SRINIVASA RAMANUJAN (1887-1920)

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PREFACE

India has a rich heritage of Science and Technology. Whether it is the invention of Zero long ago or launching of more than 100 satellites in space in the modern era our Scientists have done it successfully. Unfortunately, our glorious past has been long forgotten. Vijnana Bharati, through Vidyarthi Vigyan Manthan (VVM), is trying to inculcate the feeling of national pride, about our Scientific and Technological past, in the future citizens of India.

The objective of Vidyarthi Vigyan Manthan is not just to hunt for the science talent amongst the young minds, but also to develop and nurture the scientific temperament in the younger generation. VVM aims at doing so by making the students aware about the lives and achievements of scientists of Indian origin, who have mostly stayed and worked in India. We hope that reading about these scientists will inspire the young minds and focus their attention towards their motherland and the achievements of the sons and daughters of the country.

This year, we have focused on two scientists who were born and brought up in pre-independent India in poor families and did their studies and most of their work in India. Through this write-up we intend to make the readers go through the ups and downs and various obstacles they had to scale to achieve the great heights in their carrier. Reading about their lives makes us realize that when there is a strong will to succeed and passion for your chosen goal, no adversity can ever stop you.

Team VVM

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SRINIVASA RAMANUJAN

In September 1887, two months before her child was due to be born, a nineteen-year-old Kumbakonam girl named Komalatammal travelled to Erode, her parental home, 150 miles upriver, to prepare for the birth of the child she carried. That a woman returned to her native home for the birth of her first child was a tradition so widely observed that officials charged with monitoring vital statistics made a point of allowing for it.

It was here that a son was born to her and her husband Srinivasa, just after sunset on the ninth day of the Indian month of Margasirsha- or Thursday, December 22, 1887. On his eleventh day of life, again in accordance with tradition, the child was formally named, and a year almost to the day after his birth, Srinivasa Ramanujan Iyengar and his mother returned to Kumbakonam, where he would spend most of the next twenty years of his life. "Srinivasa"-its initial syllable pronounced *shri-was* just his father's name, automatically bestowed and rarely used; indeed,



on formal documents, and when he signed his name, it usually atrophied into an initial "S." "Iyengar," meanwhile, was a caste name, referring to the particular branch of South Indian Brahmins to which he and his family belonged. Thus, with one name that of his father and another that of his caste, only" Ramanujan" was his alone. As he would later explain to a Westerner, "I have no proper surname." His mother often called him Chinnaswami, or "little lord." But otherwise he was, simply, Ramanujan.



Ramanujan's mother, Komalatammal, sang *bhajans*, or devotional songs, at a nearby temple. Half the proceeds from her group's performances went to the temple, the other half to the singers. With her husband earning only about twenty rupees per month, the five or ten she earned this way mattered; never would she miss a rehearsal. Yet now, in December 1889, she *was* missing them, four or five in a row. So one day, the head of the singing group showed up at Komalatammal's house to investigate. She saw that two-year-old Ramanujan was suffering from smallpox.

Ramanujan's family was a case study in the damning statistics. When he was a year and a half, his mother bore a son, Sadagopan. Three months later, Sadagopan was dead. When Ramanujan was almost four, in November 1891, a girl was born. By the following February, she, too, was dead. When Ramanujan was six and a half, his mother gave birth to yet another child, Seshan-who also died before the year was out.

Much later, two brothers did survive-Lakshmi Narasimhan, born in 1898, when Ramanujan was ten, and Tirunarayanan, born when he was even teen. But the death of his infant brothers and sister during those early years meant that he grew up with the solicitous regard and central position of an only child.

For Ramanujan's first three years, he scarcely spoke. Perhaps, it is tempting to think, because he simply didn't choose to; he was an enormously self-willed child. It was common in those

days for a young wife to shuttle back and forth between her husband's house and that of her parents, and Komalatammal, worried by her son's muteness, took Ramanujan to see her father, then living in Kanchipuram, near Madras.

There, at the urging of an elderly friend of her father's, Ramanujan began the ritual practice of *Akshara Abhyasam:* his hand, held and guided by his grandfather, was made to trace out Tamil characters in a thick bed of rice spread across the floor, as each character was spoken aloud.

Soon fears of Ramanujan's dumbness were dispelled and he began to learn the 12 vowels, 18 consonants, and 216 combined consonant-vowel forms of the Tamil alphabet. On October 1, 1892, the traditional opening day of school, known as *Vijayathasami*, he was enrolled, to the accompaniment of ancient Vedic chants, in the local *pial* school. A *pial* is the little porch in front of most South Indian houses; a *pial* school was just a teacher meeting there with half a dozen or so pupils.

But five-year-old Ramanujan, disliking the teacher, bristled at attending. Even as a child, he was so self-directed that, it was fair to say, unless he was ready to do something on his own, in his own time, he was scarcely capable of doing it at all; school for him often meant not keys to knowledge but shackles to throw off.

For about two years, Ramanujan was shuffled between schools. Beginning in March 1894, while still at his mother's parents' house in Kanchipuram, he briefly attended a school in which the language of instruction was not his native Tamil but related yet distinct Telugu. There, sometimes punished by having to sit with his arms folded in front of him and one finger turned up to his lips in silence, he would at times stalk out of class in a huff.

In a dispute over a loan, his grandfather quit his job and left Kanchipuram. Ramanujan and his mother returned to Kumbakonam, where he enrolled in the Kangayan Primary School. But when his other grandfather died, Ramanujan was bounced back to his maternal grandparents, who by now were in Madras. There he so fiercely fought attending school that the family enlisted a local constable to scare him back to class. By mid-1890s, after an unhappy six months in Madras, Ramanujan was once more back in Kumbakonam.

Srinivasa Iyengar, twenty-four at his son Ramanujan's birth and about five years older than his wife, was a clerk in a sari shop, just as his own father, Kupuswamy, had been. Normally, such a clerk remained one all his life-waiting on customers, taking orders, performing routine paperwork, perhaps traveling to nearby villages to collect bills.

Day after day, year after year, he was at the shop, largely absent from Ramanujan's early life. Indian society generally left the father little role to play at home, casting him as an aloof, physically undemonstrative, even unwelcoming figure whose relationship with his children was largely formal. Srinivasa was almost invisible, his name largely absent from family accounts. "Very quiet," a boyhood friend of Ramanujan called him. Someone else would resort to the word "weightless." But even had he been otherwise, he could scarcely have competed with Komalatammal as an influence on their son.

Komalatammal, whom Ramanujan resembled physically, was, in the words of one account, "a shrewd and cultured lady."

She poured prodigious energy into her spiritual life. In Hindu families, the women were apt to be more pious, and more scrupulous about observing tradition, than the men. So it had been in her own family; her mother was said to have gone into hypnotic trances that placed her in communion with the gods. And so it was in Ramanujan's family. Komalatammal was fiercely devout, held prayer meetings at her home, sangat the temple, pursued astrology and palmistry. Always, the name of their family deity, the Goddess Namagiri of Namakkal, was on her lips. "An exceptionally gifted lady with psychic powers and a remarkable imagination" was how one friend of the family described her. She had "a remarkable repertoire of mythological stories and used to tell me stories from [the] ancient Mahabharata and Ramayana to [the] later Vikramaditya legends." Any pause in the telling was cause for yet another murmured appeal to Namagiri.

From his mother, Ramanujan absorbed tradition, mastered the doctrines of caste, learned the puranas. He learned to sing religious songs, to attend pujas, or devotions, at the temple, to eat the right foods and forswear the wrong ones-learned, in short, what he must do, and what he must never do, in order to be a good Brahmin boy.

Ramanujan's native language was Tamil, one of a family of Dravidian languages that includes Malayalam, Canarese, and the musical-sounding Telugu. European scholars acclaimed Tamil for its clear-cut logic; "a language made by lawyers and grammarians," someone once called it. Spoken from just north of Madras within a broad, kidney-shaped region west to the Nilgiri Hills and south to Cape Comorin at the tip of the subcontinent, as well as in northern Ceylon, Tamil represented no out-of-the-way linguistic outpost. It had its own rich literature, distinct from the Hindi of the north, going back to the fifth century B.C., boasted a verse form reminiscent of ancient Greek, and was spoken by almost twenty million people. While a pupil at Kangayan Primary School, Ramanujan studied English from an early age, and in November 1897, just shy of ten, he passed his primary examinations-in English, Tamil, arithmetic, and geography scoring first in the district. The following January, he enrolled in the English language high school, Town High.

Town High School had its origins in 1864 in two houses on Big Street, a main thoroughfare near the heart of town. When, some years later, the local college dropped its lower classes, a group of public-spirited citizens rushed to fill the vacant academic niche from below, through an expanded Town High. They would tear down the old buildings, erect a new one on the existing site.

The school, which stood about a five-minute walk from Ramanujan's house, drew the cream of Kumbakonam youth and launched them into college and career. Alumni would later recall it with genuine fondness. And it nourished Ramanujan for six years, bringing him as close as he'd ever come to a satisfying academic experience.

Ramanujan's gifts became apparent early. Ramanujan entered Town High's first form at the age of ten, corresponding to about an American seventh grade. And already while he was in the second form, his classmates were coming to him for help with mathematics problems.

Ramanujan's family, always strapped for cash, often took in boarders. Around the time he was eleven, there were two of them, Brahmin boys, studying at the nearby Government College. Noticing Ramanujan's interest in mathematics, they fed it with whatever they knew. Within months he had exhausted their knowledge and was pestering them for math texts from the college library. Among those they brought to him was an 1893 English textbook popular in South Indian colleges and English preparatory schools, S. L. Loney's *Trigonometry*, which actually ranged into more advanced realms. By the time Ramanujan was thirteen, he had mastered it.

Ramanujan learned from an older boy how to solve cubic equations. He came to understand trigonometric functions not as the ratios of the sides in a right triangle, as usually taught in school, but as far more sophisticated concepts involving infinite series. He'd rattle off the numerical values of 7r and e, "transcendental" numbers appearing frequently in higher mathematics, to any number of decimal places. He'd take exams and finish in half the allotted time. Classmates two years ahead would hand him problems they thought difficult, only to watch him solve them at a glance.

He became something of a minor celebrity. All through his school years, he walked off with merit certificates and volumes of English poetry as scholastic prizes. Finally, at a ceremony in 1904, when Ramanujan was being awarded the K. Ranganatha Rao prize for mathematics, headmaster Krishnaswami Iyer introduced him to the audience as a student who, were it possible, deserved higher than the maximum possible marks. An A-plus, or 100 percent, wouldn't do to rate him. Ramanujan, he was saying, was off-scale.

It first came into his hands a few months before he left Town High School, sometime in 1903. Probably, college students staying with Ramanujan's family showed him the book. In



any case, its title bore no hint of the hold it would have on him: A Synopsis of Elementary Results in Pure and Applied Mathematics.

In essence, the book was a compilation of five thousand or so equations, written out one after the other-theorems, formulas, geometric diagrams, and other mathematical facts, marching down the page, tied together by topic, with big, bold-faced numbers beside each for cross reference. Algebra, trigonometry, calculus, analytic geometry, differential equations-great chunks of mathematics as it was known in the late nineteenth century,

ranged not over a whole shelf of textbooks, but compressed within two modest volumes (the second of which Ramanujan may not have seen until later).

"The book is not in any sense a great one," someone would later say of it, "but Ramanujan has made it famous."

The *Synopsis* was a product of the genius of George Shoobridge Carr. Except that Carr was no genius. He was a mathematician of distinctly middling rank who for years tutored privately in London; the book was a distillation of his coaching notes.



In 1904, soon after discovering Carr, Ramanujan graduated from high school and entered Government College Kumbakonam's with а scholarship awarded on the strength of his high school work. He was an F.A. student, for First Arts, a course of study that, by years in school, might today correspond to an associate's degree but in India, then, counted for considerably more.

