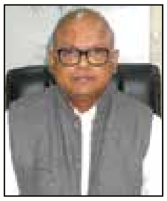
This far and no further I suppose



Dr. R. Gopichandran

One of the most often repeated barriers responsible for low science visibility in news media is the reticence of scientists. Equally important is the claim to knowledge (or the lack of it) about poor preference given by news media to science. I am inclined to say, both statements are probably unsubstantiated. These are at best some broad-brush comments and should be tackled with concerted efforts to not retard transitions to better engagement amongst the two. I suppose, it is important to engage with scientists to communicate; not so much about the results of their investigations but about the process of understanding and practising principles of science. The latter is the core element of scientific temper common citizens have to be inspired with. My case is for effective science popularisation. Microbiologists could be a case in point. For instance, they may be willing to help understand prey-predator relations, responses by cells to stimuli and adaptations by populations to propagate despite odds. These are essential elements of systems understanding that can stimulate interest in the applications of scientific thinking and can be with equal emphasis across disciplines. This is quite different from asking them about the contribution their work has made to monetary benefits for the society; or if their work has fetched any international recognition. In defence of scientists, I will say; they are justified in their reticence; because their insights and contributions to the landscape of knowledge are undermined, when we do not acknowledge the nuances of such knowledge-centred gains. Their contributions may in fact create newer cascades of knowledge or even strengthen some incrementally. The news media too should not be blamed for its unresponsiveness. Why can't good work be articulated in a manner that will elicit a keen response from them for ready and large scale publication? It is equally important to upfront state the limits and limitations of emerging knowledge and the consequences of applications of such knowledge; especially to gain the confidence of the discerning common citizen reader.

Two important considerations guide me on the submission I make, in the context of the all that I have said above. We cannot deny the fact that there is significant volume of information in the public domain on progress in S&T in our country. Many newspapers and some leading popular magazines serve this purpose. Will it therefore be right to ask if these can be significantly scaled-up further; networked and assisted with articulation that may attract common citizen's attention in much greater numbers than now? This question about numbers becomes important because we ask about the number of people who actually take up science as career paths or even acknowledge the value of knowledge benefits derived through S&T efforts. Many scientists from our labs gain significant national/international recognition for their excellence. It will be wise to therefore stop all cacophony about the two claims I started with and get down to business. The agenda will be to upscale spread, depth and visibility of science and technology related development and leadership in our country through a concerted effort. Can we create/strengthen knowledge networks amongst research and development institutions to communicate with greater frequency and clarity about progress, strengths and successes? Is it possible to invite media-savvy science communicators to articulate in a manner that will attract media to publish ever more? This coming together is quite important in today's context, especially when missions of the government focus on S&T-led development.

Climate change impacts management, waste-to-energy, conservation and enhancement of natural resources with implications for sustainable development, eco-system services, water, sanitation and health correlates, drudgery reduction and resource-efficient production and consumption are some of the easier entry S&T interfaces that have to be given their due attention through well informed community action. It is time we take up the task of reaching the unreached and creating robust knowledge-centred enabling circumstances, guided by empirical evidences about the preparedness of players to comprehend and communicate. This far and no further on the dilemmas please. We will have to come together to assist the development agenda of our country through value added S&T communication. Scientists/technologists, news media and citizens have equally important roles in this context.

Email: r.gopichandran@vigyanprasar.gov.in

Editor : R Gopichandran
Associate editor : Rintu Nath
Production : Manish Mohan Gore and Pradeep Kumar
Expert member : Biman Basu
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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Big Bang from Nothing

Govind Bhattacharjee
E-mail: govind100@hotmail.com

There was absolutely nothing at the beginning of time and space; it was a complete void. Human imagination falters at the thought of such a void. Out of this unthinkable, all-pervading void arose a stir, a random quantum fluctuation, and time and space and all the matter and energy that is our universe – this unfathomably beautiful ocean of existence – sprang into being. It was a creation *ex-nihilo* – out of nothing. This tiny fluctuation of the vacuum would ultimately turn into the Big Bang, creating the universe of countless galaxies and stars, and in course of time, creatures capable of wondering at the mystery of their origin.

It is indeed strange and bizarre that nothingness would have such a wondrous creative potential latent in it. The idea that a void could convert itself into such a remarkable plenum of existence was first suggested by Edward Tryon, an American scientist in the journal *Nature* in 1973. It has long been known that every physical phenomenon in this universe is guided by a set of conservation laws in which some particular physical quantities like electric charge or total energy or total momentum remain unchanged; we say these quantities are 'conserved'. Tryon in his paper 'Is the Universe a Vacuum Fluctuation?' pointed out that the sum of all the conserved charges for the whole universe was consistent with being zero. Similarly, the total energy of the universe also adds up to zero. It is because while the energy of all the matter ($E=mc^2$) is positive, the energy of the gravitational field through which they interact is negative.

That energy can be negative is in itself a strange idea, but strange ideas are what science takes sustenance from. Gravity is the strangest and the most bizarre of all the forces in nature. Every mass attracts every other mass, and thus has its own gravitational field over which the attractive force of its gravity acts and pulls at every other mass with a force, which is inversely proportional to the distance between them. The gravitational energy of the objects is zero, when they are at 'infinite' distance away.

When a body is brought near to another from far away under the attractive force of their gravity, the energy of the bodies is liberated rather than expended, i.e., they lose energy. They start with zero gravitational energy, and end up with negative energy. This is what is meant by saying that the energy of the gravitational field is negative. Any object, say a planet or a star, contain an infinite number of small masses put together, and thus has a definite amount of negative gravitational energy. In contrast, the mass-related energy of the body is always positive, being equal to the product of its mass and the square of the velocity of light ($= mc^2$).

What Tryon showed was that if the star is squeezed into a singularity, a point where the quantities that are used to measure its gravitational field tend to become infinite, its negative gravitational energy will continue to increase and then, at the singularity, its positive mass energy will exactly cancel the negative gravitational energy. Thus, the negative energy of the universe can be shown to cancel all the positive energy leading to a vacuum state equivalent to zero energy. This means it would take no energy to create the universe. And thus the laws of physics are perfectly consistent with the creation of a universe *ex-nihilo*, out of a void, and the universe could emerge out of the void without violating the law of conservation of energy, a sacrosanct principle of physics. It was a random event which occurs purely governed by chance, guided by no laws, and, therefore, needing no lawmaker or God.

That the universe has zero net energy could also be experimentally found from the rate of expansion of the universe. The rate of cosmic expansion depends on the overall density of mass in the universe, i.e., the amount of matter per unit volume. This quantity, denoted by the Greek letter omega (Ω), can be measured. The latest measurement reveals that it is close to unity. If it were less than unity, then the universe would continue to expand forever and it would be 'open'; if it were more than unity, then the expansion of the universe would come to a grinding halt, resulting in the collapse of all matter in a 'Big Crunch' as grand as the 'Big Bang' and the universe would be 'closed'.

The first 300,000 years since the Big Bang was filled with radiation which was so hot that matter could then exist only in a dense state of 'plasma' consisting of protons and electrons at extremely high temperature. However, plasma is opaque to radiation, and even if it was possible to look as far back into the past towards the Big Bang, the surface of the 300,000-year-old universe would permanently block our sight and we would not be able to 'see' anything earlier than that, since we can see only with the help of light. Therefore, the 300,000-year-old universe is the earliest frame of reference for any measurement to be made.

At 300,000 years, the temperature of the incredibly hot Big-Bang universe had dropped to only 3000 kelvins[1] when electrons started combining with protons forming neutral atoms, mostly of hydrogen, and the universe started becoming transparent to radiation. From then on, atoms would start absorbing and re-emitting the photons that would be scattered by other particles of matter, making the universe transparent to light. As the expansion continued unabated, cooling the universe, the colour of radiation changed gradually – from yellow to orange to red to a deep red and then to the darkness of deep space. The universe had expanded about 1,000 times since then and the wavelength of the photons has also stretched by the same factor. As temperature dropped ultimately to only 2.73 kelvins, the sea of photons would thus fade away slowly, changing from high-energy gamma radiation to the low-energy microwave radiation. This cosmic microwave background radiation was detected by Arno Penzias and Robert Wilson in 1964 with their radio telescope, which earned them a Nobel Prize.

The microwave background radiation is uniform and homogenous. Since our reference frame is the 300,000-year-old universe, we can assume that matter and energy were distributed uniformly in that universe. If we can take a picture of our 300,000-year-old universe, we would be able to see all the nascent structures in that universe – the small lumps of matter that were formed till that time arising from tiny perturbations in matter and energy in the very early universe. These lumps would later evolve into galaxies, stars and planets that would define the large-scale structure of the universe billions of years later. This would enable us to measure whether the universe is open, closed or flat. If the universe was close, the lumps of matter would be close together making for higher density (Ω>1), while in an open universe they would be scattered farther away from each other and Ω would be less than 1. If the universe was flat, Ω would be close to 1.

An arc on the surface of this universe 300,000-year-old that subtends an angle of 1 degree at Earth would cover a distance of about 300,000 light years across. But here our assumption of one degree needs a qualification. The angle would actually be determined by the geometry of the surface of the universe.

On a flat surface, light rays travel in straight lines and a triangle traced by them would consist of three straight lines enclosing 180 degrees, as we know from Euclidean geometry. But in a closed universe shaped like a sphere, such a triangle would include more than 180 degrees; light rays in such a universe would converge when we look backwards in time. In an open universe shaped like a saddle, the three angles would enclose less than 180 degrees and light rays would curve outwards as we follow them backwards in time. Thus whether the angle covered by a distance on 300,000 light years on the surface of the 300,000-year-old universe would be exactly one degree, or more or less would depend on the geometry of this universe.

To determine the geometry, an experiment was designed in 1997, and repeated in 2003, called BOOMERANG (Balloon Observation Of Millimetric Extragalactic Radiation ANdGeophysics). It mapped the 3 K microwave sky by circling over Antarctica at an altitude of 42 kilometres, to avoid any contamination by far hotter temperatures elsewhere on Earth. The high-altitude balloon, with the help of an onboard microwave radiometer, captured the image of a small part of the microwave sky, 'displaying hot and cold spots in the radiation pattern'. This pattern replicated the structure of the 300,000-year-old universe, since that structure would have remained unaffected by the subsequent 'dynamical evolution' of the universe. The image of the microwave sky was compared with the computer simulations of images for closed, open or flat universe. The captured image showed an uncanny resemblance with the simulated image for a flat universe, indicating that its geometry is Euclidean, not curved. The BOOMERANG results were reported in 2000, after 50 million observations for each of 16 channels at four frequencies in the microwave radiometer, and indicated that the universe was indeed flat.

