Nominations for President

Nomination of George Andrews

Richard Askey

Who is George Andrews? According to Freeman Dyson, George Andrews is the chief gardener in Ramanujan's Garden. This is true, but is only part of who George Andrews is. He is a number theorist with an honorary doctorate in physics. He is a long-time user of computers in his own research, who has written about the harm technology can do in mathematics education. He is primarily a problem solver, yet one paper with Rodney Baxter and Peter Forrester has had a major impact in mathematical physics with currently 490 citations in the Web of Science.

George Andrews received his Ph.D. from the University of Pennsylvania with a thesis on mock theta functions, written under Hans Rademacher. Google Scholar shows only three papers mentioning mock theta functions before 1966, when George published his thesis. The first was a paper of G. N. Watson. Next was Hardy's Harvard Tercentenary Lecture which only mentioned Ramanujan's last letter where mock theta functions were partially described and some examples given. The third was a paper written by Leila Dragonette [later Leila Bram] based on her thesis supervised by Rademacher.

These three contained most of what was known about mock theta functions before the 1966 papers of Andrews began a career that seemed to be one of "unfashionable pursuits", to use the title of a paper by Freeman Dyson which first appeared in the *Mathematical Intelligencer* and later as a chapter of his book, "From Eros to Gaia".

The first ten years of George's professional career were marked with many papers on basic hypergeometric functions, another then unfashionable pursuit; some combinatorics which was then starting to become fashionable; and some number theory, which has never gone out of fashion although the parts of it George dealt with were not fashionable then. George spent a year on leave at MIT. At Rota's suggestion, he edited the "Collected Papers" of P. A. MacMahon. He also wrote a book, "The Theory of Partitions", for the *Encyclopedia of Mathematics and Its Applications* series which Rota edited.

George came to the University of Wisconsin-Madison for a year, 1976-77. In the spring he went to Europe for two meetings in France. Since he was not teaching and airfare abroad was less expensive if you spent 21 to 45 days, he also went to Cambridge to look for old work in the Wren Library of Trinity College. This changed his life.

What George found was a bit over 100 pages of mathematical claims in the distinctive handwriting of Srinivasa Ramanujan. These pages had been found by J. M. Whittaker when he went to G. N. Watson's home to look at Watson's papers in preparation for writing an obituary article. To Whittaker, they looked like more of what had been published earlier by the Tata Institute, Ramanujan's *Indian Notebooks*. Robert Rankin and Whittaker deposited these pages at Trinity College. Probably the next person to look at them, after more than ten years, was George.

Unfashionable work sometimes plays a vital role, and in these pages there were some results about mock theta functions. Of course the words "mock theta functions" did not appear, just some series which George recognized. It is very unlikely that anyone else who was alive then would have recognized the real importance of these sheets, which must have been work Ramanujan had done after he returned to India. Ramanujan's only mention of mock theta functions was in his letter to Hardy about nine months after he had returned to India, and he wrote that he had recently found these functions.

George has worked part time for thirty years on the 600-plus results stated or hinted at in what he called Ramanujan's Lost Notebook. In December, 1987, these one-hundred-plus pages plus other unpublished work of Ramanujan were published by Narosa, with an introduction

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by George. Recently the first of what is likely to be four volumes giving proofs of almost all of Ramanujan's claims was published by Springer. Andrews and Bruce Berndt wrote the first volume and will be writing the remaining ones. This late work of Ramanujan may end up being the most important work he did, but time will have to tell since most of it has not really been understood yet. There are some gems in this collection. One led to the discovery of a partition statistic which Dyson had conjectured existed in a paper he wrote as an undergraduate at Trinity College. Ramanujan had proven that the number of partitions of $5n+4$ is always divisible by 5, the number of partitions of $7n+5$ is divisible by 7 and the number of partitions of $11n+6$ is divisible by 11, plus much more. Dyson found a way of breaking the partitions of $5n+4$ into five groups of equal size, and this method worked for $7n+5$, but he was unable to prove this conjecture. However, this method failed for $11n+6$. Dyson called his method of splitting into equal parts the rank, and conjectured that a different way should exist which works for $11n+6$. This he called the "crank". A way of doing the decomposition was found by Andrews and one of his Ph.D. students, Frank Garvan. This is only one of many gems which either have been obtained from the claims in these sheets or will be found when we understand more about what Ramanujan was doing.

