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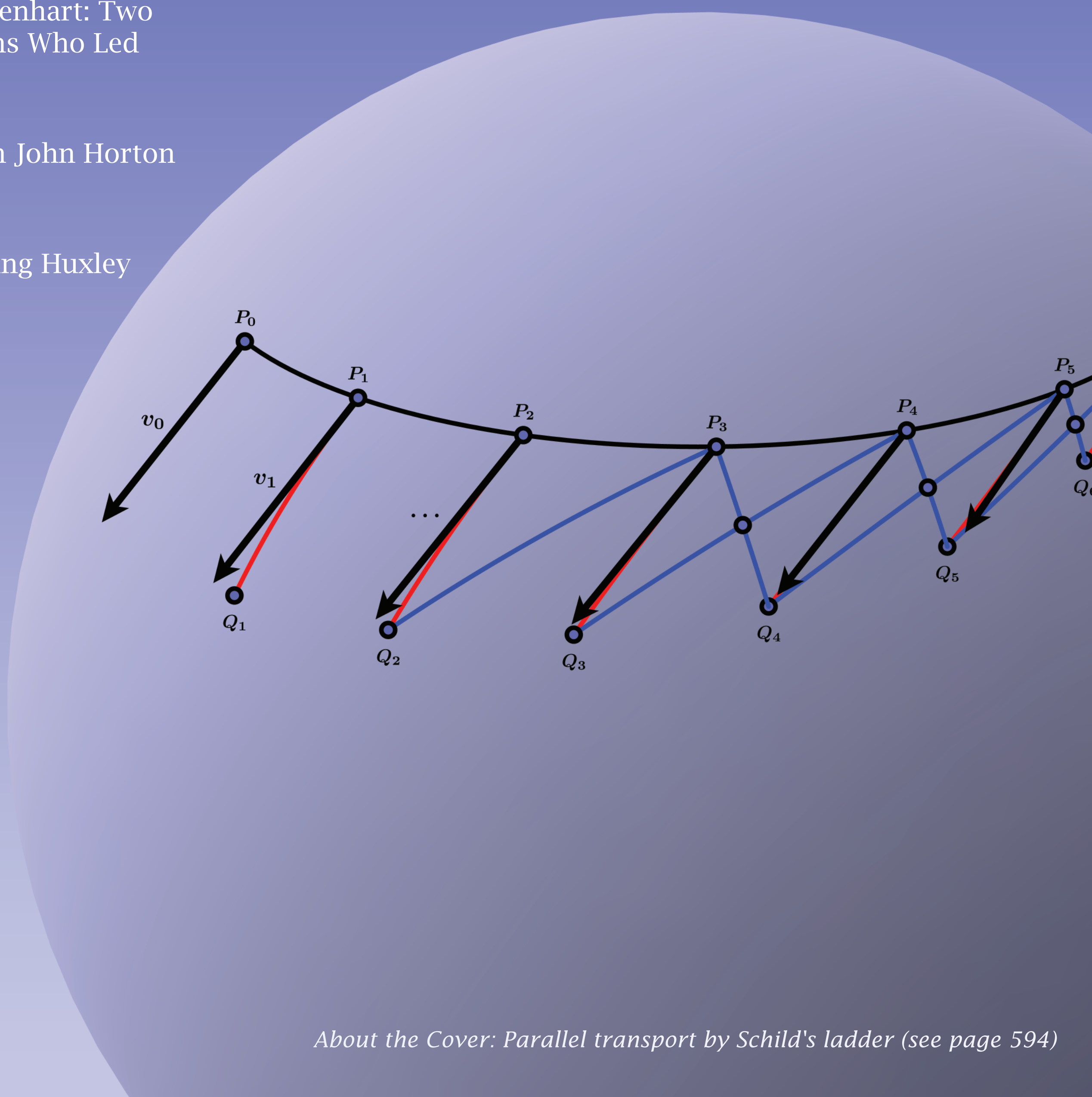
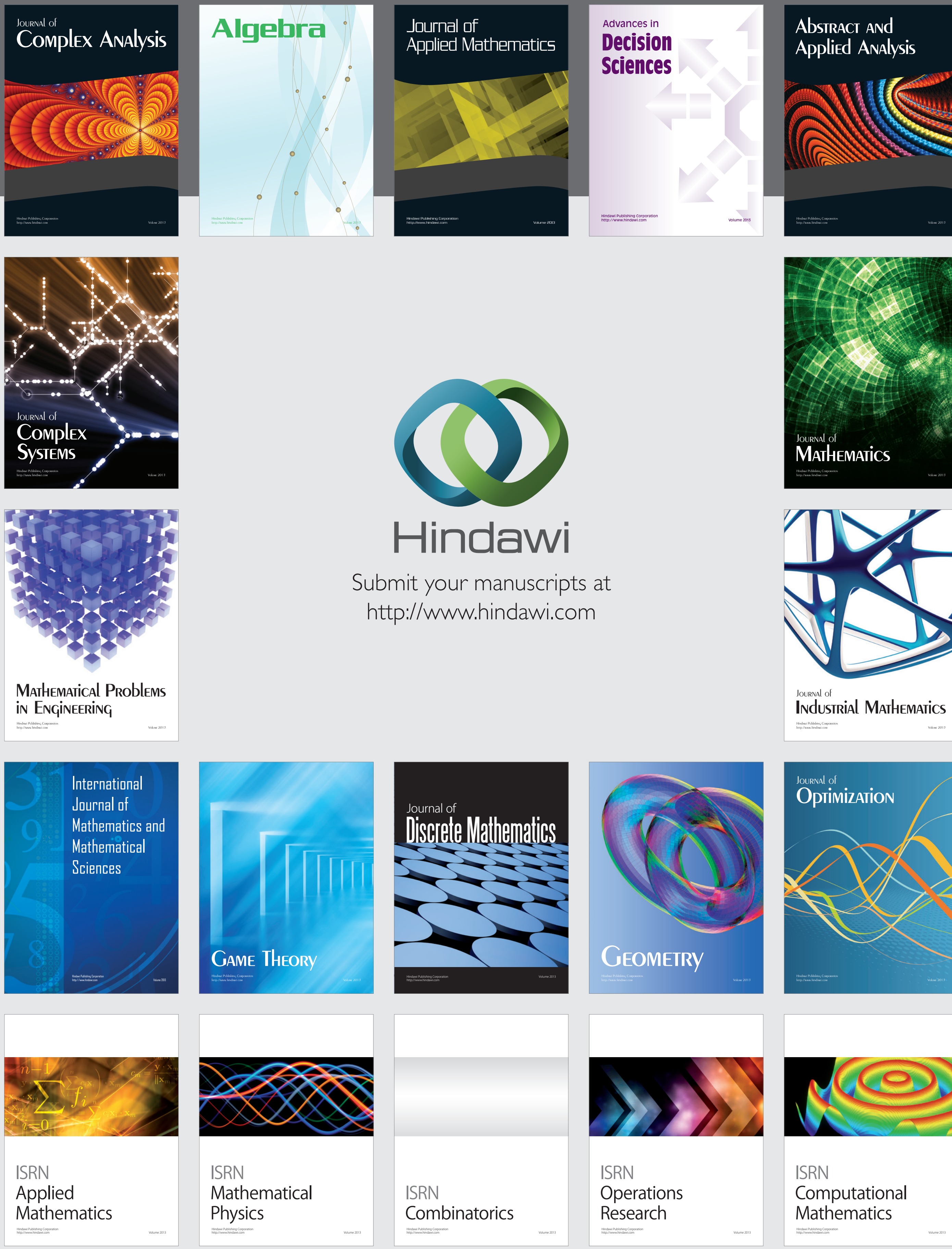


About the Cover: Parallel transport by Schild's ladder *(see page 594)*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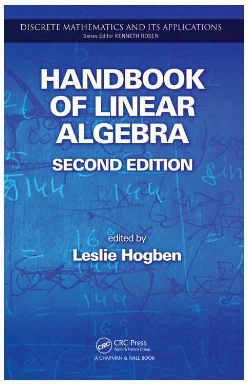

This highly praised handbook has been updated and expanded to incorporate the latest linear algebra concepts, applications, and computational software packages. In an easy-to-use format, it guides readers from the very elementary aspects of the subject to the frontiers of current research. It also describes software packages for linear algebra computations, including MATLAB®, Maple™, and *Mathematica*®.

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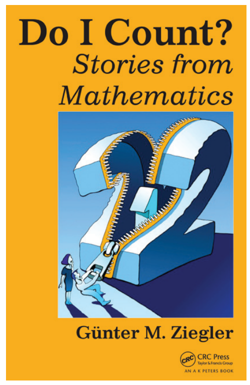

In this book of mathematical stories, the well-known and highly esteemed author provides a surprisingly entertaining tour of unfamiliar territory. Focusing on the doing and making of mathematics, he describes stories about numbers, problems, people who do math, and the places where mathematical discoveries are made.

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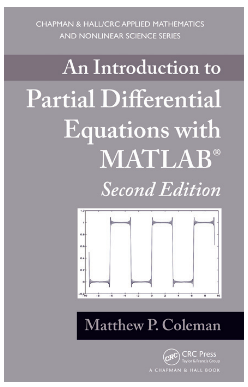

Updated throughout, this second edition of a bestseller illustrates the usefulness of PDEs through numerous applications and helps readers appreciate the beauty of the underlying mathematics. It shows how PDEs can model diverse problems, from the spread of algae along the ocean's surface to the quantum mechanical behavior of a hydrogen atom. MATLAB® code is available online.

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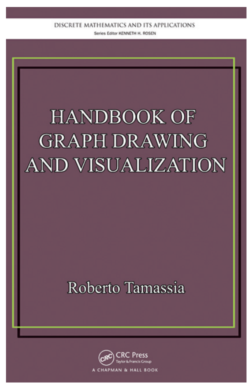

This handbook provides a comprehensive survey of the field, from its combinatorial and geometric foundations to its applications in various areas of the physical, life, and social sciences. It presents in-depth coverage of combinatorial, geometric, and algorithmic foundations as well as numerous graph drawing algorithms and graph drawing systems.

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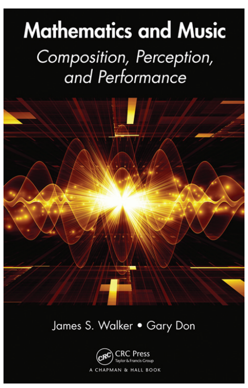

This accessible text explores the many links between mathematics and different genres of music, deepening readers' understanding of music through mathematics. The authors extensively use the powerful time-frequency method of spectrograms to analyze the sounds created in musical performance. Video demos, music software, and more are available on the book's CRC Press web page.

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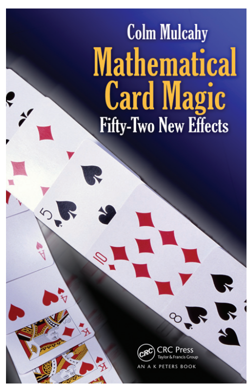

Featuring numerous original creations—many of which have appeared in the author's MAA column *Card Colm*—this book presents an entertaining look at mathematically based card tricks. Three chapters address the growing field of two-person mathemagic, which uses subtle information theory principles to communicate.

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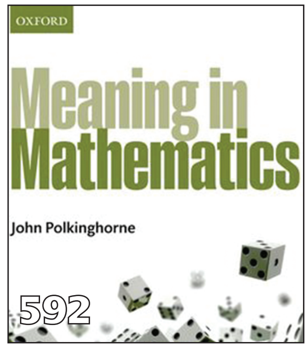

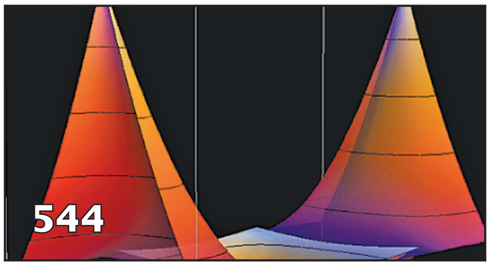

The May issue offers an unusual panorama of topics for our delectation. These include an article about Andrew Fielding Huxley, half brother of the writer Aldous Huxley, Nobel Laureate, and distinguished mathematical scientist. Also a fascinating interview with John Horton Conway. We have an article about two scions of Gettysburg College who became important presidents of the AMS. And there is a feature about geodesic springs in the Euclidean sphere. Finally, we have an Opinion Column by Congressman Jerry McNerney.

—Steven G. Krantz, Editor

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Opinion

Make the Voice of Mathematicians Heard

As a mathematician and U.S. congressman, I am honored to be invited to write to mathematicians around the country in the *Notices* "Opinion" column. Your work has meaning and purpose and affects people's lives on a daily basis. Mathematics plays a critical role in telecommunications, medicine, understanding space, modeling thousands of mechanical and electrical processes, neuroscience, and much more. Your profession is both ancient and noble, and I hope that your work inspires the next generation of mathematicians to carry on the tradition of developing great mathematics. That is why it is so important that we come together to support the field of mathematics, raising awareness of the power of mathematics not only within our ranks but among the general public and politicians in Washington, D.C., and inspiring the next generations of mathematicians.

In order to maintain and grow the field of mathematics, inspiration must filter down to colleges, high schools, and elementary schools. You understand clearly that by the time someone is a junior or senior in high school, if they don't already have a solid background in mathematics, they will be at a severe disadvantage with regard to any career in science or engineering.

Not only is your theoretical work important, but our society will continue to need the tools and insights developed in the mathematical sciences. The challenges that humanity faces are daunting. Global warming, cyber attacks, the availability of fresh water and arable land, microbic threats, global financial stability, resource depletion, and nuclear conflicts are serious issues we're facing right now. Each of these threats can be better understood, and therefore better managed, with mathematical tools. There are commendable efforts in place, such as Mathematics for Planet Earth, that attempt to focus on some of these large problems. For many decades there was a trend of mathematics moving away from possible applications towards pure mathematics, resulting in some very beautiful theory. Now we see these fields applied in helpful ways in the real world. It is important that we apply these great theories to understand and manage our problems and to continue making efforts to develop new mathematical languages specifically to understand the challenges we as a society face.

We all know that achieving these goals and investing in mathematics research don't come free, and the community will not continue to innovate without a concerted effort to make sure that the field of mathematics remains a priority for institutions that support research. In the United States, money for mathematical research predominantly comes from the National Science Foundation (NSF) and is then conducted at public and private universities and other institutions. There are some corporate dollars that fund mathematical research, and some money comes from private donations. Most mathematicians rely on these institutions for their livelihoods, pausing only to consider the source of this funding as it relates to their own research projects. It's really in the nature of most mathematicians not to worry about such issues and focus on their work. This is unfortunate, because mathematicians have significant prestige in our society, and a little involvement will go a long way to ensure that funding continues. The nation and much of the world are facing very tough choices of how to allocate public monies, which is why we must take the time to make sure our community is well represented.

There are ways to show your support for the NSF and other programs so that they will be noted in Washington. It is important to develop relationships with your members of Congress. You can arrange regular visits to their home offices and have a large organized group of mathematicians visit Washington on a yearly basis. Get to know your representative and senators personally by visiting their offices. I encourage you to keep them abreast of some of your research projects and give them updates once in a while. I wish you all the best and hope you are successful in developing theory in 2013.

—Jerry McNerney
U.S. Representative
California's 9th Congressional District

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Letters to the Editor

Nathan Rosen and Black Mountain

Thank you for your excellent article in the February 2013 *Notices* on von Neumann and the book review of *Transcending Tradition*. Having been educated in North Carolina, I was especially interested in the discussion of Black Mountain College in the latter. One prominent faculty member there not mentioned in the review was the Jewish physicist (and disciple of Einstein) Nathan Rosen. Although I earned my Ph.D. in physics at Duke University, I was allowed to take courses at the University of North Carolina in Chapel Hill. I took advantage of this leniency to take three courses from Professor Rosen who had left Black Mountain to join the U.N.C. faculty. This was a real thrill for me, as Professor Rosen was famous for his studies of the hydrogen molecule and, more so, for his discovery, along with Boris Podolsky and Einstein, of the so-called "EPR Paradox" of quantum mechanics, a subject of much theoretical debate and experimental study throughout the twentieth century. (It was the inspiration for the seminal work involving Bell's Theorem, for example.) Rosen was more or less forced to leave U.N.C. by the threat of a U.S. government investigation of his alleged "communist sympathies". (The university was by no means complicit in his departure.) He and his wife emigrated to Israel where he lived to a ripe old age and did very well, becoming, as I recall, president of the Ben-Gurion University. I had the opportunity to visit him twice in Israel and once he visited me in Ann Arbor, where I was teaching at the time. He always greeted me as an old friend. If I am not mistaken, the vacancy created by Rosen's departure was filled by a close friend of mine, Eugen Merzbacher, who went on to become chairman of the U.N.C. physics department, president of the American Physical Society, and author of a definitive textbook on quantum mechanics. He is still in Chapel Hill, living with his wife now in a retirement home and still active, although well into his nineties, in various activities related to physics and Judaism. Merzbacher has informed me that Professor Rosen used to return to Chapel Hill during the summers where he collaborated with Merzbacher on various research projects.

—Paul F. Zweifel
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(Received January 22, 2013)

In Defense of Technology for Mathematical Talks

In response to V. V. Peller's commentary, "Utilization of technology for mathematical talks: An alarming situation" [*Notices*, February 2013]:

I sympathize with many of the author's points, but disagree with the tendency to blame the computer as a platform for mathematical presentations, and by extension the conclusion that conferences should be required to provide blackboards for presenters. I, too, dislike heavy reliance on slides, especially when cluttered with dense notation. For short presentations, I use slides myself, but few of them, typically fewer than ten for a fifteen- to twenty-minute talk. Slides should provide only some linear structure, not much content, for a talk. I frequently switch between slides and other software to show graphics or interactive demonstrations.

The same has been true since before computers became a mainstream mode for presentations: when giving a short talk using an overhead projector, I would always have a few prepared slides, and carry blank slides and dry-erase pens so that I could be prepared to take a different path based on audience response. In a longer talk or class, I frequently use a computer, but almost never slides: I use a tablet computer with an app such as LectureNotes (by Acadoid, for Android) or Notability (by Ginger Labs, for iOS), which turns the tablet into a portable whiteboard when connected to a projector.

The author acknowledges both the advantage of computers for presenting difficult graphics and the problem of having to turn lights on and off and put screens up and down when using both a blackboard and a computer. There is another advantage of tablet apps which, being unfamiliar with them, the author doesn't anticipate: no matter how many blackboards are available, total space is limited, but the apps can store an unlimited number of handwritten screens. If an audience member wants a copy of the notes after a talk, I can either print a copy or email the stored document. The apps can even record audio from the presentation.

I think what the author observes about use of computer-based slides today represents not a failure of the computer as a platform for the presentation, but rather inadequately creative use of the platform for a dynamic presentation. All I ask is that the author not blame the computer for presentations by people who don't know how to take advantage of such a powerful tool.

—Tom Leathrum
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(Received January 25, 2013)

Displaced Mathematicians: A Plea for Accuracy

I was a little bit puzzled by the front cover of the February 2013 *Notices* (Vol. 60, No. 3). Who is counted as "displaced"? For example, Heinz Hopf moved to Zurich in 1931 as the successor of Hermann Weyl, who then took up a chair in Göttingen (see, e.g., `http://www-gap.dcs.st-and.ac.uk/history/Biographies/Hopf.html`). Weyl thereafter left Göttingen in 1933 because of the Nazis. So Hopf was not "displaced", but left Germany when he accepted a regular job offer (he stayed in Switzerland until his death; in 1943 he took Swiss citizenship because the Nazi authorities caused trouble). But I might consider Weyl as "displaced", even though he moved out of Germany of his free will, before he was forced out.

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(Received February 7, 2013)

The Geodesic Spring on the Euclidean Sphere with Parallel-Transport-Based Damping

Jason M. Osborne and Gregory P. Hicks

Figure 1. Identification of Curves on the Sphere with Orientations of a Robotic Arm. In this article, pointing a robotic arm is achieved using a generalized mass-spring-damper (MSD) control design on the sphere.

In this article differential geometric methods are applied to the design of a tracking algorithm which compels a particle that is constrained to the unit sphere $\mathbb{S}^2$ into a moving target that is also constrained to the sphere. By tracking we mean that both the position and velocity of the chasing particle are made to match that of the target particle. A mechanical system analog of this mathematical scenario is the pointing of the end effector of a robotic arm whose range of motion is restricted to the surface of a sphere (see Figure 1). At the heart of this article is the 1D mass-spring-damper (MSD) system on the real line, which is reviewed and summarized in Sidebar 1 (see page 11), so as to be easily extensible to a unit sphere $\mathbb{S}^2$-generalization. This spherical generalization, depicted by ( ) in Figure 1, is the so-called *geodesic spring* tracking algorithm. Essentially, the spring ( ) pulls the robotic arm close to its goal configuration, and the damper ( ) dissipates the kinetic energy of the arm so that it eventually reaches and stops at the goal configuration.

There are some new mathematical avenues explored in this article; however, with the belief that a good example can often be as useful as a good theorem, this article's main purpose is to instantiate the more research-oriented articles on which it is founded. Specifically, while the geodesic spring (with damping) design is theoretically formulated on a general Riemannian manifold in [1], in this article we actually implement this general result on a specific manifold, namely $\mathbb{S}^2$. In so doing, one is confronted with the *geometric*, *coordinate-free*, *nonlinear*, and *almost global* nature of the control design that, at least to these authors, provides an additional layer of understanding of the general theorem.

The authors' broader hope for this article is that, by providing an example which is completely expressed in closed form, some insight may be gained by the reader into the control and

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stabilization of systems on manifolds. While this article is narrowly focused on the manifold $\mathbb{S}^2$, the potential usefulness of its results are limited only by the imagination of the reader to formulate a problem in terms of a specific Riemannian manifold of interest. For example, as exceptionally relayed and detailed by [2], in his investigations of surface curvature, Gauss invented a mapping of normal vectors on a surface $\mathbb{S}^2$. This map, now called the *Gauss map*, and some of the techniques of this article on $\mathbb{S}^2$ are used by [3] to devise a geometric-based guidance law for an interceptor problem. That is, unlike this article, where the goal is to match both the position and velocity of a reference trajectory $r(t) \in \mathbb{S}^2$, the goal in an interceptor problem is to match only position $r(t_f) \in \mathbb{R}^3$ for some intercept time t_f; the velocity at which the interception is made is immaterial. An additional avenue for exploration of the techniques of this article is to a Riemannian manifold called the *Poincaré upper-half plane*, denoted $\mathbb{H}^2$, where, as in $\mathbb{S}^2$, the geodesic and parallel transport equations both have closed-form realizations. Perhaps then the control design of this article on $\mathbb{H}^2$ might find some application to electrical impedance tomography [4] and to microwave technology [5], where the geometry of $\mathbb{H}^2$ is shown to play a role.

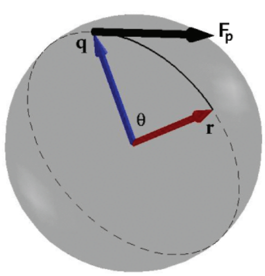


Figure 2. Geodesic Distance on $\mathbb{S}^2$. The geodesic distance is given by $\theta = \arccos(\langle r, q\rangle)$ where θ is the angle subtended by the segment of the great circle (geodesic, black solid line) between q and r. Projecting the differential of $\frac{1}{2}\theta^2$ onto the tangent plane at q yields a vector $F_{\mathcal{P}}$, which can be interpreted as a geodesic-spring force pushing q towards r.

A broad outline of this article is as follows. In Sidebar 1 (page 11) we review the 1D MSD. Those readers already familiar with the material from this section and who want to learn about its generalization to the geodesic spring system on a Riemannian manifold could proceed to "History of the Geodesic Spring", where a general theorem is outlined. In "MSD System on $\mathbb{S}^2$" we instantiate this general theorem on the sphere $\mathbb{S}^2 \subset \mathbb{R}^3$, and in "Implementation of MSD System on $\mathbb{S}^2$" we present several examples and simulations.

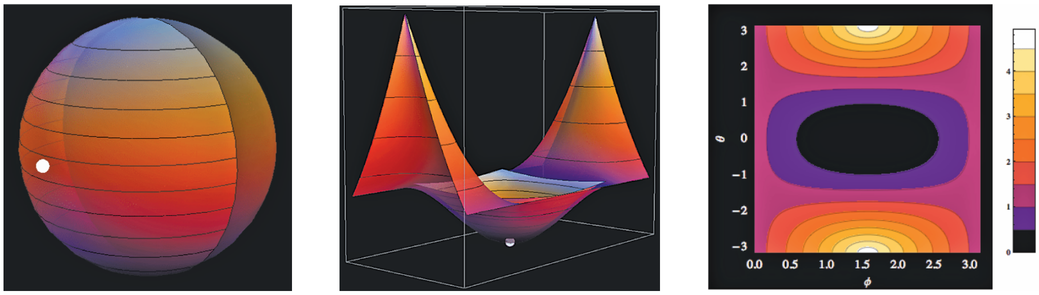
History of the Geodesic Spring

The evolution of the 1D MSD system to its general form on a Riemannian manifold can be traced to the evolution of a *configuration error function* ϕ and the *transport map* $\mathcal{T}$ pairing. For the purposes of this article, we think of a Riemannian manifold Q simply as a surface $S \subset \mathbb{R}^3$ that is equipped with an inner product $\langle\cdot,\cdot\rangle$, which effectively induces a definition of distance between points $q, r \in Q$. A more formal definition of Riemannian manifold, though not necessary for this article, can be found in most books on differential geometry (for example, [6], [7]). In general, the value $\phi(q,r)$ is a measure of the difference (not necessarily distance) between q and r and satisfies $\phi(q,r) \to 0$ as $q \to r$. The transport map $\mathcal{T}$ is discussed shortly. The geometric setting of [8] is the Euclidean sphere $\mathbb{S}^2 \subset \mathbb{R}^3$. One of the control problems solved in [8, Problem 2.2, p. 6] is to steer asymptotically a point particle q constrained to $\mathbb{S}^2$ to a *fixed* reference $r \in \mathbb{S}^2$. The authors use the function

(1)
$$\frac{1}{2}\left[\mathrm{dist}_{\mathbb{S}^2}(q,r)\right]^2 = \frac{1}{2}\left[\arccos(\langle r,q\rangle)\right]^2 = \frac{1}{2}\theta^2$$

to obtain a *geodesic spring* force $F_{\mathcal{P}}$ on $\mathbb{S}^2$ (illustrated in Figure 2) that stabilizes a curve $q(t)$ to fixed r. Since $q, r \in \mathbb{S}^2$ and $\arccos(\langle r,q\rangle) \to 0$ as $q \to r$, then (1) is an example of a configuration error function $\phi(q,r)$ with sample plots shown in Figure 3. A comparison of this plot with Figure B1 along with the discussion in Sidebar 1, shows that (1) plays the role of a quadratic potential function on $\mathbb{S}^2$ centered at $r \in \mathbb{S}^2$. Extending the quadratic potential $V(q)$ on $\mathbb{R}$ to the quadratic potential $\phi(q,r)$ on $\mathbb{S}^2$ is the first step in generalizing the 1D MSD to $\mathbb{S}^2$.

In an effort to generalize the damping force, [9, Chapter 11], [10], and [11, Chapter 4] work within the context of Riemannian manifolds, of which the surface $\mathbb{S}^2 \subset \mathbb{R}^3$ is but one example. Within this broader geometric setting, Bullo et al. introduce the general definitions of a pair of mappings called the *configuration error* and the *transport map*, which are denoted by ϕ and $\mathcal{T}$, respectively. Recall from Sidebar 1 that, when the tracker $q(t)$ is confined to the real line $\mathbb{R}$ and when the target $r \in \mathbb{R}$ is fixed, the difference $e(t) \triangleq q(t) - r$ (the position error) makes sense as a difference in $\mathbb{R}$ and further that the time derivative of the error (the velocity error) is simply $\dot{e} \triangleq \frac{d}{dt}e(t)$. In the transition to a Riemannian manifold Q (think of Q as a surface $S \subset \mathbb{R}^3$) with $q(t) \in S$ and a moving reference $r(t) \in S$, some care needs to be taken when differencing the velocity vectors $\dot{q}$ and $\dot{r}$, which lie in two separate tangent planes: one at $q(t)$ and the other at $r(t)$, respectively. This differencing is achieved by Bullo et al. through the introduction of a transport map $\mathcal{T}$, which transports $\dot{r}$ into the tangent plane at q, denoted $\mathcal{T}\dot{r}$, where the differencing with $\dot{q}$ makes sense using the vector space properties of the tangent plane T_qS. That is, as a result of the transport



(a) Plot of region of $\mathbb{S}^2$ about the point $r = (1,0,0)$.

(b) Plot of ϕ on $\mathbb{S}^2$ and region of $\mathbb{S}^2$ in spherical coordinates (cf. Sidebar 5). The result is a potential well centered about $R = (\theta,\phi) = (0,\pi/2)$, which generates an attractive force with a strength that is proportional to the distance from R.

(c) Contour plot of ϕ in spherical coordinates, which shows that the potential well is centered at $R = (0,\pi/2)$.

Figure 3. Illustrations of the Potential Function $\phi(q,r) = \frac{1}{2}\left[\mathrm{dist}_{\mathbb{S}^2}(q,r)\right]^2 = \frac{1}{2}\left[\arccos(\langle r,q\rangle)\right]^2$.

map $\mathcal{T}$, a new definition of the velocity error on a Riemannian manifold is given by

$$\dot{e} \triangleq \dot{q} - \mathcal{T}\dot{r} \in T_qS.$$

With these general mappings ϕ and $\mathcal{T}$, Bullo et al. generalize the 1D MSD error system from Sidebar 1 as follows. Newton's equation for a free particle constrained to a Riemannian manifold is the geodesic equation

$$\frac{D\dot{q}}{dt} = 0,$$

where $\frac{D}{dt}$ denotes covariant differentiation along the curve $q(t)$. The general idea of covariant differentiation on a Riemannian manifold is addressed in most differential geometry books and can be illustrated in terms of, and indeed historically developed from, differentiation on a surface $S \subset \mathbb{R}^3$. Specifically, the covariant derivative at $q \in S$ is the standard derivative followed by a projection onto the tangent plane to S at q,

$$\frac{D}{dt} = \mathrm{proj}_q \circ \frac{d}{dt}. \tag{2}$$

Defining a proportional (spring) force $F_{\mathcal{P}}$, a derivative (damping) force $F_{\mathcal{D}}$, and an additional so-called feed-forward force $F_{\mathcal{FF}}$ (which compensates for the nonzero accelerations of $r(t)$)

$$F_{\mathcal{P}} \triangleq -k_{\mathcal{P}}\,\mathrm{proj}_q\,(d_q\phi) \triangleq -k_{\mathcal{P}}\,e \in T_qS,$$

$$F_{\mathcal{D}} \triangleq -k_{\mathcal{D}}(\dot{q} - \mathcal{T}\dot{r}) \triangleq -k_{\mathcal{D}}\,\dot{e} \in T_qS,$$

$$F_{\mathcal{FF}} \triangleq \frac{D}{dt}\left[\mathcal{T}\dot{r}\right] \in T_qS$$

we find that Newton's equation with forcing ΣF is the closed-loop system.

$$\frac{D\dot{q}}{dt} = \Sigma F = F_{\mathcal{P}} + F_{\mathcal{D}} + F_{\mathcal{FF}}, \tag{3}$$

This simplifies to the error system

$$\frac{D\dot{e}}{dt} + k_{\mathcal{D}}\dot{e} + k_{\mathcal{P}}e = 0.$$

A word or two on notation is in order at this point. The vector $v_r = d_r\phi$ (the derivative of ϕ with respect to r) *is* in the tangent plane T_rS, but the vector $\mathrm{proj}_r(v_r)$ is in the tangent plane (see Sidebar 2, page 12). From now on we denote the vectors $\mathrm{proj}_r\,(d_r\phi)$ and $\mathrm{proj}_q\,(d_q\phi)$ by $d_r\phi|_r$ and $d_q\phi|_q$, respectively. Assuming that ϕ and $\mathcal{T}$ satisfy a *compatibility condition*

$$\langle d_r\phi|_r, \dot{r}\rangle = -\langle d_q\phi|_q, \mathcal{T}\dot{r}\rangle, \tag{4}$$

where $\langle\cdot,\cdot\rangle$ is the dot (inner) product on $\mathbb{R}^3$ applied to tangent vectors to S, the time derivative of the total energy $L = \frac{k_{\mathcal{D}}}{2}\langle\dot{e},\dot{e}\rangle + k_{\mathcal{P}}\,\phi(q,r)$ along the solution to the forced dynamics reduces to

$$\begin{aligned}\frac{dL}{dt} &= k_{\mathcal{P}}\left[\langle d_q\phi|_q, \dot{q}\rangle + \langle d_r\phi|_r, \dot{r}\rangle\right] + k_{\mathcal{D}}\left\langle \frac{D\dot{e}}{dt}, \dot{e}\right\rangle \\ &= -k_{\mathcal{D}}\langle\dot{e},\dot{e}\rangle \le 0 \quad [k_{\mathcal{D}} > 0].\end{aligned} \tag{5}$$

Equation (5) indicates that the energy function is decreasing and guarantees that $q = q(t)$ Lyapunov stabilizes to $r = r(t)$. Assuming technical conditions on the *uniformity* of ϕ [9, p. 536] and *boundedness* assumptions on, for example, $k_{\mathcal{P}}$ and $k_{\mathcal{D}}$ [9, pp. 540–541], it is proven in [9, Chapter 11] that $q = q(t)$ exponentially stabilizes to $r = r(t)$. This theorem (hereafter referred to as Bullo's Theorem) can be summarized as

Bullo's Theorem. *The solution e to the error system $\frac{D\dot{e}}{dt} + k_{\mathcal{D}}\dot{e} + k_{\mathcal{P}}e = 0$ satisfies $e \to 0$ as $t \to \infty$ so long as the mappings $(\phi,\mathcal{T})$ that define $e \triangleq d_q\phi|_q$ and $\dot{e} \triangleq \dot{q} - \mathcal{T}\dot{r}$ are compatible in the sense of $\langle d_r\phi|_r, \dot{r}\rangle = -\langle d_q\phi|_q, \mathcal{T}\dot{r}\rangle$.*

The objective now is to actually construct such a compatible pair of functions. In an attempt to implement Bullo's Theorem, [1] showed that the geodesic distance and parallel transport on a Riemannian manifold lead to such a compatible pair of mappings.

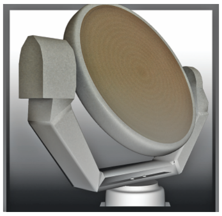


Figure 4. A Double Gimbal Mechanism (DGM).

A difficulty faced with the use of this pair is a reliance on numerical solutions to the geodesic equation (as a nonlinear, two-point boundary value problem) and to the parallel-transport equations (as a linear, possibly time-dependent, initial value problem). In [12], the geodesic distance and parallel transport pairing was utilized on a Riemannian manifold called the *double gimbal torus*, which encapsulates the physics of the double gimbal mechanism (DGM) shown in Figure 4. For a special DGM (called the *flat* DGM), the parallel-transport and geodesic equations can be expressed in closed form, and the closed-loop equations (3) reduce to a system of uncoupled 1D MSD error systems. However, for a general DGM (that is, *nonflat*), the formulation of the closed-loop dynamics still requires numerical solutions.

The works cited here are by no means a complete list and represent only those most directly related to this article. For a broader range of references addressing control design on spheres and the use of geodesics in optimal control, see, for example, [13], [14], and the references and introductions of works cited in this section.

MSD System on $\mathbb{S}^2$

The goal of this section is to first give the details of the closed-form constructions of both the compatible configuration error and transport map pairing and the closed-loop dynamics (3). The configuration error function ϕ is recognizable as the quadratic potential well centered on $r(t) \in \mathbb{S}^2$ from (1) shown in Figure 3. As illustrated in Figure B1, this potential is sufficient to attract the curve $q(t) \in \mathbb{S}^2$ into the vicinity of $r(t)$. The main focus of "A Compatible Pair of Mappings on $\mathbb{S}^2$" below is the geometric construction of a transport map, shown to be parallel transport along the geodesics of $\mathbb{S}^2$. As illustrated in Figure B1, this transport map is used to define a source of friction on the potential surface that eventually slows the curve $q(t)$ to $r(t)$ located at the bottom of the quadratic potential well.

A Compatible Pair of Mappings on $\mathbb{S}^2$

Define a configuration error function ϕ and transport map $\mathcal{T}$ pairing on $\mathbb{S}^2$ by

(6)
$$(\phi, \mathcal{T}_{r\to q}) = \left[\frac{1}{2}(\arccos(\beta))^2, \beta I_3 + \left(\frac{1-\beta}{\langle \omega, \omega\rangle}\right)\omega\otimes\omega + \widehat{\omega}\right],$$

where $\beta \triangleq \langle q, r\rangle = \cos(\theta)$, $\omega \triangleq r \times q$, and $\omega\otimes\omega$ is defined by its action on a vector v as $(\omega\otimes\omega)(v) \triangleq \langle \omega, v\rangle\,\omega$. Furthermore, the mapping $\widehat{\cdot}$ is defined by

$$\hat{v} = \widehat{\begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix}} = \begin{bmatrix} 0 & -v_3 & v_2 \\ v_3 & 0 & -v_1 \\ -v_2 & v_1 & 0 \end{bmatrix} \tag{7}$$

and has the property $\hat{v} * w = v \times w$, where $*$ is matrix-vector multiplication. The geometric interpretation of the transport map $\mathcal{T}_{r\to q}$ is revealed as parallel transport by considering the Frenet-Serret frame along the segment of the great circle between r and q. The vectors r and q lead to the orthonormal set $\{r, \mathrm{vers}(q^{\perp r})\}$, which can then be used to define the curve

$$\sigma(\tau) \triangleq \cos(\tau)\, r + \sin(\tau)\,\mathrm{vers}(q^{\perp r}). \tag{8}$$

Geometrically, $\sigma(\tau)$, $\tau \in [0, 2\pi)$, is the great circle in the plane defined by the orthonormal vectors $\{r, \mathrm{vers}(q^{\perp r})\}$ with $\sigma(0) = r$ and $\sigma(\theta) = \beta r + \sin(\theta)\,\mathrm{vers}(q^{\perp r}) = q$. In general, the legs of the Frenet-Serret frame $F(\tau)$ along an arbitrary curve $\sigma(\tau)$ are defined by the vectors

$$T(\tau) = \mathrm{vers}\left(\frac{d}{d\tau}\sigma(\tau)\right)$$

and

$$N(\tau) = \mathrm{vers}\left(\frac{d}{d\tau}T(\tau)\right),$$

and $B(\tau) = T(\tau) \times N(\tau)$. Specifically along the great circle $\sigma(\tau)$ defined in (8), the Frenet-Serret frames at $r = \sigma(0)$ and $q = \sigma(\theta)$ are computed to be

(9)
$$F_r = \{T_r, N_r, B_r\} = \{\mathrm{vers}(q^{\perp r}), -r, \mathrm{vers}(r \times q)\},$$

(10)
$$F_q = \{\sin(\theta)N_r + \cos(\theta)T_r, \cos(\theta)N_r - \sin(\theta)T_r, B_r\}.$$

Comparing (9) and (10), the two frames F_r and F_q are related by the equation $F_q = T * F_r$ where T is a rotation matrix given by

$$T = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix}. \tag{11}$$

Consequently, the equation $F_q = T * F_r$ is interpreted geometrically to mean that F_q (the frame at q) is obtained by an anticlockwise rotation of F_r (the frame at r) around the $r \times q$ axis through the angle subtended by the great circle between r and q. With the means now to transport the Frenet-Serret frame field from r to q, the transport of v_r (a vector at r) to v_q (a vector at q) is a two-step process:

Step 1. Compute the components of v_r relative to the frame F_r by finding the coefficients c_i of $v_r = \sum_{i=1}^{3} c_i F_r^i$. These components are readily

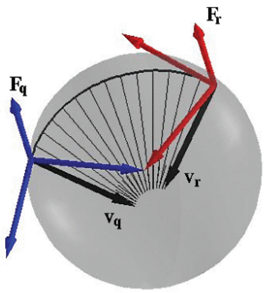


Figure 5. Parallel Transport on $\mathbb{S}^2$. Shown are the transport of Frenet-Serret frame F_r to F_q and the transport of the vector v_r to v_q. Geometrically, the parallel transport of the vector v_r to v_q on $\mathbb{S}^2$ is an anticlockwise rotation around the $r \times q$ axis through the angle subtended by the great circle between r and q.

computed to be $c_i = \langle v_r, F_r^i \rangle$, since F_r is an orthonormal frame field.

Step 2. Define the vector v_q with the components from Step 1 and the frame F_q to obtain $v_q \triangleq \sum_{i=1}^{3} c_i F_q^i$.

Taken together these two steps define a transport mapping called *parallel transport* along the great circle between r and q.

Figure 5 illustrates both the parallel transport of the frame field F_r to F_q and a specific vector v_r to v_q. While this definition of parallel transport is geometrically intuitive, it is a coordinate-based definition. In contrast, the transport mapping $\mathcal{T}_{r \to q}$ from (6) is a coordinate-free expression. In a coordinate system given by the ordered, orthonormal basis $\mathcal{B} = \{T_r, N_r, B_r\}$ from (9), the matrix of the transport map $\mathcal{T} = \mathcal{T}_{r \to q}$ relative to $\mathcal{B}$ is found by applying the transport map to each of the basis vectors. A straightforward computation using (B8)–(B12) determines that the matrix of the transport map $\mathcal{T}$ is equal to the matrix T from (11) and the transport map $\mathcal{T}_{r \to q}$ is in fact the coordinate-free expression for parallel transport on $\mathbb{S}^2$.

The mappings ϕ and $\mathcal{T}$ from (6) are now shown to satisfy the compatibility condition (4) where $d_q \phi|_q = -\hat{q}^2(d_q \phi)$ and $d_r \phi|_r = -\hat{r}^2(d_r \phi)$ are the vectors on $\mathbb{S}^2$ obtained by projecting the vectors $d_q \phi$ and $d_r \phi$ in $\mathbb{R}^3$ onto the tangent planes $T_q\mathbb{S}^2$ and $T_r\mathbb{S}^2$, respectively (cf. Sidebar 2). A straightforward computation determines the derivative of ϕ with respect to q and its projection to be

$$d_q \phi = -\,(\theta / \sin(\theta))\, r, d_q \phi|_q = -\theta \operatorname{vers}(r^{\perp q}).$$

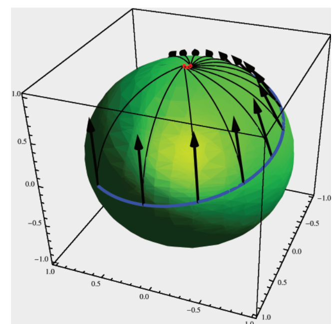
Similarly, the projection of the derivative of ϕ with respect to r is $d_r \phi|_r = -\theta \operatorname{vers}(q^{\perp r})$. Therefore the right-hand side of (4) is computed to be

(12)

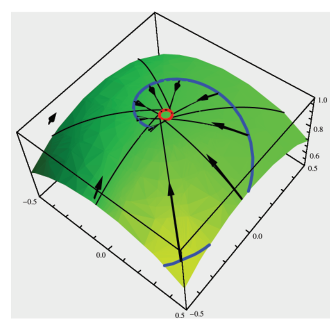
$$\begin{aligned}
& -\langle d_q \phi|_q, \mathcal{T}_{r \to q} v_r \rangle \\
& = \theta \beta \langle \operatorname{vers}(r^{\perp q}), v_r \rangle + \theta \langle \operatorname{vers}(r^{\perp q}), \omega \times v_r \rangle \\
& \overset{(B8)}{=} \langle \theta \beta \operatorname{vers}(r^{\perp q}) - \theta(\omega \times \operatorname{vers}(q^{\perp r})), v_r \rangle \\
& \overset{(B12)}{=} \langle \theta \beta \operatorname{vers}(r^{\perp q}) - \theta \operatorname{vers}(q^{\perp r}) - \theta \beta \operatorname{vers}(r^{\perp q}), v_r \rangle \\
& = \langle d_r \phi|_r, v_r \rangle .
\end{aligned}$$

Since the equality in (12) holds for an arbitrary vector $v_r \in T_r\mathbb{S}^2$, ϕ and $\mathcal{T}_{r \to q}$ form a compatible configuration error and transport map pair, and, consequently, they can be used to implement Bullo's Theorem on $\mathbb{S}^2$.

Recall from Sidebar 1 that the potential function $V(q) = \frac{1}{2}(\operatorname{dist}_{\mathbb{R}}(q, r))^2$ generated the spring force $F_{\mathcal{P}} = -k_{\mathcal{P}} \nabla V = \pm k_{\mathcal{P}} \operatorname{dist}_{\mathbb{R}}(q, r)$, where the direction of the force $\pm$ is chosen so that $F_{\mathcal{P}}$ points from position q to fixed reference r. Unlike the 1D case, where there are only two directions $\pm$ (left, right) to select from, on the sphere there are an infinite number of directions to choose from, namely, one for every vector $v_q \in T_q\mathbb{S}^2$. Strategically selecting



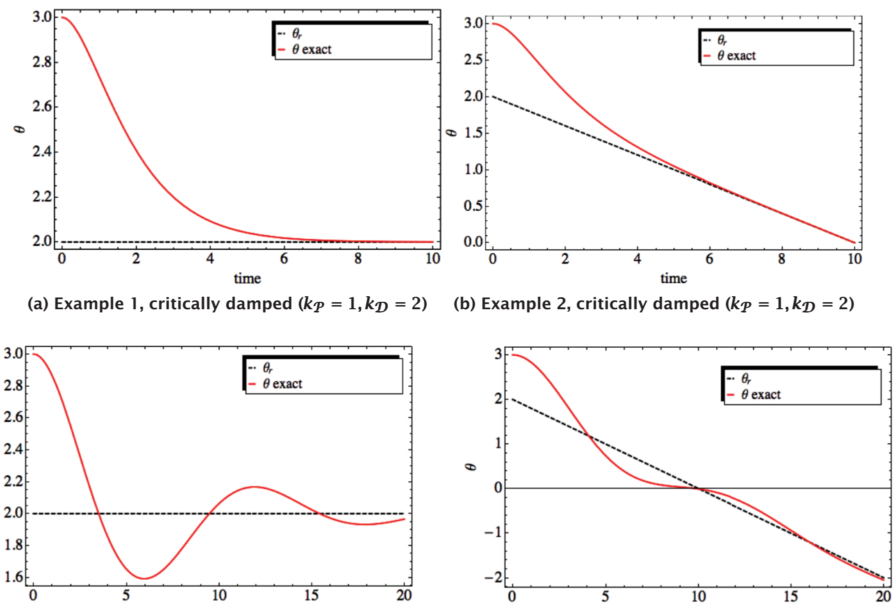
(a) Geodesic Distance θ is large away from the goal, so the strength (length) of spring force $F_{\mathcal{P}}$ is also large.



(b) Geodesic Distance θ is small near the goal, so the strength (length) of the spring force $F_{\mathcal{P}}$ is also small.

Figure 6. Illustration of the Spring Force $F_{\mathcal{P}} = -k_{\mathcal{P}} \operatorname{vers}(r^{\perp q})\, \theta$ of the Proportional-Derivative Force $F_{\mathcal{PD}} = F_{\mathcal{P}} + F_{\mathcal{D}}$. Notice that the force $F_{\mathcal{P}}$ is directed along the segment of the geodesic (great circle) connecting the blue configuration curve to the red reference curve (in this case a fixed point). The strength (length) of the spring force is proportional to the distance between the current and reference configuration.

the direction vector for $F_{\mathcal{P}}$ on $\mathbb{S}^2$ is at the heart of the geodesic-spring design. For the potential function $\phi(q, r) = \frac{1}{2}(\arccos(\langle q, r \rangle))^2$, the generated geodesic-spring force is $F_{\mathcal{P}} = -k_{\mathcal{P}} d_q \phi|_q = k_{\mathcal{P}} \operatorname{vers}(r^{\perp q})\, \theta$. That is, $\operatorname{vers}(r^{\perp q})$ is the direction



(a) Example 1, critically damped ($k_{\mathcal{P}} = 1, k_{\mathcal{D}} = 2$) (b) Example 2, critically damped ($k_{\mathcal{P}} = 1, k_{\mathcal{D}} = 2$)

(c) Example 1, underdamped ($k_{\mathcal{P}} = k_{\mathcal{D}} = 0.3$) (d) Example 2, underdamped ($k_{\mathcal{P}} = k_{\mathcal{D}} = 0.3$)

Figure 7. Closed-Loop System Behaves as a Geodesic Spring (Example 1 and 2 Illustrated). When the reference $R(t)$ (by choice) and $Q(t)$ (by appropriate choice of initial conditions) are restricted to a geodesic (the equator in this case), the exact solution $Q(t) = [\theta(t), \phi(t)]$ to the closed-loop system behaves as a 1D MSD about the equilibrium $R(t)$. These plots should be compared to Figure B2.

of the force $F_{\mathcal{P}}$ with strength given by the geodesic distance θ between q and r (see Figure 6).

Control Forces on $\mathbb{S}^2$

Having shown that ϕ and $\mathcal{T}$ from (6) are a compatible pair on $\mathbb{S}^2$, we can now theoretically apply Bullo's Theorem on $\mathbb{S}^2$. To actually implement this theorem, we must compute the resulting proportional derivative and feedforward forces ($F_{\mathcal{PD}} = F_{\mathcal{P}} + F_{\mathcal{D}}$ and $F_{\mathcal{FF}}$, respectively) which stabilize the configuration curve q to the reference curve r in the closed loop. Unlike the general Riemannian manifold case in which the geodesic equations (as a nonlinear, two-point boundary value problem) and the parallel transport equations (as a linear, possibly time-dependent, initial value problem) have at best only numerical solutions, closed form expressions of these forces on $\mathbb{S}^2 \subset \mathbb{R}^3$ lead to a result that generalizes the MSD error system to $\mathbb{S}^2$.

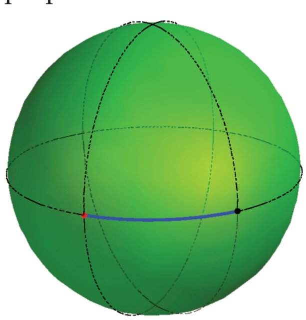


Figure 8. Illustration of Critically Damped Motion in Example 1 along the Equator from the $\theta = 3$ Longitude to the $\theta = 2$ Longitude.

Result 2.1. (MSD System on $\mathbb{S}^2$) Let $q = q(t) \in \mathbb{S}^2$ be the solution to the nonlinear dynamic equations for a free particle

$$\frac{D\dot{q}}{dt} = \mathrm{proj}_q\left(\frac{d\dot{q}}{dt}\right) = -\hat{q}^2\left(\frac{d\dot{q}}{dt}\right) = \ddot{q} - \langle \ddot{q}, q\rangle\, q = 0$$

and let $r = r(t) \in \mathbb{S}^2$ be a known reference curve. The compatible pair of functions $(\phi, \mathcal{T})$ defined by (6) *generates closed-form expressions of the external forces $\Sigma F = F_{\mathcal{PD}} + F_{\mathcal{FF}}$ $[k_{\mathcal{P}} > 0, k_{\mathcal{D}} > 0]$ given by*

$$\begin{aligned} F_{\mathcal{PD}} &= F_{\mathcal{P}} + F_{\mathcal{D}} = -k_{\mathcal{P}}\, d_q\phi|_q - k_{\mathcal{D}}\left(\dot{q} - \mathcal{T}_{r\to q}\dot{r}\right), \\ &= k_{\mathcal{P}}\left(\frac{-\arccos(\beta)}{\sqrt{1-\beta^2}}\right)(r - \beta\, q) \\ &\quad - k_{\mathcal{D}}\left[\dot{q} - q\times(\dot{r}\times r) - \alpha\omega\right], [\beta = \langle r, q\rangle], \end{aligned}$$

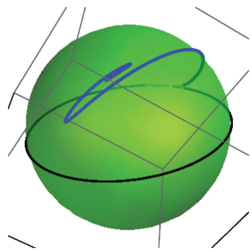
where $\alpha \triangleq (1-\beta)\dfrac{\langle \omega, \dot{r}\rangle}{\langle \omega, \omega\rangle}$ and

$$\begin{aligned} F_{\mathcal{FF}} &= \frac{D}{dt}\left[\mathcal{T}_{r\to q}\dot{r}\right] = q\times(\ddot{r}\times r) + \langle q, \dot{r}\times r\rangle\,(\dot{q}\times q) \\ &\quad + \dot{\alpha}_q\,\omega + \alpha\,(\dot{r}\times q) + \dot{\alpha}_r\,\omega - \beta\,\alpha\,(\dot{q}\times q), \end{aligned}$$

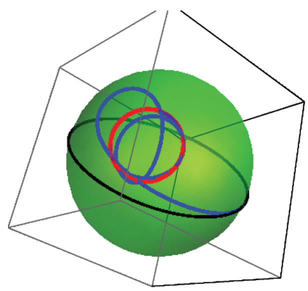
with

$$\dot{\alpha}_q \triangleq \% + (1-\beta)\left[\frac{\langle \dot{r}\times q, \dot{r}\rangle + \langle \omega, \ddot{r}\rangle}{\langle \omega, \omega\rangle} - 2\frac{\langle \omega, \dot{r}\rangle\langle \dot{r}\times q, \omega\rangle}{\langle \omega, \omega\rangle^2}\right],$$

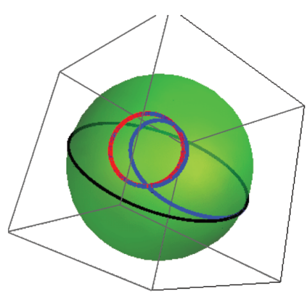
$$\dot{\alpha}_r \triangleq \% + (1-\beta)\left[\frac{\langle r\times \dot{q}, \dot{r}\rangle}{\langle \omega, \omega\rangle} - 2\frac{\langle \omega, \dot{r}\rangle\langle r\times \dot{q}, \omega\rangle}{\langle \omega, \omega\rangle^2}\right],$$



(a) (Spherical Coordinates, underdamped). Reference is a fixed point.



(b) (Stereographic Coordinates, underdamped). Reference is a "short" circle.



(c) (Stereographic Coordinates, critically damped). Reference is a "short" circle.

Figure 9. Tracking on the Euclidean Sphere (3D view of Figure 10 (a, b, c), respectively). In all three cases, red is the reference curve $r(t)$, black the solution to $D\dot{q}/dt = 0$, and blue the configuration curve $q(t)$ solution to $D\dot{q}/dt = \Sigma F = F_{\mathcal{PD}} + F_{\mathcal{FF}}$. Notice that when the forces ΣF are applied, the blue solution turns away from the black curve and tracks the red curve. Therefore, the chasing objective is achieved. The control algorithm is coordinate free, meaning that it can be easily adapted to any coordinate system. The algorithm allows for near-global, large-angle maneuvers of the chasing particle.

and $\% = -\dfrac{\langle q, \dot{r}\rangle \langle \omega, \dot{r}\rangle}{\langle \omega, \omega \rangle}$. The closed-loop dynamics of the particle q subjected to these forces are $\frac{D\dot{q}}{dt} = \Sigma F$. Since ϕ and $\mathcal{T}$ are a compatible pair, then in the closed loop and by Bullo's Theorem, $q(t) \to r(t)$ as $t \to \infty$ (provided the uniformity and bounding assumptions [9, pp. 536, 540–541] are met and provided that q and r never become antipodally positioned).

