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The Calculus Affair

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

India at Large Hadron Collider (LHC)

Dr. Subodh Mahanti

The Standard Model is widely accepted modern theory of elementary particles and their interactions. This model classifies the elementary particles into three broad groups—leptons or the light particles (such as electron), hadrons or the heavier particle (such as protons and neutrons, that are formed from quarks) and bosons, the carriers of fundamental forces. Leptons and hadrons interact by exchanging bosons, each of which is responsible for a different fundamental force. Photons mediate the electromagnetic force, which affect all charged particles. Gluons mediate the strong nuclear force, which affects quarks. The weakons (intermediate vector bosons) mediate the weak nuclear force, responsible for the reactions that fuel the Sun and for the emission of beta particles from certain nuclei. The Standard Model stipulates that all particles acquire mass through their interaction with Higgs boson (popularly referred to as God Particle). The Standard Model takes into account 18 particles—six quarks (up, down, charm, top, strange, and bottom), six leptons (electron, electron neutrino, muon, muon neutrino, tau and tau neutrino) and six mediator bosons (gluon, photon, W^+, W^-, Z^0 and Higgs). The search for Higgs boson proved to be more difficult. The main objective of the Large Hadron Collider (LHC) also called the Big Bang Experiment is to prove or disprove the existence of Higgs boson. The LHC is a multi-billion Euro research facility created by CERN (Counseil European pour la Recherche Nucleaire but later renamed as Organisation Europeenne pour la Recherche Nucleaire). In English it is called European Organisation for Nuclear Research. The total estimated cost of LHC is about 4.5 billion euro (the currency of the European Union) and its annual operating budget is about 800 million euro.

The recent announcement that LHC had finally caught a glimpse of the elusive Higgs boson created world-wide excitement. The very name of the particle (Higgs boson) connects the name of one of India's best known physicists Satyendra Nath Bose. The fundamental particles in the universe are divided into two groups—fermions (named after the Italian physicist Enrico Fermi) and bosons. The pursuit at LHC will not end at finding the answer whether the Standard Model is correct (if Higgs boson exists) or not (if Higgs boson does not exist). It will continue to delve into some other fundamental issues in particle physics like supersymmetric particles, detailed structure of the top quark, and heavy gauge bosons. It will also search for a new phase of strongly interacting matter at extremely high energy densities called the Quark Gluon Plasma (QGP) and also look for the constituents or the conditions which create dark matter in the universe.

India's participation in the Mega Science Pursuit that is LHC is very significant. Scientists from India have taken part in building the LHC machine and two of the four experiment set-ups or detectors viz., CMS (Compact Muon Selenoid) Detector and ALICE (A Large Ion Collider Experiment). It is the CMS Experiment which led to the discovery of the highly elusive Higgs boson. ALICE has been built to search for QGP. India has also contributed significantly in the development of the Worldwide LHC Computing Grid (WLCG).

India's collaboration with CERN began in the 1960s in the form of scientist-to-scientist and institutional collaboration. The first recognition of India's involvement with the LHC came up in 1980s when scientists from the Tata Institute of Fundamental Research (TIFR), Mumbai made significant contribution to the development of L3 detector. In 1991, the Department of Atomic Energy (DAE), Government of India and CERN signed an agreement of cooperation for a period of 10 years. Under this agreement the Raja Ramanna Centre for Advanced Technology, Indore, successfully supplied a few subsystems for the upgradation of Large Electron Positron collider (LEP)-200 project. This agreement made it possible for high energy physicists working in different DAE institutions and universities (supported by the DST as part of the agreement signed between DST and DAE) to take part in research in particle physics being carried out at CERN and to make important contributions in a frontier area of research. In March 1996, India joined the newly launched LHC project. This was made possible by a protocol signed between DAE and CERN. India agreed to provide in-kind contributions in terms of ideas, hardware and skilled manpower. Realising the significance of India's contribution, the CERN Governing Council accorded India the Observer Status. Soon India will become an Associate Member of the CERN,which will take India's collaboration to a new height. India has arrived at global mega science scene through its participation at LHC. India is also participating in the FAIR project in Germany, and TMT project in USA. Several other international consortia have approached India for participation.

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Editor : Subodh Mahanti
Associate editor : Rintu Nath
Production : Manish Mohan Gore and Pradeep Kumar
Distribution : Harish Goyal
Expert members : Biman Basu and Devendra Mewari
Address for correspondence : Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi-110 016
Tel : 011-26967532; Fax : 0120-2404437
e-mail : info@vigyanprasar.gov.in
website : http://www.vigyanprasar.gov.in

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The Calculus affair

Rintu Nath
E-mail: rnath@vigyanprasar.gov.in

It was a lazy Sunday morning in the study room. I just finished my homework. Uncle was still engrossed with his morning newspaper. I did not wish to disturb him. So I turned to the sports page of the newspaper. The London Olympic was the big news. Reports covered success stories of Olympians Vijay Kumar, Sushil Kumar, Yogeshwar Dutt, Gagan Narang, MC Mary Kom, Saina Nehwal and Paralympian Girisha Nagarajegowda – it was indeed very proud moments for every Indian.

"What's the link between the numbers: 10^0, 9.58, 9.63 and 10^2?" uncle asked without looking away from the newspaper. The question was certainly directed towards me.

I was slightly perplexed. 'They are all rational numbers,' I tried to reason.

"A letter or word clue now: I, WR, OR, and C," uncle could perceive my hesitation.

"Roman numerals I is for 1 or 10^0, C is for 100 or 10^2. Now, WR and OR... wait a second...World Record and Olympic Record...Usain Bolt." I almost screamed.

"Fantastic. Yes, the Jamaican sprinter Usain Bolt is the fastest man on the earth holding the 100 metre World Record (9.58s) and Olympic Record (9.63s)." My uncle put the rejoinder.

"And he is also the first man in the history to achieve 'double double' by winning both the 100 metre and 200 metre Olympic sprint titles in successive two Olympics - in Beijing and London," I added.

"That's right. Don't forget that behind these achievements, there are hundreds of hours of discipline, dedication, devotion and determination. Put yourself in a situation when hours of preparations must be executed in less than 10 seconds. That's a real inspiration for everyone!" Uncle said.

"And someone is repeating the same feat two times in a row – that's unbelievable!"

"You are quite right Googol."

"At least the mathematicians are in a better job – they can always repeat their performance with perfection, can't they?" I joked.

"That's fair to say, Googol. But it might not be always true. Well, here is riddle for you. When does a mathematician say: mathematics is painful?"

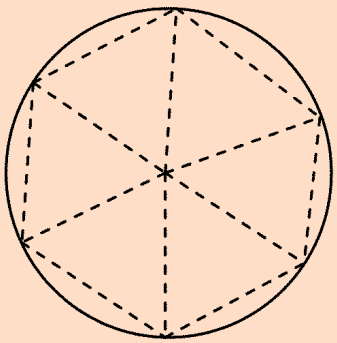
"Mathematicians feel mathematics is painful!" I was surprised.

"The answer is: Calculus," uncle quipped seeing my puzzled face.

"I know calculus is a branch of mathematics, but I did not get why a mathematician feels calculus is painful," I was still baffled.

"My dear Googol, you did not get the pun. Etymologically, the word 'calculus' originated from the Greek word 'kalyx' meaning the pebble or small stone. The original meaning of this word is still retained in the medical science where it means a stone, or concretion, formed in the gallbladder, kidneys, or other parts of the body."

"I got it now. If a mathematician gets a calculus in the gallbladder, it is indeed painful to him or her. But how did the term get into to the vocabulary of mathematics?" I asked.



The area of a circle is approximately equal to the sum of the areas of all the triangles. If more triangles are constructed to fit in the circle, result will be more accurate. This is the method of exhaustion and it is similar to integral calculus

"It is said that about 15 BC, the Roman architect and engineer Vitruvius mounted a large wheel of known circumference in a small frame. When it was pushed along the ground by hand, it automatically dropped a pebble into a container at each revolution, giving a measure of the distance travelled. It was, in effect, the first odometer. So the calculus or pebble was used as a tool for counting process, which was the origin for the word 'calculate' in mathematics. This term was also picked up by mathematician later to describe a special branch of mathematics: Calculus."

"I have heard about calculus, but I don't know anything about this. Uncle, please tell me more about calculus."

"Calculus is a mathematical technique, mainly developed in the seventeenth century. It is a very powerful technique that has profound impact on mathematics."

"Who developed the concepts and methodologies of calculus?" I asked.

Gottfried Leibniz (1646-1716)

"The German mathematician Gottfried Wilhelm Leibniz and the English physicist Sir Isaac Newton independently developed calculus. However, an idea similar to calculus was conceptualised much earlier." Uncle replied.

Isaac Newton 1642 - 1727

"Please tell me how calculus was conceptualised," I was eager to know.

"During the third century BC, the Greek mathematician Archimedes used the method of exhaustion while trying to measure the area of a circle. He approximated a circle using many triangles and calculated the approximate area of a circle. This method is similar to what is known as integral calculus now."

"What happened after that?"

"In the 14th Century, the Indian mathematician Madhava of Sangamagrama and the Kerala School of Astronomy and Mathematics stated many rules on infinite series and approximations. These are considered to be similar to many components of calculus."

"This is great! India has a long tradition

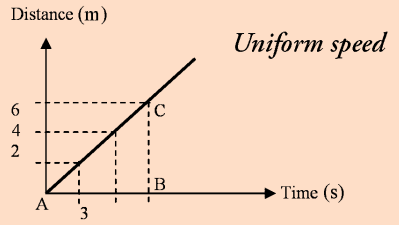
of mathematics. You told me that zero was first conceptualised in India. Ramanujan is one of the greatest mathematicians of the world and he contributed extensively in developing different branches of mathematics. It is no wonder that India also contributed to the development of the concept of calculus as well."

"You are right," uncle replied.

"I want to know more about calculus, please explain it to me."

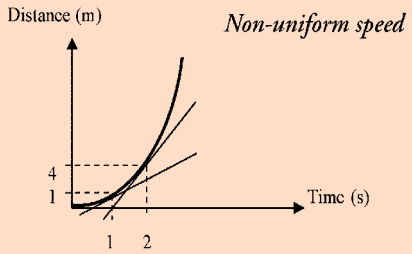
"To put it in simple words, calculus is a mathematical technique which aids in solving two very practical types of problems. First, the varying rate of change, and secondly, measuring the area of irregular shape or volume of irregular three dimensional objects." Uncle said.

"What is the varying rate of change?" I was eagerly waiting for a breeze of mathematical ideas from my mathematician uncle.



Speed = $\frac{Distance}{Time} = \frac{2}{1} = \frac{4}{2} = \frac{6}{3} = 2$ metre/second

As ratio of distance to time is same at all time, the graph represents uniform speed.



Speed is different at different time. This is non-uniform speed.

