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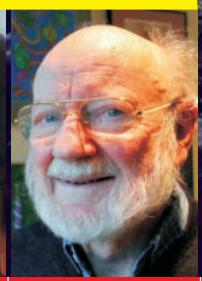
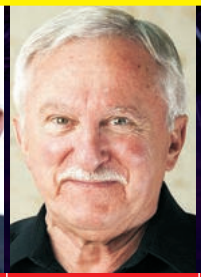
Denizens of the Deep

NOBEL PRIZES IN SCIENCE 2015

Physiology or Medicine			Physics		Chemistry		
							
Satoshi Omura	Youyou Tu	William Campbell	Takaaki Kajita	A. B. McDonald	Tomas Lindahl	Paul Modrich	Aziz Sancar

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

Always keep to the left side of the road

Dr. R. Gopichandran

I cannot thank my school enough for the discipline it imparted in me through the message stated in the title of this editorial. I was at the Shrine Vailankanni School in Madras (now Chennai) during the best of my formative years; namely the primary school stage. The blue boards with bold white letters, along the tree filled open space at the centre of the school's premises conveyed this and several other messages. I could see the relevance of these messages for common and personal good in daily life. This message is a case in point.

I imbibed the spirit of the message because of which I could avoid accidents. Importantly I did not create nuisance for others that would have otherwise arisen if I did not abide by the value the message stood for. However, I was as vulnerable to disasters that were caused by the non- compliant. The ones who did not keep to the left side of the road through sheer insolence or self-proclaimed righteousness had the potential to inflict serious pain. Such adversities opened my mind to a deeper meaning of the message. It was about compliance with values for common good even when no one was watching. It translated into so simple a task as pausing at a road junction before moving on even when signals or the policeman were not there. I seem to be convinced; this is a proof of the direct link between scientific temper and human values.

Amazingly, the elasticity of the message is clear when I travel in countries with traffic arrangements opposite to ours. I had to then keep to the right side of the road. This reinforced scientific temper in me. I could recognise the fact that manifestations of common good and circumstances that enable them could also be location specific. I saw the open-endedness of thinking scientifically and recognise the value of locally evolved systems of governance for common good. I therefore did not argue that my understanding of keeping to the left was alone correct and that ironically citizens of other countries having to keep to the right were wrong to my thinking.

The third manifestation of this message was a growing conviction that I should not throw stones at others when I myself was living in a fragile glass house. This meant, I do not stand even a remote a chance of protecting myself from the consequences of pointing at other's mistakes when I myself do not respect/acknowledge the wisdom or compliance of fellow travellers. Credibility comes only from real-life practise of values. Importantly I realise I do not have the right to even ask for compliance if I am most non-compliant. I cannot therefore also stand in judgement on others for their demeanour.

I often wonder why people jump signals even in the presence of a traffic policeman. Is it not quixotic and misplaced bravado at best to defy traffic rules? Do we not receive messages about the need to comply and the consequences of breaking traffic rules? The absolute need to refrain from speaking over the phone or text while driving cannot be overemphasised. Yet we see the disdain and almost contempt many fellow citizens show to these calls for common good. This takes me to some questions fundamental to the design and implementation of communication strategies that hope to infuse and enhance scientific temper. Is it realistic to expect large-scale change among citizens in perception and practice of scientific temper? How do we assess/ensure credibility of the communicator? Is it about firewalls that allow only the agenda of science and filter out agendas that are not truly scientific? I will be happy to stay on the left side of the road as a proof of my insight to recognise the limitations I am bound by. I remain grateful to my school for the message and the inspiration to experience its value.

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GAGAN- A Satellite-based Aircraft Navigation System

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On 13 July 2015 India's Civil Aviation Minister launched a satellite based navigation system named GAGAN (GPS-Aided Geo Augmented Navigation) jointly developed by the Indian Space Research Organisation (ISRO) and the Airports Authority of India (AAI). GAGAN would make airline operations safer, more efficient and cut down costs and reduce congestion.

Until now air traffic management over the Indian sky was carried out with the aid of ground-based radar sites. The aircraft has to pass over these sites to receive navigational instructions, via radio signals, on the position, speed, altitude, route, etc. With increasing air traffic, the air routes are becoming congested, slowing down traffic movement. Radar control also restricts air route availability. Further, dissimilar procedures and standards from airport to airport result in changes in flight profiles at the boundaries. With the satellite-based navigation system, the pilot can be provided with on-board position for precision and non-precession landing approaches as well as for en route applications. This will result in the opening up of the air connections to a large number of small airports, which lack the conventional full-fledged navigational facilities.

India is the fourth country after USA, European Union, and Japan to offer space-based satellite navigation services to the aviation sector. The backbone of all these systems is the satellite-based Global Positioning System (GPS) launched by the United States of America in the 1980s. The International Civil Aviation Organisation (ICAO) has endorsed the GPS as the core satellite constellation to provide worldwide seamless navigation for civil aviation.

What is GPS?

GPS consists of three main segments: 1) The satellite constellation; 2) the ground control network; and 3) the user equipment. The satellite constellation is made up of 24 to 32 solar-powered satellites, which revolve around the Earth, in six orbital planes at an altitude of about 20,200 km. Their main function is to continually broadcast ranging and navigational signals. These are in the form of pseudo random codes (PRC), transmitted as low-power radio waves in the L band, carrying information on their position in space and time. Each satellite is identified with a unique PRN code and equipped with an atomic clock for precise timing.

The ground control network consists of six stations across the globe. They constantly monitor the satellites for their health and fine-tune their orbital data, which is transmitted back to them.

The user equipment is a GPS receiver. It captures the ranging and navigational signals from the satellites in view and compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. By measuring its distance from a few more satellites, the receiver can determine the user's position by a procedure known as triangulation and display it on the unit's electronic map. A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS receiver can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more. Anyone with a suitable GPS receiver – an individual hiker, a vehicle on road, a ship or an aircraft, can receive the signals for navigation purposes.

The position accuracy of the GPS is about 20 and 30 metres in the horizontal and vertical directions respectively. Though this may be adequate for ocean and road transport navigation, aircraft navigation requires much greater accuracy. For example, the International Civil Aviation Code (ICAO) stipulates that the navigation system should provide a horizontal and vertical position accuracy of 16 metres and 6 metres respectively. The integrity or the correctness of the information should be 1 to 2 × 10^{-7}, which means correct to more than one out of ten million times. It should alert the receiver within 6 seconds, if the navigation system is out of tolerance and cannot be used. It should also be capable of continuous operation without interruption.

Sources of error

Thus, the accuracy and integrity of the GPS is not sufficient for air traffic management and navigation, particularly during precision approach. Inaccuracies arise from several sources such as the ionosphere, drift in the satellite orbits (ephemeris), clock drift and signal degradation. These have to be augmented to make the GPS signals suitable for civil aviation navigation.

Ionospheric correction

The upper part of the atmosphere, from about 85 km to 1,000 km from the surface of the Earth is called ionosphere. Here, solar radiation ionises air molecules by knocking electrons out of them. Electrons in the ionosphere scatter the GPS signals as they pass through the ionosphere, causing delay in their passage. Since position determination is based on the time taken by the signal to travel from the satellite to the GPS receiver, this delay introduces inaccuracies in range calculations.

The extent of delay in signal transmission is not the same at all locations on Earth at all times. This is because the ionisation in the ionosphere varies with a number of factors like the time of the day, season, solar activity. It also depends upon the geographical location such as poles, auroral zones, mid-latitudes, and equatorial regions. India is situated near the equator where the ionospheric variation is very high, resulting in range inaccuracies of the order of 25 to 50 metres. Correcting for ionospheric delay by suitably modelling the ionosphere over the Indian airspace is a challenging job. To do this, a grid of 25 precisely surveyed ground-based ionospheric reference stations, separated by 500 km, has been set up across

the country. Each station equipped with a dual frequency GPS receiver, which collects raw pseudo range measurements from all the visible GPS satellites. These are further analysed to generate a suitable ionospheric model to determine the signal delay over that part of the Indian sky. ISRO scientists have successfully developed an ionospheric model for the Indian region.

Ephemeris correction

The orbital positions of the satellites change due to natural phenomena such as gravitational force from the Sun, Moon and pressure from solar winds. It is necessary to know the exact positions of the satellites for accurate range measurement. This is achieved through the use of precision ranging using the radio frequency signals as well as laser. There is always some error introduced due to the difference in the actual ephemeris and the estimated one. This introduces some error in the location.

Clock drift correction

Highly stable atomic clocks are used in the navigation satellites for ensuring precision in the position accuracy. Even then, the minute drift in the onboard atomic clock due to the orbital velocity of the satellites and the reduced gravitational field in space far away from the Earth introduce drifts, which translate to signal travel time errors. Fortunately the errors are systematic in nature and it is possible to correct for it to a large extent.

Multiple path correction

The signals coming from the satellites may also undergo multiple reflections and diffractions by objects like mountains, water bodies, tall buildings, etc., on their path. This leads to degradation in their quality resulting in errors in range measurements. The error can be reduced by suitable choice of antennae and receivers.

Using these correction procedures, GAGAN augments the GPS signals for aircraft navigation over the Indian sky.

