Mathematics at Trinity

Bill Tutte
The Man Who Knew Infinity
Ramanujan
Maths Olympiad
In this issue we celebrate Trinity’s distinction in mathematics, in film, and in film about mathematics. The presentation of the Academy Award for Best Actor to Eddie Redmayne (2000) for his portrayal of Stephen Hawking in *The Theory of Everything* was announced just before we went to Press. I am sure all members of the College would wish to congratulate him on both his award and his performance.

Last summer Trinity was the setting for part of *The Man Who Knew Infinity*, a film about the life of Srinivasa Ramanujan (e1918), a mathematician of extraordinary genius. Our Senior Tutor Catherine Barnard (e1996) was on hand to interview Dev Patel, who played Ramanujan. For those keen to revive their dormant mathematical talents, Sir Timothy Gowers (1982) describes one of Ramanujan’s more accessible solutions.

Trinity mathematicians were prominent as code-breakers at Bletchley Park. The achievements of Bill Tutte (1935) in this area were particularly important. His work is described here by Béla Bollobás (1963).

The Mathematics Olympiad encourages both competition and friendship between mathematicians of school age. Many successful competitors have become undergraduates of the College, and many in turn have helped with mentoring and administration. Adam Goucher (2012) and James Aaronson (2012), graduate students at Trinity, give an account of the Olympiad and describe its appeal.

I should like to thank all the contributors for their willingness to send in copy at a very busy time of the academic year.

Dr Neil Hopkinson (e1983)
Fellow, Editor
W.T. Tutte (1917–2002)

Professor Bill Tutte was not only a great mathematician, who was instrumental in elevating the fledgling subject of combinatorics into an important area of mathematics, but also the greatest codebreaker of WWII.

Bill was an undergraduate in our College, and was awarded a Prize Fellowship (in today’s terminology, a Junior Research Fellowship) well before he finished his PhD.

William Thomas Tutte was born in Newmarket on 14th May, 1917. At the time his father, a gardener, and his mother, a cook and housekeeper, were working in Fitzroy House, a horse racing stable. The depression that followed WWI hit his parents hard, so young Bill lived in four different places before he turned six. At this time they returned to the Newmarket area, so that his father could work in the Rutland Arms Hotel. At eleven, Bill won a scholarship to the Cambridge and County Day School, where his interest in mathematics was awakened by Rouse Ball’s Mathematical Recreations and Essays. Nevertheless, in 1935 he came up to Trinity to read Natural Sciences, specialising in chemistry.

In Trinity Tutte struck up a life-long friendship with three of his contemporaries: Leonard Brooks, Cedric Smith and Arthur Stone. It soon became apparent that Tutte, the chemist, was even more of a mathematician than his friends. With characteristic modesty, as they wrote later, the four students called themselves the Important Members of the Trinity Mathematical Society or, simply, The Four. The Four became interested in an unusual question Paul Erdős had brought to England the year before: ‘Can a square be tiled by finitely many squares of different sizes?’ Briefly: ‘Is there a PSS, a Perfect Squared Square?’. Unbeknown to The Four, this question of recreational mathematics had been looked at by many people, including the distinguished Russian analyst Nikolai Luzin, who claimed, but did not prove, that there was no PSS. The Important Members worked on this problem for three years. After many failed attempts, they established a connection between PSSs and currents in an electrical network satisfying Kirchhoff’s laws, and found a PSS of order 69 (that is a PSS made up of 69 small squares). Curiously, a few months before the publication of this result, Sprague, a mathematician in Berlin, had published a PSS of order 55. A few years ago, to celebrate this achievement of its Important Members, the smallest ‘simple’ PSS (of order 21) was chosen to be the logo of the Trinity Mathematical Society.

This ingenious bit of mathematics of The Four had momentous consequences. When WWII broke out, Tutte was summoned by his Tutor, Patrick Duff, and was told to go to Bletchley for an interview for a war job. Following this interview and a few weeks in London in a cryptographic school, Tutte joined the small but elite Research Section of the Government Code and Cypher School at Bletchley Park, the forerunner of GCHQ in Cheltenham.

It is well known that the cryptographers at Bletchley Park, led by Alan Turing, were very successful with the German machine-cipher called Enigma. Much less is known about Tutte’s role in breaking the incomparably harder and much more important machine-cipher Fish. In the early 1930s the French, and later the British, obtained from a spy an operating manual and two sheets of monthly key settings for the three-wheeled Enigma machine, and they also acquired a commercial machine. In spite of this, they were unable to decipher secret German messages. However, when they passed all this information to Polish Intelligence, three young Polish mathematicians in Poznań managed to work out the internal wiring of the German military machine, and even built an electromechanical device to help with deciphering messages. When Germany overran Poland, the Polish codebreakers tremendously surprised their French and British counterparts when they gave them copies of the German military Enigma machine, and passed on everything that they had discovered. All this was only the beginning: the codebreakers at Bletchley Park had to keep up with the modifications the Germans kept introducing; they had to break the codes quickly for the results to be of any use. To achieve this, Turing designed a ‘bombe’, an electromechanical device much beyond what the Poles had built. By the end of the war, about two hundred bombes had been built to keep up with the flow of messages. Although the Enigma used by the German Army remained recalcitrant, the cryptanalysts at Bletchley Park were experts at breaking Navy and Air Force Enigma messages.
Enigma used Morse codes and was for low-level communications. In addition to Morse codes, from 1941 the Germans used radio links: at Bletchley this non-Morse traffic became known as Fish. As Enigma, Fish came in three flavours: Army, Air Force and Navy. Although nobody at Bletchley Park had any idea what machines produced Fish, the codebreakers were determined to break the code used by the Army, which they named Tunny. This was a high-level cipher used between generals in the field and their command centres; many of the messages were signed ‘Adolf Hitler, Führer’.

