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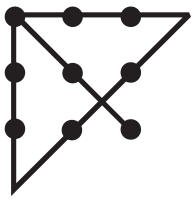
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Can creativity be nurtured?

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The first use of the word 'Creativity' occurred in 1875 and represents the quality of being creative or the ability to create (something) new. The word itself is synonymous with ingenuity to create, innovation or invention of that which was not known already and which is original.

The following 'Nine Dots Puzzle' in Sam Lloyd's 'Cyclopedia of Puzzles' :



represents thinking 'outside the box', which is considered the *sine qua non* to creativity. One of the many solutions to the puzzle is to link all the dots with four straight lines, as in the figure above (with a pencil on a paper, starting from one dot and going over each dot once and only once) illustrates thinking outside the square boundary of the nine dots.

In this article, the life and work of Physicists: Satyendra Nath Bose, Sir C.V. Raman, S. Chandrasekhar and E.C.G. Sudarshan and two mathematicians Srinivasa Ramanujan and Kannan Soundararajan are detailed highlighting briefly their achievements, with the hope that it would be possible for us to draw possible conclusions as an answer to how talent and creativity can be nurtured.

"Lives of great men all remind us
We can make our lives sublime
And departing leave behind us
Footprints in the sands of time." – Henry Wadsworth Longfellow.

Satyendra Nath Bose (January 1, 1894 – February 4, 1974)



S.N. Bose was a student of the Hindu High School, Calcutta and the Presidency College, Calcutta. Among his teachers were Jagadish Chandra Bose and Prafulla Chandra Roy, who influenced him and his career. After his M.Sc. in Physics from the University of Calcutta, he joined the Dacca University (now in Bangladesh) in 1921. He translated Albert Einstein's General Theory of Relativity from German into English and contacted Einstein who appreciated this effort.

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In 1924, Bose derived Max Planck's blackbody radiation formula without reference to Classical Physics and sent it to Einstein along with a letter requesting him to communicate the same to the Zeirschrift für Physik journal, if he found it worthy of publication. Einstein was stimulated by this article to write his own article on the new statistics proposed by Bose, which today is taught as Bose-Einstein statistics. The quantum mechanical concept of spin was introduced to explain the atomic spectral doublets by Wolfgang Pauli. While the electron is a spin half particle, the photon postulated by Einstein to explain the photoelectric effect is a spin 1 particle. Half-integral spin particles obey Fermi-Dirac statistics and integral spin particles obey Bose-Einstein statistics. "S.N. Bose's work on particle statistics which clarified the behaviour of photons (the particles of light in an enclosure) and opened the door to new idea of Microsystems that obey the rules of quantum theory, was one of the top ten achievements of the 20th century Indian science and could be considered in the Nobel Prize class," wrote Jayant Vishnu Narlikar in his book entitled 'Scientific Edge : The Indian Scientist from Vedic to Modern Times', (Penguin Books India (P) Ltd., New Delhi, 2003).



Einstein in his study (Berlin, 1919)

Bose - Einstein statistics was introduced for Photons by Bose and generalize to atoms by Einstein, in 1924 – 1925, as stated earlier. The statistics introduced by Bose is characterized by the expression he derived for the number of particles in an energy state 'i' which is : $n_i = g_i / [\, e\,(\varepsilon_i - \mu) / kT - 1\,]$

with $\varepsilon_i > \mu$ and where n_i is the number of particles in state *i,*

g_i is the degeneracy of state *i,*

ε_i is the energy of the *i*-th state,

μ is the chemical potential,

k is Boltzmann's constant, and

T is absolute temperature.

Max Planck, in 1900, proposed a mathematical formula to fit empirically the radiation formula. Twenty years later, in 1920, Professor Satyendra Nath Bose, at the University of Dhaka, in British India, used the concept of the Photon introduced by Einstein (to explain the Photoelectric effect in 1905) and derived the Planck's law of radiation by proposing different states for the photon. Bose particles into cells and described statistical independence of the cells of Phase Space, instead of statistical independence of particles. The two polarization states allowed by such a system exhibit totally symmetric wave functions. Bose was able to develop the statistical law which governs the behaviour of photons successfully but when Bose submitted his paper to journals in Europe it was rejected, since the referees were unable to comprehend the path-breaking contents of the paper. So, Bose who had in 1924, translated Einstein's papers on relativity from German into English, decided to send the paper to Einstein requesting him to send it to the Zeitschrift für Physik journal, if he found it worthy of publication. In his article, Bose derived the radiation formula by systematically developing the statistics of massless (mass zero) particles without the constraint of particle number conservation. Bose derived Max Planck's law for Blackbody radiation by proposing different states for the Photon. Instead of statistical independence of particles, Bose put the particles into cells and described statistical independence of cells of Phase Space. Such systems allow two polarization states, longitudinal and transverse, and the wave functions – written as a product of the spatial, spin and isobaric spin parts – are totally symmetric (as opposed to being totally antisymmetric for the half-integral spin particles, which obey Fermi-Dirac statistics).

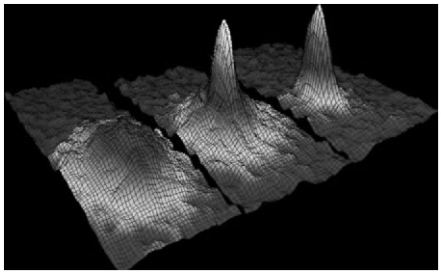
In recent years, Bose-Einstein statistics has also been used as a method for term weighting in information retrieval. The method is one of a collection of 'Divergent From Randomness (DFR)' models, the basic notion

being that Bose-Einstein statistics may be a useful indicator in cases where a particular term and a particular document have a significant relationship that would not have occurred purely by chance. A source code for implementing the DFR model is readily available from the Terrier Project at the University of Glasgow.