Architecture of GAGAN

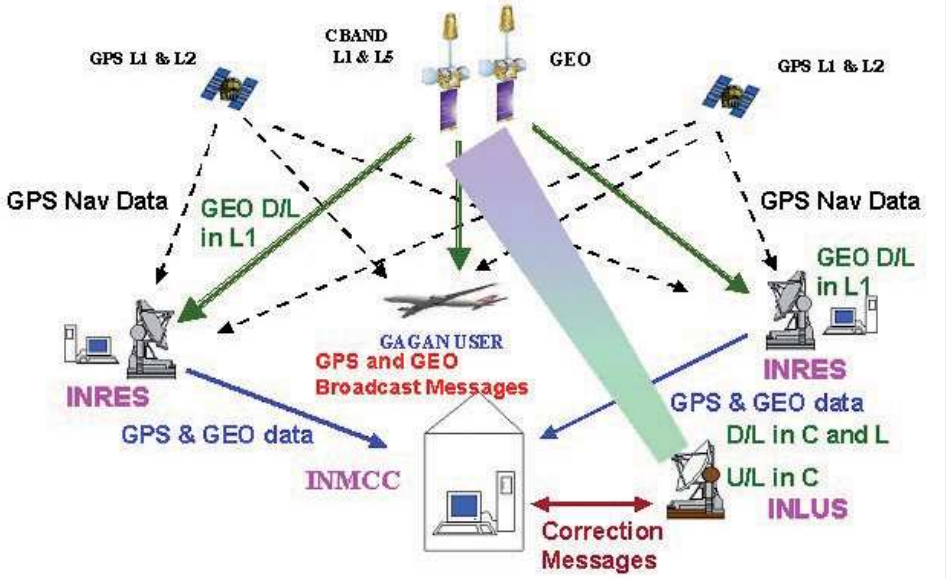
As with GPS, GAGAN also consists of three segments: the space segment, the ground segment, and the user segment. The space segment of GAGAN consists of two geosynchronous communication satellites GSAT-8 and GSAT-10 which were launched on 21 May 2011 and 29 September 2012, respectively. They are positioned above the equator on the Indian Ocean at longitudes 55 degree and 82 degree. They carry a dual frequency L1 and L5 navigation payload compatible with the GPS. Both these satellites broadcast the same message, ensuring system redundancy. A third satellite GSAT-15 will be launched later to serve as a spare, in case if either GSAT-8 or GSAT-10 fail.

GSAT-8 with GAGAN payload beaming on Indian air space

The ground segment consists of fifteen Indian Reference Earth Stations (INRES), an Indian Master Control Center (INMCC), and two Indian Navigation Land Uplink Stations (INLUS). The Reference Stations are located at Ahmedabad, Bengaluru, Thiruvananthapuram, Port Blair, Delhi, Kolkata, Guwahati, Jammu, Dibrugarh, Patna, Bhubaneshwar, Nagpur, Goa, Porbandar and Jaisalmer within the respective airport perimeters. Each station, connected to the INMCC at Bengaluru, is provided with three GPS receivers/antennae subsystems to receive GPS signals. At every stage provision has been made for redundancy.

Each IRNES station collects data from all three antennae and processes them to compare the position as determined by the GPS satellite signals against their own precisely surveyed location. This information is then sent to the INMCC. The INMCC uses these data to calculate the differential corrections and the ionospheric delay estimates for each of the monitored GPS satellites and the ionospheric grid stations respectively. It also estimates the integrity and the availability of the GPS satellites. All these messages are then uplinked through the INLUS, also at Bengaluru, to the geostationary satellites GSAT-8 and GSAT-10, which then broadcast

GSAT-8 and GSAT-10 satellites



GAGAN Architechture

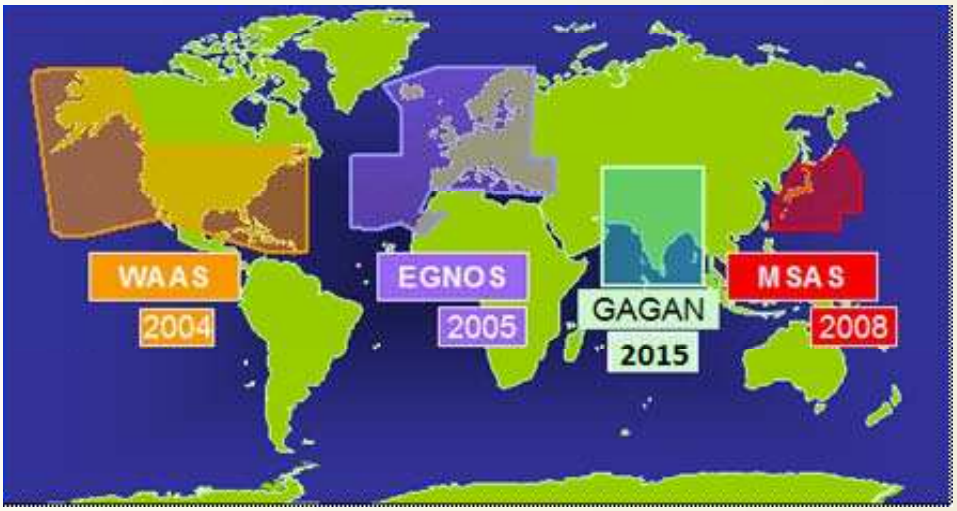
the messages on the same GPS frequency but with a different PRN code to the compatible GAGAN receivers in the user segment.

Using these signals the receiver apply all the corrections required and determine its accurate GPS position along with other necessary information like the horizontal and vertical protection limits. The pilot can use this information for navigation en route and for landing. The pilot can also broadcast this information, along with other aircraft-specific data to other aircraft and to the air traffic control facilities to obtain seamless navigation service for all phases of flight from takeoff to landing over the Indian airspace. Pre-commissioning tests have demonstrated that GAGAN is capable of better than 7.6-metre accuracy in both vertical and horizontal, and time-to-alert better than 6.2 seconds, meeting the IACO standards. The new navigation system will benefit 50 operational airports in India right now. GAGAN will provide augmentation service not only over India, but also over the Bay of Bengal, South East Asia, Middle East, and up to Africa.

Interoperability and compatibility

GAGAN is not the only satellite-based augmentation system (SABS) for navigation in civil aviation. The USA commissioned its SBAS version known as Wide Area Augmentation System (WASS) in the early 1990s. Since then the European Geostationary Navigation Overlay System (EGNOS) and the Japanese satellite augmentation system (MSAS) have been operating over their respective airspaces. All these systems use the GPS as the core satellite constellation and comply with the ICAO standards. GAGAN's footprint, while covering the Indian air space, overlaps the EGNOS and MSAS footprints, enabling it to provide seamless navigation to aircraft on a global scale and providing interoperability. All the above mentioned systems are designed to ensure mutual compatibility.

Although is designed primarily for civil aviation, GAGAN can cater to other applications. All the GPS applications could advantageously use the GAGAN signal which will ensure not only accuracy but also integrity. Such applications include railways and maritime vessels, surveying, geodesy, security agencies, telecom industry and so on. Even individual users in India can benefit from GAGAN since the higher positional accuracy will enable them to navigate themselves through the narrow lanes in both urban and rural areas, which otherwise will be difficult.



GPS Augmentation systems in the World

GAGAN service is free of charge. Anybody in the coverage area and possessing the commercially available special GPS receivers can get the benefits of GAGAN.

The next step

As stated earlier, GAGAN and all the above systems are based on GPS signals. GPS was developed by the United States Government primarily to provide American forces with an accurate means of navigation anywhere on the globe. Military operations all over the world have come to rely on satellite navigation. But there is no guarantee that the system will be accessible in conflict situations. Therefore the Indian Government is establishing an indigenous Indian Regional Navigation Satellite System (IRNSS), like the GPS, to provide position information in the Indian region and around 1,500 km off the Indian mainland.

The space component of the system will have seven satellites orbiting at an altitude of 36,000 km, carrying payloads to generate the navigation signals. As of March 2015, with four satellites (IRNSS-1A to 1D) already launched, Indian scientists are now conducting tests to ascertain whether the system's signals provide the required positional accuracy. Since the ground and user segments are the same as those of GAGAN, the experience gained during GAGAN implementation will lead them to the successful completion of the tasks related to the IRNSS.

Dr. M.S.S. Murthy retired as a senior scientist from the Bhabha Atomic Research Center, Mumbai in 1997. He is a popular science writer and authored a number of books.

Indispensable Abrasives

Dr. Chaganty Krishna Kumari
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During the festival of '*Makara sankranti*' in the month of January, young boys like to display their kite flying skills. Kites are tied to a thread and flown in the wind. Watching colourful kites of various shapes and sizes swaying in the blue sky is indeed a feast to the eyes. In kite fighting, two kite fighters try to cut off the thread of each other's kite by pulling the thread of his own kite rubbing against the other's. The thread of winner's kite cuts the opponent's thread making the opponent's kite drifts away with the wind while keeping his own kite flying. The real excitement lies in cutting in each other's kite threads.

The key item in this game is a material called *manja* coated on the thread to make it highly abrasive. Traditional *manja* is a mixture of gum, powdered glass and rice paste. This pulp is coated on cotton thread by rubbing to give it a fine and 'cutting edge'. The finer the glass powder is, the better cutting edge it produces and the more are the chances to cut the other flier's thread. Today, many kite fliers use industrial adhesives and abrasives like alumina to make *manja. Manja*-coated abrasive strings are also used by kite fighters in Afghanistan, Nepal, Pakistan, Bangladesh, and Chile.

What is an abrasive?

Apart from the kite *manja*, we come across many other abrasive things in our daily life. One simple example of an abrasive is corn starch, which is a mild abrasive. Others include sand and grit, and pumice stone. All abrasives work by scraping away a softer surface. The difference in hardness between the abrasive and the surface they are worked on is what allows the abrasive to work, the abrasive being the harder of the two substances.

Abrasives are usually used to cut, polish, grind or sharpen the surface of materials with which they come in contact. Abrasives need to possess good hardness, toughness and refractoriness. Hardness is the ability of a substance to resist scratching; toughness is the ability of it to cause indentation or to scratch aother material; while refractoriness is the ability to withstand high temperature (frictional heat). Common examples include pumice, sandpaper, emery, and sand. Each of these minerals has a different hardness, allowing for a particular application.