The cipher messages were in the 5-bit 32-letter Baudot Teleprinter Code alphabet, and were produced by the Lorenz 40/42 teleprinter cipher attachment. Each encrypted message of Tunny started with a sequence of twelve letters, occasionally even expanded into common personal names like Anton, Bertha, etc. It was assumed that these twelve letters specified the settings of twelve wheels.

The codebreakers were helped by a serendipitous event on 30th August 1941, when a long message from Athens to Vienna could not be read clearly by the recipient, and the German operator resent the message with the same wheel settings but with slightly different punctuation and word-spaces. This enabled the veteran cryptanalyst Brigadier John Tiltman to work out a piece of the Tunny key. In spite of this lucky break, all the might of the cryptographers at Bletchley Park had done, only that he must be elected. So in October 1945 Littlewood told the Electors that Tutte must be given a Fellowship for his secret work, and Tutte duly became a Fellow of the College.

But what about his PhD? He could not submit his codebreaking results in a PhD dissertation, so he returned to his old love, graphs. Working independently of his supervisor, Shaun Wylie, who had also returned to Cambridge from Bletchley Park, he wrote an outstanding dissertation on algebra and graph theory, and, especially, the combination of the two. After he received his PhD in 1948, he accepted a position in Toronto at the invitation of the great geometer Donald Coxeter (a former Research Fellow of the College). A year later he married Dorothea Mitchell, and in 1962 he moved to the University of Waterloo (founded in 1958), officially retiring in 1982. Bill and Dorothea did not live in Waterloo, but in the tiny village of West Montrose, just over ten miles from the campus. Their house was near a local landmark, a covered bridge (the only one in Ontario): they enjoyed their beautiful garden, went for long hikes and canoed on the river.

Tutte was a phenomenal codebreaker, but his achievements in mathematics are even greater. However, as this article is for a general audience, I shall not say much about his results. Today’s combinatorics is a flourishing and dynamic branch of mathematics, attracting many of the most talented young mathematicians. This is due mostly to two giants: Paul Erdős, who visited the College many months of deep thinking, Tutte broke the back of the problem. As he wrote many years later: “At this stage the rest of the Research Section joined in the attack ... Thus were the entire workings of the Tunny machine exposed without any actual physical machine or manual thereof coming into our hands.”

Not surprisingly, the messages they managed to decode were too old to be of any interest. It was imperative to use Tutte’s discoveries quickly, so the computations had to be done mechanically. This mechanization was carried out by the technical genius Tommy Flowers, who built the pioneering electronic computer Colossus for this purpose. Soon coded messages could be broken in 24 hours, and these were passed on to the military as “Ultra” intelligence. By the end of the War, ten Colossus machines were working on Tunny codes.

Bill Tutte and Tommy Flowers are the two unsung heroes of WWII. Breaking Tunny is often called the single greatest intellectual feat of WWII: it remained extremely important to the end of the war. (In fact, well beyond the end, since by keeping its breaking secret, the British could break the messages of the Soviets, while during the Cold War happily used the Lorenz machines they had taken from the Germans at the end of WWII.) In particular, “Ultra” messages were vital in the decisive battle of Kursk and in the weeks leading up to D-Day. The official historian of British Intelligence, Harry Hinsley, wrote that the “Ultra” intelligence produced at Bletchley Park shortened the war by two to four years, and that without it the outcome would have been uncertain.

Sadly for Tutte and Flowers, their achievements were Official Secrets until a few years ago, and as a result they received far too little recognition for their war work. Perhaps Flowers was short-changed even more than Tutte, as he had to suffer in silence while the glory of building the first electronic computer went to others. At least a bronze bust commissioned by BT reminds us of him – in contrast, ironically, many of our scientists are celebrated with works of art they would have hated: in Newmarket there is an installation to celebrate Bill Tutte, and in Tallahassee there is a mobile to honour the great physicist Paul Dirac. It seems that almost all the accolades go to Alan Turing, who was indeed a great mathematician – a host of books, a beautiful bust at Bletchley Park, and even a Hollywood film sing his praise.
times, and was a VFC for a term, and Bill Tutte. Erdős championed extremal and probabilistic combinatorics, while Tutte developed structural graph theory in conjunction with algebra. Tutte’s work on the foundation of matroid theory, building on his 1948 dissertation, his numerous deep results on structural graph theory, and the introduction of the Tutte polynomial, had a profound influence on mathematics going beyond combinatorics. He was greatly respected by all the combinatorialists. To celebrate his 60th birthday, in May 1977 I organized a well attended international meeting in the College. At the conference dinner he was happily reunited with his tutor, Patrick Duff, and both of them gave witty and memorable speeches.

