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Establishing identity: the biometric way

Alfred Werner
Founder of coordination chemistry

(1866-1919)

Inside

Editorial: Why should scientists communicate with lay persons? 39

Alfred Werner: Founder of coordination chemistry 38

Establishing identity: the biometric way 35

Graphene - Two-dimensional carbon sheets 32

Interview with Prof Robert F. Berry 30

When the Pregnancy Goes Wrong Tiding Over the Woes of Miscarriage 27

Recent Developments in Science and Technology 25

VP News 21

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

Why should scientists communicate with lay persons?

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An advisory note has been prepared by the Committee on Freedom and Responsibility in the Conduct of Science. This was drafted when the committee convened about three months back in Bogota, Colombia to reflect on the responsibility of scientists for effective communication of the research they do. International Council of Science Unions has constituted this committee and has circulated the advisory note for consultation and debate.

The glaring disconnect between perception of the common man and the research in universities and laboratories is worrying the scientific community. This realisation is an important step and the charter to the committee is therefore very important and timely. A more activist camp has been arguing that scientists have the moral responsibility to publicly discuss the social implications of their research and this must include warnings of potential dangers.

There are complexities and uncertainties in communicating science as well as new opportunities, as the electronic and digital media – television, radio, internet, CD ROMs, etc. – become accessible. Most scientists have remained silent about their work even in sectors where the public has been eager to understand a natural phenomena or a man-made development. This has given space to political commentators to debate on subjects with inadequate comprehension of the subject or description of the implications of the work or emphasis on trivial issues while the major issues have attracted inadequate attention. Only scientists, however, can best describe the importance of their work and how research is conducted; the ways how funds are sourced; the impact of their work; and the importance of peer review.

The debates on GM foods, environmental clearances for large projects and energy generation based on nuclear route in the last few years have been engaging the public in India as well as many other societies. Commentaries in the print and electronic media have largely been monopolised by a few who are basing their arguments on selected data and ideological interpretation. There may be vested interests behind the reports designed to create a bias in the reader/ viewer for strategic gains. An informed public would be empowered to analyse such reports and reach their own conclusions.

Improving the level of understanding of science among the lay people is a challenge. Very few scientists – social or material – are trained in the various stages of such a study. We have not given adequate attention to developing expertise among the youth for developing a self-enlarging system of research, publications, mentors, institutes, etc., in this area.

A social science academy deliberated on this among other issues at Guwahati in December last. The sentiments expressed by the delegates at seminars, symposia and plenaries need to be formalised into resolutions for specific institutions and departments for action. Outreach of science and technology was discussed because of the importance it has acquired over the last two decades.

Scientists must overcome negative feelings for journalists even if earlier experience has been not always positive. Journalists must obtain the views of scientists and researchers and present these logically without tilting statements to allow misinterpretation.

The advisory note by the Committee on Freedom and Responsibility proposes draft guidelines on effective communication. Papers in research journals do not test skills needed for reaching out to the non-specialist. This is a responsibility towards the public who ultimately support civil, strategic, or defence research. Achieving a balance between complacency and alarm, when commenting on emergency developments, is emphasised. It calls for training in communications to be made a key component of science education.

Perhaps, the last recommendation should form a component in formal science courses at universities, as has been adopted in Business Administration or Law. Is there an opportunity for Vigyan Prasar and other such central organisations to give the issue an early consideration and shape an initiative that meets the requirement of the community and is attractive to active scientists?

The scientific community is willing to view science communication as an integral part of its responsibility. The professional societies and science academies can take a lead in the process. Institutional and other support would be possible from Vigyan Prasar.

☐ **Anuj Sinha**

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Alfred Werner
Founder of coordination chemistry

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1913 was a memorable year, Rabindranath Tagore became the first Indian to receive the Nobel Prize for creating "sensitive, fresh and beautiful verse." And Alfred Werner became the first Swiss chemist to win it for throwing "new light...on the linkage of atoms in molecules." The poet eulogised the mind that is without fear. Such was the mind of Werner who "shook chemistry to its utmost foundations" at the turn of the century.

Animesh Chakravorty in *Resonance*, September 1999

From 1892 he (Werner) worked on the inorganic complexes of metals. This large class of chemical compounds had seemed confused; the sort of structure theory that had served well in organic chemistry did not appear to apply, and neither did ordinary valence rules. Werner brought a new view to them.

Dictionary of Scientists, Cambridge University Press, 2003

Alfred Werner belonged to the same generation of chemists as those who erected the beautiful structure of modern chemistry on the foundations laid by the old guards. Remember, that when these chemists built their molecular structures during the late nineteenth century, involving molecules containing sometimes several dozens of atoms, the concepts about electrons were still nebulous—many were not even sure of the real existence of atoms. What they relied on were basically had experimental facts, and clear logic.

N. C. Datta in *The Story of Chemistry*, Universities Press (India) Limited, 2005

Alfred Werner was the first Swiss citizen and also the first inorganic chemist to win the Nobel Prize (1913). He was awarded the Nobel Prize "in recognition of his work on the linkage of atoms in molecules, by which he has thrown fresh light on old problems and opened new fields of research, particularly in inorganic chemistry". It was Werner's coordination theory which formed the basis for modern coordination chemistry. His work on the spatial relationships of atoms in inorganic complexes led to the foundation of inorganic stereochemistry. In fact, Werner for the first time demonstrated that the stereochemistry is a general phenomenon and not merely confined to organic chemistry.

Coordination chemistry is a branch of chemistry that describes the chemistry of metals and metal ions in their interaction with other molecules or ions. A coordination complex (also called metal complex) usually refers to a structure containing a central atom or ion (usually of a metal) bonded to a number of molecules or anions called ligands or complexing agents. The particular atom of the ligand involved in direct bonding with the central atom or ion is called the donor atom. A ligand can donate more than one pair of electrons.

A coordination compound is a compound that contains a coordination complex. The terms "coordination complex" and "coordination compound" are often synonymously used. It may be noted that the terms "coordination compound" and "coordination complex" are somewhat flexible in the sense that their meanings have evolved and changed with the development of inorganic chemistry.

Alfred Werner

The term "coordination" refers to the coordinate covalent bonds between the ligands and the central atom or ion. In coordinate covalent bonds a ligand donates electrons from a lone pair into an empty metal atom orbital. There can be organic ligands; for example, alkenes whose pi bonds can coordinate to empty metal atom orbitals. Zeise's salt $K^+[PtCl_3(C_2H_4)]^-$ is a coordination complex in which ethane, an organic group, acts as ligand.

Many metal complexes have spectacular colours and are used as pigments. Such spectacular colours result from the electronic transitions by the absorption of light. Chemists were familiar with coordination complexes like Prussian blue and copper vitriol much before they understood their chemical nature.

Werner was born on 12 December 1866 in a small town of Mulhouse (Mulhausen) in Alsace (which was then part of France but it was annexed by Germany in 1871). His father J. A. Werner was a foundry worker and locksmith and his mother was Salome Jeanette Werner (*nee* Tesche). At an early age Werner developed an interest in chemistry.

Werner began his education in Mulhouse; first at the Ecole Libre des Feres (1872-1878) and then at the Ecole Profesionelle (1878-1885). The latter was a technical school, where he studied chemistry. During his one-year compulsory military service in the German army (1885-1886), Werner took some organic chemistry courses at the Technical University (Technische Hochschule) in Karlsruhe. In 1886, he joined the Federal Institute of Technology (Eidegenossische Technische Hochschule) in Zurich, Switzerland. He did very well in chemistry but his performance in mathematics was poor. In 1889, Werner received a degree in technical chemistry and continued to work for his doctorate degree under the supervision of his teacher Arthur Hantzsch, an eminent organic chemist.

Werner received his doctorate degree in 1890. His doctoral thesis was titled "On the spatial arrangement of atoms in nitrogen

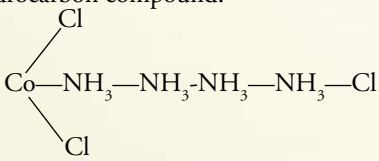
Joseph Achille Le Bel

compounds." The thesis, written under the supervision of Hantzsch, was a true classic of science writing on stereochemistry. It extended the concept of tetrahedral carbon developed by Joseph Achille Le Bell and Jacobus Henricus van't Hoff to the nitrogen atom. In inorganic chemistry it was real a breakthrough. As Animesh Chakravorty wrote: "An inherent 'lack of belief in authority...and an urge towards the truth' drove him. The edict of spatial orientation of bonds (stereochemistry) as a special feature of carbon alone did not sound logical to him. And he took to the mission of liberating stereochemistry from a mere speciality to an all-pervading generality. Werner was inventing a new paradigm in chemical science."

After receiving his doctorate degree Werner decided to pursue an academic career. He did not get an opportunity immediately. He went to Paris where he worked during 1890-1891 under Berthelot at the College de France. In 1893, Werner was appointed associate professor at the University of Zurich, and in 1895 he was promoted to full professor. Werner became a Swiss citizen in 1894. He taught organic chemistry till 1902. After that he started teaching inorganic chemistry, but he continued to teach organic chemistry as well.

Before Werner, the understanding of valence bonding and geometry in metal amine complexes such as $Co(NH_3)_6Cl_3$, which were also called molecular compounds, was really very confusing. In 1847, Frederick Augustus Genth, who worked with the German chemist Robert Bunsen at Marburg, Germany synthesised a number of ammonia-cobalt compounds. Genth's results were published in 1851 by which time Genth had moved to USA. Wolcott Gibbs, an American chemist started investigations on the compounds synthesised by Genth. In 1856, Genth and Gibbs jointly described the syntheses and analyses of 35 ammonia-cobalt compounds. The unusual properties and striking colours reported by Genth and Gibbs posed a challenge to theoretical chemists.