The use of abrasives goes back to the earliest man's rubbing of one piece of hard stone against another to shape a weapon or a tool. Early humans used a variety of tools made of stone or wood to prepare their food for cooking. These simple tools required a lot of human energy to crush, pound, and grind seeds, grains, or nuts needed to make flour or meal.

The Mohs scale of mineral hardness was devised by Friedrich Mohs, a German mineralogist, in 1812. To devise the scale, he selected ten minerals as a basis because they were common; thus the scale is not linear, but a bit arbitrary. It is a measure of the relative hardness and resistance to scratching between minerals. Among them the hardest is diamond whose hardness value on this scale is 10 and the least hard is talc, which has a hardness of 1.

The hardness of a few common household materials are as follows: Plastic 1, salt 2.3, fingernail 2.5, gold, silver 2.5-3.0, copper coin 3.5, platinum 4-4.5, window glass 5.5, ceramic tile 7.0.

Abrasives may be classified as natural and synthetic. Abrasives may also be classified based on hardness as hard, moderate and soft. Natural abrasives are mostly minerals and occur in natural deposits that can be mined and processed for use with little alteration. The following are some of the natural abrasives:

1. Corundum is crystalline, brown-to-grey in colour and very hard. It is used in grinding wheels to grind glass/lens/metals, and in ruby lasers
2. Diamond exists in three major forms: diamond (gem grade); borts, which are diamonds that are off-colour or faulty; and carbonado, which are black diamonds mined from Brazil. They have good hardness, but due to lack of lustre do not find application in jewellery. They are commonly used as abrasives. Abrasive-grade diamond is crystalline, chemically inactive and hard. It is used in drilling bits, saw-teeth for cutting rocks, in grinding wheels and engraving tools
3. Emery is composed of 50-75% alumina (crystalline), 20-40% magnetite, and 12 % other minerals, with a dark grey-to-black colour. Its hardness depends upon alumina content and usually taken as 8 on Mohs scale. Emery is

Mhos Hardness Scale

Mohs hardness	Mineral	Chemical formula
1	Talc	$Mg_3Si_4O_{10}(OH)_2$
2	Gypsum	$CaSO_4.2H_2O$
3	Calcite	$CaCO_3$
4	Fluorite	CaF_2
5	Apatite	$CaF_2)3Ca_3(PO_4)_2$
6	Feldspar	$K_2O.Al_2O_3 6H_2O$
7	Quartz	SiO_2
8	Topaz	$Al_2SiO_4(F,OH)_2$
9	Corundum	Al_2O_3
10	Diamond	C

used in emery paper and cloth used for polishing, also in bits of cutting and drilling tools

4. Garnets are tri-silicates of calcium/aluminium/magnesium/iron/manganese or chromium. Common garnet is calcium aluminium iron silicate with a hardness of 6-7.5 on Mohs scale, used as bearing pivots in watches, in glass grinding and fixed to paper or cloth to polish wood or metals,
5. Quartz is mostly pure crystalline SiO_2 with moderate hardness. Hydrated form of SiO_2 is called flint. Impure grey quartz is used in sand paper and as granules in grinding machines used to grind flour, pigments and ores.

Before the beginning of the 20th century, when natural abrasives like emery, corundum, and garnet were falling short of industry's demands, the American inventor Edward G. Acheson discovered a method of making silicon_carbide in electric furnaces, and scientists at the Ampere Electro-Chemical Company in Ampere, NJ, USA, developed alumina. In 1955 the General Electric Company succeeded in manufacturing synthetic diamonds. Synthetic diamonds proved superior to the natural product in many applications. Most natural abrasives have now been replaced by synthetic materials because nearly all industrial applications demand consistent properties. Due to uniformity in the composition of synthetic abrasives, the hardness at various points also remains uniform. With the exception of natural diamond, most of nature's abrasives are too variable in their properties.

The following are some of the synthetic abrasives:

1. Silicon carbide or carborundum is chemically inert, has high thermal stability, and a hardness of 9.3 Mohs. It is used in cutting tools, for grinding of cast iron, brass, bronze, porcelain and marble, polishing of leather and lenses and as refractory in furnace.
2. Boron carbide (B_4C) is chemically inert, with Mohs scale hardness of 9.7, and resists oxidation better than diamond. It is used in grinding dies, cutting and sharpening hard high-speed tools

Manufactured abrasives are classified into three types:

1. **Bonded abrasives** are abrasive materials contained within a matrix. The matrix is called a binder and is often clay, a resin, a glass or a rubber. The most common abrasive used is aluminium oxide. Silicon carbide, tungsten carbide and garnet are also used.
2. **Coated abrasives are created by fixing abrasives** to a form of backing material like paper, metal, rubber, resin, cloth and polyester. Sandpaper is the best example of coated abrasive.
3. **Superabrasives** are materials possessing superior hardness and abrasion resistance, developed to meet the needs of modern industry. They include cubic boron nitride (CBN) and diamond.

Industrial applications

The most important application of abrasives is in grinding. Grinding wheels (bonded abrasives) may remove upwards of half a tonne of metal per hour while grinding away the imperfections from the surface of a bar of stainless steel. Fast-spinning grinding wheels, as small as 0.55 millimetres in diameter, are used to grind miniature precision ball-bearings to accuracies measured in micrometres.

In the automotive industry, only abrasives can produce the tight fit required between piston rings and cylinders to prevent the escape of compressed vapours of petrol or diesel. Valves and valve seats are ground to highest precision. Bearing surfaces in the engine, transmission, and wheels need specific finish, size, and roundness to assure frictionless rotation. These can be achieved only with abrasives.

Abrasive wheels have replaced steel saws in many places. Thin, abrasive cut-off wheels are capable of sawing through nearly every material known, at rates faster than those of metal saws, while generating less heat and producing a better cut surface. Some space-age metals, because of their hardness, can be cut only with abrasive wheels. Granite, marble, slate, and various building blocks are cut to size with diamond abrasive wheels.

The sharpening of all types of tools continues to be a major grinding operation. Drills, saws, reamers, milling cutters, broaches, and the great spectrum of knives are kept sharp by abrasives. Coarser-grit products are used for their initial shaping. Finer-grit abrasives produce sharper cutting edges. Ultra-sharp tools must be hand-honed on natural sharpening or honing stones or leather. Even grinding wheels may require some sharpening. Specially designed steel disks or diamond tools are used to remove dull abrasive cutting edges and create a sharp cutting surface.

In foundries and steel mills, grinding wheels and coated abrasive belts remove the unwanted portions of castings, forgings, and billets. Abrasive grit is pressure-blasted against the metal to clean it in preparation for painting. Metal shot is used on softer metallic castings.

Abrasive-coated paper or cloth is used for cleaning and polishing soft and precious metals (gold, silver, platinum, etc.). They are also used to shine leather, clean lens, windscreen, etc. In a few places abrasives are used in the form of loose powder for polishing hard metal and wood. Some cleaning products also contain abrasives suspended in a paste or cream. For example, tooth paste contains calcium carbonate, silica, or mica as a "polishing agent" to remove plaque and other matter from teeth as the hardness of the abrasive used is less than that of tooth enamel but more than that of the plaque. Abrasives may also be used to prepare surfaces for application of paint and varnish.

Without abrasives it would be impossible to make machine parts that fit together precisely, and there would be no automobiles, airplanes, appliances, or machine tools. From the relatively soft particles used in household cleansers and jeweller's polish to the hardest known material diamond, abrasives are indispensable for the manufacture of nearly every product made today.

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Dr. Chaganty Krishnakumari is a Telugu popular science writer, well-known for her unique creative presentation of complex scientific subjects in a captivating narrative style. She retired as Reader and Head, Department of Chemistry from Singareni Collieries Women's College, Kothagudem, Telangana.

2015 Nobel Prizes in Science

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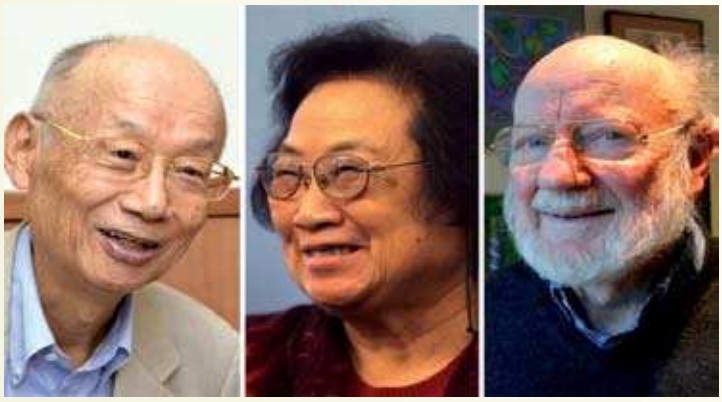
Physiology or Medicine

Diseases caused by parasites have plagued humankind for millennia and constitute a major global health problem. In particular, parasitic diseases affect the world's poorest populations and represent a huge barrier to improving human health and wellbeing. The Nobel Prize in Physiology or Medicine for 2015 has been awarded to three scientists who developed therapies against parasitic infections such as malaria and filariasis. The winners are: William C. Campbell, a microbiologist at Drew University in Madison, New Jersey, USA; Satoshi Ōmura, a microbiologist at Kitasato University in Japan; and Youyou Tu, a pharmacologist at the China Academy of Chinese Medical Sciences in Beijing.



Nobel in Physiology or Medicine
(Left to right): Satoshi Omura, Youyou Tu, William Campbell

In the 1960s, the main treatments for malaria were chloroquine and quinine, but they were proving increasingly ineffective. In 1967, China established a national project against malaria to discover new therapies. As part of the project, Tu and her team screened more than 2,000 Chinese herbal remedies to search for drugs with antimalarial activity and found an extract from the wormwood plant *Artemisia annua* to be especially effective. By 1972, chemically pure artemisinin had been isolated by her team.

