The Man Who Knew Infinity: A Life of the Genius, Ramanujan Study Guide

The Man Who Knew Infinity: A Life of the Genius, Ramanujan by Robert Kanigel

BOOKRAGS

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Plot Summary

The Man Who Knew Infinity is a book about two important mathematicians, their relationship, and how it shaped their lived and the world around them. One of these men, Ramanujan was a genius of unusual strength who would go on to develop some of the most interesting mathematical conjectures and theorems of the century, if not of all time. Yet he had only the most bare education in backwaters of South India. The other man, G. H. Hardy, was the most respected English mathematician of his day and the product of the best schools in England. Ramanujan was a genius, but it took Hardy to recognize and bring the young man to England. For several years, their collaborations at Cambridge produced mathematical research that is still be mined today for interesting results.

The book begins in South India where Ramanujan was born and lived most of his life. He came from a poor family in an obscure village outside of the South Indian capital of Madras. His family was poor but they were also members of the most distinguished part of Indian society, a caste known as Brahmins. For centuries the Brahmins were the priests and educated class of Hindu India and in Ramanujan's time, they continued to strictly observe their strict regimens of purity and religious devotion. By all accounts, Ramanujan was a strict Brahmin his whole life. Early on however, he developed an interest in mathematics but lacking any real formal education in the subject, his knowledge of mathematics was drawn almost exclusively from one book he found as a young man. Soon he was devoting all of his time to his mathematical research to the exclusion of school and work. Lacking a degree or a good job, Ramanujan began to send his research to English mathematicians, hoping that they might take an interest in his work.

Many English mathematicians dismissed the letters as not worth pursuing but G. H. Hardy, one of the most distinguished mathematicians of his time took them seriously and contacted the young man. Eventually Hardy, convinced of Ramanujan's genius, arranged to have Ramanujan come to Cambridge. Once the young man arrived, Hardy and Ramanujan developed some of the most important math of the century. Despite his success in mathematics, the devout Brahmin Ramanujan was alienated in England. His strict devotion to his vegetarian diet, his lack of exercise, and his long hours of work led to an eventual physical breakdown. Ramanujan fell ill with what some doctors believed to be tuberculosis. After improving to a degree, Ramanujan returned to India.

Once in India, Ramanujan found his family in disorder. His wife from an arranged marriage was fighting with his mother and no one seemed to get along. In this atmosphere, Ramanujan fell ill again and this time unfortunately, he did not recover. He died at the young age of thirty, continuing to do mathematics until the day he died. He never saw his friend Hardy again and years later when Hardy was himself near death, Hardy would claim that the best work of his life was to discover and help Ramanujan.

Chapter 1 - In the Temple's Coolness

Chapter 1 - In the Temple's Coolness Summary and Analysis

The Man Who Knew Infinity begins with a description of the Indian town Kumbakonam and the notable Cauvery river. The great mathematician Ramanujan, the subject of the book, lived most of his life in Kumbakonam, although his mother Komalatammal, traveled back to her ancestral home in Erode, about 250 km southwest of the Southern Indian metropolis of Madras. Ramanujan was born on Thursday, December 22, 1887 in Erode. Although one day he would be known the world over simply as "Ramanujan", his full name was Srinivasa Ramanujan Iyengar. As his name indicates, Ramanujan was a member of the Brahmin caste, specifically the Branch of Brahmins dedicated to the worship of the Hindu god Shiva.

In early childhood, Ramanujan suffered from a case of smallpox that left his face pockmarked for the rest of his life. Life in South India was hard then as it is now and childhood illness and death were common. He quickly learned the native Tamil language, although he did not speak until he was three. Even early on, Ramanujan displayed a marked self-direction and self-will and a considerable intelligence. His dislike of his local teachers and his temperament made his time in school less productive than it might have otherwise been. He excelled in math but neglected and did poorly in his other studies. Ramanujan also suffered from a mosquito-borne illness that made some activities uncomfortable. This, coupled with his love of mathematics led Ramanujan to be overweight, something uncommon in the poverty and famine-stricken India.

Ramanujan was raised as a Shaivite Brahmin, a member of the learned and priestly class of Hindu India. Although his family was not by any means rich and his father was a low-level clerk; Ramanujan internalized the religious and cultural beliefs of his caste. By all accounts, Ramanujan was very religious, spending lots of time as a young man worshipping in the temple of the local deity. Ramanujan practiced the customary Brahmin vegetarianism as well and it was clear the young man was possessed of a considerable bent towards asceticism and religious devotion befitting his caste. Shiva, the god that Ramanujan's branch of Brahmanism worshipped, was a god of fierce destruction. His family also worshipped their traditional family deity Namagiri in the temple close to their house.

Although the young Ramanujan had trouble in school, he excelled at math from an early age. He was the star of his math class in school and he learned analytic trigonometry from an old book he found. He was awarded all the possible honors that his schools could bestow on him. As his mathematical interest deepened and developed, he began to redirect his devotion that was focused mainly on religion and his relationship with his mother towards math. This devotion and interest in mathematics would only grow over time.

