



# DREAM 2047

January 2014

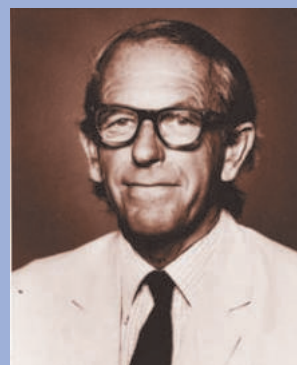
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## Fractals: The Fabric of Nature

**Frederick Sanger**  
(The only person to win the  
Nobel Prize twice in Chemistry)



(1918-2013)

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# Classic insights from Jean-Yves Le De'art Foreword



Dr. R. Gopichandran

People engaged in science (and technology) communication must get hold of the book titled *Science Communication Today: International Perspectives, Issues and Strategies*, 2013 (Eds) Baranger P and Schiele B, CNRS Editions, Paris. Seventeen insightful chapters represent the ideas presented and deliberated on at the 4th Journées Hubert Curien, held in Nancy, France from 2 to 7 September 2012 as part of the conference on mediation of sciences.

Four important objectives of the conference reflect the synthesis we as communicators are looking for, especially when the spread and depth of challenges in communication appears to be growing by the day. This is with special reference to continually evolving complexities in understanding phenomena with a special emphasis on limitations of tools and techniques. Agendas that determine communication are equally important modulators of the processes and impacts of communication. Climate change impact management is a typical case in point. This is also because mitigation and adaptation strategies have a significant bearing on livelihoods, lifestyles and willingness to adopt preventive strategies, wherein the role of individuals and institutions is critical. Credibility of communicators and messages delivered are central to success in this case as in others too with a large public policy and programmes interface. In this context, I take this opportunity to highlight Jean-Yves's reference to the following in his foreword to the cited publication. This is especially because they appear to reflect some strands of thinking directly relevant to India too. He refers to the report of the Parliamentary Agency for scientific and technical choices assessment Number 4214 (January 2012) that was aimed at helping mainstream science in systems of learning.

The initiative referred in the report was to build on

science's innate strengths to overcome challenges of poverty and inequalities that do not seem to be obliterated even by significant advances in science and technology. Three ideas that represent the direct and immediate applications of science have been proposed as useful focal points. (1) Popularise science in schools through special emphasis on the scientific method and enhance scientific and technical information in media. The latter could be by training science journalists to communicate appropriately and consistently so through several media. These should stimulate innovation and help duly recognise the virtues of failure; so that useful lessons could guide transitions. (2) Bridge gaps between higher education, research and innovations, and (3) establish and strengthen public support for innovation. These are parts of holistic science communication methods and should mutually reinforce.

Two related aspects in this context are transparency and knowledge that are easily understood, appreciated and imbibed by all stakeholders. A special emphasis is citizens so that they exert their choice on public policy and decision making on related aspects. Education, public consultation and media communication are useful means to achieve this goal of better reception by citizens. Importantly Jean-Yves articulated the above framework of science communication for inclusive growth to overcome challenges posed by deviant choices, pathways and applications of science, not sensitive to inequalities generated while pursuing fragmented development goals. The cited foreword rightly calls for holistic approaches in science (and technology) communication to serve as a tool for to help deliver a portfolio of sustainable, locally relevant and feasible solutions.

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# Frederick Sanger

## The only person to win the Nobel Prize twice in Chemistry



Dr. Subodh Mahanti

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“For his nucleic acid work Sanger shared the 1980 Nobel Prize and became the first to win two Nobel Prizes in Chemistry. His work has given new, surprising and detailed knowledge of both proteins and genes and has stimulated others in the field.”

*The Cambridge Dictionary of Scientists*, Cambridge University Press, 2002

“In 1955, after some ten years’ work, Sanger established the complete amino-acid sequence of the protein bovine insulin. This was one of the first protein structures identified, and Sanger received the Nobel Prize for chemistry in 1958 in recognition of his achievement. Sanger’s work enabled chemists to synthesise insulin artificially and generally stimulate research in protein structure.”

*A Dictionary of Scientists*, Oxford University Press, 1979

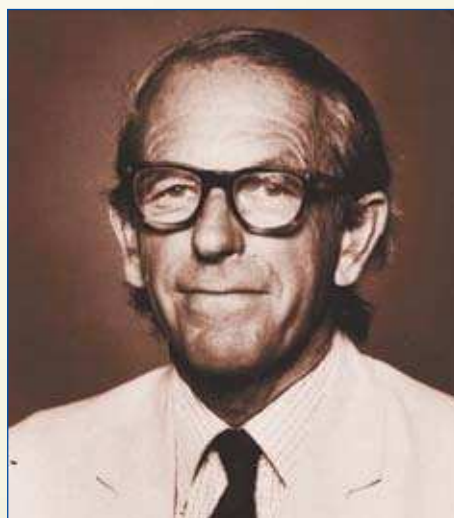
“Fred’s (Sanger’s) work transformed our understanding of life on Earth and is the foundation of developments in healthcare from understanding inherited disease to developing new cancer treatment.”

Professor Sir Mike Stratton (quoted from <http://www.cambridgenetwork.co.uk/news/fred-sanger-1918-2013>, retrieved 22 November 2013).

Frederick Sanger (Fred to his colleagues and friends) is regarded as father of genomics. His two key inventions namely the techniques of sequencing of proteins and nucleic acids transformed the fields of molecular biology, genetics and genomics. His methods have enabled scientists to understand the blueprint of life. He was the first person to obtain a protein sequence and he pioneered the DNA sequencing. Sanger’s method of DNA sequencing was a way to ‘read’ DNA. Commenting on the death of Sanger, Craig Venter, a pioneer in synthetic biology and founder of the J. Craig Venter Institute said: “He (Sanger) twice changed the direction of the scientific world, first with the sequencing of insulin...and second with his then new method of (DNA) sequencing.”

Sanger’s elucidation of the structure of insulin was an essential prerequisite for laboratory synthesis of insulin. The techniques developed by Sanger for determining the sequence in which amino acids are linked in proteins paved the way for determining the structure of other complex proteins.

Sanger was the only person to win the Nobel Prize twice in Chemistry. He won the 1958 Nobel Prize in Chemistry for discovering insulin’s structure. He won his second Nobel Prize in Chemistry in 1980 (which he shared with Walter Gilbert and Paul Berg) for his work



Frederick Sanger

on sequencing of DNA molecules. He was the second person to get two Nobel Prizes in the same field. The first was the American Physicist John Bardeen (1908-1991) who got two Nobel Prizes in Physics (1956 and 1972). Marie Curie (1867-1934), the Polish-born French physicist is the only other scientist to receive



John Bardeen

two Nobel Prizes in science but in two different fields—Physics (1903) and Chemistry (1911). Linus Pauling (1901-1994), an American chemist, also won two Nobel Prizes but he got only one

Nobel Prize in science (Chemistry, 1954) the other one was in Peace (1962). It should be noted that only four persons have been awarded the Nobel Prize twice in the history of Nobel Prize.

Sanger was an unusually self-effacing person. He once described himself as “just a chap who messed about in his lab.” However, the fact is that there will be hardly any disagreement over the fact that it is impossible to overestimate or exaggerate the impact of Sanger’s work on modern biomedical science. He rejected a knighthood because he did not want to be called “Sir”. He was extremely courteous. He was truly a ‘gentle’ man.

Sanger was a conscientious objector because of his Quaker religion. An individual who “claimed the right to refuse to perform military service” on the grounds of freedom of thought, conscience, and/or religion is called a conscientious objector. During the Second World War, Sanger was assigned as an orderly to a hospital near Bristol. In 2003, Sanger along with other British Nobel Laureates signed a petition condemning the 2003 American and British attack on Iraq.

Frederick Sanger was born on 13 August 1918 in the village of Rendcomb, Gloucestershire, England. His father, also named Frederick Sanger, was a physician, a general practitioner. His mother Ciecely



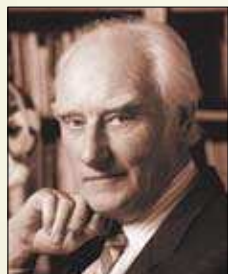
Marie Curie

Crewsdon Sanger was the daughter of a wealthy cotton manufacturer. Ciecely's father was a Quaker and her husband also became a Quaker after their marriage. A Quaker is member of the Society of Friends, founded by George Fox in England around 1650. The Friends have no formal creed, rites, liturgy, or priesthood and they reject violence in human relations, including war. When Sanger was five years old his family moved to Tanworth-in-Arden, a small village in Warwickshire. In 1927, Sanger was admitted to a preparatory school run by Quakers. At the age of 14, Sanger joined the Dorset's Bryanston School. The School adopted the Dalton Plan of education, an educational method put forward by Helen Parkhurst in 1908 in US as an attempt to rectify the ills of the school system of the time. Sanger preferred this system of education.

Sanger's family wanted him to study medicine and become a medical practitioner like his father. But Sanger decided to pursue a career in science, because he wanted to be 'problem solver'. In 1936, Sanger entered the St. John's College of Cambridge University. Initially he studied chemistry and physics but later he took up biochemistry, then a new field. He obtained a bachelor's degree in 1939. In his college according to his own description he "was above average but not an outstanding scholar." He spent another year to take up an advance course in biochemistry. In 1940, he joined the Biochemistry Department of Cambridge University for pursuing his PhD work. It was the time of Second World War but he was allowed to continue his PhD as he was a conscientious objector. He did not get any scholarship and he had to support himself. He could manage because his mother was the daughter of a prosperous cotton manufacturer. Initially he worked with Bill Pirie and his problem was to find out whether edible proteins could be obtained from grass. However, when Pirie left he started working under Albert Neuberger (1908-



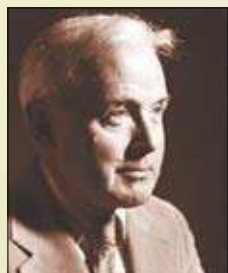
*Linus Pauling*



*Francis H. C. Crick*



*Aaron Klug*



*Hugh Esmor Huxley*

1996). In 1943, Sanger obtained his PhD degree. His PhD thesis was on the metabolism of the amino acid lysine and a problem relating to the nitrogen content of potatoes.

After his PhD he joined the protein research group of the biochemist Albert C. Chibnall, who had moved from Imperial College in London to Cambridge. He started working on identifying free amino groups in insulin, a hormone that regulates glucose and other nutrients. He developed methods to order the amino acids in insulin and he was able to demonstrate that proteins were ordered molecules. Sanger won his first Nobel Prize (1958) for this work. The work was very significant. Before Sanger biologists knew that proteins were made up smaller units called amino acids but nothing much was known how they were

joined together. Protein researchers of the time were broadly divided into two groups. One group thought it would not be possible to analyse proteins chemically as they were complex mixtures. The other group thought proteins were distinct chemical compounds. To many, the order in which the amino acids were linked together had no real implication. Sanger demonstrated that the ordering of amino acids was crucial. This insight proved to be vital for understanding exactly

how the information stored in DNA gets transmitted to proteins. From this it was inferred that DNA and RNA molecules which were involved in making proteins must display a sequence of their constituents, the nucleotides. The new methods of separation and purification developed by Sanger made it possible to determine structure of protein molecules. Sanger also developed methods for determining the sequence of building blocks; that is, amino acids in insulin. After determining the structure of insulin Sanger developed methods

to study proteins; particularly he studied the active centres of some enzymes.

In 1951, Sanger became a member of the external staff of the UK Medical Research Council at Cambridge. He was elected a Fellow of King's College, Cambridge University. In 1962, he moved from his laboratories in the Biochemistry Department of the university to join the newly created UK Medical Research Council Laboratory of Molecular Biology (LMB) at Cambridge University as the Head of the Protein Chemistry Division. Among his colleagues at LMB were Francis Harry Compton Crick (1916-2004), an English molecular biologist, Aaron Klug (1926- ), Lithuanian-born British chemist, Hugh Esmor Huxley (1924-2013), a British biologist,

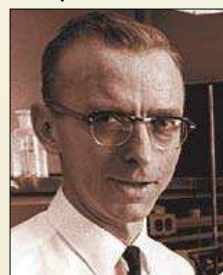


*John C. Kendrew*

and John Cowdery Kendrew (1917-1997), an English biochemist and crystallographer.