The proof of this result is purely computational and requires only repeated use of the straightforward fact that differentiation of both the inner product and the cross product satisfy the "product" rules

$$\frac{d}{dt}\left[v(t) \times w(t)\right] = \dot{v}(t) \times w(t) + v(t) \times \dot{w}(t),$$
$$\frac{d}{dt}\langle v(t), w(t)\rangle = \langle \dot{v}(t), w(t)\rangle + \langle v(t), \dot{w}(t)\rangle.$$

However, the derivative of the transport map presents some subtleties. Since the configuration $q(t)$ is time-varying and the reference $r(t)$ can be, in general, time-varying, the derivative of $\mathcal{T}\dot{r}$ is a total derivative

$$\frac{d}{dt}\left[\mathcal{T}_{r(t)\to q(t)}\dot{r}(t)\right] \triangleq \frac{d}{dt}\left[\mathcal{T}_{r(t)\to q}\dot{r}(t)\right] + \frac{d}{dt}\left[\mathcal{T}_{r\to q(t)}\dot{r}\right],$$

where

$$\mathcal{T}_{r(t)\to q(t)}\dot{r}(t) = q(t) \times (\dot{r}(t) \times r(t)) + \left[1 - \langle q(t), r(t)\rangle\right] \mathrm{proj}_{r(t)\times q(t)}\dot{r}(t)$$

and where

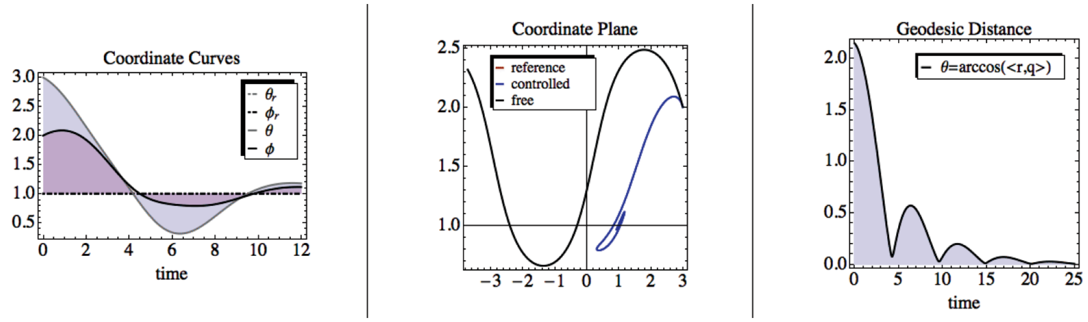
(13)
$$\frac{d}{dt}\left[\mathcal{T}_{r(t)\to q}\dot{r}(t)\right] = q \times (\ddot{r}(t) \times r(t)) + \dot{\alpha}_q (r(t) \times q) + \alpha_q (\dot{r}(t) \times q),$$

(14)
$$\frac{d}{dt}\left[\mathcal{T}_{r\to q(t)}\dot{r}\right] = \dot{q}(t) \times (\dot{r} \times r) + \dot{\alpha}_r (r \times q(t)) + \alpha_r (r \times \dot{q}(t)),$$

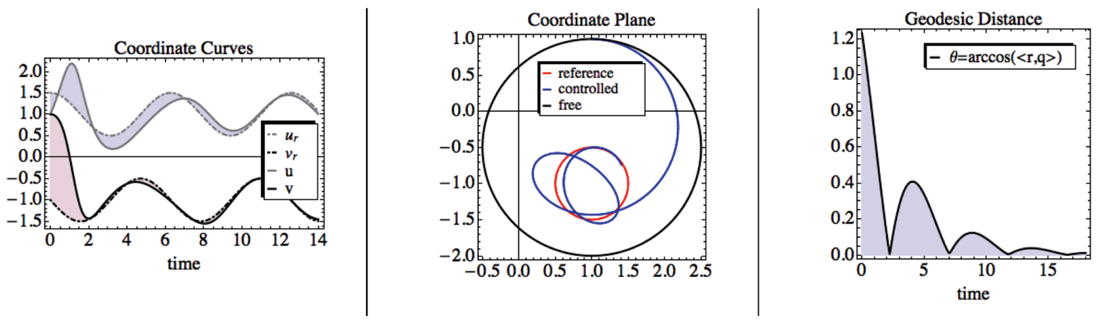
with $\alpha, \dot{\alpha}_q, \dot{\alpha}_r$ defined as in the statement of the result. Notice that a distinction is being made between the time-dependent and the fixed quantities. For example, $\frac{d}{dt}\left[\mathcal{T}_{r(t)\to q}\dot{r}(t)\right]$ indicates that the regular time derivative is taken of $\mathcal{T}_{r(t)\to q}\dot{r}(t)$ with q fixed and $r(t)$ time varying. Now, recall that while $v_q = \mathcal{T}_{r\to q}\dot{r} \in T_q\mathbb{S}^2$, the derivative (or acceleration) $\frac{d}{dt}(v_q)$ does not generally lie in $T_q\mathbb{S}^2$. To ensure that the derivative of v_q lies in $T_q\mathbb{S}^2$, one must follow the derivative by a projection. That is, covariant differentiation must be used rather than regular differentiation. Computing the projections $-\hat{q}^2(\cdot)$ and $-\widehat{q(t)}^2(\cdot)$ of (13) and (14), respectively, and adding the results complete the computation of the feedforward force $F_{\mathcal{FF}}$.

Implementation of MSD System on $\mathbb{S}^2$

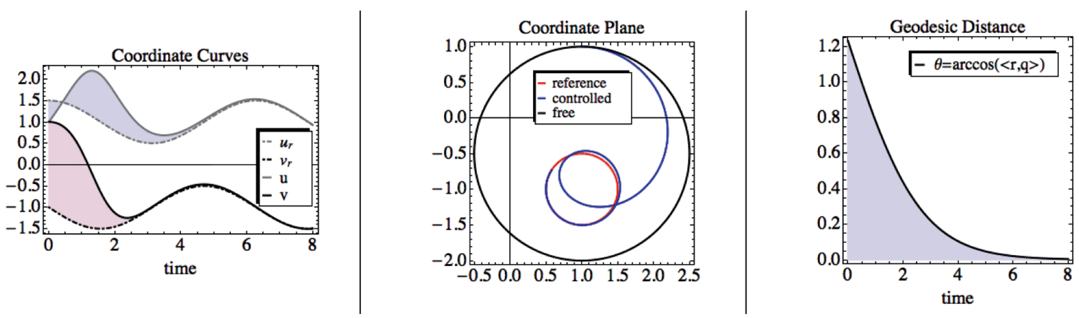
With the external forces $\Sigma F = F_{\mathcal{PD}} + F_{\mathcal{FF}}$ now defined in terms of the intrinsic geometry of $\mathbb{S}^2$, Result 2.1 is *coordinate free* and can be implemented using any set of coordinates on $\mathbb{S}^2$ (see Sidebar 3). This distinction is important to note. It is only *after* we have formulated the



(a) (Spherical Coordinates) $k_{\mathcal{P}} = k_{\mathcal{D}} = 0.4$, $\theta_0 = 3$, $\phi_0 = \pi/2$, $\dot{\theta} = 0$, $\dot{\phi} = 0.2$, $\theta_r = 1$, $\phi_r = 1$



(b) (Projection Coordinates) $k_{\mathcal{P}} = k_{\mathcal{D}} = 0.5$, $u_0 = 1$, $v_0 = 1$, $\dot{u} = 1$, $\dot{v} = 0$, $u_r = 0.5\cos(t) + 1$, $v_r = -0.5\sin(t) - 1$



(c) (Projection Coordinates) $k_{\mathcal{P}} = 2$, $k_{\mathcal{D}} = 1$, $u_0 = 1$, $v_0 = 1$, $\dot{u} = 1$, $\dot{v} = 0$, $u_r = 0.5\cos(t) - 1$, $v_r = 0.5\sin(t) + 1$

Figure 10. Simulations of Result 2.1 in Spherical and Projection Coordinates. In the projection coordinates simulations, the reference curve (red) is the coordinate form of a "short" circle. Since this reference curve is *not* a geodesic, the closed-loop dynamics do not present a closed-form solution. Instead, numerical solutions must be considered. The geodesic distance is computed by $\arccos(\langle r(t), q(t)\rangle)$ where, in projection coordinates, for example, $r(t) = \Phi_{sp}([u_r(t), v_r(t)])$ and $q(t) = \Phi_{sp}([u(t), v(t)])$. See Figure 9 for the trajectories on the sphere.

control law that coordinates are introduced. This is in contrast to *first* introducing coordinates, say spherical coordinates, to formulate the free dynamics $\frac{D\dot{q}}{dt} = 0$ and *then* devising the control forces $\Sigma F = F_{\mathcal{PD}} + F_{\mathcal{FF}}$ to achieve the tracking objective. This method would be a *coordinate-based* approach and works for the chosen coordinate system and no other.

In this section we give two examples that, in spherical coordinates, have closed-form solutions due to the fact that the reference curve $r(t)$ and the configuration curve $q(t)$ are restricted to the equator (a geodesic). We also present simulations (shown in both stereographic and projection coordinates in Figure 10) where the reference curve is *not* the equator (i.e., *not* a geodesic). Exact solutions to this case are unknown to this author and so numerical solutions are considered. The goal of each example is to demonstrate that no matter the coordinate system, the geodesic spring design with parallel-transport-based damping exhibits the behavior of a mass-spring-damper error system in the geodesic distance.

Examples

Two examples of Result 2.1 with closed-form solutions are presented. These two examples are informed by a general theorem [1, p. 5] which proves that for the configuration and transport map pairing $(\phi, \mathcal{T})$ given by (6), the geodesic distance exhibits the behavior seen from the 1D MSD in Figure B2. The first example is the simplest example of the closed-loop error system from Result 2.1, namely, the fixed reference case.

Example 1 ($\dot{r} = 0$). In spherical coordinates, let r be a fixed reference with coordinate description $R = [\theta_r, \phi_r] = [2, \pi/2]$, and assume the initial conditions $\{\theta(0) = 3, \phi(0) = \pi/2, \dot{\theta}(0) = 0, \dot{\phi}(0) = 0\}$ for the configuration curve $q(t)$ with coordinate description $Q(t) = [\theta(t), \phi(t)]$. In other words, both $q(0)$ and r start on the equator and have zero initial velocity. Because the reference is fixed, the transport map of $\dot{r}$ and its derivatives is 0, and the closed-loop error system of Result 2.1 reduces to $\frac{D\dot{q}}{dt} = F_{\mathcal{PD}}$ with

$$F_{\mathcal{PD}} = F_{\mathcal{P}} + F_{\mathcal{D}} = -k_{\mathcal{P}}\, d_q\phi|_q - k_{\mathcal{D}}\, \dot{q} \, [k_{\mathcal{P}} > 0, k_{\mathcal{D}} > 0]$$
$$= k_{\mathcal{P}} \left(\frac{-\arccos(\beta)}{\sqrt{1-\beta^2}} \right) (r - \beta\, q) - k_{\mathcal{D}}\, \dot{q} \;\; [\beta = \langle r, q \rangle].$$

The *first* and *third* equations of the closed-loop error system are

$$\ddot{\theta} + 2\mathfrak{ct}_\phi \dot{\theta}\dot{\phi} + k_{\mathcal{D}}\dot{\theta} + k_{\mathcal{P}} \%_1 = 0, \tag{15}$$
$$\ddot{\phi} - \mathfrak{c}_\phi \mathfrak{s}_\phi \dot{\theta}^2 + k_{\mathcal{D}}\dot{\phi} + k_{\mathcal{P}} \%_2 = 0, \tag{16}$$

where

$$\%_1 = \frac{\arccos\left(\mathfrak{c}_\phi \mathfrak{c}_{\phi_r} + \mathfrak{c}_{\theta-\theta_r}\mathfrak{s}_\phi \mathfrak{s}_{\phi_r}\right) \mathfrak{s}_{\theta-\theta_r}\mathfrak{s}_{\phi_r}}{\mathfrak{s}_\phi \sqrt{1 - \left(\mathfrak{c}_\phi \mathfrak{c}_{\phi_r} + \mathfrak{c}_{\theta-\theta_r}\mathfrak{s}_\phi \mathfrak{s}_{\phi_r}\right)^2}}$$
$$\%_2 = \frac{\arccos(\mathfrak{c}_\phi \mathfrak{c}_{\phi_r} + \mathfrak{c}_{\theta-\theta_r}\mathfrak{s}_\phi \mathfrak{s}_{\phi_r})(-\mathfrak{c}_{\phi_r}\mathfrak{s}_\phi + \mathfrak{c}_\phi \mathfrak{c}_{\theta-\theta_r}\mathfrak{s}_{\phi_r})}{\sqrt{1 - (\mathfrak{c}_\phi \mathfrak{c}_{\phi_r} + \mathfrak{c}_{\theta-\theta_r}\mathfrak{s}_\phi \mathfrak{s}_{\phi_r})^2}}$$

and where, for example, $\mathfrak{c}_{\theta_r-\theta} = \cos(\theta_r - \theta)$, $\mathfrak{s}_\phi = \sin(\phi)$, and $\mathfrak{ct}_\phi = \cot\phi$.

Why the first and the third equations? Note that computing the free particle dynamics on $\mathbb{S}^2$ by $\frac{D\dot{q}}{dt} = \ddot{q} - \langle \ddot{q}, q \rangle\, q = 0$, where $q(t) = \Phi_{sc}([\theta(t), \phi(t)])$ yields three equations:

$$\ddot{\phi} - \mathfrak{c}_\phi \mathfrak{s}_\phi \dot{\theta}^2 = 0, \tag{17}$$
$$\mathfrak{c}_\theta \mathfrak{s}_\phi \dot{\theta} + \mathfrak{c}_\phi \mathfrak{s}_\theta \ddot{\phi} - \mathfrak{c}_\phi^2 \mathfrak{s}_\theta \mathfrak{s}_\phi \dot{\theta}^2 + 2\mathfrak{c}_\theta \mathfrak{c}_\phi \dot{\theta}\dot{\phi} = 0, \tag{18}$$
$$\mathfrak{c}_\theta \mathfrak{c}_\phi \ddot{\phi} - \ddot{\theta}\mathfrak{s}_\theta \mathfrak{s}_\phi + \mathfrak{c}_\theta \mathfrak{c}_\phi^2 \mathfrak{s}_\phi \dot{\theta}^2 - 2\mathfrak{c}_\phi \mathfrak{s}_\theta \dot{\theta}\mathfrak{s}_\phi = 0. \tag{19}$$

Solving (17) for $\ddot{\phi}$ and then substituting the result into (18) and (19) yields the same result:

$$\ddot{\theta} + 2\mathfrak{ct}_\phi \dot{\theta}\dot{\phi} = 0.$$

Consequently, only the *first* and *third (or second)* of the free particle equations are distinct. The equations

$$\ddot{\phi} - \mathfrak{c}_\phi \mathfrak{s}_\phi \dot{\theta}^2 = 0,$$
$$\ddot{\theta} + 2\mathfrak{ct}_\phi \dot{\theta}\dot{\phi} = 0$$

are the typical form (in spherical coordinates) of the geodesic equations on $\mathbb{S}^2 \subset \mathbb{R}^3$. With the addition of the external forces ΣF, the closed-loop dynamics $\frac{D\dot{q}}{dt} = \Sigma F$ also have redundancies. As in the free particle case, the first and third equations are distinct.

Given the geodesic spring motivation of the closed-loop error system, (15) and (16) have a closed-form solution. For the chosen initial conditions, the solution must stay on the equator $\phi = \phi_r = \pi/2$ (since $\dot{\phi}(0) = 0$) and behave like a 1D MSD measured from θ_r. The claim is $Q(t) = [\theta(t), \phi(t)] = [\theta_r + \vartheta(t), \pi/2]$, with $\vartheta(t)$ the solution to the 1D MSD initial value problem $\ddot{\vartheta} + k_{\mathcal{D}}\dot{\vartheta} + k_{\mathcal{P}}\vartheta = 0$ with $\vartheta(0) = \theta(0) - \theta_r = 1$, and $\dot{\vartheta}(0) = \dot{\theta}(0) = 0$ is the exact solution to (15) and (16). Since $\dot{\phi} = \ddot{\phi} = 0$, $\mathfrak{c}_\phi = 0$, and $\mathfrak{s}_\phi = 1$, (16) is trivially satisfied. Under the same assumptions and since $\dot{\theta} = \dot{\vartheta}$, $\ddot{\theta} = \ddot{\vartheta}$, $\theta_r - \theta = \vartheta$, (15) simplifies to an equation in ϑ as

$$\ddot{\theta} + k_{\mathcal{D}}\dot{\theta} + k_{\mathcal{P}}(\theta_r - \theta) \longrightarrow \ddot{\vartheta} + k_{\mathcal{D}}\dot{\vartheta} + k_{\mathcal{P}}\vartheta = 0.$$

For example, when $k_{\mathcal{D}} = 2$ and $k_{\mathcal{P}} = 1$, $\vartheta(t) = e^{-t}(1 + t)$ is the critically damped solution to $\ddot{\vartheta} + k_{\mathcal{D}}\dot{\vartheta} + k_{\mathcal{P}}\vartheta = 0$ with $\vartheta(t) \to 0$ as $t \to \infty$. It follows that $\theta(t) = \theta_r + \vartheta(t)$ is the critically damped solution to (15) where $\theta \to \theta_r$ as $t \to \infty$. Figure 8 shows the solution (blue curve) $q(t) = \Phi_{sc}[\phi_r + \vartheta(t), \pi/2]$ on $\mathbb{S}^2$. Figures 7(a) and 7(c) corroborate the underdamped and critically damped solutions.

Example 2 ($\dot{r} \neq 0$). This second example extends the first example to consider a moving reference $r(t)$ along the equator. In spherical coordinates, let $r(t)$ be the reference with coordinate description $R(t) = [\theta_r(t), \phi_r] = [2 - \frac{t}{5}, \pi/2]$, and assume the initial conditions $\{\theta(0) = 3, \phi(0) = \pi/2, \dot{\theta}(0) = 0, \dot{\phi}(0) = 0\}$ for the configuration curve $q(t)$ with coordinate description $Q(t) = [\theta(t), \phi(t)]$. Since the reference is no longer fixed and yet lies on the geodesic (equator), it follows that $\langle \omega, \dot{r} \rangle = 0$; therefore, the middle term of the transport map is 0. Consequently, the closed-loop error system of Result 2.1 reduces to $\frac{D\dot{q}}{dt} = F_{\mathcal{PD}} + F_{\mathcal{FF}}$ with

$$F_{\mathcal{PD}} = F_{\mathcal{P}} + F_{\mathcal{D}} = -k_{\mathcal{P}}\, d_q\phi|_q - k_{\mathcal{D}} \left(\dot{q} - \mathcal{T}_{r\to q}\dot{r} \right)$$
$$= k_{\mathcal{P}} \left(\frac{-\arccos(\beta)}{\sqrt{1-\beta^2}} \right) (r - \beta\, q) - k_{\mathcal{D}} \left[\dot{q} - q \times (\dot{r} \times r) \right],$$
$$F_{\mathcal{FF}} = \frac{D}{dt} \left[\mathcal{T}_{r\to q}\dot{r} \right] = q \times (\ddot{r} \times r).$$

The third equation of the closed-loop system is trivially satisfied along the equator $\phi = \phi_r = \pi/2$. In terms of the new variable $\vartheta = \theta_r - \theta$, which defines $\ddot{\theta} = \ddot{\vartheta}$, $\dot{\theta} = \dot{\vartheta} - \frac{1}{5}$, the first equation simplifies to

$$\frac{k_{\mathcal{D}}}{5} + k_{\mathcal{P}}(\theta_r - \theta) + k_{\mathcal{D}}\dot{\theta} + \ddot{\theta} = 0 \longrightarrow k_{\mathcal{P}}\vartheta + k_{\mathcal{D}}\dot{\vartheta} + \ddot{\vartheta} = 0.$$

Therefore, as in the first example, the solution to the first and third equations of the closed-loop system is given by $Q(t) = [\theta(t), \phi(t)] = [\theta_r(t) + \varphi(t), \pi/2]$, where $\vartheta(t)$ is a solution to

$\ddot{\vartheta} + k_{\mathcal{D}}\dot{\vartheta} + k_{\mathcal{P}}\vartheta = 0, \vartheta(0) = 1, \dot{\vartheta}(0) = 1/5$. Figures 7(b) and 7(d) corroborate the underdamped and critically damped solutions in this example.

Simulations

Simulations of Result 2.1 are performed in spherical and stereographic coordinates using Mathematica's NDsolve command.

Sidebar 1. 1D Mass-Spring-Damper (MSD) System

Consider a particle of mass m constrained to move on a frictionless rod (analogous to the real line $\mathbb{R}$). Assume that the particle, initially at position q_0, is set into motion by an initial force that imparts an initial velocity v_0 to the particle but after which is subject to no other outside forces. That is, the particle is *free* with external forces $\Sigma F = 0$. As a differential equation, the free dynamics for the particle are given by Newton's equation $\Sigma F = ma$, specifically,

$$\text{(B1)} \qquad \frac{d\dot{q}}{dt} = 0$$

with solution $q(t) = v_0 t + q_0$. Depending on the direction (left, $-$) or (right, $+$) of the initial velocity, the particle's position $q(t) \to \pm\infty$ as $t \to \infty$. Forcing the particle to approach a *fixed* reference position r (rather than $\pm\infty$) can be achieved by connecting the particle to the rod with a spring-damper where the linear spring has a stiffness modeled by the constant $k_{\mathcal{P}} > 0$ and the damper provides a resistance modeled by the constant $k_{\mathcal{D}} > 0$. Define the proportional (spring) force $F_{\mathcal{P}}$ and the derivative (damping) force $F_{\mathcal{D}}$ by

$$\text{(B2)} \quad F_{\mathcal{P}} \triangleq -k_{\mathcal{P}}\, e(t) \quad \text{and} \quad F_{\mathcal{D}} \triangleq -k_{\mathcal{D}} \frac{d}{dt}\left[e(t)\right],$$

where $e(t) \triangleq q(t) - r$ is the error between the particle's position $q(t)$ and the fixed reference position r. It follows that Newton's equation $m\frac{d\dot{q}}{dt} = \Sigma F$ with external forces $\Sigma F = F_{\mathcal{P}} + F_{\mathcal{D}}$ simplifies to the 1D mass-spring-damper (MSD) error system

$$\text{(B3)} \qquad \ddot{e} + 2\delta\dot{e} + \omega^2 e = 0,$$

where $\delta = k_{\mathcal{D}}/2m$, $\omega = \sqrt{k_{\mathcal{P}}/m}$, and $\dot{e}, \ddot{e}$ denote in this case the first and second time derivatives of $e(t)$. The solution to this error system is a standard result in introductory ordinary differential equations. For any initial conditions q_0, v_0, the error $e(t) \to 0$ as $t \to \infty$. In other words, the position of the forced particle $q(t)$ approaches the reference position r as $t \to \infty$. Consequently, depending on the selections for δ and ω, the control objective $q(t) \to r$ is achieved in an underdamped, overdamped, or critically damped manner (see Figure B2).

While the control objective has been achieved, the result is rather unsatisfactory in the sense that we are not left with much understanding about how this result was achieved. What is the big picture, and how might knowing it aid in extending this spring design to the sphere? To begin answering this question, consider more closely the forces $F_{\mathcal{D}}$ and $F_{\mathcal{P}}$. The control objective is partially achieved by the addition of the spring force $F_{\mathcal{P}}$, which can be interpreted in terms of the quadratic potential function

$$\text{(B4)} \qquad V(q) = \frac{1}{2}\text{dist}_{\mathbb{R}}(q,r)^2 \triangleq \frac{1}{2}|q-r|^2.$$

This potential can be viewed as a quadratic well centered at the fixed reference r, as shown in Figure B1, that generates a (restoring) force $F_{\mathcal{P}} = -k_{\mathcal{P}}\nabla V$ on the particle directed toward the reference r with a strength proportional to the distance between the particle's position q and reference r. In other words,

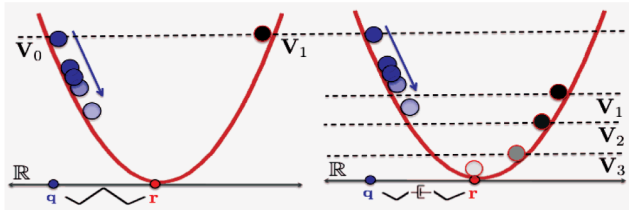
$$\text{(B5)} \quad F_{\mathcal{P}} = \pm k_{\mathcal{P}}\,\text{dist}_{\mathbb{R}}(q,r) = -k_{\mathcal{P}}(q-r) = -k_{\mathcal{P}}e,$$

where the direction $+$(right) or $-$(left) of the force is given by the expression $-(q-r)/|q-r|$. Due to energy considerations, the spring force $F_{\mathcal{P}}$ alone is not enough to achieve the control objective. Specifically, for zero damping $\delta = 0 \implies F_{\mathcal{D}} = 0$, the total energy L (kinetic energy $\frac{1}{2}\dot{q}^2$ plus potential energy $\frac{1}{2}\omega^2(q-r)^2$) of the particle along the solution to $m\ddot{e} = F_{\mathcal{P}}$ is a constant function of the initial position and velocity of the particle, and therefore the spring force $F_{\mathcal{P}}$ alone cannot dissipate the energy. Introducing the external damping force $F_{\mathcal{D}}$, the total derivative of the total energy of the particle along the solutions to $m\ddot{e} = F_{\mathcal{D}} + F_{\mathcal{P}}$ (equivalently, $\ddot{e} = -2\delta\dot{e} - \omega^2 e$) is

$$\begin{aligned} \frac{dL}{dt} &= \dot{q}\ddot{q} + \omega^2(q-r)\dot{q} = \dot{e}\ddot{e} + \omega^2 e\dot{e} \\ &= \dot{e}(-2\delta\dot{e} - \omega^2 e) + \omega^2 e\dot{e} \\ \text{(B6)} \qquad &= -2\delta\dot{e}^2 \le 0. \end{aligned}$$

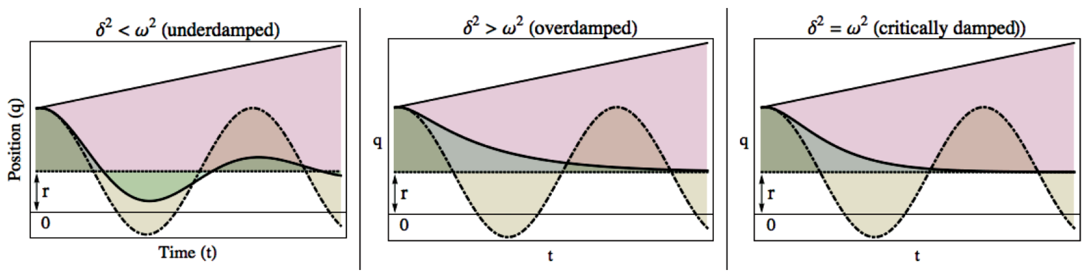
For the cases $\delta^2 > \omega^2$ and $\delta^2 = \omega^2$, Figure B2 (bottom, middle, right) illustrates that $\dot{e} \ne 0$, in which case $\frac{dL}{dt}$ is strictly negative, and therefore the total energy of the particle must dissipate to 0. Even when $\dot{e} = 0$ ($\delta^2 < \omega^2$), Figure B2 (bottom, left) illustrates that the total energy of the particle eventually dissipates to 0. In all three cases, the control objective $q(t) \to r$ is achieved.

In this article, the forces $F_{\mathcal{D}}$ and $F_{\mathcal{P}}$ are extended to the sphere $\mathbb{S}^2 \subset \mathbb{R}^3$ in order to stabilize a particle $q \in \mathbb{S}^2$ to a time-dependent reference curve $r(t) \in \mathbb{S}^2$. The overarching control methodology is to create a potential well, this time on the sphere, centered on the moving reference $r(t)$. The resulting potential force along with a geometrically defined damping force achieves the control objective $q(t) \to r(t)$.

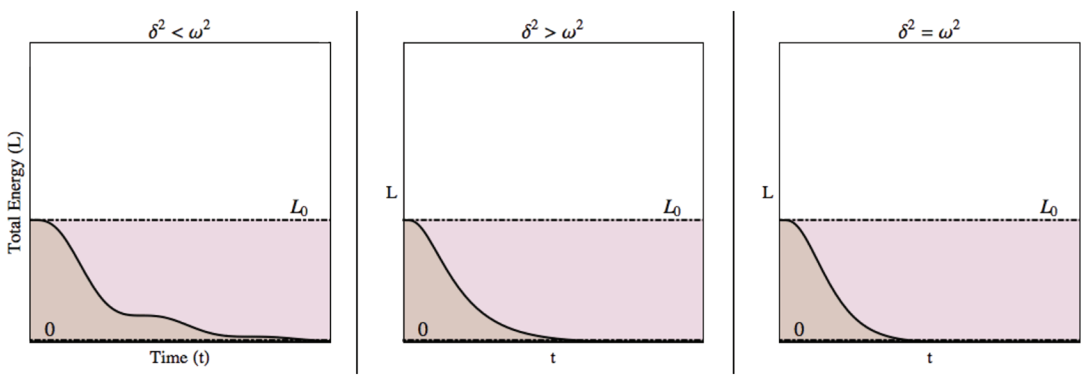


(a) (left) The potential function $V(q)$ can be viewed as a quadratic potential well centered at $r \in \mathbb{R}$ in which the particle q is constrained to roll about. As q is released from its position of maximum potential V_0, its energy is converted to purely kinetic energy at the bottom of the well and again to maximum potential at $V_1 = V_0$. The particle q will continue to roll around the point r but never settle on it. (b) (right) With the inclusion of a damping force, thought of as a source friction on the potential surface, the potential energy of particle q dissipates from V_1 to V_3, and eventually $V = 0$ where the reference position r is located. Consequently, in the presence of damping, q settles on r. The overarching control methodology in this article is to create a quadratic potential surface (well), this time centered on a moving reference $r(t) \in \mathbb{S}^2$ (see Figure 2). The resulting potential force, along with a geometrically defined damping force, which defines a source of friction on the potential surface will achieve the control objective $q(t) \to r(t)$ on the sphere.

Figure B1. Illustration of the Potential Function $V(q) = \frac{1}{2}\left[\mathrm{dist}_{\mathbb{R}}(q, r)\right]^2 = \frac{1}{2}(q - r)^2$ and Damping.



(a) The damped solution (heavy solid line) to the MSD error system (B3) is plotted for various values of δ^2 and ω^2 and overlaid with the free solution (the straight line) and the nondamped solution (dot-dashed line). In each case, the damped solution approaches the equilibrium position r.



(b) The total energy of the damped solution (heavy solid line) is plotted for various values of δ^2 and ω^2 and overlaid with the total energy of the free solution and the energy of the nondamped solution (the constant dot-dashed line), both of which are equal to L_0. In each case, the energy of the damped solution approaches 0.

Figure B2. 1D Mass-Spring-Damper (MSD) Summary.

Sidebar 2. Visualization of Notation

The following equations illustrate the interaction between the inner product, cross-product, and projection and are a collection of the computations needed to prove the results of this article:

(B7) $$v \times (w \times z) = \langle v, z\rangle w - \langle v, w\rangle z,$$

(B8) $$\langle y, (w \times z) \times v\rangle = -\langle v, (w \times z) \times y\rangle,$$

(B9) $$-\hat{r}^2 q = -(q \times r) \times r = q - \beta r \triangleq q^{\perp r},$$

(B10) $$||q^{\perp r}|| = ||r^{\perp q}|| = \sin(\theta),$$

(B11) $$(r \times q) \times r^{\perp q} = q^{\perp r} + \beta r^{\perp q} = \sin^2(\theta) q,$$

(B12) $$(r \times q) \times \mathrm{vers}(q^{\perp r}) = -\sin(\theta)\, r,$$

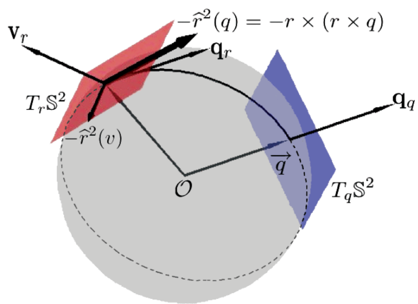


Figure B3. Visualization of Notation. Points $r, q, v \in \mathbb{S}^2 \subset \mathbb{R}^3$ are identified with the vectors $\vec{r}, \vec{q}, \vec{v}$ at the origin $\mathcal{O} \in \mathbb{R}^3$. Often the vector symbol $\vec{\cdot}$ is suppressed. The vectors v, r, q can be translated (without stretching or tilting) to the points $r, q \in \mathbb{S}^2$ to obtain the vectors q_r, v_r, q_q. Often the point of attachment is suppressed.

where $\beta \triangleq \langle q, r\rangle = \cos(\theta)$ and where $\text{vers}(\cdot)$ is the length-normalization mapping on vectors v defined by $\text{vers}(v) = v/||v||$. The mapping $\hat{\cdot}$ is defined in (7). Equation (B7), the standard triple cross-product formula, is the main equation from which the other equations are derived. In general, the vectors q_r and v_r are not in the tangent plane to $\mathbb{S}^2$ at r (denoted $T_r\mathbb{S}^2$). According to (B9) and as shown in Figure B3, $q^{\perp r} = -\hat{r}^2 q \in T_r\mathbb{S}^2$ and $-\hat{r}^2 v \in T_q\mathbb{S}^2$. That is, the operators $-\hat{r}^2(\cdot)$ and $-\hat{q}^2(\cdot)$ act as projections onto the tangent planes to $\mathbb{S}^2$ at r and q, respectively. Therefore the covariant derivative operator at $q \in \mathbb{S}^2$ from (2) can be explicitly given by

$$\frac{D}{dt}\Big|_q = -\hat{q}^2 \circ \frac{d}{dt}. \tag{B13}$$

Note that $r^{\perp q} \triangleq -\hat{r}^2(q)$ is the vector at q pointing tangent to the geodesic segment (black solid curve) connecting q to r. In this article, we construct a force $F_{\mathcal{P}} \propto r^{\perp q}$ that compels a particle $q(t) \in \mathbb{S}^2$ towards a moving target $r(t) \in \mathbb{S}^2$. It is important that the applied forces, like $F_{\mathcal{P}}$ for example, be tangent to the sphere. Otherwise, the curve $q(t)$ will leave the sphere, and, using the robotic arm analogy, the tool tip of the robotic arm will no longer be constrained to the sphere.

Sidebar 3. Spherical and Projection Coordinates

Spherical and stereographic projection coordinates are the two coordinate systems employed in this article. The general concept of coordinates on $\mathbb{S}^2$ can be illustrated using the example of stereographic projection. Since we are viewing the unit sphere $\mathbb{S}^2$ as a subset of $\mathbb{R}^3$, one description of the sphere is the algebraic relation $x^2 + y^2 + z^2 = 1$ between the *three* variables (x, y, z). Imagine now that a light source and planar screen are placed at the north and south poles of a translucent sphere, respectively. Any region on the sphere will then cast a shadow onto the screen to create a two-dimensional representation of that region (see Figure B4). The *two* variables which describe the position of the shadow are the (stereographic) projection coordinates of $\mathbb{S}^2$. The spherical coordinate (θ, ϕ) and stereographic (south pole) projection coordinate (u, v) representations of the sphere $\Phi_{sc} : \mathcal{D}_{sc} \subset \mathbb{R}^2 \to \mathbb{S}^2_{sc} \subset \mathbb{S}^2$ and $\Phi_{sp} : \mathcal{D}_{sp} \subset \mathbb{R}^2 \to \mathbb{S}^2_{sp} \subset \mathbb{S}^2$ are given by

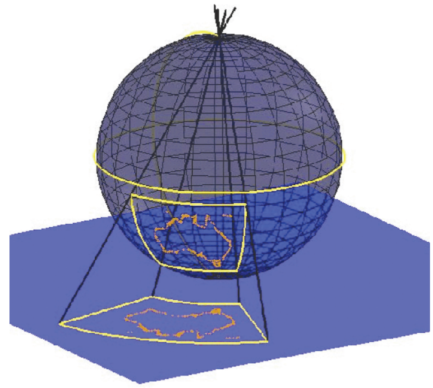


Figure B4. Stereographic Projection Illustration. Because the geodesic spring control design is coordinate independent, it can be implemented in any coordinate system. The coordinates defined by stereographic projection are ideal because of the large domain of definition, $\mathbb{S}^2$ – north or south pole.

$$\Phi_{sc}(\theta, \phi) = [\cos(\theta)\sin(\phi), \sin(\phi)\sin(\theta), \cos(\phi)], \tag{B14}$$

$$\Phi_{sp}(u, v) = \left[\frac{2u}{1 + u^2 + v^2}, \frac{2v}{1 + u^2 + v^2}, \frac{1 - u^2 - v^2}{1 + u^2 + v^2}\right], \tag{B15}$$

where $\mathcal{D}_{sc} = (0, 2\pi) \times (0, \pi)$ and $\mathcal{D}_{sp} = (-\infty, \infty) \times (-\infty, \infty)$ are the domains chosen so that Φ_{sc} and Φ_{sp} are one-to-one mappings. For completeness, the mapping which assigns to each point $(x, y, z) \in \mathbb{R}^3$ its projection coordinates (u, v) is

$$\Phi_{sp}^{-1}(x, y, z) = \left[\frac{2x}{1 + z}, \frac{2y}{1 + z}\right]. \tag{B16}$$

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Coble and Eisenhart: Two Gettysburgians Who Led Mathematics

Darren B. Glass

As of 2012, sixty-one people had held the office of president of the American Mathematical Society. Of these fifty-nine men and two women, ten received undergraduate degrees from Harvard. Another five received their undergraduate degrees from Columbia University. Five schools have had three alumni apiece go on to serve as AMS president, and none of the schools on this list would surprise anyone—Princeton, Yale, Cambridge, Texas, and Chicago have all been centers of mathematics at various times. Three more schools have had two alumni each become AMS president: MIT, Wesleyan University, and Gettysburg College. Yes, there have been more Gettysburg College alumni to serve as AMS president than many schools whose math programs are far more renowned.

The story is even more interesting when one notes that the two Gettysburg College alumni served as back-to-back presidents of the AMS, with Luther Pfahler Eisenhart serving in 1931–1932 and Arthur Byron Coble serving in 1933–1934. Furthermore, they graduated from Gettysburg, then known as Pennsylvania College, a year apart, with Eisenhart one of the sixteen members of the class of 1896 and Coble one of the twenty-six members of the class of 1897. In other words, of the 134 students who were attending Gettysburg College in 1895, two of them would receive Ph.D.'s in mathematics from Johns Hopkins and go on to be the president of one of the most important academic societies in the world. In this article, we take a closer look at this coincidence.

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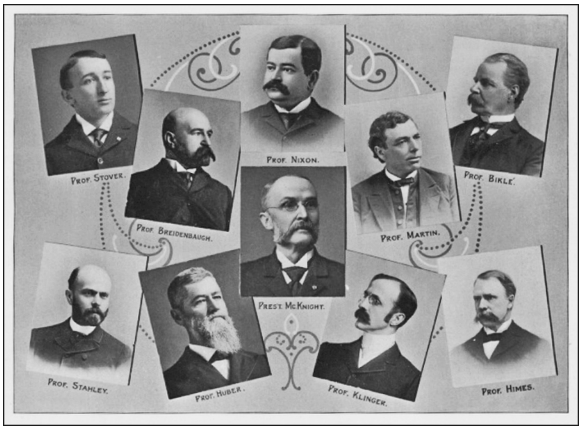
Pennsylvania College circa 1890.

Mathematics at Gettysburg

The end of the nineteenth century was a time of change in the world of higher education in general and mathematics in particular. In their book *A History of Mathematics in America before 1900* [26], Smith and Ginsburg write that "from 1875 to 1900 a change took place that may well be described as little less than revolutionary. Mathematics tended to become a subject per se; it became 'pure' mathematics instead of a minor topic taught with astronomy and physics as its prime objective." Much of this revolution was occurring at the newly founded Johns Hopkins University, which was the first American university to offer graduate programs in mathematics and featured the prominent mathematicians J. J. Sylvester and Arthur Cayley on its faculty.[1]

[1] *For more information on mathematics at Johns Hopkins and in the United States more generally in this era, the*

Panorama of Pennsylvania College, 1897.



Pennsylvania College Faculty, 1898.

One of the earliest graduate students in mathematics at Johns Hopkins was Henry B. Nixon, who received his Ph.D. in 1886 with a dissertation entitled "On Lamé's Equation". Nixon was born in North Carolina in 1857 and earned a bachelor's degree from the University of North Carolina in 1878. While a graduate student at Hopkins, he coauthored the *Bibliography of Linear Differential Equations* with J. W. Fields [24], the initiator of the Fields Medal. Nixon began teaching at Pennsylvania College in 1888 when the college's previous professor of mathematics, Luther Croll, fell ill. Pennsylvania College had been founded in the town of Gettysburg by the Lutheran theologian Samuel Simon Schmucker in 1832 and changed its name to Gettysburg College in 1921.

According to Charles Glatfelter's history of Gettysburg College, entitled *A Salutary Influence* [16], Nixon was one of only four faculty members hired between 1868 and 1904 who had a doctorate degree. As was typical of schools of its kind in the late nineteenth century, the curriculum of the college was highly regimented, with all students pursuing either the Classical Course or the Scientific Course. Prior to 1890 one's course determined all classes one would take at the college. Students in either course were expected to enter the college knowing "Arithmetic complete, including the Metric System; Elementary Algebra; Geometry to Book III (Wentworth's)" [1]. The catalog described the college's program in mathematics thusly:

> The instruction in the department of Mathematics is conveyed by the constant and systematic study of approved textbooks, interspersed with familiar lectures; the student being assisted by full and frequent explanations from the Professor, and being constantly subjected to rigid examinations. The progress of every student is also tested by his being required to perform miscellaneous exercises, in which the principles acquired are applied to the solution of particular problems.

More precisely, the coursework in mathematics expected of all students at Pennsylvania College was described as follows:

Freshman Year	First Term	Geometry (Wentworth) 4
	Second Term	Geometry of Planes (Wentworth); Algebra (Wentworth) 4
	Third Term	Algebra (Wentworth), Plane Trigonometry (Wentworth) 4
Sophomore Year	First Term	Plane Trigonometry and Mensuration (Wentworth) 3
	Second Term	Analytical Geometry (Newcomb) 3
	Third Term	Analytical Geometry (Newcomb), Spherical Trigonometry (Wentworth), Surveying and Navigation (Wentworth) 3
Junior Year	First Term	Differential Calculus (Newcomb) 2, Higher Surveying* 2
	Second Term	Integral Calculus (Newcomb) 2
	Third Term	None
Senior Year		None

A modern reader looking at this list of courses is likely to be surprised by how elementary the coursework was, with no students taking material past the Integral Calculus, a subject that many students a hundred years later would complete by the end of their first year at college. It is worth pointing out that Pennsylvania College was not unusual in this respect at that time, as a consideration of mathematics curricula at some other small colleges in the region will show.

author recommends the book The Emergence of the American Mathematical Research Community, 1876–1900 *by Parshall and Rowe* [25].

Students at Swarthmore College had four courses of study to choose from, but all four required very similar mathematics requirements to students at Pennsylvania College [4]. The curricula of Williams College was also similar [28].

As Smith and Ginsburg noted, "It will therefore be observed that the work in the freshman year of college was, in the first half of the century, merely that of a mediocre high school of the twentieth century, a fact which testifies to the poor work done in the field of mathematics in the preparatory schools of the time" [26, p. 72]. Moreover, at most colleges the mathematics program culminated in courses on astronomy and navigation, indicating that the pure mathematics revolution discussed earlier had not yet trickled down to undergraduate curricula. Gettysburg College was also introducing elective courses into the curriculum in the last decade of the nineteenth century, and one of the first electives officially on the books was a mathematics course that included "Analytic Geometry of three dimensions; differential equations; Mechanics" [3]. The faculty and trustees felt that the curriculum was not as robust as they would like and added a section to the Gettysburg College catalogue in 1891: "Called 'Needs of the College', it listed five so-called departments in which additional 'teaching force and apparatus' were required…it is a stark commentary on the fate of the College during the next thirteen years to observe that the very same notice…appeared in the 1904 catalogue" [16, p. 296]. It was not until 1915 that Gettysburg would hire additional faculty in mathematics.

Eisenhart

Luther Pfahler Eisenhart was born to Charles Augustus Eisenhart and Emma Catherine Pfahler on January 13, 1876, in York, Pennsylvania. Charles Eisenhart's primary occupation was as a dentist, but Luther himself wrote of his father that dentistry may have "made sufficient income to meet the expenses of his growing family, but his intellect was too active to be satisfied by dentistry. Electricity appealed to him and he organized the Edison Electric Light Company in the early eighties. The telephone also made an appeal. He experimented with telephones and in the late nineties organized the York Telephone Company" [21]. He also patented a method of using electricity to supersede the use of anesthetics in extracting and filling teeth, which made him one of the most prominent dentists in Pennsylvania [15]. Charles's mother was Elizabeth Schmucker, whose brother was Samuel Simon Schmucker, the Lutheran pastor and theologian who founded the Lutheran Theological Seminary in Gettysburg as well as Pennsylvania College.

Luther was the second of six sons, and he showed great intelligence from an early age. Under his mother's tutoring, he finished his primary schooling in three years instead of the standard six. In September 1892 he enrolled at Pennsylvania College and was active in all aspects of college life. *The Spectrum*, the yearbook of Gettysburg College, lists Eisenhart as a member of the Philomathean Literary Society and the Phi Kappa Psi fraternity, the recording secretary of the Athletic Association, and the captain of the baseball team, for which he played third base. Luther was awarded the Muhlenberg Freshman Prize and the following year tied with another student for the Baum Prize, which is "given to the student showing the greatest proficiency in mathematics through his or her sophomore year." He earned honorable mention for the Hassler Medal in Latin and won the Graeff Prize in English. The catalog also lists him as one of four students to receive "First Honors" upon graduation, and he delivered the valedictory for the class of 1896.

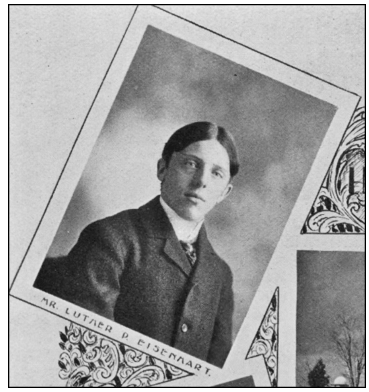
After graduation Eisenhart continued to live in Gettysburg. He spent a year as a "Tutor in Mathematics and Natural Science", living in Stevens Hall and working with the students at the Gettysburg Academy, a preparatory school. Following this year, Luther went to Johns Hopkins, where three years later he received a doctoral degree for writing a dissertation entitled "Infinitesimal Deformation of Surfaces". In the fall of 1900, Eisenhart was appointed as an instructor of mathematics at Princeton University, a position that earned $800 per year, and five years later he was accorded the rank of assistant professor when Woodrow Wilson, then president of the university, began the preceptorship program. In 1908 Eisenhart married Anna Maria Dandridge Mitchell, and they had a son, Churchill, in 1913. Churchill went on to become a prominent statistician in his own right, holding the position of chief of the Statistical Engineering Laboratory at the National Bureau of Standards from 1947 until 1963. Anna died shortly after the birth of their son, and Luther married Katharine Schmidt five years later. Luther and Katharine eventually had two daughters together.

In 1925 Luther Eisenhart became dean of the faculty at Princeton, and Katharine took it upon herself to socialize the wives of graduate students. One student recalls that "she took that job seriously…she wanted these girls to learn how to be faculty wives, to know all the correct social procedures. She not only had regular meetings, talking with them, but she also arranged for them to visit prominent homes…where they could practice the social graces" [2, Mood].

Through all of these positions Eisenhart was a model faculty member, excelling in all three of the traditional areas of research, teaching, and governance. During his career, Eisenhart published nearly one hundred papers and a half dozen books in addition to supervising seven doctoral students. There were two main themes to his scholarly work, although it all falls into the category of differential geometry. Early in his career Eisenhart looked at deformations of surfaces, continuing the work he had done in his dissertation. In particular, he was interested in understanding global properties of manifolds by looking at their local structure. Eisenhart's first book was a graduate-level textbook entitled *A Treatise in the Differential Geometry of Curves and Surfaces* [14], originally published in 1909. This book grew out of courses that he had taught at Princeton and covered aspects of the field that were considered classical at the time as well as more modern topics. In particular, the book contained sections on twisted curves and surfaces, ruled surfaces, minimal surfaces, deformations, and triply orthogonal systems of surfaces. Several reviews lauded the book for its discussion of "moving trihedrals", a subject about which one reviewer said, "The student will hardly find himself at home in the literature of to-day without an intelligent acquaintance with them." While Eisenhart's book was not the first textbook on the subject published in America, it was very influential. Archibald writes that "the work was of great value in introducing the American student to an important field by the most modern method of the time" [5].

Eisenhart published a research monograph entitled *Transformations of Surfaces* in 1923. The aim of this book was to consider surfaces in $\mathbb{R}^3$ and various transformations, which can be put into two categories, F-transformations and W-transformations, depending on how they act on certain nets. Eisenhart's book summarized work done by others, including Bianchi, Darboux, Guichard, Ribaucour, and Tzitzeica, while further developing it as well. A review in the *Bulletin of the AMS* says that "to unify such a diversity of material in a natural and effective fashion is not simple, and the author is to be congratulated on the masterly way in which he has succeeded" [19].

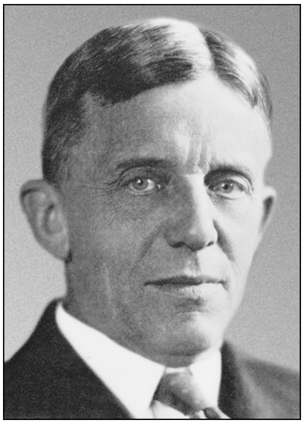
Around this time, Eisenhart's scholarly thoughts were becoming increasingly influenced by the work of Albert Einstein on general relativity. In particular, Riemann's work on the generalization of surfaces to spaces of higher orders and Ricci's subsequent work on the tensor analysis and absolute calculus applied very well to the types of forms that turned up in Einstein's models. Inspired by this work, he wrote two books, *Riemannian Geometry* [13] and *Non-Riemannian Geometry* [12], the latter of which was based on his series of lectures in the AMS Colloquium Series. As with his other books, these became standard references in the field. Eisenhart wrote two more books, one of which was a treatise on Lie algebras, which were originally a tool developed in the study of Riemannian geometry but which had become an object of study in their own right by the time he wrote *Continuous Groups of Transformations* [11]. His final book was another textbook published in 1940, entitled *An Introduction to Differential Geometry* [14], which expanded on his earlier textbook to include the innovations in the field over the previous three decades.



Luther Eisenhart as instructor at Gettysburg Academy.

In addition to his scholarly work, Luther Eisenhart loved teaching and insisted on teaching courses every term during the forty-five years he spent at Princeton without a single sabbatical. His son, Churchill, recalls that "Dad wanted to teach a freshman course even when he became Dean of the Graduate College in order to get a feel for what the new generation of students was like. He felt it important to keep your hand on that pulse. And he was very much against the idea of what you might call a research mathematician who doesn't do any ordinary teaching" [2, C. Eisenhart]. His teaching was based on the philosophy that "teaching methods must be designed to encourage independence and self-reliance, to evoke curiosity, and stimulate the imagination and creative impulse" [22]. He emphasized classroom discussion, and classes were often held with a student at the blackboard. Joseph Daly said that "he could get the guys so aggravated that they had to try to prove examples, but I also got some other things out of it. I began to think of mathematical philosophy, with a mathematical formulation of course, the Descartes sort of thing" [2, Singleton].

Eisenhart had strong opinions on teaching and curricular matters, many of which can be directly attributed to his experiences at Gettysburg College. He believed that the purpose of education was to teach students how to teach themselves. In his



Luther Eisenhart, AMS president 1931–1932.

obituary of Eisenhart, Lefschetz quotes him on the subject:

> Henry B. Nixon gave me books to study and report when I had any questions; there were no class sessions. The same plan on a more extensive basis was followed in senior year. This experience with the value of independent study led to my proposal in 1922 that the undergraduate curriculum for juniors and seniors in Princeton should provide for independent study, which was adopted and has continued. [21]

The above proposal he refers to was called "The Four-Course Plan". While students had traditionally taken five courses at a time, they would now take only four courses, typically two in a major field and two other courses that would now be considered general education. Additionally, all students would take independent studies with faculty, culminating in a mandatory senior thesis. When it was first introduced, this curriculum was quite controversial. Faculty feared that it would be too much work for them, alumni worried that it would hurt the chances of the football team, and students had concerns that it would be too much work. Several seniors composed a verse that described their attitudes about this curriculum, singing, "Luther Pfahler Eisenhart, efficient from the very start; But he's condemned in the eyes of man for originating the four-course plan." In fact, the opposition was strong enough that a committee was appointed to investigate. In the end, Eisenhart was able to give evidence that the new curriculum was beneficial to students' experiences. Eventually, the ideas of majors and senior theses gained wide acceptance, with many schools adopting similar curricula.

Several new programs were established at Princeton under Eisenhart's watch, including the Near East studies program. Many people give him credit for starting the statistics program, as it was during his tenure at Princeton that the first probability courses were taught and also that the first statistician, Sam Wilks, was hired. This latter decision was controversial within the program, with much of the mathematics faculty not believing that statistics belonged in a mathematics department and many of the social scientists on campus agreeing. Eisenhart also helped to build several programs outside the mathematics department.

Eisenhart was also a significant contributor to both the mathematical community and the world of higher education more generally. In addition to serving as the president of the American Mathematical Society, he spent time as president of the American Association of Colleges, as vice-president of the National Academy of Sciences and of the American Association for the Advancement of Science. He also served as one of the founding members of the Middle States Commission on Institutes of Higher Education beginning in 1919.

In addition to the many ways in which he served his profession, Eisenhart also had several opportunities to serve his country. In 1940 he chaired a joint committee of the National Academy of Sciences and the National Research Council tasked with developing policies for dealing with scientific publications that might have military applications. Twice Eisenhart was asked to sit on committees established by the National Academy of Sciences to give reports to Congress about congressional apportionment,[2] including one that he chaired.

Eisenhart was serving as both the dean and head of the mathematics department at Princeton when the Institute for Advanced Study (IAS), a think tank also located in Princeton, New Jersey, was founded. The fact that the institute's first "school" was in mathematics served as both a fortuitous opportunity for Princeton's math department and a potential risk. On one hand, it would bring some of the greatest mathematical minds of the time to Princeton in order to do mathematics. On the other hand, the institute was recruiting faculty from Princeton's ranks, as it was easier to recruit faculty who would not have to move to a different town, let alone a different country. As dean, it was incumbent upon Eisenhart to navigate these political waters in an effort to help the two institutions thrive rather than hurt one another. Luckily, Eisenhart and IAS founder Abraham Flexner got along well and worked together to help improve both institutions, although they often would pursue the same people to join their faculty ranks. One example was John von Neumann, who eventually chose to be employed at the IAS despite a prior commitment to Princeton. Eisenhart had good reasons for allowing this to happen, but it alienated many trustees, and some observers have suspected that it cost him the presidency of Princeton.[3]

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[2] *The Constitution of the United States specifies that each state should receive proportional representation in Congress but is surprisingly vague on how many members the House of Representatives should have and how they should be divided among the states. The author would refer the interested reader to Szpiro's book* Numbers Rule: The Vexing Mathematics of Democracy, from Plato to the Present [27].

[3] *Batterson discusses all of these political wranglings in his account of the founding of the IAS, entitled* Pursuit of Genius: Flexner, Einstein, and the Early Faculty at the Institute for Advanced Study [6].

Eisenhart also got into a sticky political situation related to the International Congress of Mathematicians. Traditionally, the location of the ICM is decided after a country's professional association of mathematicians extends an invitation. Eisenhart, along with L. E. Dickson, invited the congress to meet in New York City in 1924 without the official backing of the American Mathematical Society. This was particularly controversial, as the United States and Great Britain had been excluded from the 1920 Congress in Strasbourg, and in the end the congress was moved to Toronto.[4] It was therefore especially significant that it was Eisenhart who in 1936 again invited the International Congress to be held in the United States, emphasizing that "mathematics is international…it does not recognize national boundaries."

Despite the fact that his true professional interests always seemed to be teaching and research, Eisenhart viewed these administrative responsibilities as something that should be done without complaining. When asked whether his father enjoyed administrative work, his son Churchill Eisenhart responded that "I think it was a thing that he felt should be done, and he didn't let it interrupt him very much…To give you an illustration, I don't know what year this was, but the mathematical society was meeting somewhere. Dad said to his wife, 'Katy, I'll have to be gone the next couple days, because I have to go to the mathematical meeting.' 'Oh, Luty,' she said, 'you know you really need a rest,' and so forth. 'Why don't you take a few days off?' He said, 'I can't. I'm the president. I have to give a talk.' That was the first time that she knew he was the president" [2, C. Eisenhart]. He was greatly respected as an administrator for his no-nonsense attitude. Another rhyme that the students composed about him discussed the showers that he had installed in Fine Hall: "Here's to Eisenhart, Luther Pfahler / At Mathematics, he's a whaler / He's built a country club for math / Where you can even take a bath."

Throughout his life, Eisenhart remained connected to Gettysburg College. He became a trustee of the college in 1907, and early in his time as a trustee served on a committee that looked at the admissions standards of the college in an attempt to raise them in response to a report expressing concerns that the college was not meeting national standards for higher education. In 1910 Gettysburg College was looking for a new president, and Eisenhart's name was one of the top choices; in particular, polls of the various alumni clubs throughout the country regularly listed him as the second or third choice for the position. In the end, he was not chosen as president, although it is interesting to note that the choice was William Granville, another mathematician and the author of one of the most influential calculus texts of the first half of the twentieth century [17], along with the book *The Fourth Dimension and the Bible* [18]. Eisenhart continued to serve as a trustee of the college until 1916 and received honorary degrees in both 1921 and 1926.


Arthur Coble as a Pennsylvania College student.

Eisenhart also received degrees from Columbia, Lehigh, Duke, Princeton, Johns Hopkins, and the University of Pennsylvania. In 1937 he was named Officer of the Order of the Crown of Belgium by King Leopold III. In 1945 Luther Eisenhart retired from Princeton University, although he did not lead the stereotypical life of leisure. He continued to be a prolific scholar, publishing nearly thirty additional papers, including a series of papers on "A unified theory of general relativity of gravitation and electromagnetism". He also remained active in professional societies, and the American Philosophical Society chose him to be their executive director, a post that he held until 1959. He died on October 28, 1965, at which time several of his faculty colleagues wrote of him that "in two centuries of Princeton's history few scholars did more to shape the future of the University."