Over the thirty years since these sheets were found, Andrews has done a lot of other work. One important result came about when Rodney Baxter solved the hard hexagon model in statistical mechanics, rediscovered the Rogers-Ramanujan identities and proved them, but had some other conjectures he could not prove. Kurt Mahler suggested Baxter write Andrews and ask for help. George was able to prove the remaining identities. This ultimately led to the ABF-model which was introduced in the Andrews, Baxter, Forrester paper mentioned earlier. In a different direction, he has been involved in computer algebra, helping to design a computer algebra package called Omega to work on complicated partition problems. This is joint work with people in Austria.

As a teacher and lecturer, George Andrews is excellent. He is the 2007–2009 George Polya lecturer for the MAA. Earlier he gave the Hedrick Lectures to the MAA, the J. S. Frame Lecture to Pi Mu Epsilon, the award lecture to the U. S. Math Olympiad Team and many other invited lectures. He won the Allegheny Region Distinguished Teaching Award from this MAA section. About ten years ago one of our undergraduates went to Penn State for a semester for their MASS program. When she came back she raved about the course she had taken from George Andrews. She is now chair of a high school mathematics department. Here is what she wrote in reply to my asking for comments.

> "I went to Penn State's MASS Program just so that I could take George Andrews' Number Theory class (because you told me to!), and I was not disappointed. The class was fabulous. Professor Andrews is a master teacher, and I have rarely had so much fun working so hard. He is clearly brilliant, and he made us believe that we too could begin to understand the mathematics that he loved. I can remember being in class, sitting on the edge of my chair, holding my breath in excitement, waiting to see what would come next. I can remember not being able to stop grinning because the work he was doing with us was so beautiful and so much fun. I spent hours upon hours doing anything and everything he asked of us both because I wanted him to be proud of my work and simply because it was so fascinating. One of the things that really stood out to me was how much grace and kindness he had. I've never regretted leaving the world of mathematics and becoming an educator, but a part of me will always wish that I could have studied with him more. When I first became a teacher, I decorated the back wall of my classroom to look like his Number Theory book. It gave me a chance to talk about some fun math with my students, it represented how much fun learning can be, and it reminded me of a wonderful teacher that I want to be more like."

Some of the service George has done at Penn State is chairing the Mathematics Department twice, which I consider cruel and inhuman punishment to have to do this a second time; served on a Dean Selection Committee and a Presidential Selection Committee; and along with many other committees has recently been chair of the Undergraduate Studies Committee in the Mathematics Department. The last is an indication of the importance George Andrews feels about education. He has a family background for this since his mother was a teacher trainer in the earlier part of the last century.

Nationally he has been on the committee which wrote problems for the Putnam Exam; served on the AMS Committee on Libraries, another area of concern for George; the AMS Committee on the History of Mathematics; as well as many others. George is a Member of the National Academy of Sciences, and a Fellow of the American Academy of Arts and Sciences. These are just a couple of indications that his mathematical work has made his "unfashionable pursuit" a thing of the past; it has become fashionable in a number of different areas. A very striking indication of this happened last year when the National Academy of Sciences made the first of an annual award for the best paper which appeared in the Proceedings of the National Academy of Sciences. The award went to a then graduate student in mathematics, Karl Mahlburg. The title of Mahlburg's paper is "Partition congruences and the Andrews-Garvan-Dyson crank". Even more recently, the place where mock theta functions fit into the rest of mathematics has been discovered by Kathrin Bringmann and Ken Ono.

In Dyson's article "Unfashionable Pursuits", he wrote the following: "The leading institutions of higher learning offer security and advancement to those who skillfully follow the fashion, and only a slim chance to those who do not." We have Penn State to thank for hiring someone who worked in an unfashionable field and rapidly recognized the gem they had hired.

The mathematics community needs someone who can explain what mathematics is and why it is important.

George Andrews can do this very well. The AMS needs a strong leader who is wise, is very good at listening to others, and knows how to inspire others to work at their highest level. George Andrews has done this not only with students, but also with colleagues in the mathematics department and with faculty members in other departments. He will do this as president of the American Mathematical Society.

Nomination of John W. Morgan

Hyman Bass and Robion Kirby

John Morgan is a mathematician's mathematician. He exemplifies many of the qualities that mathematicians celebrate—broad scientific vision, creative imagination, technical power and virtuosity, mathematical rigor, clarity and elegance of exposition, intellectual generosity, a gift for high level collaboration, and the sheer good-natured and unpretentious enjoyment of doing mathematics. And he has as well served the profession and demonstrated leadership at high levels with distinction. For example, he served on the Board of Trustees of MSRI, which he chaired during a period of important transition; on the Science Policy Committee of the AMS; on the Steering Committee of the IAS/Park City Institute; on the organizing committees of numerous conferences and congresses; as an editor of several premier journals (for example, the *Journal of the AMS*, *Inventiones*, *Geometry and Topology* [of which he was a founding editor]); and as chair of an outstanding mathematics department. It is hard to imagine anyone better suited to serve as president of the AMS.

