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COVID, OXYGEN, SpO2
AND OXIMETER

CLIMATE CHANGE:
A CHANGE
WE CAN'T IGNORE

CHRISTIAN SAMUEL
FREDRICH HAHNEMANN
FATHER OF HOMOEOPATHY



**COCCOLITHOPHORES
FIXING THE EXCESS
CARBON DIOXIDE**

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MY WORD

NAKUL PARASHAR

Time to Restore the Ecosystem

FIFTY

years and counting! Since 1972, we have been celebrating June 5 as the World Environment Day. This year too we shall be celebrating it in India amidst the dark of the pandemic's second surge. Whenever we talk of environment, what normally comes to our mind are the thick clouds of smoke emanating from the chimneys of the eighties and the nineties or the thick flow of effluents from the factories into our once-pristinely fast-flowing rivers. Kudos to efforts by activists both at the governmental and the non-governmental level, a lot has been done so far. Yet, a lot more remains to be done. Biodiversity has been badly affected. The WWF report of 2020 reveals that there is 68 per cent of species loss in the last fifty years. Similarly, in the last five decades, conversion of land for agriculture has resulted in more than seventy per cent of global biodiversity loss and a similar amount of tree cover loss. In fact, in a list of top five global risks facing our planet, most are related to our ecosystem, its loss, repair, and restoration. Chief among them are the failure of climate change mitigation and adaptation, environmental damage like oil-spills in the oceans and seas, radioactive leakages, and natural disasters like tsunamis, earthquakes, geomagnetic storms, and volcanic eruptions. There is a lot that remains to be repaired and restored in our ecosystems, especially in developing and under-developed nations. This is what broadly defines the theme of this year's World Environment Day.

Of course, charity begins at home. We individuals should be the first ones to restore biodiversity. What we buy and consume defines our acts in this direction. How we influence our fellow citizens by making right choices in our consumerism has a very

important role to play as well. Our acts can create mass awareness, and thus define the market strategies accordingly. We've all seen how individual choices have brought organically grown vegetables and fruits into vogue during the past two decades. Consumer choices affect the private sector. Manufacturing is guided by host ecosystems thereby enforcing sustainable business practices.

Our mix of rural and urban living does play an important role in restoring the ecosystem. The UN predicts that by 2050, eighty per cent of the global population will live in the urban regions. This clearly means that cities would play a very important part in restoration of the ecosystem.

Political will and efficient governance are the other important factors in controlling biodiversity loss and preserving nature for the future generations. Health, food, water, and fresh air to breathe are irrefutable parameters upon which the entire human race hinges.

Schools and teachers, both in the rural and urban area, have a role in a big way. Youth using the medium of social communication, can be the most effective carrier of messages about how our acts have brought losses to our biodiversity.

Despite all, efforts continue. The Great Green Wall from Senegal to Djibouti is one such large multinational effort that was initiated in Africa. But that is not enough. Sources of oxygen, the natural oxygen factories, our forest cover has to be increased. Otherwise, it will be too late!

Please stay safe, and more importantly, stay happy! A happy mind will secure greater strength.

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RECENT DEVELOPMENTS IN SCIENCE AND TECHNOLOGY

SCIENTISTS PINPOINT SOURCE OF HAZARDOUS SOLAR PARTICLES

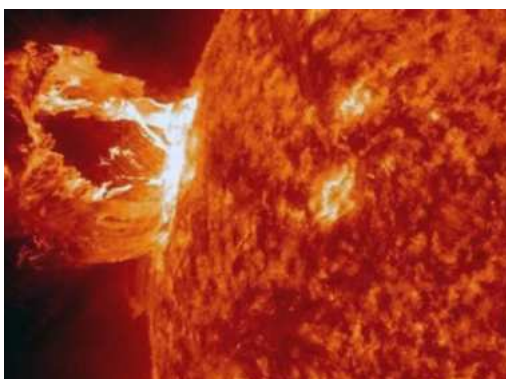
The Sun constantly emits high-energy particles that can be hazardous to air passengers and affect satellites. These particles shoot from the Sun at high speed during solar storms. While the Earth's magnetic field keeps a majority of these particles at bay, preventing them from reaching our planet, some do manage to reach, and when they do, they disrupt satellites and electronic infrastructure, as well as posing a possible radiation risk to astronauts and people travelling in planes.