One can only guess at the effects of a book like Carr's *Synopsis* on a mediocre, or even normally bright student. But in Ramanujan, it had ignited a burst of fiercely single-minded intellectual activity. Until then, he'd kept mathematics in balance with the rest of his life, had been properly attentive to other claims on his energy and time. But now, ensnared by pure mathematics, he lost interest in everything else. He was all math. He couldn't get enough of it. "College regulations could secure his bodily presence at a lecture on history or physiology," E. H. Neville, an English mathematician who later befriended Ramanujan, would write, "but his mind was free, or, shall we say, was the slave of his genius."

Meanwhile, he ignored the physiology, the English, the Greek and Roman history he was supposed to be studying; he was no longer, if he'd ever been, "well-rounded." Back in 1897, his high standing on the Primary Examination had depended on excelling in many subjects, including English. Letters known to be written by him later, while showing no special grace, were competent enough, as were his mathematics notebooks when he used words, rather than symbols, to explain something.

Yet now, at Government College, he failed English composition. "To the college authorities," E. H. Neville observed later, "he was just a student who was neglecting flagrantly all but one of the subjects he was supposed to be studying. The penalty was inevitable: his scholarship was taken away."

His mother, of course, was incensed and went to see the principal. How could he refuse her son a scholarship? He was unequaled in mathematics. They had never seen his like. The principal was polite, but firm. Rules were rules. Her son had failed the English composition paper, and miserably so. That was that.

Still, he managed to hang on for a few months, showing up for class enough to earn a certificate in July 1905 attesting to his attendance. The effort must have taxed him. He'd lost the scholarship, and everybody knew it. His parents were under a heavy financial burden; he knew that, too. He felt pressure to do well in his other subjects, yet he didn't *want* to lay mathematics aside for their sake. He was torn and miserable. He endured the situation until he could endure it no longer. In early August 1905, Ramanujan, seventeen years old, ran away from home to Vishakhapatanam.

It was to Pachaiyappa's-pronounced Pa-shay-a-pas-College that Ramanujan was bound when, one day early in 1906, he arrived at Egmore Station in Madras, so tired and disoriented that he fell asleep in the waiting room. A man woke him, took him back to his house, fed him, gave him directions, and sent him on his way to the college.

Ramanujan, eighteen years old now, aimed to be a student at Pachaiyappa's college. A year after his failure in Kumbakonam, he was giving college another try in Madras.

For a time, he lived a few blocks away from Pachaiyappa's in a small lane off the fruit bazaar on Broadway in his grandmother's house. It was dingy and dark. And the air seemed to hang, static and close. But at least he was back in school.

Ramanujan's new math teacher, shown his notebooks, came away so impressed that he introduced him to the principal-who, on the spot, awarded him a partial scholarship. Though interrupted by a bad bout of dysentery that brought him back to Kumbakonam for three months, Ramanujan's early days at Pachaiyappa's College seemed filled with new promise.

Everyone was struck by Ramanujan's gifts; but there was nothing new in that. Nor was there anything new in that nothing tangible came of it. For his experience in Kumbakonam now repeated itself at Pachaiyappa's.

At Government College, it was English that had been his undoing. Now, among other subjects remote from mathematics he had to master, there was physiology. And this he found not merely boring, but repellent.

Ramanujan, it need hardly be said, flunked physiology. Except for math he did poorly in all his subjects, but in physiology he reached particularly impressive lows, often scoring less than 10 percent on exams.

He'd take the three-hour math exam and finish it in thirty minutes. But that got him exactly nowhere. In December 1906, he appeared again for the F.A. examination and failed. The following year, he took it again. And failed again.

Government College, Kumbakonam, 1904 and 1905 ... Pachaiyappa's College, Madras, 1906 and 1907.

Viewed one way, then, for at least the five years between 1904 and 1909, Ramanujan floundered-mostly out of school, without a degree, without a job, without contact with other mathematicians. For five solid years, Ramanujan was left alone to pursue mathematics.

He received no guidance, no stimulation, no money beyond the few rupees he made from tutoring. But for all the economic deadweight here presented, his family apparently discouraged him little-not enough, in any case, to stop him. India, it might be said, left room for the solitary genius in him as it would for the sage, the mystic, the sanyasi. His friends, his mother, and even his father tolerated him, made no unduly urgent demands that he find work and make something of himself.

Indeed, in looking back to Ramanujan's early years, Neville would refer to "the care free days before 1909." And, in a sense, they were. In some ways, they were the most productive of his life. Ramanujan had found a home in mathematics, one so thoroughly comfortable he scarcely ever wished to leave it. It satisfied him intellectually, aesthetically, emotionally.

One day late in 1908, Ramanujan's mother was visiting friends in the village of Rajendram, about sixty miles west of Kumbakonam. There she spied a bright-eyed wisp of a girl, Janaki

(Janakiammal), daughter of a distant relative. She asked for the girl's horoscope-the first step in virtually every arranged marriage in India-drew her son's horoscope on the wall of the house, compared it to that of the girl, and concluded that yes, this would make a good match. Negotiations ensued for the marriage of Ramanujan and Janaki, then about nine years old. Finally, on July 14, 1909 Janaki took the *saptapadi*, or seven steps, that made the marriage irrevocable.



But though outward circumstances had changed little, Ramanujan had entered a new stage of life. Hindu thinking sees life passing through four stages. As brahmacharya, you are a student, learning the spiritual and intellectual ropes. As grihasta, occupying the longest span, you area householder, with responsibilities to home and family. As vanaprastha, or "inhabitant of the forest," you begin to throw off the bustle of family life and seek solitude, introspective calm. Finally, as sanyasi, you relinquish everything-family, possessions, attachments-in pursuit of spiritual fulfillment. At his wedding, in heading off for Benares, Ramanujan had ritually opted for this last stage. But in fact, he was now a grihasta.

He had responsibilities now. He had a wife. His father was pushing fifty. No longer was he a free spirit, left "ranging with delight" through mathematics, happily on his own. It was time that he assume the mantle of adulthood.

Ramanujan sought now not a scholarship, nor even the chance to be a mathematician, but just a job, a chance at a future, a new life. For the next two years, the sheer desperation of his lot sent him across South India, first from Kumbakonam as his base and then, increasingly, Madras.

Once again, he took to the rails, though he would often have to depend for his ticket on friends and well-wishers. To the English, even first-class seats were a bargain. But for Ramanujan, round-trip to Madras at a quarter-anna or so per mile for the crowded third-class carriage was worth more than a week's pay to his father, the equivalent of more than a hundred pounds of rice.

Sometime late in 1910, Ramanujan boarded a northbound train from Kumbakonam and, about halfway to Madras, got off at Villupuram, just west of Pondicherry, the coastal city then still in French hands. At Villupuram, he changed trains for the twenty-mile trip west to Tirukoilur, a town of about nine thousand that was headquarters of its district. In Tirukoilur, V. Ramaswami Iyer held the midlevel government post of deputy collector. (Iyer, also spelled Aiyar, was the caste name of Brahmins who worshipped Siva, and was ubiquitous in South India.)

What made Ramaswami especially worth traveling to see was that he was a mathematician; in particular, he had recently founded the Indian Mathematical Society. Everyone called him "Professor," though he held no academic post. Back while a student at Presidency College, it seems, he had contributed mathematical articles to the *Educational Times* in England. Its editors, assuming he was a college professor, addressed him as such, and the name stuck.

Now, as ever, Ramanujan came armed with his notebook. The Professor looked at it. He was a geometer, and the mathematics he saw before him was mostly unfamiliar. Still, at least in the glow of memory, "I was struck by the extraordinary mathematical results contained in it." Did that mean he would give Ramanujan a job in the *taluk* office? Hardly. "I had no mind to smother his genius by an appointment in the lowest rungs of the revenue department," he wrote later. So he sent him on his way, with notes of introduction, to mathematical friends in Madras.

One of them, a charter member of the Mathematical Society, was P. V. Seshu Iyer, a pinchfaced man with glasses who'd been one of Ramanujan's professors at Government College. Since about 1906, they'd not seen one another. Now, four years later, Seshu Iyer had moved up to Presidency College in Madras. Ramanujan met him there, notebooks in hand, but also this time with Ramaswami Iyer's recommendation. He left with leads and yet other notes of introduction.

He went to see S. Balakrishna Iyer, then himself just starting his career as a mathematics lecturer at Teachers' College in the Madras suburb of Saidapet. Would he, Ramanujan asked, recommend him to his English boss, a certain Dodwell, for a job as a clerk? It didn't matter how poorly it paid; anything would do. Balakrishna served him coffee, looked at his notebooks, which he didn't understand, and later went to see Dodwell three or four times on Ramanujan's behalf. Nothing came of it. "I was not big enough," apologized Balakrishna Iyer later-not important enough to exert any influence.

In December, Ramanujan went to see R. Ramachandra Rao, who was indeed "big enough." Educated at Madras's Presidency College, he had joined the provincial civil service in 1890, at the age of nineteen, and in time rose to become registrar of the city's Cooperative Credit Societies. Now he was district collector of Nellore, a town of about thirty-five thousand, a hundred miles up the East Coast Railway from Madras. Earlier in the year, he had been named "Dewan Bahadur," which was something like a British knight. All this, and he was a



mathematician, too, serving as secretary of the Indian Mathematical Society, the group Ramaswami Iyer had founded four years earlier, and even sometimes contributing solutions to problems posed in, its *Journal*. Intelligent, wealthy, and well connected, R. Ramachandra Rao was just the kind of paternal figure, at the head of a retinue of family and friends, through whose offices one got things done in India.



Ramachandra Rao sent Ramanujan to Seshu Iyer, saying it would be cruel to let him rot in a backwater like Nellore. No, he would not give him a job in the local *taluk* office but rather would seek for him some scholarship to which, despite his penchant for failing examinations, he might be eligible. Meanwhile, let him stay in Madras; he, Ramachandra Rao, would pay his way.

Monthly, from then on, Ramanujan began receiving a money order for twenty-five rupees. It wasn't much. But it was enough to free him from economic cares. Life opened up for him. Now, more decisively than before, he left the Kumbakonam of his youth behind and, from

early 1911 and for the next three years, stepped into the wider world of South India's capital, Madras.

In May 1911, Ramanujan left the place he shared on Venkatanarayan Lane and moved to a little alley boarding house, On Swami Pillai Street, bearing the inflated name "Summer House." There he lived for the rest of the year and much of 1912 with close to a dozen others, mostly students, who frequented a Brahmin-run restaurant on Pycroft's Road, the main street of a neighborhood known as Triplicane.

Lightened by the load Ramachandra Rao's generosity had lifted from his shoulders, Ramanujan was happy, or something close to it. Now, after that anxious, groping two years following his marriage, he was surrounded by friends, doing what he liked to do, carefree and cheerful.

C. R. Krishnaswami Iyer, who'd known him at Pachaiyappa's and now shared a room with him in Summer House, remembered how once Ramanujan stayed up exclaiming on astronomical wonders till late into the night. Finally, Krishnaswami's cousin, his sleep shattered by Ramanujan's monologue, poured a pot of water over him; *that* would cool his fevered brain, he said. But Ramanujan took it all in stride. Ah, yes, are freshing *Gangasnanam-a* purging bath in the River Ganges; could he have another?

1911 was a good and hopeful year. It was the year the capital of India was shifted, with great pomp and ceremony, from Calcutta to Delhi. The year a new sewer system, complete with underground conduits, sand filters, and pumps, was being installed in Madras. The year its oil-lit streets began to give way to electricity. And it was the year Srinivasa Ramanujan's first paper appeared, in the *Journal of the Indian Mathematical Society---representing* his initial step onto the stage of Indian mathematics, and the world's.

For centuries, India had stood its mathematical ground against the rest of the world. But now, that was ancient history; of late it had added little to the world's mathematical treasure. Only a line of brilliant mathematicians in Kerala, on the subcontinent's southwest tip, broke the gloom that otherwise extended back to the great Bhaskara of the twelfth century. The birth of the Mathematical Society could not ensure a rebirth. But its founders-hungry to connect with the West, proud of their country's heritage yet soberly aware that reverence for the past was no substitute for present achievement-surely hoped it did.