Outside combinatorics, Tutte was greatly underestimated: although he was elected into an Honorary Fellowship of Trinity, he became an FRS decades late, only after he had retired from Waterloo, and was never awarded a knighthood, let alone the peerage he so richly deserved. Canada was kinder to him: in 1958 he was made an FRSC, and in 2001 he became an Officer of the Order of Canada.

Dorothea, without whom one could not imagine Bill, died in 1994, and a couple of years later Bill moved back to England. Sadly, he did not settle in Cambridge, where he would have found a stimulating environment with college life, plenty of mathematics and many visiting mathematicians, but returned to Newmarket. Some years later he moved back to Waterloo, where on 2nd May 2002 he succumbed to congestive heart failure, complicated by lymphoma of the spleen.

Tutte’s contribution to the war, and thereby our lives, is hard to overstate. This contribution was barely acknowledged during his lifetime, but, after two TV programmes about the Bletchley Park codebreakers and a campaign by a Newmarket newspaper, news of his wartime achievements reached Downing Street and prompted David Cameron to write the letter of thanks to his niece, Mrs Jeanne Youlden, from which we quoted at the beginning of this article. The sentiments expressed in this letter, dated 30th March 2012, are a fitting tribute to Bill Tutte.

“I am writing to you to express my personal thanks and the United Kingdom’s gratitude for the work of Professor William ‘Bill’ Tutte. The success of cryptographers at Bletchley Park was an iconic British triumph of the Second World War and their achievements represent one of history’s greatest intelligence successes.”

Opposite: Dorothea and Bill: Birthday Dinner, Old Kitchen, 17th May 1977. This page: Tutte at Trinity.
The Man Who Knew Infinity

Trinity has academic stars aplenty, but the arrival of film stars and crew for the production of *The Man Who Knew Infinity* in August 2014 caused a stir.

Jeremy Irons (*Brideshead Revisited*) and Dev Patel (*Slumdog Millionaire*) were in College to film the true story of Srinivasa Ramanujan (Patel), the mathematical genius who grew up in poverty in Madras but whose remarkable talents were recognised by GH Hardy (Irons) and his long-time collaborator JE Littlewood.

During his short life, Ramanujan independently compiled nearly 3,900 results, the majority being identities and equations. Nearly all his claims have now been proven correct, although a small number of results were actually false and some were already known. They were both original and highly unconventional: the Ramanujan prime and the Ramanujan theta function, for example, have inspired considerable further research.

Ramanujan spent nearly five years in Cambridge collaborating with Hardy and Littlewood, and he published part of his findings while at Trinity. Hardy and Ramanujan had markedly different personalities. Their collaboration was a clash of cultures, beliefs and working styles. Hardy was an atheist and an apostle of proof and mathematical rigour, Ramanujan a deeply religious man who relied strongly on his intuition.

Ramanujan was awarded a Bachelor of Science degree by research (this degree was later renamed PhD) in March 1916 for his work on highly composite numbers. The paper, more than 50 pages in length, proved different properties of such numbers. Hardy remarked that it was one of the most unusual papers seen in mathematical research at that time and that Ramanujan showed extraordinary ingenuity in handling the subject. On 6 December 1917, Ramanujan was elected to the London Mathematical Society. He became a Fellow of the Royal Society in 1918, the second Indian to do so (following Ardaseer Cursetjee in 1841) and he was one of the youngest Fellows in the history of the Royal Society. He was elected “for his investigation in Elliptic functions and the Theory of Numbers.” When elected in October 1918, he became the first Indian to be made a Fellow of Trinity College.

When asked about the methods employed by Ramanujan, Hardy said that his solutions were “arrived at by a process of mingled argument, intuition, and induction, of which he was entirely unable to give any coherent account.” He also stated, “I have never met his equal, and can compare him only with Euler or Jacobi.” In May 2011, Professor Bruce C. Berndt of the University of Illinois, during a lecture at IIT Madras, stated that over the last 40 years, nearly all Ramanujan’s theorems have been proven right, and that there has been an increasing appreciation of his work and brilliance.

As the film shows, it was Hardy who persuaded Ramanujan to come to Trinity, despite the initial opposition of his mother (high caste Brahmins did not travel abroad). He arrived just before the outbreak of the First World War, and his time in Cambridge was far from easy. Never a well man, he suffered greatly in the Cambridge winters. Shortages and the absence of good vegetarian food made matters worse, and he became seriously ill in 1917. Although he was well enough to travel back to India the following year, he died soon afterwards at the age of 32.

The film, directed by Matt Brown, is adapted from the book of the same title by Robert Kanigel, who came to Trinity to watch the filming. Nevile’s Court was turned into a field hospital; Great Court served as a backdrop for some of the most powerful encounters between Hardy and Ramanujan. Extras strolled...
across the Court dressed as students and dons in gowns and tweeds.

