Beginnings of modern mathematics in India

Joseph W. Dauben[1,*] and Rohit Parikh[2]

[1]Research Center for Humanities and Social Sciences, National Chiao-Tung University, 1001 University Road, Hsinchu City, 30010 Taiwan
Department of History, Herbert H. Lehman College, CUNY; and Ph D Program in History, The Graduate Center,
The City University of New York, 365 Fifth Avenue, New York, NY 10016, USA
[2]Department of Computer Science, Brooklyn College, CUNY; and Ph D Programs in Computer Science, Mathematics and Philosophy,
The Graduate Center, The City University of New York, 365 Fifth Avenue, New York, NY 10016, USA

Introduction

INDIA has a long and venerable tradition in mathematics (see note 1). Its most basic and influential contribution was the place-valued decimal number system, but there is much more to the story of Indian mathematics than that, especially following the recovery of Indian intellectual life in the second half of the 19th century. Under British governance, universities were established in Calcutta, Madras and Bombay in 1857. These were meant primarily to train Indians to enter the colonial bureaucracy as adjunct administrators under British rule, largely to serve the requirements of various government agencies and the judicial system (see note 2). Higher education in India was not expected, therefore, to produce mathematicians, research scientists or creative academics. In fact, 'independent thinking was regarded as a needless luxury and was often actively discouraged'. What the British wanted were well-trained civil servants – not independent-thinking scholars[1].

Indian universities were patterned on the model of the University of London. This meant that they were decentralised, comprised of separate colleges where 'the teaching was onerous and the opportunity to influence students limited' (see note 3). Pay was poor and could not hope to attract the best minds. Worse, those who came from Britain to oversee the universities 'were the less successful products of the British system'[2]. This was especially detrimental in the case of mathematics:

> The large majority of the mathematicians who came to India did no research of their own, encouraged none in others, and transmitted a constipated view of mathematics to those with whom they came into contact. These same men were also often placed at the head of entire education programs for the provinces (large states into which India was then divided)[2].

This unfortunate state of affairs was not helped by the fundamentally passive nature of the Indian student:

> The negative effects of the British system in India were made worse by the Indian mentality. There was a passiveness, not to say fatalism, among even the intellectual elite. However well Indians might follow a trail already blazed, there were few who were ready to take the risks of striking out on their own[2].

The one British mathematician who may be said to have had a brief but positive effect on mathematics in India at the beginning of this century was W. H. Young, who was especially interested in real analysis and the new set theory developed by Georg Cantor. Young had studied at Göttingen where he lived with his wife, the mathematician Grace Chisholm Young, from 1897 to 1912 (ref. 3). Independently of Lebesgue, Young developed a similar theory of the integral and did important work on Fourier series as well (the Young–Hausdorff inequality is one of Young's noteworthy achievements). In 1913, unable to find a suitable full-time position in Europe, he accepted a position in Calcutta, teaching there every winter for three years while teaching Philosophy and History of Mathematics at the University of Liverpool each spring. Young gave up his position at the University of Calcutta in 1916, and finally settled as Professor of Pure Mathematics at Aberystwyth in 1919.

Calcutta University was fortunate in having an especially insightful and sympathetic Vice Chancellor, Sir Asutosh Mookerjee, who was himself profoundly interested in mathematics. Although he was a lawyer by profession (and from 1904 a judge of the Calcutta High Court), he found time to publish a few papers of his own on algebraic curves and differential equations. When he was appointed Vice Chancellor of Calcutta University in 1906, Mookerjee was determined to encourage research and support the best mathematicians that could be found. Not only did he bring such talented Indian mathematicians to Calcutta as S. Mukhopadhyay and N. R. Sen, he was instrumental in helping to establish the Calcutta Mathematical Society in 1908.

In the first quarter of the 20th century, Indian exposure to Western science resulted in two notable geniuses, S. A. Ramanujan (1887–1920) and the Nobel prize-winning physicist, C. V. Raman (1888–1970). Mathematicians the world over know of Ramanujan and his extraordinary talents (see below). Nevertheless, the history of mathematics in India in the 20th century is not primarily the story of unusual exceptions, of isolated individuals, but of the collective efforts of an entire nation to pursue

*For correspondence. (e-mail: jdauben@gc.cuny.edu)

excellence, not only for the sake of pursuing mathematics at the very highest levels, but for the sake of teaching the next generations to be even better mathematicians than their predecessors. Remarkably, at the beginning of the century, two outstanding institutions appeared in India at virtually the same time, both dedicated to promoting mathematics in India in as serious and professional a way as possible.

Founding of the Indian Mathematical Society

The professional history of mathematics in India in the 20th century may be said to coincide with the founding of the Indian Mathematical Society in 1907. Remarkably, this was not the result of mathematicians teaching in India, but was due to the efforts of V. Ramaswami Aiyar a civil servant (he was Deputy Collector at Gooty) who encouraged a few friends to join him in creating a group to promote their mutual interests in mathematics (see note 4). It was on Christmas Day, 25 December 1906, that he made the following brief proposal:

> I believe several friends interested in mathematics have felt the present lack of facilities for seeing mathematical periodicals and books. This is a very great disadvantage we are suffering from. I propose, therefore, that a few friends may at once join and form a small mathematical society and subscribe for all the important mathematical periodicals, and as far as possible, for all important books in higher mathematics. We may call the society 'The Analytic Club' for the present and have it in view to give it a broader basis with a suitable name by and by. Our work immediately will be to obtain all the important periodicals and new books and circulate them to members (see note 5).

Aiyar's idea for a Society in India was inspired by the Edinburgh Mathematical Society. In 1895, when he joined the staff of the Maharaja's College in Mysore, J. Weir (who was Principal of the College and also Professor of Mathematics) made Aiyar his assistant and nominated him for membership in the Edinburgh Society. '*The Proceedings of the Society*, which I received, gave me my first glimmer of hope that a Mathematical Society like the Edinburgh could, perhaps, be formed in India'[4]. But by the end of the year, Aiyar had passed a Civil Service Examination and left teaching to accept a post as Deputy Collector in Madras.

A decade later, 1906 was a fateful year for India, science and the Indian Mathematical Society:

> There was a feeling in India that it was the time of a large awakening. There was considerable political agitation then, owing to the partition of Bengal. But men also saw that, before India could become great, we needed advancement in many different directions. Our great countryman, Sir J. N. Tata, had these problems in mind and had laid the foundation of a considerable industrial and intellectual advancement. But his great scheme of a Central Research Institute for India made no provision for mathematical advancement. One day I put myself the question 'Can I not be of some help in advancing the interests of Mathematics in India'. The spirit of the times made me think seriously about the question[5]. . .

With the Edinburgh Society still in mind, Aiyar took the faculty lists from the universities in Madras and Bombay, and wrote to everyone who had taken the M.A. degree or a first class B.A., or who were teaching in the various colleges. As he recalls:

> The list was encouraging. There were men of distinction like Dastur, Sanjana, Apte and Paranjpye in the Bombay Presidency. There were men like Hanumantha Rao, my own teacher Swaminatha Aiyar, Ramachandra Rao, Naraniengar, Ramesam, Venkataswami Naidu, and so on, in my Presidency. On perusal of the long list, it occurred to me that, if by some magic, I could only put all these names into a Society, then, with Euclid, I might say, Q.E.F. (what is required is now done)[5].

Having just seen a copy of the *Quarterly Journal of Mathematics*, he also began to wonder 'how many such delightful bits, we in India may be missing by not seeing the leading journals. This made me more eager than ever to try to form a Mathematical Society'. As a result, Aiyar was inspired to write his brief letter of 25 December 1906, to which the response was well beyond anything he had expected:

> It was V. Ramaswami Aiyyar, then Deputy Collector at Gooty, who in 1907 addressed a few friends interested in Mathematics for securing facilities for advanced study in the subject by way of Mathematical books and journals. About twenty gentlemen responded and the formation of the 'Analytical Club' was announced in the Madras Papers on the 4th of April 1907. From the very outset the non-parochial and universal character of the Society was in evidence. These first twenty foundation members consisted of two men in revenue service, two Engineers, a Superintendent in the Accountant General's Office, while the rest were teachers in Colleges. Classifying by provinces, there were three Professors from the Bombay Presidency, and the remaining 17 from Madras (see note 6).

Initially, the Analytical Club directed its energies primarily to collecting journals and establishing a reference library for mathematics. To keep members informed, bi-monthly 'progress reports' were circulated which also

Frontispiece to the Silver Jubilee commemorative volume of the *Journal of the Indian Mathematical Society*, 1933, **20**, facing p. 7.

contained original questions set by members. Soon original articles were included – the first in October of 1908, by R. P. Paranjpye, 'On the Cardioide', and another by M. T. Naraniengar on 'The Nine Points Circle'. As more and more members sent in questions and solutions, as well as articles for the 'progress reports', the Managing Committee finally agreed to issue a regular journal. The first issue appeared in February of 1909 as *The Journal of the Indian Mathematical Club* (under the editorship of M. T. Naraniengar, Professor of Mathematics at the Central College in Bangalore) (see note 7). By then, the membership had climbed to a total of 79.

In its early years the Analytical Club was headquartered at Fergusson College in Poona (Bombay Presidency) (see note 8). The College's Principal, R. P. Paranjpye was made an honorary member of the Society and agreed to serve as Honorary Librarian. Poona itself was an auspicious choice – as the Society acknowledged in honoring the efforts of Ramaswami Aiyar in founding the Society: 'It may not be out of place to mention that with the true scholar's freedom from provincial bias, you, a Madrasi, arranged to locate the Head-quarters of the Society at Poona, in the Bombay Presidency – a step which gave our Society the unique position of being an All-India Institution'[6].

Interest in advancing mathematics in India was not limited, however, to Madras and Bombay. As Ramaswami Aiyar, in his own reflections of the history of the Indian Mathematical Society, later recalled:

> When our Society was formed in 1907 its membership was confined to the Madras and Bombay areas. But soon afterwards Mr Balak Ram was introduced as a member by Dr Paranjpye. Mr Balak Ram was a fine product of the young University of Punjab, and, ever since he joined, he has been a pillar of strength to our Society. He soon got in for us many members from Punjab. The Calcutta Mathematical Society was under formation at the time and there were reasons to fear that the Punjab area would go over to the Calcutta Society as Punjab formed a part of the extensive area of the old Calcutta University. But Mr Balak Ram made that area safe for our Society. He has performed for us the mathematical annexation of the Punjab (see note 9).

Within a few years the library was sufficiently successful in gathering both books and journals that it was necessary to employ two assistant librarians. By 1909 the library consisted of two large book cases, about 250 books, and about 150 volumes of journals. Of the latter, the library regularly received about 30, virtually all of which were obtained through exchanges for the Society's own *Journal*. By 1932 the library had grown to a total of 450 books and 1775 bound volumes of periodicals. By then the Society was receiving nearly 50 journals, nearly 30 of which were still in exchange for the Society's journal – making it an even more valuable commodity for the Society than merely a means of communicating mathematical results among its members[7].

Within just three years of the formation of the Analytical Club, it had a membership of 126 and had changed its name three times, finally deciding to reflect its diversity as the Indian Mathematical Society, with a new constitution adopted in 1911. Leading supporters of the Society were Paranjpye, Wilkinson, Dewan Bahadur Ramachandra Rao and Balak Ram. Among its early Presidents (all of whom were pictured in a photo-montage at the beginning of the Jubilee volume), some were local administrators with an interest in mathematics, others were mathematicians or school principals. The Society's first president, B. Hanumanta Rao (1907–1912), taught mathematics at the Engineering College at Madras. Among early Presidents were R. N. Apte (1912–1915); E. W. Middlemast (1915), who had served as Principal of Presidency College in Madras; Dewan Bahadur Ramachandra Rao (1915–1917), a secretary to the Madras Government; A. C. L. Wilkinson (1917–1921), Principal of the Deccan College; as well as H. Balak Ram (1921–1926), V. Ramaswami Aiyar (1926–1930), M. T. Naraniengar (1930–1932), and P. V. Seshu Aiyar, who was elected to the presidency of the Society in 1932.

