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VP News

Inside




Science Communcation in Mizoram

An initiative has been taken to enhance activities in S&T Communication in Mizoram jointly by Vigyan Prasar and Doordarshan. A meeting was organized with Shri Lalthansanga Varte, Station Director, All India Radio, Mizoram and Mizoram Council for Science & Technology and Environment on 3 May 2006 to discuss the possibility of producing a science serial in Mizo, the local language. To begin with, a decision was taken to produce a 13-part radio serial on the topic "Conservation of Environment and Sustainable Development in Mizoram." To enhance the science contents on Doordarshan in Mizo, a discussion was held with Shri C. Lalrasonga, Director, Doordarshan Kendra, Aizawl. As a result of the deliberations, it was agreed to produce a 13-part science quiz in Mizo for school children. A meeting was also held at St. Paul's Higher Secondary School to initiate activities related to VIPNET Science Clubs.

On 4 May 2006, a meeting was held at Mizoram Science Centre at Aizawl with the representatives from organizations and individuals engaged in the field of S&T Communication in Mizoram. The meeting was organized by Mizoram Council for Science, Technology and Environment. Those present included Dr. V,B. Kamble, Director, Vigyan Prasar, Shri B.K. Tyagi, Scientist, Vigyan Prasar, Shri K. Tlanthanga, DDG, Doordarshan, New Delhi, Shri C. Lalrasonga, Director, DDK, Aizawl, Dr. Vanlal Zara, Principal Scientific Officer, Mizoram Council for S&T and Environment, and representatives from AIR, Science Teachers' Association of Mizoram, Mizoram Science Society, and Post Graduate Science Teachers' Association. Following the deliberations, it was agreed that a workshop would be organized for the development of scripts for the radio and TV serial respectively.The resource persons would be drawn from the aforementioned organizations. Mizoram Council for S&T and Environment would be the nodal agency with Dr. Vanlal Zara as the nodal officer. The members present were quite enthusiastic in initiating the science clubs activity in the State, and affiliating these clubs to the VIPNET Science Clubs. It may be stated that this initiative was a first of its kind in the State of Mizoram.

Meeting at St. Paul's Higher Secondary School : From left : Shri K. Tlanthanga, Doordarshan; Shri B.K. Tyagi, VP; Dr. V.B. Kamble, VP; Dr. Vanlal Zara, Mizoram Council for S&T and E, and Bro. M.K. Devassy, Principal.

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Editor : Dr. V.B. Kamble

Communicating Science & Technology in the North-East

The North-East India is characterized by lofty mountains, lush green valleys, breath-taking beauty, and dense forests teeming with a variety of flora and fauna. The entire region is inhabited largely by simple and exotic tribal people leading a pastoral life. Yet, every State of this wonderful Land of the Seven Sisters (actually eight including Sikkim) has its own distinctive and rich culture and heritage with varied dance forms, music and festivals.

Over the years, the North-Eastern States have shown a significant improvement in the literacy rates. According to the 2001 census, Mizoram recorded the highest literacy (88.8 per cent) in the region - only next to Kerala (90.9 per cent). It is only Arunachal Pradesh with literacy rate of 54.3 per cent that needs to catch up with the rest of the States in the region. Almost all of the States have provided a primary school within a distance of 1 km.

Given the ethnic diversity, difficult terrain and communication, and a large number of languages and dialects spoken by the local groups, surely it becomes a challenge popularizing Science and Technology (S&T) in the North-Eastern States. Assam has a long tradition of science popularization. Other States in the North-East, however, have followed the suit only gradually over the last two decades. Organisation of events like National Science Day and National Children's Science Congress have become regular features in the North-Eastern States today, as in other parts of the country. Intermittent activities like Bharat Jana Vigyan Jatha (1987), Bharat Jana Gyan Vigyan Jatha (1992), and the campaigns built around Total Solar Eclipse (1995 and 1999), Venus transit (2004), and World Year of Physics (2005) proved to be instrumental in providing fiillip to promote S&T popularization activities in the region.

We recently visited Mizoram to explore the possibility of stepping up S&T communication and popularization programmes in the State. We were pleasantly surprised to find that three organisations, viz., Science Teachers' Association of Mizoram (STAM), Mizoram Science Society and Post-Graduate Science Teachers' Association have been actively involved in S&T popularization. STAM has a membership of some 550 science teachers from schools and colleges of Mizoram. They regularly organize students' activities and even bring out a popular science monthly magazine in Mizo, the local language. We discussed the possibilities of initiating several programmes with the members of these organizations. To begin with, they were very happy to receive us since it was only occasionally that someone from mainland visited them for such a purpose! They evinced a keen interest in using media for S&T communication through Mizo. As a result, a radio serial on environment for broadcast from AIR, Aizawl, and a television serial (a science quiz) for telecast from DDK, Aizawl, are already on the anvil with their active participation. They were also quite enthusiastic to immediately launch the science clubs activity in the schools of Mizoram. Incidentally, this is a joint effort of Vigyan Prasar, Doordarshan, All India Radio, and the Mizoram State Council for Science, Technology and Environment.

Surely, the situation is not very different in other States. Besides physical isolation from the mainland, there is a deficiency of resources – financial and technical. They only need a little push in order they can step up their efforts in S&T popularization to the level of some of the leading States of the mainland. Our experience in Mizoram has a few lessons for all of us. First, there has to be a continuous interaction with the local S&T popularization groups in all the States of the North-East. Second, Government organisations need to play a pro-active role in initiating and sustaining the S&T popularization activities in each State - their responsibility cannot end once they have disbursed the grants for a specific activity. Third, media need to be used to the fullest extent - print, radio, television and the internet - to produce and disseminate software in the local language / dialect of each state. Every North-Eastern State has a radio station of AIR and a Doordarshan Kendra. It is hence imperative that conscious efforts are put in to produce and broadcast / telecast programmes in the local languages / dialects on appropriate topics relevant to the State. It may be of interest to note that every state capital in the North-East has a few television channels in the local language that could be utilised for

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Pythagoras

Greek mathematician, astronomer and mystic

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"It is impossible to disentangle Pythagoras's own views from the later accretions of mysticism and neo-Platonism, but he had a profound influence on Plato and on later philosophers, astronomers and mathematicians."

Chambers Biographical Dictionary (1997)

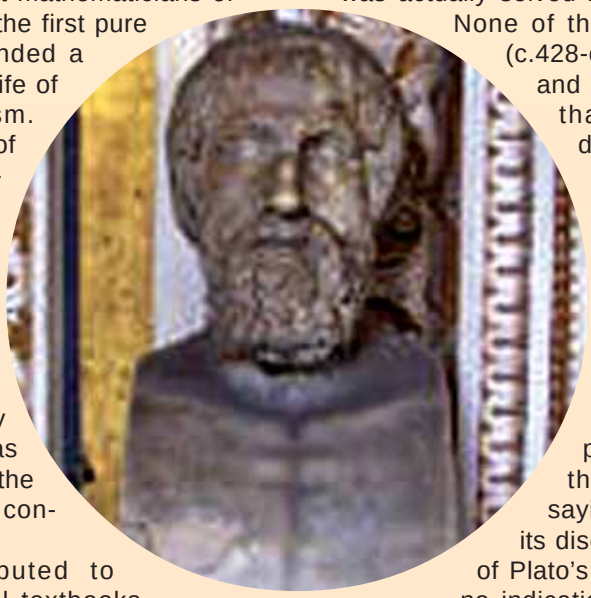
"'All things are numbers,' Pythagoras once said. And despite some mystical and bizarre beliefs he held about numbers, we owe him a major debt for his insistence that through mathematics we could get a grip on understanding the world."

History of Science: From the Ancient Greeks to the Scientific Revolution by Ray Spangenburg and Diane K. Moser (1999)

"Although Pythagoras's ideas on the significance of numbers were erroneous, his contributions were important in mathematics: few ideas are more fundamental than that of irrational numbers."

Cambridge Dictionary of Scientists (2002)

Pythagoras is one of the most important figures in the history of Greek philosophy. His contributions to the development of mathematics are regarded extremely important. Some people even tend to regard Pythagoras as one of the greatest mathematicians of all time. He is often regarded as the first pure mathematician. Pythagoras founded a secret brotherhood devoted to a life of political and religious mysticism. Pythagoreans, as the members of the brotherhood were called, followed an ascetic regime of dietary taboos, self-examination, and study aimed at purifying the soul. 'In their ethical practices, the Pythagoreans were famous for their mutual friendship, unselfishness, and honesty.' They put emphasis on astronomy, geometry and theory of numbers. Pythagoras and his followers first established the idea of geometry as a logically connected sequence of propositions.



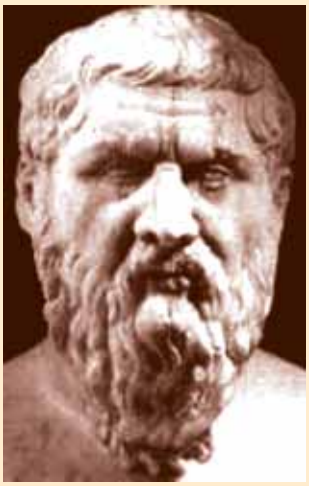
Pythagoras

Some of the ideas attributed to Pythagoras are taught in school textbooks even today. This gives enough reason to know about Pythagoras, whose name was attributed to something discovered more than 2,500 years ago and which is still relevant enough to find a place in school textbooks. Unfortunately Pythagoras' whole life is shrouded in myths and legends.

