition. The lecture series brings to the CU Boulder community leading mathematicians from around the world.
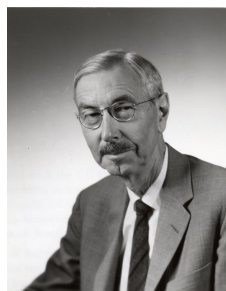
Kempner Mathematics Colloquium

Aubrey Kempner and Burton Jones at Kempner home in 1952

The Kempner Colloquium, weekly expository lecture series, was created in 1963 by the faculty in honor of Emeritus Professor Aubrey J. Kempner who served as head of the Mathematics Department from 1925 until his retirement in 1949. Professor Kempner's inaugural lecture consisted of Reminiscences of the University of Goettingen where he received his Ph.D. under Edmund Landau in 1911. The Kempner Colloquium Endowment Fund was established by gifts from faculty ($15,000), College of Arts and Sciences ($10,000) and CU Math alums including a major gift of $25,000 from alumnus Dr. William J. Leveque who had been greatly influenced at CU by Professor Kempner.

B. W. Jones and W. E. Briggs Teaching Excellence Awards

Professor Burton W. Jones was a member of the Mathematics Department faculty from 1949 until his retirement in 1971. Under his leadership as Department Head from 1949 to 1963 the department grew to a position of

national leadership. To preserve the memory of their distinguished colleague, the faculty contributed gifts to endow the Burton W. Jones Teaching Excellence Award for a graduate student teaching assistant.

B. W. Jones   W. E. Briggs

When Professor William E. Briggs retired in 1988, gifts by faculty were made for a memorial in recognition of his distinguished service as a faculty member (1955-1988) and Dean of the College of Arts and Sciences (1963-1980). Since Briggs and Jones had been close friends who greatly valued good teaching, it was decided in 2007 to establish a separate William E. Briggs Teaching Excellence Award with both awards funded by a joint endowment.

Burnett Chandler Meyer Instructorships

Burnett Meyer

The Burnett Meyer Instructorships were inaugurated in 2009 by a bequest of more than $2,000,000 from the estate of the late Emeritus Professor Burnett Chandler Meyer, a member of the CU Boulder mathematics faculty from 1957 until his retirement in 1990. A portrait and plaque in honor of Professor Meyer has been placed in the Mathematics Building third floor.

Frances C. Stribic Scholarships

Frances Stribic was a member of the CU Boulder Mathematics Faculty from 1926 until her retirement in 1965. Finding the need for someone to teach Statistics, Professor Stribic prepared herself in that subject and not only
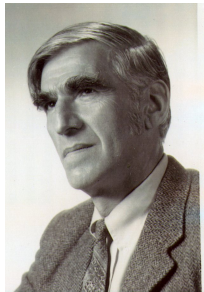
Frances Stribic and Dorothy Martin

taught it but also did research applications jointly with psychology Professor Dorothy (Happy) Martin. Professor Stribic was an outstanding teacher, well respected by her students and colleagues. In 1990 her friend Happy Martin established the Stribic Scholarship Endowment Fund, awarded each year to a female graduate student chosen by faculty for excellence in mathematical scholarship.

Wolfgang J. Thron Mathematics Fellowship

In 1999 Emeritus Professor Wolfgang Joseph Thron expressed his faith in and devotion to the University of Colorado with a gift of $216,000 to establish the W. J. Thron Mathematics Fellowship Endowment Fund.   An award is given each year to an outstanding graduate student in the Mathematics Department. Professor Thron joined the Mathematics Department in 1954 and became Emeritus Professor in 1985. He served as Department Chair from 1972 to 1974 and served as thesis advisor to 21 Ph.D. students. In 1980 Thron was elected to the Royal Norwegian Society for Sciences and Letters (Det Kongelige Norske Widenskapers Selskap) for outstanding creative research in mathematics and for his great inspiration to others to do creative work. He was awarded the University of Colorado Medal for outstanding contributions to the university and for his distinguished career as a scholar, teacher and research mathematician.

Wolfgang J. Thron

John H. "Jack" Hodges Scholarship

In 2010 with a gift of $25,000, Emeritus Professor John H. Hodges endowed a scholarship for competent undergraduate students of mathematics with financial need. He had considered bequeathing the scholarship fund but decided: "Who knows how long anybody is going to last? I'd like to do it while I am still around." Hodges was a member of the CU Boulder Mathematics faculty from 1960 to 1993 and continued teaching for two more years. He served for one term as department chair, was a Ph.D. thesis director for many students and was a recipient of (essentially) every
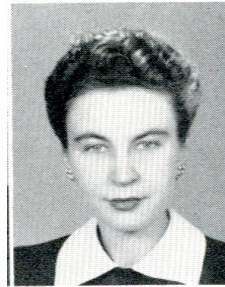
Jean and Jack Hodges

teaching and service award given at CU including: The CU-student initiated Teaching Recognition Award, the Boulder Faculty Assembly Teaching Excellence Award, the Outstanding Service to the University Award and the Burton W. Jones Teaching Excellence Award given by the Mathematical Association of America (Rocky Mountain Section).