I asked Dev Patel how he thought Ramanujan would have felt arriving in Trinity – “overwhelmed” was the immediate reply. “As a boy from Madras, he would have been in awe of the students, of the buildings.” The chapel, too, would have been overwhelming. “From the perspective of a strict Brahmin it would seem very foreign.”

How did Dev Patel prepare for the role? He read part of the book, but not all of it – the film is different. He watched documentaries, but most of all he worked with the script: “The words jumped off the page.” He was very conscious that Ramanujan would have felt like a “fish out of water” entering into this “unlikely friendship” with Hardy. And what about the maths? Patel was up front. It had been a struggle learning the formulae. He was coached by a Professor of Mathematics to get the language right to prepare him for his Good Will Hunting moment.

Ramanujan independently compiled nearly 3,900 results, the majority being identities and equations. Nearly all his claims have now been proven correct

For Patel, coming to Trinity was “the final piece of the jigsaw.” He had never been to Cambridge before and he was overwhelmed by the architecture: “It can make you feel small.” The scene where Hardy encourages an awkward Ramanujan to walk on the grass of Nevile’s Court and not along the side (“You’re a Fellow, aren’t you?”) rang very true. But he also recognised that today’s Cambridge is different from the city of a hundred years ago: there are women at the university now, and it is much more ethnically diverse.

And what message does Dev Patel hope the film will send? Stories about underdogs are always in demand, but he also wanted to show that maths was an art and that, in Ramanujan’s case, the intuition and distinctiveness of that talent needed to be nurtured and not destroyed. And he hoped to show students that they should lift their sights and aim high.
Ramanujan and the Partition Function

The story of Srinivasa Ramanujan, who wrote a letter to G. H. Hardy in early 1913 full of remarkable mathematical statements, came to Trinity in 1914 to work with Hardy, became a Fellow of the Royal Society and a Fellow of Trinity in 1918, and died in 1920 at the age of 32, is a famous one.

Ramanujan is now known as perhaps the purest mathematical genius there has ever been, and the body of work he left behind has had a deep influence on mathematics that continues to this day. Much of his work is too difficult to explain to the layperson, but one of his most notable results, concerning the so-called partition function, is an exception to this, and gives some idea of how unusual a mathematician he was.

To appreciate it fully, it helps to be aware of an important distinction. Consider first the well-known Fibonacci sequence 1, 1, 2, 3, 5, 8, 13, 21, ..., where each term of the sequence is obtained by adding together the previous two terms. A natural question to ask is whether there is a formula for \( F_n \), the \( n \)th Fibonacci number, and it turns out that there is. Rather surprisingly (at least until one has seen how the formula is derived), \( F_n \) is equal to

\[
1 \sqrt{5} \left( \left( \frac{1 + \sqrt{5}}{2} \right)^n - \left( \frac{1 - \sqrt{5}}{2} \right)^n \right)
\]

This is an example of an exact result: it tells us that \( F_n \) is given exactly by an expression that is built up out of standard operations such as addition, multiplication, taking square roots, and raising to powers.

Now let us look at the sequence 2, 3, 5, 7, 11, 13, 17, 19, 23, ... of prime numbers. Is there a formula for \( p_n \), the \( n \)th largest prime number? Many people have tried to find one in the past, but the overwhelming consensus is, and has been for a long time, that no useful formula for \( p_n \) exists. However, there is a simple and very useful approximate formula: the \( n \)th prime number is roughly equal to \( n \ln(n) \), where \( \ln \) is the natural logarithm. A better approximation turns out to be \( n \left( \ln(n) + \ln(\ln(n)) - 1 \right) \). If we set \( n = 1000 \) in this formula we obtain 7840.40001..., while the actual value of the 1000th prime is 7919, a difference of about 1%.

It is more usual to look at an equivalent question: how many prime numbers are there between 1 and \( n \)? Here, a good approximation is \( n \ln(n) \) and an even better approximation is \( n \left( \ln(n) + \frac{1}{\ln(n)} \right) \). This result, proved independently by Hadamard and de la Vallée Poussin at the end of the 19th century, is one of the most famous in all mathematics. However, it leaves open the question how good the approximation is, and this is the most famous unsolved problem in all mathematics, known as the Riemann hypothesis.

The partition function counts the number of ways a number can be split up as a sum of smaller numbers. To give an example, here is a list of ways of splitting up the number 5.

There are seven ways of doing it (if we include the “trivial” one that writes 5 as 5), so the value of the partition function at 5 is 7. We write this as \( p(5) = 7 \).

To be precise, \( p(n) \) is the number of ways of writing \( n \) as a sum of positive integers in decreasing order. To give another example, since

\[
6 = 5 + 1 = 4 + 2 = 4 + 1 + 1 = 3 + 3 = 3 + 2 + 1 = 3 + 1 + 1 + 1 = 2 + 2 + 1 + 1 = 2 + 1 + 1 + 1 + 1 = 1 + 1 + 1 + 1 + 1 + 1.
\]

the value of \( p(6) \) is 11. We can put the values together to form another sequence, which begins 1, 2, 3, 5, 7, 11, 15, 22, 30, 42, 56, 77, 101, 135, 176, 231, 297, 385, ... .

