R.N. 70269/98
ISSN : 0972-169X

Postal Registration No.: DL-SW-1/4082/12-14
Date of posting: 26-27 of advance month
Date of publication: 24 of advance month

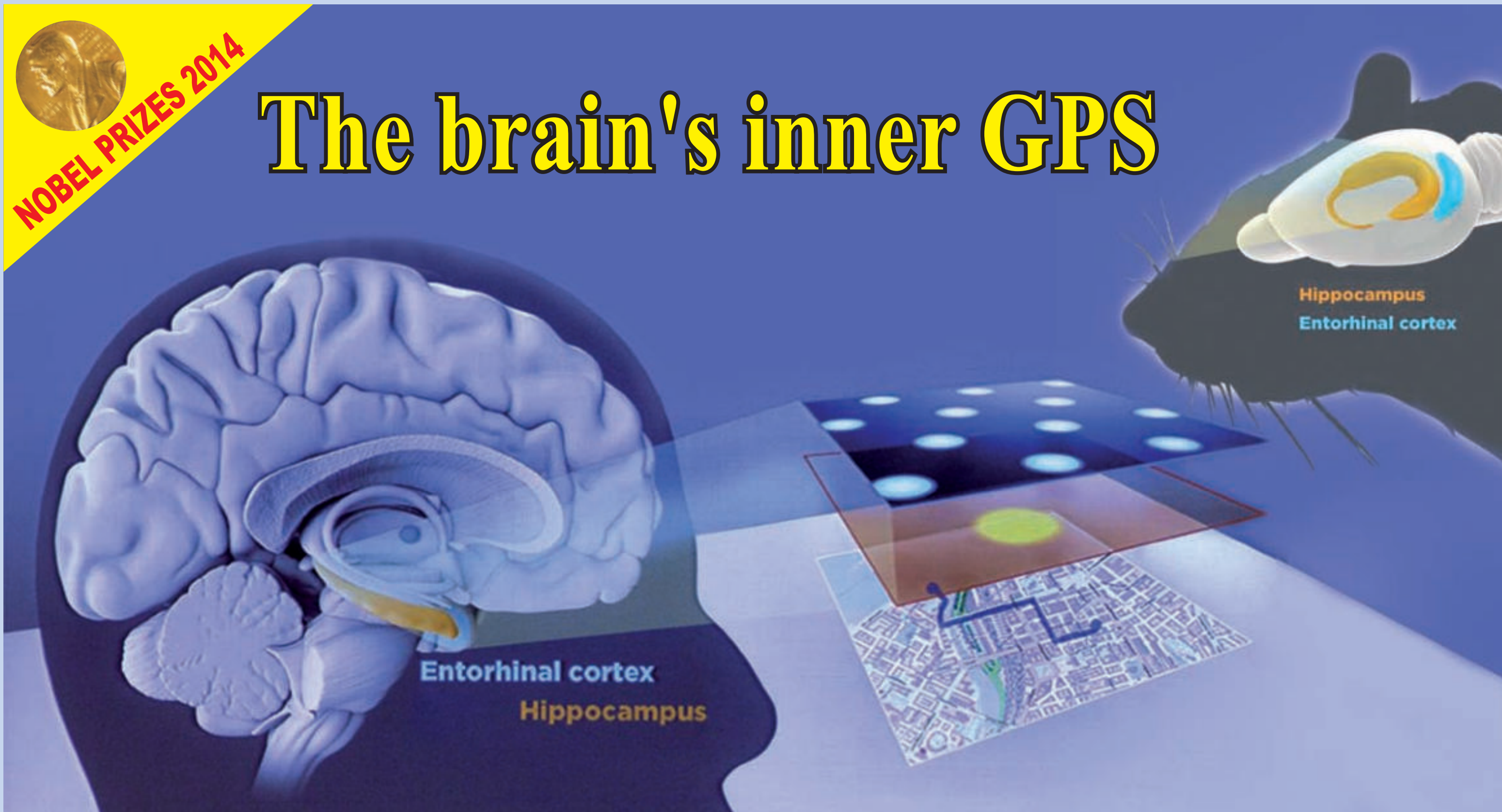
Vigyan Prasar

DREAM 2047

December 2014 | Vol. 17 | No. 3 | Rs. 5.00

NOBEL PRIZES 2014

The brain's inner GPS



Editorial: When will we learn, after all?? 35
The brain's inner GPS 34
What is the Civil Nuclear Liability Act? 33
300 years of the 'Longitude Problem' 30
Mouth-watering aromas 26
Heel pain: Bringing it to "heal" 23
Recent developments in science and technology 21

Physiology or Medicine

John O'Keefe   May-Britt Moser   Edvard I Moser

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

When will we learn, after all??

Dr. R. Gopichandran

The Swachh Bharat campaign is a classic opportunity for us to come together to clean up our external living environment. Did not all the obvious waste in our environs accumulate enough to wake us from our slumber before the call? Did we really need a call for a national level thrust? Would not the success of this call depend on local level individual action? Are we scientifically tempered enough to act on our own accord even if there is no call for action?

Yet another case in point is the emphatic call for our (we fellow citizens') attention to adulterated sweets sold at Diwali time. Programmes on television channels over the years have highlighted the extent of adulteration and health consequences of consuming such sweets. Despite the best efforts to propagate and even engage with consumers with inputs from experts and regulatory/punitive action, there are no signs of abatement or any change in the attitudes of consumers.

For a moment I wish to stand back and ask if people are not adequately information-empowered or do they deliberately overlook the consequences of bad choices or inaction? If it is the case of the firstly stated dilemma, can we say, significantly up-scaled outreach and engagement programmes will resolve issues? I will be a bit sceptical on this count. A large number of sensitisation programmes by the government, civil society institutions, news media, bilateral and multilateral institutions have always reached out to us and yet we seem to have ignored the call. Is it therefore a case of collective callousness that does not lend itself to any correction? This level of callousness probably reflects a flippant approach steeped in attitudes of indifference.

The two community-level challenges cited are probably reflective of larger scale attitude related indifference including depredation we inflict on our environs and natural resources. Any attempt to set these right cannot simplistically call for "infusing/enhancing scientific temper" because of three important considerations. (i) Hands-on remediation and preventive strategies have to be demonstrated along with more emphatic implementation of regulations. These have to be at significantly large scales, going beyond small-scale pilots. (ii) Incentives for compliance and maverick positives may inspire others too to gradually move into self regulation. These are conspicuous by their absence, especially from a systemic and cross-cutting point of view. Awareness and sensitisation interventions cannot be viewed as stand-alone thrusts. This is probably because behaviour and deliberate choice based on wisdom for common good are influenced by several intrinsic and extrinsic determinants. (iii) Any attempt to resolve these tangles should also take into account the level of preparedness of stakeholders to comprehend the information that is presented to them. An understanding of the architecture of enabling circumstances to ensure transitions is also critical. Interpretations on the expressions or manifestations of scientific temper or their absence cannot be based on assumptions or be driven by piecemeal analyses. The cases of cleanliness drives/keeping away from adulterated sweets in particular, create the context for detailed investigations on the dynamics of communication and their impacts as enablers of sustainable development.

The call for a clean India therefore provides a valuable opportunity to consolidate our efforts to interpret these circumstances and initiate holistic approaches that can be sustained over significantly long periods of time. The upcoming International Year of Light (2015) and International Year of Soils (2015) provide valuable additional opportunities that can be embedded in the holistic framework. The wisdom in communities to tackle these and related challenges has to be mainstreamed in these initiatives as useful entry points for collective and ready accepted action. We have to progress beyond rhetoric in all these cases. The credibility of communicators cannot be overemphasised in this context. It is essential to ask if such communicators propagate their own agenda or the agenda of science in its true spirit.

Email: r.gopichandran@vigyanprasar.gov.in ■

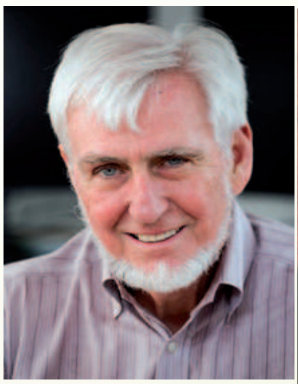
Editor : R Gopichandran
Associate editor : Rintu Nath
Production : Manish Mohan Gore and Pradeep Kumar
Expert member : Biman Basu
Address for correspondence : Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi-110 016
Tel : 011-26967532; Fax : 0120-2404437
e-mail : info@vigyanprasar.gov.in
website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

Published and Printed by Manish Mohan Gore on behalf of Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi - 110 016 and Printed at Aravali Printers & Publishers Pvt. Ltd., W-30, Okhla Industrial Area, Phase-II, New Delhi-110 020 Phone: 011-26388830-32.

The brain's inner GPS

Biman Basu
E-mail: bimanbasu@gmail.com

The sense of place and the ability to navigate are some of the most fundamental functions of our brain. When we go to an unknown place we find it very difficult to find our way around. But when we visit a known place that we had visited before, everything appears so familiar. Why is it so? How does our brain remember places? How does the brain create a map of the space surrounding us that help us navigate our way through a complex environment? These questions have occupied the minds of philosophers and scientists for centuries, but no answers could be found. At last, we know the answer now and the credit for finding it goes to three scientists who share this year's Nobel Prize in Physiology or Medicine. The three scientists – British-American researcher John O'Keefe, and Norwegian couple May-Britt Moser and Edvard I Moser – discovered cells that constitute an internal positioning system in the brain and works like an inner 'GPS', making it possible for us to orient ourselves in space. O'Keefe gets half the prize amount while the other half will be shared between the Moser couple.