Chapter 2 Ranging with Delight

Chapter 2 Ranging with Delight Summary and Analysis

In 1903, when Ramanujan was 16, he somehow got a hold of a copy of A Synopsis of Elementary Results in Pure and Applied Mathematics. The book, written by a English mathematician named George Shoobridge Carr, was a collection of more than five thousand equations, theorems, and formulas that had originally served as Carr's tutoring notes when he was a private math tutor in London. The book is notable because although there is a logical flow to the elements of the book, there is little explanation of the solutions or the logic that goes into solving the various problems presented. A smart student would have to do the work themselves to see how the different formulas and equations in the book led from one to another. The book, in other words, did not have the painstaking proofs that other, similar books on elementary mathematics would have had. It did not, so to speak, "show its work." Ramanujan used this book as his main text as he worked through the entire book, finding different ways to solve the problems presented. Sometimes, his solutions, although right in their conclusions, took odd routes. Instead of solving some problems analytically, as a typical mathematician would do, Ramanujan would often use his tremendous ability to mentally calculate. He would solve the problem by inputting different values in for the variables and looking at how the equation worked out. This technique would get him into trouble in some of his early work on number theory as the equations could have strange properties with really large or really small numbers. The effect of the book, although, is hard to overstate on Ramanujan's future. Working through the text gave him the unorthodox yet basically correct mathematical skills that he would need to pursue mathematics more seriously.

After high school, Ramanujan earned a scholarship based on his mathematical process in high school to Kumbakonam's Government College. The college was small and in a small town in a backward part of India, but it was still good enough to earn the name the "Cambridge of South India." Unfortunately, Ramanujan neglected his studies in all subjects other than math and his scholarship was eventually withdrawn. His parents could not afford to pay his way without the scholarship and he was forced to leave the college. Despite having no real prospects and very few connections, Ramanujan ran away from home at the age of seventeen to Madras.

Ramanujan began attending math lectures at the Pachaiyappas College in Madras. His math teacher, N. Ramanujachariar, was so astounded by Ramanujan's talents that he became something of a mathematical companion to the older professor. Still, Ramanujan's old ways began to creep up again and he refused to do many of the things that were required in his other classes to excel. Eventually he was forced to leave his new college as well. He was now living at home without a degree or any employment. He attempted tutoring for a time, but his excessively abstract understanding of calculus

and other math areas made his tutoring unhelpful for the less intelligent students. Ramanujan spent his time at home on his porch writing out his mathematical investigations into his notebook. Through fits and starts, Ramanujan began to develop his own mathematical insight into how numbers and the basic principles of mathematics worked. He saw his investigations as a semi-religious investigation into the secrets of the universe and a kind of religious devotion through mathematical manipulation. Although his mathematical work was beginning to develop, his father and mother had grown tired of their son spending all day on the porch scribbling in notebooks. It was time for him to do something with his life. The decided to find young Ramanujan a wife through an arranged marriage.

The Search for Patrons

The Search for Patrons Summary and Analysis

In India at that time, it was common for parents of a young man to find a suitable wife among friends of the family or prominent villagers even if the girl was very young. In Ramanujan's case, his mother found a young wife for him living among friends in a nearby village. The girl's name was Janaki and she was only nine years old. Of course, they would have to wait until she was older before the man and wife could actually consummate their marriage and live together, but picking a wife was the first step in this process. Ramanujan was, by all accounts, not a particularly desirable husband to most eligible young women. He was a little fat and he still bore the scars of his early bout with smallpox. Although he would later do great things, no one saw very much in him at the time than a very intelligent man who refused to get a job and did not have a college degree.

Ramanujan's marriage to his nine-year-old bride bore all the signs of impending disaster. First, Ramanujan and his family were late for the wedding because their train was forced to stop along the way. There were also interruptions of the wedding such as the screaming of a local deranged woman, a fire amongst the musicians, and other ritualistic problems. Still, the wedding eventually occurred although Janaki would not join Ramanujan for three years until she reached puberty.

Ramanujan, after his marriage, was no longer able to just sit on his porch and work through mathematical problems. With a wife to support, he needed to find some way to make money. Another problem made the situation even worse. At this time, Ramanujan developed a swelling in his scrotum caused by a mosquito-borne disease. The disease itself was not threatening although the swelling itself would make life very uncomfortable. Ramanujan would need to drain his scrotum periodically to prevent it from swelling to much. hese surgeries would often cause Ramanujan to spend a day or two in bed recovering and the ailment would bother him for most of his life.

While he waited for his wife to join his family, Ramanujan spent the next several years traveling in South India looking for work. Ramanujan would look up friends or distant relatives to stay with and to receive introductions to people who might help him get a job. Lacking any traditional credentials, Ramanujan would use his notebooks as evidence of his intelligence. In an interview, he would show the interviewer his work, hoping that he could get a job on the strength of the past work alone. Eventually he found a patron who supplied him with enough money to move to Madras and spend more time on his math. In 1911 with the support of his patron and living in Madras, Ramanujan published his first academic paper in an Indian mathematics journal.

Ramanujan developed an association with the recently formed Indian Mathematical Society. Through discussions with his fellow mathematicians, Ramanujan offered a challenge that he would later solve in his first article. The challenge involved finding a

solution to a series of nested square roots or square roots of square roots. An infinite series of square roots posed interesting challenges. The paper and the solution to the problem involved a Bernoulli number defined as a series of infinite operations. Bernoulli numbers are strange. For example, Bernoulli number 32 = 7709321041217/510. Still, despite their strangeness, they appear throughout math and science. Ramanujan claimed that Bernoulli number n divided by n is always a prime number or a natural number that can only be divided by itself and 1. Ramanujan's paper was exciting but it did not involve the typical detailed proof of a professional mathematician. Instead, it followed his leaps in intuition and his strange logic. It also turned out that Ramanujan was not exactly right since the Bernoulli number 20 divided by 20 is not a prime number. Still, Ramanujan's first paper was interesting enough to impress his peers.