We can of course try to find a formula for the \( n \)th term of this sequence, but it is better to start with a less precise question: does this seem like the kind of problem where one would expect an exact formula, or is it more likely to be one where the best we can hope for is a good approximation? The
evidence is mixed. On the one hand, there are several very interesting exact relationships between different functions related to the partition function, which leads one to think that perhaps an exact formula can be found. On the other hand, the sequence has some curious features that would be hard to capture with a neat formula: for instance, if we take the sequence of differences of successive terms, we obtain the sequence $1, 1, 2, 2, 4, 4, 7, 8, 12, 14, 21, 24, 34, 41, 55, 66, 88, \ldots$, which increases in a strange stuttering way.

Here is a paragraph from a famous paper, entitled *Asymptotic Formulae in Combinatory Analysis*, by Hardy and Ramanujan.

The theory of partitions has, from the time of Euler onwards, been developed from an almost exclusively algebraical point of view. It consists of an assemblage of formal identities, many of them, it need hardly be said, of an exceedingly ingenious and beautiful character. Of asymptotic formulae, one may fairly say, there are none. So true is this, in fact, that we have been unable to discover in the literature of the subject any allusion whatever to the question of the order of magnitude of $p(n)$.

The words “algebraical” and “identities” here are referring to exact formulae, whereas the word “asymptotic” refers to approximations like the one in the prime number theorem.

Hardy and Ramanujan decided to investigate the partition function from an asymptotic point of view, and they did indeed obtain an asymptotic formula, but the tale had an astonishing twist. Their first progress was a simple argument that showed that $p(n)$ lies between $H e^{2\sqrt{n}}$ and $K e^{2\sqrt{n}}$ for two suitable real numbers $H$ and $K$. This was already enough to give some idea of the rough way that $p(n)$ grows as $n$ grows.

They then obtained a significant improvement, showing that $p(n)$ is approximately given by the formula

$$\frac{1}{2\sqrt{2}} \sum_{k=1}^{n} \sqrt{k} A_k(n) \frac{e^{\frac{\pi}{3} \sqrt{\frac{2}{3} \left(n - \frac{1}{24}\right)}}}{\sqrt{n}}.$$ 

I shall not attempt to say what all the component parts of this formula mean. Suffice to say that the mathematics that goes into this formula is very deep (for instance, the appearance of the number 24 in the formula is related to the appearance of the same number in seemingly very different contexts).

How good is this approximation? Even Hardy and Ramanujan themselves were surprised by the answer. If you choose $\epsilon$, the number of terms in the sum, in an appropriate way (it should be around the square root of $n$), then this formula gives an answer that is accurate to within less than 1. In other words, although this is an asymptotic formula, it is so accurate that you can work out the exact answer by simply working out the approximation and taking the nearest integer to it. Let me quote the paper again.

We owe the theorem to a singularly happy collaboration of two men, of quite unlike gifts, in which each contributed the best, most characteristic, and most fortunate work that was in him. Ramanujan’s genius did have this one opportunity worthy of it.

Many mathematicians, myself included, would have been satisfied with this approximation. But Hardy and Ramanujan went much further, obtaining the following even better approximation for $p(n)$:

We owe the theorem to a singularly happy collaboration of two men, of quite unlike gifts, in which each contributed the best, most characteristic, and most fortunate work that was in him. Ramanujan’s genius did have this one opportunity worthy of it.
The Maths Olympiad

Since then, the Maths Olympiad has evolved into the largest and most prestigious competition worldwide, with teams from over one hundred countries at the latest instantiation.

Trinity’s involvement in the International Mathematical Olympiad spans this entire history. The combinatorialist Béla Bollobás, a Fellow of Trinity and of the Royal Society, represented Hungary in the first three years of this competition, achieving a perfect score in 1961. The United Kingdom joined in 1967, when the team included Simon P. Norton, a Trinity alumnus who made invaluable contributions to the Classification of Finite Simple Groups, an epic proof spanning hundreds of articles, tens of thousands of pages, and several decades. Since then, over half of the 267 people representing the United Kingdom have matriculated at Trinity.

In particular, one remarkably fruitful year included both Imre Leader and Sir Timothy Gowers on the same team, the latter subsequently winning a Fields Medal for his research connecting combinatorics and functional analysis. This was further developed by his student Ben Green, also a Trinity alumnus and IMO participant (now Waynflete Professor of Mathematics at Oxford), who together with Terence Tao applied this research to prove that there are arbitrarily long arithmetic progressions of prime numbers. Kevin Buzzard, an algebraic number theorist currently based at Imperial College London, attained a perfect score in the IMO before joining the lengthy list of Trinitarians who scored highest in the Mathematical Tripos alongside Charles Babbage (who designed the first mechanical computer) and Lee Hsien Loong (current Prime Minister of Singapore).

