Non-trivial feats: A review of recent awards in mathematics for science librarians

Short title: Awards in mathematics for science librarians

Keywords: Math, Awards, Prizes,

Abstract

In 2012 this publication reviewed the winner of international awards in mathematics with an analysis of winner of the Fields Medal (Meier 2012). In the four years since there have been multiple mathematics prizes and awards of various renown with a particularly historic Fields Medal - the first female mathematician ever to be honored. In this article the focus will only be on recent winners of awards, but additional prizes in mathematics will be included. Librarians should follow mathematical awards in order to collect related materials and keep aware of trends in the field.

Introduction

There is still debate today between those who believe mathematics is an existing truth to be discovered and those who describe advances in this science as invention. Both sides will agree that innovation and progress by mathematicians proceeds at an amazing pace with remarkable proofs and theories developed with increasing speed in our digital world. Far from the classic stereotype of the lone mathematical genius, modern math is built on conversation and collaboration. Each year new platforms for sharing and discussing mathematics are developed and a new generation of mathematicians is being educated.

While the Nobel Prize exists for most sciences, and is covered elsewhere in this issue (CITE?), no Nobel is awarded for mathematics. An equivalent may be the Abel Prize, also awarded by the Norwegian Academy of Science and Letters, though it does not have the longest (established in 2003) or most distinguished history among awards for mathematicians. Both the Fields Medal, first awarded in 1936, and the Wolf Prize in Mathematics, established in 1978, have longer tenures, though all will be covered in detail below.

The Fields Medal

Awarded by the International Mathematical Union (IMU), the Fields Medal not only has a long history (Tropp 1976) but also some unique restrictions. It is only awarded to mathematicians under the age of 40 years both to encourage future success and partly recognizing innovation occurs early in mathematical careers. During the official IMU meeting, the International Congress of Mathematicians (ICM), held every four years, up to four Fields Medals may be awarded. At the last meeting in 2014 in Seoul, Korea the full potential four Medals were awarded to Artur Avila, Manjul Bhargava, Martin Hairer, and Maryam Mirzakhani (International Mathematical Union 2014). The Fields Medal does not have the monetary value of the Nobel Prize, currently at 15,000 Canadian dollars. The Fields Medal was established in 1936 it is not
awarded for any particular paper, but the citations do acknowledge the most important contributions to mathematics from the winners.

Artur Avila is the first Brazilian to win the Fields Medal. As a teenager, he won the International Mathematical Olympiad and began working with mathematicians in high school (Lin and Klarreich 2014). He was also honored with the Michael Brin Prize in Dynamical Systems awarded at Penn State University in 2011. Avila’s work in Dynamical Systems, mathematical models of systems that begin with simple rules that evolve into complexity. This relatively new field has been the work of four separate Fields Medalists since 1994. His work bring more certainty to systems that are heavily affected by chaos theory, where small changes have great effects in a larger system over time. He collaborated on papers to find stability within the chaotic fluctuation of trajectories and population growth beyond certain limits. He also contributed to a solution to the “Ten Martini Problem” in the physics of Schrodinger operators. Avila now works part of the year at the Institute for Mathematics in Jussieu, France and part at his alma mater the Institute of Pure and Applied Mathematics in Brazil.

Manjul Bhargava is the child of Indian immigrants to Canada and the first Canadian to be awarded the medal. His mother was a mathematician at Hofstra University, and Bhargava showed a very early mathematical mind. He is the 5th Harvard PhD graduate to be awarded the Medal and the 6th Princeton professor, the 2nd youngest Full Professor in the history of the school. Indeed, working in New Jersey, USA at either Princeton or the Institute for Advanced Study (IAS) is a common characteristic of Fields Medalists. Bhargava studies number theory working primarily with whole numbers often in sequences, like the Fibonacci sequence (1, 1, 2, 3, 5, 8…) It can often be seen or applied in real world patterns like the number of petals on a flower. Bhargava tackled the problem of elliptic curves, produced by equations with exponents 3 or less, and if there are rational solutions to these equations. One of the Millennium Prize Problems is in this area (CMI 2016).

Unlike the other medalists, Martin Hairer’s award could be said to stem from a single paper in stochastic partial differential equations SPDE. He joins Vaughan Jones as an alumni of the University of Geneva among winners with a PhD in physics, one of the X physicists awarded. His paper proposed a new approach to SPDEs using mathematics similar to calculus and may provide a new language and toolset for mathematicians working in this area. SPDEs are relevant to the behavior of subatomic particles, most applicable to physics. There is a large amount of “noise” in certain systems that seem chaotic, but can sometimes be described by certain differential equations. Picture the spikes in a wavelength of music that are not smooth like a regular curve, so a new approach was needed to represent the values of this system.

