Registered with the Registrar of Newspapers of India: R.N. 70269/98

ISSN : 0972-169X
Postal Registration No. : DL-11360/2005

Monthly Newsletter of Vigyan Prasar

DREAM 2047

March 2005 Vol. 6 No. 6 Price: Rs. 5.00

VP News

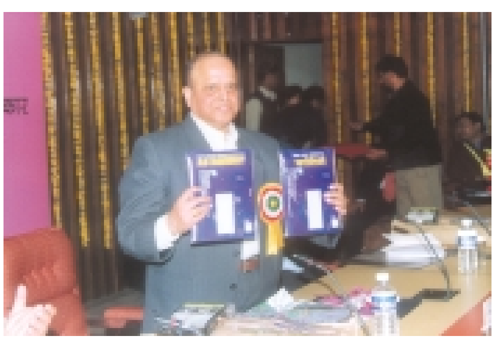
Release of Interactive DVD on Vigyan Rail and Astronomy Kit

Shri Kapil Sibal, Hon'ble Minister of State (Independent Charge) for Science & Technology and Ocean Development, releasing the DVD "Vigyan Rail – Science Exhibition on Wheels" Prof. V.S. Ramamurthy also seen.

Befitting the National Science Day, Vigyan Prasar released an interactive DVD "Vigyan Rail – Science Exhibition on Wheels" and an activity kit on "Astronomy" on February 27, 2005 at Technology Bhawan, Department of Science and Techniology.

Shri Kapil Sibal, Hon'ble Minister of State (Independent Charge) for Science & Technology and Ocean Development, released the DVD. Present on the occasion were

contd. on page....20



Dr. K. Kasturirangan, Hon'ble Member, Rajya Sabha, and former Chairman ISRO, releasing the kit on Astronomy

Inside

Dr. Harikrishna Devsare, *Consultant, Vigyan Prasar, receiving the NCSTC National award for Best Efforts on Science and Technology popularization among Children for the year 2004. The award was conferred on him by Shri Kapil Sibal, Hon'ble Minister of State (Independent Charge) for Science & Technology and Ocean Development on February 27, 2004 at the National Science Day Function at Technology Bhawan, New Delhi. The award consists of Rs. 100,000 (Rupees one lakh only) in cash, a memento and a citation. Also seen in the picture (from L to R) Prof. K. Kasturirangan and Prof. V.S. Ramamurthy. Dr. Devsare was also conferred Sahityakar Samman by Hindi Academy, Govt. of Delhi on 06 March 2005.*

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

Published and Printed by Dr. Subodh Mahanti on behalf of Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi - 110 016 & Printed at S. Narayan & Sons, B-88, Okhla Indl. Area, Phase - II, New Delhi - 110 020

Editor : Dr. V.B. Kamble

Regaining the Past Glory

In a recent issue, *New Scientist,* the famous British science magazine, has published a special report on India. It states that India is poised to be the next knowledge super-power and a world-beating nation in the making. This sounds too good to be true especially when we consider our country to be a nation of a billion plus presenting curious contrasts. We are the world's eleventh largest economy though we have more than a quarter of the world's poorest people. We are the sixth largest emitter of carbon dioxide (perhaps a dubious measure of a country's progress!), yet hundreds of millions of people do not have a steady electrical supply. We have 250 universities catering to 32 lakh science students, and still 39 per cent of adult Indian cannot read or write. And yet, these contradictory sets of images are real! Then, how is it that *New Scientist* visualizes India to be the next knowledge super-power?

There is no gainsaying the fact that a visible change has taken place in India over the past five years in the social and economic context. More than hundred information technology and science-based firms have established their R&D labs in India. These are all hi-tech companies, which have come to India to find innovators whose ideas are expected to take the world by storm. *New Scientist* suggests that the changes in India have indeed been profound. The impact of Information Technology (IT) industry on the economy has been enormous. During the last year alone, IT contributed 3 per cent of India's gross domestic product (GDP). Incidentally, GDP for a country is defined as the total value of all goods and services produced within the country per year. Further, India is steadily emerging a world-leader in several hi-tech areas like pharmaceuticals and biotech.

Today, India's space programme is largely self-sufficient and aims to soon be completely independent of the foreign support. Our latest rocket, the geosynchronous launch vehicle is able to lift large satellites into geostationary orbit. Only a few months ago, GSLV launched a two-tonne EduSat, the world's first satellite dedicated to providing support for educational projects. The proposed Astrosat and the Moon Mission are the other missions making headlines. Genetically modified crops have already started making an entry into the fields that can beat diseases which traditional breeding has failed to tackle. The number of mobile phone users in India out-numbered fixed line subscribers in October 2004. Today, the number of mobile phone subscribers is close to 52 million. Bharat Biotech sells the hepatitis B vaccine for about Rs. 10 per shot, which cost earlier nearly 20 times more. This became possible through a new and efficient process developed in India. Indian-made drugs have led the fight against AIDS even in Africa. The Giant Metre-wave Radio Telescope – the world's largest low-frequency radio telescope and India's biggest basic science project is already attracting astronomers all-over the world.

The gradual transformation in social and economic conditions that science and technology has brought about in the country cannot be over-emphasized. Fishermen have begun using mobile phones to price their catch before they make it to the port. So do the farmers before they send their produce to the market. Technology companies are extending Internet connections to the remotest of locations. We have already begun using homegrown space technology to improve literacy skills and impart education in far-flung areas. True, the efforts are piece-meal and the progress slow, but technology can speed-up the process of social and economic transformation. We cannot be industrially and economically advanced unless we are technologically advanced. But, what role does science have to play in the process of development? We cannot be technologically advanced unless we are scientifically advanced – as told by Professor C.N.R. Rao to *New Scientist*.

The report quotes Professor R.A. Mashelkar, DG, CSIR, about the need to revamp the university system. Today, we are producing about 5,000 Ph.D.s in science. We should be producing five times more, he says. According to Professor C.N.R. Rao, the changes described above will be for nothing if students chose not to study science. He points to the increasing numbers in recent years that have chosen to study IT and Management. This trend has had a negative impact on science, according to him. Professor Mashelkar hopes that as science-based companies grow and demands for the fresh-blood increases, salaries will rise and more students will opt for science.

Although India is on the threshold of becoming a knowledge superpower, *New Scientist* also points out the gulf between the academic world and industry stating that the notion that scientific ideas lead to technology and from there to wealth is not widespread in India. However, since 1991 with economic liberalization, the situation has considerably changed. With competition from multi-nationals, Indian companies are now forced to come up with new ideas, and academics are prompted to promote their ideas to industries. Until recently, India did not have a

(Contd. on page ....30)

Editor : V.B. Kamble

Address for correspondence : Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi-110 016; Tel : 26967532; Fax : 26965986
e-mail : vigyan@hub.nic.in
website : http://www.vigyanprasar.com

James Clerk Maxwell

The Creator of the Unified Theory of Electromagnetism

❑ Subodh Mahanti
e-mail : mahantisubodh@yahoo.com

"The greatest change in the axiomatic basis of physics—in other words, of our conception of the structure of reality—since Newton laid the foundation of theoretical physics was brought about by Faraday's and Maxwell's work on electromagnetic phenomena…before Maxwell people conceived of physical reality—in so far as it is supposed to represent events in nature—as material points, whose changes consist exclusively of motions, which are subject to total differential equations. After Maxwell they conceived reality as represented by continuous fields, not mechanically explicable, which are subject to partial differential equations. This change in conception of reality is the most profound and fruitful one that has come to physics since Newton…"

Albert Einstein

"The unification of electricity, magnetism and light represented the crowning achievement of classical physics in the nineteenth century. Maxwell's equations give us the mathematical basis necessary for understanding electromagnetism in just the same way as Newton's laws of motion and of universal gravitation enable us to comprehend mechanics. The areas of applications covered by Maxwell's theory are remarkable. They include all electromagnetic and optical devices such as electric motors, electric generators, radio, television, radar, computers, microscopes, telescopes and telecommunication systems."

Mauro Dardo in Nobel Laureates and Twentieth Century Physics, Cambridge University Press, 2004

"Like Einstein, and in contrast to Newton or Faraday, Maxwell made his enormous advances in physics without excessive mental strain. He excelled in his sure intuition in physics, in applying visual models or mathematical methods without being tied to them, and above all in freeing himself from preconception and in exercising his creative imaginations.

The Cambridge Dictionary of Scientists (2nd Edition, 2002)

Maxwell was the most able theoretical physicist of the nineteenth century. In fact he is even acclaimed as the father of modern physics. He was a perfect complementary to Michael Faraday, the greatest experimentalist of the nineteenth century. Maxwell developed a revolutionary set of four equations called general equations of the electromagnetic field that verified the existence of electromagnetic fields proposed by Michael Faraday and showed that magnetism and electricity are not two different fields but parts of the same unified field, the electromagnetic field. These equations are now called Maxwell equations. "The whole system of wireless telegraphy is a development of the original and surprising theory of Clerk Maxwell, embodying in mathematical form the experimental researches of Faraday." Maxwell postulated that light is a form of electromagnetic radiation exerting pressure and carrying momentum. Maxwell expounded his theory in his Treatise on Electricity and Magnetism published in 1873. The special theory of relativity, as Einstein himself stated, owes its origins to Maxwell's equations of the electromagnetic field. Maxwell is regarded as one of the founders of kinetic theory of gases.