Many Trinity alumni are intimately involved as volunteers in the training and selection process. Imre Leader, James Cranch and Vesna Kadelburg have all served as either Leader or Deputy Leader of the team, and many current students assist in other aspects. In particular, there is a rigorous selection procedure in the form of a national competition, imaginatively referred to as the British Mathematical Olympiad. This takes the form of two rounds of increasing difficulty, sat in schools and known affectionately as BMO1 and BMO2.

Based on the results of BMO2, the UKMT selects teams for two smaller international competitions, the Romanian Master in Mathematics, which was won in its first incarnation by the British team, and the relatively new European Girls’ Maths Olympiad, which aims to counteract the gender imbalance at the IMO. This competition began in Cambridge in 2012, and many of the competitors have gone on to study at Trinity.

However, the main result of the British Maths Olympiads is that around 20 of the highest scoring participants are invited to spend a long weekend at the beginning of April in Trinity. This camp is held in Burrell’s Field, where the students essentially sleep and do maths. At the camp, they undergo several problem sessions, which are sheets of problems pre-prepared by a teacher or helper, who goes through the problems with the students, hoping to make them better at solving questions of this type.

Trinity has been a great driving force for Mathematical Olympiad training, and it seems likely to remain so for the foreseeable future.
Not everything is confined to Burrell’s Field; however. The students have the opportunity to enjoy their meals in Hall, and, perhaps more importantly, the selection exams tend to be held in the Old Combination Room. These are gruelling four-and-a-half-hour papers, with only three problems for the students to do. After two such papers (on different days!) the camp ends, and a group of volunteers, many of whom are former or current Trinity students, mark the papers and select the top 8 or 9 students to proceed to the final round of selection to decide a team of six to participate at the International Mathematical Olympiad.

The Easter camp is by no means the only camp held at Trinity, though. Before the IMO each year, the UK team undergoes a final week of training and time zone adjustment in preparation for the contest. In 2011, for example, the competition was held in the Netherlands, making the UK a natural choice as venue for the camp, and of course this was held in Trinity as well. This camp is held jointly with the Australian team, and one of the highlights is the Mathematical Ashes, a (perhaps not so) friendly competition to win the ashes of the scripts of the first year’s losing team. There are other instances of collaboration with other delegations, including a joint Anglo-Hungarian training camp taking place over the New Year by a woodland-enclosed lake thirty miles west of Budapest. In return, we occasionally have Hungarian students attend our Easter camp. This alliance has recently extended to include a member of the Irish team training in our hallowed halls and cloistered courtyards.

Trinity has the knack of attracting the majority of the UK IMO participants, with most students at the Easter camp going on to study maths as undergraduates at Trinity (a notable exception being Julian Huppert, who studied Biological Chemistry at Trinity before becoming Member of Parliament for Cambridge). There, alongside their studies, many of them volunteer with the UKMT. For example, the Easter camp typically has several Trinity students help out with tasks ranging from making tea to marking scripts and invigilating exams.

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The Easter camp is not the only place Trinity students volunteer. Many also help with the Mentoring Scheme. The UKMT e-mails many IMO hopefuls a sheet of problems each month. The participants try to solve the problems, and they email their attempts to a mentor, someone who may have participated in maths competitions at school and now helps younger students. Unsurprisingly, many Trinity students help out with this scheme. As well as this, over 1000 students sit BMO1 and a similar number sit the bespoke Mathematical Olympiad for Girls, with 200 of the highest scorers progressing to BMO2. Marking these takes a small army, and many Trinity students volunteer their time to help in this regard.

As Trinity’s population of international students has increased, so has the number of Trinitarians who represent other delegations at the International Mathematical Olympiad. In addition to representatives of the majority of European countries, we have a large Australian contingent, something to which the joint UK and Australia pre-IMO camp may have contributed.

Trinity has been a great driving force for Mathematical Olympiad training, and it seems likely to remain so for the foreseeable future.
New Fellows

Claudio Castelnovo
Dr Claudio Castelnovo (Teaching Fellow in Physics) works in the Theory of Condensed Matter group of the Cavendish Laboratory. His research interests are in the area of emergent and out of equilibrium phenomena in strongly correlated many body systems. Current research topics include the effects of hard constraints in classical and quantum systems; the emergence of long time scales in freezing and glassy systems; frustrated magnetism, specifically spin liquids and spin ice; topological order; from the study of manifolds, the emergence of new types of order, from the identification of emergent magnetic monopole excitations in spin-ice to the role of thermal fluctuations in topological computing.

Sean Paul Curran
Sean was elected a Junior Research Fellow for his research in Medieval Musicology. His thesis was entitled “Vernacular Polyphony, Vernacular Book Production, and the Motets of the La Clayette Manuscript (Paris, Bibliothèque nationale de France, nouv. acq. fr. 13521)”. This thirteenth century manuscript combines 55 notated motets with a large collection of vernacular texts that include translations of saints’ lives, scriptural stories and prayers, and a bestiary. Its analysis required an understanding of thirteenth-century polyphony and its notation. Old French and Medieval Latin, codicology and palaeography. The manuscript is a jigsaw puzzle: it is heavily damaged, and several parts are clearly incomplete. Though it has long been acknowledged as one of the most important sources of thirteenth-century music, its physical form was considered an accident of its later history, irrelevant to the thirteenth-century meanings of the music. By studying the physical construction of the manuscript, Sean discovered that such compositions were performed within lay aristocratic settings, in which the laity were involved as performers and hearers.