Maryam Mirzakhani is the first female mathematician to be awarded the Fields Medal and also the first Iranian. She was working at Princeton when awarded the Medal (as was Manjul Bhargava), earned her PhD from Harvard (the 5th alum to win), and is currently working at Stanford University. She is the first medalist since Kunihiko Kodaira in 1954 who primarily publishes in MSC 32 “Several complex variables and analytic spaces”. Mirzakhani’s most
significant work involves hyperbolic surfaces, which are surfaces that do not have ordinary geometry so equations describing them operate in a much different way than in the real world. This allowed her to provide a new proof for a problem proposed by Edward Witten, an earlier Fields Medalist. She has also worked on problems in moduli spaces and geodesics, which are often described as billiard tables of various shapes and anticipating the trajectory of a ball on the surface.

**The gender barriers in math**

It has taken 78 years and almost 60 Fields Medals for a woman to be awarded the honor. Later in the article you will not see any female mathematicians, other than Mirzakhani, among the list of prize winners. In contrast, the Nobel Prize in its third year was awarded to Marie Curie, though over time only 5% of Nobel Prizes have gone to women with less than ½ for science and medical discoveries. Perhaps the Fields Medal in particular is difficult for a woman in mathematics to attain due to its restriction that the winner must be younger than 40 years old. Though there is recent research to suggest that women no longer have a longer time to PhD than men (Van Noorden 2015).

Despite many notable female mathematicians over time (Riddle 2014), there is symbolism and inspiration when prestigious and international awards show the diversity of the profession. There has been stagnation and even a slight downturn in the number of PhDs awarded to women in mathematics (Velez et al. 2015). It is not sustainable that with about ⅓ of the profession as women that so few have received honors, and the trends seem to indicate that bias and barriers of the past are decreasing. Only time will tell.

**The Wolf Prize in Mathematics**

The annual Wolf Prizes are given in a number of fields, one of which is mathematics, which can honor up to three mathematicians each year (Wolf Foundation 2015). Below the winners since 2012 will be reviewed, but overall there have been 56 honorees recognized for their achievements in mathematics. In some years the mathematics Prize is not awarded at all, such as 2016. It includes a cash awarded of $100,000. Since there are few restrictions placed on the award, other than being able to accept the prize in Israel, many Fields Medalists have also gone on to win the Wolf Prize in Mathematics. It often seems that the Wolf Prize is a career or lifetime achievement award, though it is often awarded earlier than the Abel Prize (see Tables 1 and 2).

The most recent recipient of the Wolf Prize in Mathematics is James Arthur, who has a PhD from Yale University and has worked at the University of Toronto since 1979. He has numerous other accolades, uniquely Canadian science and mathematics awards. His citation is “for his monumental work on the trace formula and his fundamental contributions to the theory of autotrophic representation of reductive groups.” Arthur has literally wrote the book on the subject, *An Introduction to the Trace Formula*, and the most recent version shares his name
“Arthur-Selberg trace formula.” It was essential to Wiles proof of Fermat’s theorem and has had a profound impact on number theory.

The 2014 Wolf Prize was awarded to Peter Sarnak of the Institute for Advanced Study and Princeton University. He was born in South Africa and received his PhD from Stanford in 1980. His citation was “for his deep contributions to analysis, number theory, geometry, and combinatorics,” so unlike James Arthur no one discovery or branch of mathematics is the source of Sarnak’s award. This work in number theory, primarily integers and whole number, has had a strong impact on computer science outside of pure mathematics. He has been honored with numerous other awards for his work and papers, and been elected to AAAS, the National Academy of Science, and the Royal Society of London.

George Mostow was awarded half of the Wolf Prize in 2013. He received his PhD from Harvard, and he worked primarily at Johns Hopkins University and Yale until his retirement in 1999. The majority of his work was in geometry and Lie (pronounced Lee) group theory. His most celebrated work was the Strong Rigidity Theorems, which is often referred to as the Mostow rigidity theorem. This found unique multi-dimensional objects can be defined by sets of base points in finite dimensions, which can be used to prove many other mathematical theorems. Michael Artin received the other half of the Wolf Prize in 2013 after a long career in mathematics. Born in Germany, his family fled the country in the 1930s. He obtained his PhD from Harvard in 1960 and worked mainly at the Massachusetts Institute of Technology (MIT). His “fundamental contributions to algebraic geometry” lead to his award, which also recognized his long career of research in this branch of mathematics.

