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The Diverse World of Polymers

Hermann Staudinger	Wallace Carothers	Paul John Flory
		
(1881-1965)	(1896-1937)	(1910-1985)

Inside

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

Careers and Competition

Doctors have respect in society and earn well. They have long working hours though and a very long preparatory period. Engineers also have a respectable standing in the society and in the matrimonial market. The workshops are noisy and field work involves exposure to wind, sun, snow and rain. Management graduates earn fabulous salaries. They have challenging roles and are in the line of fire if results don't match expectations. Show business artists have glamorous lifestyles but spend most of their working time with greasepaint and under arc lights. The civil service enjoys proximity to power. There appear endless career choices and students are naturally indecisive while facing options for courses and colleges after school graduation.

Entry to most preferred career choices are competitive and involve two or more phases of education and selection examinations. Entering one's preferred career calls for preparation and determination. A mismatch can ruin one's life and happiness, resulting in lack of interest and poor performance in work. It could leave one as a misfit with low opportunities for growth and satisfaction. Perhaps this may reflect on the earning potential also. It is therefore a very important and critical decision.

There are several aptitude tests that can be useful for guiding a young person. Some may be available on line and others at career counselling centres. While alternatives need to be examined, an important aspect to be considered and understood is one's strengths and weaknesses. These are meant to assess various abilities of an individual and match these with the requirement of a career. After an overall assessment a student has a clearer understanding of her/his interests and likings that can help plan the course of action for the next step.

Students at graduation need skills to write their academic profiles, forwarding letters and face job placement interviews. In the coming decade increasing opportunities will be announced on web pages and searching for opportunities will have to be much smarter than placement opportunities in the university or the employment pages of national dailies. Mentors have a significant role in guiding the youth.

Selecting a university and a course should not be a gamble. Adequate search should give due weightage to the course and the institution. Some rankings can be quite confusing rather than help in a rational choice. Other factors can be scholarships and fee structures, proximity to home, etc.

One initiative is a web portal that gives profiles of opportunities for science graduates. Job requirements, salaries, profiles of some outstanding employers and successful professionals may be highlighted. The list must mark those careers that are projected to have many openings, high growth or attractive compensation. New and emerging careers, often in inter-disciplinary areas may be listed. In the broad field of science one can find opportunities in research, academics, administration/management, and planning and policy formulation. Lateral movements are being encouraged.

Where does a career in science communication figure with young graduates? The growth in mass media both electronic and print has been phenomenal. There have also been more opportunities for the private sector to grow and issues of science and development are receiving more attention and therefore higher visibility. Competent science communicators are in demand either as free lancers or with a media house.

Research laboratories and multilateral organisations are conscious of the need to improve their image. Many of these are in the strategic interest of their programmes. Public health campaigns become more effective when backed by communicators who have a strong base in related areas of science.

Many universities offer courses in Mass Communication with specialisation in science journalism. Some have post graduate courses in science communication. Distance education courses are also available for working professionals. Evening courses offer diplomas and certificates in selected cities.

The portfolio every candidate needs to convince the course admission committee of a good university must comprise some general articles, book and film reviews, some interviews and more. This should reflect some understanding of the science and development subjects currently in the public space. Preparing this over some months will establish more depth in the topics selected and their treatment.

Other opportunities for brilliant and talented young scientists in different fields and emerging specializations also need profiling. We have commenced a weekly segment on Lok Sabha TV from this month. Competent organisations are advised to devise mechanisms and strategies to counsel the youth.

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The Diverse World of Polymers

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"Polymers are everywhere, including in your body. Proteins, which form hair, muscles, tendons, and skin, are polymers; they consist of long chains of amino acids, and skin, are polymers; they consist of long chains of amino acids. Enzymes, which act as catalysts for various bodily processes, are proteins. An example is lactase, which helps the body to break down lactose. Insulin is also a protein."
Museum of Science—Book of Answers & Questions by Ann Rae Jonas, Adams Media Corporation, Holbrook, MA, 1996.

"We wear these man-made materials (synthetic macromolecular compounds or polymers), eat and drink from them, sleep between them, sit and stand on them; turn knobs, pull switches, and grasp handles made of them; with their help we hear sounds and see sights remote from us in time and space; we live in houses and move about in vehicles that are increasingly made of them."
Organic Chemistry (Fourth Edition) by Robert T. Morrison and Robert N. Boyd, Allyn and Bacon Inc., New York, 1983.

"Today it is possible not merely to shape and adopt materials, as man has always done, but also to create new ones designed for specific functions. For example a vast range of plastics has been devised—materials which do not rot or corrode, are strong and light, and can be made flexible or rigid, transparent or opaque, and as tough or brittle as the designer wishes."
Reader's Digest Library of Modern Knowledge, Vol.3, The Reader's Digest Associated Limited, London, 1981.

Different phases (eras) of development of human society have been characterised by materials that were predominantly used; for example, Stone Age, Bronze Age and Iron Age. The present era starting from the second half of the twentieth century may be termed as Age of Polymers. Polymers are being increasingly used in various industries including packaging, adhesives, coatings, plastics, paper, fibres, building materials, ceramics, concrete, automobile, and liquid crystals. Plastics are stable synthetic polymers that are fluid at some stage in their manufacture, when they can be shaped, and that later set to rigid or semi-rigid solids. Today plastics are used in making sheets, pipes, ropes, films, toys, bottles, knobs, handles, pens, toothbrushes, valves, gears, bearings, cases for radios, television sets and computer, boats, automobile bodies, body of modern airplane, wrappers, drainpipes, floor tiles, audio discs, shoes, hand bags, kitchen utensils, paints, adhesives, electrical insulators, water-proofing for walls, stain-resistant textiles, cosmetics, combs, tables, chairs, containers, plywood, printed circuit boards, to name a few.

Polymers are very important for plant and animal life. Today almost all facets of human life are touched by polymers. There are many important natural polymers like cellulose, lignin, rubber, proteins and nucleic acid, which are really vital for our existence. Starch and cellulose provide us with food, clothing and shelter. Proteins hold our body together and run it. Nucleic acids control heredity on the molecular level. Lignin acts as an amorphous matrix in which the cellulose fibres of wood are oriented.

Materials made of Polymers

Humans have synthesised new polymers or have modified the natural ones, for example, plastics including polyethylene, the nylons, polyurethanes, polyesters, polyvinyls, and synthetic rubbers. Bakelite, a phenol-formaldehyde polymer, was the first synthetic polymer to be developed. It was introduced by the Belgian chemist Leo Bakeland (1863-1944) in 1909. The first synthetic fibre developed was rayon. It was developed as replacement for silk in 1911.

What is a polymer?

The word 'polymer' was derived from the Greek words '*poly*' meaning 'many' and '*meros*' meaning 'part'. The original Greek word for polymer is '*polymerase*' meaning 'having many parts'. The term was coined by Jons Jacob Berzelius in 1833. However, it may be noted that Berzelius' definition of polymer was quite different from the modern definition.

The term 'polymer' encompasses a large class of natural and synthetic materials with a wide variety of properties. A polymer may be defined as any of a class of natural or synthetic materials composed macromolecules that are multiples of simple molecules called monomers. Polymers may contain some 5,000 to several million small molecules (monomers). There are many polymers which are made of only one monomer. But there are many polymers where two or three different monomers may be

combined. Polymers may contain long chains of un-branched or branched monomers or they may be cross-linked networks of monomers in two or three dimensions. The structural backbones of polymers may be flexible (as in case of natural rubber) or rigid (as in case of vulcanised rubber).

The chemical and physical properties of polymers are dependent on the chemical composition of the monomer units, length of the polymer chains, and presence or absence of cross-links between the chains. The utility of polymers has increased many folds because of the fact that it is possible to change their physical and chemical properties by altering the following factors—chemical composition of the monomer units, the length of the molecular chain and the way the monomers are arranged. Mass production of synthetic polymers began in real earnest during the Second World War when synthetic rubber was produced on a large scale for tyres and other war time applications and nylon for parachutes. Since then polymer industry has grown and diversified into one of the fastest growing industries in the world.

Polymers are mostly organic compounds. But there are inorganic materials, both naturally occurring and human-made, which have polymer-like structure. Among the naturally occurring inorganic materials having polymer-like structures are diamond, graphite, sand, asbestos, quartz, mica, and feldspar. Glass is an example of human-made inorganic material having polymer-like structure. There are mixed organic-inorganic polymers, for example the silicones having inorganic backbone of silicon and oxygen with attached organic side groups.

Classification of polymers

Polymers are often classified on the basis of i) the characteristics of the reactions by which they are formed; ii) chemical type of the monomers; and iii) mechanical response of the polymers at elevated temperature.

i) Based on the characteristics of the reactions by which polymers are formed

The process by which a polymer is created is known as polymerisation. There are two main reactions by which polymers are synthesised—addition reaction and condensation reaction. When a polymer is formed by addition reaction it is called addition polymer. In addition polymer, the monomers add together to make the polymer molecule in such a way that nothing in the monomer molecules is left out. They form a long chain of the repeating polymer. The monomers making addition polymer usually have a double bond between two carbon atoms. They are alkenes such as ethene (CH_2=CH_2). Alkenes such as chloroethene may also be monomers for making addition polymers. Most of the substances that we call plastics are addition polymers. Some of the addition polymers and their monomers are listed (Table 1).

