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Plastic Pollution of Oceans

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EDITORIAL

February Musings

Nakul Parashar

February is an exciting month every year – reasons galore! National Science Day is one of them. About 91 years ago, on 28 February 1928, noted Indian physicist Sir C.V. Raman made a discovery that is now known as the famous Raman Effect. We all remain indebted to him for his discovery that led him to be awarded the prestigious Nobel Prize in Physics in 1930. Every year, since 1987 we have been celebrating 28 February as the National Science Day (thanks to the Department of Science & Technology's NCSTC for proposing it in 1986). A number of events continue to be organised all over the country on this day every year. But it won't be enough to confine the celebration to a moment of triumph. In addition, it would be worthwhile to assess previous year's strategies, improve and relaunch effective programs that can have far more meaningful outreach and outcome.

Climate change stands high on the list. The concentration of carbon dioxide in the atmosphere is at an unacceptable level of 410 ppm. At the Katowice Climate Meet (COP24) in early December 2018, the '1.5 Degree Report' set the tone for discussions and decisions. This report, published by the Intergovernmental Panel on Climate Change (IPCC), emphasised on reducing the greenhouse gas (GHG) emissions through technology and *lifestyle changes*. While technology development to address these issues has gained momentum worldwide, it is observed that making lifestyle changes can result in a quick and required outcome. Like the developed nations with higher average income, in India too, we require a plan and movement to adopt lifestyle changes. The "Green Good Deeds" campaign launched by the Ministry of Environment, Forests and Climate Change is one such initiative that helps us identify several ways through which we can make effective lifestyle changes. So, why not we make Green Good Deeds as a way of life!

Use of environmental-friendly transport that uses less fuel and provides a healthier environment is one of the first few items on the long list of the Green Good Deeds. Besides a list of suggestions this list provides, one thing that it emphasises on is looking for vehicles that run on alternative fuels, not fossil fuels. A number of countries have vowed to achieve fossil fuel-free transportation before the turn of this and the next decade. Electro-mobility is one such endeavour. The growing number of e-rickshaws in the country is a testimony of electro-mobility's success. Yet, there is a lot more that needs to be done! Trucks, buses, cars, bikes and many more modes need to be brought under this ambit.

The Government of India realised the importance of electro-mobility and came up with the FAME scheme (Faster Adoption & Manufacturing of Electric & Hybrid Vehicles) in 2015. This scheme immediately caught the world's attention because per capita vehicle ownership in our country is low, yet the population is large. This clearly indicates that India is a very significant market!

By the way, have we ever thought that when an appliance breaks down what happens? Besides rushing to get it fixed, obviously, we wonder what went wrong. At a Nagpur-based exhibition in 2017 on 'Know-Understand-Test-Use-Home-Appliances & Learn', or KUTUHAL (meaning curiosity in Marathi) theoretical principles and working mechanisms were explained by disassembling and re-assembling commonly-used home appliances. This year too, during 9-11 February, KUTUHAL is coming up, but with a change. Instead of Home Appliances, it's going to be Health Appliances this year. It'll be our endeavour in the forthcoming issues of *Dream 2047* that we bring to our readers the highlights of this event.

Back to the National Science Day celebrations this year. Please feel free to share with us about events in your proximity and we'll be glad to accommodate as many responses as we can in our future issues (write to director@vigyanprasar.gov.in). Happy February!

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Stubborn Trash! Will nature help us wage war against plastics?

Susheela Srinivas

An accidental discovery has raised hopes to find a parallel solution to the problem of breaking down plastics. Federica Bertocchini, a researcher at the Spanish National Research Council, a scientist at Cambridge University and an amateur beekeeper, stumbled upon worms which ate through plastic! A polyethylene bag degrades naturally in 400-500 years whereas ethylene glycol degrades in two weeks' time. The experiments revealed that about 100 worms would degrade 92 milligrams of polyethylene in just 12 hours.

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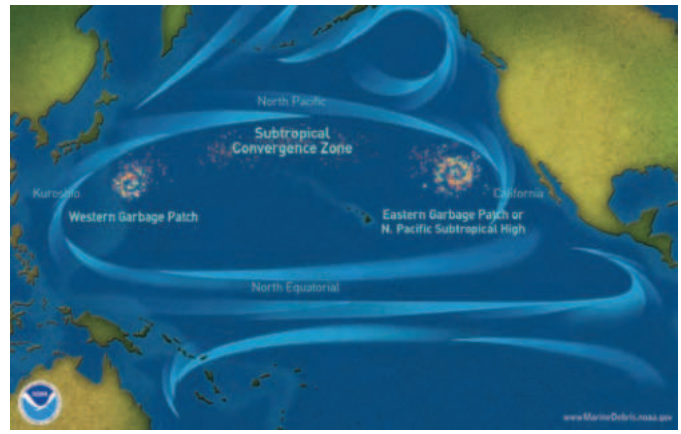
I receive a video clip on WhatsApp where divers are collecting plastic waste from the ocean bed. They are aghast at the enormity of the task at hand: the strewn garbage has carpeted the floor of the sea; scores of innocent creatures lie dead. These hapless beings, foraging for food, unwittingly chewed through the plastic litter, costing them their lives.



In another instance, a marine biologist reports the rapid spread of floating plastic and industrial debris in the oceans, covering miles of water, forming island-like structures called the 'great marine garbage patches'. Plastic has found its way to the Arctic regions too, trapped by ocean currents.

If these are a couple of examples of the plight of the oceans, the situation on land is equally appalling. The world is consuming plastics like never before: A report claims that the quantum of plastics produced in the last decade has surpassed the entire production of the last century!

According to another survey, Asian countries like China, Indonesia, Thailand and Vietnam are the major contributors to plastic pollution. The picture in India is a bleak one too; a media report states that India generates more than 15,000 tonnes of plastic waste per day; while more than 6,000 tonnes remain uncollected and littered. The survey also reveals that Delhi is the largest generator of plastic waste in India. No doubt other cities are not exempt from massive consumption either.

We have become habituated to convenience of plastics so much that every conceivable item utilises plastics directly or indirectly. Most of these translate into waste

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The saviour caterpillars

- These worms are the larvae of the greater wax moth (*Galleria mellonella*)
- They grow to a full size of a centimetre in length.
- The larvae are often used asbait for fish
- The worms commonly infest bee hives, eating the wax and destroying the hive
- The moth lays its eggs in the beehive, and the larvae hatch to feed on the surrounding wax.
- The larvae have enzymes to digest wax.
- Plastics, however, are not the natural diet of these worms.

within a year or two. In a nutshell, plastics have permeated our lives to such an extent that now it has become a menace and is looming large upon us; for, it is unthinkable for us to replace them.

What is the hype, anyway?

One is tempted to ask: What can happen by just throwing away plastic? Sadly, plastics break up but do not break down. They contribute to stubborn garbage. In other words, they do not biodegrade and reduce to elements which can in due course be absorbed by the soil. The slow breakdown takes hundreds of years.

Plastic often finds away into unattended litter, landfills, sewers and garbage dumps. Moreover, it just does not sit there. The components in plastic break up to release toxic chemicals into the atmosphere. Burning them is not a solution either: incinerating plastic waste releases harmful gases into the air. For example, CPVC, Neoprene, CPE are types of plastics, which burn by releasing dioxins, which can be lethal and are known to be carcinogenic. According to the World Health Organisation, "Once dioxins have entered the environment or body, they are there to stay due to their uncanny ability to dissolve in fats and to their rock-solid chemical stability."

The genesis

Plastics were born just over a century ago. At that time they were welcome as they were replacing animal products like shells, ivory, bone or leather, and so were thought of as environmentally friendly. The change was a boon and irreplaceable in medical equipment like IV tubes, bags and syringes, as it was a reliable and a better substitute for glass, providing better handling and sterile items. On the other hand, the range of use for plastics rose exponentially.The higher grade plastics found usein vehicles, gadgets and appliances;while the lower grade polymers were usedto manufacture an endless list of consumer items: utensils, bottles, storage boxes, cutlery, crockery,toys, stationery, fashion goods, trinkets–every consumable item had a plastic equivalent.Soon enough, most of these consumer products ended up as stubborn trash.