Lymphatic filariasis is a debilitating disease that disfigures limbs and is prevalent mostly in the poorest regions of the world. It is caused by an infection with roundworms known as filarial nematodes. In the 1970s, Campbell and Omura discovered a class of compounds called avermectins that kill parasitic roundworms that cause lymphatic filariasis. The most potent of these compounds was released in the market in 1981 as the drug ivermectin.

Physics

Two scientists share the 2015 Nobel Prize in Physics for discovering the shape-shifting behaviour of neutrinos – tiny ghostlike particles that fill the universe, travelling close to the speed of light. The winners are: Takaaki Kajita of the Super-Kamiokande experiment at the University of Tokyo, Japan, and Arthur B. McDonald of the Sudbury Neutrino Observatory at Queen's University in Canada. Neutrinos are chameleon-like particles that switch identities in an instant, which have massive implications for our understanding of the cosmos. The work the two scientists showed that neutrinos oscillate and thus they must have mass. Earlier, for more than half a century, it was presumed that neutrinos are massless neutrinos are incredibly small, but what they lack in size, they make up for in number. There are so many neutrinos in the universe that trillions of them pass through our body every second. Even a slight change in how we see these particles can have enormous implications for our understanding of the building blocks of the universe.

Nobel in Physics
(Left to right): Takaaki Kajita and Arthur B. McDonald

Using the Super-Kamiokande detector, a huge tank in an underground zinc mine holding 50,000 tons of super-purified water, Kajita and his team had announced in 1998 that neutrinos they were studying, which were generated from cosmic rays hitting the Earth's atmosphere, seemed to be changing flavours on their way to the detector because some of the muon neutrinos they had expected to reach the detector seemed to disappear. McDonald's team was coming to a similar conclusion at the Sudbury observatory. In 2001, McDonald and his colleagues showed that some of the neutrinos generated by the Sun seemed to disappear before they reached the detector, even though the overall count of neutrinos, regardless of their flavour, stayed the same. Both the observations led to only one conclusion on opposite ends of the globe: that the neutrinos were changing between the flavours, or oscillating. The discovery has far-

Nobel in Chemistry
(Left to right): Tomas Lindahl, Paul Modrich and Aziz Sancar

(Continued on page 19)

Denizens of the Deep

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The deep sea waters were humanity's cradle. Millions of years ago, fierce competition for resources had forced our daring fish-like ancestors to crawl onto the land. As life adapted to land, we began losing our potential for survival in the ocean. We learnt to burrow, to climb trees and finally to create fire. By the time we were able to stand upright; our own cradle had become an unknown entity for us. The deep seas are now an alien world: Undiscovered, cold and dark.

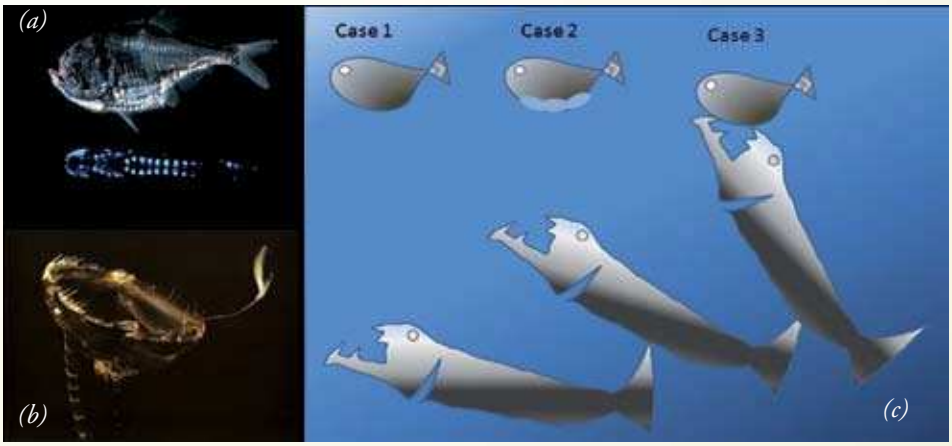

Fig. 1a. Hatchet fish with the photophores emitting blue light. (Credit: National Geographic). b. Dragon fish, a hunter of the deep with a gaping open mouth, ready to gulp down fish many times its size. (Credt: extrememarine.org.uk). c. The battle for survival – Case 1: Predator notices a hatchet fish from below; Case 2: If the hatchet fish is emitting blue light matching that coming from above, the predator is confused and does not attack. Advantage: Hatchet fish; Case 3: Some predators can screen out bioluminescence and can identify a hatchet fish from below. Advantage: predator.

Sunlight has a direct influence only up to a depth of 100 metres or so and it is only here that photosynthesis plays a major role in fuelling a vast multitude of eco systems. Leaving this thin rich slice of life in the upper layers of the ocean brings us into a far more demanding world. Below 150 metres, there are no plants. Animals here depend on the particles of drifting dead animals and plants coming down from the surface.

With increasing depth, sunlight decreases and pressure increases at the rate of 1 atmosphere for every 10 metres. One atmospheric pressure means a weight of 1.033 kg per every cm square area of a surface. So if you descend to say, 300 metres, you will face a staggering 30 kg weight pressing down on every square cm of your body. At more than a 1,000 metres down, pressure increases to 100 times that of the surface. Creatures living in such extreme environment have to develop adaptations or be wiped out. The slice of ocean ranging from a depth of 300 metres to 1,000 metres is termed as the twilight zone. It is a strange world bathed in fading blue light where, due to the lack of light, many animals have become completely transparent. In this dark blue world an animal needs to see and avoid being seen, which seems like a bit of an oxymoron since there are no hiding places at this depth. No sea floor to camouflage oneself, no coral reef to blend into; the twilight zone just comprises of an endless stretch of water. So the only way is to go invisible or become transparent. But then, mating becomes a problem. The incredible solution? Get your own light!

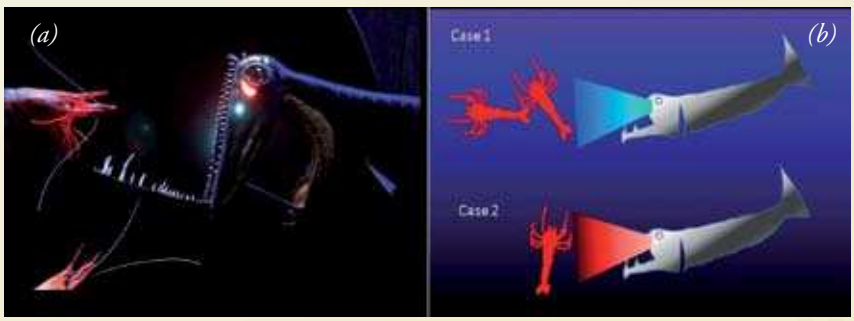

Fig. 2a. Stoplight loosejaw fish with red headlights. Observe the two sets of jaws for providing flexibility. (Credit: American Museum of Natural History). b. Hunting with headlights – Case 1: Predators approaching prey with blue head light. Prey spots the light and escapes; Case 2: Predator approaches prey with red headlight. Prey cannot see red light and therefore gets caught.

Bioluminescence is light generated by proteins through chemical reactions. Many creatures have evolved specialised proteins that use a chemical reaction and a tiny amount of energy to emit light. Others, however, have taken a strange friendship with almost invisible but countless beings thriving almost everywhere on Earth: bacteria. And in an incredible evolutionary turn of events, many creatures have evolved specialised adaptations to house these bacteria. It is a win-win situation. The bacteria get a place to thrive, while the creatures get light. Symbiotic bacteria like *Photobacterium phosphorium* and *Vibrio fischeri* live in specialised cells called photophores of twilight-zone animals. Evolution has also provided these dwellers of the depths with several proteins like "reflectins", which can reflect the bioluminescent light and increase its intensity. Imagine carrying a torch with the ability to reduce or increase the amount of light coming out. There is a second class of proteins called "modifiers", which can change the wavelength of the light emitted by the bacteria. Some of the twilight-dwellers also possess proteins like aequorin, which, in the presence of calcium, can emit light.

500 metres down, only the faintest vestige of sunlight remains. Hatchet fish, (Fig. 1a) is a common resident here and it has an excellent strategy for camouflage. It can use its photophores to match the light coming from above and thus

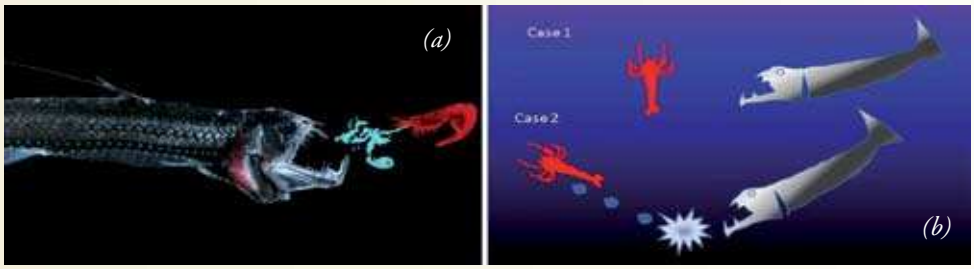

Fig. 3a. From the left, a viper fish attacking a deep ocean shrimp A. pupurea, on the right, which startles the predator with a burst of bioluminescent glue. (Credit: pbs. org.nova). b. Escape strategy of some prey – Case 1: Prey gets caught when seen by a predator; Case 2: Prey emits a bioluminescent packet that traverses some distance and then explodes with light. The predator chases the light while the prey escapes.

confuse any predator, like a wide mouthed dragon fish (Fig. 1b) Looking from below. Amazingly, if a cloud dims the sunlight, the fish also dims its bioluminescence, a phenomenon called 'counter illumination'. But some predators have developed special light-screening eyes that can differentiate between the faint blue light coming from above and the light produced by the hatchetfish (Fig. 1c). As the prey evolves, so does the predator, both locked in a cycle of ever-changing evolutionary arms race.

