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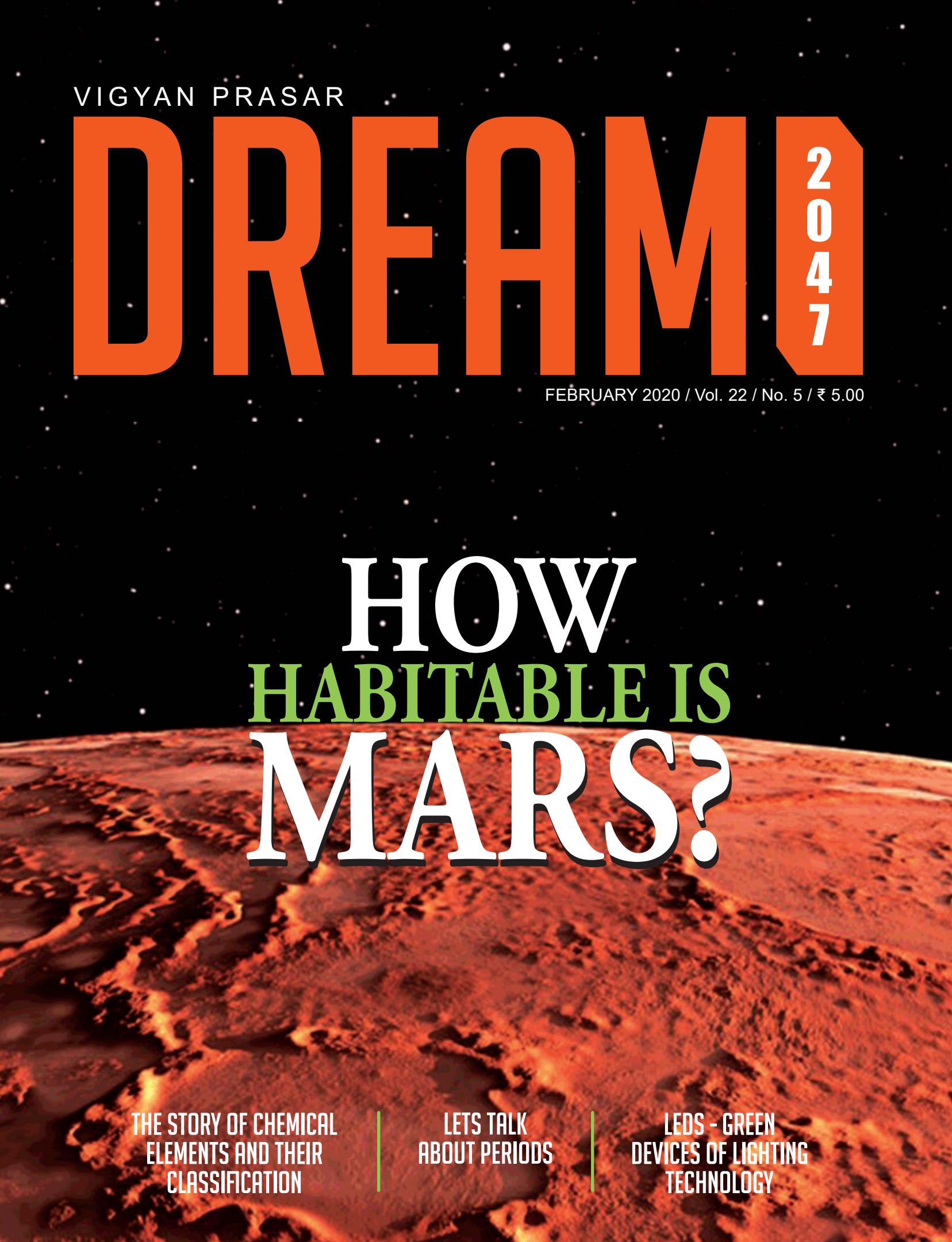

HOW HABITABLE IS MARS?

THE STORY OF CHEMICAL ELEMENTS AND THEIR CLASSIFICATION

LETS TALK ABOUT PERIODS

LEDS - GREEN DEVICES OF LIGHTING TECHNOLOGY

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EDITOR'S WORD

NAKUL PARASHAR

Spring on Mars

Neither too cold nor too warm – beautiful weather, indeed an ideal one, spread all over the nation. Flowers, especially varieties of roses, blooming all around! February isn't it? This is a time when the famous Mughal Garden in the Rashtrapati Bhawan in our national capital is let open for the public. This year, it's between Feb 6th and 14th. Ideally, it's a delight for everyone to walk around the garden amidst varieties of roses. When it comes to roses and various types of them, the name of Late Dr Benjamin Peary Pal comes to mind. Dr Pal was a world-renowned rose breeder of distinction. He created several new varieties of roses. With another notable agricultural scientist, Dr MS Randhawa, Dr Pal set up the Chandigarh Rose Garden. He was the founder President of the Rose Society and Bougainvillea Society. He also authored a number of books of which some of the well-known ones are The Rose in India, Beautiful Climbers of India, Flowering Shrubs and Environmental Conservation and Development. Dr Pal was a gifted plant breeder and geneticist, about whom Noble Laureate Dr Norman Borlaug once said, "It was during Dr Pal's leadership that the agronomic research on wheat in India equalled the best in the world. He was truly the architect of India's Green Revolution."

In continuation of the spring and roses, we present herewith some changes in the layout of the magazine. We hope that you'll like the change, and tell us how do you like it. We would look forward to your response. For this, we shall be introducing your responses in a new column called – INBOX!

In our journey so far, at Vigyan Prasar, we have gotten a lot of support and encouragement from all quarters of the society. We are grateful to one and all who've contributed in our mission. We have thus worked relentlessly hard to achieve our mandate of science communication, popularisation, and extension. A number of books, newsletters, activities, workshops, seminars, films, documentaries, DIY kits and much more – content repository has thus grown reasonably big. More than 300 titles of originally-written books, more than 400 audio-video programmes, and much more have been produced over the last thirty years. A 24x7 OTT channel called www.Indiascience.in is in operation, and so is an hour-slot on Doordarshan National Channel called DD Science. Despite a huge bank of recyclable content with us and a number of other agencies dealing with science & technology, we still find that our media requires a lot of scientific content to be fed with. The question that lies unanswered is that how and who's going to do that?

For this, India's first news agency dedicated to Science & Technology – Vigyan Samachar was finally launched. The mandate of this endeavour is to provide all four media – print, electronic, social and digital with adequate and timely news & other relevant information material. All possible publication item types shall be covered under this endeavour. To begin with, all four departments of the Ministry of Science & Technology and Ministry of Earth Sciences have come together to provide news material in a format that can be easily utilised by the representatives of all the four media.

Our cover story this time talks on Mars. It takes you through the ground facts. Fictional, it might sound – Spring on Mars!

Happy springtime!

Happy rose time!

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P. K. MUKHERJEE

LEDs (light emitting diodes) had been the real heroes in the electronics world, but now they are emerging to take a leading role in the lighting world as well. Lighting systems based on LEDs are extremely energy efficient. They are indeed the green devices of lighting technology. They not only consume less electricity but also have very long life. This is the reason why LEDs find potential applications in a variety of display devices. Early LEDs were often used as indicator lamps, replacing small incandescent bulbs. Recent developments have produced high-output white light LEDs suitable for room and outdoor area lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology. Infrared (IR) LEDs find use in remote controls of TVs and air conditioners. Coloured LEDs are used in advertisement and sign displays. They are also used to form images on a gigantic TV screens. LED rope lights and strips are a common sight these days. They are used for a variety of purposes including wedding decorations, concerts, etc.

LEDs - Green Devices of Lighting Technology

A new approach to fabricating LEDs could be used to increase their efficiency by 20 per cent while yielding higher-quality light than conventional LEDs. However, researches are going on to examine their impacts on human eye.

What are LEDs?

Basically, LEDs are just solid-state devices that emit light when connected to an electrical circuit. They are made of special kinds of materials, called semiconductors. When current is passed, light is produced as the particles that carry the current (known as electrons and holes) combine together within the semiconductor material.