In condensation polymerisation, usually water molecules are driven off as the polymer forms. Monomers forming condensation polymers have two reactive

Table 1: Some Common Addition Polymers and Their Monomers

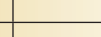
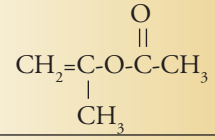
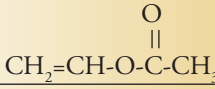
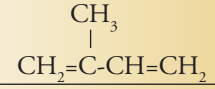
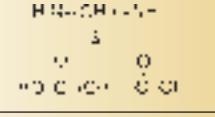
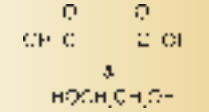
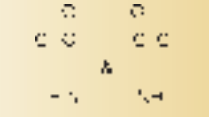
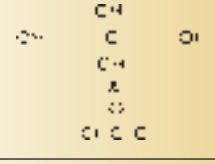
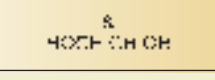
Name of the polymer	Monomer	Chemical formula monomer
Polyethene	ethene	CH_2=CH_2
Polypropene	1-propene	CH_2=CH-CH_3
Polystyrene	styrene	
Polyvinyl chloride (PVC)	vinyl chloride	CH_2=CH-Cl
Polytetrafluoroethene	tetrafluoroethene	CF_2=CF_2
Poly(methyl methacrylate)	methyl methacrylate	
Polyacrilonitrile	acrilonitrile	CH_2=CH-CN
Polyvinyl acetate	vinyl acetate	
Natural rubber	2-mythly - 1,3 butadine	

Table 2: Some Common Condensation Polymers and Their Monomers

Name of the polymer	Monomer	Chemical formula monomer
Nylon (a polyamide)	1,6—diaminohexane & hexane dioic acid (adipic acid)	
Dacron or Mylar (a polyester)	terephthalic acid & ethylene glycol	
Kevlar (a polyamide)	terephthaloyl chloride & 1,4—diaminobenzene	
Lexan (a polycarbonate)	bisphenol A & phosgene	
Polyurethane	diisocyanatobenzene & ethylene glycol	

ends, which can join together to form, for example, ester or amide links. The formation of nylon from its monomers 1,6—diaminohexane and hexane dioic acid is shown (Table 2).

NH_2-$(CH_2)_6$-NH_2 + HOOC-$(CH_2)_4$-COOH → NH_2-$(CH_2)_6$-NHOOC-$(CH_2)_4$-COOH

The product still has two reactive ends and the reaction goes on and on to form a very large chain molecule, the polymer.

Some of the condensation polymers and their monomers are listed (Table 2).

ii) Based on the chemical type of the monomers

Based on the chemical type of the monomers, polymers have been divided into two groups namely homopolymers and copolymers. In homopolymers, the repeating unit is the same throughout. For example, -A-A-A-A-A-A-A-A-A-A-.

In copolymers, there are different repeating units. Depending on the arrangement of the types of monomers in the polymer chain of the copolymers, the following arrangements can be formed:

- Random copolymers: where the different repeating units are distributed randomly
  –A-A-B- A-B-B-A-B-A-A-A-B-A-B-B-
- Alternating copolymers: where the different monomers appear in alternating sequences,
  -A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-
- Block polymers: where a long sequence of a monomer is followed by a long sequence of another monomer,
  -A-A-A-A-A-A-B-B-B-B-B-A-A-A-A-A-A-
- Graft copolymer: where there is a chain made from one type of monomers with branches of another type.