Consider the adaptations of predators like the lanternfish and the loosejaw fish. Their photophores exist just below the eyes, supplying the fish with a strong intense "headlight" to spot prey (Fig. 2a). Most bioluminescent organisms have evolved to shine blue light, presumably because blue light travel farther than any other colour in sea water, which screens out the red, orange and green lights. But some fishes like the shiny loosejaw (*Aristostomias scintillans*) have managed to produce red headlights. Most of the twilight zone fishes cannot even see red light, much less produce it. Thus this gives the shiny loosejaw a distinct advantage: a headlight incapable of being seen by the prey. The predator can approach its favourite prey, a shrimp, with full lights on and the shrimp will not even notice it approaching (Fig. 2b).

But not all shrimps are at the mercy of predators. Take for instance, the harmless looking shrimp known as the 'vomiting shrimp' (*Acanthephyra purpurea*). When this shrimp senses a threat like a hungry dragonfish approaching with the intention of having a feast, it spins in the water, releasing bioluminescent glue. This startles the attacker and makes it illuminated in the dark, making it vulnerable to attack by bigger predators (Fig. 3a). Some prey even goes to the extent of fooling the predator into chasing dummies. When facing an imminent attack, some zooplanktons discharge a packet of inactive bioluminescent material liquid. The secret lies in the fact that the flash is delayed and is triggered at a large distance from the prey. The predator chases after the flashes while the prey slips away into the darkness, unseen (Fig. 3b).

Not all prey is keen on running away. Some even scare the predators with their dazzling light show. Disturb the jelly fish named *Periphylla periphylla*, and you get a spectacular display of red and blue lights, a freaky light show used to scare away enemies.

Some predators use their light to lure prey. Meet the siphonophores, a living colony composed of two different kinds of tiny creatures called zooids. They prey on small animals using stinging cells, the stalks of which shine with a bright red light (Fig. 4a and b). The bright red light mimics the light emitted by a deep sea copepod and fools the fish to entangle themselves in the siphonophores' net. And in the context of luring fish with the use of light, the most famous hunter is of course the female angler fish (Fig. 4c). Wide open mouth, sharp, long teeth projecting from the gaping mouth at all possible angles, the female angler fish is a sight to behold. She has a special antenna which shines blue light that acts as a bait to lure fish or shrimps. (Remember the famous scene in the movie "Finding Nemo" when the protagonist clown fish and his accomplice descend into the twilight zone only to be chased around by an angry angler?)

Below 1,000 metres lies the dark or midnight zone. No sunlight whatsoever penetrates this deep. The temperature is below 4°C. Life becomes sparse in this dark, dangerous world. Since food is scarce in these depths, dark-zone predators have to be aggressive, deadly and ready to deal with prey of almost any size.

At 2,000 metres, the pressure is 400 times that at the surface. And the sea bed is mostly laden with specialised corals, sea urchins, polychaete worms and ancient scavengers like the hagfish. Living fossils like the Chimaera, bluntnose sixgill sharks have lived in seclusion in these dark depths for more than a million years. There are eco-systems at these depths under tremendous pressures, which are totally independent of the Sun's energy. At hydrothermal vents, the main energy currency is sulphide and brine pools, which are dependent on methane for their energy.

What else still lurks out there? What unknown creatures roam these depths, grasping blindly for their prey, never to have seen light?

Fig. 4a. Siphonophore, shown from the front displaying the cup shaped organs called as nectophores. The entire zone consisting of the cup like structures is called as the nectosome. (Credit: nova deep sea exploration). b. Siphonophore from the back. The bright thread-like structures include parts for feeding, hunting and reproduction. (Credit: siphonophore.org). c. Female angler fish. (Credit: National Geographic)

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Remembering a Rebel: Fred Hoyle

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Cricket loving Indians probably knew the English county of Yorkshire as the home of old style opening batsman Geoffrey Boycott. The opener was equally known for his sharp criticism of cricketing actions that he disliked. However, this batsman with impregnable defence was no exception. It's an old saying that natives of Yorkshire are by nature are stubborn as well as sharp-tongued. Another stalwart who showed this trait was from the field of science. He was none other than Fred Hoyle, the uncompromising rebel. A scientist who gave us a view of the origin of the universe, completely different from the Big Bang theory, Hoyle is remembered for contributing many more outstanding ideas to science.

One of these ideas relate to the appearance of life on Earth. Is our planet unique as far as appearance of life is concerned? Is it that life appeared in the oceans and pores of rocks of this planet or was it transported here from other heavenly bodies? A definitive answer still eludes scientists. However, those who find a point in supporting the transportation theory must remain thankful to Hoyle. In the mid-1970s Hoyle created a controversy by challenging the terrestrial origin of life. Chandra Wickramasinghe, student of Hoyle, collaborated in bringing forth a theory proposing the extraterrestrial origin of life. The source of this theory, as Hoyle once said in an interview, lay in his dislike of Darwin's theory of evolution. He was confident at a very young age that Darwin was definitely wrong! It was deepened during his college years when he met George Carson, an Irishman who was looking to establish a suitable mathematical model to disprove Darwin. Then came Chandra's experiments under instructions from Hoyle. On carrying out spectral analysis of spore-forming bacteria it was found that the spectra matched with some spectra obtained with radiations coming from space. Hoyle and Chandra were ecstatic that these bacteria were guests from outer space. The theory of *panspermia* was slowly taking shape. To their disappointment, however, most of the astronomers and biologists of the time not only disagreed but attacked their theory. But the theory does have a lot of supporters too. Even modern day physicist Stephen Hawking has spoken in supportive terms about *panspermia*.

Fred Hoyle

Hoyle had great trust in space. He tried to prove that the causes of many of our diseases came down from space and entered Earth's outer atmosphere. In a book published in 1986 titled *Viruses from Space and Related Matters* Hoyle writes, "According to medieval lore, diseases come from comets, and according to our view this is true, but only in a broad sense." His co-authors for this book were Chandra Wickramasinghe and John Watkins. Hoyle and Chandra listed several outbreaks of epidemics which they considered to be a result of attack of pathogens from outer space. Hoyle even believed that Human Immunodeficiency Virus (HIV) was extraterrestrial in origin. Till the end of his life Hoyle stuck firmly to such ideas.

Chandra was similarly dogged in his pursuit. But it must be stated that Hoyle and Chandra's conviction was by no means based on speculation. In the beginning it was only scientific arguments, but as time passed they came up with evidences collected from the laboratories. One of the pertinent questions against *panspermia* was that if life was truly cosmic how was it able to survive the harsh conditions of interstellar space? In 2003, in a remarkable paper published in *Astrophysics and Space Science* Jayant Vishnu Narlikar put forward some arguments which are worth noting. He said, "Over the last decade it has been demonstrated by several laboratory experiments that the microorganisms can survive extreme conditions of temperature, pressure and even radiation (Hoyle and Wickramasinghe 2000). Further a carbonaceous coating of even a few microns thick provides essentially total shielding against UV radiation (Secker *et al.*, 1994)." Although the paper titled 'A Balloon Experiment to Detect Microorganisms

Fred Hoyle in his laboratory at the Cambridge Institute of Astronomy in 1967 (Photograph: Donne-Getty Images)

in the Outer Space' was published in the journal *Astrophysics and Space Science* after Hoyle's death in 2001, Hoyle was listed as one of the authors along with Narlikar and eleven others

In fact balloon experiments are considered a smart, low-cost method to understand the injection of biotic entities from space into Earth's atmosphere. National Aeronautics and Space Administration (NASA) supported such experiments in the 1960s and 1970s. However, absence of mature techniques and allegations of terrestrial contamination rendered the projects unsatisfactory. The Indian Space Research Organisation (ISRO) also conducted such experiments at the turn of the century over the city of Hyderabad. Great care was taken to avoid contamination. The first one was conducted in 1999 and the second a couple of years later. In a letter to *The Lancet* Chandra Wickramasinghe, Milton Wainwright and Jayant Vishnu Narlikar said, "We detected large quantities of viable microorganisms in samples of stratospheric air at an altitude of 41 km. We collected the samples in specially designed sterile cryosamplers carried aboard a balloon launched from the Indian Space Research Organisation/Tata Institute Balloon Facility in Hyderabad, India, on Jan 21, 2001." The authors were very excited with this experiment. In the letter they went on to present some facts which is startling to say the least. They said, "We estimate that a tonne of bacterial material falls to Earth from space daily, which translates into some 10^{19} bacteria, or 20,000 bacteria per square metre of the Earth's surface. Most of this material simply adds to the unculturable or uncultured microbial flora present on Earth." The three scientists stated their hypothesis that the SARS epidemic could not be but the result of an attack form space. The battle for collecting evidence goes on.

