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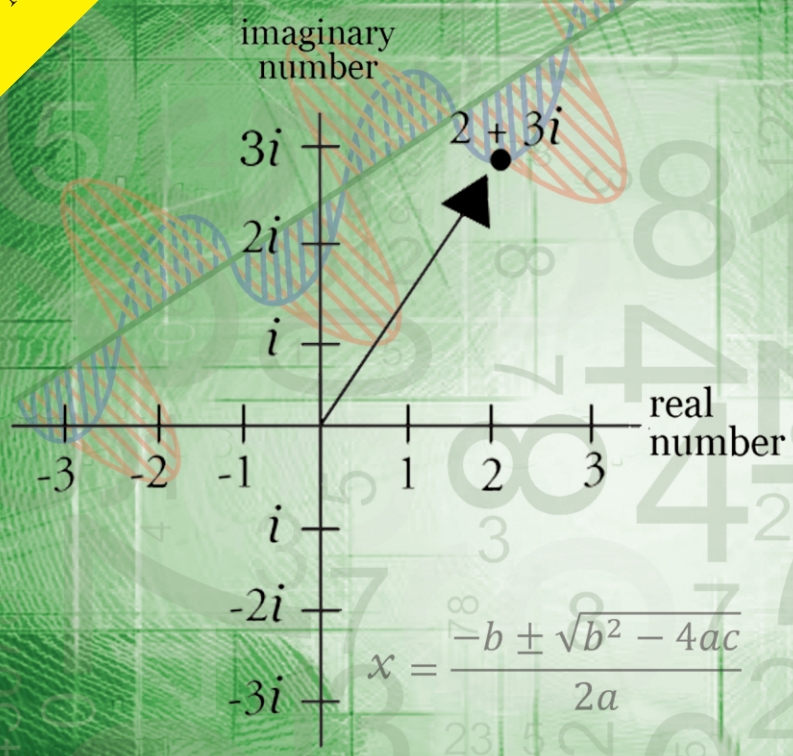
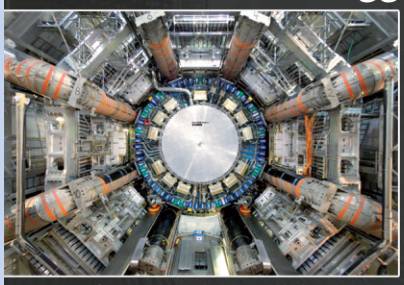
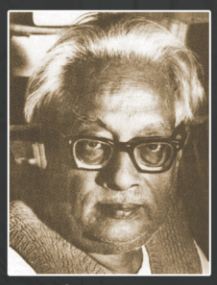
A chronicle of complex numbers



Higgs boson



A part of Large Hadron Collider (LHC)



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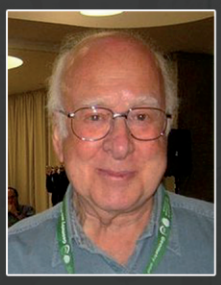

Peter Higgs

... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

The role of planetaria in science communication

Dr. Subodh Mahanti

Those who happen to watch planetarium shows are very likely to look upwards— to the sky. And once they do so, the starry heavens above fill their minds with ever increasing wonder and curiosity. The Greek philosopher Plato (c.427-c.347 BC) wrote in his celebrated work *The Republic* that "Astronomy compels the soul to look upwards and leads us from this world to another." A planetarium (plural 'planetaria' or 'planetariums') can play an important role in making people interested in science, particularly in astronomy. Planetaria can make 'hard' science 'soft' by incorporating elements of drama, style and special effects and can thus act as an important link between science and the general public.

The *Webster's New World Dictionary* (Third College Edition, 1989) defines a planetarium as "the complex revolving projector used to stimulate the past, present, or future motions or positions of the Sun, Moon, planets, and stars on the inside of a large dome." Planetarium technologies have changed over the years. Today a wide variety of technologies; for example, precision-engineered 'star balls' that combine optical and electro-mechanical technology, slide projector, video and full-dome projector systems are used for creating the celestial scenes. Today many planetaria view themselves as science education centres and not just being confined to astronomy alone. To increase its versatility modern planetara include exhibition halls, seminar rooms, a library, and an observatory.

A dominant feature of most planetaria is the large dome-shaped projection screen. Planetaria can be permanent or portable, depending on the application. Portable planetaria serve education programmes where permanent installations are not available. Planetaria domes range in size from 3 to 35 metres in diameter.

The concept of planetarium can be traced to antiquity. It is believed that Archimedes (c.287-212 BC) possessed a primitive planetarium device that could predict the movements of the Sun, the Moon and the planets. The oldest but still working planetarium is located in the Dutch town Franeker. It was built by Eise Eisinga (1744-1828), who took seven years to complete it in 1781. Today the early planetary devices are usually referred to as orreries because of the fact that an 18th century Earl of Orrey built one such device. It is generally accepted that the journey of the modern age planerarium began with Walter Baeursfeld of Carl Zeiss, Inc. The first public show of a planetarium was perhaps at the Deutches Museum in Munich on 21 October 1923.

A planetarium is a unique medium for communication of science and provides an impressive environment for science communication. The unique environment of the planetarium gives the audience an opportunity to contemplate. A planetarium developed as the theatre in which a star projector is used to recreate the night sky. Subsequently special effects projectors, sound systems, and video projectors supplemented the star projector. Today there is a shift from the familiar opto-mechanical projection of stars in combination with special effects projectors to state-of-the-art digital theatres showing full dome animations. The newest generation of planetaria, which offer a fully digital projection system using full-dome video technology, gives the operator great flexibility in not only the modern night sky as visible from Earth but also the night sky as visible from far distant in space and time. This technological shift is making planetarians or planetarium communicators (the terms often used to describe members of the professional staff of a planetarium) to re-think the way they produce their shows and present them.

In today's practice, a planetarium has a multipurpose function — it is a theatre, a classroom and immersive experience in which astronomy and other subjects are presented as learning experiences. Many planetarians or planetarium communicators are astronomers – amateur or professional – and they have their own interest to share through lectures and shows. Astronomers are not the only professionals engaged by planetaria. Planetarians include educators, producers, scientists, storytellers, artists, musicians, animators, writers, and narrators.

According to one estimate there are over 3,000 planetaria in the world and one-third of these facilities are in universities and/or public venues. Annually the planetarium facilities are visited by 90 to 100 million people. In India the first planetarium to be set up was in New English School, Pune in 1954 — the Kusumbai Motichand Planetarium. It was housed in a concrete dome having an approximate diameter of 9 metres. It had a seating capacity of 100. The Birla Planetarium at Kolkata inaugurated in 1962 was the first major planetarium in India. Mumbai's Nehru Planetarium was established in 1977 and Delhi had its planetarium in 1984. Today there are about 40 planetaria in the country.

Planetaria are among the most attractive places that can be visited by general public to learn or get a feeling about astronomy.

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In fact, planetaria reach out to a broad cross-section of society. It is a powerful and effective media to bring astronomy to the public. Planetarium shows can be divided into three broad categories: traditional (sky in a particular season), topical (show focusing on a particular topic), and timely (on a current spectacular celestial event). There are three broad categories of presentations of planetarium shows:

1. Live presentation—"What is up tonight?" or "What is in the sky tonight?" Such live programmes, which are usually very popular, enable the audience to interact. A live expert presenter can answer on-the-spot question raised by the audience. These programmes not only teach the sky but also present the latest developments in the fields of astronomy and space science.
2. Pre-recorded documentary-style programmes. Such programmes are usually presented with images, narration and soundtrack.
3. Laser shows, concerts and other assorted presentations.

The programmes which do not exploit the magic of a starry dome at its best are just another kind of performance. There should be special emphasis on live sky-based programmes. Often there is a tendency to rely more on pre-recorded documentary-style programmes because of low budget and under-staffing.

A planetarium conducts a number of other outreach activities to take science in general and astronomy in particular to the public, like lectures, seminars, video shows, astronomy courses, workshops, exhibitions, quiz contests, telescope activities, etc. To make 'planetarium experience' a truly learning experience it requires a balance between scientific knowledge (methods and contents) and technological 'sense of wonder'.

The real challenges before the director or coordinator of a planetarium are:

1. To develop an effective and clear narrative that both informs and entertains.
2. To mix the different media involved like video, sky projection, music, reading, etc., for stimulating interest and fascination in scientific topics.

Designing and producing a planetarium programme is an art. It requires the interactions of scientists, artists, communicators, technicians, animators, sound recordists, photographers, and many others.

Science is and should be the main ingredient in a planetarium. A planetarium offers a very wide exposure to astronomy and space science. Information from research institutions is a vital component for planetarium presentation. In planetaria, efforts should be made to convey the excitement of the methods of reasoning, discovering and experimenting. The shows should incorporate different cultural and scientific versions of the sky — the history of observation, cosmology, the physical characteristics of celestial objects, exploration of space, the possibilities of extraterrestrial life and so on. In planetaria, the so-called barriers between different sciences and even between science and arts get blurred. The connection between different disciplines of science and between science, culture and art needs to be highlighted without going into intricate details. A planetarium can also bring about cultural enrichment by incorporating local culture into its shows.

The primary goal of a planetarium shows should not be viewed simply as conveying specific astronomical concepts. The objective of a typical planetarium show should be to inspire curiosity and to entertain, to leave the audience with many questions and with a desire to know more and to imbue them with a greater appreciation of the universe and the process of the development of scientific knowledge. The audience should be motivated to rediscover the sky for themselves. A planetarium show should be viewed as an experience that stimulates interest in astronomy, an interest that may be fulfilled more extensively later by other means. A true planetarium communicator will not pretend to answer all possible questions or to be exhaustive in any sense. The idea should be to help the audience to: develop interest in science, understand science knowledge and engage in scientific reasoning.

Technologies are changing the way planetaria use and show the scientific content. The fascination of high technology affects both the audience (the planetarium attendees) and the planetarium functionaries or science communicators. It is true that the wonders of an artificial sky and celestial stimulation are of crucial significance in the communication process, but at the same time one should remember that what is important is to make best possible uses of the available resources without being too much influenced by the latest technology or all-sky digital device. Efforts should be made to blend technology and artistic expression for more effective communication rather than to search for the perfect, expensive technological solution for each effect.

In a planetarium the audience is set under a theatre-like stage where stories of the sky and about the sky are told. The lecturer or the recorded voice is not an academic but assumes the role of a storyteller while keeping the method and truths of science in view. This storyteller in a planetarium is a science communicator and puts astronomy in a broader cultural context, where science, history, humanities and art can come together and so that the audience or the general public can rediscover the sky as a common, familiar inheritance.