The name Pythagoras sounds so familiar mostly because of a famous theorem in geometry that goes by his name. However, very little is known about his personal life with any degree of certainty. Even we do not know with certainty whether the famous Pythagorean theorem that the square of the hypotenuse of a right-angled triangle is equal to the sum of the squares of the other two sides was actually solved by him or by one of his followers. None of the early sources, including Plato (c.428-c.348 BC), Aristotle (384-322 BC) and their pupils indicated to point out that the theorem was actually discovered by Pythagoras. In the 5th century AD, Proclus (c. 410-485 AD), the Greek neo-Platonist philosopher, in his commentary on Euclid's famous treatise on geometry, *Elements* related the theorem with the name of Pythagoras. Proclus reported: "If we listen to those who wish to investigate ancient history, it is possible to find them referring this theorem back to Pythagoras and saying that he sacrificed an ox upon its discovery." Proclus was the last head of Plato's Academy. However, Proclus gave no indication on what sources he based his assertion. There are also other reports including that of the Greek historian, biographer and philosopher, Plutarch (c.46-c.120 AD) that relate Pythagoras with the theorem. However, these reports based on two lines of verses whose context was unknown. These two lines of verses stated, "When Pythagoras found that famous diagram, in honour of which he offered a glorious sacrifice of oxen..." There are reports to identify the author of these verses as

Apollodorus the Calculator or the Apollodorus the Geometer.

It should be noted that the theorem, which goes by the name of Pythagoras, is found in the *Shulva Sutra*, a part of Vedic literature (c. 1500-c.200BC), though, there was no proof given for the theorem. The noted Indian astrophysicist Professor J. V. Narlikar has observed that the statement should be renamed as Shulva theorem. Some connection with the Pythagoras' theorem can even be seen in Babylonian mathematics found in Babylonian tablets coming from the period of the Old Babylonian Empire, which flourished in Mesopotamia between 1900 BC and 1600 BC.



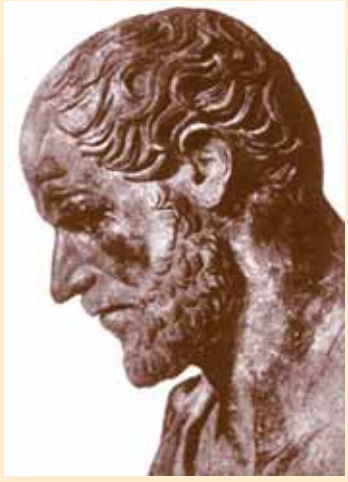
Plato

The other mathematical discoveries that are attributed to Pythagoras are: i) the sum of the angles of a triangle is equal to two right angles; ii) constructing figures of a given area and geometrical algebra; iii) the discovery of irrationals; and iv) the five irregular solids.

Pythagoreans studied various properties of numbers. The Pythagoreans believed that everything in the universe finally boiled down to numbers. They developed the concept of irrational numbers when they found that the square root of two is irrational; that is it cannot be expressed as a perfect fraction. Pythagoreans themselves were not happy with the discovery. It is said that the member of the Pythagorean brotherhood who revealed this secret to others was put to death. It should be emphasised that though Pythagoras and his followers had wrong notion about numbers, they made important contributions to the theory of numbers.

Xenocrates

Another major discovery with which Pythagoras name is associated involved the chief musical intervals that the central musical concords (the octave, fifth and fourth) correspond to the whole number ratios 2:1, 3:1 and 4:3 respectively. Many publications state that this discovery was certainly made by Pythagoras. The statement like "His (Pythagoras') greatest scientific achievement was the discovery of the mathematical relationship between the musical notes" is often found in standard publications. However, many would tend to argue that this kind of assertion is not based on definite historical evidence. It has been reported that the only early source to relate Pythagoras to this discovery was Xenocrates (c.395-314 BC), a pupil of Plato and who was an important member of Plato's Academy in its early period. But it has been argued that the early Academy was one of the main sources, which contributed to the later exaggerated tradition about Pythagoras.



Aristotle

According to one story Pythagoras discovered this relationship while passing through a blacksmith's workshop. It is stated that he noted that the sounds made by blacksmith's hammers whose weights were in the ratio 2:1 would be an octave apart and so on. There are other stories. However, in modern time it has been asserted that all such stories associating Pythagoras' name with these relationships must be false for the simple reason that the techniques for the discovery ascribed to him do not work in practice. For example, it has been reported that the pitch of sounds produced by hammers is not directly proportional to their weight. There is some evidence to indicate that the knowledge of these relationships was known to a contemporary of Pythagoras named Lasus. There is also evidence to trace the scientific verification of the discovery to Hippias of Elis (5th century BC), the Greek sophist. Now, whoever might have discovered this relationship, this was probably the first mathematical expression of a physical law and thus it marked the beginning of mathematical physics. It is also true that even if Pythagoras or his followers did not discover the relationship, they certainly appreciated its importance and considered it worth studying.

It is believed that Pythagoras wrote nothing. All statements attributed to Pythagoras are from accounts written much long after his death. There is hardly anything written on Pythagoras by his contemporaries. The earliest writings on Pythagoras, some fragments of which survived, were written about 150 years after his death. We do not know on which earlier sources these writings were based. If there were any they do not exist today. There are reports indicating that Aristotle wrote a treatise on Pythagoranism but it is lost today. Aristotle's two pupils Dicaerchus and Aristoxenus in their works mentioned about Pythagoranism in passing. These are also lost today. The first detailed accounts of Pythagoras that were found

intact in modern time were written about third century AD; that is, some 800 years after his death. Three biographies of Pythagoras appeared around the first century AD. They were by Diogenes Laertius (c. 200-250 AD), Porphyry (c. 234-305 AD) and Iamblichus (c.245-325 AD). Both Diogenes and Porphyry titled their works *Life of Pythagoras* and the work of Iamblichus was titled *On the Pythagorean Life*. These works were based on earlier sources such as Aristoxenus (c. 370-290 BC), Dicaerchus (c. 360-250 BC), Timaeus of Tauromenium (350-260 BC), Alexander Polyhistor (2nd century BC) and Apollonius of Tyana (1st century AD), which do not exist today.

Plutarch

Pythagoras was an important figure in his time as evident from the references made by Xenophanes (c. 570-478 BC) and Heraclitus (flourished around 500 BC). His fame was intact even in the days of Plato and Aristotle; that is, about 150 years after his death. Pythagoras had a profound influence on Plato and Aristotle and through them on later philosophers. However, by first century AD there was a tendency to present Pythagoras as semi-divine figure. He was credited with all that was true in Greek philosophical tradition including some of the best ideas of Plato and Aristotle. A number of treatises written in those days were published in the name Pythagoras or in the name of his famous followers. This made it difficult to distinguish between the ideas originally propagated by Pythagoras and those whose origins were falsely attributed to him.

Pythagoras was born on the Greek island of Samos, near the birthplace of Greek philosopher, Miletus sometime around 560 BC (some sources mention that he was born in the year 569 BC). It has been reported that Pythagoras' father was a Phoenician merchant from Tyre called Mnesarchus and his mother named Pythais was a native of Samos. There is a great deal of controversy about the origin and early life of Pythagoras. There are reports that indicate that Pythagoras travelled widely in the Near East, to Babylonia, Phoenicia, and Egypt. He was supposed to have undertaken these visits while living in Samos. There are reports that mention that Pythagoras visited India and he was much influenced by the teachings of Buddha. There are similarities between Pythagorean and Buddhist systems of way of life. Pythagoras had no chance to meet the Buddha himself because Buddha had died before the supposed visit of Pythagoras. It is said that Yavanacharya (the "Ionian teacher") referred to in ancient Indian texts refer to Pythagoras. Pythagoras attended the lectures given by the Ionian philosopher Anaximander (611-547 BC), an intellectual successor of Thales (c.620-c.555 BC) regarded as the founder of Greek philosophy. Pythagoras had also met Thales. It is said that Thales did not teach Pythagoras but he advised him to visit Egypt. Pythagoras' astronomy was the natural development of Anaximander's.

Anaximander

Pythagoras left his birthplace in about 520 BC, when the tyranny of Polycrates, who came to power around 535 BC, became unbearable. He settled in the city of Croton (now Crotone), a Greek colony in southern Italy, where he founded a secretive cult with religious, political and philosophical goals. The cult devoted to mathematics and mysticism. Pythagoras and his followers worked in secrecy and it is impossible to distinguish his work from his followers.

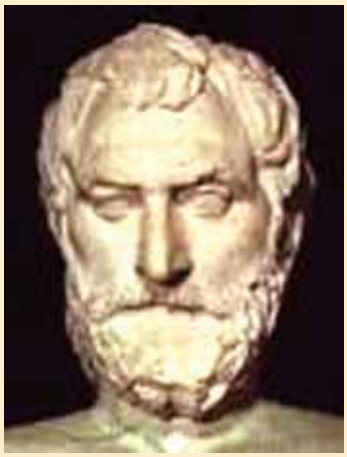
Today Pythagoras is regarded as a mathematician and an astronomer. However, early writings referring to Pythagoras gave no indication that his fame was primarily based on mathematics or on his views on universe. There is no indication in the writings of either Plato (c.428-c.348 BC) or Aristotle (384-322 BC) of the fact that Pythagoras contributed to the development of cosmology. There is also no mention of Pythagoras' work in geometry or of the Pythagorean theorem in early writings. It is interesting to note that Pythagoras' fame in his time did not rest on his contributions to mathematics and astronomy but on other reasons. He was considered an expert on the fate of the souls after death and religious rituals. Pythagoras believed in reincarnation, or in other words, the rebirth of human souls after death. Above all he was founder of a strict way of life based on dietary restrictions, religious ritual and rigorous self-discipline. His way of life attracted many devoted followers for its rigour and discipline.