In 1924, Bose and Einstein predicted the 'Bose-Einstein condensate (BEC)' as a Fifth State of Matter – solid, liquid, gas are the three most common states (or, phases) of matter. The fourth state of matter is called Plasma. Blood, most flames, lightning, the interior of the stars, the inter-stellar space and the inter-galactic space are examples of the plasma. In the BEC matter stops behaving as independent particles, and collapses into a single quantum state, which can be described with a single, uniform wave function. In the gaseous phase, the BEC remained an unverified theoretical prediction for many years. Only in 1995, the research group of Eric Cornell and Carl Wieman, of the Joint Institute for Laboratory Astrophysics at the University of Colorado, Boulder, USA, produced the first BEC. It may occur when atoms are all in the same quantum level and this happens only at temperatures which are close to absolute zero degrees Kelvin, at -273.15 degrees Centigrade.



Nobel Prize 2001
Eric A. Cornell and Carl E. Wieman.



Velocity in a gap of Rubidium as it is cooled. The starting material is on the left, and Bose-Einstein Condensate (BEC) is on the right. Eric Cornell and Carl Wieman produced the BEC at the Joint Institute for Laboraroty Astrophysics, Boulder in 1995. Eric Cornell, Carl Wieman and Wolfgang Ketterle won the Nobel Prize for Physics, in 2001.

It is to be noted that while Enrico Fermi and Paul Dirac after whom the Fermi-Dirac statistics has been named have won the Nobel Prize, Einstein of Bose-Einstein statistics is a Nobel Prize winner but Bose has missed that distinction / recognition.

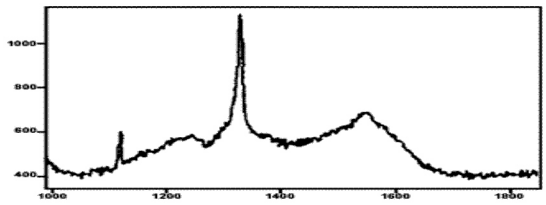
Sir C.V. Raman (7 November 1888 – 21 November 1970)



C.V. Raman



Diamond



Raman Spectrum of Diamond.

Chandrasekhar Venkataraman (C.V. Raman) was born as the second of eight children to R. Chandrasekhara Iyer and Parvathi. His father was a Lecturer in Mathematics and Physics. Raman was a student of St. Aloysius Ango-Indian High School in Vizag, Andhra Pradesh.

Raman completed his B.Sc. in Physics (1902 – 1904) securing the first place and a Gold Medal. He completed his M.Sc. in Physics, in 1907, with highest distinctions. He joined the Indian Finance Department as an Assistant Accountant General. Raman started the Indian Science Congress (ISC) in 1913. In this annual congress, he participated regularly and was the President in 1929 and 1948.

In 1917, Raman resigned his Government Job and was invited by Sir Ashuthosh Mukherjee to become the Palit Professor of Physics at the University of Calcutta. He continued to do his research work at the Indian Association for the Cultivation of Science. When he was offered an opportunity to go abroad for training he confidently asserted : "I can train Foreigners in my Lab, if they want."

On his foreign trip, in 1921, to take part in a conference at Oxford, he was impressed by the phenomenon of the whispering gallery at St. Peter's Cathedral in London and published a paper in Nature on the acoustics of the building. During his return journey, the deep blue colour of the Mediterranean Ocean struck him and he did some observations of the blueness of the waters using his Nicol prism which he always carried with him. He concluded that the blueness is not due to the reflection of the Sky, as Rayleigh thought, but due to the light scattering of water molecules. He published a note on the basis of his experiments in Nature on "The colour of the sea". Raman was nominated 10 times and the nominators wrote in favour of him. Raman was awarded the Nobel Prize in record time due to the practical significance of the discovery, as well as the good opinion of the famous contemporary scientists about his discovery. 28th February 1928 is the day when Raman discovered the effect named after him in his study of the collective modes of vibration and rotation in the inelastic scattering of a photon (light) by an atom or molecule. A small fraction of the scattered light (1 in 10 million photons) has a frequency different from the incident photon frequency and this can be observed in the spectrum of the atom or molecule. In a sense, Raman effect can be considered as the optical analogue of the Compton effect – the result of a high energy photon colliding with a target – discovered by Compton in 1923, for which the Nobel Prize was awarded to A.H. Compton, in 1927. In a sense, Raman Effect is the optical analogue of the Compton Effect and both were Nobel Prize winning discoveries.

Raman spectroscopy became a by word in laboratories all over the country and most physics department laboratories in India have a Raman spectrometer by the middle of the 20th century. In fact, Raman was nominated ten times for the Nobel Prize and he himself was so confident of winning the Nobel Prize that he booked his passage to Stockholm even before the Nobel committee's announcement was made, in 1930. The Nobel Prize in Physics was awarded to Raman "for his work on scattering of light and for the discovery of the effect named after him".