A planetarium has proved to be an indispensable means of making astronomy popular and it will continue to play this role. The future role of a planetarium should be viewed as an increasingly popular way of taking science to the masses. For realising the desired goals a planetarium should devise ways for reviewing and enriching its programmes. Some suggested strategies are:

1. Public feedback should be obtained on a constant basis. Usually a planetarium monitors impressions, comments and suggestions in a logbook. However, there should be proper surveys.
2. Regular meetings of directors of planetaria in India should be organised for sharing experiences of different programmes/ activities organised by different planetaria and technologies employed. While there cannot be a uniform approach, there is tremendous scope for learning from others' experiences.
3. A common newsletter of the planetaria in India, which can be even e-newsletter, can help in informing directors of planetaria and planetarium communicators on recent approaches/ methodologies used in planetarium communication. Such newsletter can also inform others about the science communication activities going on in Indian planetaria.
4. Training of planetarium communicators should be considered as an important aspect. Planetarium communicators, while taking material from the web or other sources, should keep in mind that they are not violating copyright laws.

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Ray Douglas Bradbury

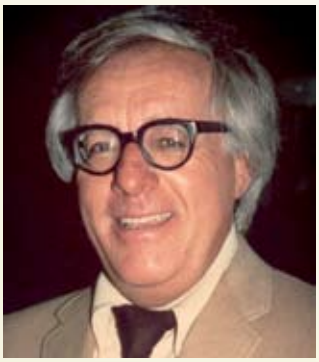
An important contributor in bringing science fiction into literary mainstream

Ray Douglas Bradbury (mostly known as Ray Bradbury) is acknowledged by many as one of the most celebrated 20th century American science fiction writers. Bradbury died on 5 June 2012 at the age of 91. Gerald Jonas, in his obituary of Bradbury published in *NY Times* (6 June 2012) wrote: "Ray Bradbury, a master of science fiction whose imaginative and lyrical evocations of the future reflected both the optimism and anxieties of his own post-war America…By many estimations Mr. Bradbury was the writer most responsible for bringing modern science fiction into the literary mainstream. His name would appear near the top of any list of major science fiction writers of the 20th century, beside those of Isaac Asimov, Arthur C. Clarke, Robert A. Heinlein, and the Polish author Stanislaw Lem." The obituary notice published in *Chicago Times* described Ray Bradbury as "an iconic science fiction author who helped bring the genre into the mainstream…"

It is true that Bradbury is generally labelled a science fiction writer. But he himself was opposed to this categorisation. He once wrote: "First of all, I don't write science fiction. I've only done one science fiction and that's *Fahrenheit 451*, based on reality. It was named so to represent the temperature at which paper ignites. Science fiction is a depiction of the real. Fantasy is a depiction of the unreal. So *Martian Chronicles* is not science fiction; it's fantasy." But then David Pringle commenting on *Martian Chronicles* wrote: "Scarcely a "novel", and scarcely science fiction—his space rockets are like firecrackers, and his Mars people are Halloween ghosts, while his Martian landscape is a heightened version of southern California—it nevertheless became a classic science-fiction novel."

Bradbury wrote short stories, essays, poetry, horror fiction, mystery fiction and books for children. His notable works include: *The Martian Chronicles* (1950), *The Illustrated Man* (1951), *Fahrenheit 451* (1953), *Something Wicked This Way Comes* (1962). *Fahrenheit 451* happens to be his most successful book. The title of the book refers to the temperature at which paper ignites. The book, which portrayed a book-burning America of the near future, was an 'indictment of authoritarianism'. A large number of Bradbury's works have been adapted for television shows, radio programmes and films. His works have been translated into 36 languages, and according to one estimate, 8 million copies of his books have been sold so far. Bradbury was also a social commentator. His writing career spanned seven decades.

Bradbury himself did not consider him as a scholarly writer. He would have liked



Ray Douglas Bradbury

himself to have referred to as an 'idea writer'. He once said: "I'm not a serious person, and I don't like serious people. I don't see myself as a philosopher. That's awfully boring."

Bradbury was born on 22 August 1920 at Waukegan, a small town in Illinois. His father Leonard Spaulding Bradbury was a power and telephone lineman. His mother Esther Bradbury (*nee* Moberg) was a Swedish immigrant. The family moved to Los Angeles in 1934.

Bradbury attended Los Angeles High School. He was an active member of the School's drama club. He attended the Los Angeles chapter of the Science Fiction League, which at the time met at Clifton's Cafeteria in downtown Los Angeles. It was here he met many writers including Robert A. Heinlein, Emil Pteaja, Frederic Brown, Henry Kuttner, Leigh Bracket and Jack Williamson.

After completing his school education he could not go to a college, as his parents could not afford to support his higher education. However, he continued to read in libraries. He later wrote: "Libraries raised me. I don't believe in colleges and universities. I believe in libraries because most students don't have any money. When I graduated from high school, it was during the Depression and we had no money. I couldn't go to college, so I went to the library three days a week for 10 years." He described how he could graduate from libraries in his essay titled "How Instead of being educated in college, I was graduated from libraries." He read in libraries mostly at night as he spent the day by distributing newspapers. He truly acknowledged the importance of libraries in his life. In later part of his life he got actively involved in fund raising effort for public libraries. He was greatly influenced by Edgar Allan Poe, H. G. Wells, Jules Verne, and Edgar Rice Burroughs. He was also influenced by Robert Frost, William Shakespeare, John Steinbeck, Aldous Huxley, and Thomas Wolfe. Bradbury later commented that he learnt from Steinbeck "how to write objectively and yet insert all of the insights without too much extra comments." Bradbury believed that one could not learn to write in college. He wrote: "You can't learn to write in college. It's a very bad place for writers because the teachers always think they know more than you—and they don't."

Bradbury received a number of awards including the *O Henry Prize* (1947), *the Benjamin Franklin Award* (1954), *Bram Stoker Lifetime Achievement Award* (1988), the United States of America's *National Medal for Arts* (2004), which was presented by the US President George W. Bush, and the *Pulitzer Prize* special citation (2007). He was a member of the Science Fiction and Fantasy Hall and he had a star at the Hollywood Walk of Fame. A crater on the Moon, Dandelion Crater, named after Bradbury's novel *Dandelion Wine*, and an asteroid (*9766 Bradbury*, a main-belt asteroid discovered on 22 February 1992) was named in his honour.

Bradbury inspired his readers "to dream, think, and create". His claim that instead of being educated in college, he was graduated from libraries should inspire many and underlines the fact what libraries can do in educating people.

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A chronicle of complex numbers

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These days, I found that my uncle was very much occupied with the world of art. Recently there were several art exhibitions around the city and I accompanied him to a few of those. While I do not know much about art, I could see that my uncle was examining with meticulous care the details of all sculptures and paintings.

One evening, my uncle showed me a painting titled 'The Scream'. He said that the name is given to four versions of a composition, created as both oil paintings and pastel work, by the Expressionist artist Edvard Munch between 1893 and 1910. All works titled 'The Scream' depicts a figure with an agonised expression against the landscape of a turbulent red sky in a city in Norway. He told me the story about how the painting was born out of Munch's own experience one evening while he was walking along a path. The setting of blood red Sun in the backdrop of the landscape of the city amazed him and he sensed an infinite scream passing through nature. And 'The Scream' was born.

"'The Scream' could be an example of how to understand art. Examine the subject, identify the intricacies and complexities of objects around the subject, look for the style used by the artist, get the symbolic meaning of the composition being conveyed and so forth. Like any form of literature, art should be read and enjoyed in all its intricate details. That's why Vincent van Gogh, Pablo Picasso, Paul Cézanne, and others are so famous." uncle was trying to give me a flavour of understanding art.

"Sometime the abstract nature of art needs a lot of imagination," I said, as my little brain was trying to grasp some ideas on art.

"Googol, you would be surprised to know that a recent art exhibition in London was called 'Invisible: Art about the Unseen', which among its exhibits had pieces of papers with images drawn with invisible ink, blank paper titled '1,000 Hours Staring', a plinth titled 'Invisible Sculpture', and so forth. The very abstract nature of the exhibition is construed as meditation on seeing," my uncle went on.

"That's a lot of imagination indeed in the art world. At least, in the field of mathematics, many topics are not left to imagination," I remarked.

"Well, there is something called *imaginary numbers* in the mathematical world. But you are right – no stretch of imagination is associated with an *imaginary number*," my uncle quipped.

"Yes, I heard about this. The *imaginary number* is a part of the complex number. But uncle, I don't know much about this. Could you please tell me something more on this?" I was eagerly waiting for a breeze of mathematical ideas from my mathematician uncle.

"A *complex* number is a composite of real and imaginary numbers. Complex numbers are useful quantities that can be used in calculations. Imaginary part of a complex number is not left to the imagination of any individual and has well formulated rules. Calculations involving complex numbers produce meaningful results. However, recognition of this fact took a long time for mathematicians to accept," uncle said.

"It appears very complicated," I opined.

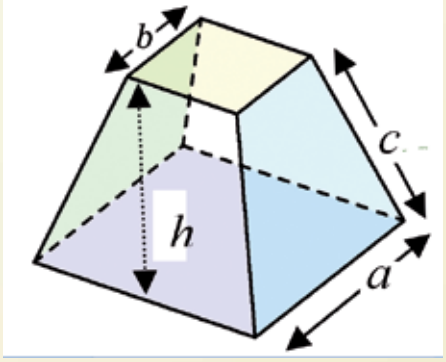
"The term 'complex number' does not mean that it's an intricate or complicated topic in mathematics. It means that there are the two types of numbers in the mathematical world, real and imaginary, and a complex number is formed by using both real and imaginary numbers together."

"But how do I visualise an imaginary number? I know about real numbers and the number line where rational and irrational numbers can be shown. Is there an imaginary number line also?"

"Indeed, there is an imaginary number line. The imaginary line perpendicularly bisects the real number line. Both number lines intersect at zero."

"Please tell me how mathematicians conceptualised the idea of some kind of number that is imaginary?"

"It appears that during first century AD, mathematician and engineer Heron of Alexandria tried to solve a problem related to measurement of volume of a truncated square pyramid, also called *frustrum* of a pyramid. Volume of such *frustrum* of a pyramid is given by $V = 1/3\ h\ (a^2+ab+b^2)$, where a and b are edge lengths of the bottom and top squares respectively, and h is height."



c = slant edge length

"But all numbers are real here, as we will be able to measure a, b, and h easily."

"That's true. But if the pyramid is a solid one, you have to measure h mathematically, as you won't be able to measure it directly," uncle replied.

"Can't h be measured from the *slant* edge length?' I wanted to know.

"You are right and that's what Heron calculated. He calculated $h = \sqrt{c^2 - 2\left(\frac{a-b}{2}\right)^2}$, where c is the *slant* edge."

"But I'm still unable to see any complex number here," I confessed.

"Okay Googol. If you put $a = 28$, $b = 4$ and $c = 15$ in this formula for h, you will get $h = \sqrt{81 - 144}$".

"I got it now! You cannot get square root of a negative number!" I exclaimed.

"Well, it's not that you cannot get that, but what you will get is an imaginary

number. $\sqrt{81-144} = \sqrt{-63}$ can be written as $\sqrt{-1} \times \sqrt{63} = i\sqrt{63}$ =," uncle replied.

"That means Heron of Alexandria discovered imaginary number."

"Not really. There was no concept of negative numbers, let alone square root of negative numbers during his time. Heron simply wrote $h = \sqrt{63}$ instead of $\sqrt{-63}$. Thus Heron missed being the earliest known mathematician to have derived the square root of a negative number."