How does mathematics advance? First, and perhaps foremost, through the creative insights and genius of mathematicians who solve problems of depth, importance, and pedigree. On this ground alone John Morgan's accomplishments are manifold, as we shall relate below.

But great and important new ideas do not automatically spread quickly or easily to the general mathematical culture, and it is only rarely that their discoverers are the best agents for such dissemination. Moreover, even the completeness and rigor of the new ideas and claims often require processing and elaboration by the broader community to be firmly established. These roles are some of the many ways that John Morgan has, throughout his career, advanced our field in timely and decisive ways. The rapid advancement and assimilation of many of the most significant mathematical developments in topology and geometry of the past several decades owe much to the writings and work of John Morgan. He is, in the words of Lee Shulman, a "steward of the discipline".

At the core of Morgan's mathematical interests are the problems of classifying manifolds—topological, smooth, analytic, and algebraic. A central thread in this century-long development is (are) the Poincaré Conjecture(s)—both the first, and the latest, chapters. The methods and ideas mobilized to treat the various instances of these problems have been absorbed from many of the central domains of mathematics—algebraic and geometric topology, differential geometry, algebraic geometry, Lie groups, geometric group theory, mathematical physics–and, at each turn, Morgan has boldly jumped in and become a leading expert in aspects of each of these areas.

Here are some of the milestones of Morgan's extraordinary career, which is a kind of tour of some of the main currents of contemporary mathematics.

0. Education: John received his Ph.D. at Rice University in 1969 (under Morton Curtis), one year after his B.S. Ed Connell once described teaching mathematics to Morgan as like pouring milk into a pitcher; no resistance. John's early work treated questions of surgery obstructions and transversality.

1. Sullivan's theory: This says, "The DeRham complex encodes all of the real algebraic topology of a smooth manifold." One of the first expositions of this theory was a widely disseminated 1972 set of lecture notes of Morgan and P. Griffiths; they were finally published in 1981, after popular demand.

2. Mixed Hodge structure on open varieties: With P. Deligne, P. Griffiths, and D. Sullivan, Morgan showed that the rational homotopy type of a compact Kähler manifold is a consequence of its cohomology. Morgan went on to establish a generalization of this to arbitrary (non-compact) varieties.

3. The Smith Conjecture: In 1938 Paul Smith proved that the fixed point set of a periodic orientation preserving homeomorphism of S^3, if not empty, is homeomorphic to a circle; and he asked if that circle must be unknotted. This was proved in 1979 for periodic diffeomorphisms. The proof was "assembled", largely through efforts of Morgan, by connecting several results of several authors, from different parts of mathematics: classical PL topology; Thurston's Uniformization Theorem for (closed, irreducible, atoroidal) Haken manifolds, which applies to one case of the Smith Conjecture; an equivariant version of Dehn's Lemma and the Loop Theorem, due to Meeks and Yau, that C. Gordon and R. Litherland showed could settle the remaining case of the Smith Conjecture; and a result on finitely generated subgroups of $SL(2, \mathbf{C})$ derived from the Bass-Serre theory of group actions on trees, that was needed in the application of Thurston's Uniformization Theorem. This work was collected in a book edited by Morgan and the first author. A detailed proof of Thurston's theorem was not then publicly available. In an 88-page chapter, Morgan provides a detailed proof of many cases of this result (the other cases being later treated by C. McMullen). Morgan wrote, "Although the general outlines and the grand themes presented in this chapter are due entirely to Thurston, the detailed logical structure

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and explicit formulations of the intermediate results are often our own. They are our attempt at imposing a logical structure, suitable to us, on what we understood Thurston to be saying. As such, the responsibility for the correctness of this detailed matter falls on our shoulders."

4. Group actions on trees: Inspired in part by the application to the Smith Conjecture, Morgan, with Peter Shalen (and others), launched an important new branch of geometric group theory–group actions on Λ-trees–with deep applications to degenerations of hyperbolic structures on manifolds. This area continues actively in geometric group theory to this day. In terms of new concepts and methods, this represents one of the most original phases of Morgan's work. A Λ-tree, where Λ is a totally ordered abelian group, is just an ordinary simplicial tree when $\Lambda = \mathbf{Z}$; in general it is "tree-like", but with edges parametrized by intervals in Λ. An important case is when $\Lambda = \mathbf{R}$. For a hyperbolic n-manifold N with fundamental group Γ, the moduli space $H^n(\Gamma)$ of hyperbolic structures on N can be identified with the "character variety" of conjugacy classes of discrete faithful representations of Γ into SO(n,1). Morgan and Shalen construct a compactification of $H^n(\Gamma)$ whose boundary points correspond to actions of Γ on $\mathbf{R}$-trees. They recover and generalize the Thurston compactification, and obtain compactness criteria for $H^n(\Gamma)$ that are weak generalizations of Mostow Rigidity. Along the way they raise and partially answer some deep questions about group actions on real trees.

