Celebrate mathematics

With this year being the 125th anniversary of Srinivasa Ramanujan's birth, s ananthanarayanan **dwells on the genius that he was**

IT'S been a century since Srinivasa Ramanujan flashed for a short while through the world of mathematics. A century, because it was around 1912 that his talent came to relevant notice, to be followed by eight years of unprecedented, and since unequalled, productivity — a corpus of originality and genius whose fascination has remained fresh and tantalising to this day. This year is also the 125th anniversary of Ramanujan's birth and has been declared by the government of India as National Mathematical Year.

Ramanujan was born in 1887 at Erode in Tamil Nadu, then Madras Presidency, and he displayed remarkable talent even when in junior school. By the time he was 13, he had mastered SL Loney's *Trignometry*, a fairly advanced standard textbook of mathematics, one that is normally completed only in university. When he was 16, he chanced upon a collection of problems, and theory in outline, which had been developed for aspirants to the Tripos Examination of the University of Cambridge. With little exposure to higher math, either in his curriculum or from his teachers, this collection of advanced and difficult problems opened the universe of number theory and higher algebra for Ramanujan.

He became fascinated by mathematics and worked at it to the exclusion of all else. While he never cleared his university exams, for want of credits in other subjects, and could not hold down a regular job, he rapidly discovered, in books or by himself, most of the mathematics that he would have learnt in a proper course of formal training. And along the way, he developed insights and broke fresh ground in the form of new formulae or theorems of clarity and power that took professional mathematicians by surprise. The work in these years was recorded, often with sketchy descriptions of the method followed, in notebooks that have now become celebrated as the first record of Ramanujan's early work.

He soon came to the attention of GW Hardy, a gifted professor at Cambridge, who was overwhelmed by the quality of his work. It was "certainly the most remarkable I have received", he said and added that Ramanujan was "a mathematician of the highest quality". Hardy lost no time in arranging for him to come over to work in England and the young Indian was soon imbibing aspects of mathematics so far unknown to him, and learning that much of what he had worked out by himself, to his chagrin, had been discovered earlier. But the academically rich environment of Cambridge made his undoubted talent flower and in the next five years, till he died at the young age of 32, he churned out a huge volume of work of the highest quality.

Nature of work

Ramanujan's life work had so much variety we cannot do better than glance at some typical areas. One of these concerned formulas to evaluate numbers that are expressed as the converging sum of an infinite series of reducing components. An example of an infinite series would be like: $1+1/2+1/4+1/8+1/16+1/32+\ldots$ where the terms rapidly get smaller so that the later additions are small indeed. It can be shown that the terms of this series never add up to more than the number 2, even if we consider infinite terms. But a series like $1+ \frac{1}{2} + 1/3 + \frac{1}{4}, +1/5 + 1/6 + \ldots$ where successive terms do not diminish as rapidly as the previous case, does not converge; but, if we go to infinite terms; adds up to infinity.

More complicated series even add up to values that can never be exactly stated, but need to be described only as an infinite series. One example of such a number is p, the ratio of the circumference of a circle to its diameter. In the correct statement of this number, the terms after the decimal point continue forever, and never even repeat, as happens with recurring decimals. The terms are therefore truly random, and series that add up to such numbers have fo long been of interest.

Ramanujan, with his uncanny, nearly inspired insight, came up with incredible formulas for such series, which bettered existing formulas by getting very close to the final decimal numbers even on evaluating only a few of the terms of the series, as the value of the terms diminished very rapidly. These formulas are hence a powerful way of generating numbers of the nature of p, correct to many decimal places, faster than by using other series expansions, where even the later terms made more substantial contributions.

Srinivasa Ramanujan

Another great area of Ramanujan's work is that of continued fractions. A continued fraction is a number that is a whole number plus a fraction. But the denominator of the fraction is also a number plus a fraction. And the denominator of that fraction is again a number plus a fraction, and so on. It would look like this:

$$x = b_1 + \cfrac{a_1}{b_2 + \cfrac{a_2}{b_3 + \cfrac{a_3}{b_4 + \cfrac{a_4}{\ddots}}}}$$

and so on

While any number can be expressed as a continued fraction by choosing the correct values for the "b" and "a" terms, we can see that it could even be a case of an "infinite" continued fraction. It is also possible, with some computation, to show that these fractions amount to a series, the infinite series representing numbers like p.