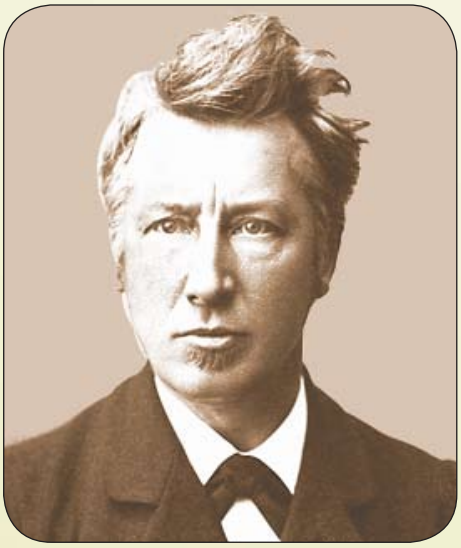
The first attempt to describe the structures of the ammonia-cobalt complexes prepared by Genth and Gibbs was made by Christian Wilhelm Blomstrand, a Swedish chemist in 1869. Blomstrand proposed a chain theory by making use of the variable valence of nitrogen. Blomstrand's structural model was further modified by the Danish chemist Sophus Jorgensen. According to this model the ammonia molecules (NH_3) in ammonia-cobalt complex are linked in a chain as CH_2 groups are linked in a hydrocarbon compound.



Blomstrand-Jogensen formula for $[Co(NH_3)_4]Cl_3$

Jorgensen prepared and examined more new ammonia complexes with metals like chromium, rhodium, platinum and cobalt and determined their physical properties.

Werner in his Nobel Lecture said: "During the great era of development of organic chemistry, during which the theory of structure was perfected, the molecular compounds had become stepchildren, and attention only continued to be given to a few of them because they were of practical interest. This neglect can be ascribed to the fact that it was impossible to develop the constitution of these compounds on the same valence principle as the constitution of organic compounds."



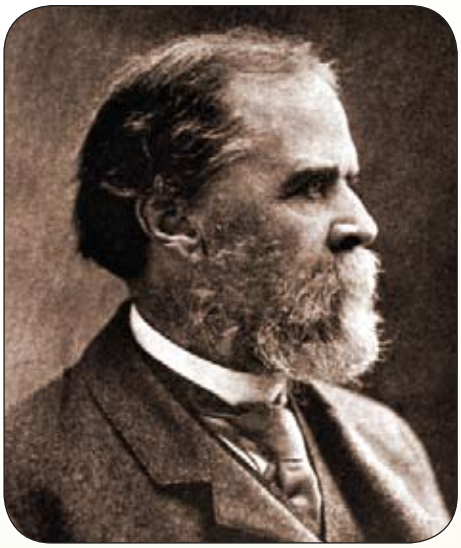
Jacobus Henricus van't Hoff

Frederick Augustus Genth

Werner published his coordination theory in 1893, which postulated that single atoms or molecules could be joined and grouped around a central atom. It is said that in the middle of night in late 1892, Werner woke up suddenly after visualising the solution for the structure of coordination complexes in a dream. Throughout the remaining night and the next day he wrote down the details of his coordination chemistry, which he published in his legendary paper "On the constitution of inorganic complexes". August Kekule also worked out the structure of benzene in his dream. It is interesting to note that before formulating the coordination theory Werner did not carry out a single experiment in the field of coordination chemistry.

Werner's theory not only explained the properties of known compounds which could not be done earlier with the help of the then existing theories, but it also predicted the existence of many unknown compounds. The important postulates of the coordination theory of Werner are:

1. In coordination compounds, central metal atoms exhibit two types of valency—primary valency and



Wolcott Gibbs

secondary valency. The primary valency, also called principal, ionisable or ionic valency, corresponds to the oxidation state of the metal ion. The secondary valency, which corresponds to coordination number, is non-ionic and it is satisfied by either negative ions or neutral molecules.

2. Every metal ion has a fixed number of secondary valencies or, in other words, has a unique coordination number.
3. The metal atom tries to satisfy both primary and secondary valencies.
4. The secondary valencies are directed towards fixed directions in space resulting in a definite geometry of the coordination compound. Based on this postulate Werner proposed that compounds having coordination number six would have octahedral configuration and compounds having coordination number four a square planar or tetrahedral configuration.

Geometrical arrangements of different ligands result from the coordination number. The most commonly observed geometries are listed below:

Coordination number	Observed geometry
2	Linear
3	Trigonal planar
4	Tetrahedral or square planar
5	Trigonal bipyramidal or square pyramidal
6	Octahedral (orthogonal) or trigonal prismatic
7	Pentagonal bipyramidal
8	Square antiprismatic
9	Tri-capped trigonal prismatic

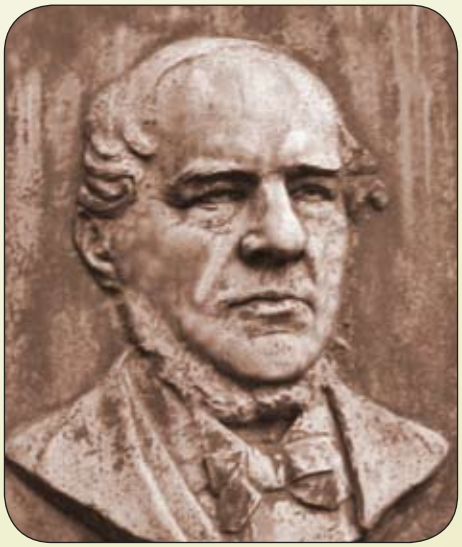
Werner's theory also predicted that different kinds of isomerism, namely cis-trans isomerism, facial-meridional isomerism, optical isomerism, and structural isomerism, may be observed in coordination complexes.

To validate his theory Werner had to work for nearly 25 years and in the process he prepared more than 8,000 compounds. In 1907, Werner prepared a compound, an ammonia-violeo salt, predicted by his coordination theory. In 1911, he resolved a coordination compound into optical isomers which helped to establish his theory.

Werner's ideas not only revolutionised inorganic chemistry but soon it found applications in many other fields, namely organic chemistry, analytical chemistry, physical chemistry, biochemistry, geochemistry and mineralogy.

Werner's life was totally devoted to science. He not only himself worked hard but he made his co-workers work very hard. He was a real hard taskmaster. He wrote two classics—*New Ideas in Inorganic Chemistry and Textbook of Stereochemistry*. The books were originally written in Swedish and both were published in 1904.

Werner was corresponding member of the Royal Society of Sciences at Gottingen and of the Physico-Medical Society of Erlangen and Chemical Society of London. He was a permanent member of the Imperial Society of Friends of Natural History, Anthropology and Ethnography of Moscow.



Christian Wilhelm Blomstrand

Sophus Jorgensen

The Chemical Society of France (Societe Chimique) awarded him the Leblanc Medal. A street in Werner's hometown Mulhouse has been named after him.

Werner died on 15 November 1919 at an early age of 53.

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7. Available Sources on the Internet.

(The article is a popular presentation of the important points of the life and work of Alfred Werner available in the literature. The idea is is to inspire the younger generation to know more about Alfred Werner. The author has given the sources consulted for writing this article. However, the sources on the internet are numerous and have not been individually listed. The author is grateful to all those authors whose works have contributed to writing this article and the sources of the pictures reproduced here.)

Establishing identity: the biometric way

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Enumerating innumerable numbers is a difficult task indeed as the current attempts of those planning the new Indian census know. Think how much more difficult it is to establish the *identity* of every person living in India. Undeterred, India is attempting to do what no other nation has done before: assign a 16-digit unique identification number to each individual living in India. The name of the project is 'AADHAR'. The broad plan is to cover the billion-plus people in the country by allotting each person, a unique number and creating a data base containing their photographs, biometric information, and details such as name, sex, and age.

Biometric-parameters are personal physical/physiological measurements of an individual such as height, weight, and hair/eye colour. These particular measurements can give a "correct" description about an individual, but the problem is that more than one individual can fit description based on the above parameters. Biometrics data should therefore be:

- highly unique to each individual,
- easily obtainable,
- stable; i.e., should not significantly change over time,
- easily transmittable for storage/retrieval and study,
- non-intrusively obtainable,
- possible to study easily without too-much special training.

Biometric parameters are of two types: Physiological and Behavioral.

Physiological biometrics involves the study of the physical traits of a person such as fingerprints. These generally remain constant over time.

Behavioral biometrics involves the study of characteristics such as voice or even signature. These may change over time.

Why establish identity?

In today's troubled times it is imperative that a fool-proof identification process be put in place. It is only too easy to hack computer databases, as many, whose identity has been stolen, know to their dismay. With computer tools easily available it is child's play to morph photographs, and instances of such foul play are too many to quote here.

Although identity-theft is assuming alarming dimensions, it is by no means a new crime. In the pre-Internet era, identity theft involved theft or forgery of paper documents such as passport or driving license. The simplest way was to forge a signature which, (although it may change over time) is a basic means of identification. Identity theft has now evolved to exploit Internet-based or even ATM transactions.

Unfortunately, although stealing another person's identity is apparently becoming easier every day; being able to prove one's identity is not as easy as it sounds. Often when applying for a ration card/passport or other official papers the question, "How can we be absolutely certain about your identification?" has to be answered. This question is actually two questions in one. The first question is, "Who are you?" The second question is, "Are you really who you say you are?" Especially for the uneducated or the poor, an inability to prove identity is one of the biggest barriers preventing them from accessing societal benefits. Even those who do not come under this category, often have to run from pillar to post because different types of identification may be required. Thus, depending on the job required, the cycle of identity verification may change.

Why biometrics?

Biometric identification is a fool-proof way of proving one's identity. This is because many physical markers that are unique and specific to an individual remain constant throughout life. These cannot be duplicated as these are biologically part of a person and inseparable from the body. Thus a biometric parameter is the inborn and intrinsic property of an individual. It cannot be stolen/copied/forged or shared. It cannot be forgotten or misplaced either. Biometric parameters can be used either independently for single-factor authentication or be used in combination with other authentication standards for multi-factor authentication. What better method to establish identity and to authenticate it?

Exploring biometric Identification in India

The AADHAR project aims to collect all ten fingerprints from the individual, a photo and an iris (eye) scan as part of the biometric data collection. The first set of numbers is expected to be released around January-February 2011 after the completion of field testing by July 2010. Once the AADHAR project is fully implemented, India will be the first country to have implemented a biometric-based unique ID system for its residents on such a large scale. A single, universal identity number will help in eliminating fraud and duplicate identities.