Coble

Arthur Byron Coble was born on November 3, 1878, in Williamstown, Pennsylvania, a small town not far from Harrisburg. His father, Reuben Coble, had served in the Civil War in the 107th Regiment of the Pennsylvania Company and worked in manufacturing along with being a general store owner. Later in life, Reuben became the president of a small bank as well as one of the founders of The Lykens Pa Knitting & Manufacturing Company, which made hosiery undergarments. Reuben married Emma Heagy from New Oxford, Pennsylvania, and the two of them had six children together, of whom Arthur was the third.

Arthur Coble arrived at Pennsylvania College in the fall of 1893 and roomed with his older brother, Charles Ray Coble, in a room near that of Luther Eisenhart in Pennsylvania Hall. Coble was not as much of a standout student as Eisenhart. He did not win any awards during his time at the college. When the Baum Prize was awarded to the sophomore student who was most proficient in mathematics, he was neither the winner nor among the six

[4]*For details, the author refers the reader to Curbera's history of the ICM, entitled* Mathematicians of the World, Unite! [9].

students listed as receiving honorable mention. He was, however, voted the secretary of his class as well as a member of the Philomathean Literary Society, the Debating Club, the Star Boarding Club, and an organization known as "Snake and Coffin". In the 1897 edition of the college's yearbook, *The Spectrum*, he listed his ambition upon graduation as "To Look Neat", while his want was "To Please Papa". Upon graduation, Coble returned to his hometown of Lykens, where he taught in the public schools for a year. In 1897 he applied to the doctoral program at Johns Hopkins, and his former professor Nixon wrote a letter on his behalf, saying that "Mr. Coble took great interest in his work. His natural ability and training recommend him to an unusual degree." He was admitted to the program and began classes in the fall of 1898, many of which he took alongside his former classmate, Luther Eisenhart. His studies at Hopkins culminated in his 1902 thesis written under Frank Morley, entitled "The Relation of the Quartic Curve to Conics", which he later published as an article in the *Transactions of the American Mathematical Society* [7].

After receiving his Ph.D., Coble spent a year teaching at the University of Missouri before returning to Johns Hopkins to continue his work with Morley. This research position was funded in part by the Carnegie Institution of Washington, which had recently been founded by Andrew Carnegie to fund scientific endeavors. Coble used the funding in part to travel to Germany, where he studied at Griefswald and Bonn with the invariant theorist Eduard Study. Coble taught at Johns Hopkins until 1918, when he accepted a full professorship at the University of Illinois Urbana-Champaign.

Coble continued his research in algebraic geometry and, in particular, on the Cremona group defined as the set of automorphisms of the field $k(x_1, \ldots, x_n)$ consisting of rational functions on n variables. Even the case where $n = 2$ is complicated, and Coble tried to understand what happens for larger n. Some of Coble's original work in the area uses invariant theory to solve general quintic and sextic equations by thinking of the Galois group of the equation as a group of Cremona transformations. As his work evolved, he was one of the first to use finite geometries to provide explicit equations for the famous "27 lines on a cubic" problem. Much of his later work involved showing connections between the appearance of zero-cycles in the theory of modular forms and the zero-cycles that arise in the study of the Cremona group. During his career Coble published twenty papers in algebraic geometry and had thirty students receive Ph.D.'s under his direction, although Halmos writes that he could have had many more:

> There is a story about him as a Ph.D. supervisor that may be apocryphal but is true in spirit. Allegedly he had an infinite sequence of Ph.D. thesis topics. Having proved a theorem in dimension 2, he had his next Ph.D. student extend the result to 3, and the one after that to 4. The story has it that Gerald Huff was the spoilsport; he settled not only 5 but every greater dimension too, and thus put an infinite number of prospective Ph.D.'s out of business. [20]

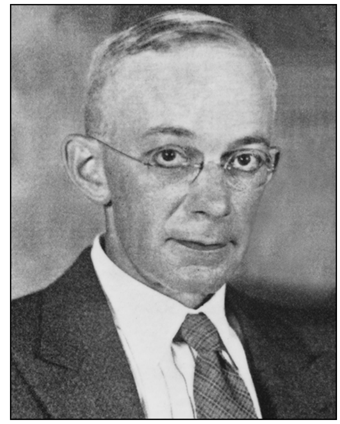
In 1893 the American Mathematical Society had started a series of meetings where prominent mathematicians were invited to give a series of talks on the topic of their choosing, which would then be written up and published as part of the Colloquium Publications series. The list of speakers reads like a who's who of American mathematicians from the early twentieth century, featuring names such as Bell, Dickson, Evans, Moore, and Veblen. Both Coble and Eisenhart were featured in the series. Eisenhart's lectures on non-Riemannian geometry were delivered at the Ithaca meetings in September 1925 and formed the basis for [12]. Coble's series of lectures, entitled "The determination of the tritangent planes of the space sextic of genus four", were delivered at the Amherst meeting in September 1928. It is interesting to note that only seventy-seven mathematicians were in attendance at Coble's talks, according to a report in the *Bulletin of the AMS*, compared to the national AMS meetings today, which draw upwards of 7,000 mathematicians. Coble's lectures were published as volume 10 of the AMS Colloquium Publications series in 1928 under the title *Algebraic Geometry and Theta Functions* [8], a book that has become a standard in the field. Upon its release, Zariski wrote very highly of Coble's book: "The principal merit of Coble's new volume [is] the geometric spirit, which seeks to discover the geometric reality hidden behind the formal properties of the functions θ. The picture of this geometric reality, which the author draws before our eyes, is as varied as it is colorful…Coble's work is a really important contribution to the theory and application of the θ-functions, and will be well accepted by competent readers" [29]. Both volumes from the AMS Colloquium Publications series have been republished many times, most recently in 2008.

Many objects in algebraic geometry are associated with Coble's name due to his work on them. A Coble curve is an irreducible degree 6 planar curve with ten double points. Various embeddings of Jacobians into projective space under theta-mappings, which can be represented as singular loci of hypersurfaces, are given the name Coble hypersurfaces. More recently, Dolgachev and Zhang have defined the notion of a Coble surface to be a nonsingular projective rational surface X with empty anticanonical linear system but nonempty antibicanonical system [10]. Coble was also an editor of many journals. At various points, he was an editor of *Transactions of the American Mathematical Society* and *American Journal of Mathematics*. He was also one of the founding editors of the *Duke Mathematical Journal* in 1935.

By all indications, Coble's preferred use of time was to do mathematics, but he had other interests as well. When asked by a colleague what he did for pleasure, he responded, "With respect to my hobbies, I can only say that they are essentially of a rather frivolous and time-consuming character. I enjoy out-of-door sports—golf, tennis, swimming, and walking, and in bad weather I turn to bridge and billiards and light reading."

Arthur Coble was not as enthusiastic in his embrace of administrative work as Luther Eisenhart had been. When the Urbana Faculty Senate published a tribute to him upon his passing, they wrote that "although he had little inclination for administrative responsibilities, he came to accept them as a necessary component of his work…He brought to these committees the calm judgment and the methodical analysis that characterized his work in other areas" [23]. Despite his aversion to administrative duties, he served as the head of the Department of Mathematics at the University of Illinois from 1934 until his retirement in 1947. During this time the department saw tremendous growth, with the graduate program in particular more than tripling in size. He also succeeded in hiring a number of prominent mathematicians to the faculty, two of whom, Joseph Doob and Oscar Zariski, would go on to also become presidents of the AMS. During Coble's time the University of Illinois was also known as a place particularly friendly to women in mathematics. It was one of the only universities with more than one woman on its faculty, and it graduated a relatively large number of women with Ph.D.'s in mathematics. Coble alone supervised five women in doctoral degrees.

There are very few records of Arthur Coble staying connected to Gettysburg College after his graduation. Several alumni magazines list him as donating money to the college, but most reports of reunions of the Class of 1897 specify that Arthur Coble could not attend due to professional obligations. One exception is the class's fiftieth reunion in 1947, which was celebrated at the Hotel Gettysburg with a dinner that Coble attended. In 1933 Coble was awarded an honorary degree of Doctor of Laws by the college.


Arthur Coble, 1933–1934, AMS president.

Arthur Coble retired from the University of Illinois in 1947 and returned to his home state of Pennsylvania. This was likely due in part to his increasing symptoms from Parkinson's disease. Following his mentor Morley's lead, he accepted a position at Haverford College but was able to teach there for only one semester before his symptoms got bad enough that he was forced to retire for good. In 1956 he was involved in a car accident that left him unable to walk, and he lived the rest of his life at the Lykens Hotel in his hometown. He died on December 15, 1966, in a Harrisburg hospital.

Conclusion

The lives of Luther Eisenhart and Arthur Coble were different in many ways, but both did great work. Eisenhart pursued a wide range of professional interests, ranging from writing textbooks to overhauling the curriculum at a major university. Coble, on the other hand, chose to focus on the mathematical problems that interested him in algebraic geometry, making him a leader in that field. Despite their differences, their paths crossed in a number of ways, not the least of which is that their academic careers began under similar circumstances, as both grew up in central Pennsylvania, graduated from Gettysburg College, and received doctorates from Johns Hopkins, where they took classes together. A couple of decades later they were coeditors of the *Transactions of the American Mathematical Society*, and they both served the Society in a number of different capacities. Both were undoubtedly leaders of the mathematical world, but they chose to express this in different ways. It is an interesting comment on the mathematical community in the 1930s that both approaches to one's career were rewarded and that both men could be elected president of the American Mathematical Society, one of the highest offices the profession has to offer.

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Editor's Note: The images of Luther Eisenhart (1931–1932) and Arthur Coble (1933–1934) are courtesy of the AMS archives. All other images in the article are courtesy of Special Collections/Musselman Library, Gettysburg College, Gettysburg, PA.

Interview with John Horton Conway

Dierk Schleicher

This is an edited version of an interview with John Horton Conway conducted in July 2011 at the first International Mathematical Summer School for Students at Jacobs University, Bremen, Germany, and slightly extended afterwards. The interviewer, Dierk Schleicher, professor of mathematics at Jacobs University, served on the organizing committee and the scientific committee for the summer school. The second summer school took place in August 2012 at the École Normale Supérieure de Lyon, France, and the next one is planned for July 2013, again at Jacobs University. Further information about the summer school is available at `http://www.math.jacobs-university.de/summerschool`.

John H. Conway is one of the preeminent theorists in the study of finite groups and one of the world's foremost knot theorists. He has written or co-written more than ten books and more than one-hundred thirty journal articles on a wide variety of mathematical subjects. He has done important work in number theory, game theory, coding theory, tiling, and the creation of new number systems, including the "surreal numbers". He is also widely known as the inventor of the "Game of Life", a computer simulation of simple cellular "life" governed by simple rules that give rise to complex behavior. Born in 1937, Conway received his Ph.D. in 1967 from Cambridge University under the direction of Harold Davenport. Conway was on the faculty at Cambridge until moving in 1986 to Princeton University, where he is the von Neumann Professor. He is a fellow of the Royal Society of London and has received the Pólya Prize of the London Mathematical Society and the Frederic Esser Nemmers Prize in Mathematics of Northwestern University.

Dierk Schleicher is professor of mathematics at Jacobs University in Bremen, Germany. His email address is `dierk@jacobs-university.de`.

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John Horton Conway in August 2012 lecturing on FRACTRAN at Jacobs University Bremen.

Schleicher: John Conway, welcome to the International Mathematical Summer School for Students here at Jacobs University in Bremen. Why did you accept the invitation to participate?

Conway: I like teaching, and I like talking to young people, and I expected to enjoy myself. I used to say about myself that if it sits down, I teach it; if it stands up, I will continue to teach it; but if it runs away, I maybe won't be able to catch up. But now it only needs to walk away and I won't be able to catch up, because I had a stroke a short time ago.

Schleicher: *Has that ever happened to you that people have run away from you in your teaching?*

Conway: Yes, after five or six hours being taught something, people edge away. You know, British students aren't so disciplined as German ones.

Schleicher: *At this summer school, there are students from twenty-five different countries, with different levels of politeness, and they have not edged* *away, quite the opposite. You are a professor in Princeton, and people come to Princeton to study with people like you…*

Conway: Yes, to some extent.

Schleicher: *…and now you come here to the students. Of course, the students we have here are even younger than most undergraduates in Princeton. Is it different for you to teach the summer school students?*

Conway: I never treat anybody any differently, roughly speaking. I teach graduate courses in Princeton, and I teach undergraduate courses. I come to places like this and other similar events in the States. I never really change my style of teaching. I don't change the topics I teach very much. If a student is a younger person, I don't go into so many details, but it is the same stuff for me. I am a very elementary mathematician, in a sense.

Schleicher: *Then you are a very deep elementary mathematician.*

Conway: I will accept your compliment, if that is what it was meant to be, but…

Schleicher: *Yes, it was.*

Conway: …How might I say this? It's harder to take easy, baby-type arguments and to find something new in them than it is to find something new in arguments at the forefront of mathematical development. All the easy things at first sight appear to have been said already, but you can find that they haven't been said.

Schleicher: *That puzzles me a bit, because you are one of the people at the forefront of mathematics—perhaps at the forefront of unexpected mathematics.*

Conway: I think the last clause I can accept. But it is my own mathematics. I discovered the surreal numbers, which are absolutely astonishing. The definitions are absolutely trivial. Nobody had thought about them before, nobody was trying. In mathematics, there are worthwhile subjects. Very famous and deep mathematicians have investigated them, and it's very hard to find anything new. Most of my colleagues at Princeton make one topic their own and become world experts on it. I don't do that. I am just interested in a lot of things. I don't get very deeply into any of them. I get moderately deep.

Schleicher: *I take this more as an indication of your modesty.*

Conway: Here is another thing I say about myself: I am too modest. If I weren't so modest, I'd be perfect. I am working on the modesty.

Schleicher: *Good luck with that work! Speaking of your modesty, what do you think…*

Conway: I don't think I am modest at all, but carry on.

Students are clearly not edging away.

Schleicher: *Let me ask the question anyway. What do you consider your greatest idea, your greatest achievement?*

Conway: I don't know. I am proud of lots of things, and I don't think there is one thing I consider my greatest achievement. My colleagues would probably say the work on group theory. I don't consider that to be my greatest achievement. I think it's pretty good, but that's about it. I am glad they value it, so it means that in their eyes I am not regarded as totally frivolous. In my eyes, I am totally frivolous. But I have two particular things I can mention. One is fairly recent, the Free Will Theorem, and the other, rather less recent, is the surreal numbers. I value them, or estimate them, in different ways: with the surreal numbers I discovered an enormous new world of numbers. Vastly many numbers, inconceivable. Nobody else has discovered more numbers than I have. In a sense, it beats so-called conservative mathematicians at their own game, because it produces a simpler theory of real numbers than the traditional theory, which has been on the books for nearly two hundred years now. So I am very proud of that and astonished I was so lucky to find it.

Free Will Theorem

The other more recent work is the Free Will Theorem, which I found jointly with a colleague of mine, Simon Kochen; I would certainly have never found it by myself. It says something at a provable level about the notion of free will, which philosophers have been arguing about for ages, two thousand years at least. It wasn't something everybody wanted to know, but it's proved at the mathematical level of certainty—very nearly, anyway. Personally, I am proud of it because I have never thought about anything like that before. I've read philosophy books, but I've never imagined

Mathematical toys and games, such as the Rubik's Cube, are always an exciting topic of mutual interest for Conway and his audience.

making any progress. In general you don't make progress on philosophical problems. Instead of tackling the problem as everybody else did, I was thinking about something else, thinking about physics, and, whoosh—something about free will could be said.

Schleicher: *So could it be that this or other discoveries of yours were shaped by coincidence or by luck?*

Conway: Partly luck. I would have never done anything without my colleague. He taught me a lot of quantum mechanics. When I was at the university in England, I took courses in quantum mechanics, including one from Dirac, the great quantum mechanic! A wonderful physicist and a shy man. I understood nothing. That was strange, but there is a famous saying by Feynman that if you meet somebody who tells you they understand quantum mechanics, then you have met a liar, and not a good liar at that. So I don't claim to understand quantum mechanics. My friend Simon Kochen taught me one thing about quantum mechanics which I understood, and I find that many physicists don't understand that one thing (of course, they understand many things that I don't). And that one thing we were able to pursue until we had this great theorem. If we make reasonable assumptions, including the assumption of free will, this one thing tells us that the little elementary particles are doing their own thing all over the universe. One atom is deciding to move a little bit leftwards and another to move a little bit rightwards. And it all very nearly cancels out, but not quite. And here [points to Schleicher] is what we call a life. You might be a robot, but I doubt it. I rather suspect you to have the same kind of consciousness as I have. And that is probably a manifestation of the freedom of the particles inside you: they do their own thing.

Schleicher: *Could you make a simple statement about what exactly, or intuitively, the Free Will Theorem says?*

Conway: Yes. [Throws a piece of paper.] I just decided to throw that piece of paper on the floor. I don't believe that that was determined at the start of the big bang, 14 billion years ago. I think it's ludicrous to imagine that the entire development of the universe, including, say, this interview, was predetermined. For the Free Will Theorem, I assume that some of my actions are not given by predetermined functions of the past history of the universe. A rather big assumption to make, but most of us clearly make it. Now, what Simon and I proved is, if that is indeed true, then the same is true for elementary particles: some of their actions are not predetermined by the entire past history of the universe. That is a rather remarkable thing.

Newton's theory was deterministic. In the 1920s, Einstein had difficulties believing that quantum mechanics was not deterministic. That was regarded as a defect of quantum mechanics. Certainly when I tried to learn quantum mechanics and didn't succeed, I thought it was a defect. It's not a defect. If the theory could predict what one of those particles could do, then that theory would be wrong, because, according to the Free Will Theorem—supposing we do have free will—a particle doesn't make up its mind what it's going to do until it does it or until shortly before it does it.

Let me describe the theorem this way. Suppose there is only a very tiny amount of free will in humans: you can press either button A or button B in a manner that is not predetermined. That is a very tiny part of what we normally consider free will for humans. And if we have that tiny amount of free will, so do the elementary particles, in a sense that a particle in response to some experiment can choose which path, C or D, that it follows. It has free action. It chooses C or D in a manner that is not a predetermined function of all the information in the past history of the universe.

Schleicher: *You believe that humans have free will.*

Conway: I do. Strict determinism tells us that all of our actions are predetermined by the past history of the universe. I don't know, maybe it is. I can't disprove it. I can prove that I can't disprove it. I can prove that you [points to Schleicher] can't disprove it either. But I believe anyway that humans have free will.

Schleicher: *That is your belief.*

Conway: And it is very strong. If you or somebody else doesn't believe this, I am not going to argue with you, because I know that I can't disprove the determinist's position. After giving lectures on this subject in various places, sometimes I have asked whether there were any determinists in the audience. Usually in an audience of a hundred, twenty people put their hands up. They are usually among the most intelligent members of the audience, because it takes some intelligence to disbelieve something that everybody else feels is obvious or to believe something that everybody else feels is ludicrous. Several times people have come up to me and told me they were determinists and expected me to argue the matter. But since I've proved that nobody can disprove determinism, what is the point in trying to disprove determinism? I have no argument with determinists or, I should have said, I have no *arguments* with determinists.

Schleicher: *The usual interpretation of quantum mechanics is that the behavior of the elementary particles is simply random.*

Conway: You know, randomness doesn't help. If the action of each particle were a predetermined function of its past plus a random string of bits, then we might as well suppose that this string of bits was produced just before the universe was created, and this is excluded just as well as totally deterministic behavior.

Cellular Automata

Schleicher: *One achievement of yours that you didn't mention is one that you are perhaps best known for, the invention of the Game of Life, the theory of cellular automata.*

Conway: Yes, that is true. And sometimes I wish I hadn't invented that game.

Schleicher: *Why?*

Conway: Well, because I am pretty egotistical. When I see a new mathematical book for a general audience, I turn to the index, I look for a certain name in the back, and if I see this name, it shines out at me somehow. And it says, page 157, pages 293–298, or whatever. So I eagerly turn to those pages, hoping to see some mention of my discoveries. I only ever see the Game of Life. I am not ashamed of it; it was a good game. It said things that needed to be said. But I've discovered so many more things, and that was, from a certain point of view, rather trite—to me anyway. It is a bit upsetting to be known for this thing that I consider in a way rather trivial. There are lots of other things to be discovered about surreal numbers. And the Free Will Theorem is recent, and therefore I am still flushed with enthusiasm about it.

Schleicher: *I understand what you are saying. But is it possible that the Game of Life has perhaps not been fully developed or understood? Maybe there is a theory waiting to be discovered?*

Conway: No, it's been overdeveloped. You won't interest me in the Game of Life.

Schleicher: *But Steven Wolfram is very interested in cellular automata. Doesn't he think it is the future of everything?*

John Conway likes to challenge people in a game of "dots and boxes"—that game is often played in high schools but has surprisingly deep mathematical content.

Conway: I think he is wrong. And I am rather astonished that he has the opinions that he has, because he supposedly studied physics. I shouldn't say "supposedly"—pardon me. He should be aware of the fact that the universe behaves in a manner that—at least most competent physicists believe—is not deterministic. And cellular automata are things that, like the life game, are deterministic. So in my opinion, it's provable that the universe is not a cellular automaton.

Schleicher: *I am a bit surprised to hear you say that one should believe what the majority of scientists in a particular field say. Have you ever cared about the opinion of the majority?*

Conway: No, not very much. But physics is not my profession. And I suppose I just try to bolster this opinion by saying it's not only me. I'm surprised Wolfram believes that the universe is a cellular automaton. I met him a long time ago, and he was very friendly. He was chiefly interested in the Game of Life. I remember walking with him and a friend of his when we both attended a conference near Marseilles. We used to walk down to the Mediterranean along the nice rocky path and then come back the same way after spending an hour at the beach, talking all the time about—well, largely about things like cellular automata, but also about philosophy and other things. I didn't see him for a long time, and then we had a discussion that wasn't entirely amicable about ten years ago. I met him again last year or the year before at the celebration of the life of Martin Gardner, and we fell back into our old habit of having interesting intellectual conversations. It's rather funny, because he made his millions by starting a company and doing a good thing. This man could give me one or two million dollars without noticing.

Conway is always ready for any kind of mathematical game.

I don't think that Wolfram's theories are tenable. His book is very interesting, but as the explanation of the universe—I don't think he's got the right idea, possibly because he doesn't understand the one thing of quantum mechanics that I do. Lots of physicists don't understand this. I won't claim any special virtue in understanding it. It took me ten years to do so by talking with my friend Simon Kochen for several hours a day, except Saturdays and Sundays, talking about quantum mechanics, trying to understand it. Really, we didn't know what we were talking about. We were talking about particular problems at various times. But in retrospect, perhaps I should say, it was predetermined that we would go to the Free Will Theorem! But of course it wasn't predetermined. I don't believe anything is predetermined, roughly speaking. Things concerning large inanimate objects are predetermined. This tree is not going to start walking around the lawn. The building, I hope, is not going to fall down. Physical laws, as regards inanimate objects, have a high degree of predetermination. But as regards animate objects, such as people walking around on the lawn and a dog that might accompany them, that doesn't look predetermined to me. I can't prove that it isn't. And nobody else can.

Inventing the Game of Life

Schleicher: *What made you invent the Game of Life, and how did it happen?*

Conway: I was telling you of my *Jugendtraum*, my youth dream, that undecidable complexity is not as far out as one might expect but might happen just around the corner. There was a book called *Automata Studies*, one of those orange Princeton books, that gave me quite a lot of topics to think about. One of them was a mention of von Neumann's cellular automaton, which was a universal computing device in the sense that it could emulate any other computer. This was a very complicated thing, with twenty-nine states and a neighborhood of five cells, and it had a very long list of transition rules that would be virtually impossible to check. Von Neumann had designed this thing carefully so as to have this universality property. I thought you didn't have to design it, because it would happen almost automatically, given a sufficient amount of complexity.

One metaphor that has been with me for a long time is the following: I like to think of a huge abandoned warehouse equipped with logical devices such as AND, OR, and NOT gates. Suppose a maniac lived there who would solder together a big number of these devices just randomly. Then with enough time you could learn how to program this, and it wouldn't take a lot of intelligent design so that the big circuit would be unpredictable and probably even universal. This idea also underlies my recent paper on amusical permutations, which I wrote for the *American Mathematical Monthly* special issue that you invited me to contribute to.

It happens on several occasions that people have proved something like universality assertions, and then people start to think that that proof is an estimate of how complicated a universal device has to be. Let me give you a number of examples. Gödel proved his famous incompleteness theorem by inventing things called "Gödel numbers" for propositions and then talking about the statement with Gödel number n and evaluating this for the parameter equal to n and so on. The books used to say that the Gödel number of any statement of any interest must be enormously big, but I didn't see why these had to be so big. Similarly, it is often said that a universal Turing machine has to be terribly complicated, but I didn't see why that had to be so. You see, von Neumann's universal cellular automaton had twenty-nine states and very complicated transition rules, and I didn't think that was necessary, so I tried to find a much simpler automaton that was universal too.

The Game of Life was, I think, my first foray into the field—well, I'm not quite certain whether it was really the first. I guessed it would be universal.

Schleicher: *And how did you discover it?*

Conway: I tried out dozens and dozens of different automata, not necessarily to see whether they were universal, because that is rather difficult to work out. I tried to design rules that were unpredictable in behavior but that I could study for long enough to learn how to program them. If you are shown into the warehouse that I mentioned and had only one day, you wouldn't learn how to program it [the big circuit]. In the case of the life game, I studied this with a little community of graduate students. We studied different sets of rules, played them on Go boards over what I think was eighteen months—not all the time, but every now and then during coffee breaks. We eventually found this wonderful system that appeared to be universal. The day when we thought it would be successful I very much remember. Richard Guy was staying in Cambridge, which he didn't often do. He was given the job of blinker-watcher, as he is a very precise sort of person. Blinkers are three sets of aligned cells that alternate in period 2.

Schleicher: *I know the Game of Life well: when I was in high school, this was a hot topic among all the math folks there, and it was the first computer program I ever wrote in binary machine code on my first computer.*

Conway: We did this all by hand on Go boards with blinkers, and other small objects—you don't have to update them in every generation. You just have to keep a note on whether it's an even or odd generation. Only when the rest of the game is getting near it do you bother to update it. To keep track of these small objects is the job of the blinker-watcher. At one point, he said, "Come over here! My bit is walking!" And indeed it was. That was the discovery of the glider. In the *Winning Ways* book there is a little piece on gliders, and it says, "Some guy said 'my bit is walking',", and this "guy" was Richard Guy. We had thought of things like "spaceships" when trying out all sorts of rules. This was the first time that a spaceship actually happened: five cells at any given time, and they appeared naturally. Of course we discussed this, because we had hoped our cellular automaton would be universal and in order to have a computer in which, instead of wires and pulses of electricity, you had paths on which gliders (or something) were actually traveling. As soon as we discovered them we set about having them crash; there are about forty different ways of crashing them. That led eventually to the proof of universality.

I offered a prize for anyone who could come up with a Life configuration whose population grew indefinitely. That aim was purposely stated rather widely. What I had wanted was what it eventually became—something that would emit gliders regularly—but I thought anything that just showed that the typical configuration didn't just die off or settle down would be interesting. Later on, people found "3–4 Life". I don't remember the details. Here the population is rather large. Nobody ever proved that it is universal. More or less every system you can't understand is probably universal, but if you can't understand it, how can you prove anything about it?

The problem with Life is the problem with understanding a little bit about it and then studying it long enough to identify components that would eventually lead to universality. It's interesting that nobody else has since found a simple thing that's universal. That doesn't mean it's not there; I think it's all over the place! But it means nobody spent the roughly one year (of coffee times) that it takes to find it.

John Conway is always surrounded by students no matter where—such as here during an excursion at the summer school.

Schleicher: *You just mentioned you offered cash awards. Of the awards that you offered, did you have to pay most of them, and were you ever surprised you had to pay something you didn't expect?*

Conway: I didn't offer cash awards all that often…

Schleicher: *…you even did that to me when we met first, almost twenty-five years ago, and then played a little trick on me [both laugh].*

Conway: There was this famous case, rather stupid of me. I had a little problem about whether a certain sequence tended to infinity. I was giving a lecture at Bell Labs—quite a big lecture, actually. There I proposed two forms of the problem, an easy one and a hard one. For the easy one I offered US$100, and I said that for the hard one I would offer ten times as much, hence US$10,000…

Schleicher: *…and that from you, the master of mental computation!*

Conway: I might even have repeated this wrong number, $10,000, afterwards. There was a person at Bell Labs, Colin Mallows, who solved the harder problem. I was quite happy and wrote him a check for $1,000. Neil Sloane said it was $10,000, and I didn't believe it, but it was on tape. I am not sure whether I ever listened to the tape again, I suppose I must have, and I wrote a check for $10,000. I talked to my wife, and we decided we wouldn't buy the new car we were planning to buy; she was very good about it. Mallows got the check for $10,000, but he said he wasn't going to accept it. I said, "You don't have to feel bad about it" and tried to persuade him a bit, but not terribly hard [smiles]. He then accepted the check for $1,000. I think he

Screenshot from the interview in 2011 at the summer school. This was supposed to be a brief conversation, but developed spontaneously into a one-hour interview, interrupted only when the camera batteries died.

framed the $10,000 check in his office but didn't cash it.

Schleicher: *This is a beautiful and famous story that even made it into the* New York Times*!*

Conway: It actually turned out he made a mistake. The first question was whether a certain sequence converged to 1/2, and the second question was what the last time was when it differed from the limit by more than 1/20. Much later it turned out that his answer was actually wrong. His ideas were basically right, but he had overlooked a stupid thing and I hadn't caught it, so the whole thing was replete with mistakes on all sides. Incidentally, this was not a sequence I had invented myself: it had been proposed by A. K. Dewdney, the author of a "Flatland revival" book. The sequence starts with $f(0) = 0$, $f(1) = 1$, and $f(n) = f(n - f(n-1)) + f(n - f(n-2))$.

Good or Bad Influence?

Schleicher: *I'd like to ask you about something different now. Some of your achievements have had a great influence on people, especially on young people, and many of them consider you a role model or a hero. How do you feel about this?*

Conway: Let me say, I may have had a great influence on a lot of people, but quite often that influence has been to the bad.

Schleicher: *Why is that?*

Conway: I feel very guilty; I have one particular person in mind. He didn't get a Ph.D. because he became too interested in the kinds of games I was teaching him. I suspect that sort of thing has happened quite a lot, not necessarily to the extent of damaging a person's career as much as I fear I have in that case, but by making it harder for people to concentrate on the work they should be doing, because I am telling things that are more interesting. So I'm rather worried when I influence people.

Schleicher: *Let me ask the question again which I asked at the very beginning. Why did you invest the time to come to the summer school to talk to young students day and night?*

Conway: First of all, concerning the possibility that I might do them harm in the manner I just mentioned: I can't do much harm in one week or so. Hippocrates, the father of medicine, said, "First, do no harm." So, when I come to a summer school like this, I'm fairly sure I'm doing no harm.

Schleicher: *I'm surprised that you have these worries.*

Conway: I might do good. I am reminded of something. I wrote the book *On Numbers and Games*. Just before, I had read John Bunyan's *The Pilgrim's Progress*. He has a little rhyme at the front of his book. He said he showed it to various people, and some said, "John, print it"; others said, "Not so." Some said, "It might do good;" others answered, "No." This rhyme seemed so wonderful in application to my book that I quoted it at the end of the preface of *On Numbers and Games*. Incidentally, I was imprisoned in the same prison in which John Bunyan was imprisoned about three hundred years earlier. When I was a student I participated in a "ban the bomb" demonstration. There was a magistrate who asked everybody a few questions and then sent us to jail. I don't think it was literally the same building Bunyan had been in, but it was a pretty old building. So I have a fellow-feeling for John Bunyan. Of course, his book is called *The Pilgrim's Progress*, and his pilgrim is called Christian. I am not religious, certainly not so religious as John Bunyan was. So, in some sense, the book is alien to me, except that I recognize the "Slough of Despond", a phrase he used to refer to being depressed.

Schleicher: *For how long?*

Conway: I was very depressed in 1993. I attempted suicide. And I very nearly succeeded. That was just personal problems—my marriage was breaking down.

Schleicher: *I was asking about the prison term.*

Conway: That was, I think, eleven days. That's the number I remember. My memories are unreliable, as I am discovering increasingly now. I have a biographer now, Siobhan Roberts. She wrote a biography of Coxeter, the famous geometer. She asked if she could assemble a biography of me, to which I initially said no, but she persisted, and eventually I said yes. Every now and then I say something to Siobhan about something I did, and she says, "That is not consistent with the letter you wrote on July 27th, nineteen-sixty-something, to Martin Gardner." That shows you what memory is like. And my role, whatever it was as I remember it, is always distinctly better than what Siobhan finds that the facts show.

Schleicher: *You mentioned Martin Gardner several times. He dedicated a book to you.*

Conway: Yes, I forget which book; it might be *Mathematical Carnival.* When Elwyn Berlekamp, Richard Guy, and I wrote the book *Winning Ways*, we dedicated it to Martin. I don't remember the dedication.

Schleicher: *"To Martin Gardner, who brought more mathematics to more people than anyone else."*

Conway: Yes, it was "to more millions than anyone else." We put in the word "millions" because Lancelot Hogben wrote a book called *Mathematics for the Millions.* I think that dedication is true, and it's amazing Martin Gardner did that, because he didn't understand very much mathematics. He certainly didn't do mathematics. Perhaps it's unfair to say he didn't understand. I've been rereading his book of essays. He was one of the most knowledgeable men ever, and that shines forth in his book of essays. But to his misfortune, he's still known chiefly for his "Mathematical Games" column in *Scientific American*, which he wrote for twenty years or more. It's more frivolous. He fell into the games column by accident: He wrote an article about hexaflexagons, which are ingenious paper toys that somebody else discovered. It wasn't his column yet; it was an article in the magazine. He died last year, several months after his ninety-fifth birthday.

Schleicher: *We are very happy that we have one of the young participants, Joris, here. You have a question for Professor Conway.*

Joris: *Professor Conway, what did you do to get where you are now in your career?*

Conway: [Laughs] I grew old. It's rather difficult to say. I am rather proud of the fact that, in some sense, I never applied for an academic position in my life. What happened: I was walking down King's Parade, the main street in Cambridge, after I received my Ph.D. The chairman of the mathematics department said, "Oh, Conway, what have you done about applying for jobs?" And I said, "Nothing." "I thought that might be the answer," he said, "Well, we have a position in our department, and I think you should apply." And I said, "How do I apply?" And he said, "You write a letter to me." And I said, "What should I put in that letter?" Then he lost his patience, pulled out of his pocket a letter—which had been written on one side—turned it over, and scribbled "Dear Professor Cassels"—that was his name—"I wish to apply for dot-dot-dot." He handed it to me, and I signed it. It would have been nice if I'd gotten the job. I didn't that year, but I got the same job the next year with the same letter.

Farewell at the airport after another friendly visit: Dierk Schleicher (left) and John Conway.

Keep Six Balls in the Air

How did I do it? I don't know. I was astonishingly lucky. I literally remember my former undergraduate teacher telling my then wife that John would not be successful. She asked why. And he said, "Well, he does not do the kind of mathematics that's necessary for success." And that's true. I really didn't do any kind of mathematics. Whatever I did, I did pretty well, and people got interested in it—and that's that. I did have a recipe for success, which was always keeping six balls in the air. Now I have had a stroke, so I can't catch those balls terribly well. But what I mean is: Always be thinking about six things at once. Not at the same time exactly, but you have one problem, you don't make any progress on it, and you have another problem to change to. I had a set mix: one of the problems could be a crossword puzzle in the newspaper or something like that. Nowadays it might be a Sudoku puzzle. One of them might be a problem that would instantly make me famous if I solved it, and I don't expect to solve it, but don't give up on it; it's worth trying. There must also be one problem where you can definitely make progress just by working hard enough. Then when the guilt level rises sufficiently—and I felt guilty in Cambridge for not doing any work—you could make progress. It is sort of a routine problem that is not completely dead and might be useful. So that is my recipe for success. I don't think you asked me for a recipe for success. Maybe you did.

Joris: *A little bit.*

Conway: By the way, it will cost you a quarter [smiles].

Enjoying Mathematics

Schleicher: *What message would you like to send to the participants of this summer school or to our future participants?*

Conway: The main component of the message is: Enjoy yourself! Of course, there is a subsidiary thing: Don't just enjoy yourself by fooling around and doing nothing. If it gets to the point where you feel that you must study something and understand it terribly deeply, and it ceases to be enjoyable—well, do something else, sleep it off, hope that it goes away, and come back again. That has been my recipe for everything. I have enjoyed myself all my life doing mathematics. I've had ups and downs in my life, but they've never been concerned with mathematics really. Mathematics has always been a sort of anodyne for me. If my life gets on top of me, then I can think about mathematics and put my personal problems aside for a moment. It's hard now. I walk with a cane, I wake up with my leg hurting, and I'm conscious every day that I'm in my seventies. I used to think I was twenty-five—I stayed twenty-five for roughly forty-five years. I don't feel twenty-five anymore as I always used to. It is very sad. Age is really catching me.

Schleicher: *Yet I have to tell you that the same smile, the same inspiration, the same mathematical depth, and the impression you leave on me are the very same as twenty-five years ago when we met in Princeton. That is something that I enjoy, and I'm sure that all the students enjoy.*

Conway: You are not consoling me. I still feel old. I don't feel as creative as I did a few decades ago. I'm not entirely dead; I did prove the Free Will Theorem. It's already five or six years old, and that is a good piece of creative work. And I am proud of it. But these ideas don't come as fast as they used to.

Schleicher: *These theorems don't come every day, but what comes every single day here—and maybe this is a good conclusion for this interview—is that the students enjoy how accessible you are. They always are around you. We would very much like to thank you for coming here to Bremen and to this International Summer School.*

Conway: I would like to thank you for inviting me—and pestering me until I actually came! I enjoy the students, talking to them, playing games with them, answering questions about mathematics when I can. And it's my life really: I tend to find young people to whom to teach something, or not necessarily teach something, but play games with them and learn from them, if necessary.

Schleicher: *We are very happy that you are here. Thank you very much.*

Conway: Thank you.

Andrew Fielding Huxley (1917–2012)

Michael C. Mackey and Moisés Santillán, Coordinating Editors

In *A Mathematician's Apology*, G. H. Hardy wrote: "A mathematician, like a painter or a poet, is a maker of patterns. The mathematician's patterns, like the painter's or the poet's, must be beautiful; the ideas, like the colours or the words, must fit together in a harmonious way." In our opinion these sentiments also apply to all other areas of science. The work of Andrew F. Huxley (who passed away on May 30, 2012) is one of the finest examples not only because of its importance to applied mathematics, biomathematics, and physiology but also because of the beauty of the underlying conceptual framework. A. F. Huxley has justifiably become one of the best-known scientists of the twentieth century.

A. F. Huxley was the youngest son of the writer and editor Leonard Huxley and his second wife, Rosalind Bruce, half-brother of the writer Aldous Huxley and biologist Julian Huxley, and the grandson of biologist Thomas H. Huxley. In 1947 he married Jocelyn Richenda Gammell (Chenda) Pease (1925–2003), the daughter of the geneticist Michael Pease and his wife, Helen Bowen Wedgwood.

From 1935 to 1938 A. F. Huxley studied physics, mathematics, and physiology at Trinity College, Cambridge, where he met Alan L. Hodgkin. At the time, high table included a glittering array of scientific talent, including J. J. Thomson, Lord Rutherford, F. W. Aston, A. S. Eddington, F. G. Hopkins, G. H. Hardy, F. J. W. Roughton, W. A. H. Rushton, A. V. Hill, and E. D. Adrian.

In August 1939 Huxley joined Hodgkin at the Marine Biological Laboratory at Plymouth for his first introduction to research, and they succeeded in recording electrically from the inside of the squid giant axon. However, this work was interrupted by the outbreak of World War II. For the first year of the war, Huxley was a clinical student, but when medical teaching in London was stopped by air attacks, he changed to work on operational research in gunnery, first for the Anti-Aircraft Command and later for the Admiralty.

In 1941 Huxley was elected to a research fellowship at Trinity College, Cambridge, and he took up this position at the beginning of 1946, together with a teaching appointment in the Department of Physiology. On his return to England after a research stay in the laboratory of Kenneth S. Cole, Hodgkin teamed up with Huxley to measure the electrophysiological phenomena associated with the generation of an action potential in the squid giant axon. This work was published in a brilliant series of five papers in the *Journal of Physiology* in 1952. The final one [Hodgkin and Huxley, 1952d] is an intellectual tour de force, combining both experimental data analysis and mathematical modeling (the Hodgkin-Huxley equations). This work earned Hodgkin and Huxley the Nobel Prize in 1963, along with J. C. Eccles, "for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane."

Huxley, the mathematician/physiologist, was not content to stop at the Hodgkin-Huxley model, however, and went on to publish in 1957 his celebrated review of muscle contraction data and its synthesis into the mathematically formulated cross-bridge theory, a theory that still stands in its essential ingredients today.

Huxley held college and university posts in Cambridge until 1960, when he became head of the Department of Physiology at University College London. In 1969 he was appointed to a Royal Society Research Professorship, which he held until 1983, when he became Master of Cambridge University's Trinity College. Named a fellow of the

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Royal Society in 1955, he served as its president from 1980 to 1985. In 1974 he was knighted.

We present below a brief account of the two major scientific contributions by Huxley: the Hodgkin-Huxley equations and the sliding filament theory, followed by brief personal pieces written by some of Andrew Huxley's close collaborators, friends, and students.

The Hodgkin-Huxley Equations

The work for which Huxley is best known is his formulation with Alan Hodgkin of the "Hodgkin-Huxley equations" in the final paper [Hodgkin and Huxley, 1952d] of a series of five papers published in 1952 [Hodgkin et al., 1952], [Hodgkin and Huxley, 1952a], [Hodgkin and Huxley, 1952b], [Hodgkin and Huxley, 1952c], [Hodgkin and Huxley, 1952d]. The first of the Hodgkin-Huxley equations, which accounts for the dynamics of the membrane potential of the axon (measured relative to extracellular fluid), V, is

$$C_m \frac{\partial V}{\partial t} + I_i = I_a + D\frac{\partial^2 V}{\partial x^2}, \tag{1}$$

where x is the distance along the axon, I_i is the current carried by ions moving through the membrane, and I_a is the current applied to the axon from an external source. The brilliance of the work of Huxley with Hodgkin came in their meticulous characterization of the ionic current I_i, which from their experimental work they deduced consisted of the sum of three independent currents carried by sodium (Na^+), potassium (K^+), and a "leakage" current so $I_i = I_{Na} + I_K + I_L$. Using the voltage clamp technique, they were then able to characterize the way in which these three currents depended on both membrane potential V and time t. Introducing the notion of an equilibrium potential for these three ionic species (e.g., the equilibrium potential V_{Na} for sodium is that value of the membrane potential V for which there is no net sodium current), they then further assumed that the currents were given by an "ohmic" relation such that each current was proportional to the driving force for each ion and the proportionality factor for each was a conductance:

$$\begin{aligned} I_{Na} &= g_{Na}(V - V_{Na}),\\ I_K &= g_K(V - V_K),\\ I_L &= g_L(V - V_L). \end{aligned}$$

From these three relations they were then able to deduce the dependence of the conductances g_{Na}, g_K, g_L on both potential V and time t. The factor g_L was found to be independent of (V, t), but g_{Na}, g_K were highly nonlinear functions of (V, t) and the problem they then faced was how to characterize this dependence.

The problem was solved for potassium by assuming $g_K = \bar{g}_K[n(V,t)]^4$, where $\bar{g}_K > 0$ is a maximal conductance and n is a so-called gating variable satisfying the simple differential equation

$$\frac{dn}{dt} = \alpha_n(1-n) - \beta_n n. \tag{2}$$

This was used to fit the experimental data, and from these fits they were then able to deduce the dependence of α_n, β_n on V. Since the temporal evolution of the conductance $g_K(V, t)$ at constant V had a distinctly sigmoidal nature, they concluded that n had to be raised to the fourth power to reproduce this property. In their final paper, Hodgkin and Huxley speculated that the form for the potassium conductance might represent the movement of what we now call a molecular subunit that regulated the opening and closing of the potassium gate. The fourth power would arise if it was assumed that four subunits had to be simultaneously in the correct position for potassium to move across the membrane.

The description of the behavior of the sodium conductance was conceptually the same, though more complicated in detail, since they had to assume that the equation for the sodium current was given by $I_{Na} = g_{Na}(V - V_{Na})$ with $g_{Na} = \bar{g}_{Na}[m(V,t)]^3 h(V,t)$, where m was an activation variable and h was an inactivation variable. Thus three m subunits had to be open to allow Na^+ to cross the membrane, but one h subunit could stop that movement. The kinetics of m and h were described by

$$\frac{dm}{dt} = \alpha_m(1-m) - \beta_m m \tag{3}$$

and

$$\frac{dh}{dt} = \alpha_h(1-h) - \beta_h h. \tag{4}$$

From the behavior of g_{Na} as a function of t at constant V, the functional dependence of the activation (α_m, β_m) and inactivation (α_h, β_h) rate constants on V was deduced.

Equations (1)–(4), along with the expressions for the α's and β's, are now known as the Hodgkin-Huxley equations and were the first proposed to explain the nature of the action potential in an excitable cell based firmly on experimental evidence. The explanation that they offered was impressive in its breadth, because the solutions conformed to the "form, duration and amplitude of (the action potential), both 'membrane' and propagated; the conduction velocity, the impedance changes during the (action potential); the refractory period; ionic exchanges; subthreshold responses; and oscillations." Though mention was not made in [Hodgkin and Huxley, 1952d] about difficulties in the solution of the equations, Hodgkin in his autobiography [Hodgkin, 1992, p. 291] notes that it

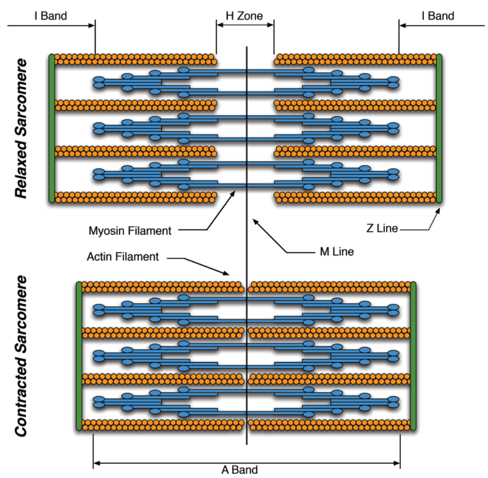

Figure 1.

took Huxley three weeks of work using a Brunsviga mechanical calculator to compute one solution to equations (1)–(4).

Setting aside the difficulties that Hodgkin and Huxley had in solving their proposed equations, there is something buried in their structure that is even more astonishing. The kinetic equation for the temporal evolution of $g_K(V,t)$, as pointed out, could be interpreted as requiring the simultaneous opening of four n subunits. We now know that potassium channels are tetrameric structures with four subunits that must all be in the correct position before ion movement is allowed.

The Hodgkin-Huxley equations were not only extremely influential in the further development of physiology, but they also had a great impact on mathematics. With respect to the full equations, the study of waves in nonlinear parabolic partial differential equations (reaction diffusion equations with excitable dynamics) was initiated by Hodgkin and Huxley when they calculated a traveling wave solution to their equations. Since this initial work, the study of these types of systems has become a flourishing area of research, with applications in biology as well as many other applied areas. Furthermore, various reductions of the Hodgkin-Huxley equations (e.g., the Fitzhugh-Nagumo equations) have provided an extremely active and fertile area of development in dynamical systems theory over the past sixty years.

The Sliding Filament Theory

Huxley was also instrumental in clarifying the mechanisms underlying muscle contraction. He built the first working interference microscope to follow changes in the striation patterns in muscle when it changes length, and this led him (with Rolf Niedergerke) to lay the foundation of what has become known as the sliding filament theory [Huxley and Niedergerke, 1954].

Myofibrils are one of the most abundant constituents of a muscle fiber. They are long proteinic filaments aligned along the cell longitudinal axis. Under the microscope it becomes apparent that they are composed of a repeated series of so-called sarcomeres, with sarcomeres appearing as dark and light bands and lines (see Figure 1).

Among other structural elements, sarcomeres consist of thin and thick filaments that overlap, as depicted in Figure 1, thus explaining the sarcomere arrangement of bands and lines. Thin filaments are mainly made of the protein actin, while the major component of thick filaments is the protein myosin. The I-band is the zone of thin filaments that is not overlapped by thick filaments, the A-band contains the full length of thick filaments, and the H-zone is the zone of thick filaments that is not overlapped by thin filaments.

According to the sliding filament theory, sarcomeres are the muscle's basic contracting unit. Contraction occurs because the two ends of the thick filaments slide along the thin filaments in opposite directions toward the Z-lines. As this happens, the A-bands do not change their length, whereas the I-bands and the H-zone shorten. All this causes the Z-lines to come closer, therefore causing sarcomere contraction.

The sliding filament theory has been fully corroborated since it was proposed, but it was necessary to develop experimental techniques that were not available at the time this theory was introduced. Since a direct experimental verification was impossible when the theory was proposed, [Huxley, 1957] developed a mathematical model to examine testable consequences of his theory.

A central assumption in the model was that myosin heads, which can attach to (by forming cross-bridges) and detach from specific sites on the actin protein, are responsible for moving the myosin along actin filaments. This assumption predates the notion of rotation of the myosin head. As a matter of fact, it was debatable at that time whether the cross-bridges played an important role in generating the relative sliding of the two filament types. Huxley considered a half-sarcomere (as depicted in Figure 2) and pictured

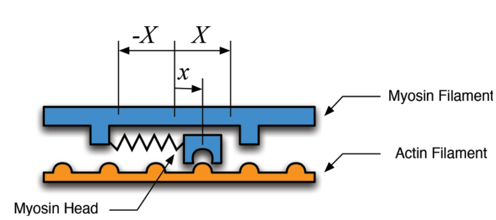

Figure 2.

the myosin heads as attached to the parent myosin filament by elastic tails. He further assumed that when the muscle is stimulated, those heads in the neighborhood of a binding site in the actin filament can be expected to attach to it. Force would then be applied to the actin filament by the stretched elastic tail of the cross-bridge, a contracting force if the elastic tail is in a state of extension. Since a contraction velocity would tend to shorten the elastic tail, in order for such a force to be created, one must assume that the tail is already extended when the cross-bridge is formed. Huxley proposed that this extension could originate from thermal agitation. However, this agitation would likely make the tail extend or contract with the same probability. Hence, Huxley suggested that attachment would, by means of an unspecified chemical-mechanical mechanism, be facilitated for cross-bridges that are displaced positively and be more difficult for those whose tails are in a resting position or contracted.

This conceptual model can be translated into equations by letting $n(x,t)$ denote the density of heads attached to the actin filament at position x and time t and $v(t)$ represent the actin-filament contraction velocity. A balance equation can then be written as

$$\frac{\partial n(x,t)}{\partial t} - v(t)\frac{\partial n(x,t)}{\partial x} = F(x,t) - G(x,t),$$

where $F(x,t)$ and $G(x,t)$ respectively represent the myosin head binding and detachment rates. Huxley further assumed that these functions are given by $F(x,t) = (U - n(x,t))f(x), G(x,t) = n(x,t)g(x)$. In these equations U represents the total density of possible cross-bridges, which is assumed to be independent of both x and t. Furthermore, in agreement with the nonuniformity of the attachment rate, the functions $f(x)$ and $g(x)$ are assumed to be

$$f(x) = \begin{cases} ax & \text{if } 0 \le x \le h, \\ 0 & \text{otherwise,} \end{cases}$$

$$g(x) = \begin{cases} b & \text{if } 0 \le x \le h, \\ cx & \text{otherwise,} \end{cases}$$

where a, b, c, h are all constant. In particular $b \gg 1$, while h is chosen to be smaller than the maximum myosin-tail extension length, X. Finally, the total force exerted by the attached filament tails can be computed as

$$F(t) = \int_{-X}^{X} \mathcal{E}(x)n(x,t)dx,$$

in which $\mathcal{E}(x)$ represents the elastic force due to a myosin tail elongated a length x. In his paper, Huxley assumed this function to be given by $\mathcal{E}(x) = \mathcal{E}_m x$, with $\mathcal{E}_m$ the tail elastic modulus. Solving these equations by employing the method of characteristics, Huxley was able to reproduce the celebrated force-velocity curves (experimentally obtained by A. V. Hill) with a proper choice of parameter values. Another important success of this model was that it correctly predicted the dependence of longitudinal stiffness on the speed of shortening, which had not previously been measured. Huxley himself was aware of his model's incompleteness; however, despite all criticisms, its influence in the evolution of cross-bridge theories has been paramount: practically all current theories qualitatively share the central features of Huxley's model.

Lincoln E. Ford

Personal Remembrances

I was a somewhat disinterested student until my first course in physiology in medical school. What I learned was that physiologists were positing theories of how things worked and conducting experiments to test their theories. I became especially fascinated with the nerve work of Hodgkin and Huxley. In my day it was almost a certainty that all medical graduates would be drafted, so, to indulge my interest in research, I applied to go to the NIH as a commissioned officer to fulfill my National Service obligation. While there I worked with Richard Podolsky, and from the NIH I went to the Peter Bent Brigham Hospital, where I learned that there was a great deal of useless research being done. Wanting to be a better researcher, I asked Podolsky if he would recommend me to Andrew Huxley, which he very kindly did. It was a terrific experience. Andrew had peculiar work habits that meshed very well with my own. He lived in Cambridge and came up to London for the middle three days of every week. We usually ate supper together two nights per week and then worked until 11 o'clock or sometimes later.

At a personal level, Andrew Huxley was kind and sympathetic, particularly to younger scientists, but he had a reputation for being ferocious. This arose, in large part, from his overcommitment. He only rarely turned down a request for help or to be on a committee, with the result of being chronically short of time. There is a class of person who joins committees for the pleasure of dominating the discussion, frequently with specious arguments. He almost always spoiled their fun with irrefutable logic that decimated their arguments and greatly shortened the discussion.

Of all the very intelligent things he did in his life, by far the smartest was his asking Richenda to marry him. She once told me that what she

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regarded as her primary role was to provide a secure home life for Andrew and their six children so that he could get on with his work without other worries, and she did this admirably.

Clara Franzini-Armstrong

Clay M. Armstrong and I were postdocs with Sir Andrew at University College London in the sixties. The imposing atmosphere of University College's physiology and biophysics departments, with their tradition of muscle/nerve research (A. V. Hill, B. Katz), the gloomy, old-fashioned laboratories, and the ceremony of afternoon tea in the library were a part of the experience. Most important was the interaction with Sir Andrew. Despite his encouraging gentleness, I was awed. His accomplishments had established him as an innovative and rigorous scientist, and it was quite clear that his mind was always immersed in meaningful thoughts. We claimed that we could hear the gears moving in his mind while he was performing mental computations.

Clay and I have been deeply influenced by A. F. Huxley's work. Two cherished lessons from Sir Andrew were honesty in publication and the fact that motherhood and science are not inconsistent. Even though he had suggested my postdoc project and guided me through it, Sir Andrew did not coauthor the final paper, because he had not directly contributed to the actual performance of the work. I have tried to follow that precept throughout my life. The arrival of my first child in the middle of my postdoc period did not disturb him; he just gave me a generous period for recovery and kept my position open. I went on to have three more children and to enjoy a life in science. I owe that to his encouragement.

Saul Winegrad

I first met Sir Andrew Huxley when I was a postdoctoral fellow working at NIH. I became rather enthusiastic during my presentation to him, when he listened attentively for several minutes and then said, "You needn't take credit because nature is so clever." I thought, "Boy, did I blow this one." At the end of the discussion Professor Huxley said that it was important to "treasure your exceptions," and he then invited me to pursue my research in London where I also met and married my wife, Dilys.

Picture of Andrew Huxley taken by Saul Winegrad on the occasion of Huxley's 90th birthday celebration. Courtesy of Saul Winegrad.

The years that followed were filled with deepening friendship and memorable experiences, some of which stand out. During one of our early visits to the Huxleys at Cambridge, Andrew was particularly interested in showing Dilys and me the Fellows Room at Trinity College, Cambridge University. Restrictions would not allow Dilys to enter, but Andrew wanted both of us to see it. He went ahead to reconnoiter, looking around corners and along corridors. He then signaled for us to come, and so we did. Andrew was more chuffed than we at having successfully broken tradition. We then followed tradition and dined with him at high table at Trinity, followed by Stilton cheese, claret, and superb port at the Masters Lodge.

Andrew once said to me, as he was reviewing a thesis in which the author had praised the multidisciplinary approach, that multidiscipline is fine, especially when all of the disciplines are present in the same person. I shall miss him for his warm friendship, his ability and willingness to bring his powerful intellect to problems outside his own major interest, and his intellectual honesty and integrity. I shall miss him and all of these admirable characteristics present in one person.

J. Walter Woodbury

In late July 1961 I spent an afternoon at University College London with Andrew Huxley. Knowing Huxley's penchant for mathematics, I summarized some research from my lab showing that current injected into a single cell in a planar sheet of rat atrium spreads to adjacent cells and that the steady state current spread was accurately described by the 2-D equivalent of the 1-D cable equation. The solution is a Bessel function of the

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Picture of Andrew Huxley taken by Walter Woodbury in July 1961. Courtesy of J. Walter Woodbury.

second kind with imaginary argument. I mentioned in passing that I hadn't worked out the solution of the 3-D cable equation. He was obviously intrigued, because when I saw him a day or two later at the Physiological Society meetings at Oxford, he had worked out the 3-D solution!

