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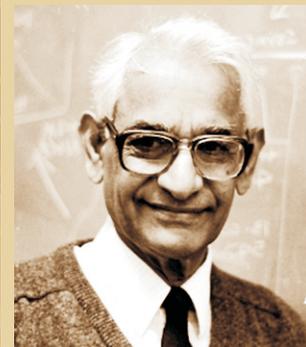
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Year 2012

The Mysterious

Har Gobind
Khorana



(1922-2011)

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Taking ahead the message of the International Year of Chemistry-2011



Dr. Subodh Mahanti

The year 2011 was celebrated as the International Year of Chemistry (IYC-2011) throughout the world. The idea behind the celebration was to reiterate the importance of chemistry in enhancing our understanding about the physical world and the role played by it in making our lives more comfortable and what it can do in ensuring the existence of human beings on planet Earth. The theme of the IYC-2011 was “Chemistry—Our Life, Our Future”. Among others the two most important goals of IYC-2011 were: to make common people better appreciate the role of chemistry in their daily lives and to attract young brilliant students to chemistry. Like in other parts of the world, in India also a number of activities were organised as part of celebration of IYC-2011. Research institutions, universities, colleges, schools, science academies, scientific departments/agencies of the government of India, and science communicators took active part in the celebration. Different activities like seminars, conferences, workshops, exhibitions, public lectures, etc., were organised. As in the case of World Year of Physics-2005, International Year of Planet Earth-2008, International Year of Astronomy-2009 and International Year of Biodiversity-2010, Vigyan Prasar organised various activities during IYC-2011—production of radio and television programmes highlighting different aspects of chemistry that have direct bearing on our daily life, innovative demonstration experiments, activity kits, posters, desk calendar on the theme of IYC-2011, workshops for chemistry teachers, exhibitions, and so on.

We need to carry on the activities initiated during the year to realise the objectives of IYC-2011, which have far-reaching consequences with regard to the present and future existence of human beings. There are a number of problems associated with energy, materials, the environment, natural disasters, water, food and health, which need to be tackled on urgent basis. These problems have assumed global character and unless these problems are tackled in a sustainable manner the very existence of human beings is in danger. To solve these problems practitioners of chemistry have to play an important role.

We need to present chemistry to aspiring science students as an attractive, challenging and creative scientific discipline, as it was in the beginning of its development. No doubt it is a challenging task. This is more so because of the fact that though chemistry has played a decisive role in shaping human civilisations during different ages, the public image of chemistry is far from encouraging. Chemistry cannot boast of the glamour of the other competing disciplines. Chemistry mostly deal with mundane things – materials for making different objects, fertilisers, insecticides and pesticides, dyes and pigments, coal and petroleum, medicines, plastics, detergents and so on. And chemists have been dealing with these things for centuries. So it is natural the following questions are likely to arise in the minds of aspiring students: Is there scope for exciting new developments in chemistry or is most of the chemistry already done? Should students avoid chemistry and choose better career options? What would the future of chemistry look like? Will chemists have enough interesting, challenging and intellectually stimulating work to do? Convincing answers need to be provided.

Chemistry is not simply about mundane things. Revolutions in information technology and space exploration could not have been possible without development of new materials. Search for new materials has been a major concern of chemists since the beginning of their discipline. Chemistry’s role in increasing the life-expectancy is obvious. We need to realise that it is chemistry which can play an important role in achieving the dream of sustainable development. However, to achieve this goal, chemists will require changing the ways and means of chemistry. In this context it is important to mention the mission of the initiative called “Crystal Faraday Partnership’ of the Chemistry Innovation Network of the British government: “In the developed world, it is recognised that only 7% of production materials used in a process end up in the final product and that 80% of products are discarded after a single use. It is essential, therefore, that we seek to reduce material resources and ensure that any materials released to environment are not toxic, harmful or persistent.” It is heartening to note that green chemistry has emerged to take up this challenge and its practitioners and advocates put emphasis on designing safer chemicals and products; designing less hazardous chemical syntheses; using renewable feedstock; using catalysts, non-stoichiometric reagents; avoiding chemical derivatives; maximising atom economy; using safer solvents and reaction conditions; increasing energy efficiency; designing chemicals and products which are easy to degrade after use; analysing in real-time to prevent pollution and minimising the potential for accidents. These are also called the twelve principles of green chemistry.

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Har Gobind Khorana

The chemical biologist who played a crucial role in deciphering the genetic code

Dr. Subodh Mahanti

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“From 1960-70 he (Khorana) was at Wisconsin, and while there he carried out valuable syntheses of polynucleotides with known base sequence. These were of great value in establishing the ‘genetic code word dictionary’. This refers to the fact that the four bases (A, C, G and T) present in DNA chains are ‘read’ in linear groups of three (codons), as was known by the late 1950s...Khorana had a major part in the work which established the dictionary, by his synthesis of all 64 codons. This was an essential step in the future development of molecular biology.”

The Cambridge Dictionary of Scientists (2nd edition), Cambridge University Press, 2002

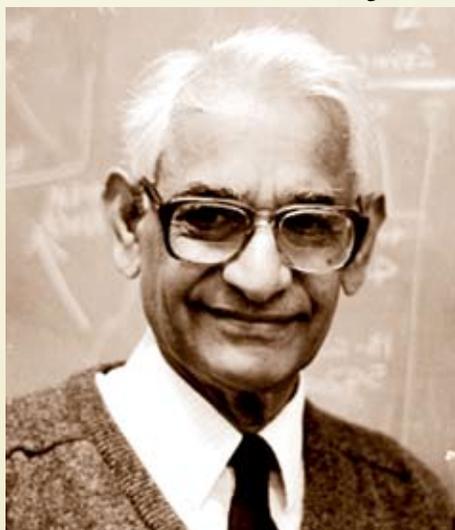
“...Khorana’s next major achievement came in 1970, when he announced the synthesis of the first artificial gene. The same year he moved to the Massachusetts Institute of Technology, where, by 1976, his team had made a second gene, which (unlike the first) was capable of functioning in a living cell. Such work has far-reaching possibilities, bringing scientists a step nearer to understanding gene action. The future could see artificial genes being used to make valuable proteins (e.g., insulin) and perhaps to cure human hereditary diseases.”

A Dictionary of Scientists, Oxford University Press, 1999

“The structural chemistry of the nucleic acids, which developed over a period of some seventy years in many countries, progressed step-by-step from the chemistry of the constituent purines, pyrimidines and the sugar moieties, to work on the nucleosides and then onto the nucleotides. A distinct climax was reached in 1952 with the elucidation of the internucleotidic linkage in nucleic acids by Brown and Todd and their coworkers...Shortly thereafter, the Watson-Crick structure for DNA was proposed, which focused attention, in particular, on the biological meaning of its physical structure. It is also about this time the hypothesis that linear sequence of nucleotides in DNA specifies the linear sequence of amino acids in proteins was born.

Har Gobind Khorana in his Nobel Lecture delivered on 12 December 1968

Har Gobind Khorana’s work helped unravel the genetic code and explain how proteins are made. He discovered a process that is fundamental to life. Khorana and his team established that the biological language common to all living organism, is spelled out in three-letter words – each set of nucleotides coding for a specific amino acid. Khorana was awarded Nobel Prize in 1968 jointly with Robert William Holley (1922-1993) and Marshall Warren Nirenberg (1927-)



Har Gobind Khorana

“for their interpretation of the genetic code and its function in protein synthesis.” Khorana was the first scientist to synthesise oligonucleotides. Khorana’s researches led to the establishment of genetic engineering as a new branch of science. Khorana rose from a very humble background to become one of the greatest scientists working in the molecular biology in the 20th century because of his extraordinary drive discipline and striving for excellence. He was a pioneer and visionary.

One of Khorana’s colleagues at the Massachusetts Institute of Technology Uttam L. RajBhandary wrote: “As a mentor, Khorana set high standards. He was loyal to the people who helped him and to the institutions at which he worked. He could be demanding, but he was no more so of others than he was of himself. One associate said:



Robert William Holley



Marshall Warren Nirenberg

‘He showed us what excellence in science was and we learnt to recognise it.’ Gobind was modest, humble and avoided publicity. He loved music, swimming and long walks, and had a curiosity that lasted until the end.” Khorana gave lot of thought before selecting a research problem. The difficulty or the time needed to solve a problem did not really bother Khorana as long as it was of fundamental importance. An oft quoted statement made by Khorana was: “If you want to get far, you have to travel alone.”

Khorana was born on 9 January 1922 (it has been reported that 9th January is his official date of birth, but his exact date of birth is not known) in a small village Raipur, Punjab (now in Pakistan). His father Ganpat Rai Khorana was a Patwari, a village taxation official in British-India government

system. Commenting on his father Khorana wrote: "Although poor, my father was dedicated to educating his children and we were practically the only literate family in the village inhabited by about 100 people."

Khorana's early education was under a tree in his village where the local teacher conducted open classes. He later attended D.A.V. High School in Multan, Punjab. In school he was greatly influenced by one of his teachers, Ratan Lal. He was awarded a government scholarship for higher studies. He studied chemistry in the Punjab University, Lahore from where he obtained a BSc degree in 1943 and an MSc degree in 1945.

In 1945, a Government of India Fellowship made it possible for Khorana to go to England where he studied for PhD degree at the University of Liverpool under the supervision of Roger J. S. Beer. After doing his PhD, Khorana went to the Swiss Federal Institute of Technology (Eidgenössische Technische Hochschule or ETH) in Zurich,

where he worked as postdoctoral research student for 11 months on alkaloid chemistry with Vladimir Prelog. It may be noted that Prelog was awarded the Nobel Prize in Chemistry in 1975 "for his work into the stereochemistry of organic molecules and reactions." Khorana's stay at Zurich was short. He did not receive any fellowship and he



Vladimir Prelog

sustained himself on savings. Khorana's stay at Zurich, though short, played a decisive role in shaping his scientific career. Khorana was greatly influenced by Prelog. Acknowledging his debt to Prelog Khorana said in his Nobel Lecture, "Fortunately, I was accepted by Professor V. Prelog of the Eidgenössische Technische Hochschule, Zurich, as a postdoctoral student. The association with this great scientist and human being influenced immeasurably my thought and philosophy towards science, work and effort." His stay at Zurich was very important for another reason. It was at Zurich that Khorana met his wife Esther Elizabeth Sibler. Commenting on the role played by his wife in his life Khorana wrote: "Esther brought a consistent sense of purpose in my

life at a time when, after six years' absence from the country of my birth, I felt out of place everywhere and at home nowhere."