AADHAAR

It is interesting that a recent newspaper article (*Deccan Herald* 25 April 2010) has reported that India is also going ahead with a database for biometric identification of hardcore criminals. The Automated Finger Print Identification Systems (AFIS) for the purpose of identification of criminals has been introduced in 22 states and the Union Territory of Puducherry. Police stations are creating, maintaining, and using this database to enable easy sharing of real-time information across police stations and districts at the state-level as well as national-level, thereby resulting in improved

investigation, crime prevention, better tracking of criminals.

The report also says that, under the Crime and Criminal Tracking Network and System (CCTNS) Project, (mission-mode project under the National e-Governance Plan) every police station in India will be provided with fingerprint reader. Fingerprints are just one of the many ways in which a criminal with a past record can be tracked. Fingerprinting is possibly the best known form of biometric identification and it is firmly associated (in the mind of the common man) with police casework. So much so that it is tempting to quote David Sedaris who said, *"All of us take pride and pleasure in the fact that we are unique, but I'm afraid that when all is said and done the police are right: it all comes down to fingerprints."*

Fingerprinting

The patterns of ridges on the fleshy part of our fingertips are unique: no two individuals — even identical twins — have fingerprints that are exactly alike. Sir Francis Galton suggested the first basic system for classifying fingerprints based on grouping the patterns into arches, loops, and whorls. This has since evolved tremendously.

Fingerprint ridges are formed during the third to fourth month of foetal development and persist lifelong. These patterns of ridges and valleys leave impressions (fingerprints) on whatever they touch. The prints clearly show up when the fingers are dirty. However, even when not visible to the unaided eye, latent prints are left behind which can be "lifted" using well-established techniques. Injuries such as minor burns or cuts do not wipe out or change the pattern – the new skin grows displaying the same pattern. This is what makes fingerprints so useful in establishing identity even though cases where hardened criminals have used cosmetic surgery to eliminate all fingerprints are known.

An interesting bit of related information is that the chemotherapy drug capecitabine can, over time, lead to the loss of fingerprints. This fact gained prominence in 2009 when Mr .S, a 62-year-old Singaporean cancer patient was detained at an American airport because he could not be fingerprinted, as his fingerprints had vanished!

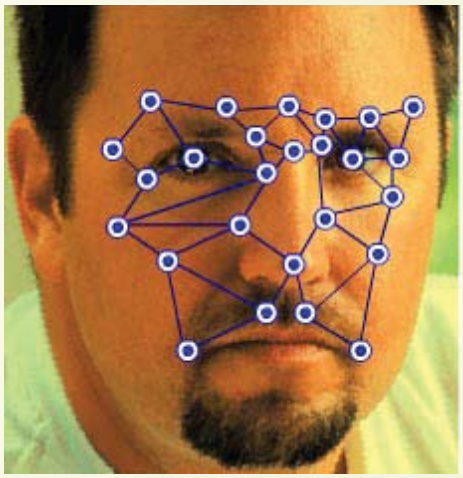
The art and science of fingerprinting has a history closely associated with India! Many know that it was in 1788 that German anatomist Johann Christoph Andreas Mayer recognised that fingerprints are unique to each individual. However, few know that it was in Hooghly (close to Kolkata), in 1858 that Magistrate Sir William James Herschel initiated fingerprinting in legal matters. He used fingerprints on contracts, etc., and also documented pensioners' fingerprints to prevent collection of money after the person's death. He also fingerprinted prisoners on sentencing to prevent frauds aimed at avoiding a prison sentence.

The first ever Finger Print Bureau in the world was established at Writer's Building at Calcutta (now Kolkata) in 1897. It is widely believed that Khan Bahadur Azizul Haque and Rai Bahadur Hem Chandra Bose did most of the work that became the basis of the system for fingerprint classification. Unfortunately, the credit went largely to their senior, Sir Edward Henry. The Central Finger Print Bureau came into being in 1955 in Kolkata. Today, The Fingerprint Society (UK) awards the Aziz ul Haque and Hem Chandra Bose prize for an innovative project in the area of forensic identification with high potential to make an impact in the field.

Face recognition

"Look at me," we say and when we say so, "look at my face", is what we mean. It is the face we recognise first and facial features are what we primarily use to distinguish between one person and another. While this is an innate ability, computer technology has only recently reached a level where it can "recognise faces" albeit the ability is not at par with ours (as yet).

Basically, computers study relative distances between common landmarks on the face to generate a unique "faceprint." Biometric facial recognition systems usually analyse the overall structure, shape and proportions of the face taking into account the distance between the eyes, nose, mouth, and jaw edges; upper outlines of the eye sockets, the sides of the mouth, the location of the nose and eyes, the area surrounding the cheekbones, etc. To prevent a photo from being used to defraud it, face-biometric scanners make the user smile/blink/nod their head. Also, facial-thermography technique is used to record the heat of the face so that a



mask cannot be used to trick it.

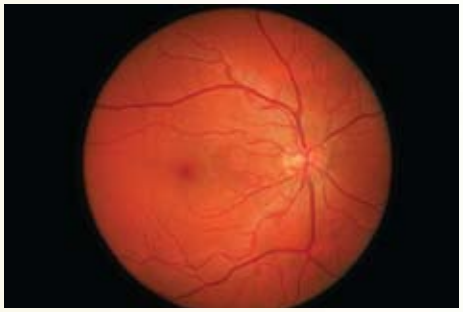
This technique can be used from a distance so that the person may not even be aware of it. It is usually a good tool for authentication as opposed to identification.

Voice analysis

The analysis of the cadence, pitch, tone, and frequency of a person's voice can be used to identify a person. It is used as a password where the lock will open only when the authorised person gives a voice command. It is also used to identify bank customers phoning in as an addition/alternative to conventional passwords. Basically, it works by taking a sample of a customer's voice, storing its pattern and then matching when the customer calls again. However, it is almost sure that the poor customer who has a sore throat and is calling from a place where background noise level is high or has a faulty phone line will have trouble establishing identity!

Hand-geometry

Hand-geometry involves the measurement and comparison of the different physical characteristics of the hand. The shape of the hand changes with age, arthritis and other deformities -- even weight gain/loss. Finger length, thickness, and curvature, etc, are thus not used so much for identification but for authentication. However, hand-geometry devices have been in use since the early 1980s. Although these cannot differentiate between a living hand, a hand that has been chopped off, and a cadaver's hand, still, it is the first biometric measurement to enjoy widespread computerised use, especially when used along with fingerprinting.



Palm vein authentication

As the blood vessels crisscross under our skin these give rise to a definite and unique pattern that can be used to identify a person. Infrared beam is used to penetrate the hand and the veins in the person's palm show up as black lines which can be matched to an earlier "recording." Palm vein matches have a high level of authentication-accuracy because the vein patterns of the palm are complex in design. Since contact is not necessary to study the vein patterns, the method is hygienic. Also, palm-vein patterns cannot be "forged". This method works equally well in situations where *1:1* or a *1: many* matches are required. ATM kiosks sometimes use this technology as do some sophisticated computer mouse.

Retina scan

A retina scan involves the use of low-intensity light to study the pattern formed by the capillary blood vessels located in the back of the eye. The best part is that this pattern remains unchanged throughout life. A retina scan cannot be faked as it is not (yet!) possible to forge a human retina. Also, the retina taken from a dead person decays too rapidly and cannot be used trick a retinal scan machine (despite what best-selling novels depict). It is reported that a retinal scan has an error rate of 1 in 10,000,000. Retina biometrics systems are best suited for meeting high security requirements and have had a long history of use in the military or security vault locking systems in banks.

Iris scan

The iris is the pigmented, connective tissue that controls the pupil. It is formed in early life and once fully formed, it remains stable throughout life. The iris of the eye has pattern that is unique to an individual. An iris scan analyses over 200 points of the iris and compares it with a previously-recorded image template. Glasses, contact lenses, and even eye surgery does not change the iris pattern. The Iris scanner cannot be deceived by using a photo or even an iris taken from a dead person because iris-scanning systems vary the light and check if the pupil is dilating or contracting as it should in response to the light.

Iris scans were proposed in 1936, but it was not until the early 1990's that algorithms for iris recognition were created. This system is highly accurate and reportedly there is no known case of a false acceptance for iris recognition. It is also non-intrusive and hygienic and necessitates no physical contact. It is perfect for passports and border/prison//access security control.

Future scan

Biometric systems are slowly and surely coming into their own and replacing the more traditionally used systems of identification/ authentication. Currently biometric-systems are expensive and only larger organisations/ governments use them extensively. However, as with almost all technology solutions, less-expensive versions are on their way. It is therefore to our advantage if we are aware about the strengths and weaknesses of these systems because sooner or later we will be asked to cooperate on identification/ authentication drives as nations gear up to improve security. ■

Form IV (see rule 8)

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

Sd/-
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Graphene - Two-dimensional carbon sheets

Biman Basu
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Carbon is a unique element; in fact, it is one of the most intriguing elements in the Periodic Table. The entire living world is built around carbon thanks to its unique ability to join together to make long chains. Carbon exhibits remarkable properties, some of which are paradoxical. For example, one of its allotropes – diamond – is the hardest naturally occurring substances known, while another – graphite – is one of the softest substances known. Both are three-dimensional forms of carbon. During the past two-and-a-half decades new allotropes like fullerenes (zero-dimensional), and nanotubes (one-dimensional) have been discovered.