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-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-
          |                   |
          B-B-B-B-            B-B-B-
```

iii). Based on the mechanical response at elevated temperature

Based on the mechanical response at elevated temperature polymers have been divided into two main groups: thermoplastics, thermosets, and elastomers.

Thermoplastic polymers can be repeatedly softened by heating and then solidified by cooling. This is because intermolecular forces that keep the molecules together are weak in thermoplastic polymers and so the materials soften when subjected to heat and on cooling it returns to its original position. Because, thermoplastic polymers can be formed and reformed in so many shapes, they have wide range of applications. Most linear polymers and those having branched structure with flexible chains are thermoplastic polymers. Polyvinyl chloride, polybutadiene, polystyrene, polyacrylonitrile, polyacrylates, polycarbonates, polyethene, polymethylpentene, and polymethyl methacrylate are examples of thermoplastic polymers.

Polymers causing pollution

Thermoset polymers cannot be reshaped again and again by heating and cooling because once heated they solidify or "set" irreversibly. Unlike thermoplastic polymers, thermoset polymers are three-dimensional networked polymers with a high degree of cross-linking between different chains. They are harder and stronger than thermoplastic polymers. Thermoset polymers have better dimensional stability. They find uses in processes requiring high temperatures. Vulcanised rubber, Bakellite, melamine resin, epoxy resin, polycyanurates, and polyester resins are examples of thermoset polymers.

Hermann Staudinger

Elastomers are polymers which can be stretched easily to several times their normal length and on removing the stress they rapidly return to their original dimensions. In elastomers, the chains are cross-linked but unlike thermoset polymers they have low cross-linking density. As a result the chains in elastomers have some degree of freedom to move but at the same time the cross-linking prevents the chains to move permanently relative to each other. Natural rubber is an example of elastomer.

Wallace Carothers

Polymer structure

A proper understanding molecular structure of polymers did not emerge until the 1920s. This was in spite of the fact that there were significant advances in synthesis and characterisation of polymers. Before the 1920s, chemists put forward the so-called association theory to explain chemical nature of polymers. According to this theory polymers were clusters of small molecules or colloids held together by unknown forces. Further, it used to be believed that polymers did not have definite molecular weights.

It was Hermann Staudinger (1881-1965), a German chemist, who first proposed in 1922 that polymers consisted of long chains of atoms held together by covalent bonds. For over a decade Staudinger's idea regarding the chemical nature of polymer did not find wide acceptance, but eventually it did find acceptance. To test the controversial theory of Staudinger, Wallace Carothers (1896-1937), an American chemist, carefully joined small organic molecules to produce long molecular chains and studied their properties. Carothers' work not only validated Staudinger's theory but also demonstrated that polymers could be rationally synthesised. In 1953, Staudinger was awarded the Nobel Prize for

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The man behind composting technology: Prof. Sultan Ahmed Ismail

Prof. Sultan Ahmed Ismail is an Indian soil biologist and ecologist. He is known for his technology *vermitech*, which is used to recycle organic garbage into valuable fertiliser using local varieties of earthworms and is also applied in soil bioremediation.

One of the chief resource persons in India on composting technology (especially vermicomposting) to several government and non-government agencies Prof. Ismail is associated with the Department of Science and Technology, Government of India, in the development of a module for children on vermicomposting as a sustainable ecological practice. He also conducted a project for the Department of Environment, Government of Tamil Nadu for implementing vermicomposting in 50 schools in Chennai and also delivered several lectures including more than 200 schools across the country and abroad creating awareness on environment, solid waste management and vermicomposting. He is currently associated with the Consumer Association of Penang (CAP), in creating awareness on organic farming, vermitech and waste management among educational institutions and organic farmers of Malaysia.

Recipient of many international and national awards Prof. Ismail has authored number of books on Vermitech, Vermiculture and Vermocology. He is honoured with a D.Sc. in Zoology from the University of Madras in 2001 for his research in the field of soil ecology - earthworms - waste management. He is also the Managing Director of Ecoscience Research Foundation.

Recently Er Anuj Sinha, Director, Vigyan Prasar and Consultant, Department of Science & Technology interacted with Prof. Sultan Ahmed Ismail on science education, outreach of science and his love towards earthworms. Here are excerpts of the interaction.

Er Anuj Sinha: You have been a passionate teacher for most of your professional life. What are your observations on the curriculum, syllabus, books and evaluation methods of undergraduate classes? How have the changes been useful to the students?

Prof. Sultan Ahmed Ismail: Curriculum and syllabus are unique in our pattern of education although these are not very helpful to the student in some of the modern sciences. For example we all know the speed at which computers and their sciences are evolving, the syllabi do not change at the same speed. Moreover with education becoming self-financed it is becoming difficult for sincere students with an interest to learn to be able to join institutions offering modern courses due to fee structure. Institutions on the other hand cannot be blamed for the fee structure, as they have to generate funds to retain their staff as well as bear their recurring expenses. The cost of imported books and journals is growing rapidly. Indian books though are brilliant in many subjects; books from abroad become necessary for keeping up with current information.

Dr Sultan Ahmed Ismail interacting with students in a science outreach programme

I have gradually started feeling "is education only for those who can afford?" Introspection in this is a must.

I have never been satisfied by the evaluation methods, external or internal. I have my reservations on the yardsticks applied during such evaluations. There may be exceptions, but in general in most institutions of higher learning understanding of a subject is not evaluated.

AS: Thank you, Sir, I hope this frank opinion will reach the right ears. Do you see a change in the competence level of students who enrolled for the B.Sc. course over the past few decades? Has there been a major difference in the students from urban and rural backgrounds? At the end of the course is there a homogenization among the students?

This urban rural divide is not based on the urge to learn or to involve with tough work but the ability to understand English and to some extent the subject as well. Yes, there is a marked difference in these two. May be, soft skills and communication in English need to be strengthened in not only rural but also in some urban schools. Some students totally depend on rote memory to clear the exams. Strengthening of school education is essential for the future generation to cope with modern subjects. Education in basic sciences also needs sprucing up.

By the end of the course sometimes rural students outsmart their urban counterparts. Role of parents is very significant in higher education. Broad based education at the graduate level with specialisation at the post graduate level seems more rewarding than specialisation at the graduate level. Having had the good fortune to walk steadily through all the levels in my professional career – demonstrator, lecturer, assistant professor, reader and then Head of the Department - I recommend this with confidence.

AS: You made friends with earthworms rather early. Why did you select these humble creatures? Has this been a satisfying friendship?

SAI: I started teaching at my alma mater The New College, Chennai (Madras then) from November 1974 and my research on earthworms started in 1978. As Paulo

Coelho writes, it was the Universe that conspired for me to work on earthworms. I wish to share here an interesting story. A student of mine, Kaleemur Rahman, who had completed M.Sc in Zoology and could not obtain a seat in M.Phil, in the University of Madras but was keen to pursue research, approached me in 1978 when I had just completed my M.Phil. The Ethological Society of India was to conduct a conference and had called for papers to be presented in animal behaviour. I needed live organisms to work to suit this theme and the only live specimens in the laboratory on that day were the earthworms. My work started on earthworms with the species *Lampito mauritii* and Kaleemur became my research assistant. There has been no looking back from that day. Today I am known through the earthworms and I feel it a very gratifying and satisfying friendship with the earthworms. When Ms Swahilya of *The Hindu* newspaper asked me the philosophy behind my research, I said "*As long as I live I shall go through the earthworms, and when I am gone the earthworms will go through me…*"

AS: I like your black humour Dr Sultan Ismail, your backyard at home is a laboratory. What have been the merits and demerits of bringing your passion and professional curiosities home? Has Mrs Ismail been supportive?

SAI: Very true, the backyard of my home is a laboratory. In fact staff and students of other institutions visit my home to study the various eco-friendly technologies I have been using. My research would have been incomplete if I had not applied the same in my own place. Tasneem (Mrs Ismail) has been supportive though initially in 1981 I was at the receiving end of a lot of comments. I did not have any infrastructure and had the earthworms in my bedroom. They had crawled over the bed one day and she looked at them as competitors till she recognised they shared only the bed and not me ;-). As an acknowledgment of her support, my book on earthworms *The Earthworm Book* (initially titled *Vermicology)* is dedicated to her.

AS: I know she is very proud of your work. Dr. Ismail, you have encouraged school students and nurtured their creativity through science clubs, science congresses and competitions. What has proved most effective in making a student adopt a career in teaching or research?

SAI: Science clubs and competitions promote a competitive spirit to perform at school level. Interest in science develops in a student through his/her teacher. If the teacher at the school or college level is good and enthusiastic then children invariably tilt towards that subject. I preferred to study zoology because of the impact of my teacher Professor Nandakumar who taught me in the Pre-University class (class XII today). I was lucky to have some excellent teachers notably Prof H Md Mohideen of The New College who without hesitation permitted me to start research in my Department, and Professors G J Phanuel (late) of MCC and Prof V A Murthy (late) of Loyola College as my Research Supervisors who kindled interest and joy of scientific research with social relevance. Teachers, especially from schools, need several motivational workshops and programs not just refresher and re-orientation programmes that exist today. I am glad most of my students have taken up science teaching or research as their career, profession and passion. Some have even been extending their work to societal needs. I can say with pride that there are both urban and rural and even overseas students who get attached to my Department.