While working on his second paper, he began looking for jobs and eventually found some work on the periphery of the British Indian Civil Service. Ramanujan was not happy there and he began to send letters to British Mathematicians asking for help. Eventually, after several negative responses, one of the greatest mathematicians of his time at Cambridge, G.H. Hardy agreed to help Ramanujan.

Hardy

Hardy Summary and Analysis

G.H. Hardy was the British mathematician of his age. Not only were his mathematical skills considerable, but he also had a youthful beauty appreciated by many of his associates at Cambridge, including the secret society called the Apostles. The Apostles were a society formed to select the best and the brightest of Cambridge undergraduates and to gather together for serious conversations. Over time, the Apostles would include the cream of Cambridge intellectuals. Hardy was friends with many of the Apostles who would form the Bloomsbury Group, including John Maynard Keynes, Virginia Woolf, G.E. Moore, and others. Like many of the members of the group, Hardy considered himself, first and foremost, an artist. His interest in mathematics and his work in the subject had no, as he famously claimed, practical importance. They were "useless" in the sense that they dealt with the pure mathematics of number theory and other subjects remote from any engineering or scientific uses. A Brahmin of sorts in his own rights, Hardy was not descended from the privileged.

In English society at the time, much of one's future could be determined by what kind of school one went to for what we would call "high school." The aristocracy, bound for Cambridge and Oxford, would attend what the English call a "public school" or what we would call a very exclusive and expensive private boarding school. These schools were very expensive and since Hardy came from a middle class family of teachers, he needed to do well on the entrance exam and earn a fellowship to attend. Hardy, already very adept at math, won a fellowship to the oldest and one of best public school, Winchester. Hardy hated Winchester and despised the rigid discipline and cruel ways of the school. He despised his school so much that even though he adored the game of cricket and was, by all accounts, a very good player, he refused to play on his school's team. Hardy would continue to be an avid cricket follower for the rest of his life.

After leaving Winchester, Hardy broke the mold and decided to attend Trinity College, Cambridge. It was traditional for Winchester graduates to attend New College, Oxford. Hardy, however, realizing the mathematical tradition of Cambridge and eager to leave the Winchester legacy behind, applied for and was awarded a fellowship to attend Trinity, arguably the best of the Cambridge colleges. A student at Cambridge at this time did not really take classes because they were assigned a tutor that would direct their studies. Most of these studies were independent. Math education was even more idiosyncratic. A student of mathematics organized his education around the dreaded Cambridge Tripos. The Tripos were a series of grueling oral exams that occurred over several days towards the end of the student's third year. Students were then ranked according to how well they had done on the exams and those scoring the highest, "Senior Wranglers" were treated as celebrities in the academic world of Cambridge. Almost all of the time spent in college by a math student in those days was spent with private tutors drilling for the test. Hardy hated the focus on what he called "Tripos math" that he broke tradition and took his exam during his second rather than third year. Later

in life, Hardy would attempt to abolish the Tripos with only limited success. He ended up scoring as a Wrangler and not as a Senior wrangler.

While at Cambridge, Hardy developed an interest in "Continental Mathematics." English mathematics and Continental Mathematics had been divided since the great debates between Newton and his rival Leibniz. The followers of Leibniz had transformed Newton's method of calculating integrals and infinitesimals into an analytic system. English mathematics still employed Newton's somewhat cumbersome methods. Hardy would take this "analysis" and translate it into language that the English could understand, bringing English mathematics up to speed with their continental counterparts.

Calculus involves dividing some amount into smaller and smaller units until the division approaches zero. The method is absolutely necessary to understand and model motion and for physics generally. One way to understand calculus or the way that Newton had understood it, is to think of it as a tool to solve problems related to motion. Another way is to understand calculus in a purely mathematical sense. One can derive the key tools of calculus analytically rather than showing their use. If done this way, mathematical analysis can be put on a more solid and secure footing. Hardy used his articles and reviews of continental works on mathematics to introduce his English compatriots to a more useful approach. Eventually his book, A Course of Pure Mathematics, was widely read and began to change the discipline.

I Beg to Introduce Myself

I Beg to Introduce Myself Summary and Analysis

On January 16th, 1913, Ramanujan wrote Hardy a letter that described Ramanujan's situation in Madras as a clerk and tried to give an indication of his mathematical skill. Ramanujan explained that he had discovered the value to a prime number function that solved a problem that Hardy proposed in an earlier paper. This prime number function had been a mystery to the world's greatest mathematicians for years and now Ramanujan claimed, in a letter to a stranger, that he had solved the problem. He also included several pages from his notebook in the letter to show Hardy his credentials. Ramanujan's theorems and formulas were odd by the standards of English mathematics. His notation was unfamiliar and non-standard. This caused Hardy to wonder whether or not the letter was a hoax or the work of a crank rather than a genius. A day after receiving the letter, he took it to a friend John Littlewood. Littlewood was a math prodigy.

Littlewood and Hardy spent days pouring over Ramanujan's letter. Ramanujan defined in a mathematically precise and novel way definite integrals and showed several infinite series that could produce rational numbers. It was the infinite series that he described that struck Hardy and Littlewood as being mathematically important. Mathematicians for decades later would try to systematically prove many of the theorems in Ramanujan's letter and it was clear to Hardy that this was not the work of a crank, but rather the work of genius.