Pythagoras' original ideas about the universe were somewhat similar to those found in Platonic myths. It was a universe where planets were considered as instruments of divine vengeance and the Sun and the Moon were seen as isles of the blessed where human beings could aspire to go after performing good work. It was later Pythagoreans like Philolaus and Archytas who developed the Pythagoras' universe in a more scientific and mathematical direction. While speculating about the nature of the universe, Pythagoreans proposed that the Earth was not at the centre of the universe. They thought

that a fire was at the centre of the universe and the Earth moved around this central fire. Further according to Pythagoreans, the central fire could not be seen by us as our side of the Earth always pointed away from the fire. Pythagoreans were the first to propose the spherical shape of the Earth. They believed that this spherical Earth in turn was surrounded by a spherical universe. Pythagoreans also believed that all the heavenly bodies, Sun, Moon, planets and stars were not only spherical in shape but they also moved in perfect circles. They believed so because the spherical shape was a 'perfect' form in mystical sense. They pointed out the separate nature of stars and the planets. Although this observation that stars were different from the planets was an important step forward, the Pythagoreans' belief in the perfect circular motion of heavenly bodies and spherical nature of the universe created a lot of confusion in astronomy.

Proclus Diadochus

It is not very certain when and where the death of Pythagoras occurred. It is believed Pythagoras died in Metapontium, where he had come after his cult was attacked by a noble of Croton. Pythagoras was around 100 years old at the time of his death. According to some reports Pythagoras died in 490 BC. The cult established by Pythagoras started rapidly expanding after 500 BC. Because of its political nature, the cult was violently suppressed around 460 BC. Many members of the cult were killed and their meeting places were sacked and burned.



Thales

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Science Caravan – 2006

Vigyan Prasar has taken a new initiative to conduct a science caravan 2006 – A mobile Science Exhibition for schools in Delhi. Under this project, science exhibitions/ demonstrations would be conducted in 27 government schools and 5 public schools.

During 20-21 April 2006, VP organized the first Science Caravan programme in Queen Mary Public School, Tis Hazari, New Delhi. Alongwith a science quiz, a workshop on food adulteration, astronomy, puppet show, hydroponics, nature, kits & toys was organized during the two-day programme.

A section of the paticipants attending the workshop

Folk Art Forms for Radio Science Serial

Vigyan Prasar is in the process of producing a 13-part radio serial in the Chhattisgarhi dialect and the scripts for same in the local folk style already have been prepared. In view of the fact that many of the members of the folk troupe are illiterate, a six-day rehearsal camp for Chhattisgarhi folk artistes was organized from 16 to 21 April 2006 at Village Barda, Dist. Durg, jointly by Vigyan Prasar and the State Health Resource Center (SHRC), Raipur, to train local folk troupes in how to present the scripts. More than 20 local artistes participated in the camp led by Shri Bhishma Dev, a renowned writer, artist and radio artiste of Raipur. Dr T V Venkateswaran, Scientist, VP also participated in the camp. The radio serial is likely to commence broadcast from stations of All India Radio in Chhattisgarh from 5 June 2006.

To elicit local support, a meeting was held on 17 April 2006 at Raipur with several voluntary agencies and NGOs like Bharat Gyan Vigyan Samiti, Asha Abhiyan, Jan Darshan, IPTA, CG Vigyan Sabha and Sparsh participated and agreed to put in efforts to enhance the listenership of the programme.

Science and Technology of Nanomaterials

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There have always been demands from technology for the development and discovery of new materials with tailor-made properties. The most well known example of this is the 'electronics' technology, which has a continuous demand for the miniaturization of its components. For example, the computers of yesteryears used to occupy two to three rooms, one for the console and memory storage systems, and the others for the card feeding and punching machines. The personal computers (PC) of today, which occupy just a corner of the table, are much more powerful compared to those early versions. Moreover today we have even smaller computers like the laptops, the palm held, and the ones in the cell phones, etc. This has become possible simply because of the state of art of miniaturization. The components used in electronic devices have gone through successive changes – from the vacuum tubes to semiconductor devices to integrated circuits to VLSI's. Nowadays a chip of one centimetre square area can contain as many as 10,000 devices. As a consequence of this miniaturization not only have the machines become smaller but there has also been a large saving in power consumption, resulting in the reduction in their cost.

Gordon Moore, a computer scientist made the observation in 1964 that the number of devices placed on a chip was going to double every 18 to 24 months. His observation has not been violated till today; consequently his observation has come to be called the "Moore's law". However, if this process of miniaturization continues, soon we will come to a stage when the electrical connectivity between the devices has to be replaced by optical connectivity. This will require the use of optoelectronic materials. Consequently, drastic changes in the computer industry will be called for. At present this technology is mainly based on the material silicon. Unfortunately silicon, which is a semiconductor with a small band gap, is not a light emitter and as such cannot be used for optical communication. The solution will be to find a new material that will be compatible with the requirements of the new technology. This in turn demands for the change of base of the industry, which will be rather expensive.

Alternatively, silicon can be modified in some way such that its optical properties get suitably changed and it can be used for optical communication. One way to change the properties of a material is to reduce its size. On reducing the size of bulk silicon to nanometre scale, its band gap increases. Furthermore it can change over to a direct band gap material. These are the requirements for a semiconductor to emit visible light. Thus nanometre-sized silicon can find use as an optoelectronic device; hence will retain its place in the industry.

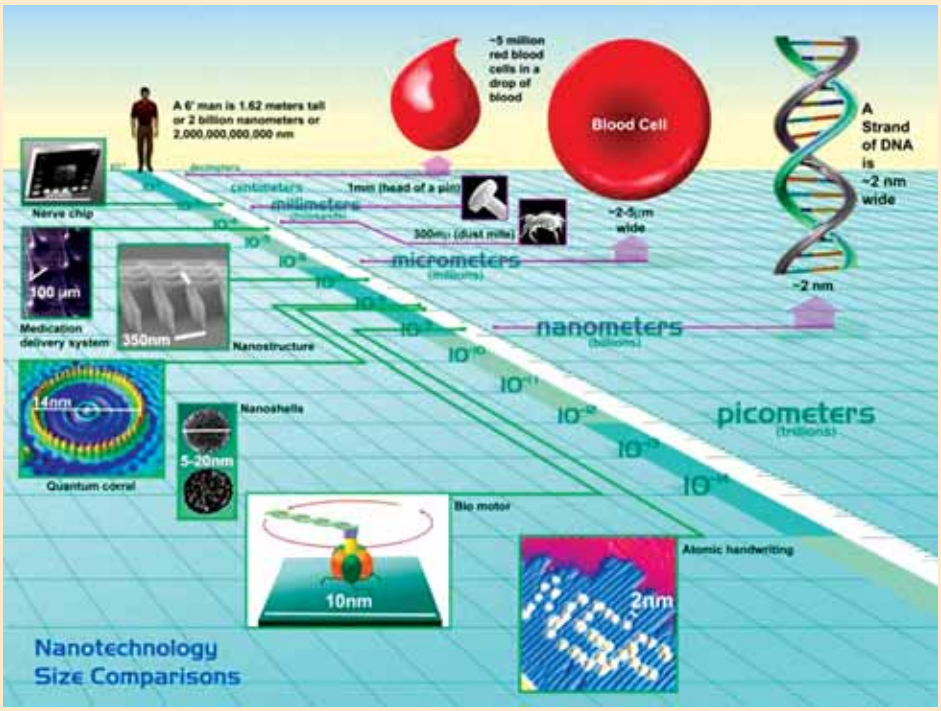

Fig. 1 : Nanoscale

The question then is: What are nanoparticles and why do the properties of materials change when one gets down to this size?

Bulk materials have sizes ranging from microns to millimetres and above. The change in properties with reduction in size can be crudely illustrated with the simple example of a piece of chalk. One can write on a blackboard with a piece of chalk. This is so because the chalk is white, and as we write tiny pieces of the chalk material are removed due to friction and stick to the blackboard. If we break the piece of chalk into two, we can still write with any of the two pieces. However, if we continue to break the pieces, a limit will be reached when the piece will not be visible, and then it will not write on the blackboard any more. Thus below a critical

size the piece of chalk loses its capability to write on the blackboard.

As compared to bulk material a nanoparticle is one the size of which varies from a few nanometres (nm) to about 100 nm. Needless to say that 1 nm = 10^{-9} m. Let us put this length in its proper perspective by comparing it with the size of an atom. We study about atoms and are more familiar with atomic sizes, which are a few Angstroms (Å), with 1 Å =10^{-10} m, which means 1 nm = 10 Å. Therefore, to fix our ideas on sizes, it may be mentioned that three to four atoms on a line will amount to a nanometre.

Even though we deal with atoms, we cannot see them. Therefore, it may be of further help in visualizing the size by considering our familiarity with a needle. One nanometre is a millionth part of the size of the tip of a needle. A spherical particle with a diameter of 3nm contains as many as 900 atoms.

These days 'nanoscience' and 'nanotechnology' have become buzzwords. One can hear everybody talking about them. So what does these terms deal with? This is what we are going to discuss in this article. However, before coming to an elaboration on the science of nanoparticles, it may be more exciting to give some examples of nanotechnology.

Nanotechnology

It was mentioned in the introduction that on reducing the size of a bulk material to nanometre size its properties get changed drastically. These changed properties can be made use of to develop new technologies. The possibility of one such new technology using nanoparticles of silicon was also mentioned. In what follows we shall give some examples of new nanotechnologies which have either been developed or are in the pipe line.

(a) Scratch resistant plastic lenses

Many of us wear spectacles in order to rectify the defective vision of our eyes. Normally the spectacles consist of a pair of appropriate lenses made of glass. Why glass? Because glass is transparent to visible light and grinding it to make lenses is rather easy. However, as the vision of the eyes deteriorates, one has to progressively use thicker and thicker lenses. Consequently the lenses weigh heavily as they sit on the bridge of the nose, causing a lot of discomfort to its wearer. It would be nice if we could replace glass by some lighter and transparent material for making lenses. Plastic is one such appropriate replacement material. It can be made transparent, it is light and lenses can be easily made out of it by moulding. Then, why do people not use plastic lenses? Because the surface of a plastic lens easily scratches and a couple of scratches on the lens can reduce its transparency. So it would be nice if the surface of the plastic lens can be made scratch resistant. This was a problem for the material scientist. Lo and behold they came up with a solution. If the surface of the plastic lens is coated with a layer of the nanoparticles of the ceramic material zirconia (zirconium oxide) it becomes scratch resistant while retaining its transparency. However, we know from our day-to-day experience that when a piece of glass shatters its pieces become opaque. So how is it that the lens coated with nanoparticles retains its transparency? The answer to this will be discussed in the next section. Nonetheless a technology has come up making use of this property of nanoparticles. Now scratch-resistant plastic lenses are available in the market.