Such numbers where the sequence is essentially random are useful when expanded to a very large number of decimal places. In such an expansion, especially running to thousands of places, selecting any place to start would result in a sequence that would be unpredictable unless the starting point were known. Ramanujan's work made important contribution in the field, again with formulae that generate the expansions with the least computation. Such expansions have become useful to generate codes in e-commerce and, hence the value of formulae like Ramanujan's that generate the expansions efficiently.

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Puzzles at a village inn

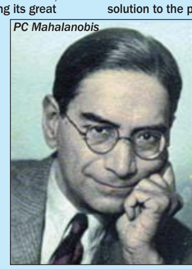
THE English magazine, *Strand*, carried a regular page of puzzles and problems under the title "Perplexities". The *perplexities* column of its December 1914 issue was written as a story — "Puzzles at a village inn" — and it worked in a report about the German excesses in the Belgian town of Louvain, where the Nazis were setting houses on fire, street by street, and destroying its great library.

A friend's address

The problem was to work out the number of a house on a street of Louvain. The writer spoke of a street where the houses were on one side and were numbered serially — one, two, three, and so on. The writer's friend stayed on the street, but the only thing the writer knew was that all the numbers on one side of the house added up to exactly the same as the numbers on the other side! And *Perplexities* invited readers to work out the friend's house number and visit him in the spring! Another bit of information was that there were at least 50 houses in the street, but not as many as 500.

It was PC Mahalanobis, who later became a great statistician, who brought the problem to Ramanujan. Mahalanobis himself had used trial and error and had worked it out in a few minutes.

Ramanujan did it his way. He got the answer too, at once. But he did it by developing one of his celebrated "continued fractions". The method immediately gave the only solution to the problem with more than 50 and less than 500 houses — No. 204 in a street of 288 houses. 1+2+3+4+... +277 adds up to 20706, which is the same as 205+206+...+288!



PC Mahalanobis

What is more, Ramanujan's method was the solution at once for the whole class of problems like this. For instance, if the number of houses was eight, then the solution was No. 6, because 1+2+3+4+5 = 15 and 7+8 = 15!

Unleashing spider web power

steve connor **reports on a breakthrough that may pave the way for new biomaterials that could be used in medicine and engineering**

SCIENTISTS have created genetically-modified silkworms that can spin the much stronger silken threads of spiders in a technological breakthrough that promises to revolutionise the production and use of new materials made with spider silk.

For more than a quarter of a century scientists have been trying to find ways of producing industrial-scale quantities of spider silk because, weight for weight, it is stronger than steel and almost as tough as bulletproof Kevlar. A net woven from pencil-thick rope spun from spider silk, for instance, could in theory catch a fighter jet in flight without breaking.

However, unlike the caterpillars of the silk moth *Bombyx mori*, spiders are territorial, aggressive and prone to cannibalism, making it impossible to rear them in the population densities required for commercial silk production. Researchers have attempted to overcome this difficulty by transferring into silkworms the key spider genes responsible for making the silk threads used in the draglines of the Golden orb-web spider. The result was a genetically-modified "transgenic" silkworm that produced a mixture of its own silk combined with the far tougher and stronger threads of spider silk within the mile-long threads of its cocoon.

The researchers, led by Professor Don Jarvis of the University of Wyoming, in Laramie, have published their study in the journal *Proceedings of the National Academy of Sciences*, showing how they created transgenic silkworms capable of making composite fibres with silk threads from both spiders and commercial silkworms.

"On average, the composite fibres produced by our transgenic silkworm lines were significantly tougher than those produced by the parental animals and as tough as native dragline spider silk fibre. In best-case measurements, the composite fibre produced by one of our transgenic silkworms was even tougher than the native dragline spider silk fibre," the scientists said.

Professor Don Jarvis (right).

Some possible uses for spider silk had already been identified in medicine, such as new kinds of biomaterials for wound dressings, artificial ligaments, tendons, tissue scaffolds and microcapsules for drug delivery, they said. Other uses could include materials used in bulletproof jackets and engineering.

Ever since scientists first identified the spider genes involved with silk production, biotechnologists have tried to create genetically-modified alternatives to spiders. Synthetic spider silk genes have been transferred into bacteria, tobacco plants and even goats, which produced limited quantities of silk proteins in their milk.

However, none of the transgenic microbes, plants or animals carrying spider silk genes have been able to produce sufficient quantities of the pure proteins needed for commercial-scale production.

But it is hoped that the *Bombyx mori* silkworm, which has a proven record in industrial silk production, may finally offer a solution to the scale-up problem.