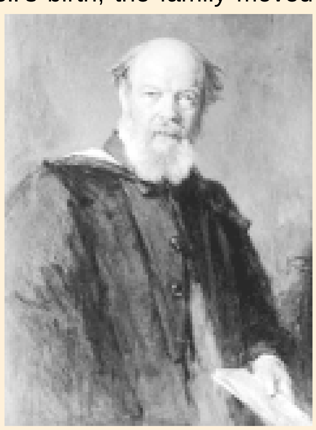
James Clerk Maxwell

Maxwell was the first Cavendish Professor of Experimental Physics in the Cambridge University. In 1874 Maxwell established the Cavendish Laboratory, a unique institution in physics, which was subsequently to be headed by a succession of men of genius. The Laboratory produced graduates who dominated physics for generations. Maxwell was a shy and somewhat eccentric person.

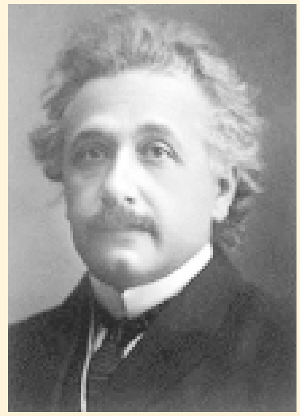
Maxwell was a deeply religious man. He was a simple man with a strong sense of humour. He was known for his devoutness and modesty. Maxwell did not live long enough to see his theories validated experimentally. He died at an early age of 48. Widespread public recognition of his contribution to science and technology came only in the last years of the nineteenth century. As days passed, the relevance of Maxwell's contribution became more and more evident. Today, the design of tools and devices for a large number of electrical technologies like radio, microwave, radar, optical communications, lasers, power generation and transmission, electronic components and so on are based on the correct understanding and application of Maxwell's equations. Even the most exiting new promising technologies like lasers, fiber-optics, induction motors and so on are heavily dependent on the application of Maxwell's theory.

Michael Faraday

Maxwell was born on June 13, 1831 in Edinburgh, Scotland. It may be noted that it was in 1831 that Michael Faraday made his most influential discovery, electromagnetic induction. Maxwell's father John Clerk had taken the name of Maxwell as heir to the estate of Glenlair in the Galloway region of Scotland. The Maxwells were comfortably well-off land owners. Maxwell's mother died when he was just eight years old. Maxwell's father, an educated man, well-versed in the law and interested in science and invention had great influence on his son's education. Shortly after Maxwell's birth, the family moved to their estate at Glenlair, where he enjoyed a country upbringing. It is said that his natural curiosity displayed at an early age. When Maxwell was just three years old, he was described as follows: "He is a very happy man, and has improved much since the weather got moderate; he has great work with doors, locks, keys etc., and 'Show me how it doos' is never out of his mouth. He also investigates the hidden course of streams and bell-wires, the way the water gets from the pond through the wall and a pend or small bridge and down a drain…" His parents had planned that he would be educated at home till the age of 13 and then he would join the Edinburgh University. But the plan could not be carried out as his mother died. He was sent to the Edinburgh Academy, Edinburgh in 1841. His friend P. G. Tait described Maxwell's school days in the following way "At school he (Maxwell) was at first regarded as shy and rather dull. He made no friendships and spent his occasional holidays in reading



P. G. Tait



Albert Einstein

old ballads, drawing curious diagrams and making rude mechanical models. This absorption in such pursuits, totally unintelligible to his schoolfellows, who were then totally ignorant of mathematics, procured him a not very complimentary nickname. About the middle of his school career however he surprised his companions by suddenly becoming one of the most brilliant among them, gaining prizes and sometimes the highest prizes for scholarship, mathematics, and English verse." His mathematical abilities were exceptional. At 15, he submitted to the Royal Society of Edinburgh a paper on the drawing of oval curves. His paper was so impressive that many members of the society felt that it could not have written by someone so young. The paper titled "On the description of oval curves, and those having a plurality of foci", was read to the Royal Society of Edinburgh on April 06, 1846.

He joined the Edinburgh University at the age of 16. At Edinburgh he first began to direct his attention to physics. In 1850, Maxwell joined the Trinity College of the Cambridge University. At Cambridge he came in contact with some of the finest mathematical and scientific minds in Britain. His tutor at Cambridge was William Hopkins. In 1855, he was elected a Fellow of the Trinity College. P. G. Tait in an article in the Proceedings of the Royal Society of Edinburgh wrote"…he brought to Cambridge in the autumn of 1850, a mass of knowledge which was really immense for so young a man, but in a state of disorder appalling to his methodical private tutor. Though the tutor was William Hopkins, the pupil to a great extent took his own way, and it may safely be said that no high wrangler of recent years ever entered the Senate-house more imperfectly trained to produce 'paying' work than did Clerk Maxwell. But by sheer strength of intellect, though with the very minimum knowledge how to use it to advantage under the conditions of the Examination, he obtained the position of Second Wrangler, and was bracketed equal with the Senior Wrangler, in the higher ordeal of the Smith's Prize." In 1854 he graduated with a degree in mathematics from Trinity College. He obtained the position of the Second Wrangler. The First

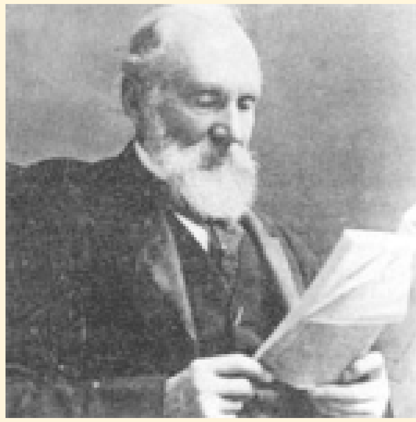
Edward John Routh

Wrangler in that year was Edward John Routh (1831-1907), the British mathematical physicist who made contribution to classical mechanics, including procedure for eliminating cyclic co-ordinates from equations of motion.

Maxwell was short of stature and hesitant to speech but nonetheless he made a deep impression on those around him. Describing Maxwell's undergraduate days, William Thomson (Lord Kelvin) wrote: "...Scholars dined together at one table. This brought Maxwell into daily contact with the most intellectual set in the College, among whom were many who attained distinction in later life. These in spite of his shyness and some eccentricities recognized his exceptional powers....The impression of power which Maxwell produced on all he met was remarkable; it was often much more due to his personality than to what he said, for many found it difficult to follow him in his quick changes from one subject to another, his lively imagination started so many hares that before he had run one down he was off on another."

In 1856 Maxwell was appointed a Professor of Natural Philosophy at Marischal College, Aberdeen, Scotland. In 1860 Maxwell moved to London as professor of natural philosophy and astronomy at King's College, London, where he spent five years and then moved back to Scotland to take care of his family estate where he spent his time by researching and writing. He made periodic trips to Cambridge. In 1871, Maxwell accepted an offer from Cambridge to be the first Cavendish Professor of Experimental Physics at Cambridge. This was the most substantial recognition Maxwell received in his lifetime. He accepted the post rather reluctantly. However, he devoted his time to establish the new Cavendish Laboratory. He designed the laboratory and helped set it up. The Laboratory was formally opened on June 16, 1874. Maxwell was the first Director of the Cavendish Laboratory, which was to become one of the most famous physics laboratories in the world.

Maxwell's General Equations of the Electromagnetic Field were first presented in his famous memoir entitled "A Dynamical Theory of the Electromagnetic Field" published in 1865. This was one of the greatest papers in theoretical physics of the nineteenth century. Maxwell after reading the works of William Thomson and Michael Faraday, believed that the lines of force conceived by



Lord Kelvin

Heinrich Hertz

Hendrik Lorenz

Faraday to visualize the magnetic and electric phenomena represented something real. Beginning in 1856, with his paper "Faraday's lines of Force", Maxwell produced a long series of articles which revolutionized ideas about electricity, magnetism and light. Maxwell wrote: "As I proceeded with the study of Faraday, I perceived that his method of conceiving the phenomena was also a mathematical one, though not exhibited in the conventional form of mathematical symbols. I also found that these methods were capable of being expressed in the ordinary mathematical form, and thus compared with those of the professed mathematicians." After carefully exploring the implications of Faraday's ideas, Maxwell developed analogies and models to show how these ideas can be related to familiar concept and finally he formulated the mathematical expressions making up famous equations of the electromagnetic field. Before Maxwell came into the picture, it was widely believed that there was a fundamental difference in the descriptions of nature used by mathematicians and those by physicists, with a more purely physical outlook. This was a reason why Faraday's theoretical ideas were not closely examined by mathematicians. However, Maxwell's work changed all of this. Maxwell was much influenced by William Thomson. Maxwell wrote: "I was aware that there was supposed to be a difference between Faraday's way of conceiving phenomena and that of the mathematicians, so that neither he nor they were satisfied with each other's language. I had also the conviction that this discrepancy did not arise from either party being wrong. I was first convinced of this by Sir William Thomson, to whose advice and assistance, as well as to his published papers, I owe most of what I have learned on the subject."

While presenting his theory Maxwell wrote: "The theory I propose may...be called a theory of Electromagnetic Field, because it has to do with the space in the neighbourhood of the electric or magnetic bodies...The electromagnetic field is that part of space which contains and surrounds bodies in electric or magnetic conditions...in order to bring these results within the power of symbolical calculation, I then express them in the form of the General Equations of the Electromagnetic Field."