Sanger initiated his studies on sequencing ribonucleic acids. Sequencing RNA was not an easy task as they were much larger molecules compared to proteins. Robert William Holley (1922-1993), an American biochemist, and his group were the first to sequence RNA. They sequenced alanine-transfer RNA by using partial hydrolysis methods somewhat similar to the methods used by Sanger for sequencing insulin. Transfer RNA molecules have many unusual nucleotides and it was realised that the partial method could not be applied to other RNA molecules having only four types of nucleotides.

Sanger jointly with George G. Brownlee and Bart G. Barrel developed a two-dimensional electrophoresis method for sequencing RNA. Sanger jointly with Kjeld Marcker discovered in 1964 the formylmethionin tRNA, which initiates protein synthesis in bacteria. By 1967 Sanger and his group had sequenced the 5S ribosomal RNA, a small RNA of 120 nucleotides. Sanger and his group wanted to sequence a messenger RNA so that the



*Robert William Holley*

genetic code could be determined. However, by the time they perfected the method the genetic code had been worked out mainly by the works of Marshall Warren Nirenberg (1927-2010) and Hargovind Khorana (1922-2011), an Indian-born American

biochemist using *in vitro* protein synthesis techniques. The RNA sequence worked out by Sanger's group helped confirm the genetic code.

After RNA, Sanger turned his attention to DNA. DNA sequencing is the identification of the precise sequence of nucleotides in a sample DNA. The main difficulty in taking up DNA sequence studies was the immense size of DNA molecules. There were no suitable enzymes to cut DNA molecules in smaller pieces. Sanger developed methods to overcome these problems. His first method was called 'plus and minus' method (developed jointly with Alan Coulson). This involved two closely related methods that generated short oligonucleotides with defined 3' terminuses. The plus and minus method differed from the earlier methods by the fact that it did not use partial hydrolysis. The plus and minus method produced a series of DNA molecules of varying lengths that could be separated by using polyacrylamide gel and visualised using autoradiography. Sanger used the enzyme DNA polymerase to make new molecules of DNA from single-strand templates. Both plus and minus sets are separated on the same gel and sequence is read from either system one confirming the other. In 1977, phiX174, a bacteriophage, a virus that infects bacteria, became the first organism to have its entire genome mapped. The phiX174 genome had approximately 5,375 bases. This was done at Sanger's laboratory by using the plus and minus method.

The plus and minus method was not entirely free from problems. So Sanger developed a more efficient method called dideoxy method. It is also known as Sanger method (named after Frederick Sanger, its inventor). The method was called dideoxy method because of the critical role played by dideoxy nucleotides. It involves selective incorporation of chain-terminating dideoxynucleotides by DNA polymerase in *in-vitro* replication. The dideoxy method allows long structures of DNA to be rapidly and accurately sequenced. Sanger later sequenced the DNA of a human mitochondrion, which had 16,000 nucleotides. This was the first



Warren Nirenberg

human genetic material to be mapped. In 1982, Sanger and his group sequenced the genome of a bacteriophage called lambda. It was an important virus and model organism for molecular biology and its genome contained 48,000 base-pairs. To sequence the genome of lambda Sanger developed the whole-genome shotgun method, a method used for sequencing. After his retirement in 1983 he spent most of his time working in his garden.

Sanger was brought up as a Quaker but in his later life he became an agnostic. He explained his change of belief by saying that he lacked hard evidence to support his religious beliefs. He said: "My father was a committed Quaker and I was brought up as a Quaker and for them truth is very important. I drifted away from those beliefs—one is obviously looking for truth, but one needs some evidence for it. Even if I wanted to believe in God, I would find it very difficult. I would need to see proof."

Besides his two Nobel Prizes he received a number of other awards including RSC Corday-Morgan Prize (1951), Royal Medal of the Royal Society (1969), the William Bate Hardy Prize of the Cambridge Philosophical Society (1976), Copley Medal of the Royal Society (1977), Albert Lasker Basic Medical Research Award (1979), Louisa Gross Horwitz Prize (1979), Order of Merit (1986), Commander of the British Empire (1963). He was a foreign member of the American Academy of Arts and Science, American Society for Biochemistry and Molecular Biology, and Japanese Biochemical Society. He was elected as a Fellow of the Royal Society, London in 1954.



Hargovind Khorana

In 1992, the Wellcome Trust and the UK Medical Research Council established a Sanger Centre (which later became the Sanger Institute), a research centre for doing research on genomic science. The Institute was officially opened by Sanger himself on 4 October 1993. Its founder Director was John Sulston. The Sanger Institute is located in the Wellcome Trust Genome Campus near Hinxton, UK. At the time of its establishment, the Institute had only 50 people, but it went on to become one of the world's largest genomic research

centres, employing over 900 people. The Sanger Institute served as one of the major centres for DNA sequencing in the Human Genome Project.

In 2007, the Wellcome Trust gave a grant to the British Biochemical Society for cataloguing and preserving the 35 laboratory notebooks in which Sanger had recorded his path-breaking research. Sanger died on 19 November 2013 at the age of 95. He was the last living double Nobel Laureate.

Jeremy Farrar, the present Director of Wellcome Trust, which established an Institute named after Sanger, commenting on Sanger's death said: "I am deeply saddened to learn of the death of Fred Sanger, one of the greatest scientists of any generation and the Briton to have been honoured with two Nobel Prizes. Fred can fairly be called the father of genomic era: his work laid the foundations of humanity's ability to read and understand genetic code, which has revolutionised biology and is today contributing to transformative improvements in healthcare."

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*(The article is a popular presentation of the important points on the life and work of Frederick Sanger available in the existing literature. The idea is to inspire the younger generation to know more about Frederick Sanger. The sources consulted for writing this article have been listed. However, the sources on the Internet have not been individually listed. The author is grateful to all those authors whose writings have contributed to writing this article. The author is also grateful to the sources from which illustrations/photographs have been reproduced.)*

# Unravelling the cell's transport system



**Biman Basu**

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The human body is a highly complex system with a vast transport system consisting of the heart, blood vessels, and the approximately 5 litres of blood that the blood vessels transport. The body's transport system is responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body. Much of the substances carried and delivered by the body's transport

system are produced by cells, which make up the key organs. The billions of cells which make up the body are packed with precise machinery. In order for a cell to function properly it needs the right materials in the right place at the right time. How the cells are able to do it was a mystery till now. The

Nobel Prize in Physiology or Medicine for 2013 has been awarded to three scientists – Americans James E. Rothman and Randy W. Schekman, and German Thomas C. Sudhof – who have solved the mystery of how the cell organises its transport system. Disruptions of this delivery system contribute to diabetes, neurological diseases and immunological disorders.

It has been known that each cell in the body is a factory that produces and exports or imports molecules. For instance, insulin is manufactured and released into the blood and chemical signals called neurotransmitters are sent from one nerve cell to another. These molecules are transported around the cell in small bubble-like structures called vesicles. Vesicles are tiny bubbles of fat which act as the cell's internal shipping service. They can send material such as enzymes, neurotransmitters and hormones,

around the cell. Or they can fuse with the outer surface of the cell and release their contents into it. The three Nobel Laureates have discovered the molecular principles that govern how this cargo is delivered to the right place at the right time in the cell.

As it turns out, the chemical molecules are moved around the cell in vesicles, and each scientist discovered different facets

away from a hot stove, and communicate. Undoubtedly, reaching the right molecule to the right target at the right time is a complex and difficult task. In fact, the molecular traffic within cells is as complicated as rush hour in any city, as the work of the three Nobel winners has revealed.

Randy Schekman of the University of California at Berkeley was fascinated by

how the cell organises its transport system and in the 1970s decided to study its genetic basis by using yeast as a model system. Through genetic screening he identified yeast cells with defective transport machinery, giving rise to a situation resembling a poorly planned public transport system. Vesicles piled up in certain parts of the cell.

He discovered a set of

genes that controlled the vesicle traffic. He found that mutations in three genes resulted in a "situation resembling a poorly planned public transport system".

James Rothman of Yale University was also intrigued by the nature of the cell's transport system. When studying vesicle transport in mammalian cells in the 1980s and 1990s, he discovered that a protein complex enables vesicles to dock and fuse with their target membranes. In the process, proteins on the vesicles and target membranes bind to each other like the two sides of a zipper. Since there are many such proteins and they bind only in specific matching combinations, it is

ensured that cargo is delivered to a precise location. The same principle operates inside



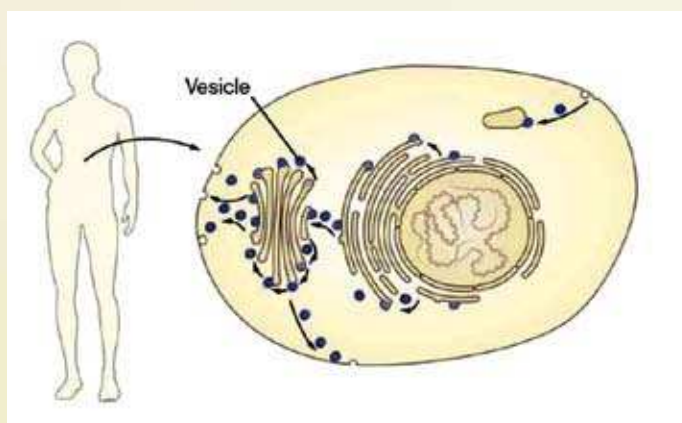
*James E. Rothman*



*Randy W. Schekman*



*Thomas C. Sudhof*



*Vesicles inside a cell*

example, pancreatic cells make insulin and release it in the blood. Chemical signals called neurotransmitters are sent from one nerve cell to another to allow people to everything – walk, talk, sing, pull their hand

*Continued on page 35*

# Elementary Particles: A Brief History



Vinay B Kamble

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## The atom

Ever since *Kanaada* in India and Democritus in Greece, people have speculated all matter to be made up of particles. However, in modern times, one could state that elementary particle physics came into being in 1897, with JJ Thomson's discovery of the electron. Thomson correctly surmised that the electrons carry negative charge and are essential constituents of atoms. However, this gave rise to a problem. Since the atoms are very much heavier than the electrons and are electrically neutral, a compensating positive charge must be distributed within the atom. He thus came up with the 'plum pudding' model in which electrons were distributed like plums in a pudding of heavy paste of positive electrical charge.

The plum pudding model, however, was repudiated by Ernest Rutherford's famous alpha scattering experiments in 1911, which established that the positive charge was concentrated in a tiny core at the centre of the atom, or nucleus, and that the electrons revolved around this nucleus the way planets revolve around the Sun. The atoms are, however, almost empty space in the sense that the electrons are revolving around the nucleus at a very long distance, almost 100,000 times further away as compared to the nuclear dimensions.

In 1913, physicist Niels Bohr demonstrated that electrons were confined into clearly defined, quantised orbits, and could jump between these orbits, but could not spiral inward or outward in intermediate states. These orbits were called stationary orbits. An electron needs to absorb or emit only specific amounts of radiation (electromagnetic energy) to make transitions between these fixed orbits.

## The proton and the neutron

In 1919, Ernest Rutherford identified the hydrogen nucleus as just one heavy, but positively charged particle with electric charge equal to that of the electron. He called it proton (meaning the "first"). Proton is nearly 1,800 times heavier than the electron. In 1932, the neutron, a particle with zero

charge but with mass almost equal to, but only slightly more than that of the proton, was discovered by physicist James Chadwick in Cambridge, England. Isotopes of elements were then explained as atoms having exactly the same number of "protons" as the original element (that is, the same atomic number), but with a different number of "neutrons" within the nucleus. The chemical properties of all the isotopes of any particular element remain the same. Life was very simple then – just electron, proton and neutron making all the elementary particles!

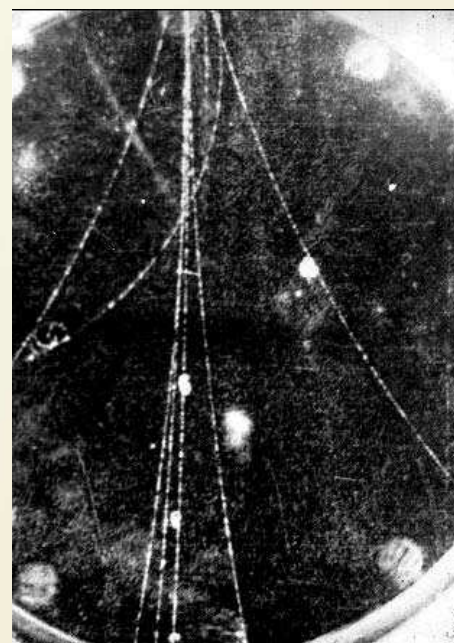
In the decades that followed, rapid developments in theory and experiment helped improve tremendously our conceptual understanding of the atomic phenomena. The electromagnetic radiation behaved as if it were particles as evidenced by Planck's quantum theory of radiation and the explanation of the photoelectric effect by Einstein. It now turned out that at atomic level, particles behaved as if they were waves. It gave rise to what is known as Quantum Mechanics. Quantum mechanics was able to explain observations of atomic behaviour that previous models could not. The planetary model of the atom was discarded in favour of one that described atomic orbital zones around the nucleus where a given electron is most likely to be observed. There is no gainsaying the fact that better understanding of quantum phenomena and technological advances helped in further development of particle physics.