(b) Dirt repellant trains

When travelling in a train we generally find the compartments very dirty, particularly in India. The outer side of the compartments is usually coated with a thick layer of dust and other dirt particles. This makes the train journey sometimes unpleasant. It would be nice if the train compartments could be made dirt repellant. This can indeed be done by painting the outside of the compartments with an emulsion containing nanoparticles. Because of the extremely small size of these particles, the painted surface will be so smooth that dirt cannot stick to it and the compartments would remain clean. Of course, one has to first overcome the problem of making the paint with nanoparticles stick to the surface to be painted. Now such dust-resistant trains are running in Europe.

Material scientists are trying to use this idea even to make clothes dirt repellant. To achieve this, fabrics are integrated with nanoparticles to make their surface smooth. A well-known example of this is Teflon-coated ties, which are avail in the market today. One can stretch one's imagination further and even design clothes that can control body temperature, by integrating appropriate nanomaterials into the fabric.

(c) Ceramic motor vehicle engines

The engine of a motor vehicle is usually made of cast iron or some alloy. When gasoline is ignited inside the engine it produces very high temperatures and the gases formed during the process of its burning generates very high pressures, which makes the piston move and in turn runs the vehicle. At the same time, the gases released are extremely corrosive under these conditions of high temperature and high pressures and attacks the metal interior of the engine reducing its lifetime. This could be avoided if the body of the engine were made of some corrosion-resistant material such as ceramics.

Ceramics are usually the oxides of transition and rare earth metals. China clay is one such material. We know that strong acids are stored in china clay bottles, because these do not affect the bottle. So why not make vehicle engines out of ceramic materials? Unfortunately, ceramics are brittle. When crockery made out of china

clay are dropped, these shatter into pieces. Certainly, one cannot make vehicular engines with brittle materials! For this purpose the material has to be malleable and ductile so that it can withstand shock, and also it can be moulded. If ceramics could be modified to make them malleable, then they would make ideal materials for making long-lasting vehicular engines. In fact, ceramics when prepared in the nanoparticle size become malleable. So motor vehicle manufacturers are eagerly looking forward to put this into practice. The question then is: Why are nanoceramics malleable? We have to wait till the discussion on the science of nanoparticles for the answer.

(d) Hyperthermia: A treatment for cancer

When a part of the body becomes cancerous its cells multiply in an uncontrolled manner. The food consumed by a cancer patient mostly goes to nourish the cancerous cells, because these need the energy for their uncontrolled multiplication. So any drug can be easily delivered to these cells when mixed with the nutrients taken by the patients. Nanoparticles of magnetic materials usually carry large magnetic moments compared to their bulk counterparts; a phenomenon known as 'super-paramagnetism'. When mixed with the food consumed by the patient these magnetic nanoparticles would accumulate near the cells affected by cancer. Under normal conditions the magnetic moments of these accumulated nanoparticles would be randomly oriented. If a strong magnetic field is applied from outside over the regions of the body infected with cancer then the magnetic moments associated with the nanoparticles would align themselves along the direction of the magnetic field. Thus the magnetic moments will make a transition from the disordered state to the ordered state. This transition would be associated with a release of energy, because a disordered system has more thermal energy compared to an ordered system. The released energy would appear as heat and increase the temperature of the region where the cancerous cells are present. If the temperature rises to about 48ºC it would kill the cancerous cells. Thus the treatment of cancer can be effectively carried out by the judicious use of magnetic nanoparticles.

This method of treatment of cancer is called 'hyperthermia', which means unusually high body temperature. The large magnetic moments of the magnetic nanoparticles can also be affectively used to deliver drugs to their destination in the diseased parts of the body. When these particles are attached to the molecules of the drug and injected into the blood stream, they can be guided by external magnets to those parts of the body where the drug should act.

These few examples clearly demonstrate how technologies can be developed in diverse areas of science using the new properties of nanomaterials. Before we discuss more about possible nanotechnologies let us make an attempt to understand why the properties of a material change so drastically when its size is reduced to nanometres.

Science of nanomaterials

We have seen above that nanotechnology is based on some new properties acquired by materials when prepared in the nanometer size. For example, zirconia nanoparticles become transparent and do not scatter visible light; ceramic materials, which are brittle, become malleable and ductile when reduced to nanoform; and magnetic nanomaterials acquire large magnetic moments. Not only these but also that the strength of metals increases many folds; the electrical resistance of some semiconductors become dependent on the applied voltage; the melting and sintering temperatures of some materials decrease drastically; and some ceramics and transition metals show better catalytic properties when prepared in nanoform. The question that remains to be answered is: Why does such dramatic change in properties occur; can we understand it? If we understand the physics of nanomaterials, it may help us to make better use of them. We may be closer to achieving the success of producing tailor-made materials. In order to understand this, we must first review our understanding of the properties of bulk materials, and then see how they change when their sizes are reduced.

(a) Transparency of nanoparticle-coated plastic lenses

From our day-to-day experience we know that when a sheet of glass is shattered, its pieces become opaque. So it may appear rather puzzling how a plastic lens coated with nanoparticles of zirconia becomes transparent. The answer to this puzzle lies in the size of the nanoparticles itself. Zirconia is a ceramic material – an oxide of zirconium – which is an insulator in its bulk form. Hence it has a large band gap in its electronic energy spectrum, which makes it transparent to visible light. When its size is reduced to nanometer scale, the band gap increases further so the nanoparticles retain their transparency to visible light. So the light is not absorbed by these tiny particles, but can they be scattered resulting in opaqueness, as it happens in the case of shattered glass! The wavelength of the visible light falls in the range of 360 to 800 nanometres, whereas the size of nanoparticles lie any where between 1 to 50 nm. This size being too small compared to the wavelength of light would not scatter the incident light.

This can be explained by considering the simple analogy of a cyclist riding his bicycle on a road full of ditches. If the ditches are too small compared to the diameter of the wheel of the cycle he can ride through them with out any problem. But if the sizes of the ditches are comparable to the wheel diameter and he tries to ride through them then he will simply fall. Thus the cyclist will never reach his destination, and we can say that he was scat-

tered by the ditches on the road. In this analogy the ditches are the nanoparticles and the diameter of the cycle wheel is the wavelength of light.

(b) The malleability and ductility of ceramic nanoparticles

How is it that a brittle material like a ceramic becomes malleable and ductile when its size is reduced to nanometres? The property of malleability and ductility of a polycrystalline material depends on the size of the crystalline grains constituting the sample. Usually in bulk samples the grain sizes are of the order of microns (= 10^{-6} m). Hence in polycrystalline bulk samples there are less number of grain boundaries (regions separating a grain from its surrounding grains), because of which it is difficult to move the grains over each other by applying stress. Hence polycrystalline bulk ceramics are brittle. But when prepared in nanometre size the number of grain boundaries increases enormously, which allows the grains to move under applied stress. Hence, when prepared in nanoform polycrystalline ceramics acquire malleability and ductility, and can be used to make engines for motor vehicles.

The technicality of grains, grain boundaries, and their movement under stress can be understood in terms of a simple analogy. Consider a heap of broken bricks. If you put your foot on top of the heap and press, it will not go down simply because; the broken brick pieces being larger in size the number of boundaries between the pieces are less, and they can resist the pressure of your foot. On the other hand if you perform the same experiment with a heap of sand, your foot will immediately go down. In this case the sizes of the sand grains are small, so the number of grain boundaries is large, which allows the grains to move under the pressure of your foot. In a similar way nanoceramics are malleable and ductile.

(c) Strength of materials increases in nanoform

The best-known example of this is copper. On reducing the size of a piece of copper to 50 nm its strength doubles as compared to the bulk value. When the size is further reduced to 6 nm its strength becomes 5 times that of the bulk value. How does this happen? What determines the strength of a material? The strength of a crystalline material is determined by the ease with which an atomic plane slides over its neighbouring planes on application of stress. The easier it is to make the plane slide the lesser is its strength.

Presence of defects in the solid facilitates the sliding of the atomic planes over each other. In particular, an extended defect called a 'dislocation', which is intrinsically generated in a crystalline lattice, help in the sliding of the atomic planes and thereby are responsible for the reduction of the strength of a material. When a stress is applied the dislocation moves in the direction of the stress, which can result in the fracture of the material. However, in a polycrystalline material these dislocations are generated in the grains, which are surrounded by grain boundaries where the motion of the dislocations get arrested, preventing a fracture.

In this scenario how can we understand the increase in strength of the material when it is produced in the nanoform. In the nanomaterial there are large numbers of grain boundaries, which arrest the motion of the dislocations and stop the sliding of the planes before they moved too far to cause a fracture. At first it was thought that it is this arresting of the motion of the dislocations which increases the strength of the nanomaterials compared to their bulk counterparts. But more recently this view has changed; scientists argue that the grains being of nanometre sizes the nanoparticles cannot even sustain dislocations. As a result, the crystallites being dislocation free their strength would be much larger than their bulk counterparts.

Again the technicality of sliding of atomic planes due to the motion of dislocations under stress can be understood by means of a simple analogy. Consider a carpet spread over the floor in the room. If you want to slide it over the floor by pulling it from one end, you have to apply enormous force to overcome the force of friction opposing the motion. However, before pulling the carpet if you push it from the opposite end so that the carpet gets lifted up in the middle forming a ridge then it becomes easier to pull the carpet. The ridge in the carpet is like the dislocation in a crystal, and moving the ridge by pulling the carpet, corresponds to the motion of the dislocation by the applied stress. If the carpet is not large it may not be possible to form a ridge by pushing it from the opposite end, because there won't be enough area of the carpet in contact with the floor to provide the required frictional force to form the ridge. In the later case there is no other alternative but to pull the carpet, which is going to cost lot more energy.

