

Life and work of the Mathemagician Srinivasa Ramanujan

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Introduction

Srinivasa Ramanujan, hailed as one of the greatest mathematicians of this century, left behind an incredibly vast and formidable amount of original work, which has greatly influenced the development and growth of some of the best research work in mathematics of this century. He was born at Erode, on Dec. 22, 1887. There were no portents to indicate that he would, in a short life-span of 32 years 4 months and 4 days, become comparable to the all-time great Euler, Gauss and Jacobi, for *natural genius*.

There are two aspects of interest to biographers and mathematicians regarding Ramanujan: his life and his work. Mathematicians, who are interested in his work, have to contend with not only his publications in journals which are precise and profound, but also with his Notebooks which are a treasure house of intriguing results stated without proofs and lacking perspective with contemporary mathematical work. Those who attempt to write biographic articles on Ramanujan have to surmount the time barrier to reconstruct a story from all the indirect information accessible and to them, Hardy on Ramanujan [1] is akin to Boswell on Samuel Johnson. The challenge to the mathematicians who work on any of his thousands of recorded results, which are still shrouded in mystery, is to prove the same with what was accessible to Ramanujan in those days in the form of books and publications. While the individual writer's perception of Ramanujan will depend upon his/her background and imagination, the task of the mathematician is perhaps unenviable, in comparison.

Anyone who ever heard of Srinivasa Ramanujan and reads the compelling rags-to-intellectual-riches story of Ramanujan contained in the two Notices, one by G.H. Hardy and the other by Dewan Bahadur R. Ramachandra Rao and P.V. Seshu Iyer, published in the *Collected papers of Srinivasa Ramanujan* [2], would be moved by the achievements of the unorthodox mathematical genius under adverse circumstances. The lack of formal education, lack of appreciation and a job, in the beginning of his career and ill health during the last few years of his life, did not prevent him from being creative in Mathematics. This is indeed something not easy to comprehend, for

often one would buckle under similar trying circumstances. In these lectures, I will present an account of his romantic life, provide a few glimpses into his mathematics and relate the increasing interest in his work and its relevance even today.

Formal education

Ramanujan's father, Mr. K. Srinivasa Iyengar, was an accountant to a cloth merchant in Kumbakonam. His mother was Komalattammal and Erode was her parental home. He was the first of three sons to his parents. Very little is known about his father and not even a photograph of his seems to be available. His mother was convinced of the greatness of Ramanujan and she zealously protected and projected his interests all through his life. She is portrayed as a shrewd, cultured lady and her photograph is available in some books on Ramanujan.

Ramanujan was sent to Kangeyam Primary School in Kumbakonam at the age of seven. During his school days, he impressed his classmates, senior students and teachers with his extraordinary intuition and astounding proficiency in several branches of mathematics - viz. arithmetic, algebra, geometry, number theory and trigonometry. In later years a friend of his, C.V. Rajagopalachari, recounted the following incident ([3], p.83) which happened when Ramanujan was in his third form: In an arithmetic class on division, the teacher said that if three bananas were given to three boys, each boy would get a banana. The teacher generalised this idea and said that any number divided by itself would give one. Ramanujan asked:

Sir, if no banana is distributed to no student, will everyone still get a banana ?

Another friend who took private tuition from Ramanujan also recalled [4] that Ramanujan used to ask about the value of zero divided by zero and then answer that it can be anything since the zero of the denominator may be several times the zero of the numerator and vice versa and that the value cannot be determined. He stood first in the Tanjore District Primary Examinations held in November 1897, and this entitled him to a half-fee concession in the Town High School at Kumbakonam, where he studied from 1898 to 1903, until he passed the Matriculation Examination of the University of Madras (1904).

At the age of 12, Ramanujan is said to have worked out the properties of arithmetical, geometrical and harmonic progressions. Once a senior school student [3], posed to Ramanujan, who was in the fourth year at school, the following problem:

If $\sqrt{x + y} = 7$ and $x + \sqrt{y} = 11$, what are the values of x and y ?

Ramanujan's immediate reply to this question – which was expected to be tackled by only a sixth year student – that $x = 9$ and $y = 4$, won for him a friend who in later years took him to the collector of Nellore¹.

The senior mathematics teacher of the school, Ganapathy Subbier, had such confidence in Ramanujan's ability that year after year he entrusted Ramanujan with the task of preparing a conflict free time-table [5] for the school, which had about 1500 students and 30 or more teachers. Ramanujan won prizes for his outstanding performance in mathematics and mastered Loney's *Trigonometry, Part II*, in his fourth year at school. He won many prizes [6] in his second, fourth and sixth years at High School.

To augment the family income, Ramanujan's mother took in a couple of students from Tirunelveli and Tiruchirapalli as boarders. Noticing Ramanujan's precocity in mathematics these undergraduate students are purported to have given him an elementary introduction to all branches of mathematics. In 1903, through these friends from the Kumbakonam Government College, Ramanujan obtained G.S. Carr's: *A Synopsis of Elementary Results, a book on Pure Mathematics*, which contained propositions, formulae and methods of analysis with abridged demonstrations, published in 1886.

Carr presented in this book 4865 formulae [7, p.3], without proofs, in algebra, trigonometry, analytical geometry and calculus. This book is similar to the modern day compilations like the *Table of Integrals, Series, and Products*, by I.S. Gradshteyn and I.M. Ryzhik (Academic Press, New York, 1994). Prof. P.V. Seshu Aiyar and Mr. R. Ramachandra Rao, in their biographies of Ramanujan [2] state that:

It was this book which awakened his genius. He set himself to establish the formulae given therein. As he was without the aid of other books, each solution was a piece of research so far as he was concerned.

¹If one does not guess this answer, the result can be obtained by setting $x = m^2, y = n^2$, then take the difference between the two simultaneous equations and factorise to get: $(m - n)(m + n - 1) = 4$, which has integer solutions only for $m = 3, n = 2$ and hence $x = 9, y = 4$.

It is the considered opinion of many (cf. Kanigel [8], p.57) that in proving one formula, he discovered many others and thus, Ramanujan laid for himself a foundation for higher mathematics. Also, at about this time, he started noting his results in Notebooks.

The first public recognition of his extraordinary prowess came when he was awarded a special prize – the Sri K. Ranganatha Rao Prize – at the annual prize distribution ceremony of the Town High School, in 1904, for proficiency in mathematics. Ramanujan passed his Matriculation Examination in 1904 and joined the Government Arts College in Kumbakonam. As a result of his success in a competitive examination in Mathematics and English composition, he secured the Junior Subrahmanyam Scholarship. In the F.A. (First Examination in Arts) Class, Ramanujan had to study English, Sanskrit, Mathematics, Physiology and the History of Rome and Greece. Partly due to his pre-occupation with researches into mathematics, he neglected the study of other subjects. He went to his mathematics lecturer with a number of original and very ingenious results in finite and infinite series. Prof. P.V. Seshu Aiyar exhorted him but advised him not to neglect the study of other subjects. Unfortunately, he did not pass in English and Physiology and hence was not promoted to the senior F.A. class in January 1905. He lost his scholarship. His mother, who played a domineering role in his life, tried to persuade the Principal of the Government Arts College to take note of Ramanujan's extraordinary mathematical ability and appealed for a continuance of the scholarship, but to no avail.