## More particles

During 1932, the same year in which neutron was discovered; positron (antielectron) was discovered by Carl Anderson while observing tracks of cosmic ray particles in a cloud chamber (a device used for detecting ionising particles). We may note that in 1927, Dirac had predicted the existence of antimatter, which is identical to ordinary matter except that it has the opposite set of quantum properties, such as the electric charge, compared to the matter we know in the everyday world. Thus a positron has the same mass as that of an electron, but opposite

charge. When matter and antimatter interact, they annihilate each other completely and are converted into pure energy as a pair of energetic photons, or light quanta as they are called.

During 1930s and 1940s, a few other subatomic particles were discovered. Notably among them was the *muon* using cloud chamber measurements. Though this is really a "mu lepton", it was mistaken for the *pion* (pi meson) which was predicted by



Cloud chamber tracks

Hideki Yukawa in 1935 as responsible for keeping protons and neutrons bound inside the nucleus. Yukawa's exchange particle pion (which he called meson since its mass was between that of the electron and the proton) was eventually discovered in 1947. In the same year, *kaon* (K meson) was discovered. It was one of the many particles discovered in cosmic ray tracks that were later termed "strange". Why call it "strange"? We may note that it is the cosmic rays that are colliding with atomic nuclei producing kaons (K mesons) via the strong nuclear force. But the strange thing about them was that they seemed to live much too longer than expected, some  $10^{-10}$  seconds as against  $10^{-20}$

seconds expected. Though the time  $10^{-10}$  seconds looks very short; on particle physics scale it is some ten billion times longer than expected!

We may note that not all the new particles discovered were “elementary”, though they were called so. Later, it was discovered that many of them had substructure and were composed of still smaller particles. We would rather call them “subatomic” particles to distinguish them from “truly” elementary particles, which do not show any substructure.

## After the Second World War

After the Second World War, many more subatomic particles were discovered, initially in cosmic ray interactions and then with accelerators with their energies steadily increasing over the years. They were also complemented by new and more sensitive detection methods. These particles both confirmed existing theories of particle physics, and inspired new ideas about the working of matter. In 1955, *antiproton* was discovered in Berkeley, California, by colliding two energetic protons up to an energy of 6.4 GeV (1 GeV =  $10^9$  eV, 1 eV = 1 electron volt, which is the energy an electron would gain while accelerating through a potential difference of one volt). *Electron neutrino* was detected in 1956, which was proposed by Wolfgang Pauli in 1931 to explain the apparent violation of energy conservation in beta decay – a kind of radioactivity in which beta rays (electrons or positrons) are emitted from the nucleus. It appeared that the electron neutrino had zero mass; however, today we know that it does have mass, although very small. At the time it was simply referred to as neutrino since there was only one known neutrino. *Muon neutrino* was detected in 1962 and was shown to be distinct from electron neutrino by a group headed by Leon Ledermann.

However, by this time, the small neat garden had turned into a big jungle with hundreds of particle species, and there were attempts to classify them into various groups. Some people even likened the situation to a *particle zoo*! The plethora of strongly interacting particles was divided into two great families – *baryons and mesons* – and the members of each family were distinguished by properties like charge, strangeness and mass. But, beyond that there was no rhyme or reason at all. This predicament reminded

many physicists of the situation in chemistry a century ago, before the days of the periodic table of elements, when scores of elements had been identified, but there was no underlying order or system.

## The eightfold way

The last four decades of the 20th century could rightly be termed as the golden era in which many advances were made in our understanding of the fundamental constituents of matter. This was a time, when the large number of subatomic particles already detected awaited a Periodic Table! The Mendeleyev of the particle physics was Murray Gell-Mann who proposed a scheme, the so called *The Eightfold Way*, in 1961, that arranged baryons and mesons into weird geometrical patterns according to their strangeness and charge. His scheme predicted a few particles that were not hitherto discovered, but were eventually discovered – just the way he had predicted. (It is interesting to note that the situation was similar to Dmitri Mendeleyev’s periodic table in the latter half of the nineteenth century. There were three famous “holes” in the Periodic Table (gaps) that he formulated; and he predicted that these elements would be discovered to fill the gaps. In due course all the three elements – gallium, scandium,

and germanium were discovered.)

The term “Eightfold Way” was coined by Gell-Mann, in an allusion to one of the principal teachings of the Buddha (*āryāshtāṅgamaṛga* – *The Noble Eightfold Path*), to refer to the eight quantum numbers that appear in the mathematics predicting the patterns. The Eightfold Way patterns revealed an underlying structure in the families of particles, which can be explained by “truly” elementary particles called *quarks*.

They are six quarks together. Each quark has its own *antiquark* and all have fractional charge. The quark model asserts that every baryon is composed of a combination of three quarks, and every antibaryon is composed of a combination of three antiquarks. Every meson is composed of a pair of a quark and an antiquark.



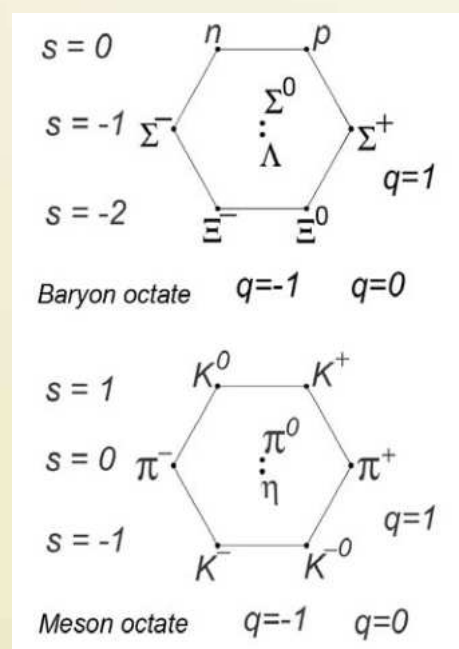
Murray Gell-Mann

Quarks cannot be observed directly but through deep inelastic scattering experiments and the ways in which they are expected to decay into observable particles.

Leptons (the “light” ones) are elementary particles that do not experience the strong nuclear force. Rather, they experience the weak force. There are six leptons together with corresponding six antileptons, and all are fermions or spin  $\frac{1}{2}$  particles.

Baryons are particles that interact with the strong force and form the group of most numerous particles. They are fermions or spin  $\frac{1}{2}$  particles, and include the proton and the neutron. All mesons are bosons, and hence have integral values of spin. There are about 120 species of baryons, and about 140 species of mesons known today!

Baryons and the mesons both feel the strong force and are collectively called hadrons. All hadrons are affected by the strong nuclear force and are said to be strongly interacting particles. However, hadrons also participate in processes that involve weak force along with leptons as in the case of decay of baryons (say, beta decay of neutrons or protons); or decay of mesons.



Gell-Mann's eight-fold way

## The Standard Model

Over the years, particle physicists have come up with the Standard Model in which all matter can be thought of as being composed of combination of six types of quark and six types of lepton. The Standard Model was driven forward sometimes by new

|         | Fermions               |                        |                          | Bosons         |                        |
|---------|------------------------|------------------------|--------------------------|----------------|------------------------|
| mass    | 2.4 MeV/c <sup>2</sup> | 1.7 GeV/c <sup>2</sup> | 171.2 GeV/c <sup>2</sup> | 0              | 125 GeV/c <sup>2</sup> |
| charge  | 2/3                    | 2/3                    | 2/3                      | 0              | 0                      |
| spin    | 1/2                    | 1/2                    | 1/2                      | 1              | 0                      |
| name    | u                      | c                      | t                        | γ              | H                      |
|         | up                     | charm                  | top                      | photon         | Higgs boson            |
| quarks  | d                      | s                      | b                        | g              |                        |
|         | down                   | strange                | bottom                   | gluon          |                        |
| leptons | ν <sub>e</sub>         | ν <sub>μ</sub>         | ν <sub>τ</sub>           | Z <sup>0</sup> |                        |
|         | electron neutrino      | muon neutrino          | tau neutrino             | Z boson        |                        |
|         | e                      | μ                      | τ                        | W <sup>±</sup> |                        |
|         | electron               | muon                   | tau                      | W boson        |                        |

Standard Model

experimental discoveries and sometimes by theoretical advances; and spanned many decades and many continents. The current formulation was worked out in the mid 1970s when the existence of quarks was experimentally confirmed. Since then, discoveries of the bottom quark (1977), the top quark (1995), and the tau neutrino (2000) have given further credence to the Standard Model.

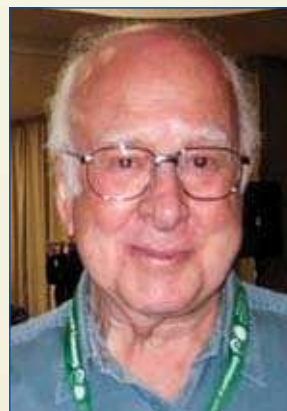
The six types of quark and six types of lepton are distinguished by the different ways in which they react to the fundamental forces. The six quarks are called *up*, *down*, *charm*, *strange*, *bottom*, and *top* (in order of mass). The six leptons are the *electron*, *electron-neutrino*, *muon*, *muon-neutrino*, *tau*, and *tau neutrino*. Though the familiar electron is a fundamental particle, the proton and the neutron are not. A proton is composed of two up quarks and one down quark. A neutron is composed of one up and two down quarks. The charge of up quark is  $+2/3$ , while that of down quark is  $-1/3$ . The charge of the electron, muon, and tau, however, is  $-1$ ! Electron-neutrino, muon-neutrino, and tau-neutrino are charge-neutral; that is, they do not carry any charge. Quarks and leptons have spin  $1/2$ , a property of a class of particles called *fermions* that follow Fermi-Dirac statistics abiding by Pauli's exclusion principle, allowing only one particle in one quantum state.

In addition, there are five gauge bosons (photon, gluon,  $Z^0$ , and  $W^+$  and  $W^-$ ). Thus, six quarks, six leptons and five gauge bosons are the 17 *basic* particles of the Standard Model of elementary particles. One more particle, the Higgs boson, though not a gauge boson, is postulated by the Standard Model. We note that every fundamental particle has an antiparticle which carries an electric charge

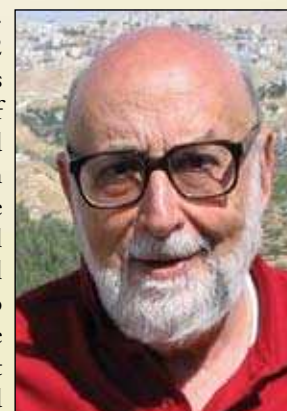
that is opposite of the charge on the particle. Thus we have 6 quarks and 6 antiquarks; and 6 leptons and 6 antileptons. As regards the bosons – photon, gluon, and  $Z^0$  are their own antiparticles, while antiparticle of  $W^-$  is  $W^+$ . Together, they are responsible for some 200 composite particles (protons, neutrons, mesons, etc) that we observe in various circumstances through different combinations and at different energies. Standard Model also postulates Higgs Boson ( $H^0$ ), which is its own antiparticle. If we include graviton (spin 2 and hence a boson), which is supposed to be the carrier of gravitational interaction and its own antiparticle, though not included in the list of the Standard Model, the total number of the fundamental particles would add up to 31. (In Box 1 are given the landmark discoveries of the last four decades that has placed the Standard Model on a firm footing.)

### BOX 1: A Few Landmark Discoveries in Particle Physics 1970-2012

- **1970:** Deep inelastic scattering at Stanford Linear Accelerator Centre show that proton contains much smaller point-like objects, later identified as up and down quarks
- **1974:**  $J/\psi$  meson discovered that demonstrated the existence of the charm quark (proposed in 1964)
- **1975:** Tau electron discovered
- **1977:** Upsilon meson discovered demonstrating the existence of the bottom quark. (proposed in 1973)
- **1977:** Evidence for the fifth quark (bottom) found.
- **1979:** Gluon observed indirectly.
- **1983:** W and Z bosons discovered by (predicted by Sheldon Glashow, Abdus Salam, and Steven Weinberg)
- **1995:** Top Quark discovered
- **1995:** Antihydrogen produced and measured at CERN.
- **2000:** Tau neutrino first observed directly at Fermilab
- **2011:** Antihelium-4 produced and measured
- **2012:** A particle exhibiting most of the predicted characteristics of the Higgs boson discovered by researchers conducting the at CERN's Large Hadron Collider.