The colour emitted by an LED depends on the semiconductor material it is built of. A diode made of gallium arsenide (GaAs) emits red light while a diode made of gallium phosphide (GaP) emits green light. Using other semiconducting materials diodes emitting yellow, orange colours, etc., have also been developed.

The development of white LEDs became possible only after the invention of blue-light emitting diodes or blue

Illustration By: BIPRO KUMAR SEN

LEDs. The development of blue LED was posing difficulties. However, in 1997, blue LED was finally created, thanks to the efforts of the Japanese scientists Shuji Nakamura, Isamu Akasaki and Hiroshi Amano. They were able to create blue LED by using gallium nitride (GaN) and indium gallium nitride (InGaN). The creation of blue LED by the scientist-trio virtually revolutionised the field of lighting technology. It became possible to generate white light by combining the outputs from red, green and blue LEDs. Generally, Nobel prizes are awarded for somewhat arcane and hard-to-grasp discoveries. However, the Nobel Prize Committee realised the real-world importance of this innovation and awarded the scientist-trio the Nobel Prize in Physics for the year 2014.

The history of development of LEDs

In 1907, the British scientist Henry Joseph Round, while working as an assistant to Guglielmo Marconi in the Marconi Lab, discovered that an electric current passed through silicon carbide produces light. However, nobody took a serious note of Henry's work. In the mid-1920s, Russian radio researcher Oleg Vladimirovich Losev observed that diodes used in radio receivers emitted light when current was passed through them. In 1927, Losev published a paper about his research in a Russian journal. Later, he also published

James Robert Biard

the details of his work in German and British journals.

Losev used Einstein's new quantum theory to explain how electrons produce the light without releasing heat. He also wrote a letter to Einstein asking for his help in developing the theory of LEDs. But, incidentally, he received no reply from Einstein. While no practical LED could be created out of Losev's work, his research did pave the path for future development of LEDs.

In 1950, British scientists using gallium arsenide developed an LED that could emit light in the infrared region of the spectrum. This may be said to be the first ever attempt to develop infrared (IR) LED. Eleven years later, in 1961, Robert Biard and Gary Pittman working with Texas Instruments invented and patented an IR LED. This was, in fact, the first LED. However, the light emitted by it being in the infrared region of the spectrum, was beyond the visible range. Actually, Biard and Pittman accidentally developed the IR LED when they were attempting to invent a laser diode.

In 1962, Nick Holonyak, a consulting engineer with General Electric Co. invented the first visible LED. Holonyak used gallium arsenide phosphide to create this LED. In 1972, electrical engineer George Crayford invented the first yellow LED for Monsanto Co. Crayford also invented a red LED that was ten times brighter than Holonyak's.

Nick Holonyak (1928)-inventor of the first red LED

It should be noted that Monsanto Co. was the first to mass-produce visible light LEDs. In 1968, Monsanto produced red LEDs used as indicators. But it was not until 1970s that LEDs became popular when Fairchild Optoelectronics began producing low-cost LED devices.

Credentials of LEDs

The most important credential of LEDs is that they are highly energy efficient as they consume very little power. The great secret of energy efficiency exhibited by

How light-efficient are LEDs?

Light is measured in a unit called 'lumen'. The average efficiency of an LED bulb is 100 lumens per watt (lm/W) while that of an incandescent bulb is only about 16 lm/W. The CFLs, on average, have an efficiency of 70 lm/W. For a source of light to be 100 per cent efficient it, hypothetically, needs to produce 680 lm/W. By this standard, the luminous efficiency of LEDs today is about 14.8 per cent while that of the old-fashioned incandescent bulbs is around 2.3 per cent. The luminous efficiency of CFLs varies between the previous two figures at an approximate 10.3 per cent. Since the LED technology is constantly undergoing improvement, it is only expected that in future we would be able to achieve even higher luminous efficiency.

LEDs lies in the fact that they produce light directly without having to pass through an intermediate stage. In other sources of man-made light, only a fraction of electrical energy is converted into light. For instance, in the case of incandescent bulbs, electrical energy is first converted to heat energy to heat the filament, which subsequently emits light. About 90 per cent of the energy goes in heating the filament and only 10 per cent is converted to light.

In the case of fluorescent tubes or compact fluorescent lamps (CFLs), the electrical energy is first used to ionise a gas, which subsequently produces light by fluorescence of a special material (called phosphor) that is coated on the inside of the tube or CFL. However, LEDs neither have a filament nor a gas; they function solely through movement of electrons through semiconducting materials. So, LEDs are more energy efficient and emit brighter light compared to other artificial light sources. Also, they are long lasting. They can last for 1,00,000 hours or more. That means if you buy an LED today, you would need to throw it after using it for more than 25 years! Sounds incredible but true. Calculation is simple: there are 365 days in a whole year and normally a bulb is used for 10 hours a day in an average household. Compared to an LED bulb, an incandescent bulb lasts for only 1,000 hours and a CFL for around 8,000 hours.

However, LED bulbs present a high up-front cost compared to incandescent bulbs or CFLs. But, in the long run, they indeed prove cost effective by saving a lot of energy. The worldwide thrust, therefore, is to use LEDs for general lighting purposes. Statistics show that about one-fourth of global electricity consumption is used for lighting purposes.

In view of very low power requirements, LEDs can effectively be powered by solar panels. This has great potential of benefitting 1.5 billion people across the globe who lack access to electricity grids.

Glimpse of a typical decoration using LEDs

New types of LEDs

Conventional white LEDs used for illumination purposes give out bright light closer to daylight. But, now warm-white LEDs have also been developed. These LEDs produce a yellow hue, close to that produced by incandescent bulbs. They produce less glare and work more efficiently in fog. Also, they give an aesthetic look. Warm-white LEDs were initially started in Korea and Malaysia not very long time ago. But, now they are being used in other countries as well. In India, warm-white LEDs are being used to give aesthetic look to roundabouts, parks and fountains in New Delhi.

Potential health risks of LEDs

It has been found that LEDs might affect your eye, particularly the health of retina. This might sound unbelievable, but some studies indicate that the risk cannot be ruled out either. The latest to raise the red flag is the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), the country's government-run health watchdog. In a 400-page report, it has stated that the blue light in LED lighting can damage the retina. "Exposure to an intense and powerful (LED) light is 'photo-toxic' and can lead to irreversible loss of retinal cells and diminished sharpness of vision," said the report.

Like most other countries, LEDs are used widely in our country, both outdoors and indoors. LEDs with high intensity are also increasingly being used in automobile headlights.

Although LEDs are energy efficient, they produce more blue light compared to the old-fashioned incandescent bulbs. According to eye specialists, theoretically LED lights have the potential to damage retinal cells. However, they say that there is a need for large-scale clinical studies to determine the intensity and duration of such exposures that can be damaging. "Conclusive data is needed before raising an alarm", they say.

Another area of concern is the marked constant flicker and glare in LED lights. Most LEDs available in India have high flicker rates not suitable for overall eye health. Some studies point out that the factors that make flicker worse include longer duration of exposure, greater area of retina receiving stimulation, greater brightness of the flash, and its higher contrast with surrounding luminance.

In fact, artificial lighting is an integral part of our everyday life. We spend an average of 10-12 hours under these lights. It is, therefore, important that LED lights need the photobiological safety standards prescribed internationally. The issues of flicker and glare are actually associated with poorly manufactured LEDs.

The issues of eye health, particularly the health of retina are associated with LEDs. However, there is no conclusive evidence yet that LEDs do hurt the retina. It may be relevant to mention that last year (2018) the European Commission had stated that there is no evidence that the normal usage of LEDs can adversely affect the health of common people. In its statement, the Commission also pointed out: "However, there is insufficient research on the health effects of LED lighting and many topics should be investigated further, particularly the effects of flicker." D

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LOVELEEN BRAR

Lets Talk About Periods

Demystifying the taboo around menstruation is important to ensure healthy living for women and girl-child. It is imperative to spread knowledge and make everyone aware of safe menstrual hygiene practices.