As I prepared to leave, I asked Professor Huxley for permission to take a photograph of him. He readily agreed and carefully composed himself in his office chair. As you can see, the photo turned out very well. He was quiet, unfailingly polite and cordial, the embodiment of the reserved British gentleman. I knew from his papers that he was an enormously talented, insightful, and creative scientist. My overall impression was that behind the reserve there was a highly capable and genuinely caring human being. There is a pleasant glow attached to my memory of the afternoon I spent with Andrew Huxley.

Albert M. Gordon

I was privileged to work with and study under Andrew Huxley as a postdoctoral fellow in his laboratory at University College London (UCL) from December 1960 until June 1962. I had just completed my Ph.D. in solid state physics from Cornell University and was making the transition to physiology and biophysics. The Prof (as we called him) had just moved to UCL as the Jodrell Professor in Physiology and department head. He was now working on muscle, having developed the sliding filament theory of contraction, along with others.

The Prof provided the complete model of what it meant to be a scientist, combining excellence in experimentation, in instrumentation, and in mathematical theory. His experiments were carefully controlled and designed to clearly test important hypotheses. The hypotheses came out of his theoretical studies. The experiments were possible because of his dexterity in dissection combined with his excellence in instrumentation. He showed that it was not sufficient to just have a hypothesis to explain qualitatively the experimental data, but that one needed mathematical models that could explain the experimental observations.

Andrew Huxley was an outstanding scientist, mentor, and friend. I will miss him and the annual Christmas card with his photographs of scenes from his favorite vacations in Scotland and the Lake District.

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Reinhardt Rüdel

To begin with, I must say that I am suffering from a progressive paralysis of the legs, which was not yet evident in the years 1968 to 1970, when I was working as a postdoc in the lab of A. F. Huxley. Prof, as we used to call him confidentially yet respectfully, had a general predilection for competitions. This was well known to us from the annual departmental outings when he was eager to win all games, in particular the tennis tournament, the "yard-of-ale" (his record: 23 s!), and even the harmless musical chairs!

Frank Lehmann-Horn and I organized the 7th International Conference on Neuromuscular Diseases in Munich, 1990. One of our novel ideas was to add the theoretical subjects of physiology, pharmacology, and genetics to the canon of clinical subjects treated at the conference. To convince the skeptical clinicians, we asked Professor Huxley to participate in the conference as a kind of figurehead. Of course we organized a press conference for our star guest. The journalists asked him all kinds of questions about squid neurons and his Nobel Prize, but he could not be diverted from expressing his happiness about his theoretical work having so quickly assumed such importance for the understanding of human diseases. He stressed that this was another example of pure research being a useful forerunner to applied research.

Prof also came to our social event, a Bavarian get-together in one of Munich's most famous beer halls, the *Löwenbräukeller*. Beer is served there only in steins of one liter. Participants in the evening told me afterwards that they were impressed by Professor Huxley's purposeful

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method of mustering the jar before he put it to his mouth with one hand without spilling a drop. On the other hand, they reported that the muscle expert seemed a bit stranded when he had to dissect the enormous grilled *haxen* (calf's leg) that followed. After dinner we engaged in a wheelchair ballet. The dancers wearing reflecting jackets under stroboscopic illumination operated in perfect synchrony, obtaining almost unnoticeably supportive momentum from their partners.

When I drove him to the airport two days later I asked him about his favorite impressions of the conference. Huxley pondered for a moment, and then he replied with the little stutter that was characteristic for him when disclosing an opinion: "Well, I was most impressed by the wheelchair ballet." I considered this as highest appreciation.

Vincenzo Lombardi

My collaboration with Andrew Huxley was fundamental in my scientific education and the most important driving force for my research achievements. My first visit to his laboratory at the University College London took place from October 1979 to July 1980, when he developed the striation follower, the optoelectronic apparatus for investigating the function of molecular motors inside a muscle cell, with still presently unequalled resolution. At that time Andrew was busy most of the day with his duties as president of the Royal Society and often came to the lab only after dinner. He usually spent quite a large part of the night testing and assembling the optical components, checking the performance of the electronic circuits I had built during the day, and planning my work and tests for the following day. Back in Florence I was able to set up my lab thanks to the enthusiasm and generous perseverance of Andrew in involving his coworkers in every single step during the realization of his ideas.

Andrew is rightfully recognized as one of the most prominent scientists of the twentieth century. He was an extraordinarily gifted man of science, but he also possessed other not-so-popular qualities, such as his natural curiosity for any aspect of life, his widespread knowledge of the natural sciences, and his dedication to the education of youngsters.

Andrew was an exceptionally interesting and pleasant person. For instance, during his visit to my country house in Fietri, Chianti, in the summer of 1989, Andrew enjoyed in a special way discovering the variety of butterflies in the yard and astonished everybody by following them and telling the proper scientific name of each species. From my first visit to his lab at University College London in 1980 and until April 2011, we exchanged hundreds of letters that accompanied and supported my life in any sort of event. These letters are my personal legacy and remind me of his role as *Magister vitae*.

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Gabriella Piazzesi

In 1990 I started to collaborate with Professor Huxley after he and Vincenzo Lombardi had moved the laboratory from University College London to the Department of Physiology of the University of Cambridge. As a researcher at the University of Florence, I had the opportunity to spend one month a year in his lab.

During my collaborative visits, several times I had the honor to be invited to join him for dinner at Trinity College or to have supper in his house in Grantchester, where I could enjoy the familiar and warm atmosphere he and his wife, Richenda, extended to me. On the occasions that the data analysis and discussion required us to meet but I was unable to go to Cambridge, he and Richenda came to Florence. Beyond the scientific work, this was a perfect opportunity to reciprocate their hospitality, exploiting the unique Florence environment. A most remarkable quality of Andrew was his ability to freely share with his younger coworkers any aspect of life.

Makoto Endo

I worked under Professor Andrew Huxley from September 1962 to April 1964 at the Department of Physiology, University College London. The results of our work were reported in my name only. Huxley declined to add his name to the report as being the person to suggest this work to me and giving his valuable advice throughout the experiments because, he pointed out, he himself had not carried out the experiments. I adopted this attitude in my later work with postdocs.

Huxley visited Japan several times, the first time being in summer 1965 to attend the Physiological Congress held in Tokyo. He stayed in Tokyo about a month, and toward the end he gave a lecture on his famous work on nerve excitation at Waseda University. While in Japan he became interested in Japanese, about which he knew nothing before coming. After only three weeks he could read both types of Japanese alphabets and even some Chinese characters. He then proposed to give his lecture in Japanese! He was confident enough,

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because he had successfully done a similar thing in Russia despite having no previous knowledge of Russian. People at Waseda University were quite apprehensive but were steamrollered by Huxley's self-confidence.

Huxley gave me the English manuscript of his lecture two days before his lecture, and I translated it into Japanese. With the aid of a Japanese-English dictionary, Huxley checked the Japanese version, commenting that unless he knew what he was talking about, the lecture would be unsuccessful. Having rushed through the translation, I made a mistake: I wrote "Osmotic pressure is low," whereas it should have been "Osmotic pressure is high." Huxley came to me and politely said that this sounded odd but was probably how it should be said in Japanese, allowing me to find my mistake! His lecture at Waseda University was extremely successful. He was even able to insert a joke and make everybody laugh. We were even more amazed, because after returning to England, his Japanese vocabulary further increased!

Jan Lännergren

It is now thirty-nine years since I pushed open the heavy oak door marked "Anatomy" in Gower Street, entering University College London. High ceiling, a smell of wax polish, stairs leading upwards. At the second floor there was the entrance to Andrew Huxley's lab (previously occupied by the legendary muscle physiologist A. V. Hill). Inside there were three people: Bob Simmons, Lincoln Ford, and Andrew Huxley ("Prof"—I soon learned that all called him Prof). He was very kind and very welcoming and presented the other two.

Setting up for the experiments at King's was probably the most exciting and instructive time of my whole stay in London. Prof was present during the whole process, and it was absolutely marvelous to realize how deep his knowledge of optics and other things was. During that time I learned a massive amount of basic optics. Prof was very patient and took ample time to explain things to his humble pupil. He also suggested a course in optics at King's, which I took.

In summary, my one and a half years with Prof, later Sir Andrew F. Huxley, was the most enjoyable and educating period of my scientific life. I am extremely grateful for having had the opportunity to work together with a true scientific giant.

Top: Picture of the mechanical calculator Andrew Huxley used to do the calculations of the propagated action potential. Bottom: Andrew Huxley and Lee D. Peachey. Pictures taken in 2009. Courtesy of Lee Peachey.

Lee D. Peachey

I have many fond memories of Andrew Huxley, going back more than fifty years. I first met him in 1956 while I was a graduate student at the Rockefeller Institute for Medical Research (now Rockefeller University) when he visited for a week to lecture and meet with the students. In June of 1958, I joined Huxley in Cambridge. That first collaboration was the beginning of a long friendship with Andrew and led to several more collaborations. It seemed as if nothing was too big for Andrew to master or too small to be worthy of his full attention. Our relationship also had a personal side. Andrew and Richenda were very good friends to my wife, Helen, and me and opened many doors for us.

During my last visit with Andrew in 2009, I asked about the mechanical calculator that he had used to do the calculations of the propagated action potential. He found it, sat down with it, and

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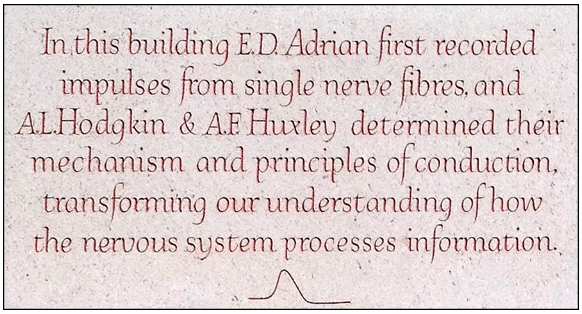

Plaque mounted in July 2012 outside the Department of Physiology, Development and Neuroscience, Cambridge University, to commemorate the sixty-year anniversary of the famous Hodgkin and Huxley 1952 publications. Photograph courtesy of Professor Idan Segev.

became totally engrossed, reminding himself when to turn the crank, when to flip the lever to move the carriage left or right, and so on.

Andrew Huxley's intellectual brilliance and skill as an experimenter, his infectious enthusiasm in all things, and his generosity in sharing his knowledge rubbed off on me and on many others who worked with him, and through us to more generations of physiological scientists. It was very special to have known him for so long and to have gained so much from our friendship and collaborations. He was a very important part of my life.

David R. Trentham

Perhaps of greatest interest to this readership is the impact on mathematics of the Hodgkin-Huxley equations in that they describe an excitable nonlinear system that has a solution in the form of a nonlinear solitary wave. As these waves are different from solitons in conservative nonlinear systems, their discovery made a huge impact in the emerging field of nonlinear dynamics and their applications in biology and engineering [Scott, 1975]. Apart from providing the mathematical basis for the entire fields of neural [Scott, 1975] and cardiac [Noble et al., 2012] modelling, the Hodgkin-Huxley equations became one of the cornerstones in the theory of nonlinear waves (autowaves) in physical, chemical, and biological excitable systems [Krinskiĭ, 1984], [Guckenheimer and Holmes, 1997], [Keener and Sneyd, 2009]. Interestingly, after decades of research, soliton-like behavior was also discovered in the Hodgkin-Huxley equations [Aslanidi and Mornev, 1999].

In July 2012 the Huxley family celebrated the life of Andrew on the grounds of his lovely home in Grantchester, near Cambridge. It was a beautiful summer's day and memorable for the gathering of Huxley, Darwin, Pease, and Wedgwood family members. One could imagine a similar reunion of such names in the same idyllic surroundings a century earlier. The dynastic nature of these families is well embedded in English culture, as is reflected in the ditty below, which appeared in *Punch* [Anon., 1964] following the engagement of Angela Darwin (née Huxley), one of the guests present.

A *DARWIN* is marrying a *HUXLEY*
A fate which no Darwin escapes;
For the Huxleys speak only to Darwins,
And the Darwins speak only to apes.

How Andrew would have enjoyed being at such a gathering!

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AMERICAN MATHEMATICAL SOCIETY

Call for Applications & Nominations

Chief Editor of the *Bulletin*

Applications and nominations are invited for the position of Chief Editor of the *Bulletin of the American Mathematical Society* to commence with the January 2015 issue. The Society seeks an individual with strong mathematical research experience, broad mathematical interests, and a commitment to communicating mathematics to a diverse audience. The applicant must demonstrate excellent editorial judgment and communication skills.

The *Bulletin* publishes expository articles on contemporary mathematical research written in a way that gives insight to mathematicians who may not be experts in the particular topic. Many of the expository articles are invited. The *Bulletin* also publishes reviews of selected books in mathematics and short articles in the Mathematical Perspectives section, both by invitation only.

The *Bulletin* is published quarterly with articles posted individually to the AMS website before appearing in an issue.

The Chief Editor has editorial responsibility for the *Bulletin* within broad guidelines. The Chief Editor is assisted by two boards of associate editors (one for Articles and one for Book Reviews), nominated by the Chief Editor, who help to fashion the contents of the *Bulletin* and solicit material for publication. AMS staff in Providence provide all production support. The Chief Editor will operate from her or his home institution with part-time secretarial support. In order to begin working on the January 2015 issue, some editorial work would begin early in 2014.

Nominations and applications (including curriculum vitae) should be sent by August 30, 2013, to:

Dr. Donald McClure, Executive Director
American Mathematical Society
201 Charles Street
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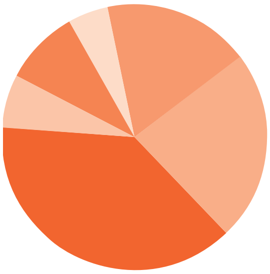
ams@ams.org

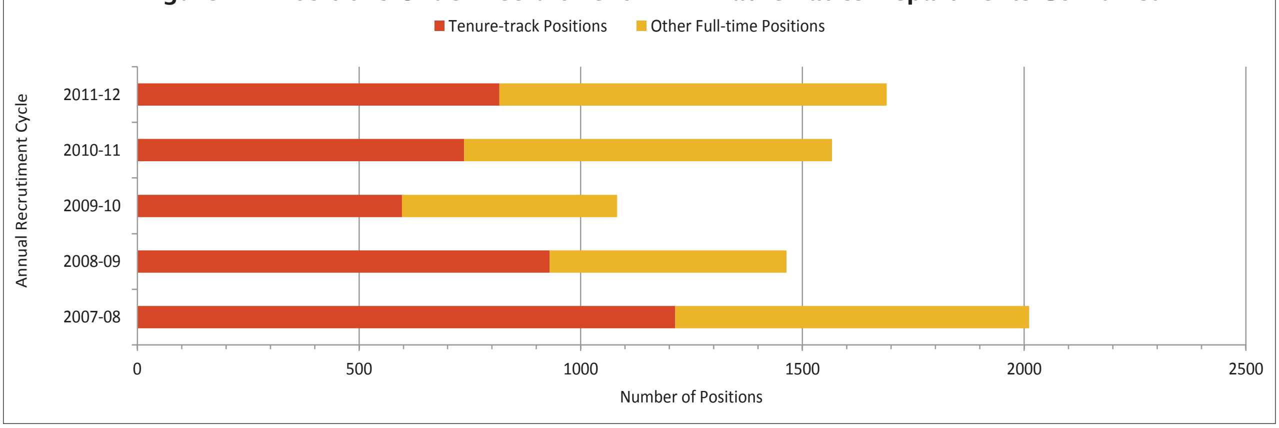


Report on 2011–2012 Academic Recruitment and Hiring

Richard Cleary, James W. Maxwell, and Colleen Rose

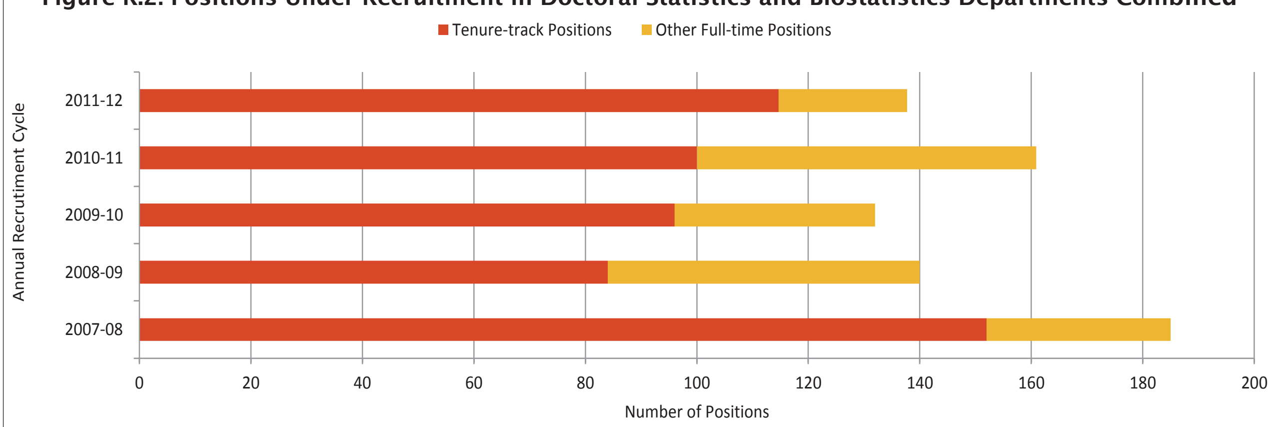
The number of full-time positions under recruitment in mathematics departments increased during the 2011–2012 academic recruitment cycle (for employment beginning in fall 2012.) The total number of positions under recruitment by all mathematics departments combined was 1,693[1]. This number is up 8% from the 2010–2011 total and up 57% from the 2009–2010 total. (Note: Throughout this report, the term tenure-track encompasses positions that come with tenure as well as those which provide the option of earning tenure at some point after appointment.)

Figure R.1: Positions Under Recruitment in All Mathematics Departments Combined



The doctoral statistics and biostatistics departments combined saw a decrease (14%) in the level of recruitment. These groups consist of 93 departments and so constitute a much smaller employment pool than the approximately 1,400 mathematics departments. In 2011 there were approximately 2,081 full-time faculty in the statistics and biostatistics departments combined compared to approximately 22,033 full-time faculty in all mathematics departments combined.

Figure R.2: Positions Under Recruitment in Doctoral Statistics and Biostatistics Departments Combined



[1] *All numbers reported are estimates made to account for non-responding departments. See page 593 for response rates.*

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Positions Under Recruitment

The overall number of positions under recruitment increased for the second consecutive year among the mathematics departments. There was a 15% increase for the doctoral mathematics departments combined, a 14% decrease for the masters mathematics departments group and a 9% increase for the bachelors mathematics departments group. Similarly, the increases in tenure-track positions under recruitment for these same department groupings were 14%, 13%, and 8%, respectively.

Figure R.3: Positions Under Recruitment in All Mathematics Departments by Highest Mathematical Sciences Degree Offered

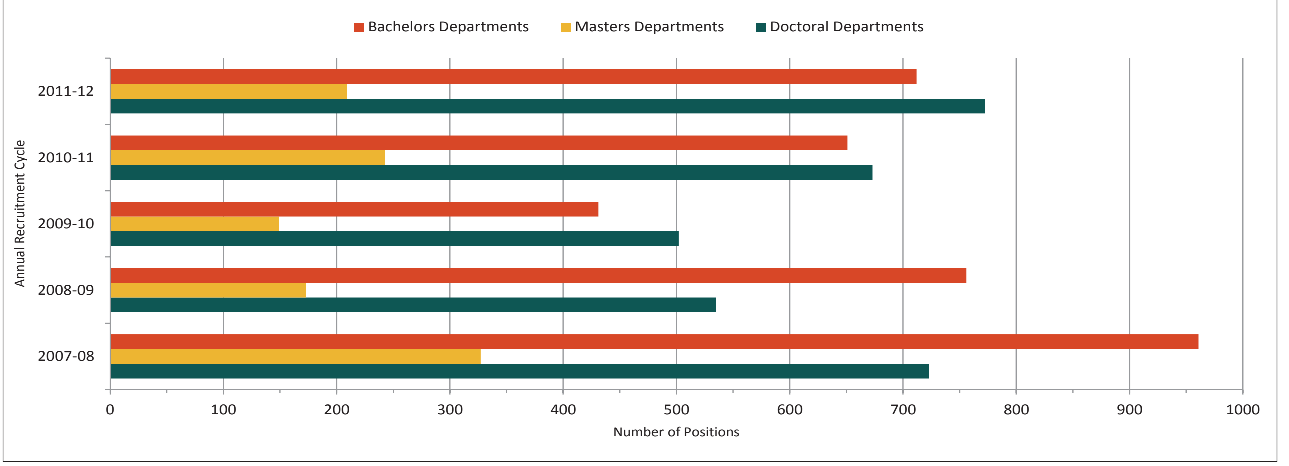
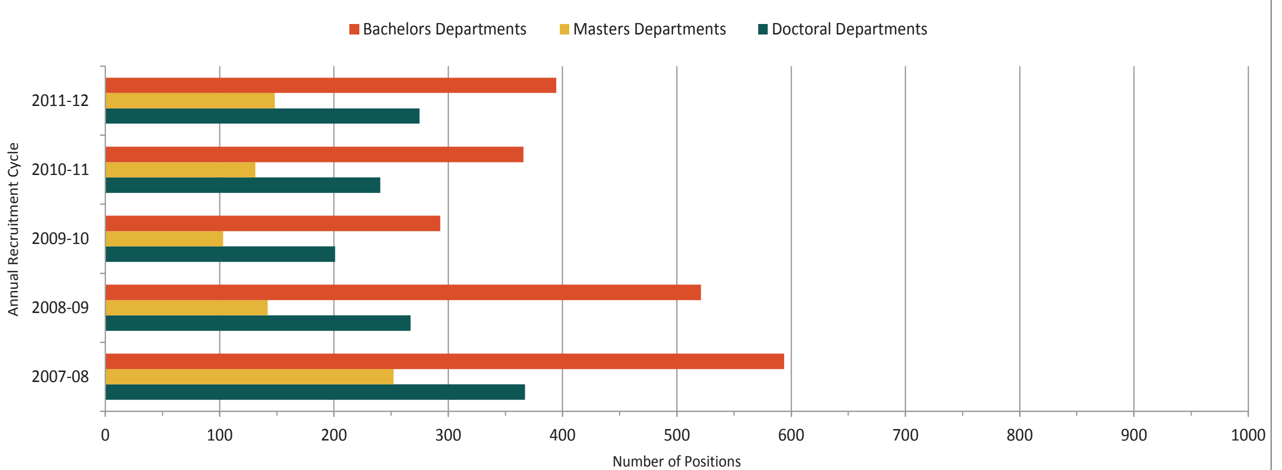


Figure R.4: Tenure-track Positions Under Recruitment in All Mathematics Departments by Highest Mathematical Sciences Degree Offered



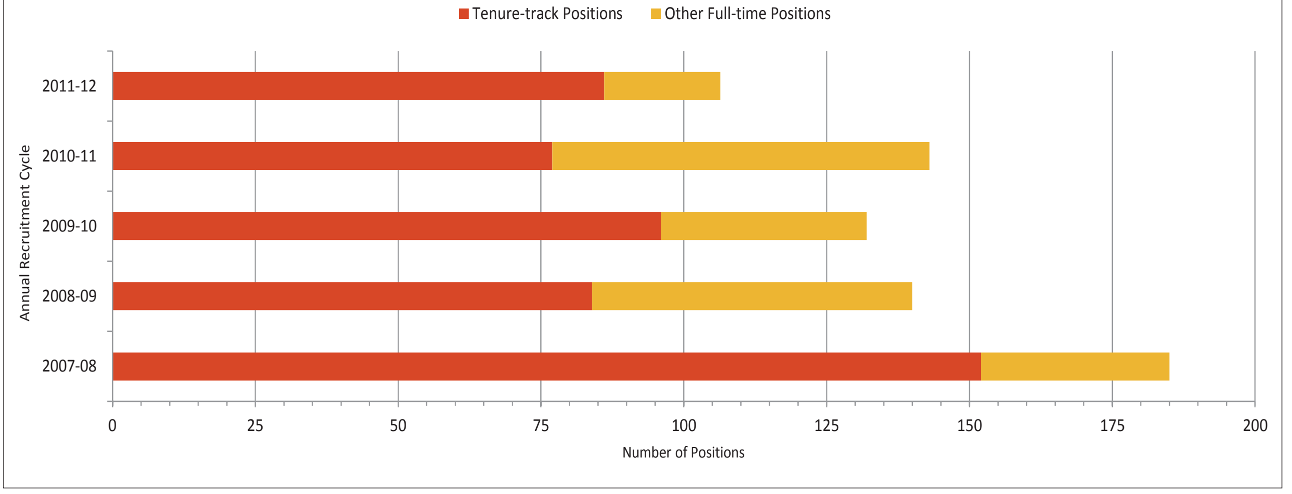
Positions Filled

A total of 1,504 positions were filled during the 2011–2012 academic cycle for employment beginning in fall 2012 by all mathematics departments combined. This total is up 7% from the 2010–2011 total and up 57% from the 2009–2010 total.

Figure F.1: Positions Filled in All Mathematics Departments Combined

The situtation for doctoral statistics departments and biostatistics departments combined was somewhat different, as demonstrated by the accompanying figure. The total of filled positions is down 34% from the 2010-2011 total and down 19% from the 2009-2010 total.

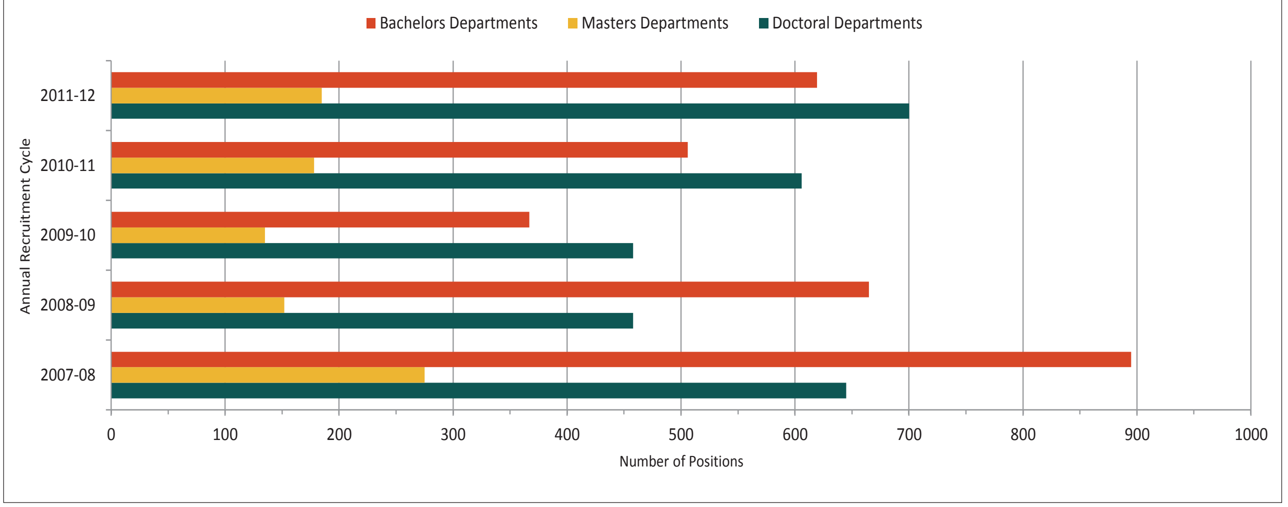
Figure F.2: Positions Filled in Doctoral Statistics & Biostatistics Departments Combined



Positions Filled

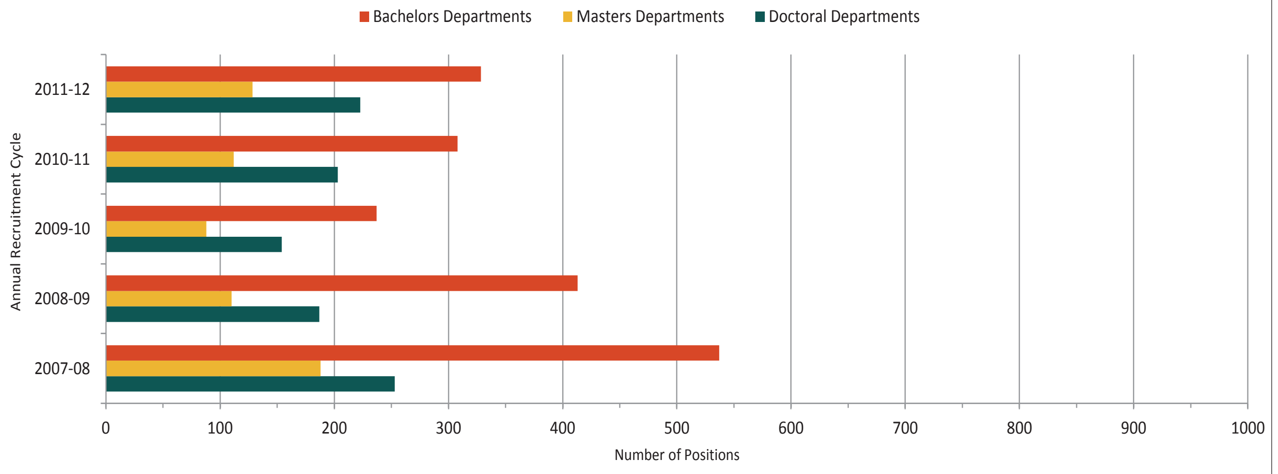
The increase in positions filled for fall 2012 also varied widely among the various reporting groups within all mathematics departments. For the doctoral mathematics departments combined, the number of positions filled was 700, an increase of 16% from the fall 2011 and up 53% from fall 2010 counts. For the masters departments the count was 185, up 4% from fall 2011 and up 37% from the fall 2010 count. For the bachelors departments the count was 619, up 22% from fall 2011 and up 69% from fall 2010.

Figure F.3: Positions Filled in Mathematics Departments by Highest Mathematical Sciences Degree Offered



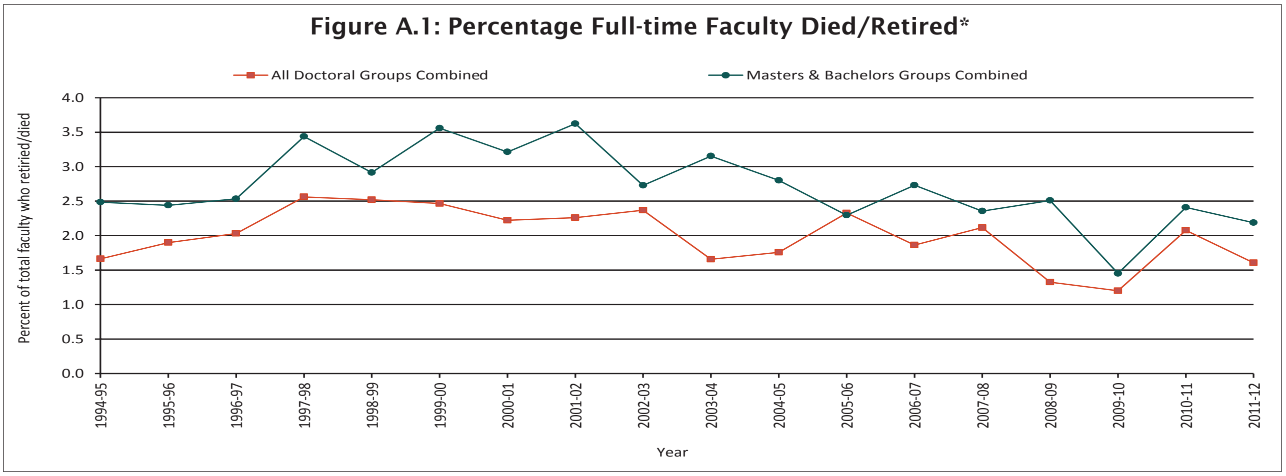
The total tenure-track positions filled during the 2011-2012 recruitment cycle by all mathematics departments combined was 680, up 9% from the 2010–2011 total of 623. This total is up 42% from the 2009–2010 figure of 479 and down 4% from the 2008–2009 total of 710.

Figure F.4: Tenure-track Positions Filled in Mathematics Departments by Highest Mathematical Sciences Degree Offered



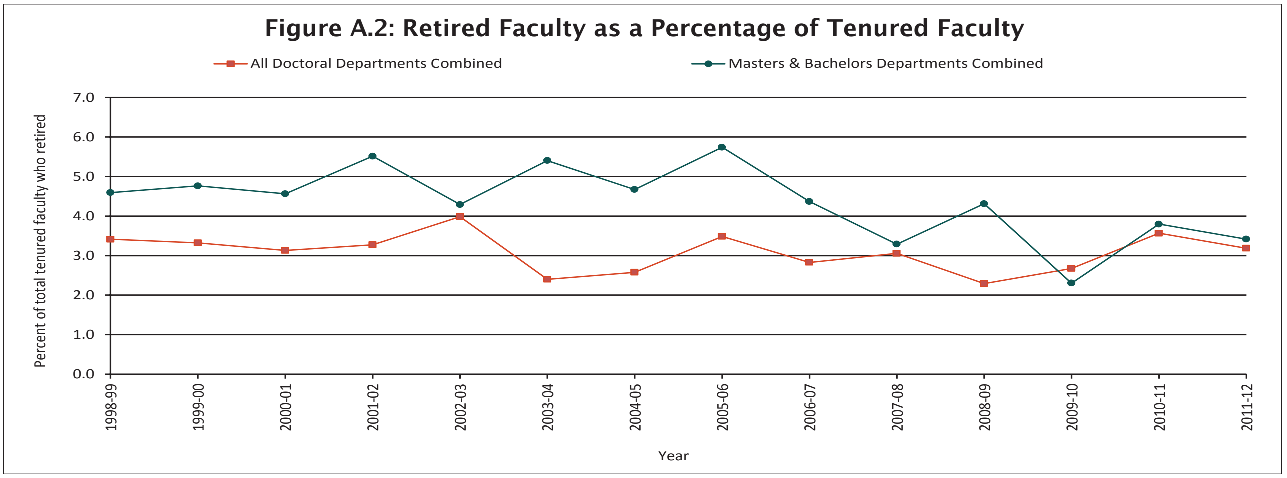
Faculty Attrition

Figure A.1 shows the trends in attrition from deaths and retirements among the full-time faculty for the academic years 1994–1995 through 2011–2012. In the late 1990s attrition leveled off, then began dropping after 2000, reaching the lowest rate of attrition in 2009–2010.



* The percentage of full-time faculty who died or retired is the number of faculty who died or retired at some point during the academic year (September 1 through August 31) divided by the number of full-time faculty at the start of the academic year.

Figure A.2 shows an alternative way of looking at the trends in annual faculty retirements compared to that offered in Figure A.1. It seems highly likely that the vast majority of individuals who are reported by their department as retiring are, in fact, members of the tenured faculty. Given that, it makes sense to look at the ratio of those retiring during an academic year to the total tenured faculty at the start of that year, as is done in A.2. Data collected for the last two years confirms that approximately 90% of those retiring where tenured.



* Each percentage in this figure is the number of full-time faculty that retired at some point during the academic year (September 1 through August 31) divided by the number of full-time tenured faculty at the start of the academic year.

Departmental Groupings and Response Rates

Starting with reports on the 2012 AMS-ASA-IMS-MAA-SIAM Annual Survey of the Mathematical Sciences, the Joint Data Committee has implemented a new method for grouping the doctorate-granting mathematics departments. These departments are first grouped into those at public institutions and those at private institutions. These groups are further subdivided based on the size of their doctoral program as reflected in the average annual number of Ph.D.'s awarded between 2000 and 2010, based on their reports to the Annual Survey during this period. Furthermore, doctorate-granting departments which self-classify their Ph.D. program as being in applied mathematics will join with the other applied mathematics departments previously in Group Va to form their own group. The former Group IV will be divided into two groups, one for departments in statistics and one for departments in biostatistics.

For further details on the change in the doctoral department groupings see the article in the October 2012 issue of *Notices of the AMS* at `http://www.ams.org/notices/201209/rtx120901262p.pdf`.

Math. Public Large consists of departments with the highest annual rate of production of Ph.D.'s, ranging between 7.0 and 24.2 per year.
Math. Public Medium consists of departments with an annual rate of production of Ph.D.'s, ranging between 3.9 and 6.9 per year.
Math. Public Small consists of departments with an annual rate of production of Ph.D.'s of 3.8 or less per year.
Math. Private Large consists of departments with an annual rate of production of Ph.D.'s, ranging between 3.9 and 19.8 per year.
Math. Private Small consists of departments with an annual rate of production of Ph.D.'s of 3.8 or less per year.
Applied Mathematics consists of doctoral degree granting applied mathematics departments.
Statistics consists of doctoral degree granting statistics departments.
Biostatistics consists of doctoral granting biostatistics departments.
Group M contains U.S. departments granting a master's degree as the highest graduate degree.
Group B contains U.S. departments granting a baccalaureate degree only.

Listings of the actual departments which compose these groups are available on the AMS website at `www.ams.org/annual-survey/groups`.

Survey Response Rates by New Groupings

Faculty Recruitment & Hiring Response Rates

Group*	Received (%)
Math. Public Large	17 of 26 with 17 recruiting (65%)
Math. Public Medium	28 of 40 with 26 recruiting (70%)
Math. Public Small	37 of 64 with 28 recruiting (59%)
Math. Private Large	13 of 24 with 13 recruiting (54%)
Math. Private Small	18 of 28 with 14 recruiting (64%)
Applied Math.	14 of 24 with 12 recruiting (58%)
Statistics	24 of 59 with 16 recruiting (41%)
Biostatistics	13 of 36 with 11 recruiting (36%)
Masters	86 of 179 with 47 recruiting (48%)
Bachelors	392 of 1010 with 161 recruiting (39%)
Total	642 of 1496 with 345 recruiting (43%)

* Doctoral programs that do not formally "house" faculty and their salaries are excluded from this survey.

Other Information

The interested reader may view additional details on the results of this survey and prior year trends by visiting the AMS website at `www.ams.org/annual-survey`. Survey results for the doctoral departments in statistics and biostatistics are available there.

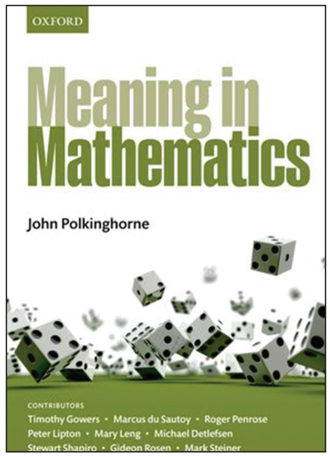
Acknowledgements

The Annual Survey attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the Data Committee and the Annual Survey Staff, we thank the many secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

Deep Questions on the Nature of Mathematics

Reviewed by Michael Heller

Meaning in Mathematics
Edited by John Polkinghorne
Oxford University Press, 2011
US$34.95 , pp. xii+159
ISBN-13: 978-0199605057



"Is mathematics a highly sophisticated intellectual game in which the adepts display their skill by tackling invented problems, or are mathematicians engaged in acts of discovery as they explore an independent realm of mathematical reality?" (p. 1). This is a question that has been asked many times and in manifold ways. This particular formulation is by John Polkinghorne, the editor of the volume under review. Two mathematicians (Timothy Gowers and Marcus du Sautoy), two mathematical physicists (Roger Penrose and John Polkinghorne), and six philosophers (Michael Detlefsen, Mary Leng, Peter Lipton, Gideon Rosen, Stewart Shapiro, and Mark Steiner) convened in Castel Gandolfo and in Cambridge (there is no mention when) to discuss the issue. The mathematicians spoke mainly about their experiences in doing mathematics, while both mathematical physicists argued strongly for discovering the "independent realm of mathematical reality," and the philosophers preferred to immerse themselves in sophisticated analyses and doctrinal subtleties. The question itself belongs to the category of questions that have never led to definite answers, but the very fact that they are asked so often has a certain metaphysical significance. It is well captured by John Polkinghorne (notably also in the form of a question): "The status of mathematics bears upon an answer to the fundamental metaphysical question, 'What are the dimensions of reality?' Do they extend beyond the frontiers of a domain that is capable of being fully described simply in terms of exchanges of energy between material constituents, located within the arena of space-time?… Or, on the contrary, is it the case that true ontological adequacy requires that much more be said than physicalism can articulate?" (p. 27). The problem, when formulated in this way, opens up a vast array of subquestions and their ramifications. Indeed, the book is rich in terms of the breadth of its topics and multilayered nature. I will dwell upon just a few points in order to sample the content of the book.

First of all, what does it mean that mathematical objects exist? Gideon Rosen notices: "Anyone who accepts basic arithmetic must agree that there are two prime numbers between 15 and 20, and hence there are at least two numbers, and hence that there are numbers" (p. 113). But do they exist in the same way as guns and rabbits? The "full-strength realists" give a positive answer to this question (Hardy and Gödel are most often quoted as supporters of this view), whereas the "qualified realists" claim that mathematical objects do exist but "are somehow metaphysically 'second rate'" (p. 114). According to Rosen, a fact is fundamental if it is not grounded in further facts, and a thing is fundamental provided it is a constituent of a fundamental fact. "Then we may identify full-strength realism about mathematics

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with the thesis that some mathematical objects are fundamental things" (p. 124). On the other hand, Rosen defines qualified realism in the following way: "Qualified realism about Fs is the thesis that Fs exist, but no fundamental fact contains an F as a constituent" (p. 125).

But is there really a problem with the existence of mathematical objects? Mary Leng argues that "if accounting for the phenomenology of mathematical discovery requires us to posit any kind of 'reality' to ground our mathematical judgments, this reality is not a realm of mathematical objects, but rather, I claim, a realm of objective facts about logical consequences" (pp. 62–63). This view is consonant with mathematical structuralism, the standpoint according to which there are structures rather than objects that eventually exist in the Platonic realm, and any such structure can be regarded as a network of inferences, objects being only "places at which inferences intersect." Mary Leng substantiates her views by the reference to the "phenomenology of mathematical practice," which places her analysis in the context of discovery and distances her from ontological questions.

A more modest way of asking about the existence of mathematical objects or structures is to inquire as to the extent to which mathematics is objective. But what does "objective" mean? It is certainly not a univocal concept. Stewart Shapiro distinguishes (after Wright) several "notions or axes of objectivity," and "a given chunk of discourse can exhibit some of these and not others" (p. 100). Shapiro focuses on one such axis, which he terms "cognitive command". In his view, a given domain satisfies the criterion of cognitive command if any disagreement in the conclusion follows either from a divergence in the information input or in an error of the inference. This raises the question of the objectivity of logic. "If logic fails to be objective, can there be any objectivity anywhere? … Any attempt to characterize how the question of objectivity is to be adjudicated will presuppose logic" (p. 107). Shapiro hopes that the situation will become "more palatable" if we take into account the Kant-Quine thesis "that there is no way to sharply separate the parts of our best theories that are due to the way the world is and the parts that are due to the way that we, the human cognitive agents, are" (ibid.). It seems that we cannot aspire towards complete objectivity, but some of our compromises do not eliminate objectivity altogether. "In short, mathematics is objective, if anything is" (p. 100), or mathematics "is a paradigm of objectivity, one of the standards by which we measure other discourses" (p. 108).

If mathematical objects or structures exist objectively, the question arises about our "noetic access" to them. The problem was taken up in an extended study by Michael Detlefsen which was intended to shed light on the question of "whether there are features of our acquisition of mathematical knowledge that support a realist attitude towards mathematics" (p. 74). As is well known, the chief proponent of such an attitude was Kurt Gödel, and the study is centered around his views. The core of Gödel's argument was that "propositional contents concerning mathematical concepts are imposed or 'forced' on us as being true in a manner similar to that in which propositional contents are imposed on us by sensory experience" (p. 76). This is best explained "by seeing it as a consequence of a perception-like experience of a realm of beings whose existence and characteristics are independent of our mental acts and dispositions, both individual and generic" (ibid.). This view poses many questions, the most obvious of them being: How reliable is the analogy between the forcedness of mathematical propositions and that of ordinary sensory perceptions? How reliable is this forcedness as an indicator of an independent reality of mathematical objects? Detlefsen subjects these problems to a detailed analysis and discusses both ancient and modern alternatives. Let us jump to his final remarks: "If forcedness is symptomatic for experience, then the mathematical propositions forced on us as true ought to be seen as the experimental part of mathematics. Pursuing Gödel's analogy we would then be led to consider the possibility of an observation/theory divide of mathematics" (p. 94). This is not a conventional view, but it had its predecessors, among others, in the person of Bolzano.

The analogy between the physical world and the world of mathematics is considered by John Polkinghorne. Our encounter with the quantum world has generated discussions between realist, instrumentalist, and positivist interpretations of some problems in the foundations of physics, and, according to him, these discussions have their counterparts in the philosophy of mathematics. Similar arguments could be quoted on behalf of the independent reality of mathematical entities as supporting the realist standpoint in the philosophy of physics. However, in these matters we cannot expect definitive answers: "the character of the conclusions reached will be insightful and persuasive, rather than logically coercive" (p. 29).

In his short essay Roger Penrose summarizes his well-known views on "mathematical Platonism". A new element that he introduces to the discussion (as compared with the other authors in this book) is the problem of the mind as an intermediary between the realm of mathematics and the physical world. He also argues that "the very fact that our minds are capable of comprehending sophisticated mathematical arguments—at least in favourable circumstances —leads us to the conclusion that the operation of conscious minds cannot be entirely computational and, accordingly, that our minds cannot be the product of entirely computational

About the Cover

Parallel transport by Schild's ladder

Reading through the article by Jason Osborne in this issue, we wondered whether there existed an intuitive explanation of parallel transport along an arbitrary path on a Riemannian manifold. Professor Google came up with two.

The first, and simplest, is the one illustrated on the cover. It constructs a series of approximations to parallel vectors by constructing approximate parallelograms along the path, essentially by laying off measuring rods along geodesics in the style of Einstein's popular accounts of relativity. This is a straightforward idea attributed to the physicist A. Schild and explained succinctly in the classic book *Gravitation* by Misner, Thorne, and Wheeler. This scheme is first order in the size of the approximating parallelograms, and is used by these authors to prove, with more or less rigor and more or less clarity, basic properties of covariant differentiation.

The second and more interesting is by means of a modern version of the ancient Chinese machine called the "south-seeking chariot". Unfortunately there are no extant models from old times, but in theory this machine maintains a pointer to a fixed direction no matter what path the chariot follows. The basic principle at work is an ingenious mechanism involving differential gears (among the oldest known) that keeps track of the difference in angle of rotation of the chariot's two wheels. There is a large literature on this device, including much advice on how to build a working model. One good reference, containing a useful bibliography, is "The south-pointing chariot on a surface" by Bernard Linet. It can be found among the physics articles on the `arxiv`.

—*Bill Casselman, Graphics Editor*
(`notices-covers@ams.org`)

physics" (p. 43). Another topic of Penrose's, "getting more out of mathematics than what we put in," is developed by Mark Steiner in a separate essay.

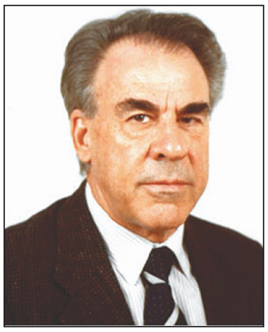
The analogy between mathematics and physics raises the question of explanation in mathematics. It is not enough to know that a given phenomenon occurs; one should also know why. Stewart Shapiro, quoting from the book *Inference to the Best Explanation* by the prematurely deceased Peter Lipton (a participant in the first colloquium), distinguishes three levels of explanation in physics: by scientific laws, by causality, and by referring to unification. It might seem that only "explanation by unification" is applicable to mathematics, but Lipton tries to extend causal explanations to mathematics as well: "The idea is that mathematical propositions stand in some sort of objective dependency relations to each other" (p. 57), and causality, in a broader sense, might be understood in this way.

Indeed, I think that the problem of causality (in a broader sense), by throwing some light on the relationship between mathematics and physics, could possibly contribute to the discussion on the foundations of mathematics. It seems that mathematics and physics are linked together not only by inspirations and applications but also on a much deeper foundational level. Let us suppose that a high-energy physicist detects disintegration of an elementary particle in a cascade of other particles and is happy to conclude that what is observed well agrees with the predictions of a theoretical model. The standard reaction to this effect would be to say that the theoretical model well agrees with a "physical reality". This suggests that we have a "physical reality" and, independently, a mathematical structure, and it just happens that this "reality" is correctly described, up to a good approximation, by this mathematical structure. However, in the eyes of the method of physics, the entire process should be looked upon in a different way. The role of mathematics in physics is not only descriptive but also prescriptive. It is a mathematical structure that determines what we should understand by the elementary particle, its interactions with other elementary particles, and its disintegration channels. When a theoretical physicist computes the behavior of a cascade of elementary particles, he treats equations of quantum field theory as expressing a kind of software of the universe. In this sense, all of the causal powers latent in the physical world come from this software. Does this tell us something about the nature of mathematics itself? I leave this as an open question.

The last paragraph testifies to the fact that *Meaning in Mathematics* is a stimulating book; it provokes the reader to his or her own reflections on the subject. This is why the book is recommended to anyone unafraid of deep questions.

Geraldo Severo de Souza Ávila—A Math Professor

José Cloves Verde Saraiva



Courtesy Rita Ávila.

Geraldo Ávila, 1983.

Geraldo Ávila was born in the rural interior of Brazil in 1933. Struggling to give their children an education, his parents moved the family to São Paulo, where Ávila would graduate in mathematics at the newly founded University of São Paulo. Soon he became assistant professor at the renowned Aeronautical Technology Institute. The Vargas era made great strides in fostering research and Ávila was one of the first talented youths to receive a CNPq grant for the Courant Institute in New York.

In 1957 Ávila married Neuza Ávila, and the couple left for New York. His doctoral dissertation was published in the journal *Communications in Pure and Applied Mathematics* in 1963.

Back home, Ávila was on the faculty and one of the main figures in the math department at the recently inaugurated University of Brasilia. However tense the moment for intellectual leaders, the March 31 revolution having imposed military rule, this first nucleus in Brasília would sow the seeds for important mathematical talents to flourish.

In 1963 Ávila spent three years in Wisconsin before transferring to Georgetown University, where he worked for seven years and was chairman of the math department. In 1972 he returned to Brazil. Among his many achievements in his home country were: expanding the library collection as director of the Science Institute, efficiently managing research programs as dean, advancing the Editorial Committee, and presiding over the Brazilian Mathematical Society. As a member of the Brazilian Science Academy, he diligently saw to the translation and publication of international math classics. His entire agenda set the Sociedade Brasileira de Matemática (SBM) on a fresh new course until 1985.

Courtesy Luís Cláudio.

Geraldo and Neuza Ávila, 2009.

The democratic ideal had gained enough momentum on the political scene by 1985 that extremist demonstrations challenged any post not taken by direct vote. It was in this tense moment of political transition that the Faculty Board appointed its new president. Of the six names on the list, Ávila was by far the favorite among the voting members on the board; he was thus installed in the final days of the administration of General Figueiredo, the last military president before the new administration ushered in the new era of democratically elected presidents.

Despite having taken office, Ávila relinquished his post after two weeks. The new government administration had no interest in supporting a university president who had been appointed during the rule of the military government, especially under pressure from groups that used the transition period as a political springboard. Ávila's name was being wrongly associated with the dictatorship.

Courtesy Rita Ávila.

Geraldo Ávila, 2008.

Ávila spent 1986 in Utah, where he wrote "Asymptotic Wave Function and Energy Distribution in Magnetodynamics", published in the prestigious German journal *J. für die reine und angewandte Mathematik*.

Back in Brazil, he would still have much to accomplish before succumbing to a fourteen-year struggle against lung cancer at age seventy-seven. He would be awarded the Jabuti Prize, finish writing his new book (to be published), re-edit his other books, work as visiting professor at Goiás University, and be selected for the SP Science Academy.

The author wishes to thank Prof. Rita Ávila for personal information and for reviewing the text.

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Bridge Named After the Mathematician Who Discovered the Chinese Remainder Theorem

Xu Wenwen and Yu Ning

Photograph by Cai Tianxin.

The Daogu Bridge, with a stone tablet at the side, was named after the ancient Chinese mathematician Qin Jiushao.

Just as there is a famous bridge built by the great scientist Isaac Newton over the River Cam in Cambridge University called "Mathematical Bridge", the Chinese city of Hangzhou also has its own such bridge, with an even longer history.

The Daogu Bridge is some seven hundred seventy years old and crosses the Xixi River near Zhejiang University's Xixi campus on Xixi Road. The stone bridge's history was known by few modern people, until Cai Tianxin, a mathematics professor from Zhejiang University, uncovered its dust-laden secrets.

According to local historical records, the bridge was built between the years of 1237 and 1241. It was demolished a decade ago during a local building project. However, in 2005 a new stone bridge was built about 100 meters away from the original location over the river, with willow trees swaying on both banks. It is now named Daogu Bridge, as Cai proposed.

"Though the site and bridge are now removed, its history and story remain," says Cai, who contributed to the renaming and attended the renaming ceremony held on the bridge on April 27. Cai says that historical gazetteers reveal that the old Daogu Bridge was named after a mathematician of the Southern Song Dynasty (1127–1279), Qin Jiushao, or spelled Ch'in Chiu-Shao (1208–1261) (Daogu is Qin's courtesy name).

Qin, regarded as one of the greatest mathematicians of the thirteenth century, created the world-renowned Chinese Remainder Theorem, considered the most famous scientific theorem of ancient China. His reputation lies in the Mathematical Treatise in Nine Sections (Shu Shu Jiu Zhang), issued in 1247, which covered matters that ranged from indeterminate analysis to military matters and surveying.

Photograph by Li Jia.

Cai Tianxin and Tang Xiaowei, academician, at the tablet ceremony at the Daogu Bridge.

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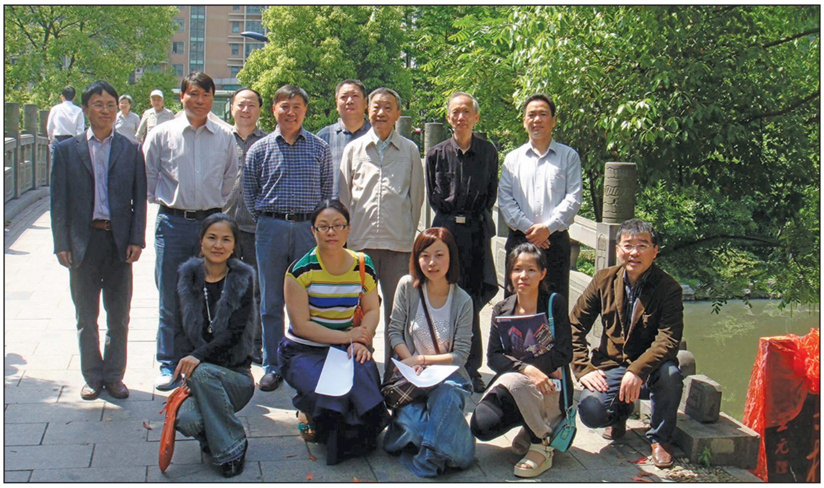

Photograph by Li Jia.

Guests and journalists at the tablet ceremony.

In the treatise, besides the Chinese Remainder Theorem, Qin also included "Qin Jiushao's formula" for finding the area of a triangle with given length of three sides, which is the same as Heron's formula, discovered earlier. No wonder the German mathematical historian M. Cantor praised him as "the luckiest genius," and American scientific historian George Sarton regarded him as one of the greatest scientists of the time.

Qin was born in Sichuan Province, and his ancestry can be traced back to Shandong. In 1219 he settled near the Xixi River in Hangzhou, a city nowadays only forty minutes away from Shanghai by bullet train, which was then known as Lin'an and was the dynastic capital when his father was assigned as an official there. "Hailed as a genius since his boyhood, he not only devoted his life to mathematics but also to many other fields, such as astronomy, engineering, and music, and even held a series of bureaucratic positions in several Chinese provinces," Cai says.

"In 1238, when Qin went back to Hangzhou for his father's funeral, the man found there was no bridge over the Xixi River, a fact which caused inconvenient transportation. As a result, the "Daogu Bridge" was built under his design as well as financial support from the local government. At the beginning the bridge was called Xixi Bridge for its location and was later altered to Daogu Bridge when Zhu Shijie, another famous mathematician from North China, traveled to Hangzhou in the early Yuan Dynasty (1271–1368) and proposed changing Xixi Bridge into Daogu Bridge in honor of Qin Jiushao.

"One reason that the bridge was forgotten and not even named after Qin is that the mathematician, who went into politics, was later, in articles written by two of his political opponents, described as a person who bribed and poisoned someone. However, centuries later in the Qing Dynasty several scholars doubted these claims and tried to rehabilitate him. Today there remains no certain answer to Qin's political merit, and time has cast a shroud over the convoluted story."