After a brief period in India, Khorana returned to England in 1949 on receiving a fellowship to work in the Cambridge University, where he spent two years. At Cambridge Khorana worked with Alexander Robertus Todd (1907-1997), who fired his interest in nucleic acid research, the pyrimidine bases that occur in nucleic acids; that is, DNA and RNA, and found their structures. Todd was awarded the Nobel Prize in Chemistry in 1957 "for his work on nucleotides and nucleotide co-enzymes."

In 1952, Khorana moved to Vancouver, Canada where he became the Director of the British Columbia Research Council's Organic Chemistry Section in the University of British Columbia. For Khorana it was a great opportunity in his professional career because he could have his own laboratory. Recalling Khorana's telling how he accepted the position at Vancouver, Uttam RajBhandary, Wolfe Professor of Molecular Biology at MIT and a colleague of Khorana said: "Gobind was so excited

that he was going to start a lab of his own. He looked at the map of Canada, saw where Vancouver was for the first time, and off he went." At the University of British Columbia, where he stayed for eight years, Khorana made his first major contribution in biochemistry. Khorana jointly with his colleague John G. Moffat developed a process for synthesising acetyl coenzyme A, an essential molecule involved in biochemical processing of proteins, fats and carbohydrates within the human body.



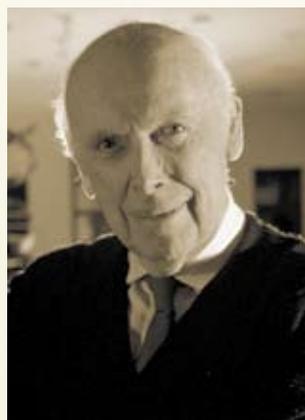
Alexander Robertus Todd

In 1960, Khorana Joined the University of Wisconsin, USA, as co-director of the Institute of Enzyme Research. In 1962 he became a professor of biochemistry. Khorana became a naturalised citizen of the United States in 1966. At the Wisconsin University, Khorana started working on synthesis of oligonucleotides.

The discovery of the DNA structure by James D. Watson and Francis H. C. Crick in 1953 and other experiments conducted

by scientists like the MacLeod-McCarty experiment, the Hershey-Chase experiment, and the Meselson-Stahl experiment told us where genetic information is held and what it looks like. What was not known was how

DNA directed the making of proteins, or what role RNA had in this processes. As we know the nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), are polymers or very long-chain molecules and the basic unit of these polymeric molecules is nucleotide. A nucleotide contains sugar (ribose in case of RNA and deoxyribose

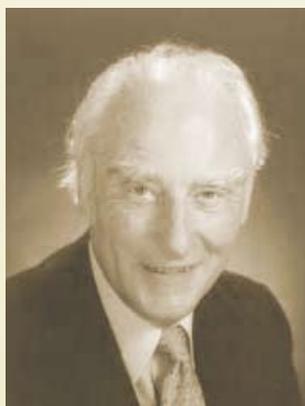


James D. Watson

in case of DNA), a purine or pyrimidine base. There are four bases adenosine (A), guanine (G), cytosine (C), thymine (T), uracil (U).

Nirenberg started the work at the National Institute of Health in Bethesda in 1958 that culminated in deciphering the genetic code in which Khorana played a very crucial role. At the time Nirenberg started work on cracking the genetic code, it was known that different combinations of three nucleotide bases (triplets) each coded for a specific amino acid and that through the operation of this genetic code amino acids

are aligned in right order to form proteins. However, there are 64 possible combinations



Francis H. C. Crick

of triplets. So the big question was which of the 64 possible combinations of triplets codes for each of 20 amino acids found in proteins. Using the techniques developed by Severo Ochoa for synthesising RNA, Nirenberg made RNA molecule that consisted entirely of uracil nucleotides. So the only triplet possible would be a uracil triplet or UUU of the genetic code. Nirenberg demonstrated that the protein made by this RNA molecule consisted entirely of the amino acid phenylalanine. This clearly demonstrated that UUU must code for phenylalanine.

The first polynucleotides used for identifying the codons were composed of either a single nucleotide or several nucleotides that, under the action of enzyme, were randomly distributed in the polynucleotide chain. Using such polynucleotides it was not possible to pair a given codon with a given amino acid or, in other words, to identify which codon corresponds to which particular amino acid. This problem was solved by Khorana, who developed an effective method for synthesising polynucleotides with a given sequence. It was not an easy task. The problems faced by Khorana were described in his Nobel Lecture: "With the knowledge of the chemical structures of the nucleic acids, the two major tasks which faced the chemists were those of synthesis and sequential analysis. Chemical synthesis of short-chain oligonucleotides began to be preoccupation in my laboratory. The types of problems that one faced were: (1) activation of the phosphomonoester group of a mononucleotide so as to phosphorylate the hydroxyl group of another nucleoside or nucleotide; (2) design of suitable protecting groups for the various functional groups (primary and secondary hydroxyl groups in the sugar rings, amino groups in the purine and pyrimidine rings, phosphoryl dissociation in the phosphomonoester group); (3) development of methods for the polymerisation of mononucleotides and for separation and characterisation of the resulting polynucleotides; and (4) evaluation of approaches to stepwise synthesis of polynucleotides of specific sequences."

In 1970, Khorana joined the Massachusetts Institute of Technology (MIT) as Alfred P. Solan Professor of Biology and Chemistry where he served until retiring in 2007. At MIT Khorana he extended his work on the synthesis of oligonucleotides to synthesis of long DNA polymers using non-

aqueous chemistry and assembled these into the first synthetic gene. He achieved this feat by using polymerase and ligase enzymes that link pieces of DNA together, as well as methods that anticipated the invention of Polymerase Chain Reaction (PCR). Later such custom-designed pieces of artificial genes found wide use in biology laboratories for sequencing, cloning and engineering new plants and animals. Khorana's inventions became automated and commercialised. And today anyone can order a synthetic gene from any of a number of companies with the desired sequence. The method of chemically synthesising genes made possible for controlled, systematic studies of how genetic structures function.

Towards the end of his professional career, Khorana got involved in research exploring the molecular mechanisms underlying the cell signaling pathways of vision of vertebrates. He primarily focussed on the structure and function of rhodospin, a light-sensitive protein found in the retina of the vertebrate eye. He also studied mutations in rhodospin.

Khorana was member of many distinguished professional bodies including that of US National Academy of Sciences and American Academy of Arts and Sciences. Khorana was a member of the Board of Governors of The Scripps Research Institute. Among the numerous awards bestowed upon him was the Merk Award of the Chemical Institute of Canada (1958), Gold Medal of the Professional Institute of the Public Service of Canada (1960), Louisa Gross Horwitz Prize of the Columbia University (1968), Albert Lasker Foundation Award for Basic Medical Research (1968), Distinguished Service Award, Watmul Foundation, Honolulu, Hawaii (1968), American Academy of Achievement Award, Philadelphia (1971), Willard Gibbs Medal of the Chicago Section of the American Chemical Society (1974), Gairdner Foundation Annual Award, Toronto, Canada (1980), Paul Kayser International Award of Merit in Retina Research (1987), National Medal of Science of USA (1987), MIT School of Science Distinguished Service Award (2000), H. K. Firodia Award for Excellence in Science and Technology (1997), Rockwell Medal of Excellence in Technology (1997), Gujar Mal Modi Innovative Science and Technology Award (2004). The Government of India recognised Khorana's contributions by

awarding him its prestigious civilian awards Padma Sri (1998), Padma Bhushan (1999), and Padma Vibhushan (2009).

The University of Wisconsin, Madison, the Department of Biotechnology, Government of India and the Indo-US Science and Technology Forum jointly created the Khorana Programme in 2007 with the following objectives: 1) providing graduate and undergraduate students with a transformative research experience, 2) engaging partners in rural development and food security, and 3) facilitating public-private partnership between the US and India.

Khorana died on 9 November 2011 in Concord, Massachusetts at the age of 89.

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(This article is a popular presentation of important points on the life and work of Har Gobind Khorana available in the existing literature. The idea is to inspire younger generation to inspire to know more about Khorana. The author has given the sources consulted for writing this article. However, the sources on the Internet are numerous and so they have not been individually listed. The author is grateful to all those authors whose works have contributed to writing this article.)

The Mysterious π



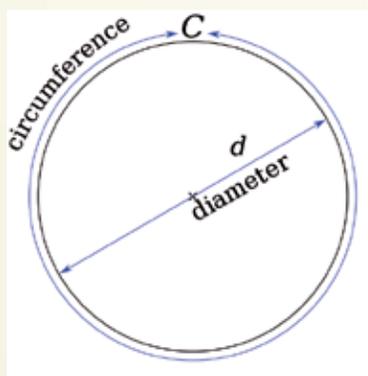
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No number has captured the attention and imagination of people through the ages as the ratio of the circumference of a circle to its diameter, known as pi (symbol π , the 16th letter of the Greek alphabet). The value of π is approximately equal to 3.14, and from the ancient Egyptians and Archimedes to Leonardo da Vinci to mathematicians using modern-day computers have tried to calculate the value of π to almost eight billion digits! Decimal representation of π never ends and never repeats. Throughout the history of mathematics, there has been much effort to determine the value of π more accurately and to understand its nature. Many formulae in mathematics, science, and engineering involve π , which makes it one of the most important mathematical constants.

used a value for this constant. Babylonians around the same time used $25/8$, or decimal equivalent of 3.125 as the value of this constant.