Self Help Groups are involved in the production of vermicompost under the guidance of Dr Ismail

Dr Sultan Ahmed Ismail advised on composting technology at University of Sciences Malaysia, Penang, Malaysia

AS: You are active on the professional level (research) as well as at the popular level (outreach). How do you balance your engagements and priorities? Our readers are often university teachers wanting to take up outreach activities and yet feeling bogged down by academic pressures.

SAI: Our academic responsibility is very primary but with some discipline one can get plenty done. I always believe in the dictum "a busy person always finds time, a lazy person never finds time". It also depends on why one does research. Is it to acquire a degree, to have more publications, to solicit an increment or a promotion, or to be the "change" to bring values to society? I will perhaps be in the last category. I have delivered almost 1,000 public lectures to all sections of the society in India and abroad.

AS: This must be a national record, Sir. You have been a very creative writer of science activity books. Which ones are you particularly happy about? Are the sales satisfactory?

SAI: I enjoy simplifying the complicated topics in science for better understanding by students, I mean from Primary School to Ph.D. - science without fun is futile. As teachers we should put in our best efforts to make science teaching livelier. I wrote an article (in 1991. 'Life science teaching; why not make it livelier? '*School Science*, 29: 20-23). By reading *Simple tasks, Great concepts* (supported by the RVPSP {NCSTC}, DST) which has been

prepared in the most simple and presentable form; blend of a science and a coffee table book, my team is confident it would attract not only teachers in India but also abroad. The book has been so designed that it would be extremely simple for a teacher to design these experiments for a student from Class 8 to Class 12. Students themselves would be able to do most of these simple tasks in the book to learn the great concepts of science without a teacher. Though designing such experiments and writing started in 1991,the real serious work of putting it on paper started in early 2009. The enormous amount of collective energy by my entire team is reflected in the book. I am confident that*Simple tasks, Great concepts*would be put to great use by schools in its real perspective. The writing of this book, not only made me glad and satisfying as I was fine tuning all 100 experiments, but also gave me extreme happiness that any child in some remote part of our country would be able to do most of these experiments even without a laboratory. My team also feels the same. We planned to upload the same and these experiments can be accessed on http://simpletasksgreatconcepts.wordpress.com/

Dr Ismail demonstrating techniques of vermicomposting to homemakers during a training programme

My favourite book remains *The Earthworm Book* (Other India Press, Goa). I have earned respect and regard more than money through these books. I am humbled to see my books used as reference books in several universities.

AS: The Children's Science Congress has established itself over the last two decades as an important platform for sharing project oriented research by school students. How can we encourage facets of science learning and research methodologies among college and university students?

SAI: Having been associated with Children's Science Congress for the past few years I find it a real great task by the organisers. There are excellent preparations by child scientists. Teachers are doing a commendable job in guiding them and the NCSTC, DST is involved in massive coordination and arrangement. The child scientists sometimes are not a "VIP" at these Congresses. Of late (the last one was held at Chennai for example) emphasis was on the inauguration and the meticulous arrangement for the "dignitaries on the dais" and not for the delegates for whom it was meant. In fact, even resource persons like me were treated shabbily. It is time to face some tough questions. May be a brain storm (real storm) is required at this juncture before December 2011. Why are these Congresses hijacked for recognition of the host institutions or individuals? Most children by the end of the programme would be disillusioned with the system but for the encouragement of their teachers and some resource persons.

Moreover I felt that the desire of the child to interact with stalwarts of science (at the Ahmedabad Congress, for instance) was miniscule. The stalwarts of science interacted with the children very formally. I feel children should have more interactive time with scientists. We can create a data base of not just the "illustrious scientists" but "scientists with passion to talk to children". An open day can be organised in the National Children's Science Congress when such scientists are available in halls and the child scientist will have the option to walk in just to talk and interact with them. That would be a dream fulfilled. The present day child does not need to be instructed, but she/he looks for guidance. I am sorry if my frank opinion hurts some friends but if we are really serious to instill in the next generation love for science then please take note of it. May be willingness of the concerned scientists to interact with child scientist through email or chat on specific days regularly may be pursued.

We have brilliant students in colleges, universities, and IITs from rural and urban centres. . Students and even teachers are not spared of a skewed view if they have a rural upbringing or if they represent ordinary institutions. Policies have to be designed to give students an assurance that they will be respected on "*what the child knows*" and not "*who the child knows*".

AS: Your observations are in the interest of the society and we can take the criticism. The social networking sites and chatting through cell phones are the medium preferred by the youth. Can you suggest means of raising awareness on issues of science and development through such means.

SAI: Not a bad idea! A child can register at a central agency who can forward a sms once a week on the most recent developments in the field of science. By sms I mean minimum characters that gives at a glance information. Even short emails (about 100 words) with links can be considered so that if interested then the student can access through hyperlinks.

Either one gets bored by the time one obtains the info required or there is an overload. The communicators must keep this in mind.

I sincerely appreciate this question and look forward to some brilliant utilisation of the new media. I am ready to offer my inputs if solicited.

AS: You are a doting grandfather. Is our generation doing enough to ensure that our grandchildren will inherit a lively and living planet when they grow up?

SAI: Ha ha ha! That's indeed wonderful. I am unable to comment on the role played by our generation and in balance would this be evaluated as positive or negative. As a grandfather I am doing my best to instill ASHA (=hope) in my two lovely granddaughters, Asma and Hafsa. They enjoy being with me in the garden asking questions on plants, earthworms, biodiversity, etc. I wish Anuj Bhai we form a 'grandparents club' and "broadcast" this information to grandchildren… as their parents are very busy building their careers.

Fruit in diet can fight pollution

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Environmental pollution impacts our health in many ways. For example, air pollutants can cause lung cancer, asthma,

bronchitis, emphysema, etc. Elderly persons, infants, pregnant women, people with heart problems, asthma, and other respiratory diseases are more vulnerable. Carbon monoxide released by motor vehicles also affect health. Large percentage of our vehicles is quite old and not well maintained. Such vehicles emit more carbon monoxide. Large percentage of households, especially in rural areas, depend on bio-fuels like dung cake, dry biomass, agricultural residues, etc., for cooking and heating. All of these have the potential to produce excess carbon monoxide. An associated problem is that very large numbers of families are forced to live in small residential units without adequate ventilation. In hilly areas and other areas where winter is severe ventilation is deliberately kept minimum as a protection against cold. Net result is that people are exposed to higher level of carbon monoxide and other pollutants generated on account of fuel burning. Carbon monoxide reduces capacity of blood to carry oxygen resulting in anoxia. Slowing of reflexes, headaches, drowsiness, dizziness, nausea are the common symptoms. Exposure to carbon monoxide can also trigger angina, heart attack, etc. People light fire during the night and close the doors, windows, etc. In absence of air, the level of carbon monoxide in the room increases with time. Because carbon monoxide is odourless and tasteless and does not cause any irritation, etc., people remain sleeping while the body suffers from anoxia resulting in silent death.

Another common air pollutant is the suspended particulate matter (SPM). It includes all kinds of fine particles which remain suspended or floating in the air. These particles are released from thermal power plants, industries, motor vehicles, stoves, etc., on account of inefficient burning of fuels and processing of materials. SPM may include carbon particles, silica particles, fine soil particles and various minerals, metals and industrial products like cement, asbestos, etc. SPM can aggravate asthma and bronchitis. Long term exposure can result in lung tissue damage, chronic respiratory diseases, cancer, premature death, etc. Silica particles entering the lung can cause silicosis.

Similarly, coal dust settled in the lungs results in "black lung disease". No doubt our body has been provided with filters in the nostrils and respiratory tract to arrest the SPM in the air. But these filters have two limitations. First, these filters cannot arrest very fine particles. Second, these filters become less effective or ineffective when the SPM content is very high in the air. Another dimension to the problem is that finer particles work as carriers for various toxic chemicals, some of which can lead to cancer.

Sulphur dioxide is another common air pollutant. It is produced on account of oxidation of sulphur present in different types of fuels. It is also produced on processing of ores and minerals containing sulphur. Sulphur dioxide in air can cause constriction of air-ways in asthma patients resulting in serious problem. It also causes bronchitis.

Oxides of nitrogen are produced due to oxidation of nitrogen present in fuels and also during industrial operations. These gases cause lung irritation and aggravate asthma, bronchitis, etc. These gases also make people susceptible to common colds, flu, etc.