Hoyle was intensely connected to space. But *panspermia* was not his real claim to fame. His contribution to the genesis of the universe is called the 'steady-state theory'. Generally speaking, it is a view that the universe is always expanding but maintaining a constant average density, matter being continuously created to form new stars and galaxies. This creation is happening at the same rate that old ones become unobservable as a consequence of their increasing distance and velocity of recession. The theory holds that a steady-state universe has no beginning or end in time; and that from any point within it the view on the grand scale is the same. Hoyle was definitely not the first to put forward such a theory. It was first put forward by Sir James Jeans around 1920. In fact, Einstein also explored a cosmic model in which the mean density of matter in an expanding universe is maintained constant by the continuous formation of matter from empty space. It was abandoned later. In 1948, Hoyle along with astronomer Thomas Gold and mathematician Herman Bondi proposed refinements to the steady-state theory. Within the framework of Albert Einstein's theory of relativity, Hoyle

A Statue of Fred Hoyle at the Institute of Astronomy, Cambridge (wikipedia)

formulated a mathematical basis for the steady-state theory, making the expansion of the universe and the creation of matter interdependent. At that time the established opinion was that the universe was created in a huge explosion. The term Big Bang that describes this theory was actually coined by Hoyle during a radio talk on BBC in a cynical fashion. Hoyle and his co-theorists had a battle at hand. Supporters of Big Bang attacked them with great enthusiasm. Hoyle, of course, was not a fellow who would back away from arguments. He fought with conviction.

Theorists look for experimental proof to prove their theory. However, during the 1950s and 1960s observed data from astronomy did not come to the aid of the steady-state theory. Discrete sources like galaxies seemed to give observational results that went against the same. But as Narlikar said, "...later, after close scrutiny all of them turned out to be unfounded". But there was one specific evidence that Hoyle could not ignore; this was the discovery of the cosmic microwave background in 1965. After this evidence came to light Hoyle felt uncertain for quite some years. But he regained his confidence and returned to his initial scepticism of the Big Bang model. He felt that it was sinking more and more into speculations with passing years. Along with Geoffrey Burbidge and Jayant Vishnu Narlikar he revived his old theory, modified it and termed it 'quasi-steady state cosmology'. This happened in 1993. This modification helped in accounting for the cosmic microwave background and elemental abundances in stars. Hoyle could also explain Edwin Hubble's expanding universe elegantly.

Why was Fred Hoyle so much against Big Bang? Were the reasons purely scientific? Or did it have anything to do with belief or disbelief in God? These are sidelights of the history of science that makes the study of the course interesting. To some, steady-state theory represents an atheist stance. Hoyle is sometimes quoted to have said that a Big Bang or a huge explosion requires the existence of a creator. On the other hand steady-state concept holds that the universe was always there but stars and galaxies keep forming through time. Queer as these ideological moorings may sound, men of science were never free from these. The cosmological debate, in fact, acquired religious and political aspects. It is reported that Pope Pious XII announced in 1952 that the Big Bang concept affirmed the notion of a transcendental creator and was in harmony with Christian dogma. George Gamow, the chief Big Bang theorist, in his turn accused the steady-state theory of having a communist bias. However, in the erstwhile Soviet Union, the land of the rise of communism, astronomers are said to have rejected both the theories as idealistic and lacking evidence.

Gamow was successful in explaining the presence of helium and hydrogen in the universe. But when it came to proposing a theory for the synthesis of heavier elements, he actually failed. Hoyle bridged this gap

with his theory of nuclear synthesis. The process though started much earlier. In 1939, Hans Bethe in his paper *Energy Production in Stars* dwelt on the different possibilities for reactions by which hydrogen is fused into helium. However, he did not address the problem of formation of heavier nuclei. Hoyle in 1946 argued that a collection of very hot nuclei would assemble into iron. In 1954 he described in detail how advanced fusion stages within stars would synthesise elements having mass between carbon and iron. It explained how the most abundant elements on Earth had been synthesised from initial hydrogen and helium. It also made clear how those elements became abundant as the galaxy aged. That was the real start of the concept of stellar nucleosynthesis. The star paper was yet to come. It appeared in the year 1957 and was authored by Margaret Burbridge, Geoffrey Burbridge and William Alfred Fowler beside Hoyle. Commonly referred to as the B^2FH, this review paper refined earlier researches and projected a consolidated picture. There was nothing fundamental in this picture, but it provided an extremely handy tool for future scientists. Although there were four authors, it is widely known that the core of the paper was the work of Fowler and Hoyle. The Burbidges only contributed the data from their stellar observations. Both of them did a remarkable job as we have discussed earlier. But only one of them got rewarded. Fowler shared the Nobel Prize in physics with our very own Subrahmanyan Chandrasekhar. Curiously enough, Hoyle was left out.

Tree being planted at IUCAA by Fred Hoyle, Jan 1994

What could be the reason for this denial? There were suggestions from some corners that *panspermia* did Hoyle in. The Royal Swedish Academy possibly did not want to associate themselves with someone who espoused a theory that said that influenza epidemics were associated with the passage of the Earth through certain meteor streams, the particles of which conveyed the virus to Earth. Scientists held it to be merely fictional. Though the big one eluded him, Hoyle received a large number of awards among which the Crafoord prize and the Balzan prize stand apart. The Crafoord prize is incidentally administered by the Royal Swedish Academy of Sciences, the same body that decides the winner of the Nobel Prizes in physics and chemistry.

Fred Hoyle was a great science populariser. Search for Extra Terrestrial Intelligence (SETI), the organisation dedicated to finding signs of life outside our planet described his popularisation efforts in these words: "Hoyle will also be remembered as one of the greatest popularisers of science in the 20th century, following in the distinguished traditions of H.G. Wells, James Jeans and Arthur Eddington. He had a rare gift of explaining complex scientific concepts in the simplest of terms, and in so doing he never failed to captivate huge audiences on radio and television, in public lectures as well as through his popular books." Among the books that he wrote the one that is particularly mention-worthy is *The Black Cloud*. Published in 1957 this was his first science fiction novel. The novel speaks of a cloud that is associated with a brain. It needs energy for survival and collects it from stars. When it comes near the Sun a catastrophe is created on Earth and the novel describes how everyone from politicians to scientists join forces to overcome the deluge.

The fictional cloud actually took shape after one of Hoyle's papers on clouds of molecular gas in interstellar space was rejected. Narlikar holds that the arguments in the paper were quite sound but the referees found it to be 'outlandish'. *The Black Cloud* was Hoyle's reaction to the rejection. He penned several other science fiction novels among which *Rockets in Ursa Major* was turned into a play for children. Many of his science fictions were co-written with his son Geoffrey. In the year 1950 Hoyle gave a series of radio talks on BBC which were later compiled into a book called *The Nature of the Universe*. As with the pen so with the microphone, he never failed to rivet the attention of his audience. He was awarded the UNESCO Kalinga Prize in 1968 for outstanding contribution to the popularisation of science.

Fred Hoyle was never a conformist. He could leave an institute that he himself formed over a disagreement and that created no repentance in him. This happened in 1972 when a policy disagreement with the authorities of Institute of Theoretical Astronomy led him to resign his directorship as well as his post of Plumian Professor at Cambridge University. He chose a small village in Lake District and started living there as a recluse. He, however, kept his research going.

The man from Yorkshire who was born on 24 June 1915 lived a long and eventful life before he passed away in the first year of the new millennium. Writing an obituary of his mentor Fred Hoyle in *Current Science,* Narlikar started with this line, "Sir Fred Hoyle, the most original and versatile astrophysicist of our times passes away on 20 August 2001."

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Sluggish liver disease— Call it, fatty liver, if you like!

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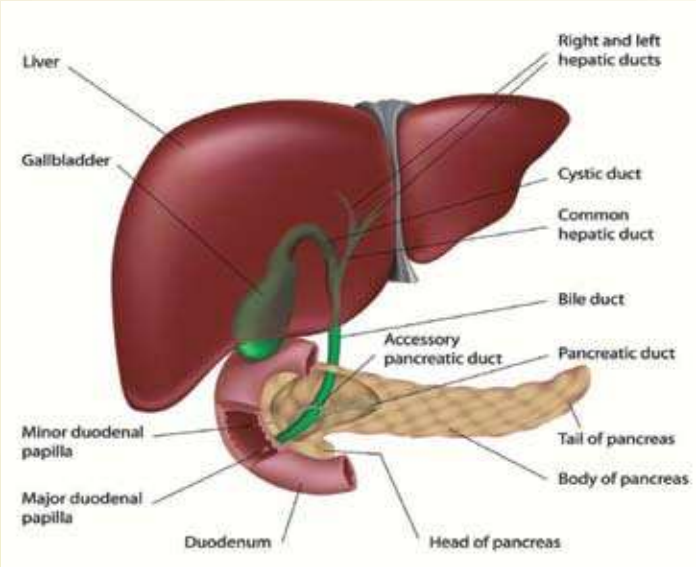
The legend of a sluggish liver has a long tradition in ayurveda. Often times, a vaidya would palpate the pulse of his client, and pick at the diagnosis. However, physicians practising modern medicine, often pooh-poohed the concept. But, amusingly, that's no longer the case. A condition that has shot into prominence in the recent years, non-alcoholic fatty liver disease now happens to be a commonly-diagnosed liver malady. Caused by a build-up of extra fat in the liver cells in people who drink little or no alcohol, many find themselves being diagnosed with this condition since the time ultrasound came to the fore.



While the diagnosis of a fatty liver does ring in an alarm bell, the good tiding is, in most people, it produces no signs and symptoms and is not associated with any serious health complications. The danger, however, plagues the few in whom the fat build-up causes inflammation and scarring of the liver tissue. This more serious form of non-alcoholic fatty liver disease is named as non-alcoholic steatohepatitis in medical parlance. In its most severe form, this malady can progress to cirrhosis of the liver, and eventually, liver failure.

How common?

Recent studies which have explored the prevalence of fatty liver and non-alcoholic steatohepatitis in the general population have found that some 20-30 per cent and 2-3 per cent people, respectively, suffer from these liver changes. The prevalence rates are higher in certain subpopulations such as people who are overweight or obese and those with type II diabetes, high cholesterol or high triglycerides. Rapid weight loss and poor eating habits also may lead to this condition.