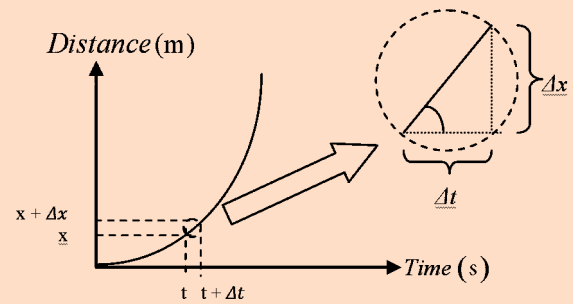
Speed at any instance, say, at t = 2 sec, can be found by differentiation

"Consider a car is moving at uniform speed. After one second it travels a distance of 2 metres, and after 2 seconds it travels a distance of 4 metres and so on. Now plot all points for each pair of observation (time and distance) on a graph taking the time in the x-axis and the distance travelled in the y-axis. Join all these points and you will get a straight line that graphically represents the distance travelled with respect to time. This straight line will make an angle with x–axis (time) (let's say, it is theta, θ). Tangent of this angle is called slope (shortened as *tan*θ). The slope represents the speed in a time-distance graph. However, if the car is accelerating then you will not get a straight line. Consider another case where the car travels 1 metre in 1 second, 4 metres in 2 seconds, 9 metres in 3 seconds and so on. If you plot all those paired observations (time and distance) on a graph now, you will get a curve. Tell me, how you will calculate the speed from this curve?" uncle asked.

"You said that the speed is changing – then how can I calculate the speed?"

"Good observation. As the speed is changing every moment, you have to calculate the speed at a given instance, say, the speed at t = 2 second – this is called the instantaneous speed. Differential calculus helps in calculating such type of problems,"

"But how do I calculate the instantaneous speed?" I wanted to know.



At time t, let the distance travelled be x

After t, let in a very small time interval Δt, the car travels Δx distance. Δt is very small, hence the part of the curve is almost a straight line, as shown inside the dotted circle.

Hence, the speed at time t can be written as: $\frac{\Delta x}{\Delta t}$

This speed is the instantaneous speed (v) at time t and is represented as $\frac{dx}{dt}$, i.e. $v = \frac{dx}{dt}$

"Say, you want to calculate the speed of the car at t = 2 second. To do that, measure the distance travelled by the car in a very short time interval Δt, after 2 seconds. Let the distance travelled in time Δt be Δx. Now, the instantaneous speed is represented as: $\frac{\Delta x}{\Delta t}$. This is the basis of differential calculus."

"But uncle, how small is the time interval Δt?"

"It's a very good question. The Δt is smaller than the smallest time interval you can imagine or think of. In mathematical parlance, this is called *infinitesimally small*."

"Why do we need to take such a small time interval?" I wanted to know.

"A very small time interval Δt signifies that the change in speed during that interval will be insignificant, but it would travel a distance Δx. Hence the ratio of change in distance (Δx) to change in time (Δt) will be same at time t as well as at ($t + \Delta t$)."

"How can we measure such a small time interval and the distance travelled in that small time interval?"

"Differential calculus will help you in solving that. Let me explain. The distance travelled by a car can be represented as a function of time t, i.e. $x = f(t)$. For example, if the car is covering 1 metre in 1 second, 4 metres in 2 seconds, 9 metres in 3 seconds and so on, then this function f(t) is t^2, i.e. $x = t^2$. If you now want to calculate speed at any instance, you can differentiate this function with respect to time t."

"Are there any rules for differentiation?" I wanted to know.

"Yes. There is a set of rules to calculate the derivative of a given function," uncle replied.

"I understood now. The derivative can be used to calculate the varying rate of change, for example, the non-uniform speed, which is the varying rate of change of distance with respect to time,' I commented.

"The derivative is useful to calculate the rate of change of any physical variable such as area, volume, pressure, force and so on. For example, using the derivative, one can calculate what will be the water pressure at certain depth of a dam having non-uniform cross-section."

"Uncle, you have mentioned two uses of calculus. You have explained the first one, i.e., how we can calculate the varying rate of change using the derivative. Please elaborate

on the second use, i.e. how calculus helps us in calculating the area of an irregular shape or the volume of an irregular object."

"Calculation of area of any irregular shapes or volume of three-dimensional objects can be done by integration. Integral calculus is also called anti-derivative. In integral calculus, the term 'integral' is used to denote the summation of values. This is represented by an elongated 'S' symbol ∫".

"That means differential and integral calculus are conceptually opposite to each other," I said.

"Well, you may say that. However, both are related. Integration deals with the summing up or the total of a variable. Referring back to our example on speed, we may be interested to know what is the total distance travelled by a car (with a variable speed) in a given time. This is possible to calculate only when you know the rate of change of speed at every instant. Please note that if the car has uniform speed, then you don't need calculus to find the distance travelled during a given interval."

"That's very interesting, please elaborate."

"Consider a car has uniform speed 10 m/s. Find out the distance travelled by it in an interval, say between the 2nd second and the 7th second"

"It's very easy – it is 10 × (7 – 2) = 50 metres," I replied.

"That's right. This signifies that in *speed-time* graph, the area under the graph (length × breadth = $v \times t$) will be the distance travelled by the car. Now, consider another car is having non-uniform speed. Consider speed is 1 metre/second when time is 1 sec; 4 metre/second when time is 2 sec; and 9 metre/second when time is 3 sec. In this case, the speed is represented by the function, $v = t^2$, v representing speed and t representing time. Can you now calculate the distance travelled between 2 second and 7 second?" Uncle wanted to know.

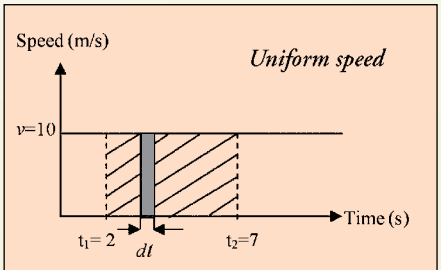
"Uncle, in the previous example you said that the distance is a function of time and it may be represented by $x = t^2$ for a particular case. Now you are saying that the speed is a function of time and it may be represented as $v = t^2$. I am a bit confused now."

"Consider these two examples are for two different cars having different rate of change of speed. In first case, distance travelled was proportional to the square of time ($x = t^2$). In that case, the speed was proportional to time, not square of time, and I have explained how differential calculus will help in calculating the instantaneous speed from the equation $x = t^2$. In the second case, the speed is proportional to the square of time and we have to calculate distance travelled in a given interval using integral calculus. Note that I used the unit 'metre' in the first example to indicate the distance, and 'metre per second' in the second example to specify the speed."

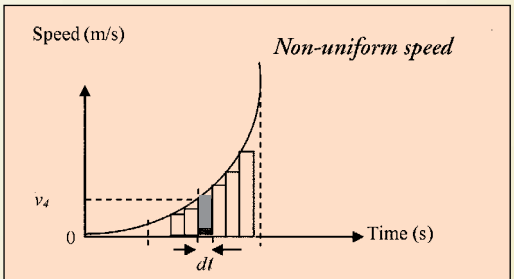
"I got it now. Let me give it a try. The speed of the car at $t = 2$ sec is 4 metre/second, and at $t = 7$ sec is 49 metre/second. Can I calculate the distance travelled in the interval of 5 sec by considering the average speed i.e. $\frac{4+49}{2} = 26.5$m/s?" I wanted to know.

"If you follow this strategy, it would be far from the actual distance travelled. Here the speed is changing at every moment, and therefore the distance travelled at every moment is different. Integration will help you in solving this kind of problem."

"Uncle, I am eager to know how to solve this problem."



Distance travelled = v × ($t_2 - t_1$)
= 10 × (7 – 5)
= 50 m
= Area under the graph



Distance travelled = Area under the graph
= Sum of areas of all infinitesimal rectangles
= $v_1 \times dt + v_2 \times dt + \ldots + v_n \times dt$
$= \sum_{k=1}^{n} v_k \times dt$

"You might have understood now that the area under the *speed-time* graph will give you the total distance travelled by the car. If the area is a simple geometric shape, like a rectangle, you can simply multiply length (speed) with breadth (time). In case of non-uniform speed, similar concept is used in an infinitesimal scale. The entire area may be filled with infinitesimal rectangles, breadth of each is dt. It (dt) is the smallest possible time interval during which the change in speed is negligible. The length of each of these infinitesimal rectangles is the speed at that moment. For example, at the time t_4, the speed is v_4. Now the distance travelled during dt interval will be $v_4 \times dt$. If such distances are calculated for the entire time interval, say $t_1 = 2$ second to $t_n = 7$ second, you have to simply add all those infinitesimal rectangles. So the area of n infinitesimal rectangles can be calculated as: $v_1 \times dt + v_2 \times dt + \ldots + v_n \times dt$. This is the method of integration. Mathematically, a shorthand of writing the full expression of this sum is given by: $\sum_{k=1}^{n} v_k \times dt$. The symbol $\sum$ signifies summation saying multiply each instance of v and dt and add all n such instances. This is also equivalent to symbol ∫ in integral calculus."

"It is amazing! That means without integration we can't calculate the area of irregular shapes."

"You are right. Extending the same concept, the volume of any irregular shape can be calculated by taking the infinitesimal volume and summing them all."

"I used to think that calculus is very difficult to understand. Now I realised that it is very interesting and easy to understand."

"Indeed it is. Not only that; using calculus we are able to solve all real problems. Perfect geometric shapes or uniform speed do not happen in the nature. Almost everything in the nature is having non-uniform characteristic – growth of plants or animals, speed of any objects etc. etc. If you want to design a bridge, you have to consider the non-uniform load and speed. The shape of the bridge will not be a simple geometric shape; its stress and strain will vary on the differential load pattern at different points on the bridge. Only calculus can help in solving such real life problems."

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The hunt for the Higgs Boson – II

Dr. Vinay B Kamble
E-mail: vinaybkamble@gmail.com

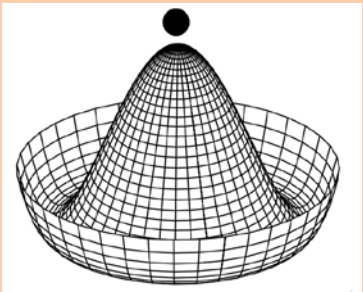
As discussed earlier, the electromagnetic force is carried by photons which have no mass, whereas the weak force is carried by particles called W and Z, which do have mass. Rather like people passing a ball, interacting particles exchange these force carriers. The heavier the ball, the shorter the distance it can be thrown; the heavier the force carrier, the shorter its range. The W and Z particles were discovered in a Nobel Prize-winning enterprise at CERN in the 1980s, but the mechanism that gives rise to their mass has not yet been experimentally identified, and that's where the Higgs particle comes in (See Figure 3). The Higgs mechanism in its basic form is the simplest theoretical model that could account for the mass difference between photons and the W and Z particles, and by extension could account for the masses of a range this mechanism is not the only possible explanation.

The experimental confirmation of the Higgs boson would place the last piece of jigsaw puzzle that Standard Model is into its designated slot. This explains why this *kolavery, kolavery di* (a Tamil pop song, *kolavery* meaning passion mixed with euphoria) when a candidate for the Standard Model Higgs boson was discovered in two independent experiments at LHC on 4 July. And yet, the Standard Model is not a complete theory since it does not include gravitation, nor does it explain entities like dark matter and several other aspects we come across in nature! What is more, there are theories like Supersymmetry (SUSY) that predicts not one but a family of bosons! We shall discuss more about it later.