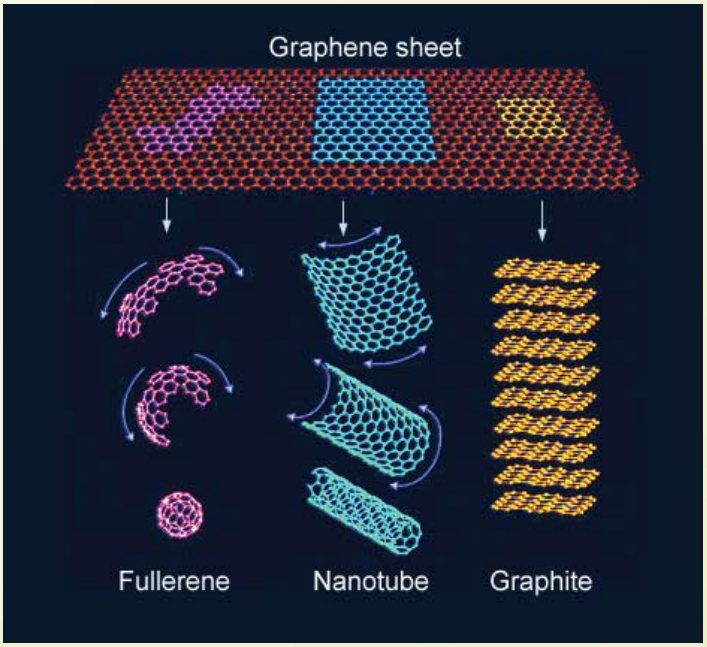
The discovery of a two-dimensional allotrope of carbon was first reported in the journal Science in 2004 by a group of physicists from Manchester University, UK, led by Andre Geim and Kostya Novoselov of Institute for Microelectronics Technology, Chernogolovka, Russia. The paper described the existence of a new class of materials – strictly two-dimensional atomic crystals – which can be seen as individual atomic layers pulled out from bulk crystals. This single layer of carbon atoms densely packed into a benzene-ring structure was named 'graphene'. In other words, graphene is a two-dimensional, giant, flat sheet of carbon atoms which is still only one-atom thick. Geim and Novoselov have been awarded the Nobel Prize in Physics for 2010 for "groundbreaking experiments regarding the two-dimensional material graphene."

Andre Geim

Konstantin Novoselov

Two-dimensional carbon sheets

Graphene is a unique material. The planar, hexagonal arrangement of carbon atoms in graphene can be considered as nothing but a single layer peeled off from the three-dimensional graphite crystal. Interestingly, it is probably the best-studied carbon allotrope theoretically – the starting point for all calculations on graphite, fullerenes and carbon nanotubes. The single-layered honeycomb structure of graphene makes it the "mother" of all carbon-based systems: the graphite used in pencils is simply a stack of graphene layers; carbon nanotubes are made of rolled up sheets of graphene; and fullerene molecules, or buckyballs are nanometre-size spheres of wrapped-up graphene. These forms of carbon were isolated long before graphene and have been used in many applications, but their electric, magnetic and elastic properties all originate in the properties of graphene.



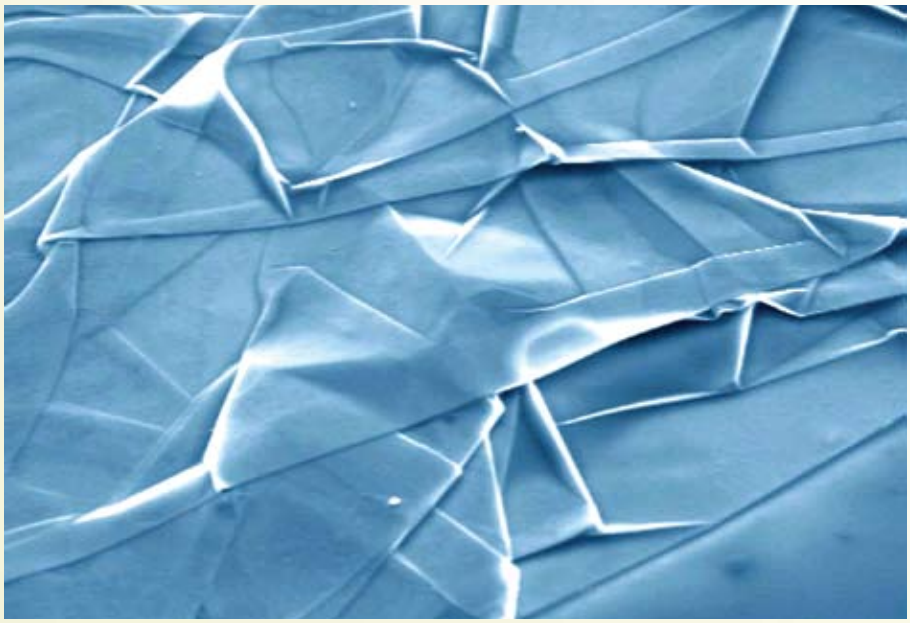
Graphene is the basic structure different forms of which produce fullerenes and nanotubes.

Numerous attempts to synthesise two-dimensional atomic crystals of carbon had been made in the past, till success finally came in 2004. The team at Manchester University used a very different and, at first glance, even naive approach to obtain graphene. One millimetre of graphite actually consists of three million layers of graphene stacked on top of one another. The layers are weakly held together and are therefore fairly simple to tear off and separate. It happens when we write something with an ordinary pencil; sometimes only a single layer of atoms, which is nothing but graphene, happens to end up on the paper. Geim and Novoselov used adhesive tape to rip off thin flakes from a larger piece of graphite in a more methodical manner. In the beginning they got flakes consisting of many layers of graphene, but when they repeated the tape-trick ten to twenty times the flakes got thinner and thinner.

It may be mentioned that graphene-like structures were already known of in the 1960s, but there were experimental difficulties in isolating single layers. In fact many scientists thought that it would be impossible to isolate such thin materials: they would become crinkled or roll up at room temperature, or even simply

completely vanish. This is when Geim and Novoselov got their second brilliant idea: in order to be able to see the results of their meticulous work, they decided to attach the flakes to a plate of oxidised silicon, the standard working material in the semiconductor industry. They started with three-dimensional graphite and extracted a single sheet (a monolayer of atoms) using a technique called 'micromechanical cleavage.' They began by converting graphite into graphite oxide in an aqueous solution. This familiar process adds oxygen-based chemical groups to the graphite surface and leads to the bulk graphite being completely separated into single sheets. The sheets remain separate because they repel each other thanks to the oxygen-based chemical groups, which have an excess negative charge. According to the researchers, this approach allows easy production of large (up to 100 µm in size), high-quality graphene crystallites.

Currently, different techniques of epitaxial growth, used to create various semiconductor materials, are the most promising as regards producing graphene for use in the electronics industry. Rolls of 70-centimetre wide sheets of graphene are the largest produced so far.



Folded sheets of graphene on a silicon plate. The image was made with a scanning electron microscope, magnified about 5,000 times. (Credit: University of Manchester. Science, *15 May 2009)*

Exceptional stability

What is most surprising about graphene is its stability. It was long believed that two-dimensional atomic crystals cannot be stable under ambient conditions because of thermodynamic constraints. But the Manchester team, for the first time, demonstrated that they are not only fairly easy to make but also quite stable.

Initially, Geim and Novoselov could only obtain micro flakes of the new material. However, despite the miniscule size they could begin to investigate the two most remarkable traits of graphene, which both influence its electrical properties. The first is the nearly perfect arrangement of carbon atoms in graphene due to the strong bonding of the atoms. At the same time, the bonds are flexible enough to allow the web to stretch by up to 20% of its original size. The lattice also enables electrons to travel long distances in graphene without disturbance.

In normal conductors, electrons often bounce like the ball in a pinball machine, which weakens the performance of the conductor. But in graphene the electrons behave like particles of light. Electrons travelling in graphene behave as if they did not have any mass and move ahead at a constant speed of about one million metres per second. This opens up the possibility of studying certain phenomena more easily on a smaller scale, i.e., without the use of a large particle accelerator.

In addition graphene has several other remarkable mechanical and electrical properties. For example, it is much stronger than steel, yet it is very stretchable. Its thermal and electrical conductivity is also high. As a conductor of electricity it performs as well as copper. As a conductor of heat it outperforms all other known materials. It is almost completely transparent, yet so dense that even helium, the smallest gas atom, cannot pass through it. Geim and Novoselov were thus able to produce, isolate, identify, and characterise graphene.

The uniqueness of graphene makes it an attractive material for a number of electronics applications. Already scientists have discovered remarkable electronic properties of the new material that could be used in place of silicon for making ultra-fast and stable transistors.

Future scenario

The extremely large conducting ability of graphene has spurred a great deal of interest in commercial circles. Graphene transistors are predicted to be substantially faster than those made out of silicon today. In order for computer chips to become faster and more energy efficient they have to be smaller. Silicon atoms being larger than carbon have a lower size limit below which they cannot function. The limit for graphene, which is made of carbon atoms, is even lower; so graphene components could be packed on a chip more tightly than possible with silicon.

One milestone was passed a few years ago when a graphene transistor was developed that was as fast as its silicon counterpart. Maybe we are at the threshold of yet another era of miniaturisation of electronics that will lead to computers becoming even more efficient in the future. So far, graphene computers are still only on the drawing board, although paper-thin transparent computer monitors that can be rolled up and carried in a hand bag have already appeared in commercials for tomorrow's consumer electronics.

The perfect structure of graphene also makes it suitable for the production of extremely sensitive sensors that could register even the smallest levels of pollution. Even a single molecule adsorbed to the graphene surface would be discovered. The list of possible applications for graphene is long and it is too early to predict what lies in future. But there is little doubt that the relentless activity that began following its discovery six years ago will eventually most likely bear fruit. ■

Higher Technical Education and Potential Opportunities for Collaborative Research

Er Anuj Sinha was invited to an Indo-UK Workshop on Holisitic and Sustainable Development in Uraban and Rural India and UK. The meet was held in mid-December 2010 at Aston University, Birmingham, UK.

Prof. Robert F. Berry, Executive Dean of Applied Science and Engineering, Aston University graciously agreed to an interview for DREAM 2047 despite his very busy academic and administrative load.

AS: Thank you for accepting my request for a discussion with readers of DREAM-2047 despite your very tight schedule over the period. The print version of this monthly magazine has a circulation of over 50,000 and is brought out in English and Hindi. There is an electronic version with several thousand more readers. Could you tell us about the significant gains from your recent visit to Delhi in early December 2010?

RB: Research Council UK and the Department of Science and Technology, India had jointly organised a workshop in Delhi to assess impact of collaborative projects. We were able to share our experiences, identify barriers and propose policy amendments to facilitate future collaborations. A very positive leadership in both organisations is facilitating this collaboration. During this visit I was also able to visit the IBM Research facilities at New Delhi and connect with old colleagues after a gap of almost two years. I had worked for IBM in the US and the UK for about 22 years.

As Dean (Engineering), Aston University, I am particularly keen to develop strong connections between researchers in India and the UK and several proposals were discussed that may develop into meaningful projects. The vast spread of the mobile phones in India has the potential for being harnessed in the development programmes over and above its obvious functions of telephony and text messaging. This has been flagged by Mr. Sam Pitroda recently and we should develop better utilisation of this highly available and accessible technology.