Greek mathematician Archimedes seemed to provide the first theoretical calculation of π around 200 BC. He said the



Unique mathematical constant

π is an irrational number, which means that its value cannot be expressed exactly as a fraction having integers in both the numerator and denominator ($22/7$ is correct up to only second decimal place, hence is only an approximate value of π).

π is also a transcendental number, which implies that no finite sequence of algebraic operations on integers (powers, roots, sums, etc.) can render its value. Proving this fact was a significant mathematical achievement of the 19th century.

The decimal representation of π truncated to 50 decimal places is:

$\pi = 3.14159265358979323846264338327950288419716939937510...$

Early History

The fact that ratio of circumference to the diameter of a circle is a constant was known for ages. However, the very first instance of its mention still remains a mystery. Most probably Egyptians mentioned about this constant in their writings on papyrus scroll as early as 1650 BC. Of course, at that time it was not mentioned as π , as we do today, but they did mention about area of a circle using a rough estimate of a constant that we term as π . There is good evidence that value as $256/81$ (which is equivalent to 3.16) was

constant takes the value between $223/71$ and $22/7$. The interesting thing is that he did not claim to know the exact value of π ; rather he mentioned about the boundary of values between which π exists. When Archimedes derived the above boundary, there was no concept of algebra or trigonometry. Neither the decimal number system was in existence. So he used pure geometry using the concepts of circle and regular polygon in deriving his expressions in term of fractions. In fact, historians have found that no mathematician was able to improve over Archimedes' method for many centuries.

The Indian mathematician Aryabhata (476-550) made the approximation of π using a regular polygon of 384 sides and gave its value as $62832/2000$, which is equal to 3.1416 and was correct up to four decimal places.

In the fifth century, Chinese mathematician Tsu Ch'ung used a variation of Archimedes' method to give the value of π as $355/113$, which is actually in the range between 3.1415926 and 3.1415927. This value of π was correct up to 7 digits and mathematicians in Europe could not better this feat for almost a thousand years.

Infinite series to calculate π

During the year 1400, Indian mathematical genius Madhava used a series to calculate π .

He used the following series:

$$\pi/4 = 1 - 1/3 + 1/5 - \dots$$

And from this series, he calculated the approximate value of π as 3.14159265359, which was correct up to 11 decimal places. Historically, this was a great achievement, since his European colleagues were still way behind this approximation during the same time.

During 17th century, with the invention of calculus by Isaac Newton (1642 – 1727) and Gottfried Leibniz (1646-1716), Archimedes' methodology to calculate the value of π was replaced with the use of infinite series expansions. In the meantime, the concepts of algebra and trigonometry were also developed to a great extent. The concept of zero and decimal system of number also led to huge advancements in mathematics. Therefore, it was easy to interpret the problem of π taking help from all these branches of mathematics. Thus, π came out of the closet of geometry to embrace arithmetic, algebra, trigonometry, calculus, and all the modern mathematics fields.

For example, with the help of algebra, trigonometry and calculus, it can be proved that:

$$\tan^{-1} x = x - \left(\frac{x^3}{3}\right) + \left(\frac{x^5}{5}\right) - \left(\frac{x^7}{7}\right) + \left(\frac{x^9}{9}\right) \dots$$

This is the well-known Gregory-Leibniz formula. It is interesting to note that in this formula, substituting x by 1 gives rise to the series, which was already used by Indian mathematician Madhava long ago.

$$\tan^{-1} 1 = \frac{\pi}{4} = 1 - \left(\frac{1}{3}\right) + \left(\frac{1}{5}\right) - \left(\frac{1}{7}\right) + \left(\frac{1}{9}\right) \dots$$

However, one drawback of the above series is that it converges very slowly and so one would need to compute the series up to a few hundred terms to compute the value of π accurately up to two decimal places.

In 1700s, Leonhard Euler (1707-1783)

provided some interesting series involving π . Some of these series involved expressions like $(\pi^2/6)$, $(\pi^4/90)$ and converged very rapidly. Later a faster and rapidly converging form of Gregory-Leibniz series was proposed by the British mathematician John Machin in 1706. He used the following identity:

$$\pi / 4 = \tan^{-1}(1/5) - \tan^{-1}(1/239)$$

Using the similar principle of Gregory series for $\arctan(x)$, Machin approximated the value of π up to 100 decimal places.

Until the advent of computer technology in the mid 20th century, the computation of π basically involved calculation of the value in a series to the extent that is manually possible. Most of the calculation involved with series given by Gregory-Leibniz, Abraham Sharp, and Machin. These series were not very efficient in computing the value of π . However, they were very elegant in nature and useful in obtaining the approximation of π reasonably well to apply in practical circumstances. Moreover, these series gave many theoretical implications and research ideas, which are still being investigated by mathematicians around the world.

During the mid-20th century, with development of computers and simultaneously some advanced algorithms for mathematical calculations, it was possible to obtain some efficient and accurate values of π and some other constants. However, until 1970s, all computer evaluations still used the classical formula like some variations of Machin's formula.

Ramanujan Era

Srinivasa Ramanujan (1887-1920), one of the greatest mathematicians of the twentieth century, discovered some new infinite series formula in 1910, but their importance was re-discovered around late 1970s, long after his death. One of his elegant formulas was like this:

$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{k=0}^{\infty} \frac{(4k)!(1103 + 26390k)}{(k!)^4 396^{4k}}$$

Each addition of a term in Ramanujan's series could give approximately additional eight digits to π . During 1985, about 17 million digits of π were accurately computed by American mathematician William Gosper using this formula. So it also proved the validity of Ramanujan's formula. In 1994, David and Gregory Chudnovsky brothers of Columbia University computed over four billion digits of π in a supercomputer



Srinivasa Ramanujan (1887-1920)

using an algorithm which was also similar in essence to the formula given by Ramanujan.

n^{th} digit of π

Most of these algorithms require the computation of previous digits to get the next digit. For examples, to get the n^{th} digit in π , a computer has to first compute all previous $(n-1)$ digits. Mathematicians started thinking of ways to calculate n^{th} digit without calculating $(n-1)$ digit.

It was found that this may be possible for binary (base 2) and hexadecimal (base 16) digits of π . In 1996, mathematicians D. Bailey, P. Borwein and C. Plouffe discovered a novel scheme of computing individual hexadecimal digits of π . More recently in 1997, C. Plouffe discovered another new



Archimedes (287BC - 212BC)

algorithm to compute the n^{th} digit of π in any base.

Colin Percival, a 17-year student from Simon Fraser University of California, USA, calculated five trillionth and ten trillionth hexadecimal digit of π . In the year 2000, he found that the quadrillionth binary digit of π is zero.

Why trillion digits?

π was always a mystery to mathematicians and so they might have tried to get to the bottom of it. A value of π up to just 37 places is sufficient for mathematicians to calculate the radius of the Milky Way galaxy with a margin of error less than the size of a hydrogen atom. So it is really interesting to see that mathematicians all over the world are so fascinated and engaged to get the value of π up to a trillion digits when for the purpose of the most accurate measurement, it does not require even first hundred digits!

The challenge of computing π has stimulated researches in many advanced areas of science and engineering. The challenge has led to many new discoveries and many new algorithms in the field of mathematics. There are also academic interests to find any statistical abnormalities or irregularities in π that could suggest that π is not a normal number.

Another reason is that calculation of the digits of π is an excellent way to judge the power and integrity of our modern computer hardware and software. If two computers compute the billionth digit of π accurately, then we can assume that these two computers are reliable for doing millions of other calculations flawlessly. One can detect the problems in hardware after obtaining the results of π digits. A similar kind of problem was once detected in Cray-2 supercomputers in 1986.

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An excellent account on history and chronology of pi may be found at: http://www-history.mcs.st-and.ac.uk/history/HistTopics/Pi_through_the_ages.html

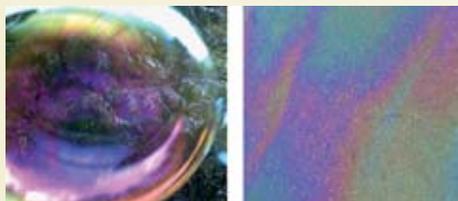
Thin Film Optical Coatings: Creating A Multicoloured World



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Every school student knows that the light from the sun as seen by the human eye consists of several colours – violet, indigo, blue, green, yellow, orange and red – which can be observed by passing sunlight through a glass prism that splits the white sunlight into its several component colours. But when we see sunlight reflected from or transmitted through a soap bubble, or reflected from an oil film on a puddle of water, we see the same colours again. When the direction from which we are viewing the soap bubble or the oil film changes, the colours that we see change as well. How does this happen? The soap or oil film, by itself, is almost colourless and transparent to the human eye. Then why do we see colours when light is reflected from them?



(a) Colours seen in (a) a soap bubble
and in (b) an oil film on water

We see these mysterious colours because of the properties of thin films, which are individually transparent, but can change the intensities of different component colours of the light falling on them according to their material compositions and thicknesses. While single thin films have a limited scope for enhancing or suppressing particular colours, a stack of thin films of different materials and thicknesses, deposited on top of each other, has a virtually unlimited scope for doing so and creating for the user an amazing range of colours as per the user's requirements. Coloured glass cannot produce even a small fraction of the range of colours that thin film optical coatings can do.

A thin film is a slice of material whose thickness is very small as compared to the length and width, and an optical thin film is one whose thickness is of the same order as the wavelength of the light interacting with it. For visible light, the wavelengths are in the range of about 380 to 760 nm (1 nm =

10^{-9} m) and so the optical thin films involved will have thicknesses in the range of 100 to 1000 nm. These films are too thin and fragile to be supported in air (a soap bubble lasts only for a short time before it bursts), and so they are deposited on the surface of a glass (and sometimes plastic) plate or lens, usually called the substrate.