Menstruation is a normal biological process and a key sign of reproductive health, yet in many cultures it is treated as something negative, shameful or dirty. The continued silence around menstruation combined with limited access to information at home and in schools results in millions of women and girls having very little knowledge about what is happening to their bodies when they menstruate and how to deal with it. A study by UNICEF revealed that 1 out of 3 girls in South Asia knew nothing about menstruation prior to getting it while 48% of girls in Iran and 10% of girls in India believe that menstruation is a disease (WaterAid 2013, Menstrual Hygiene Matters).WaterAid is an international non-profit organisation that was set up in 1981 as a response to the UN International Drinking Water & Sanitation decade (1981–1990).

Even today in India and parts of South Asia, there are families who treat a menstruating woman in a very humiliating way, and her attendance at religious function in the house or in social functions is considered inauspicious.

Why is it that the lady or the daughter of the house, who does all household chores on other days of the month, abruptly becomes polluted when she has periods? Why are menstruating women not allowed to enter temples? Why do we feel embarrassed while asking the shopkeeper for sanitary napkins? Why do shopkeepers wrap up sanitary napkins in paper or black polybags before discreetly handing them over to the customer?

We go to toilet every day to clean up our body, we take a bath, and we cut our nails, hairs. Do we talk about these the same way as we talk about menstruation? Why do girls have to talk about it in hush-hush tones? Even educated women hesitate in talking about periods and inconvenience that might be caused by it openly among male peers.

Is this because men are ill-informed, ill-prepared and ill-guided about the way one should understand and appreciate mutual biological differences?

Is it that our culture is the culprit and we have allowed certain debilitating elements of our culture to prevail and persist? Why doesn't our curiosity about menstruation's ramifications generate conversation in a scientific manner? So let's talk about it.

What is menstruation?

Menstruation, or period, is normal vaginal bleeding that occurs as part of a woman's monthly cycle. Every month, a female body prepares for pregnancy. If no pregnancy occurs, the uterus, or womb, sheds its lining. The menstrual blood is partly blood and partly tissue from inside the uterus. It passes out of the body through the vagina.

Periods usually start between the age of 11 and 14 and continue until menopause at about age 51. They usually last from three to five days.

GIRLS
and women globally miss out on daily activities because of their periods, which commonly occurs because they view menstruation as a barrier and they lack the proper education to know how their bodies work. Something that happens to half of the population around the world every month shouldn't be taboo, and breaking the silence on what is often an unspoken topic is the first step towards destigmatising.

The Menstrual Cycle

The working of this cycle is quite simple. Once a month, an egg leaves the ovaries and goes through the fallopian tubes to the uterus.

At this time, the lining of the uterus thickens with extra blood and tissue to provide a cushion for the potentially fertilised egg.

If at this time, the egg gets fertilised by sperm then the fertilised egg will attach itself to the uterus, where it will slowly develop into a baby.

However, if the egg does not come in contact with sperm and does not get fertilised, the lining of the uterus will start to break down so that it may be shed.

Along with the lining, the unfertilised egg is also shed. Hence, a girl's or woman's "period" is this time of bleeding, which happens when a female body is getting rid of this extra blood and tissue.

What is normal bleeding?

There is a range of normal bleeding – some women have short, light periods and others have longer, heavy periods. The duration and intensity of the periods may also change over time.

Normal menstrual bleeding has the following features:

- The period lasts for 3-8 days;
- The period comes again every 21-35 days (measured from the first day of one period to the first day of the next); and
- The total blood loss over the course of the period is around 30-45 ml, but secretions of other fluids can make it seem more.

Premenstrual syndrome (PMS)

It's common for women and girls to experience some discomfort in the days leading to their periods. Premenstrual syndrome (PMS) includes both physical and emotional symptoms that many girls and women get right before their periods, such as acne, bloating, fatigue, backaches, sore breasts, headaches, constipation, diarrhoea, food cravings, depression, irritability, or difficulty concentrating or handling stress. PMS is usually at its worst during the 7 days before a girl's period starts and disappears once it begins.

Many girls also experience abdominal cramps during the first few days of their periods. They are caused by prostaglandins, chemicals in the body that make the smooth muscle in the uterus contract. These involuntary contractions can be either dull or sharp and intense.

Managing periods: Menstrual hygiene

With three to eight days in a month, women spend a total of around six to ten years of their lives menstruating. Yet the importance of menstrual hygiene management is mostly neglected. Menstrual hygiene is a taboo subject; a topic that many women are uncomfortable discussing in public. In reality, however, menstrual hygiene is fundamental to the dignity and well-being of women and girls and an important part of the basic hygiene, sanitation and reproductive health services to which every woman and girl has a right. Here are some tips to help you stay clean and hygienic during your periods:

1

Change your sanitary napkin every 4-6 hours

Changing sanitary napkins every 4-6 hours is the cardinal rule to establish vaginal hygiene. Menstrual blood, when released from the body attracts various microorganisms from our bodies, which multiply in the warmth of the blood and cause irritation, rashes or urinary tract infections. Changing the sanitary napkin regularly curbs the growth of these organisms and prevents infections.

2

Wash yourself properly

Washing your vagina regularly is extremely important, because the organisms cling to your body after you have removed your sanitary napkin. Most people wash themselves regularly, but not the right way-which is using your hands in motion from the vagina to the anus, not vice-versa. Moving your hand from the anus to the vagina can lead to the transmission of bacteria from the anus into the vagina or urethra opening leading to infections.

3

Don't use soaps or vagina hygiene products

While using vaginal hygiene products everyday is a good idea, using these products during menses can turn things around. Vaginas have their own cleaning mechanism which comes into play during the menstrual cycles, and these artificial hygiene products can hamper the natural process leading to infections and growth of bacteria.

4

Discard the sanitary napkin properly

Disposing of your tampons and sanitary napkins properly is an important step. Wrap them properly before you throw them away, so the bacteria and infections do not spread. Make sure you don't flush them, since that will block the toilet. Washing your hands properly is of utmost importance after you have wrapped and discarded the used tampons and sanitary napkins, since you're likely to touch the stained area while wrapping them.

5

Beware of a pad rash

A pad rash is something that you might experience during a period of heavy flow. It usually occurs when the pad has been wet for a long time and rubs along the thighs causing it to chaff. To prevent this from occurring, try to stay dry during your periods. If you do have a rash, change your pads regularly and stay dry. Apply an antiseptic ointment, after a bath and before bed. This will heal the rash and prevent further chaffing. If it gets worse, do visit your doctor who will be able to prescribe you a medicated powder that can keep the area dry.

Menstrual problems

A variety of menstrual problems can affect girls. Some of the more common conditions are

- Dysmenorrhea, when a girl has painful periods;
- Menorrhagia, when a girl has very heavy periods with excessive bleeding;
- Oligomenorrhea, when a girl misses or has infrequent periods, even though she's been menstruating for a while and isn't pregnant; and
- Amenorrhea, when a girl hasn't started her period by the time she is 16 years old or has not developed signs of puberty by the age 14, or has had normal periods but has stopped menstruating for some reason other than pregnancy.

Girls and Women globally miss out on daily activities because of their periods, which commonly occurs because they view menstruation as a barrier and they lack the proper education to know how their bodies work. Something that happens to half of the population around the world every month shouldn't be taboo, and breaking the silence on what is often an unspoken topic is the first step towards destigmatising.