John O'Keefe

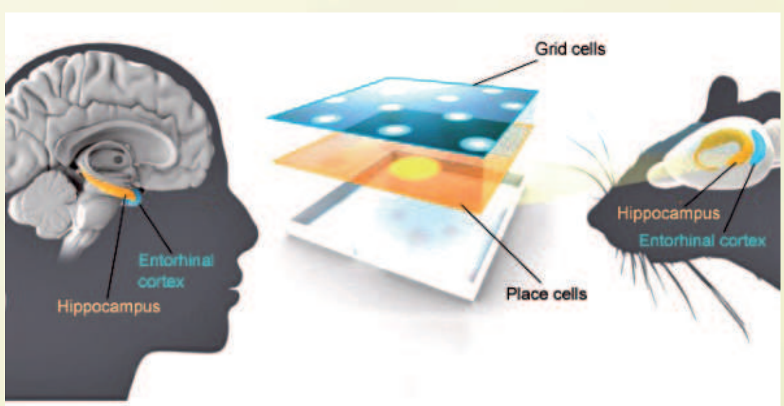
May-Britt Moser

Edvard I Moser

It was in 1971 that O'Keefe, currently director of the Sainsbury Wellcome Centre for Neural Circuits and Behaviour at University College London, UK, discovered that a certain type of nerve cells in a part of the brain called the hippocampus was always activated when a rat was at a certain place in a room. He called these cells "place cells", which constitute the first part of the brain's internal positioning system. O'Keefe could demonstrate that these place cells were not merely registering visual input, but were building up an inner map of the environment. He found that place cells were active in a way that had not been seen for any cells in the brain before. Individual place cells were only active when the animal was in a particular place in the environment, namely their place field.

By systematically changing the environment and testing different theoretical possibilities for the creation of the place fields, O'Keefe showed that place cell firing did not merely reflect activity in sensory neurons, but that it represented a complex pattern of the environment. He concluded that the place cells in the hippocampus generate numerous maps, represented by the collective activity of place cells that are activated in different environments. Therefore, he argued that the memory of an environment could be stored as a specific combination of place cell activities in the hippocampus. Together the activity of place cells may be used both to define the position in the environment at any given time, and also to remember past experiences of the environment.

Thirty-four years later, in 2005, a husband and wife team, May-Britt and Edvard Moser, currently based in Trondheim, Norway, discovered a different part of the brain which acts more like a nautical chart. May-Britt Moser, currently Director of the Centre for Neural Computation in Trondheim, Norway, and Edvard Moser, currently Director of the Kavli Institute for Systems Neuroscience in Trondheim, were studying the hippocampus to find out whether the place cell firing can be generated from activity outside hippocampus. The major input to the hippocampus comes from a structure in the rat's brain called the 'entorhinal cortex'. During their studies, the Moser couple identified another type of nerve cells, which they called "grid cells" and which formed another key component of the brain's positioning system. The grid cells showed an astonishing firing pattern. They were active in multiple places that together formed nodes of an extended hexagonal grid, similar to the hexagonal arrangements of holes in a beehive. They found that these cells generate a coordinate system and allow for precise positioning and path-finding. These intriguing cells, which are also present in humans, work much like the Global Positioning System, allowing



Diagrammatic representation of place cells in the hippocampus and grid cells in entorhinal cortex of rat and human brain. (Credit: www.nobelprize.org)

Continued on page 31

What is the Civil Nuclear Liability Act?

M.S.S.Murthy
E-mail: imurthy@hotmail.com

India has ambitious plans to boost electricity generation by many folds in the coming decades – from the current 160,000 megawatts (MW) to about 800,000 MW by 2031-32. All this cannot be fuelled by coal alone, both because of the dwindling coal reserves and because of the greenhouse gas effect. Hence, nuclear energy is expected to play a significant role to play, to the tune of about 63,000 megawatts. The present generating capacity of the 20 reactors is about 4,780 MW, while the other seven reactors under construction are expected to add another 6,100 MW by 2020.

Though India has been able to develop an indigenous nuclear power program over the past few decades, the available nuclear resources are not sufficient to meet the envisaged demand. Keeping this in mind the country entered into a civil nuclear deal with the USA in 2008, which was followed by similar agreements with many other countries. These agreements enable the country to import not only uranium – the nuclear fuel – but also entire power plants. To meet the growing demand India may have to import about 40 nuclear reactors. Since this is a multi-billion dollar business, many foreign suppliers- from France, Russia, and USA are interested in doing business with India. However, even after six years of signing the civil nuclear deal there has been little progress on this front, mainly because of some legal hurdles.

Civil liability

Though the safety of nuclear power plants has improved many folds over the past few decades, a complex technology of this type can never be assured of 100% safety. In fact, there is no technology which is totally safe. Although the probability of a nuclear event is extremely low, it is not zero. There are certain unique features associated with the operation of a nuclear power plant that put them in a separate category from the risk aspect. The consequences of an accident in a nuclear power plant would be very different from an accident in any other industrial set up (see Box).

Hence to protect the public and property and facilitate payment of compensation for any loss of life and property and damage to environment in case of a nuclear incident, a separate legal framework is required to be in place. It is generally referred to as 'civil liability for nuclear damage'. There are some international liability regimes like OECD's Pan's Convention on Third Party Nuclear Liability in the field of Nuclear Energy, 1960, and the International Atomic Energy Agency's (IAEA) Vienna Convention for Nuclear Damage of 1963, followed by the 1997 Convention on Supplementary Compensation for Nuclear Damage (CSC). Most countries which operate nuclear facilities either adhere to one of these regimes or develop their own in conformity with the international ones. Indian parliament passed the "Civil Liability for Nuclear Damage Act" in August 2010. In the normal course this should have facilitated smooth business between Indian government and the foreign suppliers. However, there are certain ambiguities and uncertainties, which have attracted strong criticism by both the Indian analysts and foreign suppliers and governments.

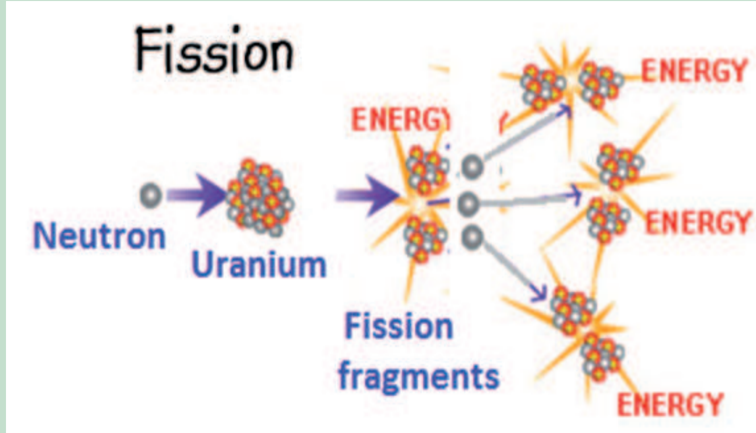
Kudankulam nuclear power plants built by Russia are outside the scope of supplier's liability. (NPCL)

The Indian Act is generally in line with the major clauses of the international conventions in that the Act incorporates the principle of 'strict liability' on the part of the operator of the facility (one who owns it). At present it is the Nuclear Power Corporation, owned by the government of India. This means that in the event of a nuclear accident, the operator will be responsible regardless of the causes of the accident. The victim need not prove negligence or any other type of fault on the part of the operator. This is necessary because, considering the technological aspects, providing such a proof will be beyond the capabilities of the complainant. It also channels the compensation only through the operator so that the victims need not knock at many doors.

Clause 6 of the Act specifies an upper limit of Rs. 1,500 crores as the operator's liability for nuclear damage in case of an accident in a nuclear power plant (lower limits are prescribed for other nuclear facilities like reprocessing plant, etc.). If the liability exceeds this limit, the Government of India will bear it up to a maximum of about 2,300 crores.

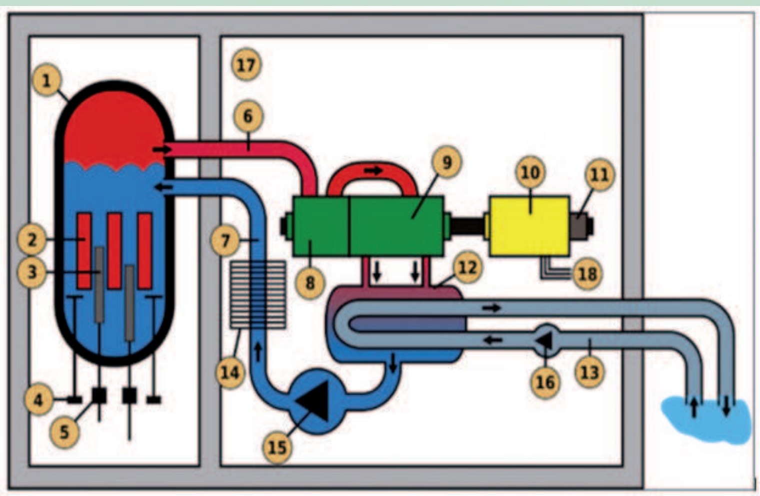
Along with the principle of strict liability on the part of the operator, the international conventions also provides for 'right of recourse' to the operator. This means that the operator can recover the compensation amount under the following circumstances: a) "*if this is expressly provided for by a contract in writing*", and b) "*if the nuclear incident results from an act or omission done with intent to cause damage, against the individual who has acted or omitted to with such intent*".

Generally electricity is produced by driving a turbine which runs a generator. In most thermal power plants the turbine is driven by steam generated by boiling water through burning coal, but oil or gas is also used). In a nuclear reactor the fuel for generting heat is an isotope of uranium (generally Uranium-235) or of plutonium (Plutonium-239). When U-235 nucleus is bombarded by slow neutrons, it splits into two parts of approximately equal mass. The process known as nuclear fission releases a huge amount of energy and two or three more neutrons. These neutrons, in turn, cause fission in other uranium nuclei resulting in a chain reaction and the production of an enormous amount of energy. By controlling the rate of the chain reaction, the energy can be used to boil water to produce steam, which in turn drives the turbine.