"When did mathematicians find the correct solution?" I wanted to know.

"Astonishingly it took many centuries to recognise square root of a negative number."

"Why did it take so long time?"

"Ancient mathematicians rejected negative numbers, as they could not physically interpret a number that is less than nothing, as zero was considered absence of anything. During the third century AD, Mathematician Diophantus, Heron's fellow Alexandrian, also completely missed the opportunity of discovering imaginary numbers only because he did not accept the idea of a negative number. In his book *Arithmetica*, Diophantus stated the following problem:

Given a right angled triangle with area 7 and perimeter 12, find its sides.

To solve it, Diophantus derived the quadratic equation $336x^2 - 172x + 24 = 0$. If you solve this quadratic equation, there will be two solutions for x and both will involve complex numbers. However, Diophantus ignored the negative sign within a square root and considered only positive root in solving the equation."

"Uncle, please wait a minute. I can solve this equation! Solution of a quadratic equation of the form $ax^2+bx+c = 0$ is given by:

$$x \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

So, here the term (b^2-$4ac$) will be: ($172^2 - 4 \times 336 \times 24$) = –2672. This will result in the square root of a negative number," I said after doing a quick calculation on my hand calculator.

"Yes, you got it right Googol. But my dear, you need to understand that we are talking about mathematics of the third century."

"I understand, the number system was not so well-developed at that time and the concept of negative number was not there at all. Please tell me what happened next."

"In AD 850, Indian mathematician Mahaviracharya gave some hints of a negative number," he stated:

"The square of a positive as well as of a negative is positive; and the square root of those are positive and negative in order"

"Mahavira was so close!"

"Indeed, Mahavira was very close in defining negative numbers, as well as square root of negative numbers," uncle replied.

"When did mathematicians calculate square root of a negative number?"

"Actually the study of complex numbers began during the 16th century when algebraic solutions for the roots of cubic and quartic polynomials were discovered by Italian mathematicians."

"Uncle, please elaborate more on this. I thought the concept of $\sqrt{-1}$ came from quadratic equation $x^2 + 1 = 0$, where $x^2 = -1$, hence, $x = \sqrt{-1}$"

"This equation can define $\sqrt{-1}$, but the concept of complex number came from an entirely different situation!"

"Please tell me, it's really very exciting," I said.

"In 1494, Italian mathematician Luca Pacioli wrote a book '*Summa de Artthmetica, Geometria, Proportioni at Proportionalita*', summarising all the knowledge of arithmetic, algebra and trigonometry. He declared that the solution of a cubic equation was impossible with the knowledge that existed during his time. However, within ten years, another Italian mathematician Scipione del Ferro solved the *depressed cubic*."

Niccolo Fontana (1499 - 1557)

"What is a *depressed cubic*?" I wanted to know.

"The general cubic is $x^3 + a_1x^2 + a_2x + a_3 = 0$, which contains all the powers of x. In a *depressed cubic*, the second degree term is missing, i.e., $x^3 + a_2x + a_3 = 0$. Solution of this form of an equation was very important. It is considered as the first step in defining the square-root of minus one, and thereby, imaginary numbers."

"Who introduced the symbol i for $\sqrt{-1}$?" I wanted to know.

"In 1777, the Swiss mathematician Leonhard Euler introduce the symbol i".

"There was a long gap between Del Ferro's solution and recognition of $\sqrt{-1}$!"

"Yes. Del Ferro and his fellow mathematicians were looking for only single real positive numbers for the solution of a cubic. They did not see that there were two complex roots. For example, the equation $x^3 + 6x = 20$ has one real solution $x = 2$. However, it also has two complex roots ($-1 + 3i$) and ($-1 - 3i$)."

"That means Del Ferro did not discover complex numbers?"

"No single mathematician can be credited for the discovery of complex numbers, as many contributed directly and indirectly in understanding the nature of complex numbers. Another Italian mathematician Niccolo Fontana, known as Tartaglia ("the stammerer") also solved cubic equation independently. In 1545, mathematician Girolamo Cardano published a book, *Ars Magna* (The great art), and gave credit to both Del Ferro and Niccolo Fontana for the solution of *depressed cubic*. Cardano also showed how to extend the solution of *depressed* cubic to all cubics."

"So the solution provided by Cardano could solve all cubic equations?"

"Yes, you're right. It was proved later that Cardano's method could solve any cubic equation. Some cubic equations yield only real roots while some yield real as well as imaginary roots."

Girolamo Cardano (1501 – 1576)

"Did Cardano mentioned anything about $\sqrt{-1}$?" I wanted to know.

"He mentioned about it unknowingly. One problem in his *Ars Magna* was:

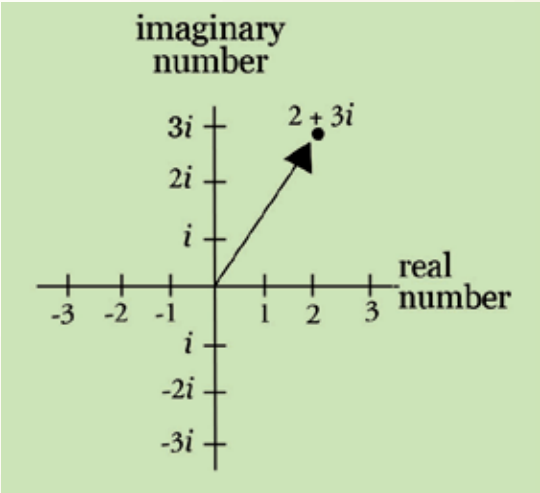
Dividing ten into two parts whose product is forty. This problem leads to the quadratic equation $x^2 - 10x + 40 = 0$. Solution to this equation

is $5+\sqrt{-15}$ and $5-\sqrt{-15}$, which Cardano called *sophistic*. Their sum is obviously 10 and product was calculated as:

$(5+\sqrt{-15})\ (5-\sqrt{-15}) = (5)(5) - (5)(\sqrt{-15}) + (5)(\sqrt{-15}) + (\sqrt{-15})(\sqrt{-15}) = 25 + 15 = 40$."

"It's surprising! It's actually an algebra using complex numbers," I wondered.

"Yes, you got it right Googol. However, Cardano did not formulate any algebraic formula using complex numbers. It was an Italian engineer and architect Rafael Bombelli, who eventually discovered how to calculate the root of a complex number using Cardano's formula."



"Why is the non-real part of a complex number called imaginary?" I wanted to know.

"Before Cardano, there were several terms used for the imaginary part of the complex number, like impossible number, improbable number, nonsense number, etc. Cardano himself used the term sophistic. The great French thinker Rene Descartes dismissed it as an 'imaginary' number which was not a complimentary statement at that time, but the name stuck in the world of mathematics."

Rafael Bombelli (1526 – 1572)

"Can complex numbers be represented using geometry?" I wanted to know.

"It's a good question. In fact Bombelli's formal meaning to $\sqrt{-1}$ still did not include the physical interpretation. Mathematicians tried to formulate the geometric meaning of $\sqrt{-1}$. A Norwegian surveyor Casper Wessel constructed graphical representation of complex number with the introduction of imaginary axis and complex plane. That is if a and b are both real then $a + b\sqrt{-1}$ is complex. $\sqrt{-1}$ is generally represented as i and $a + ib$ is a common form of representing a complex number, where a is real part and ib is imaginary part. Wessel was not a professional mathematician, but a very well known surveyor. In his paper (1797) 'On the Analytic Representation of Direction: An Attempt', to the Royal Danish Academy of Science, he introduced writing a complex number as $a + ib$."

Caspar Wessel (1745– 1818)

Carl Friedrich Gauss (1777 – 1855)

"Is Gaussian plane also a complex plane?" I wanted to know.

"That's right Googol. The German mathematician Johann Carl Friedrich Gauss made significant contribution in the geometric interpretation of complex numbers. In his honour, the complex plane is also called Gaussian plane. After Gauss's interpretation of the complex number, $\sqrt{-1}$ was accepted as a legitimate symbol."

"Can a complex number have only imaginary part?" I wanted to know.

"Certainly yes. If real part is zero, a complex number will be left with only imaginary part," uncle replied.

"What about arithmetic operation involving complex numbers?"

"There are set rules of addition, subtraction, multiplication and division of complex numbers. These rules are not very different from rules involving real numbers."

"Please tell me some applications of complex numbers," I told.

"As we discussed before, the concept of complex number is required to solve polynomial equations. Polynomial equations are constructed for mathematical modelling of many physical phenomena. The complex number system is also embedded in other branches of mathematics like geometry, trigonometry and calculus and therefore its areas of applications are manifold. Complex numbers play an important role in understanding many phenomena in physics and astronomy. Apart from the pure science, complex number is an integral part of electrical engineering to understand the circuit behaviour, electromagnetism, and control circuit feedback mechanism. In telecommunication, the signal processing and synthesis cannot be done without a fair knowledge of complex numbers. The complex number system is also an intrinsic part of quantum mechanics. There are several other applications of the complex number and the list is indeed very long."

"Uncle, thanks very much for telling me such a fascinating story of the complex number and its extensive applications. It was an enjoyable journey through the history of complex number."

"That's good. Well Googol, it's almost the dinner time now. Let's get ready for the dinner."

Suddenly I realised that I was feeling hungry, and it was certainly not my imagination!

Sources:

Paul Nahin, *An Imaginary Tale* , Universities Press

Calvin C. Clawson, *The Beauty and Magic of numbers*, Viva Books

Ian Stewart, *Cabinet of Mathematical Curiosities*, Profile Books

An excellent account on history and chronology of complex numbers may be found at: http://en.wikipedia.org/wiki/Complex_number

Unifying aspects of algebra and geometry

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2012 has been declared as the National Year of Mathematics in commemoration of the 125th anniversary of the famous mathematician Srinivasa Ramanujan. As a tribute to that great soul, it has been felt that we should make efforts towards making the teaching-learning process of mathematics in schools/ colleges interesting and user friendly. One of the issues related to such an effort is to allay some of the misgivings prevalent in the mind of the students. One such is perhaps the idea that algebra and geometry are two branches of mathematics. Let me raise the question – How different are these branches? The analytical approach taken in these two areas are different. I shall prefer to call them two facets of mathematics, rather than two branches. Students generally feel that these are two different subjects; they indeed are. But they should be able to get the essence of unification of these two subjects. Through this article three examples are being cited which bring home the concept of unification of these two facets of mathematics. We shall arrive at the same result following the two approaches.

Example No. 1

Condition of tangency

To find the condition for the straight line, $y = mx + c$ being a tangent to the circle, $x^2 + y^2 = a^2$

First method

$x^2 + y^2 = a^2$ is a circle whose centre is at the origin (0,0) and the radius is 'a'.