5. Smooth classification of 4-manifolds: In 1980 dimension 4 revealed its two faces. Michael Freedman extended the topological solution of the Poincaré Conjecture from higher dimensions to dimension 4. At about the same time, Simon Donaldson, using ideas from gauge theory, showed that, for simply connected smooth 4-manifolds the smooth classification is much more complicated. For example, there are infinite families of the same homotopy type, hence pairwise homeomorphic (by Freedman), yet not diffeomorphic. Morgan, in collaboration with Robert Friedman, Zoltán Szabó, and others, then launched an intense program of research on the Donaldson polynomials and applications to the smooth classification of complex algebraic surfaces. They found 4-manifolds with infinitely many smooth structures, and completed the smooth classification of elliptic surfaces. This work was synthesized in Morgan's book with Friedman, *Smooth 4-manifolds and Complex Surfaces* (1991).

6. Seiberg-Witten invariants: In 1994 the introduction of these monopole invariants provided a powerful new tool for studying 4-manifolds, and largely supplanted the approach to 4-manifolds using Donaldson's invariants. One of the first dramatic applications was the proof, by Morgan, Szabó, and Cliff Taubes, of a generalization of the "Thom Conjecture": *On a compact Kähler surface, a smooth holomorphic curve C with $C \cdot C \geq 0$ minimizes genus among smooth embedded Riemann surfaces in its homology class.* (A special case of this was independently proved by Kronheimer and Mrowka.) Liviu Nicolaescu, in his Featured Review of the above paper, writes, "In this truly remarkable paper, three of the best experts in gauge theory establish a generalization of a long-standing conjecture in 4-manifold topology."

7. Physical intuition for mathematicians: The remarkable confluence of theoretical physics, notably quantum and string theory, with the highest levels of pure mathematics has produced some historic role reversals. Instead of mathematical theorems being used to design experimental tests of physical theory, now physicists are using powerful physical intuition to predict subtle new results in pure mathematics, and then, in the place of physical experiments, mathematicians seek rigorous proofs to mathematically confirm the physicists' predictions. Many mathematicians were naturally eager to gain, in some mathematically friendly way, some of this uncanny physical intuition. To this end, the Institute for Advanced Study organized a remarkable special year (1996–97), making the Institute that year a kind of Mount Olympus of mathematics. John Morgan played an important part in that year, documented in two thick volumes, *Quantum Fields and Strings: A Course for Mathematicians*. In the course of such physically inspired mathematics, Morgan, together with R. Friedman and A. Borel, produced an important memoir precisely describing the moduli spaces of (almost) commuting pairs and triples in a compact connected semi-simple Lie group K; this yielded proofs of conjectures of Witten about flat K-principal bundles over tori of dimensions 2 and 3.

8. The Poincaré Conjecture: At ICM-Madrid in 2006, Grigori Perelman was awarded the Fields Medal for his proof of the original (3-dimensional) Poincaré Conjecture, and even the Geometrization Conjecture of Thurston. Perelman's proof was sketched in three technical papers, addressed to experts, and posted on the arXiv in 2002 and 2003. The approach, due originally to Hamilton, is based on detailed study of the Ricci flow. Several efforts around the world undertook to provide complete and convincing details of this monumental result. It was essential for the Fields Medal that confirmation of Perelman's proof be firmly established. This certification was provided in the ICM presentation of Perelman's work by John Morgan, based on the monograph exposition of the proof that Morgan and Gang Tian had produced. Morgan had given a course of lectures on this at the Park City Institute. The Morgan-Tian book will surely remain a definitive reference for Perelman's results for years to come. (Several others, notably B. Kleiner and J. Lott, contributed generously to the dissemination of details of Perelman's proof. Also Huai-Dong Cao and Xi-Ping Zhu have published a write-up of the proof.)

We find this mathematical trajectory breathtaking. At heart a geometer, Morgan is yet a universal mathematician, always close to the core of mathematics. As president of the AMS he would represent the finest expression of the mathematical spirit.