Ramanujan's failure to get promoted to the senior F.A. class marked the beginning of a very trying period in his life. It is not clear what he did in 1905, when he discontinued his studies and spent some months in (the present day) Andhra Pradesh region, when he set out from Kumbakonam, for the first time. He joined Pachaiyappa's College in Madras, in the F.A. class again, in 1906. One of his classmates, T. Devaraja Mudaliar, ([9], p.63 and p.65) recalls that the Chief Professor of Mathematics, P. Singaravelu Mudaliar, considered an acquisition by Pachaiyappa's College since he had the reputation of being a very successful teacher for the B.A. class, waited for Ramanujan's assistance to solve difficult problems in mathematical journals. He also recalls that a junior mathematics teacher of the F.A. class, Prof. N. Ramanujachari, allowed Ramanujan to go to the board to show the solutions to the difficult problems in algebra or trigonometry using fewer steps than the ones used by him. Senior students of the B.A. Class also sought Ramanujan's help in mathematics [10].

Ramanujan who was a strict vegetarian should have abhorred the dissection of the frog in the Physiology classes. Once, to a question on the digestive system, he is supposed to have provided a skimpy answer which he concluded with [11]: *Sir, this is my undigested product of the Digestion chapter. Please excuse me.* Another classmate of his at Pachaiyappas College recalls [12] that Ramanujan *rarely got more than 10 contempt and got something more, say 15 % to 20 % in Greek and Roman History, but managed to get about 25 % in English.* However, Ramanujan considered [12] *the problems given in . . . textbooks in Geometry, Algebra, and Trigonometry to be mental sums.*

In 1906, while studying at Pachaiyappa's College, Ramanujan lived with his grandmother in a house in a lane in George Town, Madras. After about three months, Ramanujan fell ill and discontinued his studies. However, he appeared privately for the F.A. examination in 1907. Though he secured a centum in mathematics, he failed to secure pass marks in other subjects. This marked the end of his formal education.

Formative years

It was during the period, 1907 - 12, that Ramanujan was frantically in search of a benefactor and started making contacts with those who could help him in his quest for a job to eke out a livelihood. He continued to stay in Madras after his formal education came to an end in 1907. According to Hardy:

The years between 18 and 25 are the critical years in a mathematician's career. During his five unfortunate years (1907-1912) his genius was misdirected, side-tracked and to a certain extent distorted. (Hardy [1]).

Despite the pecuniary circumstances and the stresses and strains of day-to-day existence, Ramanujan started noting down his mathematical results in Notebooks. By 1909, his Notebooks were precious to Ramanujan. For, one (F.A.) classmate of his, states [13] that Ramanujan fell ill in 1909, while living in George Town, Madras, and on a Doctor's advise, when he was being sent to the home of his parents in Kumbakonam, Ramanujan entrusted him with his Notebooks for safe keeping and stated: *If I die, please hand them over to Prof. Singaravelu Mudaliar or to the British Professor – Edward B Ross – Madras Christian College.*

Another college mate [14] of Ramanujan has stated that during his collegiate years, Ramanujan taught him the method of constructing Magic Squares, the sub-

ject of the first chapter of his Notebooks. The interest in this subject dates from his school days and is disconnected from the subject matter of the remainder of the Notebooks. Probably Ramanujan's expertise in preparing the conflict free time tables for his School inspired him to a study of these Magic Squares.

Ramanujan's investigations in continued fractions and divergent series started during this period. His betrothal to nine year old Janaki was in 1908 and his wedding took place near Karur, in 1909. Robert Kanigel [8], in his biography on Ramanujan, constructs a vivid account of this marriage arranged by his mother Komalattammal, not approved by his father, and dramatizes the foreboding of the impending disaster through the omens preceding the wedding, which was on the brink of being called off due to the late arrival of the bridegroom's party.

During this period he tutored a few students in mathematics and even sought employment as a tutor in mathematics. Disappointed at the lack of recognition, during this trying period, Ramanujan had bemoaned to a friend [4] that he was probably destined to die in poverty like Galileo! Fortunately, this was not to be.

In 1910, Ramanujan sought the patronage of Prof. V. Ramaswamy Iyer – the founder of Indian Mathematical Society – who was at Salem and asked for a clerical job in his office. The only recommendation Ramanujan had was his Notebooks which by then contained several results on Magic Squares, prime numbers, infinite series, divergent series, Bernoulli numbers, Riemann zeta function, hypergeometric series, partitions, continued fractions, elliptic functions, modular equations, etc. A scrutiny of the entries in the Notebooks was sufficient to convince Prof. Ramaswamy Iyer [15] that Ramanujan was a gifted mathematician and he *had no mind to smother his (Ramanuja's) genius by an appointment in the lowest rungs of the revenue department*. So, he sent Ramanujan back to Madras with a letter of introduction to Prof. P.V. Seshu Aiyar, then at the Presidency College, Madras. Prof. Seshu Aiyar, who had known Ramanujan as a student at the Government Arts College, Kumbakonam, when he himself was employed there as a lecturer of mathematics, was meeting him after a gap of four years and was greatly impressed with the contents of the *well-sized* Notebooks. So he gave Ramanujan *a note of recommendation to that true lover of mathematics, Dewan Bahadur R. Ramachandra Rao, who was then the District Collector at Nellore*.

The turning point

With the help of a friend, R. Krishna Rao [16], who was a nephew of Dewan Bahadur Ramachandra Rao, Ramanujan went to Tirukkoilur in December 1910. This was a turning point in Ramanujan's life. Ramachandra Rao states [17] that *in the plentitude of my mathematical wisdom, I condescended to permit Ramanujan to walk into my presence*. At that time, Ramanujan appeared to Ramachandra Rao as

a short uncouth figure, stout, unshaved, not over-clean, with one conspicuous feature - shining eyes - walked in, with a frayed Notebook under his arm He was miserably poor. He had run away from Kumbakonam to get leisure in Madras to pursue his studies. He never craved for any distinction. He wanted leisure, in other words, simple food to be provided for him without exertion on his part and that he should be allowed to dream on.

Though Ramachandra Rao gave him a patient hearing, he took a few days to look into the Notebooks of Ramanujan. At their fourth meeting, when Ramanujan confronted Ramachandra Rao with a letter from Prof. Saldhana of Bombay appreciating the genuineness of his work, Ramachandra Rao started to feel that Ramanujan's work must be examined in depth by eminent mathematicians. Ramachandra Rao himself states [17] that Ramanujan led him *step-by-step to elliptic integrals and hypergeometric series and at last to his theory of divergent series not yet announced to the world* and this converted him into a benefactor who undertook to underwrite Ramanujan's expenses at Madras for some time.