Controlled fission chain reaction in a reactor produces enormous amount of heat which can be used to boil water and produce steam.

In an actual reactor, small pellets of uranium oxide are loaded into zirconium tubes and hundreds of these are placed in a particular array. This is known as the core of the reactor. Water or heavy water is circulated around the core to remove the heat generated in the fission process and to produce steam under pressure. The rate of heat generation is controlled by inserting cadmium rods into the core to absorb excess neutrons and to reduce the fission rate.



Boiling Water Reactor Schematic: 1- Reactor pressure vessel (RPV). 2- Nuclear fuel element. 3- Control rods. 4- Circulation pumps. 5- Motor to control rods. 6- Steam. 7- Feedwater. 8- High pressure turbine (HPT). 9- Low pressure turbine. 10- Generator. 11- Exciter. 12- Condenser. 13- Coolant. 14- Pre-heater. 15- Feedwater pump. 16- Cold water pump. 17- Concrete enclosure. 18- Mains connection. (http://en.wikipedia.org/wiki/File:Schema_reacteur_eau_bouillante.svg).

From the point of view of safety, what sets a nuclear power plant apart is the build-up of radioactivity in the core and the potential for its release to the environment in case of an accident. To begin with uranium is only mildly radioactive. However, as the reactor operates, fission products, which are highly radioactive, accumulate in the core, making it millions of times more radioactive than the original fuel. In the normal functioning of a nuclear reactor this does not pose a problem. However, problems arise in case of an accident.

In a worst case scenario, loss of coolant may lead to over-heating of the core, hydrogen explosion, core melt, and release of radioactivity to environment leading to contamination of large areas far beyond the limits of the plant and even beyond the national borders, as it happened in Chernobyl in erstwhile Soviet Union and more recently in Fukushima, Japan. Though the fuel cooling system will have many layers of safety, backing one another, in a very rare event, the entire system may fail. Hence, operating a nuclear power plant needs a separate legislation to protect the people and property and to address issues of compensation in case of an accident.

The most contentious issues for the foreign suppliers of nuclear equipment are the clauses 17 (a), 17 (b) and 17 (c) of the Act, which pertain to right of recourse and supplier's liability. Though Sections 17 (a) and 17 (c) are in conformity with the international conventions, as for as the right of recourse is concerned (as given above), the Indian Act has an additional section – Section 17 (b) – which goes one step further to extend the scope of operator's right of recourse. Accordingly, the operator can exercise his right of recourse if "*the nuclear incident has resulted as a consequence of an act of the supplier or his employee, which includes supply of equipment or material with patent or latent defects or sub-standard services*". This means that if the mishap can be traced to the supply of defective material or equipment or substandard service, then the operator can claim the compensation amount form the supplier. With the experience of the Bhopal gas tragedy behind them, the Indian legislators have tried to tighten up the supplier's liability much more than what the IAEA's Convention on Supplementary Compensation has prescribed. Obviously, this clause has attracted strong criticism from foreign suppliers of nuclear equipment and services. They point out that it is in contravention with the international conventions and refuse to do business with India under such a clause.

Nuclear Liabilities

Nuclear suppliers' indemnity has a long history, not only in the Indian context, but also in the context of a few other countries. As early as in the 1960s, when India's first nuclear power plant was built in Tarapur by the General Electric Company of the USA, the supplier was totally exempt from any liability. For one thing, there was no civil liability for nuclear damage legislation in force in India at that time. Secondly, the country badly needed the know-how, which would not be available otherwise. Similar indemnity was extended to the Atomic Energy of Canada Ltd. to build two power plants (pressurised heavy water reactors) at Rawatbhata in Rajasthan. After India conducted the first peaceful nuclear explosions in 1974, the Western countries withdrew nuclear cooperation with India. However, the experience gained with the Canadian reactors helped India to indigenously design and build a chain of 16 more reactors. Meanwhile, Russia came forward to build two 1000 MW nuclear power plants in Kudankulam in Tamil Nadu. Though the agreement was signed by the two governments in 1988, work started only in 1998. These reactors are also exempt from supplier's liability. In 2008 Russia and India signed another agreement to build four more nuclear power plants under similar exemption. Thus, all the currently operating and under construction reactors are totally exempt from supplier's liability (including Indian suppliers). However, now, with the Act in place, suppliers' indemnity cannot continue any longer.

In order to ease this situation arising from the new Act and make business possible, the then Attorney General of India gave his opinion that Section 17 (a) provides a right of recourse only if it is expressly provided for in the contract in writing and the operator is free to choose not to incorporate such a provision. In that case, Sections 17 (a) and 17 (b) will have no force and the supplier will be liability free. However, other legal experts do not agree with this view.

Another contentious clause which inhibits the foreign suppliers is Section 46 of the Act. The international regimen directs all compensation only through the operator and the supplier cannot be sued by the victim. However, Section 46 of the Indian Act allows a victim of nuclear accident to file a tort case – case arising from breach of duty imposed by law – against the operator, in addition to the damages he would have to bear under the liability clause. In principle the proceedings of such a case can bring the supplier of equipment too under its ambit if the operator contends that defective equipment was the cause of the nuclear accident.

Indian commentators complain that the Act is inadequate with respect to operator's liability of Rs.1,500 corers paid as compensation. Another aspect of capping operator's liability is that according to the rules framed under the Act, if the operator exercises the right of recourse against the supplier of the nuclear reactor, the supplier has to shell out either the actual compensation amount paid by the operator or the contract amount whichever is less. Since the contract amount can be in billions of dollars, the supplier can get away paying just Rs.1,500 corers, which is too small compared with the contract amount. If the actual compensation is more than the operators liability the excess would be paid by the government of India and it has no right of recourse against the supplier.

With so many loose ends, it is no wonder that the Indo-US Civil Nuclear Deal has not borne fruits even four years after it came into existence. How these issues will be resolved in the coming years to ensure India's energy security, one has to only wait and watch.

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. ■

Continutted from page 34 **(The brain's inner GPS)**

animals to understand their location. The Mosers showed that the grid formation did not arise out of a simple transformation of sensory or motor signals, but out of complex network activity. The grid pattern had not been seen in any brain cells before! The Mosers concluded that the grid cells were part of a navigation system. These grid cells are akin to lines of longitude and latitude, helping the brain to judge distance and navigate. The grid system provided a solution to measuring movement distances and added a system of measurement to the spatial maps in hippocampus. These cells generate a coordinate system and allow for precise positioning and path-finding.

The Mosers further explored the relationship between grid cells and place cells in theoretical models, lesion experiments, and in remapping experiments. These and other studies by Mosers and O'Keefe, as well as by others, showed that there is a reciprocal influence between grid cells in the medial entorhinal cortex and place cells in the hippocampus. It is now known that grid cells, together with other cells in the entorhinal cortex that recognise the direction of the head of the animal and the border of the room, form networks with the place cells in the hippocampus. This circuitry constitutes a comprehensive positioning system, an inner GPS, in the brain. The positioning system in the human brain appears to have similar components as those of the rat brain.

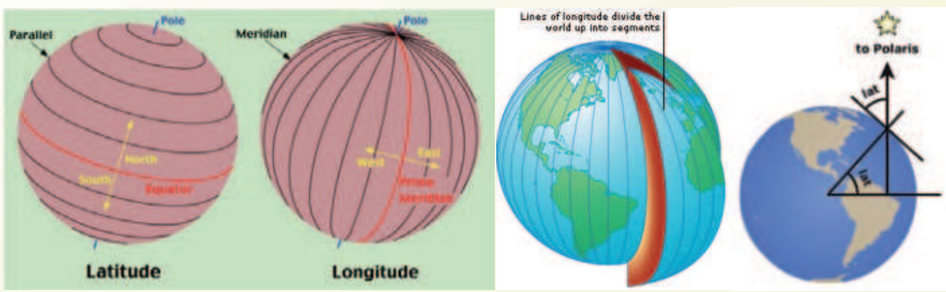
The work of the three Nobel laureates has helped researchers understand "how the brain computes spatial information to make a representation of spaces, so we can use that information to move around in the environment and do what we do every day". Brain disorders are the most common cause of disability and despite the major impact on people's life and on the society, there is no effective way to prevent or cure most of these disorders. The episodic memory is affected in several brain disorders, including dementia and Alzheimer's disease. The findings of this year's Nobel laureates may help explain why Alzheimer's disease patients cannot recognise their surroundings.

Studies of the brain's navigation system have opened new avenues for studying how cognitive processes are computed in the brain. The discoveries of place and grid cells present a paradigm shift in our understanding of how groups of specialised cells work together to execute higher cognitive functions. A better understanding of neural mechanisms underlying spatial memory is important, and the discoveries of place and grid cells have been a major leap forward to advance this endeavour. ■

300 years of the 'Longitude Problem'

Achintya Pal
E-mail: achintya.pal1952@gmail.com

Living in an era when the latitude and longitude of a place are continuously updated on GPS (Global Positioning System) while driving a car, it is indeed difficult to imagine that precise determination of longitude or latitude could at all be a problem! Very few people possibly know that in 1714, after many shipwrecks and loss of thousands of human lives due to lack of knowledge of coordinates during a voyage, the British Parliament declared a prize money of £20,000 to anyone who could find a way to fix the longitude of a place, particularly on high seas, to within half a degree, which translates to about 55 kilometres near the equator! 'Discovering the longitude' became synonymous with attempting the impossible and the problem was considered so crucial that the Longitude Act was passed in parliament and a 'Board of Longitude' was constituted. Thus, this year (2014) marks 300 years of the famous 'Longitude Problem', which bothered the seafarers of many countries much before the formal declaration was made.