The materials of the films in a thin-film optical coating are mostly transparent to visible light, though sometimes a few opaque metal films or absorbing films may also be used. The refractive indices of the transparent film materials may be less than or greater than the refractive index of the glass plate or lens on which they are deposited (about 1.52 in the visible region). They are usually called low-index and high-index thin film materials, respectively. Some of the commonly used optical coating materials are: silicon dioxide, magnesium fluoride (low-index); titanium dioxide, zirconium dioxide, silicon nitride (high index). These materials are generally electrical insulators, and are scientifically called *dielectrics*. However, a few oxides like indium tin oxide are electrically conducting, while being fairly transparent in the visible region of the spectrum.

The basic physical phenomenon behind the myriad colours created by optical thin films is the phenomenon of interference of light waves. When two light waves of a certain wavelength λ are superposed on each other, there is constructive interference (resultant amplitude is the sum of the amplitudes) if the waves are in phase, and there is destructive interference (resultant amplitude is the difference of the amplitudes) if the waves are out of phase. Thus, the interference of the two light waves results in a light wave whose amplitude can vary from a maximum in the case of constructive interference to a minimum in the case of

destructive interference (equal to zero if the amplitudes of the two waves are equal). Depending on the phase difference between the two light waves, all intermediate values of the amplitude, and therefore the intensity, of the resultant light wave, are possible. Now, when a light wave is incident on a multi-layer coating on a substrate, a large number of reflected and transmitted waves result due to multiple reflections / transmissions at each film boundary. These transmitted and reflected waves interfere constructively or destructively, depending on the wavelength of light, refractive index and thickness of each film and the refractive index of the substrate, as well as the angle of incidence. Thus the net transmitted and reflected beams are formed the relative intensities of which are determined by the interference of large numbers of light waves.

Some of the most important and commonly used thin film optical coatings - why they are required, what their structure is and where and how they are used -- are described below.

Anti-reflection coatings

When white light is incident normally on a glass plate, about 4% of the incident light intensity is reflected back from each of the surfaces of the plate; i.e., about 8% of the incident light intensity is reflected back and so about 92% of the incident light intensity is transmitted. This can cause loss of intensity in optical instruments like cameras, telescopes, microscopes, etc., which have multiple lenses and therefore several air-glass boundaries which the light from the object being viewed has to traverse before it



Uses of antireflection coatings in camera lenses, spectacle lenses and glass windows

reaches the detector/film or observer's eye. A more serious problem arises from multiple image formation by the various reflected light waves, called 'ghost images', which blur the image and reduce its resolution. Even in spectacle lenses the light from the object being observed by the wearer is reduced in intensity and the resolution of the image may be affected adversely. Besides, an observer looking at the wearer sees reflections of surrounding objects in the spectacle lenses and the eyes of the wearer are not so clearly visible. When an object is seen through a window pane from outside in broad daylight, the reflections of the surroundings are also seen and tend to blur a clear view of the object behind the window pane.

An anti-reflection coating (ARC), as its name suggests, serves to reduce the intensity of the reflected light from the surface of the substrate on which it is deposited. These are perhaps the most commonly used optical coatings, in practically all optical instruments like cameras, telescopes, microscopes, projectors, etc. ARC's are applied to the surfaces of all lenses in these instruments to cut down reflected light over the visible region, and the coated lenses often appear bluish-purple in reflection. A bunch of flowers seen through a glass pane looks strikingly different when the glass is anti-reflection coated (right hand side) as compared to uncoated glass (left hand side).

The simplest ARC is a one-layer coating that consists of a single film of specified refractive index and thickness, deposited on a substrate. It has to fulfill two conditions : (1) the refractive index of the film (n) should be equal to the square root of the refractive index of the substrate; (2) the thickness d of the film should be such that the optical thickness $n \cdot d$ should be one quarter of the wavelength of the light for which the anti-reflection coating is designed. For a typical glass substrate of refractive index 1.52, this means that the film refractive index should be 1.23. There is no suitable thin film material with such a low refractive index, and so the material generally chosen is magnesium fluoride (index 1.38) and this ARC reduces the reflected light intensity from 4% to about 1.4%. However, this reduction is only over a small range of wavelengths on either side of the design wavelength. In order to achieve anti-reflection over a wider range of wavelengths, two or more layer ARC's are used. For example, a 3-layer ARC can reduce

the reflected light intensity to less than 0.5% over almost the entire visible spectrum.

High reflectance coatings

High reflectance coatings (commonly called mirror coatings) serve the exact opposite purpose as compared to anti-reflection coatings; i.e., they reflect most of the incident light from the surface of the substrate on which they are deposited. They are used in space applications, in lasers, in the imaging optics of optical instruments like cameras, photocopiers, projectors, microfilm readers and printers, spectrophotometers, astronomical telescopes, etc.

The simplest high reflectance coatings are metallic thin film coatings, comprising films of aluminium, silver, gold, etc. They provide high reflectance from the ultraviolet through the visible to the far infrared region. For improved protection from environmental and handling hazards, the metal films are often overcoated with thin metal oxide films of Al_2O_3 , SiO_2 , etc. Aluminium coatings are very useful as front surface mirrors since they are cheap, easily deposited and have high reflectance from the ultraviolet to the far infrared region. They adhere well to glass and plastic substrates, usually do not tarnish and are used for the fabrication of most high reflectors used in optical instruments. Silver coatings provide the maximum uniformly high reflectance (nearly 98%) in the visible and infrared regions. However, as compared to aluminium they are expensive, besides being rather soft with poor adhesion to glass. Also, they get easily tarnished in air due to sulphide formation which drastically reduces their reflectance. Gold coatings have a reflectance of about 95% in the infrared region and are used in laser mirrors for carbon dioxide lasers, which operate at $10.6 \mu\text{m}$.

However, metallic mirror coatings have absorption losses of several percent. In lasers, the light undergoes multiple reflections from two mirrors and successive reflections magnify the effects of absorption. One of the mirrors should have a reflectance of close to 100% and the other mirror should be slightly transparent with negligible absorption losses. So lasers usually use all-dielectric multilayer coatings comprising films of transparent dielectric materials in the form of a stack of alternately high and low refractive index quarter-wave thick films. When the reflected waves from the

various inter-film boundaries reach the front surface, they are all in phase, resulting in a high reflectance. However, the high reflectance region is usually over a range of $100 - 150 \text{ nm}$ only, on either side of the design wavelength. But for lasers operating at a single wavelength, or optical instruments operating over a limited wavelength range, this is sufficient. The reflectance increases with the total number of films and with greater values of the ratio of the high-to-low refractive indices. A reflectance close to 100% and absorption losses as low as 0.1% are achievable with these high-reflectance coatings.

Neutral density filter coatings

Neutral density (N.D.) filter coatings cut down the intensity of an incident light beam by a specified fraction over a fairly broad wavelength range, almost independent of the wavelength of the light, producing no changes in hues of the colours of the objects being observed. That is why they are called 'neutral density filter' coatings. They are required in optical equipment like cameras to cut down the intensity of the incident light and prevent damage to photographic films, light detectors, the human eye, etc. These generally use metallic thin films of chromium, nichrome or inconel of appropriate thicknesses, deposited on hot substrates (glass or quartz). They are effective over the ultraviolet, visible and infrared regions and are hard and durable.



A scene when viewed directly (right) and through a N.D. filter (left).

Beam-splitter coatings

A beam-splitter divides an incident beam of light into reflected and transmitted components. It finds wide use in various optical instruments like navigation equipment, microscopes, measuring instruments, film projectors, etc. A simple plate beam-splitter consists of a glass plate coated with a thin metal film that separates an incident beam into a reflected beam (R) and a transmitted

beam (T). Usually the device is used in an inclined position relative to the direction of the incident beam to separate out the reflected beam spatially from the incident beam, as shown below.

Metallic beam-splitter coatings are fairly neutral (i.e. wavelength-independent) because R and T do not change much with the wavelength of the light, but they can have quite high absorption losses.

Dielectric beam-splitter coatings are used when the incident light is weak, because they have low absorption. However, a single layer coating rarely gives equal T and R . To achieve $R \approx T$ even over a short wavelength range we have to use a multilayer coating. If R and T are to have different ratios that remain fairly constant with wavelength, then complex multilayer coatings involving 5 - 8 thin films of high and low index materials and different thicknesses are required.

Colour-selective filter coatings

These coatings are used to selectively reflect/transmit the different colours or spectral components of an incident light beam. They are of various types.

Edge filters effect an abrupt change in transmittance between the stop band (low transmittance region of the spectrum) and the pass band (high transmittance region). Their operation is based on absorption or interference or both. **Interference edge filters** have a basic structure similar to that of a high reflectance dielectric multilayer coating, with alternate quarter-wave thick layers of high and low index materials. Such a coating will have alternate pass bands and stop bands. A particular class of interference edge filters are known as **dichroic edge filters**. They are used for colour printing and colour projection applications. Their combinations can be used to produce any colour hue in any intensity.

Another class of commonly used interference edge filters include what are commonly called **hot mirrors** and **cold mirrors**. As the name suggests, hot mirror coatings exhibit high transmittance in the visible region and high reflectance in the infrared region. Similarly, cold mirror coatings exhibit high reflectance in the visible region and high transmittance in the infrared region. Efficient hot mirrors and cold mirrors

can be fabricated using multilayer stacks of high and low index dielectric materials, but they are quite complex in design. They are used widely in film projection systems and operation theatre lights to reflect away the infrared component (which produces heating) and allow only the visible light to fall upon and illuminate the film or patient, respectively.

How are thin film optical coatings deposited?

The most commonly used deposition technique for thin films is physical vapour deposition in vacuum, since it provides extremely clean conditions and enables precise control of the various deposition parameters. In vacuum evaporation, the material to be deposited (called the evaporant) is heated under vacuum (chamber pressure 10^{-6} mbar or less) till the material melts or sublimates and starts evaporating. The atoms/molecules in the vapour stream travel in practically straight lines from the source

current through it (resistive heating) or by bombarding the material with a beam of focussed, energetic electrons (electron beam heating). The entire deposition process is influenced by a number of deposition parameters such as purity and form of the source material, temperature and geometry of the evaporation source, rate of evaporation of the material, pressure and composition of the residual gas, relative orientations of the source and substrate, the nature of the substrate surface and its temperature, etc. One has to maintain quite tight control over these parameters.