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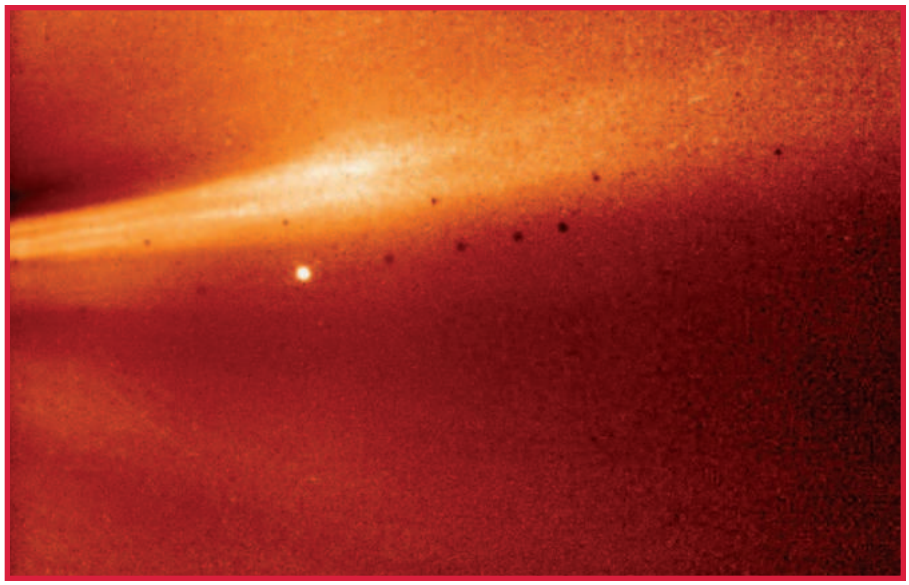
BIMAN BASU

Recent Developments in Science and Technology

First results from Parker Solar Probe released

NASA has revealed the first findings from its Parker Solar Probe sent to "touch the Sun". The spacecraft has flown closer than ever before to our Sun and has now sent back its first data from the mission. The Parker Solar Probe is to become the first spacecraft to approach closest to the Sun till date, at a distance of only 18.7 million kilometres, in January 2020. By the end of its mission in 2025, the probe will have had 24 close encounters with the Sun – getting more than three times closer to our star than it has so far. The ultimate objective is to bring the spacecraft to within 6 million kilometres from the Sun's surface during its final approach in 2025, which will bring it within the solar corona.

Launched on 12 August 2018, the Parker Solar Probe is designed to perform its scientific investigations in a hazardous region of intense heat and solar radiation. The mission includes 24 orbits around the Sun, with seven gravity-assist fly-bys of Venus and gradually diminishing perihelion distance, with its closest and final approach bringing it to within 6 million kilometres from the Sun's surface. It is expected to help researchers better understand the inner workings of the Sun. During its third and latest close approach in September 2019, the spacecraft flew close enough to the Sun to watch the solar wind speed up from subsonic to supersonic, and also through the birthplace of the highest-energy solar particles. The probe could measure a portion of the solar wind coming from a small hole in the Sun's corona near the equator. It is the closest look yet at one of the solar wind's points of origin.



This image taken on 8 November 2018 comes from the Parker Solar Probe's WISPR (Wide-Field Imager for Solar Probe) instrument. It shows a coronal streamer, a bright structure that develops over active regions of the Sun. The bright point near the image's centre is Mercury. *(Credit: NASA/Naval Research Laboratory/Parker Solar Probe)*

The initial results obtained from the Parker Probe have been reported in four papers published in the journal Nature on 5 December 2019. The four papers report what the probe's instruments observed during its first two perihelion passes, which occurred in November 2018 and April 2019, respectively. These early studies, the scientists say, have provided insights into the two fundamental questions the Parker Solar Probe mission was designed to answer. First, defying all logic, why does the Sun's outer atmosphere – or corona – become much, much hotter the farther it stretches from the Sun's surface? Corona temperatures can exceed 1.1 million degrees Celsius whereas the temperature of the solar surface is 6,000 degrees Celsius. Second, what accelerates the solar wind – a supersonic stream of protons, electrons and other particles – emanating from the corona and permeating the entire solar system?

The most startling discovery the teams

made was that magnetic fields emanating from the Sun seemed to unexpectedly flip back and forth, causing local disturbances – what scientists dubbed "switchbacks" – which can even cause them to point back at the Sun at times. The cause of these switchbacks is still a mystery to scientists, but they could eventually allow us to understand how energy flows away from the Sun and throughout the solar system. Another puzzling discovery was of strange spikes in the solar wind, where particles speed up and flip the direction of the wind's magnetic field. The spacecraft also observed the wind rotating around the Sun faster than expected. These findings could help researchers to better prepare for periods when the solar wind is particularly turbulent and knocks out radio and other communications as it washes over Earth.

The information the Parker Probe has uncovered about how the Sun constantly ejects material and energy will help scientists rewrite the models they use to understand and predict the space weather around our planet and understand the process by which stars are created and evolve. According to the scientists, what has been learned in just these three solar orbits alone has changed a lot of what we know about the Sun. The findings could also help us find new ways to protect astronauts from harsh space weather during long-distance trips through the solar system.

Incidentally, the findings reported in Nature were made during a relatively quiet phase of solar activity. According to the scientists, as the Parker Probe gets even closer to its target in the coming years, the Sun will go through an active phase and we can expect even more exciting results.

A distant star and its planets get Indian names

In a rare honour, the International Astronomical Union (IAU) has named a sun-like star after a little-known Indian physicist Bibha Chowdhuri. Its Jupiter-like exoplanet also gets an Indian name – Santamasa – meaning 'clouded'. The white-yellow star in the constellation of Sextans and its planet were hitherto known as HD 86081 and HD 86081b, respectively. The announcement of new names was made by IAU on 17 December 2019. HD 86081 is as hot as the Sun, with a surface temperature of about 6,000 Kelvin. It is 1.55 times bigger, 1.21 times massive, and 1.75 times brighter than the Sun. It is 310.93 light years away and is visible only with a telescope.

IAU selected the two Indian names at the end of a global contest called 'NameExoWorlds', which was organised as part of its centenary celebrations. The agency, which turned 100 on 28 July had allowed every country in the world to give a name to a selected pair of exoplanet and its host star. India was allotted HD 86081 and its exoplanet HD 86081b.

Bibha Chowdhuri, after whom a star has been named by IAU. *(Credit: Wikipedia.org)*

Of the two selected names, the name Bibha for the star was suggested by Ananyo Bhattacharya, a 22-year old student of Sardar Vallabhbhai National Institute of Technology, Surat and the suggestion of the name Santamasa for the planet came from 13-year-old Vidyasagar Daud of Sinhgad Spring Dale Public School, Pune. More than 110 countries took part in the naming campaign, and over 7,80,000 people participated worldwide to propose and select names for each exoplanet and its host star. In India, the campaign was coordinated by the Public Outreach and Education Committee of the Astronomical Society of India (ASI).

Before the IAU recognition, few Indians would have known about the work and contribution of Bibha Chowdhuri (1913-1991) who not only worked with Bhabha and Sarabhai at TIFR and PRL, respectively but also in the laboratory of Nobel-laureate PMS Blackett, who was also an advisor of Prime Minister Nehru on matters relating to organising scientific research in newly independent India. In addition, Chowdhuri was a part of the proton decay experiment conducted in the Kolar Gold Fields (KGF) under the leadership of MGK Menon.

Incidentally, Chowdhuri, along with DM Bose, discovered the pi-meson and published it in the journal Nature in early 1940s. After seven years of this stunning discovery, C.F. Powell made the same discovery of pions and muons by using the same process. He won the Noble Prize but Chowdhuri's contribution sank into oblivion.

Despite working with some of the leading lights of the physics fraternity in India and abroad, Chowdhuri remained an unsung hero of Indian science. She was not elected to fellowship of any of the three celebrated science academies in India nor named for any major prize. She does not figure among the 98 scientists covered in the 2008 book Lilavati's Daughters: The Women Scientists of India, edited by Rohini Godbole and Ram Ramaswamy and published by the Indian Academy of Sciences, Bengaluru.

The first public exposure of this pioneering Indian physicist's life and work came in 2018 with the publication of A Jewel Unearthed: Bibha Chowdhuri – a volume authored by renowned physicists Rajinder Singh and Suprakash C Roy and published from Germany. The naming of a star after her by IAU now puts her name in the sky!

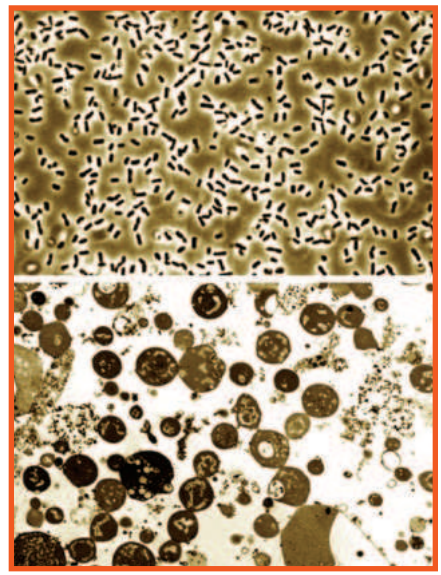
Some bacteria change shape to evade antibiotics

Widespread and indiscriminate antibiotic use is largely to blame for the emergence of antibiotic-resistant bacteria. The World Health Organisation has identified antibiotic resistance as one of the biggest threats to global health, food security, and development today. Although new antibiotics are being developed on a regular basis to counter antibiotic resistance, it appears to be a losing battle. Scientists are therefore trying to find other ways to address the problem.