One has to go back many centuries to realise that astronomical observations were the only way to determine one's position. Knowing one's position on Earth requires two very simple but essential coordinates; rather like using a street map where one thinks in terms of how far one is up/down (one's latitude) and how far side to side (one's longitude). The latitude – how far north or south of the equator one is – is relatively easy to find by the height of the Sun at midday or (in the northern hemisphere) by the angle of the pole star at night; sailors had been finding their latitude at sea for centuries. The longitude is a measure of how far *in east-west direction* one has travelled parallel to the equator. The crew of a given ship was naturally only concerned with how far in an east-west direction they were from their *own* home base.

Even when in the middle of the ocean, with no land in sight, knowing this longitude position is very simple – in theory. The key to knowing how far around the world one is from one's home is to know, at that very moment, what time it is back home. A comparison with the local time, where one is (easily found by checking the position of the Sun with a sextant) will then tell the time difference between one's present location and one's home. The Earth can be divided, like the segments of an orange, into 24 one-hour time zones, the 24 hours making up the whole 360 degrees round the globe and each hour's time difference is equivalent to 15 degrees of longitude.

The great flaw in this 'simple' theory was – how does the sailor know the time back home when he is in the middle of an ocean? The obvious simple answer could be that he carries an accurate clock with him, which he sets to home time before leaving. All he has to do is keep it wound up and running, and he must never reset the hands throughout the voyage. This clock then provides 'home time'; so if, for example, it is midday on board the ship and the 'home time' clock says it is midnight at home, it immediately becomes clear that there is a 12 hour time-difference and the ship must be exactly round the other side of the world; that is, 180 degrees of longitude away from home.

The principle is indeed simple, but the reality was that in 18th century no one had ever made a clock that could keep time accurately enough to be of any use, despite the rolling and pitching of a ship and the large changes in temperature during the voyage. Indeed, most of the then scientific community thought such a clock was impossible. Even the great Sir Isaac Newton, who was the president of the Royal Society in 1714, considered it so and strongly favoured an 'astronomical solution' to the problem. Thus began the competition – sometimes bitter – between the two schools of thought: the 'astronomical' and the 'horological' (horology is the art of clock making).

The contenders for the coveted prize came from various cross-sections of society. The power of money (the prize money was worth about £2 million today) made the Board of Longitude perhaps the world's first official research and development agency! The Board was in existence for more than one hundred years and by the time it finally got disbanded in 1828, it had disbursed funds in excess of £100,000.

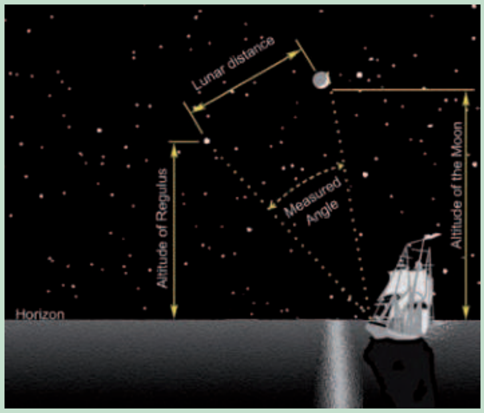
It was this prize, which inspired the self-taught Yorkshire carpenter, John Harrison (1693-1776), to attempt a design for a practical marine clock. Harrison succeeded in achieving the seemingly impossible goal of creating an extraordinary series of five prototype timekeepers after a life of dedicated work. With the work of a small band of horological pioneers following in his footsteps, the practical marine chronometer became a reality. From the early years of the 19th century and through the following century and a half, chronometers served in regular use aboard Navy ships and merchant vessels alike. It was a technological wonder of that era.

Astronomical solution

As discussed above, the problem of fixing one's longitude boils down to finding 'accurate time' at a reference location like Greenwich. For many centuries, people looked up to the heavens for a solution to the problem, just like latitude of a place was known from the altitude of pole star or the inclination of the Sun's trajectory with the

The lunar distance method

The method relies on the relatively quick movement of the Moon across the sky, completing a circuit of 360 degrees in 27.3 days (29.5 days relative to the Earth). In an hour, therefore, it moves about half a degree, or roughly its own diameter, with respect to the background stars and the Sun. Using a sextant, the navigator precisely measures the angle between the Moon and another body, which could be the Sun or one of a selected group of bright stars lying close to the Moon's path, near the ecliptic. At that moment, anyone on the surface of the Earth who can see the same two bodies will observe the same angle (after correcting for parallax error). The navigator then consults a prepared table of lunar distances and the times at which they will occur. By comparing the corrected lunar distance with the tabulated values, the navigator finds the Greenwich Time for that observation. Knowing Greenwich Time and local time, the navigator can work out longitude. Local time can be determined from a sextant observation of the altitude of the Sun or a star. Then the longitude (relative to Greenwich) is readily calculated from the difference between local time and Greenwich Time, at 15 degrees per hour.



local vertical. With establishment of the universal law of gravitation and a wealth of astronomical observations in early 18th century, scientists and navigators understood the relative motions of celestial objects better than ever before. The moving Moon, full or crescent-shaped, shone like a luminous hand on the clock of heaven; the broad expanse of sky served as dial for the celestial clock; while the Sun, the planets and the stars marked the numbers on its face.

The 'lunar distance' method of finding longitude (see Box), that had been proposed over centuries prior to 1714, gained credence and adherents as the science of astronomy improved. Thanks to Newton's own efforts in formulating the Law of Gravitation, the Moon's motion was better understood and to some extent predictable. In spite of that, this method suffered from the obvious difficulty of sighting the Moon for a few days of the lunar cycle and during inclement weather.

Horological solution (design of an accurate clock or chronometer)

During this period of highly academic and scholarly progress in astronomical observations and calculations, John Harrison stuck to his conviction that an 'accurate' timekeeper can be designed which circumvents the need for the painstaking observations and reference to pre-calculated almanacs. In comparison to the giant clock provided by the heavens, Harrison offered the world a little ticking thing in a box! Something uncanny attended the sea clock in the eyes of scientists and celestial navigators. It turned out that he stood alone against the vested navigational interests of the scientific establishment. As we will see later, instead of accolades, he was subjected to many unpleasant trials that began after the completion of his masterpiece, the fourth timekeeper H4 in 1759, the first of the series H1 being built between 1730 and 1735.

John Harrison (1693-1776)

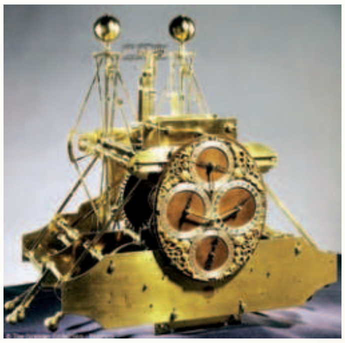
At the time, the only precision timekeepers, of any kind, were pendulum clocks. In the 1720s Harrison himself was making such clocks, which he claimed were capable of maintaining an accuracy of better than one second in a month, in spite of the fact that they were mostly made of wood. To achieve this high precision, Harrison incorporated several extremely ingenious new ideas, including a mechanism to automatically compensate for the effects of temperature. Harrison invented a special form of compensated pendulum, using a grid of brass and steel wires, to ensure his clock kept time, whatever the temperature.

He also designed his clocks to run without the need for any oil, the 'Achilles heel' of clockwork. By designing and incorporating bearings that used rolling contact, instead of sliding contact, Harrison's anti-friction bearings cleverly side stepped the problem of friction. No one before Harrison had ever made a mechanical clock to work without oil, and very few have done so since. Watches on the other hand, were universally dismissed, being seen as jewellery and not as serious timekeepers. Even the very best pocket watches of the day could only keep time to within about a minute a day and their timekeeping was generally thought of impossible to improve. So Harrison decided to create something based on his precision long case clocks, but made to withstand movement and wide temperature changes.

And so it was that in 1728 John Harrison began to design a series of 'sea clocks', as he called them, which were to become the most celebrated and arguably the most important timekeeping devices ever constructed in the history of mankind. These were the machines that led Harrison to prove, in the face of universal scepticism, that a marine timekeeper was a practical possibility. Harrison's machines led directly to the solution to the longitude problem, immeasurably strengthening the British Royal and merchant navies and saving of countless lives at sea over the next two centuries.

Harrison eventually built five timekeepers (the last two in the form of large watches) and they have generally been referred to as 'H1' to 'H5'. It should be noted that the term *marine chronometer* was not widely used until after Harrison's death. The word 'timekeeper', however, had very special significance in the 18th century. It was only used to describe a portable machine capable of high accuracy.

A detailed account of each of the devices is beyond the scope of this article and may be found by an interested reader in some of the references. Instead, we include the pictures to give an idea about how they evolved with time.



H1, created between 1730 and 1735

Trials of Harrison's timekeepers

In 1737, Harrison's first timekeeper H1 was put on board HMS *Centurion* bound for Lisbon, Portugal – a week's journey from England. The clock did not err more than a few seconds in 24 hours and the crowning glory was that on the way back, it predicted correctly the sighted land as Lizard Peninsula in Cornwall in the southern most part of Britain, more than 96 kilometres west of a place that the vessel's captain had wrongly identified! This correction greatly impressed the captain who swore an affidavit admitting his own mistake and praising the accuracy of the timekeeper. On 30 June 1737, a meeting of the commissioners of the Board of Longitude was convened for the very first time – 23 years after the board was created – citing Harrison's marvellous machine as the occasion. Harrison, honest to a fault, played down the performance of his 'baby' pointing out some 'defects' that he wanted to correct. He promised to produce another even better timekeeper that could be taken on an official trial voyage to the West Indies and ended up in getting only £250. However, he himself was dissatisfied with the second product and H2 (built between 1737 and 1739) never went to sea at all.