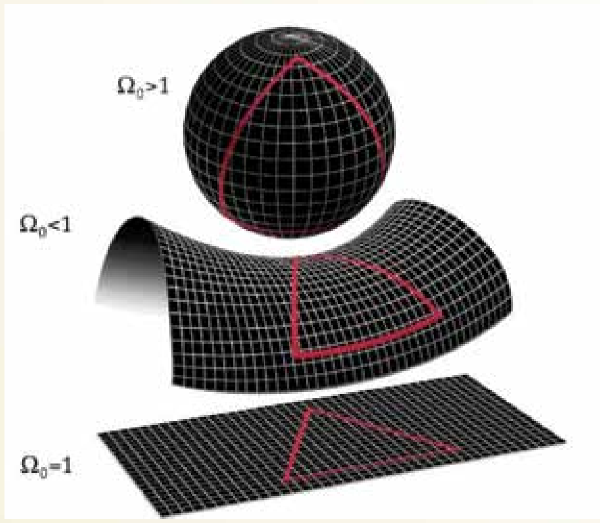


Fig.1. Three possible geometries of the universe[2]

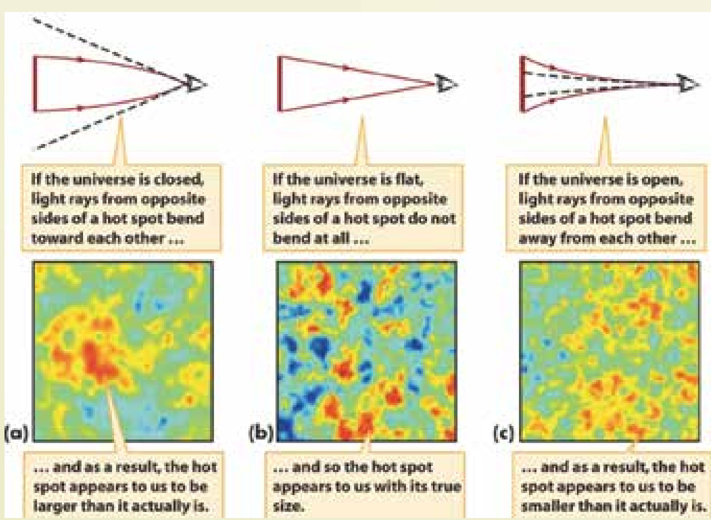


Fig.2. Appearance of hot spots in BOOMERANG experiment depending on the specific structure of the universe[3]

The results of the BOOMERANG experiment are extremely important to explain the creation of the universe, because unlike an open or a closed universe, a flat universe would not require any energy that already existed somewhere to create it. Thus quantum fluctuations alone would suffice to create such a flat universe from nothing, as postulated by Tryon.

When Hubble's observations about the expanding universe had pointed towards the Big Bang origin of the universe, physicists faced an insurmountable problem. If we wind the cosmic clock backwards, we arrive at the beginning of the universe when all matter and energy of the universe were concentrated at a point from whence the universe sprang into existence. But, then, concentration of all matter and energy at a point would imply a state of infinite compression, and space (along with time, since there can be no space without time) would disappear at such a state, as it would have been compressed infinitely so as to disappear completely. This state is known as a 'space-time singularity'. Because all laws of physics are framed in terms of space and time, there cannot be any law of physics at this point when space-time itself ceases to exist. Thus all laws of physics would break down at a singularity. How then could one explain the origin of the universe? Yet Big Bang was an established reality, tested by experiments, which could not be easily explained away. Actually Big Bang did not happen at a point in space; rather space, along with time, itself came into existence with the Big Bang.

Scientists could not find a convincing way of resolving this difficulty. As long as this mystery was not resolved, there was still the scope to invoke an all-powerful God to trigger the creation event. To understand how the problem was solved by physicists in the 1980s, we have to redirect our focus away from the grand world of stars and galaxies into the microscopic world of fundamental particles– and follow the laws that guide their behaviour, i.e. the laws of quantum mechanics.

At the turn of the 20th century, two remarkable developments had revolutionised our comprehension of the physical world. One of course was the theory of relativity, but equally remarkable was the discovery of the laws of quantum mechanics in the 1920s, which recognised probability as a fundamental feature of the atomic reality which governs all processes, even the existence of matter.

Quantum theory started with investigating the nature of propagation of light. Till then, it was held that light was propagated in the form of a continuous wave. In an ultimate break from classical physics, quantum theory proved not only that light was emitted and absorbed in a discontinuous manner; it was also propagated in a discontinuous manner, in small packets of energy called photons or quanta. In 1913, Niels Bohr applied these ideas to build up his model of the hydrogen atom, which, with astonishing simplicity, could successfully explain the radiation of spectral lines by atoms. Quantum mechanics had indeed come to stay!

But the new theory threw up more problems than it solved, as science always does. Discreteness is a property associated with particles, not with waves. We can visualise streams of particles, and if light consisted of streams of photons, each with a definite amount of energy (= Plank constant *h* multiplied by the frequency of light), then light should always behave as particles. But it was also a well-established experimental fact that light did behave as if consisting of waves, as evident from the experiments on interference of two beams of light derived from the same source, or from experiments on polarisation, i.e., cutting out some of the vibrations in the waves. They could only be explained in terms of the wave theory. A wave is a spread out thing in space while a particle, like the photon, is a localised thing. How can something which is spread out be localised at the same time? These two concepts were apparently irreconcilable.

Failure of the quantum theory to explain the wave properties of light would open up a whole new dimension about what physical reality, and that reality turned out to be far stranger than fiction. So strange was it that even Einstein, whose theories played a crucial role in establishing the nature of this reality, refused stubbornly to accept its implications, by saying that God did not play dice with the world.

Classical physics taught us that particles and waves are separate entities; together they constitute the physical reality. Quantum physics told us that in the micro-world of atoms and electrons, there was no such thing as a particle or a wave; that it depended entirely on our observation and interpretation whether an electron would behave as a particle or as a wave. Classical physics made us believe that we were independent observers in a world where the particles and waves played their respective roles to be observed and interpreted by us. Quantum physics told us that we were no longer the 'outside' observers in this universe. We are, in fact, participators in Nature's scheme of things, and being participators, we also determine the course of events. In the world of quantum mechanics, no event is an event unless it is observed. The act of observation itself interferes with the course of the event being observed and thus determines it. Thus, just as light, which is an electromagnetic wave, can behave also as streams of particles, so also a particle like electron, which exhibits the particle properties by possessing charge and mass, can also behave as a wave. How either will actually behave, however, depends on what observation we decide to make on them.

Another important pillar of the Quantum Theory is Heisenberg's 'Uncertainty Principle' which sounded the death-knell of the principle of scientific determinism. A particle is associated with certain pairs of properties, e.g., position and momentum, energy and time, etc., which according to classical physics could be accurately determined. By knowing the position and momentum of the particle precisely at any given instant, it is possible, according to classical physics, to predict its entire future course. But a particle is not simply a particle in quantum mechanics; it is only one description of the reality, the other being its wave properties. The uncertainty principle only measures the extent to which these complementary descriptions overlap.

Position and momentum (= mass* velocity) are fundamental properties of a particle. But a particle is also a wave, and a wave cannot be reduced to a point; it always shall have a spread, and this spread therefore measures the uncertainty in the position of the particle. Similarly, momentum of the wave depends on the wavelength, and the spread in wavelength also determines the uncertainty in the momentum.

The interesting thing is that the length of the region the particle occupies and the spread in its associated wavelength are not independent, but are inversely related to each other; the more we want to localise the particle by confining it to smaller and smaller regions, the higher will be the spread in wavelength. In other words, the more certain we want to be about the position of the particle, the more uncertain we shall be about its momentum and *vice versa*. The Uncertainty Principle says that the product of the uncertainties is limited by the Plank's constant *h*. The energy possessed by a particle and the time interval during which it possesses that energy also exhibit an identical relationship of uncertainty.

The consequence of this is startling – it means that during an infinitesimally small interval of time, an atomic event can possess unusually large amount of energy without violating the principle of conservation of energy. Since energy and matter are basically the same, therefore this amount of energy can be large enough to allow for the spontaneous creation of quantum particles (e.g., an electron) and its antiparticle (positron), which are equal in all respects except for the electric charge. The two charges exactly cancel each other and conform to the law of conservation of charges. Particles created from photons are called virtual particles, which do not have any real existence as they exist only for the brief time interval allowed by the uncertainty relation and then annihilate each other, liberating the energy that has gone into their making before any human device could register their presence.

The uncertainty relation thus implies that energy can be created out of nothing for extremely short time periods and virtual particles can go in and out of reality spontaneously. It allows virtual particles – 'virtual' because they cannot be observed directly;, they pop in and out of existence quantum mechanically – to carry almost infinite amounts of energy, provided they last for infinitesimally short intervals of time before disappearing again. They can be created out of nothing carrying ever larger amounts of energy and disappear again into nothing in ever shorter intervals of time. The process is a random one, and thus a vacuum randomly fluctuates between being and nothingness, between form and emptiness, though in the end they cancel each other out. Only if enough energy is supplied to this vacuum from an external source, these virtual particles in the vacuum would become real.

Thus vacuum, or empty space, in reality is not empty, but rather a plenum where matter and energy are being created and destroyed continually in a superb cosmic dance. These ideas of the relativistic quantum field theory were conclusively proved in experiments conducted at CERN, Geneva, in the giant superconducting super-collider accelerator machine where collisions between matter (made up of particles) and anti-matter (made up of anti-particles) provided the energy necessary to bring the virtual particles fluctuating in vacuum into real existence.