(d) Melting and sintering temperatures for nanomaterials

Materials in the nanoform have lower melting and sintering temperatures. For example, titania (titanium oxide) in the bulk form sinters at 1400ºC, where as prepared in the nanoform it sinters at the temperature of 600ºC. This clearly shows that there is a large reduction in the sintering temperature. While melting is a commonly understood phenomenon, let me explain what is meant by sintering and sintering temperature. To form a polycrystalline sample you take small grains of the material in a die of a given shape and apply pressure so that the grains loosely hold together forming a pallet in the shape of the die. To give strength to the pallet it has to be heated to a temperature above a certain characteristic temperature for the material for a given period of time, so that the grains in the pallet bind to form the polycrystalline sample. This process is called sintering

and the characteristic temperature for the material is called the sintering temperature.

In order to understand why the melting and sintering temperatures are lowered for nanomaterials, let me remind you that both these phenomena depend on the available surface area. Both these processes are initiated by the motion of the atoms at the surface. While for bulk materials the surface area and hence the number of atoms on the surface is small, for nanomaterials it is extremely large. Since both melting and sintering start at the surface, availability of large surface area amounts to lowering the corresponding temperatures.

(e) Catalytic properties of nanomaterials

The metals platinum and rhodium are known to be better catalysts in their nanoform. This is yet another property which depends on the available surface area, and when produced in the nanoform the surface-to-volume ratio is greatly enhanced resulting in the enhancement of their catalytic properties. It has also been established that titania in its nanoform is more efficient in removing sulphur from vehicular exhaust. When produced in nanoform not only does it acquire a large surface area but also there appear many oxygen vacancies in the material. Hence the sulphur, which first gets attached to the surface of nanoparticles of titania, migrates to the interior to fill up the oxygen vacancy, thus making the surface available for the attachment of more sulphur. The process can continue resulting in increasing the efficiency for sulphur removal from vehicular exhausts.

(f) Nanomaterials are better varisters

So far we have examined the changes in some optical, mechanical, and chemical properties of materials on reduction to nanometer sizes. Let us now look at the electrical properties. It is well known that if we apply a voltage to the two ends of a material, which is an electrical conductor, current flows through it. If the voltage is increased, the current increases, causing an increase in the electrical resistance of the conductor in turn. The increase in the resistance is mainly because of the heating of the conductor by the current. The more the current the more is the heating and the more the resistance.

However, there are materials in which the resistance decreases on increasing the current or the voltage. Such materials are known as 'varistors'. Such materials find use as a switching device. Doped zinc oxide in the bulk form is known to exhibit varistor behaviour. Polycrystalline zinc oxide is an electrical insulator, which starts conducting when doped with a suitable impurity, as also happens in many other semiconductors. A polycrystalline sample has many grains and hence grain boundaries, which scatter the charge carriers; thus contributing to the electrical resistance of the material. On increasing the voltage, the current increases heating up the material; which results in the coalescence of the grains, thereby reducing the number of the grain boundaries. This is the reason for the reduction of the resistance with increasing voltage and consequently the varistor action. It is now easy to understand why nanomaterials are better varistors. In a polycrystalline nanomaterial the grains being of nanometre size the number of grain boundaries is enormously large compared to its bulk counterpart. Hence grain boundary scattering is the major contributor to the electrical resistance of these materials. On increasing the voltage, the current and hence the heating increases causing the coalescence of the grains reducing the number of grain boundaries. The current densities in nanomaterials are orders of magnitude higher, which makes the varistor action much magnified in these systems. Thus even pure zinc oxide in the nanoform can exhibit varistor property.

(g) Band gap engineering in semiconductors nanomaterials

It is well known that semiconductors are characterized by a band gap of the order of an electron volt (ev), between the valence band, which is fully occupied with electrons, and the empty conduction band. Hence under some circumstances these can emit radiation of a specific wavelength when electrons are injected into the material. This is called electroluminescence. The same thing can also happen when electrons are promoted from the valence to the conduction band by shining light of appropriate wavelength. Under these conditions, holes will be left behind in the valence band and when the electrons and the holes recombine, radiation with energy equal to the band gap will be emitted. This phenomenon is called photoluminescence.

For either of the abovementioned phenomena to occur the semiconductor must be of 'direct band gap' type, which is a requirement arising from momentum conservation in the process of light emission. Besides, for the emission of visible light of different wavelengths the band gap must have energy appropriate to the corresponding wavelength. This in turn requires that it should be possible to tune the band gap of the semiconductor. The commonly used semiconductor silicon is an 'indirect band gap' material with the magnitude of the gap rather small compared to the energy of light in the visible range. Hence it is not a light emitter. In contrast cadmium sulphide (CdS) and cadmium selenide (CdSe) are 'wide band gap' semiconductors. Hence these are more appropriate for light emission provided their band gaps can be tuned for emission of a particular colour of light. CdSe fulfills this requirement when prepared in the nanoform. When CdSe nanoparticles prepared in different sizes are suspended in a liquid and white light is shone on the test tubes containing these suspensions, each test tube emits light of a different colour depending on the size of the nanoparticle suspended in it. This clearly indicates that the band gap of CdSe changes depending on the size of the nanoparticle; in fact, the smaller the size the

larger is the band gap of the material. As a consequence of these even materials that are not emitters of light in their bulk form start emitting in their nanoform. This is often referred to as "band gap engineering" or "quantum size effect". Thus silicon, the base material of electronics technology, can be made to emit light in its nanoform.

Fig. 2 : Fluorescence in different-sized CdSe quantum-dots

For example, if the size of the CdSe nanocrystals is between 2 to 7 nm its fluorescence can be tuned between the visible range of wavelengths of 450 to 650 nm; that is, from bluish to orange. In contrast to a bulk semiconductor where the energy levels of the electron form a quasi continuum like that for a free particle; in the case of quantum dots the energy levels form a discrete spectrum of localized states. This makes it possible for an indirect band gap semiconductor to have a direct band gap component. Hence a material like silicon in its nanoform can be made to emit visible light. These possibilities are really exciting from the point of view of technology.

(h) Maxwell's demon in biology

Nanomaterials can also help us in the development of our knowledge in other areas of science and technology, such as biology and medicine. An example of their use in the treatment of cancer was discussed earlier. Recently it was visualized that the light emitting property of nano-semiconductors can be put to use to derive information about the functioning of the biological cells; the smallest units of living organisms. In doing so the behaviour of the nanoparticles can be compared to that of the hypothetical "Maxwell's demons" of thermodynamics.

One of the laws of thermodynamics states that the entropy of a system cannot decrease. As is well known, the entropy is a measure of the disorderliness of a system. According to thermodynamics it will either remain a constant or will go on increasing, but can never decrease. In other words, it is a statement of the fact that order can never be created out of disorder. To falsify this law of thermodynamics, Maxwell visualized the existence of a mythical demon of the size of an atom or a molecule, which can distinguish between molecules in a gas moving with faster and slower velocities. Imagine such a demon being placed near a hole in a wall partitioning two chambers, one containing a gas and the other empty. The demon can allow all the faster moving molecules to pass through the hole to the empty chamber while stopping the slower ones. Thus it can create order out of disorder. The impossibility of the existence of such demons was proved rigorously in thermodynamics. However, with the discovery of semiconductor quantum dots like CdSe nanoparticles, the existence of a Maxwell's demon has become a reality for biology. These can be used as markers to learn about the *in situ* functioning of living cells.

The use of organic dyes that attach to the cell nucleus, membranes and other parts and either colour them or emit fluorescence helping to identify them was a common practice in biology. The first such dye in use was an extract of logwood (a spiny tropical American tree, *Haematoxylon campechianum*, of the pea family, having dark heartwood from which a dyestuff is obtained) to stain cells and other biological specimen. These act as reporters of biological activity. But unfortunately these are static reporters and cannot report on live action. Moreover, they bleach and lose their colour after some time and are no more able to identify cell activity. These also enter into chemical reaction with some biological molecules, which is undesirable. It is in this area that the quantum dots are found to be versatile reporters while remaining inert so far as chemical reactivity is concerned.

One of the most favourite q-dots of biology are CdSe nanoparticles. We can make CdSe q-dots in three or four different sizes and illuminate them with the same light when they would fluoresce in different colours. This property can be used for reporting about different functioning of the cell. But to do that they need to be made water-soluble so that they can enter the cell as inert objects. To enable them to report on different zones or regions of the cell they can be attached to different biological molecules, which in turn can then attach to the

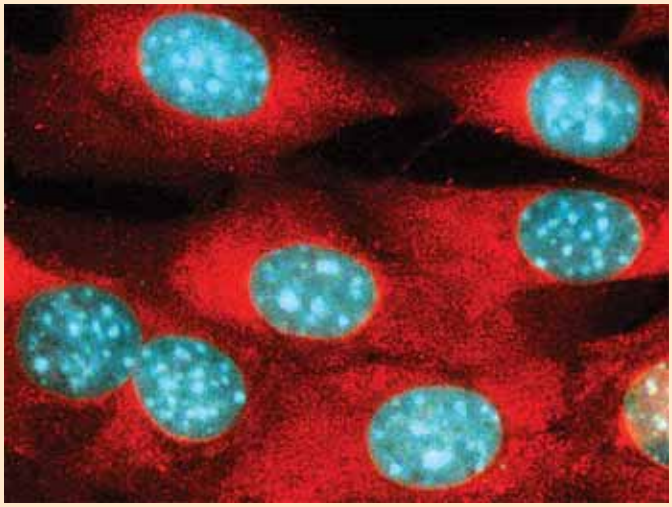

Fig. 3 : Quantum-dots in visualising biological processes

cell membranes or pass through them reporting on their activity. With this technique scientists have succeeded in detecting cancer cells at an early stage; which is a big achievement.