Paul Howard
Paul Howard (Junior Research Fellow) comes from Balliol College, Oxford. His thesis in Italian Literature was on the poet Giuseppe Gioachino Belli (1791–1863), known for his 2000 poems in Romanesco, the dialect or patois of Rome. These are highly literate Petrarchan sonnets, but their content includes comical, satirical, erotic, anti-clerical and frequently obscene renditions of the voices of the Roman populace. Popes, ghetto Jews, prostitutes, and plebeian Romans are represented, struggling with the basic issues of hunger, poverty, sex, greed, power, faith, and death. Each sonnet contains a short story, an anecdote of everyday life: the main elements of the sketch quickly unwind in the opening verses, while the last ones lead to a brilliant conclusion, often ironic, sometimes lyrical or even philosophical. Paul sees the poet as a warring rebel on the literary scene and seeks to examine his poetics and rhetoric of war through his choice of form, language and subject which are in polemical response to literary stimuli and intimately connected to the political, religious and sociological upheavals in and beyond Rome in the troubled run-up to Unification.

Ailsa Keating
Ailsa Keating (Junior Research Fellow) received her PhD in mathematics from the Massachusetts Institute of Technology in June 2014, working under the direction of Paul Seidel. She was an undergraduate student at Clare College (2005), from which she received an MA and M.Math. (“Part III of the Mathematics Tripos”). Her research pertains to an area of pure mathematics called symplectic geometry. It is a rapidly developing field, with tools drawing from many different areas of mathematics. Modern geometry is centered about the study of manifolds, smooth objects that at small enough scale look like the standard space of a fixed dimension – for instance, the surface of a ball. Symplectic manifolds are equipped with extra structure that generalizes conservation laws from classical mechanics. Also, some models in string theory, a branch of physics, allow any symplectic manifold in lieu of space-time. Ailsa’s research revolves around the following two major open questions: “What are the transformations (that is, global symmetries) of a symplectic manifold?” and “What subspaces can one fit into it?”

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James Kirby

James Kirby was elected a Junior Research Fellow for his work in intellectual history. He comes to Trinity from Balliol College, Oxford.

His doctoral thesis, “Historians and the Church of England: Religion and Historical Scholarship, 1870–1920”, was a study of the relationship between religion and advanced thought in the decades after the great Victorian crisis of religious faith. He argues that, in spite of this crisis, the Church of England remained a “learned church”, actively promoting scholarship alongside its other functions.

This was especially so in the field of history – and so the Church was to a great degree responsible for the creation of history as a modern discipline in England. The histories written at this time were therefore shaped by the religious concerns of their authors, leaving a mark on English ideas of the past that lasted for much of the twentieth century.

James’s work challenges received ideas of intellectual secularisation and casts new light on religion and history; in the words of his Elector, it “may even prompt a re-evaluation of Victorian thought across the board”.

Cheryl Misak

Cheryl Misak (Visiting Fellow Commoner) is a philosopher at the University of Toronto. In 2013, she completed a decade in academic administration, most recently as Vice-President and Provost. She received her BA from the University of Lethbridge, her MA from Columbia University, and her DPhil from the University of Oxford. She works on American pragmatism, epistemology, ethics, and philosophy of medicine. Her publications include the books The American Pragmatists (2013), Truth, Politics, Morality: Pragmatism and Deliberation (2000), Verificationism: Its History and Prospects (1995), and Truth and the End of Inquiry (1991). She has held visiting fellowships at St John’s College Cambridge, NYU, and the Goethe University. Whilst visiting Trinity she is writing a book showing that the (English) Cambridge pragmatists Ramsey and Wittgenstein were heavily influenced by the (American) Cambridge pragmatists Peirce and James.

Henry Wilton

Henry Wilton (Teaching Fellow) is a pure mathematician, working in the area of geometric group theory. “Group theory” is mathematical jargon for the study of symmetry. Geometric group theorists aim to study groups – collections of symmetries – by realising them as symmetries of interesting geometric spaces. In so doing, we also learn about the spaces themselves.

As well as geometry, Henry’s research has connections to algebra, logic and the abstract theory of computation. After his undergraduate degree at Trinity, he studied for his PhD at Imperial College. He held postdoctoral positions at the University of Texas in Austin and the California Institute of Technology, and then a lectureship at University College London, before returning to Cambridge and Trinity in 2014.

Francis Woodhouse

A Trinity graduate of the Mathematical Tripos, Francis stayed with the college during his PhD in Applied Mathematics for which he specialised in problems of microbiological fluid dynamics. His fellowship dissertation, “Cytoplasmic streaming and self-organisation of active matter”, explored the remarkable large-scale active circulation seen in the fluid contents of many plant cells. These flows, which are driven by molecular motors entraining fluid as they walk along polymer bundles, benefit cells by ensuring effective distribution of nutrients and other apparatus. Francis’ main achievement was to construct a theoretical model of how such a flow establishes itself during cell development, a hitherto poorly understood process.