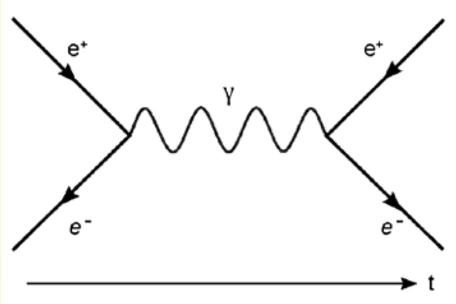


Fig.3. An electron and a positron annihilate each other producing energy in the form of gamma radiation (left), and an electron-positron pair pops out of energy as virtual particles (right)

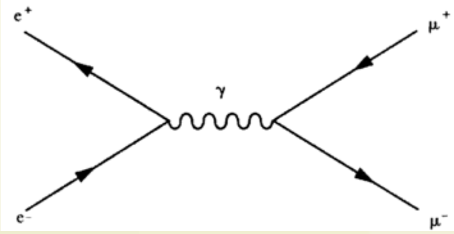


Fig.4. An electron and a positron annihilate each other producing energy in the form of gamma radiation (left), and another particle-antiparticle pair of muons as virtual particles (right)

But the problem is who supplied the extra energy to one virtual universe to create this real universe? The answer is gravity, the oldest known and perhaps the least understood physical phenomenon. The reason that real particles cannot spring into existence out of empty space is that our space today is flat in which a light ray is constrained to travel ordinarily in a straight line, and for such a space, the law of conservation of energy dominates, forbidding such 'real' creations. But at the beginning of space and time, when no law including the law of energy conservation existed, creation of 'real' particles by a random quantum fluctuation of the vacuum was a distinct possibility if space was extremely curved, like a sphere. In the first such mathematical model of the universe developed in 1978, it was shown that a fluctuation could produce a few particles and then the mutual gravitational interaction between them would cause space to become curved, leading to a cascade of more particles and more curvature of space and this would result in an expanding universe starting from a hot Big Bang.

But the problem still remained. As soon as the universe containing as much matter as it actually contains starts expanding soon after its creation, the enormous gravitational pull between all the matter confined within a volume as small as an atomic nucleus would force it to collapse upon itself, creating a new singularity in which everything would disappear instantaneously. There has to be a mechanism to expand this nascent universe, during the split second of its virtual existence, incredibly rapidly so that its size increased manifolds before gravity could start working. The puzzle was solved finally by Alan Guth and Alex Vilenkin, by suggesting a mechanism of 'inflation'. In 1983, Vilenkin had constructed a model and a mechanism for a universe in which a 'nothing', a 'void', could randomly convert itself into geometry of space-time from which a Big Bang would result. Thus space-time could come into existence out of absolutely nothing and could just as well disappear into nothing.

It is now possible for us, imperfect human beings, to look into and explain the Genesis without invoking the all-knowing intelligence of an omnipotent God. From the frothing sea of vacuum, the structure of space-time came into existence as a random event at zero time. We recall that the quantum effects become dominant when the numbers, dimensions, time are of the order of Planck's Constant (~10^{-27}) or smaller. The earliest time the calculations of relativistic quantum gravity has so far probed into is 10^{-43} second (10million trillion trillion trillionth of a second) after Genesis. This is known as the 'Planck time'. The temperature of the universe was an enormous 10^{32} kelvins, and its size of the order of Planck length, which is 1.6×10^{-35} metre. It was at this stage that gravity started asserting itself, twisting and warping the structure of space-time upon which the future events will take place. It was a microscopic and empty universe – just a point upon a timeless, space-less, perfectly symmetrical vacuum. Human imagination stumbles to grasp such a state of non-being.

The symmetry would soon break and a billionth of a second later, the cosmic cast of all matter would appear in the form of quarks, leptons and gluons, which would eventually form the atoms and molecules and stars and galaxies. The primeval void would ultimately evolve into the present cosmos. Emptiness would take form.

References

1. Kelvin scale temperature is obtained by deducting 273 from the corresponding Celsius scale temperature.
2. Source: http://timcooley.net
3. Source: http://ircamera.as.arizona.edu

Govind Bhattacharjee is a senior civil servant and a popular science writer. The article is based on Author's forthcoming book *Story of the Universe* being published by Vigyan Prasar.

Cancer and Traditional Medicine

Ratnadeep Banerji
E-mail: ratnaub@gmail.com

Charaka and Sushruta Samhitas, are two well-known Ayurvedic classics that describe cancer as inflammatory or non-inflammatory swelling and mention them as either *granthi* (minor neoplasm) or *arbuda* (major neoplasm). Ayurvedic literature defines three body-control systems, viz., the nervous system (*vata* or air), the venous system (*pitta* or fire), and the arterial system (*kapha* or water), which mutually coordinate to perform the normal function of the body. In benign neoplasm (*vataja*, *pittaja* or *kaphaja*) one or two of the three bodily systems are out of control and is not too harmful because the body is still trying to coordinate among these systems. Malignant tumours (*tridosaja*) are very harmful because all the three major bodily systems lose mutual coordination and thus cannot prevent tissue damage, resulting in a deadly morbid condition. Charaka, the Ayurvedic physician had mentioned treatment of both *arbuda* and *granthi*.

According to Sushruta, the fundamental causes of major neoplasm are pathogens that affect all parts of the body. He called the sixth layer of the skin as '*rohini*,' (epithelium) and believed that pathogenic injuries to this layer in muscular tissues and blood vessels, caused by lifestyle errors, unhealthy foods, poor hygiene and bad habits results in the derangement of *doshas*, which leads to the manifestation of tumours.

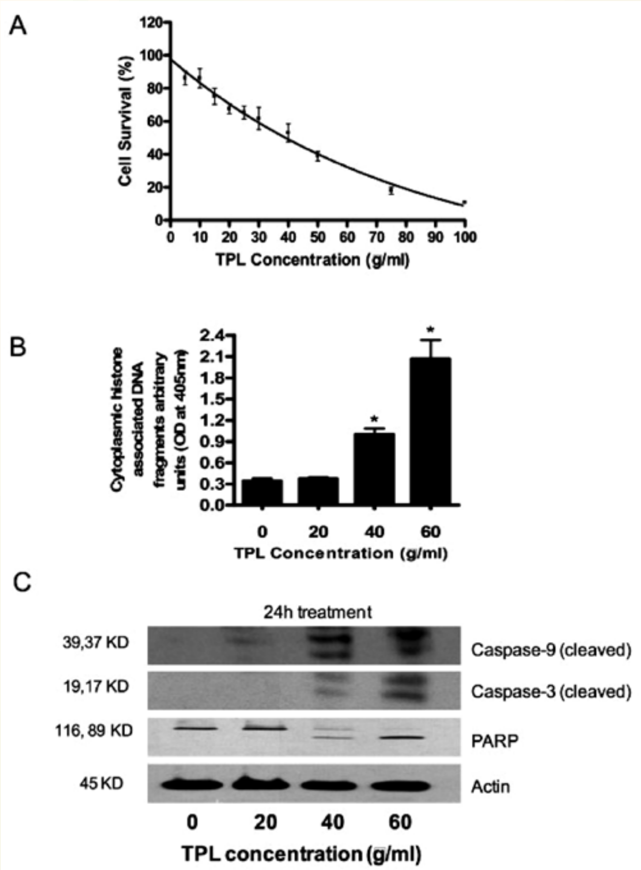


Figure 1: Reduction in pancreatic cancer cells with increasing dose of triphala.

(From: Shi Y, Sahu RP, Srivastava SK. Triphala inhibits both in vitro and in vivo xenograft growth of pancreatic tumor cells by inducing apoptosis. BMC Cancer 2008;8:294. doi: 10.1186/1471-2407-8-294.)

In Ayurveda classics, numerous references are available on the anti-cancer properties of *Semecarpus anacardium* nuts called *bhallatak* in Hindi. An extensive review describes the phytochemical and pharmacological properties of *S. anacardium*. The chloroform extract of *S. anacardium* nut possess anti-tumour action and is said to increase life-span against leukaemia, melanoma and glioma. The milk extract of *S. anacardium* produces regression of hepatocarcinoma (cancer of the liver) by stimulating host immune system.

Several compound formulations like *triphalaghrita*, *khadirarista*, *madhusnushi rasayana*, *maha triphaladya ghrita*, *panchatikta* and *guggulu ghrita* mentioned in Ayurvedic texts contain anti-neoplastic agents for management of cancer. The formulation of *triphala* possesses the ability to kill tumour cells but spares the normal cells. The differential effect of *triphala* on normal and tumour cells seems to be related to its ability to evoke differential response in intracellular reactive oxygen species generation.

Allium sativum (garlic)

Allium sativum contains plentiful of chemical compounds that are helpful in prevention and treatment of different types of cancer. Allicin is a compound possessing antioxidant and anti-cancer activities. It can penetrate very rapidly into different compartments of the cell and is completely metabolised in the liver. Experimental studies provide evidence that garlic and its organic allyl sulphur components are effective inhibitors of tumour growth.

Curcuma longa (haldi)

Curcuma longa or turmeric has potent anti-cancer properties. Curcumin has potent anti-oxidant and free-radical-removing properties which prevent DNA damage. Curcumin also has positive effects on multiple pathways of cell cycle and anti-tumour properties. It may be used for the treatment and adjuvant therapy of leukaemia and lymphoma, gastrointestinal cancers, genitourinary cancers, breast cancer, ovarian cancer,

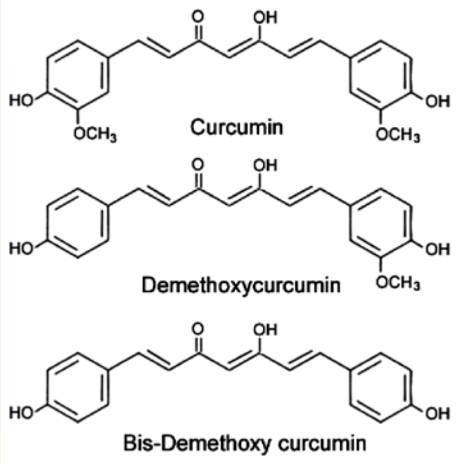


Figure 2: Structure of various curcuminoids – active molecules present in turmeric or haldi

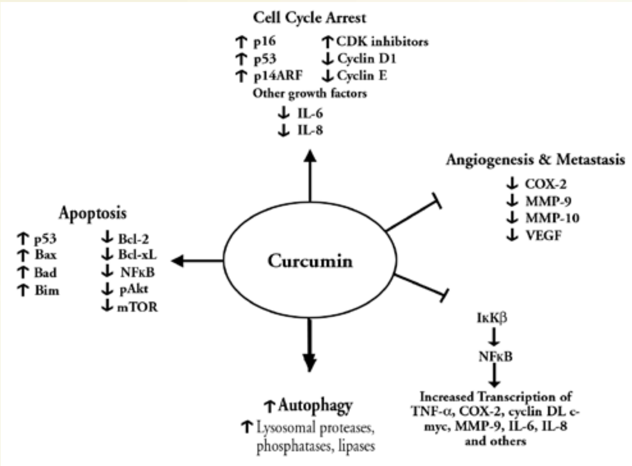


Figure 3: Anti-cancer effects of curcumin through various mechanisms by affecting different genes in the cells.