A year ago, Cai, who is also a number theorist like Qin as well as an editor of the Hong Kong-based magazine *Mathematical Culture*, and who had lived near the bridge for over eighteen years and recently visited the place, was aware that the bridge is in similar surroundings to those of the original Daogu Bridge, which drove him to the idea of renaming the new bridge with the historic name. With Cai's endeavors and support from local government, a naming ceremony was officially held.

Beside the bridge there is a tablet with the inscription "Daogu Bridge", written by eighty-three-year-old Wang Yuan, a renowned Chinese mathematician, educator, and popular science writer. On the reverse side of the tablet an article tells the historic story.

The site of the bridge is not exactly a scenic attraction, yet the city of Hangzhou is known as a tourist's paradise: the city's West Lake was inscribed on the list of World Heritage Sites, and the Xixi Wetland, which is not far from the bridge, is also a must-visit location.

Galois's First Memoir

Davide Bondoni

I appreciated Harold Edwards's contribution [Edw12, pp. 912–923], in which he explains the text of Galois's first memoir step by step. Edwards assumes our knowledge of Galois's theory as the point of departure and uses our modern tools[1] to clarify his thoughts. I agree with the method of reading the classics from our modern perspective. With good reason, Edwards advises the student to "*Study the masters!*" The problem is that these masters often worked in a social, cultural, scientific, and temporal setting that is very far from our own.

In this situation what is the best way to study the masters? Certainly, the first step is to edit the sources in the best philological way.[2] The second step is to modernize the concepts exhibited in the source. By *modernize* I mean build a bridge between us and the classic text. In the case of Galois, this entails using modern Galois theory, stressing the fact that it was not Galois's creation but rather the result of the work of many mathematicians, each of whom regarded Galois's work from his or her own personal, social, and scientific point of view. Galois theory is a collective work; it is not the genial intuition of Galois alone. As such, it does not make sense to read Galois's memoir assuming it was only his thought.

> The myth of Galois thus belongs neither to the "inside" nor to the "outside" of mathematics. It exists, still today, simultaneously in multiple spaces which may be more or less independent from that of mathematical research; spaces where it takes on different meanings and serves different agendas.[3]

Using the words of Neumann:

> Perhaps the best known myth is that Galois created his theory of groups in the evening and the night before the morning of the duel at the end of May 1832. This myth has its source in the chapter on Galois in [Bel37, pp. 362–377].[4]

For an example of modernizing, when Edwards substitutes *polynomial* for Galois's *equation*, he uses the terminology that is familiar to the 21st-century reader. Also notice what Edwards states in [Edw12, p. 913]:

> …Lemmas 2 and 3 imply a construction of a normal extension of K which is a splitting field of $f(x)$.

The concept of *normal extension* is not Galois's, but its use lets us appreciate the importance of these two lemmas. In the same way, Edwards introduces the modern concept of *automorphism* [Edw12, p. 915]. In [Edw12, p. 916, Figure 1] Edwards writes $\Phi(V)$ instead of ΦV in order to stress that Φ is a function of V. Once more, this is a modern notation.

The point is that reading the masters must develop our knowledge and serve our aims. Using Galois's own vocabulary to explain his thought would be similar to using ancient musical instruments to understand classical compositions. Of course, knowing the possibilities of the instruments lets us comprehend how a score was composed, but whoever plays these instruments is a 21st-century person who cannot ignore his own background. So knowledge of ancient performances could help a modern interpreter, but this person, whether a conductor or a performer, is not a *tabula rasa* on

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[1] *For example, the concept of* splitting field.

[2] *Regarding Galois theory, consider the most valuable efforts of Neumann* [Neu11], *which is a masterwork of precision and inner beauty.*

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[3] [Ehr11, p. 199].

[4] [Neu11, p. 383]. *Bell is amusing for his romantic taste, but indulges too much on a sort of "reveries".*

which the external data collides. He has his own experience, with which he interprets the classics.

It is more or less the same in mathematics. It is impossible to put aside our experience in abstract algebra. What is possible is to use this experience to fill in the gap between our and Galois's time. Trivially, if I write:

$$(a;b)_{ij} = \sum_h a_{ih} b_{hj},^{5}$$

does anyone understand? Is it not better to write:

$$R \circ S = \{< x, z > \mid \exists y (< x, y > \in R \wedge < y, z > \in S)\}?$$

Galois's case is similar; his writing is not clear. He refused to add particulars and sometimes omitted the proofs. This is one of the reasons that he was never accepted into the Academy. So, on the one hand, we have modern Galois theory as expounded in, for example, Artin [Art98], and on the other hand we have the obscure texts of the master. Personally, it is not easy to recover our modern Galois theory from Galois's own work. For this reason, Edwards's article is an example to imitate. He provides a key to understanding Galois's first memoir from our modern point of view by *modernizing* it a little. He has composed a sort of introduction to Galois's first memoir, which enables us to appreciate the master's work while carefully taking into account the temporal distance between us, the modern readers, and Galois.

Finally, Edwards makes the difficulty of an idiosyncratic style clear to us. Bell is right on this issue:

> Liouville then states that the referees at the Academy had rejected Galois' memoirs on account of their obscurity. He continues: "An exaggerated desire for conciseness was the cause of this defect…Clarity is, indeed, all the more necessary when one essays to lead the reader farther from the beaten path and into wilder territory …Too often Galois neglected this precept…[6]

In the same vein,

> Galois' development continued to diverge so widely from the academic course that there was never peace between him and the authorities whose approval he needed.[7]

Galois's idiosyncratic way of learning and writing did not conform to the standards of his time, and his being far from any academic institution did not help mathematicians grasp his work.

Finally, Edwards's advice to read the masters is wise, but the reader cannot be left alone with the masters' works. What I have said for Galois I could say, for example, for Taylor. Who is able to recognize our modern Taylor series at first sight in the corollarium II in [TayXV, p. 23]? Edwards builds a modern bridge that lets us move from our century to Galois's original works. His paper does not present a sharp dichotomy, philology *versus* modernizing, but rather philology as the *servant* of our modern comprehension.

Acknowledgments

I thank dt. Giorgia Boglioli for her precious linguistic revision of a draft of this paper.

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Common Core Offers the Opportunity to Reorder Math Topics to Better Emphasize Their Connections and Applications

Susan Schwartz Wildstrom

I am moved to respond to Sol Garfunkel's "Opinion" article.[1] I am a long-time high school mathematics teacher in a public school. I started teaching around the time of SMSG and have been in the trenches throughout several of the math wars. I know Dr. Garfunkel's fine work in creating interesting modeling projects and his outspoken opinion that using technology to solve problems that apply the mathematics we are teaching will better concretize students' understanding of the underlying mathematics. It sounds like a fine idea, but the reality is often very different.

Our problems in teaching mathematics begin in elementary school. Sadly, many teachers working with our children at the start of their mathematical journeys are not themselves comfortable with the mathematics they are trying to teach. They often only know one way to teach an idea and they may not fully understand how that method works and why it gives the right answers. Such a teacher confronted with an alternate creative method (perhaps suggested by a clever child or a seasoned colleague) may reject the alternative rather than trying to see how and why two methods produce the same result. Beyond stifling the creativity of students and discouraging them from trying to see how the mathematics works, such an approach is not fertile ground for applications and modeling projects in which creative exploration and possibly unorthodox methods are encouraged as a means of truly understanding what is happening. Teachers who lack confidence in their own understanding of the ideas may not want to include these sorts of activities in their classrooms.

As we implement the Common Core State Standards (CCSS) with their emphasis on fewer concepts more deeply taught, we need to ensure that our elementary school teachers are themselves learning and understanding multiple ways to solve individual problems and that they get their hands dirty in the applications and models that can be used alongside the traditional solution methods.

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[1] Sol Garfunkel, *"What's a Math Educator to Do?"*, Notices Amer. Math. Soc. **59** *(2012), 909.*

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Perhaps future preservice math classes will need to include labs that develop concepts from basic principles and contain examples of applications and modeling.

Moving forward, we see that in many algebra classes real-world collections of data are incorporated into some of the problems we use in our classes. A popular exercise involves giving students a collection of ordered pairs from experimental data that represents an unknown but linear relationship. The students' task is to find the best fit line. In many classes this is done by having the students enter the list of ordered pairs into calculators, after which they push a sequence of buttons on the calculator which then produces a linear equation for the line of best fit. They are later similarly taught to use the built-in functions for quadratic, exponential, and logarithmic regressions as well. From my observation of how this is done and taught, students don't really get an understanding of the underlying mathematical principles; they are only interested in getting the right answer, and they just want to be sure that they push the right buttons at the right times. Learning the algorithmic technological approach to solving a problem is a far cry from using modeling for an interesting application to understand mathematics. I am aware that a student in her first algebra class is probably not going to be able to understand the underlying mathematics of the least squares model, but I also do not believe that this is a particularly effective application or modeling exercise, rather something that can be used to answer a question that will appear on a state assessment.

A modeling project or a well-crafted application of a mathematical concept can reinforce understanding the underlying mathematics if it has been clearly taught and the student understands how and why it works. A poorly understood concept will not be clarified by a complex application problem, no matter how interesting or engaging the setting may be.

Dr. Garfunkel fears that CCSS might eliminate a place for modeling and applications. My opinion is completely opposite. Fewer concepts more thoroughly taught at each level would let teachers spend more time on each idea, and that could leave more time to bring in the interesting applications, connections, and extensions that are at the heart of Garfunkel's philosophy. Curriculum implementing CCSS is now being written. What a wonderful opportunity to add in strong, well-crafted examples that will reinforce what children are learning. (A trivial elementary school example might be to bring in population, income, and similar numbers to show students what large numbers look like. This would allow discussion of how to compare their sizes and estimate how large such numbers are without getting lost in the weeds of the values in the units and tens places, emphasis on place value, and how more and more digits to the left indicate larger and larger amounts, etc.)

Another of my own pet peeves (and something that CCSS could endeavor to fix) is the way we talk about making connections among mathematical concepts but in reality often teach them as though each new concept were an idea unrelated to anything students have seen before. A personal favorite is the way many algebra textbooks teach factoring of quadratic polynomials, completing the square to solve quadratic equations, the quadratic formula for solving equations, and graphing of quadratics in four different places in the course. To make matters worse, many teachers do not (when they have already taught one of these topics and are teaching another of them) take the time to connect the material to a topic already learned. So students come to think of mathematics as a set of topics, each one new and unrelated to anything they have done before. Go back to square one and start all over. I wonder how much teaching time is lost in setting the stage for new topics as if they had no connection to something students already know. Anytime we make a clear connection to ideas already learned, we give students a starting point, a set of ideas on which they can build, and a way of seeing how things connect. Using what you already know to solve a more complex problem prepares students for modeling and applications.

Over the course of the forty-plus years that I have been teaching, I have seen many "new" approaches intended to improve the teaching of math. Each probably contributed in some small way to the way I actually teach math in my classroom. But I understand and like math, so I can see how new tactics fit into what I am doing. Someone who is not confident might be unable to adapt and include new ideas in how they teach.

I believe that children begin their schooling excited about learning and eager to engage in the process. Keeping that excitement alive is key to helping students learn and understand mathematics. I hope that, as CCSS is implemented, a high priority will be adapting the way we prepare the teachers who will bring these implementations to the children in our classrooms so that these students can learn to apply the mathematics they are learning to their lives in meaningful ways.

Mostow and Artin Awarded 2013 Wolf Prize

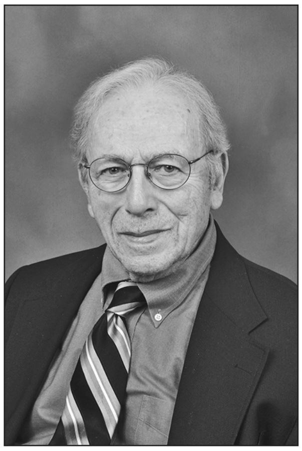

Photo: Michael Marsland/Yale.

George D. Mostow

Photo: Donna Coveney.

Michael Artin

The 2013 Wolf Prize in Mathematics has been awarded to:

George D. Mostow, Yale University, "for his fundamental and pioneering contribution to geometry and Lie group theory."

Michael Artin, Massachusetts Institute of Technology, "for his fundamental contributions to algebraic geometry, both commutative and noncommutative."

The prize of US$100,000 will be divided equally between the prizewinners. The list of previous recipients of the Wolf Prize in Mathematics is available on the website of the Wolf Foundation, `http://www.wolffund.org.il`.

Description of the Prizewinners' Work

The following descriptions of the prizewinners' work were prepared by the Wolf Foundation.

George D. Mostow has made a fundamental and pioneering contribution to geometry and Lie group theory. His most celebrated accomplishment in these fields is the discovery of the completely new rigidity phenomenon in geometry, the Strong Rigidity Theorems. These theorems are some of the greatest achievements in mathematics in the second half of the twentieth century. This established a deep connection between continuous and discrete groups or, equivalently, a remarkable connection between topology and geometry. Mostow's rigidity methods and techniques opened a floodgate of investigations and results in many related areas of mathematics. Mostow's emphasis on the "action at infinity" has been developed by many mathematicians in a variety of directions. It had a huge impact in geometric group theory, in the study of Kleinian groups and of low-dimensional topology, and in work connecting ergodic theory and Lie groups. Mostow's contribution to mathematics is not limited to strong rigidity theorems. His work on Lie groups and their discrete subgroups, which was done during 1948–1965, was very influential. Mostow's work on examples of nonarithmetic lattices in two- and three-dimensional complex hyperbolic spaces (partially in collaboration with P. Deligne) is brilliant and led to many important developments in mathematics. In Mostow's work one finds a stunning display of a variety of mathematical disciplines. Few mathematicians can compete with the breadth, depth, and originality of his works.

Michael Artin is one of the main architects of modern algebraic geometry. His fundamental contributions encompass a bewildering number of areas in this field.

To begin with, the theory of étale cohomology was introduced by Michael Artin jointly with Alexander Grothendieck. Their vision resulted in the creation of one of the essential tools of modern algebraic geometry. Using étale cohomology, Artin showed that the finiteness of the Brauer group of a surface fibered by curves is equivalent to the Birch and Swinnerton-Dyer conjecture for the Jacobian of a general fiber. In a very original paper Artin and Swinnerton-Dyer proved the conjecture for an elliptic $K3$ surface.

He also collaborated with Barry Mazur to define étale homotopy, another important tool in algebraic geometry, and more generally to apply ideas from algebraic geometry to the study of diffeomorphisms of compact manifolds.

We owe to Michael Artin, in large part, also the introduction of algebraic spaces and algebraic stacks. These objects form the correct category in which to perform most algebro-geometrical constructions, and this category is ubiquitous in the theory of moduli and in modern intersection theory. Artin discovered a simple set of conditions for a functor to be represented by an algebraic

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space. His "approximation theorem" and his "existence theorem" are the starting points of the modern study of moduli problems. Artin's contributions to the theory of surface singularities are of fundamental importance. In this theory he introduced several concepts that immediately became seminal to the field, such as the concepts of rational singularity and of fundamental cycles.

In yet another example of the sheer originality of his thinking, Artin broadened his reach to lay rigorous foundations to deformation theory. This is one of the main tools of classical algebraic geometry, which is the basis of the local theory of moduli of algebraic varieties.

Finally, his contribution to noncommutative algebra has been enormous. The entire subject changed after Artin's introduction of algebro-geometrical methods in this field. His characterization of Azumaya algebras in terms of polynomial identities, which is the content of the Artin-Procesi theorem, is one of the cornerstones in noncommutative algebra. The Artin-Stafford theorem, stating that every integral projective curve is commutative, is one of the most important achievements in noncommutative algebraic geometry.

Artin's mathematical accomplishments are astonishing for their depth and their scope. He is one of the great geometers of the twentieth century.

Biographical Sketches

George Mostow received his Ph.D. from Harvard University in 1948. He has served on the faculties of Johns Hopkins University (1952–1961) and Yale University (1961–1999). He is a member of the National Academy of Sciences (elected 1974) and has served as the president of the American Mathematical Society (1987–1988). He was awarded the 1993 Leroy P. Steele Prize for Seminal Contribution to Research for his book *Strong Rigidity of Locally Symmetric Spaces* (1973).

Michael Artin was born in Hamburg, Germany, in 1934, son of mathematician Emil Artin. He received his Ph.D. from Harvard University in 1960. He has been affiliated with the Institut des Hautes Études Scientifiques, as well as with MIT, whose faculty he joined in 1963. He was awarded the Steele Prize for Lifetime Achievement in 2002. In 2005 he received the Harvard Centennial Medal. He served as president of the AMS in 1991–1992. He is a member of the National Academy of Sciences and a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, the Society for Industrial and Applied Mathematics, and the American Mathematical Society.

Israeli President Shimon Peres will present the prizes in May at a special session hosted by the Knesset.

—Elaine Kehoe

Daubechies and Mumford Receive BBVA Foundation Award

Ingrid Daubechies of Duke University and David Mumford of Brown University have been honored with the BBVA Foundation Frontiers of Knowledge Award in the Basic Sciences category for their work in pure mathematics, which, according to the prize citation, has "strongly influenced diverse fields of application, ranging from data compression to pattern recognition." Both researchers have formulated solutions to varied and complex problems starting from the vantage point of pure mathematics but guided by a multidisciplinary approach. The award carries a cash prize of 400,000 euros (approximately US$550,000).

The jury singled out Daubechies, who trained as a physicist, for her work on "wavelets, which resulted in a new approach to data compression, with a strong impact on a multitude of technologies, including efficient audio and video transmission and medical imaging." Mumford's mathematical research has had considerable influence among theoretical physicists. He was recognized particularly for "his contributions to algebraic geometry and to the mathematics of computer vision. He has applied tools of variational calculus to the theory of vision and developed statistical models for imaging and pattern recognition. His work has had a lasting impact in both pure and applied mathematics."

A leader in the field of algebraic geometry, Mumford turned in the 1980s to a new problem: how to mathematically render the human ability to understand an image. One of his insights was that the brain operates by combining previous knowledge with what it is perceiving right now. His

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Duke Photography.

Ingrid Daubechies

Brown University.

David Mumford

mission, now being advanced by his students, is to describe this human ability in mathematical terms.

Daubechies is a theoretical physicist who moved into mathematics because of theoretical physics' urgent need for new mathematical tools and models. Wavelets form a tool that allows the deconstruction of a mathematical object or an image, for example, into simpler components. In practical terms, this deconstruction means that information-rich images can be transmitted with no loss of quality. Daubechies's work on wavelets has one of its best-known applications in the JPEG 2000 image compression standard, but it is also a powerful instrument for testing theorems in basic research in pure mathematics.

Mumford and Daubechies have both served as president of the International Mathematical Union (IMU): Mumford from 1994 to 1998, and Daubechies from 2010 to the present.

Ingrid Daubechies was born in Houthalen, Belgium, in 1954. She received her Ph.D. in theoretical physics in 1980 from Vrije Universiteit Brussel and remained at that institution as a researcher until 1987. She then worked at AT&T Bell Laboratories in New Jersey and joined the faculty of Princeton University in 1993. She has been professor of mathematics at Duke since 2011. She held a MacArthur Foundation Fellowship from 1992 to 1997. She was awarded the Steele Prize for Exposition in 1994, and in that same year gave a plenary lecture at the ICM in Zurich. She was awarded the Ruth Little Satter Prize in 1997. She received the National Academy of Sciences award in 2000, the first woman to be so honored. She was the AMS Gibbs Lecturer in 2005 and the AWM Noether Lecturer in 2006. She was elected to the American Academy of Arts and Sciences in 1993 and to the National Academy of Sciences in 1998.

David Mumford was born in Sussex, United Kingdom, in 1937. He received his Ph.D. from Harvard University in 1961. He taught at Harvard from 1961 to 1997, then joined Brown, from which he retired in 2007. He has held many visiting professorships at such institutions as the University of Tokyo, the Tata Institute of Fundamental Research, the University of Warwick, and the Institut des Hautes Études Scientifiques. He held a MacArthur Foundation Fellowship from 1987 to 1992. He was awarded the Fields Medal in 1974, was cowinner of the 2006 Shaw Prize in Mathematical Sciences, and received the 2007 Steele Prize for Mathematical Exposition.

The BBVA Foundation also awarded a Frontiers of Knowledge Award in the Information and Communication Technologies to Lotfi A. Zadeh of the University of California Berkeley, an electrical engineer whose work involves the mathematical sciences, "for the invention and development of fuzzy logic." This "revolutionary" breakthrough, affirms the jury in its citation, has enabled machines to work with imprecise concepts in the same way humans do and to thus secure more efficient results more aligned with reality.

The BBVA Foundation engages in the promotion of research, advanced training, and the transmission of scientific knowledge to society at large, focusing especially on the analysis of emerging issues in five strategic areas: environment, biomedicine and health, economy and society, basic sciences and technology, and arts and humanities.

—Elaine Kehoe

2013 Mathematics Programs That Make a Difference

Each year, the AMS Committee on the Profession (CoProf) selects outstanding programs to be designated as Mathematics Programs That Make a Difference. For 2013 CoProf selected the Nebraska Conference for Undergraduate Women in Mathematics, an annual event of the Department of Mathematics at the University of Nebraska.

Citation

Be it resolved that the American Mathematical Society and its Committee on the Profession recognize the Nebraska Conference for Undergraduate Women in Mathematics (NCUWM) for its significant efforts to encourage women to continue in the study of mathematics.

The mission of the NCUWM is to encourage undergraduate women to go to graduate school in mathematics and to increase the success of those who do. Participation at the NCUWM links young women to a network of peers that helps them maintain the confidence and motivation needed for success in graduate school. Founded in 1999, the conference has grown from fifty-three participants to two hundred seventy undergraduate women participants. In 2012 there were fifty research talks and thirty-four research posters presented by these undergraduate women. Testimony from alumnae of the conference verifies that the impact of the NCUWM has been life-changing for significant numbers of women. The conference has made a remarkable contribution to the national effort to produce more women Ph.D.'s in the mathematical sciences.

The AMS commends the Nebraska Conference for Undergraduate Women in Mathematics for its high level of commitment and successful efforts to improve diversity in the profession of mathematics in the United States.

About the Program

"It would be no exaggeration to say that [the Nebraska Conference for Undergraduate Women in Mathematics] changed my life." Kalyani Madhu wrote these words in a letter supporting the nomination of the NCUWM to receive the Programs That Make a Difference award. Madhu earned a bachelor's degree in English in 1984. Some years later, while raising her four children, she took calculus at a community college and considered getting a master's degree in mathematics and teaching high school. A professor encouraged her to attend the Nebraska conference, and by the time it was over, "my idea of what I might be able to accomplish had completely changed." Madhu received her Ph.D. in mathematics in 2011 from the University of Rochester, where she is currently an instructor.

Since its founding in 1999, the NCUWM has been a boon for women like Madhu, stimulating their motivation and interest in mathematical sciences research. The conference has touched the lives of more than 2,600 women undergraduates, who come from across the nation to attend the annual event. Participants leave energized and inspired by interactions with other undergraduates, accomplished women graduate students, and prominent women mathematicians. The conference expands horizons by providing information about educational and professional opportunities in the mathematical sciences and by boosting self-confidence and a sense of community.

The growth of the conference has been tremendous. In 1999, forty-three undergraduates attended, with thirty schools represented. In 2013, there were two hundred fifty-seven undergraduates and one hundred seven schools represented. The conference runs midday Friday through midday Sunday and is packed full of activities. As one participant put it in her department newsletter, "[Y]ou should be prepared to be exhausted by the end of it, but … you will definitely learn a lot about what being a math major means to you and what implications that has for your future."

The 2013 NCUWM provides a good example of how the conference works. There were two plenary speakers: Cathy O'Neil, an independent mathematical consultant who spoke on careers outside of academia, and Rekha Thomas of the University of Washington, Seattle, who spoke about optimization. One of the four panel discussions, "Random Bits of Advice", traditionally takes place during the banquet on the first evening of the conference and has an entertaining format designed to remove barriers of formality between the students and the role models. Another panel focused on choosing a graduate program and featured six women graduate students from six different schools. As with previous conferences, this year's had multiple role models from outside academia, including one from the National Security Agency (NSA). Several hours were devoted to the more than ninety talks and poster presentations by undergraduates. At

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the Saturday pizza dinner, one plenary speaker, panelist, or invited graduate student was assigned to each table, and participants could sit with the role model they wished to talk to.

Because the conference draws together women at a variety of educational and career stages, there is a good deal of "vertical integration" of mentoring. The younger undergraduates are inspired by the older ones who give talks and present posters, who are in turn inspired by the graduate students. Students at all levels have the opportunity to observe and interact with experienced and successful women mathematicians. Seeing themselves in these mentors is enormously empowering for the students. "Never before had I realized the community I was a part of as a woman in math, the magnitude of the field, or the boundless opportunities available to me now and in the future," one participant wrote in her department newsletter. "The NCUWM was … inspiring and invigorating."

Tracking the educational and career paths of all NCUWM participants is not feasible, but the students' nearly uniform enthusiasm and other anecdotal evidence show the positive impact of the conference. Sue Geller of Texas A&M University has been bringing students to the conference since 2000. In a letter in support of the nomination for the Programs That Make a Difference award, she wrote: "Out of the more than fifty students I have taken, only one switched into pre-med; the rest graduated as mathematics majors and most went on to graduate school in mathematics, either directly or after a few years working." Undergraduate participants often return to the conference as invited graduate students or panelists, and invited graduate students often return as panelists.

Some years back, it was almost unheard of for mathematics departments to provide support for undergraduates to attend conferences. Many departments do so today, and the NCUWM contributed to this change: For many departments, sending students to NCUWM marked the first time they sent undergraduates to any conference. The frequent—and glowing—reports about the NCUWM in mathematics department newsletters show that the conference has become a highly valued and much-anticipated event for departments across the nation. Registration fills up soon after opening in October each year.

Sponsored by the Department of Mathematics at the University of Nebraska–Lincoln, the NCUWM fits seamlessly into the department's mission. The department is a national leader in producing female Ph.D.'s in the mathematical sciences and is known for its inclusive atmosphere and nurturing approach. In recognition of this success, the department received the 1998 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring. The NCUWM was established to celebrate this award, and funds from the award were used to leverage university support for the first few conferences. Since then, the conferences have been fully supported by the National Science Foundation and the NSA.

In 2009, the Nebraska department received yet another honor, the AMS Award for an Exemplary Program or Achievement in a Mathematics Department. That award recognized the department's overall success in creating a supportive and welcoming atmosphere and in integrating research, teaching, and outreach. The present award to the NCUWM shines a spotlight on one of the department's most outstanding programs.

Kalyani Madhu posed the question, "Why did three days in Nebraska have such an impact?" The main reason, she noted, is that the conference was fun—it was fun to hear the talks, fun to meet other moms like her, fun to beat an eminent topologist at the game of Set. "Under all the fun, however, there was a sense of purpose that eliminated any frivolity… The contribution that the NCUWM makes to the advancement of the participation of women in higher mathematics is a powerful one."

About the Award

CoProf created the Mathematics Programs That Make a Difference designation in 2005 as a way to bring recognition to outstanding programs that successfully address the issue of underrepresented groups in mathematics. Each year CoProf identifies one or two exemplary programs that:

1. aim to bring more individuals from underrepresented minority backgrounds into some portion of the pipeline beginning at the undergraduate level and leading to an advanced degree in mathematics or retain them in the pipeline;
2. have achieved documentable success in doing so; and
3. are replicable models.

Previously designated Mathematics Programs That Make a Difference are: the graduate program at the University of Iowa and the Summer Institute in Mathematics for Undergraduates/Research Experience for Undergraduates at Universidad de Puerto Rico, Humacao (2006); Enhancing Diversity in Graduate Education (EDGE) and the Mathematical Theoretical Biology Institute (2007); the Mathematics Summer Program in Research and Learning (Math SPIRAL) at the University of Maryland and the Summer Undergraduate Mathematical Science Research Institute at Miami University (Ohio) (2008); the Department of Statistics at North Carolina State University and the Department of Mathematics at the University of Mississippi (2009); the Department of Computational and Applied Mathematics at Rice University and the Summer Program in Quantitative Sciences, Harvard School of Public Health (2010); the Center for Women in Mathematics at Smith College and the Department of Mathematics at North Carolina State University (2011); and the Mathematical Sciences Research Institute (2012).

2013 Award for an Exemplary Program or Achievement in a Mathematics Department

The recipient of the 2013 Award for an Exemplary Program or Achievement in a Mathematics Department is the Department of Mathematics at the University of Texas at Arlington. What follows is the selection committee's citation.

Citation

The American Mathematical Society is pleased to recognize the Department of Mathematics at the University of Texas at Arlington with the 2013 Award for an Exemplary Program or Achievement by a Mathematics Department. The mathematics department at UT-A has made a concerted and highly successful effort over the last decade to build a doctoral program whose composition reflects the demographics of our increasingly diverse nation. During the period 2005–2010 the department more than doubled its number of full-time, funded doctoral students and substantially increased its percentage of U.S. citizens and permanent residents, women and minorities (see table below).

During this period, the department granted the doctoral degree to twenty-six students of whom fifteen were U.S. citizens, seven were underrepresented minorities and eight were women. By making this transformation, the mathematics department at UT-A joined a handful of mathematics departments, all of them in regions quite remote from Texas, who have had similar success in building diverse doctoral programs. Thus, in addition to contributing significantly to the national effort to increase the number of doctoral degrees in mathematics awarded to U.S. citizens and, especially to U.S. women and students from backgrounds traditionally underrepresented in mathematics, the department at UT-A has also played an increasingly important role in carrying out this effort in its region. Indeed, departmental faculty are helping to organize a regional Gulf States Alliance that will work with the National Alliance for Doctoral Studies in the Mathematical Sciences to ensure that every student in the Gulf States region who has the desire and the talent to earn a doctoral degree in mathematics will have the opportunity to do so.

The success of the mathematics department at UT-A in transforming its doctoral program may be attributed to several factors, all of which should be replicable at departments with similar missions and demographics. Perhaps the most important of these factors is broad support and participation by faculty. For example, during the last three years, ninety-seven percent of departmental faculty either supervised a graduate student or served as a PI or co-PI on a doctoral student training grant. This broad faculty support has enabled the department to put in place a highly successful mentoring program as well as a strong professional development program. A second factor is the department's success in locating funding for its efforts. It has worked closely with UT-A administrators who have supported the department's efforts and it has also received more than four million dollars from competitive external doctoral fellowship grants.

The purpose of the Award for an Exemplary Program or Achievement by a Mathematics Department is to recognize a department that has distinguished itself by undertaking an unusual

Year	Doctoral Students (total)	U.S. Citizens or Permanent Residents	Women	Underrepresented Minority Students
2005	23	9	5	1
2010	52	29	20	8

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or particularly effective program of value to the mathematics community, internally or in relation to the rest of society.

In building and sustaining a first-rate, diverse doctoral program, the mathematics department at the University of Texas at Arlington certainly meets this criterion. In addition, the department has become a national and a regional leader in the effort to increase the number of American students of all backgrounds who earn a doctoral degree in mathematics. It is for these reasons that this department is so deserving of this award.

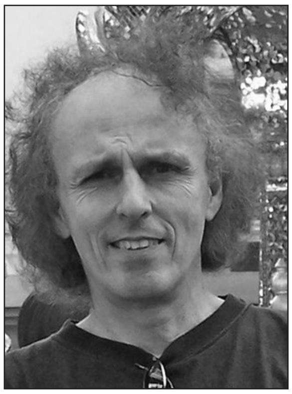
About the Award

The Award for an Exemplary Program or Achievement in a Mathematics Department was established by the AMS Council in 2004 and was given for the first time in 2006. The purpose is to recognize a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of society. Departments of mathematical sciences in North America that offer at least a bachelor's degree in mathematical sciences are eligible. Through the generous support of an anonymous donor, the award carries a cash prize of US$5,000.

The award is presented by the AMS Council acting on the recommendation of a selection committee. For the 2013 award, the members of the selection committee were: Carlos Castillo-Chavez, Annalisa Crannell, Phil Kutzko (chair), Suzanne Marie Lenhart, and Francis Edward Su.

The previous recipients of the award are Harvey Mudd College (2006), the University of California, Los Angeles (2007), the University of Iowa (2008), the University of Nebraska, Lincoln (2009), North Carolina State University (2010), the Math Center at the University of Arizona (2011), and Bryn Mawr College (2012).

JPBM Communications Award



John Allen Paulos

The 2013 Communications Award of the Joint Policy Board for Mathematics (JPBM) was presented at the Joint Mathematics Meetings in San Diego, California, in January 2013.

The JPBM Communications Award is presented annually to reward and encourage journalists and other communicators who, on a sustained basis, bring mathematical ideas and information to nonmathematical audiences. JPBM represents the American Mathematical Society, the American Statistical Association, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics. The award carries a cash prize of US$1,000.

Previous recipients of the JPBM Communications Award are: James Gleick (1988), Hugh Whitemore (1990), Ivars Peterson (1991), Joel Schneider (1993), Martin Gardner (1994), Gina Kolata (1996), Philip J. Davis (1997), Constance Reid (1998), Ian Stewart (1999), John Lynch and Simon Singh (special award, 1999), Sylvia Nasar (2000), Keith J. Devlin (2001), Claire and Helaman Ferguson (2002), Robert Osserman (2003), Barry Cipra (2005), Roger Penrose (2006), Steven H. Strogatz (2007), Carl Bialik (2008), George Csicsery (2009), Marcus du Sautoy (2010), Nicolas Falacci and Cheryl Heuton (2011), and Dana Mackenzie (2012).

Citation

The 2013 JPBM Communications Award is presented to JOHN ALLEN PAULOS, professor of mathematics at Temple University. Paulos's books, columns, reviews, speeches, and editorials have for more than twenty-five years brought mathematically informed ideas, information, opinion, and humor to a broad nonspecialist audience.

One of Paulos's early books, *Innumeracy: Mathematical Illiteracy and Its Consequences* (Farrar, Strauss, and Giroux, Hill and Wang Division, New York, 1988), was a *New York Times* bestseller for over four months in 1989. *A Mathematician Plays the Stock Market* (Basic Books, New York, 2003) appeared on *BusinessWeek*'s bestseller list in 2003. His many mathematical articles and reviews have appeared in *Scientific American*, *The Guardian, The New York Times, The Nation, The American Scholar*, and the *London Review of Books*, and his "Who's Counting" column on ABCNews.com has been running for more than a decade. He has given talks at countless venues, ranging from the Smithsonian and the National Academy of Sciences to Harvard's Hasty Pudding Club and the *Late Show with David Letterman*.

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Paulos's writings combine real-world stories, forthright opinion, and wide-ranging mathematics to entertain and inform the public, both about timely issues and about how mathematics often can and should underlie public discussion of policy.

Biographical Sketch

John Allen Paulos is a best-selling author, popular public speaker, monthly columnist for ABCNews.com, and contributor to a variety of other publications. Professor of math at Temple University in Philadelphia, he earned his Ph.D. in the subject from the University of Wisconsin-Madison. He is married and has two children, two grandchildren, and a dog named Shmata.

His writings include *Innumeracy* (*New York Times* bestseller for 18 weeks), *A Mathematician Reads the Newspaper* (on Random House's reader compilation of best nonfiction books), *Once Upon a Number* (chosen by the *Los Angeles Times* as one of the best books of 1998), and *A Mathematician Plays the Stock Market* (a brief tenant in 2003 on the *BusinessWeek* bestseller list). He has also written scholarly papers on mathematical logic and related areas, as well as scores of op-ed columns, book reviews, and articles in publications such as *The New York Times, Scientific American, The Wall Street Journal, Forbes, The Nation, Discover, The American Scholar*, and the *London Review of Books*.

The audiences he has addressed range from those in classrooms to members of the Smithsonian, from Harvard's Nieman Fellows to its Hasty Pudding Club, from mathematical associations to stock market forums, and from NASA and the National Academy of Sciences to college gatherings, including the commencement assembly at the University of Wisconsin. Paulos has appeared frequently on radio and television, including a four-part BBC adaptation of *A Mathematician Reads the Newspaper*, and appearances on *NewsHour with Jim Lehrer, 20/20, Larry King Live*, and the *Late Show with David Letterman*. In 2003 he received the American Association for the Advancement of Science award for promoting public understanding of science.

He has also been cited by cultural, business, and political commentators, has an extensive Web presence (including Twitter), and has even been the answer to a *Jeopardy*! question. With these curious credentials, he served for two years on the editorial board of the *Philadelphia Daily News*, where, as with his newspaper book, ABC columns, and stint at the Columbia School of Journalism, he tried to straddle the disparate realms of Pythagoras and Pulitzer.

Response from John Allen Paulos

I'm very honored to receive the JPBM Communications Award, especially given its previous recipients and the fact that communicating mathematics is a significant part of what I do. Like many of you, I was greatly influenced by popular communicators of mathematical ideas when I was young, particularly Martin Gardner and, a bit later, Ernest Nagel on Gödel's proof. They made clear that math wasn't just about algorithms but said something about games, magic tricks, science, math itself (Gödel), and the world. Bertrand Russell was also an early influence, although *Principia Mathematica* and his purely mathematical writings were anything but easily accessible. His philosophical and popular writings, however, primed me both to appreciate what he termed the "austere beauty" of mathematics and to realize that its study did not preclude one from commenting on topical issues and might even give one an oblique perspective on them. Nevertheless, at one time or another as an undergraduate at the University of Wisconsin in Madison, I resolved to major in classics, English, philosophy, physics, and, of course, mathematics. Despite the brief separations and flings with the above disciplines and other topics, I gradually became more deeply enthralled with the power of mathematics and came to see it as a sort of imperialist discipline capable of invading and occupying almost every other domain.

An opportunity to further the invasion came with *Innumeracy*, and I've been doing my best to advance the occupying forces for a long time, writing about the connections between mathematics and humor, philosophy, journalism and a variety of news stories, the stock market, storytelling, and other endeavors.

Much, perhaps too much, has been written about mathematical pedagogy, and I certainly don't wish to add to it here, but there is one under-appreciated motivating factor I would like to mention. Show kids that with mathematics, some facts, and sometimes a bit of psychology they can vanquish blowhards' nonsense, no matter their age or size. For some, at least, this may be a better initial selling point than mixture problems or factoring techniques.

My communicating the charm and relevance of mathematics to a large audience has been an honor in itself, as is—I want to reiterate—recognition of my efforts by the JPBM and the mathematics community generally.

—JPBM announcement

MAA Prizes Awarded in San Diego

At the Joint Mathematics Meetings in San Diego, California, in January 2013, the Mathematical Association of America awarded several prizes.

Gung and Hu Award for Distinguished Service

The Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics is the most prestigious award made by the MAA. It honors distinguished contributions to mathematics and mathematical education, in one particular aspect or many, whether in a short period or over a career.

The 2013 Gung and Hu award was presented to William A. Hawkins Jr. of the University of the District of Columbia and Director, MAA Strengthening Underrepresented Minority Mathematics Achievement (SUMMA), for his work to improve the mathematical education of underrepresented minorities and to increase their representation in the mathematical community. Since 1990 he has directed the SUMMA program. In this capacity, he has been a leader in analyzing and interpreting the current status of minorities in mathematics and in calling attention to the need for action. He has also been active in raising funds and organizing programs to bring about change.

Hawkins was one of the cochairs when the MAA Committee on Minority Participation in Mathematics was first established in the late 1980s. In 1990 he resigned from that position and took a leave from the University of the District of Columbia to become director of the then-new MAA program SUMMA. At first the MAA position was salaried through a grant from the Carnegie Corporation, but that funding ran out in the mid-1990s. Bill has continued to work, without pay, approximately half-time, directing the SUMMA program while

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working full time at the University of the District of Columbia. So although Bill is listed on the MAA staff page and works in the MAA office, he has been an unpaid volunteer for many years.

Under his leadership SUMMA has been responsible for bringing more African Americans, Chicanos, Latino Americans, and Native Americans into mathematics at all levels. He has provided sustained efforts to keep them there, from the precollege students who participated in SUMMA-supported intervention projects through the undergraduates who are learning the excitement of research experiences in the National Research Experiences for Undergraduates Program (NREUP) to underrepresented minority Ph.D.'s in mathematics and mathematics education. Their success stories are told in Hawkins's archival record, on up to the chairs of the nation's minority-serving mathematics departments. For these chairs, the annual Minority Chairs Breakfast and Meeting organized by Hawkins at the Joint Mathematics Meetings has become a primary networking event.

Since 1990 SUMMA has raised more than US$4 million in grants for programs and publications to increase minority participation in mathematics. Receiving a grant is just the first step. Hawkins has followed through, leading one successful project after another with the support of the MAA staff. Under Hawkins's guidance, in 1991 SUMMA obtained funding to carry out Middle and High School Intervention Projects. The SUMMA Intervention Projects ultimately provided seed funding, professional support, and a consortium network (SUMMAC) for over one hundred precollege mathematics enhancement programs for underrepresented minority students in forty-two states, Puerto Rico, the District of Columbia, and Canada.

SUMMA's NREUP provides an example of Hawkins's service and leadership in the mathematical community. With a small amount of start-up funding from the National Security Agency (NSA), he designed a project to support underrepresented minority students. He used that funding to give small grants to multiple sites, each having a few underrepresented minority students working together on mathematics-based research projects. In the first year there were three sites with a total of eight students; of those eight, three have entered or completed doctoral programs in the mathematical sciences and two more have done the same with master's programs in mathematics. The program has been expanded with enhanced funding from the NSA, the NSF, and other sources; to date, NREUP has hosted 386 students in eighty-six summer REU projects. Almost as important as the student success stories from these REU projects is the large cadre of project directors who now network at SUMMA panels and activities at the Joint Mathematics Meetings. Some directors have moved from NREUP support to continue their projects with funding from other sources.

Hawkins continues to provide extensive support to the Committee on Minority Participation in Mathematics. He finds topics that need to be discussed, does much of the work in putting together the agenda and getting the special guests there, and follows up on the decisions the committee has made—in brief, he acts as at least a full cochair without that title. He assumes most of the responsibility for the arrangements, agenda, invitations, and rounding up of speakers for the annual Minority Chairs Breakfast and Meeting. Bill also organizes panels, workshops, and other networking activities related to SUMMA efforts at the Joint Mathematics Meetings.

Leveraging collaborations with the Tensor Foundation, the Benjamin Banneker Association, Texas Instruments, and the Sloan Foundation, Hawkins promotes access, equity, and encouragement for traditionally underrepresented mathematicians at all levels. Whether it be supporting precollege intervention projects, providing otherwise unaffordable technology, or making available other resources for success, he has done wonderful work throughout the years and is not bothered by the fact that his efforts often are taken for granted. He works to address issues and needs in the mathematics community without regard to compensation, recognition, or expressions of appreciation.

Hawkins earned his B.S. in mathematics and M.S. in physics from Howard University before earning an M.A. and Ph.D. in mathematics from the University of Michigan. He joined the faculty of what became the University of the District of Columbia (UDC) in 1970 and served as department chair for five years. Taking leave, he worked as the director of the MAA Strengthening Underrepresented Minority Mathematics Achievement (SUMMA) program from 1990 through 1996, when he returned to UDC. He continues to direct SUMMA.

Chauvenet Prize

The Chauvenet Prize recognizes a member or members of the MAA for the writing of an outstanding expository article. First awarded in 1925, the prize is named for William Chauvenet, who was a professor of mathematics at the United States Naval Academy.

The 2013 Chauvenet Prize has been awarded to Robert Ghrist of the University of Pennsylvania for his article "Barcodes: The persistent topology of data", *Bulletin of the American Mathematical Society* **45** (2008), no. 1, 61–75. This article is an intriguing survey of some recent developments in computational algebraic topology that find application in the detection of patterns in large sets of high-dimensional data. The author uses attractive illustrations to introduce the reader to the mathematical concept of persistent homology and to its graphical representation through barcodes. Although the human eye and brain are marvelously adept at recognizing features inherent in a pointillist painting, discovering structure in a cloud of points in three dimensions or in thirty dimensions presents a formidable challenge that demands effective computational tools. A promising idea is to fatten the points into balls and to seek topological information that is stable under variation of the radii of the balls. This idea underlies the new theory of persistent homology, which has been developed by various researchers over the past decade. Barcodes—parametrized versions of Betti numbers—provide a convenient picture of persistent homology. The author's engaging exposition includes a discussion of how persistent homology has been exploited to tease out subtle regularities within a large set of nine-dimensional vectors derived from a database of digital photographs. This survey article reveals modern applied mathematics at its best: sophisticated abstract mathematics in the service of real-world data analysis.

After earning an undergraduate degree in mechanical engineering from the University of Toledo, Robert Ghrist earned a Ph.D. in applied mathematics from Cornell University (1995), writing a thesis on knotted flowlines. In 2008 Ghrist was appointed as the Andrea Mitchell University Professor of Mathematics and Electrical and Systems Engineering at the University of Pennsylvania. Ghrist is the recipient of NSF CAREER (2002) and PECASE (2004) awards for work focusing on topological methods in applied mathematics, with applications including robotics, sensor networks, fluid dynamics, and more. His joint work with Vin de Silva was honored by *Scientific American* (2007) in "SciAm50 Top Research". He is the recipient of several teaching awards and enjoys teaching not only his Penn students but also his four children at home, as well as his tens of thousands of calculus students via Coursera, starting January 2013.

Euler Book Prize

The Euler Book Prize is given to the author(s) of an outstanding book about mathematics. Mathematical monographs at the undergraduate level, histories, biographies, works of mathematical fiction, and anthologies are among the types of books eligible for the prize. The prize was given for the first time in 2007, the three-hundredth anniversary of the birth of Leonhard Euler.

Persi Diaconis (Stanford University) and Ron Graham (University of California San Diego) have been awarded the 2013 Euler Book Prize for *Magical Mathematics: The Mathematical Ideas That Animate Great Magic Tricks* (Princeton University Press, 2011).

This magical book, based on the authors' lifelong passion for magic and mathematics, presents a selection of entertaining tricks that are easy to perform and yet have interesting mathematics inside them. The tricks are surprising yet curiously difficult to explain; the mathematics is simple yet fundamental; the explanations are beautifully clear and even elegant. Along the way we are treated to interesting asides about the people and ideas that inspire magical mathematics. Many of the card tricks discussed are mathematically elegant and some are new. Usually a trick is described by its effect, followed by how and why it works and, for many tricks, variations. For some tricks the discussion continues with new mathematics, new tricks, and suggestions for further investigation. The exposition is enlivened by personal anecdotes, some history of the tricks or of outstanding magicians, and digressions to related topics. Martin Gardner and the authors were longtime friends, and nine pages of Chapter 10 include several of Gardner's tricks. The mathematical prerequisites (e.g., permutations, binary arithmetic, modular arithmetic) are gently introduced and accessible to novices. But there's also plenty of substance for mathematicians, who will enjoy interesting applications of basic graph theory, combinatorics, topology, de Bruijn sequences, Penrose tiles, Steiner trees, elementary group theory, and a special shuffle leading to a result known as the Ultimate Gilbreath Principle, with its mysterious connection to the Mandelbrot set. The writing is relaxed and conversational and so casual and unstudied that even the theorems and proofs are irresistible. It's a perfect coffee table book that can be picked up, thumbed through, and sampled at will, with lots of pictures and diagrams to make it tempting. The book perfectly fits the description of the Euler Book Prize, being "exceptionally well written," having "a positive impact on the public's view of mathematics," and presenting "mathematics as it is related to other areas of arts and sciences." Martin Gardner's expository mathematics has been described as "capable of turning innocent youngsters into mathematicians and mathematicians into innocent youngsters." This book is a worthy companion to Gardner's collection and will have the same effect. Diaconis and Graham have made a significant contribution to the literature of expository mathematics.

Persi Diaconis is the Mary Sunseri Professor of Mathematics and Statistics at Stanford University. He works in probability, mathematical statistics, combinatorics, and group theory, with a focus on real-world applications, such as "How many times should a deck of cards be shuffled to mix it?" (work with David Bayer) and "Is coin tossing 'physics' or 'random'?" (work with Susan Holmes and Richard Montgomery). He has been on the faculty of Harvard and Cornell but is most well known from ten years on the road as a traveling magician. An early MacArthur Fellow, Diaconis is a member of the U.S. National Academy of Sciences.

Ron Graham is the Irwin and Joan Jacobs Professor of Computer and Information Sciences and professor of mathematics at the University of California San Diego. He works in a variety of mathematical areas that include combinatorics, number theory, discrete geometry, and theoretical computer science. He spent many years at Bell Labs, during which time he also taught at Princeton University, Stanford University, the California Institute of Technology, the University of California Los Angeles, and Rutgers University. He has served as president of both the American Mathematical Society and the Mathematical Association of America, as well as president of the International Jugglers Association. He is a recipient of the Leroy P. Steele Prize for Lifetime Achievement from the AMS, and he is a member of the U.S. National Academy of Sciences.

Haimo Awards for Teaching

The Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching were established in 1991. These awards honor college or university teachers who have been widely recognized as extraordinarily successful and whose teaching effectiveness has been shown to have had influence beyond their own institutions.

The 2013 Haimo Awards were presented to Matthias Beck (San Francisco State University); Margaret Robinson (Mount Holyoke College); and Francis Su (Harvey Mudd College). The following is taken from their prize citations and biographical information.

Matthias Beck uniquely and excellently combines teaching and research with writing textbooks, mentoring, and outreach to the wider community. Students in his classes at all levels—from classes for prospective elementary school teachers to analytic number theory—are interested and active participants. Beck is an accomplished research mathematician who also knows pedagogy. Colleagues who have observed Beck's classes testify that he is a superb lecturer, one who asks just the right questions to keep the students thinking about the key issues. His presentations appear almost spontaneous, but through Beck's choice of examples and order of development, reveal a master teacher at work.

Beck has received a National Science Foundation (NSF) research grant and was a member of the editorial boards of the *Journal of Number Theory* and of *Expositiones Mathematicae*. Beck is the author of forty-seven published papers, most in prominent journals. Eleven of these papers, which include publications in the *Journal of Combinatorial Theory Series A, Mathematische Annalen*, and *Mathematische Zeitschrift*, have student coauthors. Beck has coauthored two well-reviewed undergraduate textbooks published by Springer: *The Art of Proof: Basic Training for Deeper Mathematics* and *Computing the Continuous Discretely: Integer-Point Enumeration in Polyhedra*. Both books appear on the MAA's Basic Library List; Springer has published the second also in German and Japanese.

Another grant from the NSF supports Beck's work in enhancing the preparation of graduate students, with the goal of increasing the percentage entering Ph.D. programs, particularly among underrepresented minorities. In the first two years of this program, fifteen of the sixteen M.A. students supported were accepted into Ph.D. programs, all but one with funding. One of the students Beck mentored in the program won the award for Best Graduate Presentation in Mathematics at the 2011 SACNAS (Society for the Advancement of Chicanos and Native Americans in Science) national conference. Another such student, currently in graduate school at a major research university, speaks for many in calling Beck "a professor, advisor, and mentor who is both skillful in mathematics and in the ways of life."

Since 2005 Beck has been codirector of the San Francisco Mathematics Circle, an integrated program for public school teachers and their students in grades 6–11. He has involved in the Circle both graduate students in his NSF-sponsored program and also undergraduates in a community service course organized for that purpose. His students collaborate with public school teachers to enrich their students' mathematics experiences. His work in the Circle thus benefits middle school students, high school students, mathematics graduate students, and middle school and high school mathematics teachers.

After studies at the University of Würzburg, the State University of New York (SUNY) Oneonta, and Temple University and postdoctoral positions at SUNY Binghamton, the Mathematical Sciences Research Institute (MSRI), and the Max Planck Institute in Bonn, Matthias Beck arrived at San Francisco State University, where he is currently an associate professor in the mathematics department. His research is situated at the intersection of combinatorics, geometry, and number theory; he is particularly fond of counting integer points in polyhedra and the application of these enumeration functions to various combinatorial and number-theoretic topics and problems. His two books, *Computing the Continuous Discretely* (with Sinai Robins) and *The Art of Proof* (with Ross Geoghegan), hint at the fact that he enjoys mixing research and teaching activities; another sign of the same fact is his track record of mentoring numerous research students and postdocs at the Mathematical Sciences Research Institute–Undergraduate Program (MSRI-UP), San Francisco State, and the University of California Berkeley.

Margaret Robinson is a dedicated professor with a deep passion for mathematics and an incredible understanding of people. She is praised for her energy, joyful and generous spirit, creativity, imagination, patience, and ability to inspire. Her students appreciate her hands-on, animated teaching style and her ability to bring the inquisitive nature of mathematics to life. Her colleagues admire the way in which she is able to inspire students to do "Herculean amounts of work" in order to meet the high standards she sets for her classes. She pushes students to move beyond their comfort zone while providing a supportive and encouraging learning environment. She has a special gift for transforming students into mathematicians. Exhibiting incredible flexibility, Robinson brings her passion for mathematics into every one of her courses—courses that span the introductory and upper levels, as well as the pure, applied, and interdisciplinary. In her twenty-five years at Mount Holyoke, she has taught well over eighteen different courses, including an interdisciplinary introductory course entitled Unity of Science, an intermediate course (developed with a biologist and a physicist) entitled Making Sense of Biological Signals, Introductory Statistics, Design of Experiments and Analysis of Variance, Differential Equations, History of Mathematics, Real Analysis, Complex Analysis, Abstract Algebra, Algebraic Geometry, and Elliptic Curves. Most notably, Robinson's success shines in a course entitled Laboratories in Mathematical Experimentation, a course in which students learn to make conjectures and write their first proofs. Robinson empowers her students to explore and to create their own mathematical ideas while treating her students as less-experienced equals. Her success in guiding majors into mathematical research is extraordinary, and she has shared this success with over thirty-five other undergraduates from across the nation who have participated in the seven Research Experiences for Undergraduate (REU) programs in number theory she has conducted over the past two decades. In 2010 Robinson's success was recognized with the Mount Holyoke College Teaching Award.

Robinson has also had a profound impact on numerous young women nationwide who have been fortunate enough to participate in short courses she has taught through the Summer Math Program (SMP) at Carleton College and the Summer Program for Women and Mathematics at the Institute for Advanced Study (IAS). In 2009 and again in 2011 she taught an intensive four-week course in p-adic analysis for the SMP, and in 2006 she taught a course exploring zeta functions for the IAS program. These young women cite admiration for Robinson's talents and appreciation for the role model she has become for them.

Margaret Robinson received her B.A. from Bowdoin College in 1979 and her Ph.D. from Johns Hopkins University in 1986. Before coming to Mount Holyoke College, she taught for one year at Hampshire College. Her research interests are in number theory, especially p-adic analysis and local zeta functions. She conducted her first summer REU program during the summer of 1992, and in 1997 her department jointly coauthored the book *Laboratories in Mathematical Experimentation: A Bridge to Higher Mathematics* using materials from the course that had already become central to the Mount Holyoke mathematics major. Her experiences working with REU students and teaching the laboratory class have been central to her growth as a teacher of mathematics.

Francis Su is an outstanding teacher who inspires students to discover and explore the fun and excitement of mathematics. In a memorable 2006 James R. C. Leitzel Lecture that served as the basis for a 2010 *American Mathematical Monthly* article, Su describes how he tries to turn students into discoverers, teachers into coadventurers. He accomplishes this laudable goal not only with his own students at Harvey Mudd College but also with middle school students that he regularly visits, with students around the world who read his fun facts and watch his videos on the Internet, and with fellow teachers who read his articles and attend his presentations and workshops. Su teaches a wide repertoire of courses at Harvey Mudd College. Students at all levels praise his enthusiasm and clarity, while colleagues effuse that he maintains very high standards. He has instituted a highly successful program of undergraduate student research that has produced twelve peer-reviewed papers with undergraduate coauthors, with several more in progress. More impressive than the research findings of these projects is the impact that the research experiences have had on students, the vast majority of whom have continued their study of mathematics and credit Su with kindling their love of mathematics and their ability to think mathematically. Su has also been involved with curricular reform at Harvey Mudd College, developing innovative courses for both math majors and general education students. He has also overseen an explosion of interest in the Putnam Exam on his campus.

Outreach to middle school students is another passion and talent of Su's. He has developed and led discovery-based mathematical enrichment lessons for local middle school students and also for Math Path, a summer camp for children aged eleven to fourteen. Participants in these lessons have remarked that Su changed their conception of what mathematics is.

Su's impact has embraced the Internet as a vehicle through which to reach larger groups of students. He developed a habit of starting each of his classes with a mathematical "fun fact" that captured students' interest, and he has produced a website that allows students and teachers around the world to learn about these fun facts. This website receives about one million visits per year.

Moreover, he has recorded videos of real analysis lectures that have become very popular online. Other avenues through which Su popularizes mathematics are his award-winning expository writing and extensive public speaking.

Su is the Benediktsson-Karwa Professor of Mathematics at Harvey Mudd College. He received his B.S. in mathematics from the University of Texas at Austin and his Ph.D. from Harvard University. His research is in geometric combinatorics and applications to the social sciences, and he has coauthored numerous papers with undergraduates. He also has a passion for teaching and popularizing mathematics. From the MAA he received the 2001 Merten M. Hasse Prize for expository writing and the 2004 Henry L. Alder Award for distinguished teaching. He authors the popular "Math Fun Facts" website and iPhone app. His hobbies include songwriting, gardening, and photography, and he is active in multiple ministries of his church. Just like mathematics, these are modes of creative expression that divinely blend structure and freedom, truth and beauty, reflection and action.