Prof. Seshu Aiyar also communicated the earliest contributions of Ramanujan to the Journal of the Indian Mathematical Society (I.M.S.) in the form of questions. These appeared in 1911 and in his brief and illustrious career Ramanujan proposed in all 59 questions or solutions to questions in this journal. The first fifteen page article entitled: *Some properties of Bernoulli numbers* appeared in the same 1911 volume of the journal of the I.M.S. In it Ramanujan stated eight theorems embodying arithmetical properties of the Bernoulli numbers, indicating proofs for three of them; two theorems are stated as corollaries of two others, while three theorems are stated as mere conjectures. Prof. Seshu Iyer states [18]: *Ramanujan's methods were so terse and novel and his presentation was so lacking in clearness and precision, that the ordinary reader, unaccustomed to such intellectual gymnastics, could hardly follow him.*

Ramanujan lived in a small house, called 'Summer Hous'e, in Sami Pillai Street,

Triplicane, Madras, accepting reluctantly a monthly financial assistance from the collector of Nellore for about a year. Later he declined this help and from Jan. 12 to Feb. 21, 1912, he worked as a clerk in the Accountant Generals Office, on a salary of Rs.25/- per month. Not satisfied with this job, Ramanujan applied for and secured a post in the Accounts Section (Class III, Grade IV clerk on a salary of Rs.30/- per month) in the Madras Port Trust, with the help of Mr. S. Narayana Iyer, the Manager of Port Trust, who was the treasurer of the IMS and a friend of Profs. V. Ramaswamy Aiyar and P.V. Seshu Aiyar.

Mr. Narayana Aiyer was a good mathematician and was a great source of support to Ramanujan. He was not only instrumental in Ramanujan being offered a job in the Madras Port Trust, but also in securing for Ramanujan the life-long support of Sir Francis Spring. When Ramanujan was living in No. 580, Pycrofts Road, Triplicane, Madras, he used to meet Mr. Narayana Iyer and work out Mathematics on two big slates. Narayana Aiyer's son N. Subbanarayanan relates the role his father played in the career of Ramanujan [18, p. 112]:

My father, being a fairly good mathematician himself, was unable to capture the strides of Ramanujan's discoveries. He used to tell him, "When I am not able to understand your steps, I do not know how other mathematicians of a critical nature will accept your genius. You must descend to my level and write at least ten steps between the two steps of yours". Sri Ramanujan used to say, "When it is so simple and clear to me, why should I write more steps?" But somehow my father slowly got him round, cajoled him and made him write some more, though it used to be a mighty task of boredom to him.

Dewan Bahadur Ramachandra Rao wrote to Sir Francis Spring, Chairman of Madras Port Trust, about Ramanujan. He also induced Prof. C.L.T. Griffith of the Engineering College, Madras to take interest in Ramanujan and Prof. Griffith in turn wrote [19] in November 1912, to Sir Francis Spring, the Chairman of Madras Port Trust about the very poor accountant who was a most remarkable mathematician and asking him to keep Ramanujan happily employed until something can be done to make use of his extraordinary gifts. As stated before, these efforts resulted in Ramanujan's entry into Port Trust, on March 1, 1912, as a Clerk in the Accounts Department. This may well be considered as the turning point in his career prospects. He held this clerical post for 14 months. His wife joined him during this period and Ramanujan shifted his residence to Saiva Muthiah Mudali Street in George Town. This period also marked the beginning of the appreciation of his scholarship and re-

searches in mathematics.

Prof. Griffith wrote to Prof. M.J.M. Hill, of University College, University of London, on Ramanujan's work and he received a reply in December 1912. Unfortunately, Prof. Hill [20] could not find time to study the results. He observed that *the book which will be most useful to him is Bromwich's Theory of Infinite Series, published by Cambridge University Press (or Macmillan)* and gave advice as to how Ramanujan could get his papers published. In a sequel to this reply, dated 7 December 1912, Prof. Hill wrote to Prof. Griffith [21]:

Mr. Ramanujan is evidently a man with a taste for Mathematics, and with some ability, but he has got on the wrong lines. He does not understand the precautions which have to be taken in dealing with divergent series, otherwise he could not have obtained the erroneous results you send me, viz.

$$\begin{aligned} 1 + 2 + 3 + \dots + \infty &= -1/12, \\ 1^2 + 2^2 + 3^2 + \dots + \infty^2 &= 0, \\ 1^3 + 2^3 + 3^3 + \dots + \infty^3 &= 1/240. \end{aligned}$$

The sums of n terms of these series are:

$$n(n+1)/2, \quad n(n+1/2)(n+1)/3, \quad [n(n+1)]^2/2$$

and they all tend to ∞ as n tends to ∞ . I do think you can do no better for him than to get him a copy of the book I recommended, Bromwich's Theory of Infinite Series, published by Macmillan and Co., who have branches in Calcutta and Bombay. Price 15/- net.

It is not as though Ramanujan was not aware of the apparent absurd looking nature of the results on divergent series. Ramanujan, in his second letter to Hardy [22], wrote:

I have got theorems on divergent series, theorems to calculate the convergent values corresponding to the divergent series, viz.:

$$\begin{aligned} 1 - 2 + 3 - 4 + \dots &= 1/4, \\ 1 - 1! + 2! - 3! + \dots &= 0.596, \\ 1 + 2 + 3 + 4 + \dots &= -1/12, \\ 1^3 + 2^3 + 3^3 + \dots + \infty^3 &= 1/24. \end{aligned}$$

Theorems to calculate such values for any given series (say, $1 - 1^1 + 2^2 - 3^3 + 4^4 - 5^5 + \dots$), and the meaning of such values. I have also dealt with such questions When

to use, where to use, and how to use such values, where do they fail and where do they not ?

Hill failed [23] to discern the origin of the results of Ramanujan and the three sums of the integers, their squares and their cubes are indeed the values of $\zeta(-n)$, for $n = 1, 2, 3$, respectively².

Ramanujan published two short notes, one *On question 330 of Professor Sanjana* and another a *Note on a set of simultaneous equations*, in the IMS journal, in 1912. When Ramanujan approached Prof. Seshu Aiyar with some theorems on Prime Numbers, his attention was drawn to G.H. Hardy's Tract on *Orders of infinity*. In it, Ramanujan observed that ([III], p.xxii): *no definite expression has yet been found for the number of prime numbers less than any given number*. Ramanujan told Prof. Seshu Aiyar that he has discovered the required result. This made Prof. Seshu Aiyar suggest communication of this and other results to Mr. G.H. Hardy – a Fellow of the Royal Society and Cayley Lecturer in Mathematics at Cambridge – a world famous mathematician, who was ten years Ramanujan's senior.

The years of fruition

The life of Ramanujan, in the words of C.P. Snow [24] *is an admirable story, and one which showers credit on nearly everyone* [25]. Ramanujan's first letter [26] to Prof. Hardy, dated 16th January 1913, is a historic letter. It contained the bare statements of about 120 theorems, mostly formal identities from the Notebooks. This collection obviously represented what Ramanujan himself considered were results of importance. Ramanujan wrote:

Dear Sir,

I beg to introduce myself to you as a clerk in the Accounts Department of the Port Trust Office at Madras on a salary of £20 per annum. I am now about 23 years of age. I have had no University education but I have undergone the ordinary school course. After leaving school I have been employing the spare time at my disposal to work at Mathematics. I have not trodden through the conventional regular course

²The Riemann zeta function is defined as: $\zeta(s) = \sum_{n=1}^{\infty} 1/n^s$, $Re\ s > 1$. The ζ function has a unique analytic continuation to the points $s = -1$, where we get $\zeta(-1) = -1/12$, which is what Ramanujan writes as: $1+2+3+\dots+\infty = -\frac{1}{12}$. This result is used in the zeta function regularization method, by String theorists, in recent times.

which is followed in a University course, but I am striking out a new path for myself. I have made a special investigation of divergent series in general and the results I get are termed by the local mathematicians as ‘startling’

I would request you to go through the enclosed papers. Being poor, if you are convinced that there is anything of value I would like to have my theorems published. I have not given the actual investigations nor the expressions that I get but I have indicated the lines on which I proceed. Being inexperienced I would very highly value any advice you may give me. Requesting to be excused for the trouble I give you,

I remain, Dear Sir,

*Yours truly,
(sd) S. Ramanujan.*

Prof. Hardy, the professional mathematician, who was aware that he was *the first really competent person who had the chance to see some of his work*, found some of the series formulae intriguing, some of the integral formulae (which were classical and known) vaguely familiar and he could prove some integral formulae with effort but these were to him the least impressive. However, some of Ramanujan’s formulae were *on a different level* and obviously both difficult and deep, which even Hardy [27] *had never seen anything in the least like them before* and which he has state ‘*defeated me completely*’.