(Figure 2 and 3 are from the research article: Wilken R, Veena MS, Wang MB, Srivatsan ES. Curcumin: a review of anti-cancer properties and therapeutic activity in head and neck squamous cell carcinoma. Mol Cancer 2011;10:12. doi: 10.1186/1476-4598-10-12)

head and neck squamous cell carcinoma, lung cancer, melanoma, and neurological cancers.

Anticancer property of *Ocimum sanctum (tulsi)*

The experimental studies carried out on fibrosarcoma cells in culture have demonstrated that *Ocimum sanctum* exhibits anti-cancer activity. Fresh leaves of *O. sanctum* have been shown to enhance immunity and also to possess anti-carcinogenic properties in experimental animals. *Tulsi* has been found to decrease the incidence of chemical-induced neoplasia in experimental animals. Eugenol, a flavonoid present in many plants including *tulsi*, exhibits anti-metastatic activity.

Anti-cancer properties of fenugreek seeds have been proven after proper pharmacognostic and phyto-chemical analysis. *Syzigium aromaticum* (clove) too exhibits cytoxicity against several kinds of cancer cell lines of various anatomical derivations.

The electrochemical behaviour of the anticancer drug emodin hydroxyanthraquinone present in *Aloe vera* leaves has a specific activity against neuroectodermal tumour (a tumour of the central or peripheral nervous system). The cytotoxicity mechanism consists of the induction of apoptosis (cell suicide), whereas the selectivity against neuroectodermal tumour cells is founded on a specific energy-dependent pathway of drug incorporation. *Glycyrrhiza glabra* (liquorice) is active against prostrate cell line and so is *Terminalia chebula* called *haritaki* in Hindi, active against leukaemia cell line.

AYUSH (Department of Ayurveda, Yoga and Naturopathy, Unani and Siddha and Homeopathy) has developed an Ayurvedic coded drug AYUSH-QOL-2C for improvement in quality of life in cancer patients, which is currently in clinical trial.

Veeramezhugu is an anti-cancer formulation in the Siddha system. It is a poly herbo-metallic preparation comprising *veerum* (corrosive sublimate), *rasam* (mercury), *pooram* (calomel), *lingam* (cinnabar), *sudam* (camphor), *sambirani* (benzoin), *perungayam* (asafoetida), *vediuppu* (potassium nitrate), *navacharam* (ammonium chloride), *vengaram* (borax), *nervalam* seed (*Croton tigilium*) and honey. The Siddha pharmacopoeia holds out several potent formulations for tackling cancer.

Researchers at the National Cancer Institute, USA have found that plant-derived compounds have been an important source of several clinically useful anti-cancer agents. These include vinblastine, vincristine, paclitaxel and many others. Many botanical compounds, which have been demonstrated to have positive effects in cancer therapy, have a long history behind them. For example, it was recently demonstrated that the green tea anti-oxidant EGCG (epigallocatechin-3-gallate) significantly slowed breast cancer growth in female mice: its use is attested in ancient Japanese texts. Promising and selective anti-cancer effects have been observed with saffron (stigmata of *Crocus sativus*) but not yet in clinical trials. The search for anti-cancer lead compounds has been the mainstream of marine chemistry. As a result, a number of natural marine products with unique mechanisms of action have been identified and recently entered clinical trials.

The use of juice, peel and oil of *Punica granatum* or pomegranate has also been shown to possess anti-cancer activity, including interference with tumour cell proliferation, cell cycle, invasion and angiogenesis.

Myrrh is derived from the dried resin of desert trees, *Commiphora myrrha* and other species. In biblical terms, it was chosen, along with frankincense and gold, as a gift of the Three Wise Men to the newborn Christ. Hailed for its anti-inflammatory and disinfectant properties, myrrh has historically been used for ailments as diverse as stomach pain, indigestion, poor circulation, wound healing, certain skin diseases and irregular menstrual cycles. What makes myrrh such an exciting player in the anti-cancer field is not only how well it kills cancer cells in general, but how it kills those that are resistant to other anti-cancer drugs. It is believed to work by inactivating a protein called Bcl-2, a natural factor that is overproduced by cancer cells, particularly in breast and prostate cancers. Although myrrh compound does not appear to be as powerful as other anti-cancer drugs derived from plants – such as, vincristine, vinblastine and paclitaxel – its advantage seems to lie in the fact that it can harm cancer cells without harming healthy cells, something these other drugs do not do.

Vinca alkaloids are isolated from the periwinkle plant *Vinca rosea*. Extracts of *Vinca rosea* possess many therapeutic effects including anti-tumour activity. Vincristine, vinblastine and vindesine are the first vinca alkaloids with anti-tumour activity to be identified. Vinorelbine is the first new second-generation vinca alkaloid to emerge. Vinflunine has been synthesised by superacid chemistry and is now being widely studied in phase I–III clinical trials.

Owing to the benefits of traditional medicines, WHO has included integrative oncology as one of the primary objectives of treatment and prevention of cancer.

Ratnadeep Banerji is a senior feature writer, author and documentary maker.

**Based on an Indo-US workshop on fighting cancer with traditional medicine organised in March 2016 by AYUSH Ministry of the Government of India and the Department of Health & Human Services of the Government of USA along with National Institute of Health (US) and National Cancer Institute (US).*

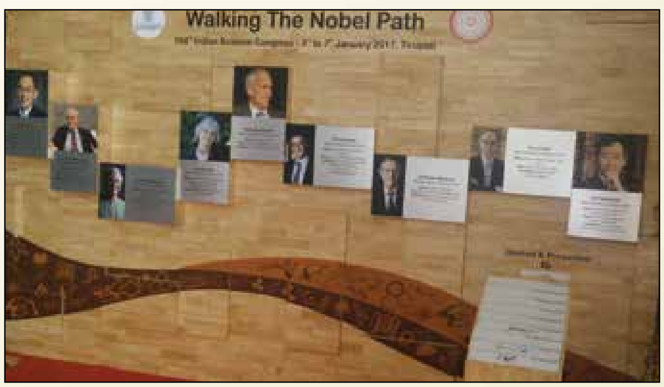
Nobel Talks at Science Congress Highlight New Developments

The 104th session of the Indian Science Congress held in Tirupati in the first week was attended by half a dozen Nobel Prize winners. The lectures delivered by the Nobel laureates were a major attraction during the week-long session of the Congress. All the lectures were attended by thousands of scientists, researchers and students, and were followed by lively interaction with the laureates. Here are highlights of the Nobel lectures at Tirupati written by editorial team of the Indian Science News and Feature Service (T.V. Venkateswaran, Dinesh C Sharma, Navneet Kumar Gupta and Bhavya Khullar):

Of teleportation and quantum systems

"Teleportation of living beings will remain in science fiction" opined Serge Haroche, joint winner of the 2012 Nobel Prize in Physics along with David Wineland for their work in 'advancing ability to control and observe individual quantum systems', while answering a question posed by a student after his lecture at the 104th Indian Science Congress held at Tirupati. Prof. Haroche compared the process of photocopying with teleportation and said, "teleportation is like obtaining a copy from the photocopying machine", although the crucial difference would be that "in the case of an original copy that remains after being copied, the teleported object would not remain." While he opined that teleporting inanimate objects could be feasible, he said, "it is highly impossible in teleporting a cat or a human being" and such a dream would forever remain in the realm of science fiction.

Prof. Haroche's lecture highlighted how our intuitive ideas fail in the realm of microcosms. He said, "When it comes to the smallest components of our universe, our usual understanding of how the world works ceases to apply. We have entered the realm of quantum physics". To illustrate the point, he recalled the double-slit experiment, one of the most famous experiments in quantum physics, which clearly demonstrates the weird quantum world. When macro-scale objects, say cricket balls, are shot at a barrier with two parallel slots, the objects travel straight through either of the slots and leave marks at two distinct vertical patches on the screen behind the barrier. Instead, if we use electrons or photons, they create an interference pattern of parallel dark and bright bands, instead of two vertical bands. Even if electrons are released one by one, the theory says interference pattern would still be seen; suggesting that each electron somehow travels through both slits at the same time and interferes with itself, like a wave instead of a particle. On the other hand, if we set up a detector near the slits to find if indeed an electron has passed through that slit, then the electrons stop creating an interference pattern and instead distinct hits are recorded, as in case of classical particles.



Nobel gallery at the Indian Science Congress, Tirupati

For a long time, many quantum phenomena could only be examined theoretically and thought experiments remained merely in the realm of theory. For example, American theoretical physicist John Wheeler wondered in 1978 what happens if the decision to open or close one of the slits is made after the particle has left the source and started travelling towards the slits. If an interference pattern is still seen when the second slit is opened, we would be forced to conclude that our decision to measure the particle's path affects its past decision about which path to take, or to abandon the classical concept that a particle's position is defined independently of our measurement. This thought experiment was experimentally verified only recently. Prof. Haroche pointed out, with the advances in quantum theory, many new devices could be fabricated which in turn helped experimental verification of the quantum theory. Prof. Haroche's ingenious experiment to 'trap' and capture photons using a new kind of trap in which microwave photons are made to bounce back and forth inside a small cavity between two mirrors, about three centimetres apart, helped study quantum phenomena when matter and electromagnetic waves interact.

Going deep in search of neutrinos

The one of its kind, India-based Neutrino Observatory is expected to come up at Bodi hills in Pottipuram village, Theni district of Tamil Nadu later this year. The world-class underground laboratory set in a deep cavern will use a 50,000-tonne magnetised iron calorimeter that includes the world's most massive magnet to detect particles called muons that are produced on rare occasions when neutrinos interact with matter. The setting up of the India-based Neutrino Observatory will boost basic science research in India, especially in the south.

The India-based Neutrino Observatory is an ambitious project that stems from the work of the 2009 Physics Nobel Prize winner Professor Takaaki Kajita, who shared details of his research at the Science Congress. Neutrinos are supposed to be neutral and weakly interacting particles which were produced in abundance in the Big Bang and continue to be produced by the Sun and from collision of cosmic rays hitting the Earth's atmosphere. In the standard model of particles and fields, neutrinos were supposed to be massless. Prof. Kajita found that the elusive neutrino which was once accepted to be massless actually has mass. His discovery refuted the well-established model of an atom, once found in physics textbooks across the world.