The deposition of optical thin films is carried out in a vacuum coating chamber which is a cylindrical glass/stainless steel bell-jar, or a rectangular box with an opening front door having a vacuum-tight viewing window.

In order to ensure the desired accuracies in film composition, uniformity and thickness, manual monitoring and control are often inadequate. Modern plants are fully computer-controlled: the operator enters in the desired thin film sequence, the deposition parameters and thickness of each film, the transmittance / reflectance versus wavelength characteristics desired from the multilayer thin film coating, etc. The computer controls the deposition of each film in sequence until the multilayer deposition is complete. Some sophisticated thin film multilayer coatings such as ultra-narrow bandpass interference filters may comprise up to 300 individual films and their deposition may take up to 10 hours.

In conclusion, thin film multilayer optical coatings can tailor the intensities and colours (wavelengths) of the reflected and transmitted beams from a substrate according to the requirements of the user over a very wide range. However, they do involve fairly involved computer aided design programs and quite sophisticated equipment for their deposition.



Optical thin film coating plant [M/s Leybold Heraeus]

to the surface to be coated with hardly any collisions with the residual gas molecules in the chamber and get deposited on it in the form of a thin film since it is relatively cool. For materials like TiO_2 , Al_2O_3 , etc., which lose oxygen during vapour formation, the condensed film will have a different chemical composition from the coating material. Then the oxygen deficiency has to be made up by introducing oxygen into the chamber during deposition (reactive deposition). The heating of the material is effected by placing the material on a filament or in a boat of a metal like molybdenum, tantalum or tungsten and heating it by passing an electric

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Sleep Apnoea

The Curious Stop-Start-Snorty Breathing in Sleep

Sleep apnoea is a potentially serious sleep disorder. It is a temporary cessation of breathing during sleep. Classically, those who suffer from this condition record breathing stoppages for at least 10 seconds at least five times an hour and following this brief lull, quickly begin to breathe again. The mild version of sleep apnoea causes few symptoms, but a severe disorder may lead to low oxygen levels, which can cause serious symptoms.

The disorder is most common in people who smoke, drink alcohol, or are overweight. It may occur at high altitudes. The middle-aged and older adults and those having a block in the breathing tract, an abnormally small throat opening, or a neurological disorder, are particularly liable to develop sleep apnoea. However, the disorder can affect anybody, sometimes even children.



And if tonight my soul may find her peace
in sleep, and sink in good oblivion,
and in the morning wake like a new-opened flower
then I have been dipped again in God, and new-created.
—D H Lawrence
Shadows



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In children, enlarged tonsils or enlarged adenoids are the most common cause of obstructive sleep apnoea in children.

Central sleep apnoea

In this rare type, the region of the brain and the nerves that regulate breathing do not function normally, and this causes the disorder. Causes of central sleep apnoea include brain damage following a head injury or a stroke.

Risk factors

Anyone can develop obstructive sleep apnoea. However, certain factors put

you at increased risk, including:

Being overweight

More than half of those with obstructive sleep apnoea are overweight. Fat deposits around your upper airway may obstruct your breathing. However, not everyone who has obstructive sleep apnoea is overweight and vice versa. Thin people can develop the disorder, too.

Being a smoker

Smokers are more likely to have obstructive sleep apnoea.

Using alcohol, sedatives or tranquillisers

These substances relax the muscles in your throat.

Having a large neck

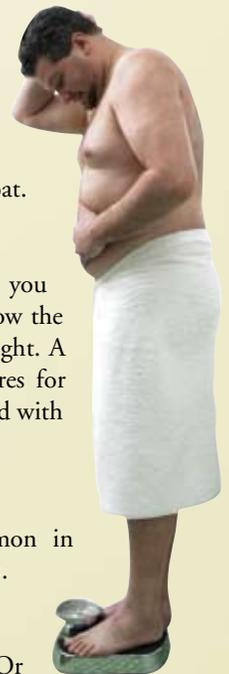
The size of your neck may indicate whether you have an increased risk. A thick neck may narrow the airway and may be an indication of excess weight. A neck circumference greater than 43 centimetres for men and 38 centimetres for women is associated with an increased risk of obstructive sleep apnoea.

Having high blood pressure

Obstructive sleep apnoea is relatively common in people with high blood pressure (hypertension).

Having a narrowed airway

You may inherit a naturally narrow throat. Or



Types of sleep apnoea

Sleep apnoea can be divided into two types: obstructive sleep apnoea, which is common and caused by the blockage of the airway; and central sleep apnoea, which is rare and caused by a problem with the nerves that control breathing.

Obstructive sleep apnoea

This condition occurs when the muscles in the back of your throat relax too much to allow normal breathing. These muscles support structures including the soft palate, the uvula — a triangular piece of tissue hanging from the soft palate, the tonsils, and the tongue.

When the muscles relax, your airway narrows or closes as you breathe in and breathing may be inadequate for 10 to 20 seconds. This may lower the level of oxygen in your blood. Your brain senses this impaired breathing and briefly rouses you from sleep so that you can reopen your airway. This awakening is usually so brief that you don't remember it.

You can awaken with a transient shortness of breath that corrects itself quickly, within one or two deep breaths, although this sequence is rare. You may make a snorting, choking or gasping sound. This pattern can repeat itself five to 30 times or more each hour, all night long. These disruptions impair your ability to reach the desired deep, restful phases of sleep, and you'll probably feel sleepy during your waking hours.

Being overweight particularly around the neck area or having a large tongue or a small mouth can also cause or contribute to the obstruction. Men aged between 40 and 60 are the typical sufferers.

your tonsils or adenoids may become enlarged, which can block your airway.

Having chronic nasal congestion

Obstructive sleep apnoea occurs twice as often in those who have consistent nasal congestion at night, regardless of the cause. This may be due to narrowed airways.

Having diabetes

Obstructive sleep apnoea is three times more common in people who have diabetes.

Having a family history of sleep apnoea

If you have family members with obstructive sleep apnoea, you may be at increased risk.

Being male

In general, men are twice as likely to have obstructive sleep apnoea.

Being older

Obstructive sleep apnoea occurs two to three times more often in adults older than 65.

Being postmenopausal

A woman's risk appears to increase after menopause.

Symptoms

The symptoms of obstructive sleep apnoea develop gradually, and it may be a partner or another member of your family who first notices your disturbed sleep. Central sleep apnoea may develop suddenly, depending on the cause.

The symptoms of sleep apnoea may include:

- Excessive daytime sleepiness (hypersomnia)
- Restless, unrefreshing sleep
- Poor memory and concentration
- Morning headache
- Loud snoring
- Observed episodes of breathing cessation during sleep
- Abrupt awakenings accompanied by shortness of breath
- Awakening with a dry mouth or sore throat
- Difficulty staying asleep (insomnia)
- Difficult-to-control high blood pressure
- Change in personality
- Frequent passing of urine at night
- In men, impotence

Complications

Obstructive sleep apnoea is potentially a serious medical condition. Complications may include:

Heart and circulatory problems

Sudden drops in blood oxygen levels that occur during obstructive sleep apnoea increase blood pressure and strain the cardiovascular

system. Many people with obstructive sleep apnoea develop high blood pressure, which raises the risk of heart failure and stroke. The more severe the obstructive sleep apnoea, the greater the risk of high blood pressure.

People with obstructive sleep apnoea are also much more likely to develop abnormal heart rhythms such as atrial fibrillation. If there is underlying heart disease, these repeated multiple episodes of low blood oxygen (hypoxia or hypoxemia) could lead to sudden death from a cardiac event.

Daytime fatigue

The repeated awakenings associated with obstructive sleep apnoea make normal, restorative sleep impossible. People with obstructive sleep apnoea often experience severe daytime drowsiness, fatigue and irritability. They may have difficulty concentrating and find themselves falling asleep at work, while watching TV or even when driving. This may result in accidents.

Children and young people with obstructive sleep apnoea may do poorly in school, have reduced mental development or have behaviour problems. Treatment of obstructive sleep apnoea can improve these symptoms, restoring alertness and improving quality of life.

Psychological problems

People with obstructive sleep apnoea may also complain of memory problems, morning headaches, mood swings or feelings of depression, and a need to urinate frequently at night (nocturia).

Eye problems

Some research has found a connection between obstructive sleep apnoea and certain eye conditions, such as glaucoma and optic nerve swelling (papilledema). Successful treatment of the sleep disorder usually resolves the eye condition, as well.

Difficulties with spouse/room partners

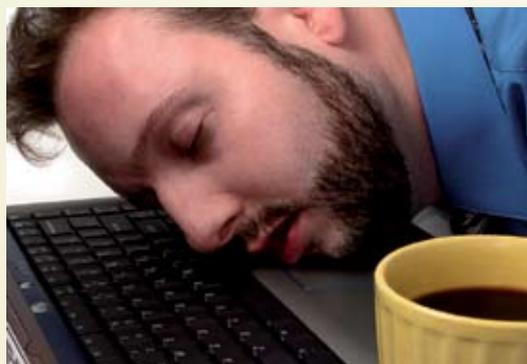
Loud snoring can keep those around you from getting good rest. This may eventually disrupt your relationship. It is not uncommon for a spouse/room partner to choose to sleep in another room. Many bed partners of people who snore are sleep deprived as well.

Risk of complications with medications and surgery

Obstructive sleep apnoea also is a concern with certain medications and general anaesthesia. If you have obstructive sleep apnoea, you may be more likely to experience complications after major surgery because you are prone to breathing problems, especially when sedated and lying on your back. Before you have surgery, tell your doctor if you have obstructive sleep apnoea. Undiagnosed obstructive sleep apnoea is risky in this situation.