In 1859, a large solar storm called the 'Carrington Event' caused widespread issues with telegraph systems across Europe and the United States. Given our reliance on electricity today, a repeat storm of such magnitude could be far more devastating.

Till now, the source of these storms was not known with certainty. Now, researchers at University College London (UCL) and George Mason University in the US say they have located where on the Sun these particles come from. This may help in better predicting when they might strike again.

Their findings, published in the journal *Science Advances*, indicate that the particles have the same "fingerprint" as plasma located low in the Sun's corona, close to the middle region of the Sun's atmosphere.

According to the scientists, they have observed for the first time "exactly where solar energetic particles come from



Coronal Mass Ejections (CMEs) are large expulsions of plasma and magnetic fields from the Sun's corona.

on the Sun". They say their evidence supports theories that these highly charged particles originate from plasma that has been held down low in the Sun's atmosphere by strong magnetic fields.

Once released, these energetic particles are accelerated by eruptions that travel at a speed of a few thousand kilometres a second. Energetic particles can arrive at Earth very quickly, within several minutes to a few hours, with these events lasting for days.

Researchers made the discovery using measurements from NASA's 'Wind' satellite, located between the Sun and Earth. They looked at a number of solar energetic particle streams, each lasting at least a day, in January 2014. These particles came from a region of the Sun known as '11944', which had an extremely strong magnetic field.

Billions of tonnes of magnetised plasma are periodically ejected into space by the Sun's churning convection currents in the upper layers of its atmosphere. These 'coronal mass ejections' (CMEs) travel at speeds of up to 11,000,000 kilometre per hour, and the Sun can fire off as many as 20 per

week, depending on where it is in its 11-year activity cycle.

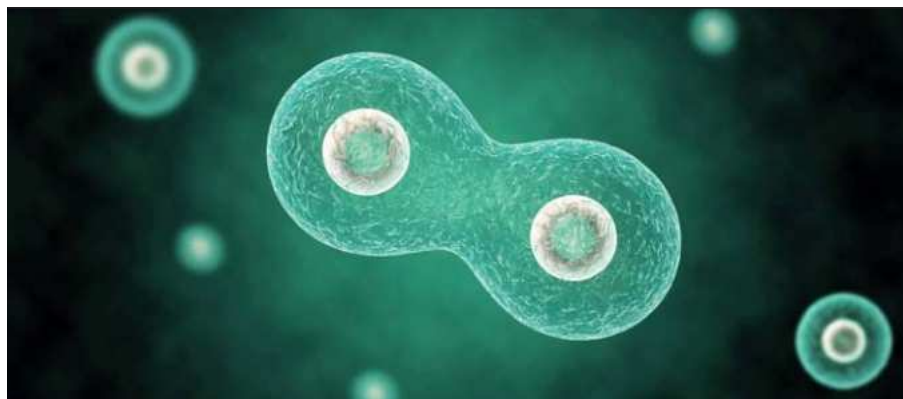
According to scientists, if a massive CME struck the Earth today, it could damage the electronics in orbiting satellites, disrupting navigation and communications systems, as well as the GPS time synchronisation that the internet relies on to function. It would also create a surge of electromagnetic radiation in the atmosphere, causing huge currents in our power grids which could burn out electrical transformers, leading to outages.

But there is no need to panic because this is a worst-case scenario. Scientists monitoring the Sun would be able to give us a couple of days' warning of a dangerous CME, and in that time, vulnerable satellites could be shut down temporarily, and power grids reconfigured, in order to limit the disruption.