We know from geometry that a tangent is always perpendicular to the radius. So, for the desired tangency, the perpendicular distance from (0,0) on $y = mx + c$ must be equal to a. The equation of the straight line can be rewritten as

$mx - y + c = 0$

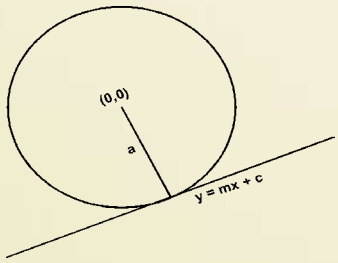


Fig 1.1: The straight line $y = mx + c$ is tangent to $x^2 + y^2 = a^2$

So, the perpendicular distance from (0, 0) on it is

$$\frac{m.0 - 0 + c}{\sqrt{1+m^2}} = \frac{c}{\sqrt{1+m^2}}$$

$$\therefore \quad a = \frac{c}{\sqrt{1+m^2}}$$

or $\quad c^2 = a^2 (1 + m^2)$ .....(1.1)

The result (1.1) is the desired condition of tangency.

Now, we shall apply a second method.

Second method

The points of intersection of the straight line, $y = mx + c$ and the circle, $x^2 + y^2 = a^2$ can be obtained by solving the two equations. In general the straight line will intercept a chord and there will be two points of intersection. In order that the straight line is a tangent, the two points of intersection will coincide; in other words, they would be identical.

In order to solve the equation, we replace 'y' in the equation of the circle by $(mx + c)$, to obtain

$x^2 + (mx + c)^2 = a^2$

or, $(1 + m^2) x^2 + 2mcx + (c^2 - a^2) = 0$ ..... (1.2)

(1.2) is a quadratic equation in x. So it will have two roots, which will be identical when the discriminant of (1.2) is zero.

That is,

$(2mc)^2 - 4(1 + m^2)(c^2 - a^2) = 0$

or, $4m^2c^2 - 4(c^2 - a^2 + m^2c^2 - a^2m^2) = 0$

or, $c^2 = a^2 + a^2m^2$

$c^2 = a^2 (1 + m^2)$ ..... (1.3)

(1.3) is identical with (1.1)

In this method we have not used any geometrical property. We have only applied the theory of quadratic equations – a purely algebraic approach – and have arrived at the same result. Thus it establishes the desired unification.

Let us now go over to the next example.

Example 2

A bus moves along a straight path between two bus stops separated by a distance x. It starts from the first stop and moves with uniform acceleration till it attains a velocity V. Thereafter it moves with uniform retardation and finally comes to rest at the next stop. Show that the time taken is $t = 2x/V$.

It is basically a problem of mechanics. It can be worked out using the principles of linear motion with uniform acceleration.

Refer to Fig 2.1. A and B are the end points.

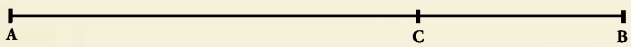


Fig 2.1: A and B are the end points. $AC = x_1$, $CB = x_2$

The bus moves from A to C with a uniform acceleration, say f_1 and let it take time t_1, at C it attains velocity, V, from C to B it moves with uniform retardation, say f_2 and let it take time t_2. We then have

$V = f_1t_1 = f_2t_2$ ..... (2.1)

$t = t_1 + t_2$ ..... (2.2)

$V^2 = 2f_1x_1 = 2f_2x_2$ ..... (2.3)

And $x = x_1 + x_2$ ..... (2.4)

So we have

$t_1 = V/f_1$, $t_2 = V/f_2$

$\therefore\ t = t_1 + t_2 = V(1/f_1 + 1/f_2)$ ... (2.5)

Again,

$x_1 = V^2/2f_1$, $x_2 = V^2/2f_2$

$\therefore\ x = x_1 + x_2 = V^2/2\,(1/f_1 + 1/f_2)$ ... (2.6)

From (2.5) and (2.6), we get

$x = t.V/2$ *or* $t = 2x/V$ (proved)

In this method, we applied purely algebraic operations based on the principles of linear motion with uniform acceleration. We shall now apply geometrical principles to work out the same problem.

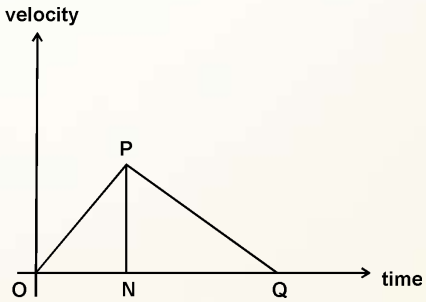


Fig 2.2: Velocity vs. time graph for the motions described in Example 2

The velocity-time graph (Fig 2.2) for motion under uniform acceleration is a straight line. The initial instant is O. Due to acceleration, it attains a velocity, V given by P and PQ is the graph for retardation. Q indicates the time instant at which it comes to rest. So, $OQ = t$. The displacement during t is the area under the velocity-time graph, i.e. $\Delta OPQ = \frac{1}{2}\, OQ.PN$

$\therefore\ x = \frac{1}{2}\ t.V$

or $t = 2x/V$ (which is the same result)

Here we have used the velocity-time graph and the geometrical result that the area of a triangle = ½ *base* × *altitude*. Here the principle of mechanics got reflected through the velocity-time graph, but rest was geometry. It again establishes the unification between algebra and geometry.

We shall now take up our third and final example. It is about the proof of the famous inequality, $AM \geq GM \geq HM$

Example 3

Using Geometry to prove AM ≥ GM ≥ HM

The inequality $AM \geq GM \geq HM$ is quite well known and in text books we find its proof using algebraic techniques. Here, it is proved using geometrical considerations. It brings home the point that the backbone of any mathematical treatment is the logic behind it which can be approached through any method - be it algebra, geometry or any branch of mathematics. Thus the proof is a reflection about the unification of the different branches of mathematics.

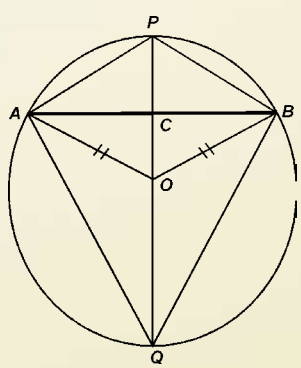


Fig 3.1

Refer to Fig 3.1. AB is any chord of a circle whose centre is at O. PQ is the diameter of the circle perpendicular to AB. It intersects the chord at C. PA, PB, QA, QB are joined.

We know that AB is bisected by PQ. So $AC = BC$ and $AB = 2AC$.

Let $PC = p$, $CQ = q$

$\angle PAQ = 90^\circ$, being the angle in the semi-circle. So ΔPAQ is a right angled triangle and so are triangles PAC and QAC. We know that the triangles PAC, QAC and PAQ are similar and as a consequence of which

$$AC^2 = PC.CQ = pq$$

$$\therefore\ AC = \sqrt{pq} \qquad \ldots(3.1)$$

AB, being a chord is generally less than the diameter PQ. They are equal if and only if C and O coincides i.e. $PC = CQ$.

In other words,

$PQ \geq AB$, equality holds only when $PC = CQ$

$$\text{or, } PQ \geq 2AC$$

$$\text{or, } \frac{PQ}{2} \geq AC \qquad \ldots(3.2)$$

$$\text{or, } AC \leq \frac{PQ}{2}$$

$$\therefore\ AC^2 \leq \frac{PQ.AC}{2}$$

$$\text{or, } \frac{2AC^2}{PQ} \leq AC$$

$$\text{i.e. } AC \geq \frac{2AC^2}{PQ} \qquad \ldots(3.3)$$

Combining (3.2) and (3.3), we get

$$\frac{PQ}{2} \geq AC \geq \frac{2AC^2}{PQ}$$

$\therefore$ From (1)

$$\frac{p+q}{2} \geq \sqrt{pq} \geq \frac{2pq}{p+q}, \text{ equality holds only when } p = q \qquad ..(3.4)$$

The relation (4) establishes that for two numbers p and q, $AM \geq GM \geq HM$ and that the equality holds only when the two numbers are equal.

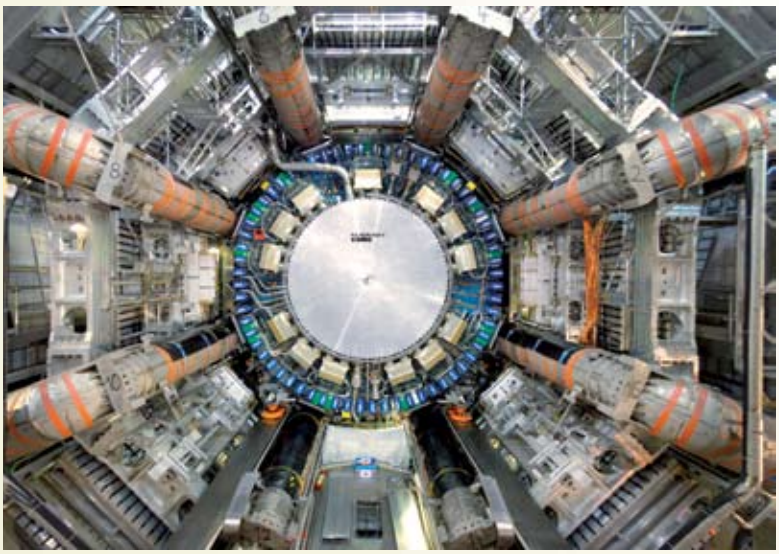
Thus, we started from a very rudimentary inequality in geometry, that is, a chord of a circle is less than its diameter (they are equal only when the chord passes through the centre) and arrived at the very conspicuous inequality, $AM \geq GM \geq HM$. The two inequalities apparently seem to be delinked from each other.

Thus the proof provides a testimony to the unifying aspect of two branches of mathematics – algebra and geometry.

Dr. C. K. Ghosh, Director, NCIDE, IGNOU, New Delhi ■

Higgs boson –
a missing link between energy and mass

How was the Universe created? How were the billions of galaxies stars and planets created? Scientists always wanted to know answers to these questions with certainty. A major breakthrough in the particle physics came in 1970 when physicistsrealised that the unification of four fundamental forces in nature, namely gravitational, electromagnetic, strong and weak nuclear forces may be the key in formulation of a model to explain the creation of the Universe. Scientists found enough evidence to suggest unification of at least two of four fundamental forces – weak force and electromagnetic force–and proposed a model, called Standard Model, to explain the Universe as it exists today. However, one of the requirements of such a unifying model entails that all particles are massless – something which is apparently not true! After all, electron, proton, and neutron – all have definite masses. How can we then explain the creation of mass and the Universe, as we see it today? Physicists Peter Higgs, Robert Brout and François Englert came up with a solution to solve this conundrum. They suggested that particles had no mass just after the Big Bang. As the early Universe ($1/10^{32}$ second after the Big Bang) cooled and the temperature fell below a critical value (10^{28} Kelvin), an invisible force field called the 'Higgs field' was formed together with the associated 'Higgs boson'. The field prevails throughout the cosmos: any particle that interacts with it isgiven a mass *via*the Higgs boson. The stronger the interaction, the heavier they become, whereas particles that never interact are left with no mass. Photon, which is the carrier of the electromagnetic field, is an example of a particle with no mass and hence it does not interact with the Higgs field.