However, more investigation is called for before putting the use of q-dots into a common practice for any diagnostic activity, just to ascertain that their use does not cause any toxicity. One way of making these quantum dots nontoxic is to coat them with some inert material. This is precisely what has been achieved at Cornell University in USA. As described above, a q-dot fluoresces much more brightly than a dye molecule, making it a desirable reporter of cell activities. The Cornell University product has a core shell structure: these are nanoparticles consisting of a core of about 2.2 nm diameter consisting of several dye molecules, surrounded by a shell of silica molecules, making the size of the entire particle about 25 nm in diameter. These are nick named the 'Cornell Dots'. Like q-dots the Cornell dots are at least 20 to30 times brighter than the single dye molecule in solution and resist photo bleaching, a process by which dyes in solution rapidly lose their fluorescence. Also, unlike q-dots the Cornell dots are mostly chemically inert. The silica shell is silicon dioxide: essentially glass. Silica is benign, cheap and easy to attach, and it is totally compatible with silicon manufacturing technology. This opens up enormous possibilities for their use in life sciences and in information technology. These dots also raise an intriguing physics question: Why do they fluoresce so brightly? One explanation could be that the silica shell protects the core of dye molecules from the corroding affect of the solvent.

Nonetheless, the possibilities with quantum dots in imaging, diagnostics and site-selective drug delivery into cells are exciting and extensive. There is the possibility that they will emerge as biosensors, bio-analytical agents, etc., with multifarious uses. The many faceted monitoring of cells using q-dots of varying sizes and coatings, to report on what is happening at different sites in the cell is still at a developmental stage. When fully developed we will find many applications of these biological Maxwell's demons.

Production of nanomaterials

Nanoparticles can be produced in many different ways in the laboratory. All these methods of production can be roughly classified into two different categories; namely (i) the bottom-up approach, and (ii) the top-down approach. In the bottom-up approach the nanoparticles are assembled by putting together its constituent atoms or molecules. Whereas the second approach involves reductionism where one starts with the bulk material and reduces its size step by step to produce the nanoparticles. In each category there can be several techniques of production. For example, in the bottoms-up approach there are the methods based on chemical and electro-chemical routes, which are suitable for the production of nanoparticles of semiconductors like CdS and CdSe. Then there are the methods of epitaxial growth where the material is put together atomic layer by atomic layer. These include the methods of "molecular beam epitaxy" (MBE) and "metal organic chemical vapour deposition" (MOCVD). Both these methods are often used for the production of quantum dots and quantum wires. These methods have the great advantage of producing materials with very high quality of growth, and are suitable for producing samples for laboratory experiments. But the cost of production is rather high, which limits their use for commercial fabrications.

The "cluster generators" and the "low energy cluster beam deposition" (LECBD) techniques also belong to the bottom-up category. The cluster generators are commonly used for the production and study of free atomic clusters of different sizes. One of the most important discoveries made using this technique is that of the fullerene molecule consisting of 60 carbon atoms (C_{60}). The method of LECBD can be used to deposit atomic clusters of selected sizes on different substrates, which makes it more convenient than free clusters to study their properties. However, again these methods are more appropriate for the production of samples for laboratory use.

Finally to give an example of the top-down approach, one can mention the method of "ball milling". This method is often used to produce nanoparticles of metals and alloys; where one starts with bulk samples and reduces their size to nanometres by grinding them in a ball mill. This method can be adopted for commercial production as well.

A detailed description of the methods of production of nanomaterials is beyond the scope of this article. However, the principle of the method for large-scale production of nanomaterials can be easily understood from the description of a phenomenon of common day-to-day occurrence. Consider the process of boiling water in the middle of a room on a cold winter night in a hill station. Outside the room the temperature may be at subzero level. The glass windowpanes, which are in exposed to the outside, are also at that temperature. As the water boils the steam generated would drift towards the windowpanes, by the convection current set up due to the temperature difference. As the steam comes in contact with the cold windowpane, it will immediately freeze and tiny crystallites of ice will form on the glass. At the instant of formation, these ice crystallites will be of nanometre sizes, and as you wait they grow to mesoscopic and macroscopic sizes and become visible to the naked eye. This, in fact, is the principle of the method of large-scale production of nanomaterials for commercial use.

Ingots of the material to be converted into nanoparticles are heated in an oven and brought to the temperature where it starts to evaporate. A hollow cylinder, which is cooled by passing liquid nitrogen through

it, is placed nearby. When vapours of the evaporated material drift towards the surface of the cylinder, tiny nanocrystallites of the material are deposited on the surface of the cylinder, which is rotated to avoid coalescence and growth of the crystallites. The surface of the cylinder is scraped, with a suitable scraper and the nanomaterial is collected. The nanocrystallites can be analysed to check their microstructure and grain sizes. This method can be used to produce the nanomaterial in quantities of kilograms.

Conclusion

In this article we have outlined briefly what nanomaterials are, and how new technologies can evolve using the unusual properties of these materials in their nanometre sizes. Also we attempted to provide qualitative explanations of the origin of these changed properties and mentioned the methods of the production of the materials in their nanoform. In principle, the any particle can be reduced to nanometre size, which opens up an enormous possibility for the development of new technologies. This is basically the reason for the continuing emphasis on the study of nanomaterials at a scientific level. The more we understand these materials the wider would be the potentiality for their use. At the present juncture one of the major problems that engage the efforts of the material scientists is to evolve some method for the production of nanomaterials in mono-dispersive form. So far all the methods used produce these with a distribution of sizes, and when one talks about particles of a given size it refers only to the average size. Mono-dispersive nanoparticles of a given material as building blocks are expected to have exotic properties, the study of which is of interest purely from scientific point of view. The only such solid that exists at present is fullerene. We know that fullerides (compounds formed by substituting metal atoms for one or more carbon atoms in the fullerene molecule), which are bad conductors of electricity in their pure form, become metallic when doped with alkali atoms and even become superconductors at comparatively high temperatures. Besides, their electrical and magnetic properties show dramatic changes with the choice and concentration of the dopants. Overall the capacity to manipulate such solids increases manifolds resulting in their futuristic use. Related materials that also exhibit many exotic properties are the carbon nanotubes. Scientists are visualizing their use in making nanoelectronic devices and in engineering applications with such exotic ideas as dent-resistant cars to earthquake-resistant buildings.

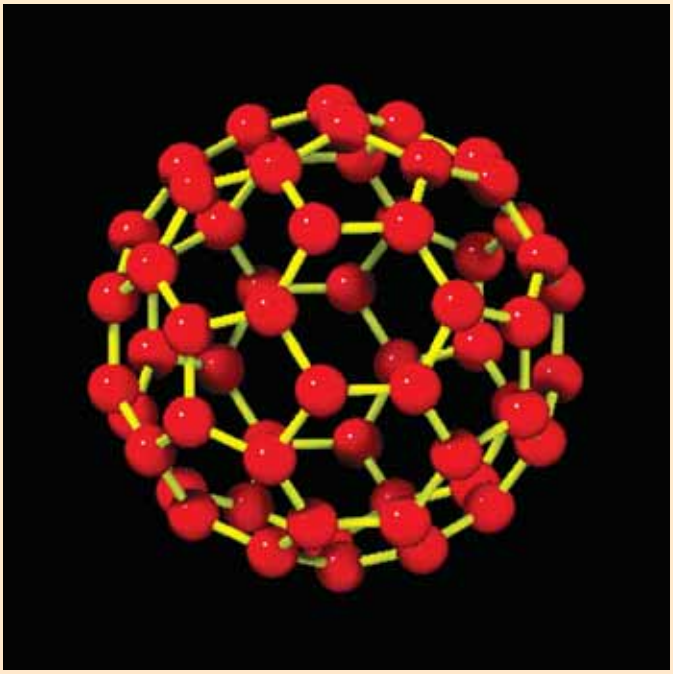

Fig. 4 : Fullerene

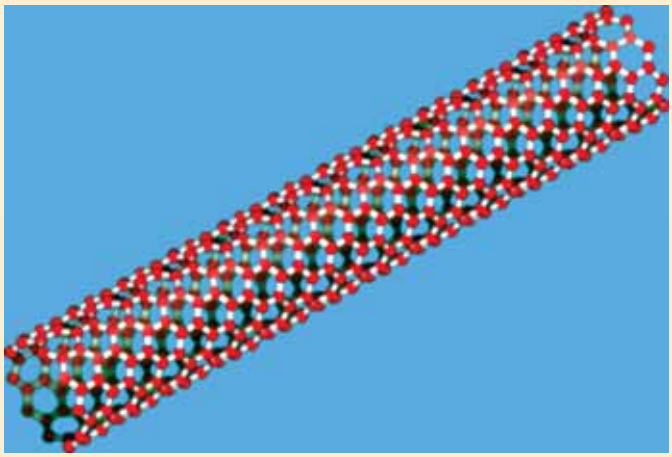

Fig. 5 : Carbon nanotube

Acknowledgement

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This article is the outcome of a large number of talks delivered to a diverse audience; starting from high school students, to the students of different colleges and universities, to general public, with a positive and encouraging response every where. This prompted me to put the content of the talk to a printed form, with the hope that it may provide some food for thought to many other readers.

Prof. S. N. Behera was former Director of Institute of Physics, Bhubaneswar. A gifted speaker and an author, he takes keen interest in science popularization. He can be contacted at Physics Enclave, H I G – 23/1 Housing Board Phase 1, Chandrasekharpur, Bhubaneswar-751016, Orissa, INDIA.

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Copernicus and Astronomy

❑ Dr. K.D. Abhyankar

The introduction of the heliocentric planetary system by Copernicus is an important landmark is the historical development of science in general and astronomy in particular. The difference between Aristotle's cosmology, which was universally accepted in Europe before its advent, and the mechanical world view based on Newtonian physics, which followed it, is so fundamental that the change brought about by the ideas of Copernicus is often called the

Nicolaus Copernicus

Copernican revolution. The impact of this revolution was of course keenly felt in the western civilization to which it was indigenous. In fact the revolution had to face strong opposition from the Christian Church before it succeeded in establishing itself which the work of Galileo, Kepler and Newton. It should be illuminating to see how the western philosophers and theologians had to perform an agonizing reappraisal of their time-honoured concepts about Universe and God. It would help us in developing the much-needed scientific outlook.