It was into this nascent new world that Ramanujan "came out," as it were, as a mathematician in 1911. He had met Ramaswami Iyer, the society's founder, the previous year when, in search of a job, he had traveled to Tirukoilur. Now Ramanujan's work was appearing in volume3 of Ramaswami Iyer's new *Journal-which*, like most mathematics publications, opened its pages to provocative or entertaining problems from its readers.



Appearing in the *Journal* of *the Indian Mathematical Society*, Ramanujan was on the world's mathematical map at last, if tucked into an obscure corner of it. He was starting to be noticed. Early the following year, K. S. Srinivasan, a student at Madras Christian College who'd known Ramanujan back in Kumbakonam, dropped by to see him at Summer House.

"Ramanju," he said, "they call you a genius."

For about a year, Ramanujan lived on Ramachandra Rao's generosity. He was mathematically productive, peppering the Mathematical Society *Journal* with one interesting new problem after another, and completing a second paper. But he was, after all, unemployed, and this grew to bother him. Not long before, through one of his patrons, Ramanujan got a temporary job in the Madras Accountant General's Office, making twenty rupees per month, but held it only a few weeks. Now, early in1912, Ramachandra Rao had turned to others among his influential friends, and Ramanujan was applying for a new job:

The letter was dated 9th February 1912. It listed Ramanujan's return address as 7, Summer House, Triplicane. It was addressed to The Chief Accountant, Madras Port Trust.

The port of Madras carried more than 60 percent of the Madras Presidency's imports and exports to Britain. Each year, twelve hundred ships called there, bringing in iron and steel, machinery, and railway equipment, and leaving with hides, piece goods, indigo, and raw cotton. Still, by early in the century, it was a troubled operation needing major changes. Placed in charge of the Port Trust in 1904, and as its chief engineer charged with overseeing those changes, was Sir Francis Spring.

A bald man with sleepy eyes, white mustache, and goatee, known in Madras as among the first in South India to own his own motorcar, Sir Francis was in his second career. Born in Ireland in 1849, a graduate of Trinity College in Dublin, he had joined the India Government engineering service in 1870 and for more than thirty years had played a key role in the development of the South Indian Railways System, where he had, among other feats, spanned the Godavari River with a big railroad bridge. For these accomplishments, he had been named knight commander of the Indian Empire in 1911. Seven years before, he'd come to the Port Trust, and with him he'd brought S. Narayana Iyer.

Narayana Iyer was not an engineer by training; the British had set up Indian colleges to train bright clerks to administer the bureaucracy, not equip them to get along without European technical expertise. The son of a Brahmin priest, he held an M.A. from St. Joseph's College, in Trichinopoly, where he'd stayed on to become a lecturer in mathematics. There he'd met Sir Francis. At the Port Trust, he was, as office manager and then as chief accountant, the highest-ranking Indian. Sir Francis relied on him heavily.

These two men, Sir Francis Spring and Narayana Iyer, were to play an important role in Ramanujan's life over the coming years. But now, on March 1, 1912, three weeks after he'd applied for the job, Ramanujan knew only that he worked under them as a Class III, Grade IV clerk in the accounts section, earning thirty rupees per month.

During all this time, Janaki had been far from her husband's side, shuttling back and forth between her parents in Rajendram and her mother-in-law's house in Kumbakonam for "training" in the wifely arts. Now, late in 1912, past puberty and with Ramanujan in a steady job, the two finally became man and wife in something more than name.

Summer House in Triplicane was about three miles from Ramanujan's new job at the offices of the Port Trust opposite the harbor complex north of Fort St. George. So a few months after

starting the job, Ramanujan had moved much closer, joining his grandmother in a little house on Saiva Muthiah Mudali Street, off Broadway, in the district known as Georgetown. And it was there that, three years after their marriage, Janaki-along with Ramanujan's mother, Komalatammal-joined him.

Narayana Iyer, a member of the Mathematical Society and long its treasurer, was not just Ramanujan's immediate superior, but his colleague. In the evenings, they would retire to the elder man's house on Pycroft's Road in Triplicane. There, they'd sit out on the porch upstairs overlooking the street, slates propped on their knees, sometimes until midnight, the interminable scraping of their slate-pencils often keeping others up. Sometimes, after they had gone to sleep, Ramanujan would wake and, in the feeble light of a hurricane lamp, record something that had come to him, he'd explain, in a dream.

Narayana Iyer was no mean mathematician. But in working with him he found that Ramanujan's penchant for collapsing many steps into one left him as lost as a dazed Watson in the wake of a run of Sherlock Holmes logic. How, Narayana Iyer would ask, could he expect others to understand and accept him? "You must descend to my level of understanding and write at least ten steps between the two steps of yours." What for? Ramanujan would ask. Wasn't it obvious? No, Narayana Iyer would reply, it was not obvious. Patiently, he would persist, cajoling him, in the end sometimes getting him to expand a little on his thinking.

It wasn't long before Narayana Iyer was not just a boss to Ramanujan, nor even just a colleague, but advisor, mentor, and friend. "Some people," Janaki later recalled him saying, "look upon him [Ramanujan] as ordinary glass, but they will remain to see him soon to be a diamond." He brought Sir Francis around to his view, too, making him Ramanujan's champion as well. And it was in coming to the attention of Sir Francis and to the web of contacts radiating out from him that, sometime around the middle of 1912, Ramanujan stepped into *British* India. He had grown up and lived almost his entire life with only the barest contact with the British. Now that was about to change.

For some time now, many had advised Ramanujan that no one in India properly understood him, that he'd not be able to find there the expertise and encouragement he needed, that he should instead write to Cambridge, or elsewhere in the West, for help. One who did was Singaravelu Mudaliar, his old professor at Pachaiyappa's College, to whom he had drawn close during his brief time there. Another was Bhavaniswami Rao, one of Ramanujan's professors at Kumbakonam College. A third was his friend Narasimha, with whom he had lived in Park Town a couple of years before.

More recently, Narayana Iyer probably gave him similar advice. India was a quarter of the way around the globe from Europe, but the mail was cheap, reliable, and-long before airmail shrank the world surprisingly fast; people grumbled if letters to England took as long as two weeks. And so, in late 1912 and early 1913, it was to the international mails that Ramanujan turned. In letters drafted with the help of Narayana Iyer, Sir Francis Spring, and perhaps P. V. Seshu Iyer, he began to write leading mathematicians at Cambridge University, including with his letters samples of his work.

He wrote to H. F. Baker, who held a long string of high honors as a mathematician, including a fellowship of the Royal Society, and had been president of the London Mathematical Society until two years before. Could Baker offer him help or advice? Either through the kind of formulaic letter of polite discouragement that important men learn to write, or by returning his unsolicited material without comment, or by ignoring his letter altogether, Baker said no.

Ramanujan wrote to E. W. Hobson, an equally distinguished mathematician, also a Fellow of the Royal Society, and holder of Cambridge's Sadleirian chair in pure mathematics. Hobson, too, said no.

On January 16, 1913, Ramanujan wrote to still another Cambridge mathematician, G. H. Hardy, who at thirty-five, a generation younger than the other men, was already setting the mathematical world of England on its ear. Could Hardy help him? And Hardy said yes.

"No one who was in the mathematical circles in Cambridge at that time can forget the sensation" caused by [Ramanujan's] letter, wrote E. H. Neville years later. Hardy showed it to everyone, sent parts of it to experts in particular fields. (Midst all the excitement, Ramanujan's original cover letter, along with one page of formulas, got lost.) Meanwhile, Hardy had sprung into action, advising the India Office in London of his interest in Ramanujan and of his wish to bring him to Cambridge.

It was not until a windy Saturday, February eighth, the day following his birthday, that Hardy sat down to deliver to Ramanujan the verdict on his gifts that Cambridge already knew. "Trinity College, Cambridge," he wrote at the top, and the date, then began: "Dear Sir, I was exceedingly interested by your letter and by the theorems ... " With an opening like that, Ramanujan would, at least, have to read on.

But in the very next sentence, Hardy threw out his first caveat: "You will however understand that before I can judge properly of the value of what you have done, it is essential that I should see proofs of some of your assertions. "

Proof. It wasn't the first time the word had come up in Ramanujan's mathematical life. But it had never before borne such weight and eminence.

Carr's *Synopsis*, Ramanujan's model for presenting mathematical results, had set out no proofs, at least none more involved than a word or two in outline. That had been enough for Carr, and enough for Ramanujan.

Now, Hardy was saying, it was *not* enough. The mere assertion of a result, however true it might seem to be, did not suffice. And all through his letter to Ramanujan he would sound the same insistent theme.

On the whole, Hardy's letter was lavish with encouragement. True, some of Ramanujan's theorems were already well known, or were simple extensions of known theorems. But even these, Hardy allowed, represented an achievement. "I need not say that if what you say about your lack of training is to be taken literally, the fact that you should have rediscovered such interesting results is all to your credit."

Littlewood was also intrigued by Ramanujan's work, Hardy mentioned, even adding as a sort of appendix, "Further Notes Suggested by Mr. Littlewood." Most of these dealt with Ramanujan's work on prime numbers, a subject in which Littlewood had recently made a stunning, if not yet published, advance. So Hardy's message from Littlewood carried an especially fervent plea: "Please send *the formula* for the no. of primes & ..."-here it was again-"as much proof as possible quickly."

Hardy's whole letter was like that-shot through with urgency, with a barely contained excitement, that Ramanujan would have been dull indeed not to sense. At the bottom of page 6, Hardy wrote, "I hope very much that you will send me *as quickly as possible"-he* underlined it with a veritable slash across the page-"a few of your proofs, and follow this more at your leisure by a more detailed account of your work on primes and divergent series."

And he went on: "It seems to me quite likely that you have done a good deal of work worth publication; and if you can produce satisfactory demonstration, I should be very glad to do what I can to secure it."

Hardy's letter probably arrived late in the third week of February. But his endorsement of Ramanujan had reached Madras earlier. Almost a week before writing Ramanujan, Hardy had contacted the India Office and, by February 3, a certain Mr. Mallet had already written Arthur Davies, secretary to the Advisory Committee for Indian Students in Madras.

Later in the month, Davies met with Ramanujan and, at Sir Francis Spring's behest, Narayana Iyer, apprising him of Hardy's wish that Ramanujan come to Cambridge. But as Hardy soon learned, Ramanujan wasn't coming. Religious scruples, or a cultural resistance that verged on it, got in the way; Brahmins and other observant Hindus were enjoined not to cross the seas. And that, it seemed for a long time, was that.

Meanwhile, in Madras, the balance delicately poised since Ramanujan's meeting with Ramachandra Rao in late 1910, teetering inconclusively between success and failure, now came down firmly on Ramanujan's side. All that had been wanting was for a mathematician of unimpeachable credentials to weigh in with a verdict. Now Hardy had delivered it.

On February 25, Gilbert Walker was shown Ramanujan's work. Walker was a former Senior Wrangler, a former fellow and mathematical lecturer at Trinity, and was now, at the age of forty-five, head of the Indian Meteorological Department in Simla. Now, as Walker was passing through Madras, Sir Francis prevailed on him to look through Ramanujan's notebooks. The next day, Walker wrote Madras University, asking it to support Ramanujan as a research student. "The character of the work that I saw," he wrote the university registrar,

"impressed me as comparable in originality with that of a Mathematics fellow in a Cambridge College; it appears to lack, however, as might be expected in the circumstances, the completeness and precision necessary before the universal validity of the results could be accepted. I have not specialised in the branches of pure mathematics at which he has worked, and could not therefore form a reliable estimate of his abilities, which might be of an order to bring him a European reputation. But it was perfectly clear to me that the University would be justified in enabling S. Ramanujan for a few years at least to spend the whole of his time on mathematics without any anxiety as to his livelihood."

Spring, who had introduced Walker to Ramanujan's work, and everyone else at the Port Trust knew that Ramanujan had Hardy's imprimatur. If Walker harboured any doubt as to Ramanujan's merits, Hardy's verdict erased it.