EXTRA 100 MILLION YEARS BEFORE EARTH SAW PERMANENT OXYGEN RISE

It is known that early Earth did not have oxygen. The permanent rise of oxygen in the Earth's atmosphere, which fundamentally changed the subsequent nature of Earth's habitability, occurred much later than thought, according to new research.

The study by an international team led by the University of Leeds and including researchers from the University of California-Riverside, Harvard University,



Single-celled synthetic organism divides like normal bacterial cells.

According to the scientists, identifying these genes is an important step towards engineering synthetic cells that do useful things. Such cells could act as small factories that produce drugs, foods and fuels; detect disease and produce drugs to treat it while living inside the body; and function as tiny computers.

Scientists at JCVI had earlier constructed the first cell with a synthetic genome in 2010. However, they didn't build that cell completely from scratch. Instead, they started with cells from a very simple type of bacteria called a mycoplasma. They destroyed the DNA in those cells and replaced it with DNA that was designed on a computer and synthesized in a lab. This was the first organism in the history of life on Earth to have an entirely synthetic genome. They called it JCVI-syn1.0.

Since then, the scientists have moved forward and have been working to strip that organism down to its minimum genetic components. The super-simple cell they created five years ago, dubbed JCVI-syn3.0, was perhaps too minimalist. The researchers have now added 19 genes back to this cell, including the seven needed for normal cell division, to create the new variant called JCVI-syn3A. This variant has fewer than 500 genes. In contrast, the *E. coli* bacteria that live in our gut have about 4,000 genes. A human cell has around 30,000.

One stop-motion video showed JCVI-syn3.0 cells – the ones created five years ago – dividing into different shapes and sizes. Some of the cells formed filaments. Others appeared to not fully separate and line up like beads on a string. Despite the variety, all the cells in that video are genetically identical. However, another video showed the new JCVI-Syn3A cells dividing into cells of more uniform shape and size.

Says Strychalski, “Life is still a black box. But with this simplified synthetic cell, scientists are getting a good look at what’s going on inside”.

the University of Southern Denmark and the University of St Andrews, also provides an explanation for some of the most extreme climate episodes to have affected the Earth, when the planet was repeatedly covered with ice.

According to the study, the first-time oxygen was significantly present in Earth's atmosphere was about 2.43 billion years ago, and this marks the start of the ‘Great Oxidation Event’ – a pivotal period in Earth's history.

Although the Great Oxidation Event led to oxygen levels that were still much lower than today, it dramatically changed the chemical composition of the planet's surface and set the stage for the subsequent course of biological evolution on Earth, which ultimately led to a planet teeming with life.

By analysing rocks from South Africa, which were deposited in the ocean at the time of the Great Oxidation Event, the researchers discovered that early atmospheric oxygenation was short-lived, and oxygen did not become a permanent feature of the atmosphere until much later.

According to them, the Great Oxidation Event fundamentally changed Earth's environment and habitability. This early period of oxygenation was thought to have occurred between about 2.43 and 2.32 billion years ago.

However, the oxygenation of the atmosphere was highly unstable over a period of about 200 million years, “with permanent atmospheric oxygenation occurring about 100 million years later that previously thought.”

These findings, published in the journal *Nature* on 29 March 2021

([dx.doi.org/10.1038/s41586-021-03393-7](https://doi.org/10.1038/s41586-021-03393-7)), also suggest a direct link between fluctuations in atmospheric oxygen concentration and greenhouse gas concentrations.

“Our new data show that the permanent rise of oxygen actually occurred after the final major glaciation of the period and not before it, which had previously been a major puzzle in our understanding of links between early atmospheric oxygenation and intense climatic instability.”

SINGLE-CELLED SYNTHETIC ORGANISM THAT BEHAVES LIKE NORMAL BACTERIA

Five years ago, scientists created a single-celled synthetic organism that had only 473 genes and was the simplest living cell ever known. However, this bacteria-like organism did not behave like normal bacteria when growing and dividing, and produced cells with wildly different shapes and sizes.

