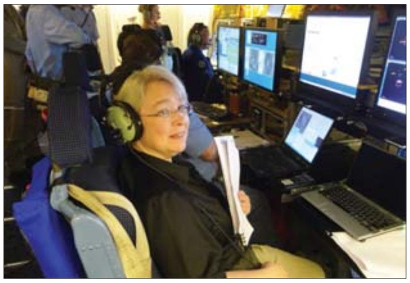
Bridging the gap

In India, the frontiers of science need to connect with common people, says s ananthanarayanan


Margret "Peggy" Piper, a high school teacher from Chicago who participated in the Sofia flight.

EVEN while India grapples with providing bare literacy to vast numbers, there is a case for making science education more real and accessible. Connecting the school student with science, as done by professionals in research and industry, would open channels to the grasp of science principles and act faster than conventional pedagogy. The initiatives of universities and research establishments in the USA to bridge the widening divide between advanced science and the school and community may have lessons for India to make use of its specialised science capability to maximise the value of a struggling educational system.

The National Aeronautics and Space Administration's Stratospheric Observatory for Infra-red Astronomy is a fully operational observatory aboard a modified Boeing 747, equipped with a 17-tonne, 2.5-metre (100-inch) telescope designed for the best performance in the infra-red and the sub-millimetre range of the spectrum. Light in this region is completely absorbed by the atmosphere and is not accessible by ground-based telescopes. Sofia flies at altitudes of 39,000-45,000 feet, which is clear of 99 per cent of atmospheric water vapour, which absorbs light in the infra-red and sub-millimetre range. In this way, Sofia complements the Hubble, Spitzer, Herschel and James Webb space telescopes and the major ground-based telescopes.

Sofia enables measurement of the sizes of non-luminous solar system objects by observing how long they are able to block out a distant star, and observe their composition and atmospheric structure. The 100-inch reflector has the resolution to observe the details of distant formations and helps answer questions about the evolution of the universe, how organic molecules necessary for life may come about and the nature of the black hole at the centre of the Milky Way. "It's much better than a mountain top observatory and cheaper and more convenient than a space telescope," said Nasa's Dana Backman.


Teachers at Yerkes Observatory.

While Sofia is a state-of-the-art facility for astronomers and space scientists, Nasa extended its ongoing outreach to an *airborne astronomy ambassadors'* programme by taking science and astronomy teachers in schools on a 10-hour flight aboard Sofia to participate in real life astronomy research, shoulder-to-shoulder with professionals. And it is planned to carry many more teachers during the current year and the next.

Margret "Peggy" Piper, a high school teacher from Chicago who participated in the Sofia flight, said she also worked with astronomers and other teachers in the outreach programme of Chicago's Yerkes Observatory. Yerkes involves students in its regular research projects and has an education programme where it conducts workshops and provides teacher resources.

Another such resource for first hand exposure to astronomy research is the International Astronomical Search Collaboration, where 12 universities, worldwide, work with high schools and colleges at no cost to them.

Early this month, Peggy was part of the American Astronomical Society's winter meeting where she met and spoke to the press and visitors to explain what the Sofia science flight was about and how the experience would impact and motivate students. Excerpts from an interview over the telephone with this writer:

Peggy: …we are called the Airborne Astronomy Ambassadors and our mission is to bring the things that we learn on flight to our students and our community… we needed to have some experience with astronomy and of course reaching students and the public. And the flight gave us first hand experience of what we teach.

I was able to sit in the jump-seat behind the pilots for takeoff. That was incredible. The pilots explained what they were doing and the fact that they needed to stay pointed in a certain direction instead of heading towards a landmark. That is part of the science/technology I took back, it relates to my physics class where we do vector problems with airplanes and winds.

I see that you saw some physics in action…

Yes. That was just the beginning. There was the concern with the amount of fuel, because flying at such great heights for so long requires a different calculation of the amount and mix of the fuel. There is less atmosphere up there at 44,000 feet, so less oxygen.

Something of the "under the hood" stuff of flying?