Peter W. Higgs

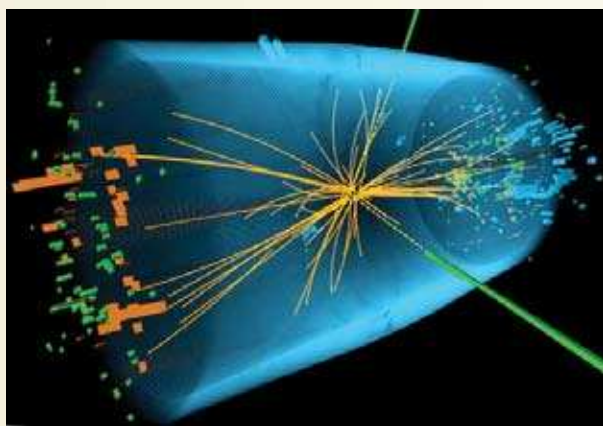


François Englert

### Just a few particles

We saw that there are only 17 *basic* particles in the Standard Model. Of these, 6 are *fermions* such as *quarks* that make up neutrons and protons in nuclei. Of the 6 *leptons* three are electron, muon, and tau; and the corresponding three charge-neutral leptons are the electron-neutrino, mu-neutrino, and the tau-neutrino. Electrons go around the nuclei composed of protons and neutrons (which are, of course, composite particles made of up and down quarks). *Quarks and leptons are the particles that make up matter*. Five particles are called *gauge bosons*. *These are the particles that transmit forces and thus allow fermions to interact*. The Higgs boson, though *not* a gauge boson, is required *not* to transmit force, but to give mass to other particles in the Standard Model.

François Englert and Peter W. Higgs were jointly awarded the Nobel



*Discovery of Higgs-boson*

Prize in Physics in 2013 for the theory of how particles acquire mass. In 1964 they proposed the theory independently of each other (Englert together with his now deceased colleague Robert Brout). In 2012, their ideas were confirmed by the discovery of the Higgs boson at the CERN laboratory outside Geneva in Switzerland. This was the last missing piece in the jigsaw puzzle of the Standard Model. Indeed, if it were not for the Higgs boson, all particles in Standard Model would be reduced to zero mass, and would travel through the Universe at the

speed of light forever, including every particle in our body!

## Yet all is not well

Gravity and electromagnetism are familiar to us. The weak and strong forces are relatively new. Electromagnetism is responsible for current in wires, electricity in our homes, radio, television, and telecommunication, including chemical binding in atoms and molecules and chemical reactions. The strong nuclear force binds atomic nuclei together and makes

them stable, and it acts only through quarks. Weak interactions are most noticeable when particles undergo beta decay (radioactivity in which electrons or positrons are emitted) from nuclei, and in the production of deuterium and then helium from hydrogen that powers the Sun's thermonuclear process. This is how the Sun shines and we get energy. The weak force is felt by both quarks and leptons, unlike strong force which is felt only by quarks. If two leptons come within the range of weak force, it is possible for them to change into other leptons. The Standard

Model includes the electromagnetic, strong and weak interaction; however, *it does not include gravity.*

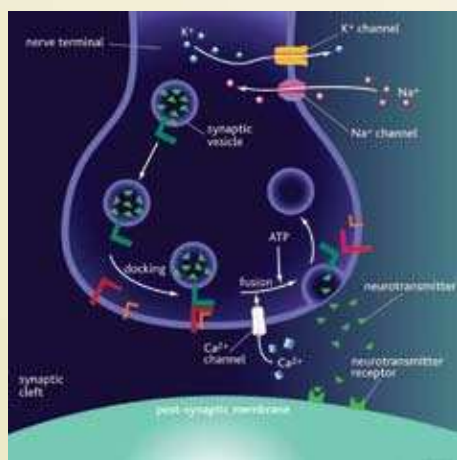
So, we, and everything we see in the universe is made of just a few elementary particles! However, it does not mean this is the end of the story! The Standard Model has faced several challenges of late, and it appears we need to go much beyond the Standard Model. It does not include gravity, nor can it account for the dark matter in the Universe. It accounts only for the four per cent of the Universe –stars, galaxies and everything else in the Universe we observe, including us – is made! Let us see how the story unfolds!

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(Former Adviser, DST & Former Director, Vigyan Prasar, New Delhi)

## Continued from page 39 (Unravelling the cell's transport system)



*Transport of neurotransmitters by synaptic vesicles*

the cell and when a vesicle binds to the cell's outer membrane to release its contents. Rothman found proteins embedded in the vesicles which act as the docking mechanism, ensuring the cargo is released in the correct location.

Thomas Sudhof, originally from Germany but now at Stanford University in the US, was interested in how nerve cells communicate with one another in the brain. The signalling molecules, called neurotransmitters, are released from vesicles that fuse with the outer membrane of nerve cells by using the machinery discovered by Rothman and Schekman. But these vesicles are only allowed to release their contents when the nerve cell signals to its neighbours. In the 1990s, Sudhof studied how signals are transmitted from one nerve cell to another in the brain, and how calcium controls this process. He identified molecular machinery that senses calcium ions ( $\text{Ca}^{2+}$ ) and triggers vesicle fusion, thereby explaining how temporal precision is achieved and how signalling substances like neurotransmitters can be released from the vesicles on command. He identified molecular machinery that responds to an influx of calcium ions and directs neighbour proteins rapidly to bind vesicles to the outer membrane of the nerve

cell. Sudhof's discovery thus revealed how signals instruct vesicles to release their cargo with precision.

The discoveries of the three laureates are significant in that they have had a major impact on our understanding of how cargo is delivered with timing and precision within and outside the cell. Their work has demonstrated that vesicle transport and fusion operate, with the same general principles, in organisms as different as yeast and humans. The system is critical for a variety of physiological processes in which vesicle fusion must be controlled, ranging from signalling in the brain to release of hormones and immune system proteins such as cytokines. Defective vesicle transport occurs in a variety of diseases including a number of neurological and immunological disorders, as well as in diabetes. Without this wonderfully precise organisation, the cell would lapse into chaos and life wouldn't be possible.

# Fractals: The Fabric of Nature



**Soumya Maitra**

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*"Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line."*

– Benoit Mandelbrot

The world around us is seldom regular in shape and form. Look around you and you will come across innumerable such objects and phenomena of varying degrees of freedom and dimensions. For instance, how would you describe the shape of clouds or the leaves on the branches of a tree? Ever wondered what shape the lightning bolts look like? How about the steady flow of water in a stream or a river? How can you define or measure the coastline of a country if it is not a straight line? Do these objects, so abundant and freely occurring in nature, resemble anything we learnt in our school geometry? They don't have the inherent property of length or angle that we associate with regular geometrical figures. Yet, if we observe closely, they seem to follow patterns of their own. Despite being irregular, their entire form seems to resemble the same shape or features as one or more of its parts. There is beauty in their asymmetry.

Nature seems to be in harmony between order and chaos. While on the one hand she gives us such precise patterns as the hexagonal honeycombs that honeybees are so fond of making, on the other she derives pleasure in creating magnificent landscapes such as mountain ranges and coastlines which are hard to define, but whose entirety looks like a part, which in turn looks just like the next smaller part, and so on to the minutest scale. And this self-similarity is the fabric of nature with which she weaves



*The scale invariant fractal structure of a leaf shows up when we look closer.*



*A cross between a cauliflower and a broccoli, the romanesco is a perfect example of fractals occurring in nature. Each stock resembles the vegetable itself, and the same fractal patterns show up in the protrusions or buds in each stock, and so on.*

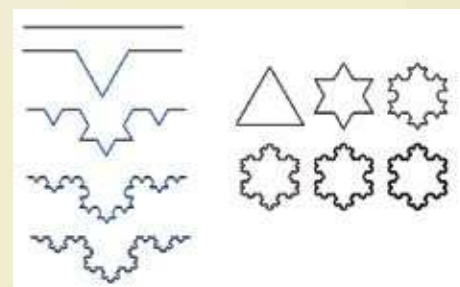
the world around us. Mathematicians have a term for such a shape: Fractal. Fractal is in our lungs, kidneys, blood vessels. It's in the neuron structure of our brain; in the clouds and the lightning bolts we see in the sky; in the stock of broccoli, cabbages or cauliflowers we eat; in the rivers and fjords we set sail on; in the branches and nodes of a tree and leaves of a fern; in the snowflakes and the ice and frost crystals in caves; in the mountain ranges and shorelines; even in the growth of population, and many more. The list is endless.

Mathematicians had long recognised the visual complexity of nature, but lacked a rigorous and well-defined framework in which to describe them. It was towards the end of 1970s and the beginning of 1980s that a Polish-born French-American mathematician named Benoit Mandelbrot showed the so-called chaotic phenomenon or rough objects in nature have an underlying hidden structure – a degree of order. Mandelbrot's idea was driven by not what he saw in nature, rather by what it took to produce what he saw. His theory of

roughness laid the mathematical foundation of the fractal geometry of nature. And the geometry had its foundation on two very intrinsic characteristics of nature: endless repetition which gives rise to the self-similarity, and non-integral dimensions known as fractal dimensions.

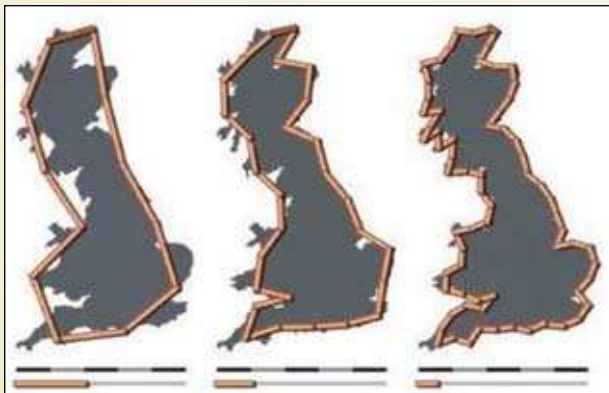
The Koch Curve is perhaps the simplest mathematical construct that can be used to illustrate the idea of self-similarity. It was a Swedish mathematician named Helge von Koch who in 1904 described the Koch Curve as a continuous curve without tangents, constructible from elementary geometry. Starting with a single straight line segment; every subsequent step creates four times as many line segments as in the previous step. And in each such repetition each line segment is one-third the length of the segments in the previous one. The Koch curve therefore is of infinite length over infinite iterations.

While self-similarity is easy to perceive in naturally occurring objects and phenomena as an intrinsic property, fractal dimension is purely a mathematical concept that Mandelbrot conceived in explaining the fractal geometry of nature. One of the problems that he addressed in his research was how to define or measure the coastline of a country, in particular that of Great Britain. A coastline is the area where the land meets the sea, typically forming the boundary of



*The infinite Koch Curve. When the curve is closed on itself, it gives rise to the Koch Snowflake, another beautiful fractal*

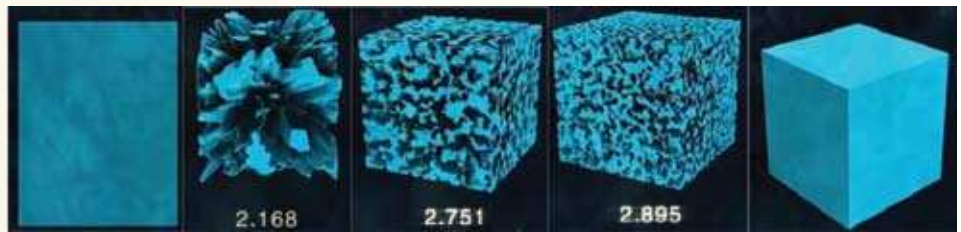
a country. If you observe any coastline you will notice that coastlines are rarely a stretch of straight lines, but rather seemingly an infinite extent of irregular broken lines and indentations. In classical or Euclidean mathematics, everything is extremely regular – straight lines, circles, pyramids, triangles – they are all perfect geometric shapes. Such geometry cannot be used to define and measure the dynamic coastlines with precision, and poses a problem for cartographers and governments alike. In order to understand this better, recall that in Euclidean geometry a straight line has a dimension of one, a plane (for instance a square or a rectangle, or even a triangle drawn on paper) has a dimension of two, while a cube or a pyramid has a dimension of three. While these are nice concepts, they won't help measuring the coastline of a country. The fact that the unit of measurement used leads



*The coastline of the United Kingdom as measured with measuring rods of 200 km, 100 km and 50 km in length. The resulting coastline is about 2,350 km, 2,775 km and 3,425 km; the shorter the scale, the longer the measured length of the coast. As the length of the measuring stick is scaled smaller and smaller, the total length of the coastline measured increases. (Source: Wikipedia)*

to different measures for the same coastline, and therefore it is infinitely difficult to arrive at a precise value.