Scientists have now identified seven genes that can be added to tame the synthetic cells' unruly behaviour, causing them to neatly divide into uniform copies. This success was achieved through a collaboration between the J. Craig Venter Institute (JCVI), the National Institute of Standards and Technology (NIST), and the Massachusetts Institute of Technology (MIT) Centre for Bits and Atoms in USA, according to a report in the journal *Cell* (DOI: [10.1016/j.cell.2021.03.008](https://doi.org/10.1016/j.cell.2021.03.008)).

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COVER STORY

SWATI NAGAR, SHRAMIK PATIL, AND RAHUL MOHAN



COCCOLITHOPHORES: FIXING THE EXCESS CARBON DIOXIDE

GLOBAL

Warming and Climate Change

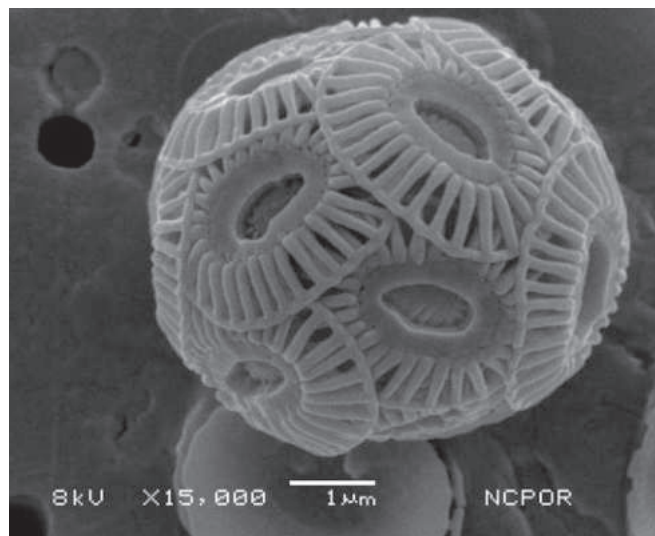
are the buzzwords that we hear these days quite often. Since 1900, the global atmospheric Carbon Dioxide (CO_2) concentration has almost doubled from ~296ppm to 419ppm, chiefly because of human activities. This increase of anthropogenic (human induced) CO_2 has resulted in warming up of the atmosphere due to 'Greenhouse Effect'. Not surprisingly, world over, efforts to sequester or use excess CO_2 is on before it is too late. In this effort both land and ocean plants, especially those floating microorganisms in ocean called phytoplankton, play important role. Just a few microns in size and present only in the upper 200-300 meter, a depth up to which sunlight can penetrate, they can soak up almost 50% of the excess CO_2 released in the atmosphere. Among these are tough little giants called Coccolithophores.

There are different types of phytoplanktons that live in the ocean. Some of them are known to form mineralized shells or exoskeletons made up of calcium carbonate shells or silica; whereas some are organic walled (i.e. without any shells or skeletons). The two well-known examples of carbonate and siliceous walled phytoplankton are coccolithophores and diatoms, respectively. All the mineralizing as well as non-mineralizing phytoplankton form the base of marine food web play a crucial role in capturing dissolved CO_2 .

Among the marine phytoplankton, coccolithophores are one of the abundant group widely distributed in the world ocean-from coastal to open ocean waters and from low to high latitude oceans. Interestingly, coccolithophores use CO_2 for both photosynthesis as well as for making their calcite shells. Thus they play a crucial role in the global carbon cycle.