Ever since the prediction of the Higgs boson and formulation of the Standard Model, physicists have been directing efforts to produce this particle in the laboratory. However, they had to wait until 1990s when high-energy accelerators became available, beginning with the Large Electron-Positron (LEP) Collider at CERN, Geneva; and in the first decade of the present century at next generation Tevatron Proton-Antiproton Collider at Fermilab in the United States. LEP accelerated electron and positron beams up to 100 GeV each and brought them to collide head-on. This implied collision energy of 200 GeV. Experiments at LEP ruled out the Higgs particle with a mass of less than 114.4 GeV. It was shut down in 2000, and then dismantled in order to make room for the construction of the Large Hadron Collider (LHC). Later, the search was taken up at Tevatron at Fermilab. Incidentally the name Tevatron refers to the energy of the protons and antiprotons which were accelerated to 1 trillion-electron-volts (TeV), or a collision energy of 2 TeV. Tevatron was shut down in 2011.

The LHC that went into operation in March 2010 is the most powerful accelerator in the world today. This gigantic scientific instrument is situated 100 metres underground near Geneva, where it spans the border between Switzerland and France. This is the largest and the most complex particle accelerator in the world installed in a tunnel of 27-km circumference, or a ring of about 4.3-km in radius. The particles are guided by thousands of cylindrical magnets supercooled to −271.3°C, close to absolute zero! It can accelerate two beams of sub-atomic charged particles called hadrons –

Spontaneous Symmetry Breaking



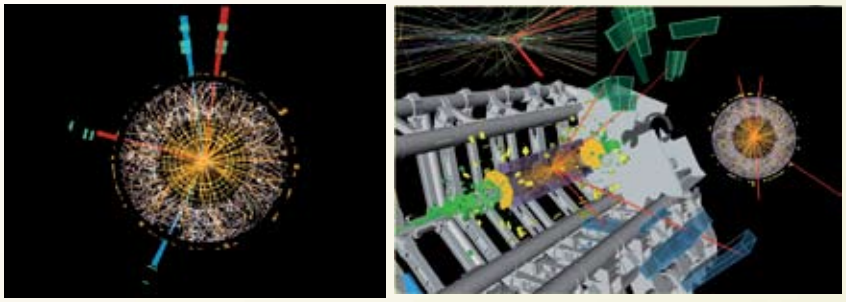
The secret of nature is symmetry, but much of the texture of the world is due to mechanisms of symmetry breaking. There are a variety of mechanisms wherein the symmetry of nature can be hidden or broken. A more profound way of breaking or hiding symmetry is the phenomenon of spontaneous symmetry breaking. Here, the laws of physics are symmetric but the state of the system is not. Associated with spontaneous symmetry breaking is the phenomenon of symmetry restoration. If one heats a system that possesses a broken symmetry it tends to be restored at high temperature. Thus a ferromagnetic material can be magnetized at low temperature (or even at room temperature) with all the little atomic magnets aligned in the same direction. This is a state of broken rotational symmetry. As the temperature increases the atoms vibrate more and more. Finally when the temperature is greater than a certain critical value the fluctuations win out over the forces that tend to align the atomic magnets and the average magnetization vanishes. Above the critical temperature the system exhibits rotational symmetry. Such a transition from a state of broken symmetry to one where the symmetry is restored is a phase transition. We believe that the same phenomenon occurs in the case of the symmetries of the fundamental forces of nature. Many of these are broken at low temperatures. Very early in the history of the universe, when the temperature was very high, all of these symmetries of nature were presumably restored. The resulting phase transitions, as the universe expanded and cooled, from symmetric states to those of broken symmetry have important cosmological implications. Another example is the electroweak interaction that can manifest itself into electromagnetic and weak components on spontaneous symmetry breaking. We could understand the phenomenon of spontaneous symmetry breaking through the example of a Mexican hat. The hat has a rotational symmetry, and it is respected as long as long as the ball sits on top. However, the moment ball falls the symmetry is spontaneously broken.

protons or heavy ions – in opposite directions around the tunnel at 99.99 per cent of the speed of light, picking up energy in each lap. It is here where LHC succeeded while Tevatron did not.

Some of the particles moving in opposite directions crash into each other at four intersection points at an energy never before reached in a particle accelerator. The maximum energy of the protons is 7 TeV (tera-electron-volt). This implies the corresponding energy of 14 TeV when they collide head-to-head! Incidentally, 1 TeV of energy is the energy an electron gains when it accelerates through a potential difference of 1 trillion volts. Further, when the two beams collide, they generate temperatures more than 100,000 times hotter than the heart of the Sun, concentrated within a minuscule space. As a result of the violent collisions, these particles would be transformed into packets of energy, which would in turn condense back into various intriguing types of particles – some of them never even seen before! Huge detectors and equipment spaced along the tunnel observe the spray from the collisions for analysis by scientists from all over the world. Incidentally, the largest, ATLAS (A Toroidal LHC Apparatus), has a detector which is seven stories tall. The heaviest, CMS (Compact Muon Solenoid), is heftier than the Eiffel Tower! These are the two experiments engaged in the search of the elusive Higgs boson at LHC. How much was the cost of LHC when it was built? Over 5 billion US dollars!

Surely, Higgs boson cannot be detected directly since its lifetime is very short, only about 10^{-22} seconds. It soon decays into other subatomic particles through various channels. For example, the Higgs could decay through the channels H → two photons; H → two tau leptons; H → WW; H → ZZ, and others. It is by observing these decays that the Higgs boson could be identified.

How do we pick out the "right" events for the decay of the Higgs? A Higgs signal would appear as an excess number of events over the large background. Indeed, this makes task of looking for a needle in a haystack much easier! The effort is directed towards identifying picking up such excess that is statistically significant. What do we mean my statistically significant? Statistical significance is measured in terms of what is called standard deviation (called sigma). The signal should be at least at "5 sigma level" over the background. This means that only one experiment in three million would see an apparent signal this strong in a universe without a Higgs. In other words, the probability of the background alone fluctuating by this amount or more is about one in three million. The scientists therefore need to look at a lot more collision events so that events producing the signal they are looking for stack up and give a statistically significant peak of excess events.

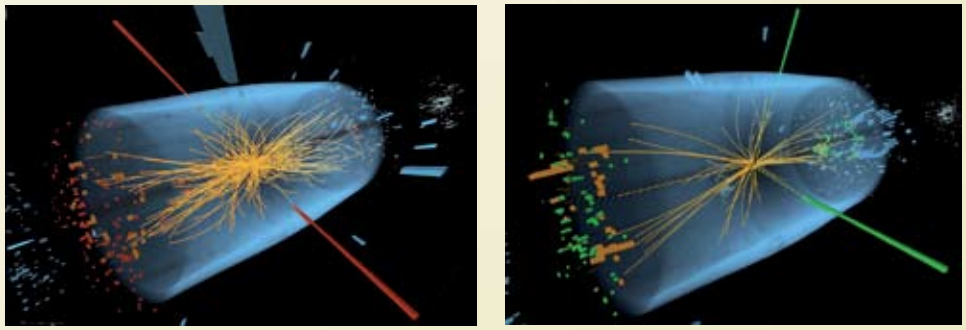


(A) (B)

(A) Candidate Higgs decay to four electrons recorded by ATLAS in 2012
(B) Candidate Higgs Decay to four muons recorded by ATLAS in 2012.
(Photo credit : http://www.atlas.ch)

ATLAS concentrated its efforts on two complementary channels: Higgs could decay into either two photons or to four leptons. Both of these channels have excellent mass resolution. However, the two-photon channel has a modest signal over a large but measured background, and the four-lepton channel has a smaller signal but a very low background. Both channels showed a statistically significant excess at about the same place: a mass of around 126 GeV. A statistical combination of these channels and others puts the significance of the signal at 5 sigma.

CMS studied five main Higgs boson decay channels. Three channels result in pairs of bosonic particles (γγ, ZZ or WW) and two channels result in pairs of fermionic particles (bb or ττ), where γ denotes a photon, Z and W denote the force carriers of the weak interaction, b denotes a bottom quark, and τ denotes a tau lepton. The γγ, ZZ and WW channels are equally sensitive in the search for a Higgs boson around 125 GeV and all are more sensitive than the bb and ττ channels. CMS observed an excess of events at a mass of approximately 125 GeV with a statistical significance of 5 sigma. The evidence is strongest in the two final states with the best mass resolution: first the two-photon final state and second the final state with two pairs of charged leptons (electrons or muons). It was interpreted as that due to the production of a previously



(A) (B)

(A) Event recorded with the CMS detector in 2012 at 8 TeV. The event shows characteristics expected from the decay of the Standard Model Higgs boson to a pair of photons (dashed yellow lines and green towers). The event could also be due to known standard model background processes.

(B) Event recorded with the CMS detector in 2012 at TeV. The event shows characteristics expected from the decay of the Standard Model Higgs boson to a pair of Z bosons, one of which subsequently decays to a pair of electrons (green lines and green towers) and the other Z decays to a pair of muons (red lines). The event could also be due to known standard model background processes.

(Photo credit : http://cms.web.cern.ch)

unobserved particle with a mass of around 125 GeV. Within the statistical and systematic uncertainties, results obtained in the various search channels are consistent with the expectations for the Standard Model Higgs boson.

On 4 July by Joe Incandela and Fabiola Gianotti, the spokespersons of CMS and ATLAS respectively, in their presentation, stated that both the experiments observed a "new particle" in the mass region around 125-126 GeV at 5-sigma level. Both the experiments, incidentally, have worked entirely *independently* of each other. Further, both the results are consistent with each other within the experimental errors. However, more data are needed to establish whether this new particle has all the properties of the Standard Model Higgs boson or whether some do not match, implying new physics beyond the Standard Model. Incidentally, Indian scientists played an important role in the CMS experiment.

Beyond the Standard Model

The Standard Model developed in 1960s and 1970s does not include answers to many basic questions such as how to unify electroweak forces with strong or gravitational forces. It cannot even explain mysteries of the universe, answers to which have their roots in the world of fundamental particles. At the time of the Big Bang, the universe had no dimensions at all. How did the universe, infinitely dense at the time of the Big Bang, evolve into a vast Universe full of stars and planets we live in today? As the early universe expanded, energy should have condensed into equal amounts of matter and antimatter, which would then annihilate each other on contact, reverting to pure energy. Thus, the universe should really be empty! But, there was more matter than antimatter and therefore we exist! Given the energy and the temperatures at which the LHC works, the experiments planned may help physicists understand why the universe grew with just enough more matter than antimatter.