Exactly. After takeoff I spent the rest of the flight with the scientists in the back. Part of the time was observing their work and understanding the process that needed to happen to obtain images. There is a group of engineers that controls the telescope and a group of engineers / astronomers that work with the camera and then a group that maintains the operations of the craft itself, things like opening and closing the door of the telescope.

There was one astronomer on the plane and I followed his science. He was Bob Rubin, studying the Saturn Nebula. I read his abstract and asked him a lot of questions. He was looking at the gases in the nebula for variations in hydrogen. He was using the bands of the infra-red as a spectrometer to determine where the H alpha lines where strongest.

How did it impact your understanding of astronomy research?

It brought my learning to life to see a professional at work. The camera was developed by a team at Cornell University and the principal scientist was on board because the camera was still newly installed. He also explained how his camera worked and the various ways of calibrating the images.

It was both astronomy and the technology of astronomy?

Yes! There were at least 25 crew members, all doing different jobs to make this flight happen, not to mention the folks on the ground. Bringing back to the students the coordinated effort necessary was important. There were many meteorological insights as well that I share both with my physics, astronomy and meteorology students. The thinness of the atmosphere and the shear winds at that height are very real. We learn about it, but this made it real.


The German-built 100-inch telescope. Pic courtesy L3 Communications.

Great, you saw "in the flesh" what was in theory?

Yes! Then the great intangible is the fact that my students now have a teacher who has actually done these very real things.

You think the experience would make you a more credible and convincing, therefore more effective teacher?

It brings a certain respect and pride and inspiration for them to do more as well. Yes, definitely more credible.

You feel empowered?

Also more confident, so that all leads to more effective. Definitely empowered. I feel more able to do these things, and my students are more excited and confident that they can do authentic science in the scientific community, And it carries on, not just through me, but through my students and I believe my colleagues and the community. Regular people can participate in real scientific endeavours that they maybe thought were beyond them Nasa's science flight for teachers is only part of the awareness that science cannot keep receding from common people, faster and faster, like the expanding universe. In India, infra-red astronomy is a long way off, there are millions who may never make it to primary school. But can we wait till good numbers are literate before we think of a formal science familiarising programme?

Drawing on universities, research centres and industry to consciously share technology with common people would bring in a feeling of inclusion and scientific temper without the intermediate of formal schooling. And doing this with teachers would be doubly beneficial, by filling the community with confident and credible "ambassadors". The spinoffs would be more science, economical living, population control and literacy.

The writer can be contacted at simplescience@gmail.com

Continuous flow

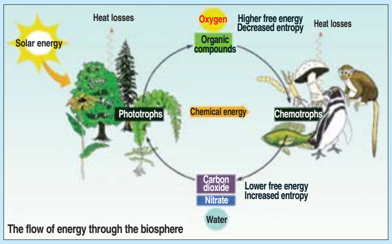
tapan kumar maitra explains the importance of energy in the biosphere

SO far, we have seen that both chemotrophs and phototrophs depend on their environment for the energy they need, but differ in the forms of energy they can use. Chemotrophs require organic molecules, whereas phototrophs trap solar radiation and transduce it into chemical bond energies.

Solar energy is trapped by phototrophs and used to convert carbon dioxide and water into more complex (and more reduced) cellular materials in the process of photosynthesis. As we will see, the immediate products of photosynthetic carbon fixation are sugars but, in a sense, we can consider the entire phototrophic organism to be the "product" of photosynthesis, because every carbon atom in every molecule of that organism is derived from carbon dioxide that is fixed into organic form by the photosynthetic process.

Chemotrophs, on the other hand, are unable to use solar energy directly and depend on the chemical energy of oxidisable molecules. The energy needs of chemotrophs can be met either anaerobically (in the absence of oxygen) by fermentation, or aerobically (in the presence of oxygen) by the complete oxidation of chemical compounds in the process of aerobic respiration. Chemotrophs, therefore, depend completely on energy that has been packaged into fermentable or oxidisable food molecules by phototrophs.