When to see a doctor

Consult a doctor if you experience, or if your partner observes the following:



- Snoring loud enough to disturb your sleep or that of others
- Shortness of breath that awakens you from sleep
- Intermittent pauses in your breathing during sleep
- Excessive daytime drowsiness, which may cause you to fall asleep while you're working, watching television or even driving a vehicle

Many people don't think of snoring as a sign of something potentially serious, and not everyone who snores has obstructive sleep apnoea. But be sure to talk to your doctor if you experience loud snoring, especially snoring that's punctuated by periods of silence. With obstructive sleep apnoea, snoring typically is loudest when you sleep on your back, and it quiets when you turn on your side.

Ask your doctor about any sleep problem that leaves you chronically fatigued, sleepy and irritable. Excessive daytime drowsiness (hypersomnia) may be due to other disorders, such as narcolepsy.

Going for a doctor's appointment

If you suspect that you have obstructive sleep apnoea, you will likely first see your family doctor. Your doctor may refer you to a sleep specialist.

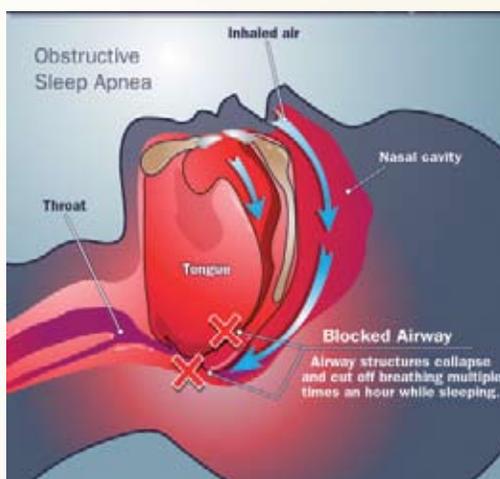
It is a good idea to be well prepared for your appointment. Here is some information to help you get ready for your appointment, and to know what to expect from your doctor.

Things to do

When you make your appointment with a sleep doctor, ask if there is anything you need to do in advance, such as keeping a sleep diary. In a sleep diary, you record your sleep patterns — bedtime, number of hours slept, night-time awakenings and awake time — as well as your daily routine, naps and how you feel during the day. You may be asked to record a sleep diary for one to two weeks.

Write down any symptoms you're experiencing, including any that may seem unrelated to the reason for your appointment. Write down key personal information, including new or ongoing health problems, major stresses or recent life changes. Make a list of all medications, vitamins or supplements you're taking. Take your spouse/bed partner along, if possible. Your doctor may want to talk to your partner to learn more about how much and how well you're sleeping. Write down questions to ask your doctor. Preparing a list of questions can help you make the most of your time with your doctor.

For obstructive sleep apnoea, some basic questions to ask your doctor include: What is likely causing my symptoms? Other than the most likely cause, what are other possible causes for my symptoms? Is my condition likely temporary or chronic? What kinds of tests do I need? What is the best course of action? Are there any restrictions that I need to follow? I have other health conditions. How can I best manage them together? Don't hesitate to ask other questions that occur to you.



What to expect from your doctor

A key part of the evaluation of obstructive sleep apnoea is a detailed history, meaning your doctor will ask you many questions. These may include: When did you begin experiencing symptoms? Have your symptoms been continuous or occasional? Do you snore? If so, does your snoring disrupt anyone else's sleep? How often do you snore? Do you snore in all sleep positions or just when sleeping on your back? Do you ever snore, snort, gasp or choke yourself awake? Has anyone ever seen you stop breathing during sleep? How refreshed do you feel when you wake up?

Do you experience headache or dry mouth upon awakening? Are you tired during the day? Do you doze off or have trouble staying awake while sitting quietly or driving? Do you nap during the day? Do you have any family members with sleep problems? Do you use tobacco or drink alcohol? What medications do you take?

All of these questions are relevant to your problem, and you should answer them truthfully.

Immediate measures to take

Till such time that a definite treatment is initiated, try taking a few general measures. These may help alleviate the obstructive sleep apnoea, and include:

Trying to sleep on your side

Most forms of obstructive sleep apnoea are milder when you sleep on your side rather than on your back or your tummy.

Avoid drinking alcohol close to bedtime

Alcohol worsens obstructive sleep apnoea by relaxing the muscles at the back of the throat. Taking a daily nightcap is therefore best avoided.

Avoid sleeping pills

Sleeping pills also have the same problem as alcohol. They relax the muscles at the back of the throat and worsen obstructive sleep apnoea.

If you're drowsy, avoid driving

If you have obstructive sleep apnoea you may be abnormally sleepy, which can put you at higher risk of motor vehicle accidents. To be safe, schedule rest breaks. At times, a close friend or family member might tell you that you appear sleepier than you feel. If this is true, try to avoid driving.

Try and lose weight

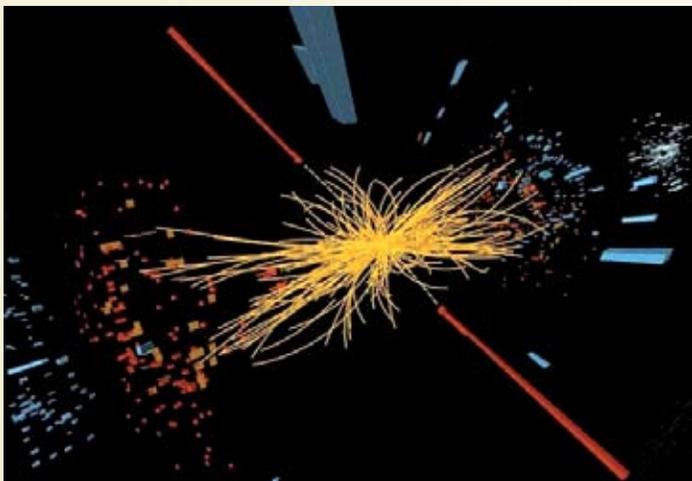
Losing weight is healthy if you have obstructive sleep apnoea. Too much weight around the neck reduces the diameter of the upper air passage. By losing weight, you may find relief if that be the case. ■

Next month: Sleep Apnoea—
Diagnosis, Remedies and Treatments

Recent developments in science and technology

Tentative evidence of Higgs boson found

Physicists working with the Large Hadron Collider at CERN, Geneva have announced that they have got the first indications of the existence of the Higgs boson or Higgs particle from the two giant particle detectors



Two large teams of scientists working with two detectors at LHC separately saw what they believe are telltale tracks of the Higgs particle.

– the ATLAS and CMS at LHC. Two large teams of scientists working with the two detectors separately saw what they believe are telltale tracks of the Higgs particle in the aftermath of about 400 trillion proton collisions carried out since January 2011. The indications came in the forms of particles with a certain energy detected by the two teams. The announcement was made by the teams at CERN on 13 December (*Science* 16 December 2011).

Mass of energetic particles is usually expressed in terms of energy. According to Einstein's theory energy and mass are equivalent and one can be converted into the other according to the equation $E = mc^2$, where E is the energy, m the mass and c the velocity of light. Hence mass m can be expressed as E/c^2 . As the speed of light is a constant, it can be assigned a value of 1, making energy and mass equivalent. Incidentally, Higgs bosons, if they exist, are massive. The ATLAS (A large Toroidal LHC Apparatus) experiment at LHC revealed evidence that the Higgs particle has a mass of about 126 gigaelectronvolts or GeV.

Physicists working on the CMS (Compact Muon Solenoid) experiment released similar evidence for a particle with a mass of about 124 GeV. If we remember that a proton has a mass of 0.938 GeV, in relative terms, the Higgs boson is about 130 times as heavy as the proton.

Here it must be mentioned that particles with a mass of this magnitude could be created only at a powerful particle accelerator like the LHC, which accelerates protons to a velocity of 99.999 per cent the speed of light and makes them collide head-on, releasing a total energy of some 14 trillion electron volts or teraelectronvolts (TeV). It replicates the conditions of the first

billionth of a second after the universe began. Part of this released energy can transform into particles as heavy as the Higgs.

The Higgs boson is a subatomic particle that is predicted to exist according to the Standard Model – a quantum field theory, which is devised to explain how subatomic particles interact with each other. Built up over the last 70 years, the Standard

	Fermions			Bosons	
Quarks	u up	c colour	t top	γ photon	Force carriers
	d down	s strange	b bottom	Z z-boson	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W w-boson	
Leptons	e electron	μ muon	τ tau	g gluon	
	Yet to be confirmed			Higgs boson	

The Standard Model



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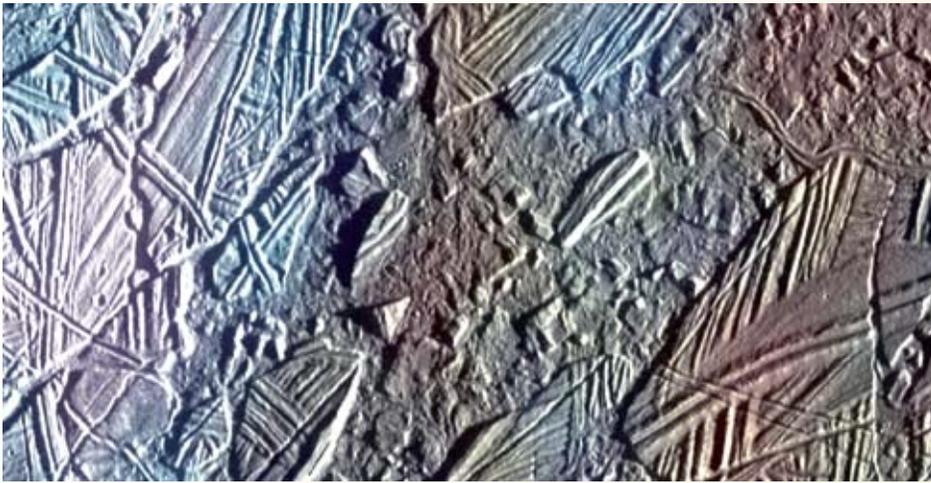
Model is the most successful attempt yet to create a single theory describing the forces and particles that make up our universe. The Standard Model describes all the elementary particles as well as the strong, weak, and electromagnetic forces. In the Standard Model, there are 16 fundamental particles – 12 particles of matter and 4 force carrier particles. An additional particle, known as the Higgs boson, is included to explain why the others (except photon and gluon, which have no mass) have mass. It is predicted to be the heaviest of the fundamental particles.