The Great Oceanic Patches

- Vast areas in the middle of the oceans have huge plastic debris, resembling islands as huge as a continent!
- The primary source of this garbage is estimated to be lost cargo in the oceans and discarded consumer plastics from beaches, divers, ships, damaged fishing gear and the like.
- These items are drawn to the middle of the oceans by oceanic currents called gyres.
- Astudy conducted in 2015 reports a similar patch developing as far as the Arctic.

Earth is turning into a plastic planet!

Researchers at the University of Georgia (UGA) in the US found that by 2015 humans had generated 8.3 billion metric tonnes of plastic and nearly 6.3 billion metric tons was converted to waste. With the current trend, by 2050, 12 billion metric tons of plastic waste will be added to the environment.

According to Jenna Jambeck, associate professor of engineering at UGA, since plastics do not biodegrade effectively, the waste so generated will remain in the environment for hundreds or even thousands of years. She draws attention to the effective waste management practices.

Most of the plastic we use and throw away are made of a material that is designed to last forever. Even the ones that go for recycling are down cycled– that is, reduced to a lower grade product for one more time use– before they end up in landfills or discarded as litter. In fact, many of these are finding their way into our waterways. Even those that can be up-cycled or recycled involve elaborate processes and consume large quantities of natural resources.

In another study, scientists predicted that the plastics are reaching our oceans so rapidly that by 2050 there will be more plastic in the sea than fishes. The pollutants get transferred to the food chain, severely maiming the life forms and their evolution.

Is there no way out?

Science is frantically searching for better alternatives to replace plastics. While products made from corn-starch, paper and other plant-based materials are good substitutes, the production of these materials is expensive and is unable to meet the enormous demands.

A significant chunk of plastic waste comes from the consumer industry. With our penchant for plastic goods, for their economy and convenience, it appears to be difficult to eliminate them. In reality, what we lack is sensitivity towards the hazards plastics can create to our environment. It is easy to refuse a plastic item and choose an eco-friendly alternative. Hence a collective social discipline and awareness cango a long

Be the change you wish to see

The five R-way:

- **Refuse:** Carry bags, cling films, food carriers and packages, cutlery, use-and-throw pens, toys and a score of other items you come across, which if given a thought, will surely have an eco-friendly substitute.
- **Reduce:** Drastically reduce the use of plastics. Opt for glass, steel or other safe metals for bottles, tiffin boxes, mugs and cups.
- **Re-purpose:** Find ways to reuse the plastic you have on hand. For example, plastic containers can be reused as planters, bins and storage boxes instead of just throwing them away.
- **Re-cycle:** Wherever they are unavoidable, make efforts to deposit them at recycling units/collection centres.
- **Responsibility:** Develop civic responsibility. Scrupulously segregate garbage, pick up litter and sensitise your family/neighbourhood/ for effective waste management.

way in repairing and controlling the damage to a large extent.

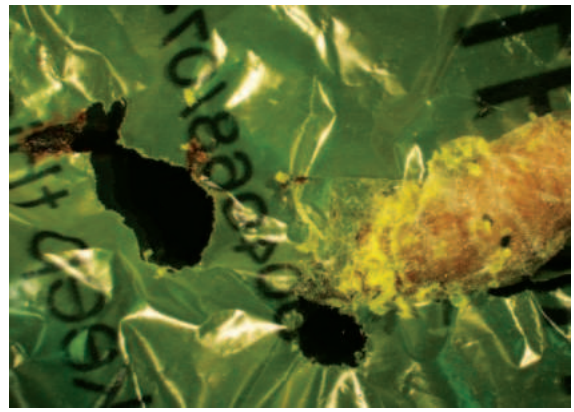
Though seemingly minuscule, an individual's contribution to changehas its roots in the wisdom of the adage: 'tiny droplets make a mighty ocean'.

Nature to the rescue

An accidental discovery has raised hopes to find a parallel solution to the problem of breaking down plastics. Federica Bertocchini, a researcher at the Spanish National Research Council, a scientist at Cambridge University and an amateur beekeeper, stumbled upon worms which ate through plastic! Her bee collection at her home had developed a wax worm infestation(these worms attack the bee hive and eat through the bees wax, causing damage to it). Noticing the infestation, she carefully removed the worms and placed them in a plastic bag. However, after a few hours, she saw the bag develop holes, and the worms had escaped! Excited, she began wondering what had happened to the plastic that was chewed away. The investigation began immediately.

In a paper published in *Current Biology* on24 April2017, Bertocchini and her colleagues described 100 wax worms chewing through a polyethylene shopping bag(the type people use at an astounding figure of one trillion per year). Along with her co-researchers, Bertocchini began analysing the worms' digestion process. Soon it was concluded that the wax worms were indeed breaking down plastic: the polyethylene chemical bond was being broken down and converted to ethylene glycol, an organic compound.

For comparison, a polyethylene bag degrades naturally in 400-500 years whereas



ethylene glycol degrades in two weeks' time. Their experiments revealed that about 100 worms would degrade 92milligrams of polyethylene in just 12 hours.

To further test if the worms were eating the plastic, the scientists ground a few worms and applied on the plastic bag. After a few hours, the bag developed holes. The result further strengthened the theory that particular gut enzymes and bacteria were at work inside the body of the worm.

Worms by the sacks ful, then!

Does this mean we have to see worms crawling all over to rid plastics? Not really. The researchers are looking into the worms' digestive mechanism instead. They are trying to understand how chemicals in these worms break down plastics.

They intend to look deeper into the chemistry of the wax worms' gut. The results will be used to reproduce similar compounds in the lab.Surmising on the worms' ability to

(Continued on page 24)

Enterprising efforts

One person who saw treasure in the plastic garbage was Professor Rajagopalan Vasudevan. An alumnus of Madras University, Vasudevan specialises in waste management. This chemistry teacher devised a way to transform plastic litter into a substitute for bitumen. (Bitumen is widely used in asphalting of roads.) The resultant plastic roads were found to be more durable and cost-effective as they replaced nearly 15 per cent of the expensive bitumen. His innovative solution also addresses the efficient management of hazardous plastic waste. Due to the success of his scheme, many rural areas in India enjoy better and sturdy roads.

Boyan Slat, 23, believes plastic is an excellent material which needs proper handling and should not be discarded in ways to harm the environment. He proposes to clean up 50 per cent of the oceans in the coming five years. Founder and head of a non-profit group Ocean Cleanup, this young environmentalist from The Netherlands proposed an innovative method to clean up the current oceanic patches and rid them of plastic debris in the coming decade. The project aims to set up V-shaped barriers in the sea, which will be fastened to the sea beds but will be floating on the surface. These barriers are so structured that they allow the water of the oceanic currents to flow through, while the plastic garbage will be drawn to the centre of the barriers' vortex. The captured plastic will be drawn away into floating towers and then carried away by ships. This project has received both appreciation and scepticism from experts worldwide. However, many experts have joined hands with Slat to support his proposal. The Netherlands government has funded Ocean Cleanup, and a prototype is underway.

Mulling Over Mills: The *Gharat*

Alpy Sharma and Sanjay Kr. Uniyal

In the midst of a thick jungle, relatively away from habitation but close to a stream is a small hut with no doors and a shabby roof. The path to the hut is dotted by hues of multitude shades not be found elsewhere. Within the hut is installed a masterpiece of indigenous technology that grinds and grinds. One can see people carrying loads of grains into the hut to be ground into flour. Welcome to the gharat.

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The history

Recognising that grains are coarse and chewing them took a toll on human oral health, grains were pounded between stones to make flour. This led to coming up of querns (primitive stone mills) around 1100 BC. The flat upper stone of the quern was fitted with a handle that made grinding relatively easy. Locally, querns in Himalaya were and are referred as *jandra*. However, it was still laborious and a time-consuming task. The rotating quern paved way for animal driven mills that were first used in the Middle East during early Biblical times. By the 2ndcentury BC the Romans introduced water mills where the gushing water drove the mills and made large-scale milling cheap and easy.