The Abel Prize

The Abel Prize is might be the most similar prize to the Nobel, though Norwegian rather than Swedish, it has a comparable monetary award and is given annually to a living mathematician (Norwegian Academy of Science and Letters 2016). There have been 17 winners since 2003 since during three of the years the prize was shared between two recipients. As opposed to the Fields Medal this price can be seen as a lifetime achievement award either for a single monumental discovery or a career of many contributions to the field of mathematics. The past four years have seen both types of honorees, including some mathematicians famous beyond the profession.

In 2016 Sir Andrew Wiles was awarded the Abel Prize “for his stunning proof of Fermat’s Last Theorem by way of the modularity conjecture for semistable elliptic curves, opening a new era in number theory.” Since the publication in 1994 of his historic proof of the almost 400 year old theory written in the margins of a book by Pierre de Femat, Wiles has been the subject of many popular books on the proof and his eight year, solitary process in creating the solution. It even took years to verify the proof, and when an error was found, Wiles was able to correct it. He has built the proof on centuries of work, most recently on forms of mathematical geometry called elliptic curves and seemingly unrelated modular forms. Wiles has also been awarded the Wolf
Prize in 1996 among many other accolades following this proof that was eventually published in
1995 under the title “Modular elliptic curves and Fermat’s Last Theorem” in *Annals of
Mathematics*.

In 2015 the Abel Prize was awarded to two mathematicians: John F. Nash Jr. and Louis
Nirenberg. If John Nash’s name sounds familiar it is likely due to the 2001 film *A Beautiful Mind*,
which was loosely based on his biography of the same title. It chronicled his path to the 1994
Nobel Prize in Economics for his work in game theory and decision making. A graduate of
Carnegie Institute of Technology (now Carnegie Mellon), Nash completed his graduate work at
Princeton. He worked first at MIT but then began his collaboration with Louis Nirenberg at the
Courant Institute of Mathematical Science at New York University (NYU). Nirenberg had spent
his entire career at Courant before and after collaborating with nash on “striking and seminal
contributions to the theory of nonlinear partial differential equations and its applications to
geometric analysis.” Nash accepted his Abel Prize just days before his death alongside his wife
in a taxi car crash.

While not well known to the general public, Yakov Sinai is a renowned figure among
mathematicians. He was awarded the Abel Prize in 2014 “for his fundamental contributions to
dynamical systems, ergodic theory, and mathematical physics.” He was born and spent most of
his career in Moscow, Russia and the Landau Institute of Theoretical Physics before accepting
a concurrent position at Princeton in 1993. As a mathematician and researcher in physics, Sinai
has worked both in dynamical systems that try to determine solutions for chaotic systems, and
he has worked in stochastic models that use statistics to estimate solutions. He is also a
recipient of the Wolf Prize in 1997 and the American Mathematical Society (AMS) Steele Prize
for Lifetime Achievement in 2013. His work is cited as a vital bridge between the two fields as
math is a tool for physicists in their work from planetary motion to the behavior of subatomic
particles.

It is evident that the Abel Prize recognizes the highest achievements in mathematics as its
laureates often have many other awards. This is especially true of the 2013 award winner
Pierre Deligne. He was previously awarded the Fields Medal in 1978 and the Wolf Prize in
2008. This Abel Prize was “for seminal contributions to algebraic geometry and for their
transformative impact on number theory, representation theory, and related fields,” but in
particular for his proof of the Weil conjectures. Also known as Zeta functions, these
mathematical objects count the number of solutions to an equation in different number systems
such as in a variety of dimensions. Deligne proved the most difficult of the conjectures in 1974
almost 25 years after the problem was first introduced by Andre Wiel (a 1979 Wolf Prize
recipient).

**Rolf Nevanlinna Prize**
In addition to the Fields Medal, the IMU also awards the Nevanlinna Prize every four years for outstanding contributions to mathematics in the computational and information sciences. The prize was established in 1981 with the first award occurring in 1982. The creation of this prize reflects the emerging importance of computers in mathematics during the late 20th century. It includes a medal and carries a cash award similar to the Fields Medal. While many of the winner are primarily computer scientists, because that field developed out of mathematics they are also mathematicians or hold dual posts at their institutions.

Subhash Khot was awarded the Nevanlinna prize in 2014 and is a professor of computer science at the Courant Institute of Mathematical Sciences at NYU. Khot has mainly been honored for his development of the “Unique Games Conjecture”, which made an assumption about how difficult it is to create algorithms to approximate the difficulty of computer science problems. Similar to the P vs NP problem, which decides whether a computer can quickly solve a problem and verify the solution, this conjecture has helped computer scientists since prove that some problems are impossible to approximate while others can be estimated. While many of these results depend on his assumption, which is the “conjecture” part, some related theories have actually been proven even if Unique Games turns out to be incorrect.