The Higgs boson was proposed as a mechanism to explain mass by six physicists, including the British physicist Peter Higgs, in 1964. Particles acquire their mass, it is theorised, through interactions with an all-pervading field, called the Higgs field, which is carried by the Higgs boson. But till date the elusive particle has not been discovered.

Scientists say that two experiments at the LHC saw hints of the Higgs at the same mass, which is quite significant. But they are not yet calling it a 'discovery' because they do not have sufficient data yet. Another complicating factor is that these tantalising hints consist only of a handful of events among the billions of particle collisions analysed at the LHC. However, if it exists, Higgs boson would be very short-lived, quickly decaying – or transforming – into more stable particles. There are several different ways this can happen, which provides scientists with different routes to search for the boson.

Subsurface ocean on Europa

Jupiter's innermost icy moon Europa is slightly smaller than the Earth's Moon. Like the Earth, Europa is thought to have an iron core, a rocky mantle and an ice covered surface. During several fly-bys in the 1990s NASA's *Galileo* spacecraft discovered geologic features on the surface of Europa that pointed to the existence of liquid water

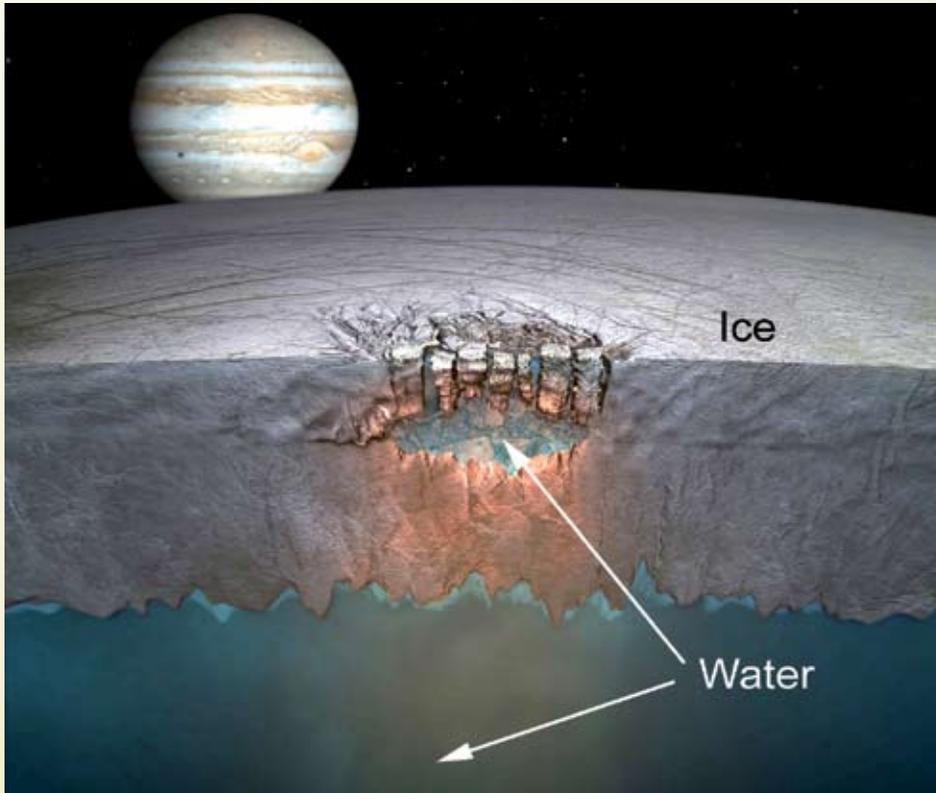


Close-up of Europa's icy surface showing chaos terrains. (Credit: NASA)

below the moon's icy crust. The images showed plains of bright ice, cracks that run to the horizon, and dark patches that likely contain both ice and dirt. While data from various instruments on the *Galileo* spacecraft indicated that liquid water might exist below the icy surface, no conclusive proof was found till recently.

Now, scientists have concluded, based on images of shifting surface features

and data from a magnetometer aboard the *Galileo* spacecraft, that Europa hides a liquid ocean beneath its icy crust. But just how thick the outer ice layer is remains a mystery. Some researchers think it could be just a few kilometres deep; other scientists think it is much thicker, maybe as much as 30 km deep. Scientists also hypothesise that hydrothermal vents might heat the oceans from below and provide a suitable environment for life



Scientists speculate the existence of a vast ocean below Europa's icy shell. The cracked surface shows up as chaos terrains on the surface. (Image Credit: Britney Schmidt / Dead Pixel FX / Univ. of Texas at Austin)

(*Nature*, 24 November 2011 | doi:10.1038/nature10608). The study was done by B.E. Schmidt, a postdoctoral fellow at the University of Texas at Austin's Institute for Geophysics, and his colleagues.

In arriving at the conclusion the scientists focussed on *Galileo* spacecraft images of two roughly circular, bumpy features on Europa's surface called chaos terrains. Based on similar processes seen here on Earth — on ice shelves and under glaciers overlaying volcanoes — they developed a four-step model to explain how the features form on Europa.

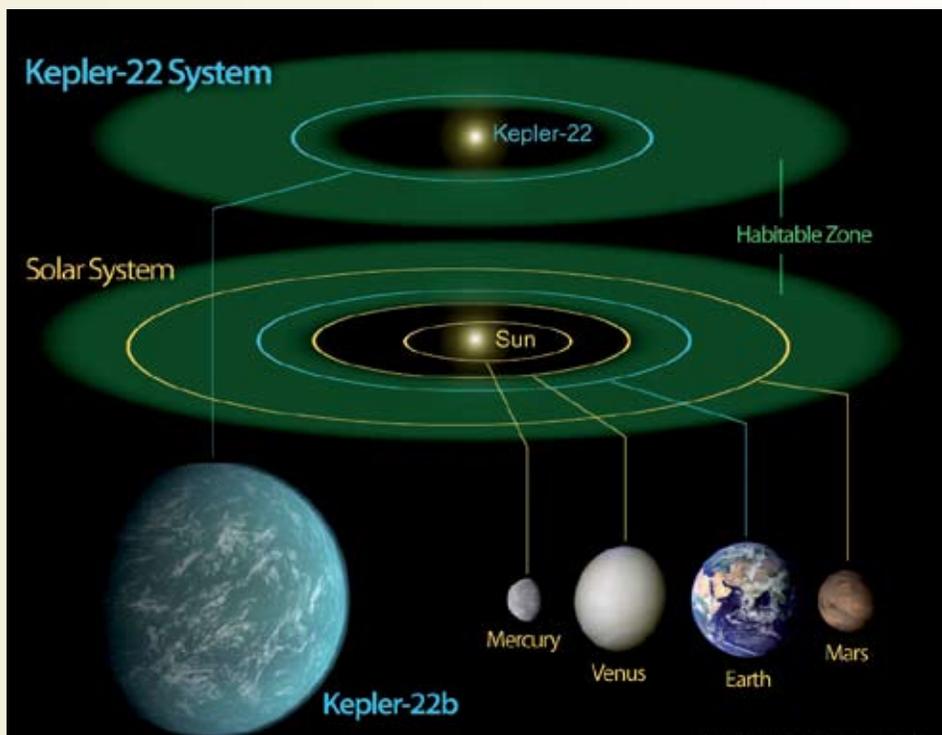
According to the scientists, Europa's ocean is deep enough to cover the whole surface of the moon and contains more liquid water than all of Earth's oceans combined. However, being far from the Sun, the ocean surface is completely frozen.

More significantly, the study showed that Europa's surface is still active. The data suggest there is significant exchange between Europa's icy shell and the ocean beneath. This, according to the scientists, could mean that Europa's global subsurface ocean is a potential habitat for life outside Earth in our solar system. But any confirmation of the presence of life could come only from a future spacecraft mission designed to probe below the ice shell.

Kepler discovers first Earth-like planet

NASA's *Kepler* spacecraft has discovered the first Earth-like planet yet outside our solar system. The new planet is located within the "habitable zone" of a Sun-like star where liquid water could exist on a planet's surface. The newly confirmed planet, named Kepler-22b, is about 2.4 times the radius of Earth and is the smallest yet found to orbit in the middle of the habitable zone of a star similar to our Sun. Scientists do not know yet if the new planet has a predominantly rocky, gaseous or liquid composition, but its discovery is considered a significant step in the ongoing search for Earth-like planets. Though Kepler-22b is not the first such planet to be detected in recent years, it is the first one orbiting a star similar to our Sun and at a distance where it is capable of possessing liquid water, which most scientists regard as essential for life to exist.

To look for planets *Kepler* routinely measures dips in the brightness of more than 150,000 stars to search for planets that cross



This diagram compares our own solar system to Kepler-22, a star system containing the first “habitable zone” planet discovered by NASA’s Kepler mission. (Image credit: NASA/Ames/JPL-Caltech)

in front, or “transit,” the host stars. *Kepler* requires at least three transits to verify a signal as a planet. Candidates require follow-up observations to verify they are actual planets. The *Kepler* science team uses ground-based telescopes and the *Spitzer Space Telescope* to review observations on planet candidates the *Kepler* spacecraft finds. The star field that *Kepler* observes in the constellations Cygnus and Lyra can only be seen from ground-based observatories between March and September every year. The data from these other observations help determine which candidates can be validated as planets. Of the 54 habitable zone planet candidates reported in February 2011, Kepler-22b is the first to be confirmed.

Kepler-22b is located 600 light-years away. While the planet is larger than Earth, its orbit of 290 days around a Sun-like star resembles that of our world. The temperature on the newly announced planet could be just right for life — about 22°C, a perfect spring day on Earth. The planet’s host star belongs to the same class as our Sun, called G-type, although it is slightly smaller and cooler. According to the project scientists, Kepler-22b marks the best candidate yet for a life-bearing world beyond our solar system.