The wheels of Ramanujan's career, for ten years barely creaking along, now, greased by Hardy's approval, began to whirr and whine like a finely tuned race car engine. If Ramanujan had doubts about what Hardy's endorsement might mean to him, they had been dispelled by the last two days and Walker's ringing endorsement. On February twenty-seventh, he wrote Hardy a second letter, again packed with theorems. "I am very much gratified on perusing your letter of 8th February 1913," he wrote. "I have found a friend in you who views my labours sympathetically."

In fact, it was not just Walker, Spring, and others in the Madras mathematical community who had been fortified by Hardy's letter. It was Ramanujan himself. For all his confidence in his mathematical prowess, Ramanujan needed outside approval, affirmation. Now he had it.

Hardy's letter *took him seriously*. And the pronouncement delivered by this unseen F.R.S., this man reputed to be the finest pure mathematician in England? It was no vague, empty one filled with glowing accolades that Ramanujan might, in an anxious moment, dismiss, but rather nine pages of specific, richly detailed comment: a statement Ramanujan had written on his sixth page of theorems about a series expressible in terms of pi and the Eulerian constant could be deduced from a theorem in Bromwich's *Infinite Series* (the book M. J. M. Hill, in his letter of two months before, had advised that he consult). A theorem on the same page involving hyperbolic cosines Hardy himself had proved in *Quarterly Journal of Mathematics*. Hardy *knew*.

On March 13, spurred by Walker's letter, B. Hanumantha Rao, professor of mathematics at the engineering college, invited Narayana Iyer to a meeting of the Board of Studies in Mathematics to discuss "what we can do for S. Ramanujan.... You have seen some of his results & can help us to understand them better than the author himself." On the nineteenth, the board met and recommended to the syndicate, the university's governing body, that Ramanujan receive a research scholarship of seventy-five rupees a month-more than twice his Port Trust salary for the next two years.

But when the syndicate met on April 7, Ramanujan's case encountered a setback. Such scholarships were reserved for those with master's degrees, and Ramanujan lacked even a bachelor's; why, he'd flunked out of every college he'd ever attended. By one Indian account, it was the English-led by Richard Littlehailes, an Oxford-educated professor of mathematics at Presidency College and later portrayed as one of Ramanujan's champions-who invoked this technicality and, "with all their vehement speeches," lined up against him. In any case, the syndicate's vice-chancellor, P. R. Sundaram Iyer, chief justice of the Madras High Court, then rose. Did not the preamble of the act establishing the university, he asked, specify that one of

its functions was to *promote research?* And, whatever the lapses of Ramanujan's education, was he not a proven quantity as a mathematical researcher?

That argument won the day. "The regulations of the University do not at present provide for such a special scholarship," the registrar later wrote. "But the Syndicate assumes that Section XV of the Act of Incorporation and Section 3 of the Indian Universities Act, 1904, allow of the grant of such a scholarship, subject to the express consent of the Governor of Fort St. George in Council."

By April 12, Ramanujan had learned the good news. The scholarship set him free to do mathematics, to attend lectures at the university, to use its library. So that now, as Neville would write, he "entered the Presidency College in Madras to practice as a virtue that single minded devotion to mathematics which had been a vice in Kumbakonam nine years earlier."

Ramanujan the special research student, Ramanujan the friend of Cambridge was now a hot topic in Madrasi circles, and people were forever trooping through his house, as if to do him homage. In August, his name came up at a get-together of professors and their students; everyone marvelled how Ramanujan had garnered such intellectual standing "without," as one there that evening put it, "the help of books or teachers."

In September, Narayana Iyer submitted some theorems on the summation of series to the *Journal of the Indian Mathematical Society*, at one point adding: "The following theorem is due to Mr. S. Ramanujan, the Mathematics Research Student of the Madras University."

On October 26, perhaps out to win over one who had before campaigned against Ramanujan's scholarship, Narayana Iyer took Ramanujan to see Richard Littlehailes, professor of mathematics at Presidency College and soon to become Madras's director of public instruction. Ramanujan was never good at explaining his own methods, so Narayana Iyer did the talking. Littlehailes assured them that, after the first of December, he looked forward to studying Ramanujan's results.

In November, the mathematician E. B. Ross of Madras Christian College, whom Ramanujan had met a few years before, stormed into class, his eyes glowing. "Does Ramanujan know Polish?!?" he asked his students. Ramanujan didn't, of course. Yet his most recent quarterly report had anticipated the work of a Polish mathematician whose paper had just arrived by the day's mail.

As a research scholarship holder, Ramanujan's only obligation was to prepare reports every three months detailing his progress. He delivered three of them in late 1913 and early 1914, all dutifully on time. Like much of his work, the theorems he described had their roots in his notebooks; some went back to notes appearing around page 180 of his first notebook, some to chapters 3 and 4 of the second. Most of them dealt, with evaluating definite integrals.



"At present," he wrote in his first report, addressed to the Board of Studies in Mathematics and dated August 5, 1913, "there are many definite integrals the values of which we know to be finite but still not possible of evaluation by the present known methods." The theorem he offered-it would later be called "Ramanujan's Master Theorem"- would provide means of evaluating many of them. "This paper," his cover letter noted, "may be considered the first installment of the results I have got out of the theorem." More, he promised, were coming soon as indeed they were in the second and third reports.

Finally, though, in early January, Ramanujan found a long letter from Hardy, responding to a proof he had earlier supplied, pointing out its flaws, and showing how they had led him astray. "You will see that, with all these gaps in the proof, it is no wonder that the result is wrong." But, Hardy went on, walking on eggs, "I hope you will not be discouraged by my criticisms. I think your argument a very remarkable and ingenious one. To have proved what you claimed to have proved would have been about the most remarkable mathematical feat in the whole history of mathematics." And oh yes, there was one more thing. "Try," he added almost carelessly," to make the acquaintance of Mr. E. H. Neville, who is now in Madras lecturing. He comes from my college and you might find his advice as to reading and study invaluable."

This was not exactly a lie, but it wasn't the whole truth either. Hardy had more in mind than getting Ramanujan the right books to read. He had made Neville the instrument of his plan. He had deputized him to bring Ramanujan to England.

Around New Year's Day in 1914, Hardy's man, Eric Harold Neville, arrived in Madras. He had, of course, one additional charge-to convince Ramanujan to come to England.

After one of the first lectures, Ramanujan was introduced to him. This was not "the uncouth, unshaven, unclean figure of Ramachandra Rao's picture," Neville would write later, "but a man at once diffident and eager." As for his English, once so poor it had undermined his school career, "ten years had worked wonders, for a more fluent speaker or one with a wider and better used vocabulary I have seldom met."

At least three times they sat down together with Ramanujan's notebook. Neville was stunnedso much so that when, after their third meeting, Ramanujan asked him whether he might like to take the notebook away to peruse at his leisure, it struck him as "the most astounding compliment ever paid to me. The priceless volume had never before [so Neville assumed] been out of his hands: no Indian could understand it, no Englishman could be trusted with it."

And so now he struck, acting on Hardy's charge to him: would Ramanujan come to Cambridge? Anticipating a negative response, Neville silently marshaled his arguments. Yet now, unaccountably, he didn't need them. "To my delight and surprise," he wrote later, he learned" that Ramanujan needed no converting and that his parents' opposition had been withdrawn."

What miracle had wrought this transformation? By one account it was K. Narasimha Iyengar, a family friend with whom Ramanujan had stayed in Madras early in 1911 and with whom he had remained in touch since, who helped get Ramanujan's mother, certainly a key obstacle, to

acquiesce to the trip. Seshu Iyer also exerted pressure on her, Ramaswami Iyer and Ramachandra Rao on Ramanujan." I lent all the weight of my influence to induce him to go," recalled Ramachandra Rao later. So did M. T. Narayana Iyengar, the Bangalore mathematician and editor of the *Journal of the Indian Mathematical Society* who had worked closely with Ramanujan three years before to get his first paper ready for publication; scrupulously orthodox himself, his arguments carried added weight. But if these influences may be said to have ultimately triumphed, they did not by themselves change Ramanujan's mind. Something more was needed-something, at least for public consumption, beyond his mother's merely human will, or Ramanujan's. Neville learned what it was: "In a vivid dream his mother had seen [Ramanujan] surrounded by Europeans and heard the goddess Namagiri commanding her to stand no longer between her son and the fulfillment of his life's purpose." Details differ, but this and other versions of the story agree in substance-that permission for Ramanujan to go came personally through the intervention of the goddess Namagiri, residing in her shrine at Namakkal.

The key obstacle removed, Neville set about addressing Ramanujan's other doubts. Money to get to England and live there? Don't worry, Neville assured him, that would be taken care of His English was not very good? It was, Neville said, good enough. His vegetarianism? That would be respected. And examinations? Having flunked virtually everyone he'd ever taken in college, he was pained at the prospect of taking anymore-yet knew that doing so was the inevitable lot of Indian students in Europe. No, Neville reassured him, *he* would not have to take any.

Next, Neville wrote Hardy to say that it was now time to address the financial obstacles to Ramanujan's visit to England. He, Neville, would try to find money in Madras. But should he fail, as he later paraphrased his letter, "the money must somehow be found in England.... Financial difficulties must not be allowed to interfere."

Hardy apparently forwarded Neville's pronouncement to the India Office, because he soon received from C. Mallet, secretary for Indian students (who a year before had relayed word of Ramanujan's refusal to go to England), a worried reply. "Mr. Neville's letter rather alarmed me, because it seemed to me that he was encouraging Ramanujan to come to England without any real prospect of providing for him when he got here." Too often, he had found, Indian students arrived without enough money, only to meet with "disappointment and misery."

In the bluntest terms, Mallet advised Hardy that "no money for this purpose can be got from the India Office." Furthermore, he doubted whether Trinity or Cambridge would come up with any, and he didn't think Madras could either. He was not sanguine. And he infected Hardy with his pessimism. "I'm writing in a hurry to catch the mail," Hardy wrote Neville, a bit frantically, "and warn you to be a little careful"; the money *had* to be there, else Ramanujan couldn't come. He and Littlewood might together contribute fifty pounds a year for the contemplated two years of Ramanujan's visit-"Don't tell [Ramanujan] so"-but that came to only about a fifth of Ramanujan's needs.

In any case, by the time he'd heard from Hardy, Neville already had money matters well in hand. Littlehailes had introduced him to people influential in the university or government, and everywhere he talked up Ramanujan. "The discovery of the genius of S. Ramanujan of

Madras," he'd written Francis Dewsbury, registrar of the university, on January 28,"promises to be the most interesting event of our time in the mathematical world." It was a thoughtful, rather grandly stated letter, all aimed at precisely One end-funding Ramanujan's stay in England. "I see no reason to doubt," it concluded,

that Ramanujan himself will respond fully to the stimulus which contact with Western mathematicians of the highest class will afford him. In that case, his name will become one of the greatest in the history of mathematics, and the University and City of Madras will be proud to have assisted in his passage from obscurity to fame.

Next day, Littlehailes himself took up the attack, formally asking Dewsbury for a 250-poundper-year scholarship, coupled with a 100-poundgrant to equip Ramanujan with Western clothes and book passage to England. "Ramanujan," he wrote, "is a man of most remarkable mathematical ability, amounting I might say to genius, whose light is metaphorically hidden under a bushel in Madras."

The following week Lord Pentland himself, governor of Madras, became the target of this bombardment of Madras officialdom on Ramanujan's behalf. Sir Francis wrote Pentland's private secretary, C. B. Cotterell:

I am anxious to interest him in a matter which I presume will come before him within the next few days-a matter which under the circumstances is, I believe, very urgent. It relates to the affairs of a clerk of my office named S. Ramanujan, who, as I think His Excellency has already heard from me, is pronounced by very high mathematical authorities to be a Mathematician of a new and high, if not transcendental, order of genius.

Spring had just learned that the university was prepared to set aside ten thousand rupees, equivalent to more than six hundred pounds, or enough for two years in England. But the decision hinged on higher approval. And here, he said, "His Excellency may perhaps be able to interfere with advantage."