Coccolithophores structure and function

The name coccolithophores means grains or seeds of stone (kókkos=grain; líthos=stone; phóros=carry). Coccolithophores are literally tiny grains of stone. Their size generally ranges between 1 to ~60 micron in diameter and are best visible under Scanning Electron Microscope and Polarizing Microscope. They have a tough outer shell, made of small intricate calcite plates or discs called coccoliths. The shells are also a record of past climate change, because the shells, like tree rings, are formed in layers during favourable conditions, and thus they show the environmental conditions in which they thrived. The tough shells probably protect the organisms from being grazed by other organisms and also help in keeping them afloat or to sink to the bottom. When coccolithophores bloom on the surface, they represent the health of the oceans. After death, they accumulate at the bottom as sediments



Scanning Electron Microscopic image of *Emiliana huxleyi*, the most abundant coccolithophore living in the world oceans

providing information on the past climate. Thus, living or dead, coccolithophores provide a measure of ocean health. Though, light in weight, coccolithophores sink quite rapidly to the ocean floor, a phenomenon known as 'marine snow'. The degraded faecal matter of animals and other material may adhere to the shells of dead phytoplankton helping them to sink fast. On an average, coccolithophores sink at the rate of 20-200 m per day. Once settled at the bottom, they become the pages of history, often termed as nannofossils. Nannofossil-rich oceanic sediments are often retrieved using long pipes to obtain information on past climatic conditions.

At present, more than 250 living coccolithophore species have been documented from a variety of oceanic habitats. Though too minute in size, their high number and large turnover



The White Cliffs of Dover in England (Source: <http://www.whitecliffsodover.co.uk/> Photo by Jpellgen)

rates make coccolithophores responsible for nearly 50% of the total carbonate deposition in the ocean sediments. The amount of coccoliths in the geological record can be easily gauged by looking at the 130-metre-tall White Cliffs of Dover in England. The cliff is estimated to have formed over thousands of years of sedimentation of coccolithophores. Several man-made structures like Egyptian pyramids are constructed utilizing sediments rich in these calcium carbonate shells.

Coccolithophores sometimes form massive blooms extending from several hundreds to thousands of kilometers. These blooms are mostly dominated by single species, e.g., *Emiliania huxleyi*. Their number may range as much as few hundreds to few thousands cells per ml. The blooms are so massive that they can be easily seen from satellites too as whitish milky objects in the ocean. It is estimated that the efficiency of the CO₂ drawdown by the coccolithophores will be limited and largely hampered by the increasing man-made CO₂ emission and global warming in the upcoming decades. It is thus crucial to understand how coccolithophores will respond to the future anthropogenic emission. An important question to ask is will coccolithophores get more vulnerable or will they adapt and accelerate CO₂ sequestration?



Satellite image of coccolithophore bloom (Source: NASA Space Observatory)

Water vapour is another potent greenhouse gas that amplifies CO₂ effect. Rise in temperature due to addition of CO₂ adds more water vapour to the atmosphere and further elevates the temperature. However, water vapour is short-lived in the atmosphere, and precipitates as snow or rain. On the other hand, carbon dioxide is the longest lived greenhouse gas and continues its effect on global warming from years to decades to millennia. Although as a result of the Paris Agreement, many countries have reduced their emissions, more

BASELINE OF ANTHROPOGENIC ACTIVITIES: WILL IT BE A BIG THREAT?

Burning of fossil fuel is one of the major contributors to the increased atmospheric carbon dioxide and thus global warming. We use fossil fuels (directly or indirectly) in our daily life by variety of means, for instance, driving of vehicles, use of electricity for daily needs, to charge computer, cellphones, and for 'n' number of purposes. The recent 'Global Carbon Project' estimated that from 1850 to 2019 human activity has emitted nearly ~2400 gigatons of CO₂ in the environment, out of which ~953 gigatons of carbon has been added to the atmosphere and rest has been absorbed by the terrestrial plants and oceans. The major jump of CO₂ occurred from early 1950s and concomitant growth in population and industrialization. This also complies with the GAIA hypothesis (proposed by British scientist James Lovelock in 1972) which suggests that in Earth's complex