In 1998, in an experimental facility in a mine in Japan, called the Super Kamiokande detector, Prof. Kajita found that neutrinos were created in reactions between cosmic rays and the Earth's atmosphere. Contrary to the well-accepted theory of that time, his experiments proved that neutrinos had mass. This has led to a search for newer sub atomic particles, which could be discovered in the near future. The Kamiokande detector is located at the Kamioka Observatory 1000 meters below the ground in a mine near Kamioka town.

New avenues to fight antimicrobial resistance

You could kill a living biological cell by shutting down the factory that synthesises all its protein – the ribosome. Ribosomes translate nuclear signals or RNA into proteins that are vital for cellular growth, life, and reproduction. Ribosomes in bacteria and in higher organisms such as humans are different in their structure. If only we could find drugs that specifically bind to, and inhibit the ribosomes of bacteria without affecting the synthesis of proteins in humans, we would have antibiotics that hit the bulls-eye, according to Nobel laureate Ada E. Yonath.

Prof. Yonath along with Thomas A. Steitz and India-born scientist Venkatraman Ramakrishnan shared the 2009 Nobel Prize for Chemistry for their discovery of the structure and function of ribosomes. With the help of high-resolution images, they found that the unique structure of ribosomes enables them to place substrates and catalyse the formation of proteins, just like enzymes. This has helped elaborate the mechanism of action of more than 20 new antibacterials to date.

"We can also know if a drug binds the active site of the ribosome *in silico* (conducted or produced by means of computer modelling or computer simulation), by simulating the binding of 3D structures of drug and ribosome, using a computer program, said Prof Yonath. This has opened new avenues of research in the field of molecular drug design. Pathogens are continuously evolving resistance to available antibiotics. This discovery could help scientists design new antibacterials to combat growing menace of multidrug-resistance.

Live streaming of molecules a reality

Viewing 'live' streaming of small molecules inside a living biological cell with ultra-high-resolution seemed impossible before the 1980s. After the discovery of single-molecule super-resolved fluorescence microscopy by Professors William E Moerner, Eric Betzig, and Stefan Hell in 2000, the impossible became a reality.

Laboratories across the globe now use fluorescence microscopy to obtain highly resolved images of cellular molecules like proteins. These molecules could be of sizes up to 10 nanometres – a hundred times thinner than the human hair. Scientists can now track the dynamic movement of molecules in living cells, their localisation and even interaction with other molecules.

A question that often bothers us is: Why should one measure a single molecule in the first place and why is it so important? Prof. Moerner answered this question with an interesting analogy – "Baseball analogy". While overall batting score of a baseball team may be very good, there could be players in the team who do not bat at all; they could just be good bowlers. Similarly, in the absence of super-resolution imaging we observe an overall or 'ensemble effect' of all the molecules; the behaviour or dynamics of individual molecules could be totally different. Hence, super-resolution imaging could be of immense importance in studying single molecules like DNA.

"In future, we could view binding of drugs and effects of toxins on single molecules like DNA, with high sensitivity, specificity, and high spatial resolution. A moderately trained lab technician could do all this, in negligible time and effort," Prof. Moerner said during his talk at the Science Congress.

Earlier, a normal (optical) microscope could distinguish between two closely placed objects or structures with a limited capacity or resolution. The wavelength of light set a limit to the level of detail possible. The discovery of single-molecule super-resolved fluorescence microscopy, that won the Nobel Prize for Chemistry in 2014, circumvented the limitation of the optical microscope. It used fluorescence, a phenomenon in which certain substances become luminous after they are exposed to light. In the new method, fluorescence in individual molecules is triggered by light, and an image of ultra-high-resolution is achieved by combining images in which different molecules are activated. This makes it possible to track processes occurring inside living cells. Prof. Moerner's research had begun at IBM, San Jose, California in early 1980s where he could measure the optical absorbance of single molecules.

Building "three zero" society

A new society of 'three zeroes' could help us rebuild the world or a new civilisation by 2050, which will be free of greed and full of human health. The 'three zero' society is a dream and vision of Professor Muhammad Yunus, who is the winner of the 2006 Nobel Prize in Peace, for his contribution in social and economic development of the poor in Bangladesh and other countries.

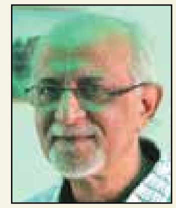
'Zero poverty' is the primary goal of an ideal society that Prof. Yunus envisages. "Three decades from now, we should be building poverty museums, where our future generations would go to know what poverty looked like, because for them, it won't exist," he said while addressing the Science Congress. 'Zero Unemployment' is the second goal. "99% of the total world wealth resides in the hands of its 1% population, and that is unfair", he said. The world where there is no wealth concentration and humans become job creators instead of job seekers, would be the world for all. 'Zero net carbon emissions' is the third goal. This is to save our planet, Earth, from the damage that we, humans have caused.

Prof. Yunus recounted his long journey to promote microfinance, which began in a famine-struck village near his college in Chittagong where he taught economics, soon after the liberation of Bangladesh. In his endeavour to help the poor who were oppressed by loan sharks (those who lend money on unacceptable terms), he started a revolution that changed the lives of millions of women and their families. He introduced the concept of *Grameen* bank in 1983 that provided microcredit; that is, loans to poor people on easy terms. India too, tried to adopt the concept in Andhra Pradesh, but failed because it was misinterpreted and wrongly implemented. Today, he advocates and helps countries in setting up microcredit institutions to eradicate poverty and misery, empower women, and generate employment.

Jean Tirole (Toulouse School of Economics, University of Toulouse, France), the 2014 Economics Nobel laureate, spoke about the challenges of digital economy.

Indian Science News and Feature Service.

Of Scientists and Units

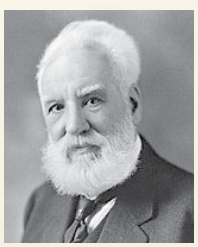


Dr. Bhupati Chakrabarti
E-mail: bhupati2005@yahoo.co.in

Let me share with you an experience that I had very recently. I went to an electrician's shop to get back one table fan that he took for servicing. He requested me to wait for a while as he had a few customers to deal with and I found one such customer was asking for a 23-watt CFL lamp. A new customer entered the shop and he placed his order. It was a 15-ampere plug and before he could be served the third customer put his request for a 12-volt eliminator. My intention is not to highlight the brisk business the electrician was doing, but to draw your attention to a few words that came after the merchandise the people wanted to purchase. These are all different units named after the scientists.

Alessandro Volta

Once I came out of the shop on the street I met one of my friends who wiped out sweat from his face and asked me "Well it's hot today. Isn't it? It must be 36 degrees today". I agreed with him with a nod as I could understand that he was talking about the day's temperature. I concurred with his guess as I knew it must be around 36 degrees Celsius. However, as it happens quite often, he also did not bother to mention the full unit. I discovered that the unit is named after a Swedish scientist named Anders Celsius. The other units mentioned above are equally popular and are named respectively after the Frenchman Andre Marie Ampere, Italian Alessandro Volta, and the Englishman Sir James Watt. Yes, the electrical units of current, voltage and power we use have come from their names.



Alexander Graham Bell

One German scientist with the name of George Simon Ohm actually was hiding between Prof. Ampere and Prof. Volta. If we divide volt by ampere we get the unit of electrical resistance 'ohm' that comes from the name of the German scientist. Incidentally, we may not be using the electrical resistance per se for everyday work, but it is actually a very important component in electronic industry and experiments. However, when tiny carbon resistances are sold the unit 'ohm' is often not mentioned. People refer to 2.2 k, 1 k or 1 M, remaining silent about the German scientist Ohm. They actually talk respectively of 2.2 kiloohms 1 kiloohms and 1 megaohms.

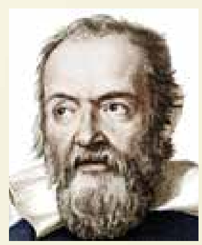
Anders Celsius

Large numbers of SI units of physical quantities derive their names from the names of scientists. Among them Lord Kelvin and Andre Marie Ampere have the distinction of being the scientists whose names are among the seven SI base units. The SI unit of temperature 'kelvin' (K) and the SI unit of electric current 'ampere' (A) come from the names of the British and French scientists while the others, namely kilogram, metre, second, mole and candela do not bear the name of any scientist.

Andre Marie Ampere

However, we have a number of physical quantities that are formed by suitably combining two or more quantities expressed by the base units and are known as derived units. For example, speed is the length or distance divided by time and in SI its unit is 'metre per second'. This unit of speed does not have any special name but a good number of derived units have got their names from the names of scientists. Acceleration is a derived quantity and it has the dimension of length divided by square of time. Force emerges when mass is multiplied by acceleration and its SI unit should have been 'kilogram-metre per second squared' (kg m/s^2). But this unit has got the special name 'newton' after Sir Isaac Newton. Some of these derived units have taken the names of scientists as such, but some of them are derived with a small variation from the original surname of the concerned scientist. As we have mentioned, 'volt' comes from Volta and the SI unit of capacitance 'farad' comes from Michael Faraday. This farad being a quite large unit we often deal with micro (10^{-6}) and pico (10^{-12}) farads in the electronic circuits. Moreover there is a quantity known as one 'faraday' of electricity, which is close to 96,485 coulombs (written as 96,485 C) per mole. This is the amount of electricity or charge that we need to pass through an electrolyte solution or in a molten electrolyte to have one gram-equivalent of any material from the electrolyte deposited on the appropriate electrode.

The definition of one faraday carries coulomb with it. This is the name of another French mathematician and physicist Jean Augustine Coulomb whose name is used as the SI unit of electric charge. Interestingly, as electric current is associated with electric charge very intimately, if we multiply one ampere with the unit of time, i.e., second, we get coulomb.



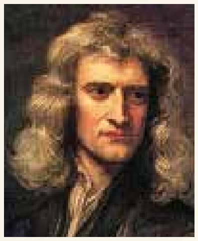
Galileo Galilei

Apparently one Englishman Michael Faraday maintains a distance with another Englishman James Watt, the unit of power, but a scientist from the British Isles comes closer to watt. He is James Prescott Joule and the SI unit of energy carries his name. As it was in the case of coulomb and ampere watt, here also watt, the SI unit of power watt when multiplied by second gives us energy measured in the SI unit 'joule' (symbol J).