He had already gone to bat for Ramanujan once when, the year before, he had consented to his special research scholarship. Now he was ready to "interfere with advantage" again. "His Excellency cordially sympathizes with your desire that the University should provide Ramanujan with the means of continuing his researches at Cambridge," his secretary wrote back to Spring, "and will be glad to do what he can to assist."

The scholarship was approved. The last roadblock was gone. Ramanujan was going to England.

On February 26, Binny & Co. sent Ramanujan his second-class ticket.

On March 11, Sir Francis wrote the steamer agents to make sure he got vegetarian food enroute.

On March 14, Ramanujan accompanied his wife and mother to Madras's Egmore Station. Ten years before, he had arrived here to begin his studies at Pachaiyappa's College. Now, he

wept: he was dispatching his family to Kumbakonam, so they would not have to witness his painful transformation into a European gentleman.

His friends coached him in Western ways. Still taking a proprietary interest in his young protege, Ramachandra Rao decreed that his *kutumi*, the long bunched-up knot of hair at the back of his head, had to go. And it was done. Further, Ramanujan must wear Western clothes. Soon Richard Littlehailes was driving him around town on his motorcycle, Ramanujan in the sidecar, shopping for collars and ties and stockings and shoes and shirts.

For a few days Ramanujan stayed in the country, at the house of a friend of Ramachandra Rao's who lived European-style, learning how to use knife and fork-though "under the strict stipulation," as his patron observed, "that nothing but vegetable food should be served." But even this tentative step into alien ways left Ramanujan unhappy. "He did not relish food being served by strange servants."

The morning of its departure, an official send-off was held in Ramanujan's honor, organized by Srinivasa Iyengar, the advocate general. On hand were Professor Middlemast and Sir Francis Spring, prominent judges, and Kasturirangar Iyengar, publisher of the *Hindu*. So was Narayana Iyer who had worked so closely with Ramanujan, the incessant clicking and scraping on their slates keeping people in his house up all night. "My father made a strange request to him," his son N. Subbanarayanan would record many years later. "As a memento my father wanted to exchange his slate with Ramanujan's slate, [a request that] was granted. Perhaps my father thought that he may get an inspiration from the slate during [Ramanujan's] absence."

Finally, there was nothing left to do. Ramanujan was on board, his well-wishers left behind. At about ten o'clock on the morning of March 17, 1914, the *Nevasa* slipped slowly away from the dock. The *Nevasa* docked first at Plymouth, then steamed up the English Channel and arrived at the mouth of the Thames on April 14. It was a bright, lovely day, a little warmer than usual, without so much as a trace



of overcast-more of the run of fine weather that, on Easter Sunday, two days before, had brought Londoners out to the parks and streets of the city by the hundreds of thousands. Now, waiting for Ramanujan at the dock was Neville and his older brother, who had arrived there by car. They drove to 21 Cromwell Road, in the South Kensington district of London, a reception center for Indian students just arrived in England. The National India Association had offices there. Several rooms in the stately Georgian styled corner building were available to students passing through. But unlike most Indians in England, Ramanujan had by his side, in Neville, a Cambridge don to help smooth the way. He also met A. S. Ramalingam, a twenty-three-year-old engineer from Cuddalore, south of Madras, who had been in England for four years and who also tried to help him feel at home.

In any case, Ramanujan survived whatever rigors Cromwell Road could inflict and on April 18 went with Neville to Cambridge. Soon he was settled in Neville's house on Chestertown Road, in a little suburb of Cambridge just across the River Cam from the town itself. Neville and his new wife, Alice, had moved in the year before and now, for two months in the spring of 1914, it was Ramanujan's introduction to the English home.

There was, of course, business to attend to-fees to pay, paperwork to work through. Hardy and Neville took care of most of it. A printed list of first-year students, prepared after Michaelmas Term (pronounced *Mih*kel-miss, and starting in mid-October) of the previous year, listed each student alphabetically. Now, squeezing it in between Pugh, F. H. and Rawlins, J. D., someone dipped his pen in black ink and wrote in Ramanujan's name by hand.

Meanwhile, Ramanujan had already set to work with Hardy and Littlewood; Littlewood, for one, saw him about once a week, Hardy much more often. Ramanujan was productive, working hard, happy. "Mr. Hardy, Mr. Neville and others here are very unassuming, kind and obliging," he wrote home in June.

Ramanujan had not come to Cambridge to go to school. But arriving in time for the Easter term, which began in late April, he did attend a few lectures. Some were Hardy's. Others, on elliptic integrals, were given by Arthur Berry, a King's College mathematician in his early fifties. One morning early in the term, Berry stood at the blackboard working out some formulas and at one point looked over to Ramanujan, whose face fairly glowed with excitement. Was he, Berry inquired, following the lecture? Ramanujan nodded. Did he care to add anything? At that, Ramanujan stood, went to the blackboard, took the chalk, and wrote down results Berry had not yet proved and which, Berry concluded later, he could not have known before.

Soon the word was getting out about Ramanujan. W. N. Bailey, then an undergraduate, heard "strange rumors that he had been unable to pass examinations, and that he had run away from such terrors. But apart from these rumors we only knew that his name was Ramanujan, and even this was pronounced wrongly,". People didn't often see him; he was usually busy in his rooms. But when they did, they noticed him-remembered his squat, solitary figure as, in the words of one, he "waddled" across Trinity's Great Court, his feet in slippers, unable yet to wear Western shoes.

In early June, after about six weeks on Chestertown Road, Ramanujan moved into rooms on Staircase P in Whewell's Court. It would be "inconvenient for the professors and myself if I stay outside the college," he wrote to a friend.

In Whewell's Court, only about five minutes from Hardy's rooms, Ramanujan could look out his window across to where Hardy had lived as an undergraduate twenty years before. But Ramanujan had more than twenty years' worth of mathematical catching up to do. His education had ended, in a sense, when George Shoobridge Carr put the finishing touches on his *Synopsis* in 1886. And Carr's mathematics was old when it was new, mostly barren of anything developed past about 1850.

Ramanujan, then, had much to learn. But, then again, so did Hardy.

ADDITIONAL MATERIAL FOR SENIORS

Together now in Cambridge, there was no longer the need for those long, awkward letters, across a gulf of culture and geography, with all their chance for misunderstanding. Now, as he would for the next few years, Ramanujan saw Hardy nearly every day and could show him the method he had developed in India that he'd been loath to describe by international post. Meanwhile, Hardy had the notebooks themselves before him and, with their author by his side, could study them as much as he wished.



Many of the 120 theorems Ramanujan had sent him in those first two letters, Hardy could see now, had been plucked intact from the notebooks. Here, in chapter 5, section 30 of the second notebook, was what Ramanujan had written in the first letter about a class of numbers built up from "an odd number of dissimilar prime divisors." From chapter 5 also came much of the work going into Ramanujan's first published paper on Bernoulli numbers. In chapter 6 was that bizarre stuff from the first letter about divergent series that, Ramanujan had feared, might persuade Hardy he was destined for the lunatic asylum- the one where 1+2+3+4+ ...unaccountably added up to - 1/12. On its face, that was ridiculous; yet it sought to give meaning to divergent series-which at first glance added up to nothing more revealing or precise than infinity. But now Hardy found something like Ramanujan's reasoning behind it, which involved a "constant" that, as Ramanujan wrote, "is like the center of gravity of a body"-a concept borrowed from, of all places, elementary physics.

A few of Ramanujan's results were, Hardy could see, wrong. Some were not as profound as Ramanujan liked to think. Some were independent rediscoveries of what Western mathematicians had found fifty years before, or a hundred, or two. But many-perhaps a third, Hardy would reckon, perhaps two-thirds, later mathematicians would estimate—were breathtakingly new.

The notebooks would frustrate whole generations of mathematicians, who were forever underestimating the sheer density of mathematical riches they contained. In 1921, after having for seven years been exposed to them, Hardy would note that "a mass of unpublished material" still awaited analysis. Two years later, having devoted a paper to Ramanujan's work in chapters 12 and 13 of his first notebook, on hypergeometric series, he had to report that those were, in fact, "the only two chapters which, up to the present, I have been able to subject to a really searching analysis."

Plainly, then, in the months after Ramanujan arrived in England, Hardy and Littlewood could hardly have more than skimmed the surface of the notebooks, dipping into them at points, lingering over particularly intriguing results, trying to prove this one or simply understand that one.

But this first glance was enough to reinforce the impression left by the letters. After the second letter, Littlewood had written Hardy, "I can believe that he's at least a Jacobi." Hardy was to weigh in with a tribute more lavish yet. "It was his insight into algebraical formulae,

transformation of infinite series, and so forth, that was most amazing," he would write. In these areas, "I have never met his equal, and I can compare him only with Euler or Jacobi."

The following year, 1915, would see a flood of papers published by Ramanujan. But 1914, the year of his arrival in England, saw only one. Comprising mostly Indian work, it appeared in the *Quarterly Journal of Mathematics* under the title "Modular Equations and Approximations to pi."

Ramanujan's paper was "of the greatest interest and contains a large number of new results." If nothing else, it was astounding how *rapidly* some of his series converged to pi. Some of Ramanujan's series, on the other hand, converged with astonishing rapidity. In one, the very first term gave pi to eight decimal places. Many years later, Ramanujan's work would provide the basis for the fastest-known algorithm, or step-by-step method, for determining pi by computer.

Since his arrival in England, he'd been writing home regularly-at first, three or four times a month, and even now, during 1915, twice a month or so, regularly assuring his family that he maintained his vegetarianism and his religious practices. His letters to friends back in India scarcely mentioned the war, but rather told of his work and his progress, inquired after family members, even occasionally gave advice. To his two brothers back in India, he sent a parcel full of books of English literature.

For a while after he came to Cambridge, apparently, Ramanujan's shyness was read as unfriendliness, and students sometimes taunted him. But by now he was a more popular, even legendary figure, his room accorded the status of a shrine. "It was a thrill to me to discover on reaching Cambridge in July 1915 that I was going to be a contemporary of Ramanujan," recalled C. D. Deshmukh, until then a student at a college in Bombay. "Ramanujan's current achievements were common talk amongst us Indian students." Ananda Rao remembered Ramanujan at tea parties and other social gatherings, mixing freely among both English and Indians. Mahalanobis, with whom he took Sunday morning strolls, recalled him as reserved in large groups, expansive in small ones.

In any case, he was the toast of the Indian *students-the* mathematical genius, the man whom the English had moved heaven and earth to bring to Cambridge.

At Cambridge, every student had a tutor who looked after him and monitored his progress. Ramanujan's was E. W. Barnes, who would call Ramanujan perhaps the most brilliant of all the top Trinity students (which included Littlewood) to have come before him. Though later to become a bishop in the Anglican church, Barnes was now a mathematician of some standing; he had been one of Andrew Forsyth's earliest disciples, had with Hardy been among the leading advocates of Tripos reform, and had made substantial mathematical discoveries of his own.

Now, in November 1915, he wrote Francis Dewsbury, registrar of the University of Madras, of Ramanujan's progress, which he termed "excellent. He is entirely justifying the hopes entertained when he came here." His two-year scholarship, soon coming to an end, ought to be "extended until, as I confidently expect, he is elected to a Fellowship at the College. Such

an election I should expect in October1917." Ramanujan, he was saying, was in line to become a Fellow of Trinity.

In Madras, Sir Francis Spring joined the chorus, specifically requesting a two-year extension of Ramanujan's scholarship. Through the late fall and early winter of 1915-1916, Madras authorities debated whether the scholarship should be extended for one year or two. If just one, Spring wrote Dewsbury, Ramanujan was inclined not to return to India during the summer of 1916 as planned; for should his scholarship end in the spring of 1917, he'd be back in India just nine months later anyway.



The university held, however, that, if the Trinity fellowship went through, its own scholarship would overlap. So one year, with the possibility of further extensions, it was.

Ramanujan had no official college duties. He could do as he pleased. He could immerse himself in mathematics without fretting over financial want, either his own or his family's. Yet something still nagged at him. His lack of a degree, the tangible public marker of academic achievement. In his case, it was the merest formality. But he *wanted* it.