Focusing on a species exhibiting an especially well-organised “barber’s-pole” pattern of streaming in its giant cylindrical cells, he combined motor dynamics with both microscopic and macroscopic hydrodynamics to explain how several independent processes, each ineffectual on its own, can reinforce in a self-organising cascade to form the observed patterns of streaming.
Trinity Women’s Network


Trinity welcomed its first female graduate student in 1976, its first female Fellow in 1977, and the first women undergraduates in 1978. Since then, Trinity has supported more than 2,700 successful female members of College.

Last year, the Office for National Statistics put the average full-time gender pay gap at 9.4%, the narrowest since comparative records began in 1997. Much of the credit for this can be attributed to the efforts of women and men who support equal opportunities and rights for women. When men and women offer support and guidance to women, and solidarity with each other in support of this cause, our world – and our College – will be a better place.

Building on this momentum, the Alumni Relations & Development Office is pleased to announce the launch of a new Alumni group – the Trinity Women’s Network.

To celebrate the launch, we are delighted to invite alumni to an inaugural event on 6 May 2015 to launch the Trinity Women’s Network. The event will be hosted at Shearman & Sterling, 9 Appold Street, London EC2A 2AP from 19.00.

The Network will build on Trinity’s track record of supporting different interest groups and professions through various alumni programmes.

It aims to:

- Support Trinity alumnae through networking and events
- Assist and inspire current female undergraduates and postgraduates in their chosen studies and careers
- Spotlight Trinity’s many distinguished female graduates
- Encourage women’s initiatives in other Colleges and across the university

The TWN looks to provide an inclusive forum with events typically open to all alumni and members of College, male and female, and aims to complement existing alumni networks.

Please contact the AR&DO on alumni@trin.cam.ac.uk if you would like to be involved with the TWN.

We are grateful for ideas and volunteers.
1546 Society

The Annual Fund provides the College with vital supplementary income that can be used to fund areas of need around the College. It is regular giving at a level comfortable for you that makes such a significant difference.

Trinity is relatively new to fundraising in comparison with the other Cambridge colleges, and the proportion of our alumni giving is currently 9%, well below the 20% or more of some colleges. Now more than ever we are encouraging alumni to show their support for Trinity by joining the 1546 Society and making a gift to the College.

Trinity is seeking your support to maintain and strengthen its position as an outstanding institution in which to learn, teach and conduct research. It is noteworthy that philanthropy in comparative US institutions has been remarkably successful over the last 20 years; in the same time that Trinity raised £15m, Stanford raised an astonishing $10bn from its alumni.

But why do we need your support? The College’s £936m endowment allows for £33.3m to be spent each year, but this money is already committed to maintaining teaching, research and the day-to-day running of the College. This limits our ability to address other immediate College priorities, such as awarding a greater number of bursaries or providing further resources for our world-class research.

The whole of your gift will go directly to the fund of your choice. Results will be immediately tangible, and even the most modest gift will help us achieve our goals.

To recognise your generosity, membership to the 1546 Society begins with the following:

**Giving Levels:**
- £15.46 per month or £185.52 per year will qualify those who graduated more than 10 years ago.
- £15.46 per quarter or £5.15 per month will qualify those who graduated less than 10 years ago.

As an appreciation of your generous support, you will receive a 1546 Society donor pin, an invitation to a special event, and recognition in our annual list of donors.

To celebrate the launch of the 1546 Society, a generous alumna has offered to match fund the first £10,000 of new regular gifts received.

For further information, please contact Nathaniel Gliksman, Annual Fund Officer, by emailing annualfund@trin.cam.ac.uk or by calling +44(0)1223 338548.
The Inaugural Fellows’ London Research Talks

You had to be quick off the mark to get tickets for the inaugural Fellows’ London Research Talks on 19th February.

The 80 tickets advertised online had sold out within the hour. The venue was Kettner’s in Soho, next door to Soho House, not I imagine the usual haunt of Trinity Junior Research Fellow Dr Dmitri Levitin (e2010), or for that matter Fields Medallist Sir Timothy Gowers FRS (1982).

Alumni and guests packed the elegant rooms above Kettner’s restaurant to hear, first of all, Sir Timothy Gowers. On ‘Will Computers Ever Be Able to Solve Interesting Problems?’ Sir Timothy promised to keep it (relatively) simple for us non-mathematicians. I was particularly interested to hear that so-called “eureka” moments are not really such – it’s just a question of a lot of very small steps. It seems that computers can be programmed to find proofs of theorems using logical steps, although many of these proofs aren’t very interesting to mathematicians. How can they work out whether it’s a proof worth doing? That’s the unsolved question – still some way off.

Dr Dmitri Levitin followed with “When Scientists Were Humanists”. He argued that present-day scientists would benefit from a much better grounding in the humanities, not something that is encouraged by our system of education, with its chasm between the arts and sciences. He gamely competed against a backdrop of Chinese New Year drumming for most of his talk, and this added a certain Soho edge to the evening.