How about dark matter? What is so 'dark' about it? Observations of the motion of distant galaxies indicates that they are subject to more gravity than their visible matter could possibly account for, implying existence of some exotic hidden matter in the mix. Where did this dark matter come from? In fact, out of the total matter and energy content in the universe, what we observe is just about 4 per cent matter in the form of stars and galaxies. What we do not observe is the 22 per cent of dark matter and remaining 74 per cent being "dark energy". Higgs mechanism hence may account for only the 4 per cent of the matter that we observe! How do we explain the dark matter and dark energy, then? A theory called Supersymmetry could possibly explain this. According to it, every fundamental particle had a much more massive counterpart in the early universe. Indeed, the electron might have had a massive partner that physicists refer to as the 'selectron'. Similarly, the muon might have had the 'smuon', and the quark might have had 'squark'. Many of those supersymmetric partners would be unstable. However, one kind of particles may have been just stable enough to survive till today without interacting with any other particles. Could they might be dark matter? By smashing particles like protons at energies and temperatures that existed at the earliest moments of the universe, the LHC could reveal the particles and forces that were responsible for everything that followed. Supersymmetry also predicts a family of Higgs bosons. Where does the Higgs boson observed at LHC fit in? Let us wait and watch.

A crowning glory

Why spend such huge money and brainpower over such accelerators and smashing particles? Computers we use today have become possible due to the development of microprocessors, and without the development of quantum physics, there would be no microprocessors, no computers, no Internet, and no World Wide Web! It may be interesting to note that WWW was invented at CERN. But, what is it that a big accelerator like the LHC expected to do, anyway? Accelerators are routinely used by physicists to study the smallest known particles – the fundamental building blocks of all things. LHC is expected to revolutionise our understanding, from the very small world deep within atoms to the vastness of the universe. The experiments at the LHC are expected to answer fundamental questions like the origin of mass or the nature of the so-called dark matter. It could even give rise to new questions! Indeed, the experimental data using the higher energies reached by the LHC could push the frontiers of knowledge further ahead, helping us understand the fundamental laws of nature better, help confirm established theories, look beyond what we already know today; and also throw up new technologies as by-product.

The discovery of the Higgs boson is, without any shadow of doubt, a crowning achievement of one of history's most successful theories. But, it could also herald, almost certainly, the beginning of its own undoing and its replacement by a better theory! In any case, the discovery of the Higgs boson is something to celebrate.

(*Concluded*)

Dr Vinay B Kamble is a physicist and science communicator. He was an Adviser with the Department of Science and Technology and Director, Vigyan Prasar, before he moved to Ahmedabad in 2009.

Continued from page 36

(The Calculus Affair)

"I have heard that extensive mathematical modelling is required for any space mission. I think that calculus is required for such kind of applications."

"You are right. The mathematical modelling and associated calculus helps us to understanding our universe, its past, present and the future. Mathematical modelling using calculus is also an essential component of quantum mechanics to know the micro world of atom and its nucleus, and many other branches of science. Calculus is used extensively by epidemiologists to model epidemic scenarios to explore how a disease would spread and what intervention strategies would help in combating the disease. In short, calculus plays the most vital role in explaining many concepts in physics, chemistry, biology, medicine and other subject areas. Its applications encompass the atoms to the universe, and thereby solving many real life problems."

"It's amazing! Uncle, thank you very much for introducing me to the world of calculus. The other day, I was reading a book on Tintin's adventure to the Moon. After exploring the exciting world of calculus, I had the same feeling as Professor Calculus exclaimed after his lunar exploration: what an adventure!" □

Coral Reef:
A paradise of marine biodiversity

Dr. Amrita Singh
E-mail: amrita_arsenic@rediffmail.com

Almost three-quarters of the Earth's surface is covered with water, of which nearly 71 per cent is salty, forming the marine habitats of seas and oceans. Marine species comprise approximately one half of the total global diversity ranging from 3 million to 500 million species. Two very interesting and distinctive shallow-water marine continuities of tropical and subtropical waters are mangrove swamps and coral reefs. Both are important "land builders", which help to form islands and extended shores. The reefs build up to sea level by biological deposition of calcium carbonate. Islands can form in the reef either as a result of a lowering of the sea level, or as a result of pounding surf and wind action that pile up broken reef chunks and coral sand above sea level so that terrestrial plants can start development.

Although corals are animals (phylum Coelenterate), a coral reef is not a heterotrophic community. Rather it is a complete ecosystem with structure built of dead organisms. Coral reefs support an extraordinary biodiversity although they are located in nutrient-poor tropical waters. Coral reefs develop only in tropical and subtropical Western Atlantic and Indo Pacific Oceans within 30° North and 30° South latitudes. They are widely distributed in shallow waters (less than 46 m deep) and require warm water temperatures (20° to 28°C). Persistent cold currents prevent coral reefs from developing along the western edges of continents.

All coral reefs are built in the same way. Only the outer layer has living coral animals. Beneath this thin layer of tiny polyps are layer upon layer of skeletons of past generations. Corals are basically simple cylindrical organisms called 'polyps' about one cm in length. The polyp's body wall is made up of outer layer and an inner layer. The inner layer of cells surrounds a single digestive cavity. In between the two layers, it is filled with an inert jelly-like substance. The oral disc (mouth or anus) is edged with tentacles and cilia, which help in prey capture.

Millions of polyps in coral colonies create a reef and ridge that approaches the sea surface. Besides polyps, calcium-containing algae, molluscs, debris of shells from the shore, and chemically precipitated carbonates of calcium and magnesium are the principal builders of coral reef. At night coral polyps extend their tentacles and capture zooplanktons – mainly small crustaceans and fish larvae – which may pass over the reef from adjacent ocean waters. Night-time is also a period of activity for lobsters and many other invertebrates that spend the day in dark recesses of the reef. Some corals eat zooplankton or small fishes while others consume organic debris.

Coral reef in Lakshdweep. A coral reef is a complete ecosystem with structure built of dead organisms and supports an extraordinary biodiversity.

Depending on their location, coral reefs are classified in three categories: fringing reef, barrier reef, and atoll. Fringing reefs are found near the shore and extend out from the shores of islands and continents. Narrow water channels called lagoons lie between the reef and shore. These reefs are common along tropical coasts and form in low-rainfall areas. They are mainly composed of coral sand, mud, dead and live coral colonies and other animals. The Hawaiian Islands are the best example of this type of reefs. Barrier reefs are separated from the shore by channels or lagoons. These types of reefs are elongated accumulations of corals lying at low-tide level. A barrier reef includes patch reef, bank reef, and back reef. Northeastern Australia's Great Barrier Reef is an amazing example of such a reef. Atolls are islands of coral with a shallow lagoon in the centre. Formation of atoll is a magnificent and unique phenomenon. Deep-sea atoll arises in the deep sea and continental atoll is found on the continental shelf. Lakshadweep and Maldives islands in the Indian Ocean are composed of atolls.

Role of algae in coral reef

Coral reefs are energetically self-sustaining and with well-defined trophic levels of producers and consumers. A coral reef resembles a tropical rain forest that represents a great source of biodiversity. Although stony corals are major contributors to the limestone substrate, the calcareous red algae (*Porolithon sp*) may be of equal or greater importance. These algae contribute to the reef structure as well as primary production on the reef. Each polyp has algae living inside it (endozoic) called zooxanthellae. The endozoic algae (*Symbiodinium* sp) consist of small, round yellow cells embedded in polyps which supply photosynthetic products to corals. Other kinds of algae live in the calcareous skeleton around and below the animal bodies. Still other species of algae (fleshy and

calcareous types) are found everywhere over the limestone substrate. Together, the animal and algae form a relationship beneficial to both. The photosynthesising alga provides food for the coral, and the coral provides protection and nutrients for itself as well as its resident alga by capturing zooplankton. Free living algae grow in crevices of the coral and provide food for sea urchins, sea cucumbers, brittle stars, many kinds of molluscs, and colourful fishes.

The filamentous algae enmeshed in the skeleton of living corals are adapted to low light intensity and are rich in chlorophyll. They often give the greenish colour to living coral mass. The skeletal algae are members of the Chlorophyta, order Siphonales. Algae supply plenty of carbon as nutrients to the corals so that they may grow and reproduce fast in order to construct the reef and corals in turn pass essential nitrogen and phosphorus to the algal species. Algae facilitate the rapid biochemical deposition of calcium salts into the skeleton of corals.

Role of corals in coral reef

Corals produce large amounts of mucus which protects the delicate animals from siltation. Large quantities of mucus slough off into the water where it aggregates with other organic material, thus providing a nutritious source of food for various consumers. Corals provide access of sunlight to their harboured algae and for this corals mostly live in ocean waters less than 100 m deep and also avoid building colonies in chilled, highly turbid and less saline marine water. Corals remain calm and quiet during the day to protect themselves from their predators as well as from ultraviolet. Reefs are paradise for a wide variety of fishes, as corals provide numerous hiding spots for about a thousand species of fishes. The top predators such as sharks, moray eels, crabs, etc., lurk in crevices, holes and cavities of reefs where they grow with abundance of food materials. Other animals such as shellfishes, crabs, sea urchins, sea cucumbers, brittle stars, wrasses, etc., also find good shelter in caves and nooks of reefs. Natural pigments in coral tissue produces a wide range of colours like red, orange, yellow, green, blue and purple. Various types of reef-builder corals include pineapple coral (*Montastrea cavernosa*), star coral (*Galaxea fascicularis*) with white star-shaped polyp, brain coral (*Diploria strigosa*) with brain like ridges, sea fan (*Gorgonia* sp) with typical hand fan-like look, mushroom coral (*Fungia* sp) that look like a big fluffy mushroom, and organ-pipe coral (*Tubipora* sp) with many vertical tubes.

Odd fishes of the corals

Coral reefs are a showcase for bizarre fishes. Fishes have developed many different shapes. These are the eels, long skinny fish that look more like snakes. Some species carry enough venom in their bodies to kill several humans. Stonefish has a stone-like appearance and has sharp venomous spines that contain enough poison to kill a man. Spot fin Lionfish (*Pterais antennata*) is a beautiful fish that has sharp spines coated with a poisonous mucous and are capable of delivering a painful sting which may kill a man. Mushroom scorpionfishes are characterised by their bizarre appearance and the numerous spines that cover their bodies. These spines contain strong venom enough to cause a very painful wound. Leafy seadragon is a rather unique species of seahorse. It has evolved an elaborate system of camouflage by growing leafy extension on its body that resembles seaweed. It can often be found floating in clumps of seaweed. Flying gurnard is a fish with large wing-like pectoral fins, which help them to swim low over the sand while searching for food. The sharp-nose pufferfish has beautiful colours and spots. There is a large black spot near its black fin, which resembles an eye and helps draw the attention of predators towards the fish's tail. The long-spined porcupinefish fill their bodies with water until they swell like a balloon and appear too large to be eaten by predators.

