Humanistic Mathematics Network Journal

Issue 20 Article 15

7-1-1999

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Srinivasa Ramanujan (1887-1920), although self-taught in mathematics, is considered one of the greatest mathematicians of this century. Born on December 22, 1887, in Erode, Tamil Nadu State, India, Ramanujan was one of India's greatest mathematical geniuses. He made substantial contributions to the "analytical theory of numbers and worked on elliptic functions, continued fractions, and infinite series;" yet, he had only a vague idea of what constituted a "mathematical proof" [1]. Though he "failed Fine Arts at the Madras University," he was eventually recognized as "a natural genius" by G.H. Hardy of Trinity College, Cambridge [1]. He died in 1920, at the age of 32, after a long illness. Ramanujan's path was obstructed by many obstacles: "poverty, a lack of a university education, the absence of books and journals, working in isolation in his most creative years" [2, p. 1]. Few mathematicians had to experience these kinds of obstacles. His theorems still confound mathematicians today, almost eight decades after his death.

Srinivasa (pronounced shri) Ramanujan Iyengar was born December 22, 1887, in his mother's parental home, 150 miles upriver from his parents' home. Srinivasa was his father's name, automatically given to him, but rarely used. Ramanujan means the "younger brother of Rama, the model of Indian manhood" whose story was handed down from generation to generation through "Ramayana, India's national epic" [3, p. 11]. This name was also picked as he shared other astrological similarities with the Saint Ramanuja, who lived in the 1100's. Iyengar was the "caste name, the branch of South Indian Brahmins" [3, p. 11], to which he and his family belonged. He became known as Ramanujan.

One of the challenges that Ramanujan faced occurred when he was two years old. A smallpox outbreak, which was responsible for "4,000 deaths in the Tanjore District," infected Ramanujan [3, p. 12]. Ramanujan managed to survive but carried the scars all of his life. His family met with other tragedies. His mother would lose three children before the birth of another son, when Ramanujan was 10 years old. His youngest brother was born the year he turned 17. Ramanujan was brought up as the centre of attention, similar to an only child.

There are stories of Ramanujan being a strong-willed child who acted out by rolling in the mud if he did not get his way. In the first three years of his life, he hardly spoke, although he did learn the "12 vowels, 18 consonants, 216 combined consonant-vowel forms of the Tamil alphabet" soon afterwards [3, p. 13]. His temperament caused him to have unexpected reactions to stress, as in breaking out with hives.

In October 1892, he began school. He was the child who was fond of asking questions and who challenged the teachers with questions such as, "Who was the first man in the world? How far is it between the clouds?" [3, p. 13]. There is not too much known about his childhood except that he liked to be by himself and that he was back and forth between schools because he disliked attending school. There is also mention that Ramanujan was obese, in a culture where "obesity was virtually unknown" [3, p. 14]. This obesity stayed with him into adulthood, until his illness.

Ramanujan's father was largely absent from his life, and rarely mentioned in the documents. He was an accountant for a cloth merchant in Kumbakonam, and in Indian society was left with "little role to play at home" [3, p. 18]. Though all of Ramanujan's relatives were "of high caste," they were very poor [4, p. 1]. His mother was described as a "shrewd and cultured lady" [3, p. 18]. She monitored his friends, his time and his decisions. When the time came, she found him a wife.

At the age of 7, Ramanujan was sent to the High School of Kumbakonam, and remained there for 9 years. His "exceptional abilities" began to appear before he was ten [4, p. 2]. He passed the primary examinations in English, Tamil, Arithmetic, and Geography, and came first in the district. Although his native language was Tamil, with the ascent of Britain in India, English was the language of the country's rulers and the "ticket of

admission to the professions" [3, p. 25].

Because Ramanujan's family was poor, they took in boarders who were studying at the Government College. These boarders acquired mathematics texts for Ramanujan, as well as taught him how to solve cubic equations. By the age of 12, Ramanujan had mastered Loney's *Trigonometry*, which included topics such as "exponential function, logarithm of a complex number, hyperbolic functions, infinite products, and infinite series" [2, p. 1]. At 15, Ramanujan was captivated by Carr's *A Synopsis of Elementary Results in Pure Mathematics*, with its compilation of 6000 theorems, which he had borrowed from the college's library. While *Synopsis* had given him direction, it had "nothing to do with his methods, the most important of which were completely original" [3, p. 45]. Carr's book was to have a great influence on his life.