Hardy contacted the India office and attempted to secure the necessary documents for Ramanujan to come to Cambridge. He also sent Ramanujan a letter telling him how excited he was to see Ramanujan's work but that he would need to show some proofs of the work that he had done. Unfortunately, proofs were not Ramanujan's strong point and this was a problem that would persist. The larger problem though was Ramanujan's cultural and religious opposition to sea travel. Brahmins did not tend to travel over the sea and Ramanujan, at least for now, was intent to keep it that way. In his response to Hardy, Ramanujan somewhat arrogantly suggested that the desire for proofs on Hardy's part was misplaced and that if he would help Ramanujan financially, he would get proofs. Through the help of Hardy and some of his friends in India, Ramanujan was given a mathematical research position at Madras University.

During this period as a research fellow at the university, Ramanujan concentrated day and night on mathematics. He had little contact with his now 14-year-old bride. She was basically uneducated and could not really understand the smallest of problems that Ramanujan was working on at the time. In some of his progress reports to the university, he began to develop what later became known as "Ramanujan's Master Theorem" or a method to integrate all finite definite integrals. He also continued to send proofs back to Hardy. Some of his proofs were later proved incorrect, but the

conclusions that he made are considered correct. As he worked day and night on mathematics, he made considerable progress in an unconventional way.

Later Hardy sent his friend Neville to Madras to give a series of lectures at the university. He advised Ramanujan to contact Neville. His ulterior purpose was to get Neville to convince Ramanujan to come to Cambridge. After meeting Ramanujan, Neville informed Hardy that Ramanujan had decided to risk being outcaste and shunned by his Brahmin cohorts and to come to Cambridge. Ramanujan claimed that the local god Namagiri came to him in a dream and told him to go to England. After that it was only a matter of finding the money for his trip and stay in England. Money was eventually supplied by a scholarship. Ramanujan, with some reluctance, left his wife, mother, and Brahmin traditions behind to leave for England on the Nevasa. He worried about his lack of knowledge of English ways and how he would remain a vegetarian in England. Despite these misgivings, Ramanujan sailed away on March 14th, 1914.

Ramanujan's Spring

Ramanujan's Spring Summary and Analysis

The trip from India to England was not an easy one in those days. The sea voyage left Ramanujan seasick and home sick. He was uncomfortable with strangers and wary about his future in England. The trip through the Red Sea took several days on very hot days, reaching consistently 100 degrees. Ramanujan passed the time playing games and writing letters to his family. Finally, on April 14, about a month after he left, Ramanujan arrived in London. Ramanujan was met by his acquaintance, Neville. Neville took him to Cambridge and helped him fill out the necessary paperwork. In the early days at Cambridge, Ramanujan stayed with Neville and his wife at their large home. By all accounts, the Neville's were very hospitable and enjoyed Ramanujan's company. However, Ramanujan needed to be closer to his collaborator Hardy and moved to a room at the college.

Hardy, Littlewood, and Ramanujan began working through the young man's notebooks. There were thousands of strange formulas and theorems littered through the many notebooks. Hardy believed that as many as 1/3 to 2/3 of the work in the notebooks was sound and original. Later, scholars would try to work through Ramanujan's notebooks to prepare them for publication and many decades later, the task remains uncompleted and a testament to the richness of those notebooks. One of his strangest theorems was a divergent series 1+2+3+4+5...=-1/12. The reason why the infinite addition of real numbers should add up to -1/12 was unclear and Ramanujan could not produce a proof that his theorem suggested. Yet he proposed an interesting constant underlying the behavior of various divergent series. Hardy, during this period, compared Ramanujan to Leonard Euler, one of the greatest mathematicians who ever lived. Ramanujan, like Euler was what is known as a "formalist." A formalist in mathematics is a thinker who is interested in showing the connections between different formalism and formal properties. At the time, formalism was disparaged, although Ramanujan would contribute to its revival.

Some of Ramanujan's earliest work at Cambridge involved examinations into properties of pi. Pi is a mathematical constant used in geometry to determine the circumference of a circle. It is approximately 3.14, although the decimal places can be worked out indefinitely. Ramanujan, however, was interested in the interesting properties that underlay pi. For instance, e, Euler's constant and an interesting constant in its own right, raised to the power of the imaginary number i ($\sqrt{-1}$) and pi or $e^{i\pi} = -1$. Different convergent series can give closer and closer approximations of pi in a greater or lesser number of operations. Ramanujan's series gave an incredibly close approximation of pi in only 8 operations. In fact, his algorithm is so good that it is still used as the basis of many computer programs to determine pi. Despite his mathematical advances, however, Ramanujan was still having trouble fitting in to English society and some things as simple as wearing shoes or using silver ware rather than his hands to eat

seemed alien. Still, despite the culture shock, Ramanujan was happy in his English home.

In 1914, Ramanujan and Cambridge's peace was broken by the onset of World War I. Cambridge was host to several regiments of soldiers and day-to-day life was considerably altered. Ramanujan's mind was still firmly focused on mathematics however. One evening, Ramanujan's friend and fellow countryman, P.C. Mahalanobis read a puzzle from the paper. The puzzle was easy enough to solve, but in solving that problem, Ramanujan, using a series of nested fractions, found the solution to all problems like that one. Almost instantly, Ramanujan's mind had converted a simple puzzle from the newspaper into a complete solution to all similar problems. Ramanujan possessed many rare mathematical talents, but his greatest talent was his intuition. He claimed that the goddess Namagiri gave him his mathematical insights. Unfortunately, the goddess did not supply Ramanujan with the proofs for many of his insights and some of them were wrong. For instance, in one of his first letters to Hardy, Ramanujan claimed to have solved the 6th Riemann hypothesis dealing with the rate of decay of prime numbers in a number series. It turned out that his conclusion was an approximation that was very close to solving the problem but only close. During this period, Hardy spent a lot of time developing Ramanujan's rigor without harming his insight. Meanwhile, the war raged on outside the college.