Nicolus Copernicus was born on 14 February 1473 at Torun in Poland. At first he went to the University of Cracow where he studied mathematics. But his uncle, who was the bishop of Ermland, wanted him to join the Church Order. So Copernicus went to Italy where he studied Greek at Bologna and later, law and medicine at the University Canon of Frauenberg, where he helped the poor with his knowledge of medicine. However, while at Bologna he was associated with the astronomer Dominico Novarra. Under his influence Copernicus became interested in astronomy, which became his life-long passion. Soon he became a well-known astronomer of Europe.

In 1514, Copernicus was invited by the Pope to give his opinion on the badly needed reform of the calendar. But he refused to give his opinion because he did not think that the positions of the Sun and the Moon were known accurately enough. He was not satisfied with the geocentric system of Ptolemy, which he thought was too cumbersome. After searching old Greek literature he came upon the idea of a moving Earth put forward by Cicero, Philoaus and Heraclides. Accordingly, the daily rising and setting of celestial objects was attributed to the rotation of the Earth around its north-south axis, and all the planets including the Earth were considered to move around the central Sun. Only the Moon moved around the Earth. Copernicus computed new orbits of the planets on this basis. His mathematical treatise *The Revolutions of the Celestial Orbs* was published in Germany in 1543 in spite of opposition from the Protestants like Luther and Molanchtion. The printed copy of the book was brought to Copernicus on his deathbed; he died on 24 May 1543. The Prutenic Tables of planetary positions prepared by Erasmus Reinhold utilizing the Copernican method were later used in 1582 for the calendar reform introduced by Pope Gregory.

The heliocentric system of Copernicus was immediately successful in many respects as compared to the geocentric system of Ptolemy.

(i) The apparent retrograde and non-uniform motions of planets could be easily explained as due to the Earth's motion around the Sun.

(ii) The order of the planets could be unambiguously established according to their distances from the Sun.

(iii) Closeness of Venus and Mercury to the Sun in the sky was shown to be a geometrical consequence of their inferior orbits. Further, the phases of Venus like those of the Moon, predicted by Copernicus, were later confirmed by Galileo.

(iv) All motions in the Copernican system were from west to east and the angular speed decreased uniformly with increasing distance, reducing to zero for the distant stars.

(v) The relative sizes of the orbits of all the planets were uniquely fixed. In this way Copernican heliocentric system brought out the harmony in the observed motions of celestial objects.

Let us now consider the arguments put forward against the ideas of Copernicus. We shall first look at the philosophical and theological objections.

1. Motion of the Earth was found to be contrary to the Bible. This argument is no longer taken seriously. But in the beginning it was hard to refute. When the motion of the Earth was finally established the

leaders of the Church argued that the written words of the Bible are not to be taken literally. They are to be understood in terms of metaphors and symbols.

2. According to Aristotle's cosmology, all things in the universe were divided into two categories. All celestial bodies above the sphere of the Moon and including it were thought to be pure, incorruptible and changeless. The terrestrial bodies were impure, corruptible and liable to degeneration and death. If the Earth were allowed to become a planet moving around the Sun it would become a celestial body, implying that the celestial bodies are also corruptible. This argument was met when empirical evidence showed that there are spots on the Sun, which appear and disappear. Similarly comets, which are definitely changeable, and the new stars or novae were shown by precise observations to belong to the celestial regions beyond the Moon. Hence there was no need to distinguish between pure celestial and impure terrestrial objects. In fact, modern astrophysical investigations show that all stars and galaxies are made of the same 92 elements as are found on Earth.

3. Aristotle's cosmology, which was the basis of Christian theology, was based on the central position of humans in the universe. It was the unique human being on Earth at the centre of the universe who was redeemed by Christ, the Son of God. Now if the Earth were removed from the central position in the universe and made a mere planet around one of the stars, namely the Sun, then the above theology collapses. In fact, one can think of other civilizations on other distant planets that would have their own prophets. If this were true, how could one deny more than one prophet on Earth itself?

It is for the Christian religious leaders to tackle these questions now because we are already in the space age when contact with other extraterrestrial intelligent civilizations seems quite possible. However, Christianity has often shown the vitality to adjust its faith to new discoveries of science. But it was hard in the beginning and people like Bruno had to die at the hands of inquisitors for holding the view that the universe is infinite and it contains many planetary systems with intelligent beings on them.

Let us now consider the scientific objections to the Copernican hypothesis of the moving Earth.

1. The first objection was that if the Earth rotated around an axis passing through its centre then light things like air and clouds would appear to fly out while the objects on the surface of the Earth would be thrown out by the centrifugal force. Actually nothing of this sort happens because everything is held by Earth's gravitation and is carried with it in its diurnal rotation. There are numerous evidences of this fact in meteorology and ballistics.

2. Although the rotation of the Earth was shown to be plausible there was no actual physical proof of the same, but about four hundred years after Copernicus the French physicist Jean-Bernard-Léon Foucault performed an experiment, known as the Foucault pendulum experiment, which proved that it is indeed the Earth and not the heavens that rotates. (The experiment is easily understood if we imagine ourselves at the North or South Pole. If we hang a pendulum from the roof of a dome and allow it to oscillate freely in a plane, the plane of the pendulum will seem to rotate in the same direction as the stars in the sky. This happens because, the plane of the pendulum and position of the stars are fixed while the Earth rotates under the pendulum.)

3. In Aristotle's philosophy it was argued that all heavy terrestrial things like earth and water move downward because they have a tendency to move towards the centre of the universe, which coincides with the centre of the Earth. If the Earth moved around the Sun there would be no centre of the universe towards which these bodies could move. This argument is countered by the fact that it is only objects on Earth that move towards its centre; objects on any other celestial body would be attracted to the center of that body and fall down with respect to it. Further, as shown by the artificial satellites, objects can be thrown up never to return again if sufficient upward thrust is provided.

4. The most important argument against the motion of the Earth around the Sun was the absence of observed parallax in the motion of stars – shift in the positions of nearer stars relative to the distant stars that ought to be caused by the motion of Earth. Such motion was not observed during the times of Copernicus. So he argued that the stars must be very far away. However, Tycho Brahe, the great observational astronomer of the sixteenth century did not accept the idea of a moving Earth precisely because of this fact. Instead he proposed his Tychonic system in which the Sun and the Moon moved around the Earth while all the other planets moved around the Sun.

The motion of the Earth was scientifically proved when Henderson, Bessel and Struve measured the first few parallaxes between 1837 and 1839. Since then parallaxes have been measured for nearly 6,000 stars. In addition, the motion of the Earth is also reflected in the apparent motion of approach and recession of stars with a period of one year, as shown by the periodic Doppler shifts of the Fraunhofer lines in their spectra.

We shall now briefly sketch the development of astronomy after Copernicus. The Copernican system, which provided a new working model of the solar system, did not solve the problem of the planetary motions. In spite of its inner harmony it still needed a large number of uniform circular motions superposed on one another for each planet. Between 1596 and 1619 Johannes Kepler showed that the

orbits of all planets are ellipses with Sun at one of the foci. Further, instead of the uniform angular motion he obtained the law of constant areal velocity with respect to the Sun. In this way the central position of the Sun in the planetary system was geometrically established. The *Rudolphine Tables* of planets issued by Kepler in 1627 on the basis of his new discoveries far exceeded in accuracy all the previous almanacs and made them obsolete.

The solution of the problem of the planetary motions was completed by Newton's discovery of the universal law of gravitation in the latter part of the 17th century. Newton not only derived mathematically the Kepler's laws of planetary motions, but he also showed that the principle of gravitation applies equally to the motion of the Moon around the Earth and the motion of a falling body or projectile near the surface of Earth. Further, he explained the phenomena of tides and the precession of equinoxes by the same principles.

The next two centuries saw the development of Newton's ideas into the grand edifice of celestial mechanics, which explained even the minor deviations in the motions of planets caused by perturbations of other planets and successfully predicted the existence of the planets Neptune and Pluto. Similarly, comets were shown to be members of the solar system obeying the same laws as the planets. In the last hundred years Newton's law of gravitation has been successfully applied to binary stars, star clusters, and multiple galaxies. The clustering of galaxies seen through the entire universe is a testimony to the validity of the Newton's law of gravitation over vast distances in space.

The triumph of celestial mechanics, which was based on the universal nature of gravity, was so great that all branches of science became mechanically oriented. In this way a mechanical worldview developed and determinism and rationalism gained ground.

In conclusion, the story of astronomy and science since the introduction of the Copernican system shows the slow displacement of dogmatic and superstitious attitude by a more rational empirical outlook, which is known as the scientific way of thinking. Empiricism is nothing but an objective systematization of everyday experience. This method is not contrary to our traditional spiritual outlook, which is a systematization of moral experience. Hence reconciliation of spirituality and science advocated by our leaders is possible. But this can be achieved only by the elimination of dogma and superstition. While dogma has seldom had a hold on the Indian mind, we have a strong need of overcoming superstition. When this happens the Copernican revolution would finally arrive in our land.

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Insomnia

Bed Down to Sleep Well

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Sleep is a superb health formula. If tired, your limbs are aching and your mind is in a spin. Yet, take a few hours of sleep and you wake up feeling completely recharged and full of vigour, a totally new person.

Most men and women spend a third of their lives in the land of nod. Infants seem to enjoy sleep the most – sleeping a good twelve hours each day. Most grownups sleep seven to eight hours each night, while the elderly sleep a little less. The timing, duration and internal structure of sleep vary a great deal among different individuals, but studies find that adults who habitually sleep less than four hours or greater than nine have increased mortality rates as compared to those who sleep seven to eight per night.