Maxwell's equations of electromagnetic field described the evolution in space and time of electric and magnetic fields generated by charges, magnets and currents. These equations also demonstrated that the two cannot be separated. An electric field changing with time would invariably generate a magnetic field, which would induce an electric field in adjacent regions of space and which in turn would generate a magnetic field. And this process goes on. Maxwell demonstrated that electric and magnetic fields are not two different fields but part of a single unified field—the electromagnetic field.

Maxwell's equations of electromagnetic field predicted the existence of electromagnetic waves—changing electric and magnetic fields propagating outward in all directions result in a wave disturbance traveling in empty space. Maxwell calculated the speed at which the electromagnetic waves propagate. By taking into consideration of the values of purely electric and magnetic measured quantities Maxwell calculated that electromagnetic waves traveled approximately at the speed that of light. From this observation Maxwell came to the conclusion that light itself must be an oscillating electric charge. He concluded that light itself was electromagnetic radiation. Maxwell did not stop there. He proposed that light (and infrared and ultraviolet radiation) was probably just one of a large family of radiations caused by charges oscillating at different velocities. Maxwell wrote: "The velocity is so nearly that of light, that it seems we have strong reasons to conclude that light itself (including radiant heat and other radiations if any) is an electromagnetic disturbance in the form of waves propagated through the electromagnetic field according to electromagnetic laws." Maxwell predicted the existence of other forms of electromagnetic radiations with frequencies and wavelength outside the infrared and ultraviolet regions. The German physicist Heinrich Rudolf Hertz (1857-1894) detected radio waves in 1887 and this led to the general acceptance of Maxwell's theory. Maxwell's theory was developed further by the Dutch physicist Hendrik Antoon Lorenz (1853-1928).

Hermann von Helmholtz

Maxwell proposed that light travelled through an invisible medium, which he named ether. This medium filled all space "unbroken from star to star." In 1873, Maxwell wrote: "There can be no doubt that the interplanetary and interstellar spaces are not empty but occupied by a material substance or body, which is certainly the largest, and probably the most uniform, body of which we have any knowledge." Maxwell was not the first to propose that some invisible medium fill the vastness of the space. The genesis of the idea can be traced back to the ancient Greeks. For Maxwell there was an obvious need for proposing the idea of the ether. If light was a wave then it seemed obvious that it had to be wave traveling in some medium. Later it was proved that Maxwell's idea of the ether was erroneous. Albert Abraham Michelson (1852-1931), an American physicist, while working with Hermann Ludwig Ferdinand von Helmholtz (1821-1894) in Germany, tried to verify the existence of ether experimentally. Michelson set out to measure the speed with which the earth moved through the ether. Michelson thought that in a universe filled with stationary ether, the planet Earth would meet resistance as it moved through the ether. And in the process the moving Earth would create a current, a sort of "wind" in the ether. In such a situation a light beam moving with the current would be carried along it but the light beam moving against the current would be slowed down. To measure such differences Michelson built an instrument called interferometer. This device could split a beam of light into two halves running perpendicular to each other and then it could rejoin the split beam. In this way it was possible for the device to measure the difference in the speeds of the two beams of light with great accuracy. Michelson based on his own experiments concluded that "The result of the hypothesis of a stationary ether is...shown to be incorrect, and the necessary conclusion follows that the hypothesis is incorrect." Michelson carried out his experiments again and again to rule out any experimental errors. He was joined by Edward Williams Morley (1838-1923). Together they carried out a very precise experiment but failed to detect the existence of ether. Some other experiments designed to demonstrate the existence of ether also failed.

Albert Abraham Michelson

Henry Cavendish

Maxwell made significant contributions to the development of thermodynamics. He was one of the founders of the kinetic theory of gases. His theory brought a new subject, the statistical physics, into being. This linked thermodynamics and mechanics. Maxwell's theory is still widely used as a model for rarefied gases and plasmas.

Maxwell had written a paper, "On the Stability of the Motion of Saturn's Rings" for entering the competition for the Adams Prize of 1857 of the St John's College, Cambridge. In this paper, Maxwell argued that the only structure of Saturn's rings that was consistent with the accepted laws of mechanics was "one composed of an indefinite number of unconnected particles." He illustrated his argument, built on a skillful mathematical analysis, with a model. The model constructed by Maxwell still can be seen in the Cavendish Laboratory at Cambridge. The then Astronomer Royal of England, Sir George Biddell Airy (1801-92), described the Maxwell's paper as "one of the most remarkable applications of Mathematics to Physics that I have ever seen." In 1610, when Galileo first viewed the planet Saturn with a telescope, he saw what appeared to him to be little stars attached to the planet. In 1655, that is after 45 years of Galileo's observation, the Dutch physicist and astronomer Christiaan Huygens (1629-1695) discovered that these were in fact rings circling Saturn. In the 1980s, the Voyager space probes showed us that Saturn's rings are made of millions of particles, ranging in size from dust to many meters in diameter and thus proved the prediction made by Maxwell based on his mathematical skill.

Christaan Huygens

In 1860, Maxwell was awarded the Rumford Medal of the Royal Society for his work on colour perception. By using devices called "colour wheel" and "colour box" constructed by him, Maxwell demonstrated how mixtures of different colours were perceived by different people. In this work he was helped by his wife, Katharine Mary Dewar. Maxwell's work on colour perception is viewed as the beginning of the science of quantitative colorimetry. Maxwell by using red, green and blue filters produced the first true trichromatic colour photograph, of a Scottish tartan ribbon. He displayed this photograph to Faraday and others at the Royal Institution in 1861. Maxwell's process of colour photography was the forerunner of today's modern colour photography. He also invented the "fish-eye" lens.

Maxwell edited Henry Cavendish's papers. And this work occupied much of his time between 1874 and 1879. Cavendish only published two papers and left twenty packages of manuscript on mathematical experimental electricity. Commenting upon Maxwell's work in this period, R. L. Smith-Rose in his biography of Maxwell titled James Clerk Maxwell: A physicist of the nineteenth century (1948) wrote: "…Maxwell entered upon this work with the utmost enthusiasm: he saturated his mind with the scientific literature of Cavendish's period; he repeated many of his experiments, and copied out the manuscript with his own hand…The volume entitled 'The Electrical Researches of the Honourable Henry Cavendish' was published in 1879, and is unequalled as a chapter in the history of electricity."

George Biddell Airy

James Clerk Maxwell died on November 05, 1879 in Cambridge. The year Maxwell died, Albert Einstein was born. "Like Maxwell's work in the 19th century, Einstein's would dominate much of the century to come."

We conclude by quoting Max Plank on Maxwell: "His name stands magnificently over the portal of classical physics, and we can say this of him; by his birth James Clerk Maxwell belongs to Edinburgh, by his personality he belongs to Cambridge, by his work he belongs to the whole world."

References

1. Spangenberg, Ray and Diane K. Moser. The History of Science: In the Nineteenth Century. Hyderabad: Universities Press (P) Ltd., 1999.
2. Spangenberg, Ray and Diane K. Moser. The History of Science: From 1895 to 1945. Hyderabad: Universities Press (P) Ltd., 1999.
3. Dardo, Mauro. Nobel Laureates and Twentieth-Century Physics. Cambridge: Cambridge University Press, 2004.
4. A Dictionary of Scientists. Oxford: Oxford University Press, 1999.
5. The Cambridge Dictionary of Scientists (Second Edition). Cambridge: Cambridge University Press, 2002.
6. O'Connor, J. J. and E. F. Robertson. James Clerk Maxwell (An article available on the internet).
7. Heilbron, J. L. (Ed.). The Oxford Companion to the History of Modern Science. Oxford: Oxford University Press, 2003.
8. Domb, C. James Clerk Maxwell: 100Years Later. Nature, No. 282, pp. 235-239, 1979.
9. Campbell, L. and W. Garnett. The Life of James Clerk Maxwell. London, 1882 (WWW version).

Material available on the internet was also referred to.

Regaining the..... (contd. from page 35)

tradition of patenting. Now institutions and academics have begun filing for patents in earnest, opening avenues for interactions with foreign companies. What is more, we need to realize that science cannot be an exclusively intellectual pursuit but must be relevant economically and socially.

Indeed, centuries ago India was a knowledge superpower. In today's world, though we are not yet a knowledge superpower, we do stand on the threshold. It is estimated that the rewards for India of a thriving science based economy could be huge. If continued with the same vigour, we could regain the past glory as the world's knowledge hub. India could then emerge as the third largest economy in the world in the year 2050, after China and the US.