So far the *Kepler* telescope has spotted 2,326 candidate planets outside our solar system with 139 of them potentially habitable ones. Even though the confirmed Kepler-22b is a bit big, it is still smaller than most of the other candidates. It is closest to Earth in size, temperature and star than either of the two previously announced planets in the zone.

New compound to target drug-resistant bacteria

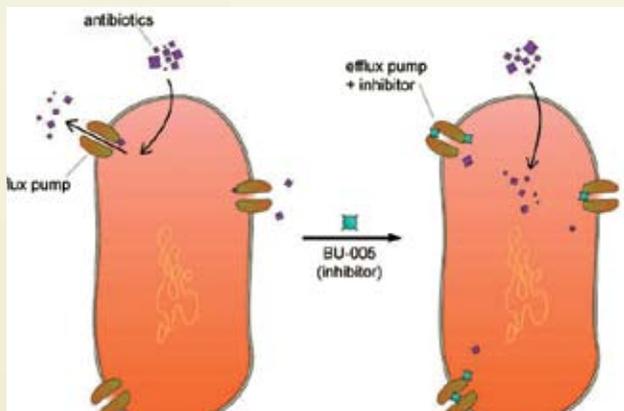
Drug resistance has become a serious health problem in many countries and more and more bacteria are becoming resistant to even the most powerful antibiotics, mainly as a result of overuse and misuse of antibiotics. Scientists have been making serious efforts to fight drug resistance but with little success. Recently researchers have created a new compound that can make drug-resistant bacteria again susceptible to antibiotics.

Bacteria employ a

mechanism called efflux pumps to expel antibacterial drugs to make them ineffective. Sitting in the cell walls or membranes of bacteria, efflux pumps are proteins that spot and expel drugs that breach those membranes to enter the bacteria. In some cases, the pumps have become so advanced they can recognise and expel drugs with totally different structures and mechanisms. Jason K. Sello, assistant professor of chemistry at Brown University in Providence, Rhode Island in the US, and colleagues, have developed a technique to block the efflux pumps of bacteria by using a synthetic compound called BU-005, making them vulnerable again to antibiotics. In experimental studies, the compound prevented the bacterium *Streptomyces coelicolor* (a relative of the human pathogen *Mycobacterium tuberculosis*) from expelling chloramphenicol, one of the oldest antibacterial drugs (*Bioorganic and Medicinal Chemistry*, 15 December 2011).

BU-005 belongs to a class of compounds called C-capped dipeptides that appear to disarm a family of drug-efflux pumps used by Gram-positive bacteria, which include the dangerous MRSA and tuberculosis strains. Until the recent discovery, scientists thought C-capped dipeptides only worked against drug-efflux pumps used by Gram-negative bacteria such as *E. coli*, *Salmonella*, *Pseudomonas*, *Helicobacter*, etc.

Sello and his team selected BU-005 from a collection of nearly 100 C-capped dipeptides they had prepared and tested. They have also developed a new, shorter, two-step process to screen a collection of structurally diverse C-capped dipeptides for compounds with new or enhanced activities.



Bacteria use efflux pumps to rid themselves of antibiotics, becoming drug-resistant until newer antibiotics are developed. By blocking those pumps with an inhibitor, researchers can restore the potency of old antibiotics to which bacteria have become resistant. (Credit: Sello Lab/Brown University)

Requirement of Editors and Translators for 'Dream 2047'

Continued from page 2 (Editorial)

Vigyan Prasar (VP), a national institution under the Department of Science & Technology, Government of India for science and technology communication amongst several activities brings out a monthly bilingual popular science magazine "Dream 2047". Please visit our web (www.vigyanprasar.gov.in) to peruse recent issues. Present circulation of this magazine is 50000. Scientific institutes, science clubs, newspapers & magazines and individuals interested in S & T communication subscribe to this magazine. VP invites applications from interested and experienced individuals to edit "Dream 2047" (Hindi, English). The job will be on a month to month basis. Description is given below:

- (i) Editing of English version of the magazine.
- (ii) Editing of Hindi version of the magazine.
- (iii) Online editing

VP is also seeking applications from interested and experienced individuals to translate popular scientific write-ups from English to Hindi and Hindi to English.

Token honorarium as per norms is paid on completion of each assignment.

Last date of submission of application: 15 February 2012

Interested individuals are requested to send their detailed bio-data along with the recent passport size photograph to the following address:



Registrar, Vigyan Prasar

A-50, Institutional Area, Sector-62, NOIDA (201309)

Phone: 91-120-240 4430,35 Fax: 91-120-2404437

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There is a long way to go before traditional chemistry is replaced by green chemistry. It should be emphasised that green chemistry is nothing but more challenging and inspiring chemistry. There is an unlimited scope for creativity in green chemistry and this needs to be popularised among students and researchers. To make green chemistry a reality in near future it will require concerted action of agencies funding research in chemistry, regulatory bodies for monitoring pollution, industries, and educational and research institutions. We should remember that the targets of green chemistry are laudable and if achieved we will be closer to sustainable development. However, even green chemistry is not the ultimate solver of every problem that needs to be solved before achieving sustainable development. As someone has argued, most of the principles of green chemistry are aimed at being less bad. A long-term positive goal should be kept in mind. Chemistry has a very challenging future full of creativity. The challenges before the chemists of today and tomorrow should be debated in schools, colleges and universities and among general public.

The future of chemistry will be bright only if more and more bright young students get attracted to this important discipline of science. Unfortunately, as it is evident from our limited interaction with large number of students and teachers across the country, students in schools find the teaching of chemistry boring and uninspiring. This is mainly because despite chemistry being basically an experimental science, students are not given enough opportunities to observe and conduct experiments. This situation needs to be changed. This can be done without any major investment. A properly conducted experiment can easily attract the attention and fire the imagination of high school students. There are other ways to make teaching and learning chemistry a fun and exciting experience. While teaching chemistry many interesting anecdotes associated with development of chemistry as a scientific discipline should be narrated. Teaching of chemistry should be made relevant to the home, the environment and future changes and developments within the society. This was a message the IYC-2011 wanted to convey. Science communicators have an important role in taking the message far and wide. ■

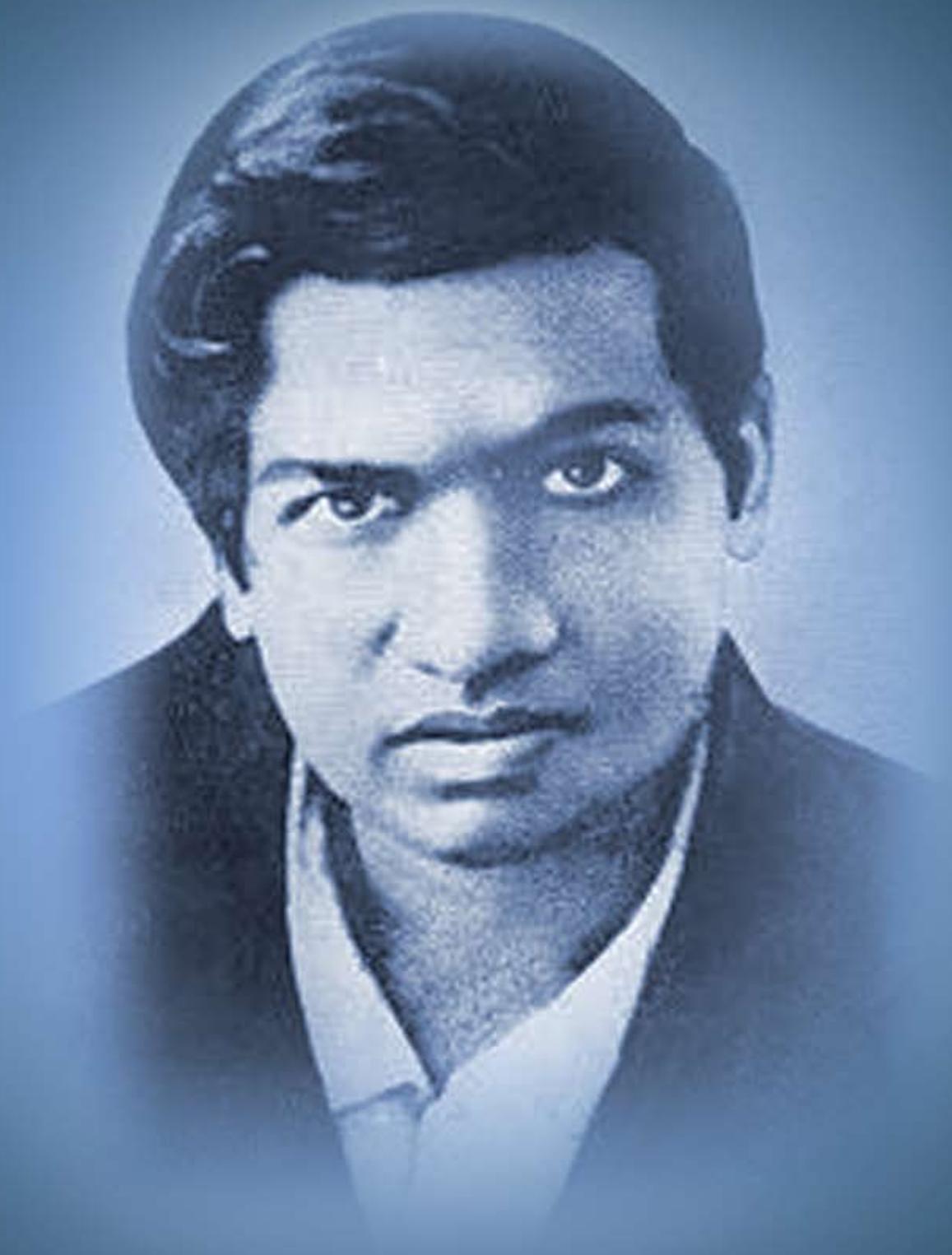
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I, Subodh Mahanti do hereby declare that to the best of my knowledge and belief, facts mentioned above are true.

Sd/-
Subodh Mahanti



Srinivasa Ramanujan
(22 December 1887–26 April 1920)