Chern Medal 2014
Phillip Griffiths was awarded only the 2nd Chern Medal for lifetime devotion to mathematics and outstanding achievements. This adds to his accolades of the 2008 Wolf Prize in Mathematics and the Steele Prize for Lifetime Achievement from the AMS in 2014. Griffiths obtained his PhD from Princeton and worked there before moving on to Harvard, Berkeley, Duke, and eventually back to New Jersey to the Institute for Advanced Study (IAS). He was lauded for his contributions to algebraic and differential geometry, but also for his teaching and mentoring of students in mathematics. His leadership of IAS and advocacy for science in public policy were also cited in his honor. This wide-ranging impact beyond just research on the community of mathematicians puts him in the same realm as the eponymous Shiing-Shen Chern. Indeed the two were “collaborators and lifelong friends.” As a geometer he is recognized as a great communicator and visualizer of mathematics creating paths and connections across the field.

Carl Friedrich Gauss Prize 2014
Stanley Osher was awarded the third ever Gauss Prize for impact of mathematics in technology and everyday lives. He obtained his PhD at New York University (NYU) and now works at the University of California, Los Angeles (UCLA). Osher developed a fundamentally new approach to model how shapes change using slices of a three-dimensional representation to predict the behavior of a two-dimensional space. This mathematical revelation is used heavily in computer animation for almost every major animated film today. It is also used in the design of airplanes, medical scanning, and other visual applications. While it is often difficult to communicate the
importance and impact of mathematics on our daily lives, Osher’s work has clear and immediately recognizable benefits, which is the embodiment of the Gauss Prize.

**Leelavati Prize**


Adrian Paenza was awarded the Leelavati Prize in 2014 for “his decisive contribution in changing the mind of a whole country about the way mathematics is perceived in daily life.” This Prize uniquely recognizes outreach to the greater public from the field of mathematics. The first and only other honoree is Simon Singh, a British popular science writer who has authored many mathematics best sellers such as *Fermat’s Last Theorem* and *The Simpsons and Their Mathematical Secrets*. Paenza is an Argentinian mathematician who obtained his PhD from the University of Buenos Aires and taught there for over 2 decades. His long running TV program “Scientists Made in Argentina” interviewed scientist and challenged audiences with mathematical problems each show. His other media efforts including TV, newspapers, and books have had an impact throughout South America and the world.

**Leroy P. Steele Prize for Lifetime Achievement**

http://www.ams.org/profession/prizes-awards/ams-prizes/steele-prize

The American Mathematical Society (AMS) Leroy P. Steele Prize for Lifetime Achievement developed out of a publication based award, which was divided into three new awards in 1993. It also resulted in the Steele Prize for Mathematical Exposition honoring a book or research paper, and the Seminar Contribution to Research annually awarded in a different branch of mathematics in a six-year rotation. The 2017 Lifetime Achievement prize was awarded to James Arthur, who is already profiled above for his 2015 Wolf Prize.


In 2016 the Steele Prize for Lifetime Achievement was awarded to Barry Simon, a mathematical physicist at the California Institute of Technology with a PhD from Princeton University. His work on quantum mechanics and related fields has resulted in hundreds of publications as “significant research achievements, highly influential books, and mentoring of graduate students and postdocs.” His mathematical insights and tools have been used in pursuit of Heisenberg problems, Schrodinger operators, and proofs of symmetry.

**Clay Mathematics Institute (CMI)**

The CMI is a private, non-profit foundation based in the U.S. with officers in the U.K. It is best known for the seven Millennium Prize Problems established to “recognize some of the arguably most difficult problems with which mathematicians were struggling at the turn of the millennium.” Since they were established in 2000 only one of the problems, the Poincare Conjecture, has been solved. This underlines how many difficult, fundamental mathematical problems still exist and that they can endure for centuries. Similar to the “grand challenges” in other fields, these goals seek to inspire mathematicians to many other discoveries along the path to the larger problems. http://www.claymath.org/millennium-problems/
Beginning in 1999, CMI also recognizes achievement in mathematics with the Clay Research Award. These awards are made by the scientific advisory board of the Institute with no call for nominations. One or more mathematician may be honored in any given year, five received the award in 2007. While some of the citations note lifetime achievement, most of the award citations recognize a specific breakthrough, often going to early career mathematicians. In fact many Fields Medalists and winners of other accolades have received the Research Award. As examples, Terry Tao won the award before his Fields Medal yet Maryam Mirzakhani won the award contemporaneously. http://www.claymath.org/research