The *gharat* and its components

Most of us know it as a water mill, but to the people ofthe Himalaya it is a symbol of ingenious innovation that has been relentlessly grinding grains to feed them. The *gharat* is perhaps the best example of indigenous technology that has socio-cultural ramifications. Simply because it derives energy from flowing water, it is located near streams locally called the *khools*. In Himalaya, majority of the *gharat*s are of the vertical-shaft type and are used for the sole purpose of grinding.The various components of *gharat* sync together and team up to make what it takes to grind (Figure 1 a-e). The *flume or chute* is a wooden structurethat guides diverted water from the *khools*on to the bladesof the vertical shaft. *Grain feeder or hopper* is a funnel-shaped wooden structure that stores and feeds grains to the milling stones. All these components are made up of locally available resources.

Advantages of *gharat*

Apart from being a masterpiece of technological innovation, the *gharat*is a meeting place of cultural importance. People sitting around the *gharat* discussing, enjoying and gossiping is a common scene. Further, since *gharat*is made from locally available resources, the investment and maintenance cost isvery low. And as it is poweredby water, therunning cost is almost nil. People cherish the taste of the flour obtained from *gharat*-what companies now advertise as benefits of "low temperature grinding". Thus, a simple functional technology with multiple ramifications highlights the importance of the *gharat*.

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Dr. Sanjay Kr. Uniyal is a Principal Scientist at the same Institute. Email: suniyal@ihbt.res.in

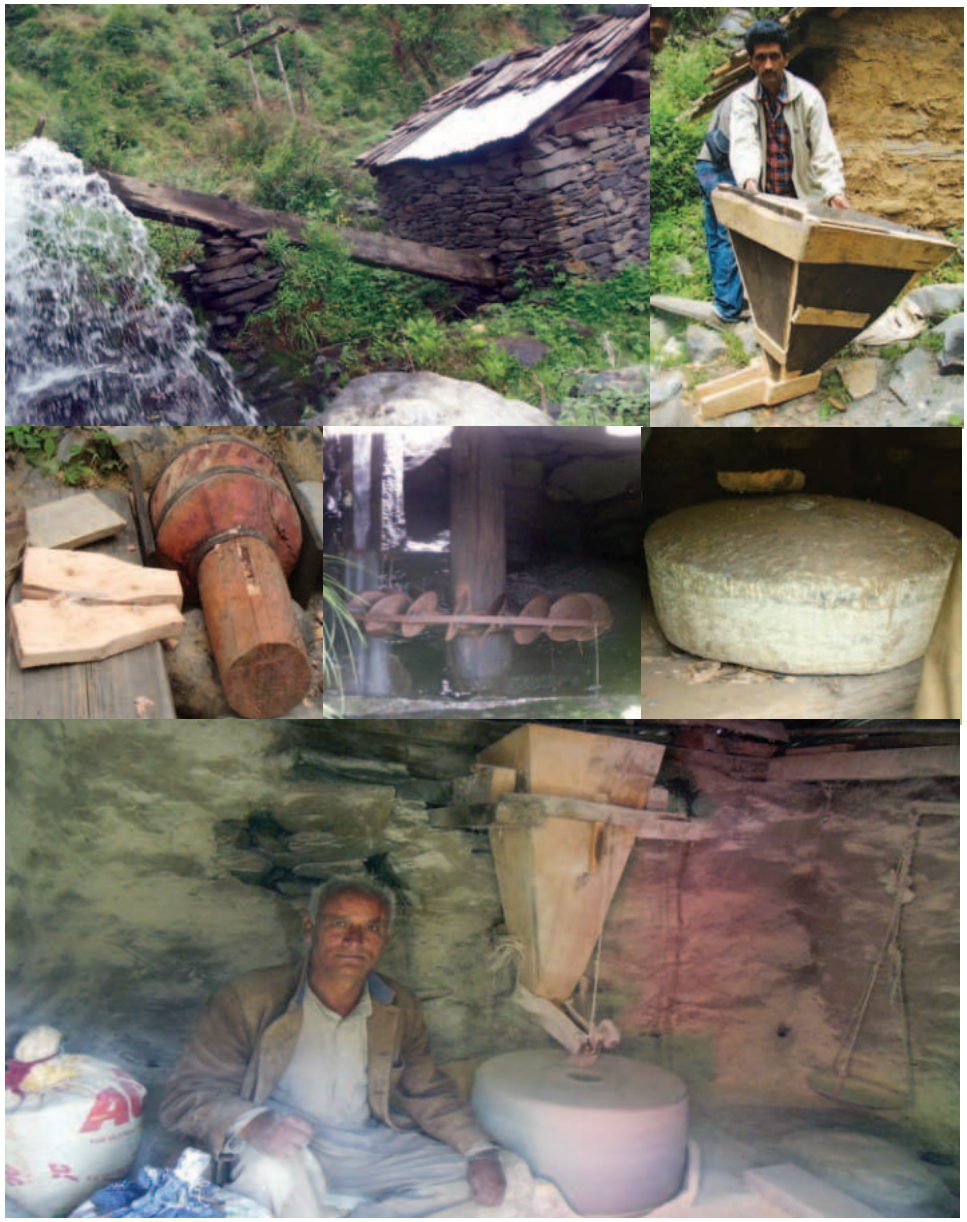

Figure 1: Various components of gharat and milling in progress.(a)Flume that diverts water on to the blades.(b)Hopper or a grain feeder that feeds grains for grinding.(c)Runner has blades, made of wood or iron, fitted to it.(d)The mill stone, rotation of which grinds the grain.(e)A happy miller and milling in progress. (Photo credits: 1a and e Alpy Sharma. All others: Sanjay Kr. Uniyal)

What is the concern

While close to 3lakh *gharat*s are estimated to be there in the Himalayan region, a whopping 40% are noted to be seasonal or defunct. Unfortunately, the indigenous knowledge associated with *gharats* and their makingis also fast dying**.** This represents anirreparable loss of our rich cultural heritage. It is probably the fate of water mills across the globe that motivated Edwin Miller to pen "The water-wheel goes round and round, with heavy sighs of mournful sound".

Why *gharat* are fading

There is no doubt that modernisation and market forces have taken a toll on indigenous systems and the*gharat* is no exception.Prevalence of electric/gasoline driven mills,even in the interior areas of Himalaya, have certainly contributed to this. Easy and door-step availability of flour has also limited the use of *gharats*. This in turn has led to loss of folk knowledge on the use and making of *gharats* and hill people today don't knowwhat resources are to be used for making the different parts of *gharat*and how they are to be processed. Now this knowledge is limited to only a few elderly people. Further, drying up of *khools* that power these *gharats* and non-availability of resources in the nearby areas that go into making of *gharats*are other important reasons that limit its use.

What next?

Recognising the importance of *gharats*, their revival and upgradation is the need of the hour. Devising energy-efficient *gharats*with multiple utility (meeting energy requirements of local people) need tobe seriously considered. In fact,emphasis is now being placed on this and many initiatives have been launched.Awareness creation that highlight the importance of our rich traditions such as he *gharat* becomes important (Figure 2). An innovation that has sustained and fed human communities since time immemorial should not be left to wither away.

Figure 2: Posters and replica of gharat at the Regional Science Centre, UCOST, Dehradun highlight the importance of awareness creation.

The Science of Sex Determination: Need for Public Awareness


Dr Rajesh Grover and Dr Loveleen Kaur Brar

Realising the necessity to change the attitude of society, a project titled "Women empowerment through genetic literacy: An Innovative Intervention" was conceived by Pushpa Gujral Science City, Kapurthala to create awareness at various levels to deal with the problem and empower women by building their self-esteem. The project sanctioned by NCSTC DST, GOI envisages setting up of Genetic Literacy Clubs in schools and villages across Punjab.

Obsession with the male child is still a sad reality in India. It thrives in the nooks and alleyways of our mindsets, cosseted by centuries of conditioning. Like a shape-shifting amoeba, it manifests in many ways, in different contexts. Though determination of the sex of an unborn child is prohibited, many clinics in India offer these services to the eager parents. And if it turns out to be a girl, some families go for an abortion. If the lucky one survives, many families refuse to let anyone know that a girl child is born, and they try to hide the news. Those who get to know the news may even convey a message of condolence.