Equally a sign of the growing importance of mathematics in India, by 1932 membership in the Society had grown to 300 and included every province in India, as well as members living abroad and a few honorary members like Professors Whittaker, G. H. Hardy, G. A. Miller and Sir C. V. Raman. Of these, it was estimated that most, nearly 250, were engaged in teaching mathematics at one level or another. In addition to publishing its *Journal*, the primary work of the Society was the organization of Biennial Conferences and maintenance of the Society's central library at Poona, which was responsible for circulating books and periodicals among members of the Society.

Unfortunately, the Society's first attempt to arrange a meeting (in 1913) failed for a lack of members willing to present papers. This was considered an essential part of any meeting, and three years later, when the idea arose again, a lack of original papers again seemed to preclude an actual meeting. When Rao Bahadur P. V. Seshu Aiyar (Iyer) offered to organise the meeting if it were held in Madras, he also undertook to solicit a dozen papers for the meeting, and the success of his efforts led to the first Conference of the Society held in Madras in December 1916. Not only was the meeting 'satisfactorily' attended, but thirteen original papers were presented. In turn, the Conference stimulated a number of members to produce original papers for presentation, 'and the Editor of the journal too was glad to find in these papers enough matter for the journal for at least a year'. In fact, the results of the meeting were so productive, not only for the Society's members but for its journal as well, that it was decided such meetings should be held every two years. When the Society celebrated its 25th anniversary in 1932 in

Bombay, 94 conferees attended the meeting and heard 35 papers read.

The Calcutta Mathematical Society

There could be no better sign that India was ready to devote serious attention to mathematics on a national scale than the fact that at virtually the same time, two mathematical societies were founded in very different parts of the country, the first centered around Bombay, the second on Calcutta. Having already met in 1908, the first volume of the *Journal of the Calcutta Mathematical Society* reported its 'third Monthly Meeting' (held on 23 January 1909) at the Senate House. The Honourable Mr Justice Asutosh Mookerjee was announced as President of the Society, six new members were proposed for membership, including its first woman, Snehalata Maitra, and the gift of 57 books to the Society was gratefully acknowledged. The Society met monthly, in Senate House, where generally one or two papers would be presented for discussion (for example, at the February meeting, Ganesh Prasad presented a brief account of solutions of partial elliptic differential equations)[8]. The Society's major undertaking was publication of its journal, the *Bulletin of the Calcutta Mathematical Society*, which unlike its counterpart administered from Poona, was devoted strictly to publication of research papers in mathematics. It did not carry notices of meetings, book reviews, research problems and their solutions, news of the profession, or any material other than occasional reports of the Annual General Meetings of the Society.

Ganesh Prasad (1876–1935)

Prasad, 'one of the earliest influential figures in Indian mathematics', studied in Cambridge and Göttingen before returning to India where he first taught briefly in Allahabad. From 1905 to 1923 he taught in Benares, where he founded the Benares Mathematical Society. In 1923 he accepted a position in Calcutta, and succeeded Sir Asutosh Mookerjee as President of the Calcutta Mathematical Society.

Much of Prasad's mathematical work was in the British tradition, on potential theory and the summability of Fourier series, although he also wrote papers on differential geometry and surfaces of constant curvature. He was among the first to bring continental influences to India from his studies in Europe, and was considered 'a very powerful figure in mathematical circles'[2].

One of Prasad's best students, B. N. Prasad (1899–1966) also studied abroad (in Liverpool and Paris), and also worked primarily on Fourier series. But more than his teacher, he recognized the shortcomings of the British educational system, and instead, advocated that schools in India should be modelled on the French example of the Ecole Normale Supérieure in Paris. From 1932 to 1946 he taught as a lecturer in Allahabad, was then promoted to Reader and later, in 1958, to Professor shortly before his retirement. Given his lifetime commitment to Allahabad, it is not surprising that he was the founder of the Allahabad Mathematical Society.

In addition to Ganesh and B. N. Prasad, the University of Allahabad also claimed among its foremost applied mathematicians V. V. Narlikar and A. C. Banerji (1891–1968). Narlikar, primarily interested in mathematical physics and relativity theory, taught primarily at Benares; Banerji taught at Allahabad from 1930 to 1952, where he also served as Vice Chancellor of the University.

Srinivasa Aaiyangar Ramanujan, FRS (1887–1920)

The English mathematician and great number theoretician, G. H. Hardy, described Ramanujan as a mind of 'profound and invincible originality':

> . . . a man whose career seems full of paradoxes and contradictions, who defies almost all the canons by which we are accustomed to judge one another, and about whom all of us will probably agree in one judgment only, that he was in some sense a very great mathematician[9,10].

Ramanujan, from a poor but Brahmin family, was educated at his local high school in Kumbakonam, where he placed first in the Tanjore province primary examination in 1897. But it was a borrowed copy of George Shoobridge Carr's *Synopsis of Pure Mathematics*, which he read for the first time in 1903, that served to awaken his interest in mathematics: 'From then on, mathematics was nearly his only interest. He jotted down his results in a notebook which he carried with him and showed to people who were interested'[14].

Ramanujan was especially adept at numerical calculation, and had an uncanny memory for numbers. But his English was poor and his nearly exclusive preoccupation with mathematics kept him from successfully completing his education. Although he passed the entrance examination of the University of Madras and obtained a 'first class' place, he repeatedly failed examinations that would have allowed him to continue his studies either at the Government College in Kumbakonam (where he won the Subrahmanyam scholarship), or at Pachaiyapa's College in Madras (from which he dropped out due to illness)[12]. In 1910, his teacher K. S. Patrachariar sent Ramanujan to Ramaswami Aiyar (then at Tirukoilur), knowing that Aiyar would be better able to appreciate Ramanujan's abilities. Ramanujan stayed with Aiyar for three days, giving Aiyar an opportunity to examine 'those remarkable notebooks in which he had recorded the numerous results of his discovery. There was little or no explanation given but the results were of a very striking character. I put him some test questions in order to find out if his methods were really based on sound principles'[4]. Convinced that they were, Aiyar asked Ramanujan if there was anything he might do to help:

> [Ramanujan] said he was badly in need of employment and suggested that I might put him as a teacher in one of the elementary Schools belonging to the Taluk Board of which I was President. I told Ramanujan that it would be sacrilege on his talents to put him to teach in an Elementary Board School but that I had been thinking out if I could not be of help to him in a real manner[4].

Meanwhile, he sent Ramanujan to Dewan Bahadur R. Ramachandra Rao (who later served as President of the Society (1915–1917) and was a 'relatively wealthy' mathematician), hoping that in the meantime he might be able to find a menial clerkship for Ramanujan[12]. Rao describes the subsequent interview he had with Ramanujan in vivid terms:

> 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 opened his book and began to explain some of his discoveries. I saw quite at once that there was something out of the way; but my knowledge did not permit me to judge whether he talked sense or nonsense. Suspending judgment, I asked him to come over again, and he did. And then he had gauged my ignorance and showed me some of his simpler results. These transcended existing books, and I had no doubt he was a remarkable man. Then, step by step, he led me to elliptic integrals and hypergeometric series and at last his theory of divergent series not yet announced to the world converted me. I asked him what he wanted. He said he wanted a pittance to live on so that he might pursue his researches[13].

Rao supported Ramanujan for several years in Madras while trying (but failing) to secure a government fellowship for him (see note 10). In 1912, Narayana Aiyar found a clerkship for Ramanujan in the Port Trust Office (of which he was the manager), where his mathematical talents were soon discovered:

> Sir Francis Spring, President of the Port Trust, and Dr G. T. Walker, FRS, came to discover that there was a mathematical genius rotting in the Port Trust Office and, thanks to their intervention, the Research Scholarship that I had anxiously hoped for was eventually secured for Ramanujan. After becoming a Research Scholar, Ramanujan became the architect of his own further advance by those first letters that he wrote, to Prof. Hardy, giving some hundreds of his results. These led Prof. Hardy to realize that Ramanujan was a mathematician of a high order, and he warmly took the steps required to get Ramanujan to go over to England for study and made his genius world known[4].

Discovery of the great South Indian mathematician, S. Ramanujan, was considered 'the proudest achievement of the (Indian Mathematical) Society'[5]. His contributions to the Society's *Journal* first appeared in 1911, and his first article on 'Some properties of Bernoulli's numbers', in the words of the journal's founding editor, M. R. Ry. M. T. Naraniengar Avergal, 'attracted considerable interest' (see note 11). Similarly, it was results on the distribution of primes and other discoveries in difficult areas of number theory that attracted Hardy's interest. Meanwhile, Ramanujan had been offered a scholarship to attend the University of Madras, where he could devote his efforts full-time to mathematics.

One stipulation of the scholarship was that Ramanujan write quarterly reports about his work, of which he submitted three before he left for England (see note 12). The following year, however, the English mathematician E. H. Neville was lecturing at the University, and while there managed to convince Ramanujan to accept Hardy's offer of a place at Cambridge. Because he was devoutly religious, Ramanujan was reluctant to leave India, especially over the objections of his mother. But according to Seshu Aiyar and Ramachandra Rao[13], after Ramanujan and his mother had premonitions in which the goddess Namagiri appeared to them in dreams, they believed she sanctioned his going to England. Consequently, supported by a 'very favorable fellowship'[14], Ramanujan went to Trinity College, Cambridge, where he began to make rapid progress under the influence of Hardy and Littlewood. Over the next five years he published 21 papers (some of them jointly with Hardy).

Ramanujan had a special talent for the formal manipulation of infinite series, especially asymptotic and divergent series, and he developed a theory of the latter based upon the Euler–Maclaurin summation formula, one of Ramanujan's favourite tools (see note 13). He devoted considerable attention to integrals and continued fractions, combinatorial properties of numbers – including construction of magic squares – series inversions, iterations of the exponential function, Eulerian polynomials, Bernoulli Numbers and the Riemann Zeta Function. Ramanujan also made significant contributions to the theory of divergent series, sums related to the harmonic series or the inverse tangent function, analogues of the gamma function, infinite series identities, transformations and evaluations, as well as representations of integers as sums of squares and lattice points inside the circle. In addition to his strictly number theoretic work (much of it analytic number theory, including study of composite numbers and prime divisors), the results that stimulated greatest interest dealt with the partition of numbers based on congruences and the powers of primes. A joint paper written with Hardy on the asymptotic value $p(n)$ of the number of partitions of a given number n was especially remarkable, 'since not only did their formula give good approximations to the values already calculated but also seemed to give an exact expression for $p(n)$' (see note 14).

His work on theta functions was especially remarkable. As the German mathematician Frobenius explained:

> In the theory of theta functions it is easy to establish an arbitrarily large set of relations; however, the difficulty starts when the question is to find a way out of this labyrinth of formulas (see note 15).

Ramanujan must have had some method for generating the formulas he discovered. Possibly he knew some (possibly all) of Schröter's formulas for modular equations, but he must have had more general formulas in mind as well since what he achieved went well beyond what can be deduced using Schröter's methods alone[12]. Ramanujan once described his methods to his colleague P. C. Mahalanobis when the two were in Oxford. Mahalanobis had posed a problem in combinatorics; what amazed him was the way in which Ramanujan gave his answer – not in terms of a specific solution for the problem, but instead, as a very general solution based on a continued fraction. How, he asked, had Ramanujan done it? Ramanujan replied:

> Immediately I heard the problem [said Ramanujan] it was clear that the solution should obviously be a continued fraction; I then thought, Which continued fraction? And the answer came to my mind[15].

As George Andrews remarks, Ramanujan carefully studied what are now called the Rogers–Ramanujan identities, as well as continued fractions, especially the 'glorious' Rogers–Ramanujan continued fraction; somewhere there must have been a master formula by which Ramanujan managed to generate his results. And yet, despite the attempts of many mathematicians since to discover what those more general methods might have been, they remain elusive (see note 16).

In 1918, Ramanujan was made a Fellow of Trinity College and elected to the Royal Society. But, the year before, stricken by a mysterious illness, he had progressively begun to lose weight and energy. Although admitted to a variety of sanatoria in England, due to World War I Ramanujan was not able to return to India until 1919, when he finally returned to Madras. There he continued to work on q-series and produced his 'lost notebook'[14,16]. A stipend of £ 250 had been arranged for him at the University of Madras, but by then his health had deteriorated considerably and his refusal to follow any medical advice led to his death a year later, in April of 1920, at the age of 32. Apart from his mathematical results, Ramanujan's greatest legacy was the example he set for other young students in India, which 'encouraged many talented Indians to choose a risky career in Mathematics in preference to seeking a more lucrative and secure future in other professions'[17].