The English Chill

The English Chill Summary and Analysis

Ramanujan made tremendous progress in his mathematical work at Cambridge. However, he never really fit in with English and especially Cambridge society. Ramanujan saw himself primarily as a Brahmin and stuck to his Brahmin habits and strictures as much as possible. One of these was his vegetarianism. To the Brahmin, the food that one ate was important to the spiritual health of the soul. Ramanujan refused to eat the meat that was the center of the English diet and learned not to trust the college cafeteria's claims that a certain dish was or was not vegetarian. This effectively excluded him from the important social ritual of meals at the high table of Cambridge Fellows. Instead, Ramanujan cooked most of his meals on a small stove in his room. It was not only the food taboos that separated Ramanujan. He was possessed of extreme sensitivity to the opinions of others as well. For instance, on one occasion after inviting some friends over for a simple meal that he cooked, two of the guests who were women, declined a third helping. This so insulted and embarrassed Ramanujan, who took their lack of desire for a third helping as a verdict on his cooking as a whole, that he fled the house and went to Oxford until the women had left.

Ramanujan's experiences were characteristic of Indians thrust into the rarefied society of Cambridge or Oxford. Gandhi, who also attended Cambridge some years earlier than Ramanujan, had experienced similar alienation. Ramanujan was extremely shy and sensitive, but some of his alienation was due, no doubt, to the affected coldness and indifference of the English. Ramanujan would dress in traditional Indian clothing and perform his daily rituals before changing and going out to meet his English colleagues. He even avoided reading his own papers to the English mathematical societies of which he was a member.

Ramanujan and Hardy were, at this time, working on is a part of number theory known as "partitions." Partitions are the number of ways that other numbers can be added to the sum of another number. For instance, the number three has two partitions, 1+1+1 and 2+1. Four has five partitions and as the number increases, the partitions grow as well. Ten has 42 partitions and 50 has 204,226 partitions. While one could figure out the number of partitions by going through all of the possible combinations, mathematicians had long sought a way to determine the number of partitions for a given number in a more precise way. The great mathematician Euler suggested an algorithm for determining partitions, but the exact values of the terms involved were never defined. Ramanujan, led by his intuition, developed a method that he thought would work, but it was only approximate. This led Hardy and Ramanujan to use an inexact but powerful method known as the "circle method" to approximate partitions. Over time though, they determined that their "approximation" was very accurate. Later mathematicians, using the work of Hardy and Ramanujan would develop an exact solution, although many think that Ramanujan would have discovered it himself if his mathematical intuition had not been reigned in by Hardy. This along with several other papers during this period led

Hardy and Neville to nominate Ramanujan to be a Fellow at Trinity college and also to be elected to the Royal Society. Ramanujan was elected to the Royal Society, but it took two tries to get him elected as a fellow at Trinity.

One of the reasons, aside from his accomplishments, that he was elected at so young an age as a fellow in the Royal Society was that many around him, Hardy included, believed that Ramanujan would not live very much longer. The wartime rationing, the long hours he worked, and his vegetarianism all contributed to his extremely poor health. He was eventually diagnosed as having tuberculosis and sent to a sanatorium. In the sanatorium Ramanujan refused to eat and did not improve. Meanwhile, his mother in India was intercepting his wife's letters to him in England, making Ramanujan believe that his wife had not written to him. All of this made Ramanujan homesick and morose. His depression culminated with a suicide attempt in the winter of 1918 when the young Indian threw himself in front of a subway train somewhere in London. Miraculously, he survived and was taken to the hospital where his illness only worsened. At this point, Ramanujan was convinced that the he needed to return to India.

In Somewhat Indifferent Health

In Somewhat Indifferent Health Summary and Analysis

Eventually, Ramanujan recovered enough that Hardy and others believed it was possible and prudent for him to travel to India. Ramanujan desired to return to his home and, by all accounts, probably never intended to return to England. At this point, despite his elections to Trinity college and the Royal Society, Ramanujan still did not see himself as a success. Some blame his colleague, Hardy, for his coldness to Ramanujan. Others believe that Ramanujan was never capable of truly believing that he had accomplished something of true value in mathematics until he had solved all the problems that perplexed him. After moving to a new home to recover more and successfully petitioning Cambridge for a stipend that would be paid to him after his return to India, Ramanujan set off on his return voyage to his home.

India had changed during his long absence. Many Indians had heard of Ramanujan's honors and he had become a kind of celebrity. His family's troubles, especially the conflict between his wife and his mother, had intensified. In fact, they were so bad that Ramanujan's wife was not even at the dock to meet him on his arrival. He absence was no the result of a lack of interest on her part, rather it was because she had been living apart from his family for sometime now and they had not informed her that her husband would be arriving. She later learned about his arrival from the newspaper.

Many noted that Ramanujan had changed since he was last in India. He was no longer friendly and spirited, but rather sullen and cold. He snapped at his wife and mother and spent all of his time on math. Eventually, over the wishes of his mother, Ramanujan and his wife began living together and they started to develop a real relationship. His mother and wife continued to fight, however, and as they fought, his old illness returned and intensified. His doctor diagnosed him as having tuberculosis, and prescribed rest and care. Later the doctor complained that the fighting between Ramanujan's wife and mother prevented him from receiving the care that he needed. On April 26, 1920 with his wife beside him, Ramanujan finally succumbed to his disease and died.