Factors that can increase your risk

Non-alcoholic fatty liver disease occurs when your liver has trouble breaking down fats, causing fat to build up in your liver tissue. But doctors aren't sure what exactly causes the disease. A wide range of conditions, abnormal states and diseases can, however, increase your risk of developing these changes in the liver. These include the following:

- Obesity
- Type 2 diabetes
- High cholesterol
- High levels of triglycerides in the blood
- Metabolic syndrome
- Polycystic ovary syndrome
- Sleep apnoea
- Rapid weight loss
- Underactive thyroid (hypothyroidism)
- Underactive pituitary gland (hypopituitarism)
- Gastric bypass surgery

Recognising the symptoms

Usually, non-alcoholic fatty liver disease produces no significant signs and symptoms. When symptoms occur, they may include:

- Fatigue
- Weakness
- Loss of appetite
- Pain in the upper right abdomen
- Weight loss
- Nausea

If the symptoms worsen, and cause fluid build-up in the abdomen (ascites), splenic enlargement, spider-like blood vessels around the umbilicus, yellowing of the skin and eyes (jaundice), itching, swelling of the legs (oedema), and mental confusion, think that the disease has progressed to cirrhosis of the liver.

Types of non-alcoholic fatty liver disease

Non-alcoholic fatty liver disease can take several forms — from harmless to life-threatening. Forms include:

Non-alcoholic fatty liver

It's not normal for fat to build up in your liver, but it won't necessarily hurt you. In its simplest form, non-alcoholic fatty liver disease can cause excess liver fat, but no complications. This condition is thought to be very common.

Non-alcoholic steatohepatitis

In a small number of people with fatty liver, the fat causes inflammation in the liver. This can impair the liver's ability to function and lead to scarring of the liver, producing cirrhosis. Studies suggest that of those with non-alcoholic steatohepatitis, some 20 per cent people will develop cirrhosis, and 8 per cent people might die due to their liver-related condition over a 10-year period. Risk factors for the adverse clinical outcome include people older than the age of 45, the presence of diabetes or obesity, a ratio of greater than 1 between the

enzymes aspartate aminotransferase and alanine aminotransferase, and changes in the microscopic structure of liver.

Non-alcoholic fatty liver disease-associated cirrhosis

Liver inflammation leads to scarring of the liver tissue. With time, scarring can become so severe that the liver no longer functions adequately, resulting in liver failure.

Seeing the doctor

You may take an appointment with your family doctor or a general practitioner if you have persistent signs and symptoms suggesting fatty liver disease. If your family doctor were to suspect that you may have a liver problem, such as non-alcoholic fatty liver disease, you may be referred to a doctor who specialises in the field. A gastroenterologist or a liver specialist (hepatologist) is specially trained to handle the condition.

Before you go to see your doctor, draw a list of all medications, as well as any vitamins or supplements that you may be taking. This is important, especially since some medications can also produce a fatty change in liver. Take all relevant medical records, such as records of any tests you've had, including the blood work and ultrasound reports.

Your doctor is likely to take a detailed history, ask you a number of questions, and check you out physically. S/he may ask you to undergo a number of tests.

Tests and procedures

A variety of laboratory tests and procedures can come in useful in the diagnosis of non-alcoholic fatty liver disease. These tests include:

Blood tests

Liver function tests, including tests of liver enzymes, may help your doctor make a diagnosis. You may also be asked to take the lipid profile test, which would help determine the blood cholesterol and triglyceride values.

Imaging procedures

Imaging procedures used to diagnose fatty liver disease include ultrasound, ultrasound elastography, computerised tomography (CT) scan and magnetic resonance imaging (MRI). Of these tests, the simplest and the least expensive is the ultrasound test. Doctors can diagnose a fatty liver on ultrasound and can grade the change using a severity scale.

Ultrasound elastography is a useful test to pick on scarring of the liver and worsening of changes, which may lead to cirrhosis of the liver. It is also a simple test of non-invasive kind.

Liver tissue testing

If it's suspected that you have a more serious form of non-alcoholic fatty liver disease, your doctor may recommend a procedure called liver biopsy. It is typically done using a long needle inserted through your skin and into your liver to remove liver cells. The tissue sample is examined in a laboratory to look for signs of inflammation and scarring.

Making a difference

Should you be diagnosed with non-alcoholic fatty liver disease, you would be best advised to take a number of steps which can help keep a control over the condition.

Lose weight

If you're overweight or obese, reduce the number of calories you eat each day and increase your physical activity in order to lose weight. If you've tried to lose weight in the past and have been unsuccessful, ask your doctor for help.

Choose a healthy diet

Eat a healthy diet that's rich in fruits, vegetables and whole grains.

Exercise and be more active

Plan at least 30 minutes of exercise most days of the week. If you're trying to lose weight, you might find that more exercise is helpful. If you don't already exercise regularly, get your doctor's OK first and start slowly.

Control your diabetes

Follow your doctor's instructions to stay in control of your diabetes. Take your medications as directed and closely monitor your blood sugar.

Lower your cholesterol

A healthy vegetarian diet, exercise and medications can help keep your cholesterol and your triglycerides at healthy levels.

Protect your liver

Avoid things that will put extra stress on your liver. For instance, don't drink alcohol. Follow the instructions on all medications and over-the-counter drugs.

The treatment

Currently, there's no active treatment for non-alcoholic fatty liver disease. Instead, doctors typically recommend ways to treat the risk factors that contribute to the condition. For instance, if you're obese, your doctor would advise you to lose weight through diet, and exercise.

Vaccinations

Your doctor may also advise that you receive vaccinations against hepatitis A and hepatitis B to help protect you from viruses that may cause further liver damage.

Vitamin E

Vitamin E and other natural antioxidants could help protect the liver by reducing or neutralising the damage caused by inflammation. However, the evidence to this effect is still incomplete. What's more, vitamin E may have side effects, such as an increased risk of death and, in men, an increased risk of prostate cancer. Discuss the benefits and risks of vitamin E with your doctor.

Recent Developments in Science and Technology

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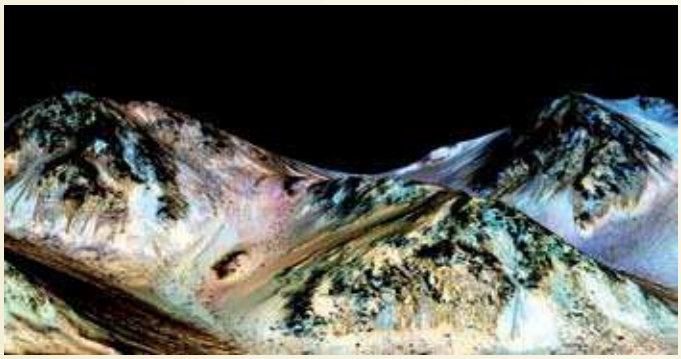
Mars has flowing water

Evidence of flowing water has been found on Mars. Images sent back by NASA's Mars Reconnaissance Orbiter (MRO) spacecraft reveal dark streaks on sandy slopes on the Red Planet that scientists believe are made by flowing water. The streaks are probably made by brine that runs down steep hills during warm months and freezes during winter. The identification of waterlogged salts in these streaks fits with the idea that they are formed by the underground flow of briny water that wets the surface.



100-metre-long dark streaks on Mars have long been thought to be evidence of flowing water. (Credit: NASA/JPL/University of Arizona)

MRO's HiRISE (High-Resolution Imaging Science Experiment) camera had first spotted these intriguing streaks in 2010. The narrow streaks appear on slopes during warm seasons, lengthen, and then fade when conditions become cooler. Liquid water runs down canyons and crater walls over the summer months on Mars, according to researchers who say the discovery raises the chances of the planet being home to some form of life. The trickles leave long, dark stains on the Martian terrain that can reach hundreds of metres downhill in the warmer months, before they dry up in the autumn as surface temperatures drop.

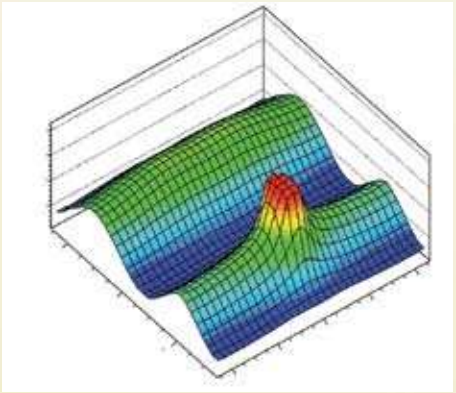
Corroborating the theory of liquid water, a team of researchers led by Lujendra Ojha of Georgia Institute of Technology, Atlanta, USA, have now found evidence of hydrated minerals on these slopes that can only be produced in presence of water. The new evidence also comes from the imaging spectrometer on-board MRO, which separates light into its constituent wavelengths to reveal the chemicals present on the Martian surface. The instrument found the signatures of magnesium perchlorate, magnesium chlorate and sodium perchlorate – all hydrated salts that require water to form and also contain molecules of water. According to the researchers, the chemicals appear in the summer, when the dark streaks are visible, and disappear along with the features when temperatures drop in winter (*Nature Geoscience*, 27 September 2015 | doi:10.1038/ngeo2546).

The findings provide yet more evidence that Mars is not a dry and barren landscape but rather a dynamic place that changes with the seasons – and, just maybe, holds the ingredients necessary for life. Liquid water is considered one of the essential ingredients for life and its presence raises the question of whether Mars, which appears so dry and barren, could possess niches of habitability for microbial Martians. According to scientists, the dark streaks on Mars may be a prime spot to search for signs of extra-terrestrial microbes. However, many mysteries remain. For one, scientists do not know where the water is coming from. One possibility is underground aquifers, frozen during winter, melting during summer and seeping to the surface.