Indeed, the case of Ramanujan is a story of success in spite of itself, for his remarkable discoveries were basically autodidactic until he reached Cambridge. His genius was basically neglected, lost to a system that failed to encourage his efforts. And yet his remarkable discoveries showed what an individual of determination might achieve, despite the adversity of his local circumstances. Thanks to Ramanujan, Indians ever after could feel a sense of pride, confident that mathematics was indeed an area in which it was possible to excel in the modern world:

> Ramanujan's emergence was a watershed for another important reason. It showed (to anyone who was willing to think) that important and even beautiful things could be done in an environment where power was in unsympathetic and uncomprehending hands, and where creative isolation was pervasive. It broke down the psychological barriers and captured the imagination of many. I do not think it is entirely accidental that great scientific personalities like Raman, Bose, Harish-Chandra and Radhakrishna Rao rose within a couple of decades of Ramanujan[1].

Fifth Conference of the Indian Mathematical Society, Bangalore, 1926

More than 40 mathematicians attended the Fifth Conference of the Indian Mathematical Society held at the Central College of Bangalore in April 1926. Greetings were sent by the Maharaja of Mysore and the work of two students abroad, R. Vaidyanathaswami, awarded a D.Sc. from St Andrews University, and G. S. Mahajani, who won the Smith's Prize at Cambridge, were warmly mentioned[18].

Remarkably, showing the Society's very Eurocentric focus, in its 'Consolidated Progress Report for 1925–1926' twelve journals were listed as 'up-to-date' in the Society's library in Poona – eight were French, three German, along with the Swedish journal *Acta Mathematica*. Remarkably, no British nor American journals were mentioned, although the library did subscribe to nearly a dozen English and American periodicals; the Carnegie Institute in Washington DC was also mentioned for contributing nearly a dozen new books to the Society's library (see note 17).

In a welcoming address comparing Indian mathematics with the best in Europe, both pure and applied, Brajendranath Seal, Vice Chancellor of Mysore University, noted that the former Ramanujan was an exemplar, as were Raman and Meghnad Saha, for applied mathematics:

> Indeed, the cultural environment in Bengal appears to favour the application of mathematical functions to physical problems – that in Madras favours the delight in pure forms and their rhythmic procession. But of one thing I am certain, the two most original advances in the Mathematics of today lie in directions which have a peculiar fascination for the Indian mind. On the one hand, the Logic of Mathematics, with special reference to the concept of class as applied to numbers, as well as the entire development of numbers, sets of points, aggregates and fields (after Cantor and Dedekind); on the other hand, the Relativity Theory with reference to space-time and the four-dimensional world (see note 18).

André Weil in India: the French Counterbalance to British influence

It was in 1929 that André Weil first met Syed Ross Masood, in Paris. Masood had just accepted the Vice-Chancellorship (Presidency) of the Aligarh Muslim University, not far from New Delhi. The University, founded by his grandfather, had been in a state of decline which Masood was expected to reverse. Although it was well-known throughout Muslim India, Masood was determined to bring the University to international attention, and the best way to do that, he was convinced, was to counterbalance British influence by creating a chair for French civilization, which he promptly offered to Weil. Remarkably, after waiting several months with no word from Masood, Weil suddenly received a cable from India: 'Impossible create chair French civilization. Mathematics chair open. Cable reply'[19].

Weil was soon in Aligarh, expected to teach basic mathematics and prepare a report on the University's Department of Mathematics, upon which the fates of his four colleagues (one professor, one reader and two lecturers) would depend. Not only was Weil concerned about the quality of the staff, he believed the entire curriculum needed serious revision. Weil only retained the reader and one of the lecturers. The problem subsequently was to find their replacements[19].

As luck would have it, of one hundred applicants, one stood out – Triukkannapuram Vijayaraghavan – a student of Hardy's at Oxford. Vijayaraghavan had no degree but several publications on approximation and Tauberian theorems. 'His impeccable Oxford English, which he spoke with a slight Madras lilt, and his no less impeccable turban of raw silk made him acceptable to everyone'[19]. A Brahmin from the Tamil-speaking part of southern India, he was 'a very sharp mathematician, doubtless overly influenced by Hardy; but having no diploma, he hardly stood a chance of obtaining a post in any Indian university, much less in a Muslim university like Aligarh, but for the happy accident of my presence there'[19]. Together, Vijayaraghavan and Weil began to lay plans to reshape the Department of Mathematics.

The following year Weil appointed Damodar Dharmananda Kosambi, 'a young man with an original turn of mind, fresh from Harvard where he had begun to take an interest in differential geometry'[19]. Attempts were made to improve the library, where the only books in English were very much out of date. With funds from the University, Weil sent to Leipzig for new books. Later, during his summer vacation, he actually returned to Europe and while there, visited Leipzig specifically to 'purchase a library for my department'. He also introduced a number of changes not only in the curriculum, but in the examination system as well, which formerly only served to create panic among the students who never knew what was to be required of them. Any chance that Weil might have succeeded in sustaining a first-class department with first-class students was thwarted almost immediately, largely for political and personal reasons:

> I was still seen as Masood's creature, and a pamphlet in Urdu was circulated inveighing against him and criticizing me for importing French mathematics into India: according to the author of the pamphlet, only English mathematics was suited to the Indian mind[19].

Meanwhile, Vijayaraghavan left Aligarh for a position in Dacca in 1931. Although Weil had hoped to build up 'a team of young mathematicians who truly loved their work', before he had a chance to do so, although he had already made up his mind to resign, his contract was terminated, and soon Weil was back in France where he was supported by a grant from what later would be known as the Centre National de la Recherche Scientifique.

Conference of the Indian Mathematical Society, 1931

Weil was still in India when the Seventh Conference of the Indian Mathematical Society met in Trivandrum, capital of Travancore (now called Kerala, with its capital Thiruvananthapuram, in the southernmost part of the country), in April 1931. Since the previous meeting in Nagpur in 1928, 27 new members had been added, and nearly 75 delegates attended the meeting, which opened in the Jubilee Town Hall. M. T. Naraniengar, who delivered the Presidential Address, was pleased to note that since its founding in 1907, the Society now comprised nearly 300 members. After surveying ways in which the IMS could help support and advance mathematics in India, he offered a brief list of important recent results and events in mathematics, concluding with a discourse on the subject of science and religion – a not uncommon subject for books, articles and public lectures on such occasions. In closing his lecture, M. T. Narayana Iyengar stressed that 'Mathematics, with its conceptions of infinities, imaginaries and higher dimensions is peculiarly fitted to help us to become truly orthodox and religious. May our Society be the means of removing skepticism and developing truth, piety and diligence!'[20].

The Secretary's report announced annual contributions promised to the society from the Madras, Annamalai and Bombay Universities intended to 'ease our financial position' and 'enable the Society to increase the scope of the journal'[20]. At the Society's Business Meeting, it was decided that for the 'further progress of mathematics in India', a Committee be formed to report on how mathematics was being taught in Indian Universities, and to recommend improvements. In addition to inviting the Society to hold its next meeting at Aligarh University, André Weil suggested the Society invite 'eminent Professors from abroad to deliver lectures on special subjects, the expenses being shared by the different Universities which join the movement' (see note 19).

The following afternoon, Weil offered a survey of his own on 'Mathematics in Indian Universities'. Not only was better preparation of better teachers imperative for the schools, but at the University level, Weil urged that in addition to specialists, teaching should address practical applications and not forget the need to provide 'intellectual and moral training which any University, worthy of the name, has the duty to impart'[19]. In particular, Weil endorsed straightforward teaching, and was critical of the English system and the esoteric preparation required solely for the purposes of passing examinations:

> It follows that problem-solving should never be practiced for its own sake; and particularly tricky problems must be excluded altogether. The purpose of problems is twofold: either to drill the student in the application of some method of special importance, or to develop his originality by guiding him along some new path[19].

On the subject of rigour, Weil was emphatic:

> Rigour is to the mathematician what morality is to man. It does not consist in proving everything, but in maintaining a sharp distinction between what is assumed and what is proved, and in endeavouring to assume as little as possible at every stage. The student should therefore be gradually accustomed, by means of startling examples, to question the truth of every unproved proposition, until at last he is able to deduce from the ordinary axioms everything that he has learnt[19].

What impressed André Weil most about this first meeting he attended of the Indian Mathematical Society was 'the eagerness and openness of mind evident among the younger generations, a sharp contrast with the routine in which their elders were mired. I judged this to be a good omen for the future of mathematics in India. This optimism was actually somewhat premature, but later developments showed that it was not entirely unfounded'[19].

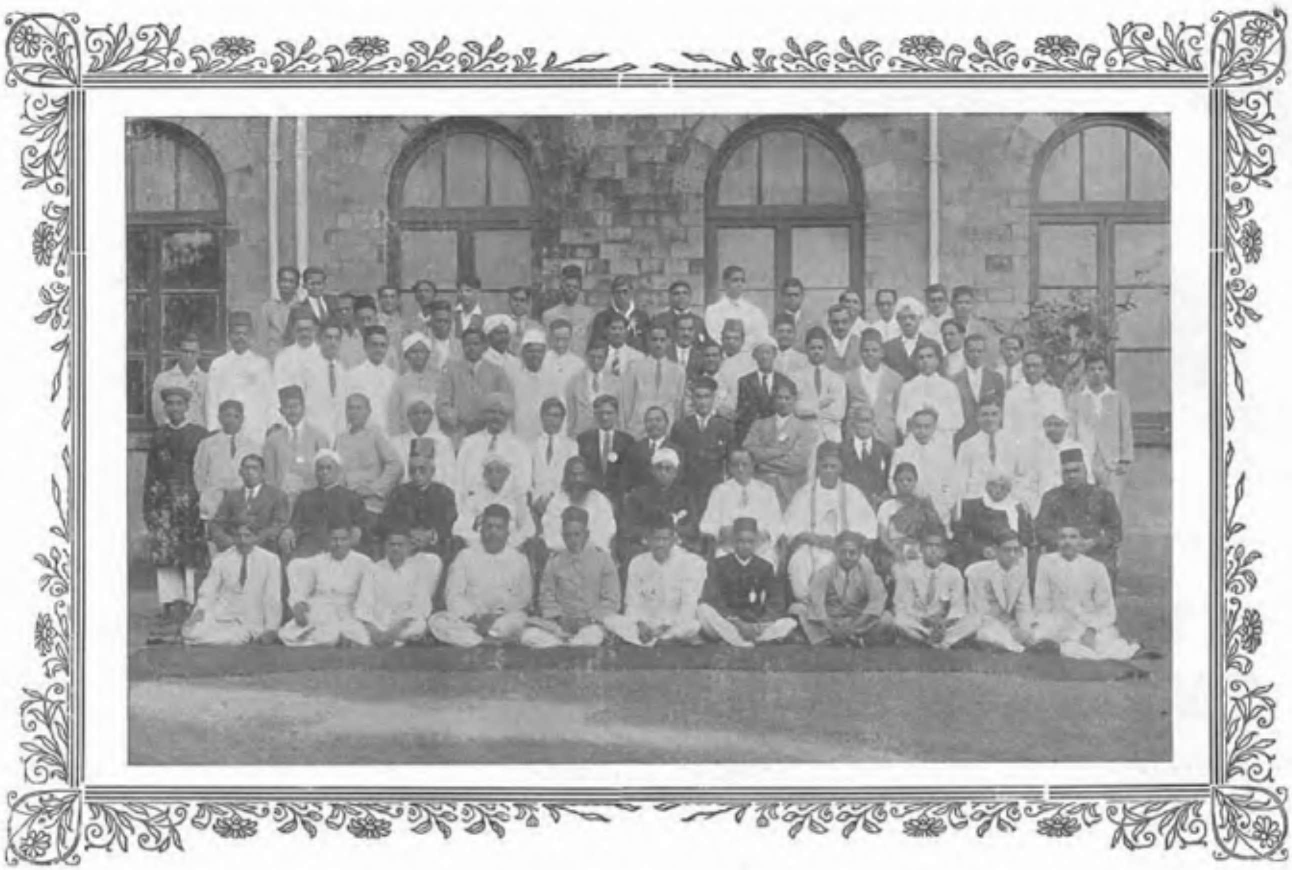
Silver Jubilee of the Indian Mathematical Society, 1932

The Eighth Conference of the Indian Mathematical Society was not held at Aligarh, as Weil had proposed, but at Bombay where the Society convened at the Royal Institute in December 1932 to celebrate its 25th anniversary. Bombay University made a generous contribution in support of the meeting of Rs 1000, and the Society contributed Rs 100 (see note 20). Among those present were V. Ramaswamy Aiyar, who had been instrumental in founding the Society in 1907.