AS: Aston University organised the discussion on sustainable development in UK and India with experts from both countries. This has been an opportunity for me to be able to visit Birmingham and interact with you. What is your assessment of the gains from this symposium? How could this have become more productive?

RB: Your independent advice on the subject under discussion was very important.

Prof Robert F. Berry, Executive Dean of Applied Science and Engineering, Aston University

For example, highlighting the difference between India and UK regarding the nature of losses and wastes in the food value supply chain. We need to focus on the problems of the population at the bottom of the pyramid.

Reaching science to people and empowerment of the poor, particularly women, is key to any intervention. The challenge to explore how this can become more productive for people from the poorer districts of Rajasthan or Bihar is extremely helpful.

Such symposiums serve many important functions by bringing experts together. In future, to make these kinds of discussions more productive we should build in more time for reflection and informal discussions. Such breakout time is simply not possible in a virtual or video conference, and is precisely the reason we need to meet physically together.

AS: Research projects in engineering faculty at Aston are influenced by the interaction with experts from India who are seeking solutions to problems that are high priority there. How do you view this trend and how can there be more reciprocity by engineering research institutes of excellence in India?

RB: Part of the answer may be found in increasing the level of exchange of faculty and researchers and enabling joint supervision of research. For example, we are working on one particular faculty exchange between IIT-Ropar and Aston University in Computer Science for a period of six weeks in 2011. Developments in Communication Technology are opening more opportunities at affordable costs for intense and frequent exchange among experts geographically separated. For this trickle to become a flow, we will have to develop stronger personal chemistry. I refer to the process of defining problems, finding solutions and tackling issues across the two societies as a brokerage challenge. We need to work on this more intensely to be able to institutionalise it. The real challenge is to find those problems that we can solve only by working together.

AS: The solutions developed by experts laboratories here in Aston need pilot testing before dissemination in the field. What measures are in place or are proposed to make this more effective?

Let me illustrate this with an example. Samples of biomass in India are being collected, labelled, packed and dispatched for characterisation at Aston. An industry partner could potentially develop similar characterisation facilities at much less cost in India. This could be useful in the experiment and save time. It could also find market in the UK as well as other countries. This low-cost replication manufacture requires engagement with several partner institutions. We are working with Indian industries; partners today and exploring this kind of opportunity in the context of current and future research projects.

Engagement with industry would be to a great advantage in many other areas – for example in utilising sewage sludge; a material we clearly can't be shipping overseas! We are working at expanding and strengthening such networks.

AS: There have been very encouraging

collaborative research and development projects in applied areas at Aston. Are solutions developed by laboratories at Aston and other UK institutes, in your opinion, reaching the community for which these have been developed? What are the constraints in UK and how do these differ vis-à-vis India?

RB: I will limit the response to the area of energy. At IIT-Ropar, we have identified the issue of open field burning of rice straw in Haryana and Punjab and how the waste can be used for producing energy. We hope to be able to devise a system that gives farmers some return by generating an entrepreneurial activity to raise revenue for the villages. Incidentally, experiments in biomass utilisation in the UK require many more clearances than in India. But equally importantly in this case we hope to be able to bring the scientific developments to the people a challenge presented to us all by Dr Ramasami, Secretary DST at a recent seminar in Delhi.

In another experiment with different algal strains the researchers require to dry the algae for combustion experiments and energy content analysis. A dewatering centrifuge from India that would have cost many times as much in the UK was adopted for this purpose. Collaborative research will, as in this example, bring costs down.

AS: You have a significant role in the initial phase of growth of IIT-Ropar. How do you envisage this relationship to evolve? What will be the takeaways for Aston because of this equation?

RB: Six decades back when the Indian Institutes of Technology were being setup a similar mentoring scheme was in place. It was tremendously successful, and people remember it to this day.

However, the relationship with the developed world institutions was much different than what it is today. I am very proud of my role in this phase of growth of IIT-Ropar. The mentor-mentee relationship will undergo metamorphosis and ten years down the line we will see the real value such partnership has brought both to the IIT and to Aston. Scholars from Ropar are vying for internship at Aston and their work will jointly be supervised by a faculty from both the institutions. A reciprocal relationship is likely to emerge shortly. The networking between supervisors will open up new windows of opportunity for collaborative projects. Already we have agreed to establish a joint research facility with IIT-Ropar to explore renewable energy for North West India.

We will be exploring similar collaborative arrangements with Punjab Technical University and other such institutions of academic excellence.

AS: You have spent the early part of your career in industry and then moved to academics. Does such lateral movement result in better learning/teaching for undergraduate and graduate students? How can more professional movement from academics to industry and vice versa be facilitated?

RB: No question about it. Real life experience is always interesting and has a huge influence on the teaching-learning process of the class room. Even applied research benefits from such long years in the industry. If there are several such members of the faculty who bring a broad spectrum of experience, the employability of the graduates improves. We give weight to research experience in the industry when we recruit faculty members.

And for the members of the faculty we allow one day a week that can be used for consultancy that has a positive impact on teaching. At Aston the School of Engineering has an Industrial Advisory Board which meets at least two times annually. This has a wide spectrum of experts, largely from the industry who review our teaching programme, research curriculum and student interaction. Some become involved in particular projects, some give guest lectures through the year and these are particularly appreciated by the students.

Aston is not unique in this regard. A focus on industrial engagement and impact is more important in the UK University research landscape. Aston is doing well in this regard and it contributes to making our programme among the best in the country.

AS: How does teaching engineering and technology differ in the two countries? Can there be early lessons for either of our systems from the other?

RB: It's incredibly hard and rather dangerous to generalise but I'll try a little!

The joint entrance examination for the entrants to undergraduate exams at IITs and some other institutions filters students as per merit and it is really the cream that enters the IIT. Other institutions in India do not have such a benefit. Students we bring over to the UK from the IITs are incredibly strong – my staff compete with each other to have them to work on projects!

But we do find that while technically strong espcially in the basic sciences and the theory of more applied sciences eg., computing they sometimes lack the extent of hands-on practical work experience that students we produce here at Aston have.

Professor Robert Berry
Executive Dean of Engineering & Applied Science

Throughout his career, Professor Robert Berry has successfully bridged the gap between academic and industry, and it was his experience working with universities that inspired him to join Aston in 2008.

Robert graduated with a BA in Computer Science from the University of Texas in 1978 and received his PhD in Computer Science in 1983. He spent more than twenty years at IBM, where he held a number of positions, most recently Chief Technology Officer for Messaging Technology. Robert is an IBM Distinguished Engineer – an executive position for technical leaders in the company. He has been a member of the IBM Academy of Technology since 1999 and was Vice-President of the Academy between 2005 and 2007 serving Europe, the Middle East and Africa.

Areas of interest

Robert's current areas of interest include instrumentation and analysis of complex systems software, systems performance, quality of service for complex systems software and event processing systems. His teaching activity includes middleware integration concepts.

Memberships and fellowships

Robert is a member of the Association of Computing Machinery and a fellow of the British Computer Society.

Aston University

Founded in 1895 and a University since 1966, Aston is a long established research-led University known for its world-class teaching quality and strong links to industry, government and commerce.

Aston University is based in the centre of Birmingham, home to over 65,000 students and one of Europe's liveliest and most welcoming cities.

It has a 40 acre campus that houses all the University's academic, social and accommodation facilities for over 9,500 students.

It is ranked 13th out of 113 UK Universities by the 2010 Complete University Guide, and 19th in the Guardian rankings 2010, good jobs, with 82% finding graduate level employment within six months of graduation, compared to a national average of less than 70%.

Aston offers a range of undergraduates and postgraduates degree programmes, and also works with the public and private sector to develop tailored Continuing Professional Development and Foundation Degree programmes.

Perhaps this is due to a lack of access to equipment and laboratories; more probably it is the consequence of a curricular decision.

One of the challenges in the UK is there appears to be a declining trend in accomplishment of incoming students in subjects like physics and mathematics and we need to remedy this situation.

AS: Availability of energy and water appear to be priority areas for research under the collaborative research effort. Which are the problems, in your opinion, that deserve to be taken up in the second list if there are more resources?

RB: The discussion at the recent RCUK/DST symposium in Delhi has helped identify areas of priority. We need to address issues of health, nutrition, sanitation, etc., in the immediate future. The issue of waste of food as flagged by you is another problem for researchers.

The rapid expansion of higher technical education in India will require close attention; Mr. Kapil Sibal has indicated that 500 million people must be skilled up by 2020 or so. This is a massive challenge. Our research efforts must attempt to address aspects of this challenge – though, as he points out, commercial investment will be needed to help address the massive scale.

AS: Have you been able to visit India as a tourist in the recent past? What have been your impressions of the developments in the society?

RB: Yes, I do sometime stay on extra weekends and try to visit friends in Jaipur and sometimes do some sightseeing. In my last visit, I took the new Metro service and spent time at Chandni Chawk in Old Delhi. I have also visited non-tourist areas in Mumbai and the experience is moving. The smells, sounds, sights – everything hits you. I find it incredibly stimulating and humbling at the same time.

Prof Robert F. Berry with Er Anuj Sinha during interview at Aston University, Birmingham, UK

The area of greatest concern is also the area receiving enormous investment: infrastructure. There seem to be huge contrast between the new shopping centres which are all steel and glass and the neighbouring slums that co-exist. The first city that I visited in India about a decade back was Bangalore. While there is the IT Park with the most modern designed buildings the neighbourhood has been neglected with shoddy infrastructure and dilapidated buildings that may actually be only 10 years older. The worry is that the new buildings and investment in roads and other transport infrastructure will fall into disrepair in only 10 more years. That clearly cannot be allowed to happen for the upfront costs on the scale required are astronomical.

Living in the UK one is very insulated from such contrasts and disparities. Planners and policy makers will have to address the issues of this contrast and do so quickly.

AS: Has the level of 'public understanding of science' in UK been a matter of the development discourse? What is the disparity in different regions? Is the rural urban divide a function of this? Is this being addressed adequately?

RB: I do not know much about this question for India, however, in the UK schools and the media appear to be the preferred channels for promoting public understanding of science. Science oriented programmes on the BBC are creative and interesting. How much of this actually results in being internalised by the viewers across the different regions of the country is a matter for study.