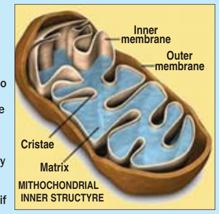
The Independent, London

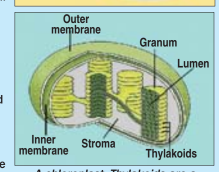
Mithochondria & Chloroplasts

In evolutionary terms, it is possible to conceive that a symbiotic relationship could have given rise to these organelles having only limited autonomy and depending on the nucleus and the cytosol of the cell for most of their specific components, writes tapan kumar maitra

MITHOCHONDRIA and chloroplasts are remarkable organelles in the way they originate and develop. Both are formed by fission of pre-existing organelles and we will see that two genetic systems are involved in the synthesis of their protein components.

During plant development, proplastids appear, which are limited by a double membrane. In the presence of light, the inner membrane grows and gives off vesicles into the matrix that are transformed into discs. These intrachloroplastic membranes are the thylakoids which, in certain regions, pile closely to form the granum. In the mature chloroplast, the thylakoids are no longer connected to the inner membrane, but the granum remain united by intergranal thylakoids. It is interesting that if a plant is put under low light intensity, the reverse sequence of changes takes place. This process is called *itiolation*, and results in the disorganisation of the membranes. The same phenomenon occurs if the plant is grown from the beginning in low light intensity. In this case, the vesicles of the proplastid aggregate to form one or more *promellar* bodies, which can develop into granum if the plant is subsequently exposed to light.





A chloroplast. Thylakoids are a phospholipid bilayer membrane-bound compartment. A granum is a stack of thylakoids folded on top of one another. The stroma is the fluid space within the chloroplast. The lumen is the fluid filled space within a thylakoid.

Both chloroplasts and mitochondria are distributed between the daughter cells during mitosis, and their number increases at interphase.

Limited autonomy

New light was thrown on the problem of the mitochrondrial and chloroplast biogenesis when it was demonstrated that these organelles contain DNA, RNAs and other components involved in protein synthesis. These two organelles are, thus, semi-autonomous and their functioning depends on the cooperation between their own genetic systems plus that belonging to the rest of the cell.

Mitochondrial DNA (mtDNA) is contained in the matrix and is probably attached to the inner membrane. mtDNA is circular and generally occurs in one copy per mitochondrion. Apparently all the mtDNA in an individual (about 10^{17} molecules in a human) are identical and contain single copies of genes. mtDNA codes for the ribosomal RNAs of mitochondria and for about 19 transfer RNAs for the 20 or so proteins that are incorporated into the inner membrane. (A striking characteristic of these proteins is that they are all hydrophobic.) Although ribosomal RNAs originate from mtDNA, all ribosomal proteins come from the cytosol. Chloroplasts contain DNA in the stroma; this DNA is much longer that mtDNA. Ribosomes and polyribosomes are also present, although the genetic information of the chloroplasts is evidently limited, and their proteins are synthesised by several mechanisms involving (1) chloroplast DNA and ribosomes, (2) nuclear DNA and cytoplasmic ribosomes, and (3) nuclear DNA and chloroplast ribosomes.

Symbiont hypothesis

At the end of the last century, cytologists like Richard Altmann and Schimper speculated, on purely morphological grounds, that mitochondria and chloroplasts might be intracellular parasites that had established a symbiotic relationship with the eukaryotic cell. Bacteria were thought to have given rise to the mitochondria and blue-green algae to the chloroplasts. The symbiont hypothesis is based on many similarities between prokaryotes and mitochondria and chloroplasts, such as the presence of DNA and ribosomes. Another similarity is evident in the location of the respiratory chain and ATPase in the bacterial plasma membrane; and in certain bacteria, the membrane forms projections called *mesosomes*, which are comparable to the mitochondrial crests.

Support for the possible prokaryotic origin of mitochondria and chloroplasts is also found in the fact that intracellular symbiosis can be found in nature. Thus *Paramecia* may contain certain bacteria, and blue-green algae may occur in simple animals. The endosymbiosis of a photosynthetic prokaryote confers upon the host the ability to capture light energy with which to synthesise various products; at the same time, it provides the prokaryote with a constant environment in which to grow and reproduce.

In evolutionary terms, it is possible to conceive that a symbiotic relationship could have given rise to the present situation, in which the organelles have only limited autonomy and depend on the nucleus and the cytosol of the cell for most of their specific components.

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