Sir Frederick Hugh Sykes, governor of Bombay and Chancellor of Bombay University, delivered the Inaugural Address. In addition to the papers presented at the meeting, two important discussions were held on teaching – one focusing on mathematics in the schools, the other in universities, through which it was hoped that improved courses, syllabi, and teaching methods would lead to 'a higher standard of mathematical instruction' (see note 21). Indeed, Sir Frederick's opening remarks (in which he noted that an important focus of the jubilee meeting was to be school and university teaching) were a sign of the times:

> If you are able to devise means whereby the study of mathematics may be made more attractive to the average boy and so develop original and sound thinking, and whereby it may be made easier for the average person to apply mathematical methods to the varied material to which they are applicable, you will deserve the gratitude not only of the School-and-College-going population but of the whole community (see note 22).

As a reflection of the broad interests the Society had grown to encompass, the three invited 'public discourses' were presented by Meghnad Saha, a Fellow of the Royal Society, who spoke on 'The present crisis in the science of dynamics', another by R. Vaidyanathaswami, FRSE, who addressed 'The nature of the continuum', and the third by the President of the Society, Rao Bahadur P. V. Seshu Aiyar, on 'The nature of mathematics and religion' (see note 23). Of special interest, in addition to the lectures presented over two days, was an excursion arranged to visit the Oriental Life Assurance Company, where members of the Society could inspect the calculating machines and automatic sorting and recording devices used by the company.



Silver Jubilee Conference of the Indian Mathematical Society, 22 December 1932, Bombay.

The last day of the meeting, 24 December, was set aside 'for celebration of the Society's silver jubilee'. The Reverend J. Mackenzie, Vice-Chancellor of Bombay University, presided over the celebration, which opened with a prayer led by students from the Royal Institute of Science. A special tribute had been arranged in honour of M. T. Naraniengar, the founding editor of the Society's *Journal* who had overseen its publication for nearly two decades. Among communications from abroad, contributions were sent on the occasion of the Society's Silver Jubilee with best wishes from R. C. Archibald (Brown), E. T. Bell (Caltech), W. Blashke (Hamburg) and G. N. Watson (Birmingham) (see note 24). Following the meeting, an excursion of all participants was made to the Elephanta Caves, where refreshments were served:

> The fresh sea breeze was a welcome change from the heated atmosphere of the lecture room and the members and delegates were in a very hilarious mood when the three motor launches began to race towards the island, where tea and light refreshments were awaiting their arrival. The party returned late in the evening and parted after mutual greetings and cheers for the President and the local Secretary[5].

Teaching and the examination system in India

As the society met on the occasion of its 25th anniversary, it faced two demanding tasks. One was a survey of the conditions of mathematical teaching in the schools and colleges across the country. Of special concern were university examinations, as well as public examinations in general, which the Society was charged to evaluate 'with a view to bring about some wholesome reforms in connection therewith'. Nor was this a matter the Society was considering for the first time. As early as 1919, A. C. L. Wilkinson, then President of the Society, addressed the Second IMS Conference held in Bombay on teaching and the examination system, but nothing came of a Committee appointed to study the matter. But later, the Society's Managing Committee was again asked to study improvements in teaching and examinations, without result. As Seshu Aiyar noted, 'Unless the members of our Society and others interested in the improvement of mathematical teaching realise the need for such an enquiry and co-operate in the work with earnestness, nothing can be achieved. It is just to make them realise the need for such an enquiry that I propose to dwell at some length on that topic'[70].

Seshu Aiyar was concerned about the inability of students to perform mental arithmetic, without paper and pencil, and chided teachers for drilling students 'in long and complicated or tricky problems, drawn from imagination and having no relation to the real life around and the simultaneous indifference to problems occurring in real life'. He was also dismayed that elementary mathematics was taught in India with no reference to the history of Indian mathematics. 'The subject consequently grows like an exotic plant in our country and is rendered dull and uninteresting. On the other hand, if the methods and processes in vogue in ancient India be given some prominence in the handling of the subject, giving the names of ancient Indian mathematicians in whose works such methods are to be found, it would rouse considerable interest in the students for the subject and also a feeling of patriotism will be ingrained in our young students' (see note 25).

It was equally important that teachers be sure they were aware of and understood the latest developments in mathematics, so that they could teach it correctly. 'The pity is our teachers do not realise that they themselves have to learn much as regards the fundamental concepts'. Seshu Aiyar went on to give typical examples of simple areas in which teachers he had interviewed clearly knew nothing of even the most basic concepts they were expected to teach. In particular, he urged the teaching of geometry and algebra 'to lead the students to clear thinking and accurate reasoning, which are so very essential to every civilized man'[70]. In India, the difficulty of teaching mathematics was compounded by the fact that it was done in a foreign language, namely English. 'No doubt students do get by heart and reproduce the geometrical proofs in the examinations but few of them can be said to have clearly grasped the logical reasoning involved'[70]. India was thus no different from any country faced with the challenge of teaching mathematics effectively: '...mathematics is often considered a dull and uninteresting subject and is dreaded by many pupils. We mathematicians must devise methods of handling the subject so as to remove that horror and make it really interesting'. One solution he offered was that 'students must be shown the usefulness and application of mathematics to other subjects, such as Physics, Geography, Domestic Science, etc.'.

In India, mathematics was taught in elementary and secondary schools, in the usual span of 11 or 12 years, followed by four years or so of undergraduate training in the colleges. Graduate programmes were primarily reserved for the universities, where most serious mathematics at the highest research levels was pursued (see note 26). Prior to independence, however, mathematics even in the universities 'meant a very watered down version of a small part of the Tripos programme, with emphasis on drill and memory. In this barren landscape there were, however, two institutions that seemed promising' (see note 27). These were the Indian Statistical Institute founded by P. C. Mahalanobis in Calcutta in 1931 (discussed below), and the Tata Institute in Bombay, created by H. J. Bhabha in 1945 (the original emphasis of the Institute was on theoretical physics, cosmic ray research in particular; for details, see below).

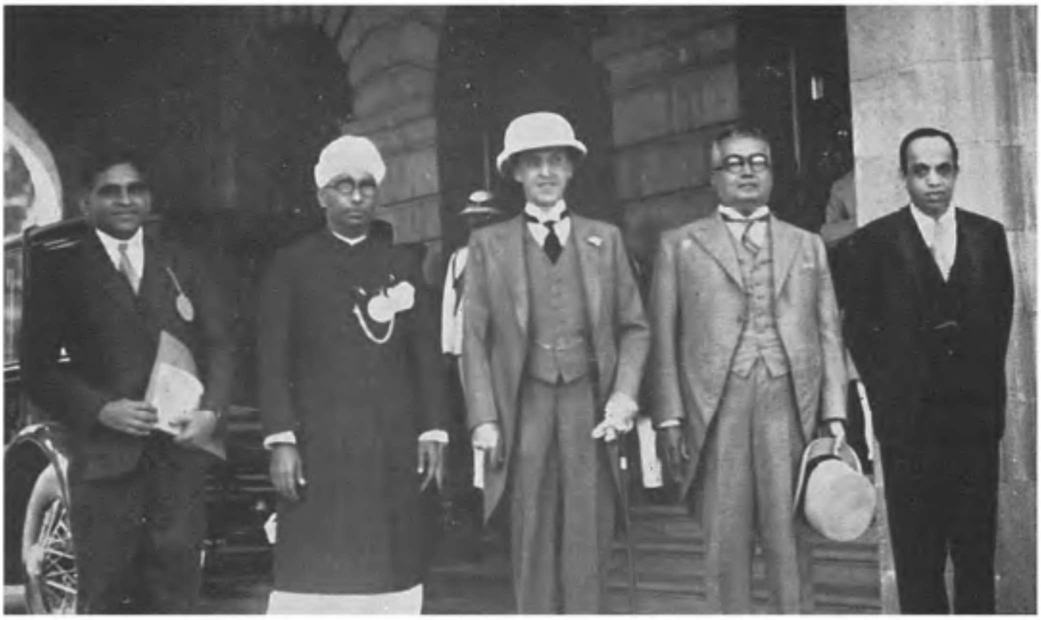
The other aim of the Indian Mathematical Society proclaimed during its jubilee year was 'a better organization of the research work in mathematics that is now attempted individually and spasmodically by our members and others capable of such work'[6]. Turning to this subject in his 'Presidential Address', Seshu Aiyar was concerned that such topics as groups, transformations, differential geometry, tensor calculus, relativity, integral equations, calculus of variations and statistical mechanics were not studied 'in India to any great extent'. Above all, 'I am sure you will all agree with me when I say that we in India have not studied all the modern subjects that are engaging the attention of European and American mathematicians'[70].

One remedy had already been suggested by V. Ramaswami Aiyar in an earlier Presidential Address to a meeting of the Society at Bangalore in 1926. This was to form reading circles to promote new subjects. Seizing upon the catchword 'MILE', he insisted that what India needed, in stages, were Entrants (or 'embryos' as he also called them), who would successively progress to become Learners, Interpreters and finally Masters. A Master, according to Aiyar, 'brings a fresh light of his own into the subject, becomes a discoverer, and extends the scope of the field[4]. Thus he urged the formation of 'compact little groups' – *Gurukulas* he called them – to study the different branches of mathematics.

When Rao Bahadur P. V. Seshu Aiyar (Iyer), President of the Indian Mathematical Society at the time of its Silver Jubilee, gave his 'Presidential Address' at the Society's Eighth Conference in Bombay in 1932, he quoted his predecessor's suggestion about forming 'compact' study groups at length, lamenting that this suggestion had not taken root earlier. Seshu Aiyar fully expected that if the Society could successfully promote such intensive studies, these would in turn stimulate considerable research resulting in many original papers, from which 'our journal too will have ever flowing matter contributed to it so as to improve in quantity as well as in quality'[70]. As a positive step towards encouraging better research, the society established a 'Jubilee Fund' in order to finance a Research Prize, 'to be awarded by it once a year or once in two years as funds permit' (see note 28).

1932: The Mathematics Student

By the time the Indian Mathematical Society celebrated its Silver Jubilee in 1932, there was more than enough research of sufficient quality to sustain the Society's *Journal*, and it was clear that in future it could not



Left to right: Professor K. R. Gunjikar, Hon. Local Secretary; Rao Bahadur P. V. Seshu Aiyar, President; H. E. Sir Frederick Sykes, Governor of Bombay and Patron of the Conference; Hon. Mr Justice Mirza Ali Akbar Kahn, Ex-Vice Chancellor, Bombay University; Mr V. N. Chandavarkar, Mayor of Bombay and Vice-Patron of the Conference.

continue to include as much elementary mathematics as teachers in the schools and their students might find useful. This problem had already been addressed by the Society's founder, V. Ramaswami Aiyar, in his 'Presidential Address' to the Fifth Conference of the Society held at Bangalore in 1926. Noting that just as mathematics developed, so too must the Society's journal, he offered the following advice:

> At present, in our Journal, different classes of matter, the higher and the elementary, are put in together: and they both experience a discomfort in thus travelling together. I think we should early separate our Journal into an Advanced part and an Elementary part. Neither of these should be sacrificed for the other. The former should be reserved for original work and for notes relating to Advanced Mathematics. The latter should be devoted to Notes, Reviews, Questions and Solutions and should be a journal for entrants, learners and interpreters, in the better known fields of Mathematics forming the subjects of study in Colleges[7].

This, Aiyar hoped, would make the journal in particular 'more effective in its purpose and more appealing to all classes of our members'. Indeed, on the occasion of its Silver Jubilee in 1932, the society decided to reserve the journal for pure research. Rather than simply divide it into two parts, it was decided to create an entirely new periodical, to be published by the society for the 'encouragement of beginners and teachers in research'[21]. Thenceforth the society also published, primarily for the benefit of students and their teachers, *The Mathematics Student*.