Ramanujan was a minor celebrity during his school years. He received merit certificates and scholastic prizes for his mathematical marks. In December 1903 he took the matriculation examination of the University of Madras and obtained "a 1st class place" [2, p. 2]. In 1904, when the headmaster presented him the K. Ranganatha Rao prize for mathematics, he introduced him to the audience by stating that "if possible, he deserved higher than the maximum possible marks" because he was off the scale [3, p. 27]. He graduated from high school and entered Government College with the scholarship awarded to him.

By this time Ramanujan was completely engrossed in mathematics. He was not interested in studying any other subject. This caused him to "fail his English and Physiology examinations" at the end of his first year at the Government College at Kumbakonam and to lose his scholarship [2, p. 2]. He ran away from home, the first of numerous disappearances.

Ramanujan was very sensitive to any failure. Through the years there were incidents where he would become hurt or angry over relatively insignificant occurrences. Once when his friend scored one point higher than he on a math quiz, he became angry and would not speak to the boy for a long time, Later, in High School, Ramanujan saw how "trigonometric functions could be expressed in a form unrelated to the right triangles in which they were rooted," [3, p. 50]. When he found out that Leonhard Euler had predicted this 150 years before, he became so ashamed, he hid his papers in the roof of his house. When a close friend stopped writing, Ramanujan wrote the friend's brother to say "he is too sorry for his failure in the Exam to write to me" [3, p. 50]. Many other events through the years would cause him to flee or react in humiliation.

In 1906, Ramanujan decided to give college another try. He entered Pachaiyappa's College in Madras, and upon seeing his Mathematical Notebooks, which Ramanujan had begun to keep in 1904, the principal awarded him a partial scholarship. Unfortunately, Ramanujan again failed the examinations and lost his scholarship. Everyone was in awe of Ramanujan's mathematical gifts, but nothing came of them.

Ramanujan struggled out of school, without a degree, without a job, and without contact with other mathematicians. He immersed himself in his Mathematics, and devoted himself entirely into recording his results in his notebooks. Without any distractions, in some ways, these may have been the "most productive days of his life" [3, p. 65].

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Ramanujan's mother must have decided that it was time for him to bring some focus to his life. In 1908, while visiting friends, she noticed a visiting young relative. She asked for the horoscope of this girl, and compared it to her son's. She decided that they were a good match and began the negotiations for the eventual marriage of Ramanujan and nine-year-old Janaki. Janaki did not see her intended husband until the wedding in July 1909. She was ten years old. Ramanujan's father, who was opposed to the wedding, did not attend. Janaki did not join Ramanujan for three years. During this time, while awaiting puberty, she prepared for her role as a wife.

Unfortunately, another health problem arose. Ramanujan developed "hydrocele, an abnormal swelling of the scrotal sac" [3, p. 72]. The solution was an

incision in the scrotal sac. The operation was simple, but because his family did not have the means for a doctor, the operation was postponed. Eventually, in January 1910, a doctor did the procedure for free.

This was a new stage in Ramanujan's life. Now that he was married, Ramanujan found it necessary to obtain employment. He travelled the rails and found jobs as a tutor. He began calling on influential friends. He was eventually sent to R. Ramachandra Rao, a wealthy mathematician, who was so impressed with the contents of Ramanujan's notebooks that he "offered Ramanujan a monthly stipend so that he could continue his mathematical research without worrying about food for tomorrow" [2, p. 2]. In 1911 Ramanujan's "first paper appeared in the *Journal of the Indian Mathematical Society*" [3, p. 82]. The paper posed the question, "What happens if n = infinity?" [3, p. 87]. No one explored this area more than Ramanujan.

In late 1912 he and Janaki began their married life, living with his mother and grandmother. Ramanujan then accepted a clerical position in the Madras Port Trust Office in 1912. Fortunately, the manager was a mathematician and encouraged Ramanujan to send his discoveries to English mathematicians. Ramanujan wrote to H.F. Baker and E.W. Hobson at Cambridge University asking for help. Both replied, no. On January 13, 1913, Ramanujan wrote to G.H. Hardy, who at thirty-five was "already setting the mathematical world of England on its ear" [3, p. 107]. Hardy replied, yes!

G.H. Hardy, a famous mathematician, was a fellow of Trinity College. He had been known to be sympathetic to the underdog. He had also been willing to "stray from safe, familiar paths" [3, p. 171]. When Hardy received Ramanujan's letter and theorems, he initially dismissed the letter. On a second look with his friend and colleague, J.E. Littlewood, the two men began to "appreciate the papers of a math genius" [3, p. 169]. Hardy would later say that "it was the strangeness of Ramanujan's theorems that struck him at first, not their brilliance" [3, p. 159].