COMBINED HEATING INFLUENCE OF GREENHOUSE GASES

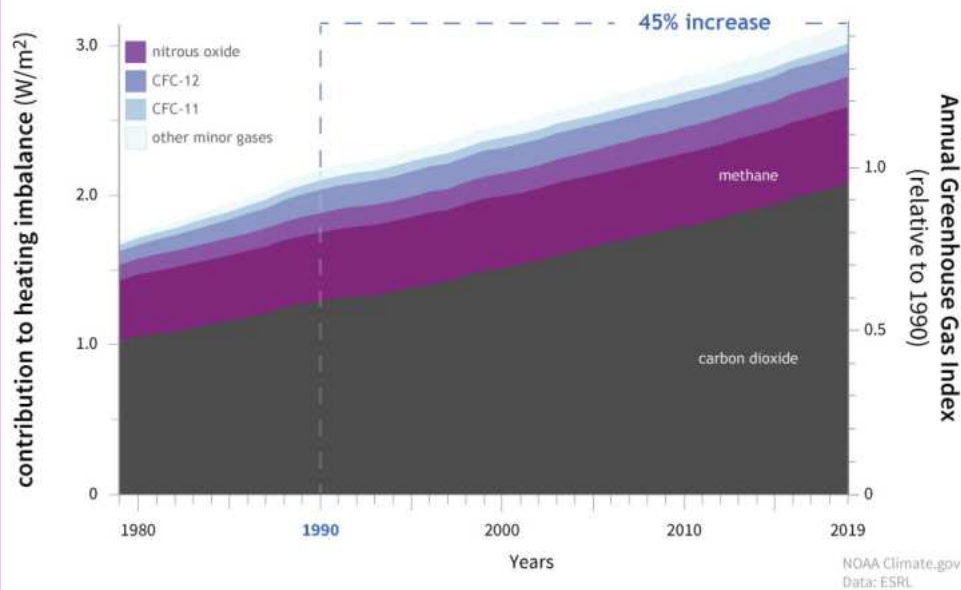


Figure showing Annual Greenhouse Gas Index and contribution to heating imbalance from 1979 to 2019.

system, organisms interact with their non-living surroundings that form a self-regulating and synergistic system to sustain life.

reduction in carbon dioxide emission is needed to avoid the worst consequences of global warming. Even during COVID-19 pandemic, the decrease in human activities could not significantly lower the carbon dioxide level. This again reiterates the need to think more in terms of change in lifestyle.

How does excess CO₂ affect oceans?

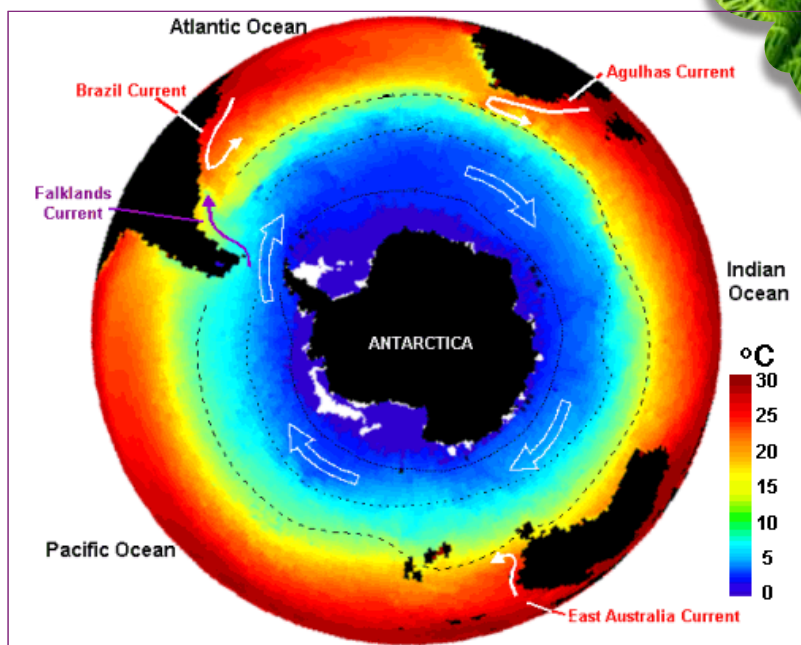
Carbon dioxide gets absorbed in the ocean through air-sea interaction. There is a fine balance between the CO₂ in the upper layers of the ocean and the atmosphere called partial pressure. Once CO₂ gets absorbed in the surface layers of the ocean, it combines with water and forms a weak acid known as carbonic acid. Carbonic acid further dissociates and forms bicarbonate ions (HCO₃⁻). During this process, a free hydrogen ion (H⁺) gets released in the water which reduces the pH of the ocean thus increasing ocean acidity (known as ocean acidification). It is estimated that during the past century, the average pH of the ocean has dropped from 8.21 to 8.10. Looking at the future threats of the ocean acidification, which may impact climate as well as economy, scientist are looking for innovative technologies to control the emission and avoid future threats.