In recent times, 1998, the Raman Effect was designated an ACS National historical Chemical Landmark in recognition of its significance as a tool for analyzing the composition of solids, liquids and gases. Raman spectroscopy is a handy tool to analyze not only atoms and molecules but also highly complex biological organisms including the human tissue. It is used as a tool to detect high frequency phonon and magnon excitations.

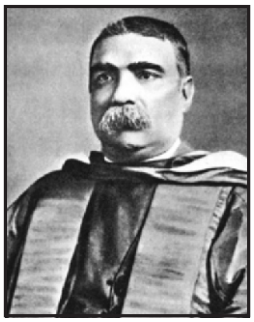
One may ask who spotted the talent of Raman first. This honour goes to none other than the renowned Sir Ashuthosh Mukherkjee (1864 –1924), 'the Bengal Tiger', a student of the Presidency College, Calcutta, who stood first in the 1883 B.A. degree examinations, of the Calcutta University, won the coveted Premchand – Roychand scholarship to complete his M.A. in Mathematics and two years later acquired an M.A. in Physics, to become the first dual degree holder of that University. He relinquished the offer of a job in the Department of Public Instruction in favour of completing his Bachelor's degree in Law. He published scholarly papers in Mathematics and Physics journals. At the age of 24, he became a Fellow of the Calcutta University. He was the Vice-Chancellor of the Calcutta University from 1906–1914 and again from 1921–1923 and was a force to reckon with in steering the University throughout his illustrious career. It as his eye to spot and nurture talent that led to his discovering and encouraging Dr. C.V. Raman, the Nobel Prize winner and Dr. S. Radhakrishnan, who became the President of India. Both were also honoured with the 'Sir' title by the British Government.

It is appropriate here to recall an interesting anecdote in the life of Ashuthosh Mukjherjee : On one occasion when Lord Curzon the Viceroy of India requested Sir Ashuthosh Mukherjee to visit England to get a first hand impression of how British education groomed Indian students to scholars. He did not accept the offer, since his mother did not grant him permission to cross the oceans (which would have made the family become 'outcaste' on his return to India, due to the then prevailing prejudices of the times). This made Lord Curzon write to him: "Tell your mother, the Viceroy and Governor-General of India commands her son to go" which only made Sir Ashuthosh Mukherjee fearlessly reply: "Then I will tell the Viceroy and Governor General of India that Ashuthosh Mukherjee refuses to be commanded by any other person except his mother, be he the Viceroy or be he somebody higher still". One cannot but admire the courage of conviction and the

love, affection and devotion he had for his mother, comparable to that of the mathematical genius Srinivasa Ramanujan, whose talent was also spotted very early by Sir Ashuthosh Mukherjee.

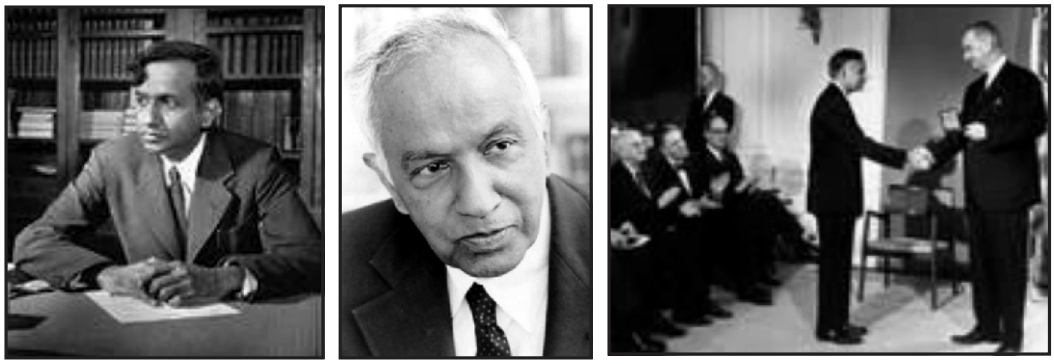
It was the vision Sir Ashuthosh Mukherjee had for the country's youth that gave him the courage to extract the best out of the colonial rulers of India. He pioneered several graduate programs in comparative literature, anthropology, psychology, industrial chemistry, ancient Indian history, and in Indian and Islamic culture. He nurtured teaching and research in languages: Bengal, Hindi, Pali and Sanskrit and persuaded and enabled European scholars to teach at the Calcutta University.

He was a Member of the 1917 – 1919 (Michael Ernest) Sadler Commission on the state of Indian education; President three times of the Asiatic Society, and of the Imperial Library Council in 1910. Being generous by nature he donated his invaluable collection of 80,000 books to the Library, which constitutes a separate section. He was the President of the inaugural session of the 1914 Indian Science Congress. For his scholarship in Pali, French and Russian, and for his service to Indian education, the pundits of Bengal conferred the title of 'Shastravachaspathi' on him and the British Government knighted him in 1911. An epitaph beneath the marble bust of his at the Ashuthosh Museum of Arts at the University of Calcutta reads:



"His noblest achievement, surest of them all
A place for his mother tongue – in step mother's hall."

S. Chandrasekhar (19 October 1910 - 21 August 1995)



Young and later day Chandra and being honoured by President of Lyndon Johnson of the United States of America.

The Nobel Prize for Physics was awarded to Subrahmanyan Chandrasekhar "for his theoretical studies of the physical processes of importance to the structure and evolution of stars", which was done during the 1930s. He shared the Nobel Prize with William A. Fowler of the California Institute of Technology.