While the units have been adopted from the names of different scientists, a simple rule has been followed. The unit when written fully will start with a small letter and not with a capital letter that is used for writing a name. So, 2 amperes (2 units of current in SI) should be written either as '2A' or as '2 amperes'. Remember, this current of 2 amperes should not be written as '2 Amperes' or '2 amp', although many people tend to write it this way.

George Simon Ohm

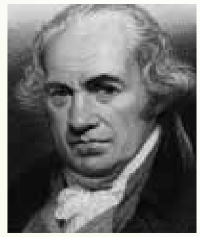
If we have two units named after two different scientists where the surnames of the both scientists begin with the same letter we need to use the first letter and one or more suitable letters from the name in one of these cases. For example, the unit of power comes from the name of Sir James Watt and 60 W may be the power of a lamp. But the magnetic flux derives its unit from the name of the French scientist W.E. Weber and 6 weber is written as 6 Wb indicating it is the unit of magnetic flux. A flux density of one Wb/m^2 (one weber per square metre) is one 'tesla', the unit named after the Serbian-American electrical engineer Nikola Tesla.


Isaac Newton

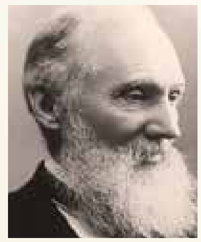
Newton is there as the unit of force in SI. But it may appear that Galileo has been left out. This is strictly speaking not true, but the situation is not that favourable for Galileo either. Since only the SI units are in use and only a handful of cgs units are still used, if we leave out the British system or the so called FPS units (still in use in very few countries including the USA), there is a unit in the name of Galileo called 'gal' or 'galileo' (symbol Gal), which is a unit of acceleration in cgs. One Gal is equal to 1 cm/s^2. For the acceleration due to gravity at the sea level, i.e., 981 cm/s^2 one may say this is 981 Gal. However, the unit has not become popular as people prefer to use 1 cm/s^2 and not Gal.


James P. Joule

Pressure is force per unit area. So in SI it is measured in newton per metre squared (N/m^2). This is also called 'pascal' derived from the name of Blaise Pascal, the famous 17th century French mathematician and physicist. However, there are quite a few units that are basically non-SI but are used even by the scientific community for their convenience. One such example is 'torr' or 'torricelli' (symbol Torr), a quite popular non-SI unit of pressure. It is expressed as millimetres of mercury or written as mm of mercury (Hg) mainly because the atmospheric pressure was first measured and expressed in terms of the height of a column of mercury. The unit has been named after the 17th century experimental scientist Evangelista Torricelli. He was more than thirty years senior to Newton and had the opportunity of becoming an assistant of Galileo for a brief period of time. In fact, 'Torr' is an abbreviated form of Torricelli. It is a unit of pressure equivalent to 1 mm of mercury in a barometer and equal to 133.32 pascals or $^1/_{760}$ of normal atmospheric pressure. Once we have introduced Torr we can express the normal atmospheric pressure as 760 Torr. Interestingly, in vacuum technology Torr is a widely used unit.


James Watt

Our concern for environmental pollution has made us conscious about the noise pollution. For identifying the level of noise pollution and preventing it rising beyond to the level of a health hazard we need to look at the intensity of the sound. Sound intensity is measured by a unit called 'decibel' (symbol dB). We now know that 75 decibel is a reasonably intense sound; firecrackers used during the festive seasons should not produce sound with intensity more than 110 dB. Decibel is essentially one-tenth of a 'bel', the unit of intensity of sound. The unit is derived from the name of Alexander Graham Bell, the inventor of telephone. Incidentally, it is a dimensionless unit. Bel is defined as the logarithm (to the base 10) of the ratio of intensity of a particular sound with that of the threshold of hearing that is taken to be 10^{-12} W/m^2. So by taking the ratio of two similar quantities we get a dimensionless quantity and then we take the logarithm of that ratio and what is obtained is defined in terms of 'bel'. Since the range of sound intensity that our ears can detect is quite large the use of logarithmic scale is helpful. Since bel as a unit is quite large it is preferable to use one-tenth of bel – the 'decibel'.


Lord Kelvin

If we take a closer look at the SI units there are more units named after scientists. The names have been given keeping in mind the contribution of the scientist in the concerned area. As mentioned earlier, the great inventor Nikola Tesla has been immortalised by the SI unit of magnetic flux density 'tesla'. The contribution of the German scientist Werner von Siemens in measuring the electrical conductivity of

Continued on page 22

SI Units (Base and Derived) bearing the names of scientists

Sl. No.	Name of the scientist	Country of the scientist	Unit of physical quantity	Unit name With symbol
1.	Lord Kelvin	England	Thermodynamic temperature	kelvin (K)
2.	Andre Marie Ampere	France	Electric Current	ampere (A)
3.	Alessandrao Volta	Italy	Emf, potential diff.	volt (V)
4.	George Simon Ohm	Germany	Electrical resistance	ohm (Ω)
5.	James P Joule	England	Energy	joule (J)
6..	James Watt	England	Power	watt (W)
7.	Heinrich Hertz	Germany	Frequency	hertz (Hz)
8.	Isaac Newton	England	Force	newton (N)
9.	Blaise Pascal	France	Pressure	pascal (Pa)
10.	Jean Baptiste Coulomb	France	Electric Charge	coulomb (C)
11.	Michael Faraday	England	Capacitance	farad (F)
12.	Joseph Henry	USA	Inductance	henry (H)
13.	Nicola Tesla	Serbia & USA	Magnetic flux density	tesla (T)
14.	E. Werner von Siemens	Germany	Conductance	siemens (S)
15.	Wilhelm Eduard Weber	France	Magnetic flux	weber (Wb)
16.	Henri Becquerel	France	Radioactivity	becquerel (Bq)
17.	Louis Harold Gray	England	Absorbed dose	gray (Gy)
18.	Rolf Maximilinum Sievert	Sweden	Dose equivalent	sievert (Sv)
19.	Anders Celsius	Sweden	Temperature	degree Celsius (°C)

Pelvic inflammatory disease – All you want to know about

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

Common in young women, pelvic inflammatory disease — or PID, as it is more commonly known — is an infection of the female reproductive organs, which usually affects the womb and fallopian tubes. The disease usually occurs due to poor pelvic hygiene, or when sexually transmitted bacteria spread from the vagina to the uterus, fallopian tubes or ovaries.

The disease may just cause a difficult-to-diagnose mild abdominal pain that may grumble on for weeks, or may present more dramatically with severe symptoms, but in most women, it causes few or no symptoms. A woman may never know that she has developed the disease, until she suffers irreversible damage to the uterus, fallopian tubes, and ovaries and develops one or the other complication. While a few women may develop a persistent pelvic pain, others may face difficulty in getting pregnant, and yet others, may step into a dire life-threatening emergency with an ectopic pregnancy which has ruptured.

A thorough physical examination by a gynaecologist coupled with a few diagnostic tests can clinch the diagnosis and pave the way for a timely treatment. The success of treatment lies in eradicating the infection with a suitable antibiotic. Starting treatment soon as the condition gets known lessens the risk of complications. Since the infection is often sexually transmitted, it is essential that the affected person's male partner must also be treated.

Causes

The most common cause of pelvic inflammatory disease is germs or bacteria, which are passed on when a woman has sex with an infected person. The most common germs are chlamydia and gonorrhoea, though sometimes, an individual may be infected with a mix of both.

Some women may develop the disease without being infected with a sexually transmitted infection. Poor vaginal hygiene, insertion of an intrauterine contraceptive device like the copper-T or childbirth may allow the bacteria to travel into the womb and cause pelvic inflammatory disease.

Recognizing the symptoms

Despite harbouring pelvic inflammatory disease, a woman may have no symptoms at all or be faced with only mild symptoms. This is especially common when the infection is due to chlamydia.

However, she is still at risk of complications. The likely symptoms that may arise include:

Pelvic pain

Pain in the lower tummy, called the pelvic area, is the most common symptom. It can range from mild to severe.

Abnormal vaginal bleeding

Abnormal vaginal bleeding, which occurs in about 1 in 4 cases. This may be periods that are heavier than usual, or bleeding between periods, or bleeding after having sex.

Vaginal discharge

Often, women with pelvic inflammatory disease develop a vaginal discharge, which may be heavy and may carry an unpleasant odour.

Dyspareunia

Some women may complain of pain during sexual intercourse.

Other symptoms

Other symptoms may include irregular menstrual bleeding, fever, painful or difficult urination and low back pain.

Risk factors

Pelvic inflammatory disease is a far more common condition than the numbers that are diagnosed. Many sexually active women develop the disease each year. It most commonly occurs in young women who are sexually active. The guilty bacteria are usually acquired during unprotected sex.

Less commonly, bacteria may enter the reproductive tract anytime the normal barrier created by the cervix is disturbed. This can happen after intrauterine device (IUD) insertion, childbirth, miscarriage or abortion.

A number of factors may increase a woman's risk of pelvic inflammatory disease. These risk factors include:

- Regular douching: this may upset the balance of good versus harmful bacteria in the vagina, and may mask symptoms that might otherwise cause you to seek early treatment.
- Recent insertion of contraceptive device, like copper-T.
- A recent abortion.

- A recent operation or procedure on the uterus.
- A previous episode of pelvic inflammatory disease or sexually transmitted disease.
- Being in a sexual relationship with a person who has more than one sex partner.
- A recent change of sexual partner. The risk goes up in those who exhibit promiscuity and have a number of partners.

Seeing a doctor

If your signs and symptoms aren't severe, but they're persistent, see your doctor as soon as possible. Vaginal discharge with an odour, painful urination or bleeding between menstrual cycles can be associated with a sexually transmitted infection. If these signs and symptoms appear, see your doctor soon. Prompt treatment of a sexually transmitted infection can help prevent pelvic inflammatory disease.

You may opt to see your family doctor, but it is better to see a gyneacologist.

Go to the emergency room if you experience the following severe signs and symptoms of pelvic inflammatory disease:

- Severe pain low in your abdomen
- Vomiting
- Signs of shock, such as fainting
- Fever, with a temperature higher than 101° F (38.3 °C)

What the doctor would do

Doctors diagnose pelvic inflammatory disease based on signs and symptoms, a pelvic exam, an analysis of vaginal discharge and cervical cultures, or urine tests.