Admission as a research student normally meant you already held a university diploma or certificate. But in his case, the requirement had been waived. And now, in March 1916, he received a B.A. "by research," on the basis of his long paper on <u>highly composite number's</u>. He'd put up his five pounds dissertation fee. He'd paid two pounds each to his examiners.

And now, a dozen years and two college failures after leaving Town High School, he had his degree.

Back in India, Ramanujan had probably never cooked in his life, had conceivably never even stepped into a kitchen. But here, with neither wife nor mother to serve him and unwilling to trust to the vegetarian purity of the college kitchen, he'd had to learn. Sometimes, on Sundays, he had Indian friends over for *rasam*, a thin peppery soup, or other South Indian fare. "Delicious," a friend later recalled. And once, S. Kasturirangar Iyengar, owner and editor of South India's preeminent English-language newspaper, the *Hindu*, visited him in Cambridge and lavished praise on the *pongal*, a lentil and rice dish, that Ramanujan served him.

Ramanujan was a vegetarian unusually strict in his orthodoxy-if not for South Indians generally then at least for those in England. In crossing the seas he had defied Brahminical strictures. He had forsaken his tuft. He mostly wore shoes and Western clothes. But as he had promised his mother, he clung fiercely to the proscriptions most central to Brahminic life, on food.

Ramanujan was not the kind of chameleon like figure who does well at the tough job of reshaping himself to fit a foreign culture; he was not flexible enough, could not sink down effortlessly into his new English life. Nor could he long be immune to that succession of subtle, slight rebuffs the ordinary Englishmen dispensed, with scarcely a thought, every day.

He would have needed to experience few incidents of aloofness and reserve to damp his sunny openness and send him running back to the cozy den of his mathematical research.

Mathematician Norbert Wiener would one day note how, in one sense, number theory blurs the border between pure and applied mathematics. In search of concrete applications of pure math, one normally turns to physics, say, or thermodynamics, or chemistry. But the number theorist has a multitude of real-life problems before him always-in the number system itself, a bottomless reservoir of raw data. It is in number theory, wrote Wiener, where "concrete cases arise with the greatest frequency and where very precise problems which are easy to formulate may demand the mathematician's greatest power and skill to resolve."

In 1916, one such problem lay in the area of number theory known as "partitions." More generally p(n), read "p of n," represents the number of partitions of any number, n, and is known as the partition function.

Ramanujan, along with Hardy, suggested a solution which was not exact but close to it. In any case, their partitions solution was big news, the circle method they'd used to come up with it a stunning success. In late 1916, Hardy dashed off an early account, under his own name but offered "as the joint work of the distinguished Indian mathematician, Mr. S. Ramanujan, and myself," to the *Quatrieme Congres des Mathimaticiens Scandinaves* in Stockholm.

Early the following year, a brief joint paper appeared in *Comptes Rendus*, as "Une Formule Asymptotique Pour le Nombre Des Partitions De *n*." And a one-paragraph reference to the French journal article appeared in *Proceedings of the London Mathematical Society* in March. The forty-page paper setting out their work in full detail didn't appear until 1918.

Ramanujan and Hardy: as a mathematical team, they would remind Pennsylvania State University mathematician George Andrews of the story of the two men, one blind and the other lacking legs, who together could do what no normal man could. They were a formidable pair. On the strength of their work on partitions alone, which by itself justified Ramanujan's trip to England, their names would be linked forever in the history of mathematics.

For Ramanujan, it was all deliciously addictive. A decade before, his discovery of Carr had left him so single-mindedly devoted to mathematics that he no longer could function as an ordinary college student. Now, something like that was at work again, only worse. For now, it was not only his own delight in mathematics that spurred him on, but the encouragement he got from Hardy. Hardy, this embodiment of all that was highest and best in the Western mathematical tradition, with his immense technical prowess and rich knowledge of the whole mathematical world of England and the Continent, was all Ramanujan could want in a colleague and mentor. And that *he* saw such breath taking originality in him could do nothing to restrain Ramanujan's eagerness to get on with their work.

His marriage in 1909 had induced Ramanujan to stitch himself back into the wider social world. Now, in England, the threads of connection were once again severed. By early 1917, he was a man on a mission, propelled toward his destiny, oblivious to all but mathematics.

After three years in Cambridge, his life was Hardy, the four walls of his room, and work. For thirty hours at a stretch he'd sometimes work, then sleep for twenty. Regularity, balance, and rest disappeared from his life.

In Hardy, Ramanujan had the intellectual companionship he'd long missed. In Cambridge, with its stately stone chapels and quiet courts and great libraries, he had before him all the riches of Western civilization. Yet now he went without much else that had sustained him, perhaps without his realizing it, in India. He went without family. Without dark, familiar faces and open, sunny Indian smiles. Without the sound of friendly Tamil. Now those hidden props to identity and self-esteem, so easy to take for granted or dismiss, had been pulled out from under him. Now there was no one even to prepare meals for him. No one, as Janaki and his mother had done, to place food into his hand as he worked. No one to remind him to sleep. No one to cool his fevered brain with a touch. No one to counsel moderation, to urge him, as it were, to come in out of the rain. Ramanujan was like a balky thoroughbred with no one to groom or feed it. And by early 1917, there had been no one since the day he'd stepped aboard the *Nevasa* three years before.

Intellectually, he had come home. But Ramanujan was more than a mind; he was a body, a complex of muscle and tissue, hormones and neurochemicals. And his body had needs that his mind scarcely knew.

A generation before, in 1890, a small book aimed at Indian students, entitled *Four Years in an English University*, was published in Madras. Its author was S. Satthianadhan, a professor of logic and moral philosophy at Presidency College in Madras. Apparently based on Satthianadhan's experiences as a student at Corpus Christi College, Cambridge, the book purported to tell Indian students what life at Cambridge was *really* like, and what Indians could learn from it. And one point it conveyed with all the force of fresh revelation was the English emphasis on sports and recreation.

Ramanujan, it need hardly be stated, did not. He had no interest in sports; if Hardy tried to interest him in cricket it didn't take. He had always been fat, largely oblivious to his body, almost pathologically sedentary. Still, he was not yet Satthianadhan's vision of the typical Indian student: "A study-worn, consumptive-looking individual, without any energy, appearing twice as old as he really is, fit rather to be an inmate of the hospital than a frequenter of the lecture room."

Indians come to study in England, of course, could not escape the alien and hostile climate and so, it was believed, risked their health. The director of the University of Edinburgh's Indian Student Hostel told the committee that the health of Indian students there was generally good, "except perhaps," he said, "in the case of those coming from the southern parts of India who suffered rather from the severity of the climate and were inclined to develop tuberculosis and disease of the chest." The president of the Royal College of Physicians in Edinburgh commented that among Indian students tuberculosis was common, it being aggravated by the climate and, in the words of the report, "the fact that the more religious of the Indian students insisted on keeping to the diet of their cult-a regime unsuited to the conditions under which they found themselves. " Ramanujan did indeed keep to the diet of his "cult". Ramanujan's strict vegetarianism had cost him, in High Table, a social outlet that might have helped keep him on a more even keel. Now, during wartime, it risked his health, too.

By 1916 the war had reached Ramanujan. The food shortages coupled with his irregular eating habits could hardly have fortified him against any diseases to which isolation, overwork, and climate may have predisposed him. In his third year in England, he embodied the distinction some physicians today make between being well and merely not being sick. He was an illness waiting to happen.

W. C. Wingfield, medical superintendent of one famous English sanatorium, would observe that the disease with which he was most familiar, tuberculosis, was brought on, or aggravated, by *faulty modes of life*, which he defined as "overwork, overplay, overworry, undernourishment, lack of necessary sunshine and fresh air, or chronic intemperance in any form." Except, perhaps, for "overplay," Ramanujan was guilty of all of them.

Both during his life and afterward, it was a matter of some mystery just what laid Ramanujan low. But *something*, in the spring of 1917, did. In May, Hardy wrote the University of Madras with news that Ramanujan was sick-afflicted with, it was thought, some incurable disease.

Was this the time to send him back to India? The idea was broached. But many Indian physicians were on war duty; getting him adequate medical care, it was thought, might be impossible. Then, too, he might never reach Indian soil; the U-boats made ocean travel perilous. The war had denied Ramanujan access to mathematicians with whom he had been brought to England to work. It had undermined his nutrition, perhaps priming him for disease. Now, sick, it helped keep him in England.

It was an anxious time. He was admitted to a "nursing home" actually a small private hospital catering to Trinity patients-on Thompson's Lane, overlooking the Cam across from Magdalene College, and within a stone's throw of the Neville house. He was very ill. The prognosis was so poor that Hardy asked the master of Trinity for help in getting word to Ramachandra Rao in India by special dispatch. Later, when Ramanujan seemed a little better, he asked Subramanian to contact Ramachandra Rao and allay any fears the earlier report had raised.

By that time, Ramanujan was out of the hospital, perhaps back in Bishop's Hostel. There is some evidence that Hardy himself nursed him for a while. But whoever did, it couldn't have been easy. Because Hardy's letter to Subramanian already bore the stamp of what was to complicate all efforts to restore Ramanujan's health: "It is very difficult to get him to take proper care of himself," Hardy wrote. Ramanujan, he was saying, was a terrible patient.

Ramanujan's stubbornness, along with the uncertainty surrounding his diagnosis, led him to see at least eight doctors and enter at least five English hospitals and sanatoriums over the next two years. Probably around October, he became a patient at the Mendip Hills Sanatorium at Hill Grove, near the city of Wells, in Somerset. There he came under the care

of Dr. Chowry-Muthu, an Indian doctor who, as it happens, had accompanied Ramanujan on the *Nevasa* three years before. Dr. Muthu was a tuberculosis specialist.

The earliest diagnosis of Ramanujan's ailment was a gastric ulcer, support for which waxed and waned all through his treatment; at one time, exploratory surgery was considered.

Blood poisoning was another possibility; an idea heard later was that, perhaps overly impressed with their presumed sterility, Ramanujan would eat canned vegetables whose labels gave assurance of their purely vegetarian origin. Bypassing proper pots and pans, the theory went, Ramanujan would cook them right in the cans, over the gas flame in his room, perhaps contracting lead poisoning from the soldered lids.

It was tuberculosis, though, for which Ramanujan was treated at Mendip Hills and for which he would most consistently be treated in the coming years, and tuberculosis-consumption, phthisis, the White Plague-which remains the most likely candidate today.

To get tuberculosis you must, in the first place, be infected with the tubercle bacillus. But many people, probably most, in India as well as in England, got infected, yet never came down sick; their immune systems successfully warded off the attack. Heredity clearly played a role in who got sick. But so, too, almost certainly, did what today might be called "lifestyle" factors. While consensus on their influence eludes the research community, the evidence gives strong credence to Dr. Wingfield's impression that "overwork, overplay, overworry, undernourishment [and] lack of necessary sunshine and fresh air" help transform otherwise failed bacterial attacks into successful ones.

Could Ramanujan's vegetarianism, made harder to nutritionally maintain by chaotic eating habits and food shortages, have set him up for the disease?

What was the crucial missing nutrient that meat or dairy products supplied? Quite possibly vitamin D-a deficiency of which may have left Ramanujan, among thousands of others, more vulnerable to the tubercle bacillus.

There is another prime source of vitamin D, one that explains why Indians back in India, for example, unlike those in Britain, have normal levels of the vitamin: the sun. The sun gives off not just visible light but ultraviolet radiation, and ultraviolet rays activate cholesterol in the skin to make vitamin D.

Ramanujan got little sun. In Cambridge, high up near the Arctic Circle, there wasn't much to begin with. And the English cloud cover blocked most of the rest. Then, too, Ramanujan didn't leave his rooms much, often working at night and sleeping by day. Even working by a sunny window would have done no good: ordinary window glass absorbs the ultraviolet rays that make vitamin D.

Both the common medical wisdom of his own day and scientific evidence from our own suggest that Ramanujan, during his first three years in England, had become fertile ground indeed for the growth of *M. tuberculosis*.