The following is a record of Hardy’s reaction to this historic letter of Ramanujan, in the words of C.P. Snow [28] :

Hardy gave the manuscript a perfunctory glance, and went on reading the morning paper. It occurred to him that the first page was a little out of the ordinary for a cranky correspondent. It seemed to consist of some theorems, very strange-looking theorems, without any argument. Hardy then decided that the man must be a fraud, and duly went about the day according to his habits, giving a lecture, playing a game of tennis. But there was something nagging at the back of his mind. Anyone who could fake such theorems, right or wrong must be a fraud of genius. Was it more or less likely that there should be a fraud of genius or an unknown Indian mathematician of genius ? He went that evening after dinner to argue it out with his collaborator, J.E. Littlewood, whom Hardy always insisted was a better mathematician than himself. They soon had no doubt of the answer. Hardy was seeing the work of someone whom, for natural genius, he could not touch who, in natural genius, though of course not

in achievement, as Hardy said later, belonged to the class of Euler and Gauss.

Hardy made up his mind that Ramanujan should be brought to Cambridge and provided with the necessary education and contact with western mathematicians of the highest class. So, Hardy, wrote to the Secretary of the Indian students, in the India Office, London, suggesting that some means be found to get Ramanujan to Cambridge and he in turn wrote, in February 1913, to Mr. Arthur Davies, the Secretary to the Advisory Committee for Indian students in Madras conveying the desire of the tutors at Trinity to get Ramanujan to Cambridge.

Sir Francis Spring, the Chairman and Mr. S. Narayana Iyer, the Manager of Madras Port Trust gave Ramanujan every possible encouragement. Dr. Gilbert T. Walker, F.R.S., Director General of Observatories, Simla, and Head of the Indian Meteorological Department, paid a visit to the harbour in Madras on February 25, 1913 and Sir Francis Spring drew his attention to the work of Ramanujan and his Notebooks. Dr. Walker, a good mathematician and a Senior Wrangler, was a former Fellow of Trinity College, Cambridge, as well as a lecturer and he said that in his opinion Mr. Hardy would be the most competent to arrive at a judgement of the true value of the work of Ramanujan. Since by then Hardy's reply had arrived (on Feb. 8, 1913), Gilbert Walker wrote [29] to Mr. Francis Dewsbury, the Registrar of the University of Madras, commending the work of Ramanujan to be *comparable in originality with that of a Mathematics Fellow in a Cambridge college*, though lacking in the precision and completeness necessary for establishing the universal validity of the results. He wrote that it was perfectly clear to him 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*. He also wanted the University to correspond with Mr. Hardy, Fellow of Trinity College, Cambridge, since Ramanujan was already in correspondence with Hardy, assuring Mr. Hardy of the University's interest in Ramanujan. The recommendation of Dr. Walker was accepted by the Board of Studies in Mathematics of the University of Madras. Then the Vice Chancellor of the University got the approval of the Syndicate overcoming the legal hurdle of awarding a research scholarship to Ramanujan who did not have the required qualification of a Masters Degree. As a measure of precaution, the consent of the Chancellor of the University (Lord Pentland, the Governor of Madras) was obtained to grant Ramanujan a special research scholarship of Rs.75/- per month for two years with the condition that Ramanujan should submit quarterly reports on his work. The Madras Port Trust granted Ramanujan two years leave (on loss of pay) to enable him to accept this scholarship from May 1913, as the **first research scholar**

of the University of Madras. Thus began Ramanujan's career as a professional mathematician.

In quick succession, Ramanujan received in the next three months, four long letters [30] from Hardy in which the latter wrote plainly about what had been proved or claimed to have been proved by Ramanujan. He clearly communicated his genuine anxiety *to see what can be done to give you (Ramanujan) a better chance of making the best use of your obvious mathematical gifts.* At last Ramanujan had found a sympathetic friend in Hardy and was willing to place unreservedly in his hands all that he had.

Ramanujan wrote again to Hardy on 27th February 1913 and sent him more formulae and explanations. On 17th April 1913, Ramanujan wrote to Hardy about his having secured the scholarship, of £60 per annum, of the University of Madras, for two years. Ramanujan took up residence at Hanumantharayan Koil Lane in Triplicane around this time and had access to books on mathematics in the University library. His wife Janaki and his mother came to live with him.

Ramanujan was initially reluctant to go abroad because of his own caste prejudices³ in those days which were compounded by the extremely orthodox views of his mother to whom he was greatly attached. At the beginning of 1914, Mr. E.H. Neville, a young mathematician and a Fellow of Trinity College, Cambridge, was in Madras as a visiting lecturer to give a series of lectures on Differential Geometry to Mathematics Honours students of the University of Madras. Mr. Hardy entrusted him with the mission of persuading Ramanujan to visit Cambridge. Mr. Neville met Ramanujan and saw his priceless notebooks. This was sufficient to convince him of Ramanujan's uncommon ability and to make him take over the initiative to overcome all the difficulties in arranging for Ramanujan's visit to Cambridge. Prof. Richard Littlehails, who was a Professor of Mathematics with the observatory in Madras introduced Neville [31] to everyone who carried weight in the University or in the civil administration. Neville, in turn, explained to them the importance of Ramanujan's stay in Cambridge, and urged them to be generous in their support.

In a letter [32], dated 28th January 1914, to Mr. Dewsbury, the Registrar of the University of Madras, Mr. Neville wrote about *the importance of securing to Ra-*

³Crossing the oceans was considered a sacrilege by the Hindu Brahmins and often people did so were, on their return to India, treated as outcastes. All relationships with the even their families were shunned!

manujan a training in the refinements of modern methods and a contact with men who know what range of ideas have been explored and what have not and prophesied that Ramanujan would respond to such a stimulus and that 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. The very next day, Prof. Littlehails also wrote [33] to Mr. Dewsbury that *Ramanujan be granted by this University a scholarship of about £250 (Sterling) together with a grant of about £100 in order to enable him to proceed to Cambridge. Ramanujan 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 proposals regarding the scholarship to be granted to Ramanujan by the University of Madras were approved. To the lasting credit of the University of Madras, the Syndicate decided within a week to set aside Rs.10,000/- to offer Ramanujan a scholarship of £250 a year plus £100 for a passage by ship and for initial outfit⁴. At the instance of Professors Neville and Littlehails, Sir Francis Spring wrote [34] to the personal Secretary (Mr. C.B. Cotterell) to the Governor (Lord Pentland) of Madras, persuading His Excellency to speedily approve the University's sanction. Government sanction too was granted within a week.