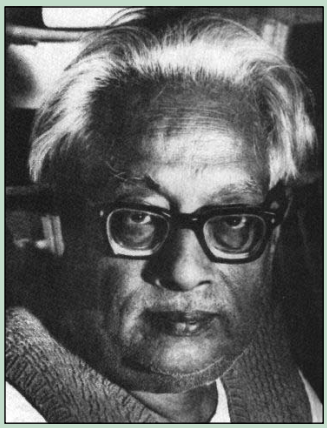
A part of Large Hadron Collider (LHC)

Till recently, the Higgs boson existed only in theory; no experimental evidence of the existence of the Higgs boson was found. During last 40 years physicists tried to find the Higgs boson and did several experiments to create conditions that could simulate the formation of the early Universe. Fermi Lab in USA used the Tevatron – a powerful particle accelerator to accelerate protons to a very high speed (99.9 % of speed of light) and then collidethem. High-speed collision was expected to create the conditions prevailing in early Universe for a brief moment. The European Organization for Nuclear Research (CERN)built the Large Hadron Collider (LHC), a larger and more powerful particle accelerator, which could accelerate protons up to 7 trillion electron volts (TeV). Scientists did a number of experiments during last two years to search for any evidence that confirms the existence of the Higgs boson.

The Standard Model does not predict an exact mass of the Higgs boson. In a particle accelerator like LHC, smashing protons at near-light speed generates a vast shower of particles that are created only at extremely high energies. Systematic analysis of data is carried out to search for a particle over a range of masses. Scientists knew that Higgs boson cannot be observed directly because of its extremely short life of "a millionth of a millionth of a millionth of a millionth of a second". They were looking for Higgs boson that only fleetingly exists in a soup of particles but leaves

Continued on page 28

Higgs boson, the long-sought particle belongs to a group of fundamental particles named after an Indian scientist Satyendra Nath Bose. Bose was a physicist specialising in mathematical physics. In 1924, while working as a Reader at the Physics Department of the University of Dhaka, Bose wrote a paper deriving Planck's quantum radiation law using a novel way of counting states with identical particles. He sent the paper to Albert Einstein, who translated it into German and got it published in *Zeitschrift für Physik* under Bose's name. The result derived by Bose laid the foundation of quantum statistics. Einstein adopted the idea and extended it to atoms. The term 'boson', named after S. N. Bose, was coined to describe subatomic energy carriers which obeyed the Bose-Einstein statistics. This led to the prediction of the existence of a state of matter, which became known as Bose-Einstein condensate, a dense collection of bosons, which was demonstrated to exist by experiment in 1995.



Satyendra Nath Bose (1894 – 1974)

Strokes

Symptoms, tests and diagnosis

Dr Yatish Agarwal
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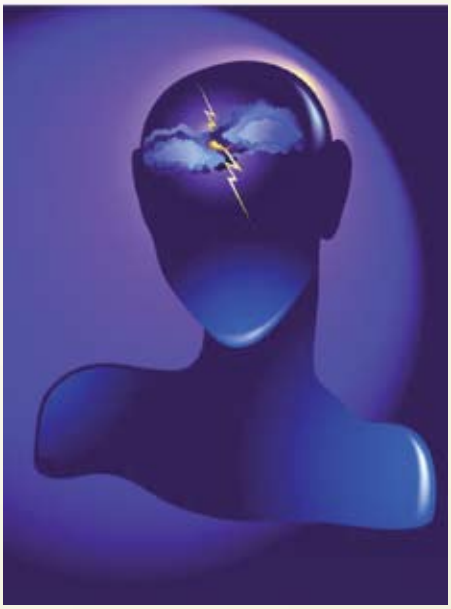
> Adversity draws men together and produces beauty and harmony in life's relationships, just as the cold of winter produces ice-flowers on the window-panes, which vanish with the warmth.
>
> —Oliver Wendell

A stroke is an event we all dread as we get older. But most of us know little more than that it may cause sudden paralysis of one side of the body, drooping of a part of the face, and possibly loss of speech. Yet, often there is more to it than that. In actuality, a stroke produces cerebral infarction, causing a part of the brain tissue to go dead. It results either from a substantial reduction in blood flow to a portion of the brain or from bleeding within the brain. The end result depends on how severe is the brain damage and how long it takes for the tissue to make good a recovery. The loss in function may be transient or lasting.



Symptoms

The symptoms and their severity vary with the extent of brain damage. Watch for these signs and symptoms if you think you or someone else may be having a stroke. You should make a mental note of when the signs and symptoms first began, since many of the treatment decisions are guided by the time lag between the first symptoms and the initiation of treatment.

Trouble with walking

You may stumble or experience sudden dizziness, loss of balance or loss of coordination.

Trouble with speaking and understanding

You may experience confusion. You may slur your words or be unable to find the right words to explain what is happening to you, a phenomenon often talked of by doctors as aphasia. Try to repeat a simple sentence. If you can't, you may be having a stroke.

Paralysis or numbness on one side of your body or face

You may develop sudden numbness, weakness or paralysis on one side of your body. Try to raise both your arms over your head at the same time. If one arm begins to fall, you may be having a stroke. Similarly, one side of your mouth may droop when you try to smile.

Trouble with seeing in one or both eyes

You may suddenly have blurred or blackened vision, or you may see double.

Headache

A sudden, severe "bolt out of the blue" headache, which may be accompanied by vomiting, dizziness or altered consciousness, may indicate you're having a stroke.

Get to your doctor

Seek immediate medical attention if you notice any signs or symptoms of a stroke, even if they seem to fluctuate or disappear. Call your local doctor or emergency number right away. Every minute counts. Don't wait to see if symptoms go away. The longer a stroke goes untreated, the greater the potential for brain damage and disability. To maximise the effectiveness of evaluation and treatment, it is best that you get to the emergency room within 60 minutes of your first symptoms.

If you're with someone you suspect is having a stroke, watch the person carefully while waiting for emergency assistance. You may need to:

- Begin mouth-to-mouth resuscitation if the person stops breathing
- Turn the person's head to the side if vomiting occurs, which can prevent choking
- Keep the person from eating or drinking

Complications

A stroke can sometimes cause temporary or permanent disabilities, depending on how long the brain suffers a lack of blood flow and which part was affected. These complications may include:

Paralysis or loss of muscle movement

Sometimes a lack of blood flow to the brain can cause a person to become paralysed on one side of the body, or lose control of certain muscles, such as those on one side of the face. With physiotherapy, you may see improvement in muscle movement or paralysis.

Difficulty talking or swallowing

A stroke may cause a person to have less control over the way the muscles in the mouth and throat move, making it difficult to talk, swallow or eat. A person may also have a hard time speaking because a stroke has caused aphasia, a condition in which a person has difficulty expressing thoughts through language. Therapy with a speech and language pathologist may improve this disability.

Memory loss or trouble with understanding

It is common that people who have had a stroke experience some memory loss. Others may develop difficulty making judgments, reasoning and understanding concepts. These complications may improve with rehabilitation therapies.

Pain

Some people who have a stroke may have pain, numbness or other strange sensations in parts of their bodies affected by stroke. For example, if a stroke causes you to lose feeling in your left arm, you may develop an uncomfortable tingling sensation in that arm. You may also be sensitive to temperature changes, especially extreme cold. This is called central stroke pain or central pain syndrome (CPS). This complication generally develops several weeks after a stroke, and it may improve as more time passes. But because the pain is caused by a problem in the brain instead of a physical injury, there are few medications to treat CPS.

Changes in behaviour and self-care

People who have a stroke may become more withdrawn and less social or more impulsive. They may lose the ability to care for themselves and may need a caretaker to help them with their grooming needs and daily chores.

As with any brain injury, the success of treating these complications will vary from person to person.

How the doctor Can Help

A stroke in progress is usually diagnosed in a hospital emergency room. If you're having a stroke, the emergency healthcare team will focus on minimising brain damage and helping you recover and avoid another stroke in the future.

In the emergency room, you may be taken care of by an emergency medicine specialist or a neurologist and nurses and medical technicians. Your emergency team's first priority will be to stabilise your symptoms and overall medical condition. Then your care will focus on determining if you are having a stroke and, if so, which type. There are different treatments for ischaemic strokes caused by artery blockage and haemorrhagic strokes caused by blood vessel rupture.

Tests and diagnosis

To determine the best treatment for your stroke, your emergency team must figure out what type of stroke you're having and what parts of your brain it is affecting. There are four main things they want to look at:

- The brain structure itself;
- The major arteries in the neck and the brain;
- The heart; and
- The blood.

A special computerised X-ray called a computed tomogram or another relatively newly developed technique — magnetic resonance imaging — enables the doctor to 'look inside' the brain and help him determine what kind of stroke the patient has had. In this way a brain infarct can be distinguished immediately from a brain haemorrhage. Other possible causes of such symptoms, such as a brain tumour, infection or a drug reaction, can also be ruled out by these tests.

These investigative tests have to be done reasonably soon after the stroke. It is important for your doctor to determine if you have actually suffered a stroke, and, if so, whether it has been caused by a clot or a bleed within the brain. A definite diagnosis is of a major importance in deciding upon the treatment. A patient who has had a bleeding in the brain should not be given medications which safeguard against clotting as they may promote further bleeding.

Physical examination

Your doctor will ask you or a family member what symptoms you've been having, when they started, and what you were doing when they began, and then will evaluate whether these symptoms are still present. The doctor will want to know what medications you take, and whether you have experienced any head injury. The doctor will also ask about your personal and family history of heart disease, transient ischaemic attacks (TIA) or stroke.

Your doctor will check your blood pressure and use a stethoscope to listen to your heart and to listen for a whooshing sound (bruit) over your carotid (neck) arteries, which may indicate atherosclerosis. Your doctor may also use an ophthalmoscope to check for signs of tiny cholesterol crystals or clots in the blood vessels at the back of your eyes.

Blood tests

Various blood tests give your care team such important information as how fast your blood clots and whether your blood sugar is abnormally high or low, whether critical blood chemicals are out of balance, or whether you may have an infection. Your blood's clotting time and levels of sugar and key chemicals must be managed as part of your stroke care. Infections must also be treated.

Computerised tomography (CT)

Brain imaging plays a key role in determining if you are having a stroke and what type. Computerised tomography angiography (CTA) is a specialised CT exam in which a contrast agent (dye) is injected into your vein and X-ray beams create a 3-D image of the blood vessels in your neck and brain.

Doctors use CTA to look for aneurysms or arteriovenous malformations and to evaluate arteries for narrowing.

CT scanning, which is done without dye, can provide images of your brain and show haemorrhages, but provides less detailed information about the blood vessels.

Magnetic resonance imaging (MRI)

In this type of imaging, a strong magnetic field and radio waves generate a 3-D view of your brain. An MRI can detect brain tissue damaged by an ischaemic stroke very well.

Magnetic resonance angiography (MRA) uses a magnetic field, radio waves and a contrast agent (dye) injected into your veins to evaluate arteries in your neck and brain.

Carotid ultrasound

This procedure can show narrowing or clotting in your carotid arteries. A wand-like device (transducer) painlessly sends high-frequency sound waves into your neck. The sound waves pass through tissue and then return, creating on-screen images.

Arteriography

This procedure gives a view of arteries in your brain not normally seen in X-rays. Your doctor inserts a thin, flexible tube (catheter) through a small incision, usually in your groin. The catheter is manipulated through your major arteries and into your carotid or vertebral artery. Then your doctor injects a dye through the catheter to provide X-ray images of your arteries.