❑ V. B. Kamble

Wavelets

A simple and computationally efficient way to represent signals and images

❑ Shivaprasad M Khened
e-mail: khened@rediffmail.com

The massive human tragedy struck by the recent killer tsunami waves across the Indian Ocean has brought to focus the significance of predicting natural disasters for minimizing human tragedy. Despite rapid developments in science and technology, the science of predicting natural calamities and weather forecasting etc have not been accurately successful. Forecasting weather or natural disasters, like the earthquake, involve handling huge and unprecedented amount of data, which are processed by super computers for proper interpretation. If for example barometric pressures are to be sampled at an enormous number of grid points for knowing how the data will evolve and for predicting a possible weather forecast, a huge amount of computer memory will be used up. A model of the atmosphere that uses a 1000 x 1000 x 1000 grid requires a billion data points and it will still be a fairly crude model. The main bottleneck therefore is in handling insurmountable amount of data and interpreting the data. The problem could possibly be reduced substantially if scientists can compress such data. Fortunately, we now have a new mathematical analysis "Wavelets", which are used extensively in multimedia for compressing the data. Wavelets enable compression of data while not loosing out on original information. The lessons of tsunami tragedy will possibly hasten the research in wavelets theory. Wavelets will most likely help in slimming down the elephantine data loaded computer models that are now in use for weather prediction, natural calamity forecasting etc, and help in possibly leading to the solution of the problem.

Mathematical transformations are applied to signals to obtain further information from that signal which is not readily available in the raw signal. Interpretation of signals are at the very heart of many scientific and engineering disciplines, and their representation problem and application of mathematical transformations to signals dates back to the nineteenth century when mathematicians perfected a useful tool, "Fourier Analysis", for correct representation of signals. The analysis of signals in frequency, and the possibilities of blocking certain frequencies within a signal, while leaving others, enables scientists and engineers to interpret signal data for innumerable applications, which may include even geologic seismic analysis. The recent killer tsunami wave attack on 26th December 2004, which led to the loss of more than 150000 human lives, was a result of a seismic activity (massive earthquake) that happened in the island of Sumatra. Prediction of earthquakes and other natural disasters have therefore become a prime challenge for the scientific community. Wavelet analysis is considered to be an exciting theory at the intersection of the frontiers of mathematics, science, and technology. It has been proved to be a unifying concept that interprets a large body of scientific research. Developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology, the theory of wavelets has already found many applications. Wavelet is a new buzz technology of the age, but wavelet mathematics is not new. Much of the research for the development of wavelets was carried out in the thirties; it's only in recent years that a commercial use has been found for them. The first applications were in astronomy, acoustics, earthquake predictions, fingerprint analysis and pure mathematics. The underlying principle of the wavelet is that whole information is contained within parts. This principle is exhibited in a hologram, and so also in nature.

Fourier Transforms

The roots of modern wavelet research date back to the early 1800s, when Jean Baptiste Joseph Fourier invented the Fourier transforms. Fourier analysis technique, in simple mathematical terms, allowed complex, periodic and non-periodic functions (or waves) to be summed up as a series of simpler functions. Fourier, a French mathematician, advocated in 1807 that, any repeating waveform (or periodic function), like the sound wave produced from the tuning fork, could be expressed as an infinite sum of trignometrical sine and cosine waves of various frequencies. Such an expression began to be called the Fourier Transforms, and the theory was termed Fourier analysis. A familiar demonstration of Fourier's theory occurs in music. When a musician plays a note; he or she creates an irregularly shaped sound wave. The same shape repeats itself for as long as the musician holds the note. Therefore, according to Fourier, the note can be separated into a sum of sine and cosine waves. The lowest-frequency waves are called the fundamental frequency of the note, and the higher-frequency notes are called the overtones. Fourier transforms have continued to find their applications especially in communication ever since.

Looking for a better alternative

During the nineteenth century Fourier transforms (FT) were used mainly to solve problems in physics and engineering. The significance of the newfound mathematical series of expressions aided scientists and engineers to think of them as the preferred way, to analyze phenomena of all kinds. These transforms were put to use in diverse applications. However an in-depth study of FT by mathematicians and scientists resulted in identifying some drawbacks in these transforms. The weakness of FT lies in dealing with sharp spikes and chopped signals because sines and cosines are, by their very nature, non-local smooth curves which stretch into infinity. FT gives the frequency information of the signal, which means that it tells us how much of each frequency exists in the signal, but it does not tell us when in time these frequency components exist. This information is not required when the signal is stationary, while it is absolutely necessary for non stationery signals like the spoken language.

As a result, throughout the twentieth century, mathematicians, physicists, and engineers who had identified these weaknesses of the FT, concluded that, FT have trouble reproducing transient signals or signals with abrupt changes, such as the spoken word. It was in this scenario that alternative methods were being researched to find solutions to the problems of representing the spoken language. Over the course of the twentieth century, scientists worked to get around these limitations to allow representations of the data to adapt to the nature of the information and to provide Time – Frequency representations. Different groups of researchers in disparate fields developed techniques to decompose signals into pieces that could be localized in time and analyzed at different scales of resolution.. Although FT is probably the most popular transform being used (especially in electrical engineering), it is not the only one. There are many other transforms that are used quite often by engineers and mathematicians. Hilbert transform, short-time Fourier transform (STFT), Wigner distributions, the Radon Transform, and of course our featured transformation, the wavelet transform, constitute only a small portion of a huge list of transforms that are now available at engineer's and mathematician's disposal. Every transformation technique has its own area of application, with advantages and disadvantages, and the wavelet transform (WT) is no exception.

Signals and Wavelets

Probably the most interesting and fascinating alternative to the Fourier transforms has been provided by "wavelets", a simple and computationally efficient way to represent signals and images. The term wavelet means a small wave. The smallness refers to the condition that this (window) function is of finite length (compactly supported). Wavelet transform is capable of providing the time and frequency information simultaneously, hence giving a time-frequency representation of the signal. The wave refers to the condition that this function is oscillatory.

One way of thinking about wavelets is to consider how our eyes look at the world. For example, in the real world, you can observe a forest from many vantage points, in effect, at different scales of resolution. From the window of an aeroplane, the forest appears to be a solid canopy of green. From the window of a car on the ground, the forest resolves into individual trees, and if you get out of the car and move closer, you begin to see branches and leaves. If you then pull out a magnifying glass, you might find a drop of dew at the end of a leaf. As you zoom in at smaller and smaller scales, you can find details that you didn't see before. If you try to do that with a photograph and expect to see clarity in the images at every level, you will be disappointed. Enlarge the photograph to get "closer" to a tree and all you'll have is an out of focus tree; the branch, the leaf, the drop of dew, will never be found. Although our eyes can see the forest at many scales of resolution, the camera can show only one object at a time. Computers do no better than cameras; in fact, their level of resolution is inferior. On a computer screen, the photograph becomes a collection of pixels. that are much less sharp than the original. Soon, however, computers everywhere will be able to do something that photographers have only been able to dream of. They will be able to display an interactive image of a forest in which the viewer can zoom in to get greater detail of the trees, branches, and perhaps even the leaves. They will be able to do this because wavelets will make it possible to compress the amount of data used to store an image, allowing a more detailed image to be stored in less space.

Wavelet algorithms process data at different scales of resolutions. If we look at a signal with a "large window," we would notice gross features. Similarly, if we look at a signal with a "small window," we would notice small features. Here is how this works: Suppose we have a signal, which has frequencies up to 1000 Hz. In the first stage the signal is split up in to two parts by passing the signal through a high pass and a low pass filters (filters should satisfy certain conditions, so-called admissibility condition). This results in two different versions of the same signal the signal corresponding to 0-500 Hz (low pass portion), and 500-1000 Hz (high pass portion). In the next step either portion of the signals (usually low pass portion) or both, are taken and the same thing is done again. This operation is called decomposition. Assuming that we have taken the low pass portion, we will now have 3 sets of data, each corresponding to the same signal at frequencies 0-250 Hz, 250-500 Hz, 500-1000 Hz. Next the low pass portion signal is taken again and passed through low and high pass filters; which will result in 4 sets of signals corresponding to 0-125 Hz, 125-250 Hz, 250-500 Hz, and 500-1000 Hz. The process is continued until the signals are decomposed to a pre-defined level. This will result in a bunch of signals, which actually represent the same signal, but all corresponding to different frequency bands. From this we will know which signal corresponds to which frequency band, and if we put all of them together and plot them on a 3-D graph, we will have time in one axis, frequency in the second and amplitude in the third axis. The 3 dimensional representations of signals will help in overcoming the problems of the FT.

The advantage of wavelet analysis is that, it helps in seeing both the forest and the trees simultaneously when one looks at the problem of seeing the entire forest and minute details of the forest. Because of these special characteristics, wavelets have now become an international standard (JPEG2000 uses wavelets for its compression) in less than a decade after their discovery. Wavelets are currently being used in fields such as signal and image processing, medical applications to analyse signals from EEG and ECG, human and computer vision, data compression, and in several other applications. Even though the average person probably knows very little about the concept of wavelets, the impact that they have in today's technological world is phenomenal.

Wavelet analysis is now considered to be an exciting theory at the intersection of the frontiers of mathematics, science, and technology. It has been proved to be a unifying concept that interprets a large data of scientific research. In addition to its intrinsic mathematical interest, its applications have considerable economic implications in the areas of signal and image compression, which have just begun to unfold. The research on Wavelet Theory and its applications in various technologies, especially in the field of data compression, as the one used by the JPEG (Joint Photographic Expert Group), has reminded us of the mathematical complexity that exist behind any data compression and transmission. By setting the "*mother wave*" for image compression and decompression ahead of time as a part of the standard, JPEG2000, has been able to provide resolution at a compression ratio of 200 to 1. The near-universal use of JPEG for image compression is a fitting tribute to the success of wavelet compression algorithms.

Developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology, the theory of wavelets has also found applications in image compression, vision analysis, study of turbulence, fractal objects, and structure of the universe etc. Wavelets are allowing network communications provider companies like Rainmaker Technologies, to develop more efficient signal filtering and noise reduction algorithms. This company claims that they will be able to equal fiber bandwidth on existing last mile cable infrastructure with this technology, and greatly increase bandwidth on other mediums, such as phone or power lines, using the wavelet compression algorithms. The Federal Bureau of Investigation (FBI), USA, too has adopted the wavelet-based algorithms for compression of elephantine amount of fingerprint data in its collection.

Wavelet is a New Compression Technology of the Video World

At its most basic level, video compression is performed when an input video stream is analyzed and information that is imperceptible to the viewer is discarded. Each incident is then assigned a code - commonly occurring events are assigned few bits and rare events will be assigned more bits of codes. These processes are called as signal analysis, quantization and variable length encoding respectively. There are four methods for compression; discrete cosine transforms (DCT), vector quantization (VQ), fractal compression, and discrete wavelet transform (DWT).

Typical Discrete Cosine Transform (DCT) systems such as JPEG and MPEG (Moving Pictures Expert Group) break images into rectangular sub-blocks in order to carry out compression. When highly compressed JPEG and MPEG images develop unnatural blocky artifacts and high quality images need a lot of storage space. Wavelet transforms work in a different way. They are intrinsically more "picture-friendly." Wavelet filters break down a whole image, examining its spatial frequency holistically in both horizontal and vertical dimensions, and filtering that information into spatial frequency-band data. The result is a very robust digital representation of a picture, which maintains its natural look even under fairly extreme compression. Wavelet is best adapted to a set of data or truncating some of it below a certain threshold. Such a data will contain repetition and redundancy, and hence be ideal for compression. With wavelets the software makes four passes at the image, building it up bit-by-bit, when Codec (Codec is a software that can compress a video source {encoding}, and play compressed video (decompress}) algorithm starts running it aims to decode all four. If it can't keep up pace with the best image pass, it takes a shot at the next best pass and so on. Because it never completely drops a frame it looks better and frames containing little or no movement will play back at the top sub-band even on a slow PC. The quality of the source material is a strong factor in the perceived quality of compression and decompression. Digitisation, compression and decompression are a high tech application to video grabbing, video recording and storage, and consequently should only be used in conjunction with equal high tech video acquisition equipment. Compression technology has brought about revolutionary changes to the multimedia PC platforms.

Compression Standards

There are two types of compression standards mainly used in the modern electronic industry namely, JPEG and MPEG. Both JPEG and MPEG are an ISO/IEC working groups. ISO (International Organization for Standardization) is a non-governmental organization that works to promote the development of standardization to facilitate the international exchange of goods and services and spur worldwide intellectual, scientific, technological and economic activity. IEC (International Electrotechnical Commission) is an international standards and assessment body for the fields of electro technology. JPEG works to build standards for continuous tone image coding. JPEG is a lossy compression technique used for full-colour or gray-scale images. It exploits the fact that the human eye will not notice small colour changes. JPEG 2000 is an initiative that will provide an image coding system using compression techniques based on the use of wavelet technology. MPEG was established in 1988 to develop standards for digital audio and video formats. There are five MPEG standards being used or in development. Each compression standard was designed with a specific application and bit rate in mind. The MPEG standards include MPEG-1, MPEG-2, MPEG-4, MPEG-7 and MPEG- 21.

In addition to the above there are three other compression technologies that are in use, namely DV (Digital Video), H.261 and H.263, and DivX. DV is a high-resolution digital video format used with video cameras and camcorders. The standard uses DCT to compress the pixel data and is a form of lossy compression. The resulting video stream is transferred from the recording device via FireWire (IEEE 1394), a high-speed serial bus capable of transferring data up to 50 MB/sec. H.261 is an ITU standard designed for two-way communication over ISDN lines (video conferencing) and supports data rates which are multiples of 64Kbit/s. The algorithm is based on DCT and can be implemented in hardware or software and uses intraframe and interframe compression. H.263 is based on H.261 with enhancements that improve video quality over modems. DivX is a software application that uses the MPEG-4 standard to compress digital video, so it can be downloaded over a DSL/cable modem connection in a relatively short time with no reduced visual quality.

History of Wavelets

Although roots of modern wavelets date back to the early 1800's, research on this topic hasn't made extreme advances until recently. The Main Contributors to the History of Wavelets include Joseph Fourier, Alfred Haar, Paul Levy, Jean Morlet, Alex Grossman, Stephane Mallat, Yves Meyer, and Ingrid Daubechies.

Jean Baptiste Joseph Fourier

From an historical point of view, wavelet analysis is a new method, though its mathematical underpinnings date back to the work of Joseph Fourier in the nineteenth century. Fourier laid the foundations with his theories of frequency analysis, which proved to be enormously important and influential. He was born is Auxerre, France in the year 1768, and he died in Paris in 1830. Although much of Fourier's life was spent in French politics under the great Napoleon, his love for science and mathematics was very apparent. In 1807, Fourier's efforts with frequency analysis lead to what we now know as Fourier analysis. His work is based on the fact that functions can be represented as the sum of trignometrical functions sine and cosines. Another contribution of Joseph Fourier was the Fourier Transform, which transforms a function that depends on time into a new function that depends on frequency.

Alfred Haar

The next known link to wavelets came from a man named Alfred Haar in the year 1909. It appeared in the appendix of a thesis he had written to obtain his doctoral degree. Alfred Haar was born on October 11, 1885 in Budapest, Hungary. In 1904, Haar traveled to Germany to study at Gottingen where he studied under Hilbert. It was here that his doctoral thesis work was done on the orthogonal systems of functions. Unlike Fourier, Haar spent the better part of his career either studying mathematics or teaching it. He died on March 16, 1933 in Szeged, Hungary. Haar's contribution to wavelets is very evident, there is an entire wavelet family named after him. The Haar wavelets are the simplest of the wavelet families. The concept of a wavelet family is easy to understand. The father wavelet (scaling function) is the starting point (a kind of a head of the household). By scaling and translating the father wavelet, we obtain the mother, daughters, sons, granddaughters, grandsons, etc.

Paul Levy

There was a gap of time in research on wavelet algorithms and their functions after Haar's contribution to wavelets, until a man named Paul Levy came to the picture. Paul Levy was born on September 15, 1886, in Paris, France. He came from a family known for their mathematical acumen. His grandfather was a mathematics professor, and his father wrote geometry papers for Ecole Polytechnique, a famous school of higher education (like a university) in Paris. Levy won several awards not only in the field of mathematics, but also in the fields of chemistry and physics. He attended the prestigious school of Ecole Polytechnique, and he also taught there later in life until he reached retirement age. He died on December 15, 1971 in Paris France.

Levy's efforts in the field of wavelets dealt with his research on Brownian motion. He discovered that the scale-varying basis function created by Haar (i.e. Haar wavelets) were a better basis than the Fourier basis functions. Unlike the Haar basis function, which can be chopped up into different intervals such as the interval from 0 to ½ or the interval from 0 to ½ and ½ to 1, the Fourier basis functions have only one interval. Therefore, the Haar wavelets can be much more precise in modeling a function. Thus, the Haar basis functions seemed to be a better tool for Levy while dealing with the small details in Brownian motion.

Jean Morlet and Alex Grossman

Even though some individuals made slight advances in the field of wavelets from the 1930's to the 1970's, the next major advancements in wavelet research came from Jean Morlet around the year 1975. In fact, Morlet was the first researcher to use the term "wavelet" to describe his functions. More specifically, they were called "Wavelets of Constant Slope." Before 1975, a man named Dennis Gabor had pondered over the idea of Windowed Fourier Analysis. This idea helped to finally consider things in terms of both time and frequency. Windowed Fourier Analysis, dealt with studying the frequencies of a signal piece by piece (or window by window). These windows helped to make the time variable, discrete or fixed. Then different oscillating functions of varying frequencies could be looked at in these windows. Morlet, also a graduate of Ecole Polytechnique, tried Windowed Fourier Analysis, while working for an oil company named Elf Aquitaine. Oil companies searched for underground oil by sending signals in the form of impulses into the ground and by analyzing their echoes. These echoes could be analyzed to tell how thick a layer of oil underground would be. Fourier Analysis and Windowed Fourier Analysis were used to analyze these echoes; however, Fourier analysis was a time-consuming process so Morlet began to look elsewhere for a solution.

When he worked with Windowed Fourier Analysis he discovered that keeping the window fixed was the wrong approach. He did exactly the opposite. He kept the frequency of the function (number of oscillations) constant and changed the window. He discovered that stretching the window stretched the function and squeezing the window compressed the function. In fact, one could see the close resemblance between the sine functions used in Fourier analysis and the Morlet wavelets. Morlet made quite an impact on the history of wavelets; however, he wasn't satisfied with his efforts by any means. In 1981, Morlet teamed up with a man named Alex Grossman and worked on an idea that Morlet discovered while experimenting on a basic calculator. The idea was that a signal could be transformed into wavelet form and then retransformed back into the original signal without any information being lost. Since no information is lost in transferring a signal into wavelets and then back, the process was called lossless. Morlet's concept is something that beginning wavelet students do all the time, but rarely think of how big a breakthrough it was. Morlet and Grossman's efforts with this concept were a complete success. The only resources they needed were a personal computer and the brainpower of two incredible mathematicians. Since wavelets deal with both time and frequency, they thought a double integral would be needed to transform wavelet coefficients back into the original signal. However, in 1984, Grossman found that a single integral was all that was needed. While working on this idea, they also discovered another interesting thing. Making a small change in the wavelets only causes a small change in the original signal. This is also used often with modern wavelets. In data compression, wavelet coefficients are changed to zero to allow for more compression and when the signal is recomposed the new signal is only slightly different from the original.