Certificates for Meritorious Service

Each year the MAA presents Certificates of Meritorious Service for service at the national level or for service to a section of the MAA. Those honored in 2013 are: Jon L. Johnson (Elmhurst College), Illinois Section; Dan Curtin (Northern Kentucky University), Kentucky Section; Yungchen Cheng (Missouri State University), Missouri Section; Jean Bee Chan (Sonoma State University) and Peter Stanek (President, Global Alliance for Preserving the History of World War II in Asia), Golden Section; Robert Rogers (State University of New York, Fredonia), Seaway Section; Jonathan Kane (University of Wisconsin-Whitewater), Wisconsin Section.

—MAA announcement

AWM Awards Given in San Diego

The Association for Women in Mathematics (AWM) presented several awards at the Joint Mathematics Meetings in San Diego, California, in January 2013.

Schafer Prize

The Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman was established in 1990. The prize is named in honor of Alice T. Schafer, one of the founders of AWM and one of its past presidents. Schafer passed away in September of 2009.

The 2013 Schafer Prize was presented to Murphy Kate Montee of the University of Notre Dame. She is a senior mathematics major and a member of the Notre Dame Seminar for Undergraduate Mathematics Research Program. Montee has consistently excelled in mathematics classes at both the undergraduate and graduate levels and has received numerous merit scholarships rewarding her extraordinary ability and promise. She has participated in multiple undergraduate research projects at Notre Dame and in two summer NSF-REU programs. Her time at the Louisiana State University REU led to a coauthored paper on the recursive behavior of ribbon graph polynomials. The following summer Montee attended the SMALL program at Williams College, where she produced two papers. The first was a single-authored paper "with lots of clever geometric arguments," predicted to appear in a strong mathematics research journal. The second, "Knot projections with a single multi-crossing", is hailed by her advisor as "perhaps the best work I have ever done with students," containing results that will have a significant influence on future knot theory research.

Montee's mentors uniformly praise her motivation and "infectious" enthusiasm for the subject, calling her "one of the most mathematically mature students I have ever known" and "exceptionally gifted". Those who have worked with her expect that she will have many more "impressive results" and an "amazing career" ahead of her, in part because of her uncanny ability to get right at the heart of a problem.

Louise Hay Award

Established in 1991, the Louise Hay Award for Contributions to Mathematics Education recognizes outstanding achievements in any area of mathematics education. Louise Hay was widely recognized for her contributions to mathematical logic and her devotion to students.

The 2013 award was presented to Amy Cohen of Rutgers University in recognition of her contributions to mathematics education throughout an outstanding forty-year career at Rutgers. Like Louise Hay, her career is remarkable for her achievements as a teacher, scholar, administrator, and human being. An elected fellow of the American

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Association for the Advancement of Science, Cohen has won many awards, including the MAA's Distinguished Service Award and a teaching award from her MAA Section.

She is principal investigator for the New Jersey Partnership for Excellence in Middle School Mathematics, an NSF-funded Math and Science Partnership Program. As part of that grant, she led the development of a geometry course for teachers. Earlier curriculum work included new mathematics courses for elementary and high school teachers, the revision of her department's precalculus program, and a course, Introductory Algebra for Returning Adults. She has served as dean of Rutgers' University College, as coprincipal investigator for her department's VIGRE grant, and as a liaison to the School of Education, serving on many education committees.

Cohen has made important contributions to mathematics education through her writing, the many talks she has given, and her service to professional organizations. For the MAA she has been a Project NExT consultant, member of the Committee on the Undergraduate Program in Mathematics, and chair of the committee to select the Leitzel Lecturer. For the AMS she was a member of the Committee on Research in Undergraduate Mathematics Education. She is on the MSRI Education Advisory Committee and was on the organizing committee for two Critical Issues in Mathematics Education workshops. For the American Institute of Mathematics she was a coprincipal investigator and organizer for two workshops on Finding and Keeping Graduate Students in the Mathematical Sciences. For AWM Cohen has served as treasurer, member of the Education Committee, and as an AWM mentor.

M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics

This award is named for M. Gweneth Humphreys (1911–2006). Humphreys graduated with honors in mathematics from the University of British Columbia in 1932, earning the prestigious Governor General's Gold Medal at graduation. After receiving her master's degree from Smith College in 1933, Humphreys earned her Ph.D. at age twenty-three from the University of Chicago in 1935. She taught mathematics to women for her entire career. This award, funded by contributions from her former students and colleagues at Randolph-Macon Woman's College, recognizes her commitment to and her profound influence on undergraduate students of mathematics.

The 2013 award was presented to James Morrow of the University of Washington. The letters of nomination describe him as a superb teacher. Annually, he teaches the year-long Honors Advanced Calculus at UW, in which he teaches students how to approach and enjoy problem solving. He challenges the students with tough problems but also provides motivation and enormous support to get them to discover the solutions. He has an outstanding record of motivating women students to pursue advanced degrees and research careers in the mathematical sciences. He accomplishes this by encouraging his students, by fostering their confidence, and by understanding and anticipating their needs as they follow their interests.

A midcareer shift in Morrow's research program from complex geometry to discrete inverse problems fortuitously extended his already well-established influence on undergraduate women (and men), primarily through the NSF-funded Research Experiences for Undergraduates (REU) he cofounded in 1988 at UW. Often described by the NSF as a model program, it has attracted a stellar group of students in its twenty-four years of existence. Included in this group are nearly thirty women who have gone on to do graduate work in the mathematical sciences, often at top-tier universities.

In support of his nomination, several women expressed sentiments conveyed in these excerpts:

"I am very grateful to Jim Morrow for the course my life has taken over the past several years. He saw potential in my application to his REU way back when I was a junior in college and I had not taken many advanced classes…. Like too many other mathematically talented women, I didn't really think about graduate school as a possibility; no one had suggested it to me…. Thanks to Jim, I did consider it, and now I am a successful student at a very good graduate school."

"I'm pretty sure that if it weren't for Jim, I never would have become a mathematician."

"Jim was the most influential professor in my undergraduate career…. His devotion to his students is unparalleled."

AWM Service Award

Ten women were presented with the inaugural AWM Service Award, which recognizes individuals for helping to promote and support women in mathematics through exceptional voluntary service to the Association for Women in Mathematics. The recipients are Margaret Bayer, University of Kansas; Holly Gaff, Old Dominion University; Rebecca Goldin, George Mason University; Rebecca Herb, University of Maryland, College Park; Victoria Howle, Texas Tech University; Pao-sheng Hsu, independent consultant and researcher; Krystyna Kuperberg, Auburn University; Rachel Kuske, University of British Columbia; Shari Moskow, Drexel University; and Erica Voolich, Somerville Mathematics Fund.

—AWM announcement

UT Arlington Wins AMS Exemplary Program Award

Allyn Jackson

Photos courtesy of UT Arlington Mathematics Department.

Ph.D. student and NSF GK-12 fellow Larrissa Owens helps middle school students, while math professor Minerva Cordero-Epperson looks on. Owens is a 4th year Ph.D. student working on modeling of wound healing. Cordero-Epperson, now Associate Dean of Science, directs the 5-year GK-12 program.

The University of Texas at Arlington is not elite. It's not the flagship campus of its university system—that distinction goes to UT Austin. It's not as well known as some of its neighbors, like Rice University and Texas A&M. It doesn't have huge resources, especially since the economic downturn. It's not an obvious place to find a stand-out mathematics department with a thriving graduate program. And yet that's just what the UT Arlington Department of Mathematics has become.

Over the past several years the department has transformed itself by making the growth and development of its graduate program its top priority. That goal led naturally to improvements in other areas—such as student mentoring, the undergraduate program, and outreach—as the department sought to develop a sufficient pool of well-prepared doctoral students. To support these activities, the department systematically pursued outside funding. As success built upon success, the faculty adopted a common vision of what the department could achieve and created a positive, can-do environment where teaching, research, mentoring, and service are all valued. For this outstanding transformation, the UTA Department of Mathematics has received the AMS Award for an Exemplary Program or Achievement by a Mathematics Department.

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Making the Case for Math

Texas has three so-called "Tier 1" research universities: UT Austin, Rice, and Texas A&M. The state has been aiming to increase the number of Tier 1 institutions, so in 2004, UT Arlington launched an initiative to move up to that level. While there is no precise definition of Tier 1, the term generally refers to institutions with a high level of research, strong graduate programs, and substantial outside funding. UT Arlington set specific targets to work toward Tier 1 status, including producing two hundred Ph.D.'s each year and having annual research expenditures of US$100 million. In 2005, with support from the state legislature, UTA was poised to invest in areas that could help it achieve these goals.

In such initiatives mathematics sometimes looks like a minor player compared to other areas of science and engineering, especially those that appear to have more research cachet and that bring in large grants. Jianping Zhu saw things differently. When he took the position as chair of the UTA mathematics department in 2005, he found a great deal of potential. What attracted him, he said, was the department's excellent reputation and its long-standing doctoral program, which was started more than forty years ago. Zhu knew some successful mathematicians who had gotten their Ph.D.'s at UTA, and he had known a former chair, the late George Fix, who left Carnegie Mellon University in the early 1990s to help build up the UTA department. UTA's expansion plans also made the position attractive for Zhu. He saw that in order to thrive the department had to align its mission with that of the university. "From that point of view, it's actually pretty easy to make the case" for mathematics, Zhu said.

He followed three main principles. First, mathematics is central to the university's teaching and research efforts. All UTA undergraduates are required to take mathematics courses, so how well the department delivers on its teaching responsibilities has a direct impact on the education mission of the university and on student retention and graduation. In addition, mathematics research underpins a broad range of interdisciplinary research in natural sciences, engineering, and social sciences. "To become a Tier 1 research university, UTA must build a strong mathematics department," Zhu said.

Second, mathematics is cost effective. "Mathematicians don't require labs," Zhu said. "They just need pencil, paper, and a computer to do their jobs." He continually made the case to the administration that, compared to laboratory-based sciences, mathematics is much cheaper.

The third principle concerns outside funding. Mathematics research grants usually are not large. "But there are scholarship grants, both at the undergraduate and graduate level, that are quite substantial in size," Zhu said. Putting the focus on that type of grant allowed the department to dovetail two needs: attracting more and better students by offering scholarship and fellowships, and showing the university that mathematics could bring in substantial grant money.

Small College Atmosphere

Zhu left UTA in 2011 to become dean of the College of Graduate Studies at Cleveland State University, and Jianzhong Su took over as chair of the UTA mathematics department. Su has been at UTA for twenty-three years and has a good perspective on how the department has changed. Before 2005, Su said, "we were like every other department—we were all busy with our own research and working with our own students." What really changed the department, he said, was a newfound focus on improving mentoring and support for all graduate students. "We are a large state university of 34,000 students…but we want to create an atmosphere that is more like a small college, where the faculty and students connect," he said. Su was graduate director in 2005 when Tuncay Aktosun joined the UTA faculty. Sharing a strong interest in and dedication to students, the two began organizing student mentoring sessions. Up until then, the main time set aside for students and faculty to interact outside of class was for meetings to advise students about which courses to take. "We found that students need help, especially new students," Zhu noted. "They need advice, and they need encouragement when they run into problems."

Creating a Ph.D. mathematician starts with students of young ages. Theresa Jorgensen, a winner of the University of Texas System Regents' Outstanding Teaching Award and co-PI of the NSF GK-12 program, works with middle school students on the mathematical game of Set during the UT Arlington Math Day.

When it became clear that students were really benefiting from the mentoring sessions, other faculty began to get involved. These sessions have helped the whole department become more close knit, fostering a welcoming atmosphere where students feel supported and problems are addressed early.

When Aktosun started at UTA, the graduate program was doing fairly well. It had twenty to twenty-five students, and in the previous decade had granted an average of three Ph.D.'s per year. But noting the low proportion of domestic students, Aktosun saw untapped potential. He led an effort to apply to the Department of Education program called Graduate Assistance in Areas of National Need, which supports departmental fellowships for graduate students who are U.S. citizens, nationals, or permanent residents. The department succeeded in getting its first GAANN grant, which ran from 2006 to 2010 and totaled US$633,000; a new application brought a second GAANN grant of US$653,000 for 2009–2012. The mathematics department was the first unit on the UTA campus to receive a GAANN grant. Since then several other UTA departments have successfully applied for GAANNs.

The GAANN fellowships prompted the mathematics department to revamp its recruiting methods. "In the old days, we were just waiting for students to apply," Su remarked. "But in the last ten years, we have been doing a lot more to reach out." The department established an annual GAANN Day, during which prospective students visit the department and interact with faculty and graduate students. Also invited are faculty from nearby institutions who might want to send their talented majors to the Ph.D. program at UTA, a tactic that Aktosun called “recruiting the mentors.” Establishing a sense of trust with these mentors is one key to successful recruiting. “Those mentors are like the parents [of the students],” Aktosun said. They want to send their students into a supportive graduate program that values and nurtures students’ talents. Many mentors have come to trust UTA in exactly that way. “We are going to support [the students], and we are going to graduate them,” Aktosun said. “Their potential is going to be used in a maximal way.” The efforts have paid off. In 2010 the department had fifty-two doctoral students, twenty-nine of whom were U.S. citizens or permanent residents, twenty were women, and eight were members of minority groups traditionally underrepresented in mathematics; efforts to increase these numbers have continued.

Much of what the department learned a lot about recruiting came from the National Alliance for Doctoral Studies in the Mathematical Sciences. The alliance aims to maximize educational and research opportunities for talented students from underrepresented groups. The UTA graduate program is now one of twenty-two alliance members that work with about one hundred eighty undergraduate mentors nationwide to ensure that students are placed in programs where they will thrive. As a regional leader in encouraging underrepresented groups in mathematics, the UTA department is now helping to organize a regional Gulf States Alliance that will work with the National Alliance to maximize opportunities for students who live in states around the Gulf of Mexico.

In addition to improving recruitment, the UTA department made a few key changes to better serve its graduate students. One small change made a big difference in the atmosphere: interspersing faculty and graduate student offices, which prompted many to leave their doors open more often and to chat more. The department revised the structure of the preliminary examinations to allow students to take the exams in an order better suited for academic progress. This change made the exam structure more student-friendly while maintaining the quality control the exams provide. There are now review sessions for the preliminary examinations, in which more-advanced graduate students help newer ones to prepare. The department offers many other opportunities for graduate students to act as role models, including through its various outreach programs. As a result, the graduate students feel a real sense of belonging and make substantial contributions to the department’s overall success.

A new component of the graduate program is a professional development course in which graduate students learn basic career “survival skills” such as communicating effectively, both orally and in writing; working in a team setting; and applying for grants. “Part of the reason for the success of the doctoral program is that we provide good professional development, so the students have found good jobs,” Zhu noted. “Our doctoral students find jobs in a variety of professions, from banking to insurance to actuarial science, to government jobs, to tenure-track faculty positions in colleges and universities.”

Success with Outside Funding

In addition to GAANN, the department received from the National Science Foundation (NSF) a five-year GK–12 grant, which supports eight graduate fellows per year. The GK–12 program is a partnership of three groups—university faculty, graduate students, and schoolteachers—that aims to boost school student interest in science, technology, engineering, and mathematics. One GK–12 activity has graduate students explaining their research to the school kids. It’s a big challenge. The graduate students spend a couple of weeks over the summer developing their presentations with the help of their faculty advisors and the schoolteachers. Su recalled the experience of one of his own graduate students, whose research concerned a diffusion equation. There was no point in writing down the equation for the 9th-graders, but maybe he could show them the solution, which is an exponential function? No, said the teacher, exponential functions do not arise until the 11th grade. The student finally came up with a way to explain what a diffusion equation is by likening it to a line of people with buckets passing a quantity of water down the line. “It’s important for mathematics Ph.D. students to have the ability to communicate with society,” Su remarked. “That way, they can make a bigger impact with their research.” Because of the intensive collaboration involved, he noted, the GK–12 program “really bonds the faculty and the students together.”

UTA faculty member Minerva Cordero-Epperson is the principal investigator on the US$2.8 million GK–12 grant; coprincipal investigators have included Aktosun, Su, and Zhu, as well as three other UTA faculty members: James Epperson, Theresa Jorgensen, and Hristo Kojouharov. All have a strong commitment to teaching; Cordero, Epperson, and Jorgensen each received the Regents’ Outstanding Teaching Award from the University of Texas System. Epperson directs the UTA Mathematics Teacher Preparation Academy, which has received about US$1 million from the Texas Higher Education Coordinating Board. These are just a few of the UTA mathematics department faculty who have successfully pursued grant opportunities; since 2011, 80 percent of the faculty have had grants.

While improving its doctoral program has been the department's top priority, it did not forget about its mathematics majors. To improve support for these students, the department successfully applied for two major grants from the NSF: an S-STEM (Scholarships in Science, Technology, Engineering, and Mathematics) grant of US$483,000 for 2008 to 2012 and a UBM (Undergraduates in Biological and Mathematical Sciences) grant of US$780,000 for 2008 to 2013. Both grants support scholarships, mentoring, and other activities designed to enrich the learning experience and enhance preparedness for the job market or graduate school. The department has also received grants from the National Research Experience for Undergraduates Program of the Mathematical Association of America, which supports REU programs aimed at students from underrepresented groups.

Grant money surely helps, but other zero-cost improvements have also made a difference. For example, the department gave the undergraduate student organization a bigger office where students could hang out and plan activities. This made them feel that "they truly have a home in the department," said Zhu. The department also includes math majors in as many graduate student activities as possible. The attention to the undergraduate program has yielded results: the number of mathematics majors jumped from around one hundred in 2005 to around three hundred today. "We would like to have more," Su said, noting that the job opportunities for math majors are good in the Dallas-Fort Worth region.

The department cultivates future math majors in programs such as the Mid-Cities Math Circle, headed by Dimitar Grantcharov, and an annual "Calculus Bowl" for high school students, run by Kojouharov. Every year the department collaborates with Riverside School, a local middle school, and the Rotary Club of Fort Worth to organize a "Math Camp": Three hundred 8th-graders and their teachers come to the UTA campus for half a day of activities designed to spark students' interest in mathematics. Over 90 percent of Riverside students are Hispanic, and most are poor. For many of them the UTA Math Camp marks their first time on a university campus. Aktosun said that when he looks at those 8th-graders, he thinks, "In six or seven years, they will be our math majors; in a decade, our doctoral students."

The UTA mathematics department is so good at everything it does it has become a testing ground for innovative programs on the campus. When there is talk of carrying out a pilot program, "the university says, 'Let math try it, and we'll see if it works,"' Su said. "We are energetic, we know what we are doing, and we make sure the program is carried out." Being the one that tries new, innovative programs gives the department an edge. "It's a way that we can make our department stand out from the crowd."

Mentoring of undergraduate students in the Math Department's S-STEM program, supported by the NSF. Math professors Ruth Gornet (standing) and Hristo Kojouharov (right) are at a SURGE working lunch meeting, where mentoring and math activities take place.

A Horse, Not a Maverick

When he first came to UTA, Zhu found that some faculty were trying to revise the departmental promotion policies so that for professors in areas of mathematics where job prospects for new Ph.D.'s are more limited than in other areas, the criterion of having Ph.D. students would not be part of promotion decisions. "The argument was, we can't get students," Zhu recalled. Today, with the growth in the graduate program, such worries have disappeared, along with much of the turf-protection mentality that produced them in the first place. "Many of the divisions and frictions that were really obvious years ago are now less obvious," he noted. "We all realize we have our differences…but we see that if we work together, we build a stronger program, and it benefits everyone in the department."

The motto of UT Arlington is "be a maverick". Aktosun is not fond of this motto and its implication that accomplishment comes only to those who go it alone. The real work is done not by mavericks, but by horses, he said. "We were able to create a good environment where everyone contributes, and everyone in the end benefits because their neighborhood becomes a nice neighborhood to live in—the department becomes a desirable place to be," he said. "Those incentives that benefit the community are what drives the horses rather than the incentives that drive the maverick." The moral: "Don't be a maverick. Be a horse."

Mathematics People

CMI Fellows Announced

The Clay Mathematics Institute (CMI) has announced two new Clay Research Fellows for 2013, both for five-year terms.

Semyon Dyatlov will receive his Ph.D. in 2013 from the University of California Berkeley. He applies the methods of microlocal analysis and dynamical systems to problems in scattering theory, quantum chaos, and mathematical general relativity. One of his research interests is scattering resonances, which are complex numbers generalizing the concept of bound states to open systems. Resonances appear in particular when studying long-time behavior of linear waves on noncompact manifolds or decay of classical correlations for chaotic flows. In his thesis Dyatlov developed a new microlocal framework to describe asymptotics of resonances and phase space concentration of associated resonant states under dynamical assumptions motivated by the wave equations on rotating black holes.

Aaron Pixton will receive his Ph.D. in 2013 from Princeton University. His research is in enumerative algebraic geometry. The topics he has worked on recently include the tautological ring of the moduli space of curves, moduli spaces of sheaves on 3-folds, and Gromov-Witten theory.

The Clay Research Fellowship provides a young mathematician employment, under ideal conditions, for a period of two to five years. A fellow may work at the location that best suits his or her research; support for travel and research expenses, as well as provisions for collaboration, are available in addition to a generous salary.

—From a CMI announcement

Miná Receives CMS Teaching Award

Ján Miná of the University of Western Ontario has been named the recipient of the Excellence in Teaching Award of the Canadian Mathematical Society (CMS). The award recognizes sustained and distinguished contributions in mathematics teaching at the undergraduate level at a Canadian postsecondary education institution.

—From a CMS announcement

Manfred Breuer (1929–2011)

Manfred Breuer, an influential mathematician and inspiring teacher, died on January 31, 2011, in Marburg, Germany, where he had been a full professor of mathematics from 1971 till 1996. Born in 1929, he attended a German high school that was located in an area under French occupation after World War II and that had to adopt the French schooling system. Out of this experience blossomed his lifelong active interest in French language, science, and culture. Breuer studied mathematics in Mainz and later in Bonn, where he got his Ph.D. in 1957, supervised by Wolfgang Krull. His thesis (1958) on Jacobian differential systems contains developments in the direction of modern symplectic geometry and Poincaré manifolds. He was Krull's assistant between 1957 and 1959, when he became fascinated with von Neumann algebras (vNAs in what follows) through Dixmier's book (1957). Breuer was then invited to Berkeley twice, in 1959–1961 and in 1963–1965. There he became acquainted with Fredholm theory in collaboration with Heinz-Otto Cordes; his Habilitationsschrift (1965) arose from these new perspectives. From 1966 to 1971, the most productive period of his career, he was a full professor at the University of Kansas in Lawrence. There he wrote his most influential work, on the Fredholm theory of semifinite vNAs (1968, 1969). In 1969 Atiyah invited him to Oxford, where he also met Singer; both were interested in Breuer's work for different reasons, while his work took new directions under their influence, as seen in his paper on bundles with vNA fibers (1973).

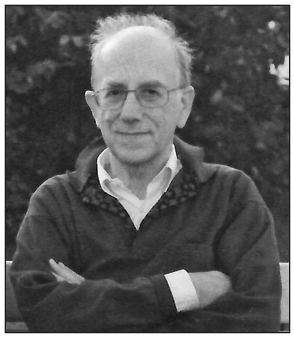

Photo by Annette Geyer.

Manfred Breuer

Breuer's collaboration with Cordes (Breuer and Cordes, 1964, 1965) emphasized homotopy theoretic arguments in Banach algebras, somehow anticipating the K-theory of operator algebras, which was fully developed only much later. In his work on Fredholm theory in semifinite vNAs, he introduces the "Breuer index", which takes values in the "index group". In modern terms, this is nothing but K_0. By choosing a faithful trace, one obtains a real-valued index. In Atiyah's influential L_2-index theorem (Atiyah, 1976), a faithful trace arises naturally from the underlying geometry, while in Breuer's more general approach no trace is preferred over any other. There are many developments arising from Atiyah's result, such as L_2-Reidemeister-Franz torsion (Carey and Mathai, 1992) or L_2-analytic torsion (Lott, 1992; Mathai, 1992), which can be seen in hindsight to have been influenced by Breuer's work.

In parallel with Breuer's investigations but completely independently, the theory of operator ideals in semifinite vNAs was developed. Both lines of research coalesced in the late 1990s in the study of semifinite noncommutative geometry; this, in turn, led to renewed interest in Breuer's work. The impetus for extending Connes's framework in the context of semifinite vNAs was only partly due to the influence of Atiyah's L_2-index theorem, since in Connes and Cuntz (1988), it had been demonstrated that the study of cyclic cohomology leads naturally to semifinite Fredholm modules. The systematic study of semifinite noncommutative geometry was begun only in 1998 in Carey and Phillips (1998) and in connection with foliation theory (à la Connes) in Benameur and Fack (2006). The motivation for Carey and Phillips (1998) was provided by Phillips's general theory of the analytic spectral flow (Phillips, 1997), which depends on the Breuer index. Breuer's approach was indeed surprisingly prescient because, with only minor modifications, it can be adapted to the situation of the local index formula in semifinite noncommutative geometry even though a complete account had to wait until 2006 (Carey, Phillips, Rennie, and Sukochev, 2006).

In his Marburg period Breuer's research interests gradually reduced to a few questions. His later years were focused on the proof of one of Kaplansky's conjectures, which says that AW^*-factors are in fact W^*-factors. Breuer's attempts at employing homotopy theoretical arguments to prove the existence of a trace in AW^*-factors, unfortunately, did not succeed. But his interest in new developments in mathematics did not fade away; they were studied in lectures and seminars well beyond the date of his retirement. With similar energy he tried to perfect his astonishing knowledge of cultural history, with special emphasis on its French sector.

Those who met Manfred Breuer in person will remember him as a penetrating and farsighted researcher, as a helpful and inspiring teacher, and as a gracious and self-effacing human being.

A pdf file of this obituary with a complete bibliography can be found at `http://www.mathematik.hu-berlin.de/~bruening/ObituaryManfredBreuer.pdf`.

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Mathematics Opportunities

Math for America Fellowships

Math for America (MfA) is a nonprofit organization with a mission to improve mathematics education in U.S. public secondary schools by recruiting, training, and retaining outstanding mathematics teachers and leaders. MfA offers fellowships for new and experienced teachers and school leaders. The MfA Master Teacher Fellowship is a four-year program that rewards outstanding experienced public secondary school mathematics and science teachers. Master Teacher Fellowships are available in Berkeley, Boston, New York City, and Washington, DC; the application deadline for these fellowships is **May 6, 2013**.

The Math for America Early Career Fellowship is awarded to public secondary school mathematics teachers early in their careers. MfA Early Career Fellows exhibit outstanding potential, a dedication to professional development, and an interest in collaboration with the Math for America community. The program provides professional support and growth opportunities for new teachers. The MfA Early Career Fellowship requires a commitment of four years. Applications are being accepted for the Early Career Fellowship in New York City. The deadline is **May 6, 2013**. For more information and to apply, see `http://www.mathforamerica.org/web/guest/apply`.

—From an MfA announcement

NSF Postdoctoral Research Fellowships

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships (MSPRF) for appropriate research in areas of the mathematical sciences, including applications to other disciplines. Awardees are permitted to choose research environments that will have maximal impact on their future scientific development. Awards are made in the form of either Research Fellowships or Research Instructorships. The Research Fellowship option provides full-time support for any eighteen academic-year months in a three-year period, in intervals not shorter than three consecutive months. The Research Instructorship option provides either two academic years of full-time support or one academic year of full-time and two academic years of half-time support. Under both options, the award includes six summer months; however, no more than two summer months of support may be received in any calendar year. Under both options, the stipend support for twenty-four months (eighteen academic-year months plus six summer months) will be provided within a forty-eight-month period.

The deadline for proposals is **October 16, 2013**. See http://www.nsf.gov/pubs/2012/nsf12496/nsf12496.htm .

—From an NSF announcement

Call for Nominations for 2014 Clifford Prize

The W. K. Clifford Prize is an international scientific prize for young researchers for excellence in theoretical and applied Clifford algebras, their analysis, and geometry. The award consists of a written certificate, one year of online access to the Clifford algebra-related journals, a book token worth 150 euros (approximately US$200) and a cash award of 1,000 euros (approximately US$1,300). The prizewinner also has the opportunity to give the special W. K. Clifford Prize Lecture at University College London, where W. K. Clifford held the first Goldsmid Chair from 1871 until his untimely death in 1879.

The prize will be awarded at the Tenth Conference on Clifford Algebras and Their Applications in Mathematical Physics (ICCA10) at Tartu (Estonia) in 2014. The deadline for nominations is **September 30, 2013**. Nominations should be sent to secretary@wkcliffordprize.org. See http://www.wkcliffordprize.org.

—Fred Brackx,
Secretary

Mentoring through Critical Transition Points in the Mathematical Sciences

The National Science Foundation (NSF) Mentoring through Critical Transition Points in the Mathematical Sciences (MCTP) program provides funds for the training of U.S. students and postdoctoral researchers in the mathematical sciences. Proposals are solicited from departments of the mathematical sciences to support projects that aim to improve training at critical transition points in the educational careers of students and junior researchers. MCTP awards are intended to support training programs that have strong potential to increase the number of well-prepared U.S. citizens, nationals, and permanent residents who pursue careers in the mathematical sciences and in other NSF-supported disciplines. The deadline for full proposals is **June 4, 2013**. For more information see http://www.nsf.gov/pubs/2011/nsf11542/nsf11542.htm.

—From an NSF announcement

Research Training Groups in the Mathematical Sciences

The National Science Foundation (NSF) Research Training Groups in the Mathematical Sciences (RTG) program provides funds for the training of U.S. students and postdoctoral researchers in the mathematical sciences. Proposals are solicited from groups of researchers based in a subarea of the mathematical sciences or linked by a multidisciplinary theme to support training at educational levels from undergraduate to postdoctoral within that focus. RTG awards are intended to support training programs that have strong potential to increase the number of well-prepared U.S. citizens, nationals, and permanent residents who pursue careers in the mathematical sciences and in other NSF-supported disciplines. The deadline for full proposals is **June 4, 2013**. For more information see http://www.nsf.gov/pubs/2011/nsf11540/nsf11540.htm.

—From an NSF announcement

International Mathematics Competition for University Students

The Twentieth International Mathematics Competition (IMC) for University Students will be held August 6–12, 2013, at American University in Blagoevgrad, Bulgaria. Participating universities are invited to send several students and one teacher; individual students are welcome. Students completing their first, second, third, or fourth years of university education are eligible. The competition will consist of two sessions of five hours each. Problems will come from the fields of algebra, analysis (real and complex), geometry, and combinatorics. The working language will be English. See the website http://www.imc-math.org.uk/ or contact John Jayne, University College London, Gower Street, London WC1E 6BT, United Kingdom; telephone: +44 (0)77 40304010; email: j.jayne@ucl.ac.uk.

—John Jayne,
University College London

News from the Bernoulli Center

The Bernoulli Center (CIB), funded jointly by the Swiss National Science Foundation and the Swiss Federal Institute of Technology in Lausanne, began its activity in March

2002. Its mission is to support research in mathematics and its applications, to organize and host thematic programs, to provide a supportive and stimulating environment for researchers, and to launch and foster collaborations between mathematicians working in different areas, as well as mathematicians and other scientists. The CIB regularly launches calls for proposals of one-semester programs. For more details, see `http://cib.epfl.ch/`.

The Bernoulli Center is hosting a Special Semester Program from July 1 to December 23, 2013, devoted to semiclassical analysis and integrable systems. The program aims to bring together specialists in algebraic aspects of the theory of classical and quantum completely integrable systems with experts in semiclassical analysis, as well as geometric and topological aspects of the theory of completely integrable systems. There is a summer school and also a conference being organized in July. The program directors are Vladimir Fock (Strasbourg), Álvaro Pelayo (IAS Princeton and Washington University), Nicolai Reshetikhin (UC Berkeley), and San Vũ Ngọc (Rennes). Details are available at `http://integrablesystems.epfl.ch/` by clicking on "Key Events".

In addition, a special event will take place during the program: a week-long conference in honor of Alan Weinstein, on the occasion of his seventieth birthday, during the week of July 22–26, 2013. This conference will be a forum to celebrate Alan Weinstein's fundamental contributions to mathematics and to thank him for many years of mentorship. The conference is organized by Henrique Bursztyn (IMPA), Rui Loja Fernandes (Urbana-Champaign), Álvaro Pelayo (IAS Princeton and Washington University), and Tudor Ratiu (EPFL). For further information see `http://integrablesystems.epfl.ch/w-conference.php`.

—Bernoulli Center announcement

Inside the AMS

AMS Holds Workshop for Department Chairs

The AMS held its annual workshop for department chairs on January 8, 2013, prior to the Joint Mathematics Meetings in San Diego, California. This one-day session focused on a number of issues facing departments today, including how to prepare the next generation of college mathematics teachers; remedial mathematics courses for undergraduate students; preparing a workforce competent in science, technology, engineering, and mathematics (STEM); and the teaching of college-level mathematics courses. The meeting is designed in a workshop format to stimulate discussion and allow the sharing of ideas and experiences among attending department chairs, which allows attendees to address departmental challenges from new perspectives.

The workshop was led by Timothy Hodges, University of Cincinnati; Helen Roberts, Montclair State University; Alex Smith, University of Wisconsin-Eau Claire; and Michel Smith, Auburn University.

—Anita Benjamin
AMS Washington Office

From the AMS Public Awareness Office

Who Wants to Be a Mathematician on Pi Day

The AMS conducted Who Wants to Be a Mathematician at Providence College on Pi Day (March 14, 2013). See highlights of the event, which has been held in Rhode Island for a lucky thirteen straight years, at `www.ams.org/programs/students/wwtbam/pi-day-2013`.

—Annette Emerson and Mike Breen

Epsilon Awards for 2013

The AMS Epsilon Fund for Young Scholars was established in 1999 to provide financial assistance to summer programs in the United States and Canada for mathematically talented high school students. These programs have provided mathematically talented youngsters with their first serious mathematical experiences. The name for the fund was chosen in remembrance of the late Paul Erdős, who was fond of calling children "epsilons".

The AMS has chosen sixteen summer mathematics programs to receive Epsilon grants for activities in the summer of 2013. The grants will support program expenses and student scholarships and, in some cases, scholarships only. The programs were chosen on the basis of mathematical excellence and enthusiasm. Award amounts were governed by the varying financial needs of each program.

The 2013 grants are awarded to: All Girls/All Math, University of Nebraska; Camp Euclid, online; Canada/USA Mathcamp, University of Puget Sound, Tacoma, Washington; Hampshire College Summer Studies in Mathematics

(HCSSiM), Hampshire College, Amherst, Massachusetts; LSU MathCircle Summer Enrichment Program, Louisiana State University; MathPath, Mount Holyoke College, South Hadley, Massachusetts; Mathworks Honors Summer Math Camp, Texas State University, San Marcos; Michigan Math and Science Scholars Summer Program, University of Michigan, Ann Arbor; New York Math Circle High School Summer Program, New York University, Courant Institute of Mathematical Sciences; PROMYS, Boston University; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayagüez Campus; Research Science Institute, Massachusetts Institute of Technology; Ross Mathematics Program, The Ohio State University; Stanford University Mathematics Camp (SUMaC), Stanford University; Summer Program in Mathematical Problem Solving, Bard College, New York; Young Scholars Program, University of Chicago.

The grants for summer 2013 are paid for by the AMS Epsilon Fund for Young Scholars. The AMS Epsilon Fund for Young Scholars has been funded by contributions of AMS members and friends; the goal of the endowment is to provide at least US$100,000 in support each summer.

For further information about the Epsilon Fund for Young Scholars, visit the website `http://www.ams.org/giving-to-ams/` or contact `development@ams.org`. Information about how to apply for Epsilon grants is available at `http://www.ams.org/employment/epsilon.html`. A fairly comprehensive listing of summer programs for mathematically talented high school students (including those with and without Epsilon grants) is available at `http://www.ams.org/employment/mathcamps.html`.

—*AMS Development Office*

Deaths of AMS Members

Bradford H. Arnold, of Happy Valley, Oregon, died on May 10, 2012. Born on October 14, 1916, he was a member of the Society for 82 years.

Paul T. Bateman, of Urbana, Illinois, died on December 26, 2012. Born on June 5, 1919, he was a member of the Society for 71 years.

Olga R. Beaver, professor, Williams College, died on December 7, 2012. Born on November 12, 1942, she was a member of the Society for 36 years.

Robert M. Blumenthal, of Lake Forest Park, Washington, died on November 8, 2012. Born on February 7, 1931, he was a member of the Society for 58 years.

David G. Cantor, of San Diego, California, died on November 19, 2012. Born on April 12, 1935, he was a member of the Society for 54 years.

Edward D. Davis, of Middletown, New York, died on February 8, 2013. Born on September 24, 1933, he was a member of the Society for 55 years.

Stefan Manev Dodunekov, professor, Bulgarian Academy of Science, died on August 5, 2012. Born on September 5, 1945, he was a member of the Society for 35 years.

J. Douglas Faires, of Pulaski, Pennsylvania, died on December 21, 2012. Born on April 27, 1941, he was a member of the Society for 46 years.

Arthur Greenspoon, associate editor at Math Reviews for over 33 years, died on February 5, 2013.

Lars V. Hörmander, professor, Lund University, died on November 25, 2012. Born on January 24, 1931, he was a member of the Society for 54 years.

Edwin H. Morris, of Birmingham, Alabama, died on October 8, 2012. Born on October 31, 1926, he was a member of the Society for 21 years.

Hiram Paley, of Urbana, Illinois, died on January 9, 2012. Born on September 9, 1933, he was a member of the Society for 56 years.

Leland L. Scott, of Oakton, Virginia, died on November 10, 2010. Born on March 31, 1919, he was a member of the Society for 62 years.

Patrick Shanahan, of Myrtle Beach, South Carolina, died on January 24, 2013. Born on August 4, 1931, he was a member of the Society for 58 years.

Constantin Tudor, professor, University of Bucharest, died on July 26, 2011. Born on August 17, 1950, he was a member of the Society for 16 years.

Reference and Book List

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Contacting the *Notices*

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are `notices@math.wustl.edu` in the case of the editor and `smf@ams.org` in the case of the managing editor. The fax numbers are 314-935-6839 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

April 30, 2013: Nominations for AWM Gweneth Humphreys Award. See `www.awm-math.org`, telephone 703-934-0163, or email `awm@awm-math.org`.

May 1, August 1, November 1, 2013: Applications for May, August, and November reviews for National Academies Research Associateship Programs. See the website `http://sites.nationalacademies.org/PGA/RAP/PGA_050491` or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email `rap@nas.edu`.

May 1, October 1, 2013: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See `https://sites.google.com/site/awmmath/programs/travel-grants`; or telephone: 703-934-0163; email: `awm@awm-math.org`; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

May 6, 2013: Applications for Math for America Master Teacher Fellowships in Berkeley, Boston, New York City, and Washington, DC, and for Early Career Fellowships in New York City. See "Mathematics Opportunities" in this issue.

May 15–June 15, 2013: Proposals for NSF DMS Workforce Program in the Mathematical Sciences. See the website `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503233`.

June 4, 2013: Full proposals for National Science Foundation (NSF) Mentoring through Critical Transition Points in the Mathematical Sciences (MCTP) program. See "Mathematics Opportunities" in this issue.

June 4, 2013: Full proposals for National Science Foundation (NSF) Research Training Groups in the Mathematical Sciences (RTG) program. See "Mathematics Opportunities" in this issue.

August 13, 2013: Full proposals for NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program. See `http://www.nsf.gov/pubs/2012/nsf12529/nsf12529.htm`.

September 15, 2013: Applications for spring 2014 semester of Math in Moscow. See `http://www.mccme.ru/mathinmoscow`, or write to: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01;

Where to Find It

A brief index to information that appears in this and previous issues of the *Notices*.

AMS Bylaws—*January 2012, p. 73*

AMS Email Addresses—*February 2013, p. 249*

AMS Ethical Guidelines—*June/July 2006, p. 701*

AMS Officers 2012 and 2013 Updates—*May 2013, p. 646*

AMS Officers and Committee Members—*October 2012, p. 1290*

Contact Information for Mathematical Institutes—*August 2012, p. 979*

Conference Board of the Mathematical Sciences—*September 2012, p. 1128*

IMU Executive Committee—*December 2011, p. 1606*

Information for *Notices* Authors—*June/July 2012, p. 851*

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National Science Board—*January 2013, p. 109*

NRC Board on Mathematical Sciences and Their Applications—*March 2013, p. 350*

NSF Mathematical and Physical Sciences Advisory Committee—*February 2013, p. 252*

Program Officers for Federal Funding Agencies—*October 2012, p. 1284 (DoD, DoE); December 2012, p. 1585 (NSF Mathematics Education)*

Program Officers for NSF Division of Mathematical Sciences—*November 2012, p. 1469*

email: mim@mccme.ru. Information and application forms for the AMS scholarships are available on the AMS website at http://www.ams.org/programs/travel-grants/mimoscow, or by writing to: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email student-serv@ams.org.

September 30, 2013: Nominations for W. K. Clifford Prize. See "Mathematics Opportunities" in this issue.

October 4, 2013: Letters of intent for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

October 16, 2013: Proposals for National Science Foundation (NSF) Postdoctoral Research Fellowships. See "Mathematics Opportunities" in this issue.

November 12, 2013: Full proposals for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

Book List

The Book List highlights recent books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. Suggestions for books to include on the list may be sent to notices-booklist@ams.org.

*Added to "Book List" since the list's last appearance.

American Mathematicians as Educators, 1893–1923: Historical Roots of the "Math Wars", by David Lindsay Roberts. Docent Press, July 2012, ISBN-13: 978-09837-004-49.

Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification, by the National Research Council. National Academies Press, 2012. ISBN: 978-0-309-25634-6.

The Best Writing on Mathematics 2012, edited by Mircea Pitici. Princeton University Press, November 2012. ISBN-13: 978-06911-565-52.

Bibliography of Raymond Clare Archibald, by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-0983700425.

Calculating Curves: The Mathematics, History, and Aesthetic Appeal of T. H. Gronwall's Nomographic Work, by Thomas Hakon Gronwall, with contributions by Ron Doerfler and Alan Gluchoff, translation by Paul Hamburg, and bibliography by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-09837-004-32.

**Charles S. Peirce on the Logic of Number*, by Paul Shields. Docent Press, October 2012. ISBN-13: 978-0-9837004-7-0.

Classic Problems of Probability, by Prakash Gorroochurn. Wiley, May 2012. ISBN-13: 978-1-1180-6325-5.

**The Continuity Debate: Dedekind, Cantor, du Bois-Reymond, and Peirce on Continuity and Infinitesimals,* by Benjamin Lee Buckley. Docent Press, December 2012. ISBN-13: 978-0-9837004-8-7.

The Crossing of Heaven: Memoirs of a Mathematician, by Karl Gustafson. Springer, January 2012. ISBN-13: 978-36422-255-74.

Elliptic Tales: Curves, Counting, and Number Theory, by Avner Ash and Robert Gross. Princeton University Press, March 2012. ISBN-13: 978-06911-511-99.

The Foundations of Geometry And Religion from an Abstract Standpoint, by Salilesh Mukhopadhyay. Outskirts Press, July 2012. ISBN-13: 978-1-4327-9424-8.

The Fractalist: Memoir of a Scientific Maverick, by Benoit Mandelbrot. Pantheon, October 2012. ISBN-13: 978-03073-773-57.

Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century, by the National Research Council. National Academies Press, 2012. ISBN-13: 978-0-309-25473-1.

Game Theory and the Humanities: Bridging Two Worlds, by Steven J. Brams. MIT Press, September 2012. ISBN-13: 978-02625-182-53.

Games and Mathematics: Subtle Connections, by David Wells. Cambridge University Press, November 2012. ISBN-13: 978-11076-909-12.

**Google's PageRank and Beyond: The Science of Search Engine Rankings*, by Amy Langville and Carl Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-526-60.

**The Golden Ticket: P, NP, and the Search for the Impossible*, by Lance Fortnow. Princeton University Press, March 2013. ISBN-13: 978-06911-564-91.

Guesstimation 2.0: Solving Today's Problems on the Back of a Napkin, by Lawrence Weinstein. Princeton University Press, September 2012. ISBN-13: 978-06911-508-02.

Henri Poincaré: Impatient Genius, by Ferdinand Verhulst. Springer, August 2012. ISBN-13: 978-14614-240-62.

Henri Poincaré: A Scientific Biography by Jeremy Gray. Princeton University Press, November 2012. ISBN-13: 978-06911-527-14.

How to Study as a Mathematics Major, by Lara Alcock. Oxford University Press, March 2013. ISBN-13: 978-0199661312.

I Died for Beauty: Dorothy Wrinch and the Cultures of Science, by Marjorie Senechal. Oxford University Press, December 2012. ISBN-13:978-01997-325-93.

Ibn al-Haytham's Theory of Conics, Geometrical Constructions and Practical Geometry, by Roshdi Rashed. Routledge, February 2013. ISBN: 978-0-415-58215-5.

In Pursuit of the Unknown: 17 Equations That Changed the World, by Ian Stewart. Basic Books, March 2012. ISBN-13: 978-04650-297-30. (Reviewed December 2012.)

Introduction to Mathematical Thinking, by Keith Devlin. Keith Devlin, July 2012. ISBN-13: 978-06156-536-31.

**Invisible in the Storm: The Role of Mathematics in Understanding Weather*, by Ian Roulstone and John Norbury. Princeton University Press, February 2013. ISBN-13: 978-06911-527-21.

The Irrationals: A Story of the Numbers You Can't Count On, by Julian Havil. Princeton University Press, June 2012. ISBN-13: 978-0691143422.

The Joy of x: A Guided Tour of Math, from One to Infinity, by Steven Strogatz. Eamon Dolan/Houghton Mifflin Harcourt, October 2012. ISBN-13: 978-05475-176-50.

Late Style: Yuri I. Manin Looking Back on a Life in Mathematics. A DVD documentary by Agnes Handwerk and Harrie Willems. Springer, March 2012. ISBN NTSC: 978-3-642-24482-7; ISBN PAL: 978-3-642-24522-0. (Reviewed January 2013.)

Levels of Infinity: Selected Writings on Mathematics and Philosophy, by Hermann Weyl. Edited by Peter Pesic. Dover Publications, February 2013. ISBN-13: 978-0486489032.

The Logician and the Engineer: How George Boole and Claude Shannon Created the Information Age, by Paul J. Nahin, Princeton University Press, October 2012. ISBN-13: 978-06911-510-07.

Manifold Mirrors: The Crossing Paths of the Arts and Mathematics, by Felipe Cucker. Cambridge University Press, April 2013. ISBN-13: 978-0521728768.

Math Goes to the Movies, by Burkard Polster and Marty Ross. Johns Hopkins University Press, July 2012. ISBN-13: 978-14214-048-44.

Math Is Murder, by Robert C. Brigham and James B. Reed. Universe, March 2012. ISBN-13: 978-14697-972-81.

A Mathematician's Lament: How School Cheats Us Out of Our Most Fascinating and Imaginative Art Form, by Paul Lockhart. Bellvue Literary Press, April 2009. ISBN-13: 978-1-934137-17-8. (Reviewed April 2013.)

Mathematical Excursions to the World's Great Buildings, by Alexander J. Hahn. Princeton University Press, July 2012. ISBN-13: 978-06911-452-04.

Mathematicians in Bologna 1861-1960, edited by Salvatore Coen. ISBN-13: 978-30348-022-60.

Mathematics in Popular Culture: Essays on Appearances in Film, Fiction, Games, Television and Other Media, edited by Jessica K. Sklar and Elizabeth S. Sklar. McFarland, February 2012. ISBN-13: 978-07864-497-81.

Meaning in Mathematics, edited by John Polkinghorne. Oxford University Press, July 2011. ISBN-13: 978-01996-050-57. (Reviewed in this issue.)

Measurement, by Paul Lockhart. Belknap Press of Harvard University Press, September 2012. ISBN-13: 978-06740-575-55.

Nine Algorithms That Changed the Future: The Ingenious Ideas That Drive Today's Computers, by John MacCormick. Princeton University Press, December 2011. ISBN-13: 978-06911-471-47.

On the Formal Elements of the Absolute Algebra, by Ernst Schröder (translated and with additional material by Davide Bondoni; with German parallel text). LED Edizioni Universitarie, 2012. ISBN-13: 978-88-7916-516-7.

Paradoxes in Probability Theory, by William Eckhardt. Springer, September 2012. ISBN-13: 978-94007-513-92. (Reviewed March 2013.)

**Peirce's Logic of Continuity: A Conceptual and Mathematical Approach,* by Fernando Zalamea. Docent Press, December 2012. ISBN-13: 978-0-9837004-9-4.

Proving Darwin: Making Biology Mathematical, by Gregory Chaitin. Pantheon, May 2012. ISBN-13: 978-03754-231-47.

**Relations Between Logic and Mathematics in the Work of Benjamin and Charles S. Peirce,* by Allison Walsh. Docent Press, October 2012. ISBN-13: 978-0-9837004-6-3.

The Search for Certainty: A Journey through the History of Mathematics, 1800-2000, edited by Frank J. Swetz. Dover Publications, September 2012. ISBN-13: 978-04864-744-27.

Secrets of Triangles: A Mathematical Journey, by Alfred S. Posamentier and Ingmar Lehman. Prometheus Books, August 2012. ISBN-13: 978-16161-458-73.

Seduced by Logic: Emilie Du Châelet, Mary Somerville and the Newtonian Revolution, by Robyn Arianrhod. Oxford University Press, September 2012. ISBN-13: 978-01999-316-13.

Selected Papers: Volume II: On Algebraic Geometry, including correspondence with Grothendieck, by David Mumford. Edited by Amnon Neeman, Ching-Li Chai, and Takahiro Shiota. Springer, July 2010. ISBN-13: 978-03877-249-11. (Reviewed February 2013.)

The Signal and the Noise: Why So Many Predictions Fail—but Some Don't, by Nate Silver. Penguin Press, September 2012. ISBN-13:978-15942-041-11.

Simon: The Genius in My Basement, by Alexander Masters. Delacorte Press, February 2012. ISBN-13: 978-03853-410-80.

Thinking Statistically, by Uri Bram. CreateSpace Independent Publishing Platform, January 2012. ISBN-13: 978-14699-123-32.

Transcending Tradition: Jewish Mathematicians in German Speaking Academic Culture, edited by Birgit Bergmann, Moritz Epple, and Ruti Ungar. Springer, January 2012. ISBN-13: 978-36422-246-38. (Reviewed February 2013.)

The Universe in Zero Words: The Story of Mathematics as Told through Equations, by Dana Mackenzie. Princeton University Press, April 2012. ISBN-13: 978-06911-528-20. (Reviewed in this issue.)

A Wealth of Numbers: An Anthology of 500 Years of Popular Mathematics Writing, edited by Benjamin Wardhaugh. Princeton University Press, April 2012. ISBN-13: 978-06911-477-58. (Reviewed March 2013.)

Who's #1?: The Science of Rating and Ranking, by Amy N. Langville and Carl D. Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-542-20. (Reviewed January 2013.)

Why Cats Land on Their Feet (and 76 Other Physical Paradoxes and Puzzles), by Mark Levi. Princeton University Press, May 2012. ISBN-13: 978-0691148540.

Classified Advertisements

Positions available, items for sale, services available, and more

MASSACHUSETTS

NORTHEASTERN UNIVERSITY
Chair
Department of Mathematics

The College of Science at Northeastern University invites applications for the position of Professor and Chair of the Mathematics Department. The Mathematics Department (www.math.neu.edu) at Northeastern is a center of excellence with a nationally and internationally recognized research faculty in pure and applied mathematics. The department currently comprises 34 full-time faculty with over $4 million in annual federal funding, about 80 Ph.D. and Masters students, and about 240 undergraduate mathematics majors (including dual majors). At the core of the department are outstanding mathematical research in a broad range of areas, an excellent graduate program with diverse graduate offerings, a vibrant undergraduate program, and highly-regarded educational outreach programs. Key goals of the department include further enhancement of its research and graduate profile through high-level faculty and graduate student recruitment, and increasing its faculty and graduate representation in applied and interdisciplinary areas. The new Chair has a unique opportunity to significantly shape the department's future growth and direction.

The required qualifications include a Ph.D. degree in mathematics or a related field; a record of research, teaching and service appropriate for the academic rank of Full Professor of Mathematics; and demonstrated administrative, leadership, and interpersonal skills.

Northeastern University is a global, experiential research university. Grounded in its signature co-op program, Northeastern today provides unprecedented experiential learning opportunities around the world. The university's rapidly growing research enterprise is strategically aligned with three national imperatives: health, security, and sustainability. Northeastern is in the process of hiring 300 new faculty. The incoming Chair will have an opportunity to contribute to this process.

Northeastern occupies a vibrant 67-acre campus in the heart of Boston, surrounded by other leading educational, health care, technological, and research institutions, as well as world-renowned venues for art and music. The campus has received an American Institute of Architects award for "most beautiful new or renovated exterior space". Northeastern University is an Equal Opportunity, Affirmative Action Educational Institution and Employer, Title IX University. Northeastern University particularly welcomes applications from minorities, women, and persons with disabilities.

A competitive salary and startup package will be provided. To apply, visit "Careers at Northeastern" at https://neu.peopleadmin.com. Click on "Full-time Faculty Positions" and search for the current position under the College of Science. You can also apply by visiting the College of Science website at http://www.northeastern.edu/cos and clicking on the "Faculty Positions" button.

Please submit a letter of interest, curriculum vitae, the names and contact information for five references, and a brief description of research. Reference letters are not required at this stage and will be solicited by the Search Committee if needed.

Informal inquiries can be addressed to Dr. Egon Schulte, Chair, Mathematics Chair Search Committee, schulte@neu.edu.

The earliest anticipated start date is July 1, 2013. Review of applications will begin in February 1, 2013, and continue until the position is filled.

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CHILE

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
Departamento de Matemáticas

The Department of Mathematics invites applications for one tenure-track position at the Assistant Professor level beginning either March or August 2014. Applicants should have a Ph.D. in mathematics, proven research potential either in pure or applied mathematics, and a strong commitment to teaching and research. The regular teaching load for assistant professors consists of three one-semester courses per year, reduced to two during the first two years. The annual salary will be approximately US$48,000.

Please send a letter indicating your main research interests, potential collaborators in our department (http://www.mat.puc.cl), detailed curriculum vitae, and three letters of recommendation to:

Monica Musso
Director
Departamento de Matemáticas
Pontificia Universidad Católica de Chile
Av. Vicuña Mackenna 4860
Santiago-CHILE;
fax: (56-2) 552-5916;
email: mmusso@mat.puc.cl.

For full consideration, complete application materials must arrive by June 30, 2013.

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Fellows of the AMS: Inaugural Class

Many professional organizations in the sciences and engineering have had a tradition of recognizing outstanding members by designating them as "fellows". The American Association for the Advancement of Science, the Institute of Electrical and Electronic Engineers, and the American Physical Society have longstanding fellows programs. The Society for Industrial and Applied Mathematics launched a fellows program in 2008.

Over the past several years, the AMS held extensive discussions about whether it should establish its own fellows program and considered various models. In 2006 and 2008, measures for establishing such a program were put to a vote by the membership and were defeated by very slim margins. Further refinements in the program structure were made, and in a vote in fall 2011, AMS members approved the creation of a new program called Fellows of the AMS.

The measure the membership approved stipulated a way to begin naming Fellows. Rather than start off with a small number of Fellows and build the number over time, the AMS has designated a large number of members, around 1,200, as the Inaugural Class of Fellows. The steady-state number of Fellows will be a percentage of the total membership. The Council chooses the percentage and will revisit the choice at least once a decade to make needed adjustments based on changes in the number of members and the history of the nomination and selection process. With this target percentage in mind, each year the Council will set the number of new Fellows to be named. Presently, the target steady-state number is 1,500, which is about 5 percent of the current number of AMS members.

To be invited to become an Inaugural Fellow, an individual had to have been an AMS member for the previous two years and had to have met one of the following criteria: he/she presented an AMS invited address, received an AMS prize, or presented an invited address at an International Congress of Mathematicians (ICM) or an International Congress of Industrial and Applied Mathematicians (ICIAM). The AMS decided also to reserve a small number of Inaugural Fellow slots for outstanding individuals who did not meet the above criteria.

A small team of AMS staff—principally professional services manager Diane Boumenot and senior programs coordinator Steven Ferucci—assembled an initial list of several thousand individuals meeting these criteria, and then matched that list against the list of AMS members. This process took about a year and resulted in a list of 1,170 people. A selection committee then reviewed the list and added an additional 50 individuals whom the committee felt qualified to be Fellows but who did not appear on the list. The main aim in selecting these additional individuals was to recognize members who had made extraordinary contributions beyond research.

In fall 2012, 1,220 members were invited to become Fellows. Of these, 1,125 accepted, and the rest either did not respond or were among the 37 individuals who declined. The final list of Inaugural Fellows appears below. When the list was first posted on the AMS website in November 2012, many institutions issued news releases about their faculty appearing on the list. At the Joint Mathematics Meetings in San Diego in January 2013, a reception was held for the Inaugural Fellows, and each received a booklet with the full list of Fellows and a commemorative paperweight. Each Fellow also received a certificate by mail.