To overcome this problem, Mandelbrot thought of non-integral dimensions that would exist between two well-defined dimensions. He came up with this idea of fractal dimension as a measure of roughness, a numerical sense of disorder that can be quantified. To illustrate this, let us imagine a two-dimensional plane that is exploding into a three-dimensional cube. Planes obviously don't just evolve into cubes in nature; but this is a thought experiment. The transformation could be visualised as a slow process, where



*The plane is shown to transform into a cube, taking up fractal dimensions 2.168, 2.751 and 2.895 on its way.*

the object slowly morphs into a cube, taking up various irregular shapes on its way until it forms the perfect three-dimensional cube. All the intermediate irregular shapes could be thought of as having a fractional dimension between the integers two and three. Such dimensions are defined as fractal dimensions on the real number scale. In other words the fractal dimension gives us a sense of the object's degree of irregularity, and its closeness to the adjacent Euclidean

dimensions. Patterns that are inherently self-similar in nature typically have a fractal dimension.

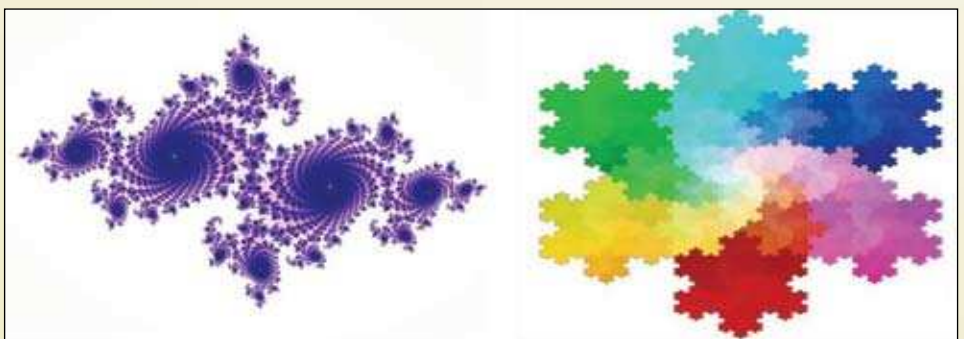
The Koch Curve was not the only fractal figure known to mathematicians prior to Mandelbrot's seminal research; there were other such fascinating constructs, most famous of which is the Julia Set, named after the French mathematician Gaston Julia. Over endless repetitions in the Julia set, arbitrarily small perturbations results in drastic changes in the sequence of iterated function values, giving rise to the chaotic beauty of the Julia set. With the advent of computers in the last five decades, visual representations of such fractals as the Koch curve and the

Julia set have taken a completely aesthetic and artistic turn.

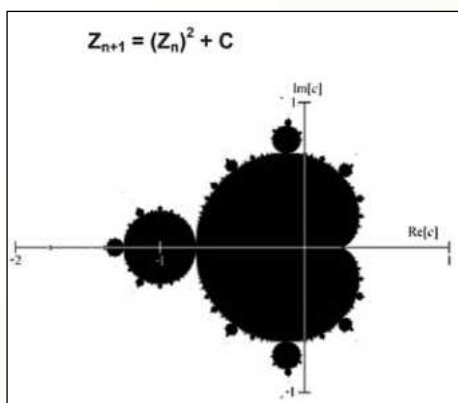
Like Helge von Koch and Gaston Julia, mathematicians were in fact aware of various fractal objects and phenomena in nature for many centuries. However, it was Mandelbrot who gave us a formal mathematical framework in which to understand the fractal geometry of nature. He formulated the following sequence as the basis of a two-dimensional fractal shape. The sequence is created by sampling complex numbers, obtained from the quadratic recurrence equation shown below. Here  $Z$  represents a variable which can take on all values in the complex plane. The parameter  $C$  is another complex number, but for any given Julia set, it is held constant. In other words, there are an infinite number of Julia sets, each defined for a given value of  $C$ . Treating the real and imaginary parts of each number as image coordinates, a graph is plotted based on how rapidly the sequence diverges. The result is the iconic image of fractal geometry, known as the Mandelbrot Set.

$$Z_{n+1} = (Z_n)^2 + C$$

So what is the study of fractals good for? Is it an object of fascination for the pure mathematicians alone that finds manifestation in a computer program, or does it have any usefulness in the practical world? Does it have any purpose other than forming the mathematical basis for such fancy designs as the Mandelbrot set, the



*Perhaps the most artistic and beautiful of all the mathematical fractals is the Julia Set (left). On the right is a computer artist's rendering of the Koch Snowflake. (Source: Wikipedia).*



A mathematician's depiction of the Mandelbrot set. A point  $c$  is coloured black if it belongs to the set, and white if not.  $\text{Re}[c]$  and  $\text{Im}[c]$  denote the real and imaginary parts of  $c$ , respectively. (Source: Wikipedia).

Julia set, or the Koch curve? As it turned out, fractals are the true embodiment of the proverb "handsome is as handsome does"! Ever since the pioneering work of Benoit Mandelbrot, fractals have been applied in such diverse fields as geology, medicine, cosmology, engineering, computer graphics and animation, and social sciences.

One of the most interesting applications has been in the field of computer graphics and animation. Computer graphics artists use a variety of fractal forms to create textured landscapes and other intricate

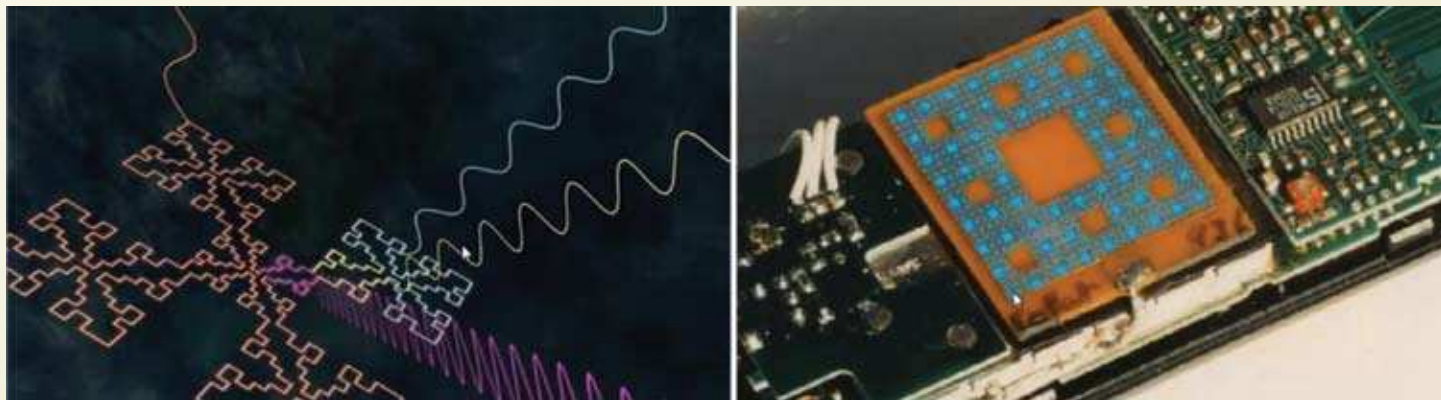
*Jedi* where it was used to create the landscape of the moons and outline the stars. Endless repetition, which gives rise to one of the defining characteristics of a fractal, was used to create the landscape that mimicked the real world.

Another application that has affected all of us in the world today with far reaching consequences is in modern telecommunication technology that uses a fractal design for building the radio-frequency antenna in a cell phone for responding to a wide range of frequencies. Using a fractal design enables the antenna to be receptive to a wide spectrum of frequencies while at the same time being compact in size to be contained in the same physical handset. This receptivity to wide range of frequencies help the modern cell phones to offer different features to the consumer such as Bluetooth, Wi-Fi, and GPS, each of them on a separate frequency and without having to use separate antennas for each of them. Imagine what a cell phone would look like if it had to use a separate antenna for each of its unique frequency needs! This has led to a wide spread use of fractal antennas all over the world, not just in cell phones, but in all sorts of communication devices.

Very recently fractal algorithms have been implemented in the lossy compression of data and images. The best example

into a single standard DVD. However, while the compression achieved is significantly larger than other compression algorithms, the drawback of fractal compression is that it takes longer to decompress, making it an undesirable choice in situations that require fast compression-decompression algorithms.

These are but just a handful of practical applications, and the efficacies of fractal geometry are limitless. While the Euclidean geometry has given us such architectural wonders as the Pyramids of Egypt and the Taj Mahal, the modern geometry of fractals have found wide-spread acceptance in computer animation, cryptography and compression, and has laid the foundation of wireless telecommunication. Fractal applications are not just limited in architecture and design. They are increasingly being used in the study of economics and sociology as well. For instance, today's financial analysts are using economic models based on fractal geometry to study and predict the fluctuations in the stock market on a regular basis. Economists and sociologists are continuously studying the demographic nature of countries based on fractal models. Fractal applications are way too many to be captured in a few pages of an article. And in all of these, fractal geometry of nature provides a balance between the regular and the irregular. It is therefore quite natural that this relatively new branch of



Fractal design enables the antenna to be receptive to a wide range of frequencies. (Right) Modern radio-frequency antenna based on a fractal design is small enough in size to fit inside the mobile phone, yet powerful enough to receive and respond to a wide range of frequencies.

models. It was used in animating planets and mountains in the 1982 classic *Star Trek II: The Wrath of Khan*. The computer-generated sequences that created the landscape of the Genesis planet in the movie were made possible by the mathematics of fractal geometry. Following this success, fractal geometry was used in many other successful science-fiction movies, such as *Return of the*

is Microsoft's multimedia encyclopedia Encarta, which was available in a DVD. While there already exist standard compression algorithms for data and images, they don't work very well with multimedia artifacts such as videos, presentations, audio files, and panoramic images. Using fractal algorithms computer programmers could compress volumes of data and images worth terabytes

mathematics has set the scientific world on fire, and has carved a niche of its own.

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# IS'ON'- IS-OFF

## *Patient may have died but the operation is successful*



**Dr. T. V. Venkateshwaran**

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The news of the Comet ISON, eagerly awaited by millions around the world, fizzling out after its close encounter with Sun on 29 November 2013 was indeed a dampener for astronomy enthusiasts who have been building global campaign for about a year now. Indeed what was expected to be a celestial treat, during the December 2013 has failed to materialise. Yet the data researchers could gather on the structure and composition of ISON when it met its fate is valuable and provide insights into why and how it broke up near the Sun.

Discovered by Russian astronomers Vitali Nevski and Artyom Novichonok, the comet officially registered as C/2012 S1 was named ISON after the International Scientific Optical Network (ISON) facility near Kislovodsk, Russia used in its detection.

The observations indicated that unlike Halley and other comets it was not a Kuiper belt object but a pristine planetesimal from the Oort cloud, which is located about 5,000 astronomical units (nearly one light year) from the Sun, way beyond Pluto. Commencing its journey about 10,000 years ago, ISON traced a parabolic path indicating that this was its first journey into the solar system.

Oort cloud is speculated to be populated by leftover planetesimals from the time of the formation of Sun and the solar system about 4.5 billion years ago. ISON is the only object to be cast away from Oort cloud towards Earth in the recent past; hence by studying it one would be able to understand the conditions that prevailed during the early stage of solar system formation. While astronomers were excited about this heavenly opportunity, astronomy enthusiasts were fevered about its brightness and the celestial show it was expected to put up.

True to its namesake the comet was full of surprises right from the time of its discovery.



*This image of Comet ISON was captured on 9 October 2013 by the Hubble Space Telescope.*

The abnormal brightness with which it was shining at a distance 6.9 AU when discovered naturally aroused curiosity. It was estimated that icy material in ISON would furiously sublimate and release torrents of dust as the surface erodes under the Sun's fierce heat, particularly during its sweltering perihelion passage around the Sun. Around this time, the comet was estimated to become bright enough to glimpse just by holding up a hand to block the Sun's glare. Dubbed "comet of the century", the world of astronomers and astronomy enthusiasts were abuzz with expectations. However, the comet turned out to be a sun grazer, making its closest

approach at a distance of just 12 lakh km. Whether ISON would survive its solar encounter to become a naked-eye spectacle was an open question.