Ozone gas is commonly produced in the lower atmosphere due to reaction of certain nitrogen oxides with oxygen in the presence of sunlight. Ozone gas causes breathlessness, cough, chest pain, etc. It also reduces resistance to common colds and pneumonia.

Benzene, formaldehyde, lead, cadmium, PCBs, dioxin, etc., which are released in air from burning offuel in vehicles, and industrial activities, can cause mutations, reproductive problems, cancer, etc.

A large numbers of people in our country suffer from problems caused by water pollution. Also, deaths are common, especially among children and infants. During summer and rainy season the problem becomes more serious on account of rise in ambient temperature, which helps in proliferation of organisms causing infections. Also, rain water flowing into rivers, ponds, and lakes, etc., or percolating underground carry the contaminants and pollutants easily.

Bacteria of different types present in water cause typhoid, paratyphoid, cholera, dysentery, etc. Protozoa present in contaminated water causes amoebic dysentery. Viruses are responsible for jaundice, polio, etc. Chemicals like fluoride, arsenic, lead, mercury and other heavy metals, petrochemicals, chlorinated compounds, nitrates, nitrites, pesticides, etc., are also present in polluted water bodies the consumption of which can lead various problems including crippling, degeneration of body parts, mental retardation, cancer, etc.

At this point we should consider certain modifications in food habits for developing resistance and better immunity in general. With this aim in view we may consider including few common fruits in diet which are not expensive.

Wood apple, commonly known as *bael*, is rich in mucilage, tannins and more importantly, fibres. It acts as a potent

laxative to relieve constipation, a common problem associated with imbalanced diet and unhealthy life style. The fruit pulp can provide good nutrition while providing strength to liver, heart and stomach. It is rich in several minerals like calcium, potassium, phosphorous, sodium and also vitamins B and C, and protein. An additional benefit is that it can provide relief from peptic ulcer. Also, the fruit pulp has hydrating properties, providing strength to body and saves from heat-stroke and dehydration. Consumption of tender wood apple pulp can help in controlling dysentery as well as diarrhoea.

Guava is another fruit tree which grows widely. Guava fruit is rich in essential minerals like calcium, copper, iron, phosphorous, potassium, sulphur, and zinc. The fruit pulp

has various vitamins, fatty acids, flavonoids and saponins, which can help in keeping our body healthy and disease-free. Guava is also rich in fibres. Hence, its consumption can prevent constipation, dysentery, ulcer, etc., and more importantly cancer of the digestive tract. Guava can control high blood pressure and high cholesterol level. One particular feature of guava which is not well known is that it is very rich in vitamin C. It may contain up to 180 mg of the vitamin per 100 g of the fruit pulp. This is the reason that its consumption can provide resistance and immunity against a number of health related problems.

Another common fruit available in our country is papaya. Papaya fruit can be used unripe as well as ripe. Unripe fruit is rich in papain which improves digestion. It is highly recommended for dyspeptic persons. It also checks unwanted bacteria in the digestive tract. The unripe fruit can be consumed as such or cooked. Ripe papaya

fruit pulp is highly nutritious. It contains more carotene than any other fruit – up to 2,700 µg (microgram) per 100 g of the pulp. Beta carotene can provide protection against cancer. Papaya pulp is also rich in vitamin C, potassium, sodium, calcium, iron and proteins. It makes the body healthy and disease resistant. It also improves immunity and resistance against infections. An additional feature is that papaya pulp is a mild laxative. Its consumption can help removal of toxins reaching the body with food materials. Papaya is also a rich source of vitamin A and can help in preventing blindness in children, especially in the underprivileged section of our society.

Jackfruit is another common fruit that grows widely in India. The tree remains productive for decades. One tree can produce hundreds of fruits year after year. Young fruits are used as vegetable and also for preparation of pickles, chips, etc. Pulp of jackfruit, ripe or unripe, is highly nutritious. The unripe fruit is rich in protein, calcium, phosphorus, iron, vitamin C, riboflavin and thiamine etc. The ripe fruit is sweet and it is rich in carotene, carbohydrate, calcium, potassium, and vitamin C. Pulp of the ripe fruit is advisable for people suffering from piles. It also acts as an effective laxative. The seed is rich in protein, calcium, phosphorus, iron, carotene, vitamin C, riboflavin and thiamine. At places the seed is roasted and eaten or cooked as vegetable. Jackfruit is not a costly fruit. If people consume jackfruit,

nutritional deficiency can be cured to a great extent. Also, it will provide immunity against infections and toxic substances.

Jamun is another common fruit which grows extensively in the country. It is grown as avenue tree, on roadside, and also close to dwelling units. The fruit pulp improves

digestion and it is diuretic and a potent detoxifying agent for the body. The pulp is a good source of vitamin C, folic acid, carotene and fibre. It is also rich in calcium, magnesium, potassium, sodium, iron, and phosphorous. Hence it increases body immunity against various problems.

Gooseberry (*amla*) grows wild in forests and is also cultivated. During its growing season it is not expensive. The pulp of gooseberry is extremely rich in vitamin C and pectin. Pectin helps in reducing blood cholesterol. Tannins in the fruit protect the vitamin C from getting denatured during processing. The fruit pulp also protects against anemia, constipation, cough, asthma, bronchitis, colic, peptic ulcer, diarrhea, dysentery, etc.Also, it has antibiotic properties. Thus, gooseberry is a potent tonic, protects against several

health problems and acts as a rejuvenating agentThat is the reason that gooseberry is an important ingredient for several Ayurvedic and Unani formulations.

Another fruit which is cheap but nutritious is tamarind (*imli*). Tamarind is commonly used in certain parts of the country for regular cooking. But in other areas its use is limited. The fruit pulp is rich in fibres, calcium, phosphorous, potassium, iron, vitamin A, and vitamin C. The pulp can be consumed as such and also after processing. It can be easily converted into tasty *chutney* and refreshing drinks (*sharbat*). It can help in building body immunity against various problems including infections.

Lemon is another fruit which can help in enhancing body immunity and resistance against health related problems. Lemon is well known to contain high concentration of vitamin C. But it is not known to most people that lemon also contains high concentration of potassium. Potassium is helpful in protecting against heart problems. Lemon juice removes toxic substances from gall bladder and liver. Most important fact is that it is quite inexpensive. Also, it can be grown in the courtyard or even in pots.

Fig (*anjeer*) is generally considered expensive because it needs to be dried before transporting. Fresh fig gets spoiled easily. But in places where it is grown, it is inexpensive. In those areas people can easily consume fig. The fruit contains carbohydrates, proteins, calcium, phosphorous, potassium, sodium, vitamin A, vitamin C, niacin, riboflavin, thiamine, etc. Thus it provides nutrition and builds immunity. In addition, fig contains substantial quantity of soluble and insoluble fibres – about 2.2% by weight. Soluble fibres help in reducing blood cholesterol. Insoluble fibres help in curing constipation and protect the heart. It also provides protection against cancer.

Pomegranate (*anar*) is another fruit which grows in abundance in certain regions. Pomegranate contains large quantities of vitamins B1 and B2, niacin, calcium and phosphorous. It helps in better functioning of the kidneys, lungs and liver, which are easily affected by certain pollutants present in the environment.

Coconut is another tree which grows on its own in coastal areas and on islands. It is also cultivated. In coastal areas it is used extensively. Tender coconut water and the fruit pulp are consumed. In other regions its use is limited. Coconut water is highly nutritious, good for heart, liver, and kidneys, which are easily affected by the pollutants. Coconut also contains sugars, fibres, proteins, antioxidants, vitamins and minerals. It rehydrates the body with five essential electrolytes. Coconut contains monolaurin that has been shown to have anti-fungal and anti-viral properties.Regular consumption of coconut pulp and coconut water can thus prove useful in countering the effects of pollutants and inadequate nutrition.

There are other fruits like oranges, mango, litchi, apple, banana, etc. which look expensive in the market on account of transportation costs, storage costs and profit margins. However, these are inexpensive where these are grown. People must be encouraged to consume some of these fruits for better nutrition and health which can make them immune and resistant to pollutants and contaminants present in the environment and food. For example, banana is highly nutritious. It contains eight amino acids which our body cannot produce. Also, it is rich in fibres (about 2.5 g/100 g fruit pulp). It also contains vitamin C, calcium, iron, magnesium, phosphorous, potassium, manganese, zinc, etc. All these nutrients can help in building immunity and resistance.

Thus, we need to encourage consumption of the common fruits mentioned above, which are easily available and not expensive, on a regular basis. Selection of the fruits can be based on their availability, cost, etc. At least in areas where the fruits are grown, there is possibility that they will be inexpensive and easily available.

Understanding and Recognising Hypothyroidism

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The thyroid is a small, butterfly-shaped gland located at the base of the front of the neck, just below the Adam's apple. It is primarily engaged in production of certain hormones which have an enormous bearing on health, and affect all aspects of the body's metabolism.

Two main hormones

The thyroid gland produces two main hormones, thyroxine (T-4) and triiodothyronine (T-3). They maintain the rate at which the body uses fats and carbohydrates, help control the body temperature, influence the heart rate, and help regulate the production of protein.

The thyroid gland also produces calcitonin, a hormone that regulates the amount of calcium in the blood.

The rate at which T-4 and T-3 are released is controlled by the pituitary gland and the hypothalamus, an area at the base of the brain that acts as the "third eye" for the human system. The hypothalamus signals the pituitary gland to make a hormone called thyroid-stimulating hormone (TSH). Signalled thus, the pituitary gland releases the TSH in an amount that depends on how much T-4 and T-3 are in the blood. Based on the amount of TSH it receives, the thyroid gland regulates its production of hormones.

This process usually works well; however, the thyroid sometimes fails to produce enough hormones. Hypothyroidism—underactive thyroid—is a condition in which the thyroid gland does not produce enough of T-4 and T-3 hormones. This upsets the normal balance of chemical reactions in the body.