Mathematics in India prior to World War II

As M. S. Raghunathan has put it so succinctly:

> The twenties and thirties saw the emergence of centres of good mathematical activity at different places in the country. Ganesh Prasad was very influential in Allahabad and Banares (and later Calcutta); even if his role was not always beneficial to Indian mathematics, his personal contributions were of a high quality. B. N. Prasad who spent most of his mathematical life at Allahabad had impressive achievements to his credit. A. C. Banerjee and V. V. Narlikar are other well-known names from these centres. Ram Behari and P. L. Bhatnagar worked at St. Stephens in Delhi, the former in Differential Geometry and the latter in Summability and Astrophysics. B. R. Seth, an expert in elasticity and hydrodynamics, worked for many years in Delhi. Aligarh had the distinction of having the great André Weil on its faculty for 2 years. Weil had great regard for his colleagues like Kosambi and Vijayaraghavan, who were among the best mathematical intellects of the period. S. M. Shah is another important name from Aligarh of those days. Panjab could boast of excellent number theorists in Chowla and Hansraj Gupta. Down South Annamalai University was active in Mathematics too. Narasinga Rao with his dynamism was able to attract Ganapathy Iyer (who did excellent work in complex analysis) and the renowned number theorist S. S. Pillai to that university. Pillai who did some profound and beautiful work on the so-called Waring problem tragically lost his

> life in an air accident near Cairo on his way to Princeton. Madhave Rao at Bangalore was yet another mathematician making good contributions[17].

Prior to the Second World War, the two most active centres for mathematics in India were Calcutta and Madras. In Madras, for example, K. Ananda Rau and Vaidyanathaswami were strong mathematicians who were interested, especially Vaidyanathaswami, in advancing mathematics in India beyond the rather narrow subjects of interest to British mathematicians at the time:

> British influence was no doubt beneficial in some ways but there were drawbacks. Britain during this period was not in the forefront in mathematics. Exciting developments taking place in France and Germany under the leadership of men like Hilbert were leaving Britain behind. It is in this context that Vaidyanathaswamy's role becomes important. Yet another important influence from Madras was Rev. Father Racine, a French Jesuit who worked at Loyola College. Father Racine brought to Madras some of the French outlook and approach to mathematics. He counted among his friends people like Weil and Cartan and indirectly channeled to Madras the new ideas and approaches those stalwarts introduced in the teaching of Mathematics. Meenakshisundaram (Subbaramiah Minakshisundaram), perhaps the most gifted mathematician of his generation, was also a product of Madras of this time (see note 29).

Elsewhere, numerous mathematicians were making notable contributions to various parts of mathematics. In Delhi, St Stephen's College was one of the oldest schools in India. Among the faculty, Ram Behari (1897–1981) and P. L. Bhatnagar (1912–1976) were the most important in mathematics. Behari had studied at Cambridge and Dublin, where he was a student of J. L. Synge. Behari, who worked primarily on differential geometry, moved to the University of Delhi towards the end of his career in 1947. Bhatnagar, on the other hand, began his career at Delhi, where he taught from 1940 to 1955. As a student of Banerji and B. N. Prasad, he was interested in summability of Fourier series, but also worked in astrophysics, fluid dynamics and wrote as well on the history of ancient Indian mathematics[2]. Also interested in applications was B. R. Seth (1907–1979), who taught in Delhi from 1937 until 1949. He was interested above all in elasticity and fluid dynamics. In 1950 he accepted a position at the Indian Institute of Technology at Kharagpur (near Calcutta), where he established a circle for applied mathematics. Among those contributing to complex analysis, S. M. Shah (at Aligarh from 1930 to 1958 before moving to the United States) worked especially on entire functions, and was among the few (along with Ganapathy Iyer) to study the ideas of Rolf Nevanlinna on meromorphic functions and Picard's theorem.

In number theory, India produced a number of noted mathematicians, including S. Chowla, who studied in Cambridge under Littlewood, and who taught at Benares and Andhra before accepting a position at Lahore (after the war he left India, and in 1948 following its partition he went to the Institute for Advanced Study in Princeton. Subsequently, he held various positions in a number of American universities until his retirement in 1976). Chowla worked primarily in analytic number theory (on L-functions and Waring's problem), but he also published on combinatorics, including well-known work he did with Atle Selberg on the Epstein zeta function. Another prolific number theorist, Hansraj Gupta (1902–1988), worked primarily on partitions (see note 30). Meanwhile, in Calcutta the German mathematician F. W. Levi (1887–1966), a refugee from Nazi Germany, helped to introduce Indians to modern algebra. After the war he went to the Tata Institute in 1948, but later retired to Germany.

As for Calcutta, Sir Asutosh Mookerjee proved to be a far-sighted Vice-Chancellor who supported development of the University in every way that might enhance its prestige and intellectual mission. As a mathematician, he was especially interested in helping to found the Calcutta Mathematical Society (as already mentioned). This the University supported by helping to fund publication of the Society's *Bulletin* and other occasional volumes.

Calcutta, where there had always been a strong tradition in mathematics due in part to the fact that it was the site of India's first University, supported such influential mathematicians as S. Mukhopadhyay (1866–1937), N. R. Sen (1894–1963), R. N. Sen (1896–1974), P. C. Mahalanobis (1893–1972) and R. C. Bose (1901–1987). Of these, it was Syamdas Mukhopadhyay (sometimes referred to as Mukherji) who had been brought to the University of Calcutta by Asutosh Mookerjee in order to organize the Department of Mathematics. Mukhopadhyay's research interests included differential geometry. Among his best-known students, R. C. Bose is widely known for his work on hyperbolic geometry, as well as statistics and combinatorics. Likewise, Nikhilranjan R. Sen, an applied mathematician, worked primarily on relativity, cosmogony and fluid dynamics, although he also worked on potential theory and probability. In 1931, when P. C. Mahalonobis founded the Indian Statistical Institute in Calcutta, this assured that the city would become the nation's centre for research in statistics.

Prasanta Chandra Mahalanobis and the Indian Statistical Institute

Prasanta Chandra Mahalanobis (1893–1972) believed that statistics was 'the key technology of the present century' (see note 31). Shortly after he took his Tripos examination in 1915, his tutor W. H. Macaulay showed him the new journal *Biometrika*, and he was so interested that he took an entire set of the journal back with him to India. In 1920 Mahalanobis met N. Annandale, Director of the Zoological and Anthropological Survey of India. Annandale had surveyed 300 Anglo-Indians in Calcutta, recorded their height, head-length and breadth, as well as their nose length, and made this information available to Mahalanobis (see note 32).

As a result, in 1920–1921 Mahalanobis began analysing caste data for Bengal, paying special attention to anthropometric constants in the Anglo-Indian sample he was studying. Mahalanobis was also interested in statistically analysing problems in such diverse areas as agriculture, meteorology and education. Mathematically, he made fundamental contributions to large scale sample surveys, multivariant analysis, and is best known for the concept of D^2-statistic. The concept of group divergence had been introduced by Brajendra Nath Seal in a paper on 'Race Origin' presented at the Universal Races Congress in London in 1911. Through Seal's encouragement, Mahalanobis continued his own statistical studies despite his early training in physics and applied mathematics, and between 1922 and 1936 published 15 papers leading up to his article on the generalized distance in 1936 (see note 33).

In 1931 Mahalanobis founded the Indian Statistical Institute. It was the earliest research institution devoted to mathematics to be established in India, and in addition to Mahalanobis, among its most notable members was C. R. Rao who worked there from 1944 to 1979, when he left India for the US. Mahalanobis also brought R. C. Bose to the Institute, where he began to work on statistical questions (not unrelated to his earlier interest in geometry). Bose is best-known for disproving a conjecture of Euler on 'mutually orthogonal latin squares', undertaken in part with his student S. S. Shrikhande, who served as Chairman of the Department of Mathematics at the University of Bombay in the 1960s. Bose went to the US in 1949, where 'he seems to have had more Indian students there than in India'[2].

After the founding of the Indian Statistical Institute, especially after 1936, Mahalanobis devoted most of his time to practical statistical problems related to socio-economic conditions in India, with a special interest in agricultural production (see note 34). Meanwhile, the research he had pioneered on group divergence and the generalised distance measure was continued by colleagues and students at the Indian Statistical Institute (in particular by R. C. Bose, S. N. Roy and C. R. Rao).

Although clearly influenced by the English school of statistics, especially the pioneering work of Karl Pearson, Mahalanobis focused his studies on living populations (rather than on skull measurements), and was especially concerned with aspects of evolution and the mix of different caste-groups in India. In the post-independence era, it was C. Radhakrishna Rao who oversaw the emergence of the ISI as a leading international centre for the study of statistics. At the same time, the Institute also expanded its scope to include a wider variety of mathematical subjects than simply statistics.

English graduates returning to India: several notable examples

Born in Madras, K. Ananda Rau (1893–1966) studied both there and at Cambridge, where he took a first class in the first part of the Cambridge Mathematical Tripos in 1915, taking Part II the following year. While at Kings College, 'his mathematical gifts blossomed under the influence of G. H. Hardy' (see note 35). After returning to India, Ananda Rau taught at the Madras Presidency College, where he was appointed Professor of Mathematics in 1919. He was later honoured with the title 'Rao Bahadur', and served as acting Principal of the College on several occasions prior to his retirement in 1948.

Ananda Rau was a member of both the London and Indian Mathematical Societies, and a founding member of the Indian Academy of Sciences. As for his own research, it was devoted primarily to summability of series, to Dirichlet series for which he either extended theorems proved by Hardy and Littlewood, or established theorems they conjectured but had not proven, one of which was regarded by M. Riesz as truly 'remarkable' (see note 36). He was also interested in studying the boundary behaviour of elliptic modular functions, continued fractions and quadratic forms. Some of Ananda Rau's work on Dirichlet series later inspired Minakshisundaram and Rajagopal to establish further results of their own. At the end of his life, blind in one eye and increasingly ill, Ananda Rau's greatest pleasure was the study of numbers expressible as sums of squares, which he continued to study with his students at the Ramanujan Institute. 'Many in the Ramanujan Institute will long remember his tall spare figure, worn away so thin as to seem but a vehicle of shining thought'[22].

R. Vaidyanathaswamy also studied in Great Britain, at first with E. T. Whittaker in Edinburgh, and then with H. F. Baker in Cambridge. His primary interests were devoted to algebraic curves, homogeneous forms and birational transformations, but he also contributed to number theory, multiplicative arithmetical functions, and questions of structure where he preferred to study general properties rather than specific cases of a given problem. He worked in mathematical logic, set theory and topology as well, and wrote an important textbook on general topology. Equally notable, the first two women who were active in mathematics in India were both students of Vaidyanathaswamy, namely S. Pankajam and K. Padmavally (see note 37).

Tirukkannapuram Vijayaraghavan (1902–1955) was born in 1902, in Adoor Agaram, a village in the State of

Madras. His early career has been likened to Ramanujan's in that he failed to get an Honours degree at college. Thanks to K. Ananda Rau, his mathematical talent was encouraged and with a strong recommendation from G. H. Hardy, Vijayaraghavan was given a scholarship from the University of Madras to study in England, whereupon Vijayaraghavan spent three years studying with Hardy at New College, Oxford. His earliest results, published in the *Journal of the London Mathematical Society*, dealt with Tauberian theorems. Later papers were devoted to Abel and Borel summability, to which Vijayaraghavan applied an approach using repeated differentiation borrowed from Littlewood. Hardy, in his book on *Divergent Series*, includes as Vijayaraghavan's theorem a result on certain Tauberian conditions[23]. Vijayaraghavan was also interested in Diophantine approximations, a topic later developed more systematically by Khintchine and others, covered largely by the subject of 'transference theorems'[24].

When Vijayaraghavan returned to India, he taught briefly at Annamalai and then Aligarh, where he was a colleague of André Weil. In 1931 he left for Dacca University as Reader in Mathematics. G. D. Birkhoff was so impressed with Vijayaraghavan's work that he helped arrange for Vijayaraghavan to visit the United States as a Visiting Lecturer of the American Mathematical Society in 1936 (ref. 2). A decade later Vijayaraghavan accepted a Professorship at Andhra University in 1946, but left three years later, in 1949, to become the first Director of the privately endowed Ramanujan Institute of Mathematics at Madras. Vijayaraghavan had hoped to make the Institute an important centre for mathematical research, but his death in 1955 left this task unfinished[25].