His last days were not filled with idleness, however, and more recent mathematicians, going over his work, believe that he did some of his best and most interesting work during those days. After his death, Indian, British, and American mathematicians have discovered and collected many of Ramanujan's notebooks and unpublished works. They have been constantly editing and publishing his work since his death and their work has yet to be completed. Mathematicians, physicists, computer scientists, and even engineers have all benefited from Ramanujan's work and his legacy has been honored in India.

Epilogue

Epilogue Summary and Analysis

Hardy learned of his friend's death after he had left Cambridge and accepted a chair at Oxford, which was the final destination of so many of his classmates from Winchester. During the war, Hardy was an outspoken opponent of war and this caused him to be unpopular with many of his colleagues at Trinity. Furthermore, Cambridge had begun to increase the administrative responsibilities of Hardy, making it harder for him to focus on research. Hardy went to Oxford, but did not stay there, returning several years later to assume the most exalted position in British mathematics. During his later years, he traveled to America to lecture and developed an interest in baseball. During the 1930s, he continued to do math until late in the decade, when his powers started to wane and eventually disappear altogether. Friends commented that this eternally youthful man actually started to look old. In 1939, he had a heart attack and his health steadily declined after that. In 1947, he attempted suicide but failed. Finally, late in 1947, Hardy died. Till the end, he claimed that his greatest accomplishment was the discovery of Ramanujan.

Characters

S. Ramanujan

Ramanujan, whose full name was Srinivasa Ramanujan Iyengar was born December 22, 1887 and died April 26, 1920. He lived most of his life in several towns in south India including Madras and Kanchipuram. His interest in mathematics was piqued by early courses in his primary school and a textbook, A Synopsis of Elementary Results in Pure and Applied Mathematics, he found by an Englishman named G.S. Carr. With this book and very little other training, Ramanujan developed extremely advanced and innovative mathematical research in the following years. His interest in mathematics was so extreme and overwhelming that he took no interest in other subjects and was unable to do well in any other subjects in school. He did so poorly that he was unable in his native India to earn a college degree. Eventually, due to his interaction with other Indian mathematicians, he was able to publish several papers and get a job as a menial clerk. During this period, he wrote to several prominent English mathematicians and after receiving no reply from most of them, was contacted by G.H. Hardy, one of the most prominent English mathematicians. Hardy eventually convinced Ramanujan to come to Cambridge to continue his research. Ramanujan spent the next several years at Cambridge with Hardy essentially clarifying and publishing work from his notebooks. Ramanujan's health declined due in part to his asceticism and vegetarianism. He eventually returned to India where he later died at a young age. He is regarded by many as one of the greatest mathematicians of all time and his work is still being mined by scholars for its insights.

GH Hardy

Godfrey Harold Hardy, born February 7, 1877 and died December 1, 1947 was one of the most prominent English mathematicians of his time and was responsible for advancing the cause of pure and rigorous mathematics in England. A family of schoolteachers raised him and even though his family was not rich, he acquired an excellent early education and won a scholarship to the oldest and one of the most prestigious of English public schools, Winchester. Despite his dislike of the rigid discipline at Winchester, Hardy developed considerable skill in mathematics and eventually won a fellowship to Trinity College, Cambridge. While at Cambridge, Hardy was required to take a series of very substantial tests known as Tripos. Much of his early years were spent studying for these exams, which he attempted to abolish after he left. During these years, he developed a reputation as an accomplished mathematicians and was inducted into the elite secret society at Cambridge known as the Apostles. After his graduation, he became a fellow at Trinity college and worked to convince, through his work, his colleagues of the need to bring English mathematics up to the level of rigueur that was common in Europe. One day, he received a letter from an unknown Indian clerk filled with what looked like the work of a genius. At first, Hardy thought that the letter was part of a hoax, but later he realized that the clerk, Ramanujan, was a

bone fide genius and he convinced the man to come to Cambridge. Hardy spent several years at Cambridge collaborating with Ramanujan until the latter returned to India and died. Although a great mathematician in his own right, Hardy claimed that his greatest accomplishment was discovering Ramanujan.

GE Moore

GE Moore was Hardy's "father" or mentor in the Apostles and a colleague at Cambridge. Moore, along with Russell, was chiefly responsible for the development of modern "analytic" philosophy and he championed a philosophy of common sense. His great work, the Principia Ethica was greatly admired by his friends at Cambridge.

Prasanta Chandra Mahalanobis

Prasanta Chandra Mahalanobis was another Indian student at Cambridge and friend of Ramanujan. His primary interest was statistics and he developed several new statistical methods and founded the Indian Statistical Institute.

Isaac Newton

Isaac Newton was the great English mathematician and developer of physics in the late 17th and early 18th century. His Principia Mathematica developed the modern laws of motion and certain kinds of physics. He also developed what we now know as "calculus" and is one of the scientific and mathematical founders of the modern world.

Gottfried Leibniz

Gottfried Leibniz was a contemporary of Newton's who simultaneously developed calculus in Germany. Leibniz's calculus however, used a different method of calculation that was more precise and analytical. The differences between these two approaches would continue to divide continental and English mathematicians until Hardy attempted to convert the English to Leibniz's method.

John Littlewood

Littlewood was a friend of Hardy's and a considerable mathematician in his own right. Hardy originally showed Littlewood Ramanujan's first letter to him and it was Littlewood that told Hardy to contact Ramanujan.

Leonhard Euler

Leonhard Euler was a Swiss mathematician responsible for developing many of the conventions and notation that mathematicians still use today. He is generally considered to have been one of the most brilliant and most important mathematicians of all time.