Arteriography provides excellent pictures of the arteries in your neck and brain.

Echocardiography

This ultrasound technology creates images of your heart, enabling your doctor to see if a clot (embolus) from your heart has travelled to your brain and caused your stroke.

Your doctor may need to use trans-oesophageal-echocardiography (TEE) to see your heart clearly. During this procedure, you swallow a flexible probe with a transducer built into it. From there, the probe travels to your oesophagus — the tube that connects the back of your mouth to your stomach. Since your oesophagus is directly behind your heart, very clear, detailed ultrasound images can be created, allowing a better view of blood clots that might not be seen clearly in a traditional echocardiography exam.

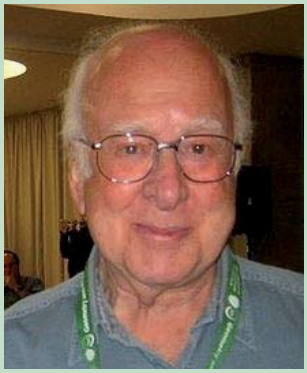
[*Next month*: Strokes—Treatments and Medications]

*Continued from page 31***(Higgs boson – a missing link between energy and mass)**

behind a trail of other particles that could prove its existence.It was predicted that Higgs boson should havea mass much more than that of protons.

Finally on 4 July, scientists of CERN announced that the long-sought Higgs boson does exist. Experiments conducted in the Large Hadron Collider yielded results that were consistent with its existence. Scientists found data corresponding to a particle weighing about 125 billion electron-volts (GeV), which is about 133 times heavier than protons, thus confirming Higgs boson. So far, this discovery is claimed to be the greatest discovery of 21st century. Some physicists are comparing this to the Apollo program that landed man the Moon in 1960. Currently, however, the finding has been termed as tentative by the CERN teams and the final confirmation may come in a few months.

Peter Ware Higgs is a British theoretical physicist and emeritus professor at the University of Edinburgh. In 1960, in his electroweak theory, he explained the origin of mass in elementary particles in general and of the W and Z bosons in particular. During 1970, several physicists predicted the existence of a high-energy particle. This was named Higgs boson, honouring the contribution of Peter Higgs in developing the theory. On 4 July 2012, CERN announced that they had experimentally established the existence of Higgs boson.



Peter Higgs (1929–)

Discovery of the existence of the Higgs boson will certainly prove to be a major milestone in our understanding of the Universe. Scientists will also look at how the Higgs boson decays or transforms into other more stable particles. This will provide more data to support the Standard Model. As Professor Incandela of the University of California, Santa Barbara, says "We're on the frontier now, on the edge of new exploration. This could be the only part of the story that's left, or we could open a whole new realm of discovery."

Discovery of the Higgs boson may just be the beginning of many more discoveries to uncover other secrets of the Universe. All matter we see comprises only 4% of the observable Universe – the rest, as proposed by the scientists, is made up of mysterious dark matter and dark energy. Definitely science will explain these mysteries in days to come.

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Recent developments in science and technology

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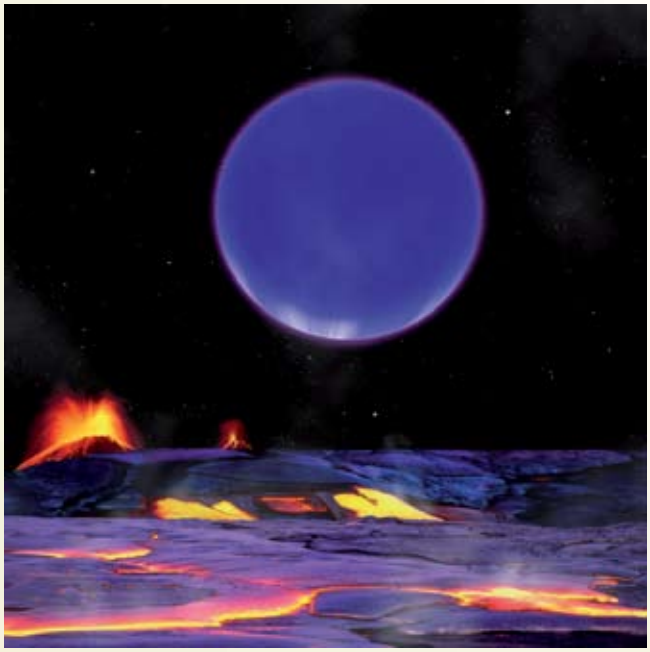
Kepler discovers a strange pair of exoplanets

Till the detection in 1988 of the first planet around a distant star, our solar system was the only planetary system known to exist. Since then, the existence of more than 700 planets orbiting around 542 stars beyond our solar system has been confirmed. But the recent discovery of a pair of planets differing widely in size and density yet orbiting the host in extremely close proximity has put planetary scientists in a quandary.

In our solar system, the compositions of the planets vary with orbital distance – the inner planets Mercury, Venus, Earth, and Mars are rocky planets in close orbits, while the gas giants Jupiter, Saturn, Uranus, and Neptune have low density and move in much wider orbits. A probable explanation of this varying composition of the planets of our solar system is also available. But, in the past few years, the detection of giant planets around other stars in close orbits gave the first clue that this pattern is not universal, and that a planet's orbit can change substantially after their formation. A whole class of exoplanets known as "hot Jupiters" are large planets with orbits smaller than Mercury's, indicating that planet formation may not follow the same rules in all cases. A newly discovered system known as Kepler-36 is even stranger because here two planets having densities differing by a large factor of eight orbit the same star with orbital distances differing by only 10%. In other words, they are in closer proximity than any two planets in our solar system, but have a larger difference in density.

The discovery was made by scientists by analysing data from NASA's *Kepler* spacecraft. The newfound system contains two planets circling a sub-giant star Kepler-36, about the same mass as our Sun but about 1.6 times the Sun's radius and situated 750 light-years from Earth. The inner of the two planets, called Kepler-36b, is a dense, rocky planet, 1.5 times the size of Earth that weighs 4.5 times as much. It orbits the star every 13.8 days at an average distance of less than 18 million kilometres. The second planet, called Kepler-36c, is a light gaseous planet 3.7 times the size of Earth that weighs eight times as much. Dubbed as "hot Neptune", it orbits the star once every 16.2 days at a distance of 19 million kilometres. That is, the outer planet orbits the star only one million kilometres; that is, less than 5 Earth-Moon distances away from the inner planet (*Science*, 21 June 2012, doi: 10.1126/science.1223269). In contrast, Mars' orbit is about 78 million kilometres outside Earth's orbit, while Venus's orbit lies roughly 43 million kilometres inside Earth's.



In this artist's conception, a "hot Neptune" known as Kepler-36c looms in the sky of its neighbour, the rocky world Kepler-36b. The two planets have repeated close encounters, experiencing a conjunction every 97 days on average. At that time, they are separated by less than 5 Earth-Moon distances. Such close approaches stir up tremendous gravitational tides that squeeze and stretch both planets, which may promote active volcanism on Kepler-36b. (Credit: David A. Aguilar)

Kepler-36 is one of the star systems observed by the NASA's *Kepler* spacecraft, which is specially designed to detect exoplanets. *Kepler* locates exoplanets via 'transits' – when a planet briefly passes in front of its host star, in much the same way as the famous Venus transit of 6 June 2012. Of course, the amount of light that is blocked is very small in these cases, but it is enough to be measured, even for relatively small planets. The shape of the light curve – the dip in received light from the star as the planet passes in front of it – reveals the size of the planet, while the time between the eclipses reveals the size of its orbit.

But in the present case detecting the two planets was not easy. Because of the large difference in size and closeness of their orbits, the smaller of the two planets Kepler 36b was hard to spot because it only blocks about 1 per cent of the light that larger planet Kepler-36c does. However, the astronomers were able to identify both as distinct bodies orbiting the same star, partly due to their mutual interaction: when one planet was slow to arrive to its transit, the other was fast, indicating they were pulling on each other gravitationally. The scientists determined the masses and radii of the two stars by using the technique of 'asteroseismology', also known as stellar seismology, by measuring the sun-like oscillations of the host star.

Peacocks communicate through infrasound

Humans can hear only within a certain range of frequencies – from 20 to 20,000 hertz (Hz). Sound of frequency below 20 Hz, known as infrasound, is inaudible to humans but can be heard by elephants whereas many animals like dogs, mice and bats can hear frequencies above 20,000 Hz, also known as ultrasound. Bird calls are of different frequencies and are used for both communication and courtship. We are all familiar with the loud, piercing call of the

Male peacocks produce two subtly distinct types of infrasonic mating sounds during courtship using their train feathers.

peacock, but a recent study has revealed that during courtship peacocks also use low-frequency sounds that humans cannot hear.

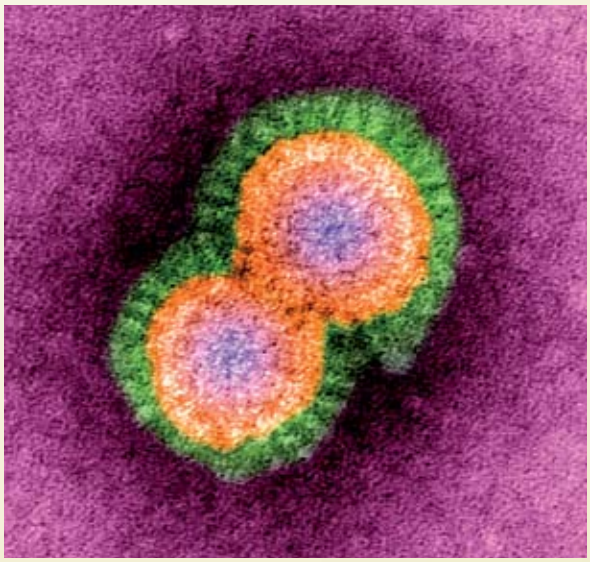
The most attractive part of a peacock is its long tail formed of magnificent eye-spotted train feathers. Normally, peacocks communicate visually and through sound. The peacock uses its tail train in an elaborate courtship display, which includes the display of its beautiful plumage, and its familiar loud, piercing call, and a unique courtship dance. During courtship, males are known to spread out their magnificent train feathers into a fan shape and shake it vigorously, which can create a ripple moving down the sides of the array, or else it can send a shudder radiating outward from the base. During both these classic moves, all a human being hears is a leaf-like rustling. But when a research team led by Angela Freeman, a biology graduate student of University of Manitoba in Canada recorded the sounds they discovered very low-pitched sounds, inaudible to humans and produced by vibrations of the spread-out feathers. The team discovered that when male peacocks display their feathers during courtship they also make deep rumbling sounds that are too low pitched for humans to hear.

When Freeman played back the recorded sound to the birds, females looked alert and males were likely to come out with the familiar loud call, indicating their response to infrasound frequencies. Freeman reported her finding at the annual meeting of Animal Behaviour Society in New Mexico, USA, on 13 June. Elephants have long been known to communicate over long distances using sound of frequency below 20 Hz. This is the first time that a bird has been shown to produce and perceive sounds below human hearing for communication.