The condition seldom causes symptoms in the early stages, but, over time, untreated hypothyroidism can cause a number of health problems, such as obesity, joint pain, infertility and heart disease. However, the good news is that accurate thyroid function tests are available to diagnose hypothyroidism, and treatment of hypothyroidism with synthetic thyroid hormone is usually simple, safe and effective once the proper dosage is established.

What causes hypothyroidism?

When the thyroid does not produce enough hormones, the balance of chemical reactions in the human body can be upset. There can be a number of causes, including autoimmune disease, treatment for hyperthyroidism, radiation therapy, thyroid surgery and certain medications. Hypothyroidism may occur due to a number of different reasons, including:

Autoimmune disease

The most common cause of hypothyroidism is an inflammatory disorder known as Hashimoto's thyroiditis, which is an autoimmune disorder. By definition, autoimmune disorders occur when the body's immune system turns against the person and produces antibodies that attack his/her own tissues. Sometimes this process may affect the thyroid gland.

Researchers are not sure why the body produces antibodies against itself. Some think a virus or bacterium might trigger the response, while others believe a genetic flaw may be involved. Most likely, autoimmune diseases result from more than one factor. However, it may happen, these antibodies affect the thyroid's ability to produce hormones.

As a consequence of treatment for hyperthyroidism

Anti-thyroid medications. People who produce too much thyroid hormone (hyperthyroidism) are often treated with radioactive iodine or anti-thyroid medications to reduce and normalise their thyroid function. However, in some cases, treatment of hyperthyroidism can result in permanent hypothyroidism.

Radiation therapy. Radiation used to treat cancers of the head and neck can affect your thyroid gland and may lead to hypothyroidism.

Thyroid surgery. Removing all or a large portion of your thyroid gland can diminish or halt hormone production. In that case, you will need to take thyroid hormone for life.

Due to certain medications

A number of medications can contribute to hypothyroidism. One such medication is lithium, which is used to treat certain psychiatric disorders. If you are taking medication, ask your doctor about its effect on your thyroid gland.

Congenital disease

Some babies may be born with a defective thyroid gland or no thyroid gland at all. In most such babies, the thyroid gland did not develop normally for unknown reasons, but some children have an inherited form of the disorder. Often, infants with congenital hypothyroidism appear normal at birth. That is one reason why most states now require newborn thyroid screening.

Pituitary disorder

A relatively rare cause of hypothyroidism is the failure of the pituitary gland to produce enough thyroid-stimulating hormone (TSH) — usually because of a benign tumour of the pituitary gland.

Pregnancy

Some women develop hypothyroidism during or after pregnancy (postpartum hypothyroidism), often because they produce antibodies to their own thyroid gland. Left untreated, hypothyroidism increases the risk of miscarriage, premature delivery and preeclampsia — a condition that causes a significant rise in a woman's blood pressure during the last three months of pregnancy. It can also seriously affect the developing foetus.

Iodine deficiency

The trace mineral iodine — found primarily in seafood, seaweed, plants grown in iodine-rich soil and iodised salt — is essential for the production of thyroid hormones. In large parts of the country, iodine deficiency is common, but the addition of iodine to table salt has virtually eliminated this problem.

Risk factors

Although anyone can develop hypothyroidism, a person is at an increased risk in the following situations:

- Are a woman older than age 50
- Have an autoimmune disease
- Have a close relative, such as a parent or grandparent, with an autoimmune disease
- Have been treated with radioactive iodine or anti-thyroid medications
- Received radiation to his/her neck or upper chest
- Have had thyroid surgery (partial thyroidectomy)

Signs and symptoms

The signs and symptoms of hypothyroidism vary widely, depending on the severity of the hormone deficiency. In general, the problems tend to develop gradually, often over a number of years.

At first, you may barely notice some vague symptoms, such as fatigue and sluggishness, or you may simply attribute them to getting older. However, as your metabolism continues to slow, you may develop more obvious signs and symptoms. The signs and symptom may include:

- Extreme tiredness
- Fatigue
- Sluggishness
- Intolerance to cold
- Constipation
- Pale, dry, thickened skin
- Swelling of the face, and puffy eyes
- Hoarse voice
- An elevated blood cholesterol level
- Unexplained weight gain
- Muscle aches, tenderness and stiffness
- Pain, stiffness or swelling in your joints
- Muscle weakness
- In women, heavy menstrual periods
- Brittle fingernails
- Generalised hair thinning
- Forgetfulness
- Slowing of thought processes
- Depression

When hypothyroidism is not treated, the signs and symptoms can gradually become more severe. Constant stimulation of the thyroid to release more hormones may lead to an enlarged thyroid, often referred to as goitre.

Hypothyroidism in children and teens

Although hypothyroidism most often affects middle-aged and older women, anyone can develop the condition, including infants and teenagers.

Hypothyroidism in newborns

Initially, babies born without a thyroid gland or with a gland that does not work properly may have few signs and symptoms. When newborns do have problems with hypothyroidism, they may include:

- Yellowing of the skin and whites of the eyes (jaundice). In most cases, this occurs when a baby's liver cannot metabolise a substance called bilirubin, which normally forms when the body recycles old or damaged red blood cells.
- Frequent choking
- A large, protruding tongue
- A puffy appearance to the face

As the disease progresses, infants are likely to have trouble feeding and may fail to grow and develop normally. They may also have:

- Constipation
- Poor muscle tone
- Excessive sleepiness
- When hypothyroidism in infants is not treated, even mild cases can lead to severe physical and mental retardation.

Hypothyroidism in children and teens

In general, children and teens that develop hypothyroidism have the same signs and symptoms as adults do, but they may also experience:

- Poor growth, resulting in short stature
- Delayed development of permanent teeth
- Delayed puberty
- Poor mental development

Advanced hypothyroidism

Advanced hypothyroidism, known as myxedema, is rare, but when it occurs it can be life threatening. Signs and symptoms include low blood pressure, decreased breathing, decreased body temperature, unresponsiveness and even coma. In extreme cases, myxedema can be fatal.

When to see a doctor

You should see a doctor if you're feeling tired for no reason or have any of the other signs or symptoms of hypothyroidism, such as dry skin, a pale, puffy face, constipation or a hoarse voice.

You will also need to see your doctor for periodic testing of your thyroid function if you have had previous thyroid surgery, treatment with radioactive iodine or anti-thyroid medications, or radiation therapy to your head, neck or upper chest. However, it may take years or even decades before any of these therapies or procedures result in hypothyroidism.

If you have high blood cholesterol, talk to your doctor about whether hypothyroidism may be a cause. And if you are receiving hormone therapy for hypothyroidism, schedule follow-up visits as often as your doctor recommends. Initially, it is important to make sure you are receiving the correct dose of medicine. And over time, the dose you need may change.

Continued from page 36 **(The Diverse World of Polymers)**

his pioneering work. The American chemist Paul John Flory's (1910-1985) work greatly improved the understanding of polymers and for which he was awarded the Nobel Prize in Chemistry in 1974.

Paul John Flory

The sequence of the repeating monomers within a polymer chain is called its primary structure. The localised shape of a polymer resulting from hydrogen bonding is called the secondary structure. Two structures preferred by most of the flexible to semi-flexible linear polymers are helical and pleated sheet/skirt-like. The overall shape of a polymer as we see in polypeptide folding is called tertiary structure. The arrangement of two or more polymer units in space is called quaternary structure. For example, haemoglobin is essentially the combination of four sub-units.

Properties of polymers

Polymers are important in human life because of their extraordinary properties. The size or length of the polymer chain greatly influences physical properties of a polymer. As the chain length increases, melting and boiling points increases. The viscosity or resistance to flow of polymers in their melt state is also dependent on the length of polymer chain. Increase in chain length decreases chain mobility but increases strength and toughness.

Polymers do not rot or corrode. They can be produced in different colours. They can be strong or elastic. They are electrical and thermal insulators. Some polymers can be moulded as and when required after first softening them by heat but some cannot be resoftened and remoulded. They can be transparent or opaque.

Future of polymers

Humankind's journey from the Stone Age to the Age of Polymers has been possible because of their urge to satiate their inborn curiosity, to do something new to make their lives more comfortable and secure, to understand the world they live in. The progress of human civilisation is linked with the development of materials. So it is no wonder that the quest of new materials has been the major preoccupation of human beings since they first appeared on the Earth and it will remain so in future. As it is said, the Stone Age did not end because there was dearth of stones. It was the urge of human beings to improve the existing situation took him to develop new materials. Human beings will continue to develop newer and newer materials. At the same time there is no doubt that in foreseeable future polymers are going to be materials of choice. They have vast potential for exciting new applications in diverse areas like molecular composites, unique separation membranes, revolutionary new forms of food processing and packaging, conduction and storage of electricity, molecular based information storage and processing, health, housing and transportation.

At present synthetic polymers have certain disadvantages. Most of the polymers are not biodegradable and so unlike natural substances, which are broken down by bacteria and fungi, synthetic polymers do not rot or break down. Extensive use of non-biodegradable polymers has created a big pollution problem. To solve this problem biodegradable polymers are being developed. Some polymers catch fire easily and some others give off dangerous fumes when they burn. These problems are also to be solved for safe use of polymers.

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Recent developments in science and technology

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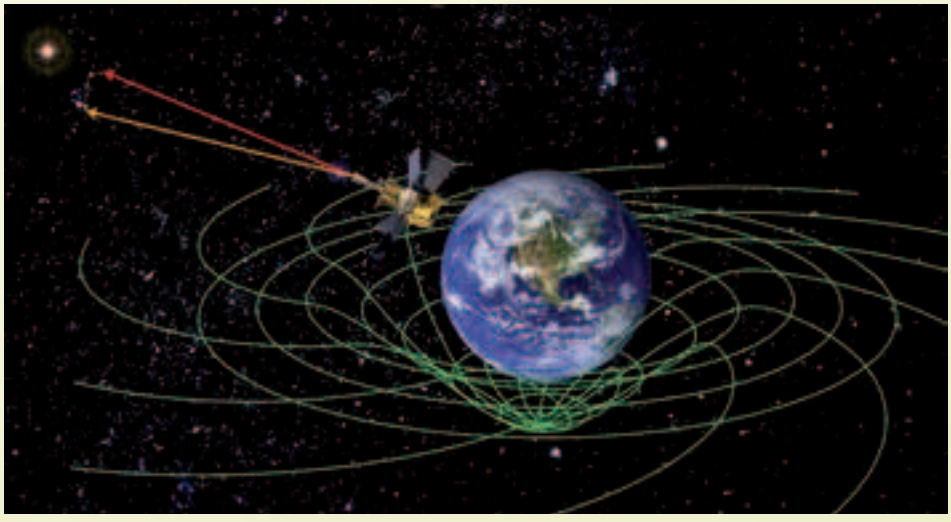