However, sleep does not come easy to all. Millions of people yearn for its comfort and remain deprived, no matter how much they try. Disturbed sleep is among the most frequent health complaint physicians encounter.

Without adequate sleep things just start falling apart. You cannot function optimally, the body suffers, the brain loses its sharpness, the mind becomes irritable and in due course, each system begins to suffer.

You could try sleeping pills, but that's neither healthy nor reposeful. The unnatural sleep the pills induce is very different from the normal sleep. Worse, there's every possibility that you might get hooked to these pills. What's best, therefore, is to adopt simple sensible measures to drift into the realm of land of nod.

UNWIND...AND RELAX : It's essential that your mind be geared for sleep. Never work up to the last moment, and then hope you will immediately fall to sleep while your mind is still racing at breakneck speed. For instance, if you come home from work at midnight, just don't expect to drop off to sleep right away.

Plan your day such that you relax for at least half an hour before going to bed. Lie back in the chair, and "let go." Let the mind wander. Gently unwind. Tensions and anxieties are gently released from the system in this simple way.

DO SOMETHING YOU ENJOY : Read a book, magazine or listen to your favourite music. Or better still, spend time with your family. Do something that soothes your mind for a while before you switch off the lights. This way you can gear your mind to a low-key pitch before nodding into prompt, relaxing sleep.

TAKE A STROLL : A short casual stroll just before you bed down helps remove tensions and anxieties from your mind and prepare it for sleep. Do not hurry. Take it leisurely. Just amble. Let a lovely sense of laziness set in. Never, never go for an extensive exercise – it can steal your sleep.

SOAK IN A BATH. There is little so relaxing as a nice shower or bath about an hour before you hit the sack. But be careful not to fall asleep in the bathtub, for this has happened!

TRY A MILK-CEREAL DRINK : A small meal of milk and cereal promotes restful sleep, and that's not just folklore. Research shows that not only this simple pre-bed drink helps induction of sleep; its effect also persists into the later hours of the night. It is preferable not to have tea or coffee, for these contain caffeine, which can chase away sleep.

EAT LIGHT : A large meal just before bedtime is never a good idea – it can keep you awake for hours. The digestive system would simply not allow you to switch off. Eat light and preferably, at least, two to three hours before you settle down to bed.

ALCOHOL IS NOT THE BEST RECIPE : Many people think of alcohol as a wonderful nightcap. It isn't. Although it may increase drowsiness and shorten sleep latency, even a moderate amount of alcohol interferes with the ability of the brain to maintain sleep and increases awakening after you have dozed off.

SET A ROUTINE : Unless your work schedule will not simply permit, it is best to set your body clock for sleep. Your sleep centre, located in the brain, will appreciate this regularity very much. Frequent late nights can upset it, making it difficult for you to fix it back.

MAKE YOUR SURROUNDINGS CONDUCIVE : Make sure that your surroundings are "open sesame" to sleep. All should be quiet, the curtains should be drawn, no light should streak into your room and you should have no luminous clocks hanging on the wall, to remind you about the time it has taken to fall asleep!

GET INTO A COMFORTABLE BED : Sleep comes best and fastest when the bed is comfortable. In the West, they even have beds which rock at a price! You may not order for a rocking bed, but do find a bed that allows you to relax completely.

YOG NIDRA WORKS : The ancient Indian science of yog nidra can work wonders. It can relax your entire system completely and purposefully. Doing it is easy. Follow the steps given here.

- Lie flat on the back. And gently stretch out.
- Start with the left toes and systematically relax this part, work up to the ankle, lower leg, knee, thigh. Do the left side, then the right.
- Then move up the body, relaxing the trunk. Then the left side fingers, wrist, forearm, elbow, upper arm and shoulder. Then move to the right side, and similarly relax that side completely.
- Now move upwards towards the neck muscles, face and scalp muscles. Just let your entire body go limp. Soon you will be fast asleep.
- Take deep breaths. Softly, slowly, rhythmically breathe in... out...in...out slow and regular.
- Tell yourself you'll be fast asleep by the time you have filled your lungs with ten deep breaths. Just try it and see!

KICK OFF DEPRESSION : Depression can interfere with sleep and awaken you prematurely, say at two or three o'clock in the morning. If you face this problem, seek help from a mental health professional. Counselling and medication can ease your mind and warm you up for restful sleep.

MELT THE FAT : Of the many ills that obesity causes, sleeplessness is the least talked about. But melt the fat and feel the difference! You would even stop snoring and truly enjoy your sleep.

RESET YOUR BODY CLOCK : Rapid time zone change sets up jet leg. You experience excessive daytime sleepiness, sleep onset insomnia, and frequent arousal from sleep, particularly in the latter half of the night. Bowel and tummy discomfort is also common. The symptom-complex is transient, typically lasting two to fourteen days depending on the direction of travel, and the traveller's age and phase-shifting capacity.

The best and the easiest way to break out of this cycle is to quickly reset your clock to the local time. Be out in the sun as much as possible. Take a walk in the morning. Spend time outdoors. Stay away till the night sets in. This will help you adopt more quickly to the local time than if you were to remain in the hotel room all day.

Good night! And sleep well!

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(Contd. from page 39)

Communicating Science & Technology in the North-East

S&T communication. Finally, it is necessary to ensure that the benefits of information and communication technology, including that of Edusat, must reach every district of the North-Eastern States.

The North-East India is the gateway to South-East Asia. The North-Eastern region shares 98 per cent of its border with Bangla Desh, Bhutan, Myanmar, Nepal and China. It is a landmass with a geographical area of 2.55 lakh sq. kms, which is a mere 7 per cent of country's total area, while the population is only about 4 per cent of the country's population. And yet, each State has its own strengths, weaknesses, opportunities and problems. Undoubtedly, it is a very, very special region. It is imperative that we recognise the strategic needs and interests of each State individually. This is especially true for S&T communication.

❒ V. B. Kamble

Recent Developments in Science and Technology

Mobile-phone signals reveal rainfall

Mobile phone masts now might inadvertently help to improve the accuracy of weather forecasts. Research carried out by Hagit Messer and her colleagues at Tel Aviv University in Israel shows that it is possible to gauge rainfall by analysing the signal fluctuations of mobile-phone base stations. The group believes that by using information that is already collected by mobile-phone companies it should be possible to create much more accurate weather models.

It is a well-known phenomenon that rain can affect mobile-phone transmissions: droplets in the air reduce signal strength, with different-sized droplets affecting specific frequencies in the signal. This is so firmly established that base stations now automatically compensate for signal attenuations as the atmospheric conditions change, and this work has been reported in the journal Science.

Now Messer has shown that this compensation can reveal useful information. Using recordings of signal-strength fluctuations taken from calls being sent back and forth between base stations, the groups were able to calculate the surface rainfall every 15 minutes during a rainstorm. These data were found to be comparable with direct rain measurements taken in Tel Aviv and Haifa.

Source: www.nature.com

Saturn's rotation puts astronomers in a spin

The rate of Saturn's spin, estimated by NASA scientists from data sent back by the Cassini spacecraft have turned out to be far from what the scientists were expecting. As a gas giant, Saturn's rotation has been historically difficult to measure. Its hazy atmospheric features shift with respect to each other and cannot be used to clock the spin rate of the planet's interior. The most commonly cited figure for Saturn's rotation period – 10 hours, 39 minutes and 22.4 seconds – was derived in 1980 from Voyager observations of radio waves generated by solar radiation hitting the planet's atmosphere. Yet Cassini has returned a result almost 8 minutes longer, a difference that defies easy explanation.

One possible explanation is that the electrically charged ionosphere surrounding Saturn is "slipping" relative to the planet's rotation. This ionosphere influences the shape of the magnetic field, so a change in the friction between the ionosphere and upper atmosphere, due perhaps to seasonal variations in solar illumination, might account for the difference between the Voyager and Cassini data.

According to the scientists "The knowledge of the rotation period is a very important ingredient when you try to model the interior of a planet like Saturn."

Source : www.newscientist.com

Treatment hope for haemorrhagic fever

A vaccine has shown effectiveness in treating deadly Marburg disease – a haemorrhagic fever closely related to the disease caused by the notorious Ebola virus – for which there is currently no cure. The study carried out in monkeys represents the first successful treatment of the disease, which causes internal bleeding at multiple sites and is usually fatal.

The vaccine was first reported in June 2005, when Thomas Geisbert and colleagues at the US Army Medical Research Institute of Infectious Diseases, announced that they had successfully immunised a number of crab-eating macaque monkeys that were then infected with Marburg virus.

The same team has now taken the vaccine a step forward by testing it as a treatment after exposure to the virus, rather than before. Five rhesus monkeys were infected with a high dose of Marburg virus and were then injected 20 to 30 minutes later with the vaccine. They all survived for at least 80 days. Three other monkeys that were also infected with the virus but not given a vaccine had all died by day 12 of the study.

In a commentary accompanying the study, published in The Lancet, Stephan Becker from Germany's Robert Koch Institute describes the work as good news for health workers who are in the front line against this highly contagious virus.

Source: www.newscientist.com

Drill digs deeper than ever into Earth's crust

Since the 1950s, people have dreamed of drilling through the Earth's crust to the mantle. We are now a step closer, having reached the "gabbro" layer of oceanic crust for the first time.

About 60 per cent of the Earth's surface is covered in oceanic crust, but there are still many questions about how it forms. Gabbro, a coarse-grained rock that forms as trapped magma slowly cools, might hold some of the answers. To get their hands on some of the stuff, a team led by Douglas Wilson of the University of California at Santa Barbara bored into the ocean floor 800 kilometres west of Costa Rica.

The tough rock at times only allowed their drills to burrow 10 metres per day, but eventually, at 1,157 metres, the team hit gabbro. The hole, now 1,500 metres deep, is still about 4 kilometres short of the mantle.

Source: www.newscientist.com

Compiled by : Kapil Tripathi