H3, Harrison spent nineteen years (1740-1759) working on this immensely complex timekeeper. For many years he was convinced it would win him the longitude prize

H3 (1740-1759) was supposed to be Harrison's final word in timekeeper design, but even after 19 years of painstaking labour, H3 was stubbornly refusing to reach the necessary accuracy. Although Harrison learned a great deal from this Herculean endeavour, and incorporated a number of brilliant inventions into H3, its ultimate role was solely to convince him that the solution lay in another design altogether. The lack of desired success level of the sea clocks 1, 2 and 3 were due mainly to the fact that their balance wheels though large, did not vibrate quickly enough to confer the property of stability to the timekeeping. Around 1750, Harrison had also come to this conclusion and abandoned the idea of the 'Sea clock' as a timekeeper, realising that a watch-sized timekeeper would be more successful as it could incorporate a balance wheel which though smaller, oscillated at a much higher speed. Thus in the late 1750s, almost simultaneously with H3, was born Harrison's greatest innovation – H4 timekeeper that was just 13 cm in diameter and weighed 1.5 kg. It was completely different from the other machines, externally and internally it looked like a large contemporary pocket watch. H4 is an absolute *tour de force* of horological design and construction.

The board opted to test both H3 and H4 together on the same voyage. John Harrison's son William, however, embarked on HMS *Deptford* in November 1761 to the West Indies with H4 alone, because his father had seen fit to remove H3 from the running. In addition to a fantastic prediction during the voyage ending on 19 January 1762, the longitude of the destination, Port Royal, Jamaica was fixed accurately and it turned out that H4 had lost only five seconds – after 81 days at sea. The watch went back to England aboard another ship on 26 March and in spite of very rough weather it was found that H4 was still ticking and its adjusted cumulative error, to Jamaica and back, amounted to just under two minutes!

H4 (1749), from the front and back

The prize should have gone to John Harrison then and there because his watch had achieved all that the Longitude Act demanded, but then started the period of intrigue and possibly one of the earliest anecdotes of politicking in scientific circle. Events conspired against him and withheld the funds from his deserving hands. He was paid only £1,500 and the board concluded in its report in August 1762 that the tests have *not* been sufficient to determine the longitude at sea and H4 must submit to a new trial back to the West Indies for the second time. He was 'assured' of another £1,000 when H4 returned successfully from its second stint at sea.

It so turned out that the Board of Longitude, dominated by astronomers (Head of the Royal Observatory, the Astronomer Royal, was a member of the board), academicians and admirals, did not have any knowledge of the watch or what made it run so accurately. They were incapable of understanding its mechanism, but they began hounding Harrison early in 1763 to explain it to them. More and more conditions were imposed for getting the full prize money and even after the second successful trip with H4 to Barbados in March 1764, the board offered to hand over only *half* the reward money on the condition that Harrison hand over all the sea clocks and a full disclosure of the magnificent clockwork inside H4. To receive the *full* amount he would have to supervise production of not one but *two* duplicate copies of H4 – as proof that its design and performance could be duplicated!

Things became even worse during the tenure of Nevil Maskelyne as the Astronomer Royal. Maskelyne considered himself a contender for the prize due to his significant work on the 'lunar distance' method that apparently never met the accuracy criterion. The board insisted that the timekeepers be handed over to it and the government and in May 1766, Maskelyne himself turned up, without warning, at Harrison's home to take them away! Dejected Harrison completed his fifth watch H5 – visually simpler in design than H4 – in 1770. By this time, desperate for recognition and rightfully feeling that they deserved the remaining prize money, William Harrison sought the support of King Gorge III, himself having keen interest in astronomy and advances in watch making. The King tested H5, with extremely good results, at his own private observatory in Richmond and then promised the Harrison his support. This resulted in a Parliamentary debate and the award to Harrison of the remaining prize money, as a bounty from Parliament. This, including expenses, came to £23,000, considerably more than the total prize money but highly fragmented!

Restoration of Harrison timekeepers to glory

After a long period of shoddy maintenance and neglect in Royal Observatory, the invaluable machines in the annals of scientific development were noticed and salvaged in 1920 by Lieutenant Commander Rupert T. Gould, a Navy officer. All the timepieces were cleaned, dismantled and painstakingly reassembled between 1920 and 1933. During Gould's celebrated lecture, to the Society for Nautical Research, on 'Harrison and his Timekeepers' in 1935, all the timekeepers were exhibited together, working. They were all then set up in the new National Maritime Museum (NMM) galleries in 1937, but were removed again in 1939 and sent to Cambridge for protection during World War II. Thus Gould did a great service by restoring one of the engineering marvels in the history of mankind.

Postscript

It may be said that though the natural satellite of the Earth ('lunar' method) lost out to the tiny device carved out by a mortal in the 19th and large part of 20th century, its artificial counterparts (the GPS satellites) triumphed in continuously fixing the longitude as well as the latitude any time anywhere on Earth to an accuracy of less than a metre or to even centimetres in case of military applications. Living in this age of great scientific and technological advancements, one cannot help paying tributes not only to those great scientific minds who solved the longitude problem in their own ways, but also to those who ventured out into the high seas to explore unknown destinations with only scanty knowledge of their whereabouts!

Further Reading

1. *Longitude:* Dava Sobel (Bloomsbury, NY)
2. Abridged internet version of *Time Restored: The Story of the Harrison Timekeepers and R.T. Gould, 'The Man who Knew (almost) Everything',* by Jonathan Betts, published by NMM & Oxford, 2006
3. Figures are taken from different sources on the internet

The author is a PhD in theoretical physics from the Tata Institute of Fundamental Research (TIFR), Mumbai and retired as an executive of Oil & Natural Gas Corporation (ONGC). He has interest in astronomy and astrophysics.

Mouthwatering Aromas

Dr. Chaganty Krishna Kumari
E-mail: chaganty_krishnakumari@yahoo.com

Our sense of taste is actually a combination of three senses, taste, smell, and colour. The brain interprets signals from taste, smell, and vision before turning them into an impression of the food's taste. If we forget to put turmeric powder in the preparation of *'rasam'* the brain doesn't approve the dish. The red chilies, the small black mustard seeds, etc. – correctly fried in ghee and added finally to the preparation – also attracts us. Thus sight too plays an important role in our perception of food's flavour and taste. We need visual clues to identify flavours and taste.

Usually we can recognise only four tastes – sweet, salt, sour, and bitter. The Japanese use '*kombu*' seaweed as an ingredient in their traditional cuisine, which has a unique taste

Saccharina japonica
http://en.wikipedia.org/wiki/Kombu

not similar to any of the four tastes known earlier. Kikunae Ikeda, a researcher at Tokyo Imperial University, had been interested in seaweed broth since his childhood. In order to find out the components of this broth, he started research on the broth that is usually used for the dish *yudofu* (boiled tofu). In 1907, he succeeded in extracting a white crystalline substance from the *kombu* seaweed. He identified it as monosodium glutamate which was responsible to the distinctive taste of the *kombu*. Professor Ikeda called this new unique taste, identified by him, *'umami'* since it did not fit with the other four identified tastes. The existence of umami, proposed by Prof. Ikeda as the fifth taste in addition to sweet, sour, salty, and bitter, was disputed in academic circles for a long time. However,

Kikunae Ikeda
wordpress.com

glutamic acid receptors were subsequently found in the sensory cells in taste buds on the surface of the tongue, and umami taste has been recognised internationally.

Monosodium glutamate (MSG) is a salt of glutamic acid and one of the building blocks that make up vegetable and animal proteins. All protein containing food items such as meat, fish, vegetables, dairy products contain glutamate. It is richest in

lemon

groundnuts, cheese, tomato, and shitake mushrooms. Many of these foods have been traditionally paired to enhance their natural flavour. Glutamate helps in digestion, and our body itself produces around 48 grams of glutamate every day. Mother's milk contains ten times more of it than cow's milk.

There were reports of nausea, numbness, and dizziness associated with the use of MSG. However, World Health Organisation (WHO), the US Food and Drug Administration (FDA) and the American Medical Association carried out numerous studies and ruled out such a doubt regarding the safety in using MSG as a food additive.

Flavouring substances are used as additives in a wide range of food products to enhance or intensify flavour of natural food products. They are also used to add flavour to food products that do not have desired flavours.

There are four categories of flavourings which are used as food additives.

1. Flavouring substances
2. Flavouring preparations
3. Process flavourings
4. Smoke flavourings

Flavouring substances

These are chemical substances with flavouring properties are called flavouring substances. Under this category we have the following:

(i) Natural flavourings
(ii) Nature identical flavourings
(iii) Artificial flavourings, (which are not nature identical)

(i) Natural flavourings

These are products mostly of animals, trees, and plants which can be cleaned and used raw while preparing food items. Examples include ginger, coriander leaves, lemon juice, etc. Some natural flavourings are produced during the preparation of food

Peppermint

by microbiological, physical or enzymatic processes. The flavours associated with cheese, curd, and alcoholic drinks are the result of fermentation, while those with meat, chocolate, toast, deep oil-fried food and coffee are due to roasting and frying. Fermentation, roasting and toasting create specific chemical reactions producing mouth-watering aroma in food.