Among his major contributions, Vijayaraghavan obtained significant results related to one of Borel's conjectures made in 1899 for second order differential equations – a subject in which Hardy was also interested, and perhaps passed the problem on to Vijayaraghavan[26,27]. What Vijayaraghavan managed to show, actually, was that there were no such generalizations of the sort Borel had suggested (see note 38). On the other hand, Vijayaraghavan successfully extended results of Hardy's on algebraic numbers, and algebraic integers greater than 1 with conjugates absolutely less than 1 are sometimes called Pisot–Vijayaraghavan numbers. Considerable research has been done subsequently on this subject, further extending results discovered by Vijayaraghavan in the 1940s[28,29].

Independence and mathematics in India after 1947

In 1947, independence from Great Britain meant that for the first time in India, science and with it mathematics could be considered in terms of truly national goals:

> Here [India] was fortunate to have Jawaharlal Nehru as her first prime minister. For, unmatched among the Indian leaders of that (or any other) era, Nehru had a vision of greatness for Indian Science, the ability to articulate it, and the willingness to take concrete steps to realize it. His efforts led to enormous national support to new institutes as well as to some of the institutes for advanced work that had been established in earlier times, but were still struggling for visibility and recognition. The force provided by his leadership lifted the mathematical sciences in India to the modem epoch[1].

And yet, while independence may have held out great hope and enormous potential for progress, it also entailed substantial responsibilities as well, responsibilities that in many cases the British had left native Indians ill-equipped to handle:

> With the advent of independence, there were drastic changes. Opportunities seemed to expand. New institutions were being rapidly created. There was a demand for quick progress. The leadership of the mathematical community which had functioned reasonably well within the limited parameters of the British period was suddenly called upon to shoulder responsibilities of a much higher magnitude. They were by and large ill equipped for such a task both in terms of intellectual and organisational ability, even if they functioned with the best of motivations. There were two exceptions: P. C. Mahalanobis who continued his good work in Calcutta and K. Chandrasekharan in Bombay[17].

The Tata Institute of Fundamental Research

The Tata Institute, founded in 1945, was the 'brainchild' of H. J. Bhabha (see note 39). Impressed by the model of the Institute for Advanced Study in Princeton, Bhabha consulted with John von Neumann, André Weil and Hermann Weyl before making any initial appointments. Subsequently, he asked K. Chandrasekharan (who happened to be in Princeton) to return to Bombay to direct the new School of Mathematics at the Tata Institute in Bombay. Chandrasekharan, a student of Ananda Rau and Vaidyanathaswamy, later had close contacts with Vijayaraghavan as well. His interests included intuitionistic logic and functions of a complex variable, but later he also began to work on multiple Fourier series and related topics in analysis.

In 1944, when Marshall Stone visited Madras, he wanted to meet the best mathematicians then working in India, including Chandrasekharan and Minakshisundaram. It was Stone who helped secure a place for Chandrasekharan at the Institute for Advanced Study, where Hermann Weyl was especially influential since

Chandrasekharan served as his assistant for one year. While at the Institute Chandrasekharan met many important mathematicians, including C. L. Siegel, A. Selberg and S. S. Chern. He also began to collaborate with S. Bochner on various topics, including Fourier series and transformations, as well as Dirichlet series, and with Ralph P. Boas on derivatives of infinite order[17].

Having agreed to head the Tata Institute, Chandrasekharan returned to India in 1949, and within a decade had made it the most important centre for mathematical research in India. All along his efforts were greatly assisted by Homi Bhabha, whose appreciation for mathematics meant that it would receive strong support. Perhaps like its counterpart in Princeton, it was the fact that mathematics required few facilities that meant it would be among the earliest of the research groups to find a home in the Tata Institute. Although the first professors appointed in mathematics were F. W. Levi and D. D. Kosambi, 'neither of whom seem to have taken any major initiatives', the arrival of Chandrasekharan in 1949 would change all that:

> [Chandrasekharan] initiated a programme of recruitment and training students. He recognised that even the most talented of our students had inadequate exposure to modern developments and the Masters Degree was poor preparation to embark on first rate research. Our senior mathematicians were unable by and large to get out of the old fashioned ways set by British influence and this had to be broken. He recruited students with great care and had their progress assessed continuously. An excellent judge of mathematical talent and ability, he recognised the need to be ruthless in weeding out material that did not measure up to the high standards needed to grow excellence[17].

It was Chandrasekharan who launched a graduate programme in mathematics, assisted by K. G. Ramanathan. Students having successfully completed their master's degrees were hand-picked for advanced training, laying the foundation for the first generation of research mathematicians systematically trained in India. Those who showed special promise were encouraged to study abroad as well.

Equally important was Chandrasekharan's success in attracting foreign visitors of the highest calibre to the Institute. Among many, those who were most influential, especially in the early days of the Institute, were Warren Ambrose, Samuel Eilenberg, J. B. S. Haldane, Andrei Kolmogorov, Laurent Schwartz, Carl Ludwig Siegel and Norbert Wiener (see note 40). Many came to lecture for extended periods, and found receptive graduate students who had been picked with great care by Chandrasekharan. 'The young men responded admirably to the intellectual feast provided by the stalwarts from the West and in a short period of a decade and a half after his arrival, the school of Mathematics at TIFR had gained a formidable international reputation.'

R. Narasimhan, who first went to the Tata Institute in 1957, recalls in vivid detail:

> When I joined the school of mathematics at TIFR in 1957, the atmosphere there was heady. Nothing seemed as important or as exciting as mathematics. New subjects were being talked about constantly and trying to learn them was a challenge. Listening to a colleague try out his ideas and attempting to understand and improve on them was the best instruction one could have. And then there was the excitement of working on problems oneself[2].

It was Chandrasekharan's idea, for example, to schedule periodic International Colloquia, and over the course of his directorship the Institute became especially known for research on algebraic geometry, complex analysis, Lie groups, discrete subgroups and number theory. In fact, the Tata Institute's School of Mathematics has achieved its success in part by concentrating on select areas where talent was readily available: namely, it focuses on algebra, number theory and geometry. Unfortunately, the example has not served to inspire similar ventures in other parts of India. According to M. S. Raghunathan, 'the success story of TIFR has unfortunately no parallels elsewhere in the country. There are a few other centers where good work is being done. . . . Elsewhere there may be isolated individuals performing well but the general level of research leaves much to be desired'[17].

The Institute itself was directly affected when Chandrasekharan left India for Switzerland in 1965, and Bhabha died in a plane crash in 1966. Subsequently, the Tata Institute has been unable to absorb the loss of its two most visionary members, and this has changed the atmosphere. But of the outstanding figures associated with the Institute during this difficult period was C. P. Ramanujam, 'one of the most powerful mathematical minds to emerge in India since the mid-fifties', and in many ways, 'a singular figure'[2]. Ramanujam met a tragic end when he was only 36. Having been diagnosed a schizophrenic 10 years earlier, he read everything he could on the subject, decided it was an incurable affliction, and decided to take his own life. But before he did so in 1974, he had accomplished an extraordinary amount, especially in analytic number theory:

> Ramanujam came to TIFR in 1957 with a great deal of knowledge of deep mathematics. This would be unusual anywhere; in India, it was indeed exceptional. He was one of those rare people who feel completely at home in all branches of mathematics. Thus he understood sophisticated analysis as deeply as he did Grothendieck's view of algebraic geometry which appears very abstract, but illuminates the fundamental

> relation between geometry and arithmetic. Ramanujam helped many of the people at TIFR to understand difficult subjects. It was natural to turn to him when one reached an impasse in one's work.
>
> In his short mathematical life, Ramanujam did some very profound work. This included definitive solutions of well known problems (as with his solution of Waring's problem for number fields) as well as the introduction of methods and results which formed the basis of progress by others (the Kodaira–Ramanujam vanishing theorem, characterisation of the affine plane, . . .)[2].

Among foreign mathematicians Ramanujam met through the Tata Institute were Max Deuring (in 1958) and I. R. Shafarevich (in 1964). Ramanujam later wrote up for publication Deuring's lecture notes on 'The theory of algebraic functions of one variable' (Deuring later said of Ramanujam's notes that they 'left nothing to be desired'[31]), and Shafarevich's 'Numerical models and birational transformations of two dimensional schemes'[30,32]. In 1968 he also wrote up, with improvements of his own, a series of lectures by David Mumford on Abelian varieties, and went on to continue Mumford's lectures himself, writing up his own notes on Tate's theorem on homomorphisms between Abelian varieties over finite fields. This led to original and important contributions to algebraic geometry. Upon his death, his 'enormous private library' of mathematical books was bought by the Institute[30].

1950: The Ramanujan Institute of Mathematics

When Alagappa Chettiar, a well-known educator of his day, founded the Ramanujan Institute of Mathematics in 1949, T. Vijayaraghavan was invited to serve as its first Director. Initially, it was primarily a workplace for Vijayaraghavan and his colleague C. T. Rajagopal. Lack of funds prevented Vijayaraghavan from bringing visiting scholars or younger, postgraduate students to the Institute, but until his death in 1955, he encouraged as many students as he could, including C. P. Ramanujam and R. Narasimhan.

When Vijayaraghavan died in 1955, C. T. Rajagopal (1903–1978) succeeded him as Director of the Ramanujan Institute. Rajagopal had already served for many years as librarian of the Indian Mathematical Society, which had come to be housed at the Institute, and under Rajagopal's directorship, the Institute was eventually affiliated directly with the University of Madras as an Institute of the Department of Mathematics.

Rajagopal was another student of K. Ananda Rau, who recognized his 'exceptional intelligence' and under whose guidance Rajagopal completed his B.A. (Honours) courses at the Madras Presidency College in 1925 (passing the Honours Examination in mathematics with first rank)[23]. At first Rajagopal worked in the Madras Accountant General's office, but in 1930 began his teaching career with a position at the Annamalai University. A year later he joined the Department of Mathematics at the Madras Christian College, where he taught for nearly two decades. In 1951, he moved to the Ramanujan Institute at the invitation of its first Director, his former classmate and good friend, T. Vijayaraghavan (see note 41). When Vijayaraghavan died in 1955, Rajagopal succeeded him as Director of the Institute, and it was under Rajagopal's leadership that the Institute continued to grow, achieving international recognition as a national centre for mathematical research in India.

Rajagopal retired from the Institute in June of 1969, but continued his research up to the time of his death. His publications fall roughly into three categories, studies of sequences, series and summability; functions of a complex variable; and the history of medieval Kerala mathematics. Many of Rajagopal's early papers were devoted to the generalization and unification of tests for convergence of series of positive terms, including Tauberian theorems. Later Rajagopal devoted several years to the study of Fourier series which resulted in a series of seven publications, in part refining Tauberian theorems and drawing on work by colleagues like Chandrasekharan and Minakshisundaram. He also continued to pursue his early interest in functions, especially periodic meromorphic functions, and over nearly three decades (beginning in 1941), he published 13 papers on the theory of functions of a complex variable, several of them in collaboration with A. R. Reddy, M. Varadarajan and T. V. Laksminarasimhan.

With another of his students, M. S. Rangachari, Rajagopal pursued, especially in the last few years of his life, gap Tauberian theorems, high-index theorems, and the history of medieval Kerala mathematics (see note 42). As early as 1944 he had published a paper (with K. M. Marar) 'On the Hindu quadrature of the circle' and 'Gregory's series in the mathematical literature of Kerala', and continued his historical interests a few years later with A. Venkataramanwas and T. V. Vedamurthi Aiyar, publishing several more joint-papers on historical topics. The last of these, 'On an untapped source of Medieval Keralese mathematics', was written with M. S. Rangachari in 1978. One of Rajagopal's concerns in his study of Kerala mathematics was to produce satisfactory modern forms of proof for three series that first appeared in a Malayalam compendium in Sanskrit, the *Yuktibhasa*, and later recognised as Gregory's power series for arc tan x and Newton's power series for $\sin x$ and $\cos x$ (see note 43).