Satellite experiment vindicates Einstein's theory

Gravity is the most fundamental force in nature; it affects all of us all the time. But, gravity is still among the least understood natural phenomena; we still do not completely understand it. When Albert Einstein came out with his general theory of relativity in 1916 it forever changed our notions of space and time, and it gave us a new way to think about gravity. Einstein described gravity as a disturbance in the curvature of space and time. Space and time, according to Einstein are woven together, forming a four-dimensional fabric called 'space-time.' The mass of Earth dimples this fabric, "much like a heavy person sitting in the middle of a trampoline."

In his general theory of relativity Einstein had predicted two extraordinary effects – the 'geodetic effect' and the 'frame-dragging effect'. Geodetic effect is the bending or distortion the local space-time near Earth caused by the planet's mass. Frame dragging can be defined simply as the bending out of shape of space and time near a rotating body with a large mass due to the dragging of space-time around them, much as turning a heavy bowl twists a table cloth beneath it. However, detecting the geodetic effect and frame dragging is a tremendously complex task because their magnitude is extremely small – as small as only a few parts per trillion (10^9), which means that scientists needed to either analyse a very massive object – a gas giant, a star or a black hole – or build a very accurate satellite. Both these effects have recently been detected by a unique satellite-based experiment called Gravity Probe B. The findings were announced by Stanford University physicist Francis Everitt, principal investigator of the Gravity Probe B mission, at a press conference at NASA headquarters on 4 May 2011.

Gravity Probe B (GP-B) was a satellite-based mission launched by NASA in 2004 to measure the two key predictions of Einstein's general theory of relativity by monitoring the orientations of ultra-sensitive gyroscopes relative to a distant guide star. GP-B used four spherical gyroscopes and a telescope, housed in a satellite orbiting 642 km above the Earth's surface, to measure in a new way, and with unprecedented accuracy, the geodetic effect and the frame-dragging effect. The GP-B team arrived at the final experimental results for this landmark test of Einstein's 1916 predictions after 31 years of research and development, 10 years of flight preparation, a 1.5-year flight mission, and five years of data analysis.

The principle of working of GP-B is quite simple. When a spinning gyroscope is put into orbit around the Earth, with the spin axis pointed toward some distant star as a fixed reference point, the gyroscope's axis should continue pointing at the star forever in absence of external forces. But if space is twisted, as predicted by Einstein's theory, then the direction of the gyroscope's axis should drift over time. GP-B measured the twists of space-time by noting this change in direction relative to the reference star.



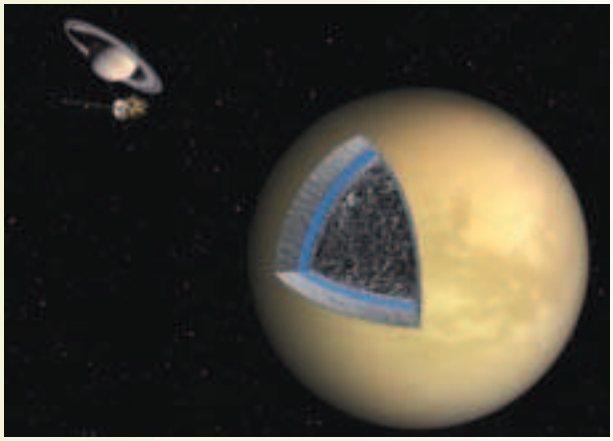
An artist's concept of Gravity Probe-B measuring the curved space-time around Earth. [Credit: NASA]

GP-B is actually the second NASA physics experiment to test aspects of general relativity. The first, Gravity Probe A, launched in 1976, compared elapsed time in three identical hydrogen maser clocks – two on the ground and the third travelling for two hours in a rocket, and confirmed the Einstein red-shift prediction to 1.4 parts in 10^4.

Titan may have a subsurface water ocean

Saturn's largest moon Titan, which is larger than planet Mercury, has sprung yet another surprise. In 2005 when the space probe *Huygens* landed on Titan, it found rivers and lakes filled with liquid methane and a hydrologic cycle based on methane – the only world besides Earth known to have liquid on its surface. The latest is the discovery of a liquid-water ocean beneath Titan's surface. The discovery was made by a team of researchers led by planetary scientist Rose-Marie Baland at the Royal Observatory of Belgium using data sent back by the *Cassini* spacecraft, which has been observing Titan from orbit.

The researchers used imaging data collected by *Cassini*'s Synthetic Aperture Radar during 19 separate passes over Titan between October 2005 and May 2007. The radar can see through Titan's dense, methane-rich atmospheric haze, detailing never-before-seen surface features and establishing their locations on the moon's surface. Using data from the radar's early observations, the scientists and radar engineers established the locations of 50 unique landmarks on Titan's



An artist's illustration showing the likely interior structure of Saturn's moon Titan. In addition to the hazy surface of Titan (yellow), the layers in the cutaway show an ice layer starting near the surface (light gray), an internal ocean (blue), another layer of ice (light gray) and the mix of rock and ice in the interior (dark gray). In the background are the Cassini spacecraft and Saturn, not to scale. [Credit: NASA/JPL]

surface. They then searched for these same lakes, canyons and mountains in the reams of data returned by *Cassini* in its later flybys of Titan. They found prominent surface features had shifted from their expected positions by up to 30 km, which meant that the crust was moving and suggested that it rested on liquid, probably water. Further, analysis of the data about Titan's rotation and orbit revealed an unusual rotational inertia; that is, its resistance to changes in its motion, also known as moment of inertia or angular mass. It was discovered that Titan does not move like a uniformly solid body of its previously assumed density and mass. Rather, its motion – both around its own axis and in its orbit around Saturn – are more in line with an object that is not uniformly solid.

Titan has an orbit very similar to our Moon's; for instance, it always presents the same face toward its planet. However, Titan's axis of rotation is tilted by about 0.3 degrees. This tilt, according to the researchers, is rather high, given the estimate of Titan's moment of inertia, or its resistance to changes to its rotation. But this apparent anomaly could be explained by assuming that Titan is a solid body that is denser near the surface than at its centre, which would, however, be contrary to what is known about the structure of all planets and their moons. Another more likely explanation is that Titan is not solid all the way through, but has an icy shell overlying a liquid-water ocean, an icy mantle and an icy, rocky core.

On the basis of the observations the researchers have proposed a new model for Titan, which assumes the presence of a liquid-water ocean beneath an ice shell. The researchers were able to determine the temperature and consistency of Titan's slushy innards by measuring the gravitational tugs registered by *Cassini* as it flew by the cloudy Saturnian moon. According to the researchers, the new model gives a closer agreement between the moment of inertia and the rotation of the moon, strengthening the possibility that Titan has a subsurface water ocean (*Astronomy & Astrophysics*, 14 April 2011, DOI:0.1051/0004-6361/201116578).

However, according to the researchers, it is still not known how far below the surface, how deep, and exactly what kind of liquid is present, although water satisfies the density data. The research team's models can give a wide range of thicknesses for the liquid ocean, anywhere from five to 425 km, as well as for the icy shell, anywhere from 150 to 200 km.

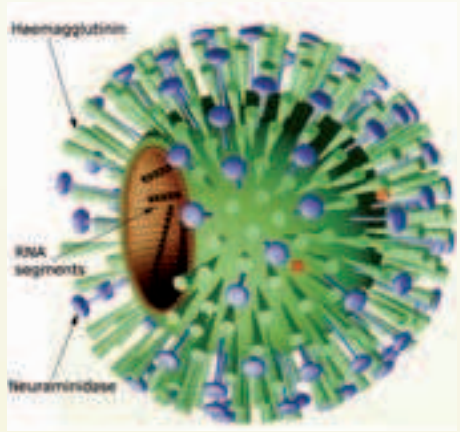
In order for this model to be proved unambiguously many more calculations need to be done and more data reviewed. And more possibilities considered, too. At the same time, Titan may be newest name in the short list of moons believed to possess subsurface oceans, alongside Jupiter's Europa and Ganymede and sister Saturnian moon Enceladus.

Anti-flu drugs designed on a computer

Haemagglutinin refers to a substance that causes red blood cells to agglutinate or clump together. Influenza haemagglutinin is a type of hemagglutinin found on the surface of the influenza viruses and is responsible for binding the virus to the cell that is being infected. Recently a team of American computational biologists (Sarel J. Fleishman, *et al.*) designed and produced two novel proteins that strongly bind to influenza haemaglutinin that enables the virus to enter cells and inactivate it, thereby preventing infection. Built with the help of more than 200,000 personal computers around the world, the new proteins may one day serve as effective therapies against flu and other viral diseases (*Science*, 13 May 2011).

Protein-protein interactions are critical for many biological processes, and over the past several decades, this importance has prompted researchers to investigate the physical and chemical bases of protein binding. The recent work demonstrates the success achieved so far in understanding and being able to predict protein-protein interactions, and even designing proteins that bind to a pre-selected surface on a specific virus. The primary novelty of this work is the use of computational methods to generate the high-affinity binders. Common existing approaches involve using animal immune systems to generate antibodies, or screening large 'libraries' of candidate proteins.

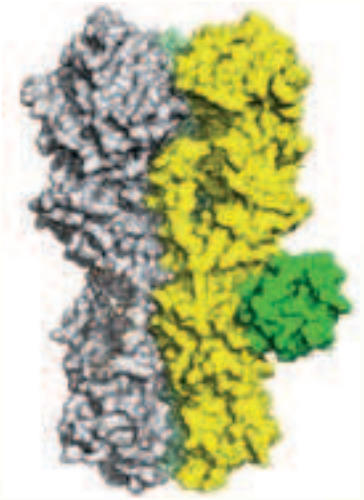
Under the microscope, influenza or 'flu' viruses look like spherical pincushions. The 'pins' consist of two proteins:



The structure of the influenza virus showing the haemagglutinin and neuraminidase units.

haemagglutinin, which allows the virus to stick to a host cell; and neuraminidase, which allows it to eventually escape. The different versions of these proteins give flu viruses their names. For example, a virus with a haemagglutinin from group 1 and a neuraminidase from group 1 would be called H1N1 – the same type that caused a pandemic in 2009.

The two proteins are the key to the virus's ability to infect, and if they could be somehow made ineffective it is possible to cripple the virus. Then it will no more be able to infect or spread. But these proteins, like any other, have complex three-dimensional shapes that allow them to interact with their targets. To deactivate them, designer



Model of haemagglutinin stem (grey and yellow) with bound designer protein (green). [Credit: David Baker]

molecules would be required that perfectly fit into their active sites, like sticking gum in a lock. To design the protein molecules Fleishman and his team relied upon state-of-the-art software that took around 20 international groups of scientists to create. It took over 100,000 hours of parallel computing time.

In the end they came up with 73 designs, which they brought to life using yeast. They engineered yeast to manufacture the designer proteins and shunt them to their surface, where they could be easily tested against flu haemagglutinin. In this way, the team could test their designs quickly without having to actually purify the proteins.

In the tests, only two of the 73 designs stuck to flu haemagglutinin. One of them fit in a way that almost exactly matched the predictions of the team's software. By making slight changes in the amino acids in their designer proteins, Fleishman and his team managed to improve the fit even further. This proved the principle – virtual protein design can work. In the present case, although the model still needs improvement, the significant point is that it was able to successfully predict an interaction between two proteins.