In a serendipitous discovery, researchers from Newcastle University in England have confirmed for the first time that bacteria can change form to avoid being detected by antibiotics in the human body. While studying samples from elderly patients with recurring urinary tract infections, they have found that a bacteria can lose its cell wall – the common target of many groups of antibiotics. This finding goes against the current thinking about the bacteria's ability to survive without a cell wall, also known as "L-form switching". Scientists believe that L-form switching might contribute to recurrent infections by helping bacteria hide from the immune system and resist the antibiotics.

Katarzyna Mickiewicz, researcher, of Newcastle University, who led the research, says, "The cell wall gives the cells a regular shape (for example a rod or a sphere), making them strong and protecting them and also makes them highly visible – particularly to the human immune system and antibiotics like penicillin. However, bacteria can occasionally survive without their cell wall and the body's immune system cannot detect the L-form of bacteria nor can antibiotics, making the bacteria immune to antibiotics".

What the researchers discovered was that in the presence of antibiotics, the bacteria are able to change from a highly regular walled form to a completely random, cell wall-deficient L-form state. In this form the body cannot easily recognise the bacteria so doesn't attack them – and neither do antibiotics (Nature Communications, 26 September 2019 | DOI: 10.1038/s41467-019-12359-3).



Optical micrograph of the normal form of Bacillus subtilis bacteria *(top)* shows its normal rod-shape; electron micrograph of the L-form *(bottom)* shows change in shape.

According to Mickiewicz, "In the L-form, the bacteria are flimsy and weaker, but some survive, hiding inside the body. However, in a healthy patient, the L-form bacteria left would be destroyed by their hosts' immune system. But in a weakened or elderly patient, like in our samples, the L-form bacteria can survive. They can then re-form their cell wall and the patient is yet again faced with another infection. And this may well be one of the main reasons why we see people with recurring UTIs."

The research also found that L-form bacteria is difficult to identify by traditional methods used in hospital as the gel used destroys the bacteria as they are put into it. Therefore, a special detection method that did not destroy the wall-deficient cell was needed to support the weaker L-form bacteria, enabling them to be identified in the lab.

According to the researchers, before we can fully understand how important L-form switching is compared to other forms of antibiotic resistance, further research using more patients will be needed. It will also be important to investigate what role L-forms may play in other recurrent infections, such as sepsis or pulmonary infections. Nevertheless, the new finding can be considered a breakthrough in our understanding of antibiotic resistance.

The researchers hope that the new findings will help find a way to clear the L-form bacteria from the body and prevent development of antibiotic resistance. Combining cell-wall-active antibiotics with ones that would kill L-forms might be one solution of fighting antibiotic-resistant infections. The team will be carrying out further research with trials in patients who have had treatment. D

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REQUEST TO THE AUTHORS

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-Editor

R. P. CHAMOLI AND A. M. PAINULY

The Story of Chemical Elements and Their Classification

The Periodic Table has gone through many changes since Dmitri Ivanovich Mendeleev came up with his original Table in 1869. It is still regarded as one of the greatest breakthroughs in the history of chemistry.

INTRODUCTION

There is an old Chinese proverb: "If you want to learn about the future, you have to look into the past". In the history of science, the formulation of the Periodic Table in 1869 by the Russian chemist, Dmitri Ivanovich Mendeleev ranks as one of the greatest ideas that can be compared to Charles Darwin's theory of evolution. The periodic table encompasses a significant part of our knowledge in chemistry that is a central science, occupying a pivotal position at the interphase of almost all the branches of science. It has had a tremendous impact on the development of chemistry in particular, and science in general. The periodic table portrays all the known chemical elements (63 at the time of Mendeleev and 118 at present). It is the most ubiquitous icon of science and technology that has become a symbol of research and development.

The year 2019 marked the completion of 150 years since periodic table was first published by Mendeleev. To commemorate this monumental event, the year 2019 was declared as the "International Year of Periodic Table (IYPT 2019)" by the UNESCO. The objective of this declaration was to remember the past achievements of our devoted scientists and gain new momentum for enhancing global awareness for sustainable development and meeting the challenges in the sphere of energy, education, agriculture, health and other critical sectors.

CONCEPT OF ELEMENTS

As the periodic table deals with chemical elements, it would be worthwhile to give a general idea about the elements. The word 'element' comes from Latin word, *elementum* meaning 'first principle' or most 'basic form'. Elements are the simplest form of the matter and are the building blocks of the universe. Every element is composed of only one type of particles or atoms and cannot be reduced to a simpler substance by ordinary process. The difference between the elements and atoms is that elements are substances in any quantity while atoms are fundamental units.

Centuries before Christ, Greek and Indian philosopher had started thinking about the composition of matter. The Greek philosopher, Empedocles (500-430 B.C.) postulated that all matter is composed of four elements – fire, water, air and earth. This concept of four elements was also accepted by Aristotle (384-322 B.C.). He suggested that these four elements are associated with qualities of heat, cold, wetness and dryness by means of which they could be interconverted. Almost during the same period (600-500 B.C.), Indian philosophers also developed an identical concept. The *Samkhya Philosophy* of India envisaged that the matter was composed by *five 'bhutas'*, i.e., five elements – *akaasa* (sky), *vayu* (air), *tejas* (fire), *ap* (water) and *kshiti* (earth). This concept of five *'bhutas'* has been depicted in many scriptures and epics.

However, these concepts of elements were found to be untenable by the Anglo-Irish natural philosopher, chemist, physicist, and inventor Robert Boyle as mentioned in his famous book *The Sceptical Chymist* published in 1665. By then it was well established that elements could combine to form other substances and that they could be extracted and separated from other substances while the four or five elements predicted by Greek and Indian philosophers did not exhibit such behaviour. The discovery of the elements is associated with history of human civilisation. Historical ages have been named after the major materials that

were used in different periods for making tools and instruments – Stone Age, Bronze Age and Iron Age are a few examples.

Extraction of elements from ores was known in ancient times, although it was not known what an element is. A few elements such as gold, silver, iron, copper, lead, tin and mercury have been known since antiquity. These elements were known in Ancient India as well, and each of them was associated with a heavenly body such as Sun, Moon, Mars, Venus, Saturn, Jupiter, and Mercury, respectively. They have been mentioned in the Ancient Indian medical treatise *Charak Samhita*. During this period, in addition to the above mentioned seven elements, sulphur and carbon were also known.

The first systematic discovery of elements started in 1669, when German alchemist, Hennig Brand isolated phosphorous from a sample of urine. Alchemists were the forerunners of modern chemists who carried out the first experiments in chemistry in their quest for preparing gold from base metals making the use of an illusionary or legendary '*Philospher's Stone*'. Although they could not get success in achieving their goal, their futile attempts culminated in the discovery of many other substances and useful chemical procedures. They played a significant role in the development of chemistry and chemical technology. Amazingly, the famous scientist Isaac Newton was also an alchemist!

The elements, arsenic, antimony and bismuth, were also discovered by alchemists. By the middle of the nineteenth century about 63 elements were discovered and existence of many others was anticipated. It was observed that elements had remarkable differences in their characteristic features to the extent that often it appeared that they have very little in common. Elements such as oxygen, hydrogen, chlorine and nitrogen were gases; others like mercury and bromine were liquids; and remaining were solids under normal conditions. Platinum and iridium were very hard metals whereas sodium and potassium were soft metals. Lithium was so light that it could float on water; on the other hand, osmium was 22½ times heavier than water. Mercury was the only metal that was liquid at room temperature. In presence of air, gold never tarnished while iron got rusted very easily.