In the future, Fellows of the AMS will be chosen by a selection committee, composed of twelve AMS members who are already Fellows. Nominations for Fellows may be made by AMS members between February 1 and March 31 each year; a member may make at most two nominations. While the exact number will be set annually by the Council, the AMS anticipates naming about 75 new Fellows each year in the coming decade. When the steady-state of 1,500 Fellows has been reached, it is expected that there will be around forty new Fellows slots each year due to attrition.

During the six years that the Fellows of the AMS program was discussed within the Society, there was strong support as well as some strong opposition. Supporters and opponents had ample opportunity to air their views in venues such as Council meetings and in the pages of the *Notices* (see, for example, the pro and con pieces in the August 2006 issue, with Ronald J. Stern writing for the program and David Eisenbud against, and in the September 2011 issue, with Eric M. Friedlander for and Frank Morgan against; there have also been several Letters to the Editor). Today, the Society leadership believes that Fellows of the AMS program enjoys widespread support within the community. The program has already begun having one of its intended effects, namely, to boost recognition for exceptional mathematicians within their own institutions. The hope is that, as Fellows of the AMS becomes an established part of Society activities, it will be an effective way to highlight and celebrate the outstanding achievements of the mathematical sciences community.

For additional information about the Fellows program, as well as instructions for making nominations, visit the web page `www.ams.org/profession/ams-fellows`.

—Allyn Jackson

Goals of the AMS Fellows Program

- To create an enlarged class of mathematicians recognized by their peers as distinguished for their contributions to the profession.
- To honor not only the extraordinary but also the excellent.
- To lift the morale of the profession by providing an honor more accessible than those currently available.
- To make mathematicians more competitive for awards, promotion, and honors when they are being compared with colleagues from other disciplines.
- To support the advancement of more mathematicians in leadership positions in their own institutions and in the broader society.

Responsibilities of Fellows

- To take part in the election of new Fellows,
- To present a "public face" of excellence in mathematics, and
- To advise the President and/or the Council on public matters when requested.

A'Campo, Norbert M.L., University of Basel
Abhyankar*, Shreeram, Purdue University
Abikoff, William, University of Connecticut, Storrs
Ablowitz, Mark J., University of Colorado, Boulder
Adams, Colin C., Williams College
Adams, Jeffrey, University of Maryland
Adem, Alejandro, University of British Columbia
Adler, Roy, IBM Research
Agmon, Shmuel, The Hebrew University of Jerusalem
Agol, Ian, University of California, Berkeley
Aizenman, Michael, Princeton University
Aldous, David, University of California, Berkeley
Alexeev, Valery, University of Georgia
Alladi, Krishnaswami, University of Florida
Allcock, Daniel, University of Texas at Austin
Allman, Elizabeth S., University of Alaska Fairbanks
Alperin, Jonathan L., University of Chicago
Andersen, Henning Haahr, Centre for Quantum Geometry of Moduli Spaces (QGM), Aarhus University
Anderson, David F., University of Tennessee, Knoxville
Anderson, Donald W., University of California, San Diego
Anderson, Michael T., Stony Brook University
Andrews, Benjamin, Australian National University and Tsinghua University
Andrews, George E., Pennsylvania State University
Antman, Stuart S., University of Maryland
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To everyone whose names appear on these pages – including those who have chosen to remain anonymous—I want to say thank you! Your resolve to make a difference through your giving is working. Its positive impact will be felt this year and in the future. We at the AMS appreciate and are grateful for your commitment.

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Robert V. Perlis
Charles Samuel Peskin
Troels Petersen
John W. Petro
David A. Pierce
Jonathan Pila
Steven Pincus
Mark A. Pinsky
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Vera S. Pless
David J. Pollack
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Michael F. Quinn
Eric Todd Quinto and Judith Anne Larsen
Cary Baker Rader
David E. Radford
Louis B. Rall
Dinakar Ramakrishnan
Melapalayam S. Ramanujan
R. Michael Range
Salvatore Rao
Dwijendra K. Ray-Chaudhuri
S. W. Rayment
Maxwell O. Reade
Charles S. Rees
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Ernestine Reeves-Hicks
Eugenio Regazzini
John H. Reinoehl
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Michael Bela Revesz
Robert J. Reynolds
Charles W. Rezk
Martin G. Ribe
Stephen J. Ricci
John H. Rickert
Benjamin Rickman
Robert D. Rigdon
William Riley
Jose Rio
Thomas W. Rishel
Roberto R. Rivera
Joel L. Roberts
Anne Drinkwater and Paul C. Roberts
Joseph B. Roberts
Derek J. S. Robinson
Herman Roelants
David E. Rohrlich
Judith Roitman
Dale P. O. Rolfsen
Guillermo Romero Melendez
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William L. Stamey
Paul H. Stanford
Dennis W. Stanton
Christopher W. Stark
Dudley S. Stark
Jack Douglas Stecher
Sherman K. Stein
David R. Steinsaltz
John G. Stevens
Paul K. Stockmeyer
Harold J. Stolberg
Alexander P. Stone
Lawrence D. Stone
Emil J. Straube
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Thomas G. Street III
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Garrett James Stuck
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David Swailes
William J. Sweeney
Roman Sznajder
Shigeo Takenaka
Hisao Tanaka
Yoshihiro Tanaka

Daniel Joseph Tancredi
Elliot A. Tanis
Leon H. Tatevossian
Jean E. Taylor
Keith A. Taylor
Samuel James Taylor
Eduardo Tengan
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Lawrence E. Thomas
Robert Thompson
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Spiros Peter Tsatsanis
Kazô Tsuji
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Johan Tysk
Jeremy Taylor Tyson
Mfon Okon Udo
Michael Lawrence Ulrey
Frederick William Umminger
Yasushi Unai Unai
Ashish K. Upadhyay
John A. W. Upton
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Jan Harm Van der Walt
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Jose Zero
Shengxin Zhu
Ernst-Wilhelm Zink
Steven M. Zucker
Paul F. Zweifel
Paul J. Zwier

On November 16, 2012, members of the AMS Executive Council and Board of Trustees gathered with management staff to celebrate the rededication of the Donor Wall of Honor. Chair of the Board of Trustees Ron Stern, left, and Executive Director Don McClure, right, gave brief remarks before unveiling the Donor Wall of Honor. Acknowledging those who have made gifts to the AMS of $1,000 or more in one year, the Wall has been on display at the Providence, RI, AMS Headquarters since 1995. Added to the Wall were 26 new nameplates, a fourth name plaque, and a masthead plaque that quotes Isaac Newton, “If I have seen further it is by standing on the shoulders of giants.” The AMS is grateful to its donors for their abiding commitment to enrich mathematics and pleased to maintain the Donor Wall of Honor as a token of its gratitude.

American Mathematical Society

AMS Award for Mathematics Programs *That Make a Difference*





Deadline: September 13, 2013

This award was established in 2005 in response to a recommendation from the AMS's Committee on the Profession that the AMS compile and publish a series of profiles of programs that:

1. aim to bring more persons from underrepresented backgrounds into some portion of the pipeline beginning at the undergraduate level and leading to advanced degrees in mathematics and professional success, or retain them once in the pipeline;

2. have achieved documentable success in doing so; and

3. are replicable models.

Preference will be given to programs with signifigant participation by underrepresented minorities.

One or two programs are highlighted annually.

Nomination process: Letters of nomination may be submitted by one or more individuals. Nomination of the writer's own institution is permitted. The letter should describe the specific program(s) for which the department is being nominated as well as the achievements that make the program(s) an outstanding success, and may include any ancillary documents which support the success of the program(s). The letter of nomination should not exceed two pages, with supporting documentation not to exceed three more pages. Up to three supporting letters may be included in addition to these five pages.

Send nominations to:
Programs That Make a Difference
c/o Ellen Maycock
American Mathematical Society
201 Charles Street
Providence, RI 02904
or via email to ejm@ams.org

Recent Winners:

2013: Nebraska Conference for Undergraduate Women in Mathematics (NCUWM).

2012: Mathematical Sciences Research Institute.

2011: Center for Women in Mathematics, Smith College;
Department of Mathematics, North Carolina State University.

2010: Department of Compuational and Applied Mathematics (CAAM), Rice University;
Summer Program in Quantitative Sciences, Harvard School of Public Health.

AMS
American Mathematical Society
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AMERICAN MATHEMATICAL SOCIETY

AMS EXEMPLARY PROGRAM AWARD

The AMS Award for Exemplary Program or Achievement in a Mathematics Department is presented annually to a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of the society. Examples might include a department that runs a notable minority outreach program, a department that has instituted an unusually effective industrial mathematics internship program, a department that has promoted mathematics so successfully that a large fraction of its university's undergraduate population majors in mathematics, or a department that has made some form of innovation in its research support to faculty and/or graduate students, or which has created a special and innovative environment for some aspect of mathematics research.

The award amount is $5,000. All departments in North America that offer at least a bachelor's degree in the mathematical sciences are eligible.

The Award Selection Committee requests nominations for this award, which will be announced in Spring 2014. Letters of nomination may be submitted by one or more individuals. Nomination of the writer's own institution is permitted. The letter should describe the specific program(s) for which the department is being nominated as well as the achievements that make the program(s) an outstanding success, and may include any ancillary documents which support the success of the program(s). The letter should not exceed two pages, with supporting documentation not to exceed an additional three pages.

Nominations with supporting information should be submitted to www.ams.org/profession/prizes-awards/nominations. Those who prefer to submit by regular mail may send nominations to the AMS Secretary, Professor Carla D. Savage, North Carolina State University, Department of Computer Science, Campus Box 8206, Raleigh, NC 27695-8206. The nominations will be forwarded by the Secretary to the Prize Selection Committee.

Deadline for nominations is September 15, 2013.

Officers of the Society 2012 and 2013 Updates

Except for the members at large of the Council, the month and year of the first term and the end of the present term are given. For members at large of the Council, the last year of the present term is listed.

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Members of the Council, as provided for in Article 7, Section 4 (last sentence), of the Bylaws of the Society.

Hélène Barcelo 2/12–1/16
Ralph L. Cohen 2/11–1/15
Tara S. Holm 3/13–1/17
Bryna Kra 2/10–1/14
Joseph H. Silverman 2/09–2/13

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***Colloquium* Editorial Committee**
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***Proceedings* Editorial Committee**
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Karen Vogtmann 2/08–1/18

Call for Nominations

2014

Frank and Brennie Morgan AMS-MAA-SIAM Prize

for Outstanding Research in Mathematics by an Undergraduate Student

The prize is awarded each year to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics. Any student who is an undergraduate in a college or university in the United States or its possessions, or Canada or Mexico, is eligible to be considered for this prize.

The prize recipient's research need not be confined to a single paper; it may be contained in several papers. However, the paper (or papers) to be considered for the prize must be submitted while the student is an undergraduate; they cannot be submitted after the student's graduation. The research paper (or papers) may be submitted for consideration by the student or a nominator. All submissions for the prize must include at least one letter of support from a person, usually a faculty member, familiar with the student's research. Publication of research is not required.

The recipients of the prize are to be selected by a standing joint committee of the AMS, MAA, and SIAM. The decisions of this committee are final. The 2014 prize will be awarded for papers submitted for consideration no later than June 30, 2013, by (or on behalf of) students who were undergraduates in December 2012.

Questions may be directed to:

Barbara T. Faires
Secretary
Mathematical Association of America
Westminster College
New Wilmington, PA 16172

Telephone: 724-946-6268
Fax: 724-946-6857
Email: faires@westminster.edu

Nominations and submissions should be sent to:

Morgan Prize Committee
c/o Carla Savage, Secretary
Box 8206
Computer Science Department
North Carolina State University
Raleigh, NC 27695-8206

Call for NOMINATIONS

The selection committees for these prizes request nominations for consideration for the 2014 awards, which will be presented at the Joint Mathematics Meetings in Baltimore, MD, in January 2014. Information about these prizes may be found at www.ams.org/profession/prizes-awards/prizes or in the January 2012 issue of the *Notices*, pp. 79-100.

BÔCHER MEMORIAL PRIZE

The Bôcher Prize, awarded for a notable paper in analysis published during the preceding six years, is awarded every three years. To be eligible, papers must be either authored by an AMS member or published in a recognized North American journal.

FRANK NELSON COLE PRIZE IN NUMBER THEORY

The Cole Prize in Number Theory, which recognizes a notable paper in number theory published during the preceding six years, is awarded every three years. To be eligible, papers must be either authored by an AMS member or published in a recognized North American journal.

LEVI L. CONANT PRIZE

The Levi L. Conant Prize is presented annually for an outstanding expository paper published in either the *Notices* or the *Bulletin of the American Mathematical Society* during the preceding five years.

Nominations with supporting information should be submitted using the online form available here: www.ams.org/profession/prizes-awards/nominations. Include a short description of the work that is the basis of the nominations, including complete bibliographic citations. A brief curriculum vitae for the nominee should be included. Those who prefer to submit by postal mail may send nominations to AMS Secretary, Carla Savage, Box 8206, Computer Science Department, North Carolina State University, Raleigh, NC 27695-8206. The nominations will be forwarded by the secretary to the appropriate prize selection committee, which will make final decisions on the awarding of these prizes.

Deadline for nominations is June 30, 2013.

125th Anniversary
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Call for NOMINATIONS

The selection committees for these prizes request nominations for consideration for the 2014 awards, which will be presented at the Joint Mathematics Meetings in Baltimore, MD, in January 2014. Information about these prizes may be found at www.ams.org/profession/prizes-awards/prizes or in the January 2012 issue of the *Notices*, pp. 79-100.

JOSEPH L. DOOB PRIZE

The Doob Prize recognizes a single, relatively recent, outstanding research book that makes a seminal contribution to the research literature, reflects the highest standards of research exposition, and promises to have a deep and long-term impact in its area. The prize is awarded every three years and the book must have been published within the six calendar years preceding the year in which it is nominated. Books may be nominated by AMS members, members of the selection committee, members of AMS editorial committees, or by publishers.

LEONARD EISENBUD PRIZE FOR MATHEMATICS AND PHYSICS

The Leonard Eisenbud Prize for Mathematics and Physics honors a work or group of works that brings mathematics and physics closer together. Thus, for example, the prize might be given for a contribution to mathematics inspired by modern developments in physics or for the development of a physical theory exploiting modern mathematics in a novel way. The prize is awarded every three years for a work published in the preceding six years.

DISTINGUISHED PUBLIC SERVICE AWARD

This award, which is made every two years, recognizes a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

Nominations with supporting information should be submitted using the online form available here: www.ams.org/profession/prizes-awards/nominations. Include a short description of the work that is the basis of the nominations, including complete bibliographic citations. A brief curriculum vitae for the nominee should be included. Those who prefer to submit by postal mail may send nominations to AMS Secretary, Carla Savage, Box 8206, Computer Science Department, North Carolina State University, Raleigh, NC 27695-8206. The nominations will be forwarded by the secretary to the appropriate prize selection committee, which will make final decisions on the awarding of these prizes.

Deadline for nominations is June 30, 2013.

125th Anniversary
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Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at http://www.ams.org/cgi-bin/mathcal-submit.pl. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at http://www.ams.org/mathcal/.

May 2013

* 21–24 **Encounters Between Discrete and Continuous Mathematics**, Institute of Mathematics, Eötvös Loránd University, Budapest, Hungary.

Description: Our goal is to bring together researchers from different fields, build new connections and highlight cooperation possibilities. There will be special sessions devoted to time integration of partial and delay differential equations, operator semigroups and evolution equations, and dynamic processes on networks.

Main speakers: Wolfgang Arendt (Ulm), Etienne Emmrich (Berlin), László Erdös (München), Sergey Korotov (Bilbao), Balázs Szegedy (Toronto), László Székelyhidi (Leipzig), Gerald Teschl (Wien), Vincenzo Vespri (Firenze), Zahari Zlatev (Roskilde).

Organizing committee: András Bátkai (Budapest), István Faragó (Budapest), László Lovász (Budapest), Rainer Nagel (Tübingen), Alexander Ostermann (Innsbruck).

Information: http://www.cs.elte.hu/applanal/events/encounters/.

* 27–31 **Geometric methods in PDE's: Indam meeting on the occasion of the 70th birthday of Ermanno Lanconelli**, Cortona, Arezzo, Italy.

Description: The scope of this conference is to celebrate the 70th birthday of Ermanno Lanconelli and to bring together Italian and foreign mathematicians to favour the discussion in the areas of research where Ermanno Lanconelli has been particularly active. Second order linear and nonlinear partial differential equations with non-negative characteristic form, Geometric problems related to the underlying algebraic, geometrical or topological structure, application to complex geometry and CR manifolds. These fields are the objects of active research and development, and possess a remarkable degree of interrelation in their pure and appllied aspects.

Information: http://lanconelli2013.dm.unibo.it/.

* 27–June 1 **5th Women in Mathematics Summer School on Mathematical Theories towards Environmental Models**, The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy.

Description: The school aims at approaching different core problems of pure and applied mathematics in a multidisciplinary perspective. It will consist of short courses focusing on four topics of current research: 1. Nonlinear Partial Differential Equations; 2. Dynamical Systems and Bifurcation Theory with Applications to the Dynamics of Planet Earth; 3. Isogeometric Analysis; 4. Numerical Analysis of Environmental Flows. Each short course consists of an introductory part, a more advanced one, together with problem solving and tutorial sessions. The European Women in Mathematics summer schools aim at providing a stimulating intellectual environment for Ph.D. students and post-docs from different countries and different mathematical disciplines. A major scope is to encourage the active participation of women in higher mathematics. Partici-

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.

An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. If there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to notices@ams.org or mathcal@ams.org.

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **eight months** prior to the scheduled date of the meeting.

The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June/July, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: http://www.ams.org/.

pants and lecturers will be of both sexes. This Summer School is part of the international initiative "Mathematics of Planet Earth 2013".
Information: http://agenda.ictp.it/smr.php?2468.

* 28–31 **ESF Exploratory Workshop: Noise in Decision Making: Theory Meets Experiment**, Sant Fruitós de Bages, Catalonia.
Organizers: Albert Compte, IDIBAPS, Barcelona; Gustavo Deco, Universitat Pompeu Fabra; Jaime de la Rocha, IDIBAPS, Barcelona; Alex Roxin, Centre de Recerca Matemàtica; Klaus Wimmer, IDIBAPS, Barcelona.
Information: http://www.crm.cat/2013/DecisionMaking.

* 29–June 2 **The Fourth Conference on Computational and Mathematical Population Dynamics (CMPD4)**, Taiyuan, China.
Description: The previous joint conferences were CMPD1 (Trento, Italy, 2004); CMPD2 (Campinas, Brazil, 2007); CMPD3 (Bordeaux, France, 2010).
Goal: Of this international conference is to bring together leading researchers from different fields (applied mathematics, biology, computer science, ecology, epidemiology, medicine, public health, etc.) to report and communicate with each other about their current work on computational and mathematical population dynamics. The conference will also provide a unique opportunity for graduate students and postdoctoral fellows to interact with leading researchers in these areas.
Information: http://202.99.210.182:2013/Home/Index/1.

June 2013

* 3–7 **Workshop on Slow-Fast Dynamics: Theory, Numerics, Application to Life and Earth Sciences**, Centre de Recerca Matemàtica, Bellaterra, Barcelona.
Speakers: Freddy Dumortier (Hasselt University), Jean-Pierre Françoise (Pierre & Marie Curie University), Olivier Faugeras (INRIA Sophia Antipolis), G. Bard Ermentrout (University of Pittsburgh), Antoni Guillamon (Universitat Politècnica de Catalunya), John Guckenheimer (Cornell University), Christopher K. R. T. Jones (University of North Caroline).
Organizers: Peter De Maeschalck, University of Hasselt; Mathieu Desroches, INRIA; Mark Kramer, Boston University; Martin Krupa, INRIA; Serafim Rodrigues, University of Plymouth; Alexandre Vidal, University of Evry; Haiping Zhu, University of York.
Information: http://www.crm.cat/2013/WKEarthSciences.

* 10–11 **Workshop on Emergence, Spread and Control of Infectious Diseases**, Centre de Recerca Matemàtica, Bellaterra, Barcelona.
Organizer: Andrei Korobeinikov, Centre de Recerca Matemàtica, Bellaterra, Barcelona.
Committee: Àngel Calsina, Universitat Autònoma de Barcelona; Joan Saldaña, Universitat de Girona; Vladimir Sobolev, Samara State Aerospace University.
Information: http://www.crm.cat/2013/InfectiousDiseases.

* 10–14 **Fourth International Conference on Geometry, Dynamics, Integrable Systems – GDIS 2013**, Udmurt State University, Izhevsk, Russia.
Main topics: Nonholonomic mechanics and multi-body dynamics, systems with friction, classical mechanical integrable systems, optimal control and mechanics, algebro-geometric methods in mechanics, applications to robototechnics and biomechanics.
Information: http://www.mi.sanu.ac.rs/~gdis2013/.

* 11–14 **Continued Fractions, Interval Exchanges and Applications to Geometry**, Centro di Ricerca Matematica Ennio De Giorgi, Palazzo Puteano, Piazza dei Cavalieri 3, Pisa, Italy.
Description: The workshop will focus on the interplay between dynamical systems and arithmetic, and in particular on the study of arithmetic algorithms of significance in dynamics and geometry.
Registration: Is free. Participants are requested to register on the website of the conference: http://www.crm.sns.it/event/272/registration.html whence further details and updates can be retrieved as well. Some funds are available to offer financial support to a number of selected young researchers and students for their participation in the Workshop. Applications can be made on-line through http://www.crm.sns.it/event/272/financial.html. Planned activities include a few contributed talks. Those who wish to propose a talk should send title and abstract to: dysys.pisa@gmail.com.
Deadlines: For application for financial support and talk proposal: March 31, 2013. For Registration: May 25, 2013.
Information: http://www.crm.sns.it/event/272/.

* 13–15 **30th Annual Workshop in Geometric Topology**, Calvin College, Grand Rapids, Michigan.
Description: Pedro Ontaneda of Binghamton University will give a series of three one-hour lectures on "Riemannian Hyperbolization". Attendees are invited to contribute talks. Funds, provided by the NSF, are available to support travel by graduate students and those without other sources of funding.
Information: http://www.calvin.edu/~venema/workshop13/.

* 17–20 **7th Annual International Conference on Mathematics**, Athens Institute for Education and Research, Athens, Greece.
Description: The conference is soliciting papers (in English only) from all areas of Mathematics and other related areas. Selected (peer-reviewed) papers will be published in a Special Volume of the Conference Proceedings.
Information: http://www.atiner.gr/mathematics.htm.

* 17–21 **Conference on Variational Problems and Geometric PDE's**, Granada, Spain.
Organizing committee: Joaquín Pérez, Universidad de Granada; Antonio Ros, Universidad de Granada; Francisco Martín, Universidad de Granada.
Information: http://gigda.ugr.es/granada2013.

* 18–21 **Financial Engineering Summer School (FESS2013)**, Bolsa de Barcelona, Spain.
Description: 4 courses: Damiano Brigo (Imperial College), Consistent Modeling of Counterparty Credit Risk, Collateral and Funding Costs; Jim Gatheral (Baruch College, NY), The Volatility Surface: Statics and Dynamics; Richard Martin (Longwood Credit Partners), Hedge Fund Trading Strategies; Alexander McNeil (Heriot-Watt University), Credit Risk Models and the Changing Regulatory Environment.
Organizers: Joan del Castillo, Universitat Autònoma de Barcelona, Paul MacManus, Analistas Financieros Internacionales.
Information: http://www.crm.cat/FESS2013.

* 23–30 **Bogolyubov readings DIF-2013. Differential equations, theory of functions and their applications**, Sevastopol Institute of Banking, Sevastopol, Ukraine.
Description: The conference is dedicated to Academician of National Academy of Sciences of Ukraine Professor A. M. Samoilenko on the occasion of his 75th anniversary.
Conference sections: Differential equations and nonlinear oscillations, theory of functions, mathematical problems of mechanics, mathematical modeling of economic, financial and insurance processes, stochastic differential equations.
Information: http://www.imath.org.ua/?lang=en.

* 24–28 **The Second Pacific Rim Mathematical Association Congress (PRIMA-2013)**, Shanghai Jiao Tong University, Shanghai, China.
Description: PRIMA is an association of mathematical sciences institutes, departments and societies from around the Pacific Rim, established in 2005 with the aim of promoting and facilitating the development of the mathematical sciences throughout the Pacific Rim region. Its congress is held every four years. The first congress

was held in 2009 in Sydney, Australia. The second PRIMA congress in Shanghai will feature 2 public lectures and 11 plenary speakers from distinguished mathematicians, and 23 special sessions covering all major areas of mathematics. The conference also welcomes contributed talks and other participants.

Information: http://meeting.healife.com/prima2013/en/index.asp.

Grant: The NSF has awarded a substantial grant for travel by scientists at US universities to the PRIMA Congress in Shanghai. You do not need to be a US citizen to apply. For further information and application details, please see http://www.mathprograms.org/db/programs/152. Applications from women and underrepresented minorities are especially encouraged.

* 25–28 **Advanced Course on Topics in Conformal Geometry and Geometry Analysis**, Centre de Recerca Matématica, Bellaterra, Barcelona.

Speakers: William Meeks (University of Massachusetts at Amherst), Alice Chang (Princeton University), Charles Fefferman (Princeton University).

Organizing and Scientific Committee: Sun-Yung Alice Chang, Princeton University; Maria del Mar González, Universitat Politècnica de Catalunya; Robin Graham, University of Washington; Francisco Martìn, Universidad de Granada; Paul Yang, Princeton University.

Information: http://www.crm.cat/2013/ACConformalGeometry.

July 2013

* 1–5 **Conference on Geometrical Analysis**, Centre de Recerca Matemática, Bellaterra, Barcelona.

Speakers: Spyros Alexakis (University of Toronto), Tobias Colding (Massachusetts Institute of Technology), Rod Gover (University of Auckland), Matthew Gursky (University of Notre Dame), Emmanuel Hebey (Universit Cergy Pontoise), Kengo Hirachi (The University of Tokyo), Andreas Juhl (Humboldt Universitt zu Berlin), Robert Kusner (University of Massachusetts at Amherst), Andrea Machiodi (International School for Advanced Studies, SISSA), Jie Qing (University of California at Santa Cruz), Jeff Viaclovsky (University of Wiscondin-Madison).

Organizing and Scientific Committee: Sun-Yung Alice Chang, Princeton University; Maria del Mar González, Universitat Politècnica de Catalunya; Robin Graham, University of Washington; Francisco Martìn, Universidad de Granada; Paul Yang, Princeton University.

Information: Visit http://www.crm.cat/2013/CGeometricalAnalysis/.

* 1–5 **Oxford Conference on Challenges in Applied Mathematics (OCCAM)**, St Anne's College, Oxford, United Kingdom.

Description: OCCAM is delighted to announce a major conference celebrating five years of international, interdisciplinary, collaborative applied mathematics to be held in Oxford from 1-5 July 2013. The Oxford Conference on Challenges in Applied Mathematics (OCCAM) will cover the four keys areas of: Continuum mechanics (Monday, July 1), energy and resources (Tuesday, July 2), bioscience (Wednesday, July 3), methodologies (Thursday, July 4th and Friday July 5th). The conference will be both a celebration of what we and our partners have achieved so far and an insight into the latest thinking from scientists across the academic world. In the spirit of OCCAM there will be plenty of time for delegates to get involved via Q & A, discussion, and informal collaboration.

Confirmed speakers: Available on the conference homepage and registration is via online form only: http://www.maths.ox.ac.uk/groups/occam/events/occam/registration.

Information: http://www.maths.ox.ac.uk/groups/occam/events/oxford-conference-challenges-applied-mathematics.

* 8–12 **Mathematics of Planet Earth Australia 2013**, RMIT, Melbourne, VIC, Australia.

Description: This conference is the central academic event of Maths of Planet Earth Australia 2013. The conference will provide a forum for researchers, educators, students, contributors, users of mathematical knowledge and industries to exchange ideas, discuss research findings and new advancements in mathematics and statistics highlighting the influence the mathematical sciences have on solving the challenges of our planet.

Conference themes: Complex systems, scientific data mining, earth system modeling, mitigating natural disaster risk and bioinvasion and biosecurity.

Information: http://mathsofplanetearth.org.au/events/2013/.

* 9–12 **Moduli-Operads-Deformations**, Buskerud University College, Kongsberg, Norway.

Description: The main purpose of the conference is to stimulate and promote interactions between the following major research areas: moduli, deformation theory, operads, dynamics.

Main topics: Include, but are not limited to: Architecture and dynamics of clone/operadic systems, deformation theory and quantization, Hopf algebra, integrable models, Lie theory, representation theory, mathematical methods of quantum physics, moduli, noncommutative geometry, quantum information.

Information: http://www.agmp.eu/mod13.

* 15–19 **General Algebra and its Applications GAIA2013**, La Trobe University, City Campus, Melbourne, Victoria, Australia.

Description: Join us at this conference Down Under! This conference is built around the celebration of the retirement and 65th birthday of eminent Australian algebraist Professor Brian Davey. The main theme is universal algebra, its applications and neighbouring disciplines. This includes, but is not limited to, orders and lattices, semigroups, algebraic logic and model theory, algebraic methods in computer science. The conference incorporates workshop elements and is partially sponsored by the Australian Mathematical Sciences Institute and the Australian Mathematical Society.

Information: http://gaia.ltumathstats.com.

* 15–19 **Symmetries of Discrete Systems and Processes**, Decin, Czech Republic, North Bohemia.

Description: The aim of the conference is to present recent results on symmetries of discrete systems and processes and their application in physics, integrable systems etc. The conference will give the participants a unique opportunity to present their results in this field, see the results of others and discuss the many foreseeable developments. Conference participants are invited to submit original papers to the electronic journal SIGMA (Symmetry, Integrability and Geometry: Methods and Applications). Each paper will pass through the standard peer reviewing procedure of SIGMA.

Information: http://spmdd.fjfidecin.cz/conference-details.

* 22–25 **Moscow International Conference "Israel Gelfand Centenary"**, Russian Academy of Science, Leninski Ave., Moscow, Russia.

Description: Russian Academy of Sciences together with the Moscow Mathematical Society and Independent University of Moscow organize an international conference dedicated to the centenary of Israel Gelfand.

Invited speakers: J. Bernstein, B. Bollobás, P. Etingof, L. Faddeev, D. Fuchs, A. Goncharov, D. Kazhdan, A. Kirillov, M. Kontsevich, I. Krichever, A. Kushnirenko, Yu. Manin, S. Novikov, A. Okounkov, G. Olshanski, A. Shen, S. Smirnov, A. Vershik, V. Zakharov, A. Zamolodchikov. The conference will also feature talks related to Gelfand's work in biology, applied mathematics, and mathematical education.

Information: http://gelfand100.iitp.ru/.

* 22–August 9 **Complex Geometry**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: This program concerns the study of the various geometric properties of complex manifolds, and more generally complex analytic varieties. Complex manifolds/varieties arise naturally in and are deeply connected to other branches of mathematics, including hyperbolic geometry, symplectic geometry, number theory and mathematical physics such as string theory. The aim of this program is to bring together groups of complex analysts, complex differential geometers and complex algebraic geometers to: (i) explain to other groups their methods and techniques; (ii) survey recent developments and disseminate their own research findings relating broadly to the area of complex geometry; (iii) chart new directions of research; and (iv) explore possible collaborations, especially among the different groups.
Information: `http://www2.ims.nus.edu.sg/Programs/013complex/index.php`.

* 23–26 **4th Canadian Conference on Nonlinear Solid Mechanics (CanCNSM2013)**, McGill University, Montreal, Quebec, Canada.
Description: CanCNSM Conferences are intended to provide an international opportunity for communicating recent developments in various areas of nonlinear solid mechanics and materials. After 3 successful conferences in Victoria (1999), Vancouver (2002) and Toronto (2008), the 4th Canadian Conference on Nonlinear Solid Mechanics will be held in July 23–26, 2013 at McGill University which is best recognized for its research and discoveries in different fields of science. The framework of CanCNSM2013 is truly multidisciplinary and scientists from all over the world are encouraged to contribute to the conference. The technical program will include 6 plenary speakers, regular sessions including contributing papers, and 29 mini-symposium sessions on pre-defined topics of nonlinear solid mechanics as well as areas of linear solid mechanics that are bridging nonlinear aspects.
Information: `http://cancnsm2013.mcgill.ca/index.html`.

August 2013

* 5–16 **International Cimpa School: "New Trends in Applied Harmonic Analysis Sparse Representations, Compressed Sensing and Multifractal Analysis"**, Mar del Plata, Argentina.
Description: The purpose of this school is to focus on two particularly active areas which are representative of new interactions between harmonic analysis and signal and image processing that had striking developments in the last 10 years: "Sparse Representation and Compressed Sensing" and "Multifractal Analysis". Graduate students are encouraged to participate.
Deadline: For Registration is April 7, 2013.
Confirmed Courses by: Patrice Abry, Ingrid Daubechies, Hans Feichtinger, Simon Foucart, Kathryn Hare, Stéphane Mallat, Thomas Strohmer, Stéphane Seuret, Vladimir Temlyakov.
Confirmed Plenary Speakers: John Benedetto, Pete Casazza, Patrick Flandrin, Eugenio Hernández, Gitta Kutyniok, Michael Lacey, Yurii Liyubarsky, M. van der Hoop, Sandra Saliani, Rodolfo Torres, Rene Vidal, Yang Wang, Przemyslaw Wojtaszczyk.
Information: Check the website for updated information: `http://nuhag.eu/cimpa13`.

* 12–17 **18th International Summer School on Global Analysis and Applications**, Juraj Pales Institute, Bottova 15, Levoca, Slovakia.
Description: The 2013 Summer School is the 18th International Summer School on Global Analysis and Applications, organized every year since 1996 by professor Demeter Krupka and his collaborators (see Global Analysis and Applications and Past Summer Schools). It is held in the beautiful medieval town of Levoca, written in the UNESCO list (`http://whc.unesco.org/en/list/620`). Like in the past, the programme of the school consists of two courses, delivered by recognized specialists in the field. Newly, to support the young participants in their scientific activity, the commented poster session is organized, contributions are published in abstract books and there is also a time reserved for discussions. The following social events will be organized: sightseeing tours around the town of Levoca and surrounding parts of beautiful Slovak region Spis, conference party.
Information: `http://www.lepageri.eu/ga2013/`.

* 12–October 11 **Mathematical Horizons for Quantum Physics 2**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Quantum theory is one of the most important intellectual developments of the early twentieth century. Since then there has been much interplay between theoretical physics and mathematics, both pure and applied. In this tradition, it is the objective of this IMS Programme to bring together mathematicians whose work has a bearing on quantum physics, with researchers in mathematical physics and theoretical physics whose work will benefit from the mathematical progress. The Programme will consist of four overlapping three-week sessions, each devoted to a selected topic: Quantum information theory; information-theoretic approaches to thermodynamics; many-particle systems and open quantum systems.
Information: `http://www2.ims.nus.edu.sg/Programs/013mhqp/index.php`.

* 19–23 **Differential Geometry and its Applications**, Masaryk University, Old campus, Brno, Czech Republic.
Invited Plenary Speakers: Andrei Agrachev, Trieste, Italy; Serguei Barannikov, Paris, France; Karsten Grove, Notre Dame, USA; Shrawan Kumar, Chapel Hill, USA; Ernst Kuwert, Freiburg, Germany; Colleen Robles, College Station, USA; Jian Song, Rutgers, USA; further speakers in negotiation.
Parallel Programme Sessions: Riemannian and pseudo-Riemannian Geometry and Submanifolds (chaired by O. Kowalski); General Geometric Structures (chaired by I. Kolár); Algebra, Geometry, and Mathematical Physics (chaired by S. Merkulov and O. Rossi); Special Structures and Representation Theory (chaired by A. Cap and J. Slovák); Geometric Complexity Theory (chaired by J. M. Landsberg); Finsler Geometry and its Applications (chaired by Z. Shen); Geometry of Vision and Neurogeometry (chaired by D. Alekseevsky); Geometry of Non-linear PDEs (chaired by A. Vinogradov).
Information: See the web page for more information and registration: `http://www.math.muni.cz/DGA2013/`.

* 19–23 **GAP XI Pittsburgh - Geometry and Physics "Seminaire Itinerant"**, University of Pittsburgh, Pittsburgh, Pennsylvania.
Description: This is the eleventh edition of the annual GAP conference and summer school: Geometry and Physics: "Séminaire itinérant", "Higher Geometry and Quantum Field Theory".
Mini-course speakers: Ulrich Bunke (Regensburg), Kevin Costello (Northwestern), Stephan Stolz (Notre Dame).
Plenary speakers: To be announced.
Fee and support: The attendance fee is $0. There will be limited support for travel and housing for young U.S. participants. It is recommended to apply early.
Deadline: For applications is May 15, 2013.
Information: `http://www.geometryandphysics.org/`.

* 23–25 **14th International Pure Mathematics Conference 2013**, Islamabad, Pakistan.
Location: The entire conference will be organized under one roof at the Margalla Hotel, in the modern, peaceful and beautiful federal capital of Pakistan located at the footsteps of the scenic Margalla Hills.
Description: The conference is the 14th international conference in the series of Pure Mathematics Conferences that take place in Islamabad every year in August/September. It is a thematic conference on algebra, geometry, and analysis held under the auspices of the Pakistan Mathematical Society (`http://www.pakms.org.pk`) and Algebra Forum (`http://www.algebraforum.org.pk`).
Housing/grants: There will be free housing for foreign participants. Some travel grants are available for foreign speakers. Several free

recreational trips will be organized in and around Islamabad introducing the unique local and multi-ethnic culture.

Registration: For registration please fill in the on-line registration form at http://www.pmc.org.pk and find more information therein. The conference is convened by Professor Dr. Qaiser Mushtaq (Department of Mathematics, Quaid-i-Azam University, Islamabad, Pakistan, president@pakms.org.pk). http://www.pakms.org.pk.

September 2013

* 4–6 **Loday Memorial Conference**, Institut de Recherche Mathématique Avancée (IRMA), Strasbourg, France.

Description: Jean-Louis Loday, directeur de recherche CNRS in Strasbourg, suddenly passed away on June 6, 2012. This conference, in his memory, aims to give a general picture of the research that he passed down to the mathematical community, notably the study of the interplays between algebraic K-theory and cyclic homology, and the applications of the theory of algebraic operads.

Speakers: Pierre Cartier (IHES), Alain Connes (Collège de France), Pierre-Louis Curien (Université Paris 7), Vladimir Dotsenko (Trinity College Dublin), Alice Fialowski (Eötvös Loránd University), Hebert Gangl (Durham University), Grégory Ginot (Université Paris 6), Lars Hesselholt (Nagoya University), Mikhail Kapranov (Yale University), Teimuraz Pirashvili (Leicester University), Maria Ronco (Talca University), Christophe Soulé (IHES), Jean-Yves Thibon (Université Paris Est), Boris Tsygan (Northwestern University), Bruno Vallette (Université de Nice).

Information: http://www-irma.u-strasbg.fr/article1351.html.

* 9–11 **Aachen Conference on Computational Engineering Science (AC.CES)**, AC.CES takes place at RWTH Aachen University (SuperC building), Germany.

Description: AC.CES will bring together leading experts in theory, method development, and applications in computational engineering. The main objectives of the conference are to present cutting-edge research and to foster the growth of a stronger CES community, as well as to facilitate collaborations and cross-fertilization of ideas across the different CES disciplines. The conference consists of a series of plenary sessions featuring invited talks by leading experts; these will be accompanied by poster sessions. During the three days topics such as uncertainty quantification, inverse problems in materials science, computational biology, model order reduction, optimization and control, as well as imaging/tomographic inversion will be presented and discussed. The following invited speakers have confirmed their attendance at AC.CES: http://www.ac-ces.rwth-aachen.de/MainContents/KeynoteLect.php. If you have specific questions contact the organizers at acces@aices.rwth-aachen.de.

Information: http://www.ac-ces.rwth-aachen.de/.

* 12–14 **The Algerian-Turkish International Days on Mathematics 2013**, Fatih University, Istanbul, Turkey.

Description: The aim of this conference is to provide a platform for scientific expertise in mathematics to present their recent works, exchange ideas and to bring together mathematicians to improve collaboration between local and international participants.

Information: http://atim.fatih.edu.tr/.

* 21–23 **The First International Conference on New Horizons in Basic and Applied Science Session "Aspects of Mathematics and its Applications"**, Hurghada, Egypt.

Description: The first international conference "New horizons in basic and applied science" (ICNHBAS) provides a unique opportunity for scientists, scholars, engineers and students from the universities, technologists, entrepreneurs and policy makers all around the world to present current researches being carried out in basic and applied science area. The conference promotes for the delegates to exchange new ideas and application experiences face to face, to establish business or research relations and to find global partners for future collaboration. The conference will also have numerous invited talks from distinguished scientists from all over the world, to interact with the experts in their fields and to foster interdisciplinary collaborations required to meet the challenges of modern science, technology and society. All the papers that are submitted to the conference will undergo a review process for either oral or poster presentation.

Information: http://www.nhbas2013.com.

October 2013

* 24 **3rd IMA Mathematics in Defence**, QinetiQ, Malvern, United Kingdom.

Description: This conference brings together a wide variety of mathematical methods with defence and security applications. The conference programme will include keynote speakers, contributed presentations and poster sessions as well as refreshment breaks for informal discussions. It is intended for mathematicians, scientists and engineers from industry and academia, as well as government and military personnel who have an interest in how mathematics can be applied to defence problems.

Information: http://www.ima.org.uk/conferences/conferences_calendar/3rd_mathematics_in_defence.cfm.

* 28–31 **Groups, Group Rings, and Related Topics GGRRT 2013**, United Arab Emirates University, Al Ain, United Arab Emirates.

Description: The conference will include talks given by well-known invited algebraists and a poster session. In parallel, a workshop on GAP (Groups, Algorithms, and Programming) System for Computational Discrete Algebra will be given by the GAP Development Group of St. Andrews University (UK). Conference proceedings will be electronically edited by the scientific committee. In addition, selected peer-reviewed papers will be published in a special edition of the *International Journal of Group Theory*. The social activities will include a short trip to Jebel Hafeet, a conference dinner, and a trip to Dubai ending with a dinner on a boat cruising along Dubai Creek.

Registration and abstract submission: Must be before September 15th, 2013. A discount will be given for early registration (before June 15th, 2013).

Information: http://www.cos.uaeu.ac.ae/department/mathematical/conferences/GGRRT_2013/.

November 2013

* 11–14 **SIAM Conference on Geometric and Physical Modeling (GD/SPM13)**, The Curtis, A DoubleTree by Hilton Hotel, Denver, Colorado.

Description: This conference is sponsored by the SIAM Activity Group on Geometric Design, incorporating the 2013 SIAM Conference on Geometric Design and the 2013 Symposium on Solid and Physical Modeling.

Information: http://www.siam.org/meetings/gdspm13/.

* 11–15 **Mal'tsev Meeting 13**, Sobolev Institute of Mathematics SB RAS, Novosibirsk, Russia.

Description: Mal'tsev Meeting is an annual conference on algebra, mathematical logic, and their applications. In 2013, the event is dedicated to an anniversary of Professor Larisa L. Maksimova.

Topics: Include nonclassical logics, computability, theories of groups, rings, and other classical algebras, model theory and universal algebra, applications in computer science, and other related areas of mathematics.

Information: http://www.math.nsc.ru/conference/malmeet/13/index.html.

December 2013

* 18–20 **6th Indian International Conference on Artificial Intelligence**, Tumkur (near Bangalore), India.
Description: The 2013 International Conference on Advances in Data Mining and Security Informatics (DMSI-13) and the 2013 International Conference on Image, Video and Signal Processing (IVSP-13) will also be held at the same time and place. We invite draft paper submissions. IICAI is a series of high quality technical events in Artificial Intelligence (AI) and is also one of the major AI events in the world. The conference will be held every two years to make it an ideal platform for people to share views and experiences in AI and related areas.
Information: For more details visit: `http://www.iiconference.org`.

March 2014

* 10–26 **School and Workshop on Classification and Regression Trees**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Classification and regression trees are an integral part of the toolbox of data mining, machine learning, and statistics. The year 2013 marks the fiftieth anniversary of the publication of the first journal article on the subject. New techniques have added capabilities that far surpass the early methods. Modern classification trees can partition the data with linear splits on subsets of variables and fit nearest-neighbor, kernel-density, and other models in the partitions. Regression trees can fit almost every kind of traditional statistical model, including least-squares, quantile, logistic, Poisson and proportional hazards models, as well as models for censored, longitudinal and multi-response data. The purpose of the workshop is to bring together current experts in the field to discuss recent developments and generate ideas for future research. The purpose of the school is to introduce the subject to other researchers and practitioners who are interested to learn the techniques.
Information: `http://www2.ims.nus.edu.sg/Programs/014swclass/index.php`.

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

May 2014

* 26–30 **Constructive Functions 2014**, Vanderbilt University, Nashville, Tennessee.
Description: The focus of this conference is on all aspects of constructive function theory, from asymptotics to zero distribution, and on minimum energy problems on manifolds. The conference will honor the 70th birthday of Ed Saff.
Information: `http://www.math.vanderbilt.edu/~constructive2014/`.

June 2014

* 2–5 **VI Workshop on Dynamical Systems: On the occasion of Marco Antonio Teixeira's 70th birthday (MAT70)**, Águas de Lindóia, Sao Paulo, Brazil.
Description: In 2014 we wish to celebrate Marco Antonio Teixeira's 70th birthday and his significant mathematical contribution. With this in mind, we wish to honor him with a Scientific Conference to be held in a small tourist town in the interior of the state of São Paulo, Águas de Lindóia, from June 2–5, 2014.
Main topics: Non-Smooth Dynamical Systems and Conservative/Reversible Dynamical Systems.
Information: `http://www.mat70.com/`.

* 23–28 **6th International Conference on Advanced Computational Methods in Engineering**, NH Gent Belfort, Gent, Belgium.
Description: ACOMEN 2014 is the 6th event in a successful series of interdisciplinary international conferences, which aims to bring together a diverse community of mathematicians, engineers, and physicists involved in applied sciences, mathematics and developing advanced computational methods. The main topics of ACOMEN include but are not limited to: applied mathematics, numerical analysis and computational mathematics, financial mathematics, optimization and optimal control, inverse problems, computational finance, computational electromagnetism, fluid dynamics, heat transfer and porous media flow, computational chemistry, computational biology and medicine, computational geosciences high-scale and parallel computing, software for scientific computations.
Information: `http://www.acomen.ugent.be`.

November 2014

* 11–January 25 **Inverse Moment Problems: The Crossroads of Analysis, Algebra, Discrete Geometry and Combinatorics**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Applications of moments of measures in polynomial optimization led to a number of breakthroughs in optimization and real algebraic geometry, as well as to better understanding of ways to encode measures. Other similar threads are recently seen in the theory of integration on polytopes and counting of integer points in polytopes, as well as in quantum computing. The aim of the program is to futher investigate relations between these topics and inverse moment problems, i.e., questions of reconstructing measures from a set of its moments, which are traditionally attacked by purely analytic tools. Activities will include two 4–5 day research conferences, one quantum computing workshop, and one graduate student winter school/workshops.
Information: `http://www2.ims.nus.edu.sg/Programs/014inverse/index.php`.

September 2015

* 1–August 31 **Call for Research Programmes 2015-2016**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: The CRM invites proposals for Research Programmes during the academic year 2015–2016 in any branch of mathematics and its applications. CRM Research Programmes consist of periods ranging between two to five months of intensive research in a given area of mathematics and its applications. Researchers from different institutions are brought together to work on open problems and to analyze the state and perspectives of their area.
Deadlines for submission of proposals: November 29, 2013, for preliminary proposals and October 25, 2013, for final proposals.
Information: `http://www.crm.cat/en/Pages/DetallCrida.aspx?ItemID=7`.

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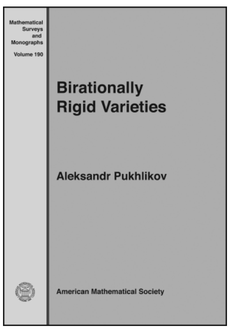
Algebra and Algebraic Geometry



Birationally Rigid Varieties

Aleksandr Pukhlikov, *University of Liverpool, United Kingdom*

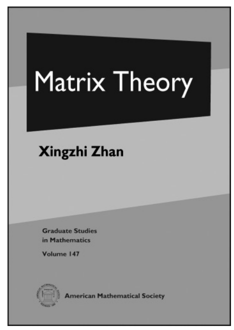
Birational rigidity is a striking and mysterious phenomenon in higher-dimensional algebraic geometry. It turns out that certain natural families of algebraic varieties (for example, three-dimensional quartics) belong to the same classification type as the projective space but have radically different birational geometric properties. In particular, they admit no non-trivial birational self-maps and cannot be fibred into rational varieties by a rational map. The origins of the theory of birational rigidity are in the work of Max Noether and Fano; however, it was only in 1970 that Iskovskikh and Manin proved birational superrigidity of quartic three-folds. This book gives a systematic exposition of, and a comprehensive introduction to, the theory of birational rigidity, presenting in a uniform way, ideas, techniques, and results that so far could only be found in journal papers.

The recent rapid progress in birational geometry and the widening interaction with the neighboring areas generate the growing interest to the rigidity-type problems and results. The book brings the reader to the frontline of current research. It is primarily addressed to algebraic geometers, both researchers and graduate students, but is also accessible for a wider audience of mathematicians familiar with the basics of algebraic geometry.

Contents: Introduction; The rationality problem; The method of maximal singularities; Hypertangent divisors; Rationally connected fibre spaces; Fano fibre spaces of $\mathbb{P}^1$; Del Pezzo fibrations; Fano direct products; Double spaces of index two; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 190

July 2013, approximately 368 pages, Hardcover, ISBN: 978-0-8218-9476-7, LC 2013001454, 2010 *Mathematics Subject Classification:* 14E05, 14E07, 14J45, 14E08, 14E30, 14M22, 14M10, 14M20, 14J30, 14J40, **AMS members US$78.40**, List US$98, Order code SURV/190



Matrix Theory

Xingzhi Zhan, *East China Normal University, Shanghai, China*

Matrix theory is a classical topic of algebra that had originated, in its current form, in the middle of the 19th century. It is remarkable that for more than 150 years it continues to be an active area of research full of new discoveries and new applications.

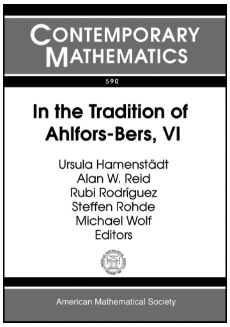
This book presents modern perspectives of matrix theory at the level accessible to graduate students. It differs from other books on the subject in several aspects. First, the book treats certain topics that are not found in the standard textbooks, such as completion of partial matrices, sign patterns, applications of matrices in combinatorics, number theory, algebra, geometry, and polynomials. There is an appendix of unsolved problems with their history and current state. Second, there is some new material within traditional topics such as Hopf's eigenvalue bound for positive matrices with a proof, a proof of Horn's theorem on the converse of Weyl's theorem, a proof of Camion-Hoffman's theorem on the converse of the diagonal dominance theorem, and Audenaert's elegant proof of a norm inequality for commutators. Third, by using powerful tools such as the compound matrix and Gröbner bases of an ideal, much more concise and illuminating proofs are given for some previously known results. This makes it easier for the reader to gain basic knowledge in matrix theory and to learn about recent developments.

Contents: Preliminaries; Tensor products and compound matrices; Hermitian matrices and majorization; Singular values and unitarily invariant norms; Perturbation of matrices; Nonnegative matrices; Completion of partial matrices; Sign patterns; Miscellaneous topics; Applications of matrices; Unsolved problems; Bibliography; Notation; Index.

Graduate Studies in Mathematics, Volume 147

July 2013, approximately 254 pages, Hardcover, ISBN: 978-0-8218-9491-0, 2010 *Mathematics Subject Classification:* 15-01, 15A18, 15A21, 15A60, 15A83, 15A99, 15B35, 05B20, 47A63, **AMS members US$52**, List US$65, Order code GSM/147

Analysis



In the Tradition of Ahlfors-Bers, VI

Ursula Hamenstädt, *University of Bonn, Germany*, **Alan W. Reid**, *University of Texas at Austin, TX*, **Rubí Rodríguez**, *Pontificia University Catholic of Chile, Santiago, Chile*, **Steffen Rohde**, *University of Washington, Seattle, WA*, and **Michael Wolf**, *Rice University, Houston, TX*, Editors

The Ahlfors–Bers Colloquia commemorate the mathematical legacy of Lars Ahlfors and Lipman Bers. The core of this legacy lies in the fields of geometric function theory, Teichmüller theory, hyperbolic geometry, and partial differential equations. However, the work of Ahlfors and Bers has impacted and created interactions with many other fields of mathematics, such as algebraic geometry, dynamical systems, topology, geometric group theory, mathematical physics, and number theory. Recent years have seen a flowering of this legacy with an increased interest in their work.

This current volume contains articles on a wide variety of subjects that are central to this legacy. These include papers in Kleinian groups, classical Riemann surface theory, translation surfaces, algebraic geometry and dynamics. The majority of the papers present new research, but there are survey articles as well.

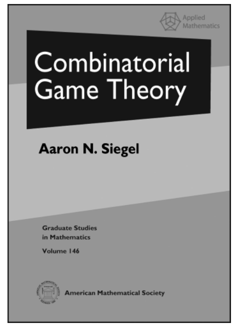
This item will also be of interest to those working in geometry and topology.

Contents: **S. Dowdall**, **M. Duchin**, and **H. Masur**, Spheres in the curve complex; **C. Florentino** and **S. Lawton**, Character varieties and moduli of quiver representations; **E. Fujikawa**, Periodicity of asymptotic Teichmüller modular transformation; **Z. Ibragimov**, Hyperbolization of locally compact non-complete metric spaces; **A. Isopoussu**, **K. Peltonen**, and **J. T. Tyson**, Quasiregular maps and the conductivity equation in the Heisenberg group; **C. Judge**, Pushing points on pillowcase covers; **T. Koberda**, Entropy of automorphisms, homology and the intrinsic polynomial structure of nilpotent groups; **G. F. Lawler**, Continuity of radial and two-sided radial *SLE* at the terminal point; **M. Matsuzaki** and **Y. Yabuki**, No proper conjugation for quasiconvex cocompact groups of Gromov hyperbolic spaces; **H. Miyachi**, A differential formula for extremal length; **O. Ostapyuk**, On convergence to the Denjoy-wolff point in the parabolic case; **S. Pal**, Construction of a closed hyperbolic surface of arbitrarily small eigenvalue of prescribed serial number; **J. Paupert**, A simple method to compute volumes of even-dimensional Coxeter polyhedra; **P. Poggi-Corradini**, Some remarks about analytic functions defined on an annulus; **H. Shiga**, On injectivity radius in configuration space and in moduli space.

Contemporary Mathematics, Volume 590

May 2013, approximately 190 pages, Softcover, ISBN: 978-0-8218-7427-1, 2010 *Mathematics Subject Classification:* 20-XX, 30-XX, 31-XX, 32-XX, 33-XX, 42-XX, 51-XX, 53-XX, 57-XX, 58-XX, **AMS members US$60.80**, List US$76, Order code CONM/590

Applications



Combinatorial Game Theory

Aaron N. Siegel, *San Francisco, CA*

Combinatorial game theory is the study of two-player games with no hidden information and no chance elements. The theory assigns algebraic values to positions in such games and seeks to quantify the algebraic and combinatorial structure of their interactions. Its modern form was introduced thirty years ago, with the publication of the classic *Winning Ways for Your Mathematical Plays* by Berlekamp, Conway, and Guy, and interest has rapidly increased in recent decades.

This book is a comprehensive and up-to-date introduction to the subject, tracing its development from first principles and examples through many of its most recent advances. Roughly half the book is devoted to a rigorous treatment of the classical theory; the remaining material is an in-depth presentation of topics that appear for the first time in textbook form, including the theory of misère quotients and Berlekamp's generalized temperature theory.

Packed with hundreds of examples and exercises and meticulously cross-referenced, *Combinatorial Game Theory* will appeal equally to students, instructors, and research professionals. More than forty open problems and conjectures are mentioned in the text, highlighting the many mysteries that still remain in this young and exciting field.

Aaron Siegel holds a Ph.D. in mathematics from the University of California, Berkeley and has held positions at the Mathematical Sciences Research Institute and the Institute for Advanced Study. He was a partner at Berkeley Quantitative, a technology-driven hedge fund, and is presently employed by Twitter, Inc.

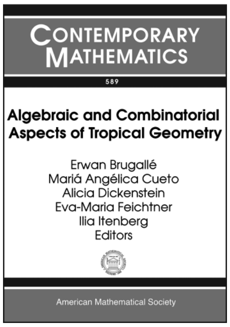
This item will also be of interest to those working in discrete mathematics and combinatorics.

Contents: Combinatorial games; Short games; The structure of $\mathbb{G}$; Impartial games; Misère play; Loopy games; Temperature theory; Transfinite games; Open problems; Mathematical prerequisites; A finite loopfree history; Bibliography; Glossary of notation; Author index; Index of games; Index.