The pressure to have sons is terrifying - mothers who bear daughters are beaten or cast aside by husbands and in-laws desperate to escape the financial burden of a girl's dowry. The cultural pressure for male heirs is so strong that women having daughters receives innumerable bits of advice on how to conceive a male child. We find it in the all-too-common refrain – 'May you beget a son.' Or *dhoodo nahaao puto phalo* (Alternate version: 'I want a grandson next year.') or in the well-meant (but often unsolicited) advice of elderly women who tell you – just which rites on what days will please which god to beget a male child. In the benediction heard often on Janmashtami – 'May a baby Krishna fill your household with his tinkling footsteps next year!' It is a very common practice to blame the mother when a girl child is born. The mother is often shouted at and affronted for not being capable of delivering a boy. All this is because in India, the unlettered and even the educated are ignorant about what decides the gender of a baby. Ignorance of science and blind beliefs contribute to this sorry state of affairs. If giving birth to a baby girl is such an atrocious crime, shouldn't we at least know for sure who's really responsible of committing it? Is it really the mother?

To better understand, let's look at how sex is determined

Chromosomes are thread-like molecules that carry hereditary information for everything from an individual's height to eye colour. They are made of protein and one molecule of DNA, which contains an organism's genetic instructions, passed down from parents. In humans, animals, and plants, most chromosomes are arranged in pairs within the nucleus of a cell. Humans have 22 of these chromosome pairs, called autosomes (Figure 1) in addition to an additional pair of sex chromosomes making a total of 46 chromosomes. The sex chromosomes are referred to as X and Y, and their combination determines an individual's sex. Human females have two XX chromosomes while males possess an XY

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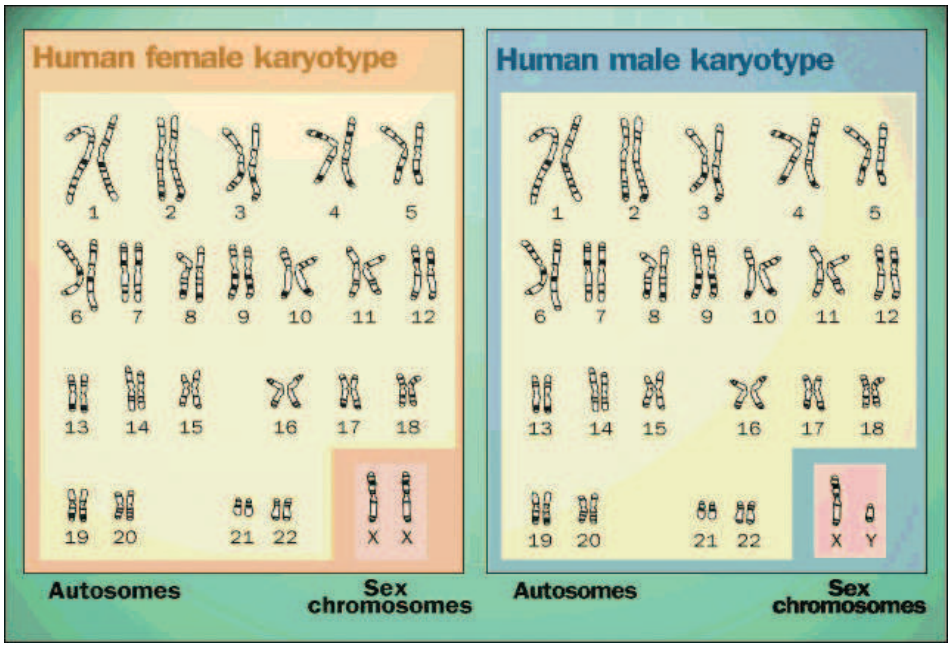

Figure 1. Male and female karyotype

pairing. This XY sex-determination system is found in most mammals as well as some reptiles and plants.

Whether an unborn baby has XX or XY chromosomes is determined when a sperm fertilises an ovum or egg. Unlike the body's other cells, the cells in the egg and sperm - called gametes or sex cells - possess only one chromosome. Gametes are produced by meiosis cell division, which results in the divided cells having half the number of chromosomes as the parent, or progenitor, cells. In the case of humans, this means that parent cells have two chromosomes and gametes have one.

During fertilisation, gametes from the sperm combine with gametes from the egg to form a zygote. The zygote contains two sets of 23 chromosomes, for the required 46. All of the gametes in the mother's eggs possess X chromosomes. Half of the father's sperm contains X chromosomes and the other half Y chromosomes. Thus the sperm is the variable factor in determining the sex of the baby. If the sperm carries an X chromosome, it will combine with the egg's X chromosome to form a female zygote. If the sperm carries a Y chromosome, it will result in a male zygote (Figure 2).

It is a biological fact that the Y chromosome, the presence of which makes a male baby, is contributed by the father. The meaning is obvious: it is the father and never ever the mother who is responsible for the gender of the child. Facts like this, however, mean little or rather nothing at all in a society where men are in charge, making frequent and fitful messes, and women are allotted the thankless task of cleaning up their mess.

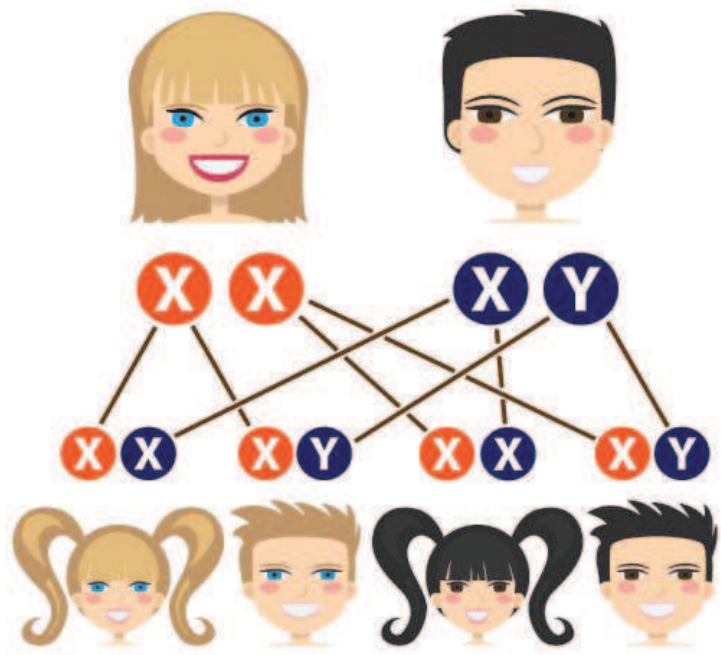

Figure 2. Sex determination in humans

The status of women in India has been subject to many great changes over the past few millennia. With a decline in their status from the ancient to medieval times, to the promotion of equal rights by many reformers, their history has been eventful. In modern India, women have held high offices including that of the President, Prime Minister, Speaker of the Lok Sabha, Leader of the Opposition, Union Ministers, Chief Ministers and Governors. We live in a wild society where women are blamed for rape, molestation, liable for men's leering stares since they look desirable, and it is not surprising that they are also blamed for bringing girls into this world. It is unfortunate that the true facts that decide the gender of a child are not given wide publicity. If this fact gets publicised, the blame game will ease, providing the much needed relief to women and perhaps we might be saving thousands of crimes perpetrated on womenfolk as a punishment for the "sin" of giving birth to a girl.

Realising the necessity to change the attitude of society, a project titled "Women empowerment through genetic literacy: An Innovative Intervention" was conceived by Pushpa Gujral Science City, Kapurthala to create awareness at various levels to deal with the problem and empower women by building their self-esteem. The project sanctioned by NCSTC DST, GOI envisages setting up of Genetic Literacy Clubs in schools and villages across Punjab with an objective to organise activities like interactive talks, screening documentary, conducting play/drama/nukkar nataks to highlight issues like scientific basis of sex development in human foetus, genetic disorders, early diagnosis of disorders, implication of declining sex ratio, and importance of girl child.

Acknowledgement

We are immensely grateful to SEED Division, Department of Science and Technology, New Delhi for funding the project "Women empowerment through genetic literacy: An Innovative Intervention".