Stephane Mallat and Yves Meyer

The next two important contributors to the field of wavelets were Yves Meyer and Stephane Mallat. Although Meyer is a mathematics professor from France and Mallat was a former student of Ecole Polytechnique (where Meyer used to teach), the two first met in the United States in 1986. Mallat was very intrigued by a paper Meyer had written about his orthogonal wavelets. They spent three days researching work being done on wavelets in many different applied fields. At the end of their research, Multi-resolution Analysis for wavelets was born. This idea of multi-resolution analysis was a big step in the research of wavelets. The scaling function of wavelets was first mentioned in the works of Mallat and Meyer, and it allowed researchers and mathematicians to construct their own family of wavelets using its criteria.

Ingrid Daubechies

Ingrid Daubechies is a wavelet researcher and a professor at the Princeton University. She was born in Houthalen, Belgium and earned her Ph. D in Physics in 1980. She is the first full female professor for Princeton University. Around 1988, Daubechies used the idea of multi-resolution analysis to create her own family of wavelets. These wavelets were of course named the Daubechies Wavelets. Daubechies wavelet family satisfies a number of wavelet properties. They have compact support, orthogonality, regularity, and continuity. The regularity property is satisfied because the Daubechies wavelets can reproduce linear functions. Finally, the continuity property is satisfied because the Daubechies wavelet functions are continuous even though they are not very smooth and not differentiable everywhere.

Wavelets in the Future

With the foundations of wavelet theory securely in place, the field has grown rapidly over the last decade. Newer and newer applications of wavelet transforms are being identified in engineering applications. Mathematicians are working constantly in trying to find answers to some of the unresolved important theoretical questions associated with the wavelets. Although wavelets are best known for image compression, many researchers are working on using wavelets for pattern recognition. In weather forecasting, for example, they might slim down the phenomenal data loaded computer models that are now in use. If the weather models use wavelets, they could view the data the same way weather forecasters do, concentrating on the places where abrupt changes occur, warm fronts, cold fronts and the like. Other problems in fluid dynamics have been tackled in the same way. Wavelets are also being used in studying the shock waves that are produced by a bomb explosion. Wavelets also have a promising future especially in animation movies. To draw a cartoon character, the animator only has to specify where a few key points go, creating a low-resolution version of the character. The computer can then do a reverse multiresolution analysis, making the character look like a real person.

Research is currently on to produce better kinds of wavelets for generating two and three-dimensional images. David Donoho and Emmanuel Candès of Stanford University have proposed a new class of wavelets called "ridgelets," which are specifically designed to detect discontinuities along a line. Other researchers are studying "multiwavelets," which can be used to encode multiple signals traveling through the same line, such as colour images in which three-colour values (red, green, and blue) have to be transmitted at once.

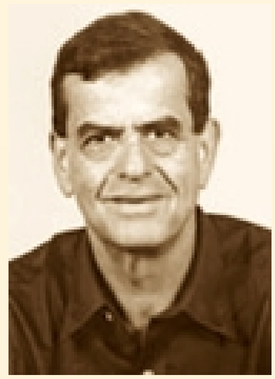
The wavelet transform is a relatively new concept (just about 10 years old), but yet there are quite a few articles and books written on them. However, most of these books and articles are mostly written by professional people, mostly for other professionals. Such is the complexity of this subject, that majority of the literature available on wavelet transforms are of little help, if any, to those who are new to this subject. When I first started working on writing this article on wavelet transforms, especially for a popular science magazine such as Dream 2047, I have struggled to figure out what was going on in this mysterious world of wavelet transforms. Yet I decided to try and initiate the readers into this new exciting field of science/mathematics, which has immense future prospects. Let me confess that after all my efforts I still consider myself quite new to the subject, and I also have to confess that I have not completely figured out any of the theoretical details on the mathematical transformations, which of course have not been covered in the article. In an article meant for popular science magazine targeting school children in particular, I feel that theoretical details are not necessarily necessary.

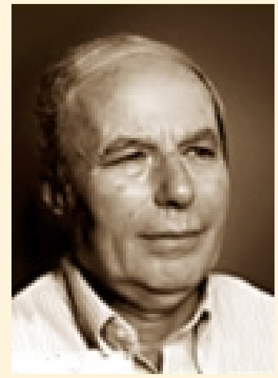
Shivaprasad M Khened, Curator, Nehru Science Centre, Mumbai

Molecular Death Tags

❑ Biman Basu
e-mail: basu_biman@yahoo.com


Irwin Rose


Aaron Ciechanover


Avram Hershko

Life is a complex process, involving myriads of different chemical reactions that help keep us alive. All living things – plants, animals and us humans – are mostly built up of proteins. A human cell contains some hundred thousand different proteins. These perform numerous functions – as accelerators of chemical reactions in the form of enzymes, as signal substances in the form of hormones, as important actors in the immune defence and by being responsible for the cell's form and structure. New proteins are built and some old ones are routinely destroyed to keep the life process going.

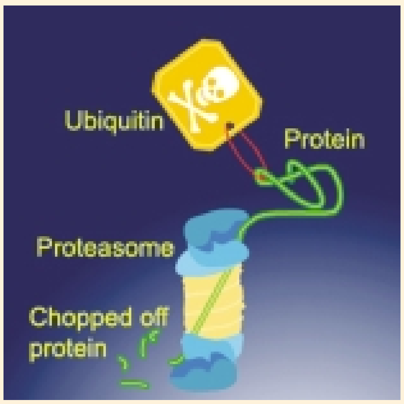
Much research has been done in the past on understanding how the cell controls the synthesis of a certain protein, and at least five Nobel Prizes have been awarded in this area. But researchers had paid little attention to the reverse process – the degradation of proteins that are damaged or have outlived their usefulness – although a number of simple protein-degrading enzymes were known. For example, it was known that in the small intestine the enzyme trypsin breaks down proteins in our food to amino acids. Likewise, a type of cell organelle, the lysosome, in which proteins absorbed from outside are broken down, had long been studied.

One factor common to all these protein degradation processes, which take place outside the cell, is that they are not energy-dependent; that is, they do not require extra energy in order to function. But experiments as long ago as the 1950s had shown that the breakdown of the cell's own proteins does require energy. This anomaly had long puzzled researchers. Why should the breakdown of proteins within the cell require extra energy? The mystery was solved by the work of two Israeli professors Aaron Ciechanover, and Avram Hershko of Technion-Israel Institute of Technology in Haifa, and an American scientist, Irwin Rose of the University of California, Irvine, for which they were awarded the Nobel prize for Chemistry for 2004. The three scientists made fundamental discoveries concerning how cells regulate the breakdown of intracellular proteins with extreme specificity as to target, time and space. They showed that protein degradation in cells takes place in a series of step-wise reactions leading to the proteins to be destroyed being labelled with a polypeptide called ubiquitin – a kind of molecular death-tag.

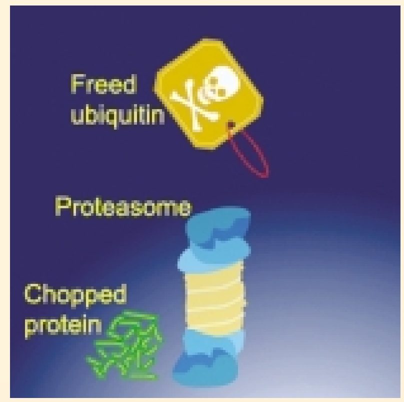
Studies in 1977 had shown that a cell-free extract from immature red blood cells could catalyse the breakdown of abnormal proteins in an ATP-dependent manner (ATP = adenosine triphosphate – the cell's energy currency). The first clue about the existence of ubiquitin came in the late 1970s when Ciechanover and Hershko were trying to remove the haemoglobin from immature red blood cells using chromatography. They discovered that the extract could be divided into two fractions, each inactive on its own. But it turned out that as soon as the two fractions were recombined, the ATP-dependent protein degradation restarted. In 1978 the researchers reported that the active component of one fraction was a heat-stable polypeptide with a molecular weight of 9,000, which they termed APF-1 (active principle in fraction 1). This protein later proved to be ubiquitin.

The decisive breakthrough in the research was reported in two papers that Ciechanover, Hershko and Rose published in 1980 the Proceedings of the National Academy of Sciences of the USA. Until that time the function of APF-1 was entirely unknown. In the first paper they showed that APF-1 was bound covalently, i.e., with a very stable chemical bond, to various proteins in the extract. In the second paper it was further shown that many APF-1 molecules could be bound to the same target protein; the latter phenomenon was termed 'polyubiquitination'. It is now known that this polyubiquitination of substrate proteins is the triggering signal that leads to degradation of the protein in the proteasome. It is this reaction that constitutes the actual labelling, that marks the protein molecule for death.