This offer of the University of Madras was made to Ramanujan in February 1914. He sent his wife and mother back to Kumbakonam, changed the traditional hair-style of a brahmin, viz. a tuft, and got his hair trimmed in European style and left Madras by s.s. Nevasa on 17th March 1914. Prior to his departure, he arranged with the University for £60 a year to be sent to his parents in Kumbakonam, out of his annual scholarship amount. Mr. Arthur Davies and Prof. Littlehails attended to all the details regarding Ramanujan's passage to England. Except for the first three days when he was sea-sick, Ramanujan enjoyed the voyage and reached London through the Channel and the Thames on 14th April 1914. He was received by Mr. E.H. Neville and his brother at the docks and stayed at Cromwell Road for a few days before going to Cambridge on the 18th evening. He remained for a few days in Mr. Neville's house before moving to the college premises for stay, which even though costlier than lodging houses, was more convenient for him and the professors. Ramanujan wrote [35] to his friend that *Mr. Hardy, Mr. Neville and others here are unassuming, kind and obliging. As soon as I came here, Mr. Hardy paid £20 to the college for my entrance*

⁴The second class fare between London and Bombay was £32, in 1914, or about Rs. 480 – *British Passenger Liners of the Five Oceans*, By C.R. Vernon Gibbs (London: Putnam, 1963, p.63). ([8], p.397).

and other fees and made arrangements to give me a scholarship of £40 a year.

Ramanujan was admitted by Mr. Hardy to Trinity College which supplemented his scholarship with the award of an exhibition of £60 a year, to augment the £250 a year scholarship awarded by the University of Madras.

Though Ramanujan had access only to Carrs Synopsiss– and perhaps, to a few other books⁵ – still, in the words of the historian J.R. Newman [36], he *arrived in England abreast and often ahead of contemporary mathematical knowledge. Thus, in a lone mighty sweep, he had succeeded in recreating in his field, through his own unaided powers, a rich half century of European mathematics. One may doubt whether so prodigious a feat had ever before been accomplished in the history of thought.*

To Mr. Hardy [37] Ramanujan’s friend, philosopher an discoverer:

The limitation of his knowledge was as startling as its profundity. Here was a man who could work out modular equations, and theorems of complex multiplications, to orders unheard of, whose mastery of continued fractions was, on the formal side at any rate, beyond that of any mathematician in the world, who had found for himself the functional equation of the zeta-function, and the dominant terms of many of the most famous problems in the analytic theory of numbers, and he had never heard of a doubly periodic function or of Cauchys theorem, and had indeed but the vaguest idea of what a function of a complex variable was. His ideas of what constituted a mathematical proof were of the most shadowy description. All his results, new or old, right or wrong, had been arrived at by a process of mingled argument, intuition and induction, of which he was entirely unable to give a coherent account.

With such a natural genius, Hardy collaborated and tried to teach, as he wrote, *the things of which it was impossible that he should remain in ignorance. It was impossible to allow him to go through life supposing that all the zeroes of the zeta function were real. So I had to try to teach him, and in a measure I succeeded, though I obviously learnt from him much more than he learnt from me* [38].

Hardy did not attempt to convert Ramanujan into a mathematician of the modern school but enabled him to go on producing original ideas in his classical mould with

⁵From the article of Mr. Narayana Iyer’s son [Ref. 18, p.112], Ramanujan had access to a book on Jacobis elliptic functions. Unfortunately, it is not possible to ascertain, from the records of the Library of the University of Madras, what books were available for reference to Ramanujan.

rigorous proofs for the theorems he discovered.

The period of Ramanujan's stay in England almost overlapped with the years in which World War I took place. *One of the lecturers went to war*⁶ wrote Ramanujan [39] to a friend in India and Ramanujan felt that *the other professors . . . lost their interest owing to the . . . war*. One of the professors had remarked that Ramanujan was in England at the most unfortunate time. There were about 700 students before the war, but this number was reduced to 150 by November 1915.

Initially Ramanujan asked for and obtained some South Indian food items (like tamarind, coconut oil, etc.) by post parcel from his home, as well as from a company in London but by January 1915, he wrote [23] to a friend of his in India that *now as well as in the future I am not in need of anything as I gained control over my taste and can live on mere rice with a little salt and lemon juice for an indefinite time*. His difficulty of getting proper food was alleviated by the availability of good milk and fruits. Being a vegetarian he had no option but to cook for himself.

He was attending a lecture by Mr. Berry at the University on elliptic integrals. Mr. Berry was working out some formulae on the black-board and a glance at Ramanujan's face, alight with excitement, caused him to ask Ramanujan whether he was following the lecture and whether he had anything to say. At this Ramanujan went to the black-board and much to everyone's surprise wrote down some of the results which were yet to be proved. This anecdote was recalled by Dr. P.C. Mahalanobis [40], the eminent Indian statistician, who joined King's College, Cambridge, in October 1913, and took a mathematics course by Prof. Hardy. The following is another anecdote about Ramanujan from Dr. Mahalanobis [40]: *I was fortunate in forming a good friendship with Ramanujan very soon. It came about in a somewhat strange way. One day, soon after his arrival, I went to see Ramanujan in his room in Trinity College. It had turned quite cold. Ramanujan was sitting near the fire*⁷. *I asked him whether he was quite warm at night. He said that he was feeling the cold though he was sleeping with his overcoat on and was also wrapping himself up in a shawl. I went to his bedroom to see whether he had enough blankets. I found that his bed had a number of blankets but all tucked in tightly, with a bed cover spread over them. He did not know that he should turn back the blankets and get into the bed. The bed cover was loose; he was sleeping under that linen cover with his overcoat and shawl. I showed him how to get under the blankets. He was extremely touched. I*

⁶Ramanujan was perhaps referring to the departure of Mr. J.E. Littlewood.

⁷Ramanujan's room had electricity and he was provided with a gas stove.

believe this was the reason why he was so kind to me.

Ramanujan wrote a few articles soon after he reached Cambridge and in June 1914, Hardy presented some of the results from Ramanujan's Notebooks at a meeting of the London Mathematical Society. However, in January 1915, Ramanujan wrote [41] to a friend in India that his notebook is sleeping in a corner for these four or five months. Ramanujan was more interested in getting new results (and partly due to the ongoing war), he decided to publish the old results worked out in his Notebooks after the war. After about a year and a half at Cambridge, Hardy wrote to the Registrar of the University of Madras, that Ramanujan *is beyond question the best Indian mathematician of modern times. He will always be rather eccentric in his choice of subjects and methods of dealing with them. But of his extraordinary gifts there can be no questions; in some ways he is the most remarkable mathematician I have ever known.*

Hardy's letter [42] and official report to the University, as well as an appeal by Sir Francis Spring to the University to continue the assistance extended by it to Ramanujan, made the University (in December 1915) extend the scholarship up to March 1919.

Honours

During his five year stay in Cambridge, Ramanujan published 21 research papers containing theorems on definite integrals, modular equations, Riemann's zeta function, infinite series, summation of series, analytic number theory, asymptotic formulae, modular functions, partitions and combinatorial analysis. His paper entitled *Highly Composite Numbers* which appeared in the Journal of the London Mathematical Society, in 1915, is 62 pages long and contains 269 equations. This is his longest paper. The London Mathematical Society had some financial difficulties at that time and Ramanujan was requested to reduce the length of his paper to save printing expenses. Five of these 21 research papers were in collaboration with Hardy. Ramanujan also published 5 short notes in the Records of Proceedings at meetings of the London Mathematical Society and six more in the journal of the Indian Mathematical Society.