Freeman and her colleagues found that male peacocks actually produce two subtly distinct types of infrasonic mating sounds. The first type, which the scientists dubbed the 'shiver train', is produced by vibrations from the centre of the long feathers to the edge of the plumage. This is used when females are far away. The second type, called 'pulse train', is delivered when a female is close; it is produced by vibrations emanating from the base of all the long feathers.

Can research lead to a bird flu pandemic?

Avian influenza, commonly known as 'bird flu', is flu infection in birds. The bird flu virus, also known as H5N1, has caused several outbreaks among wild birds and domesticated poultry. Occasionally, the virus that causes the bird infection can change (mutate) to infect humans, but it has not been shown to spread between people. The first case of bird flu infection in humans was recorded in Hong Kong in 1997. The epidemic was linked to chickens and classified as avian influenza A (H5N1). Human cases of the disease have since been reported in Asia, Africa, Europe, Indonesia, Vietnam, and the Pacific islands. Hundreds of people have become sick with this virus and more than 60% of them have died. However, although since it first appeared in 1997, H5N1 has decimated poultry flocks and killed more than 600 people, it has not touched off a pandemic in humans because it hardly ever spreads from one person to the next.



Electron micrograph of H5N1 virus.

The avian flu virus (H5N1) has been known to survive in the environment for long periods of time. Infection usually spreads by contact with contaminated surfaces. That is why most cases of bird flu in humans have been reported from people working with poultry who came in contact with infected birds or their droppings, or ate raw or undercooked poultry meat and eggs. Birds infected with this flu can continue to release the virus in their faeces and saliva for as long as 10 days during which it can infect humans.

Till recently, the H5N1 virus was not known to be transmissible through air or aerosols; that is, by sneezing or breathing. To become a pandemic, the virus would have to be able to spread via tiny droplets spewed out during coughing or sneezing, as happens with the human flu virus. And that is what recent research has shown is possible – that the virus may mutate easily and become transmissible through respiratory droplets. If that happens, it could start a deadly worldwide epidemic. And that is why the publication two research papers on H5N1 in the journals *Nature* (2 May 2012) and *Science* (22 June 2012) raises concern because it opens up the possibility of misuse of the published data for bioterrorism.

The first paper reports the findings of a Japanese-US team headed by Yoshihiro Kawaoka at the University of Wisconsin-Madison, USA. To find out if H5N1 could evolve easy transmissibility between humans, the researchers carried out mutation on the haemagglutinin (HA) gene of the virus, which produces the protein that the virus uses to stick itself to host cells. The researchers combined this gene with others from a highly transmissible flu virus, the

H1N1 strain that caused a pandemic in 2009. According to the researchers, the mutations allowed the hybrid virus to bind more strongly to mammalian cells and copy itself at high enough levels to be readily transmitted via respiratory droplets (*Nature*, 2 May 2012 | doi:10.1038/nature10831).

The second paper, by a team led by virologist Ron Fouchier of Erasmus MC in Rotterdam, the Netherlands, describes how a handful of mutations might give the H5N1 avian influenza virus, which normally infects birds, the potential to move easily between mammals and touch off a human flu pandemic. Fouchier's team started out with an actual H5N1 virus isolated from a human victim in Indonesia. Then they inserted several mutations they knew might help the virus spread among mammals. When ferrets were infected with the mutated virus it could infect some ferrets in nearby cages by airborne spread (*Science*, 22 June 2012 | doi: 10.1126/science.1213362).

Although some scientists look at the results as a matter of concern, the good news is that none of the ferrets died after airborne infection with the mutant H5N1 viruses. The researchers also found that the mutated virus was sensitive to the drug Tamiflu, and ferrets that had been given an H5N1 vaccine produced antibodies against the mutant strains.

Both the papers provide evidence that it may be possible for the bird flu virus to acquire mutations that could allow it to spread between people via respiratory droplets and cause a pandemic. However, it may be noted that these mutations have not arisen naturally in the wild; they have only been created in the lab. According to some sources, rather than being a cause of concern, the findings will help national public health agencies that monitor influenza viruses, allowing them to make plans to cope with the next epidemic or pandemic flu that may emerge in humans.

Why tomatoes taste bland

Many of the fruits and vegetables we use today are products of selective breeding to improve certain desirable characteristics. The tomato is one such fruit which originated in South America and is now grown around the world. The tomato that we gat today is the product of more than 70 years' of breeding by farmers in an attempt to standardise the colour of an unripe tomato to a uniform shade of green instead of a tomato that has a pale green base and a patch of dark green around the stem of the tomato. Farmers preferred to select tomatoes that are uniformly light green at the time of harvesting. But in the process of breeding for uniform colour, the taste quality of a standard tomato has been altered, with significant reduction in the amount of sugar present. That is why present-day tomatoes taste so bland. Research has now identified a gene responsible for the formation of the dark green ring around the stem of a tomato (properly named green shoulders), is also associated with producing excess sugar in a tomato plant and other sources of flavour in the ripe tomato.

Green tomatoes: wild (left), modern (right), and ripe (behind). Tomatoes have been genetically altered through breeding so much, that they now produce much less sugar through chloroplast than they did in the past. (Credit: Hakan Aktas)

To find out how tomato breeders got rid of the green shoulders in unripe tomatoes to make it of uniformly pale green colour, Ann L. Thomas Powell of the University of California, Davis, USA, and colleagues crossed cultivated varieties of tomatoes with wild species. By selecting those plants with dark green shoulders and crossing them back with the cultivated varieties, they narrowed down the culprit to a region on chromosome 10. Then, using the recently completed tomato genome sequence they then identified the gene as SlGLK2 – a so-called transcription factor, which controls when and where other genes are switched on or off. In wild tomatoes, SlGLK2 increases the formation of chloroplasts, the compartments in plant cells that carry out photosynthesis, making the unripe wild tomatoes look darker green around the stem. Powell and her team found that in tomatoes marketed today, SlGLK2 is inactive. According to them, through excessive breeding of different tomatoes, farmers have created a massive effect by developing a form of hybrid tomato with the necessary sugar-producing SIGLK2 gene turned off, accounting for the lack of sugar production and taste in modern-day tomatoes. The researchers tested about a dozen varieties of tomatoes from Asia and Europe and all had the same mutation. However, by inserting an intact copy of the gene into tomatoes, the researchers could increase the amount of glucose and fructose in ripe fruits by up to 40%, they report (*Science* 29 June 2012 | doi:10.1126/science.1222218). According to the researchers, the content of lycopene, an antioxidant that could have significant health benefits, was also increased and they suggest that the higher sugar content should make the fruits more palatable. They further add that the intact gene could be crossed back into tomatoes by traditional breeding to make tomatoes tastier. ■

Science radio serial for Kargil and Leh regions of Jammu and Kashmir

As part of the ongoing activity of Vigyan Prasar in popularising science using the medium of radio, a two-day workshop was organised at All India Radio, Kargil (J&K) during 24-25 May 2012, to deliberate and brainstorm on the possible themes and topics to be taken up in the proposed radio serial in Balti/Purugi language. This language is spoken by millions of people living in Kargil, Leh and also in Baltistan, Askardu, etc., across the border. District Kargil has huge underdeveloped area, which also remains cut off from rest of the state and other parts of the country for about six months due to snow-blocked roads and the mercury dipping up to –30°C in Zanskar and Drass areas of the district. One can imagine the hardship of the people of this area during winter, and radio is the only medium available to them during this period. Besides, this area is rich in minerals, and known for fruits and flower cultivation; it has rich water resources and a range of glaciers.

Shri S.K. Srivastava, Station Director, AIR Kargil; Shri Tashi, Executive councilor, Tourism; Shri Kacgho Ahmad Ali, Chief Executive Councilor Kargil; Shri Haji, Executive Councilor, PWD; and Shri Nisar Naseem, Programme Executive, AIR Kashmir during the inaugural session

Participants of the workshop

The workshop was organised in association with Radio Kashmir Srinagar (J&K). Around 30 local experts, associated with media – both from print and digital – from districts nearby Kargil were invited to attend the workshop. Shri Nisar Naseem, Programme Executive, Radio Kashmir Srinagar, Shri S.K. Srivastava, Station Director, All India Radio Kargil, Shri Kapil Tripathi, Scientist, Vigyan Prasar, and Shri Biswajeet Chanda, Finance Officer, Vigyan Prasar collectively coordinated the programme. In the Inaugural session Shri Kacgho Ahmad Ali, Chief Executive Councilor, Kargil, Shri Haji, Executive Councilor, PWD, and Sh. Tashi, Executive Councillor, Tourism were also present.

Script writers associated with AIR also took part in the workshop. Inputs were gathered from all the participants about local issues and 13 topics related to agriculture, health and hygiene, dry food processing, superstitions, climate change and glacier melting, power generation, medicinal plants, etc., were identified and assigned to the writers for the development..

The serial would attempt to explain natural phenomena, demystify natural occurrences and superstitions prevailing in the community and discuss the rich practical knowledge garnered by the community in form of the medicinal plants and techniques for weaving and so on.

(Report : Kapil Kumar Tripathi) ■

Letters to the editor

The enigmatic 'e'

The article, "The Enigmatic '*e*' " (*Dream 2047*, June 2012) was very good and informative. I and my 12th standard son Arnab was enjoyed reading it.

The way of remembering first few decimal points draws much attention and now it cannot be forgotten.

However, three more points would have made your article more complete. These are:

1) A little idea about what exactly the mathematical calculation did Napier make (must be a series) in order to calculate logarithm.
2) Instead of just the series expansion of *e*, more general, i.e., series expansion of *e* to the power *x* could be presented.
3) The very interesting fact that, x-th root of *x* is the maximum for $e = x!$ *e*-th root of e = 1.444667861.. , which is the maximum.

Here, I shall narrate a story (same type as yours story with Googol):

In one of the course exercises of my 12th standard son Arnab, the problem came of square root of 2 and cube root of 3. He found that the latter is larger, whereas 4-th root of 4 (which is basically same as square root of 2) is again smaller than cube root of 3. So the maximum must lie somewhere in the interval 2 to 4.

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Prime Numbers

I liked the article on prime numbers (*Dream 2047*, April 2012). It was absolutely amazing. Expect more to come.

Deepthi.
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Science fiction writers in English

I read your editorial on Science Fiction (*Dream 2047*, May 2012) and found it very informative. The subject interests me,especially science I have also written on the subject. Titled "The Eyeball and the Bubbles". You have mentioned some prominent Indian writers who have written in regional languages. Are you aware of any who has written in English? It may give a fillip to this activity if you can organisea meeting of some of the prominent Indian writers to discuss the current trends and to suggest ways and means to promote science fiction in India. I wonder if Vigyan Prasar can take the initiative in this matter.

S.A. Khan
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Transit of Venus-2012 - A report

One of the massive campaigns across the country completed recently by Vigyan Prasar is the transit of venus-2012. Vigyan Prasar organized about 15 national level orientation workshops across the country. Nearly 750 resource persons were trained through the workshops. Each resource persons were provided with the sufficient resource material in the form of telescope, kits, books, solar filters, films on transit, etc.