Unlike earlier times, this time the study of ISON was not just global but *celestial*. While in earlier times astronomy relied solely on ground based observations, today with space assets spread across the solar system it was possible to keep close watch on ISON with interplanetary eyes.

NASA's Deep Impact mission (renamed EPOXI) that intentionally crashed an impactor onto comet Tempel-1 on 4 July 2005 and performed a close fly-by of Comet Hartley2 in 2010 was turned towards Comet ISON. The well-equipped instruments aboard EPOXI, designed to study comets, were deployed to image Comet ISON during January 2013. The data derived from these observations revealed unusual activity at this great distance and also that the comet is rich in carbon monoxide and carbon dioxide.

Subsequently during March 2013, astronomers from the University of Maryland at College Park (UMCP) and Lowell Observatory used NASA's Swift satellite to study ISON using its Ultraviolet/Optical Telescope (UVOT). With this data the team embarked on estimating the size of the nucleus of the comet. While Comet ISON was at 740 million km from Sun, the UVOT observations revealed that the comet was



*Comet ISON, imaged by an amateur astrophotographer in the UK on 15 November 2013. (Credit: Damian Peach/SkyandTelescope.com)*

spewing 51,000 kg of dust and only about 60 kg of water every minute. Usually it is the water vapour that carries the dust, and hence the amount of the dust and the sublimation of water should be almost equal. The mismatch between the amount of dust and water produced indicated that water sublimation was not yet powering its jets because the comet was still too far from the Sun. This implied that perhaps other more volatile materials, such as carbon dioxide or carbon monoxide ice, were fuelling

ISON's extraordinary activity. Further, comparing the amount of gas needed for a normal comet to blow off dust at the rate observed for ISON, the scientists estimated that the nucleus was roughly 5 km across, a typical size for a comet. This assumes that only the fraction of the surface most directly exposed to the Sun, about 10 percent of the total, was actively producing jets.

When the inbound comet subsequently passed about 10.8 million km from Mars around 1 October 2013, using the High Resolution Imaging Science Experiment (HiRISE) camera of the Mars Reconnaissance Orbiter (MRO) currently orbiting Mars, first space photos of ISON were taken. In the images taken on 29 September 2013 the comet appeared rather dim but the image was useful for estimating the size of nucleus. Three additional observations of ISON were undertaken on 1 and 2 October when the comet made its closest approach to Mars. The estimates arrived from the analysis of the pictures from these observations indicated that the comet was relatively small; perhaps no more than 600 metres across and not 5 km as was initially estimated.

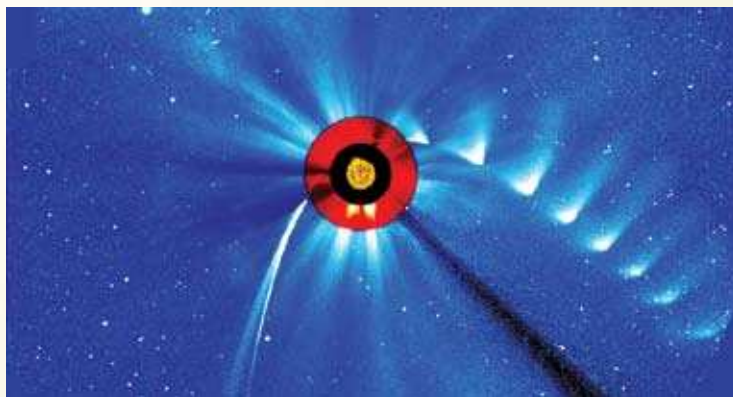
To resolve this question, Earth-bound space telescopes such as the Hubble Space Telescope and the Spitzer Space Telescope were put to use to image the comet. While the former put an upper limit of 2 kilometres for the radius of Comet ISON's nucleus, the latter put a lower limit of 200 metres for the diameter of the comet's nucleus. Therefore the actual value should be somewhere in between.

When the comet passed Mercury during the third week of November, NASA's MESSENGER probe stationed in orbit around the planet recorded thousands of spectroscopic measurements. The scans revealed signatures of carbon, oxygen, sulphur, sodium and other elements present in ISON's nucleus. In addition there are spectral structures which have not been deciphered yet.

During the last week preceding its perihelion approach various solar physics observatories were deployed to study the comet. NASA's Solar Terrestrial Relations

Observatory (STEREO) and Solar Dynamics Observatory (SDO), and joint European Space Agency/NASA Solar and Heliospheric Observatory (SOHO) along with the X-Ray Telescope on the JAXA/NASA Hinode mission tracked the comet when it rushed towards the Sun.

The day when Comet ISON made its perihelion approach it was a pure drama. Using the SOHO and SDS and the STEREO the plight of the comet was tracked continuously. The comet could be



*Path of Comet ISON at perihelion. Comet ISON starts as a streak (left), disappears into the Sun's corona (red) and fades (right) as it emerges from the close encounter. This composite, time-lapse image shows the comet's path from 28 November to 1 December 2013. The images were captured by ESA/NASA's SOHO mission.*

seen nearing the Sun with a long tail; but as it made its hairpin turn around the Sun, there was no trace of it. Some scientists rushed to announce that the comet is dead. Lo and behold! There was another twist in the story. The coronagraph images showed that the comet appeared to brighten after moving beyond the Sun, raising false hopes that it had survived its close encounter with the Sun. But the brightening turned out to be just momentary. Ultimately, the comet broke up under the intense heat and tidal forces near the Sun, disappointing stargazers who had hoped to catch a view of what some had predicted would be the "comet of the century."

As the comet approached its perihelion pass it would have encountered intense heat of Sun, as high as 2,600°C. Even hardest materials like diamond would have sublimated in this heat and it is no wonder compact ISON broke up easily and evaporated just into a puff. Astronomers speculate that the fragmentation of the nucleus occurred well before its perihelion pass. If it broke up early

its pieces would have spread out because of the tidal forces near the Sun: the closer pieces would be pulled more strongly by gravity, luring them farther in, whereas the pieces on the back side of the clump would lag due to a lessened gravitational pull. Coming out the other side of the Sun, the same process would happen in reverse. When the cloud briefly coalesced again, the clump might have appeared to re-brighten before dimming out again. Perhaps this is why the comet appeared bright before its perihelion pass and immediately thereafter, giving rise to false hope that the comet has survived the close encounter with Sun.

The breakup of ISON near the Sun was indeed a mystery in one sense. Comet Lovejoy (C/2011 W3), another sun-grazing comet, made its perihelion pass even much closer but survived in 2011. By comparing observations of both comets, astronomers speculate that Comet Lovejoy – a Kuiper belt short period comet – is very different in its composition to ISON – an Oort cloud object. Lovejoy has indeed made close encounters with Sun many times, yet survived it all. The

way the ISON evaporated in matter of hours indicates that perhaps ISON's outer layer was raw and possibly volatile without hardier crust to withstand the solar heat and pull.

Although ISON is dead in popular conception, it could still have lessons to teach. Astronomers are considering deploying the Hubble, Spitzer and Chandra space telescopes to make observation to look for dust left over from the wrecked comet. The dust and materials left over from the disintegrated Oort cloud comet could tell lot more about the origins of the solar system. ISON is down but not out for scientists; a lot more insights will follow when all the data that have been garnered in the past seven months from the telescopes all over the world, including 13 space observatories and hundreds of amateur astronomers, are synthesised and analysed. Astronomers are optimistic about the data that they were able to collect in the past one year from this pristine comet fresh out from the Oort cloud.

# Harikrishna Devsare: Doyen of children's literature

The fine writer who devoted his whole life to children's literature, finally, breathed his last on Children's Day (14 November 2013). India's most well-known creator of children's literature Dr. Harikrishna Devsare is no more, but he will ever live and inspire us through his literature.

Dr. Devsare was a happy-go-lucky person. Whenever difficulties came in his life he never accepted defeat. He fought them out, live life on his own terms, and kept smiling always, under all circumstances. He would laugh even in pain and continued writing even in the ICU of the hospital he was admitted in. So strong was his desire to write that inspite of his old age and several health problems he held his pen firmly and flowing. Dr. Devsare's death marks the end of an era in children literature in India.

Harikrishna Devsare was born on 9 March 1938 in Nagod (Madhya Pradesh). In 2011, Sahitya Academy honoured him for his lifelong contribution to children's literature. In the span of 75 years of his life Devsare wrote 300 books and earned many times more reputation.



*Harikrishna Devsare*

children. In this context the following statement of Dr. Devsare is relevant:

"I will only say that the children reading fairy or ghost tales are likely to get away from scientific point of view because they will be inclined towards superstitions and those engaged in science communication know it



**Kapil Tripathi**

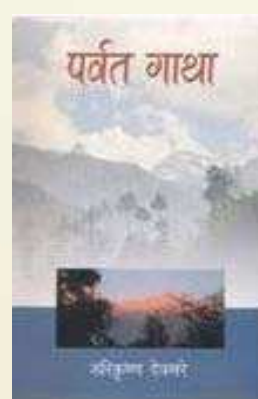
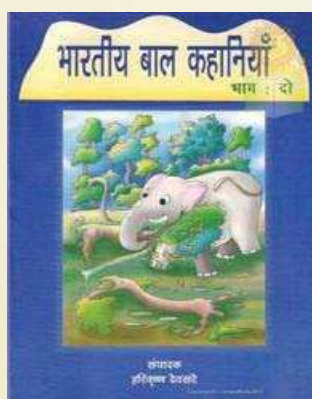


**Manish Mohan Gore**

for almost 22 years and from there after taking voluntary retirement, he accepted the responsibility of editing popular children's magazine *Parag*. Under the editorship of Dr. Devsare the magazine gave a new dimension to children's stories. These stories and the popular editor of *Parag* left an indelible imprint on the minds of millions of children of India. Children who grew up reading the stories of Dr. Devsare are now discharging their responsibility as teachers, scientists, social workers, journalists and story writers.

Scientific thinking related search brought Dr. Devsare in the fold of Vigyan Prasar. Here he in association with Dr. Subodh Mahanti, Convener Publication Programme and the then Director Dr. Narendra Sehgal and later Dr. Vinay Kamble paved the way for developing necessary scientific literature for children and adolescents. Dr. Devsare made all-out effort to get more and more science books published and disseminated in Hindi by Vigyan Prasar. He remained associated with the publication programme of Vigyan Prasar for seven years.

In addition to publication programme



*Some selected popular books written by Devsare*

Devsare was the first individual to earn a Ph.D on Indian children's literature. In the beginning he also wrote fairy tales and stories on traditional lives, but with time he realised that such stories cannot inculcate scientific wisdom in children's minds. Therefore, he himself pioneered and introduced scientific content in his children's stories and paved the way to develop scientific thinking in

well how deeply superstitions are rooted in our country. So I will advise children that they should read science fiction, because, when we read something with a view of science, we easily understand what is possible and what is not. Science fiction gives them new vision, new thinking and meaningful idea of the future."

Dr. Devsare served All India Radio

Dr. Devsare played a crucial role in convening the national language committee of Vigyan Prasar and to promote wide use of Hindi in its office. Dr. Devsare played an important role in fulfilling the objectives of Vigyan Prasar and the Institution will always remain indebted to him for his contribution.

(Translated by: R. S. Dass) ■

# Frozen shoulder— Simple Mantras to take home

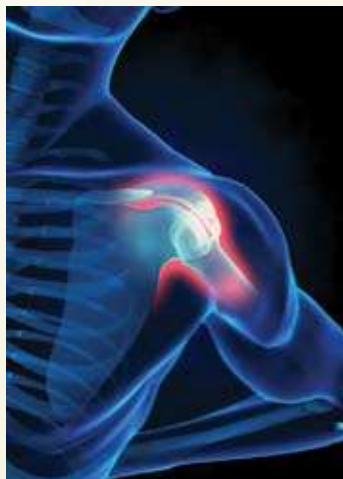


**Dr Yatish Agarwal**  
e-mail: [dryatish@yahoo.com](mailto:dryatish@yahoo.com)

Stiffness and pain in a shoulder joint, severely restricting its movement, is known as 'frozen shoulder'. A common condition, it may occur due to inflammation resulting from an injury to the shoulder region. The risk of developing a frozen shoulder also increases if a person is recovering from a medical condition or procedure that affects the mobility of the arm — such as limb weakness or paralysis faced following a stroke or in women, following a mastectomy. However, in many people, frozen shoulder develops for no apparent reason. The condition occurs most frequently in people over the age of 40 and is more common in women. People who have diabetes mellitus are more susceptible to the condition.