Particles and Nobel Prizes


Bhupati Chakrabarti and Chinmoy Kumar Ghosh

Particle physics has emerged as a wide and significant area. The question of addressing 'how everything was formed' or 'how everything is made of' are very challenging questions to many scientists who are trying to solve the jigsaw puzzle by proposing different models that would be able to take care of all the observations in physics. In the process, a large number of particles have been predicted.

The year 2012 was marked as the year of the Higgs Boson–an elusive particle that was predicted nearly 50 years ago. The time gap was because of the need for a massive and immensely expensive particle accelerator called the Large Hadron Collider (LHC) that was available only in the first decade of the 21st century. Of course, it was also the technical and scientific manpower drawn from across the globe that made the detection of the Higgs Boson possible.

J.J. Thomson

The discovery got an enormous media attention and the entire world was rocking and the hype was in the form that the 'god particle' has been discovered. As expected, the Nobel Prize in Physics for 2013 went to Peter Higgs with Francois Englert, one of the living members of another group that also predicted the existence of the particle. The standard model of the atom got a boost and it looked like one step forward to unravelling the mystery of creation of the universe.

The Higgs Boson is the latest particle that got a Nobel Prize or its discoverers, but the tradition goes back to the 1890s. Sir J. J. Thomson also a British physicist who discovered the first sub atomic particle, namely the electron, won the Nobel Prize in Physics in 1906. He actually identified the electron in his research with cathode rays way back in 1897. Once the tiny negatively charged particle appeared from inside an atom, Sir J.J. was in a way compelled to come up with a model of an atom known as the 'plum pudding' model. Since an atom is electrically neutral he had no choice but to place positive charges inside the atom to take care of neutralisation of the negative charges. Interestingly, Sir J. J. Thomson did win the Physics Nobel Prize in 1906 but the citation did not mention his discovery of electron. It said that the prize was "in recognition of the great merits of his theoretical and experimental investigations on the conduction of electricity by gases".

We know that these investigations by Sir J. J. Thomson led to the discovery of electron, but it appears the Noble Committee at that time was hesitant to acknowledge it. Apparently the existence of subatomic particles and the discovery of electron possibly did not make much of a wave as it happened with the Higgs Boson. So the Nobel committee, it appears, played 'safe' and that way we can say that the discoverer of the first elementary particle did receive a Physics Nobel Prize but not

James Chadwick

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for the discovery of the particle.

However, by now the scientific community knew the atom has a negative constituent and logically it should have a positive constituent as well for an atom to be electrically neutral. In 1911, New Zealand-born British physicist Ernest Rutherford in 1911 actually planned to experimentally find out the positive charge inside the atom as predicted by Sir J.J. Thomson. He planned his famous experiment on alpha particle scattering and could actually demonstrate the existence of positive charge inside the atom as a very tiny point. His observation of heavy alpha particles virtually getting deflected by 180 degrees and moving in the opposite direction made him to comment "as if a cannonball is getting deflected by a tissue paper" and that comment is now the part of physics history.

Carl Anderson

Yukawa

The entire journey of discovery of fundamental particles has really followed this track after that. Gradually this became a pattern. There is a theoretical prediction by one or may be two scientists or groups, occasionally some additional confirmation by some other group of scientists, and then some experimental scientists was designing a suitable experiment to discover the particle. The entire exercise turned out to be a very well-known route to a Nobel Prize. Incidentally, Lord Rutherford, already a Nobel laureate in Chemistry in 1911, did get the location of a very tiny, small nucleus inside the atom and identified its positive charge. He did put forward his own model of an atom known as the nuclear atom model. But the formal discovery of protons did not take place. That possibly deprived the Sir J. J. Thomson and Lord Rutherford duo to get another Nobel Prize each, this time as a pair – as Thomson predicted positive charge in the atom and Rutherford discovered it.

C.F. Powell

E Gino Segre

Over time, this prototype began to take a deeper root. By the end of the First World War the existence of proton was accepted by the scientific community. After all, way back in 1899, even before the discovery of the electron, the first trace of nuclear particles had come to be known through the discovery of radioactivity. Henri Becquerel had discovered radioactivity in 1896 and it was known that substances like uranium emitted two kinds of 'rays' that darkened photographic plate. The nature of the two kinds of 'rays' was identified by Rutherford in 1899 as positively charged alpha and negatively charged beta particles.

Alpha particles are essentially a combination of two protons with a pair of neutrons. But after their discovery, the scientific community took more interest in the properties of alpha particles and in the application of them in different scientific experiments and did not show that much of interest about its origin. Nuclear research actually gained momentum after the First World War. By this time, Rutherford became sure about the existence of neutron and predicted its properties. Rutherford specially instructed his students and associates to detect one particle that provides the mass but no charge to the nucleus and the hunt was picked up quite seriously by Rutherford's students.

Samuel Chao Ting

Burton Richter

Simon van der Meer

C Rubbia

Before the actual discovery of neutron by James Chadwick, once again from the Cavendish Laboratory in 1932; but the master stroke came from none other than P. A. M. Dirac in 1927. He predicted the existence of positron the look-alike particle of electron with a positive charge. One year later E. Majorana of Spain independently confirmed the theoretical prediction of positron and the ground for looking for the particle became stronger. We have to remember that in a way this particle was not there in the structure of hydrogen atom as given by Bohr. American physicist C.A. Anderson actually took up the search for positron by designing a suitable experiment. He also became successful in the year 1932. So in a single year we had two new particles –neutron and positron –discovered. The outcome was obvious. The 1935 Physics Nobel Prize was shared by James Chadwick and C.A. Anderson. What about Dirac? Well, he already had the Prize in 1933, though Majorana never got it. The harsh reality in the race of all awards is that the second is always a 'glorious' loser.

Interestingly, artificial radioactivity was discovered in 1935. Artificially induced radioactivity was essentially a task of bombarding suitable light nuclei with alpha particles or with deuterium nuclei to induce radioactivity in them. The entire process involved a nuclear reaction that left the product nucleus with the

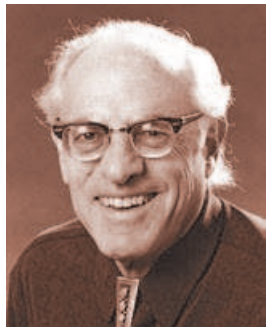
Table 1. Discovery of fundamental particles that fetched the Nobel Prize

Name of the particle	Predicted by whom and when	Scientists who discovered them	Year of discovery	Nobel Prize (who and when)	Nationality of the Nobel Laureates	Remarks
Electron	Some sketchy 19th century suggestions	Sir John Joseph Thomson	1897	1906 (Sir J.J. Thomson	Great Britain	Discovered during the study of cathode rays
Proton	E. Rutherford 1911	E. Rutherford (indirectly)	1920	No Nobel Prize was awarded		E. Rutherford won 1908 Chemistry Nobel and he introduced the name 'proton'
Neutron	E. Rutherford 1920	James Chadwick	1932	1935 J. Chadwick	Great Britain	Rutherford won 1908 Chemistry Nobel Prize
Positron	P.A. Dirac (1927) and E. Majorana (1928)	Carl David Anderson	1932	1936 Carl D. Anderson	USA	Dirac won the 1933 Physics Nobel Prize. No Nobel was won by Majorana
Pi meson (or pion)	H. Yukawaa 1935	C.F. Powell	1946	1949 (H. Yukawa, and 1950 C.F. Powell)	Japan, Great Britain	Meson actually fetched two separate Nobel Prizes, both unshared
Antiproton	P.A.M Dirac 1933	Owen Chamberlin, Emilio Segre, Clyde Weignad, and Thomas Ypsilantis	1955	1959 Emilio Gino Segre and Owen Chamberlin	Italy and USA	Dirac predicted it in his 1933 Nobel lecture
Electron neutrino	W. Pauli 1930	Clyde Cowan Frederick Reines	1956	1995 Frederick Reines	USA	Nobel Prize came 40 years after the discovery of the particle. Fermi and Pauli got 1938 and 1945 Nobel but for other works.
Muon neutrino	L. Lederman 1962	L. Lederman, Melvin Schwartz, and Jack Steinberger	1962	1988 Leon M. Lederman, Melvin Schwartz, and Jack Steinberger	USA, USA and Switzerland	The award came 26 years after the discovery
J/ψ meson	S. Glashow and James Bjorken 1964	Burton Richter andSamuel Ting	1974	1976 Burton Richter and Samuel Ting	USA (Both)	James Bjorken did not get a Nobel Prize
Tau lepton		Martin Perl and colleagues	1975	1995 Martin L. Perl	USA	Nobel Prize came after 20 years of discovery
W and Z bosons	A.Salam, S. Weinberg and S.Glashow 1979	Carlo Rubbia, Simon van deer Meer	1983	1984 Carlo Rubbia, Simon van deer Meer	Italy, Netherlands	Abdus Salam, Steven Weinberg, and Sheldon Glashow won1979 Physics Nobel Prize
Higgs boson	Peter Higgs F. Englert, and Robert Brout 1964	CERN A large pool of scientists and technologists	2012	2013 Peter Higgs and F. Englert	Great Britain andBelgium	Nobel Prize came after nearly 50 years