Rajagopal (known affectionately as CTR by his students) was a member of the Indian Mathematical Society (which he served as honorary Librarian for over 15 years), and of the London Mathematical Society. He was an elected Fellow of the Indian Academy of Sciences (Bangalore) and of the Indian National Science Academy, and also served as both Vice-President and later President of the Allahabad Mathematical Society. In 1963, he delivered the presidential address at the annual meeting of the Indian Science Congress, in which he gave a concise survey of summability methods in India[33]. He co-authored (with V. R. Srinivasaraghavan) *An Introduction to Analytical Conics*, published by Oxford University Press in 1955. In fact, Rajagopal was one of the most prolific Indian mathematicians working in India, and in the course of his career published well over one hundred articles, many of them in such prestigious journals abroad as the *Annals of Mathematics*, *Bulletin of the American Mathematical Society*, *L'Enseignement Mathématique*, *Journal of the London Mathematical Society*, *Mathematische Zeitschrift*, *Rendiconti del Circolo Mathematico di Palermo*, *Proceedings of the Edinburgh Mathematical Society* and the *Tôhoku Mathematical Journal*, among many others, including the major journals published in India.

Golden Jubilee of the Indian Mathematical Society, 1957

Although it had moved from its home on the campus of the University of Poona to New Delhi in 1950, the Indian Mathematical Society returned to Poona to celebrate its Golden Jubilee on the campus of the University of Poona in December of 1958. The Society used the occasion to invite articles by the country's most distinguished mathematicians, and most were published in a special Jubilee volume of the *Journal of the Indian Mathematical Society*. As noted in its preface, the volume was intended to represent 'a full cross-section of the various branches of mathematics in which research work is being carried on'[21]. And indeed, the list is impressive both for the individuals it includes and the breadth of research the volume encompasses. It is as if the hope described by the Society's founder, V. Ramaswami Aiyar, on the occasion of his 'Presidential Address' to the Society in 1926 – that India would one day represent the entire spectrum of mathematics at the highest level – had by mid-century come true. Among the authors included in the Jubilee volume were K. Ananda Rau ('Application of modular equations to some quadratic forms'), R. P. Bambah ('Some problems in the geometry of numbers'), P. L. Bhatnagar ('Propagation of small disturbances in a viscous compressible fluid of finite electrical conductivity'), S. Chandrasekhar ('The stability of inviscid flow between rotating cylinders'), and V. S. Krishnan ('Uniform demigroups and duality').

The Calcutta Mathematical Society: 50 Years of the *Bulletin*

The Golden Jubilee of the Society was celebrated 'in a befitting manner', with various functions scheduled over a month from 25 December 1958 through the end of January 1959. During its annual meeting, the Society continued to express its thanks and close ties to Calculta University, which printed the *Bulletin* free of charge. The University also agreed to publish a Commemoration Volume of the Society in honour of the Golden Jubilee, for which a 'good number of papers from eminent Mathematicians of the world' had been received. It also noted that a letter had been sent:

> ...to the Calcutta University appreciating with gratitude the help and encouragement which the Calcutta University with its motto of 'Advancement of Learning' has rendered to the Calcutta Mathematical Society by nourishing it and by publishing its Bulletin for the long stretch of nearly half a century free of charge. The Society has always considered the University of Calcutta as its most benevolent patron and will continue to think so in future with an earnest hope that the Society will not be deprived of the patronage and the University of Calcutta will continue the printing of its Bulletin without cost as in the past[34].

Nevertheless, the Society's financial condition remained one of continuing 'hardship', and the same report made the previous year was repeated, that the library's periodical subscriptions had been maintained, but only 'by an entire suspension of the purchase of recently published reference books and important newly published research periodicals'. It also renewed its appeal to the government: 'We should earnestly hope that our National Government (central and Provincial) would appreciate the necessity of mathematical researches in the country at this present juncture of scientific development of the world and render their substantial help to the Society for this purpose' (see note 44). Unfortunately, the Government of India made no contribution to the Society in its Jubilee year, and the total income from the Government of West Bengal and the National Institute of Sciences was only Rs 3000. Again the finance report warned that 'the Society is almost on the verge of a collapse'[34].

The following year, financial difficulties not withstanding, the Society managed to complete renovation of its library, and sponsored a series of symposia devoted to recent advances in different branches of mathematics. Symposia on teaching mathematics in the schools were also held, and another on fluid mechanics and its teaching at the post-graduate and research levels. Above all, a special volume reporting on the progress of research in mathematics in India over the past 50 years was also published. Moreover, it was noted that through journal exchanges, the Society received 132 journals in return. But over the same year it was only able to purchase five books for the library, and actually paid subscriptions for only 16 journals[35]. The Government of India, however, resumed its contributions, and this helped mitigate somewhat the Society's immediate financial difficulties.

Historians of mathematics in India

Interest in the history of mathematics in India may be linked not only to its own very long history of contributions to mathematics and such notable names as Brahmagupta, Bhāskara, etc., but to an interest in the 20th century in its pedagogical uses. There are also the contributions history of mathematics makes to the intellectual history of India generally.

Nearly unique because of his interest in the history of modern mathematics was Ganesh Prasad (1876–1935). A graduate of Allahabad University, he left India in 1899 to study mathematics at Cambridge with Hobson, Forsyth and Larmor, and at Göttingen with Klein, Hilbert and Sommerfeld. He returned to India in 1904, and began his career as a teacher lecturing at Queen's College, Benares. After serving as Ghose Professor of Applied Mathematics at Calcutta University, and as Principal of Benares Hindu University, he accepted the Hardinge Chair in Higher Mathematics at Calcutta University. He also served briefly as an elected member of the legislative council of UP, but 'gave the public life a go-by at the earliest opportunity and entered his homely study as the fit habitation of a scholar'[36]. As for his mathematics, 'he was an analyst pure and simple. Arithmetisation was his favourite method. Really he was Weierstrass's successor – although Klein's pupil'[36]. As for his service to mathematics in India, he served as President of the Calcutta Mathematical Society for more than a decade, 1924–1935.

His earliest mathematical paper (1901) was devoted to the potential of ellipsoids of variable densities. Prasad also developed a method of expanding arbitrary functions in series of spherical harmonics (1912) that was included in Hobson's book and had applications to quantum physics. His most important paper (1929) was devoted to the differentiability of the integral function. Among his historical studies was a study of 'Mathematical physics and differential equations at the beginning of the 20th century', and a two-volume compendium, *Some Great Mathematicians of the 19th Century*, devoted to the great names of European mathematics. His interest in history of mathematics was strong enough that several years before his death he established the Krishnakumari Ganesh Prasad Prize and Medal, in memory of his daughter, for 'the best thesis embodying the result of original research or investigation in a topic connected with the history of Hindu Mathematics before AD 1600' (see note 45).

Among Indians interested in the history of mathematics in India, Bibhutibhusan Datta (1888–1958) and Avadhesh Narayan Singh (1901–1954) were both students of Prasad and pioneers who studied Sanskrit and other materials related to the history of mathematics in India[72]. Datta undertook detailed studies of original Sanskrit works and in 1932 published *The Science of the Sulba* based on an in-depth analysis of the *Śulba-sūtras*, the earliest mathematical documents that survive encompassing the mathematical knowledge of ancient India.[37] Before he gave up history of mathematics for the life of an itinerant monk, he and Singh together produced a valuable compilation in two volumes: *History of Hindu Mathematics: A Source Book*[38]. Singh was also responsible for establishing a section for Hindu Mathematics at Lucknow University.

Mathematics in India

This has been a very brief survey of the 'beginnings of modern mathematics in India', from which it is apparent that from the beginnings recounted here, India has gone on to produce scientists and mathematicians of world-class stature. It has its Nobel Prize winners and mathematicians of the highest order, including rare geniuses like Ramanujan and specialists of internationally recognized caliber. Indeed, it is in the century to come that India can expect to realize the potential of its own visionaries, individuals like the many remembered here who helped to set the stage for an indigenous development of mathematics in India today.

Notes

1. The history of mathematics in India is as much a history of the political, economic and social factors that have together formed the country in the 20th century as it is a history of individual geniuses like Ramanujan and the collective energies reflected in the Calcutta or Indian Mathematical Societies. At its best, it is a story of dedicated teachers, bright students, and the individuals or institutions that supported them. In writing this account of the history of modern mathematics in India, we are grateful for the help of a number of individuals who have supplied information, copies of papers they have written, or commented on earlier drafts of the history presented here. Above all, M. S. Raghunathan provided us with a copy of a lecture that he delivered at the Indian National Science Academy in 1993, 'Mathematics in India in the 20th Century'[17]. A detailed study by R. Narasimhan, 'The Coming of Age of Mathematics in India'[2], has also been very informative. This treats primarily the first half of the 20th century, and explicitly does not consider Indians who worked mostly abroad – including S. Chandrasekhar and Harish-Chandra.
2. Throughout this paper, references are made to major Indian cities and states as they were referred to at the time in question; thus we refer to Calcutta, Bombay and Madras, whose current names are Kolkota, Mumbai and Chennai. To avoid confusion, we have referred to conventions in use at the time that the events related took place. Note that the 'State of Madras' is now the 'State Of Tamil nadu'. For general histories of modern India, readers may consult among many other authoritative studies Watson[40], and Worswick and Embree[41]. Calcutta, it should be noted, served as the capital of India for nearly a century, from 1833 until 1912; see also ref. 2.
3. Two colleges in India actually pre-dated the three universities founded in 1857, Presidency College in Madras and St Stephen's College in Delhi.
4. Ramaswami Aiyar, in his 'Presidential Address' to the Fifth Conference of the Indian Mathematical Society[4], provides personal reflections on his life as a mathematician, the founding of the Indian Mathematical Society and its subsequent early history. Although his name is variously spelled as Aiyyar and Iyer, Aiyar is used in