## Symptoms

The symptoms of frozen shoulder often develop gradually over a period of weeks or months. They can typically be categorised into three stages. Each of these stages can last for several months.



### **Painful stage**

During this stage, whenever you try and move the shoulder, be it any type of movement, you feel considerable pain. The pain is severe and is often worse at night, sometimes disrupting normal sleep patterns.

### **Frozen stage**

With time, the pain gradually begins to diminish. However, the shoulder becomes stiffer, and the range of motion (the extent to which a joint or group of muscles can be flexed or extended) decreases notably. For some people, who have a severe condition, the pain may travel down the arm to the elbow.

### **Thawing stage**

During the thawing stage, the range of motion in the shoulder begins to improve.

## Causes

The bones, ligaments and tendons that make up the shoulder joint are encased in a capsule of connective tissue. Frozen shoulder occurs when this capsule thickens and tightens around the shoulder joint, restricting its movement.

Doctors aren't sure why this happens to some people and not to others, although it's more likely to occur in people who have recently experienced prolonged immobilisation of their shoulder, such as after surgery or an arm fracture.

## Risk factors

Although the exact cause is unknown, certain factors may increase a person's risk of developing frozen shoulder.

### **Age and sex**

People 40 and older are more likely to experience frozen shoulder. Most of the people who develop the condition are women.

### **Immobility or reduced mobility**

People who have experienced prolonged immobility or reduced mobility of their shoulder are at higher risk of developing frozen shoulder. Immobility may be the result of many factors, including:

- Weakness of the limb or paralysis following a brain stroke
- Following an injury to the rotator cuff (more simply, the set of muscles and tendons that secures the arm to the shoulder joint and permits rotation of the arm)
- Broken arm
- Recovery from surgery

### **Systemic diseases**

People who have certain medical problems appear to be predisposed to develop frozen shoulder. These conditions include:

- Diabetes mellitus (raised blood sugar)
- Hyperthyroidism (overactive thyroid)
- Hypothyroidism (underactive thyroid)
- Parkinson's disease
- Tuberculosis

## When to see the doctor

If you have pain in the shoulder that lasts for more than a few days, you should consult your doctor.

### **Who to consult**

While you may initially consult your family physician, he or she may refer you to a doctor who specialises in orthopaedic medicine or alternatively, a specialist in physical medicine and rehabilitation.

### **Preparing for the consultation**

Before you go to meet your doctor, you may consider writing down a detailed description of the symptoms. Like, when did your symptoms begin, are there any activities that worsen the symptoms, and did you ever injure that shoulder. You should also build a brief summary of the major medical problems that you may be having such as diabetes, and all the medications you take. Finally, list the questions you might want to ask the doctor.

## Tests and diagnosis

Your doctor will probably diagnose frozen shoulder from the symptoms and an examination of your shoulder. During the physical

exam, your doctor may ask you to perform certain actions, to check for pain and evaluate your range of motion. These may include:

- **Hands up:** Raise both your hands straight up in the air, like a football referee calling a touchdown.
- **Touching the opposite shoulder:** Reach across your chest to touch your opposite shoulder.
- **Back scratch:** Starting with the back of your hand against the small of your back, reach upward to touch your opposite shoulder blade.

Your doctor may also ask you to relax your muscles while he or she moves your arm for you. This test can help distinguish between frozen shoulder and a rotator cuff injury. Frozen shoulder can usually be diagnosed from signs and symptoms alone. However, some doctors may suggest imaging tests — such as X-rays or an MRI — to rule out other structural problems.

## Treatments and drugs

### Medications and physiotherapy

Over-the-counter pain relievers, such as aspirin and ibuprofen, can help reduce pain and inflammation associated with frozen shoulder. In some cases, the treating doctor may prescribe prescription pain-relieving and anti-inflammatory drugs.

### Physiotherapy

A physical therapist can use diathermy or heat treatment to soothe the muscles and ease the pain. Once the pain becomes less, he or she may teach you stretching exercises to help maintain as much mobility in your shoulder as possible.

### Shoulder exercises

These exercises may improve your shoulder's range of motion:

#### Exercise 1

Let your arm hang down like a pendulum, and then gently swing it back and forth or in circles.



#### Exercise 2

Pretend your fingers are your feet and walk your fingers up a wall.

Most frozen shoulder treatment involves controlling shoulder pain and preserving as much range of motion in the shoulder as possible.



## Surgical and other procedures

Most frozen shoulders get better on their own within six to 18 months. For persistent symptoms, your doctor may suggest:

### Steroid injections

Injecting corticosteroids into your shoulder joint may help decrease pain and improve shoulder mobility.

### Joint distension

Injecting sterile water into the joint capsule can help stretch the tissue and make it easier to move the joint.

### Shoulder manipulation

In this procedure, you receive a general anaesthetic so you'll be unconscious and feel no pain. Then the doctor moves your shoulder joint in different directions, to help loosen the tightened tissue. This procedure is however not free of complications.

### Surgery

If nothing else has helped, you may be a candidate for surgery to remove scar tissue and adhesions from inside your shoulder joint. Doctors usually perform this surgery arthroscopically, with lighted, tubular instruments inserted through small incisions around your joint.

## Lifestyle and home remedies

Continue to use the involved shoulder and extremity in as many daily life activities as possible within the limits of your pain and range-of-motion constraints. Applying heat or cold to your shoulder can help relieve pain.

### Acupuncture

Acupuncture is a procedure that has been used in China for thousands of years. It involves inserting extremely fine needles in your skin at specific points on your body. Typically, the needles remain in place for 15 to 40 minutes. During that time they may be moved or manipulated. The needles are hair thin and flexible and are inserted superficially, and hence, the treatment is relatively painless.

### Transcutaneous electrical nerve stimulation (TENS)

A TENS unit delivers a tiny electrical current to key points on a nerve pathway. The current, delivered through electrodes taped to your skin, isn't painful or harmful. It is not known exactly how TENS works, but it's thought that it might stimulate the release of pain-inhibiting molecules (endorphins) or block pain fibres that carry pain impulses.

### Outcome

Even though the signs and symptoms of a frozen shoulder may worsen over time and seem to be never-ending, they generally always resolve, usually within one or two years. So, don't lose heart and keep your calm, you will be fine!

# Recent developments in science and technology

— Biman Basu, E-mail: [bimanbasu@gmail.com](mailto:bimanbasu@gmail.com)

## When a comet is not a comet

Comets are often described as ‘dirty snowballs’ that occasionally come into the solar system



*These NASA/ESA Hubble Space Telescope images reveal a never-before seen set of six comet-like tails radiating from a body in the asteroid belt designated P/2013 P5. The picture on the left shows as it was on 10 September and the one on the right as seen on 23 September 2013.*

from distant sources. As a comet approaches the Sun the solar heat starts evaporating ice and dust from the solid body of the comet, producing the well-known ‘tail’ characteristic of comets. Tails vary widely in size – some are short while others may stretch millions of kilometres. The tail becomes smaller as the comet moves further and further away from the Sun.

Comets usually display two tails – a brighter one, made up of dust, and another much fainter one, made up of ionised gas. The ionised gas tail is usually not visible in most comets. The tail of a comet becomes visible only by reflected sunlight and always points away from Sun, irrespective of whether the comet is moving towards or away from the Sun. This is because the pressure of solar wind always pushes the fine dust particles that make up the tail away from the Sun.

Recently, astronomers have been baffled by the appearance of a bizarre comet-like object that shows not one but several bright tail-like structures. A strange object with half a dozen comet-like tails was first spotted by the Pan-STARRS survey telescope in Hawaii at the end of August in August in

the asteroid belt between Mars and Jupiter, leaving astronomers wondering what it could be. Astronomers believe the strange object is probably not a comet but an asteroid and does not contain any ice. But unlike all other known asteroids, which appear simply as tiny points of light, this asteroid, designated P/2013 P5, resembles a “rotating lawn sprinkler”. Detailed study of the object, designated as P/2013 P5, has revealed it to be quite small – only about 240 metres across (*Astrophysical Journal Letters* 7 November 2013 | doi: 10.1088/2041-8205/778/1/L21).

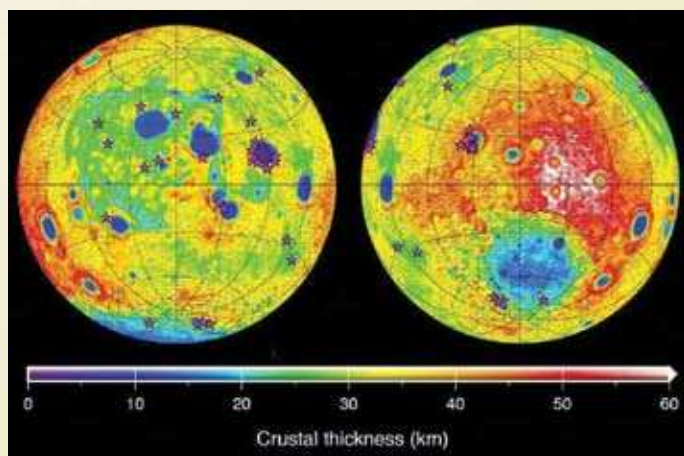
Because the object was “unusually fuzzy-looking,” scientists used the Hubble Space Telescope to take a more detailed image on 10 September, revealing the six tails. When astronomers observed it again 13 days later on 23 September, the tails looked quite different and were pointed in different directions, suggesting that the object had rotated. According to David Jewitt of the University of California at Los Angeles, who led the study, “It’s hard to believe we’re looking at an asteroid. We were dumbfounded when we saw it. Amazingly, its tail structures change dramatically in just 13 days as it belches out dust”. Unlike a comet, which is made up of mostly ice and dust, asteroids are rocky bodies. While a typical comet’s tail is formed by jets of gas and dust evaporating from the comet’s body, researchers don’t think that process is responsible for the six

tails on P/2013 P5. They believe the ‘tails’ of P/2013 P5 are made up of mainly dust particles ejected from the asteroid by its fast rotation.

One interpretation given by the astronomers is that the P/2013 P5’s rotation rate increased to the point where its surface started flying apart, ejecting dust in episodic eruptions. According to Jessica Agarwal of the Max Planck Institute for Solar System Research, in Lindau, Germany and co-author of the paper, careful computer modelling has shown that the P/2013 P5’s tails could have been formed by a series of impulsive dust-ejection events. Radiation pressure from the Sun stretched the dust into tail-like streamers.

## New light on the structure of the Moon

Even without a telescope, one can see that the Moon’s surface has light and dark areas. The brighter areas are mountainous highlands. The darker areas are called maria, meaning ‘seas’ in Latin. But the maria are neither seas nor do they contain any water. They actually are large, lava-filled, impact basins that were created by asteroid impacts about four billion years ago. The bright lunar highlands have more craters than the maria, indicating they are older and have been bombarded for



*This map of the crustal thickness of the Moon was generated using gravity data from NASA’s GRAIL mission and topography data from NASA’s Lunar Reconnaissance Orbiter. (Credit: NASA/JPL-Caltech/ IPGP)*

a longer time. Recent analysis of data from the lunar-orbiting twins of NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission indicate that both the near side and the far side of the Moon were bombarded by similarly large impactors, but they reacted to them much differently because of different surface characteristics.

Although the origin of lunar basins was known reasonably well, understanding these impact basins has been hampered by the simple fact that there is a lack of consensus on their size. Most of the largest impact basins on the near side of the Moon have been filled with lava flows, which hide important clues about the shape of the original land surface that could be used for determining their dimensions.

The GRAIL mission measured the internal structure of the Moon in unprecedented detail for nine months in 2012. Flying in formation around the Moon, the twin GRAIL spacecraft made precise measurements of the lunar gravitational field. With the data, GRAIL scientists have redefined the sizes of massive impact basins on the Moon. GRAIL data has uncovered the origin of massive invisible regions in Moon's interior that make the Moon's gravity uneven, a phenomenon that affects the operations of lunar-orbiting spacecraft. Maps of crustal thickness of the Moon generated by GRAIL revealed more large impact basins on the near-side hemisphere of the Moon than on the far side. This seemed very surprising if both hemispheres had received the same number of asteroid impacts in the past.