radioactive property. The concerned nuclei used to show beta activity, i.e., disintegrated usually through beta decay. The discovery of the phenomenon of artificial radioactivity also fetched a Nobel Prize in Chemistry to its discoverers Irene Curie, and her co-worker and husband Francis Joliot Curie. Irene was the daughter of two Nobel Laureates, Marie and Pierre Curie.

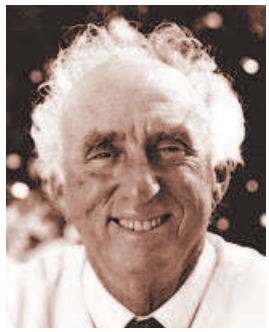
In the 1940s there was a lull in the discovery of the elementary particles because of the obvious reason; the Second World War. In fact numbers of projects for particle hunt were shelved as that was not a priority scientific area of research at the time of War.

The availability of the right kind of materials and equipment became very difficult in different laboratories because the scientific research at that time used to depend in a big way on the materials and equipment produced in Germany and Britain and both the nations were involved in war.



Frederick Reines

In this connection the unfortunate story of two Indian scientists Prof D. M. Bose and Ms Bibha Choudhury may be mentioned. In their study of cosmic raysat higher altitudes in a laboratory located in Darjeeling, West Bengal, they could detect the path of an unknown particle in the photographic plate. They published these results in *Nature*, mentioning that the particles should have a mass of about 200 times the mass of an electron. In fact, they had observed the track of pi mesons in the photographic plate used in a cloud chamber. However, they wanted to have more photographs for confirmation. As it was 1942 and the War was in full swing they could not get the right kind of photographic plate from the West and in the process they could not come up with the final confirmatory results. In Europe, C. F. Powell followed the exactly same technique and confirmed the particle as pi meson or pion. He went on to share a Nobel Prize in Physics in 1949 along with the Japanese physicist Heidi Yukawa who actually had predicted the existence of the particle through theoretical calculations in 1949.



Mertin Perl

Things only began to get momentum from mid-1950s and by that time it was clear that the hunt for the tiny particles actually demand huge funds and other supports in the form of technical and scientific manpower, engineering skill and a huge pool of dedicated team of researchers. Later on, skills like the development of suitable software, data analysis, improvement in the communication and networking also were the part of the whole exercise. Table 1 will be able to give us some idea about the total scenario, but this is not an exhaustive one.

The case of neutrino physics is very interesting in the sense that as many as eight scientists, both physicists and chemists, have won or shared Nobel Prizes for the discovery of different types of neutrinos and their properties. The list includes W. Pauli (Physics, 1933), Leon Lederman, Melvin Schwartz, Jack Steinberger (Physics, 1988) Frederick Reines and Martin L. Pearl (Physics, 1995), and Takaki Kajitaand Arther B. Mcdonald (Physics, 2015, for the discovery of neutrino oscillation that shows that the neutrino has mass). Since neutrino physics is still a very active field we may see more Noble Prizes related to the properties of neutrino.

Francois Englert

Particle physics has emerged as a wide and significant area. The question of addressing 'how everything was formed' or 'how everything is made of' are very challenging questions to many scientists who are trying to solve the jigsaw puzzle by proposing different models that would be able to take care of all the observations in physics. In the process, a large number of particles have been predicted and at the same time it has been found that the experimental set-up for their identification or discovery is immensely expensive and the technological and scientific skills needed are highly challenging. So it is difficult to predict how many more Nobel Prizes could be awarded in the near future for the discovery of fundamental particles. Large Hadron Collider (LHC) is running as an example of 'big science' with worldwide collaboration in so many fields starting from technological manpower to software development. And the small particles actually demand large facilities for their detection or tend to remain elusive. So not only the Prize but the particles, it appears, will continue to remain hard to pin downat least for some time now. ■

Peter Higgs

Stubborn Trash! Will nature help us wage war against plastics?

(*continued from page 32*)

digest plastic, the researchers opine that since both wax and plastics have similar chemical structure, a particular molecule or enzyme could be responsible for the digestion. They propose to isolate this molecule and produce it in the lab. The researchers are amazed at nature's ways and are thrilled to find solutions just by looking around.

Future prospects

The team hopes to isolate the gene that produces the wax-digesting enzyme; this could later be introduced into bacteria like *E.coli* or phytoplankton (found in the oceans). They, in turn, could be used to degrade the plastic in the oceans.

However, these prospects need careful handling as there are strict regulations and laws governing the release of genetically modified organisms into the environment. Of course, the obvious way would be to breed wax worms and scatter them on the plastic waste. However, the hurdle for this is the assumption that the worms would be happy on a plastic diet alone.

The researchers also need to determine if the worms were only chewing through the plastic to escape or were using it as a food source. Another question that lurks in their mind is whether the worms would be happy with a plastic diet alone, without being fed up soon.

Science still needs to find answers to these puzzles before working out on an effective solution.Perhaps with a little help from nature, we may find ourselves equipped to wage war against the human-made menace of plastics. ■

Benefits of Sugarcane Juice

Dr V.H.Mulimani

Sugarcane juice is full of essential antioxidants that help strengthen our immune system by multiple folds. They fight against a number of diseases including those of liver and digestive system. These antioxidants also neutralise the bilirubin levels in the body.

Sugarcane (*Saccharumofficianarum*) is one of the most important members of the plant kingdom. Sugarcane belongs to the grass family. It is perennial plant which grows from 2.5 to 4.25 metres. With sufficient care, it grows upto 7.5 metres. The diameter of stem varies 2.5 to 8cm and it has several joints after every few centimetres.

Origin and distribution

Sugarcane is indigenous to India. It has beencultivated here since theVedic period and is mentioned in the ancient scriptures. Alexander the Great and his soldiers carried sugarcane from India to the west around 325 BC. The people of New Guinea were probably the first to domesticate sugarcane, sometime around 8,000 BC. Sugarcane is now grown all over the world. India stands first in sugarcane cultivation followed by Brazil, Cuba, China, Mexico, Pakistan, the USA, SouthAfrica and Columbia. Belonging to the grass family, sugarcane is easy to grow anywhere and is available at very low costs.

The juice is extracted from the cane by pressing it through iron rollers. It is nutritious and refreshing. It contains about 15 percent natural sugars and is rich in organic salts and vitamins.

Health benefits of sugarcane juice

Sugarcane juice has amazing benefits for our health. It is used for drinking or sweetening. In summer days, it forms a soothing drink. A little lime juice, and ginger may be mixed in the juice to improve its flavour.

Sugarcane juice is known to be extremely beneficial for curing instances of febrile seizuresthat are extremely common in growing kids.A febrile seizure, also known as a fever fit or febrile convulsion, is a seizure associated with a high body temperature but without any serious underlying health issue. They most commonly occur in children

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Constituents of sugarcane*

Food value		Minerals	
Moisture	90.2%	Calcium	10 mg
Protein	0.1%	Phosphorous	10 mg
Fat	0.2%	Iron	1.1 mg
Minerals	0.4%		
Carbohydrates	9.1%		
Total	100%		
*Value per 100 gm edible portion Calorific value 39			

between the ages of 6 months and 5 years. They cause protein loss, thus making it a risk for the body. Sugarcane juice is known to replenish this loss of protein.