In reflection Hodges said: "I had the GI Bill. It was a blessing for the whole country. The GI Bill changed the character of education in the United States. I feel some desire to carry that on for other people."

Sieglinde Talbott Haller Math Scholarship

In 2014, Sieglinde "Linda" Talbott Haller, with a gift of $900,000, endowed scholarships for students in the Department of Mathematics.

A 1941 graduate of CU, Ms. Haller was herself a scholarship recipient. She was a competitor on the CU Swimming and Diving Team and she was also involved with production of the yearbook publication.

Sieglinde Talbott Haller

Richard Laver Graduate Fellowship

The Richard Laver Graduate Fellowship was established in 2014 in memory of the late Emeritus Professor Richard Laver by his brothers, John and Michael Laver, his wife Sherrie and a family friend. Their gift of $65,000 will provide support for Ph.D. students in the Mathematics Department. Rich Laver joined the faculty in 1974 and became Emeritus Professor in 2008.

He earned a Ph.D. from the University of California, Berkeley in 1969 under the direction of Ralph McKenzie, making him the "academic brother" of CU Professor Keith Kearnes and "academic grandson" of CU Emeritus Professor J. Donald Monk. Laver was a celebrated set theorist, chess player and a life-long athlete, hiking and walking until the end of his life.

Richard Laver

Endowments, *(continued from p. 13)*

Frank F. Islam Scholarships

With a gift of $52,000 CU alumnus Frank Islam endowed two scholarships. The Frank F. Islam Mathematics Scholarship in honor of Emeritus Professor William. B. Jones and the Frank F. Islam Scholarship in memory of Emeritus Professor Wolfgang J. Thron. Born in India, Islam immigrated to the U.S. at the age of 15 and earned bachelor's and masters degrees in Computer Science from CU.

Frank F. Islam

Adele Leonhardy Memorial Scholarship

The Adele Leonhardy (B.A. Math 1924) Memorial Scholarship was established by a legacy gift from her estate. Awards are given to graduate students or upper division undergraduates majoring in mathematics who demonstrate excellence in their studies and are preparing to teach mathematics. Adele Leonhardy was born in Carbondale, Colorado, and grew up in Fruita near Grand Junction.

While attending the University of Colorado from 1917 to 1924 she taught elementary school in Boulder to pay for her educational expenses. After graduate work at the Universities of Chicago and Missouri she taught mathematics at Stephens College until her retirement in 1967. Professor Leonhardy understood the difficulty of working one's way through college. She dedicated her life to teaching. Her gift will enable future generations of students to become teachers of mathematics.

Marlene Massaro Pratto and David Pratto Scholarship in Mathematics

Marlene and David Pratto established a scholarship in mathematics with a 2014 gift of $50,000. Marlene Pratto received a B.A. in mathematics degree from CU in 1960. David Pratto is a CU Boulder graduate in Sociology.

William Reinhardt Memorial Lectures

The William Reinhardt Memorial Lecture Endowment Fund was established by family, colleagues and friends of Professor Reinhardt, a member of the Mathematics Faculty from 1967 until his untimely death on June 22, 1998 at the age of 59. The Reinhardt Memorial Lectures reflect his deep interest in the foundations and philosophy of mathematics.

George and Clara Moreno Scholarship to assist undergraduates

CU alumnus George Moreno and his wife Clara have given a wonderful donation to the Department of Mathematics that will greatly enrich the lives of our undergraduates. For each of the next five years they have given money for the George and Clara Moreno Scholarship, which will go to a math major from a group traditionally underrepresented in mathematics. Students apply for the scholarship by writing a one-page essay describing their interest in mathematics and what they plan to do with their mathematical training after graduation. The Morenos have also given money over the same period to fund student activities.

Clara and George Moreno

George Moreno graduated from CU Boulder in 1975 and spent a total of 10 years in Boulder before become a high school teacher in Denver. He credits his Boulder days for kindling his lifelong interest in running (he used to run 30 miles a week --- and up Flagstaff Mountain --- and still walks 5-10 miles every day), and remembers fondly concerts at Folsom Field by the Grateful Dead, Fleetwood Mac, and the Rolling Stones. He had a work study job at the National Bureau of Standards (as NIST was known in the day), which allowed him to enjoy lunch breaks at the then-new campus rec center.