Hardy urged Ramanujan to come to Cambridge in order that his "superb mathematical talents might come to their fullest fruition" [2, p. 3]. Because of his strong Brahmin convictions, which included not crossing the seas, Ramanujan declined. Gilbert Walker, a former mathematical lecturer at Trinity College, was sent to Madras to ask for support for Ramanujan as a research student. Ramanujan was paid "75 rupees per month for two years" beginning in May 1913 [3, p. 174]. He began sending a collection of theorems to Hardy. Ramanujan worked all hours, barely in contact with anyone, including Janaki. His sole mission was to pursue mathematics and to submit progress reports every three months. He continued his long distance correspondence with Hardy.

In 1914 E.H. Neville, who was sailing to India to lecture at the University of Madras, was asked by Hardy to convince Ramanujan to come to Cambridge. There are conflicting stories that Ramanujan had a vision in which the goddess Namagiri told him to travel to a foreign land. Whether this was "divine inspiration" or Ramanujan's method of obtaining permission to travel abroad, no one knows for sure [3, p. 189]. Some stories state that his mother had the vision.

While growing up, Ramanujan had lived the life of a traditional Hindu Brahmin. He wore the "kudimi, the topknot," his "forehead was shaved," he was "rigidly vegetarian" and followed the "rituals and ceremonies" of his religion [3, p. 130]. By sailing the seas, he would now be excluded from his caste: "friends, family would not have you in their homes," there would be "no bride or groom for the child," a "married child could not visit you," nor could you go into "temples, funerals" [3, p. 185]. Gandhi had suffered the same fate when he went to England for his education. On March 17, 1914, Ramanujan, wearing Western clothes and short hair, sailed for England.

The next three years were productive for Ramanujan. He and Hardy worked closely together and "profited immensely from each other's ideas" [2, p. 4]. All of Ramanujan's manuscripts would pass through Hardy's hands, who edited them for publication. The year of his arrival, 1914, Ramanujan had published one paper. By 1915, he had "a flood of papers published" [3, p. 208]. If Ramanujan had wanted recognition, he got it in 1915 when "nine papers appeared in the *Journal of the Indian Mathematical Society*" [3, p. 230].

The war came in 1914. In 1915-16, Madras debated whether or not to extend his scholarship and decided to extend it for one more year. In 1916 Ramanujan re-

ceived the degree that had escaped him so many times before. He received a B.A. by research. But, Ramanujan found it difficult adjusting to the English climate, and found it increasingly difficult to obtain the food he required to maintain his vegetarian diet. He became ill, and was soon spending most of his time in hospitals and sanitoria. He began to lose weight and energy and was eventually diagnosed with tuberculosis. Although very ill, he continued his mathematical work, and even apologized to Hardy for failing to do more.

Hardy recalled visiting Ramanujan in Putney while he was very ill. He remarked to Ramanujan that the cab he had arrived in had a number which was a "rather dull one" and hoped that it was not an "unfavourable omen" [4, p. 12]. The number was 1729. Ramanujan immediately answered, "No, it is the smallest number expressible as a sum of two cubes in two different ways. $1729 = 12^3 + 1^3 = 10^3 + 9^3$" [4, p. 12]. Ramanujan would also discuss the "ties between God, zero, and infinity" [3, p. 31]. When asked where he got some of his answers, he would often say, "The answer came to my mind" [3, p. 215].

Although Ramanujan's mind was still sharp, his body was now failing. He became picky about his food, complained constantly, and would not do what the doctors recommended. He continuously changed hospitals and doctors. During this time his letters from home ceased, and his isolation increased. During a short release from the hospital, Ramanujan had invited a friend and his fiancée, and her chaperone, over for dinner. He served soup, offered a second helping which was accepted by his friend, but when the fiancée and the chaperone refused, he left his home by taxi and did not return for four days. When asked by his friend why he had behaved in such a way, he replied that he was "hurt and insulted that the ladies did not want more" [3, p. 237]. For someone so self-confident about mathematics, Ramanujan still had an almost "pathological sensitivity to the slightest breath of public humiliation" [3, p. 50].