Economic importance

The coral reef is a stable, species diverse, well-adapted ecosystem with a high degree of internal symbiosis. The corals have great economic significance in diverse fields. Coral skeleton, which is basically calcium carbonate, is used as building material and raw material for construction materials like cement, line, mortar, etc. Exquisite and expensive decorative items and ornamental pieces are manufactured from corals. Corals have been found to be good sources of sun-protective chemicals. The rigid exoskeletons of marine corals are used to fill voids in bones caused by fractures. Chemicals called pseudopterosins obtained from a sea fan (Pseudopterogorgia) provide protection from sunburn or chemical irritants used in cosmetics preparations. Small pointed structures called spicules of red coral (*Gorallium nobile*) have deposits of red coloured calcium carbonate and is extensively used in jewellery. The coral gorgonian, *Octocorallia* sp, is a source for fucosol, an analgesic-cum-anti-inflammatory product. The sea-fan *Pseudo-pteragorgia elisabetrae* is a source of more than 35 cosmetic products including an anti-inflammatory compound. An anticancer drug Discodermolide is extracted from the deep-sea sponge *Discodermia* sp through culture and chemical synthesis. A natural product obtained from *Palythoa toxica*, a soft coral found in tide-pools in Hawaii, may used in the isolation of a very complex molecule called Palytoxin, which is a potent agent for fighting cancer. The Horseshoe crab *Limulus* has been used in various ways to cure certain ailments like body pain and rheumatism. Its blue blood (haemolymph) could be used to detect dangerous bacterial endotoxins in drugs, medical devices and even water. In India, this crab species is found is large numbers along the coast of Orissa. Chitosan is a chemical product derived from crab and shrimp shells. It is used for bandages and artificial skin in burn graft cases as it promotes healing.

Nowadays the coral reefs are threatened by pollution along the coast line. Sewage and industrial wastes, oil, spills, sedimentation, siltation, water stagnation, excess of UV radiation, and thermal pollution are all beginning to take their toll. Unexpectedly, coral reefs are also threatened by a predator population explosion. The culprit is a starfish called the "crown of thorns" (*Acanthaster planci*). They threaten the integrity of the whole reef and are spreading to other parts of the world. Excess fishing has considerably reduced the population of reef fishes. Use of poisons by fishermen to get more yields from sea is severely damaging the corals. All in all, mankind has much to learn from the coral reef about recycling and how to prosper in a world of scarce resources. The message, of course, is to establish better symbiosis with the plants and animals on which we depend.

Dr. Amrita Singh, Environmental Biology Laboratory, University Department of Botany, T. M. Bhagalpur University, Bhagalpur – 812007, Bihar

Dizziness

That unforgettable distressing spin

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

> To sum up: 1. The cosmos is a gigantic fly-wheel making 10,000 revolutions a minute. 2. Man is a sick fly taking a dizzy ride on it. 3. Religion is the theory that the wheel was designed and set spinning to give him the ride.
>
> —H. L. Mencken, *A Mencken Chrestomathy*, Part 1

To be dizzy is a terrible experience. Your head swims, you are woozy and wobbly, and you clutch for support. You feel as if everything is in a spinning mode. Until that feeling of being on roller coaster eases off, you feel awful. You may also experience nausea or start puking.

This false sensation of movement — or a sense that you or your surroundings are spinning or moving — is termed vertigo in the medical parlance. It can be caused by myriad clinical conditions. For instance, it could be the ill functioning of the organs of balance in the inner ear (the vestibular apparatus), the nerve that connects the inner ear to the brain, or the areas of brain concerned with balance. Equally, the defect might lie with the neck, trunk or leg muscles, sensory receptors in the joints, or eyes. Or the cerebellum — the trilobed structure of the brain, lying at the back of the upper portion of the midbrain and lower to the occipital lobes (part of the cerebral cortex in either hemisphere of the brain lying in the back of the head), that is responsible for the regulation and coordination of complex voluntary muscular movement as well as the maintenance of posture and balance.

Should any of these organs, nerve pathways or brain centres fail to function well, the world might seem to go into a wobble or spin.

This sudden sensation that you're spinning or that your head is spinning inside, may also commonly relate to a condition which doctors prefer to call as 'benign paroxysmal positional vertigo' (BPPV). Characterised by brief episodes of mild to intense dizziness, its symptoms are triggered by specific changes in the position of your head, such as tipping your head up or down, and by lying down, turning over or sitting up in bed. You may also feel out of balance when standing or walking.

Although benign paroxysmal positional vertigo can be a bothersome problem, it is rarely serious except when it increases the chance of falls. You can receive effective treatment for benign paroxysmal positional vertigo during a doctor's office visit.

Rarely, the problem may relate to an entirely unrelated cause. An oppressive stuffy environment, overpowering stench, poor hydration, adverse effect of a medication, abnormally low blood sugar, or bad heart — the culprits can be many.

Symptoms

The signs and symptoms of vertigo, including benign paroxysmal positional vertigo, develop suddenly and may last from a few minutes to several days, occurring either intermittently or constantly. The condition can be very distressing, and, in severe cases, may make it impossible to walk or stand.

The symptoms may include:

- Dizziness
- A sense that you or your surroundings are spinning or moving (vertigo)
- Light-headedness
- Unsteadiness
- A loss of balance
- Blurred vision associated with the sensation of vertigo
- Nausea
- Vomiting

Episodes of benign paroxysmal positional vertigo and other forms of vertigo can disappear for some time and then recur.

Activities that bring about the signs and symptoms of BPPV can vary from person to person, but are almost always brought on by a change in the position of your head. Abnormal rhythmic eye movements (nystagmus) usually accompany the symptoms of benign paroxysmal positional vertigo. Although rare, it is possible to have BPPV in both ears.

When to see a doctor: the red flags

Generally, see your doctor if you experience any unexplained dizziness or vertigo that recurs periodically for more than one week. Although it is uncommon for dizziness to signal a serious illness, see your doctor immediately if you experience dizziness or vertigo along with any of the following:

- A new, different or severe headache
- A fever of 101°F (38°C) or higher
- Double vision or loss of vision
- Hearing loss
- Trouble speaking
- Leg or arm weakness

- Loss of consciousness
- Falling or difficulty walking
- Numbness or tingling
- Chest pain, or rapid or slow heart rate

The signs and symptoms listed above may signal a more serious problem, such as stroke or a cardiac condition.

What the doctor would do

Your doctor must patiently listen to your symptoms, and analyse them circumspectly. He may ask a number of questions, such as: What are your symptoms, and when did you first notice them? Do your symptoms come and go? How often? When symptoms occur, how long do they last? Is one or both of your ears affected? Does anything in particular seem to trigger your symptoms, such as certain types of movement or activity? Do your symptoms include vision problems? Do your symptoms include nausea or vomiting? Do your symptoms include headache? Have you lost any hearing? Have you had any weakness, numbness or tingling in your arms or your legs? Have you had any difficulty talking or walking? Have you had chest pain? Are you being treated for any other medical conditions? What medications are you currently taking, including over-the-counter and prescription drugs as well as vitamins and supplements?

When the history taking is done, he is likely to carry out a thorough examination of the neck, ears, eyes, nervous system, heart and major blood vessels. In fact, he has to be no less than a Sherlock Holmes to sleuth the true problem. He may do a series of tests to determine the cause of your dizziness. During a physical examination, your doctor will likely look for signs and symptoms of dizziness that are prompted by eye or head movements and then decrease in less than one minute; dizziness with specific eye movements that occur when you lie on your back with your head turned to one side and tipped slightly over the edge of the examination bed; involuntary movements of your eyes from side to side (nystagmus); and inability to control your eye movements

Referral to specialist doctors

If this initial clinical examination draws a blank, your doctor may refer you to an ear, nose and throat (ENT) specialist or a doctor who specialises in the brain and nervous system (neurologist).

These facilities are however, only available at the larger healthcare centres.

Tests and diagnosis

If the cause of your signs and symptoms is difficult to diagnose, your family doctor or the specialist you have gone to, may ask for a series of tests to determine the cause of your dizziness. These tests may include:

The Caloric test

This test is carried out by an ear, nose and throat (ENT) specialist. The doctor uses air at different temperatures, which he blows into your ear to assess the function of your vestibular apparatus.

Electronystagmography

The purpose of this test is to detect abnormal eye movement. Electronystagmography (ENG), which uses electrodes, or videonystagmography (VNG), which uses small cameras, can help determine if dizziness is due to inner ear disease by measuring involuntary eye movements while your head is placed in different positions or your balance organs are stimulated with water or air.

X-ray neck

A neck X-ray may be done to look for abnormalities in the neck vertebrae and their joints. A birth defect such as blocked vertebra or age-related wear and tear changes in the neck by way of cervical spondylosis can produce vertigo.

CT Scanning or Magnetic Resonance Imaging

Should you also have tinnitus — a sound in one ear or both ears, such as buzzing, ringing, or whistling, occurring without an external stimulus — your doctor may ask for CT scanning or Magnetic Resonance Imaging. This is to rule out *acoustic neuroma* — a non-cancerous brain tumour of the nerve that carries sound and balance information from the inner ear to the brain — or other lesions such as *multiple sclerosis* that may be the cause of vertigo.

(Next issue: Dizziness: Causes and Cures) □

Recent developments in science and technology

Biman Basu
E-mail: bimanbasu@gmail.com

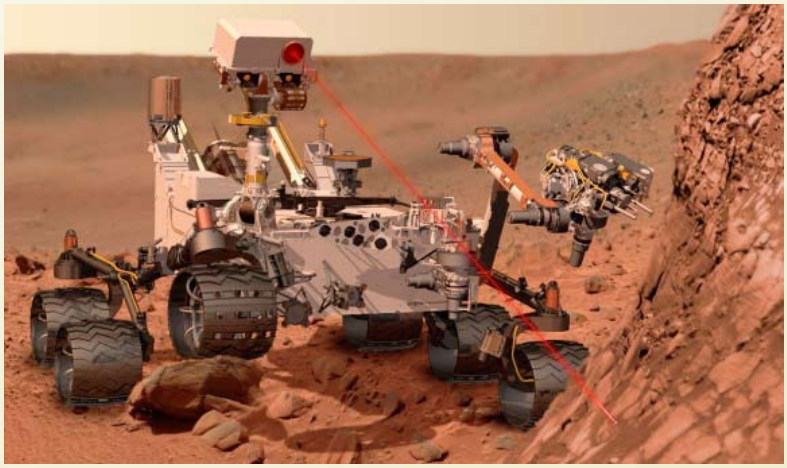
Curiosity mission to Mars

The landing of Curiosity on Mars on 6 August 2012 was different from all previous Mars missions in many ways. The 900-kg Mars rover was the heaviest yet to be landed on Mars and was the most difficult attempted by the NASA till date. For the first time rockets were used to slow down the landing craft and a huge parachute was deployed to slow the craft down after it entered the Martian atmosphere. Finally, NASA used a unique crane to soft land the rover gently on the floor of the Gale Crater on Mars. Immediately after landing, *Curiosity* sent back the first images of the Martian surface. It was technological ingenuity at its best.

Mars has been a popular destination for space faring nations for many years, but less than half of the missions sent so far could achieve even partial success. Two thirds of all non-US missions to Mars have failed. The US record has been much better. Of the 25 total Mars missions, more than two-thirds have succeeded. The US has attempted eight landings, of which seven, including the current one, has been successful. But compared to all the previous missions, the landing of *Curiosity* was a far greater challenge. It involved a highly complex six-stage sequence for landing that allowed no room for even the smallest error. No wonder, the landing sequence, which took 7 minutes, was dubbed by NASA as "Seven minutes of terror". Even a slight deviation from the planned manoeuvres would have led to total failure. The worst thing was that, since the spacecraft was almost 250 million kilometres from Earth at the time of landing, information about any malfunction would take as long as 14 minutes to reach the Mission Control at Jet Propulsion Laboratory. Ironically, information about the perfect landing also took that long to reach Mission controllers at the Jet Propulsion Laboratory near Los Angeles.