Ramanujan was awarded the B.A. degree by research in March 1916 for his work on Highly composite numbers and published as a long paper. Ramanujan's dissertation bore the same title and included six other papers. Ramanujan was registered

as a research student in June 1914 and the prerequisite of a diploma or a certificate, as well as the domiciliary requirement of six terms must have been relaxed in his extraordinary case. It is unfortunate that a copy of this dissertation is not to be found in the records of the University [43]. According to Hardy [44], this work of Ramanujan *is a very peculiar one, standing somewhat apart from the main channels of mathematical research. But there can be no question as to the extraordinary insight and ingenuity which he has shown in treating it, nor any doubt that the memoir is one of the most remarkable published in England for many years.*

Ramanujan's designated tutor who monitored his progress at Trinity College, Cambridge, was E.W. Barnes, who considered Ramanujan as perhaps the most brilliant of all the top Trinity students, which included Littlewood [45]. Hardy was immensely satisfied with the progress of Ramanujan and wrote so to the Registrar of the University of Madras supporting an extension of Ramanujan's two-year scholarship *... until, as I confidently expect, he is elected to a Fellowship at the College. Such an election I should expect in October 1917.* Later, in June 1916, in an official report on the progress of Ramanujan's work in England to the University's Registrar, he wrote: *cdots it is already safe to say that Mr. Ramanujan has justified abundantly all the hopes that were based upon his work in India, and has shown that he possesses powers as remarkable in their way as those of any living mathematicians. ... I have said enough, I hope, to give some idea of his astonishing individuality and power. India has produced many talented mathematicians in recent years, a number of whom have come to Cambridge and attained high academical distinction. They will be the first to recognize that Mr. Ramanujan's work is of a different category.*

In spite of the war which was raging, which deprived Ramanujan of the center stage which he would otherwise have held with his brilliant research work in the midst of his peers, the confidence he kindled in Hardy was enough to win for him recognition and laurels very soon, but, unfortunately, the first signs of illness appeared in Ramanujan in the spring of 1917.

Thanks to the unstinted efforts of Hardy, who did his best to get Ramanujan due recognition, he was elected a Fellow of the Royal Society of London in February 1918. The Records of the Royal Society, dated December 18, 1917, include the following certificate for the candidature of Ramanujan (then a Research student in Mathematics at Trinity College, Cambridge) for election to the Fellowship of the Royal Society⁸:

⁸A copy of this document is an exhibit in the Ramanujan Museum in Royapuram, Madras.

Qualifications (Not to exceed 250 words):

Distinguished as 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 π ', Quarterly Journal, vol. 45; 'New expressions of Riemann's function $\zeta(s)$ and $\chi(t)$ ', ibid, vol. 46; 'Highly composite numbers', Proc. London. Math. Soc., vol. 14; 'On certain arithmetical functions', Trans. Camb. Phil. Soc., vol. 22; 'On the expression of a number in the form $ax^2 + bey^2 + cz^2 + dt^2$ ', Proc. Camb. Phil. Soc., vol. 19.

Joint author with G.H. Hardy, F.R.S., of the following papers: 'Une formule asymptotique pour le nombre des partitions de n ', Comptes Rendus, 2 Jan. 1917; 'Asymptotic Formulae for the distribution of numbers of various types', Proc. London Math. Soc., vol. 16; 'The normal number of prime factors of a number n ', Quarterly Journal, vol. 47; 'Asymptotic Formulae in Combinatory Analysis', Proc. London Math. Soc., (awaiting publication).

being desirous of admission into the ROYAL SOCIETY OF LONDON, we the undersigned propose and recommend him as deserving that honour, and as likely to become a useful and valuable Member.

This nomination was proposed by G.H. Hardy and seconded by P.A. MacMahon. The signatories with 'Personal knowledge' of Ramanujan were, besides Hardy and MacMahon, J.H. Grace, Joseph Larmor, T.J.I.A. Bromwich E.W. Hobson⁹, H.F. Baker, J.E. Littlewood and J.W. Nicholson. Besides these 9 signatures were the signatures of E.T. Whittaker, A.R. Forsyth and A.N. Whitehead, under those who knew him from General Knowledge. This certificate on a printed form of the Royal Society has been filled by hand (and the hand writing appears to be that of Mr. Hardy), delivered at the Apartments of the Society on the 18th Dec. 1917 and read to the Society on the 24th January 1918.

As a consequence, Ramanujan was, awarded on Feb. 28, 1918, the Fellowship of Royal Society, London, and the citation read:

Srinivasa Ramanujan, Trinity College, Cambridge. Research student in Mathematics Distinguished as a pure mathematician particularly for his

⁹Note that E.W. Hobson and H.F. Baker, who had not replied to letters written by Ramanujan from India, being signatories.

investigations in elliptic functions and the theory of numbers.

In recent times¹⁰, I came to know from Prof. R.H. Dalitz, F.R.S., that the signature of Ramanujan is not in the book of the Royal Society. According to Prof. Dalitz: *The book is indexed, so it is just not there. The reason undoubtedly is that he was ill in that period and could not go to the Royal Society to sign it. There are other examples of well-known F.R.Ss who somehow didnt get their signature into the book. That means that he did not ever attend any meeting of the Royal Society; if he had, they would have brought out the book and not let him go until he had signed. Of course, it was also war-time, which meant that there were as few meetings as possible.*

Ramanujan was elected to a Trinity College Fellowship, in October 1918, which was a Prize Fellowship worth £250 a year for six years with no duties or conditions. These awards acted as great incentives to Ramanujan who discovered some of the most beautiful theorems in mathematics, subsequently.

Hardys letter to the Registrar of the University of Madras, Mr. Dewsbury, dated Nov. 26, 1918 [46] struck a hopeful note: *There is at last, I am profoundly glad to say, a quite definite change for the better. I think we may now hope that he has turned the corner, and is on the road to recovery. His temperature has ceased to be irregular, and he has gained nearly a stone¹¹ in weight. The consensus of medical opinion is that he has been suffering from some obscure source of blood poisoning, which has now dried up; and that it is reasonable to expect him to recover his health completely and if all goes well fairly rapidly.*

Ramanujan's symptoms were predominantly night-time fever, loss of weight leading to his emaciated looks and these caused depressions which once drove him to the limit of attempting suicide¹². These symptoms made the doctors consider various diagnosis, at different times: gastric ulcer, malaria, tuberculosis, cancer of the liver, etc. In recent times, with hind sight, vitamin B_{12} deficiency (something unknown to the world at that time) has been diagnosed as a possibility [47]. The recovery alluded to by Hardy in his letter to Dewsbury was obviously the reason why Ramanujan was persuaded to return to India, with the hope that he would soon recover and return to take up the Trinity College Fellowship awarded to him for five years.

¹⁰Private communication by e-mail from Prof. Dalitz, Oxford University, dated March 29, 1996.

¹¹One stone weight is equal to 14 pounds.

¹²A story which was recounted many years after his death, by the Astrophysicist Dr. S. Chandrasekhar, Nobel Laureate, as told to him by Prof. Hardy, and reproduced in Ch. 5 of Ref. 7.