The whole universe consists of various elements and their compounds. Heavy elements like iron are present in the core of the Earth while light elements such as oxygen, hydrogen, carbon and silicon are present in Earth's crust. A major part of Earth's crust is composed of silicon and oxygen. Sand contains silicon and oxygen. Gold is a relatively rare element. There is about four million times more iron than gold in the Earth's crust. The living world is full of different kinds of elements and large varieties of their combinations. Just four elements: carbon, hydrogen, oxygen and nitrogen are endlessly assembled inside the bodies of all the living beings to form various molecules which are necessary for life. In addition to its role in formation of bones, phosphorous is involved in the structure of DNA molecules which orchestrates life in all its forms. Sulphur is present in the structure of proteins, helping them to hold their complex shapes. Among the metallic elements, iron is responsible for the red colour of our blood and helps it to transport oxygen to different parts of the body. Chlorophyll is the green colouring matter of the green plants, and due to presence of magnesium in its structure, it is capable of using solar energy for the synthesis of basic food material – carbohydrate. Sodium and potassium are involved in transmittance of electric signals between the cells.

The periodic table formulated by Mendeleev is a unique combination of organisation and inference on which the entire modern chemistry rests. It is amazing that he even predicted the existence of elements that were undiscovered then.

In 1814, a Swedish Chemist, Jon Jacob Berzelius realised the importance of using elemental symbols which are the abbreviations used to represent an element. The elements were represented by initial letter of their classical names in Latin or German or English, for example hydrogen as 'H', oxygen as 'O', carbon as 'C', etc. Where two elements had the same initial, a second distinguishing letter from the classical name was also included. Thus, aurum (gold) became 'Au', argentum (silver) became 'Ag', and hydrargyrum became 'Hg'.

CLASSIFICATION OF CHEMICAL ELEMENTS

With the advancements in the field of chemistry, many new elements were discovered. In order to understand the properties of the elements and to establish a relationship between them, attempts were started for their classification. In 1789, the French chemist, Antoine Lavoisier devised a list of 33 elements. He put them in four categories:

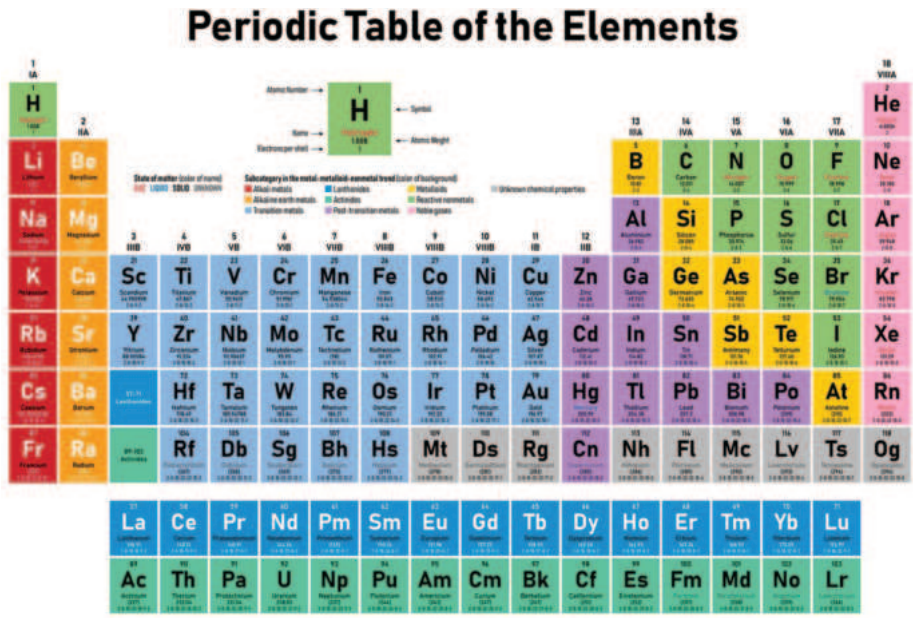
1. Gases, which were invisible but occupied space.
2. Metals, which were shiny and burnt in oxygen.
3. Non-metals, which could be used to make acids.
4. Earths, which could not be included with gases, metals and non-metals.

Amazingly, this list of Lavoisier included light, heat, and some substances such as

lime, and magnesia as elements! Lime is calcium oxide, a compound of calcium and oxygen while magnesia is a compound of magnesium and oxygen. In fact, the list contained only 23 elements instead of 33. With the advent of Dalton's atomic theory in 1803, it became known that matter is composed of atoms of different weights, and they also combine in simple ratio by weight. This theory laid the foundation of physical sciences and started a new era in the history of physics and chemistry. Based on the knowledge of atomic weights, chemists started the search for the relationship between the elements, and it was this search which ultimately, culminated in classification of chemical elements and discovery of the periodic table.

In 1817, the German chemist Johann Dobereiner observed that some elements could be arranged as triads, i.e., groups of three elements, in such a manner that atomic weight and properties of the middle element was average of the first and third elements. This observation was named as 'rule of triads'. The prominent examples of triads are calcium, strontium, barium**;** chlorine, bromine, iodine**;** and lithium, sodium, potassium. But this triad system or law of triads was applicable only to a limited number of elements. In another attempt of classifying chemical elements, French geologist, A.E. Beguyer de Chancourtois developed a three-dimensional arrangement. He transcribed a list of elements positioned on a cylinder with a circumference of 16 units in term of increasing atomic weights. Owing to various flaws, this arrangement also could not find satisfactory response.

The next important development occurred in 1865, when an English chemist, John Newlands classified the chemical elements according to increasing atomic weight and observed that similar physical and chemical properties occur after an interval of seven elements, i.e., there was similarity in the properties of first and eighth elements. He proposed the "*law of octaves*", which stated that every eighth element on the list displayed the properties similar to the first. The eighth element



starting from a given one is repetition of the first, like the eighth note of the music. Thus, Newlands introduced the idea of the elements being '*periodic*'. This system had a major flaw in that the law of octaves could not be applied to all the elements existing that time.

MENDELEEV AND HIS PERIODIC TABLE

At this juncture of confusion, uncertainty and chaos, Dmitri Ivanovich Mendeleev entered the prevailing scenario and settled the problem of classification of the elements by devising his Periodic Table. It was an epoch-making discovery in chemistry.

Mendeleev was born on 8 February 1834 in Verkhnie Aremzyani village near Tobolsk in Siberia. He was youngest of the 17 children born to Ivan Pavlovich Mendeleev and Maria Dmitrievna Mandeleev. His father was a teacher but unfortunately lost his eyesight and was unable to work. To support the family Mendeleev's mother restarted the family's abandoned glass factory. By the time Mendeleev was 13, he had lost his father and the glass factory was destroyed by fire. Maria recognised the young Dmitri's extraordinary talent and academic potential. Therefore, despite her precarious financial condition, she resolved to provide her son best possible education in Russia. After undertaking a formidable journey of four thousand miles (more than 6,400 km), she reached Moscow University with her son for his admission there. This cumbersome expedition took more than one year. But the university refused to admit Mendeleev due to his Siberian heritage. Undaunted, the mother and son moved to Saint Petersburg where Mendeleev was given admission at Saint Petersburg State University for studying chemistry and teaching with a scholarship. Soon after the admission of Mendeleev, his mother died at Saint Petersburg. When dying she said to her son: "*Be careful of illusion, insist on work and not on words, search for divine and scientific truth.*" Mendeleev received his master's degree in 1856 and was appointed as a lecturer in inorganic chemistry. In 1865, he earned his doctorates for his work on interaction of alcohols with water. He dedicated his doctoral research to his mother with these touching words: '*Conducting a factory, she educated me by her own words, she instructed by example, corrected with love, and to give me the cause of science, she left Siberia with me, spending thus her last resources and strength*'. Mendeleev wrote two famous books,

'*Organic Chemistry*', a 500-page textbook in 1861, and '*The Principle of Chemistry*' in 1869. He died on 20 January 1907 at the age of 72 in Saint Petersburg. By the time of his death, eighty-six elements had become known, and he had the pleasure of seeing the completion of his periodic table.