Cervical swab

During the pelvic exam, the examining doctor uses a cotton swab to take samples from the vagina and cervix. The samples are sent to a lab for analysis to determine the organism that's causing the infection. A swab from the urethra (where you pass urine from) and blood and urine tests may also be taken.

To confirm the diagnosis or to determine how widespread the infection is, you may be recommended other tests, such as:

Pelvic Ultrasound

This test uses sound waves to create images of the pelvic structures including reproductive organs. It may be able to show inflammatory changes in the cervix, uterus and fallopian tubes, and in the pelvic cavity.

Laparoscopy

During this procedure, performed under general anaesthetic, the doctor inserts a thin, lighted telescope-like instrument (laparoscope) through a small buttonhole incision in the lower tummy to view the pelvic organs. This is called a laparoscopy, and allows the doctor to see the uterus and tubes under direct vision.

Endometrial biopsy

During this procedure, the doctor removes a small piece of uterine lining (endometrium) for testing. This test is sometimes done to check if a patient may have changes of inflammation.

Specific treatment

Outpatient treatment is adequate for treating most women with pelvic inflammatory disease. Finding out that you have a sexually transmitted infection can be psychologically traumatic. You must put your fears at rest and take immediate steps to get treated and to prevent re-infection. The essential measures include:

Antibiotics

The doctor will prescribe a combination of antibiotics. These must be started right away. Usually, your doctor will request a follow-up visit in three days to make sure the treatment is working.

Be sure to take all of your medication, even if you start to feel better after a few days. Antibiotic treatment can help prevent serious complications but can't reverse any damage that's already been done.

Treatment for your partner

To prevent re-infection with a sexually transmitted infection, your sexual partner must also be examined and adequately treated. Unless this step is taken, you are liable to get re-infected. A partner can be infected and not have any noticeable symptoms.

Hospitalization

Hospitalization is rarely necessary. However, if you're seriously ill, pregnant or haven't responded to oral medications, you may need hospitalization. At the hospital, you may receive intravenous (IV) antibiotics, followed by antibiotics you take by mouth.

Rarely, you may need surgery. This is particularly true in cases when the diagnosis remains doubtful.

Prevention

To reduce the risk of pelvic inflammatory disease, a woman must take the following preventive steps:

Avoid douching

Douching upsets the balance of bacteria in the vagina.

Pay attention to hygiene habits

Wipe from front to back after urinating or having a bowel movement to avoid introducing bacteria from the colon into the vagina.

Practice safe sex

It is best to avoid sex with a partner whose sexual history is not quite clear to you. A use of condom every time you have sex can limit the risk.

Do not delay getting tested

If you're at risk of a sexually transmitted infection, make an appointment with your doctor and get yourself evaluated. Early treatment of a sexually transmitted infection gives you the best chance of avoiding pelvic inflammatory disease.

Will it happen again?

About 1 in 5 women who have pelvic inflammatory disease have a further episode. This is usually within two years. Reasons why this may occur include:

- If your sexual partner was not treated. You are then likely to get the infection back again.
- If you did not take the antibiotics properly, or for long enough. The infection may then not clear completely, and may flare up again later.
- Some women are more prone to infection once their womb (uterus) or tubes have been damaged by a previous episode of PID.

Possible complications

Complications do not develop in most cases if pelvic inflammatory disease is diagnosed and treated early. Possible complications include one or more of the following:

Chronic pelvic pain

Pelvic inflammatory disease can cause pelvic pain that may last for months or years. Scarring in your fallopian tubes and other pelvic organs can cause pain during sexual intercourse.

Difficulty becoming pregnant

Pelvic inflammatory disease can cause scarring or damage the Fallopian tubes and cause infertility. Despite your best tries, you're unable to become pregnant. The more times you've had pelvic inflammatory disease, the greater your risk of infertility. Delaying treatment for Pelvic inflammatory disease also dramatically increases your risk of infertility.

Ectopic pregnancy

Pelvic inflammatory disease is a major cause of tubal (ectopic) pregnancy. In an ectopic pregnancy, the fertilized egg can't make its way through the fallopian tube to implant in the uterus. This is due to damage to the fallopian tube by the infection. If you have had pelvic inflammatory disease and become pregnant, you have about a 1 in 10 chance that it will be ectopic. Ectopic pregnancies can cause massive, life-threatening bleeding and require emergency surgery.

Prof Yatish Agarwal is a physician and teacher at New Delhi's Safdarjung Hospital. He has authored 47 popular health-books. ■

Of Scientists and Units (continued from page 25)

different materials is commemorated by the unit of electrical conductivity in SI, 'siemens' (symbol S). Another German scientist Heinrich Hertz had a very brief life-span; he passed away at the young age of 37. He has been immortalised as the SI unit of frequency 'hertz' (symbol Hz). Since one hertz is actually one cycle per second, dimensionally the unit is actually the reciprocal of the second but it demands a separate name for its special role in physics. Moreover, as one hertz is essentially one cycle per second it is the same in cgs or in SI. The unit of self and mutual inductance has the unit of 'henry' in the honour of the American scientist Joseph Henry.

Radiation related units are meant for specialised use and they are part of the SI family. The contribution of French scientist Henri Becquerel ('becquerel', the SI unit of radioactivity, corresponding to one disintegration per second, symbol Bq) has been acknowledged here. Two other scientists Louis Harold Gray of England ('gray', unit of ionising radiation, symbol Gy) and Rolf Maximilinum Sievert of Sweden ('sievert', unit of ionising radiation dose, symbol Sv) are also associated with the radiation related units. Incidentally, the measurement of radiation is relatively new – barely one hundred years old – and initially the units for its measurement got names from Wilhelm Roentgen of Germany and Marie Curie of France. However, further studies led to the handling of radiation in a different way with different units. So the first Nobel laureate in Physics and the first woman Nobel laureate could not be accommodated in the SI list of units.

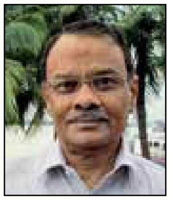
Several units named after very famous scientists are practically no more in active use for the scientific work as they do not belong to the domain of SI units. One may find them in older books of physics. These units involved the names of Oersted, Gauss, Fermi, Angstrom, and Maxwell. Oersted was used for the unit of auxiliary magnetic field in cgs and it was actually equal to dyne/maxwell; the name of Fermi (fermi) was introduced as equal to 10^{-15} metre for measurements related to nuclear physics where this scientist had a huge contribution. Now femtometre takes its place and its symbol fm very much looks like Fermi but the word 'femto' comes from Danish and Norwegian word 'femten' meaning fifteen. The Swedish scientist Anders Jonas Angstrom's name is still very familiar with physics students. The unit angstrom with a very well-known symbol of Å has long been used for expressing the wavelengths of electromagnetic radiation, particularly those falling in the visible, infrared, ultraviolet, X-ray and gamma ray region. Now of course the nanometre is used in all cases, but many elders who had studied science still feel comfortable to use angstrom to express the wavelength, especially of visible light which lies in the range of approximately 4000Å-7500Å.

Another stalwart James Clarke Maxwell is also not in the SI list though he was there (maxwell) for the unit of magnetic flux density in cgs. The German physicist and mathematician Carl Frederich Gauss was associated with the cgs esu unit of magnetic induction and in a way has bowed down to the SI unit of magnetic induction named after Nicola Tesla.

Some units that derived their names from the names of the scientists are actually no more in use for different reasons. Albert Einstein, for example has got a special position in the world of units. The unit called 'einstein' is essentially a unit of energy but it is no more in active use. It is defined as the energy of one mole (6.023 x 10^{23}) of photons. Since the photon energy is dependent on its frequency, this energy is frequency or wavelength dependent. The unit of charge-to-mass ratio of particles was given the name 'thomson' after Sir J.J. Thomson, but it is no more in use, taken over by 'coulomb per kg'.

Dr. Bhupati Chakrabarti is General Secretary, Indian Association of Physics Teachers. Formerly he was Head, Department of Physics, City College, Kolkata-700009. ■

Recent Developments in Science and Technology



Biman Basu
E-mail: bimanbasu@gmail.com

Fast radio bursts traced to distant dwarf galaxy

Ever since the discovery of radio astronomy in the early 1930s our knowledge about the universe has undergone sea change. Several decades of observation of the sky in radio waves has revealed the universe to be aglow with radio emissions from the Sun, Jupiter, and hosts of supernovae debris, pulsars and other violent sources. Occasionally, radio astronomers also encountered sudden fast radio bursts, or FRBs, which are flashes of radio waves as bright as 500 million Suns, which appeared to come from beyond the Milky Way. These objects were something quite remarkable.

Since FRBs appear from seemingly random locations and fade in just milliseconds, in the past these have mostly remained unnoticed and unobserved. Now for the first time, a team of astronomers have pinpointed the location of an FRB known as FRB 121102. Located in the constellation Auriga, the intermittent signal was first detected on 2 November 2012. Surprisingly, unlike other FRBs, which have all burst only once before disappearing into the dark night sky, FRB 121102 has flared up several times, making it the only fast radio burst known to repeat. The interesting fact that this FRB has revealed is that the source of these intermittent signals lies not in a bright galaxy but in a small, dim one – a dwarf galaxy some 2.5 billion light-years from Earth (*Nature*, 4 January 2017 | doi:10.1038/nature.2016.21235). The discovery will help clear the mystery of fast radio bursts, which have puzzled astronomers since they were first detected in 2001.

The discovery was made by a team led by Shami Chatterjee, an astronomer at Cornell University in Ithaca, New York, using the 305-metre-wide Arecibo radio telescope in Puerto Rico. Its sensitivity allowed the scientists to detect multiple bursts from FRB 121102. The team then used two other sets of radio telescopes – the Karl G. Jansky very large array (VLA) in New Mexico, and the European very-long-baseline interferometry (VLBI) network across Europe – to narrow down the location of FRB 121102 even further. Follow-up observations with the Gemini North telescope, on Mauna Kea, Hawaii, showed that the dwarf galaxy housing FRB 121102 is less than one-tenth the size and has less than one-thousandth the mass of the Milky Way.

An interesting feature of signals received from the FRBs is the slowing down of certain frequencies by the time they reach Earth. According to the astronomers, as the waves reach Earth, low-frequency ones lag behind high-frequency ones. The extent of this delay suggests that the signals have travelled through intergalactic space for potentially billions of light years. Electron clouds between the galaxies are known to interact more with low-frequency waves than with high-frequency ones, which delays the arrival of low-frequency waves at Earth and stretches the signal.