Chandra, as he is called by students, friends, admirers and colleagues, was born on 19–10–1910, as the third child of C. Subrahmanya Iyer and Seethalakshmi. His father was the brother of Sir C.V. Raman. He retired as an Accountant General. He was a violinist of repute and pioneered the mathematical study of Carnatic Music.

Chandra was educated by his parents at home through primary and lower secondary classes, before he was sent to the Hindu High School in Form IV. He was a distinguished student of the B.A. Physics Honours at Presidency College, where he had an opportunity come into contact with Professor Arnold Sommerfeld in 1928 and with Professor Werner Heisenberg, a founder of Quantum Mechanics, in 1929, when they visited India. Chandra was excited by the stimulating discoveries during that Golden Age of Physics through the Journals arriving at the Madras University Library. The book of Sommerfeld on 'Atomic Structure and Spectral Lines', and Compton's 'X-rays and Electrons' inspired him to publish his first paper on 'The thermodynamics of Compton Effect with reference to the interior of the stars', in the Indian Journal of Physics (dated 15 October 1928), four days before his 18th Birthday. Even before he completed his B.A. (Hons.) he published several papers including one on 'Compton scattering and the new statistics', in the Proceedings of the Royal Society, London.

On his long voyage to England, Chandra worked out the details of what happens to a star in its last stage of evolution. He discovered a fundamental parameter that determines the density of stars and evolved his theory white dwarf stars.

In Cambridge, Chandra worked with Ralph H. Fowler as his Ph.D. Supervisor, and with P.A.M. Dirac and S.C. Milne. As a recognition of his ability he received the 'Sheep-Shanks' Prize for Astrophysics. 'Chandrasekhar Limit' is for the maximum mass, approximately 1.4 times the Solar Mass, above which an object has too much mass to support itself against collapse by electron degeneracy pressure. He derived this white dwarf mass limit by a rigorous application of the relativistic effects. In January 1935, Chandra presented this result at a meeting of the Royal Astronomical Society, in the august presence of Arthur Eddington who had become famous as the one whose expedition to South Africa on a total solar eclipse day confirmed experimentally that light from the Sun bent by the Moon's gravitational attraction is as predicted by Einstein's General Theory of Relativity (being twice that predicted by Newton's laws).

After the presentation of Chandra, Eddington said: 'I do not know whether I will escape from this meeting alive, but the point of my paper is that there is no such thing as relativistic degeneracy'. Eddington, one of the great astronomers of the day, dismissed the flawless work of Chandra as 'a reduction absurdum of the relativistic degeneracy formula' and continued that "The star has to go on radiating and radiating and contracting and contracting, until I suppose, it gets down to a few kilometer radius, when gravity becomes strong enough to hole in the radiation, and the star can at last find peace. I think there should be a law of nature to prevent a star from behaving in this absurd way." Dejected at this remark, Chandra returned to his abode in Cambridge from London, stood before the hearth that night and said to himself, "this is how the world ends, not with a bang but with a whimper".

However, he wrote to several founding fathers of quantum mechanics, including the Nobel Prize winner P.A.M. Dirac, and all of them agreed that his derivation was flawless and that Eddington was wrong in his 'belief' which he expressed openly at the London Royal Academy meeting. This was a controversy for two decades.

Chandra had the courage of conviction to talk about it at several conferences and finally at a Paris conference asserted that Eddington was wrong. In course of time, Chandra's theory was vindicated. Hundreds of white dwarf stars have been found and none with a mass greater than 1.44 times the Solar Mass. This Chandrasekhar Limit stands out as an important discovery in Astrophysics and is contained in every book on Astronomy and Astrophysics.

Chandra's astounding productivity for five decades in a variety of fields culminating in his 'Mathematical Theory of Black Holes' won for him several awards and his influence like that of Lord Rayleigh "on science was enormous because he added to the great body of knowledge, constantly inventing many things that were not spectacular but were always important". Chandra switched fields once every 10 years and worked as hard as he only could until he had the 'personal satisfaction' of having gained a clear 'perspective' of the field, which resulted in one of seven books he authored. In fine, his quest for 'Truth and Beauty' – the title of one of the books which is a compilation of a collection of his lectures – elegance and mathematical order in Astrophysics has enriched the field.

In the case of Chandra, the biography with the title 'Chandra', by K.C. Wali details every aspect of his life and work and it is a valuable documentation of the same. His talent was spotted from his collegiate days and he had his uncle, Sir C.V. Raman as a beacon light. I had the pleasure of writing an article soon after his Nobel

Prize for 'Physics Education', a U.G.C. publication which was popular, in 1983, and sent a copy of the same to Chandra, for which he wrote a reply in his inimitable style stating : 'I cannot be objective in your assessment.



Chandra with paternal uncle C.V. Raman.

E.C.G. Sudarshan (Born on 16 September 1931)



Ennackal Chandy George Sudarshan was born at Pallam in Kottayam District of Kerala State. He had his schooling in Kerala and he joined the Madras Christian College for his B.Sc. (Hons.) and M.A. degrees. He then joined the Tata Institute of Fundamental Research, Bombay, in 1951. During his four years there he had the opportunity to come into contact with the visiting Nobel Laureates P.A.M Dirac, W. Pauli and M. G. Mayer.

Sudarshan's scientific career had a turning point when Robert E. Marshak from the University of Rochester visited the Tata Institute of Fundamental Research, Bombay, in 1954. Impressed by the clarity and the precision of the Lecture Notes of Marshak's lectures prepared by Sudarshan, Marshak requested Homi Bhabha whether he could take him as his student to Rochester. Sudarshan married Lalitha Rau, in 1954, before he left for Rochester with his wife.