There are some regional disparities in access. Just a couple of years ago I helped initiate and then execute a Royal Academy of Engineering study on "ICT for the UK's Future". Even then we found significant gaps in broadband access across regions in the UK. This is improving now – but a gap still exists. This will have consequences for science communication of course.

In general, more is needed. Our students still arrive at University with less than ideal general science understanding; I often think our educational system in the UK is too narrowing, too early in one's development.

AS: Thank you for your time, Dr. Berry. I know you have had a hectic day and yet you gamely went through with this cross examination.

RB: Thank you very much. Many questions have pushed me into reflecting on my work and our institution. I hope your readers will find value in this interaction. ■

When the Pregnancy Goes Wrong

Tiding Over the Woes of Miscarriage

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

Most pregnancies happily go to term fulfilling the dream of an expectant mother without much ado. Few people may recognise, however, that nearly 15 per cent of the normal seeming pregnancies simply go waste, ending in a miscarriage.

If this happens, disappointment is natural, but the mission is to ease the woman out of the medical emergency and nurse her through the agony. Even though the tinsel world makes us believe that in this situation either the mother or baby can survive, in real life it is generally only the mother who benefits with prompt medical care and attention.

> What sweet dreams
> Quietly fill her being
> Songs of great rejoice
> Revel her soul!
> Spread out I would
> A bed of nectar for him
> Rocking the cradle
> I would caress him
>
> —Jaishankar Prasad in *Kamayani* (translated by this author from Hindi)

For an expectant mother, a miscarriage can be very difficult to come to terms with. She may feel angry, or guilty, wondering what she did wrong. She will almost certainly feel a sense of loss.

However, if this happens to you, just remember, that it certainly is not the end of road for you. You may grieve over the lost baby, especially if the miscarriage has happened at an advanced stage of pregnancy, but the most important act to put together at this time is to nurse yourself back to normalcy.

What causes miscarriage?

Miscarriages are quite common during the first 12 weeks. Statistically, the world over, at least one in six pregnancies end in this way. At this early stage a miscarriage usually occurs if there is something wrong with the fertilised egg. Often, the egg has a genetic fault and if so, it is best that it ends this way. Sometimes, however, the egg does not embed properly, and it is for this reason, that the pregnancy aborts.

A mid-pregnancy miscarriage usually happens for one of the two reasons: either the placenta does not function properly, or the cervix is weak and lax and opens far too early. Several serious illnesses can equally be a culprit. These include severe high blood pressure, toxaemia, endocrine gland defects, and sexually transmitted diseases like cytomegalovirus, herpes simplex or Mycoplasma hominis infection.

Be whatever the cause, a miscarriage is rarely anyone's fault. Many people believe that love making during pregnancy can cause a miscarriage. This is very unlikely. If a couple make love and then the woman soon after has a miscarriage, it may seem as though intercourse was the cause, but it does not happen that way. Some couples unnecessary blame themselves in this situation when there is absolutely no reason for them to do so.

Many couples ask the question of how certain activities or life-style may affect the risk of miscarriage. With more and more women taking up jobs, the effect of work on pregnancy is one such area of concern. In general, women who wish to work may continue do so, close to or actually up to the end of their pregnancy, if they feel well and have no medical reason to quit and take rest.

People often worry also about physical exercise. While a certain amount of exercise is most certainly good for all normal pregnant women, there is, obviously, a need not to overdo. Trivial physical trauma such as travelling in a rickety bus has also often taken the blame, and wrongly so. Sometimes, a woman remembers a minor accident that immediately precedes miscarriage and concludes a cause-and-effect relationship. However, there are many documented cases where despite a severe trauma, and the woman incurring multiple fractures of the pelvis, has gone on to deliver a healthy baby without the least of an interruption.

Symptoms and Signs

A miscarriage is a 'natural abortion'. It is a termination of a pregnancy before the 28th week. Once the 28th week has passed, a baby has a good chance of survival if it is nursed carefully following its birth.

An early miscarriage often happens around the time that you would have expected to have a period. It can be rather like a period, with bleeding and a similar sort of aching pain. A later miscarriage after the first three months is more like labour itself. That's because by now the foetus has taken its form.

What to do

Any bleeding in pregnancy could be the start of a miscarriage. If you begin to bleed, consult your doctor as soon as you can—immediately if you are losing a lot of blood. You would probably be advised complete rest in bed. In about 50 per cent women

who experience bleeding and cramps early in pregnancy the bleeding will stop and the pregnancy will carry on quite normally. But in other cases the miscarriage cannot be avoided and becomes inevitable.

When the miscarriage in inevitable

That is called an inevitable abortion. In such case, the bleeding becomes heavier and cramps are more severe. On examination, the doctor may be able to feel the cervix beginning to open up and dilate and the products of conception lying at the external opening of the cervix. A pelvic ultrasound examination can settle the diagnosis. At this time the changes that have occurred are irreversible, and no therapy will prevent the abortion.

Incomplete miscarriage

Sometimes the miscarriage is incomplete, and some products of conception are not expelled. Such an incomplete abortion particularly happens in pregnancies beyond the 6th and up to the 14th week. Very often the foetal tissues are unrecognisable because foetal death may have occurred a number of days or weeks before expulsion.

In this case cramping will range from moderate to severe, and bleeding may be very extensive and actually life threatening. The bleeding may well continue until all of the remaining placental tissue is removed. The uterus will be able to contract only then, cutting off the blood vessels that are producing the haemorrhage. A pelvic ultrasound examination can diagnose the condition.

Missed abortion

Occasionally, a fertilised egg simply stops growing and dies but, for some unknown reason, labour does not ensue immediately. This is a missed abortion. In this type of abortion, the egg or the empty yolk sac may remain in the uterine cavity, sometimes for as long as eight weeks.

There is usually a clinical history of early bleeding that stops spontaneously or after some form of therapy. However, the breasts revert back to the non-pregnant state, and the size of the uterus not only ceases to increase, but actually decreases with time. Ultrasound can easily pick the condition.

What the doctor will do

If a woman has suffered a miscarriage, the doctor would usually take her in for a cleaning job. This simple operation is called a 'D & C' that is, dilation and curettage. The aim is to clean the womb. The cervix is gently opened and the lining of the womb scraped or sucked away. At the same time, medication in given for the uterus to contract so that the bleeding stops.

What if you're Rhesus negative

If a woman is Rhesus negative, it is very important for her to remember that she must receive the anti-D shot. Failure to do so may result in Rhesus sensitivity, which could affect future pregnancies and cause blood incompatibility (mismatch) between the mother and foetus leading to serious complications.

The future

A miscarriage does not mean that a woman will not be able to bear children in the future. In fact, if you have only had one miscarriage, you have a very good chance of having a successful pregnancy the next time. It is up to you whether you try to get pregnant again now or after a while. Generally, a gap of at least three to six months allows the body and mind the time to heal and be prepared for the responsibility of taking on the rigours of pregnancy.

[This column is primarily intended to educate the reader about the basics, and the do's and don'ts in a medical situation, and not as a substitute for professional medical advice. Before starting any form of treatment, please consult your physician.]

Recent developments in science and technology

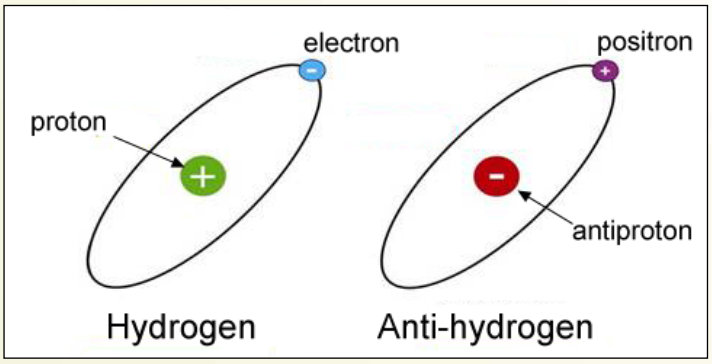
Scientists trap antimatter

In the thriller *Angels & Demons* novelist Dan Brown spins the story of a rogue priest who tries to destroy the Vatican with a vial of antimatter. In reality, however, the amount of antimatter created till date would not be enough to release sufficient energy to heat a pot of coffee! But recently physicists at CERN, the European particle physics laboratory near Geneva, have succeeded in creating and holding dozens of antihydrogen atoms for a fraction of a second, far longer than ever before. The success is considered a significant step toward making antimatter stable long enough to make it possible for scientists to study how it differs from ordinary matter.

Antimatter is matter is made up of particles with electric charges opposite those of ordinary matter. For example, antihydrogen is the antimatter counterpart of hydrogen. Ordinary hydrogen atom is made up of a negatively charged electron going round a positively charged proton at the centre. In contrast, an atom of antihydrogen consists of a positively charged electron or positron going round a negatively charged antiproton. A positron has the same mass as an electron but the opposite charge. Similarly, an antiproton has the same mass as a proton but a negative charge.

The existence of antimatter was predicted by the English physicist Paul Dirac in 1931. Work with high-energy antiparticles is now commonplace and anti-electrons or positrons are used regularly in the medical technique of positron emission tomography (PET) scanning. But in presence of ordinary matter, antimatter is highly unstable because when matter and antimatter meet, they annihilate each other instantaneously. Theory suggests that equal amounts of matter and antimatter should have been formed in the Big Bang, nearly 14 billion years ago, and physicists have long puzzled over why only matter exists today.

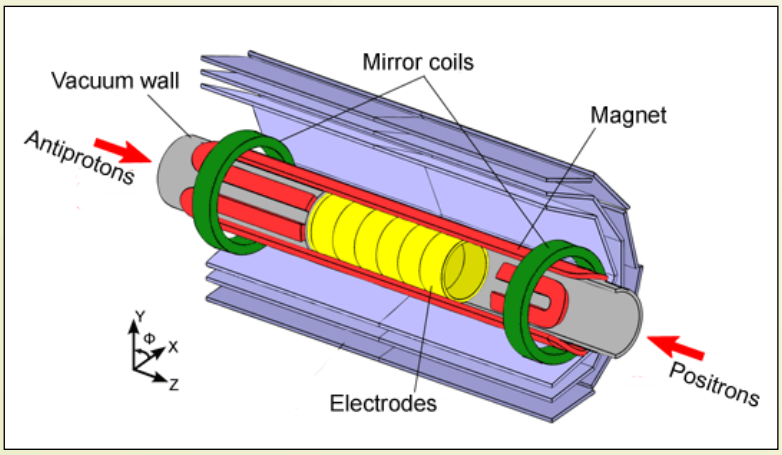
Several experiments at CERN seek to explain matter's predominance using an "antiproton decelerator" that slows the particles down to about a tenth the speed of light. Using this facility CERN physicists first made a few fleeting atoms of antihydrogen in 1995. In 2002 two teams reported ways to make lots of antihydrogen atoms at low energies.