Bertrand Russell

Friend of Moore and Hardy at Cambridge, Bertrand Russell was a brilliant philosopher who was also a dedicated pacifist. Hardy's defense of and sympathy towards Russell's pacifism alienated Hardy from Cambridge society.

Mahatma Gandhi

Gandhi is the father of modern India and was the leader of the movement to end English imperialist rule in India. He was notable for his belief in nonviolence and he also studied at Cambridge.

Objects/Places

Madras

Madras is the capital of the southern Indian state of Tamil Nadu and has long been considered the spiritual heart of India.

Caste

Indian society was, until recently, officially divided into various social classes called castes. Indian castes derive from extremely old religious documents and are unchangeable. Until very recently, Indian castes were extremely rigid and determined, to a large extent, one's social prospects in Indian society.

Brahmin

Brahmins are arguably the highest caste in the Indian caste system. Traditionally, Brahmins are the educated and priestly caste. Brahmins are meant to observe extremely strict religious rules, mostly dealing with purification.

Cauvery

The Cauvery is one of the main rivers in southern India and is considered a sacred river second only to the Ganges.

Pial

A Pial is a kind of porch used in southern India. Ramanujan did much of his early work sitting on his pial with a small chalkboard.

Brahma

One of the three members of the Hindu godhead, Brahma is the god of creation.

Shiva

One of the three members of the Hindu godhead, Shiva is a god of paradoxes and is often depicted as a god of destruction and transformation.

Vishnu

One of the three gods of the Hindu godhead, Vishnu is the god of preservation.

Prime number

A prime number is a number that can only be divided by itself and one to produce a non-fractional result.

Tripos

This is the mathematical exam that all Cambridge math students were forced to take in their third year. Many spent most of their time studying for the exams.

Themes

Creativity vs. Rigor

In The Man Who Knew Infinity, the conflict between creativity and mathematical rigor arises again and again. From Ramanujan's first letter on we are aware of Ramanujan's sparkling and original mathematical creativity. Many of the theorems he sent Hardy were true and original, but they lacked the rigorous proofs that mathematicians require traditionally. Hardy replied to Ramanujan's first letter that proposing the theorems was not enough and he needed to actually prove them. Hardy was a mathematician that prized rigor and proof above all else, while it was clear that Ramanujan was best when he was speculating and creating theorems that would be proved by others later. In fact, many of the theorems that Ramanujan developed but did not prove were later used or proved by other mathematicians. One question that arises is to what extent was Ramanujan helped or hindered by his encounter with Hardy? Was it possible that Hardy stifled Ramanujan's creativity? Could Ramanujan have been even more productive if he was allowed to more freely speculate about mathematics? We will never know but the two opposing types of thinkers that are exemplified by Hardy and Ramanujan continue to find their supporters in a variety of academic disciplines. Indeed, it was Hardy himself who so opposed the English system of educating mathematicians. A system that prized the rigor of the mind and the solving of mathematical puzzles above all else, but that also prevented students from learning "real" mathematics. Would a free and creative spirit like Ramanujan's fared any better in the English school system than he did in the Indian system?

The role of Education

One key theme that the author returns constantly and develops at some length in the final chapter of the book is the role and responsibility of education in society. It remains unclear how much any educational system can really be tailored to develop or even nurture genius. Geniuses, like Ramanujan, are almost by definition outside of the realm of traditional education. Still, the reader is left to wonder how different Ramanujan's life would have been if the Indian educational system were not so rigid and inhospitable to heterodox thinkers. After all, the fact that one of the greatest mathematicians of all time cannot earn a college degree and barely pass high school in India must be an indictment of that educational system. The Indian educational system is organized along strict beauracratically developed standards that focus on social goals aimed at the average student. These systems, paradoxically, have trouble nurturing their best students. Similarly, the English educational system that Hardy so despised was so focused on churning out a certain kind of person, the model Englishman that it had, seemingly, abandoned any pretense of educating at all in some areas. The question of what society should expect of its educational systems, whether they should be flexible or exacting, nurture geniuses or raise the average is a complicated and important theme that the author does not try to answer. Instead, he suggests that the story of both Hardy

and Ramanujan can illuminate. It is a question that will continue to animate debates in India, America, and England.

The nature of Genius

Related to the role of education and the value of creativity is the nature of genius. There is no real and accepted understanding of exactly what it means for someone to be a genius but thinkers who are generally considered geniuses, Ramanujan, Einstein, Newton, Hume and others do have certain characteristics in common. One seems to be an unusual amount of creativity in their work. Geniuses are not typically merely those who extend and continue the work of others, but rather those who strike out on their own to pursue avenues of inquiry that have either been neglected by others or that seem to have failed. The pursue what John Stuart Mill would call "experiments in living," that is, they would do something no one else had tried or thought to do. Creativity, however, may be necessary but it is surely not sufficient for genius. There are innumerable ways to be creatively wrong or crazy, it is only creativity that leads to something productive or interesting that is hailed as genius. For the genius like Ramanujan then, creativity must triumph over rigor, but the work cannot be without some rigor. Along this line of thought then, Ramanujan, one of the most creative mathematicians of all time, was a genius while Hardy, a respected and eminent mathematician known more for his rigor than his imagination, was not. This verdict seems to reflect the judgment of the author and history indicating that more than the ability to do one's job well is required for genius. A genius must do their job in a way that no one has done before and in a way that everyone recognizes is valuable.