The beginning of the end

After completing nearly five years at Cambridge, early in 1919, when Ramanujan appeared to have recovered sufficiently to withstand the rigours of a long voyage to India, he left England on 27th February 1919 by s.s. Nagoya. Four weeks later on 27th March he arrived at Bombay and soon after at Madras, thin, pale and emaciated, but *with a scientific standing and reputation such as no Indian has enjoyed before*. Professor Hardy who expressed this view [48] also hoped that *India will regard him as the treasure he is*. He urged the University of Madras to make a permanent provision for him to enable him to continue his research work. Again the University rose to the occasion by granting Ramanujan £250 a year as an allowance for five years, commencing from April 1919. He was sent back to India by Hardy with the fond hope that the warmer climate would help complete his recovery from a tubercular tendency.

Most unfortunately his precarious health did not improve, on his return to India. Fevers relapsed and in addition, his wife recalled that he suffered severe bouts of stomach pain too [49]. Ramanujan was subject to fits of depression, had a premonition of his death and was a difficult patient. He spent 3 months in Madras, 2 months in Kodumudi and 4 months at Kumbakonam. When his condition showed signs of further deterioration, after great persuasion, Ramanujan was brought to Madras for expert medical treatment, in January 1920. Despite all the tender attention he could get from his wife who nursed him throughout this period, and the best medical attention from the doctors, his untimely end came on 26th April 1920, at Chetput, Madras, when Ramanujan was 32 years, 4 months and 4 days old. His wife lived with him, after she came of age, only for a year before his departure to England, and looked after him during his illness after his return. Even during those months of prolonged illness he kept on working, though in a reclining position, at a furious pace and kept jotting down his results on sheets of paper. In his last and only letter to Hardy written after his return to India, in January 1920, Ramanujan communicated his original work on what he called ‘mock’ theta functions.

From the available evidence and retrospective diagnosis, Young [59] makes out the case for “hepatic amoebiasis”, a tropical disease contacted by Ramanujan in 1906, as the cause of his terminal illness. His reason as to why this was not recognized at that time is best recounted in his own words: *Hepatic amoebiasis was regarded in 1918 as a tropical disease (‘tropical liver abscess’), and this would have had important implica-*

tions for successful diagnosis, especially in provincial medical centers. Furthermore, the specialists called in were experts in either tuberculosis or gastric medicine. Another major difficulty is that a patient with this disease would not, unless specifically asked, recall as relevant that he had had two episodes of dysentery 11 and 8 years before. Finally, there is the very good reason that, because of the great variability in physical findings, the diagnosis was difficult in 1918 and remains so today: hepatic amoebiasis presents a severe challenge to the diagnostic skills [and] should be considered in any patient with fever and an abnormal abdominal examination coming from an endemic area.

Hardy, who was unaware that the end was to come so soon was shocked when it came prematurely. He was of the view that a mathematician is often comparatively old at 30. For, in his roll-call of mathematicians, Hardy wrote ([50], p.71): *Galois died at twenty-one, Abel at twenty-seven, Ramanujan at thirty-three, Riemann at forty I do not know an instance of a major mathematical advance initiated by a man past fifty*¹³.

Human qualities

In figure he (Ramanujan) was a little below medium height (5ft. 5in.) and stout until emaciated by disease; he had a big head, with long black hair brushed sideways above a big forehead; his face was square, he was clean shaven, and his complexion never really dark, grew paler during his life in England; his ears were small, his nose broad, and always his shining eyes were the conspicuous feature that Ramachandra Rao observed in 1910. He walked stiffly, with head erect and toes out-turned; if he was not talking as he walked, his arms were held clear of the body, with hands open and palms downwards. But when he talked, whether he was walking or standing, sitting or lying down, his slender fingers were for ever alive, as eloquent as his countenance.

The above physical description of Ramanujan was recorded by Prof. E.H. Neville [31]. Ramanujan had only one passion in life – mathematics. He devoted all his time to this subject and its development. Quoting Prof. Neville again [31], Ramanujan

¹³A few examples which can be cited which explode ‘The Myth of the Young Mathematician’ are: Newton’s Principia was written when he was in his mid 40s; when Euler, despite his blindness, produced his three volumes on integral calculus when he was in his 60s; Gauss at 34 proposed his theory of analytic functions; and in more recent times, Cartan, Poincaré, Siegel, Kolmogorov and Erdős exhibited creativity in mathematics in their later years. (Ref. Susan Landau, Notices of the AMS, vol. 44 (1997) p. 1284.)

had an *instinctive perfection of manners that made him a delightful guest or companion. Success and fame left his natural simplicity quite untouched. To his friends he was devoted beyond measure, and he devised curiously personal ways of showing his gratitude and expressing his affection. The wonderful mathematician was indeed a loveable man.*

This is in complete accord with the views of Hardy [1] on Ramanujan:

... the picture I want to present to you is that of a man who had his peculiarities like other distinguished men, but a man in whose society one could take pleasure, with whom one could drink tea and discuss politics or mathematics; the picture in short, not of a wonder from the East, or an inspired idiot, or a psychological fraud, but of a rational human being who happened to be a great mathematician.

The integrity of Ramanujan is transparent from the following statement of Hardy [42]:

All of Ramanujan's manuscripts passed through my hands, and I edited them very carefully for publication. The earlier ones I wrote completely. I had no share of any kind in the results, except of course when I was actually a collaborator, or when explicit acknowledgement was made. Ramanujan was almost absurdly scrupulous in his desire to acknowledge the slightest help.

In a letter to a friend of Ramanujan, in September 1917, Hardy wrote [51]:

He has been seriously ill but is now a good deal better. It is very difficult to get him to take proper care of himself; if he would only do so we should have every hope that he would be quite well again before very long. In this letter Hardy referred to his discovering that Ramanujan *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.* He expressed his anxiety regarding the trouble which might have arisen and wanted it to be cleared away.

Ramanujan was shy by temperament and contemplative by nature. He was a man with a great sense of humour. In the words of Neville [31]:

He had a fund of stories, and such was his enjoyment in telling them that in his great days his irrepressible laughter often swallowed the climax of his narrative.

On learning, after his return to India, that the Government and the University of Madras were insisting on his going to Thanjavur, he punned on the word [52] Thanjavur – by breaking it into three parts anTh ’, ‘s’a’v ’vnd’ ’n Tamil – and quipped that they wanted him to go to ‘Than-savu-v”r, meaning the town of his death! Later when he was shifted to Chetput, he punned on this word, ‘ch”t- ‘put, and said that he was being taken to a place where everything would be ‘very quick’. He also did not like the name of the building ‘Crynant’ where he was staying in Chetput stating that the ‘Cr’y in the word did not augur well and got himself shifted to another building ‘Gometr’a (which is the home where he breathed his last on April 26, 1920).

Ramanujan was very affectionate towards his brothers and his mother, in particular. His wife recollected [53] that he knew astrology and made astrological predictions to some extent and that he knew he would not live beyond 34 years. Sometimes, he is supposed to have made predictions for others also. He told her [54], after his return from England, that he felt very happy when the Editor of *The Hindu*, Mr. Kasturiranga Iyengar, went to his room and partook the pongal¹⁴ prepared and served by him. In later years, Janakiammal told several who visited her that Ramanujan was confident his mathematics would provide her with funds, even after his death.