The two proteins were designed to stick to version of haemagglutinin carried by the 1918 H1N1 flu, the one that killed millions of people around the world. However, the designer proteins also target a part of haemagglutinin – the 'stem' – which is unusually stable. It does not change a lot over time, and it looks very similar from strain to strain.

Human gut bacteria fall into three groups

Although it has been known for hundreds of years that the humans gut is teeming with bacteria, it is only recently that new technologies have allowed researchers to begin to understand the size and complexity of the ecosystem living within the human body. It is known that no two people have quite the same collection of bacteria, but a recent finding is revealing. Just as there are a few major blood types that divide up the entire human population, so too, a study has found, there are just three types of gut-microbe populations found in human beings. The types are not related to age, gender, nationality or diet.

Previous studies have shown that although individuals may have their own unique mix of intestinal microbes, once people reach adulthood, their microbiomes become remarkably stable. (A microbiome is the totality of microbes, their genetic elements, and environmental interactions in a defined environment.) Even after disruptions in the bacterial populations caused by therapy with antibiotics, the microbiomes rebound to their old selves, with members in the same proportions as before. Now, a consortium of researchers from Europe and Japan has found that there are other constraints too. The researchers (Arumugam, M. *et al.*) examined the DNA profiles of bacteria in faecal samples taken from 39 individuals belonging to six different nationalities. Each had a diverse group of microbes, but closer analysis revealed that the bacteria fall into three major types of communities (*Nature*, 20 April 2011, doi:10.1038/nature09944). Although the number of samples in the published paper is small, according to the researchers, results from more than 400 samples are now available and that the clustering is still evident.

Each of the newly identified microbial mixes – called enterotypes – is named for the dominant type of bacteria in the group. People with the Bacteroides enterotype have an abundance of Bacteroides bacteria (a genus of Gram-negative, bacillus bacteria) and several associated types of bacteria. Bacteroides are known to be good at breaking down carbohydrates, so it is possible that people of this type might, for example, struggle more with obesity. Likewise, people with the Prevotella (a bacteria species that causes a wide range of infections of the

There are between 300 and 1,000 different kinds of bacteria (inset) that live in the human gut.

respiratory tract, dental infections, and urinary tract infections) and Ruminococcus (anaerobic, gram-positive gut bacteria) enterotypes have more of those bacteria. Prevotella tend to degrade slimy mucus in the gut, which could conceivably increase gut pain. And some Ruminococcus help cells to absorb sugars, which might contribute to weight gain. The Ruminococcus type was the most common of the three.

The researchers did not find any correlation between a person's enterotype and the person's body weight, nationality, geographic location or diet. Although the species mix was not linked to any particular human trait, certain groups of genes or biochemical functions carried out by the bacteria did match up with traits.

One possible explanation, which the team is testing, is that a person's gut-microbe make-up is determined by his or her blood type. Alternatively, it may also be determined by metabolism: there are three major chemical pathways by which people get rid of excess hydrogen gas created during food fermentation in the colon, and the gut enterotype might be linked to those. It may also be that the first microbes a baby is exposed to as his or her immune system is developing determines the type.

According to the researchers, a person's gut type might help to determine whether people can eat all they like and stay slim, whether they will experience more gut pain than others when sick, and how well they can metabolise a certain drug. They further added that their findings may have major implications for detecting and predicting risks of disease such as intestinal cancer, diabetes, and Crohn's disease (a form of inflammatory bowel disease).

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:

"'In view of the recent announcement by the WHO about the risks from radiation, should we stop using mobile phones?"

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* July 2011" should be clearly written on the envelope.

Vigyan Prasar
A-50, Institutional Area, Sector-62, Noida 201 307 (U.P.)
Phone: 91-120-240 4430/35 Fax: 91-120-240 4437
Email: info@vigyanprasar.gov.in Website: www.vigyanprasar.gov.in

Winners of "Your Opinion" contest for April 2011

Topic: "After the recent earthquake and tsunami in Japan that caused serious damage to three nuclear power plants, do you consider nuclear energy a safe option for generating electricity to counter global warming?"

Jyoti Bhatia
8, Pradeep Kumar CHS,
Second floor, Near Paradise Theatre,
Gabriel Road,Mahim, Mumbai-400016

Nuclear power produces around 11% of the world's energy needs. Huge amounts of energy can be generated from small amounts of fuel, without the emission of greenhouse gases, as happens from burning fossil fuels. Nuclear power is reliable, but a lot of money has to be spent on safety; if anything goes wrong, a nuclear accident can be a major disaster. People are increasingly concerned about this. In the 1990's nuclear power was the fastest-growing source of energy in much of the world. In 2005 it was the second slowest-growing. The main environmental concerns for nuclear power are radioactive wastes such as uranium mill tailings, spent (used) reactor fuel, and other radioactive wastes. Although not much waste is produced, whatever is produced is extremely dangerous, being highly radioactive. These materials can remain radioactive and dangerous to human health for thousands of years. They must be sealed up and buried for many thousands of years to allow the radioactivity to die away. For all that time they must be kept safe from earthquakes, flooding, terrorists and everything else. With the rise of nuclear electrification, the volume of spent fuel and other wastes has risen substantially. Currently, scientists are working hard to make fusion reactors which have the potential of providing more energy with fewer disadvantages than fission reactors.

*****

Varenya, XC
Kendriya Vidyalaya
C/o Rajesh Kr., Shiv-Niwas
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Presently, one can say that nuclear energy is not safe for human civilisation for generating electricity. Nuclear radiation has very harmful effects on humans. Its somatic effects result in damage of body cells and causes cancer. Its genetic effects cause damage to germ cells, which is carried to later generation. Most of the nuclear waste generated in nuclear power stations cannot be destroyed. So, these wastes continue to emit radiations and remain dangerous for thousands of years. Therefore, in my view, nuclear energy is not a safe option for generating electricity.

*****

A.S. Lokesh, Student VIII Std,
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Chennai-600114.

Nuclear energy is considered a safe option for generating electricity to counter global warning. With the limited availability of fossil fuels, we cannot altogether ban nuclear plants in the light of Japan's earthquake and tsunami experience. However, we have to learn how to use nuclear plants safely. The nuclear plants should not be located in geographical locations which are prone to earthquake like in Japan. Further, to safeguard these plants from the attack of tsunami, the plants should not be located near sea shore. Also, it is high time to accelerate the development of nuclear fusion technology. At present the technology is still in laboratory experimental stage in Institute for Plasma Research, Gandhinagar, Gujarat. Unlike nuclear fission technology, which is associated with radiation hazard, the nuclear fusion technology is free from any radiation hazard. After fully developing nuclear fusion technology we can consider to ban nuclear fission technology.

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State level workshop on Innovative Experiments in Physics

Vigyan Prasar and Tripura State Council for Science and Technology (TSCST) jointly organised a state level workshop at Agartala during 18–21 April 2011. Sixty physics teachers and science communicators from Tripura participated in the workshop. The participants of the workshop were selected from registered school science clubs affiliated to TSCST and was limited to a maximum three from each subdivision.

Inauguration Function (from left):Shri Sahadeb Das, Shri Sriram Taranikanti, Dr. Samar Bagchi, Shri Rintu Nath, Shri Joygobinda Debroy, Dr. B. N. Das

Demonstration of Innovative experiments in Physics

The workshop was inaugurated by Shri Joy Gobinda Deb Roy, Hon'ble Minister of Science and Technology and Environment, Govt. of Tripura. Shri Sriram Taranikanti, Commissioner and Secretary, Department of Science and Technology and Environment, Govt. of Tripura was the Chief Guest. Other dignitaries present during the inaugural function were Shri Sahadeb Das, Director, Department of School Education, Govt. of Tripura; Professor Mihir Deb, Chairman, Tripura Pollution Control Board; and Shri M. L. Roy, Member Deputy Secretary, TSCST. Shri Rintu Nath, Scientist - E, represented Vigyan Prasar. Shri Ayan Kr Saha, Demonstrator, TSCST, coordinated the event.

In his inaugural address Shri Joy Gobinda Deb Roy said that it was a good opportunity for the participants to learn innovative methods of science teaching and implement the same in respective schools and science clubs. Shri Sriram Taranikanti, in his address, said that CDs and printed materials developed by Vigyan Prasar based on innovative activities/experiments may be translated into Bengali by Tripura State Council for S&T and distributed in schools of Tripura.

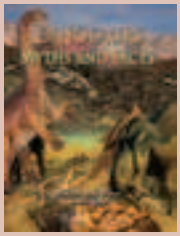
Participants of the workshop

Dr. Samar Bagchi, Dr. B. N. Das and Shri Rintu Nath conducted the workshop and demonstrated 120 innovative activities/experiments during the four–day workshop. After each session participants interacted with the resource persons, shared their opinion and performed the activity shown by the resource persons. All the participants agreed to volunteer in performing similar activities in their localities/schools to make science learning easy and interesting. A resource group will be formed by Tripura State Council for Science and Technology and activity reports will be sent to Vigyan Prasar on a regular basis.

Many of the participants demonstrated innovativeactivitiesdeveloped by them. Participants were of the opinion that hands-on activities/experiments help in understanding the concepts better and make the subject interesting. All the participants were given a certificate of participation.

Demonstration by one of the participants

Vigyan Prasar Publications



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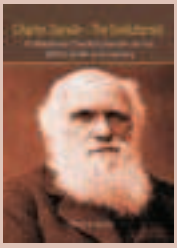

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