The Parkes telescope in Australia detected the first fast radio burst (FRB) in 2001.

According to some astronomers the discovery is surprising. With fewer stars than many galaxies, dwarf galaxies would seem to have less of a chance of hosting whatever creates fast radio bursts, including neutron stars, one of the leading candidates for the source of fast radio bursts. Much more work is needed to pin down the physical mechanism of what causes these mysterious bursts, says Chatterjee. For now, FRB 121102 is just one example. The team plans to study further with upcoming Hubble Space Telescope observations. In the meantime, they would continue to chase fast radio bursts with the hope to spot more repeating bursts and localise more in the coming years.

Fossil fuel formation likely led to rise in atmospheric oxygen

Life on Earth is primarily based on oxygen, which makes up almost one-fifth of the Earth's atmosphere. Oxygen enables the chemical reactions that animals use to get energy from stored carbohydrates – from food. But oxygen has not always been as abundant as it is today. Most scientists believe that for half of Earth's 4.6-billion-year history, the atmosphere contained almost no oxygen. Oxygen was first introduced into Earth's atmosphere perhaps as long ago as 3.5 billion years ago and certainly by 2.7 billion years ago by cyanobacteria or blue-green algae that live primarily in seawater and were the first microbes to produce oxygen by photosynthesis. During photosynthesis, the cyanobacteria produce organic carbon, the building blocks of life's molecules, and release oxygen gas. The oxygen enters into the seawater, and from there some of it escapes into the atmosphere. But, mysteriously, there was a long lag time – hundreds of millions of years – before Earth's atmosphere first gained significant amounts oxygen, some 2.4 billion to 2.3 billion years ago.

Although oxygen was present in the atmosphere as early as 2.4 billion years ago, oxygen-dependent life forms flourished only during the Cambrian Period, around 500 million years ago. The Cambrian Period marks an important point in the history of life on Earth; it is the time when most of the major groups of animals first appear in the fossil record. This event is sometimes called the "Cambrian Explosion", because of the

This black shale, formed 450 million years ago, contains fossils of trilobites and other organic material that helped support increases in oxygen in the atmosphere. (Credit: University of Wisconsin-Madison)

relatively short time over which this diversity of forms appears. It is believed the sudden dramatic diversification of animal life during the Cambrian was triggered by a sudden rise in the level of atmospheric oxygen during the period. But what caused the sudden spike in oxygen remained a mystery. Now researchers at the University of Wisconsin-Madison, USA, have found evidence that the formation of fossil fuels like coal, natural gas and oil likely raised the Earth's oxygen supply. They argue the burial of plant matter and carbon-rich organic matter allowed for the accumulation of oxygen in the atmosphere (*Earth and Planetary Science Letters*, February 2017 | DOI: 10.1016/j.epsl.2016.12.012).

According to the researchers, if green plants and organic matter are allowed to decompose when exposed to the atmosphere they consume oxygen, producing carbon dioxide. But if they are buried under sediments, no oxidation takes place and the oxygen released by plants remains in the atmosphere. And that is exactly what happens when organic matter – the raw material of coal, oil and natural gas – is buried through geologic processes.

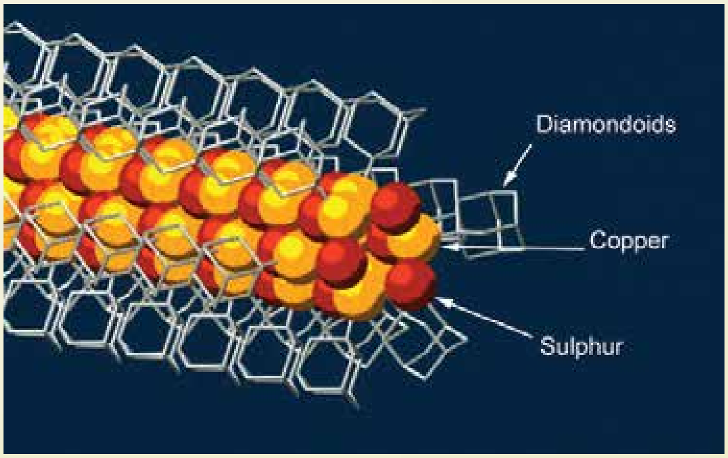
For this work, the researchers relied on a unique global geological dataset called Macrostrat. Macrostrat is a platform for the aggregation and distribution of geological data relevant to the spatial and temporal distribution of sedimentary, igneous, and metamorphic rocks as well as data extracted from them. When the researchers analysed the parallel graphs of oxygen in the atmosphere and sediment burial, based on the formation of sedimentary rock, from the Macrostrat dataset they found a distinct relationship between oxygen and sediment. Both graphs show a smaller peak at 2.3 billion years ago and a larger one about 500 million years ago. The earliest potential evidence of life on Earth is 3.5 billion years old, but the first multi-cellular animals did not appear until about 600 million years ago and were not diversified until roughly 542 million years ago in the Cambrian explosion. The new evidence shows why.

World's thinnest wire made from diamond

Diamondoids are small cage-like structures made of carbon and hydrogen. They are described as the smallest possible bits of diamond. Found naturally in petroleum fluids, these interlocking carbon cages weigh less than a billionth of a billionth of a carat (1 carat = 0.2 grams). The smallest ones contain just 10 atoms. Scientists at Stanford University and the Department of Energy's SLAC National Accelerator Laboratory in USA have discovered a way to use diamondoids to assemble atoms into the thinnest possible electrical wires, just three atoms wide. The wire, which is assembled at the nano-scale much like molecular LEGO, is made of a string of diamondoids attached to sulphur and copper atoms. The copper and sulphur atoms form a core of conducting material and the diamondoids remain on the outside, forming an insulating shell (*Nature Materials*, 26 December 2016; DOI: 10.1038/nmat4823). According to the researchers, the unique way they link up could lead to fabrics that generate electricity simply through movement.

Says researcher Hao Yan from Stanford University, "What we have shown here is that we can make tiny, conductive wires of the smallest possible size that essentially assemble themselves. The process is a simple, one-pot synthesis. You dump the ingredients together and you can get results in half an hour. It's almost as if the diamondoids know where they want to go."

Before assembling, the diamondoids are attracted to one another through van der Waals forces, which are weak forces that do not arise from covalent bonds or ionic bonds, and act over extremely small distances. (Geckos can walk upside down on the ceiling, held up by the same force.) Because of that attraction, each diamondoid links up with the next one in the chain, thereby extending the chain.



An illustration showing the basic nano-wire building block – a diamondoid cage carrying atoms of copper and sulphur – drifting toward the growing tip of a nanowire, centre, where it will attach in a way determined by its size and shape. (Credit: SLAC National Accelerator Laboratory)

The unique nano-wires have been described as "a versatile toolkit for creating novel materials". The team has already used diamondoids to make one-dimensional nano-wires based on cadmium, zinc, iron and silver, including some that grew long enough to be visible without a microscope. They have also experimented with carrying out the reactions in different solvents and with other types of rigid, cage-like molecules, such as carboranes. The cadmium-based wires could be used as light-emitting diodes (LEDs), and the zinc-based ones are like those used in solar applications and in piezoelectric energy generators, which convert motion into electricity. According to the researchers, the material can be woven into fabrics to generate energy by movement.

In short, by using different atoms in the core, it may be possible to get a different kind of conductivity, which could one day enable a wide range of applications – such as extremely tiny wires for electrical devices, or superconducting materials that conduct electricity without any loss due to their intricately formed molecular structure.

Tiny lab-grown human lungs transplanted into mice

Respiratory diseases account for nearly one in five deaths worldwide, and lung cancer survival rates remain poor despite numerous therapeutic advances during the past 30 years. Research on human lung diseases is hampered largely by the non-availability of physiologically relevant animal models for lung research. Now a team of researchers from the University of Michigan Medical School, USA, have succeeded in coaxing human stem cells to grow into three-dimensional miniature lungs, which mimic several aspects of the structure and complexity of human lungs. In just eight weeks, these mini-lungs grown from stem cells grew into mature tissues that had impressive tube-shaped airway structures similar to the adult lung airways. When transplanted into immunosuppressed mice (mice in which the immune system is suppressed by drugs) the lab-grown mini lungs were able to survive, grow and mature (*eLife*, 11 October 2016 | DOI: 10.7554/eLife.19732). This has opened up new ways to study human respiratory diseases. According to the researchers, transplanting bioengineered human lung organoids into mice could lead to a humanised model for pre-clinical studies of lung disease.

During the past decade, new models of human development and disease have emerged as a result of the ability of researchers to culture primary human tissues and derive complex three-dimensional organ-like tissues, called organoids from human pluripotent (able to develop into various different cell types) stem cells. These developments have made it possible to direct differentiation of human pluripotent stem cells in a stepwise process, which mimicked aspects of *in vivo* lung development, into three-dimensional human lung organoids.

In terms of different cell types, the lung is probably the most complex of all organs – the cells near the entrance are very different from those deep in the lung. The University of Michigan research team has been working to create these so-called lung organoids – organ-like structures grown in the lab. They developed a new three-dimensional model of the human lung by coaxing human stem cells to become specific types of cells that then formed complex tissues in a Petri dish. To make these lung organoids, they manipulated several of the signalling pathways that control the formation of organs during the development of animal embryos. First, the stem cells were instructed to form a type of tissue called endoderm, which is found in early embryos and gives rise to the lung, liver and other several other internal organs. Then they activated two important developmental pathways that are known to make endoderm form three-dimensional intestinal tissue. However, by inhibiting two other key developmental pathways at the same time, the endoderm became tissue that resembles the early lung found in embryos instead.

Lab-grown mini-lungs

This early lung-like tissue formed three-dimensional spherical structures as it developed. The next challenge was to make these structures develop into lung tissue. The researchers worked out a method to do this, which involved exposing the cells to additional proteins that are involved in lung development. The resulting lung organoids survived in laboratory cultures for over 100 days and developed into well-organised structures that contain many of the types of cells found in the lung.

Lab-grown lungs can now provide a human model to screen drugs, understand gene function, generate transplantable tissue and study complex human diseases, such as asthma. They could help researchers develop more effective therapeutics to treat lung cancer, among other lung diseases, by providing an accurate model with which to screen drug candidates.

Biman Basu is a former editor of the popular science monthly Science Reporter, published by CSIR, He is a winner of the 1994 'NCSTC National Award for Science Popularisation'. He is the author of more than 45 popular science books.