During his first two years, as a graduate student of Marshak, he formulated the Universal V-A theory of weak interactions with which he could explain four of the experimental data which could not be understood otherwise. This work in 1957, is considered as a crucial step and a breakthrough for the later day unification of electromagnetism with weak interactions and Grand Unified Theories. This outstanding contribution by Sudarshan when he was only 26-years old brought him renown and his continued contributions to Physics saw him rise soon to become a Professor and the Director of Research Program at the University of Syracuse University from 1964 – 1969 and later to a Professorship and the founding of a Center for Particle Theory at the University of Texas at Austin, from 1970, where he is continuing to be an Emeritus Professor. Sudarshan has been a Senior Professor at the Center for Theoretical Studies, in the Indian Institute of Science, Bangalore, since 1971 and from 1984 – 1987 he was also the Director of the Institute of Mathematical Sciences, during which time the IMSc saw a phenomenal growth in infrastructure, academic strength and stature.

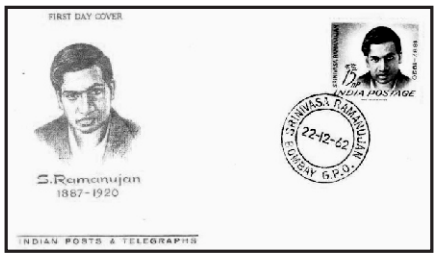
Besides weak interactions, Sudarshan has made several significant contributions to Quantum Optics, Classical Dynamics and Quantum Field Theory. For Tachyons, or faster-than-light particles, Sudarshan developed a complete Field Theory for faster-than-light particles. His research work is published in more than 200 papers and he is the author of three books: 'Elementary Particle Physics', with Marshak (Interscience, NY 1965); 'Fundamentals of Quantum Optics', with J.R. Klauder (W.A. Benjamin. NY, 1968); and 'Classical Dynamics', with N. Mukunda (John Wiley, NY, 1974).

In recognition of his meritorious achievements, he was awarded the D.Sc. (Honoris Casa) by the University of Wisconsin (1969), University of Delhi (1973) and by the Chalmers University of Technology (1984); the Padma Bhushan by the President of India (1976), the Bose Medal of the Indian National Academy (1977);

the Honours Award by the Association of the Indians in America (1976); the Science and Technology Award by the Kerala State Government (1980) and the First Physics Prize of the Third World Academy of Sciences (1985). This was in recognition for the invention of the Universal V-A Theory, a very long time after its achievement. It is significant to note that the four experiments which disagreed with the V-A theory were redone immediately after the theory was proposed and all the experiments yielded new results in complete agreement with the theory. Marshak who collected and put together best students, brought Steven Weinberg also to Rochester to discuss with Sudarshan. The first paper which was written was in this particular collaboration. In later years, the electro-weak unification won the Nobel Prize for Abdus Salam, S. Weinberg and S. Cabbibo, in 1987, giving room for one to ask why the steppingstone, the Universal V-A theory was left out of the reckoning for the Prize! In recent times, Sudarshan was honoured with the Padma Vibhushan (2007) and the Dirac Medal of ICTP (2010).

Srinivasa Ramanujan (22 December 1887 - 26 April 1920)







Srinivasa Ramanujnn hailed as a natural mathematical genius, comparable to Euler, Gauss and Jacobi. He was born as the eldest son of K. Srinivasa Iyengar, a 'gumasta" to a cloth merchant of Kumbakonam and Komalathammal an ardent devotee of Goddess Namagiri of Namakkal. He was born on December 22, 1887, a Thursday, coinciding with the day on which the Vaishnavite saint Ramanuja who established the unique non-dualistic school of Vedanta philosophy was also born. Thus, the name would have occurred to the parents or would have been considered the most appropriate by all concerned. Komalathammal, the mother of Ramanujan, had a firm conviction that the son was born as a boon to her prayers and that he was destined to make a mark in life as a mathematician. She told all concerned that she saw her son, hailed by her as Chinnaswamy ('little lord') was sitting with Britishers at a table talking to them.

Ramanujan was inarticulate until he was three years old. He was admitted to the Kangeyan Primary School and later to the Town High School in Kumbakonam. There is an archway with the name 'Ramanujan Hall' painted on it to this day in that School, where Ramanujan studied till his Matriculation in 1903.

Ramanujan was considered precocious at School and the Senior Mathematics Teacher, Ganapathy Subbiyer, entrusted by the School, which had a strength of about 1400 students, to prepare a conflict-free time-table passed on his responsibility to young school boy Ramanujan. With hind sight we may conclude that this is probably the time when he thought of filling n x n squares with integers such that the sums of the elements in each column, the sums of the elements in each row and the sum of the elements in the diagonal and the skew-diagonal all add to the same total N. The smallest magic square is 3 x 3 and when the nine squares are filled with integers 1 to 9, such that the sums of the three elements in the rows, columns, and the diagonal and skew-diagonal add to the same 15, we get the magic square:

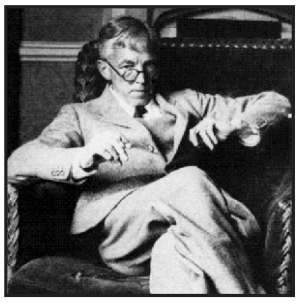
4	9	2
3	5	7
8	1	6

Ramanujan started noting down the results in a Notebook. In his Notebook 1, Chapter 1 has the title "Magic Squares" and it is 3 pages long. In Notebook 2, Chapter 1 has no heading but it is also on Magic squares and it runs to 8 pages. The contents of these chapters along belongs to the realm of recreational mathematics. The rest of the chapters deal with mathematics of a very high caliber and some of these results (about 100 chosen by him from the 3254 Entries of his in his Notebooks) were sent by him to Professor Hardy at Trinity

College, Cambridge, after he saw a statement in the book 'Orders of Infinity' authored by Hardy, at Presidency College, Madras, which read: "no definite expression has yet been found for the number of prime numbers less than any given number". He told Professor Seshu Iyer he had that expression in his Notebooks, which prompted his Professor to communicate the same to Professor Hardy at Trinity College, Cambridge.

There is no one-to-one correspondence between the contents of the corresponding chapters of Ramanujan's two Notebooks. Notebook 1 has 16 chapters while Notebook 2 has 21 chapters. This is the reason why there is a considered opinion among the followers of Ramanujan's prolific contributions to mathematics, that Notebook 2 is a revised enlarged version of Notebook 1. It is also to be noted that these Notebooks contained Entries which were like statements of theorems without Proofs. However, Hardy knew that he was capable of giving more than one Proof for each and every Entry, when asked to by anyone.

With these Notebooks to establish his mastery of mathematics, Ramanujan went to Professor P.V. Seshu iyer who was his maths teacher in Government Arts College at Kumbakonam, after he came to Madras, and later to Dewan Bahadur Ramachandra Rao, Collector of Nellore at Tirukkoilur, who was the Uncle of a classmate of Ramanujan. After 4 unsuccessful attempts, on the fifth attempt Ramachandra Rao condescended to look into the Notebooks and though he was an M.A. in Mathematics, he could not understand most of the contents of the Notebooks. He offered Rs. 20 per month to Ramanujan but asked him to return to Madras with a letter of reference to S. Narayana Iyer, M.A., treasurer in the Madras Port Trust. Once Narayana Iyer, a devotee of Ramana Maharshi, saw the Notebooks, he started to leave no stone unturned till Ramanujan whose prowess was 'hidden under a bushel' until he was in the limelight getting all the support he deserved from the Port Trust which offered him a clerical job (with no responsibilities) and the freedom to pursue his favourite pastime of discovering mathematical formulas.



Ramanujan at last found a sympathetic kindred humane human in authority who got him all the recognition from the University of Madras, first in the form of a First Ever Research Scholarship to a failed F.A. (First degree in Arts) . When Ramanujan saw at Presidency College, while he was waiting for Seshu Iyer, the book by Hardy on 'Orders of Infinity' in which he read that "no exact formula has been found for p(n), the number of prime numbers below any integer n", (and that the only known formula was the asymptotic limit of p(n) to be $n / \log n$ as n infinity, known to Gauss). He excitedly told Professor Seshu Iyer that he knew such a formula and it was one of the Entries in his Notebooks. In response, Seshu Iyer suggested that Ramanujan should write to Prof. G.H. Hardy at the Trinity College, Cambridge and Narayana Iyer perhaps helped in drafting that letter. In January 1913, this historic letter from Ramanujan in Madras reached Hardy, who ignored it when he saw it in the morning since he was accustomed to receiving letters from quacks in India and he went about his tasks for the day. In the evening, after supper, when Hardy saw that the letter had more than 100 formulas in a neat handwriting on several sheets of paper, he invited his colleague Professor J.E. Littlewood and studied the contents with him. Some Series summation formulas were familiar to him; some integral results were known to him; some of the results he could derive but with difficulty, but some continued fraction results 'defeated' him 'completely'.

Hardy then decided to get Ramanujan to England. Hardy, the true friend, philosopher and guide to Ramanujan wrote a reply which enthused Ramanujan. After some exchange of letters, Hardy did his best to get all the necessary financial support to make Ramanujan visit him at Trinity College, Cambridge. Ramanujan overcame the caste prejudices and with the orchestrated efforts of Narayana Iyer, Ramachandra Rao, Ramaswamy Iyer (the Founder of the Indian Mathematical Society (IMS) and its journal called the Journal of the IMS) and the support of the Registrar of the University of Madras and the Governor of Madras, Ramanujan was able to prepare to go Cambridge in about a year, and was in England for a period of 5 years, 1914 – 1919. During this period, he collaborated with Hardy to write 5 papers and Ramanujan to publish several more as the sole author. One of them on 'Highly Composite Numbers", a very original contribution of Ramanujan, though according to Hardy it was in the 'backwaters' of mathematics, but for originality unparalleled, along with some other publications of Ramanujan were submitted as a thesis to the Cambridge University, which in 1918, conferred the B.A. degree by research on Ramanujan. Hardy also helped in Ramanujan becoming a Fellow of the Royal Society of London. A five year Trinity College Fellowship was also secured by Hardy to Ramanujan.

However, as ill-luck would have it, Ramanujan being a strict vegetarian had to cook food by himself. He was married to Janaki in 1909 and they lived together for about an year after she came of age, and before Ramanujan left for England.