Much like condemned prisoners awaiting execution on the death row, proteins labelled by ubiquitin are then chopped into small pieces and destroyed, in barrel-shaped cellular "waste disposers" called proteasomes. Ubiquitin



The sequence of pictures show how a protein is tagged with ubiquitin and taken to proteasome, which in turn chops off the protein molecule and releases the ubiquitin molecule for reuse.



itself is not destroyed in the process. It fastens to the protein to be destroyed, accompanies it to the proteasome where it is recognised as the key in a lock, and signals that the protein is slated for destruction. Shortly before the protein is squeezed into the proteasome, its ubiquitin label is disconnected for re-use. Ubiquitin is also involved in repairing faulty DNA and quality control of newly made proteins.

Ubiquitin is a 76-amino-acid-long polypeptide that was isolated from calf thymus as early as 1975. It was assumed to participate in the maturation of white blood cells. Since the molecule was subsequently found in numerous different tissues and organisms – but not in bacteria – it was given the name ubiquitin (from Latin ubique, meaning "everywhere").

Hershko and his co-workers used an immunochemical method to study protein degradation in cells. By using antibodies to ubiquitin, they could isolate a ubiquitin-protein-conjugate from cells where the cell proteins had been labelled with a radioactive amino acid not present in ubiquitin. The results showed that cells really break down faulty proteins using the ubiquitin system, and what is most surprising is that up to 30% of the newly synthesised proteins in a cell are broken down via the proteasomes since they do not pass the cell's rigorous quality control.

Proteasomes are the cell's equivalent of a scrap heap. A human cell contains about 30,000 proteasomes, which can break down practically all proteins to 7-9-amino-acid-long peptides. This process enables the cell to break down unwanted proteins with high specificity, and it is this regulation that requires energy. The work of the three scientists demonstrated that the cell functions as a highly efficient checking station where proteins are built up and broken down at a furious rate. But the degradation is not indiscriminate; it takes place through a process that is controlled in extremely fine detail. The importance of the work of these three scientists stems from the fact that the quick removal of specific proteins tells the cell when to divide, when to turn on or turn off various functions, and when to die.

Thanks to the work of the three scientists it is now possible to understand at molecular level how the cell controls a number of central processes by breaking down certain proteins and not others. Examples of processes governed by ubiquitin-mediated protein degradation are cell division, DNA repair, quality control of newly produced proteins, and immune defence functions. Disruption of this cellular protein breakdown process leads to killer diseases like cystic fibrosis, Parkinson's disease and many types of cancer. Knowledge of ubiquitin-mediated protein degradation thus offers an opportunity to develop drugs against these diseases and others. Scientists are trying to use the process to create medicines, either to prevent the breakdown of proteins or make the cell destroy disease-causing ones. One example is the cancer drug Velcade, approved last year in the United States, which interferes with the cell's protein-chopping machine. Many other drugs that harness the protein-destroying process are under development.

Shri Biman Basu *is a well known Science Communicator and is a Scientist NISCAIR, New Delhi*

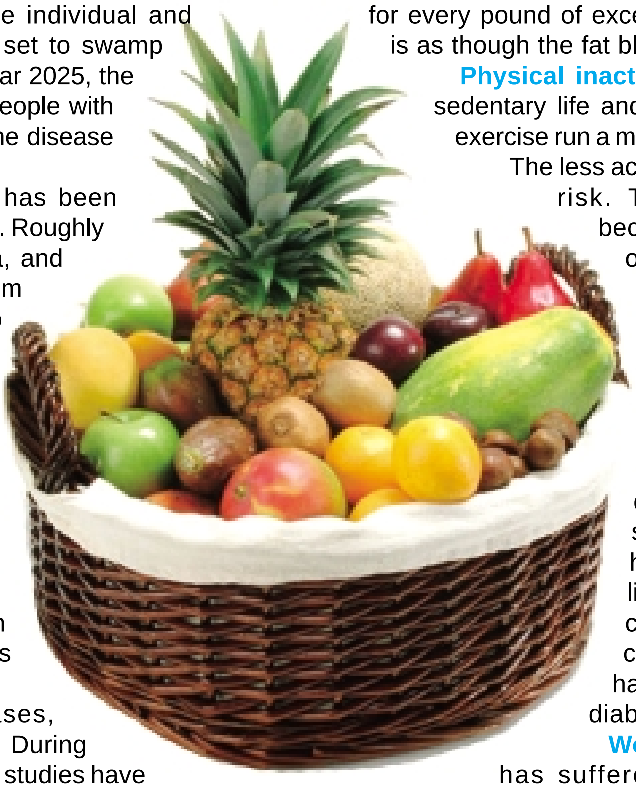
Simple Mantras to Prevent Diabetes

❑ Dr. Yatish Agarwal
e-mail: dryatish@yahoo.com

Over 35 million people in India suffer from diabetes today. Unless we take rearguard action and initiate prompt preventive steps both at the individual and community level, the disease is all set to swamp us. The predictions are that by the year 2025, the country would have over 57 million people with diabetes making it the worst hub of the disease in the world.

The rise in cases of diabetes has been exponential over the last two decades. Roughly 10-12 per cent adults in urban India, and 3-4 per cent in countryside suffer from it. Worse still, more than one-half do not even know that they have diabetes. Since the illness can jeopardize life, and carries a high risk of serious complications such as damage to the eyes, kidneys, nerves, heart, and circulatory system, efforts have been afoot to identify the risk factors that lead to the development of the disease, and confirm if any lifestyle changes can reliably prevent or delay its occurrence.

In more than 95 per cent cases, people suffer from type 2 diabetes. During the last one decade, large community studies have established some of the culprits that lead to it, and on that basis, preventive strategies have been put together. Let's see how:



Factors that increase your risk

Much as people believe, diabetes is not caused by eating too much sugar. Even though we may not quite know all its secrets, researchers have been able to confirm that certain lifestyle factors and health conditions increase the risk of developing diabetes.

Family history : You are more likely to develop diabetes if someone in your immediate family has the disease, whether it is your father, mother, brother or sister. This genetic association manifests more strongly if your sibling suffers from the disease. The risk also goes up considerably if both your parents have diabetes.

Interestingly, this genetic connection of the disease was known as long ago as 600 BC. The Susruta Samhita states this possibility in clear terms, calling it *beej janya*.

Weight : Being overweight (BMI over 25) is by far the greatest risk factor for type 2 diabetes. More than 80 per cent of people who develop this type of diabetes are overweight. The more fat you have, the more resistant your cells become to your own insulin. Studies show that the risk for developing type 2 diabetes increases by 4 percent for every pound of excess weight a person carries. It is as though the fat blocks insulin from doing its job.

Physical inactivity : Individuals who lead a sedentary life and do not find time for physical exercise run a major risk of developing diabetes. The less active you are, the greater is your risk. This risk stems from cells becoming resistant to the action of insulin.

Blood pressure and cholesterol link : If your blood pressure is high and has crossed 140/90 mm Hg, triglycerides are more than 250 mg/dl or your HDL cholesterol is less than 35 mg/dl, than it is time to pull your socks and bring some quick healthful changes in your lifestyle. These parameters are clear indicators that unless you carry out quick changes you have a definite risk of developing diabetes.

Womanly risks : A woman who has suffered from polycystic ovarian disease, or a diabetes while she was pregnant, or had given birth to a baby who was more than 9 pounds at birth should always be on the vigil for diabetes.

Age : As you grow older, your risk of type 2 diabetes increases. The risk grows once you go past the age of 45, but even younger people in the twenties, thirties and early forties must be careful. Type 2 diabetes is being increasingly diagnosed in younger set of people, mirroring the changing lifestyle.

The Obesity Connection

Your weight and your risk for developing diabetes are closely related. If you feel concerned, check your body mass index (BMI), or measure your waist, to know how much weight you have.

Body mass index

Body mass index (BMI) is a measurement based on a formula that takes into account your weight and your height in determining how much fat you carry around your body.

To determine your BMI, locate your height on the chart given here and follow that row across until you reach the column with the weight nearest yours. Look at the top of that column for the corresponding BMI rating.

Body mass index

	Healthy		Overweight		Obesity				
BMI	19	24	25	29	30	35	40	45	50
Height (Feet & inches)	Weight (in kilograms)								
4’10”	41	52	54	63	65	75	87	98	108
4’11”	43	54	56	65	67	79	90	101	112
5’0”	44	56	58	67	70	81	93	105	116
5’1”	45	58	60	70	72	84	96	108	120
5’2”	47	60	62	72	75	97	99	112	124
5’3”	49	62	64	74	77	90	102	115	128
5’4”	50	64	66	77	79	93	105	119	132
5’5”	52	65	68	79	82	95	109	123	136
5’6”	54	67	70	81	85	98	112	126	140
5’7”	55	70	72	84	87	101	116	130	145
5’8”	57	72	75	86	90	105	119	134	149
5’9”	58	74	77	89	92	107	123	138	154
5’10”	60	76	79	92	95	110	126	142	158
5’11”	62	78	81	95	98	114	130	146	163
6’0”	64	80	84	97	100	117	134	150	167
6’1”	65	81	86	100	103	120	137	155	172
6’2”	67	85	88	102	106	124	147	159	177

A BMI of 19 to 24 is considered okay (although it’s certainly better if you are nearer 19 than 24). A BMI of 25 to 29 signifies being overweight, and a BMI of 30 or more indicates obesity. Once your BMI goes over 24, your risk of developing diabetes increases.