There was, however, a clue available. Scientists had long known that the temperatures of the near-side hemisphere of the Moon were higher than those on the far side, mainly because of the higher abundances of the heat-producing radioactive elements uranium and thorium on the near side. According to the researchers, because of higher temperatures, the vast majority of volcanic eruptions occurred on the Moon's near-side hemisphere, throwing up more lava [Science, 8 November 2013 | doi: 10.1126/science.1243224, 724 (2013); 342 Science]. According to Katarina Miljkovic of the Institut de Physique du Globe de Paris, lead author of the Science paper, computer simulation of impacts indicate that impacts into a hot, thin crust representative of the early Moon's near-side hemisphere would have produced basins with as much as twice

the diameter as similar impacts into cooler crust on the far side would produce. This explains the larger number of impact craters on Moon's near side hemisphere relative to the far side.

## The coldest place in the universe

Researchers have recently identified the coldest place in the universe. Known as the Boomerang Nebula, the object has a temperature of only one Kelvin, or  $-272.14^{\circ}$  Celsius. The discovery was made by an international team of researchers led by Raghvendra Sahai of NASA's Jet Propulsion Laboratory in Pasadena, California, using the Atacama Large Millimetre/submillimetre Array, also known as the ALMA telescope.



*This image shows the Boomerang Nebula – the coldest place in the Universe.*

*(Credit: Bill Saxton/NRAO/AUI/NSF/ NASA/Hubble/Raghvendra Sahai)*

ALMA is an astronomical interferometer of radio telescopes with an array of 66 large radio dishes, installed on a plateau 5,000 metres high in the Atacama desert in Chile where almost no humidity or vegetation to block its view of the heavens.

The Boomerang Nebula is a planetary nebula located in the constellation Centaurus about 5,000 light-years from Earth. It is a relatively young planetary nebula, which is a glowing shell of ionised gas ejected from the outer layers of a Sun-like star in its final stages. According to the researchers, it is expanding rapidly, and using up energy in the process, creating a cooling effect due to adiabatic expansion – similar to what happens in a refrigerator – permitting it to stay colder than the temperatures around it. The nebula is colder than the faint afterglow

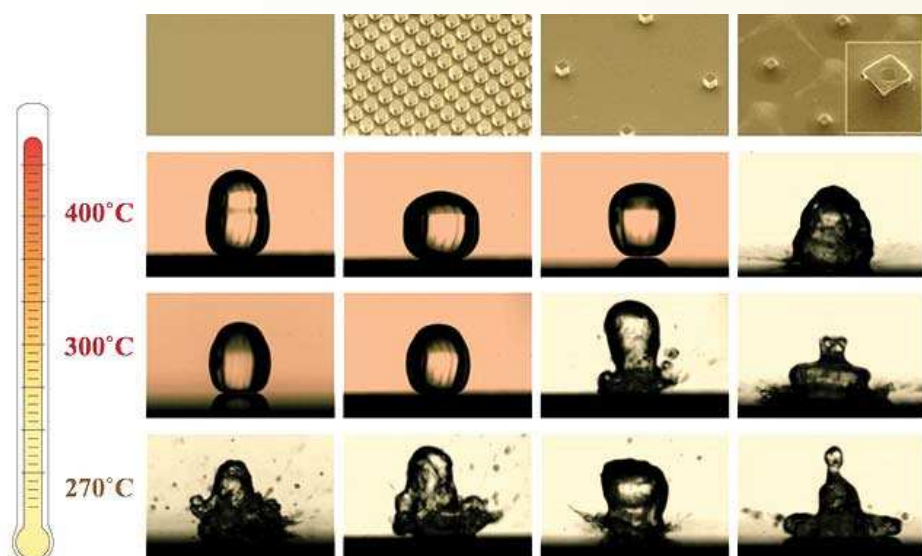
of the Big Bang (3 Kelvin), which is the natural background temperature of space. (*The Astrophysical Journal*, 18 October 2013 | doi:10.1088/0004-637X/777/2/92).

What the astronomers found is that the nebula's bow tie shape is an illusion: the actual cloud surrounding the dying star is roughly spherical. According to Sahai, what seemed like a double lobe, or boomerang shape, from Earth-based optical telescopes, is actually a much broader structure that is expanding rapidly into space. The researchers managed to figure this out by using the ALMA telescope to look for the radiation emitted by vibrating molecules of carbon monoxide that are spread throughout the dust and gas that make up the nebula. As originally observed with ground-based telescopes, this nebula appeared lopsided, which is how it got its name. Later observations with NASA's Hubble Space Telescope revealed a bow-tie-like structure. The flaps of the 'tie' are created by starlight reflecting off dust grains, but a relatively thick band of dust close in blocks that light from illuminating those grains in all directions.

According to Sahai, the new findings about the Boomerang Nebula are important for the understanding of how stars die and become planetary nebulas. Using ALMA, it was possible literally, and figuratively, to shed new light on the death throes of a Sun-like star.

## Surface designed for effective cooling

Is it always possible to cool a hot object by spraying water on it? Perhaps not, as the staff at Japan's Fukushima nuclear power plant learnt the hard way after an earthquake and tsunami struck the plant in 2011, knocking out emergency power supplies. The plant crew sprayed seawater on the reactors to cool them, but to no avail. One possible reason: Droplets cannot land on very hot surfaces. Instead, they instantly begin to evaporate, forming a thin layer of vapour and then bouncing along it, just as they do when water is sprayed on a hot cooking pan. Now a team of researchers at Massachusetts Institute of Technology, led by Kripa K. Varanasi, an Associate Professor in MIT's Department of Mechanical Engineering, has come up with a technique to cool hot surfaces more effectively by keeping droplets from bouncing and thus ensure effective cooling. The technique is to cover the surface with tiny structures and



Micrographs showing water droplets landing on specially designed silicon surfaces (top images) at different temperatures. At higher temperatures, the droplets begin to exhibit a new behaviour: instead of boiling, they bounce on a layer of vapour, never really wetting and cooling the surface. At 400°C, the droplet continues to boil only on the surface that combines microscale posts with a coating of nanoscale particles (last column). These results demonstrate that this micro-nano surface can be effectively cooled even at high temperatures. (Credit: Kripa K Varanasi et al.)

then coat it with particles about 100 times smaller. Using this approach, the researchers produced textured surfaces that could be heated to temperatures at least 100°C higher than smooth ones before droplets bounced (*Applied Physics Letters*, 11 November 2013 | doi: 10.1063/1.4828673).

The work of Varanasi's research team mainly involves tailoring or modifying surfaces to significantly improve efficiency. One of their recent creations was developing a slippery surface coating that is being used commercially as a container liner that makes toothpaste and other difficult-to-remove products, such as ketchup, slide right out of their tubes and containers – greatly reducing waste. But the objective of the present study was the exactly opposite of creating slippery surfaces. It was to design surfaces that were rough, to make liquids come into direct contact with hot surfaces without bouncing.

Vapour films are formed beneath the droplets when a liquid comes in contact with a smooth hot surface, which is a critical problem in boiling. Once the vapour films start forming, they act as a barrier to heat transfer because vapour has a lower thermal conductivity than liquid. The same thing happens when water is sprayed on a smooth hot surface and the vapour film prevents conduction of heat away from the hot surface and thus prevents effective cooling.

The phenomenon of floating of droplets on a hot surface is known as the “Leidenfrost effect”.

To overcome the problem of vapour film formation, Varanasi and colleagues designed textured surfaces using sparsely packed micron-scale structures coated with nanoparticles to create a capillary attraction effect to hold droplets in place. This “micro-nano” surface texture provides both the extensive surface area of the tiny particles and the wide spacing of the posts to let the vapour flow. According to Varanasi, the vapour that forms by the evaporation of the

droplet is able to escape through the surface texture and does not interfere with the cooling process.

This approach was confirmed by experiments. When the researchers sprayed water on their micro-nano surfaces at 400°C – the highest temperature their experimental setup could provide – the droplets quickly wet the surfaces and boiled, thereby cooling the surface.

## VP website

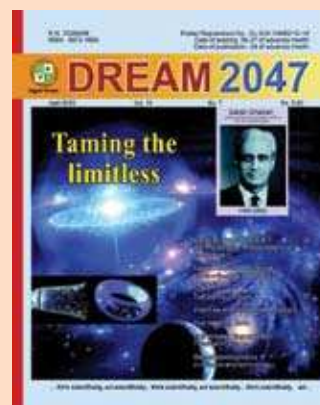


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Articles  
invited

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Vigyan Prasar invites original popular science articles for publication in its monthly science magazine *Dream 2047*. At present the magazine has 50,000 subscribers. The article may be limited to 3,000 words and can be written in English or Hindi. Regular columns on i) Health ii) Recent developments in science and technology are also welcome. Honorarium, as per Vigyan Prasar norm, is paid to the author(s) if the article is accepted for publication. For details please log-on to [www.vigyanprasar.gov.in](http://www.vigyanprasar.gov.in) or e-mail to [dream@vigyanprasar.gov.in](mailto:dream@vigyanprasar.gov.in)



# Nation-wide Sensitisation Programme on Mathematics for Teachers

Mathematics plays a very important role in a person's day-to-day life, although its involvement is not always visible. As a consequence it remains mainly hidden from public attention and becomes the subject of discussion only within certain groups. To break this perception and to popularise mathematics, particularly among students and the common man in general, there is a need to give more attention to communicating mathematics, not just definitions, theorems and proofs, but also to changing our way of thinking.

To address these issues, Vigyan Prasar has launched a "Nationwide Sensitisation Programme on Mathematics for Teachers" with the following objectives:

- i) To sensitise teachers towards the development of mathematics and bridge the gap between mathematics



*Workshop participants at Madurai*

education and mathematics communication;

- ii) To popularise everyday mathematics to help them appreciate the subject and attract more students towards mathematics stream;
- iii) To develop and promote hands-on activities on mathematics; and
- iv) To identify the basic difficulties faced by teachers in teaching mathematics.

Under this programme 30 workshops are planned to be organised in different parts of the country jointly with organisations under NCSTC-Network, New Delhi and All-India People Science Network. These workshops are to be conducted as a part of National Year of Mathematics-2012 and International Year of Mathematics for Planet Earth-2013. Mathematics teachers

of secondary and upper secondary level will be invited as participants and their registration is being done centrally through the VP website.

Before launching the programme Vigyan Prasar organised a two-day brainstorming workshop on 21-22 September 2013 at JNU Convention Centre, JNU campus, New Delhi. Thirty resource persons from academic and non-academic areas working in the field of mathematics from different organisations were invited to prepare a common module for the workshops.

The main objective of the brainstorming workshop was to identify different activities and to engage the resource persons for the forthcoming workshops.

The first workshop of the series was organised at the State Institute of Education, Jammu (J&K) on 22-23 November 2013. It was organised by the National Council for Urban and Rural Development Society, (NCURDS) Jammu. The workshop was inaugurated by Er Anuj Sinha, Chairman NCSTC-Network, Dr S.K. Raina, In-charge, State Institute of Education, Jammu and Dr T.V. Venkateswaran, Academic Head, Vigyan Prasar on 22 November 2013. Zaffar-Ullah

Khan, Founder Secretary of NCURDS, briefed the participants on the purpose of the workshop. Different sessions on 'India's contribution to mathematics', 'Mathematics in daily life', 'Teaching mathematics: an approach', 'Hands-on mathematics', etc., were organised. A documentary on Ramanujan was also screened during the workshop. The workshop concluded with experience sharing (open house discussion) where all resource persons interacted with teachers on the common issue related to mathematics teaching. Sixty-five teachers participated in the workshop. Resource material specially developed



*A view of inaugural session of Jammu workshop*

for the programme was also given to the participants.

Similar workshops were organised at Mannar Thirumalai Naicker College, Pasumalai, Madurai (TN) on 2-3 December 2013, Regional Institute of Education, Manasagangothri, Mysore University, Mysore, on 5-6 December 2013, and at Himachal Gyan Vigyan Samiti, Sauli Khadd, Mandi (HP) on 11-12 December 2013.

Twenty-six more workshops are to be organised in Assam, Tripura, West Bengal, Gujarat, Karnataka, Kerala, Tamil Nadu, Pondicherry, Andhra Pradesh, Madhya Pradesh, Maharashtra, Goa, Uttar Pradesh, Rajasthan, Uttarakhand, Jharkhand, Bihar, Chhattisgarh, Haryana, Punjab, and Delhi NCR.

Interested participants may register themselves online through VP website.



*Resource persons during brainstorming session at JNU, New Delhi*

[www.vigyanprasar.gov.in](http://www.vigyanprasar.gov.in). Tentative dates of the workshops will also be available on the website.