But since his 5-year stay had a complete overlap with the World War I, Ramanujan suffered in many ways: there was considerable delay in his getting by mail the food items (like tamarind, dhall powders, friable items which he relished, etc.) and even letters – which were screened by his dominating mother who was running the household in Madras, keeping Janaki, wife of Ramanujan, alienated from him. For half of the period of his stay, he was unwell, and doctors there treated him for tuberculosis (TB) a tropical disease for which there was no cure at that time. Eventually hoping that the warmer climate in Madras would make Ramanujan recover from TB, Hardy arranged to send him back to India.

In March 1919, Ramanujan returned by Ship and was received in Bombay by Narayana Iyer and his family and friends (but Janaki was left behind in Madras) who genuinely treated him as a V.I.P. All medical help was given on the basis of expert doctors' opinions. Neither the treatment for TB, nor the warmer climates in Kodumudi, Kumbakonam, Madras improved the health of Ramanujan, who grew weaker and died on April 26, 1920.

Surprisingly, Hardy did not write to him even a single letter and Ramanujan in his only letter in Jan. 1920 did not write to him about his deteriorating health condition but only wrote about his discovery of 'mock' theta functions and sent him many results. Hardy too felt happy when he saw the new results and so the information about the death of Ramanujan was a shock and a surprise to him.

Hardy did spend some time to study the chapter on hypergeometric series in the Notebooks of Ramanujan but gave up the task stating that he would never be able to do any other work than trying to understand the work of Ramanujan and verifying their truth and providing proofs. Hardy did bring out the "Collected papers of Srinivasa Ramanujan", published by the Cambridge University Press, in 1927, seven years after Ramanujan died. Hardy wrote to the University of Madras that he entrusted the task of editing the Notebooks of Ramanujan, to G.N. Watson and B.M. Wilson, but the premature death of Wilson, left this work unfinished. It was taken up in right earnest by Bruce C. Berndt of the University of Illinois, from 1976 and till late 1990s, during which period 'Ramanujan's Notebooks', Part I to Part V were published by Springer-Verlag and a Proof has now been provided for each one of the 3254 Entries of Ramanujan in his Notebooks. How Ramanujan, a self-taught genius, discovered so many results which were all correct will remain an enigma and a feat unparalleled in the History of Mathematics. The interested reader may refer the following websites for further details about Ramanujan:

www.imsc.res.in/~rao/ramanujan www.math.wisc.edu/~askey www.math.uiuc.edu/~berndt www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Ramanujan

On seeing the Passport Photo of Ramanujan, Hardy wrote, in 1937, "He looks rather ill, but he looks all over the genius he was"…. "I have [very rarely] encountered a pupil who could face the simplest problem involving the ideas of infinity, limit, or continuity with a vestige of the confidence with which he could deal with questions of far greater intrinsic difficulty." - G.H. Hardy.

Hardy wrote after Ramanujan's demise: "It is perhaps useless to speculate as to his history had he been introduced to modern ideas and methods at sixteen instead of twenty-six. It is not extravagant to suppose that he might have become the greatest mathematician of all time". Professor Richard Askey said: "Try to imagine the quality of Ramanujan's mind, one which drove him to work unceasingly while deathly ill, and one great enough to grow deeper while his body became weaker. I stand in awe of his accomplishments; understanding is beyond me. We would admire any mathematician whose life's work was half of what Ramanujan found in the last year of his life while he was dying."

"Years later Hardy contrived an informal scale of natural mathematical ability on which he gave himself a 25 and Littlewood a 30. To David Hilbert, the most eminent mathematician of his day, he assigned an 80. To Ramanujan he gave 100." – Robert Kanigel in 'The Man Who Infinity : A Life of the Genius Ramanujan', Charles Scribner's Sons, New York (1991); Indian edition published by Rupa & Co. (1994).

Kannan Soundararajan



Kannan Soundararajan (with a nickname 'Sound') had his early schooling at Padma Seshadri School, Nungambakkam, Chennai and when he was a student in the IX standard, his mathematics teacher came to me with him and his father.

As my interests were predominantly in Theoretical Nuclear Physics and in Mathematical Physics at that time, and I was a Professor of Physics, after a brief interaction with him, I introduced him to my colleague Dr. R. Balasubramanian ('Balu' to us, his colleagues and friends), a Number Theorist and a Professor of Mathematics and showed him the excellent journals (including the Mathematical Intelligencer) and the books in the Library on Mathematics.

Undoubtedly, he was the brightest student I had come across in my career and proved his mettle very early when Sound represented India at the International Mathematical Olympiad, in 1991, and won a Silver Medal. After I introduced him to Balu, he in turn brought him into contact with his mentor, the Number Theorist of repute at TIFR, Professor K. Ramachandra, and Professor C.S. Seshadri, an algebraic geometer (in whose name there is a constant called the 'Seshadri constant' who later became a Fellow of the Royal Society and became the Founder Director of the Chennai Mathematics Institute in Siruseri, on the outskirts of the city of Madras). The same year, 1991, Sound joined the University of Michigan for his undergraduate studies, with the necessary financial support offered to him thanks to the efforts of Professor Hugh Montgomery, a Fields medalist, including his passage to go to Michigan (and I am happy to have had a role to play in this success story, and in that sense nurtured the talent and aspirations of young Sound). Sound joined the Princeton University for his Ph.D. with Professor Peter Sarnak, with the Prestigious Sloan Foundation Fellowship. He received the first five year Fellowship from the American Institute of Mathematics and held positions at Princeton University, Institute for Advanced Study in Princeton and the University of Michigan before moving to Stanford in 2006.