Other Prizes and Awards
There are many additional prizes and awards in mathematics that will not be discussed in detail here. These awards may be given for an individual paper (such as the Bocher Memorial Prize for the best paper in Analysis) or recognize notable mathematicians in a specific branch of mathematics (such as the Chevalley Prize in Lie Theory). The American Mathematical Society (AMS) has an extensive list of prizes and awards in mathematics http://www.ams.org/profession/prizes-awards/prizes However, there are numerous other professional associations in mathematics that offer prizes, such as the London Mathematical Society https://www.lms.ac.uk/prizes/lms-prizes Even publishers have competitive awards and prizes related to publications or researchers, such as the Elsevier Awards https://www.elsevier.com/physical-sciences/mathematics/long-term-commitment-and-support-for-the-mathematics-community#award

Conclusion

There are a number of reasons for science librarians to pay attention to the winners of mathematical awards. Foremost is the importance of maintaining familiarity with the subject they are supporting through the library. There are usually popular accounts of the discoveries associated with prize winners, which can be understood even by librarians with no background in mathematics. These accounts and this article will hopefully assist librarians with communicating to their library users on the topic and highlighting library collections and services.

Mathematical awards are also a sign that the work of these mathematicians will have a lasting impact and legacy. Since mathematics uses older materials to a much higher degree than other STEM fields (Butkovich 2010, Barsky 2012), investments in these materials will have a longer payoff period in use by library patrons. A number of publishers collect the works of award winners following announcements, for example World Scientific has a series of Fields Medalists’ Lectures as well as Wolf Prize in Mathematics, which includes bibliographies, papers, and speeches by the award winners.

Postscript - A Brief Analysis of the “Triple Crown of Mathematics” (Hat Trick?)
There are few mathematicians who have been awarded the top prizes in mathematics, and even fewer have been honored with multiple. As discussed earlier, ostensibly the top three awards in mathematics are the Fields Medal, Abel Prize, and Wolf Prize. Perhaps the most difficult to predict or subjective may be the Fields Medal, which is awarded only early in a mathematician’s life so its honorees must show early success and future promise. The Wolf and Abel prizes can be considered awards for a distinguished career, though they can sometimes be awarded decades apart. In Table 1 are the few mathematicians to be awarded all three prizes. With so few it is difficult to show any correlation between these top mathematicians.

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation (longest time)</th>
<th>Fields Medal</th>
<th>Wolf Prize</th>
<th>Abel Prize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jean-Pierre Serre</td>
<td>College de France</td>
<td>1945</td>
<td>2000</td>
<td>2003</td>
</tr>
</tbody>
</table>

Table 1: Winners of the Fields Medal, Wolf Prize, and Abel Prize

It is also interesting to note the number of Wolf Prize winners that have also been honored with the Abel Prize (Table 2). Indeed, of the 17 Abel prize laureates over half of them (11 total) had previously been awarded the Wolf prize. Since there are currently 56 Wolf Prize mathematicians, almost 20% of them have also been awarded the Abel Prize. Surely if one wishes to predict future Abel Prize laureates, looking at the list of Wolf Prize winners who are still alive is a good place to start.

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation (longest time)</th>
<th>Wolf Prize</th>
<th>Abel Prize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Lax</td>
<td>Courant Institute of Mathematical Sciences, New York University</td>
<td>1987</td>
<td>2005</td>
</tr>
<tr>
<td>Lennart Carleson</td>
<td>Mittag-Leffler Institute, Sweden</td>
<td>1992</td>
<td>2006</td>
</tr>
<tr>
<td>Jacques Tits</td>
<td>College de France</td>
<td>1993</td>
<td>2008</td>
</tr>
<tr>
<td>Mikhail Gromov</td>
<td>Institut des Hautes Études Scientifiques, France</td>
<td>1993</td>
<td>2009</td>
</tr>
<tr>
<td>Andrew Wiles</td>
<td>Princeton University</td>
<td>1995</td>
<td>2016</td>
</tr>
</tbody>
</table>
Table 1: Winners of both the Wolf and Abel Prizes

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yakov Sinai</td>
<td>Landau Institute for Theoretical Physics, Russia</td>
<td>1997</td>
<td>2014</td>
</tr>
<tr>
<td>John Tate</td>
<td>Harvard University</td>
<td>2002</td>
<td>2010</td>
</tr>
</tbody>
</table>

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http://www.tandfonline.com/action/authorSubmission?journalCode=wstl20&page=instructions