A world composed solely of chemotrophs would last only so long as food supplies held out, for even though we live on a planet that is flooded with solar energy each day, it is in a form that we cannot use to meet our energy needs.



The flow of energy through the biosphere

Both phototrophs and chemotrophs use energy to carry out work — that is, to effect the various kinds of changes we have already catalogued. In the process, two kinds of losses occur. One of the principles of energy conversion is that no chemical or physical process occurs with 100 per cent efficiency; some energy is lost as heat. In fact, most processes that involve the conversion of energy from one form to another actually dissipate more energy as heat than they succeed in converting to the desired form.

Biological processes are remarkably efficient in energy conversion. Heat losses are, nonetheless, inevitable in all biological energy transaction. Sometimes the heat that is liberated during cellular processes is put to good use. As discussed earlier, warm-blooded animals use heat to maintain body temperature at some constant level, usually well above ambient. In general, however, the heat is simply dissipated into the environment and lost.

Even more fundamental is the increase in entropy that accompanies cellular activities. We will get to that in more detail shortly; here, we can simply note that every process or reaction that occurs anywhere in the universe always does so in such a way that the total entropy, or disorder, in the universe is increased. This change in entropy occurs at the expense of energy that might otherwise have been available to do useful work and is therefore an inevitable "sink" into which energy is lost.

Just as the ultimate source of nearly all energy in the biosphere is the sun, the ultimate fate of all energy in the biosphere is to become randomised in the universe as increased entropy.

Viewed on a cosmic scale, there is a continuous, massive and unidirectional flow of energy from its source in the nuclear fusion reactions of the sun to its eventual setting, the entropy of the universe. We, here in the biosphere, are the transient custodians of an almost infinitesimally small portion of that energy, but it is precisely that small but critical fraction of energy and its flow through living systems that is of concern to us. The flow begins with green plants, which use light energy to drive electrons energetically "uphill" into new chemical bonds. This energy is then released by both plants and animals in "downhill" fermentative or oxidative reactions. This flux of energy through living matter — from the sun to phototrophs to chemotrophs to heat — drives the molecular machinery of all life processes.

The writer is associate professor and head, Department of Botany, Ananda Mohan College, Kolkata

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Pinning down Higgs boson

The search for the 'God particle' could well be nearly over, writes binay malakar

SCIENTISTS at the European Council for Nuclear Research (Cern) are working very hard to discover how particles acquire mass. In fact, researchers at the Large Hadron Collider — the world's largest particle collider near Geneva, Switzerland — are trying to detect whether or not the Higgs boson, popularly known as the "God particle", really exists. The Higgs boson is a hypothetical massive elementary particle that is predicted by the Standard Model of particle physics to explain how a spontaneous breaking of electro-weak symmetry mechanism, the Higgs mechanism, takes place in nature, which in turn explains why other elementary particles have mass.

The Higgs boson is posited to have been the agent that gave mass and energy to matter after the Big Bang creation of the universe about 13.7 billion years ago. It is regarded as the key to understanding the universe around us and its job is to give the particles that make up atoms, which in turn make the universe, their mass. Without this mass, the particles would zip through the cosmos at the speed of light, unstable to bind together to form the atoms that make up everything we see in the universe, from planets to people. Its discovery would further validate the Standard Model as essentially correct, as it is the only elementary particle predicted by the SM that has not yet been observed in particle physics experiments.

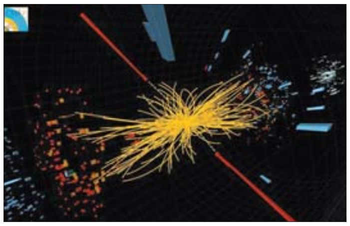

Higgs hunter: A graphic showing a collision at full power at the CMS detector control room.

According to the SM, there exists what is called the Higgs field, which permeates all of space and, in empty space, has an amplitude different from zero – ie, a non-zero vacuum expectation value. The existence of this non-zero vacuum expectation spontaneously breaks electro-weak gauge symmetry, which in turn gives rise to the Higgs mechanism.