Waist circumference

Extra weight is bad enough, but it also matters where the weight is stored. If you carry most of the weight around your belly, you are ‘apple-shaped’. If it is around your hips and thighs, you are ‘pear-shaped’. Where you store weight is for the most part inherited from your parents, but, if you are apple-shaped, you are at a greater risk for diabetes, heart disease and high blood pressure. In any case, if you carry too much weight, you should take steps to lose the extra fat.

To determine whether you are carrying too much weight around your belly, measure your waist circumference. Find the highest point on each of your hipbones and measure across your abdomen just above those highest points. A measurement of more than 39 inches in men and 34 inches in women signifies increased health risks.

Taking preventive steps to stop diabetes

You may greatly reduce your risk of developing diabetes if you take pre-emptive steps and adopt healthful changes in your living habits. No age is too early, and the sooner you realize the benefits of good nutrition, physical activity, and restriction of weight, the better are your chances of progressing in life without being affected by diabetes. If you are careful, the risk of the disease can be reduced by 50 to 60 per cent.

Eat healthy : Restrict your daily calories to suit your weight and lifestyle. Take more fibre, restrict fat to less than 30 per cent of daily calories and reduce saturated fat intake to less than 10 per cent calories. The less processed food you take, and the more natural food you take, the better it is for you.

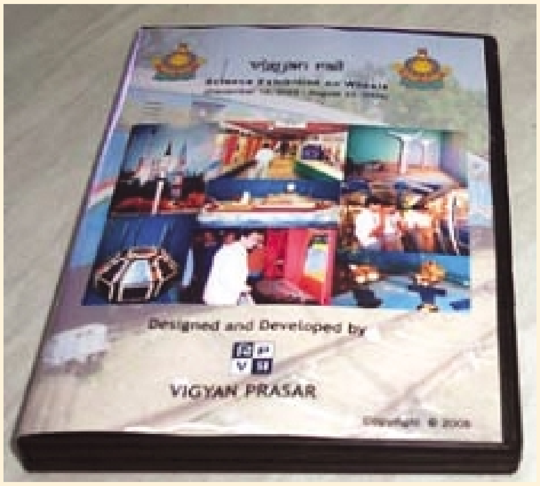
Get moving : Exercise regularly. Take a 30-minute brisk walk most days of the week. If you find it dull, you can swim, cycle, do aerobic dancing or play a sport such as badminton or tennis. The goal should be to do at least 150 minutes of exercise a week.

Maintain a healthy weight : Watch your weight. If your BMI is 24 or over, you must take proactive measures to shed weight. In 95 per cent cases, the reason of obesity is straightforward: too many calories, and too little activity. Reverse this, and you may profit!

• • •

Interactive DVD on Vigyan Rail

The DVD includes all the exhibits displayed in Vigyan Rail – Science Exhibition on Wheels. It has coach-wise panoramic view, video gallery, photographs and newspaper clips of all the stations wherever Vigyan Rail visited. This is an interactive



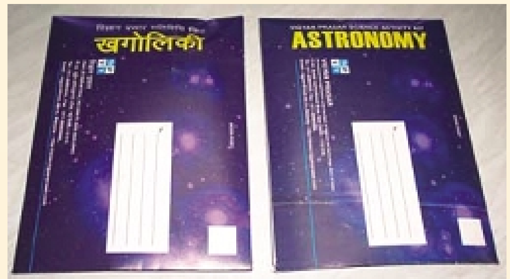
DVD with easy navigation, search, sitemap and print facility. Each DVD is priced at Rs 80 + Rs 20 postal charge. A CD-ROM version is also available at Rs 50 + Rs 20 postal charge. CD version has limited video gallery and newspaper clips.

Activity kit on Astronomy

Know more about astronomy through activities. There are 25 activities in the kit. Some of the activities are:

Star Dial: The star dial enables you to see the portion of the sky from your location at any time (night) and on any day of the year. Set the time at which you are observing the sky with the date and the month of the year. Indian equivalent names of the stars and constellations are also provided.

Sun Dial: Make your own sundial. Steps and material are provided in the kit.



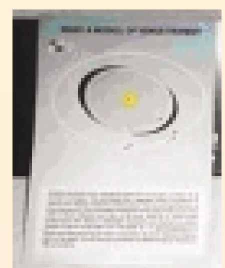
Science activity kit on Astronomy

Venus Transit: Make a model of Venus Transit to understand the phenomenon.Steps and material are provided in the kit.

Eclipse model: Understand solar and lunar eclipse. You can understand why the stars twinkle, make a pinhole camera to obtain an image of Sun, observe visible light spectra and so on. One muticolour poster (27" X 19") giving seasonal stars/ constellation charts is also provided in the kit.

The kit is available in both English and Hindi and is priced at Rs. 70 + Rs 20 postal charge.

Sun Dial



Model of Venus Transit

VP News contd from page 36

Prof. V. S. Ramamurthy, Secretary, Department of Science & Technology, Dr. K. Kasturirangan, Hon'ble Member, Rajya Sabha and former Chairman ISRO, and Dr. M.K. Bhan, Secretary, Department of Biotechnology.

Vigyan Rail was a specially designed train with twelve compartments for exhibits and activities depicting India's achievements in various fields of science and technology. It moved throughout the length and breath of the country for about eight months covering 60 stations during December 15, 2003 to August 20, 2004. Vigyan Prasar conceptualized, planned, coordinated and implemented the entire project. Vigyan Prasar has now brought out the interactive DVD on Vigyan Rail. A CD-ROM version of the same is also available.

Dr. K. Kasturirangan released the activity kit on "Astronomy". Dr. Kasturirangan also delivered the National Science Day lecture.

The activity kit on Astronomy is useful to the people in general and students in particular to learn about Astronomy through different activities. Twenty five activities are provided in the kit. Make your own Sun Dial, model of Venus Transit, Measuring the altitude of stars, Star Dial, quiz on Astronomy are example of some of the activities.

Recent Devlopments in Science & Technology

Device that Uses Air to Charge Mobile Phone

Students at Department of Industrial Design at IIT Delhi have developed a device that uses air to charge the mobile phones. For making this device students have attached a turbine with a mobile phone that's helps charge it even when the user is traveling. The energy generated by the turbine when moved by the wind energy could charge a mobile in emergency. It generates electricity to the tune of 3 to 4 watts, which is sufficient to charge a mobile phone. The specially designed turbine, which cost about 200 rupees, could be easily kept in pocket. This device would help mobile users charge their phones while traveling in bus, car or train. All they need to do is place the turbine against the wind flow.

Source : PTI, News March,2005

Starless Galaxy Found

Astronomers announced that they have discovered the first dark galaxy ever detected, a starless mass of spinning matter located some 50 million light-years away in the Virgo cluster of galaxies.

The initial sighting of this invisible object came in year 2000, from radio wave observations made using the Lovell telescope in Cheshire, England, which sketched a cloud of hydrogen atoms a million times the mass of the sun rotating in the Virgo cluster. Subsequent data from Puerto Rico's Arecibo radio telescope confirmed the existence of the object. This suggests that abundant dark matter is lurking in the cloud. If it were an ordinary galaxy, then it should be quite bright and would be visible with a good amateur telescope. Previous claims for dark galaxies have crumbled after observations using optical telescopes ultimately revealed resident stars. But scrutinizing the region using the optical Isaac Newton telescope in La Palma, Spain, the team did not spot any such signs of the ordinary.

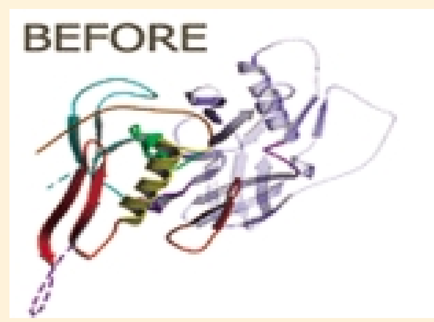
Researchers have predicted the existence of unseen galaxies in recent years, based on indications that the universe contains far more matter than the visible variety can account for. Indeed, the astronomers involved in this new work note that future surveys may well turn up many more dark galaxies

Source: Scientific American, February 2005

Teams solve structure of key HIV proteins

Shape-shifting HIV has many tricks for evading the immune system, which makes developing a vaccine particularly challenging. But researchers are beginning to gain ground: independent teams have solved the structure of two key proteins, providing crucial information about the AIDS-causing virus

Although the virus stimulates the immune system to produce many antibodies, it has a highly variable protective



membrane that allows it to evade the attack and survive in the body long term. This causes a major problem for developing an HIV vaccine.

And this is why candidate vaccines designed to stimulate the production of antibodies against HIV have failed. Today, the vaccines furthest along in clinical trials all work by inducing a cellular immune response instead, which is useful but only effective once the virus has already infected cells.

However, some patients who have lived with the virus for a long time produce 'broadly neutralizing' antibodies, also called super antibodies, which seem to be effective against many strains of HIV.

"Coming up with a vaccine that induces a broadly neutralizing antibody response is the holy grail of HIV vaccine development," says James Bradac, a virologist and chief of preclinical research and development in the division of AIDS at the National Institute of Allergy and Infectious Diseases in Bethesda, Maryland.

Source Nature.com

Compiled by : Kapil Tripathi