Mendeleev's Periodic Table came into existence in 1869 after he studied physical and chemical properties of all the 63 elements known then. He found that properties of the elements are related to atomic weights in a periodic manner. In order to reveal the relationship and find out the existing pattern in the properties of the elements, he took 63 cards, and on each card he wrote the atomic weight and properties of an element. He grouped the cards of similar properties and pinned them on the walls of his laboratory. Then he started the work of arranging and rearranging the cards to get a satisfactory classification of elements. On the afternoon of 17 February 1869, while taking a nap in his office, he saw a vivid dream of his life. In Mendeleev's own words: "*I saw in dream a table where all the elements fell into a place as required, Awakening, I immediately wrote it down on a piece of paper.*" Mendeleev noticed that when the elements are arranged in the increasing order of their atomic weights, their properties repeated in a series of periodic intervals. Therefore, he named this discovery as Periodic Table of the Elements. This discovery was published two weeks later in his historic paper '*A Suggested System of the Elements*'. He observed that there was periodic occurrence of elements with similar properties, and based on this observation, the periodic law was enunciated by him which stated that '*the properties of the elements are periodic function of their atomic weights*'. The vertical columns and horizontal columns of periodic table were named as groups and periods, respectively.

Mendeleev knew only of 63 elements, compared to 118 we know now. In his first attempt of classification, he charted only about 32 elements. Due to ambiguity in the properties of hydrogen, he assigned no place to it, and the first row was started with lithium. Odd elements (iron, cobalt, nickel) were not placed in the main groups. Later, they were placed in a separate group, namely the eighth group. Noble gases (helium, neon, argon, krypton, xenon, and radon) were undiscovered when Mendeleev classified the elements. After their discovery, they were placed in a separate group, named as zero group. For maintaining similarity in the properties of the elements, in the vertical columns (groups) some vacant places were left, which predicted the properties of the undiscovered elements.

In 1868, Julius Lother Meyer of Breslau University of Germany had also independently devised a periodic table for classification of elements which was almost similar to Mendeleev's famous version published in 1869. But the work of Lother Meyer could not be published before 1870. By that time Mendeleev had already acquired name, fame and wide publicity for his epoch-making success. Therefore, Lother Meyer could not get recognition for his work.

MODERN PERIODIC TABLE

Mendeleev had classified the elements based on their atomic weights which worked for most of the elements. But in some cases, arranging the elements on the basis of atomic weights did not work. The work of Henry Moseley in 1913 based on X-ray studies, pointed to the fact that the atomic number (proton number) rather than atomic weight is the fundamental property of an atom. Thus, it was accepted that physical and chemical properties of the elements are periodic function (reappearance of similar properties at regular intervals) of their atomic number. Consequently, atomic number became the basis of classification of elements. Based on this concept, a modified version of periodic table was designed, but the core structure proposed by Mendeleev remained undisturbed. The present form of periodic table is known as the long form. This long form of periodic table is based on electronic configuration of the elements. Based on the recommendation of the International Union of Pure and Applied Chemistry (IUPAC), the elements are arranged in eighteen groups.

LATER DEVELOPMENTS

The periodic table formulated by Mendeleev is a unique combination of organisation and inference on which the entire modern chemistry rests. It is amazing that he even predicted the existence of elements that were undiscovered then. Despite the great developments and revolutionary changes in modern science, the validity and utility of Mendeleev's periodic table remains unchanged and unchallenged even after 150 years of its inception. The periodic table remains the starting point for understanding chemistry. Although, the element 101 is named mendelevium in his honour, it is a great irony that this visionary chemist was not honoured with a Nobel Prize. Ironically, Sir William Ramsay was awarded Nobel Prize in 1904 "in recognition of his services in the discovery of the inert gaseous elements in air, and his determination of their place in the periodic system." In 1906, this coveted award went to Henry Moissan for finding fluorine, right where the periodic table had predicted. In 1906, Nobel prize committee selected Mendeleev for this honour, but due to intervention of Royal Swedish Academy, the decision was turned down. Swedish chemist Svante Arrhenius (A Nobel Prize winner in 1903 for his theory of electrolytic dissociation) spearheaded the intervention because Mendeleev was an outspoken critic of his theory. Arrhenius seized this 'appropriate' opportunity to take an inappropriate and unscrupulous revenge.

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COVER STORY

SUSHEELA SRINIVAS

HOW HABITABLE IS MARS?

Despite its hostile appearance, scientists favour colonising Mars as its resources offer scope for creating settlements. It may be soon enough that we will get to witness fantastic domed cities built on Mars where people will work and live as they look at the Earth on the horizon.

The Red Planet

EVER SINCE WE STEPPED INTO THE SPACE AGE IN THE EARLY FIFTIES, OUR fascination for Mars has only increased, resulting in the numerous robotic visitors to the Red Planet. The first probe that successfully flew by Mars was in 1965, with several following suit. In the subsequent 50 years, globally, there have been as many as 100 active Mars missions (in the making and executed), with leading space-faring nations sending orbiters, landers and rovers to Mars. The latest resident is *InSight*, Nasa's lander probe digging deep into the bowels of Mars to unravel the hidden secrets of our cosmic cousin.

The success of these missions has added valuable data to our knowledge bank about Mars; with the encouraging inputs received, the bipartisan NASA Authorisation Act and the U.S. National Space Policy of 2010 set goals for NASA to develop the capabilities to send humans to Mars by 2030. The aim: to make Mars a second home for humans.

THE LURE OF THE RED PLANET

What makes Mars so sought after? Several factors. First, curiosity and exploration are an evolutionary call for humans. We successfully stepped on the Moon and now explore further frontiers; the proximity of Mars with its physical features as a planet offers this scope. Despite Mars being cold, dry, desert-like, and in many ways unfriendly, the planet provides a high potential to reside on its soils.

Secondly, science is relentlessly seeking answers to many burning questions: our origins and the possibility of life outside Earth. The data from the robotic missions reveal that the Red Planet is in many ways evolutionarily like Earth and will provide certain missing pieces in the jigsaw puzzle of how the Earth came to be. Also, Mars was once warmer, with a thicker atmosphere and held liquid water – contributing factors that indicate that it may have supported life forms, even if microbial.

Thirdly, the call for such a mission will witness advanced technological progress in leaps and bounds. Sectors such as the utilisation of mineral resources, solar energy, high-speed space travel, space transportation, medical technology and many more will see a quantum leap, reflecting humans as an advanced civilisation capable of residing beyond Earth.

No doubt the feasibility of such missions is riddled with hurdles. However, science is always on the quest to find solutions and circumvent the problems. With technological advancement, a plethora of methods will arise, which may bring to reality all that we dream.

As we know today, Mars has no ready facilities to accommodate us, and we must provide for them from the Earth itself. Air to breathe, water and food are the primary concerns, as the first batch of exploration astronauts get ready to travel to Mars. Although initial rations will be provided, long-term and resupply of essentials from Earth for humans to live on Mars is not a viable solution. It is imperative that we should devise mechanisms to harness the planet's resources to our advantage and replenish them for sustenance.

Mars is not a replica of the Earth; however, it has abundant alternative resources which we can take advantage of and envision to make permanent settlements on its soil. So, how habitable is Mars? And, what has it on offer for us?

THE HABITAT

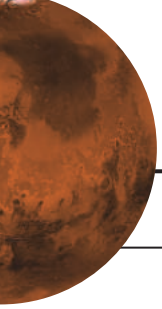
Mars' rocky terrain affords a stable surface to land and build structures. Martian terrestrial features are comparable to that of specific landforms on Earth: solid, rocky and dusty with extinct volcanoes and deep craters. The temperatures are cold like Antarctica and conditions dry and desert-like. It has long drawn seasons of summers and winters, with a Martian day almost equal to an Earth day.

A challenging feature of Mars is its intense dust storms which routinely cover vast expanses of the surface. Due to the low gravity of the planet, the dust is transported over large distances quickly and in no time. The dry dust absorbs heat and radiation, contributing to the temperature difference. The proposed human settlements would need to consider these climatic events and provide enough protection.

Mars has a thin, dry atmosphere giving rise to low atmospheric pressure of around 6-7 millibars (as a comparison pressure on Mount Everest is about 300 millibars). Human physiology is not suited to such low pressures as it becomes extremely difficult to breathe. Hence, a visitor to Mars will require a spacesuit to venture out. The settlements must be pressurised capsules, too,

CLOSE COUSINS

Parts of Antarctica, the Atacama Desert in Chile and the volcanic slopes of Hawaii have environments and landforms similar in composition to that of Mars. These act as natural simulators. Scientists are taking advantage of these regions to conduct experiments for life on Mars.



much like a spacecraft.