Experiments to find whether the Higgs boson really exists or not were also being performed by Fermilab's Tevatron until its closure on 22 December 2011, but without any definite conclusion. While the use of the term "God particle" may have contributed to increased media interest, it actually overstates the Higg boson's importance. This nickname may owe to the fact that the particle is so central to the state of physics today, so crucial to our understanding of the structure of the matter, yet so elusive. It would have been better if it would have been called the "Goddamn particle" given its villainous nature and the expense it is causing to detect its existence.

Most of the accepted theories suggest that any mechanism capable of generating masses of elementary particles must become visible at energies above 1.4 Teraelectron Volt (=TeV=10^{12} eV) therefore the LHC — where two 3.5 TeV proton beams, travelling in opposite directions at 99.99 per cent the speed of light, collided on their circular journey – is expected to confirm the existence of the Higgs boson. Proof to this effect would definitely help explain a big puzzle: why some objects in the universe, such as quarks, the constituents of protons, have mass while other objects like photons, constituents of light, possess only energy but zero rest mass. Its discovery would help explain the presence of stars, planets and humans and thus rank as one of the biggest coups for modern-day physics.

In 1964, three groups of physicists independently proposed the existence of the Higgs boson, which got its name from one of the scientists, Peter Higgs, now an emeritus professor at the University of Edinburg, Scotland. Thousands of scientists have since tried to chase down the fabled sub-atomic particle. Peter Higgs actually proposed the existence of the Higgs field – which is a scalar field and the Higgs boson is a scalar boson having no spin. Theory has it that as the universe cooled after the Big Bang, an invisible force known as the Higgs field formed This field can be pictured as a pool of molasses that "sticks" to otherwise massless fundamental particles that travel through the field, converting them into particles with mass that form (for example) the components of atoms. The more strongly the particle interacts with the field, the heavier it becomes.


A typical "candidate event" for the Higgs boson, including two high-energy photons whose energy (depicted by red towers) is measured by CMS. The yellow lines are the measured tracks of other particles produced in the collision.


The CMS detector.

Massless particles such as photons are those that do not interact at all with the Higgs field. The Higgs boson is the signature evidence of the theory — an unstable particle, created a fraction of a second after the Big Bang before decaying into smaller particles that form the building blocks of the universe. This decay would leave behind a "footprint" that shows up as a bump in their graphs. To find this, scientists attempted to recreate the conditions that existed just after the Big Bang by firing two proton beams into one another through the LHC, a 17-mile ring based deep under the Swiss-French border.

Last month, scientists at a seminar at the Cern laboratory presented clues that suggested they may have at last pinned down the elusive "God particle". But they remained cautious about their findings and insisted they were not announcing an official discovery but admitted the results were intriguing and they had not yet found anything to definitely prove or disprove that the Higgs boson particle existed. But they thought they were close enough to figure it out within a year.

The Higgs boson has long been a focus of great scientific speculation. If it does exist, it is enough to account for why everything in the universe has weight. Furthermore, it could be a key component of everything, from humans to stars and planets, as well as the vast majority (96 per cent) of the universe that is invisible (23 per cent is dark matter that is ordinary matter that does not interact even with photons and so we can't see them and hence 73 per cent is dark energy that is "mysterious". Dark energy is actually a sort of repulsive force that acts against gravitational force. Scientists hope that finding the Higgs boson could help answer many of the great mysteries of the universe. Conversely, without this corner stone of physics, many of the theories that serve as the underpinnings of human understanding of the universe would evaporate. As of December last year, the Higgs boson was yet to be confirmed experimentally, despite the huge efforts in the accelerator at Cern's LHC and Fermilab.

Right now, however, physicists are not in a position to conclude anything definitely. What they need is more study and more data. However, given the outstanding performance of the LHC last year, it is expected that they will not need to wait long for enough data and can look forward to resolving this puzzle in 2012. So till then we can only keep our fingers crossed.

The writer is assistant professor, Department of Physics, Netaji Mahavidyalaya, Arambagh, Hooghly