The final stage in the landing of Curiosity using a sky crane.

Known as Mars Science Laboratory, the mission was launched in November last year on a 570-million-kilometre journey to the Red Planet. The basic objective of the mission was to land the rover *Curiosity* on the Martian surface to begin a two-year mission seeking evidence that the Red Planet once hosted ingredients for life. Evidence of water on Mars has been aplenty, but none of the previous missions has been able to find any evidence of life – past or present – on the Red Planet. This time too, scientists do not expect *Curiosity* to find aliens or living creatures. Rather they hope to use it to analyse soil and rocks for signs that the building blocks of life are present and may have supported life in the past. It will do so by looking for organic molecule in the Martian soil and rocks. To do this, the rover will scoop up soil and drill through rocks using a laser to determine the Martian environment over geological time scales – going back to 4 billion years – and search for hints of organic compounds and elements essential to life.



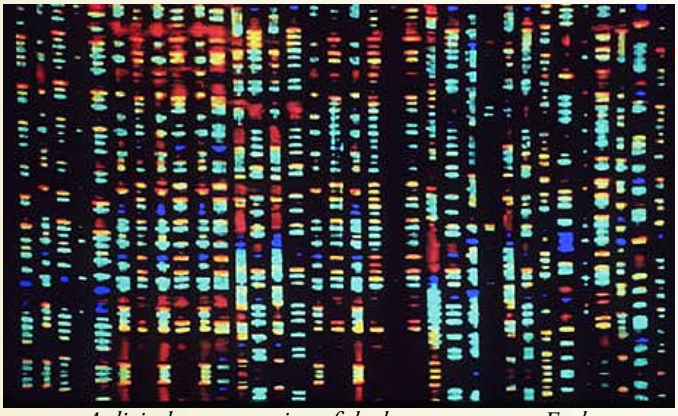
Curiosity rover using laser to analyse rocks.

Apart from being much larger and heavier than any previous Mars lander, *Curiosity* has a different power source. It is powered by the heat of decaying radioactive plutonium, which is expected to provide high power levels, day and night, for much longer than *Curiosity*'s mission life. On 22 August, *Curiosity* began driving from its landing site, which has been named for the late science fiction author Ray Bradbury.

It is worth mentioning that two engineers of Indian origin have played key roles in the successful landing of the *Curiosity*. One of the critical mission elements of the success was the 21.5-metre diameter parachute that helped reduce the speed of the capsule carrying *Curiosity* after entering the Martian atmosphere was designed and tested by Anita Sengupta, an aerospace engineer of Indian origin with NASA. Another Indian engineer, Ravi Prakash, helped in the complex manoeuvre of entry, descent, and landing of *Curiosity* that required thousands of events to happen in in precise sequence in a matter of a few minutes.

ENCODE decodes the human genome

When the draft of the human genome was published in 2000, researchers thought that they could unravel the genetic secrets of human health and disease. The human



A digital representation of the human genome. Each colour represents one the four nucleotides of DNA.

genome contains 3 billion base pairs comprised of the nucleotides A, T, C, and G out of which some 21,000 protein-coding genes were identified. Interestingly a large part of the human genome was believed to be non-coding; that is, not involved in coding for proteins. Such regions were dubbed 'junk' DNA. No one knew what their function was although such regions were known to play a vital role in establishing identity through the technique known as 'DNA fingerprinting'. Now an international consortium of hundreds of scientists working under a project called ENCODE (Encyclopaedia of DNA Elements) has deciphered a large portion of the strange language of this junk DNA and found it to be not junk at all. On the contrary it contains important signals for regulating our genes, determining disease risk, height and many of the other complex aspects of human biology that make each one of us different (*Nature*, 6 September 2012 | doi:10.1038/489052a).

The ENCODE project aims at fully describing the list of common ingredients (functional elements) that make up the human genome. When mixed in the right proportions, these ingredients constitute the information needed to build all the types of cells, body organs and, ultimately, an entire person from a single genome. It provides information on the human genome far beyond that contained within the DNA sequence – it describes the functional genomic elements that orchestrate the development and function of a human being. It has been known that a 'gene' was a piece of DNA that coded for a particular protein. When a cell needed that protein it got a copy of the gene transcribed from DNA to RNA, which would in turn be translated to make a protein. ENCODE has shown that not only the genes but as much as 75% of the human genome is transcribed into RNA at some stage in at least one of the body's different types of cell. All this RNA with transcripts has a wide variety of uses – ranging from regulating what genes actually make proteins to how much is made.

The ENCODE group is focussed on understanding not just the elements of the genome but also how they work together, as the complexity of our biology resides not in the number of our genes but in the regulatory switches. Through more than 1,600 separate experiments, analysis of more than 140 cell types, and a massive amount of data analysis, the group found about 4 million of these so-called switches and can now assign functions to more than 80 per cent of the entire genome. These newly catalogued switches not only activate and de-activate genes, but also control how much of each protein gets made and when. Compare that to the roughly 2 per cent of the genome that is responsible for the protein-coding genes that researchers have been relying on to look for diseases and traits. According to the researchers, the new data promise to improve our understanding of the human genome and also of many common diseases that might have similar genetic underpinnings.

Stem-cell therapy leads to recovery of body sensation

Stem cells are a class of undifferentiated cells that are able to differentiate into specialised cell types. Commonly, stem cells come from two main sources: Embryos formed during the blastocyst phase of embryological development (embryonic stem cells) and adult tissue (adult stem cells). Both types are generally characterised by their potency, or potential to differentiate into different cell types (such as skin, muscle, bone, etc.). Doctors and scientists are excited about stem cells because they have potential in many different areas of health and medical research. In the latest success story, people with broken spines have recovered feeling in previously paralysed areas after receiving injections of neural stem cells.

Damage to the spinal cord due to injury invariably leads to paralysis and previously such patients had also no chance of recovery. But the recent study shows that such patients could benefit from stem cell therapy. The recent study was done at the Balgrist University Hospital in Zurich, Switzerland, with three patients with paralysis who received injections of 20 million neural stem cells directly into the injured region of their spinal cord. The cells, acquired from donated foetal brain tissue, were injected between four and eight months after the injuries happened. The patients were also given a temporary course of immunosuppressive drugs to limit rejection of the cells. Before the therapy, none of the three patients had any sensation below their chest level, but six months after therapy, two of them had sensations of touch and heat between their chest and belly button. There was no change in third patient (*Neurological Research*, doi: 10.1179/016164106X115116). These three patients were the first of 12 to undergo the therapy. The encouraging news is that the sensory gains, first detected at three months after the transplant, have persisted and evolved at six months after transplantation.

However, according to some neurologists, a single mode of treatment is unlikely to be enough to restore function after spinal cord injuries. According to them, a combination of approaches including stem cells, polymer-based treatments, retraining and physical therapy would be required for optimum results. The current success, however, offers hope that in the future – perhaps when combined with drugs and physical therapy, the treatment could help make paralysis a temporary, rather than permanent, condition.

Amazon fungi help create clouds and rain

Cloud formation and rain are complicated process that scientists have tried to understand for long. It is known that to form rain drops a nucleating centre is usually required that water can condense on, which is often provided by tiny dust or smoke particles – any sort of solid matter that is light and small enough to drift about in the air. Making rain by 'cloud seeding' with certain salts is a well-known practice. A recent study has revealed how fungal spores can be an agent

In the Amazon rain forest, salty particles from spore-launching fungi help make clouds and rain.

of making rain. In the Amazon rain forest, salty particles from spore-launching fungi help make clouds and rain, according to the study. The Amazon River basin is home to the largest rain forest on Earth, covering about 6.9 million square kilometres in seven countries. The study was undertaken by an international team of researchers in an effort to understand the way nature originally caused cloud formation and subsequent rain to fall. The Amazon basin was chosen because the air here is generally free from pollution and much closer to its natural state than in other areas due to the constant influx of fresh air from over the ocean and nearly constant rainfall.

However, even pristine air contains organic gases (from plants) and particles. A forest biosphere like the Amazon releases thousands of different molecules every day – they are responsible for its rich smell. When volatile organic gases like terpenes, which give lemons their pleasant smell, loft into the atmosphere, they are oxidised by chemicals such as ozone. The transformed gases then condense into particles.

To find out which sort of particulate matter might be present in the Amazon, the researchers climbed up an 80-metre tall man-made tower and collected air samples. Upon inspection, they found three kinds of major nano-sized particles, each with high levels of potassium and covered in an organic gel, the result of organic gas condensation. The team ruled out salt from the ocean as a source due to differences in structure and distance from the sea, and finally narrowed down the list of possible sources for the salty potassium cores, to fungi spores that drift up from the forest floor. According to the researchers, the most likely source of the potassium specks are fungi, which use potassium-laden water to launch their spores, but other plants make the salts, too. The gel coating, caused by condensation of organic compounds released by plants, allows water to very easily cling to the particles leading to cloud formation and then of course rain. Because the spores come from the forest itself, the findings suggest that the Amazon River ecosystem is one giant feedback loop (*Science*, 31 August 2012 | DOI: 10.1126/science.1223264).

According to the researchers, it is a really interesting study and it raises some new questions about the role of plant-based emissions and provides a new perspective on biosphere-atmosphere interactions. It also underlines the important role of forests in creating conditions favourable for rain. More importantly, the findings support the hypothesis that the Amazonian rainforest ecosystem can be regarded as a biogeochemical reactor in which the formation of clouds and precipitation in the atmosphere are triggered by particles emitted from the biosphere. In view of the large impact of tropical rainforests on biogeochemistry and climate, the biological activity and diversity of particle-emitting organisms seem likely to play important roles in Earth history and future global change. □

Letters to the editor

Informative article

The article 'Niceties of Numbers' by Rintu Nath, published in your July issue was very informative and I am very happy to read it. I have learnt lots of things such as transcendental number, fractional number, etc., from the article The Number System table graph would be very useful for understanding and remembering the number system. The mathematical 'song' that gives the value of Pi up to thirty-one decimal places was also very interesting. But I am still waiting for something more about imaginary numbers and complex numbers.

Also, 'How to get the best of nutrition from our food' by Dr. K. Srinivasan was a wonderful article because it enabled me to learn about different types of food processing and their benefits.

Ramakanta Mohanta
Keonjhar, Odisha 758014
Email: rkmohanta@msn.com

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Venus Transit

Dream 2047 is really a pleasure to read. The editorial on Venus Transit by Dr. Subodh Mahanti (June) was excellent. Such articles are very helpful in creating interest about celestial things among students of astronomy.

Gouranga Ch De
Asstt (Sc.) Teacher
Rongram Higher Sec. School
West Garo Hills, Meghalaya

*****

Good article on brain stroke

The article on brain stroke (Dream 2047 September 2012) was really informative. It presented useful information about the latest in brain research, which was really superb and mind blowing. Thanks for providing such useful information to readers.