In the spring of 1917, Hardy wrote the University of Madras to tell them that Ramanujan had an incurable disease. The University made him a university professor at Madras, paying him "400 rupees per month, and 250 pounds per year fellowship" [3, p. 312]. He wrote back to tell them that it was too much and to donate some for educational purposes. Hardy worked successfully in having Ramanujan elected to the "Fellow of Royal Society" and the "Fellow of Trinity College, Cambridge" in 1918 [4, p. 6]. He could finally sign F.R.S. after his name.

The war prevented him from going home to India until March 1919. In 1918 Ramanujan had tried to commit suicide by throwing himself in front of a train, but was rescued when the conductor applied the brakes. Ramanujan was very ill when he arrived in India. A feud had developed between his mother and Janaki; therefore, Janaki had moved back with her brother and was not there to greet Ramanujan. He demanded that his mother send for her, which she did.

Ramanujan's health deteriorated quickly, but his relationship with Janaki improved. He was often depressed and sullen, and his mood became volatile. Janaki cared for him, and the two became closer than they had ever had a chance to be. Ramanujan's approaching death "inspired a final flurry of creativity impossible during normal times;" he sent a letter to Hardy, whom he had not written in more than a year [3, p. 323]. On April 26, 1920, Ramanujan lapsed into unconsciousness and died that morning.

The short life of Ramanujan cannot be understood without some appreciation for the mathematics that he loved and lived for. After his death many mathematicians, including G.H. Hardy, strongly suggested that his notebooks be edited and published. The first notebook was left with Hardy, and the second and third notebooks were donated to the University of Madras upon his death. The notebooks contained "new, interesting, and profound theorems that deserve the attention of the mathematical public" [2, Preface]. In 1929 G.N. Watson and B.M. Wilson began editing the notebooks, but the task was never completed until 1957, when an "unedited photostat edition of Ramanujan's notebooks was published" [2, Preface]. In 1986 Professor George Andrews of the Pennsylvania State University discovered "600 theorems on loose sheets of paper" which he termed "the Lost Notebook of Ramanujan" [1].

Ramanujan's notebooks served as a compilation of his results. He worked out most of his mathematics on a slate beforehand. In the notebooks it is clear that "infinite series abound throughout" [2, p. 6]. His love for

Bernoulli's numbers are also apparent, as they "appear in several of Ramanujan's formulas" [2, p. 7]. He developed "Magic Squares, an array of (usually distinct) natural numbers so that the sum of the numbers in each row, column, or diagonal is the same" [2, p. 16]. During most of the last year, before he went to England, he worked with the "general formulae in the theory of definite integrals" [4, p. 186]. Despite many ingenious results, "some of his theorems on prime numbers were completely wrong" [5].

In 1987, the centenary of Ramanujan's birth was celebrated all over the world. At the University of Illinois the celebrations included "a series of 28 expository lectures and several contributed papers that traced Ramanujan's influence to many areas of current research" [6, p. 1]. At Anna University, Madras, the University organized a number of "academic programmes throughout the centenary year and concluded the celebrations with an International Conference" [7, Preface]. Janaki, Ramanujan's widow, inaugurated the conference.

Ramanujan's notebooks would intrigue and frustrate whole generations of mathematicians. His life and works would captivate many. Kanigel wrote, " [the] more I learned, the more I, too, came under Ramanujan's spell" [3, p. 4]. Ramanujan's life leaves the reader captivated by an inexplicable force, Ramanujan's spell.

Ramanujan and Hardy's names would be "linked forever in the history of mathematics" [3, p. 253]. Hardy's remarks in *Ramanujan* give teachers food for thought:

> There was no gain at all when the College at Kumbakonam rejected the one great man they had ever possessed, and the loss was irreparable; it is the worst instance that I know of the damage that can be done by an inefficient and inelastic educational system [4, p. 7].

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Numbers

The animals were loaded 2 by 2
Some were yellow, some were blue.
The planets are in a row of nine
They change positions according to time.
365 days in a year
All in my calendar sitting right here.
4 score and 7 years ago
Lincoln made the South his foe.
Everything involves numbers like 1 and 2,
Including the earth and you.

Shea Ybarra

Circles

and circles are every-
where, but boys and girls do not
seem to care. They help us and help us
everyday, they are even the coins we have to
pay. they're on cars, buses and even a jet, there's
even one in the alphabet. You could roll 'em and
pull 'em and give 'em a tug, they are sometimes
the shape of a shell on a bug. A circle is
something extraordinary. If you asked
me if I liked them I'd have to say
"very."

Valentino Loiacono