L.C. Maillard

The sweet taste of fried onions or the unique aroma of roasted meat can be traced to a single process called Maillard Reaction, discovered by French chemist, L.C. Maillard in 1912. This process involves a chemical reaction between proteins and carbohydrates. Variations in the duration of roasting results in variations in the browning reaction, producing some of the most delicious flavours we are familiar with. The chemicals causing particular flavours have been identified by chemists. Methyl pyrazine gives a roasted-nut-like flavour; 2-isobutyl-3-methoxypyrazine gives green pepper flavour; acetyl-1-pyrazines popcorn flavour; and 2-acetoxypyrazine produces toasted flavours.

Flavouring substances are also extracted from natural sources for use as food additives. Lemon grass is a stalky plant with a smoky and lemony aroma. It is a perennial herb native to India and Sri Lanka. This plant grows in tropical climates, most notably in South-Asia. It is widely used in Asian cuisines, especially Thai, Malaysian, and Vietnamese cuisine with citrus-cum-ginger taste. Lemon juice may be substituted for lemon grass in a pinch, but citrus fruits cannot fully replicate its specific qualities. Natural citral is a pale-yellow liquid, $(C_9H_{15}COH)$, extracted from it.

This fragrant grass is widely used in preparation of beverages, soups, teas, herbal medicines and other dishes. It harmonises well with coconut milk, especially with chicken or seafood, and there are countless Thai and Sri Lankan recipes exploiting this combination. Its stems are also used in teas, pickles and in flavouring marinades.


Fredrich Wohler

Benzaldehyde is a colourless liquid having a characteristic flavour, first extracted from bitter almonds in 1803 by the French pharmacist Martrès. Bitter almonds are a variety of almonds having kernels that yield oil consisting mostly of benzaldehyde and some hydrocyanic acid. The sweet almond tree, *Prunus dulcis, var. amygdalus*, gives us the almonds we use in our kitchens. From these almonds comes the sweet almond oil. The bitter almond tree, *Prunus dulcis, var. amara*, also produces almond, which is broader and shorter.


Lemon grass
http://www.agriculturalproductsindia.com

Peppermint is a hybrid plant, a cross between water mint and spearmint. It has a strong, clean, fresh, minty aroma. The leaves and flowers of the peppermint are extracted by steam distillation to produce the peppermint oil. The oil is used as a food additive. It is used in the production of peppermint.

(ii) Nature identical flavourings

These are chemically identical to natural flavouring substances, but are prepared or extracted using chemical methods. The molecules of these substances prepared by chemical methods are identical with the molecules found in nature.

The family of compounds called esters is responsible for many of the pleasant smells of fruits. For example, ethyl acetate is an ester of ethanol and acetic acid prepared chemically. It is identical with ethyl acetate found naturally in many fruits such as apples, peaches, and pears.

The characteristic smell of the banana is largely due to an ester, 3-methylbutyl acetate, also known as isoamyl acetate. Banana oil is made naturally by the banana plant. It can be also produced synthetically. Isoamyl acetate is used to give banana flavour to foods. Similarly, decanal, an organic compound which is a fundamental component of the flavour of orange and can also be produced by chemical synthesis.

The most widely used vanilla flavour is due to a chemical called vanillin obtained from vanilla pods. But this flavouring is now produced chemically from plant material.

(iii) Artificial flavourings

These are substances which are not identical to flavourings found naturally. For example, chemically made ethyl vanillin or ethyl maltol have not been identified in nature

Flavouring preparations

Some substances can have a flavouring effect. Essential oils and fruit juices fall in this category if they are used for flavouring. For example, lemon juice is added to cooked pulses, curries and in our famous Indian breakfast dish called *'upma'*. Similarly coconut oil, sesame oil, ground nut oil and *ghee* (clarified butter) give their specific flavours to the food when used in the process of cooking. Addition of *ghee* to prepared food items, especially sweet dishes, enhances their taste with its characteristic flavour.

Process flavourings

The third category of flavourings includes substances which may not have aroma of their own, but when mixed and cooked together y give out tempting aroma. One of these must contain an amino group $(-NH_2)$ and the other must be a reducing sugar. This process is similar to the changes that happen when a food is cooked. These flavours are found in gravy granules. **Gravy granules** are seasoned and coloured granules of modified starch with a savoury flavour, used to make gravy; they form a gel on addition of boiling water.

Smoke flavourings

In traditional food-smoking process foods are left in wood smoke for several hours as a result of which they get smoke flavour. Smoke flavouring is a natural flavouring obtained as a concentrate by controlled burning of saw dust, woody plants, untreated and uncontaminated hardwood. Barbequed food is usually flavoured by smoke. However, the European Food Safety Authority has warned that smoke flavoured food may be toxic to humans.

Vanilla pods contain the seeds from the vanilla orchid plant

Justus von Liebig

The following 16 flavour notes are identified by flavour chemists. .

1. Green grassy; 2. Fruity ester-likes; 3. Citrus terpenic; 4. Minty camphor-like; 5 Floral sweet; 6. Spicy herbaceous; 7. Woody smoky; 8. Roasty burnt; 9. Caramel nutty; 10. Bouillon (a thin clean soup made by boiling meat and vegetables); 11. Meaty; 12. Fatty rancid; 13. Dairy buttery; 14. Mushroom earthy; 15. Celery soupy; 16. Sulphurous alliaceous.

Some flavourings are simple and composed of only one chemical, but many others are complex mixtures of several substances. When properly compounded, these mixtures provide the aroma and taste perception of a specific flavour, such as butter or strawberry. Any natural flavour is normally quite complex, with dozens or hundreds of chemicals interacting to create the taste/aroma. More than 350 flavour compounds have been identified in grape juice. Each chemical adds a distinctive note to the flavour, such as rosy, candy, caramel nutty. In raspberry, surprisingly countless flavouring compounds have been identified. This fruit contains flavour molecules of 13 hydrocarbons, 36 alcohols, 17 aldehydes, 22 ketones, 16 acids and 27 Esters.

Coffee has a complex mixture of 80 flavours. Some flavours are essentially produced by one chemical. For example, the exotic flavour extracted from vanilla orchid is due to a single chemical vanillin. Soya protein and mycoprotein are low in fat and extremely nutritious and hence may be used in place of meat. However, without the addition of a flavour, they have a bland taste. The tastes of ice- cream and margarine are unacceptable without the addition of flavours. We enjoy a variety of ice-creams because of their different flavours. Yoghurts have a natural flavour but at a low intensity. Flavourings are being added to enhance the natural flavour of yoghurts.

Table-1 Chemicals associated with specific flavours

	Chemical	Flavour
1	Allylpyrazine	Roasted nut
2	Methoxypyrazines	Earthy vegetables
3	2-Isobutyl-3Methxypyrazine	Green pepper
4	Acetyl-L-Pyrazines	Popcorn
5	2-AcetoxyPyrazine	Toasted Flavours
6	Aldehydes	Fruity Green
7	Alcohols	Bitter, medicinal
8	Esters	Fruity
9	Ketones	Butter caramel
10	Pyrazines	Brown, burnt, caramel
11	Phenolics	Medicinal, smoky
12	Terpenoids	Citrus, piney

Health effects

Even though a particular flavouring is considered safe to eat, it does not mean that it is also safe to breathe or handle by workers during manufacturing. Many substances are used in the manufacture of flavourings. The US FDA regulates flavourings to ensure they are safe when eaten. Many flavourings have been in longstanding use and are classified by the FDA as "Generally Recognised as Safe" (GRAS) to eat. However, the FDA does not require testing for other routes of exposure, such as inhalation of chemicals used by the employees in the flavour industries. Some chemicals such as diacetyl used as butter and cheese flavourings have been found to be a health hazard when inhaled.

Food additives like preservatives, flavourings, and colorants are widely used in fast foods and processed foods. Despite what different flavouring do to make food attractive, it is always advisable to have freshly prepared home-made food as they are the safest.

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.

Heel pain
Bringing it to "heal"

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

Heel pain is most often caused by plantar fasciitis, a condition that is sometimes also called heel spur syndrome when there is a calcium deposit on the underside of the heel bone. It may also relate to a number of other causes, such as a stress fracture, tendonitis, arthritis, nerve irritation, or, rarely, a cyst.

Since there are several potential causes, it is important to have heel pain properly diagnosed. An orthopaedic surgeon or a doctor who is a rehabilitation expert is able to distinguish between all the possibilities and determine the underlying source of heel pain.

Plantar fasciitis
Plantar fasciitis is one of the most common causes of heel pain. It involves pain and inflammation of a thick band of tissue, called the plantar fascia, which runs across the bottom of the foot and connects the heel bone to the toes. In this condition, the band of tissue first becomes irritated and then inflamed, resulting in heel pain.

Causes
Under normal circumstances, the plantar fascia acts like a shock-absorbing bowstring, supporting the arch in the foot. If tension on that bowstring becomes too great, it can create small tears in the tissue. Repetitive stretching and tearing can cause the fascia to become irritated or inflamed.

Factors that may increase the risk of developing plantar fasciitis include:

Age
Plantar fasciitis is most common between the ages of 40 and 60.

Faulty foot mechanics
The most common cause of plantar fasciitis relates to faulty structure of the foot. Being flat-footed, having a high arch or even having an abnormal pattern of walking can adversely affect the way weight is distributed when a person is standing and puts added stress on the plantar fascia.

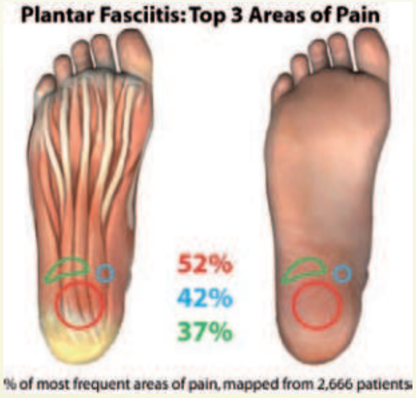
Obesity
Excess weight puts extra stress on the plantar fascia.