Ashish Gupta
ashish11944@gmail.com

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Ramanujan-Chandrasekhar: Legacy in Science" National Lecture Series

As part of the nationwide National Mathematical Year celebrations to commemorate the birth centenary of Nobel Laureate Professor S. Chandrasekhar (1910-2010) and 125th Birth Anniversary of great mathematician Srinivasa Ramanujan (1887-2012), Vigyan Prasar is organising a series of lectures on astrophysics and mathematics to be delivered at various educational institutions, colleges and universities. Resource material in the form of posters, badges, and booklets on Prof S Chandrasekhar and Srinivasa Ramanujan are being distributed to the students at the lecture venues.

Apart from the lectures, a quiz on astronomy or mathematics is also being organised at each venue. The first three winning teams in the quiz competition are presented three books: *S Chandrasekhar, Man of Science,* edited by Radhika Ramnath; *Chandrasekhar and His Limit*, by G. Venkataraman; and *Remembering Chandra*, edited by Manas Prateem Das.

Seven lectures were organised in July and August 2012. Here is a brief report.

1. Ahmednagar, Maharashtra

Local organiser: Prof R J Barnabas, Prof Dr S B Iyyer and Prof S S Munot, Ahmednagar College, Ahmednagar.

Date and venue: 24 July 2012, Ahmednagar College

Invited speakers and titles of talks:

1. Mr Arvind Paranjpye, Director, Mumbai Planetarium, "Mathematics and Astronomy of the Solar System"
2. Prof Pandit Vidyasagar, Department of Physics, University of Pune, "Effect of Microgravity on Plants and Human Being"

Quiz winning teams:

All the winning teams were from Ahmednagar College, Ahmednagar

2. Calicut, Kerala

Local organiser: Mr V S Ramchandran and Mr Jayant Ganguly, Regional Science Centre, Calicut

Date and venue: 26 July 2012, Regional Science Centre, Calicut

Invited speakers and titles of talks:

1. Dr Padmakar Parihar, Indian Institute of Astrophysics, Bengaluru, " The Orion Nebula: The Stellar Nursery".
2. Dr (Mrs) Mini K Balakrishnan, Head of Department, Dept. of Physics, Providence Women's College, Calicut, "Mathematics as a Language of Physics".

Quiz winning teams:

- First Prize: St Joseph's Anglo-Indian GHSS, Calicut
- Second Prize: Savio Higher Secondary School, Calicut
- Third Prize: Kendriya Vidyalay No. 1, Calicut

3. Dhenkanal, Odisha

Local organiser: Dr. Mrinal Chatterjee, Head, Indian Institute of Mass Communication, Dhenkanal (Odisha).

Date and venue: 3 August 2012, Indian Institute of Mass Communication, Dhenkanal (Odisha)

Invited speakers and titles of talks:

1. Mr Sandip Bhattacharya, Director, B.M. Birla Planetarium, Jaipur, "Eyes that spy the Sky"
2. Prof Madhab Chandra Dash, Former Director, State Pollution Control Board "Quest for knowledge: An Indian perspective"

Quiz winning Teams:

All the winning teams were from Indian Institute of Mass Communication, Dhenkanal

4. Satara, Maharashtra

Local organiser/collaborator: Prof Deepak Tatpuje, Vidya Deep Foundation, Satara.

Date and venue: 6 August 2012, Satara Polytechnic College, Satara

Invited speakers and titles of talks:

1. Prof Sanjit Mitra, IUCAA, Pune "Overview of Gravitational wave Astronomy"
2. Dr S D Pawar, Satara Polytechnic, Satara "Fun with Mathematics"

Quiz winning teams:

- First Prize: Yashwantrao Chavan, Science College, Satara
- Second Prize: Shahaji Raje Mahavidyalaya, Khatav, Satara
- Third Prize: Navodaya Vidyalaya Jr. College, Khavali

5. Kalahandi, Odisha

Local organiser: Mr Santosh Kumar Kar, Patani Samatha Science Club, Jai Durga High School.

Date and venue: 16 August 2012, Hotel Bikram, Narla Road, Kalahandi

Invited speaker and title of talk:

1. Mr Amitabh Pandye, Vigyan Prasar,

NOIDA "Universe at the Speed of Light"

Quiz winning teams:

First Prize: Bighneshwar High School, Narla Road

Second Prize: Government College, Bhavani Patna

Third Prize: Jai Durga High School, Narla Raod

6. Kanpur, Uttar Pradesh

Local organiser: Dr. Sunil K. Missra, Academic Advisor, Jay Narayan Vidya Mandir, Inter College, Vikas Nagar, Kanpur

Date and venue: 24 August 2012,

Invited speaker and title of talk:

1. Prof Daya Shankar Kulshreshtha, Department of Physics and Astrophysics, Delhi University, "Towards a Theory of Everything"
2. Dr. Sameer Chauhan, Dept. of Maths, IIT Kanpur "Maths & Ramanujan"

Quiz winning team:

- First Prize: Jai Narayan Vidya Mandir Inter College, Kanpur
- Second Prize: B.N.S.D. Shiksha Niketan, Kanpur
- Third Prize: Jugal Devi Saraswati Vidya Mindir, Kanpur

7. Gopalganj (Bihar)

Local organiser: Dr. Wasim, Mahila Shishu Kalyan Sansthan, Gopalganj, Bihar

Date & Venue: 28 August 2012 Gyan Bharti School, Gopalganj, Bihar

Invited Speakers & title of talks:-

1. Prof. Hardyal Singh Hora, "Prof S. Chandrashekhar's Legacy"
2. Dr. Nripendra Kumar, Shama, "Importance of National Mathematical Year 2012"

Quiz wining team

- *First Prize:* Homi Jahangir Team
- *Second Prize:* Raja Ramana Team
- *Third Prize:* Abdul Kalam Team

8. Jalna, Maharashtra

Local organiser/collaborator: Prof M L Kurtadikar, Department of Physics, JES College, Jalna

Date and venue: 30 August 2012, JES College, Jalna

Invited speakers:

1. Prof Sanjeev Dhurandar, Emeritus Scientist, IUCAA, Pune, "The March of Gravity: From Newton to Einstein"
2. Dr.Nitin Oak, "Mathematics and astronomy and astrophysics"

Quiz winning team:

- *First Prize:* B. R. Barwale College, Jalna
- *Second Prize:* Matsodari Maha-vidyalaya, Jalna
- *Third Prize:* J.E.S. College, Jalna

(Report: Dr. Arvind C Ranade, Dr. Bharat Bhusan and Dr. Rakesh K. Upadhyay)

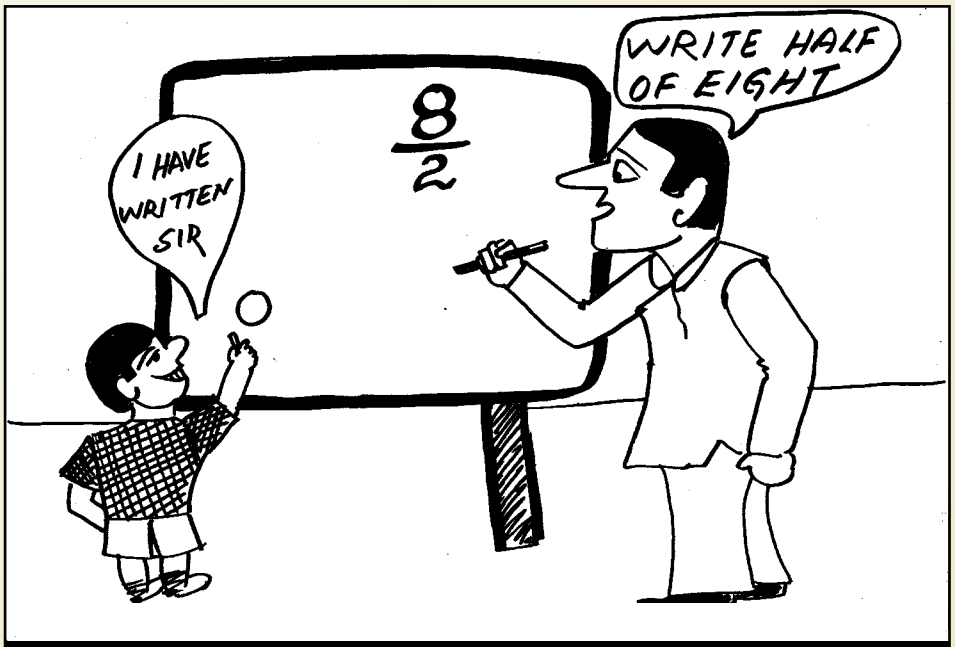
A national workshop on 'Green Revolution

Opening session of National Workshop on Green Revolution in Mizoram, Aizwal

A national workshop on 'Green Revolution in Mizoram' was held during 20-22 June 2012 at Aizwal, Mizoram. The workshop is sponsored by Vigyan Prasar and organised by All Mizoram Farmers' Union (AMFU) in co-ordination with Central Institute of Horticulture, Nagaland. The participants included 150 farmers from different villages of Mizoram. The workshop was conducted in Mizo and English languages to make the lectures more understandable and comprehensive to local farmers. The workshop stressed the need for sustainable agronomic practices to enhance productivity and make agriculture viable in Mizoram. It also highlighted the need to redevelop shifting cultivation and follow an agro-ecosystems approach to ensure ecological and livelihood security for the people of Mizoram.

It was pointed out that there is a demand for National, State and Local Governments to strengthen investment and encourage involvement of people in agriculture and the allied sectors focussing on development planning, research, extension, agro-processing (food and bamboo) and meat processing in the cooperative sector and setting up of regulated markets. A holistic community-based approach with cropping based on land capability classification and location specific is needed to meet the requirements in Mizoram.

(Report : Sachin C. Narwadiya)



Cartoon by : V.S.S. Sastri E-mail: vsssastri@gmail.com

Science and technology popularisation activities in North-Eastern States

A two-day brainstorming session was organised by Vigyan Prasar to discuss science communication activities to be taken up in North-Eastern part of India. The meeting was held at Jagadis Bose National Science Talent Search (JBNSTS), Kolkata during 13–14 August 2012. National Council of Science Museums, Bose Institute, JBNSTS, National Institute of Science Communication and Information Resources (NISCAIR), and VP collaborated in preparing a roadmap for science communication in the NE states. Member secretaries of NE State Science and Technology Councils, science communicators, representatives from All India Radio, and a number of organisations engaged in science communication were invited to the discussion. Thirty-eight delegates attended the discussion meeting and provided valuable inputs.

Dr. Subodh Mahanti (right side-standing) discussing programmes for North-Eastern states during the second day of the discussion meeting

Professor Papiya Nandy, Director, JBNSTS, welcomed the delegates and briefly described the objectives and activities of JBNSTS. She stated that representation from all the NE state S&T councils is a welcome step towards greater coordination and cooperation.

Shri G.S. Rautela, DG, NCSM, mentioned that there is a Science Centre in each of the NE states, but accessibility, and insufficient trained manpower are some of the difficulties in these states. He said one science centre is not sufficient for each state and suggested setting up of school-level discovery centres and smaller mobile science exhibitions for wider reach and participation. He also suggested that more District Science Centres may be created and existing ones may be strengthened.