But there were other reasons why Ramanujan was-and had been, and would be-unhappy during the period of his Care.

In September 1917, Hardy had written Subramanian of Ramanujan's seemingly improved prospects. In his letter, he'd noted that "it was only a few months ago-when he was for a time in a Nursing Hospital here that we discovered that he was not writing to his people nor, apparently, hearing from them. He was very reserved about it, and it appeared to us that there must have been some quarrel."

A little later, another hint: writing Hardy from Matlock, Ramanujan seems to be acquainting him for the first time with some of the most rudimentary facts of his personal life: It is true that I promised my mother that I was going home at the end of 2 years; I wrote them several letters 1 ¹/₂ years ago that I was coming over there for the long vacation; but I had many letters of protest from my mother to the effect that I ought not to come to India till I took my M.A. degree. So I gave up the idea of going there. It is not true that I am getting letters from my wife or brother-in-law or anybody. I had only a few formal letters from my wife just explaining to me why she had to leave my home....The initial S. in my name stands for Srinivasa which is my father's name. I haven't got a surname, really speaking.

Sometime in early 1917 something had gone badly wrong with Ramanujan's body; he had come down sick. But by the end of the year, it was not only his body that was troubled, but his mind. By then, certainly, he was not a happy man. Happy men do not try to kill themselves.

Hardy and Ramanujan, who saw the world through such very dissimilar eyes, had far more to overcome. Hardy had lowered about himself a lovely, lacy veil of personal defenses that was even more formidable than that of the ordinary Englishman's. An Indian admirer of Hardy would remark on his "parental solicitude" toward Ramanujan. It was an apt choice of words; their relationship was marked by distance, not comradely intimacy. Ten years older than he, Hardy remained always the parent, a kind and obliging parent, perhaps, but forbidding, demanding, and remote, too.

The ultimate barrier to their relationship, of course, was, as Hardy would write, that "Ramanujan was an Indian, and I suppose that it is always a little difficult for an Englishman and an Indian to understand one another properly."

Even so safely neutral a matter as Ramanujan's mathematical influences in India never profited from Hardy's questioning. "Here I must admit that I am to blame," Hardy would write, "since there is a good deal which we should like to know now and which I could have discovered quite easily. I saw Ramanujan almost every day, and could have cleared up most of the obscurity by a little cross-examination." But he never did, never stepped past the mathematics of the moment, "hardly asked him a single question of this kind

I am sorry about this now, but it does not really matter very much, and it was entirely natural. [Ramanujan] was a mathematician anxious to get on with the job. And after all I too was a mathematician, and a mathematician meeting Ramanujan had more interesting things to think about than historical research. It seemed ridiculous to worry about how he had found this or that known theorem, when he was showing me half a dozen new ones almost every day.

Mathematics, then, was the common ground of their relationship perhaps the *only* one other than their mutual pleasure in having found one another. Like many an Englishman, Hardy hid behind his reserve, disdaining any too-presumptuous an intrusion into Ramanujan's private life. He was not ideally suited to draw out a lonely Indian, to ease his adjustment to an alien culture, to shelter him from the English chill.

In 1916, Ramanujan's tutor Barnes had written the University of Madras that, given Ramanujan's achievements, it seemed likely he would be elected a Fellow of Trinity College the following October. But October 1917 came and went without Ramanujan's election. At the time, the college was wracked with dissension over the Bertrand Russell affair, and Ramanujan's champion, Hardy, was squarely in the out-of-favor camp. Then, too, it seems certain, in light of future events, simple racism was a factor; Ramanujan, after all, was a black man. The disappointment left Ramanujan's mood darker, the whole structure of his personality that much shakier.

It was around this time that he entered Matlock, which could hardly have lifted his spirits. English sanatoriums were typically presided over by stern, patriarchal figures, strict disciplinarians who ruled with an iron hand. And Matlock was in the mold. A friend would later recall that Ramanujan was "cowed down by Dr. Ram, who seems to have told him, 'As long as you are a patient and not well you are not free and the doctor has control over your movements.' "

He grew profoundly depressed. At One point, he had nightmares in which he was visited by images of his own abdomen as a kind of mathematical appendage with "singularities," points in space marked by indefinable mathematical surges like those he and Hardy had explored in their partitions work. Intense pain might show up at x = 1, half as much pain at x = -1, and so on. The nightmares recurred. Ramanujan was at a low ebb, balanced precariously on the edge of mental instability.

Undeterred by the Trinity rebuff and hoping to boost Ramanujan's morale, Hardy set about trying to get his friend the recognition he felt he deserved. On December 6, 1917, Ramanujan was elected to the London Mathematical Society. Then, two weeks later, on December 18, Hardy and eleven other mathematicians-Hobson and Baker were among them, as were Bromwich, Littlewood, Forsyth, and Alfred North Whitehead, Bertrand Russell's collaborator on *Principia Mathematica-together* put him up for an honor more esteemed by far than any fellowship of a Cambridge college: they signed the Certificate of a Candidate for It was this signal honor Hardy sought for his friend and for which he set out Ramanujan's "Qualifications" in his distinctive calligraphic hand:

Distinguished as a pure mathematician, particularly for his investigations in elliptic functions and the theory of numbers. Author of the following papers amongst others: "Modular Equations and Approximations to Pi," Quarterly Journal, vol. 45; "New Expressions for Riemann's Functions (s) and 2(t)," ibid, vol. 46; "Highly Composite Numbers," Proc. London Math. Soc., vol. 14 ... Joint author with G. H. Hardy, F.R.S.,

of the following papers: "Une formule asymptotique pour Ie nombre des partitions den," Comptes Rendus, 2 Jan. 1917...

Thus it continued, listing Ramanujan's papers, and ending with perhaps the most important of all-"Asymptotic Formulae in Combinatory Analysis," the big partitions paper still awaiting publication in the *Proceedings of the London Mathematical Society*.

On January 24, 1918, the names of Ramanujan and 103 other candidates were read out at a meeting of the society. If past experience applied, only a few of them would be elected as Fellow of Royal Society.

As Hardy had foreseen, the honors accorded him, especially the F.R.S., had lifted Ramanujan's spirits-leading to what Neville would term "a brief period of brilliant invention" beginning about the spring of 1918.

The paper Ramanujan mentioned, delivered to the Cambridge Philosophical Society two weeks before, represented its fullest flowering. "A recent paper by Mr. Hardy and myself," it began, referring to their joint work on partitions published earlier that year contains a table calculated by Major MacMahon, of the values of p(n), the number of unrestricted partitions of n, for all values of n from 1 to 200. On studying the numbers in this table I observed a number of curious congruence properties, apparently satisfied by p(n). Thus (1) p(4), p(9), p(14), p(19), :; 0 (mod 5), (2) p(5), p(12), p(19), p(26), :; 0 (mod 7), and so on, right down the page.

The paper was entitled "Some Properties of p(n), the Number of Partitions of n," and what made it important was that until now most "properties," of the partition function had eluded discovery. The number of partitions, p(n), recall, refers to how many ways you can add up numbers to get *n*. But of even such basic facts as, for example, whether the partition function was odd or even for a particular *n*, mathematicians remained ignorant.

Was it not time, then, that Ramanujan return to India? The reasons against doing so had disappeared. The sea lanes were safe. He had achieved all he had set out to in England. His Trinity fellowship imposed no residency requirement. He need not stick around while his Royal Society candidacy was up in the air; it no longer was. So, the thinking went, with Ramanujan on the mend why retard his recovery by keeping him in England any longer?

In any case, the wheels were being set in motion for Ramanujan's return to India the following year. But was he going back because he was really better? Or because he was worse, his chances for recovery in England seen as remote? That, at least, is what one of his Indian biographers implied later. "Mr. Ramanujan's disease had assumed serious proportions by the Christmas of 1918," wrote P. V. Seshu Iyer, referring to a time only a month removed from Hardy's letter to Dewsbury, "and caused such grave anxiety to his doctors in England, that, hoping to do him good, they advised him to return to his native home in India."

Whatever was physically wrong with Ramanujan, his progress, or decline, was glacially slow-making it easy to read slight day-to-day fluctuations in his condition any way you liked. So it may have been no great change in his health to which his return to India was really due but, more simply, the end of the war.

Hardy (whose mother had died in Cranleigh a few weeks after the armistice) could visit him more easily; beyond the usual two hours on the train into London, Putney was just a cab ride away. Once, in the taxi from London, Hardy noticed its number, 1729. He must have thought about it a little because he entered the room where Ramanujan lay in bed and, with scarcely a hello, blurted out his disappointment with it. It was, he declared, "rather a dull number," adding that he hoped that wasn't a bad omen.

"No, Hardy," said Ramanujan. "It is a very interesting number. It is the smallest number expressible as the sum of two cubes in two different ways."

This number is known as Hardy- Ramanujan number or Taxi cab number.

On March 13, 1919, two short notes by Ramanujan appeared in the *Proceedings of the London Mathematical Society;* in them, he revealed new congruence properties of the partition function and a new link between the first and second Rogers-Ramanujan identities. That same day, lightened by notebooks and other papers he had left with Hardy, but encumbered



with, among other things, at least a dozen books, a box of raisins for his younger brothers, and a big leather trunk filled with papers, he boarded the Pacific and Orient Lines ship *Nagoya*. The *Nagoya*, of the same recent vintage as the *Nevasa* only a bit smaller, was steaming for Bombay.

Now the lead page of the society's *journal*, dated April I, 1919, bore the news of Ramanujan's return. But he was coming back, it advised, "in somewhat indifferent health."

"Where is she?" asked Ramanujan of his mother as he stepped off the ship into the maw of Bombay on March 27, 1919. *She* was Janaki. His mother was there, and his brother Lakshmi Narasimhan; the two of them had set out for Bombay on the twenty-first. But not his wife. Why fret over Janaki? sniped Komalatammal. Scarcely off the boat, Ramanujan had dropped into the family snake pit. Domestic conflict had sabotaged his last three years in England. Now they dampened his arrival in India.

In fact, the two sides of the family had been out of touch for more than a year. No one knew just where Janaki was. Perhaps back in Rajendram. Or, if she had learned of Ramanujan's arrival, maybe with her sister in Madras. So, Lakshmi Narasimhan was dispatched to write two identical letters to Janaki asking that she come meet Ramanujan in Madras.

Ramanujan was offered a university professorship, which he said he would accept when his health improved. Madrasi notables trooped by to visit the convalescing genius, South India's conquering hero of the intellect, who had shown the Britishers the stuff of which South Indians were made. Now and over the next year, they rushed to pick up his medical and other expenses. They offered him their homes. Top people from the *Hindu* came by. So did Ramachandra Rao, of course, and Sir Francis Spring, and Narayana Iyer.

To shield him from visitors a little, Ramanujan's doctor, M. C. Nanjunda Rao, had him moved a half mile or so south to a place called Venkata Vilas on Luz Church Road, named for a nearby Portuguese church (known locally as *Kattu Kovil*, or Jungle Temple). Now, far from the teeming Triplicane and Georgetown of his youth, he was in the very heart of cultured Madras, peopled by high-born Brahmin intellectuals, lawyers, and scholars, who lived in large compounds, luxuriant with banana trees and betel gardens. It was here, finally, on April 6, that Janaki and her brother caught up with him, followed, about a week later, by Ramanujan's father, grandmother, and younger brother, from Kumbakonam.

After that, Janaki began to occupy a larger place in her husband's life. He grew freer in her company. He told her, more than once, "If only you had come with me to England perhaps I would not have fallen ill." In coming months, it would be Janaki who, increasingly, would care for him during the day, give him his medication, nurse him at night. When, at one point, his mother urged him to send Janaki packing, back to her parents, Ramanujan refused.