He recalls a foundational moment while attending an employment workshop at the UMC: "One of the presenters suggested you could make a good living doing the work no one else wanted to do. I kept this thought in mind when I took a second full time job while I was teaching high school math and computers. I worked the swing shift, and then the graveyard shift, for 10 years while teaching during the day." During this time he participated in the government sponsored program, Adventures In Supercomputing. This allowed him to bring computer data visualization into the high school classroom, a practice he continues today.

George owned a mobile home for a time while living in Boulder, and likes to joke that he's the only one who ever sold a mobile home for a profit! That started him investing in real estate, and besides teaching high school, he has been involved in property management for more than 30 years.

George and Clara have two daughters and six grandchildren. The Morenos enjoy travel, and have vacationed often in Mexico and Hawaii. Their travels have also taken them to Alaska, Russia, Costa Rica, Japan, Spain, England, France, and Puerto Rico, and they are making plans to visit the South Pacific.

Mathematics Department Donors 2013-2015

The University of Colorado-Boulder Department of Mathematics is grateful for the generous contributions by donors listed below. Gifts to endowments and funds make it possible to bring colloquium speakers (DeLong, Kempner and Reinhardt) to the CU Boulder campus, to offer scholarships (Haller, Hodges, Islam, Laver, Leonhardy, Pratto, Stribic and Thron) and awards to outstanding teaching assistants (B.W. Jones & W. E. Briggs) and Putnam Contest winners. Gifts (cash or securities) can be sent by returning the enclosed form Mathematics Department 2015 Annual Fund to the CU Foundation. Contributions to the Mathematics Department through the CU Foundation are tax deductible.

Steven & Beverly Aanenson
Bryan & Jean Albert
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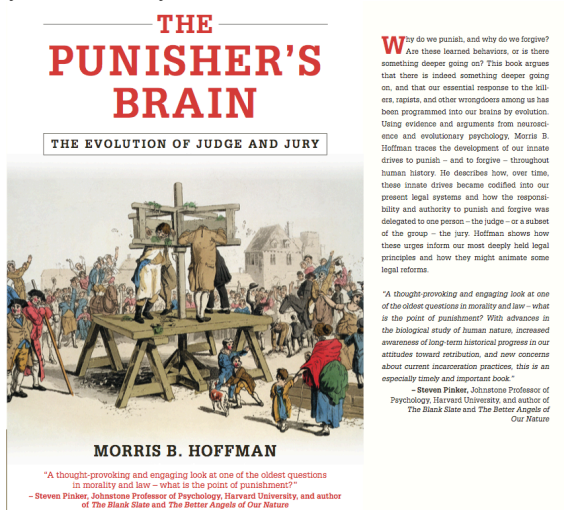   Karla Jeanette Oty, PhD
Vivian Grace McCullough

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Laura A. Michaelis-Cummings
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Clayton George Mitchell
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Alumnae/Alumni News, (continued from p. 9)

me from pursuing it. I have managed to co-author a couple neuroscience papers (doing actual experiments and publishing in science journals is sure different than publishing in law reviews!), and this spring Cambridge University Press published a book I wrote about the evolution of punishment, called The Punisher's Brain: The Evolution of Judge and Jury.

"Looking back, I still wonder whether I made the right choice in leaving math for the law. But right or wrong, the analytical skills your department helped me hone over those four years have stayed with me and served me well."

Steven Douglas Kerr (M.A. Math 1968, Ph.D. Math 1973). Dr. Kerr wrote: "Thank you for providing me my mathematics foundations for my graduate degrees and 40 years of college teaching.

Robert C. Mers (Ph.D. Math 1975). Dr. Mers remembers the following favorite CU faculty: Professors Jack Hodges, Richard Roth and Rebekka Struik. His professional career included teaching at Community College of Denver in fall 1975, Oklahoma State University spring 1976, Winston Salem State University 1976-77, North Carolina A&T State University (32 years), 1977-2009 full time and 20010-2011 part time. Awards: Outstanding Math Teacher 1990, Outstanding Math Teacher and Merit Award, College of A&S, 1992.

In retirement Dr. Mers is active in New Gardens Friends Meeting, Quaker House Board, Quaker Relations Committee, Quarterly Meeting in Working America, Democratic Party and Senior Democrats. His travels include Russia, Scandinavia, Eastern Europe, Hawaii and South America. At CU Boulder, Dr. Mers was active in the Wesley Foundation and the First Christian Church. He made many trips to the Rocky Mountain National Park and western U.S. Dr. Mers is the father of two daughters: Susan Mers Howard and Angela Mers.