Dr Subodh Mahanti, Honorary Director, VP, briefly described initiatives of Vigyan Prasar in the North-Eastern part of India. He stated that one of the main objectives of science communication is appreciation of science by common people in order to enable them to take decisions based on information and logical analysis. National institutes like NCSM, NISCAIR, VP, Bose Institute, JBNSTS and other similar organisations should be able to join hand in sharing the resources and outreach programmes for extensive and effective science communication.

Dr. Emdadul Islam, Director, Birla Industrial and Technological Museum, suggested that science outreach programmes should ideally evolve a system that will enable reaching out to a vast majority of people.

Meeting in progress

Er Gauhar Raza, Head, Science Communication through Multi-media Division, NISCAIR, talked about inculcating scientific temper among masses. He reiterated that scientific temper will ensure equality in education, gender and may be directly linked with the survival of the country.

Professor Indira Chakravarty, Chief Advisor, CCDU, Public Health Engineering Department, stressed on comprehensive and multi-sectoral awareness generation through meetings, workshops and communication material on issues like health, nutrition and related areas.

Professor Shyamal Chakrabarti, Department of Chemistry, Calcutta University, mentioned that literacy rate in North Eastern states are among the highest in the country. This advantage should be utilised by science communicators.

Dr. Haresh Chowdhary Dutta, Director, Assam Science, Technology & Environment Council (ASTEC); Dr. Aswini Baruwa, Former Director, ASTEC; Dr Anil Goswami, Former Director, ASTEC; Dr Arup Kr Mishra, Assam Engineering College; and Dr Barkataki, Former Director, State Resource Centre, Assam; discussed existing programmes in Assam and suggested new programmes to be initiated.

Science communication programmes in Arunachal Pradesh were discussed by Shri T. Ronya, Member Secretary, Arunachal Pradesh State Council for Science & Technology. Shri Vivek Kumar, Curator, Arunachal Pradesh Science Centre, Itanagar and Dr Debajit Mahanta, Scientist-C, Arunachal Pradesh State Council for Science & Technology were present.

Science communication programmes in Manipur were discussed by Th. Surendranath Singh, Executive Director, Manipur Science & Technology council and Shri Achow Singh, Programme Executive, All India Radio, Imphal. Dr. R.K. Pritamjit Singh, Scientific Officer, Manipur Science & Technology council was present.

Science communication programmes in Mizoram were discussed by Dr. Vanlal Zara, Member Secretary, Mizoram State S&T Council and Shri V.L Dinpuia, science communicator and language coordinator, AIR, Aizawl, Mizoram.

Science communication programmes in Nagaland were discussed by Dr. Zavei Hiese, Member Secretary, Nagaland State S&T Council.

Science communication programmes in Sikkim were discussed by Shri Dorjee Thinlay Bhutia, Addl. Director, DST, Govt of Sikkim.

Science communication programmes in Tripura were discussed by Shri Ayan Saha.

Shri Abhijit Bhardhan, General Secretary, Science Communicator's Forum, Kolkata; Dr Amit Chakrabarti, Ex Director, AIR, and science communicator; Ms Sudeshna Sinha and Ms. Swati Sircar from Shikshamitra, Kolkata; Dr Samar Bagchi, Ex Director, BITM, and Science communicator; Prof. Sanjib Chandra Sarkar, Vice President, Centre for Interdisciplinary Research and Education; Dr. Bhupati Chakraborty, and Dr B. N. Das from Indian Association of Physics Teachers gave presentations on different science communication programmes undertaken by them and the respective organisations.

On day two, Shri Sandipan Dhar, Consultant, North-East Council suggested formulation of common programs involving more than one North Eastern state. He said Ministry of Development of North Eastern Region may be approached for necessary funding.

Shri Rintu Nath mentioned that a roadmap for S&T communication may be prepared by the committee based on the existing resources, priority areas and difficulties. He also suggested creating online forum and database for science communicators for effective resource sharing and coordination.

Shri B. K Tyagi briefed VP programs in North Eastern states during last five years. He presented data regarding number of science clubs in each NE states, radio programs, programs related to international year of Biodiversity and Planet Earth.

Professor Sanjay K Ghosh discussed outreach and manpower development programs of Bose Institute. He mentioned that Bose Institute has two separate manpower training programmes for North-Eastern states, one for students and the other for teachers. Participants are taken from each NE state.

Based on the deliberations, action points were prepared.

(Report : Rintu Nath) ■

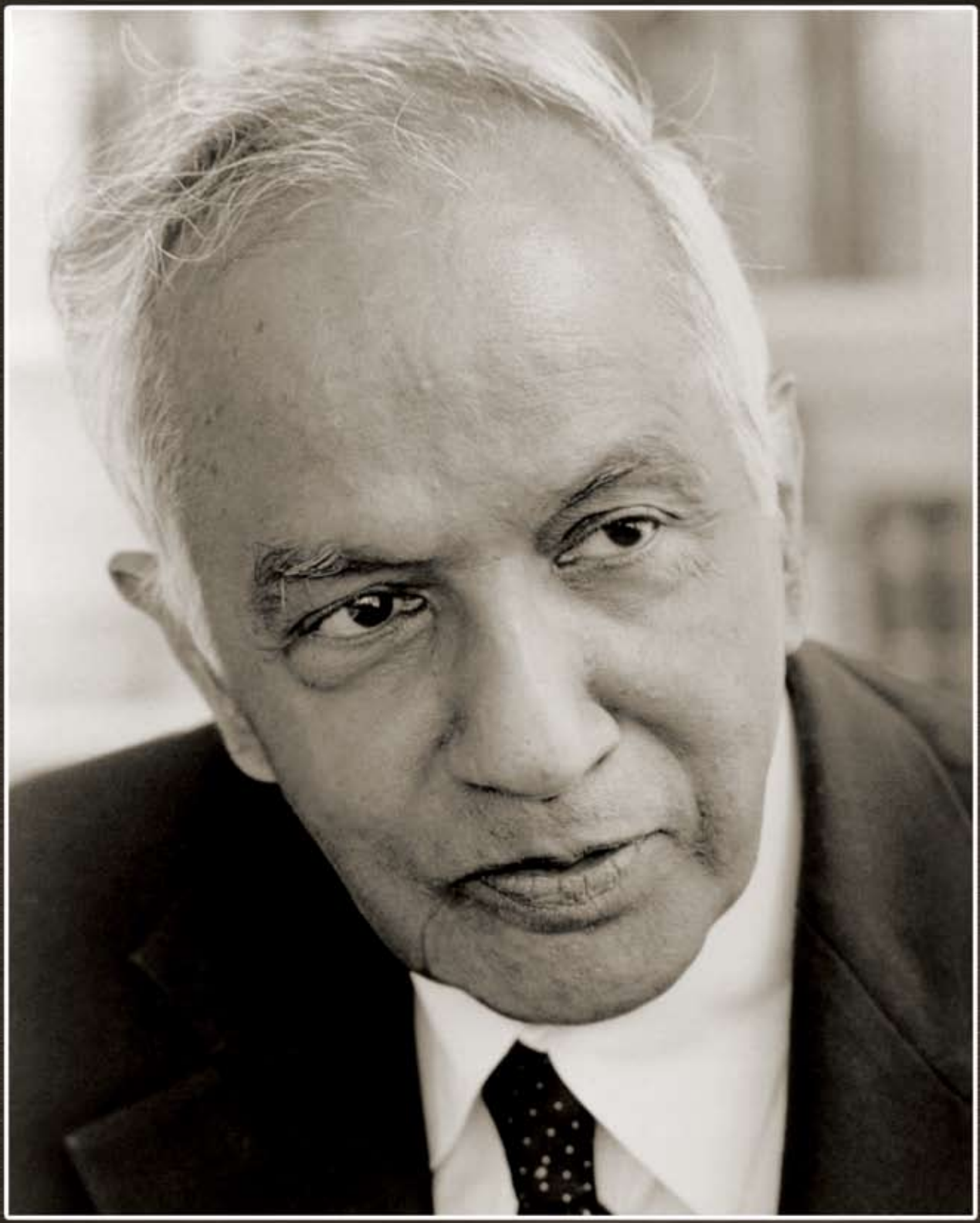
Continued from page 39 **(India at Large Hadron Collider (LHC))**

Following the initiative undertaken by Dr. T. Ramasami, Secretary, Department of Science and Technology, Government of India, a one-day national meet on "India at the Large Hadron Collider" was organised on 29 August 2012 at the Indian National Science Academy, New Delhi. The event was jointly organised by DST and DAE. The idea behind organising the meeting was to showcase Indian contributions to the construction of LHC, the CMS (Compact Muon Solenoid) experiment and ALICE (A Large Ion Collider Experiment) and the development of the LHC Computing Grid by bringing together all those who are responsible for all these achievements. Indian researchers have contributed to theoretical ideas, as evident from the high quality research papers published in top class international journals. It was an extraordinary meeting. Principal Science Advisor to the Government of India, Secretaries of Department of Science and Technology and Department of Atomic Energy, eminent scientists, and young researchers expressed their accomplishments, experiences and ideas with equal confidence and clarity. People who were involved in this ongoing effort earlier but are no more were also remembered. Today about 200 scientists and research students in India are involved with the LHC project. A sense of togetherness in scientific discovery became obvious as speaker after speaker narrated some aspect of the whole story. The collaboration with CERN has led to the convergence of national capacities. The community of high-energy physicists has been charged with new challenges. The Indian industry has found new opportunities. The collaboration has created many spin-off technologies that include detectors, ultra-pure materials, silicon chip and high-vacuum technology. It has fired the imagination of young researchers involved in the project. Team spirit, which is essential in today's science, was highly evident among the participants. There are a lot of challenging things to be done. And as rightly pointed out by Dr. Ramasami, the important thing is to consider what needs to follow rather than what has been accomplished.

The following institutions of India are taking part or in the process of taking part in the LHC project. Aligarh Muslim University, Aligarh; Bhabha Atomic Research Centre, Mumbai; Bose Institute, Kolkata; Delhi University, Delhi; Guwahati University, Guwahati; Jammu University, Jammu; Indian Institute of Technology Bombay, Mumbai; Indian Institute of Technology, Indore; Indira Gandhi Centre for Atomic Research, Kalapakkam; Institute of Physics, Bhubaneswar; National Institute of Science Education and Research; Panjab University, Chandigarh; Raja Ramanna Centre of Advanced Technology, Indore; Rajasthan University, Jaipur; Saha Institute of Nuclear Physics, Kolkata; Tata Institute of Fundamental Research, Mumbai; Variable Energy Cyclotron Centre, Kolkata; Visva Bharati University, Shanti NIketan (West Bengal). Hopefully in coming years more institutions will get chance for participation.

India's achievements in the projects related to LHC need to be conveyed to the larger scientific community and the general public. It will help renew confidence in our young scientists. We need to realise that more and more creative and motivated researchers should come forward to take up new challenges. This will be possible only if science teachers in schools play a meaningful role. The nation needs to pay attention on priority basis to the capacity building of school teachers. The DST is in the process of initiating a major programme in this direction.

Email: director@vigyanprasar.gov.in ■



Subrahmanyan Chandrasekhar

(October 19, 1910 – August 21, 1995)