Ramanujan was living in one of a group of substantial stucco houses built for the British around the turn of the century in a western suburb of the city. Given names like Sydenham, Ravenscroft, and Lismoyle, and sometimes supplied with tennis courts, they were popular with middle-rank Indian Civil Service officers and company officials. Several dozen of them had gone up along a lane perpendicular to Harrington Road, 'now called Fifteenth Avenue, but during Ramanujan's time unnamed. "Kudsia" was one of them, though apparently Ramanujan didn't stay there long. For a time, he was installed in a considerably larger one, "Crynant," in a culdesac at the end of the dusty lane. Ultimately, he would be moved to another, known as "Gometra."

It was from one of these houses that on January 12, 1920, Ramanujan wrote Hardy for the first time in almost a year.

I am extremely sorry for not writing you a single letter up to now.... I discovered very interesting functions recently which I call "Mock" theta functions. Unlike the "False" theta functions (studied partially by Prof. Rogers in his interesting paper) they enter into mathematics as beautifully as the ordinary theta functions. I am sending you with this letter some examples.

In how it would excite the active interest of mathematicians up until the present, it was a letter much like the one Ramanujan had written Hardy seven years earlier almost to the day. By one estimate, it represented "one of the most original pieces of mathematics, and in some ways the very best, which Ramanujan did."

Ramanujan's discovery of the mock-theta functions makes it obvious that his skill and ingenuity did not desert him at the oncoming of his untimely end. As much as any of his earlier work, the mock-theta functions are an achievement sufficient to cause his name to be held in lasting remembrance. To his students such discoveries will be a source of delight and wonder until the time shall come when we too shall make our journey to that Garden of Proserpine.

Sometime during late winter or early spring of 1920, while staying in "Crynant," Ramanujan complained to his mother that the "cry" of that name seemed inauspicious. Komalatammal went to Namberumal Chetty, owner of the bungalows (as well as of a small railroad) and a friend of Sir Francis Spring. Omitting Ramanujan's real reasons, Komalatammal told him her son needed a quieter place. Namberumal obliged, and Ramanujan was moved a little down the road to "Gometra," which means something like "Friend of Cows," a reference to Krishna.

Toward the end, "he was only skin and bones, "Janaki remembered later. He complained terribly of the pain. It was in his stomach, in his leg. When it got bad, Janaki would heat water in brass vessels and apply hot wet towels to his legs and chest; "fomentation," it was called, standard therapy at the time. But through all the pain and fever, through the endless household squabbles, through his own disturbed equanimity, Ramanujan, lying in bed, his head propped up on pillows, kept working.

When he requested it, Janaki would give him his slate; later, she'd gather up the accumulated sheets of mathematics-covered papers to which he had transferred his results and place them in the big leather box which he had brought from England. "He wouldn't talk to anyone who came to the house," said Janaki later. "It was always maths.... A few days before he died he was scribbling."

Early on April 26, 1920, he lapsed into unconsciousness. For two hours, Janaki sat with him, feeding him sips of dilute milk. Around midmorning or perhaps a little earlier, he died. With him were his wife, his parents, his two brothers, and a few friends. He was thirty-two years old.

Around 1948, Janaki began taking care of a small boy, Narayanan, whose mother was in the hospital and who himself suffered from typhus. She visited him in the hospital, nursed him there, brought him books for school. Later, both his parents died, and Narayanan went to live with her. When she couldn't both take care of him and support herself as a seamstress, he briefly left to attend a residential school. But when he was about fifteen, he came back to live with her for good, and she adopted him as her son.

Soon after learning of Ramanujan's death, Hardy had written Dewsbury: "Is it possible that Madras would consider the question of publishing the papers in a collected form? There should be some permanent memorial of so remarkable a genius; and this memorial would certainly be the most appropriate form." Finally, in 1927, after protracted correspondence, Cambridge University Press came out with Ramanujan's *Collected Papers*, 355 pages with almost everything he had ever published. The early Indian work was there. So was the partition function, and highly composite numbers, even questions he had posed readers of the *Journal of the Indian Mathematical Society* and the mathematical parts of his letters to Hardy.



And with its publication, as the wider mathematical world took notice of Ramanujan's work, the floodgates opened.

But if Ramanujan's life exerted a peculiar hold on mathematicians, much more so did his work. In Hungary, in 1931, an eighteen-year-old University of Budapest prodigy, Paul Erdos, had written a paper on prime numbers. His teacher suggested he read a similar proof in Ramanujan's *Collected Papers*, "which I immediately read with great interest." Then, the following year, he saw a Hardy-Ramanujan paper concerned with the number of prime factors in an integer.

Some numbers, recall, are more composite than others, a subject Ramanujan had explored in his longer paper on highly composite numbers.

A number like $12 = 2 \times 2 \times 3$ has more prime factors, three, than a number like $14 = 7 \times 2$, which has only two. The number 15 has two, while 16 has four. As you test each integer, the number of its divisors varies considerably. Well, Hardy and Ramanujan had said, we will examine not how this number varies but seek its *average* value-in the same way that you cannot predict the next throw of the dice yet can predict, on average, how often particular dice combinations will appear. Their result, loosely speaking, was that most integers have about log log *n* prime factors: note *n*, take its logarithm, then take *its* logarithm, and you wind up with a crude estimate that improves as *n* increases. But as rough as the result was, it beat anything anyone had before, and took twenty-three pages of close-grained mathematical reasoning to prove it.

For almost twenty years, Hardy later told Erdos, their theorem seemed dead in the water, no progress being made in improving it. Then, in 1934, the problem was resurrected, and in 1939 Erdos and Mark Kac were led to a theorem that took it much further. It was only then that mathematicians could look back and pronounce the Hardy-Ramanujan paper of 1917 the founding document of the field that became known as probabilistic number theory.

In Norway, in 1934, a schoolboy named Atle Selbe Over the years, then, Ramanujan was never forgotten. A 1940 listing noted 105 papers devoted to his work since his death. In the late 1950s, when Morris Newman delivered a paper at an Institute in the Theory of Numbers conference at the University of Colorado at Boulder, he began:

"As with so much in analytic number theory, the study of congruence properties of the partition function originated with Ramanujan," and used Ramanujan's early papers as a jumping-off point. And certainly by the time of the centennial of his birth in 1987, Ramanujan's reputation was secure.

On October 8, 1962, a group of men met at the three-hundred-year-old Mallikeswarar Temple, at the northern end of Linghi Chetti Street, in Madras's Georgetown district, whose streets Ramanujan had walked half a century before. Here, in the shadow of the temple's ornate gopuram, P. K. Srinivasan, a mathematics teacher at Muthalpiet High School, brought his friends together to launch a project. He had first read about Ramanujan twenty years before. Ever since, he had tried to inspire students with his example. Then, eight years before, a friend had taken him to meet Janaki and Tirunarayanan, Ramanujan's surviving brother.

Ramanujan's seventy-fifth birthday was observed across South India. Town High School, in Kumbakonam, named one of its buildings after him. A stamp was issued in his honor; two and a half million copies of his passport photo, reduced to inch-high form, colored sienna, and valued at fifteen new paise, sold out the day they were issued. In



Madras, around the time of the anniversary, a birthday celebration was held in his honor, and many of those who had been close to him or his family were in town.

Whether and how the engineers and chemists might indeed apply Ramanujan's work to the common purposes of life strikes a sensitive chord in India, beset as it is by practical problems of great urgency and less naturally inclined to trust in research whose rewards may accrue only decades or centuries later. "Several theorems of Ramanujan are now being widely used in subjects like particle physics, statistical mechanics, computer science, cryptology and space travel in the United States subjects unheard of during Ramanujan's time," *The Hindu* assured its readers in its December 19, 1987 issue. But efforts to justify Ramanujan's work on utilitarian grounds go back almost to his lifetime.

When the Ramanujan stamp came out in 1962, the Indian postal service took pains to point out the potential applications of his work: "His work and the work of other mathematicians on Riemann's zeta function, done in another context, has now been geared to the technological mill. It has been applied to the theory of pyrometry, the investigation of furnaces aimed at building better blast furnaces." And his work on mock theta functions, modular equations, and in other realms was being studied for its possible application to atomic research.

Down through the years, Ramanujan's mathematics has indeed been brought to bear on practical problems, if sometimes tangentially. For example, crystallographer S. Ramaseshan has shown how Ramanujan's work on partitions sheds light on plastics. Plastics, of course, are polymers, repeating molecular units that combine in various ways; conceivably, you might have one that's a million units long, another of 8251, another of 201,090, and so on. Ramanujan's work in partitions-on how smaller numbers combine to form larger ones-plainly bears on the process.

As it does, for example, in splicing telephone cables, where shorter subunits, of varying lengths, again add up to make a whole.

Blast furnaces? Plastics? Telephone cable? Cancer?

At a meeting of the southeastern section of the American Physical Society in Raleigh, North Carolina, in November 1988, three University of Delhi researchers presented a paper entitled "A Study of Soliton Switching in Malignancy and Proliferation of Oncogenes Using Ramanujan's Mock-Theta Functions." They were using Ramanujan's mathematics to help understand cancer, if only as a small, tangential contribution to a vast and complex subject.

When the *Hindu* noted the paper, however, it assigned the headline "Ramanujan's Maths Help Fight Cancer."

In other fields, Ramanujan's mathematics has played a more decisive role-as in, for example, string theory, which imagines the universe as populated by infinitesimally short string like packets whose movement produces particles. Grounded in the real world or not-the jury is still out-the mathematics required to describe these strings demands twentysix dimensions, twenty-three more than the three on which we manage in everyday life. Partition theory and Ramanujan's work in the area known as modular forms have proved essential in the analysis.

An important problem in statistical mechanics has also proved vulnerable to Ramanujan's mathematics-a theoretical model that explains, for example, how liquid helium disperses through a crystal lattice of carbon.

Computers, scarcely the dream of which existed in 1920, have also drawn from Ramanujan's work. "The rise of computer algebra makes it interesting to study somebody who seems like he had a computer algebra package in his head," George Andrews once told an interviewer, referring to software that permits ready algebraic manipulation. Sometimes in studying Ramanujan's work, he said at another time, "I have wondered how much Ramanujan could have done if he had had MACSYMA or SCRATCHPAD or some other symbolic algebra package. More often I get the feeling that he was such a brilliant, clever and intuitive computer himself that he really didn't need them." Then, too, a modular equation in Ramanujan's notebooks led to computer algorithms for evaluating pi that are the fastest in use today.

By the time of the centennial of his birth in 1987, Ramanujan's reputation shone with a new luster. In India, he was compared to Nehru and Nobel Prize-winning physicist C. V. Raman, both of whose centennials were being celebrated at about the same time. Three Indian films were made about his life. A Ramanujan Mathematical Society, started in 1986, published the first volume of its journal.

Celebrations were held all across South India. Andrews, Askey, and Berndt, the three American mathematicians who had most contributed to the restoration of Ramanujan's name, were kept busy shuttling all over the country, giving lectures at Annamalainagar, and Bombay, and Pune, and Gorakhpur and Madras.

In Madras, when the Narosa Publishing House issued *The Lost Notebook*, Prime Minister Rajiv Gandhi was there to sign the first copy and present it to Janaki.

Just what did Ramanujan want?

He wanted nothing-and everything.

He sought no wealth, certainly none beyond what he needed to carry out his work, and to give to his family what he felt was expected of him. He did crave respect, understanding, perhaps even a favorable judgment from history.

But what Ramanujan wanted more, more than anything, was simply the freedom to do as he wished, to be left alone to think, to dream, to create, to lose himself in a world of his own making. That, of course, is no modest wish at all. He wanted "leisure." And he got it.

In South India today, everyone has heard of Ramanujan. College professors and bicycle rickshaw drivers alike know his story, at least in sketchy outline, just as everyone in the West knows of Einstein. Few can say much about his work, and yet something in the story of his struggle for the chance to pursue his work on his own terms compels the imagination, leaving Ramanujan a symbol for genius, for the obstacles it faces, for the burdens it bears, for the pleasure it takes in its own existence.

EXCERPTS FROM 'THE MAN WHO KNEW INFINITY A LIFE OF THE GENIUS RAMANUJAN' BY

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We are thankful to Robert Kanigel for such a beautiful charaterisation of Indian Mathematics Genius