"SOUNDARARAJAN has made brilliant contributions to several areas in analytic number theory that include multiplicative number theory, the Riemann zeta function and the Dirichlet L-functions, and more recently with the analytic theory of automorphic forms and the Katz-Sarnak theory of symmetric groups associated with families of L-functions. As an undergraduate at the University of Michigan, Soundararajan made two outstanding contributions. First, in joint work with R. Balasubramanian, he proved a famous conjecture of Ron Graham in combinatorial number theory. Next he obtained some fundamental results on the distribution of zeros of the Riemann zeta function. Subsequently, in his PhD thesis, written under the direction of Professor Peter Sarnak of Princeton University, Soundararajan proved the spectacular result that more than 7/8-ths of quadratic Dirichlet L-functions have no zeros at the critical point s=1/2, thereby providing strong evidence for a conjecture of Chowla. A part of his PhD thesis is published in the Annals of Mathematics. More recently, in a paper with Brian Conrey in Inventiones Mathematicae, Soundararajan proved that a positive proportion of Dirichlet L-functions have no zeros on the real axis within the critical strip. In another paper in Inventiones Mathematicae, he and Ken Ono, assuming the generalized Riemann hypothesis, confirmed a certain conjecture of Ramanujan regarding a ternary quadratic form. Soundararajan is also a leading expert on random matrix theory and its implications in analytic number theory… His work with Hugh Montgomery shows that prime numbers in short intervals are distributed normally, but with a variance that is surprisingly different from classical heuristics. Soundararajan, considered to be one of the most creative young minds to emerge in the last decade, is currently Full Professor at the University of Michigan, Ann Arbor." – This was the citation read when he and Manju Bhargava were selected as the top candidates from a pool of brilliant young mathematicians from around the world, by an International Panel of Experts to select the candidate for the 2005 SASTRA Ramanujan Prize Committee, with Professor Krishnaswami Alladi of the University of Florida, as the Committee's Chairman. Soundararajan and Bhargava were awarded the SASTRA prize during the International Conference on Number Theory and Mathematical Physics, December 19-22, 2005, at SASTRA University, where both Kannan Soundararajan and Manju Bhargava were invited to present their work and I was a Distinguished DST-Ramanujan

Professor for Mathematical Sciences at that time in the Srinivasa Ramanujan Center, of SASTRA University, at Kumbakonam.

Soundararajan was awarded the Morgan Prize (2005), the Salem Prize (2003) besides the SASTRA Ramanujan Prize (2005) mentioned above. He was nominated for the Fields Medal at the International Congress of Mathematicians, which took place for the first time in India, in August 2010 at the University of Hyderabad. The Fields Medal is the highest award in Mathematics and offered to one mathematician, or at most four mathematicians, once in four years, and there are only fifty receipiants till date.

Concluding remarks

We should now attempt an answer to the question posed as the title of this write-up:

Sir Isaac Newton's universal law of gravitation is popularly attributed to a creative leap he experienced when he observed a falling apple. While apples have been in the picture ever since the days of Adam and Eve and the forbidden fruit, often depicted as an apple, it was not until after many millennia and only about three hundred years ago, that the equations: $\underline{v} = \underline{u} + \underline{g}t$ and $s = ut + \frac{1}{2}at^2$ were written down for the first time in the history of Science by Newton.

D.K. Simonton in 'Origins of genius : Darwinian perspectives on creativity' (Oxford University Press, 1999) showed how some of the major scientific advances of the 20th century can be attributed of creativity of individuals.

“An oft quoted model, known as the 'threshold hypothesis' proposed by Ellis Paul Torrance”, as quoted by J.P. Guilford in the 'Nature of Human Intelligence', “holds that a high degree of intelligence appears to be a necessary but not sufficient condition for high creativity .”

“While there is a positive correlation between creativity and intelligence, this correlation disappears for IQs above a threshold of around 120. Such a model is acceptable to many researchers, although it has not gone unchallenged.”– quote from Hyung Chee Kim (2005) in “Can Only Intelligent People be Creative ?” (Journal of Secondary Gifted Education, vol. 16 (nos. 2 / 3), p. 57 – 66, retrieved on 12 May 2011 from the website: //kkim.wmwikis.net /file/view/CanOnly Intelligent People Be Creative.pdf. “A study [by Getzels and Jackson] among high school students concluded that high IQ and high creativity tend to be mutually exclusive with a majority of the highest scoring students being either highly creative or highly intelligent, but not both. While this explain the threshold, the exact interaction between creativity and IQ remains unexplained”, states J.A. Plucker and J.S. Renzulli, in “Psychometric Approaches to the Study of Human Creativity”, in the edited volume of R.J. Sternberg, “Handbook of Creativity” (Cambridge University Press, 1999).

From the case studies presented, while Satyendra Nath Bose had in Einstein a willing and helpful collaborator; Sir C.V. Raman received great support from Sir Ashuthosh Mukherjee at the Indian Association for the Cultivation of Science; S. Chandrasekhar had to academically fight Arthur Eddington with his courage of conviction in his theory; E.C.G. Sudarshan had the initiative to propose to his guide R.E. Marshak a universal V – A theory of weak interactions; Kannan Soundararajan had the Padma Seshadri School teachers rising to the occasion when faced with an extraordinary talented student by bringing him into contact with established researchers in a fundamental research institute; the talent of the 'natural genius' Srinivasa Ramanujan, like the Big Bang, can only be a “SWAYAMBHU” (natural event), which we can admire in awe.

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