the text here for the sake of consistency, although bibliographic items are keyed to whatever spelling was actually used in print.
5. Aiyar mailed his suggestion to mathematicians he thought would be interested in pooling their resources for the enrichment of all. Although he hoped a half dozen or so might be found to join him in the venture, he added that he would 'consider the Club formed as soon as three friends have agreed to the proposal making with me four members'. Each was expected to subscribe to the Society at Rs 25 per year, although the system of forwarding books and periodicals from one member to the next would add an additional Rs 5 per year in membership costs for postage[7].
6. Aiyar's letter as circulated among mathematicians in hopes of founding the Society is reproduced in volume 11 of the *Journal*[5].
7. M. R. Ry. M. T. Naraniengar Avergal was also appointed to the position of joint Secretaryship with V. Ramaswami Aiyar, who quipped that Naraniengar would henceforth serve as the P.R.S. of South India, 'meaning that I was to be the "Progress Report Secretary" of the Society, and generously admitted me to the rank of the Bengal Mathematicians of that high order'. See refs 4 and 7.
8. Poona was an auspicious choice, for it was very near Bombay, and Bombay was regarded as virtually the headquarters of the Society. Moreover, 'Poona is next to Bombay a postal centre for all India, and it is practically Bombay as regards the rest of India.' Because the primary early function of the Society was to circulate by mail books and periodicals among its members, the proximity of post facilities was of the utmost practical significance. See ref. 7.
9. Indeed, the mathematicians of Calcutta formed their own Society the following year. Although invited to join in Aiyar's venture (the Indian Mathematical Club headquartered in Poona), they declined to do so. As Aiyar recalls, 'the mathematicians of Bengal were considering the formation of a separate Society in Calcutta'[4]. He goes on to describe a letter received 'from Sir Gurudas Banerji, the eminent judge, as well as a mathematician, acknowledging my letter, commending our action, and stating that they in Bengal preferred to have a Society formed in Calcutta itself, to gain our common objectives the better, and that plans for this were ready. He said that India was such a vast country that there was ample room for both the Societies to function and he wished all prosperity to our endeavours'[4].
10. Berndt reports that R. Ramachandra Rao 'unhesitatingly offered Ramanujan a monthly stipend so that he could continue his mathematical research without worrying about food for tomorrow'. See *Ramanujan's Notebooks I* (1985) (ref. 12).
11. Naraniengar went on to confess, however, that getting Ramanujan's work ready for publication was no easy matter: 'Ramanujan saw intuitively many things and could not bring himself to the level of an ordinary student of mathematics. His 'first article' had consequently to be refereed back to him no less than three times'. See ref. 5.
12. For a description of the reports, which concern interpolation formulas for integral transforms, including a generalization of Frullani's integral theorem, along with many 'unusual series expansions', see *Ramanujan's Notebooks I* (1985) (ref. 12), as well as refs 42 and 43.
13. Seshu Aiyar and Ramachandra Rao, 'Ramanujan used to say that the goddess of Namakkal inspired him with the formulae in dreams. It is a remarkable fact that frequently, on rising from bed, he would note down results and rapidly verify them, though he was not always able to supply a rigorous proof'[10,13]. Hardy, however, believed that Ramanujan was not really serious about this, and maintained that 'Ramanujan was no mystic and. . . religion except in a strictly material sense played no important part in his life'[10]. Similarly, Bruce C. Berndt agrees that, as Hardy believed, Ramanujan basically thought like most mathematicians; see *Ramanujan's Notebooks I* (1985) (ref. 12). Robert Kanigel also relates the story in his biography that Ramanujan would tell friends 'Namagiri would write the equations on his tongue. Namagiri would bestow mathematical insights in his dreams'[15]. But did Ramanujan actually believe this? The question provoked a heated response from M. Rajagopalan, B. N. Narahari Achar and S. Bellur, who basically hold that 'Ramanujan is the best authority to say how he got his intuitions on mathematics, and if he says that it is due to the goddess of Namakkal, it should be accepted'. For the debate, and further discussion, see refs 44 and 45. In addition to the dreams and supernatural goddesses, V. Kumar Murty asks 'was it his penchant for sambar (a delicious South Indian dish)?' that may account for Ramanujan's remarkable if still inexplicable discoveries[46].
14. Later, Rademacher showed that this was indeed correct[14].
15. Frobenius, quoted by Bruce C. Berndt at the beginning of *Ramanujan's Notebooks III* (1991) (ref. 12). The material from Ramanujan's notebooks dealing with modular functions takes up nearly one-half of this volume.
16. Some attempts have been successfully made, however, to identify certain 'key' theorems or formulas from which large parts of Ramanujan's results may be derived. Andrews himself has identified one such key to proving many of Ramanujan's identities for partial theta functions. R. P. Agarwal has extended hypergeometric series identities and suggested their importance to combinatoric analysis and the theory of partitions in particular (see refs 16, 47 and 48).
17. According to a catalogue of serials in the Society's library published in 1933, it was receiving 58 periodicals in all, including *The American Journal of Mathematics* (1907–1932), *American Mathematical Monthly* (1914–1932), *Annals of Mathematics* (1899–1932), *Bulletin of the American Mathematical Society* (1906–1932), *The Mathematical Gazette* (1897–1932), *Philosophical Transactions of the Royal Society* (1906–1932), *Proceedings of the Edinburgh Mathematical Society* (1896–1932), *Proceedings of the London Mathematical Society* (1865–1932), *The Quarterly Journal of Mathematics* (1906–1927), and *Transactions of the American Mathematical Society* (1907–1928). For details, see ref. 5.
18. Brajendranath Seal, in ref. 18, p. xi.
19. Weil, as reported in ref. 20, p. 43.
20. In all, 90 participants attended the conference, many of whom made special donations to help support the cost of the Conference. A full list of contributors and delegates is given in ref. 5.
21. A full report of the Eighth Conference and Silver Jubilee Celebrations of the Indian Mathematical Society was subsequently published in the *Journal of the Indian Mathematical Society*, which simultaneously served as a *Proceedings* of the meeting and bore a second title page as the *Silver Jubilee Commemoration Volume*. Of 35 papers presented on the occasion, 22 were published in the Jubilee volume. For the list of papers 'communicated', see ref. 5; most include a brief summary.
22. While the two discussion groups focusing on teaching mathematics at the school and university levels agreed better teaching was called for, the question of college level mathematics often turned to questions about what should be taught, with emphasis on such courses as mathematical astronomy, electricity and magnetism, actuarial mathematics, statistics and economics, with many participants urging that more should be done to stress practical mathematics[5].
23. This was not about mathematics *per se*, but about philosophy and methodology, from which Aiyar argued that 'both in contents and in the methods mathematics and religion have much in common between them, so much so, that if religion should be properly evolved it must follow the methods of mathematics'[49]. He went on to discuss in particular aspects of the finite and the infinite, and used transfinite numbers to interpret such passages as occur in the *Purushasuktham* about the nature of the infinities to be associated with Purusha (the Absolute or God). As Aiyar concludes, 'Thus if Purusha is described as transcending the universe of space and

time, one who knows something of these transfinite numbers can try to understand it and can say that such descriptions are not altogether imaginary or illusory'[49]. This use of transfinite set theory to help in the interpretation of the infinite theologically is similar to concerns the creator of transfinite set theory himself held to be significant in properly understanding the Absolute, or God in a comparable Christian context[50–52].

24. In all, 35 papers were communicated to the Conference. The full list may be found in ref. 5.
25. Aiyar pointed specifically to the need for introducing historical background in teaching, and noted that in order to do so, 'there are our friends like Mr. A. A. Krishnaswamy Aiyangar quite willing to do such work for us'[70].
26. For a brief description of the Indian educational system, see refs 1 and 41; see also ref. 71.
27. At the time of independence, it was feared that the universities were too bureaucratic and would be too slow to change in time to support science at international levels. Consequently, it was decided that financial support for research should be diverted primarily to institutions outside the universities, for the most part to research centres that already had established faculty and advanced students like the Indian Statistical Institute (ISI) and the Tata Institute of Fundamental Research (TIFR)[14].
28. Despite the apparent health of the Society in 1933 with a total of 265 ordinary members, only 122 were paying their dues regularly. The majority were in arrears, so that the total subscriptions raised in 1933 were actually less than in 1919 when the Society had only 186 members. With its bank account at Rs 6790, Aiyar urged those in arrears to make their payments, and noted that the society would not only try to collect arrears, but to enroll new members[70].
29. Father Racine (1897–1976) arrived in India in 1936 as part of a Jesuit Mission. He had studied mathematics in Paris with Cartan and Hadamard, and brought the new ideas of French mathematics, especially in analysis, to India. Beginning with volume 4 of 1940, Racine was invited to serve on the Editorial Committee of the *Journal of the Indian Mathematical Society*, and from time to time he would publish articles of his own[17,53,54]. He especially encouraged the brightest students to go to the Tata Institute, once it had begun to operate effectively. Father Racine returned briefly to France upon his retirement, but soon returned to a position at Loyola College in Madras, where he spent the rest of his life 'among the people for whom he had done so much'[2]. 'Fr. Racine came to India with a view of mathematics completely unlike the prevailing one. In the classroom, but especially in personal contacts outside, he communicated this dynamic view of the subject'[2]. Although Narasimhan reports that Racine arrived in India in 1937, he had already published a paper the previous year listing his affiliation as St. Joseph's College, Trichinopoly[53].
30. After receiving a first rank M.A. degree in mathematics from Punjab University, Lahore, Gupta accepted a lectureship at Sadiq Egerton College in Bahawalpur. Several years later, he moved to Government College, Hoshiarpur, where he taught from 1928 until 1958. He went on to obtain a Ph D in 1936 from Punjab University, his advanced work concentrating on partition theory. In 1954 Hansraj Gupta was appointed Professor and Head of the Department of Mathematics at Punjab University, which in 1958 moved from Hoshiarpur to Chandigarh. He retired in 1966 to Allahabad, where he died in November of 1988. In the course of his career he published over 150 articles; in 1959 his book, *Selected Topics from Number Theory*, was published by Abacus Press. For further details, see ref. 55.
31. For a biographical sketch of Mahalanobis, see ref. 57. Jerzy Neyman also provides impressions of Mahalanobis from a trip he made to India in 1956–1957 (see ref. 58).
32. For appreciations of the contributions Mahalanobis made to statistics, see refs 59 and 60.
33. The last paper on D^2-statistic published by Mahalanobis was based upon a field survey by D. N. Majumdar in connection with the population census in India of 1941. Mahalanobis used his generalized distance measure to analyse 2836 individuals belonging to 22 castes and tribes in UP (in joint research with Majumdar and Rao, he went on to publish several more papers analysing this same data). Mahalanobis's last paper on D^2-statistic also contains an historical note about the evolution of this concept since his first papers in *Biometrika*[61].
34. This work is surveyed in ref. 22.
35. The Smith Prize was awarded for an essay by K. Ananda Rau, published by Cambridge University Press in 1918 (see ref. 62).
36. For studies of Ananda Rau's life and work, see refs 2, 62, 64 and 65.
37. Among the most prominent women to succeed with careers in mathematics, mention should be made of Primala and Bhama Srinivasan; Srinivasan studies group representations and is a member of the faculty at the University of Illinois at Chicago[2].
38. Later, in a paper authored jointly with N. M. Basu and S. N. Bose, Vijayaraghavan showed that $f(x) = (2 - \cos x - \cos \alpha x)^{-1}$ was a specific example of a function satisfying a second order differential equation that increased arbitrarily rapidly for a sequence of values of x (with α a suitably specified irrational)[66,67].
39. Initially, the Institute was privately funded, but over the years the central government increased its support to TIFR so that now it is financed almost entirely by the Indian government[2].
40. See ref. 1 and additional details by e-mail to J.W.D. from R. Sridharan, 9 June 1996.
41. Among obituary notices of C. T. Rajagopal, see refs 23 and 68.
42. He seems to have been inspired in this by K. Balagangadharan; Kerala is a southwestern coastal state of India. See also ref. 23.
43. The *Yuktibhasa* was reputed to have been based on an even earlier Sanskrit original, the *Tantrasangraha*, identified with the work of an obscure Hindu mathematician Nilakantha. For details, see ref. 23.
44. See the same report, almost verbatim, ref. 34.
45. For details of the prize, to be awarded every five years by the Calcutta Mathematical Society, see ref. 69.

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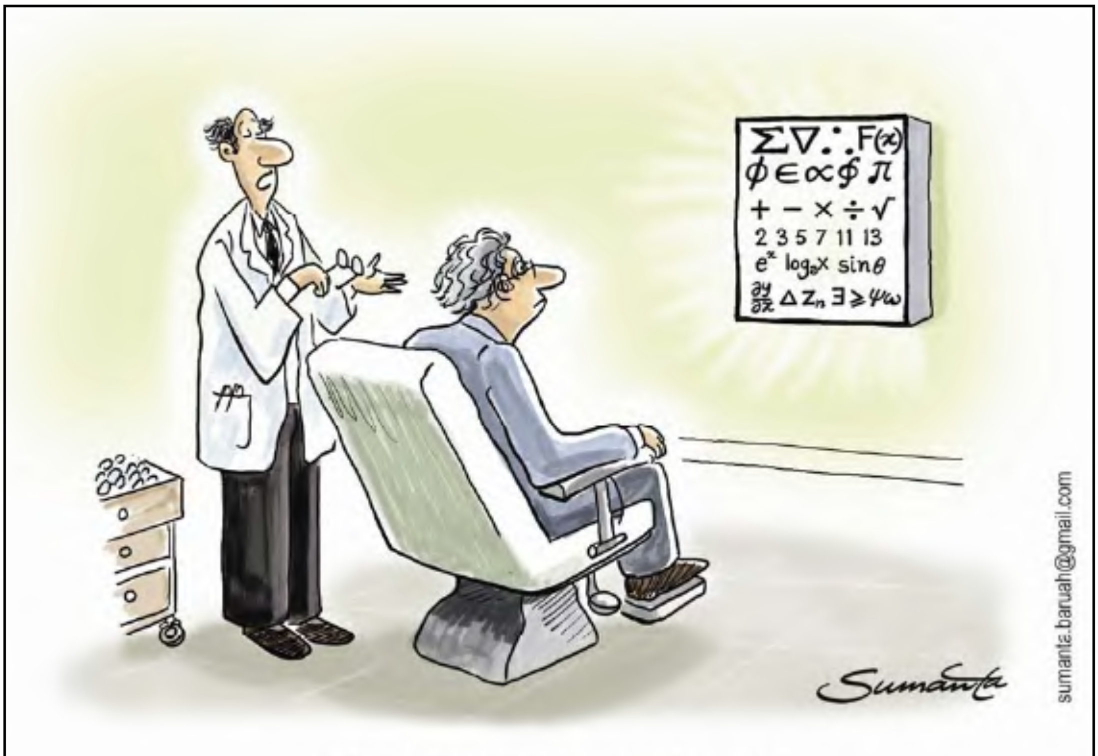

"Is it clearer now, Professor?"