Atomic structure of hydrogen and antihydrogen.

The new results come from the lab's ALPHA experiment – a collaboration of scientists from eight countries – in which a stream of antiprotons is cooled into a cloud of about 40,000 particles. The antiprotons are created in an accelerator by smashing high-energy protons into a stationary target. The antiprotons are then slowed down and cooled in a series of steps involving a storage ring and electromagnetic traps. The cloud of antiprotons is then introduced into a cloud of a couple of million positrons chilled to 40 kelvin (– 233°C). The positrons are produced by a radioactive source and then accumulated and cooled in a special trap. About once out of 10 times, an antiproton and a positron combine to make an antihydrogen atom. For roughly every 100,000 antihydrogen atoms made, researchers managed to trap just one of them using strong magnetic fields. CERN scientists succeeded in trapping 38 antihydrogen atoms for about 170 ms before they escaped and annihilated themselves against the matter in the sides of the container. The actual trapping involves a 'magnetic bottle', which confines the antimatter particles within a strong magnetic field. This was the first time antimatter atoms had been stored for long enough to measure their properties in detail (*Nature*, 17 November 2010).

Soon after, in a significant step forward, physicists at CERN also carried out the first spectroscopic measurements on a beam of antihydrogen atoms (*Physical Review Letters*, doi:10.1103/PhysRevLett.105.243401). The beams were used to carry out the first detailed studies of the energy levels in antihydrogen. The breakthrough came just weeks after researchers succeeded in trapping a few dozen antihydrogen atoms. Taken together, the two results represent major advances in studies of antimatter.



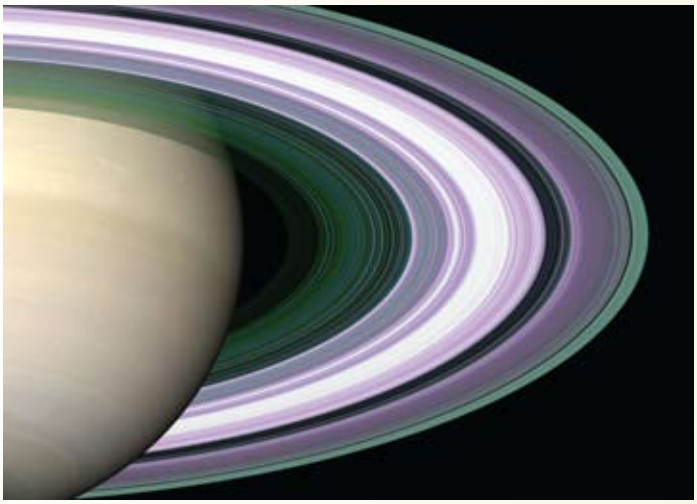
Antiprotons and positrons are brought into the ALPHA trap from opposite ends and held there by electric and magnetic fields to form antihydrogen.

Measuring in detail the energy levels in antihydrogen is important because the Standard Model of particle physics says they should be identical to those of hydrogen. Any slight differences in the "fine structure" of the levels compared to ordinary hydrogen could shed light on why there is so much more matter than antimatter in the universe.

Mystery of Saturn's rings solved

What distinguishes Saturn from the other planets of the solar system is its majestic ring system. Three other planets – Jupiter, Uranus and Neptune – also have rings, but they are insignificant when compared to Saturn's extensive ring system.

First observed by Galileo Galilei 400 years ago, who could not make out what they were, Saturn's rings long remained a mystery till the Dutch astronomer Christiaan Huygens suggested in 1655 that the planet was surrounded by a ring. But no one had any idea of what the rings were made up of. Detailed study by the *Voyager* 1 and *Voyager* 2 spacecraft in the 1980s found a lot of details, but they only increased the mystery.



alse-colour digitally reconstructed image of Saturn's rings showing difference in particle size. Purple indicates ring particles larger than 5 centimetres, while the green indicates regions with ring particles less than 1 centimetre in size. The white band indicates that the density of ring particles is too high to make a good determination. Other radio observations indicate that some ring particles can be as large as several metres across. (Credit: RSS, JPL, ESA, NASA)

There are billions of particles of varying sizes that constitute Saturn's extensive ring system. With a thickness of about 1 kilometre or less, they span up to 282,000 km, about three quarters of the distance between the Earth and the Moon. The ring particle sizes range from tiny, dust-sized icy grains to a few particles as large as mountains.

There are several theories to explain the origin of Saturn's rings. One theory suggests that the ring particles are leftover debris from the formation of the planet itself. Another idea is that the rings are debris from a satellite that for whatever reason was unable to form. Probably the most likely theory is that the particles are the result of an icy satellite that was shattered by an impact with a comet. A closely similar origin is proposed in a recent paper published online in the journal *Nature* on 12 December 2010 (doi:10.1038/nature09738). According to the author of the paper, planetary scientist Robin Canup of the Southwest Research Institute, Boulder, Colorado, USA, Saturn's rings might be the remains of a giant "lost" moon that was stripped of its icy shell before it crashed into the planet.

Using detailed computer simulations, Canup arrived at a scenario which suggests a violent origin for Saturn's rings. According to her, as the planet coalesced during the birth of the solar system more than 4.5 billion years ago, the swirling disk of gas surrounding it included several moons of various sizes. But gravitational interactions with the gas caused the moons' orbits to shrink, and one by one the moons entered death spirals and plunged into the planet. Today's ring system is the remains of a large moon, thousands of kilometres wide – roughly as large as Saturn's biggest moon, Titan – that crashed on Saturn, pulled by its immense gravity. The fragments of that final doomed moon, each originally between 1 and 50 kilometres across, probably formed an icy ring system as much as 1,000 times as massive as today's rings. In the subsequent 4.5 billion years, innumerable collisions between these large chunks produced the much smaller ring particles that now orbit Saturn. Some of the ice would have spread inward and collided with Saturn, while some material that scattered outward could have clustered over time to form Saturn's oddly icy inner moons.

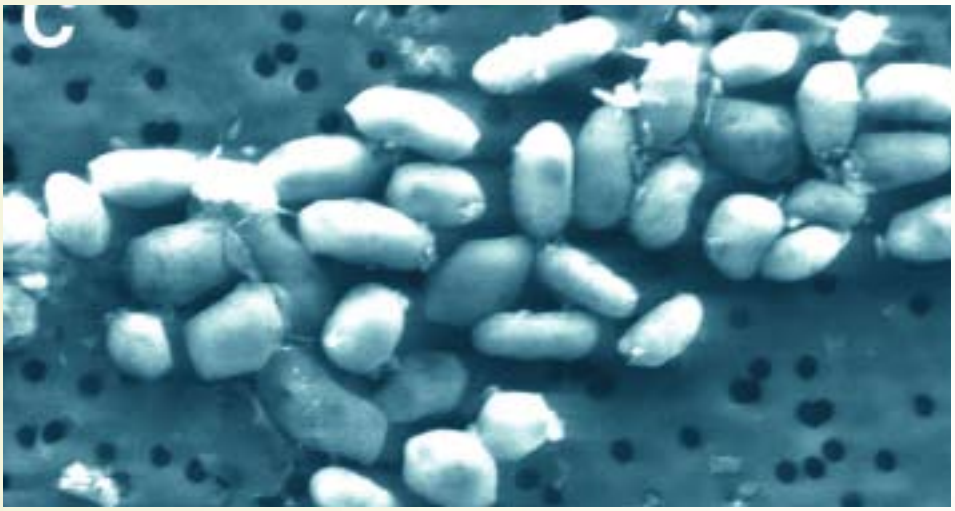
According to planetary scientists, this new theory is the first "that is really comprehensive and consistent with the facts of Saturn's rings and its satellites."

Bacteria thriving on arsenic discovered

From the tiny bacterium *Escherichia coli* to elephants, all forms of life on Earth depend on the same six elements: carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. These six elements are considered essential; it was believed life as we know it cannot exist without them. Phosphorus is critical to terrestrial life because phosphorus and phosphates are key parts of the double-helix "backbone" of DNA and the energy transport molecule ATP. At the same time, arsenic – the element below phosphorus in the same group of the periodic table – has been known to be highly toxic to living beings. But now a NASA-funded research has found a strain of bacteria named GFAJ-1, isolated from a salt lake in California, USA that can grow on arsenic, seemingly in lieu of phosphorus in its DNA and other vital biomolecules (www.sciencexpress.org/ 2 December 2010). The newly discovered microbe strain GFAJ-1 is a member of a common group of bacteria, called the Gammaproteobacteria (a class of several medically and scientifically important groups of bacteria that includes *E. coli*).

Mono Lake is an extremely saline and highly alkaline lake in California, which also has one of the highest natural concentrations of arsenic in the world.

Interestingly, although arsenic is highly toxic and phosphorus is not, the two elements have many similarities. Belonging



A scanning-electron micrograph image of arsenic-eating bacteria, which NASA says has redefined the quest for life in the universe. (Credit: Science/AAAS)

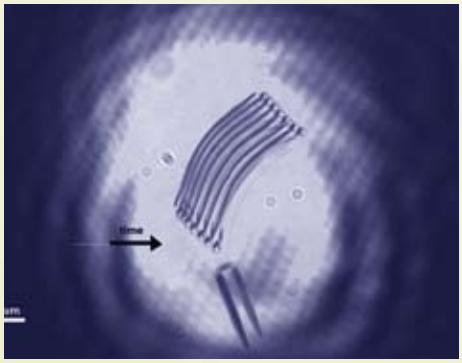
to the same group in the periodic table, arsenic and phosphorus possess similar atomic radii as well as identical electronegativity. The most common form of phosphorus involved in biological processes is phosphate (PO_4^{3-}), which behaves similarly to arsenate (AsO_4^{3-}) over the range of biologically relevant pH. In fact, it is this similarity that makes arsenic toxic to life on Earth because when incorporated in place of phosphate, arsenate probably interferes with normal metabolic process. It was to test this hypothesis that a team of scientists led by geomicrobiologist Felisa Wolfe-Simon of NASA Astrobiology Institute decided to study a strain of bacteria collected from the bottom of Mono Lake, an extremely saline and highly alkaline lake in California. Mono Lake also has one of the highest natural concentrations of arsenic in the world. Wolfe-Simon had speculated that some microbes might be able to adapt to using arsenic.