Moreover, the Martian atmosphere has very little oxygen. Hence an astronaut on Mars would require oxygen support. Another critical factor is radiation protection as the planet's atmosphere does not filter out solar particles, ultraviolet rays and cosmic rays. Surface habitats must be suitably designed to block these radiations. Subsurface structures could take advantage of the soil above to block radiations.

The human settlements on Mars are projected to be 3D printed, domed structures built ahead by robotic builders before the first batch of astronauts reaches there. Life on Mars project proposes to equip the habitats with water and oxygen generators. Also, the inhabitants would be required to grow their food for sustenance utilising sub-terrain horticultural assemblies.

Ample solar energy can be harnessed for the power requirements due to the thin atmosphere. By leveraging solar and nuclear power generation, power requirements for the settlements such as heating, chemical generators, agriculture and other tasks could be met.

FOLLOW THE WATER

The primary objective of planetary scientists is to look for signs of water sources. Liquid water is a biomarker for the existence of life forms. Apart from consumption, water is also a source from which oxygen can be extracted to provide breathable air, support agricultural activities and for making rocket fuel. Hence scientists follow the water trail and then assess the habitability of the planet.

It took 15 years of rigorous investigation by probes to confirm that Mars has water sources that can be harnessed. In its evolutionary process, billions of years ago, Mars once had rivers and oceans of liquid water on its surface. As the planet grew colder, the water froze. In its present state, liquid water does not exist on the planet's surface. However, lake beds and craters of frozen water ice have been found near the polar regions.

Also, seasonal changes aid surface salts (such as perchlorates, found in abundance on Mars) to trap water vapour from the atmosphere in their crystal structure forming brine beds. Features known as Recurring Slope Lineae (RSL) are narrow dark markings on steep (25° to 40°) slopes found on Mars. According to planetary scientists, these streaks may be evidence of liquid water. In 2011, the *Mars Reconnaissance Orbiter* confirmed the presence of brine channels running from its warmer zones down the mountain slopes.

An artists impression of a Mars Habitat *(Credit: Wikipedia)*

An artist's impression of plants growing on Mars *(Credit: Wikipedia)*

TERRAFORMING

One theoretical planetary engineering concept that picked up momentum was terraforming on Mars. By this, large habitable areas on the planet would be subjected to deliberate changes in the climate, adding greenhouse effects to it. The modified environment could make the planet more habitable to sustain life.

However, with our present technology, this is not a possibility. Moreover, it raises ethical questions of tampering with the natural, native life forms that may exist on the planet - even if they are microorganisms - of which we are not yet aware.

Another prospective water source is the polar ice caps of Mars. Here too, the robotic probes have confirmed the presence of water ice. Vast deposits of frozen water are trapped in the polar regions. In summer, a fractional part of the ice evaporates whereas in winters the caps grow to spread nearly up to the equator. The polar caps were measured to be 3 kilometres thick and when melted, could cover the surface to a depth of 5.5 metres.

Frozen water also exists under the ground on Mars. These frozen lakes – as large as the states of Rajasthan, Madhya Pradesh, Maharashtra and Odisha combined – were detected by ESA's *Mars Express* as sheets of ice or subsurface frozen lakes at the bottom of craters.

With the confirmed availability of water, the Martian habitat will be engineered to harness these sources. One project proposes that rovers will predetermine the settlement site by selecting the area where such aquifers exist. Life support structures will extract oxygen from the soil water and store them for utilisation.

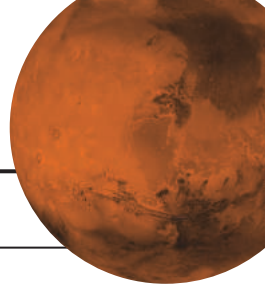
A BREATH OF AIR

Mars' atmosphere does not contain enough oxygen for humans to survive. The thin layer is predominantly carbon dioxide with very little oxygen – about 0.145%. However, it is visualised that thermic decomposition of atmospheric CO_2 can generate ample oxygen. Along with this, oxygen could be derived from water by electrolysis. So, people on Mars could locally harness oxygen for their life support systems.

The extracted oxygen would be consumed and part of it stored for low power situations such as dust storms.

A CALL FOR FARMERS!

Although initial emergency rations will be supplied from Earth to the first batch of the expedition astronauts, it is envisaged that food for sustenance should be grown on the planet itself.



Astronauts till date are multitaskers donning various hats such as geologists, biologists, doctors and many more, depending on the payload of their mission. Now, Mars-bound astronauts would be required to become expert farmers!

The first batch has the agenda to build the primary agricultural unit on Mars to grow fresh food for consumption. This setup would not only provide for their requirement but also form a base for the subsequent visitors.

Martian soil is hitherto known not to favour plant growth. However, not all Martian soil is unfavourable. An experiment conducted in the volcanic soils of Hawaii – which has a similar composition as Mars soil – indicates that plants can thrive in such environments.

Horticultural activities would be carried out in subsurface greenhouses: this is required to protect the plants from freezing temperatures above. Since we do not yet have people performing biological experiments on Mars, the closest we can achieve is to simulate the conditions. A facility just outside the International Space Station (ISS) has a Mars Simulator where biological experiments on plants and micro-organisms facilitate the testing of their survivability in Mars-like conditions. Several payloads on ISS have already successfully experimented with growing plants in space, albeit at a smaller scale.

On Earth too, planetary biologists are studying the thriving mechanisms of plants and microbes by simulating Mars conditions. Utah's Mars Desert Research Station in the USA conducts studies on the effect of temperature and atmosphere on the growth of plants.

Potatoes are great contenders as the first farm produce. Since long, NASA has been experimenting with growing them in hydroponic solutions.

Another interesting point to note is that the lower gravity of Mars works to our advantage for farming: under low gravity conditions, water flows differently on the planet; soil can hold more water and nutrients as they would drain away more slowly.

MINERAL WEALTH

Mars has many volcanoes, including the largest volcano in the solar system: Olympus Mons, a towering 26-km structure. Past volcanic activities have spewed abundant mineral wealth on the planet - many in readily mineable form. These resources when exploited could make Martian settlements to produce their metals, plastics and shields for self-sufficiency. There is a considerable scope to promote interplanetary commerce.

WIELDING THE RAYS

A significant concern of life in space is the radiation effects on humans. Prolonged exposures increase the susceptibility to cancer, genetic variations, infertility and other physiological damages. NASA has specified safe limits to its astronauts beyond which they are not allowed to live in space. Several payloads aboard ISS have ongoing research to study the effects of radiation on the human body. Biologists are working on measures to counteract the damages. From these results, NASA has increased the safe limits for their astronauts for the Mars missions.

Since Mars' thin atmosphere is an inadequate filter of harmful radiations, the habitats would have to be engineered to shield the inhabitants from radiation effects.

AN INSURANCE COVER

We live in the middle of a shooting gallery with thousands of asteroids in our path that we haven't even discovered yet. So, let's be at least a two-planet species, as a backup plan.

—Carl Sagan

HERE WE COME, MARS!

Despite its hostile appearance, scientists favour colonising Mars as its resources offer scope for creating settlements. Futurist Michio Kaku opines that we are now in the fourth wave of innovation ruled by artificial intelligence, biotech and nanotech. Genetically modifying plants and algae to thrive in the Martian climates could open new avenues for food production in space. Futuristic cities can be built on the planet by using robots to do the heavy-duty work that is adapted to the harsh conditions thereby safeguarding human resources.

Mars 2020 is the latest rover to be launched by NASA, which is on a mission to collect evidence of habitable conditions and microbial life that may have existed on the planet in the past. Slated to launch this July, the year-long mission has an agenda to demonstrate technologies that will address some of the challenges future human missions may face. Mars 2020 will collect rocks and soil and store them on Mars itself for further investigations. The technology will test the feasibility of producing oxygen from Mars' atmosphere, check the availability of water sources, improvise landing techniques, and study environmental factors that will be significant for human settlements in future.

So, it may be soon enough that we will get to witness fantastic domed cities built on Mars where people will work and live as they look at the Earth on the horizon. All that was visualised in sci-fi literature until today may soon become a reality. D

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