The presence of water on Mars has been known for quite some time. Some of the earliest missions to Mars had revealed a planet with a watery past. Pictures beamed back to Earth in the 1970s showed a surface crossed by dried-up rivers and plains once submerged beneath vast ancient lakes. Occasionally, Mars probes have found hints that the planet might still be wet. Earlier this year, NASA unveiled evidence of an ocean that might have covered half of the planet's northern hemisphere in the distant past. But this is the first time that evidence of flowing water in recent times has been found. However, the fact that the water was flowing at minus 23°C means it must be highly concentrated brine, which rules out presence of any living organism in it.

LHC produces 'primordial soup' of early Universe

Researchers from the University of Kansas working with an international team at CERN's Large Hadron Collider have produced a tiny droplet of quark-gluon plasma – also known as the 'primordial soup' – a state of matter thought to have existed right at the birth of the Universe. (Quarks are the building blocks of protons and neutrons that make up the nuclei of atoms, and gluons work like 'glue' to hold the quarks together.) The unique material was discovered inside LHC's Compact Muon Solenoid (CMS) detector by colliding protons moving at nearly the speed of light with lead nuclei that generated extremely high energy. Formed at temperatures of between 4 trillion and 6 trillion degrees Celsius – about 100,000 times hotter than the centre of the Sun – physicists have dubbed the resulting plasma the "littlest liquid", which is the hottest matter ever created on Earth (*Physical Review Letters*, 29 June 2015 | doi.org/10.1103/



Plot showing formation of quark-gluon plasma in CMS at LHC. (Credit: CERN)

PhysRevLett.115.012301). Scientists believe that about 10^{-12} seconds after the Big Bang, the Universe was made up of quark-gluon plasma, which they classify as an "almost-perfect liquid", because it has almost zero friction.

What is unique in this feat is that the researchers were able to use fewer particles than thought possible to break down protons and neutrons into their constituent parts – quarks and gluons, to create the primordial soup. When collided at high energy, each proton and neutron breaks up into three quarks each, and releases the gluons – a massless form of matter that holds the quarks together with the help of a phenomenon known as the 'strong force'. Before the recent experimental results, it had been thought the medium created in proton-on-lead collisions would be too small to create quark-gluon plasma. Physicists had initially believed that only the nuclei of large atoms such as gold would have enough matter and energy to free the quark and gluon building blocks that make up protons and neutrons.

The researchers say, the unexpected discovery would shed new light on high-energy physics because while high-energy particle physics often focusses on detection of subatomic particles, such as the recently discovered Higgs Boson, the new quark-gluon-plasma research instead examines behaviour of a volume of such particles.

While it is widely believed that about a microsecond (10^{-6} sec.) after the Big Bang the Universe consisted of quark-gluon plasma, there is still much that scientists do not fully understand about the properties of quark-gluon plasma. Being able to form quark-gluon plasma in proton-lead collisions would help scientists better define the conditions needed for its existence and understand the early Universe.

The findings may help physicists to more effectively study and understand how matter behaved during the initial few microseconds after the birth of the Universe – often referred to as the 'quark epoch' – the period in the evolution of the early Universe when the fundamental interactions of gravitation, electromagnetism, the strong interaction and the weak interaction had taken their present forms, but the temperature of the Universe was still too high to allow quarks to bind together to form hadrons. It may also help scientists to understand how the basic forces that govern our Universe, such as gravity, came to be.

New species of human ancestors discovered

In the distant past there were at least nine species in our genus, Homo, including *Homo erectus*, *Homo habilis*, and *Homo neanderthalensis*. Now scientists have discovered a new species to add to our family tree, *Homo naledi*. An international team of more than 60 scientists has announced the discovery of a brand-new species of human ancestor from a wealth of bones collected from deep inside a nearly inaccessible cave in South Africa. The team was led by Lee R. Berger, an American paleoanthropologist who is a professor of human evolution studies at the University of the Witwatersrand in Johannesburg. The new species, named *Homo naledi*, probably lived 2.5 to 2.8 million years ago, at the very root of the Homo lineage. According to geologists, the cave is no older than three million years. The name *naledi* means "star" in Sesotho, a local South African language, after the cave where the fossils were found. The researchers describe *H. naledi* as a species "with long legs and feet that look very much like ours, but with apelike, curved hands and a small brain".

A reconstruction of the skull and hand of Homo naledi, a human ancestor discovered in South Africa. (Credit Naashon Zalk for The New York Times)

The team collected 1,400 bones and 140 teeth belonging to at least 15 individual skeletons of males and females of various ages from the cave during a single short field session. The discovery constituted the largest sample for any human-like species in a single African site, and one of the largest anywhere in the world. Further, the scientists said, that sample is probably a small fraction of the fossils yet to be recovered from the chamber. The remains covered the earthen floor beyond the narrow opening of a cave. The sheer number of bones and their location hint at something even more astonishing. The researchers suggested that the nearly inaccessible location of the fossils, plus their abundance and intact condition, all point to one explanation – purposeful burial, something only modern humans are known to do. The scientists think the place could have been a burial chamber where bodies may have been left deliberately. According to the scientists, this has never been seen before in such a primitive human and could have big implications for understanding the origins of modern human behaviour (*eLife*, 10 September 2015 | doi: 10.7554/eLife.09560).

According to the researchers, an average *H. naledi* was about 150-cm tall and weighed almost 45 kg. *H. naledi*'s brain size was found to be between 465 and 560 cubic centimetres, roughly a third of the brain size of modern humans and the smallest in the genus, but the mosaic of contrasting anatomical features, including more modern-looking jaws and teeth and feet, shows that the new species belong to the genus Homo, and not Australopithecus, the genus that includes the famous Lucy species that lived 3.2 million years ago.

"Drinkable book"- A unique method to purify water

One of the biggest problems in the developing world is access to safe, reliable drinking water. Now a new and inexpensive technique of purifying drinking water is available, according to a paper presented at the 250th national meeting of the American Chemical Society in Boston, USA in March 2015. Called the "drinkable book", the pages of the book are impregnated with nanoparticles of silver or copper, which

kill bacteria in the water. As the water runs through, the bacteria absorb the silver or copper ions, which kill the bacteria.

Each book comes packaged in a 3D printed box, which converts into a filtration tray. The user simply tears out one of the pages and slips it into the tray, and can use it to filter water. The pages also contain printed information on how and why water should be filtered. In trials at 25 contaminated water sources in South Africa, Ghana and Bangladesh spread over several years, pages of the "drinkable book" successfully removed more than 99% of bacteria from water. According to Dr. Teri Dankovich, a postdoctoral researcher at Carnegie Mellon University in Pittsburgh, USA, who developed and tested the technology for the book, it has proven effective at destroying bacteria that cause diseases such as cholera, *E.coli* and typhoid. In one test, the "drinkable book" was able to kill the bacteria almost completely in samples that were contaminated with raw sewage. The "drinkable book" has now passed two key stages – showing that it works in the lab, and on real water sources.

The majority of people affected by a poor water supply and inadequate sanitation and hygiene live in developing countries. About 783 million people do not have access to clean water source and get their water from unprotected groundwater or surface water. The majority of these people live in rural settings. Dr. Dankovich says the technology is directed towards communities in developing countries who do not have access to clean drinking water.

The "drinkable book" (top). The plastic tray at left is the book case and is also used for filtering water. The pages of the book (bottom) are impregnated with nanoparticles of silver and gold to kill bacteria.

Dankovich pours contaminated pond water into a funnel containing an antimicrobial filter paper from "drinkable book" to obtain clean drinking water in a rural area of Bangladesh. (Credit: Ali Wilson)

The technique is very simple to use. All the user needs to do is tear out a page, put it in a simple filter holder and pour water into it from rivers, streams, wells, etc., and out comes clean water. The silver or copper ions kill the bacteria as they percolate through the treated page of the book. According to researchers, one page can clean up to 100 litres of water. One book could filter one person's water supply for four years.

Overall, out of all the technologies that are available, such as ceramic filters, UV sterilisation and so on – this is a promising one, because the "drinkable book" is cheap, and it is a catchy idea that people can get hold of and understand. Dr. Dankovich and her colleagues are hoping to step up production of the paper, which she and her students currently make by hand, and move on to trials in which local residents use the filters themselves.

2015 Nobel Prizes in Science

(Continued from page 29)

reaching implications in our understating of the universe.

Chemistry

The 2015 Nobel Prize for Chemistry is shared by three scientists for their work mapping, at a molecular level, how cells repair damaged DNA and safeguard the genetic information. The winners are: Tomas Lindahl of Francis Crick Institute and Clare Hall Laboratory, Hertfordshire, UK; Paul Modrich of Howard Hughes Medical Institute and Duke University School of Medicine, Durham, NC, USA; and Aziz Sancar of University of North Carolina, Chapel Hill, NC, USA. Their work provided fundamental insights into how cells function, knowledge that can be used, for instance, in the development of new cancer treatments.

In the 1970s, Tomas Lindahl had demonstrated that DNA was not stable as believed earlier. He discovered that DNA decays at a rate that ought to have made the development of life on Earth impossible. This insight led him to discover a molecular machinery called base excision repair, which constantly keeps repairing the damaged DNA.

The work of Aziz Sancar involved mapping nucleotide excision repair, the mechanism that cells use to repair UV damage to DNA. People born with defects in this repair system often develop skin cancer if they are exposed to sunlight. The cell also utilises nucleotide excision repair to correct defects caused by substances that cause mutations, among other things.

Paul Modrich had demonstrated how the cell corrects errors that occur when DNA is replicated during cell division. This mechanism, known as mismatch repair, reduces the error frequency during DNA replication by about a thousand-fold. Congenital defects in mismatch repair are known, for example, to cause a hereditary variant of colon cancer.

[Detailed accounts of the work of the laureates will be published in subsequent issues.]