Occupations that keep people on their feet
Policemen, washer men, factory workers, teachers, surgeons and others who spend most of their work hours walking or standing on hard surfaces can damage their plantar fascia.

Using wrong kind of footwear
Wearing shoes with inadequate support on hard, flat surfaces puts abnormal strain on the plantar fascia and can also lead to plantar fasciitis. This is particularly evident when one's job requires long hours on the feet. High heels can also impose strain on the foot.

Certain types of activities
Activities that place a lot of stress on the heel and attached tissue — such as long-distance running, ballet dancing and dance aerobics — can contribute to an earlier onset of plantar fasciitis.

Symptoms
Plantar fasciitis typically causes a stabbing pain in the bottom of the foot near the heel. The pain is usually worst with the first few steps after awakening, although it can also be triggered by long periods of standing or getting up from a seated position. After a few minutes of walking the pain decreases, since walking stretches the fascia. For some people the pain subsides but returns after spending long periods of time on their feet.



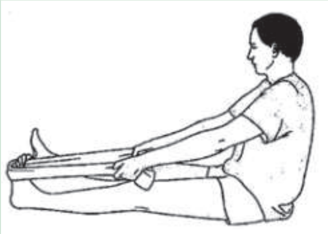
The pain may also occur in the arch of the foot. It tends to run on and increases over a period of months.

Ignoring plantar fasciitis may result in chronic heel pain that hinders your regular activities. If you change the way you walk to minimise plantar fasciitis pain, you might also develop foot, knee, hip or back problems.

While you may initially consult your family physician, he or she may refer you to a doctor who specializes in orthopaedics or who is a rehabilitation expert.

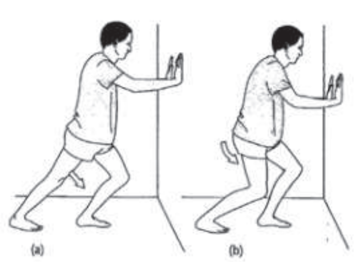
Diagnosis
Usually no tests are necessary. The diagnosis is made based on the history and physical examination of the foot. Throughout this process the doctor rules out all the possible causes for your heel pain

1. Achilles tendon and plantar fascia stretch



First thing in the morning, loop a towel, a piece of elastic of a tubigrip around the ball of your foot and, keeping your knee straight, pull your toes towards your nose, holding for 30 seconds. Repeat 3 times each foot.

2. Wall push-ups or stretches for Achilles tendon



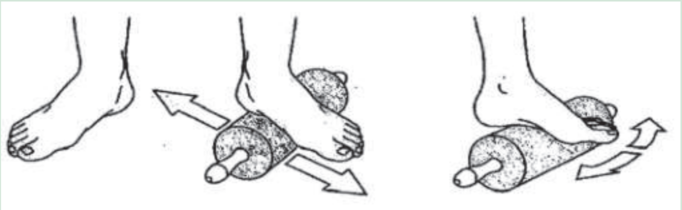
The Achilles tendon comes from the muscles at the back of your thing and your calf muscles. These exercises need to be performed first with the knee straight and then with the knee bent in order to stretch both parts of the Achilles tendon. Twice a day do the following wall push-ups or stretches: (a) Face the wall, put both hands on the wall at shoulder height, and stagger the feet (one foot in front of the other). The front foot should be approximately 30 cm (12 inches) from the wall. With the front knee bent and the back knee straight, lean into the stretch (i.e. towards the wall) until a tightening is felt in the calf of the back leg, and then ease off. Repeat 10 times. (b) Now repeat this exercise but bring the back foot forward a little so that the back knee is slightly bent. Repeat the push-ups 10 times.

3. Stair stretches for Achilles tendon and plantar fascia

Holding the stair-rail for support, with legs slightly apart, position the feet so that both heels are off the end of the step. Lower the heels, keeping the knees straight, until a tightening is felt in the calf. Hold this position for 20-60 seconds and then raise the heels back to neutral. Repeat 6 times, at least twice a day.

4. Dynamic stretches for plantar fascia

This involves rolling the arch of the foot over a rolling pin, a drinks can or a tennis ball etc, while either standing (holding the back of a chair for support) or sitting. Allow the foot and ankle to move in all directions over the object. This can be done for a few minutes until there is some discomfort. Repeat this exercise at least twice a day. The discomfort can be relieved by rolling the foot on a cook drinks can from the fridge.



other than plantar fasciitis.

Occasionally your doctor may suggest an X-ray or magnetic resonance imaging (MRI) to make sure your pain isn't being caused by another problem, such as a stress fracture or a pinched nerve.

Sometimes an X-ray shows a spur of bone projecting forward from the heel bone. These are rarely a source of pain. In the past, these bone spurs were often blamed for heel pain and removed surgically. But many people who have bone spurs on their heels have no heel pain.

Simple home treatments

Most people who have plantar fasciitis recover with conservative treatments in just a few months. Treatment of plantar fasciitis begins with first-line strategies, which you can begin at home:

Stretching exercises : Stretch your arches. Simple home exercises can stretch your plantar fascia, Achilles tendon and calf muscles. Exercises that stretch out the calf muscles help ease pain and assist with recovery.

Avoid going barefoot : Don't walk barefoot, especially on hard surfaces. When you walk barefoot, you put undue strain and stress on your plantar fascia.

Shoe modifications : Wear shoes that have good arch support, can absorb shock, and carry a slight heel. Such footwear reduces stress on the plantar fascia. Avoid high heels.

Don't wear worn-out athletic shoes. Replace your old athletic shoes before they stop supporting and cushioning your feet. If you're a runner, buy new shoes after about 900 km of use.

Apply ice: Hold a cloth-covered ice pack over the area of pain for 15 to 20 minutes three or four times a day or after activity. Or try ice massage. Freeze a water-filled paper cup and roll it over the site of discomfort for about five to seven minutes. Regular ice massage can help reduce pain and inflammation. Do not apply ice directly to the skin.

Limit activities : Cut down on extended physical activities to give your heel a rest.

Change your sport : Try a low-impact sport, such as swimming or bicycling, instead of walking or jogging.

Maintain a healthy weight : This minimises the stress on your plantar fascia.

Medications, therapy and shots

Medications

Oral non-steroidal anti-inflammatory drugs (NSAIDs), such as ibuprofen, may be recommended to reduce pain and inflammation.

If you still have pain after several weeks, see your foot and ankle

Continued on page 19

Recent developments in science and technology

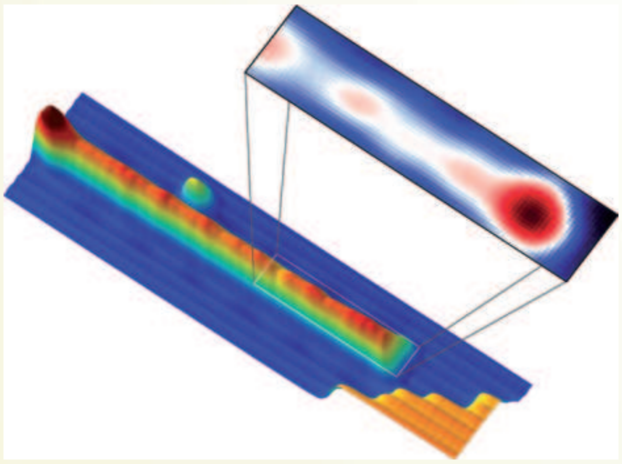
Biman Basu E-mail: bimanbasu@gmail.com

A particle that is both matter and antimatter

All known fundamental particles are either bosons or fermions. Fermions (named after the Italian physicist Enrico Fermi) are subject to the Pauli principle, which forbids two particles being in the same quantum state; bosons 9named after the Indian physicist Satyendranath Bose), by contrast, tend to bunch together in the same state. The elementary particles of matter – electrons, quarks, and neutrinos – are fermions, while photons and other force carriers are bosons.

In the world of physics, particles and antiparticles are opposite of each other; they have the same mass but opposite electric charge. For example, the antiparticle of the electron is the positively charged electron, or positron, which is produced naturally in certain types of radioactive decay. The antiparticle of proton is the antiproton, which is negatively charged. Whenever a particle comes in contact with its antiparticle they typically annihilate each other in a burst of energy. But according to a 1937 prediction by Italian physicist Ettore Majorana, some particles might be their own antimatter partners. Known as 'Majorana fermions', these particles act as both matter and anti-matter and till recently were only a theoretical concept. Particles and antiparticles annihilate each other because they have opposite charge, so Majorana fermions, which are their own antiparticles, need to be electrically-neutral. They are thought to be stable and robust. Some scientists suggest that Majorana fermions make up the mysterious 'dark matter' thought to form more than 70 % of the Universe. But, since they were predicted in the 1930s, these particles remained elusive.

Theorists had predicted the existence of Majorana fermions in materials known as 'topological superconductors', in which the interior of the material has zero electrical resistance, but the outside behaves like an ordinary conductor. For the first time,



Princeton University scientists used scanning-tunnelling microscope to show the atomic structure of a one-atom-wide iron wire on a lead surface. The zoomed-in portion of the image at right depicts the quantum probability of the wire containing an elusive particle called the Majorana fermion. (Credit: Yazdani Lab, Princeton University)

scientists of Princeton University in USA have observed a Majorana fermion inside a superconducting material.

In 2013, Ali Yazdani and Andrei Bernevig, both from Princeton University, teamed up to try to find more definitive observation of Majorana fermions by capturing an image of them. They proposed a novel approach for how the Majorana particle could occur in materials that combine magnetism and superconductivity, and how such a particle could be directly observed using a device called a scanning-tunnelling microscope.