To test her hypothesis, Wolfe-Simon collected mud from Mono Lake and cultured the microorganisms from it in increasing concentrations of arsenate. No phosphate or other phosphorus-containing compounds were added to the growth medium. When the growing bacteria were later tested they were found to have incorporated arsenic in the protein, lipid, nucleic acid, and metabolite fractions of the cells. DNA separated from the bacteria was also found to contain arsenic. In other words, the bacteria substituted arsenic for phosphorus in its cell components and still survived.

The results of this study are likely to transform ongoing research in many areas, including the study of Earth's evolution, organic chemistry, biogeochemical cycles, disease mitigation and Earth system research. These findings are also expected to open up new frontiers in microbiology and other areas of research.

Lightfoil generates lift from light

American researchers have demonstrated for the first time the optical analogue of an aerofoil that makes aeroplanes fly. Called a 'lightfoil', the device is a transparent object with specially shaped surfaces that produce a 'lift' when passing through a beam of light, in a manner similar to an aerofoil. A team of scientists led by Grover Swartzlander, a physicist at the Rochester Institute of Technology, New York have used laser beams passing through curved lenses to generate lift just like aerofoils (*Nature Photonics* | doi:10.1038/nphoton.2010.266). The effect is tiny that no one expects to make airplanes fly via laser beams. But it is possible that this effect could be useful when moving nanoscale objects, or perhaps manoeuvring solar sails in outer space.



Time-lapse images show the progression of the "lightfoil" lifted by light. (Credit: Nature Photonics)

The principle of a lightfoil is similar to that of an aerofoil: both require the pressure to be greater on one side than the other, which generates a force, or lift, in that direction. With an aerofoil, the pressure difference arises because air must pass faster over the longer, curved side to rejoin the air passing underneath. With the lightfoil, the pressure comes from light rather than air. Such "radiation pressure" was theorised by physicists James Clerk Maxwell and Adolfo Bartoli in the late 19th century, and exists because photons impart momentum to an object when they reflect off or pass through it. It is the reason, for example, that comet tails always point away from the Sun, because the Sun's rays push them that way.

Grover and his colleagues carried out computer analyses to learn how light rays refract and reflect as they enter different shaped objects and to find out if radiation pressure could generate lift in a lightfoil. Success came in the form of a rod with semi-cylindrical cross-section, which showed from the analyses that a large portion of incident light rays should leave in a perpendicular direction. The side where they leave would experience the greatest radiation pressure and, therefore, lift.

To test this prediction, Grover and his group created tiny rods shaped kind of like airplane wings – flat on one side and rounded on the other. When these micron-sized lightfoils were immersed in water and hit with 130 milliwatts of light from the bottom of the chamber, they started to move up, as expected. But the rods also began moving to the side, a direction perpendicular to the incoming light. It was this latter, perpendicular motion that, the researchers claim, proves the existence of optical lift. Tiny symmetrical spheres didn't exhibit this lift effect, the team found.

One application of the lightfoil could be to control the direction of space vehicles that rely on radiation pressure for thrust, such as the experimental solar-sail spacecraft *LightSail*-1, which the Planetary Society, a public space organisation based in USA, is planning to launch later this year. The lightfoil concept could also be used to power micromachines, or transport particles in liquids. ■

Your opinion

Dream 2047 has been inviting your opinion on a specific topic every month. The reader sending the best comments will receive a popular science book published by VP. Selected comments received will also be published in *Dream 2047*. The comments should be limited to 400 words.

This month's topic:

"Has the teaching of science in schools helped in removing the scourge of superstitions and irrational beliefs existing in our society in any significant manner?"

Response should contain full name; postal address with pincode and email ID, if any; and should be accompanied by a recent passport size photograph. Response may be sent by email (opinion@vigyanprasar.gov.in) or by post to the address given below. If sent by post, "Response: *Dream 2047* February 2011" should be clearly written on the envolope.

Vigyan Prasar
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Winners of "Your Opinion" contest for November 2010

Topic: "Can the standard of school education be raised by adopting a single curriculum for the entire country?"

Kunal Gupta
Class-X-D
6-B-4, Pawanpuri, South Ext.,
Bikaner - 334 003 (Raj.)

The standard of school education would certainly be raised by adopting a single curriculum for the entire country. Mathematics and science, which are the most important subjects, are almost common but in some states the standard is somewhat low. Some topics are covered in class IX whereas some topics are covered in class X. Similar is the case with geography, economics and civics. But a common syllabus in History may create problem because history syllabus is state specific. So, the adaption of a single curriculum may require minor changes, but the benefit will be immense. A single curriculum at school level would facilitate common evaluation for the country as a whole and would save a lot of duplicity and labour for framing separate curricula for different provinces. This will not only increase the standard of education but would also be a unifying force to understand the culture of all the states by the students. At present, NTSE (National Talent Search Examination conducted by NCERT) and all-India level exams are conducted on a single curriculum. So, the same principle of single curriculum may be adopted for school education for the entire country formed by eminent educationists.

*****

C. K. Biju,
H.S.A.- Physics,
S.N.V. Sanskrit. H.S.S.,
N. Paravur, Ernakulam (Dt.)
Kerala – 683513

In our country, there are different curricula and syllabi like CBSE, ICSE, NCERT and other state boards. Some of them are considered better than the others. This is not a good concept. It is better to adopt a single curriculum for the entire country. But the chosen single curriculum must be flexible and easy to handle at various parts of the country. This means the activities and strategies chosen for the curriculum transaction may be different with respect to the circumstances. This will raise our standard of school education. But the languages and subjects like history and culture may be different at different parts of the country. So it can be treated independently as our country has a wide range of different cultures and languages.

*****

J.M. Manchanda
Associate Professor
Shyamlal College Evening, Shahdara
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Delhi- 110032

A single curriculum at national level would ensure uniformity but cannot by itself guarantee improvement of standards. For better quality of teaching, curriculum must be periodically revised, updated and made to relate to everyday life of students. Methods of instruction are also important since use of audio-visual devices leave a stronger imprint on young minds. A single curriculum is now easier to adopt with the advent of technology and coupled with posting of e-content and e-testing may yield desired results. But the teacher shall continue to play a pivotal role enthusing young minds and creating a spirit of scientific inquiry in them. Therefore workshops to train them about implementing the common curriculum are essential.

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Awareness campaign on HIV/AIDS and mental illness and multiple disabilities

Vigyan Prasar, organised a 10-day awareness campaign on 'HIV/AIDS and Mental Illness and Multiple Disabilities in Human Beings' during 1-10 December 2010 in association with Coalition for Rural Empowerment and the United Nations Information Centre for India and Bhutan.

Red ribbon walk the zindagi walkathon was organised

The campaign was organised through road shows; stalls; kiosks; exhibits; painting, quiz, slogan, and essay competitions; banners; posters; media reports; public lectures; seminars; and interface with affected citizens and their support groups. The participants were schools, colleges, youth organisations, patient groups, writers, photographers, artists, and journalists. There was an extraordinary response and awareness among participants about the aims and objectives of Vigyan Prasar.

A large number of common citizens signed the pledge to support the cause of AIDS and came forward to help the needy. The awareness campaign had features like painting competition for youth and students on the subject "Deadly HIV Virus cutting through the Elixir of Life"; a Walk for Life (Red Ribbon Walk): the "Zindagi Walkathon" in the form of a popular road show, and an AIDS awareness campaign through specially mounted Red Ribbon Manch at Shivaji College, Indian Institute of Foreign Trade, Indian Institute of Technology, Jesus and Mary College, and Fore School of Management and a signature campaign in association with the Times of India and Delhi College of Art students. An exhibition-cum-sale of Awareness Literature on Science, AIDS and Disability by Vigyan Prasar was organised.

Er Anuj Sinha, Director, Vigyan Prasar, handed over the prizes to the winners in the august presence of the Hon'ble Minister of Health and Family Welfare, Dr (Mrs) Kiran Walia.

Red ribbon human chain was created by the participants

Experts examine the painting competition cum exhibition on AIDS awareness

On the occasion of the World Disability Day on 3 December 2010, Vigyan Prasar, in collaboration with the Coalition for Rural Empowerment and its institutes:

A candle light vigil on World Disability Day 3rd December 2010

Sudinalay for Mental Health and Shramik Referral Centre for People Living with HIV/AIDS, organised a week-long exhibition (3-10 December 2010) of paintings and photographs on 'Mentally Sick Women and Children Living with AIDS' at the Gandhi King Plaza, India International Centre, New

Er Anuj Sinha, Director, Vigyan Prasar addressing the participants on World AIDS Day 2010

Delhi. A candle light vigil was organised to commemorate the occasion. The candle light vigil was attended by Dr Kiran Walia, Er Anuj Sinha and others. The exhibition lasted 8 days and was open from 9 am to 9 pm every day.

As part of the programme a full-day seminar was organised on 8 December 2010 in association with the Institute of Human Behaviour and Allied Sciences, which was attended by doctors, care givers and users of mental health services. This seminar was a full-day deliberation on the symptoms of the mental illnesses, their prevention and cure and the public awareness mechanisms for assistance to patients and risk reduction processes.

At the closing session of the programme a quiz contest was organised on the theme: "Disability: You and I". In an amazing 16-round show, 10-year-old children demonstrated their incredible knowledge and skills on disability management. These 24 Children were nominated as brand ambassadors and trainers for children of 24 remote area schools to be identified by the Vigyan Prasar in future. Ms. Mallika Sarabhai, Ms Shobhana Narayan, and the Minister of Health, Dr. Kiran Walia graced the occasion.