Graduate Studies in Mathematics, Volume 146

July 2013, approximately 527 pages, Hardcover, ISBN: 978-0-8218-5190-6, LC 2012043675, 2010 *Mathematics Subject Classification:* 91A46, **AMS members US$71.20**, List US$89, Order code GSM/146

Discrete Mathematics and Combinatorics



Algebraic and Combinatorial Aspects of Tropical Geometry

Erwan Brugallé, *Université Pierre et Marie Curie (Paris 6), France*, **Mariá Angélica Cueto**, *Columbia University, New York, NY, and Goethe-Universität Frankfurt, Frankfurt am Main, Germany*, **Alicia Dickenstein**, *Universidad de Buenos Aires, Argentina*, **Eva-Maria Feichtner**, *University of Bremen, Germany*, and **Ilia Itenberg**, *Université Pierre et Marie Curie (Paris 6), France*, Editors

This volume contains the proceedings of the CIEM workshop on Tropical Geometry, held December 12–16, 2011, at the International Centre for Mathematical Meetings (CIEM), Castro Urdiales, Spain.

Tropical geometry is a new and rapidly developing field of mathematics which has deep connections with various areas of mathematics and physics, such as algebraic geometry, symplectic geometry, complex analysis, dynamical systems, combinatorics, statistical physics, and string theory. As reflected by the content of this volume, this meeting was mainly focused on the geometric side of the tropical world with an emphasis on relations between tropical geometry, algebraic geometry, and combinatorics.

This volume provides an overview of current trends concerning algebraic and combinatorial aspects of tropical geometry through eleven papers combining expository parts and development of modern techniques and tools.

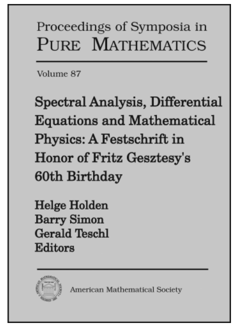
This item will also be of interest to those working in algebra and algebraic geometry.

Contents: B. Bertrand and **F. Bihan**, Intersection multiplicity numbers between tropical hypersurfaces; **B. Bertrand**, **L. L. de Medrano**, and **J.-J. Risler**, On the total curvature of tropical hypersurfaces; **M. Chan**, **M. Melo**, and **F. Viviani**, Tropical Teichmüller and Siegel spaces; **M. Chan** and **B. Sturmfels**, Elliptic curves in honeycomb form; **J. Draisma** and **B. Frenk**, Tropically unirational varieties; **W. Gubler**, A guide to tropicalizations; **Z. Izhakian**, **M. Knebusch**, and **L. Rowen**, Categorical notions of layered tropical algebra and geometry; **E. Katz**, Tropical realization spaces for polyhedral complexes; **P. Popescu-Pampu** and **D. Stepanov**, Local tropicalization; **F. Santos**, Some acyclic systems of permutations are not realizable by triangulations of a product of simplices; **K. M. Shaw**, Tropical $(1,1)$-homology for floor decomposed surfaces.

Contemporary Mathematics, Volume 589

May 2013, approximately 350 pages, Softcover, ISBN: 978-0-8218-9146-9, 2010 *Mathematics Subject Classification:* 14T05, 14T99, 51M20, 12J20, 14M25, 32P05; 14C30, 05E45, 14H52, 32S05, **AMS members US$88.80**, List US$111, Order code CONM/589

Mathematical Physics



Spectral Analysis, Differential Equations and Mathematical Physics: A Festschrift in Honor of Fritz Gesztesy's 60th Birthday

Helge Holden, *Norwegian University of Science and Technology, Trondheim, Norway*, **Barry Simon**, *California Institute of Technology, Pasadena, CA*, and **Gerald Teschl**, *University of Vienna, Austria*, Editors

This volume contains twenty contributions in the area of mathematical physics where Fritz Gesztesy made profound contributions.

There are three survey papers in spectral theory, differential equations, and mathematical physics, which highlight, in particular, certain aspects of Gesztesy's work. The remaining seventeen papers contain original research results in diverse areas reflecting his interests. The topics of these papers range from stochastic differential equations; operators on graphs; elliptic partial differential equations; Sturm-Liouville, Jacobi, and CMV operators; semigroups; to inverse problems.

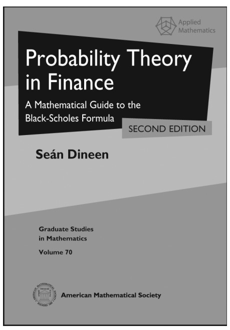
This item will also be of interest to those working in differential equations.

Contents: S. Albeverio, **E. Mastrogiacomo**, and **L. Di Persio**, Invaraint measures for stochastic differential equations on networks; **D. Bollé**, **F. L. Metz**, and **I. Neri**, On the spectra of large sparse graphs with cycles; **K. Brewster**, **D. Mitrea**, **I. Mitrea**, and **M. Mitrea**, Jones' extension operator on Sobolev spaces with partially vanishing traces; **B. M. Brown**, **W. D. Evans**, and **I. G. Wood**, Some spectral properties of rooms and passages domains and their skeletons; **J. S. Christiansen**, **B. Simon**, and **M. Zinchenko**, Finite gap Jacobi matrices: A review; **P. Exner**, Momentum operators on graphs; **G. Fragnelli**, **G. R. Goldstein**, **J. A. Goldstein**, and **S. Romanelli**, Asymptotic parabolicity for strongly damped wave equations; **A. Gomilko** and **Y. Tomilov**, On rates in Euler's formula for C_0-semigroups; **H. Grosse** and **R. Wulkenhaar**, Construction of a noncommutative quantum field theory; **K. Grunert**, **H. Holden**, and **X. Raynaud**, Periodic conservative solutions for the two-component Camassa-Holm system; **G. A. Hagedorn**, A minimal uncertainty product for one-dimensional semiclassical wave packets; **E. M. Harrell, II** and **M. L. Wong**, On a transformation of Bohl and its discrete analogue; **C. K. R. T. Jones**, **Y. Latushkin**, and **R. Marangell**, The Morse and Maslov indices for matrix Hill's equations; **A. Kostenko** and **M. Malamud**, 1-D Schrödinger operators with local point interactions: A review; **Y. I. Lyubarskii** and **V. A. Marchenko**, Inverse problem for small oscillations; **K. A. Makarov** and **E. Tsekanovskiĭ**, On the Weyl-Titchmarsh and Livšic functions; **R. Shterenberg**, **R. Weikard**, and **M. Zinchenko**, Stability for the inverse resonance problem for the CMV operator; **F. A. Sukochev**, On a conjecture of A. Bikchentaev; **G. Teschl** and **K. Unterkofler**, Spectral theory as influenced by Fritz Gesztesy; **M. Ünal** and **A. Zafer**, Prescribed asymptotic behavior for nonlinear second-order dynamic equations.

Proceedings of Symposia in Pure Mathematics, Volume 87

June 2013, approximately 389 pages, Hardcover, ISBN: 978-0-8218-7574-2, 2010 *Mathematics Subject Classification:* 34N05, 34L05, 35P05, 35L45, 46E35, 47A05, 47B36, 81T08, 81Q10, 93E03, **AMS members US$79.20**, List US$99, Order code PSPUM/87

Probability and Statistics



Probability Theory in Finance

A Mathematical Guide to the Black-Scholes Formula, Second Edition

Seán Dineen, *University College Dublin, Ireland*

The use of the Black-Scholes model and formula is pervasive in financial markets. There are very few undergraduate textbooks available on the subject and, until now, almost none written by mathematicians. Based on a course given by the author, the goal of this book is to introduce advanced undergraduates and beginning graduate students studying the mathematics of finance to the Black-Scholes formula. The author uses a first-principles approach, developing only the minimum background necessary to justify mathematical concepts and placing mathematical developments in context.

The book skillfully draws the reader toward the art of thinking mathematically and then proceeds to lay the foundations in analysis and probability theory underlying modern financial mathematics. It rigorously reveals the mathematical secrets of topics such as abstract measure theory, conditional expectations, martingales, Wiener processes, the Itô calculus, and other ingredients of the Black-Scholes formula. In explaining these topics, the author uses examples drawn from the universe of finance. The book also contains many exercises, some included to clarify simple points of exposition, others to introduce new ideas and techniques, and a few containing relatively deep mathematical results.

The second edition contains numerous revisions and additional material designed to enhance the book's usability as a classroom text. These changes include insights gleaned by the author after teaching from the text, as well as comments and suggestions made by others who used the book. Whereas the revised edition maintains the original approach, format, and list of topics, most chapters are modified to some extent; in addition, the rearrangement of material resulted in a new chapter (Chapter 9).

With the modest prerequisite of a first course in calculus, the book is suitable for undergraduates and graduate students in mathematics, finance, and economics and can be read, using appropriate selections, at a number of levels.

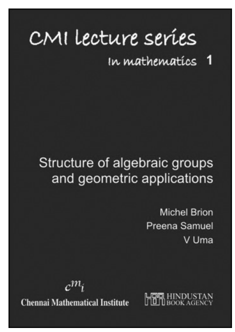
Contents: Money and markets; Fair games; Set theory; Measurable functions; Probability spaces; Expected values; Continuity and integrability; Conditional expectation; Lebesgue measure; Martingales; The Black-Scholes formula; Stochastic integration; Solutions; Bibliography; Index.

Graduate Studies in Mathematics, Volume 70

July 2013, 304 pages, Hardcover, ISBN: 978-0-8218-9490-3, 2010 *Mathematics Subject Classification:* 60-01, 91Bxx, **AMS members US$52**, List US$65, Order code GSM/70.R

New AMS-Distributed Publications

Algebra and Algebraic Geometry



Structure of Algebraic Groups and Geometric Applications

Michael Brion, *University of Grenoble I, Martin d'Heres, France*, **Preena Samuel**, *Institute of Mathematical Science, Tamilnadu, India*, and **V. Uma**, *Indian Institute of Technology, Chennai, India*

This book originates from a series of 10 lectures given by Michel Brion at the Chennai Mathematical Institute during January 2011. The book presents Chevalley's theorem on the structure of connected algebraic groups, over algebraically closed fields, as the starting point of various other structure results developed in the recent past.

Chevalley's structure theorem states that any connected algebraic group over an algebraically closed field is an extension of an abelian variety by a connected affine algebraic group. This theorem forms the foundation for the classification of anti-affine groups which plays a central role in the development of the structure theory of homogeneous bundles over abelian varieties and for the classification of complete homogeneous varieties. All these results are presented in this book.

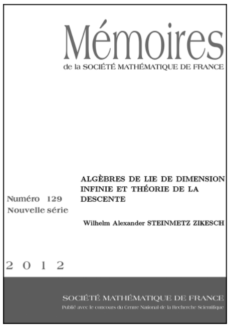
The book begins with an overview of the results, the proofs of which constitute the rest of the book. Various open questions also have been indicated in the course of the exposition. This book assumes certain preliminary knowledge of linear algebraic groups, abelian varieties, and algebraic geometry.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Overview; Proof of Chevalley's theorem; Applications and developments; Complete homogeneous varieties; Anti-affine groups; Homogeneous vector bundles; Homogeneous principal bundles; Bibliography.

Hindustan Book Agency

November 2012, 128 pages, Softcover, ISBN: 978-93-80250-46-5, 2010 *Mathematics Subject Classification:* 20G15, 14L10, 14L15, 14L17, 14L30, 14L40, **AMS members US$36**, List US$45, Order code HIN/55



Algèbres de Lie de Dimension Infinie et Théorie de la Descente

Wilhelm Alexander Steinmetz Zikesch, *Université Paris-Sud XI, Orsay, France*

A note to readers: This book is in French.

Let k be an algebraically closed field of characteristic zero and let R be the Laurent polynomial ring in two variables over k. The main motivation behind this work is a class of infinite dimensional Lie algebras over k, called *extended affine Lie algebras* (EALAs). These algebras correspond to torsors under algebraic groups over R.

In this work the author classifies R-torsors under classical groups of large enough rank for outer type A and types B, C, D, as well as for inner type A under stronger hypotheses. The author can thus deduce results on EALAs and also obtain a positive answer to a variant of Serre's Conjecture II for the ring R: every smooth R-torsor under a semi-simple simply connected R-group of large enough rank of classical type B, C, D is trivial.

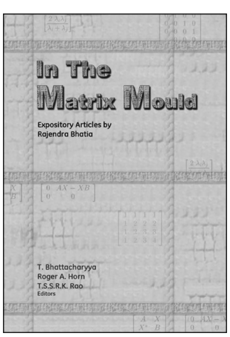
This item will also be of interest to those working in number theory.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Généralités et préliminaires; Les conjectures; Le cas ${}^1A_{n-1}$ et les groupes orthogonaux; Le cas C_n, les autres groupes du type D_n et le cas ${}^2A_n$; La conjecture B; Bibliographie.

Mémoires de la Société Mathématique de France, Number 129

December 2012, 99 pages, Softcover, ISBN: 978-2-85629-349-2, 2010 *Mathematics Subject Classification:* 17B67, 14L15, 11E57, 11E72, 11E39, 11E81, 19G12, 18E30, **Individual member US$43.20**, List US$48, Order code SMFMEM/129



In the Matrix Mould

Expository Articles by Rajendra Bhatia

Tirthankar Bhattacharyya, *Indian Institute of Sciences, Karnataka, India*, **Roger A. Horn**, *University of Utah, Salt Lake City, Utah*, and **T. S. S. R. K. Rao**, *Indian Statistical Institute, Bangalore, India*, Editors

Rajendra Bhatia has written several expository articles for renowned journals such as *The American Mathematical Monthly, Mathematical Intelligencer*, and *Resonance*. These elementary articles have often spurred research papers by other authors. On the other hand, some of his research articles present major ideas in such a simple way that they can be profitably read by beginners. This volume contains a selection of such articles compiled by the editors.

The articles, on a variety of topics in analysis and linear algebra, can be read as introductions to interesting ideas. They can also be used as a basis for projects and master's dissertations and for workshops and refresher courses for college teachers.

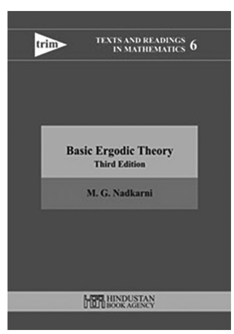
A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: with T. Ando, Eigenvalue inequalities associated with the Cartesian decomposition; **with M.D. Choi and C. Davis**, Comparing a matrix to its off-diagonal part; Matrix factorisations and their perturbations; **with P. Rosenthal**, How and why to solve the operator equation $AX - XB = Y$; **with P. Semrl**, Approximate isometries on Euclidean spaces; **with K. R. Parthasarathy**, Positive definite functions and operator inequalities; **with C. Davis**, A better bound on the variance; Pinching, trimming, truncating, and averaging of matrices; Linear algebra to quantum cohomology: The story of Alfred Horn's inequalities; Partial traces and entropy inequalities; On the exponential metric increasing property; Infinitely divisible matrices; **with J. Holbrook**, Noncommutative geometric means; Spectral variation, normal matrices, and Finsler geometry; **with J. A. Dias da Silva**, Infinite divisibility of GCD matrices; **with M. Uchiyama**, The operator equation $\sum_{i=0}^{n} A^{n-i}XB^{i} = Y$; Modulus of continuity of the matrix absolute value; Min matrices and mean matrices; The work of W. T. Gowers; Orthogonalisation of vectors; **with R. Mohan**, Triangularization of a matrix; Eigenvalues of AB and BA; The unexpected appearance of pi in diverse problems; Calculus of operator functions; A conversation with S. R. S. Varadhan.

Hindustan Book Agency

December 2012, 362 pages, Hardcover, ISBN: 978-93-80250-47-2, 2010 *Mathematics Subject Classification:* 15-XX, 15Axx, 15-02, 15-06, **AMS members US$44**, List US$55, Order code HIN/57

Analysis



Basic Ergodic Theory

Third Edition

M. G. Nadkarni, *University of Mumbai, India*

This is an introductory text on ergodic theory. The presentation has a slow pace, and the book can be read by anyone with a background in basic measure theory and metric topology. A new feature of the book is that the basic topics of ergodic theory such as the Poincaré recurrence lemma, induced automorphisms and Kakutani towers, compressibility and E. Hopf's theorem, and the theorem of Ambrose on representation of flows, are treated at the descriptive set-theoretic level before their measure-theoretic or topological versions are presented. In addition, topics centering around the Glimm-Effros theorem, which have so far not found a place in texts on ergodic theory, are discussed in this book.

The third edition has, among other improvements, a new chapter on additional topics that include Liouville's theorem of classical mechanics, the basics of Shannon Entropy and the Kolmogorov-Sinai theorem, and van der Waerden's theorem on arithmetical progressions.

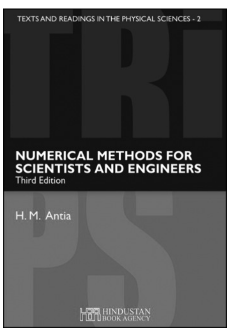
A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: The Poincaré recurrence lemma; Ergodic theorems of Birkhoff and von Neumann; Ergodicity; Mixing conditions and their characterisations; Bernoulli shift and related concepts; Discrete spectrum theorem; Induced automorphisms and related concepts; Borel automorphisms are Polish homeomorphisms; The Glimm-Effros theorem; Hopf's theorem; H. Dye's theorem; Flows and their representations; Additional topics; Bibliography; Index.

Hindustan Book Agency

January 2013, 196 pages, Hardcover, ISBN: 978-93-80250-43-4, 2010 *Mathematics Subject Classification:* 28Dxx, 60Bxx, **AMS members US$38.40**, List US$48, Order code HIN/58

Applications



Numerical Methods for Scientists and Engineers

Third Edition

H. M. Antia, *Tata Institute of Fundamental Research, Mumbai, India*

Computation is an indispensable tool in the analysis and exploration of a wide range of physical phenomena. This book presents an exhaustive exposition of the various numerical methods used in scientific and engineering applications. It emphasizes the practical aspects of numerical computation and discusses various techniques in sufficient detail to enable their implementation in solving a wide range of problems. An important addition in this revised third edition is a chapter on basic statistics.

More than 100 worked-out examples illustrate a variety of numerical algorithms. The limitations of the algorithms are also discussed, as are pitfalls in numerical computations. A special feature is the inclusion of a discussion of techniques for error-estimation. In addition, more than 500 unsolved problems (with answers) of varying difficulty are included, and more than 200 computer programs in FORTRAN and C, covering all topics, are provided as supplementary material online. These give the book a strong pedagogic focus. Examples and exercises are drawn from areas as diverse as fluid mechanics, celestial mechanics, and seismology.

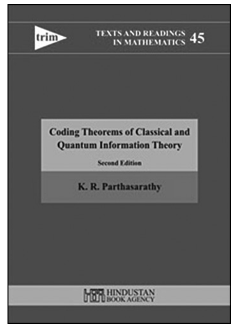
This book will be extremely useful for graduate students and researchers in all branches of science and engineering.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Introduction; Roundoff error; Linear algebraic equations; Interpolation; Differentiation; Integration; Nonlinear algebraic equations; Optimisation; Statistical inferences; Functional approximations; Algebraic eigenvalue problem; Ordinary differential equations; Integral equations; Partial differential equations; Appendix A: Answers and hints; Index.

Hindustan Book Agency

December 2012, 888 pages, Hardcover, ISBN: 978-93-80250-40-3, 2010 *Mathematics Subject Classification:* 65-00, 65-01, 65-04, **AMS members US$76**, List US$95, Order code HIN/56



Coding Theorems of Classical and Quantum Information Theory

Second Edition

K. R. Parthasarathy, *Indian Statistical Institute, New Delhi, India*

The aim of this little book is to convey three principal developments in the evolution of modern information theory: Shannon's initiation of a revolution in 1948 by his interpretation of the Boltzmann entropy as a measure of information yielded by an elementary statistical experiment and basic coding theorems on storage and optimal transmission of messages through noisy communication channels; the influence of ergodic theory in the enlargement of the scope of Shannon's theorems through the works of McMillan, Feinstein, Wolfowitz, Breiman, and others, and its impact on the appearance of the Kolmogorov-Sinai invariant for elementary dynamical systems; and finally, the more recent work of Schumacher, Holevo, Winter, and others on the role of von Neumann entropy in the quantum avatar of the basic coding theorems when messages are encoded as quantum states, transmitted through noisy quantum channels and retrieved by generalized measurements.

This revised second edition has a chapter devoted to quantum error correction theory that shows how information in the form of quantum states can be made to tunnel through a noisy environment.

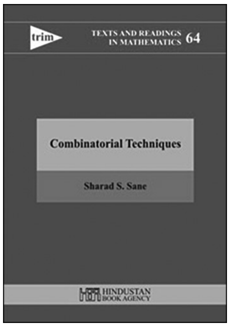
A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Entropy of elementary information; Stationary information sources; Communication in the presence of noise; Quantum coding; Quantum error correction; Bibliography; Index.

Hindustan Book Agency

January 2013, 186 pages, Hardcover, ISBN: 978-93-80250-41-0, 2010 *Mathematics Subject Classification:* 94A15, 94-02, 94A24, 37A35, 37A99, 81P68, **AMS members US$38.40**, List US$48, Order code HIN/59

Discrete Mathematics and Combinatorics



Combinatorial Techniques

Sharad S. Sane, *Michigan Technological University, Houghton, MI*

This is a basic text on combinatorics that deals with all three aspects of the discipline: tricks, techniques and theory, and attempts to blend them.

The book has several distinctive features. Probability and random variables with their interconnections to permutations are discussed. The theme of parity has been specially included, and it covers applications ranging from solving the Nim game to the quadratic reciprocity law. Chapters related to geometry include triangulations and Sperner's theorem, classification of regular polytopes, tilings, and an introduction to the Eulcidean Ramsey theory. Material on group actions covers Sylow theory, automorphism groups, and a classification of finite subgroups of orthogonal groups.

All chapters have a large number of exercises with varying degrees of difficulty, ranging from material suitable for Mathematical Olympiads to research.

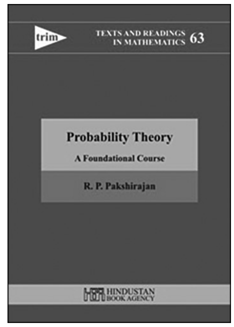
A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Basic counting; Listing combinatorial objects; Permutations; The inclusion-exclusion principle; Basic probability; Random variables; Parity; Pigeonhole principle; Some geometry; Advanced counting numbers; Recurrence relations; Generating functions; Partition theory of integers; Group action on a set; Polya theory of enumeration; Systems of distinct representatives; References; Index.

Hindustan Book Agency

January 2013, 482 pages, Hardcover, ISBN: 978-93-80250-48-9, 2010 *Mathematics Subject Classification:* 05-01, 05A10, 05A05, 05D10, **AMS members US$52**, List US$65, Order code HIN/61

Probability and Statistics



Probability Theory

A Foundational Course

R. P. Pakshirajan, *University of Mysore, India*

This book shares the dictum of J. L. Doob in treating probability theory as a branch of measure theory and establishes this relationship early. Probability measures in product spaces are introduced right at the start as a way of laying the groundwork to later claim the existence of stochastic processes with prescribed finite-dimensional distributions.

Other topics analyzed in the book include supports of probability measures, zero-one laws in product measure spaces, the Erdös-Kac invariance principle, functional central limit theorem and functional law of the iterated logarithm for independent variables, Skorohod embedding, and the use of analytic functions of a complex variable in the study of geometric ergodicity in Markov chains.

This book is offered as a textbook for students pursuing graduate programs in mathematics and/or statistics. The book aims to help teachers present the theory with ease and to help students sustain their interest and joy in learning the subject.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Probability measures in product spaces; Weak convergence of probability measures; Characteristic functions; Independence; The central limit theorem and its ramifications; The law of the iterated logarithm; Discrete time Markov chains; Index.

Hindustan Book Agency

January 2013, 564 pages, Hardcover, ISBN: 978-93-80250-44-1, 2010 *Mathematics Subject Classification:* 60-01, 60B05, 60B10, 60F05, 60F17, 60J10, 60J65, **AMS members US$54.40**, List US$68, Order code HIN/60

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday

Meeting #1090

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: February 2013
Program first available on AMS website: March 14, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Kevin Costello, Northwestern University, *Title to be announced.*

Marianne Csornyei, University of Chicago, *Title to be announced.*

Vladimir Markovic, California Institute of Technology, *Title to be announced.*

Endre Szemerédi, Siemens Corporate Technology, *On subset sums* (Erdős Memorial Lecture).

Eitan Tadmor, University of Maryland, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics, **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin-Madison.

Analysis, Dynamics and Geometry In and Around Teichmuller Spaces, **Alistair Fletcher**, Northern Illinois University, **Vladimir Markovic**, California Institute of Technology, and **Dragomir Saric**, Queens College CUNY.

Commutative Algebra and its Environs, **Olgur Celikbas** and **Greg Piepmeyer**, University of Missouri, Columbia.

Commutative Ring Theory, **Michael Axtell**, University of St. Thomas, and **Joe Stickles**, Millikin University.

Computability and Complexity in Discrete and Continuous Worlds, **Jack Lutz** and **Tim McNicholl**, Iowa State University.

Computational Advances on Special Functions and Tropical Geometry, **Lubjana Beshaj**, Oakland University, and **Emma Previato**, Boston University.

Control Theory and Qualitative Analysis of Partial Differential Equations, **George Avalos**, University of Nebraska-Lincoln, and **Scott Hansen**, Iowa State University.

Discrete Methods and Models in Mathematical Biology, **Dora Matache**, University of Nebraska-Omaha, and **Stephen J. Willson**, Iowa State University.

Extremal Combinatorics, **Steve Butler** and **Ryan Martin**, Iowa State University.

Generalizations of Nonnegative Matrices and Their Sign Patterns, **Minerva Catral**, Xavier University, **Shaun Fallat**, University of Regina, and **Pauline van den Driessche**, University of Victoria.

Geometric Elliptic and Parabolic Partial Differential Equations, **Brett Kotschwar**, Arizona State University, and **Xuan Hien Nguyen**, Iowa State University.

Graphs, Hypergraphs and Counting, **Eva Czabarka** and **Laszlo Szekely**, University of South Carolina.

Kinetic and Hydrodynamic PDE-based Descriptions of Multi-scale Phenomena, **James Evans** and **Hailiang Liu**, Iowa State University, and **Eitan Tadmor**, University of Maryland.

Logic and Algebraic Logic, **Jeremy Alm**, Illinois College, and **Andrew Ylvisaker**, Iowa State University.

Multi-Dimensional Dynamical Systems, **Jayadev Athreya**, University of Illinois, Urbana-Champaign, **Jona-**

than Chaika, University of Chicago, and **Joseph Rosenblatt**, University of Illinois at Urbana-Champaign.

Numerical Analysis and Scientific Computing, **Hailiang Liu**, **Songting Luo**, **James Rossmanith**, and **Jue Yan**, Iowa State University.

Numerical Methods for Geometric Partial Differential Equations, **Gerard Awanou**, University of Illinois at Chicago, and **Nicolae Tarfulea**, Purdue University.

Operator Algebras and Topological Dynamics, **Benton L. Duncan**, North Dakota State University, and **Justin R. Peters**, Iowa State University.

Partial Differential Equations, **Gary Lieberman** and **Paul Sacks**, Iowa State University, and **Mahamadi Warma**, University of Puerto Rico at Rio Piedras.

Probabilistic and Multiscale Modeling Approaches in Cell and Systems Biology, **Jasmine Foo**, University of Minnesota, and **Anastasios Matzavinos**, Iowa State University.

Quasigroups, Loops, and Nonassociative Division Algebras, **C. E. Ealy Jr.** and **Annegret Paul**, Western Michigan University, **Benjamin Phillips**, University of Michigan Dearborn, **J. D. Phillips**, Northern Michigan University, and **Petr Vojtechovsky**, University of Denver.

Ring Theory and Noncommutative Algebra, **Victor Camillo**, University of Iowa, and **Miodrag C. Iovanov**, University of Bucharest and University of Iowa.

Stochastic Processes with Applications to Physics and Control, **Jim Evans** and **Arka Ghosh**, Iowa State University, **Jon Peterson**, Purdue University, and **Alexander Roitershtein**, Iowa State University.

Topology of 3-Manifolds, **Marion Campisi** and **Alexander Zupan**, University of Texas at Austin.

Zero Forcing, Maximum Nullity/Minimum Rank, and Colin de Verdiere Graph Parameters, **Leslie Hogben**, Iowa State University and American Institute of Mathematics, and **Bryan Shader**, University of Wyoming.

Alba Iulia, Romania

University of Alba Iulia

June 27–30, 2013

Thursday – Sunday

Meeting #1091

First Joint International Meeting of the AMS and the Romanian Mathematical Society, in partnership with the "Simion Stoilow" Institute of Mathematics of the Romanian Academy.

Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2013
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Invited Addresses

Viorel Barbu, Universitatea Al. I. Cuza, *Stabilization of Navier-Stokes equations by boundary and point feedback controllers*.

Sergiu Klainerman, Princeton University, *Title to be announced*.

George Lusztig, Massachusetts Institute of Technology, *On conjugacy classes in the Lie group E8*.

Stefan Papadima, Institute of Mathematics of the Romanian Academy, *Geometry of homology jump loci and topology*.

Dan Timotin, Institute of Mathematics of the Romanian Academy, *Horn inequalities: Finite and infinite dimensions*.

Special Sessions

Algebraic Geometry, **Marian Aprodu**, Institute of Mathematics of the Romanian Academy, **Mircea Mustata**, University of Michigan, Ann Arbor, and **Mihnea Popa**, University of Illinois, Chicago.

Articulated Systems: Combinatorics, Geometry and Kinematics, **Ciprian S. Borcea**, Rider University, and **Ileana Streinu**, Smith College.

Calculus of Variations and Partial Differential Equations, **Marian Bocea**, Loyola University, Chicago, **Liviu Ignat**, Institute of Mathematics of the Romanian Academy, **Mihai Mihailescu**, University of Craiova, and **Daniel Onofrei**, University of Houston.

Commutative Algebra, **Florian Enescu**, Georgia State University, and **Cristodor Ionescu**, Institute of Mathematics of the Romanian Academy.

Discrete Mathematics and Theoretical Computer Science, **Sebastian Cioaba**, University of Delaware, **Gabriel Istrate**, Universitatea de Vest, Timisoara, **Ioan Tomescu**, University of Bucharest, and **Marius Zimand**, Towson University.

Domain Decomposition Methods and their Applications in Mechanics and Engineering, **Lori Badea**, Institute of Mathematics of the Romanian Academy, and **Marcus Sarkis**, Worcester Polytechnic Institute.

Geometry and Topology of Arrangements of Hypersurfaces, **Daniel Matei**, Institute of Mathematics of the Romanian Academy, and **Alexandru I. Suciu**, Northeastern University.

Harmonic Analysis and Applications, **Ciprian Demeter**, Indiana University, Bloomington, and **Camil Muscalu**, Cornell University.

Hopf Algebras, Coalgebras, and their Categories of Representations, **Miodrag C. Iovanov**, University of Bucharest and University of Iowa, **Susan Montgomery**, University of Southern California, and **Siu-Hung Ng**, Iowa State University.

Local and Nonlocal Models in Wave Propagation and Diffusion, **Anca V. Ion**, Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy, **Petronela Radu**, University of Nebraska, Lincoln, and **Lorena Bociu**, North Carolina State University.

Mathematical Finance, Stochastic Analysis, and Partial Differential Equations, **Lucian Beznea**, Institute of Mathematics of the Romanian Academy, **Paul Feehan**, Rutgers University, **Victor Nistor**, Pennsylvania State University, **Camelia Pop**, University of Pennsylvania, and **Mihai Sirbu**, University of Texas, Austin.

Mathematical Models in Life and Environment, **Gabriela Marinoschi**, Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy, and **Fabio Augusto Milner**, Arizona State University.

Mathematical Models in Materials Science and Engineering, **Marian Bocea**, Loyola University, Chicago, and **Bogdan Vernescu**, Worcester Polytechnic Institute.

Noncommutative Ring Theory and Applications, **Toma Albu**, Institute of Mathematics of the Romanian Academy, and **Lance W. Small**, University of California, San Diego.

Nonlinear Evolution Equations, **Daniel Tataru**, University of California, Berkeley, and **Monica Visan**, University of California, Los Angeles.

Operator Algebra and Noncommutative Geometry, **Marius Dadarlat**, Purdue University, and **Florin Radulescu**, Institute of Mathematics of the Romanian Academy and University of Rome Tor Vergata.

Operator Theory and Function Spaces, **Aurelian Gheondea**, Institute of Mathematics of the Romanian Academy and Bilkent University, **Mihai Putinar**, University of California, Santa Barbara, and **Dan Timotin**, Institute of Mathematics of the Romanian Academy.

Probability and its Relation to Other Fields of Mathematics, **Krzysztof Burdzy**, University of Washington, and **Mihai N. Pascu**, Transilvania University of Braşov.

Random Matrices and Free Probability, **Ioana Dumitriu**, University of Washington, and **Ionel Popescu**, Georgia Institute of Technology and Institute of Mathematics of the Romanian Academy.

Several Complex Variables, Complex Geometry and Dynamics, **Dan Coman**, Syracuse University, and **Cezar Joita**, Institute of Mathematics of the Romanian Academy.

Topics in Geometric and Algebraic Topology, **Stefan Papadima**, Institute of Mathematics of the Romanian Academy, and **Alexandru I. Suciu**, Northeastern University.

Louisville, Kentucky

University of Louisville

October 5–6, 2013

Saturday – Sunday

Meeting #1092

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: June 2013
Program first available on AMS website: August 22, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 34, Issue 3

Deadlines

For organizers: Expired
For abstracts: August 13, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Michael Hill, University of Virginia, *Title to be announced.*

Suzanne Lenhart, University of Tennessee and NIMBioS, *Using optimal control of PDEs to investigate population questions.*

Ralph McKenzie, Vanderbilt University, *Title to be announced.*

Victor Moll, Tulane University, *Title to be announced.*

Special Sessions

Algebraic Coding Theory (Code: SS 5A), **Steve Szabo**, Eastern Kentucky University, and **Heide Gluesing-Luerssen**, University of Kentucky.

Algebraic Cryptography (Code: SS 12A), **Daniel Smith**, University of Louisville.

Applied Analysis and Inverse Problems (Code: SS 9A), **Peijun Li**, Purdue University, **Jiguang Sun**, Michigan Technological University, and **Yongzhi Steve Xu**, University of Louisville.

Combinatorial Commutative Algebra (Code: SS 4A), **Juan Migliore**, University of Notre Dame, and **Uwe Nagel**, University of Kentucky.

Commutative Rings, Ideals, and Modules (Code: SS 3A), **Ela Celikbas** and **Olgur Celikbas**, University of Missouri-Columbia.

Extremal Graph Theory (Code: SS 2A), **Jozsef Balogh**, University of Illinois at Urbana-Champaign, and **Louis DeBiasio** and **Tao Jiang**, Miami University, Oxford, OH.

Finite Universal Algebra (Code: SS 6A), **Ralph McKenzie**, Vanderbilt University, and **Matthew Valeriote**, McMaster University.

Fixed Point Theorems and Applications to Integral, Difference, and Differential Equations (Code: SS 8A), **Jeffrey W. Lyons**, Nova Southeastern University, and **Jeffrey T. Neugebauer**, Eastern Kentucky University.

Harmonic Analysis and Partial Differential Equations (Code: SS 10A), **Russell Brown** and **Katharine Ott**, University of Kentucky.

Homogenization of Partial Differential Equations (Code: SS 14A), **Zhongwei Shen**, University of Kentucky, and **Yifeng Yu**, University of California, Irvine.

Mathematical Analysis of Complex Fluids and Flows (Code: SS 15A), **Xiang Xu**, Carnegie Mellon University, and **Changyou Wang**, University of Kentucky.

Partial Differential Equations from Fluid Mechanics (Code: SS 16A), **Changbing Hu**, University of Louisville, and **Florentina Tone**, University of West Florida.

Recent Advances on Commutative Algebra and Its Applications (Code: SS 11A), **Hamid Kulosman** and **Jinjia Li**, University of Louisville, and **Hamid Rahmati**, Miami University.

Set Theory and Its Applications (Code: SS 1A), **Paul Larson**, Miami University, **Justin Moore**, Cornell University, and **Grigor Sargsyan**, Rutgers University.

Topological Dynamics and Ergodic Theory (Code: SS 13A), **Alica Miller**, University of Louisville, and **Joe Rosenblatt**, University of Illinois at Urbana-Champaign.

Weak Dependence in Probability and Statistics (Code: SS 7A), **Cristina Tone**, **Ryan Gill**, and **Kiseop Lee**, University of Louisville.

Philadelphia, Pennsylvania

Temple University

October 12–13, 2013

Saturday – Sunday

Meeting #1093

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2013
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 34, Issue 3

Deadlines

For organizers: Expired
For abstracts: August 20, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Patrick Brosnan, University of Maryland, *Title to be announced*.

Xiaojung Huang, Rutgers University, *Title to be announced*.

Barry Mazur, Harvard University, *Title to be announced* (Erdős Memorial Lecture).

Robert Strain, University of Pennsylvania, *Title to be announced*.

Special Sessions

Analysis and Computing for Electromagnetic Waves (Code: SS 10A), **David Ambrose** and **Shari Moskow**, Drexel University.

Combinatorial Commutative Algebra (Code: SS 12A), **Tái Huy Há**, Tulane University, and **Fabrizio Zanello**, Massachusetts Institute of Technology and Michigan Technological University.

Contact and Symplectic Topology (Code: SS 5A), **Joshua M. Sabloff**, Haverford College, and **Lisa Traynor**, Bryn Mawr College.

Difference Equations and Applications (Code: SS 9A), **Michael Radin**, Rochester Polytechnic Institute.

Geometric and Spectral Analysis (Code: SS 3A), **Thomas Krainer**, Pennsylvania State Altoona, and **Gerardo A. Mendoza**, Temple University.

Geometric Topology of Knots and 3-manifolds (Code: SS 16A), **Abhijit Champanerkar**, College of Staten Island and The Graduate Center, City University of New York, **Ilya Kofman**, College of Staten Island and The Graduate Center, City University of New York, and **Joseph Maher**, College of Staten Island and The Graduate Center, City University of New York.

Geometric Aspects of Topology and Group Theory (Code: SS 17A), **David Futer**, Temple University, and **Ben McReynolds**, Purdue University.

Higher Structures in Algebra, Geometry and Physics (Code: SS 2A), **Jonathan Block**, University of Pennsylvania, **Vasily Dolgushev**, Temple University, and **Tony Pantev**, University of Pennsylvania.

History of Mathematics in America (Code: SS 4A), **Thomas L. Bartlow**, Villanova University, **Paul R. Wolfson**, West Chester University, and **David E. Zitarelli**, Temple University.

Mathematical Biology (Code: SS 8A), **Isaac Klapper**, Temple University, and **Kathleen Hoffman**, University of Maryland, Baltimore County.

Multiple Analogues of Combinatorial Special Numbers and Associated Identities (Code: SS 11A), **Hasan Coskun**, Texas A&M University Commerce.

Nonlinear Elliptic and Wave Equations and Applications (Code: SS 15A), **Nsoki Mavinga**, Swarthmore College, and **Doug Wright**, Drexel University.

Partial Differential Equations, Stochastic Analysis, and Applications to Mathematical Finance (Code: SS 14A), **Paul Feehan** and **Ruoting Gong**, Rutgers University, and **Camelia Pop**, University of Pennsylvania.

Recent Advances in Harmonic Analysis and Partial Differential Equations (Code: SS 1A), **Cristian Gutiérrez** and **Irina Mitrea**, Temple University.

Recent Developments in Noncommutative Algebra (Code: SS 6A), **Edward Letzter** and **Martin Lorenz**, Temple University.

Several Complex Variables and CR Geometry (Code: SS 7A), **Andrew Raich**, University of Arkansas, and **Yuan Zhang**, Indiana University-Purdue University Fort Wayne.

The Geometry of Algebraic Varieties (Code: SS 13A), **Karl Schwede**, Pennsylvania State University, and **Zsolt Patakfalvi**, Princeton University.

St. Louis, Missouri

Washington University

October 18–20, 2013

Friday – Sunday

Meeting #1094

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 5, 2013

Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 34, Issue 4

Deadlines

For organizers: Expired
For abstracts: August 27, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Ronny Hadani, University of Texas at Austin, *Title to be announced*.

Effie Kalfagianni, Michigan State University, *Title to be announced*.

Jon Kleinberg, Cornell University, *Title to be announced*.

Vladimir Sverak, University of Minnesota, *Title to be announced*.

Special Sessions

Algebraic and Combinatorial Invariants of Knots (Code: SS 1A), **Heather Dye**, McKendree University, **Allison Henrich**, Seattle University, **Aaron Kaestner**, North Park University, and **Louis Kauffman**, University of Illinois.

Automorphic Forms and Representation Theory (Code: SS 7A), **Dubravka Ban** and **Joe Hundley**, Southern Illinois University, and **Shuichiro Takeda**, University of Missouri, Columbia.

Commutative Algebra (Code: SS 11A), **Lianna Sega**, University of Missouri, Kansas City, and **Hema Srinivasan**, University of Missouri, Columbia.

Computability Across Mathematics (Code: SS 2A), **Wesley Calvert**, Southern Illinois University, and **Johanna Franklin**, University of Connecticut.

Geometric Aspects of 3-Manifold Invariants (Code: SS 10A), **Oliver Dasbach**, Louisiana State University, and **Effie Kalfagianni**, Michigan State University.

Geometric Topology in Low Dimensions (Code: SS 4A), **William H. Kazez**, University of Georgia, and **Rachel Roberts**, Washington University in St. Louis.

Groupoids in Analysis and Geometry (Code: SS 6A), **Alex Kumjian**, University of Nevada at Reno, **Markus Pflaum**, University of Colorado, and **Xiang Tang**, Washington University in St. Louis.

Interactions between Geometric and Harmonic Analysis (Code: SS 3A), **Leonid Kovalev**, Syracuse University, and **Jeremy Tyson**, University of Illinois, Urbana-Champaign.

Noncommutative Rings and Modules (Code: SS 5A), **Greg Marks** and **Ashish Srivastava**, St. Louis University.

Operator Theory (Code: SS 9A), **John McCarthy**, Washington University in St. Louis.

Wavelets, Frames, and Related Expansions (Code: SS 8A), **Marcin Bownik**, University of Oregon, **Darrin Speegle**, Saint Louis University, and **Guido Weiss**, Washington University, St. Louis.

Riverside, California

University of California Riverside

November 2–3, 2013

Saturday – Sunday

Meeting #1095

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 19, 2013
Program issue of electronic *Notices*: November 2013
Issue of *Abstracts*: Volume 34, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 10, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Michael Christ, University of California, Berkeley, *Title to be announced*.

Mark Gross, University of California, San Diego, *Title to be announced*.

Matilde Marcolli, California Institute of Technology, *Title to be announced*.

Paul Vojta, University of California, Berkeley, *Title to be announced*.

Special Sessions

Computer, Mathematics, Imaging, Technology, Network, Health, Big Data, and Statistics (Code: SS 3A), **Subir Ghosh**, University of California, Riverside.

Developments in Markov Chain Theory and Methodology (Code: SS 2A), **Jason Fulman**, University of California, Riverside, and **Mark Huber**, Claremont McKenna College.

Fluids and Boundaries (Code: SS 5A), **James P. Kelliher**, **Juhi Jang**, and **Gung-Min Gie**, University of California, Riverside.

Geometric Analysis (Code: SS 4A), **Zhiqin Lu**, University of California, Irvine, **Bogdan D Suceava**, California State University, Fullerton, and **Fred Wilhelm**, University of California, Riverside.

Geometry of Algebraic Varieties (Code: SS 6A), **Karl Fredrickson**, University of California, Riverside, **Mark Gross**, University of California, San Diego, and **Ziv Ran**, University of California, Riverside.

The Mathematics of Planet Earth (Code: SS 1A), **John Baez**, University of California, Riverside.

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel

January 15–18, 2014
Wednesday – Saturday

Meeting #1096
Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2013
Program first available on AMS website: November 1, 2013
Program issue of electronic *Notices*: January 2013
Issue of *Abstracts*: Volume 35, Issue 1

Deadlines
For organizers: Expired
For abstracts: To be announced

Knoxville, Tennessee

University of Tennessee, Knoxville

March 21–23, 2014
Friday – Sunday

Meeting #1097
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 21, 2013
For abstracts: To be announced

Baltimore, Maryland

University of Maryland, Baltimore County

March 29–30, 2014
Saturday – Sunday

Meeting #1098
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: March 2014
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 29, 2013
For abstracts: To be announced

Albuquerque, New Mexico

University of New Mexico

April 5–6, 2014
Saturday – Sunday

Meeting #1099
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: April 2014
Issue of *Abstracts*: To be announced

Deadlines
For organizers: September 5, 2013
For abstracts: February 11, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

The Inverse Problem and Other Mathematical Methods Applied in Physics and Related Sciences (Code: SS 1A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico and Enfitek, Inc.

Lubbock, Texas

Texas Tech University

April 11–13, 2014
Friday – Sunday

Meeting #2000
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 18, 2013
For abstracts: February 10, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

Analysis and Applications of Dynamic Equations on Time Scales (Code: SS 2A), **Heidi Berger**, Simpson College, and **Raegan Higgins**, Texas Tech University.

Fractal Geometry and Dynamical Systems (Code: SS 3A), **Mrinal Kanti Roychowdhury**, The University of Texas-Pan American.

Recent Advancements in Differential Geometry and Integrable PDEs, and Their Applications to Cell Biology and Mechanical Systems (Code: SS 4A), **Giorgio Bornia**, **Akif Ibragimov**, and **Magdalena Toda**, Texas Tech University.

Topology and Physics (Code: SS 1A), **Razvan Gelca** and **Alastair Hamilton**, Texas Tech University.

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday
The 2nd Joint International Meeting between the AMS and the Israel Mathematical Union.
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Special Sessions

Mirror Symmetry and Representation Theory, **David Kazhdan**, Hebrew University, and **Roman Bezrukavnikov**, Massachusetts Institute of Technology.

Nonlinear Analysis and Optimization, **Boris Mordukhovich**, Wayne State University, and **Simeon Reich** and **Alexander Zaslavski**, The Technion-Israel Institute of Technology.

Qualitative and Analytic Theory of ODE's, **Yosef Yomdin**, Weizmann Institute.

Eau Claire, Wisconsin

University of Wisconsin-Eau Claire

September 20–21, 2014

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 20, 2014
For abstracts: August 5, 2014

Halifax, Canada

Dalhousie University

October 18–19, 2014

Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 18, 2014
For abstracts: To be announced

San Francisco, California

San Francisco State University

October 25–26, 2014

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 25, 2014
For abstracts: September 3, 2014

Greensboro, North Carolina

University of North Carolina, Greensboro

November 8–9, 2014

Saturday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 8, 2014
For abstracts: To be announced

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015

Saturday – Tuesday
Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines

For organizers: April 1, 2014
For abstracts: To be announced

Las Vegas, Nevada

University of Nevada, Las Vegas

April 18–19, 2015

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 18, 2014
For abstracts: To be announced

Porto, Portugal

University of Porto

June 11–14, 2015

Thursday – Sunday
First Joint International Meeting involving the American Mathematical Societry (AMS), the European Mathematical Society (EMS), and the Sociedade de Portuguesa Matematica (SPM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For abstracts: To be announced

Chicago, Illinois

Loyola University Chicago

October 3–4, 2015

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2015
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 10, 2015
For abstracts: To be announced

Fullerton, California

California State University, Fullerton

October 24–25, 2015

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2015
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 27, 2015
For abstracts: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Central Section: **Georgia Benkart**, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: benkart@math.wisc.edu; telephone: 608-263-4283.

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Southeastern Section: **Brian D. Boe,** Department of Mathematics, University of Georgia, 220 D W Brooks Drive, Athens, GA 30602-7403, e-mail: brian@math.uga.edu; telephone: 706-542-2547.

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: lapidus@math.ucr.edu; telephone: 951-827-5910.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** www.ams.org/meetings/**.**

Meetings:

2013		
April 27–28	Ames, Iowa	p. 663
June 27–30	Alba Iulia, Romania	p. 664
October 5–6	Louisville, Kentucky	p. 665
October 12–13	Philadelphia, Pennsylvania	p. 666
October 18–20	St. Louis, Missouri	p. 666
November 2–3	Riverside, California	p. 667
2014		
January 15–18	Baltimore, Maryland Annual Meeting	p. 668
March 21–23	Knoxville, Tennessee	p. 668
March 29–30	Baltimore, Maryland	p. 668
April 5–6	Albuquerque, New Mexico	p. 668
April 11–13	Lubbock, Texas	p. 668
June 16–19	Tel Aviv, Israel	p. 669
September 20–21	Eau Claire, Wisconsin	p. 669
October 18–19	Halifax, Canada	p. 669
October 25–26	San Francisco, California	p. 669
November 8–9	Greensboro, North Carolina	p. 670
2015		
January 10–13	San Antonio, Texas Annual Meeting	p. 670
April 18–19	Las Vegas, Nevada	p. 670
June 11–14	Porto, Portugal	p. 670
October 3–4	Chicago, Illinois	p. 670
October 24–25	Fullerton, California	p. 670

Important Information Regarding AMS Meetings

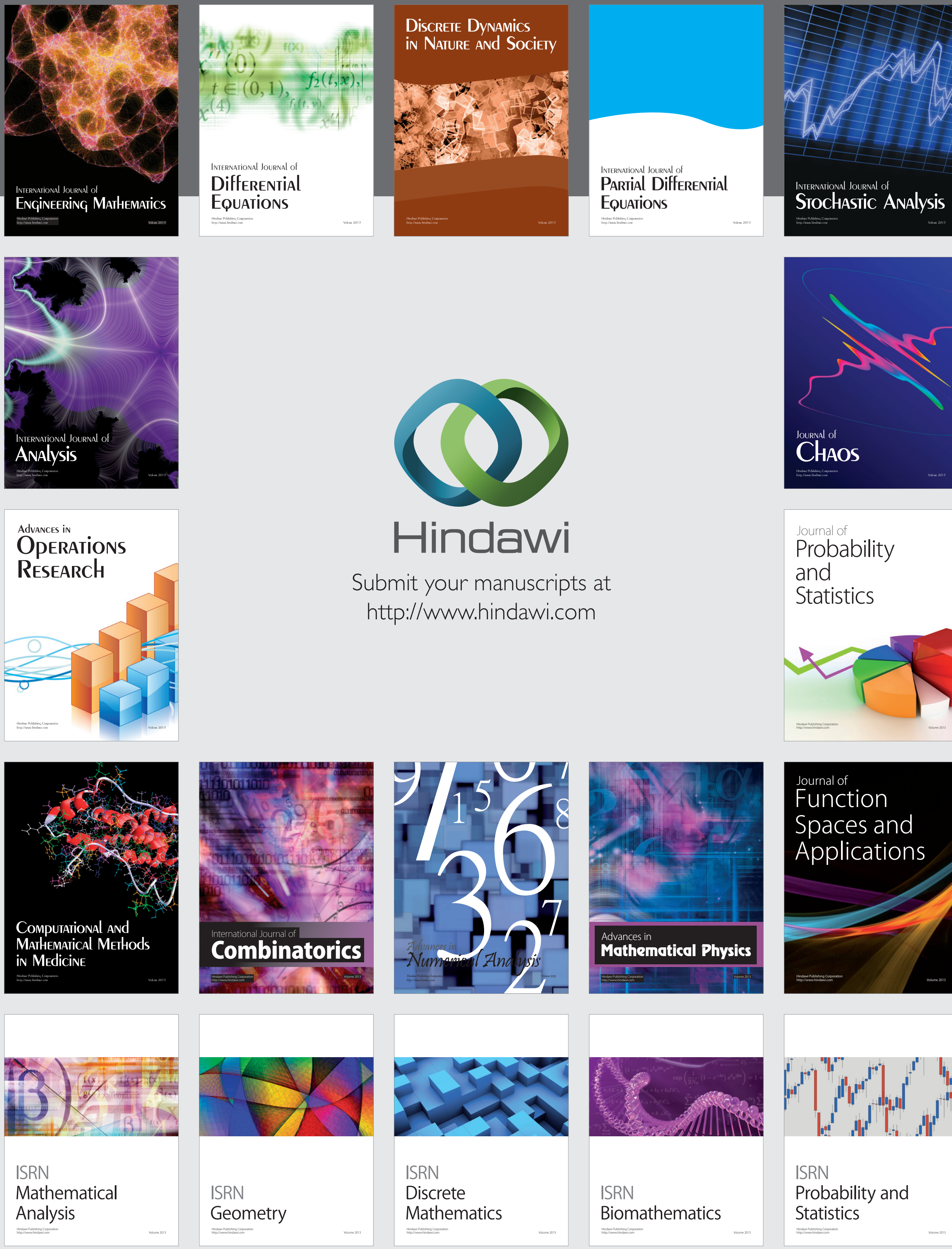
Potential organizers, speakers, and hosts should refer to page 274 in the the February 2013 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit http://www.ams.org/cgi-bin/abstracts/abstract.pl. Questions about abstracts may be sent to abs-info@ams.org. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (see http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

July 22–26, 2013: Samuel Eilenberg Centenary Conference (E100), Warsaw, Poland.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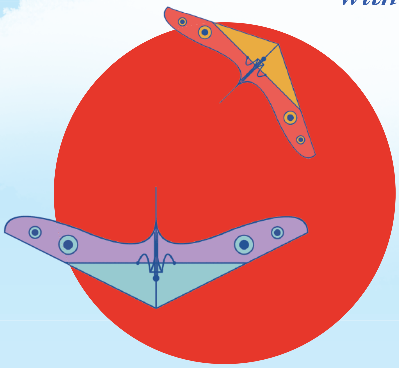


TEXTBOOK

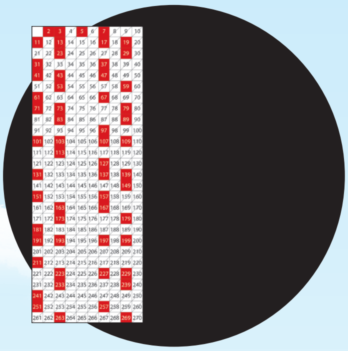
Euclidean Geometry

A Guided Inquiry Approach

David M. Clark, *State University of New York, New Paltz, NY*

This book develops a modern axiomatic approach to Euclidean geometry. Through a guided inquiry, active learning pedagogy, students are empowered to solve problems and prove theorems on their own while referring to instructors as guides and mentors. This book is particularly well suited for future secondary school teachers. An Instructor Supplement is available at www.ams.org/bookpages/mcl-9.

MSRI Mathematical Circles Library, Volume 9; 2012; 127 pages; Softcover; ISBN: 978-0-8218-8985-5; List US$39; AMS members US$31.20; Order code MCL/9



TEXTBOOK

Integers, Fractions and Arithmetic

A Guide for Teachers

Judith D. Sally, *Northwestern University, Evanston, IL*, and **Paul J. Sally, Jr.**, *University of Chicago, IL*

This book, which consists of twelve interactive seminars, is a comprehensive and careful study of the fundamental topics of K-8 arithmetic. The guide aims to help teachers understand the mathematical foundations of number theory in order to strengthen and enrich their mathematics classes. The book is intended for the professional development of teachers and is appropriate for teacher education programs, as well as for enrichment programs such as Mathematical Circles for Teachers.

MSRI Mathematical Circles Library, Volume 10; 2012; 208 pages; Softcover; ISBN: 978-0-8218-8798-1; List US$39; AMS members US$31.20; Order code MCL/10

Mathematical Circle Diaries, Year 1

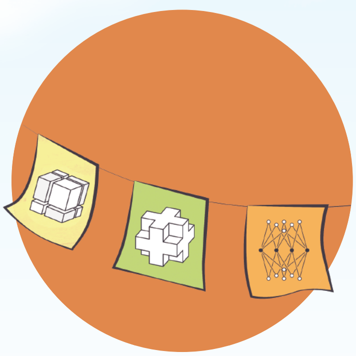
Complete Curriculum for Grades 5 to 7

Anna Burago, *Prime Factor Math Circle, Seattle, WA*

The book is a compelling testimony to our ability to overcome the alleged ills of the education system. . . . The meticulous presentation of problems, their context and solutions should make it possible for a math teacher with no circle experience to start one and make it interesting to the students. The book also aims at parents who might want to try following the author's footsteps. . . . More than an educational reform, our society (and politicians, of course) needs a change in perspective of what education of young minds is about. I do believe that Anna Burago's book spotlights the first steps in the right directions.

—Alexander Bogomolny, MAA Reviews

MSRI Mathematical Circles Library, Volume 11; 2012; 335 pages; Softcover; ISBN: 978-0-8218-8745-5; List US$25; AMS members and all individuals US$18.75; Order code MCL/11



Invitation to a Mathematical Festival

Ivan Yashchenko, *Moscow Center for Continuous Mathematical Education, Russia*

Held annually in Moscow since 1990, the Mathematical Festival is a brilliant and fascinating math competition attended by hundreds of middle school students. Participants of the Festival solve interesting mathematical problems and partake in other engaging activities, while cultivating key skills such as intuitive reasoning and quick thinking. This book contains problems presented at the Festival during the years 1990-2011, along with hints and solutions for many of them.

MSRI Mathematical Circles Library, Volume 12; 2013; 172 pages; Softcover; ISBN: 978-0-8218-6905-5; List US$25; AMS members and all individuals US$18.75; Order code MCL/12

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