Style

Perspective

The Man Who Knew Infinity is written from the perspective of the layman attempting to understand the relationship of two mathematical geniuses and their interactions with the world around them. The main interest of the author is not to explain or laud either Ramanujan's or Hardy's work, but rather to explain their significance in history. In many ways, Hardy and Ramanujan were worlds apart. Hardy, although he came from a middle class background, attended and was a product of the most exclusive schools in England, Winchester, and Cambridge. On the other hand, Ramanujan was a poor young man living in a backward area of India without much schooling. Understanding how these men became what they were and accomplished what they did is the chief goal of this book.

The average reader will not be able to understand the important contribution that either Hardy or Ramanujan made to mathematics and even an expert in the field would probably have trouble explaining their work. Consequently, the exact mathematical work of the two men plays a smaller part in the narrative of the book that it might have otherwise. Instead, this work takes the perspective of an interested sociologist or historian that uses the mathematics a background and context to examine the development of genius more generally. In this way, the reader lacking in the advanced mathematical background that one would require to fully understand Ramanujan's work is still drawn to the incredible story of the genius Ramanujan even if the mathematician Ramanujan is unapproachable.

Tone

For a book ostensibly about advanced mathematics and number theory, The Man Who Knew Infinity strikes an incredibly light and conversational tone. he author is more interested in the story of the two men involved, Hardy and Ramanujan, than he is in the math itself. Instead of a dry explanation of strange concepts in mathematics, we find a brisk and interesting history of English mathematics and academia in the early twentieth century as well as a portrait of colonial India. The prose is easy to read and the story moves along at a pace that will encourage even those who lack all interest and knowledge of mathematics. The author is clearly fascinated by the genius and oddity of his subjects and plumbs to the depths of their strange and luminescent characters. Some books in this kind of genre, popular writing about science or mathematics, can be either pedantic or condescending. However, The Man Who Knew Infinity ably avoids both of these extremes. The author clearly believes that the mathematics, although difficult to understand, is important and interesting. That interest shines through in the discussions of the math in this book. When it is time to explain the math, the author does an excellent job of translating complex mathematical concepts into language that the average reader can understand with a little patience. This is no easy task and while

the reader will not understand all of Ramanujan's significance, they will at least have a basic understanding of his contributions.

Structure

The Man Who Knew Infinity is composed of eight major chapters and a short epilogue. Each of the chapters, aside from one or two exceptions, follows the chronology of Ramanujan's life. Within each chapter, there are typically several subsections. Each section deals with one of these typically and helps to organize the narrative. The book follows two parallel storylines. One deals with the life and work of GH Hardy and the other deals with the life of Ramanujan. The book begins with the story of Ramanujan's early days in Southern Indian. It then takes up the story of Hardy's early years and his rise to maturity in the English mathematical establishment. These storylines merge when Ramanujan contacts Hardy and eventually travels to Cambridge to collaborate with him. Towards the end, the storylines diverge again when Ramanujan travels to India and eventually dies. Strangely, the last chapter deals almost entirely with the final days of Ramanujan's life in India and we must wait until the epilogue to find out what happened to Hardy after Ramanujan left Cambridge. This reminds us that although Hardy and Ramanujan were each spotlighted in the book and received almost equal time throughout, the star of the book was always Ramanujan with Hardy serving only a supporting role. Throughout, personal anecdotes are combined with mathematical explanations and sociological analysis along with straight history and biography to give The Man Who Knew Infinity the feeling of a greater breadth than it might otherwise have had. The Man Who Knew Infinity is not merely a biography in the traditional sense but also a social history of India and English mathematic during the early part of the twentieth century.

Quotes

"For Ramanujan's first three years, he scarcely spoke" (Chapter 1, pg. 13.)

"The untouchables could not even do that [enter the temple]. Nor, traditionally, could even their shadows cross the path of a Brahmin without his having to undergo a purification ritual" (Chapter 1, pg. 21.)

"Ramanujan was supremely self-assured about his mathematical gifts. Yet socially, he was a thoroughgoing conformist" (Chapter 2, pg. 51.)

"Ramanujan was an artist. And Numbers-and the mathematical language expressing their relationships-were his medium" (Chapter 2, pg. 60.)

" 'Infinite series,' one mathematician has written, 'were Ramanujan's first love'" (Chapter 3, pg. 87.)

"Hardy judged God, and found him wanting" (Chapter 4, pg. 110.)

"Good work is not done by humble men"(Chapter 5, pg. 178.)

"...if Ramanujan possessed conjurer's tricks, they were of almost Mephistopholean potency" (Chapter 6, pg. 206.)

"Hardy, in short, was a stern taskmaster" (Chapter 7, pg. 255.)

"His life [Ramanujan] was truncated, like a cone sliced off short of its vertex" (Chapter 8, pg. 356.)

"In South India today, everyone has heard of Ramanujan" (Chapter 8, pg. 359.)

"Oxford overwhelms-Cambridge beguiles" (Epilogue, pg. 362.)

Topics for Discussion

To what extent do you believe that Hardy's relationship with Ramanujan helped Ramanujan? To what extent did it hurt him?

Why was Ramanujan so unable to fit into English society? To what extent is his experience typical?

Explain Ramanujan's religious devotion and its role in his mathematical work.

Compare and contrast the different mathematical styles and personalities of Hardy and Ramanujan?

Imagine that Ramanujan and Hardy could have switched places as children. How would their lives have been different?

What responsibility does society have to geniuses? What responsibility do geniuses have to society?

What do you think makes a genius? Give examples of people that you think are geniuses and explain why.