Sugarcane juice is very useful to treatscanty urination. It keeps urinary flow clear and helps the kidneys to perform their functions properly. It is also valuable in burning micturition due to high acidity, enlarged prostate, and nephritis. For better results, it should be mixed with lime juice, gingerjuice and coconut water.

Mixed with lime juice, sugarcane juicecan hasten recovery from jaundice. It is, however, very essential that the juice is clean, preferably prepared at home. Resistance is low in hepatitis or jaundice and any infected beverage could make matters worse.

Bad breath is a major cause for social embarrassment. If person has a history of tooth decay, leading to bad breath, he should consider sugarcane juice as a home remedy. Sugarcane contains a host of minerals, such as calcium and phosphorous, which help build tooth enamel. The consistent flow of nutrients prevents decay and strengthens teeth. Also, bad breath is asymptom of nutrient deficiency that sugarcane juice helps counter. It also keeps the teeth clean.

Sugarcane is an extremely rich source of calcium that helps build skeletal strength including bones and teeth. This makes it one of the best ingredients that contribute to child's growth. A glass of tasty sugarcane juice every day prevents teeth related and bone related problems in growing children.

Sugarcane juice is a good digestive tonic. It helps a person suffering from digestive distress. Sugarcane juice in diet helps for healthier and stress-free life. Potassium present in sugarcane juice helps maintain the pH levels of stomach and facilitates the secretion of digestive juices.

Sugarcane juice acts as an instant energy booster. If a person is experiencing dehydration, sugarcane juice is one of the best sources of instant energy. It is capable of lifting up our spirit and mood within no time, leaving us refreshed and charged. Sugarcane contains simple sugars (sucrose) that are easily absorbed by our body. These sugars are utilised to replenish the lost sugar levels the body.

Sugarcane juice has been found to be a great addition to pregnant woman's diet. It facilitates safer pregnancy. This amazing juice contains trace amounts of folic acid or vitamin B9 that is known to protect from neural birth defects like *spina bifida*. Research has revealedthat sugarcane juice minimises ovulating problems in women, thereby increasing chances of conception.

Sugarcane juice can help in diabetes. Infact, it can be consumed by people with diabetes, but in moderation. Sugarcane contains sucrose that has a low glycaemic index. This helps to keep our blood sugar levels in control.

Having sugarcane juice on a regular basis helps in cleansing the body of harmful toxins and other foreign elements. It also boosts our metabolism. This detoxification process gradually leads to weight loss.

Other than boosting the immunity, sugarcane juice also helps in speeding the healingof wounds. Sugarcane juice contains sucrose that is naturally capable of healing any kind of wound in small span of time.

Sugarcane juice helps maintain kidney health and prevents the problems associated with urinary tract infections (UTI). Takinga glass of sugarcane juice mixed with lemon and coconut water twice a day can help in UTI cases. Sugarcane juice is known to increase the protein levels in the body. This prevents many kidney related diseases like stones, UTI and prostatitis. It also relieves the burning sensation that accompanies these disorders.

Since sugarcane juice is alkaline in nature, it can soothe acidity and burningsensation in our stomach and intestines. It also helps to maintain the acid-base balance in our body.

Sugarcane juice is full of essential antioxidants that help strengthen our immune system by multiple folds. They fight against a number of diseases including those of liver and digestive system. These antioxidants also neutralise the bilirubin levels in the body.

Octacosanol, an active component found in sugarcane and other natural products, has potential to reduce stress and to increase sleep and it could potentially be useful for the therapy of insomnia caused by stress. Researches from University of Tsukuba in Japan have found that octacosanolreduces stress and restores stress-affected sleep back to normal. ■

Recent Developments in Science and Technology

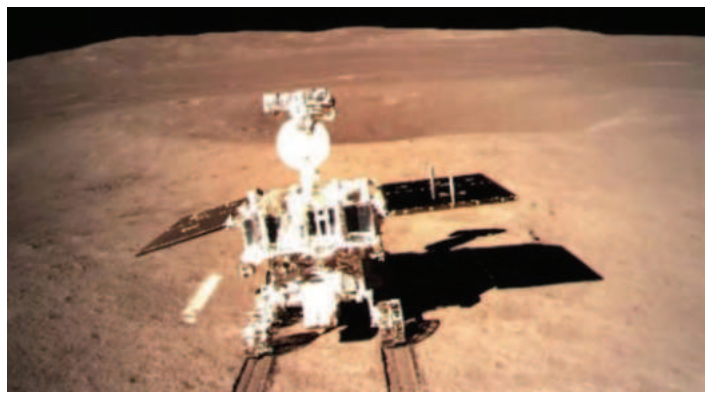
Biman Basu

Chinese craft makes historic landing on Moon's far side

In a historic first, China landed a rover called *Chang'e-4* (named after the Moon goddess in Chinese lore) on the far side of the Moon on 3 January 2019. No country has ever landed a space probe on Moon's far side, which is never visible from Earth. From Earth, we can see only one face of the Moon. This happens because the Moon takes just as long to rotate on its own axis as it takes to complete one orbit of Earth – a phenomenon called "tidal locking". Incidentally, though the far side of the Moon doesn't face Earth, it is not necessarily dark because it also sees regular day-night cycles like the visible side. So, the term "dark side" is a misnomer.

Launched on 7 December 2018, from the Xichang Space Centre in China, *Chang'e-4* took several weeks to reach lunar orbit. *Chang'e-4* landed over a special location called Von Kármán crater, a 186-kilometre-diameter feature in the South Pole-Aitken basin, full of scientific potential. Scientists say it is home to igneous rocks that may reveal clues about the Moon's internal structure and includes "fascinating volcanic constructs (mantle deposits that resemble the shape of Earth's cinder-cone volcanoes), secondary craters made by the ejecta of earlier impacts, landslides and more".

The spacecraft landed around local lunar sunrise. This timing gives the solar-powered lander and '*Yutu*' rover roughly two weeks of illumination, before they enter their first long lunar night in late January. One of the first images returned after landing showed one foot-pad of the lander sinking slightly into the lunar dust, but stable.

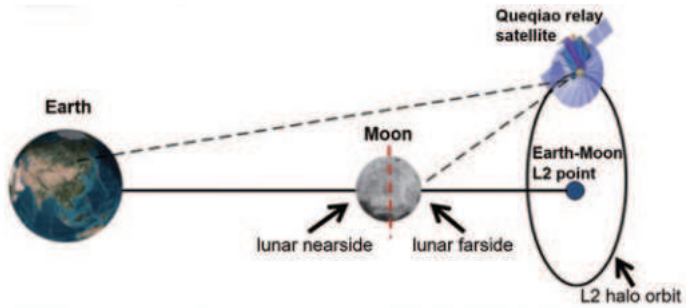


China's new lunar rover, Yutu-2, leaves Chang'e lander to leave first "footprint" on Moon's far side.

Since we cannot see the far side of the Moon from Earth it is not possible to have direct communication link with *Chang'e-4*. So, a relay satellite has to be used for communicating with the rover on the far side. Chang'e-4 uses a dedicated relay, the *Queqiao* orbiter perched in a halo orbit around the L2 Lagrange point, 60,000 kilometres beyond the Moon, where it remains constantly visible from Earth and can be used for communication.

It may be mentioned here that there are significant differences between the topographies of the near-side and far-side of the Moon. For one, the crust is much thicker on the far side, relative to the near side. "The near side is dominated topographically by the presence of large basins that have been filled to the brim with basaltic lava flows (or mare deposits), making it relatively flat and smooth and erasing any small- to mid-sized craters that may have formed". In contrast, the far side's surface generally looks rougher. Scientists don't know the reason for this difference yet. It is hoped exploration by *Chang'e-4* will throw new light on the mystery.

The *Chang'e-4* mission will be examining its new home with a battery of scientific instruments. The 2,200-kilometre-wide South Pole-Aitken basin that



Chang'e-4 lander communicates with Earth via the Queqiao relay satellite placed at Lagrange point L2.

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Von Kármán crater is embedded within is thought to be a section of exposed lunar mantle. Sampling this region could reveal information about the formation and structure of the Moon. The lander also carries silkworm eggs and plant seeds in a tiny enclosed experiment, to see how they fare growing on the Moon. In addition, *Chang'e*-4 will carry out radio astronomy observations from the radio-quiet lunar far side. Thanks to the mission's open data policy, the data collected will be shared with scientists all over the world.