Yazdani and his colleagues started with an ultrapure crystal of lead, whose atoms naturally line up in alternating rows that leave atomically thin ridges on the crystal's surface. They then deposited pure iron into one of these ridges to create a wire that is just one atom wide and about three atoms thick. The scientists then placed the lead and the embedded iron wire under the scanning-tunnelling microscope and cooled the system to minus 272°C, just a degree above absolute zero. Ultimately, the microscope was able to detect an electrically neutral signal at the ends of the wires, similar to signals characteristic of a neutral Majorana particle (*Science*, 2 October 2014 | 10.1126/science.1259327).

As expected, the new Majorana particle showed up inside a superconductor, a material in which the free movement of electrons allows electricity to flow without resistance. According to the researchers, the finding could be useful for constructing quantum computers that harness the laws of quantum mechanics to make calculations many times faster than conventional computers.

Earth's water is older than the Sun

Life on Earth is ascribed mainly to the presence of water. Till recently it was presumed that water on Earth came mainly from volcanic eruptions and also from comets crashing on Earth. Water is found throughout our Solar System – not just on Earth, but on icy comets and moons, and in the shadowed basins of Mercury. Water has also been found included in mineral samples from meteorites, the Moon, and Mars. A recent study has shown that the water found in Earth's oceans, in meteorites and frozen in lunar craters is older than the birth of the Solar System. Much of our Solar System's water likely originated as ices that formed in interstellar space long before our Sun was born. The discovery was made by a research team led by L. Ilsedore Cleeves from the University of Michigan in USA (*Science*, 26 September 2014 | doi:10.1126/science.1258055).

In their study the researchers focussed on hydrogen and its heavier isotope deuterium. The difference in masses between isotopes results in subtle differences in their behaviour during chemical reactions. By studying the ratio of hydrogen to deuterium in water molecules scientists can learn about the conditions under which the molecules formed.

The dense interstellar clouds of gas and dust where stars form have been known to contain abundant water, in the form of ice. Interstellar water-ice has a high ratio of deuterium to hydrogen because of the very low temperatures at which it forms. When a star first lights up, it heats up the cloud around it and floods it with radiation, vaporising the ice and breaking up some of the water molecules into oxygen and hydrogen, which also changes the deuterium-hydrogen ratio. Until now, it was unknown how much of this deuterium enrichment was removed by chemical processing during the Sun's birth.


Recent research shows that most of Earth's water has come from interstellar space and is older than the Sun.

To find that out, the researchers created computer models that simulated a proto-planetary disk (from which the planets were later formed) in which all the deuterium from space ice has already been eliminated by chemical processing, and the system has to start over "from scratch" at producing ice with deuterium in it during a million-year period. They did this in order to see if the system can reach the ratios of deuterium to hydrogen that are found in meteorite samples, Earth's ocean water, and comets. They found that it could not do so, which told them that at least some of the water in our own Solar System has an origin in interstellar space and pre-dates the birth of the Sun.

If indeed water came from ice in interstellar space it would have great implications, because then it would be likely, that similar ices, along with the prebiotic organic matter that they contain, are abundant in most or all planets forming around a star. According to the researchers, if water found on Earth is older than the Sun, then it would brighten the prospects of life existing on exoplanets, as it would imply that abundant, organic-rich interstellar ices should probably be found in all young planetary systems.

Sugar substitutes may trigger glucose intolerance

Non-caloric artificial sweeteners are among the most widely used food additives worldwide, regularly consumed by lean and obese individuals alike. But recent research by a team of scientists of the Weizmann Institute of Science in Israel has shown that the artificial sweeteners widely seen as a way to combat obesity and diabetes could, in part, be contributing to the global epidemic of these conditions. The researchers first experimented by adding one of three FDA-approved artificial sweeteners – saccharin, sucralose, or aspartame – to the drinking water of mice and found that they had developed glucose intolerance, while mice which drank plain water did not. But when the animals were given antibiotics to kill their gut bacteria, glucose intolerance was prevented. And when the researchers transplanted faeces from the glucose-intolerant saccharin-fed mice into the guts of mice bred to have sterile intestines, those mice also became glucose intolerant, indicating that saccharin was causing the gut bacteria to become unhealthy. On further study they found that the sugar substitutes had altered the intestinal bacteria of the mice that led to glucose intolerance (*Nature*, 9 October 2014 | doi:10.1038/nature13793).

To see if the effect extends to humans, the team first looked at 381 people in a nutritional study. They found links between artificial sweetener use, symptoms of obesity and elevated blood sugar, and the kinds of altered gut bacteria seen in the mice. In particular, the study noted a 20-fold increase in the numbers of *Bacteroides fragilis*, Gram-negative bacteria that is part of the normal flora of the human colon and is generally harmless, but can cause infection if displaced into the bloodstream or surrounding tissue following surgery, disease, or trauma.

Finally, as a proof of concept, the team enrolled seven lean and healthy volunteers – five men and two women – who did not habitually use artificial sweeteners, in a one-week experiment. In the experiment, the volunteers consumed the maximum acceptable daily dose of artificial sweeteners of about 120 milligrams daily for a week. They had their blood sugar levels checked every five minutes and underwent a daily glucose tolerance test. According to the researchers, even in this short-term seven-day exposure period, four volunteers became glucose intolerant, and their gut microenvironment shifted towards a balance already known to be associated with susceptibility to metabolic diseases, but the other three seemed to be resistant to saccharin's effects, underlining the importance of personalised nutrition and the difference between individuals. Understanding how certain chemicals alter gut bacteria may help in devising new therapeutic approaches to tackle glucose intolerance.

Ammonia directly from air, water, and sunlight

The synthesis of ammonia is one of the world's most significant industrial applications of chemistry. Ammonia is mainly used for the industrial production of fertilisers that have played a key role in maintaining world's food production. But the conventional process used in industrial production of ammonia, called the Haber-Bosch process, is highly energy-intensive. Developed in 1909, the Haber-Bosch process – often cited as the most important invention of the 20th century – involves heating purified nitrogen and hydrogen gas at very high temperature and pressure in presence of an iron catalyst. The massive chemical plants that produce ammonia consume up to 5% of the world's natural gas and belch out hundreds of millions of tonnes of carbon dioxide (CO_2) annually. Apart from large energy requirements to achieve reaction conditions, the current production method is also inefficient because it needs hydrogen gas, which is obtained by processing natural gas.

Now, Stuart Licht and his colleagues at the George Washington University in

Washington DC, USA, have come up with a process of making ammonia using water instead of natural gas as a source of hydrogen. The new 'low-energy' process uses only air and water. Wet air (steam) is bubbled through a mixture of nanoscale particles of iron oxide and molten sodium and potassium hydroxide and electric current generated from sunlight is passed through the mixture. The method uses a technology called solar thermal electrochemical production, or STEP, which is considered to be one of the most efficient solar cells currently in use. STEP when applied to making ammonia leads to production of hydrogen as a by-product. The new process uses only two-thirds the energy used in the Haber-Bosch process. According to the researchers, when electricity is applied the iron oxide captures electrons to permit water and air to directly react to form ammonia (*Science*, 8 August 2014 | doi: 10.1126/science.1254234).

Along with the elimination of the need to produce hydrogen from natural gas, the overall emissions are reduced quite significantly in the new process. The whole process also takes place at milder conditions, not requiring 450°C and 200 times atmospheric pressure, as the Haber-Bosch process does. Although the new process is better than the Haber-Bosch process, it is far less efficient than nature's way of converting nitrogen from the air to useful chemicals using nitrogen-fixing bacteria. Nonetheless, if something more efficient can replace the Haber-Bosch process, it would lower the energy input of the production of one of the world's most important chemicals and lead to a notable reduction in global CO_2 emissions. ■

Continued from page 22 **(Heel pain Bringing it to "heal")**

surgeon, who may add one or more of these treatment approaches:

Padding and strapping

Placing pads in the shoe softens the impact of walking. Strapping helps support the foot and reduce strain on the fascia.

Orthotic devices

Custom orthotic devices that fit into your shoe help correct the underlying structural abnormalities causing the plantar fasciitis. Your doctor may prescribe off-the-shelf heel cups, cushions or custom-fitted arch supports (orthotics) to help distribute pressure to your feet more evenly.

Removable walking cast

A removable walking cast may be used to keep your foot immobile for a few weeks to allow it to rest and heal.

Night splint

Wearing a night splint allows you to maintain an extended stretch of the plantar fascia while sleeping. It stretches your calf and the arch of your foot while you sleep. This holds the plantar fascia and Achilles tendon in a lengthened position overnight and facilitates stretching. This may help reduce the morning pain experienced by some patients.

Physical therapy

A physical therapist can instruct you in a series of exercises to stretch the plantar fascia and Achilles tendon and to strengthen lower leg muscles, which stabilise your ankle and heel. A therapist may also teach you to apply athletic taping to support the bottom of your foot. Exercises and other physical therapy measures may be used to help provide relief.

Steroid shots

In some cases, injecting a corticosteroid into the tender area can help reduce the inflammation and provide temporary pain relief. Multiple injections aren't recommended because they can weaken your plantar fascia and possibly cause it to rupture, as well as shrink the fat pad covering your heel bone.

Surgery

Although most patients with plantar fasciitis respond to non-surgical treatment, a small percentage of patients may require surgery. If, after several months of non-surgical treatment, you continue to have heel pain, surgery will be considered. Your orthopedic surgeon will discuss the surgical options with you and determine which approach would be most beneficial for you.

Long-term care

No matter what kind of treatment you undergo for plantar fasciitis, the underlying causes that led to this condition may remain. Therefore, you will need to continue with preventive measures. Wearing supportive shoes, stretching, and using custom orthotic devices are the mainstay of long-term treatment for plantar fasciitis. ■