Some friends of Ramanujan have remembered [55] that Ramanujan could foresee events in visions; that being an ardent devotee of Lord Narasimha he saw drops of blood in dreams (which was considered as a sign of the Lord’s grace) and that *after seeing such drops, scrolls containing the most complicated mathematics used to unfold before him, and these he set down on paper on waking only a fraction of what was thus shown to him.*

Ramanujan’s maternal grandmother was a staunch devotee of Goddess Namagiri of Namakkal. Ramanujan himself was known to his friends to be a devotee of the Goddess of Namakkal and he used to say that the Goddess appeared in his dreams and inspired him to come forth with new formulae¹⁵.

Prof. K. Ananda Rao was at Kings College, when Ramanujan was at Trinity College, and he recalled [56], in 1962, that:

¹⁴A South Indian delicacy prepared with rice, greengram, ghee, pepper, jeera and cashew nuts.

¹⁵This was probably his way of explaining away his incomparable intuition and success, to those who could not comprehend his ability to churn out continuously new results but who persisted in questioning him as to how he arrived at those results!

In his nature he was simple, entirely free from affectation, with no trace whatever of his being self-conscious of his abilities. He was quite sociable, very polite and considerate to others.

Ramanujan never forgot that as a first born he had to shoulder the responsibility of taking care of his parents. He was compassionate. Accepting the University's offer of a scholarship, he wrote to Mr. Francis Dewsbury, the Registrar of the University of Madras, in a letter [57] dated 11th January 1919, from a nursing home in Putney:

I feel, however, that after my return to India, which I expect to happen as soon as arrangements can be made, the total amount of money to which I shall be entitled will be much more than I shall require. I should hope that, after my expenses in England have been paid, 50 a year will be paid to my parents and that the surplus, after my necessary expenses are met, should be used for some educational purpose, such in particular as the reduction of school-fees for poor boys and orphans and provision of books in schools. No doubt it will be possible to make an arrangement about this after my return.

I feel very sorry that, as I have not been well, I have not been able to do so much mathematics during the last two years as before. I hope that I shall soon be able to do more and will certainly do my best to deserve the help that has been given to me.

Ramanujan concluded a letter [58] to Mr. Narayana Iyer, in November 1915, with the following words of gratitude:

I am ever indebted to you and Sir Francis Spring for your zealous interest in my case from the very beginning of acquaintance.

I would like to conclude this lecture with the following assessments of Ramanujan and his work (Bruce Berndt [60]):

- *In notes left by B.M. Wilson, he tells us how George Polya was captivated by Ramanujan's formulas. One day in 1951 while Polya was visiting Oxford, he borrowed from Hardy his copy of Ramanujan's notebooks. A couple of days later, Polya returned them in almost a state of panic explaining that however long he kept them, he would have to keep attempting to verify the formulae therein and never again would have time to establish another original result of his own.*

Neville began a broadcast in Hindustani, in 1941, with the declaration :

- *Srinivasa Ramanujan was a mathematician so great that his name transcends jealousies, the one superlatively great mathematician whom India has produced in the last thousand years.*

Commenting on the quality of the theorem's in the 'Lost' Notebook, Richard Askey says:

- *Try to imagine the quality of Ramanujan's mind, one which drove him to work unceasingly while deathly ill, and one great enough to grow deeper while his body became weaker. I stand in awe of his achievements; understanding is beyond me. We would admire any mathematician whose life's work is half of what Ramanujan found in the last year while he was dying.*
- *Paul Erdős has passed on to us Hardy's personal ratings of mathematicians: Suppose that we rate mathematicians on the basis of pure talent on a scale from 0 to 100, Hardy gave himself a score of 25, Littlewood 30, Hilbert 80, and Ramanujan 100. (Berndt [60]).*

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23. Ref. [21], p. 17.
24. C.P. Snow in his Forward to G.H. Hardy's *A Mathematician's Apology*, Cambridge University Press (1976), p.30.
25. According to C.P. Snow, Hardy was not the first eminent to be sent the Ramanujan manuscripts. There had been two before him, both English, both of the highest professional standard. They had each returned the manuscripts without comment. I don't think history relates what they said, if anything, when Ramanujan became famous. As for their identity, Snow adds that: out of chivalry Hardy concealed this in all that he said or wrote about Ramanujan. (p.33 of [24]). However, the names are given by A. Nandy (in *Alternative Sciences*, Allied Publishers, New Delhi, 1980) who claims the two to be H.F. Baker and E.W. Hobson.(also see [3] p.3).
26. C.P. Snow in his Rectorial Address delivered before the University of St. Andrews, Scotland, on 13th April 1962.
27. Ref. [1], p.9.
28. Ref. [3], p. 157-1158
29. Ref. [3], p.55.
30. Refer Bruce C. Berndt and Robert A. Rankin: *Ramanujan: Letters and Commentary*, ref. [21], for these and other letters referred to.
31. E.H. Neville, in ref. [3], p. 138-1141
32. E.H. Neville to Dewsbury, ref. [3], p. 59-660.

33. Littlehailes to Dewsbury, in ref. [3], p. 61-66.
34. Sir Francis Spring to C. B. Cotterell, in ref. [3], p. 64-665
35. Letter 2 to R. Krishna Rao, in ref. [3], p. 4-7.
36. *Srinivasa Ramanujan*, J.R. Newman, in *Mathematics in the modern World*, W.H. Freeman & Co. (1968) 73-76.
37. Ref. [2], p. xxx.
38. Ref. [8], p. 226.
39. Letter 4 to R. Krishna Rao, in ref. [3], p. 12-119.
40. Letter 1 to S.M. Subramanian, in ref. [3], p. 20.
41. P.C. Mahalanobis, in ref. [3], p. 145-148. Also, in *Ramanujan: The Man and the Mathematician*, S.R. Ranganathan, Asia Publishing House, 1967, p.81. (MN1).
42. G.H. Hardy to Dewsbury, in ref. [3], p. 76-777
43. Ref. [21], p. 137.
44. Ref. [2], p. 499.
45. Ref. [8], 233.
46. Ref. [21], p.199.
47. R.A. Rankin, Ramanujan as a patient, *Proc. Indian Acad. Sci., Math. Sci.* vol. 93 (1984) 79-1100
48. G.H. Hardy to Dewsbury, in ref. [3], p. 76-777
49. Janaki Ramanujan in [9].
50. G.H. Hardy: *A Mathematician's Apology*, (with a Foreword by C.P. Snow), Cambridge Univ. Press (1976), first published in 1967.
51. G.H. Hardy to Subramanian, in ref. [3], p. 68-775
52. Ref. [9], p.93. (N22).

53. Janaki Ramanujan, in ref. [3], p. 159-1161 (in Tamil), p. 17- 172 (English translation).
54. Reminiscences of Janaki Ramanujan, in ref. [9], p.89-991. (MT- MT7
55. T.K. Rajagopalan, in ref. [3], p. 167 and in ref. [9], p. 87; R. Srinivasan, in ref. [3], p. 165 166; R. Radhakrishna Ayyar, in ref.[4]9, p.73
56. K. Ananda Rao, in ref. [3], p. 143-144.
57. Copy of Ramanujan's letter to the Registrar, University of Madras, in ref. [9], plate 6, between pages 104-1105. Also reproduced in ref.[]2, p.xix
58. Letter to Narayana Iyer, in ref. [3], p. 32-333
59. D.A.B. Young, Ramanujan's illness, Current Science vol.67 (1994) p .967 - 972.
60. *Ramanujan's Notebooks*, Part I, Bruce C. Berndt, Springer-verlag (1975).