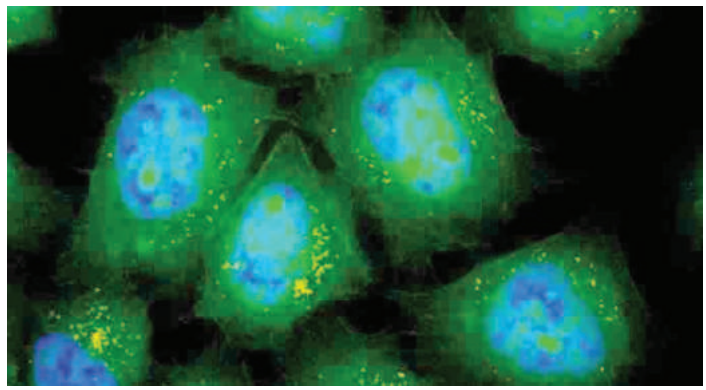
Chang'e-4 is a follow-on and virtual copy of the successful *Chang'e*-3 mission, which landed in the Mare Imbrium on Moon's near side in December 2013. China's next stated goal in lunar exploration is a sample return mission. A heavier *Chang'e*-5 lander, rover, and sample return capsule is scheduled for launch later this year.

Inhalable mRNA could treat lung disease

Messenger RNA (mRNA) is a large family of RNA molecules that convey genetic information from DNA to the ribosome, where they specify the amino acid sequence of the protein products of gene expression. It can induce cells to produce therapeutic proteins and holds great promise for treating a variety of diseases. Till now, the biggest obstacle to using mRNA for treating diseases has been finding safe and efficient ways to deliver mRNA molecules to the target cells. In a breakthrough in this direction, a team of researchers at the Massachusetts Institute of Technology (MIT) have now designed an inhalable form of mRNA. This aerosol could be administered directly to the lungs to help treat diseases such as cystic fibrosis. Asha Patel, a former MIT postdoc who is now an assistant professor at Imperial College London, led the research team (*Advanced Materials*, 4 January 2019 | DOI: 10.1002/adma.201805116).

One problem with mRNA is that can be easily broken down in the body, so it needs to be transported within some kind of protective carrier. In the present study, the researchers wanted to create an inhalable form of mRNA, which would allow the molecules to be delivered directly to the lungs. Many existing drugs for asthma and other lung diseases are specially formulated so they can be inhaled via either an inhaler, which sprays powdered particles of medication, or a nebuliser, which releases an aerosol containing the medication. But delivering mRNA was a different proposition.

There have been studies that had explored a material called polyethylenimine (PEI) for delivering inhalable DNA to the lungs. But PEI has a problem – it doesn't break down easily. As a result, with the repeated dosing that would likely be required for mRNA therapies, the polymer could accumulate and cause side effects. To avoid the potential side effects, the researchers turned to a type of positively charged polymers called hyperbranched poly (beta-amino esters), which, unlike PEI, are biodegradable.



MIT researchers have designed inhalable particles that can deliver messenger RNA to lungs. These lung epithelial cells have taken up particles (yellow) that carry mRNA encoding green fluorescent protein. (Credit: Asha Patel)

The research team created particles consisting of spheres, approximately 150 nanometres in diameter, with a tangled mixture of the polymer and mRNA molecules that encode luciferase, a bioluminescent protein. The researchers suspended these particles in droplets and delivered them to mice as an inhalable mist, using a nebuliser.

Speaking about the technique used, Patel said, "Breathing is used as a simple but effective delivery route to the lungs. Once the aerosol droplets are inhaled, the nanoparticles contained within each droplet enter the cells and instruct it to make a particular protein from mRNA."

24 hours after the mice inhaled the mRNA, lung cells were found to be producing luciferase. The amount of protein gradually fell over time as the mRNA was cleared. The researchers were able to maintain steady levels of the protein by giving the mice repeated doses, which may be necessary if adapted to treat chronic lung disease. The researchers also demonstrated that the nanoparticles could be freeze-dried into a powder, suggesting that it may be possible to deliver them via an inhaler instead of nebuliser, which could make the medication more convenient for patients. Moreover, the ability to deliver mRNA via inhalation could allow doctors to treat a range of different disease of the lung

Inhaled particles carrying mRNA in lungs (Diagrammatic)

Further analysis of the lungs revealed that mRNA was evenly distributed throughout the five lobes of the lungs and was taken up mainly by epithelial lung cells, which line the lung surfaces. These cells are implicated in cystic fibrosis, as well as other lung diseases such as respiratory distress syndrome, which is caused by a deficiency in surfactant protein. In her new lab at Imperial College London, Patel plans to further investigate mRNA-based therapeutics.

Modified photosynthesis can boost crop growth 40 per cent

Photorespiration is a respiratory process in many higher plants in which they take up oxygen in presence of light and give out carbon dioxide. This is contrary to the general pattern of photosynthesis in which carbon dioxide is taken in and oxygen is released. It is a process in plant metabolism where the enzyme RuBisCO oxygenates the molecule RuBP (ribulose bisphosphate), wasting some of the energy produced by photosynthesis in the process and leading to drastic suppression of their yield potential.

Photorespiration can be considered an aberration of the normal process of photosynthesis. Photosynthesis uses the enzyme RuBisCO and sunlight energy to turn carbon dioxide and water into sugars that fuel plant growth and yield. The RuBisCO enzymes grabs hold of CO2 and adds it to a carbon chain during photosynthesis, but often it grabs hold of an oxygen molecule by mistake. This generates toxic molecules called glycolates that plants have to expend energy to recycle into useful molecules. This fundamental flaw has been described as one of evolution's greatest mistakes. It is estimated that the grabbing of oxygen by mistake during photorespiration can reduce the efficiency of photosynthesis by as much as 50 per cent, depending on plant species and environmental conditions.

According to scientists, a few plants have evolved a solution: they concentrate CO2 inside them to reduce the odds of oxygen being grabbed by mistake. But most of the food plants, including almost all vegetables and fruits and key crops such as wheat, rice and soybeans, cannot do this. Biologists have been trying to find a solution for decades. Now researchers from the University of Illinois and U.S. Department of Agriculture Agricultural Research Service, led by Paul South, a molecular biologist with the U.S. Department of Agriculture in Urbana, Ill. have genetically engineered tobacco with a photorespiratory shortcut that are 41 percent more productive than unmodified tobacco (*Science*, 4 January 2019 | DOI: 10.1126/science.aat9077).

Photorespiration normally takes a complicated route through three compartments in the plant cell. Using genetic engineering, the scientists designed a more direct chemical pathway for photorespiration that is confined to a single cell compartment, thereby saving enough resources to boost plant growth by more than 40 percent. The team tested their hypotheses in tobacco: an ideal model plant for crop research because it is easier to modify and test than food crops, yet unlike alternative plant models, it develops a leaf canopy and can be tested in the field. According to the scientists, this is the first time that an engineered photorespiration fix has been tested in real-world agronomic conditions. Over two years of replicated field studies, the scientists found that the engineered plants developed faster, grew taller, and produced about 40 per cent more biomass, most of which was found in 50-percent-larger stems. Now, the team is translating these findings to boost the yield of soybean, cowpea, rice, potato, tomato, and eggplant. If it produces similar results in other crops, that could help farmers meet the food demands of a growing global population.

By modifying tobacco plants' genetic instructions for photosynthesis, the growth of tobacco plants could be increased by about 40 percent (left) compared with unmodified plants (right). (Credit: Claire Benjamin/RIPE Project)

This landmark study was part of Realising Increased Photosynthetic Efficiency (RIPE), an international research project that is engineering crops to photosynthesise more efficiently to sustainably increase worldwide food productivity with support from the Bill & Melinda Gates Foundation, the Foundation for Food and Agriculture Research (FFAR), and the U.K. Government's Department for International Development (DFID). ■

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I, Manish Mohan Gore do hereby declare that to the best of my knowledge and belief, facts mentioned above are true.

Sd/-
Manish Mohan Gore