The persons attended the workshop were expected to carry the dissemination of knowledge by organizing number of workshops at schools, colleges, community centers and residential places to orient children and people for Transit of Venus. In last one month, Vigyan Prasar has received more than 200 reports about the further dissemination by resource persons. Although reports are still coming, and all the reports cannot be published, therefore only few of them are getting highlighted. Vigyan Prasar is overwhelmed with tremendous response from across the country. It is observed that, large number of people gathered to see the transit. However, on the day of transit at most of places people woke up with cloudy sky but as day progressed clouds cleared at many places.

Venus transit observation at Raichur

- Prof Murtaza Ali from Amravati, Maharashtra, organized a special workshop for 50 participants from and around Amravati district.
- Ms Geeta Mahashabde from Navnirmiti, Mumbai organized one of the workshops at Pune in which participants were trained for handling of telescope and use of filters.
- Ms Seema Muralidhara from Kandivali, Mumbai organized a special programme on the 06 June 2012 for about 100 participants.
- Mr Pankaj V. Pathak from Nandurbar, Maharashtra organized a special observation camp on 06 June 2012 for 225prticipants. Observation were made using telescopic projection and ball mirror.
- Mr Sahebrao Dhondabaji Hatwar organized a programme at Digras, Yawatmal, Maharashtra for about 200 students and 30 teachers.
- Mr Vinayak Viththal Gadre from Ichalkaranji, Maharashtra a programme where 200 participants were gathered.
- Mr M. K. Gondalia from Amreli, Gujarat organized a programme for public in which about 200 people gathered.
- Ms. Renuka Bhatti, from Jalandhar, Punjab, organized many workshops in various places in and around the city and a special programme on06 Jun 2012.
- Mr Harjinder Gogana from Phgwara, Punjab organized many orientation programmes in and around the city where nearly 1000 people witnessed the event on 06 June 2012.
- Mr Kalwant Sing from Sangrur, Punjab organized many workshops at various schools in and around the Sangarur of which Venus Transit Mela organized by DIET was remarkable in which nearly 400 participants, were trained for observation of transit using telescope and filters.

People watching Venus transit through filters and telescope

- Mr Kapil Dev Soni organized a special programme at Khanna, Ludhiana Punjab, where students from 10 schools were gathered. Since weather was cloudy the event was not visible.
- Mr Rajeshwar Singh Salaria and Mr Siddharth Chander from Pathankot, Punjab organized a 'Transit Watch' on 06 June 2012 but because by cloudy sky the event was not visible.
- Mr Surinder Kumar Jindal from Samana, Patiala, Punjab organized orientation programme for 300 participants and observation were made using Solar filters Ball and mirror projector on 06 June 2012.
- Mr by Alakh Narayan Dube from Agar, Tehri Garhwal, Uttarakhand organized a programme where 1500 people observed the transit using solar filters
- Mr Ravi Kiran from Osmania University, Hyderabad, Andhra Pradesh organized a special programme on 06 Jun 2012.
- Mr JVV Srinath from Warangal, Andhra Pradesh organized a transit programme across the district where nearly 40,000 people observed the transit.
- Mr Sanjeev Kumar from Nagaram Keesara organized a special programme for 100 participants where solar filters were distributed.
- Mrs. Matilda Fernandes from Bangalore organized the training programme for about 845 student, teacher participants.
- Mr Madhushreenivasan from Hoskote, Karnataka organized a programme for 230 students and teachers from 10 different schools.
- Mr Saravannan from Coimbatore organized a transit programme at Karamadai.
- Mr G. Kannabiran from Udumalpet Tirupur, Tamilnadu, organized a programme where 1500 people participated and watched transit using ball-mirror projector and telescope and filters.
- Mr R. Ravikumar from Nagamalai, Madurai, Tamilnadu organized a programme by VP telescope and filters for about 3000 people.

- Ms. R. Pasricha from Nagipattinam, Tamilnadu organized a programme for about 1000 participants.
- Mr D. Aravindaraja from Puducherry organized a pubic show for about 25,000 participants.
- Mr Santosh Kumar Kar from Pathani Samanta science club, Narla Road Kalahandi, Orissa, organized the workshops at about 12 places across the district.
- Mr Dilip Kumar Dhal from Ingsa, PO Agalpur Bolangiri Odissa, organized a public show for about 1000 participants.
- Mr M. U. Sharif from Shivpuri, Madhya Pradesh, organized a public show for about 2000 observers.
- Mr Mahendra Khare and Mr Motiram Pawar from Chindwara, Madhya Pradsh organized a training programme for about 64 participants.
- Mr Aakash Lalwani from Chindwara, Madhya Pradesh organized a training programme for about 55 participants.
- Mr Pramod Kumar Mishra from Naini, Allhabad, organized a public show for about 3800 people.
- MR Biju Mohan from Jahangirabad Media institute, Barabanki, Lucknow UP, organized a training programme for 50 participants.
- Mrs Dr. Rekha Kahali from Jalpaiguri West Bengal organized a special programme on Transit of Venus on 06 June 2012.
- Mr Satyajit Chakrabarti from Jadavpur University Jadavpur, West Bengal organized 1100 observation centers across the state.

A boy watching Venus transit through telescope

(Report : Dr. Arvind C Ranade & Amitabh Pandey) ■

Brainstorming workshop on "Addressing household level food and nutrition security for tribal areas"

A two-day brainstorming workshop on "Addressing household level food and nutrition security for tribal areas" was organised by Vigyan Prasar in collaboration with M S Swaminathan Research Foundation (MSSRF) on 24 and 25 May 2012 at MSSRF, Chennai. The workshop was framed with the objectives to understand the existing scenario, identify appropriate technologies, scope for inter-agency learning and popularisation of successful community based food security interventions, development of practical nutrition awareness resource materials and innovative communication tools/methods for technology awareness regarding food and nutrition security for tribals in India.

There were 23 experts including scientists, government representatives, nutritionists, academicians, implementing agencies, NGOs representatives from different parts of country who took part in the deliberations and discussion on food and nutrition security issues in tribal areas. There were representatives from various states like Tamilnadu, Kerala, Andhra Pradesh, Odisha, Tripura, West Bengal, Jharkhand, Maharashtra, and Gujarat.

Workshop in progress

The workshop started with the welcome address by Ms. Bhavani RV, Project Manager from MSSRF, Chennai, followed by keynote address by Er Anuj Sinha, Former-Director, Vigyan Prasar. He outlined important issues in tribal food and nutrition security, focus areas to be addressed, importance of science and technology communication and strategies for effective communication. Dr Bharat Bhushan, Scientist C, VP, focussed on Vigyan Prasar's efforts at large-scale science popularisation and also promotion and propagation of scientific and rational outlook in the society.

The workshop had five sessions namely (1) Current nutrition scenario and emerging issues in food and nutrition security among selected tribals in India; (2) Technologies available to address household food and nutrition security for tribals – Role of government agencies, research organisations and institutions; (3) Factors affecting tribal food and nutrition security; (4) Need for nutrition education/ resource materials to improve household food and nutrition security among tribals – Brainstorming session; and (5) The way forward – Gaps and future strategies to reach out target groups – Brainstorming session.

During the deliberations, the experts presented their views regarding current status and issues related to food and nutritional security for tribal areas. During the brainstorming session there were discussions on two aspects: (1) Research areas in tribal nutrition, and (2) Development of information, education and communication resource materials. The details were discussed among experts for finalisation of future action plans. The workshop concluded with special remarks by Dr Ajay Parida, Executive Director, MSSRF. The way forward and roadmap for future activity was complied and discussed among the experts by Er Anuj Sinha, Dr Indira Chakravarty, Dr Triveni, and Dr Bharat Bhushan.

(Report: Dr Bharat Bhushan) ■

Workshop on nuclear energy awareness and outreach programme

Under the umbrella of "Public Awareness Campaign on Nuclear Energy" Vigyan Prasar, Noida, in collaboration with Gujarat Science City, Ahmedabad (Dept of Science & Technology, Govt of Gujarat) organised a regional workshop on 'Nuclear Energy Awareness and Outreach Programme'. The day-long workshop was organised in the auditorium of Gujarat Science City on 27 May 2012. The purpose of the workshop was to spread awareness and understanding on nuclear energy to help in inculcating logical reasoning skills and building scientific temper in society.

Inaugural Session in Proggress

The experts present in the workshop included Shri Dilip S. Gadhave, Executive Director, GCSC, Dr. P. M. Shah, Chief Project Engineer, Mithivirdi Project, NPCIL, Prof. K. N. Joshipura, Head, Deptt. of Physics, S. P. University, and Dr. Mainak Bandyopadhyay, Senior Scientist, Institute of Plasma Research, Gandhinagar. About 200 students of undergraduate and postgraduate departments of colleges and universities, media persons and other conscious citizens attended the workshop.

In the inaugural session, Shri Dilip Gadhave, Executive Director, GSC, briefed about the scientific programmes and activities of Gujarat Science City. Shri Narottam Sahoo, Sr. Scientist, Gujarat Science City described the role of science communication in eradicating the myths and doubts in the mind by developing a scientific approach towards societal development at large. Shri Nimish Kapoor, Scientist, Vigyan Prasar, while introducing Vigyan Prasar as an organiser, briefed about the objective of the nuclear energy awareness and public outreach programme.

Dr. P. M. Shah, Chief Project Engineer, NPCIL gave a detailed presentation on nuclear reactors functioning at different locations in the country and informed that there are 20 nuclear reactors in operation today and India ranks 6th country in the world in terms of nuclear power generation. He informed the audience about the in-depth safety approach of Indian nuclear programme and stringent safety norms followed in the country's nuclear power stations.

Dr. K. N. Joshipura, Head, Department of Physics, S. P. University, Gujarat in his keynote speech covered various aspects of energy and its importance in daily life. He discussed various sources of energy and the role of nuclear power in the present scenario with its benefits over other sources of energy. He explained that we are living in an environment which is full of natural radiation and hence there should not be any fear for radiation from nuclear power plants.

Dr. Mainak Bandyopadhyay, Senior Scientist, Institute for Plasma Research, Gandhinagar, in his inaugural address, said that fusion energy is the only long-term and eco-friendly alternative source in future. He explained that for every gram of fuel consumed, fusion energy is 10 lakh times more than that produced by any other chemical reaction or burning of fossil fuels.

The day-long workshop also included screening of a special animated film "*Budhiya Ki Sair...*" in Hindi, which gave a virtual tour of a nuclear power station in the country. The film introduced the audience to the safety measures and environment in and around nuclear power plants.

A live Youth Parliament was also organised on various aspects of nuclear energy in which the participants actively debated the issue. The Youth Parliament, after detailed discussion on pros and cons of nuclear energy in Indian scenario, passed a resolution by majority that nuclear energy is the need of the hour for the country. Myths on nuclear energy and misconceptions about radiation were discussed and decision was taken by the Youth Parliamentarians to remove the fear of radiation of nuclear energy by dissemination of factual information and promoting it as a clean and green source of energy due to its environmentally friendly nature.

(Report: Nimish Kapoor) ■