Coccolithophore in the Southern Ocean

The Southern Ocean or the waters south of ~40° S is the youngest of all the oceans which surrounds Antarctic continent and includes the southern parts of the Pacific, Atlantic and Indian Oceans. The low sea surface temperature of the Southern Ocean supports absorption of relatively more CO₂ and thus makes it one of the major carbon sinks on the planet. On the contrary, there are some regions in the Southern Ocean where water from the deep upwells and releases heat, nutrient and gases, acting as carbon source. This exactly works like a fizzy cold drink. Cold temperature in the refrigerator keeps the gas dissolved, but once warmed up, the solubility of gas reduces and it escapes to the atmosphere. In the same way, warming oceans may affect its ability to absorb excess carbon dioxide.

Coccolithophores in the Southern Oceans are expected to get affected by the increasing sea surface temperature and decreasing pH conditions. Even a slight decrease (as low as 0.1 unit) in pH may cause ~26% increase in the ocean acidity. This can disturb the coccolithophores' life cycle and productivity. The acidic oceans may also dissolve more of the tough coccolith whereas warming oceans will limit coccolithophore production and their abundance. This will also affect the overall biodiversity of the ecosystem.

In the past two decades, scientists from all over the world began wide range of studies on coccolithophores to understand its habitat and its behavior through *in-situ* and *ex-situ* observations. Since 2004, scientists from National



Map showing the sea surface temperature in the Southern Ocean
(Source: SEOS Project/Carl von Ossietzky).

Centre for Polar and Ocean Research (erstwhile NCAOR), Goa, under the aegis of Ministry of Earth Sciences, Govt. of India has been extensively studying coccolithophores in the least studied Indian Sector of the Southern Ocean (ISSO) as a part of Indian Southern Ocean Expedition. Studies have shown that the coccolithophores are shifting more towards the South, owing to change in sea surface temperature and southward migration of the oceanic fronts. Recent studies also have highlighted thickening of calcium carbonate shell of *Emiliania huxleyi* (most abundant species of coccolithophores) in the cold, low pH waters. This could be its strategy for survival in the changing environmental conditions.

Marine organisms are extremely sensitive to the changes in the environmental conditions. The projected increase in the CO₂ and subsequent rise in temperature may make oceans warmer and acidic, reducing both the abundance of coccolithophores and their ability to fix excess CO₂ in their coccoliths. This may further lead to ecosystem degradation, biodiversity loss or change in community structure, invasion of species and even extinction of the endemic species. Regular monitoring will help scientists to better understand the response of marine organisms towards changing climate and necessity to regulate CO₂ emissions for better health of the atmosphere and oceans.

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COVID-19 occupied extreme attention for more than a year, pushing many other issues to the backstage. One of them is the problem of Climate Change, which is expected to impact the globe more forcefully, but rather slowly than a pandemic. Recently, on the last Earth day, the United States hosted 2-day Leaders' Summit on Climate in which more than 40 nations participated. At the meet, the UN Secretary-General called for urgent action to reduce emissions to net-zero by mid-century as agreed upon in the Paris Climate Change Agreement. He said, "Mother Nature will not wait".

In 1966, the WMO (World Meteorological Organization) coined the term Climatic Change to define climatic variability beyond 10 years. Later, the word was replaced by Climate Change to denote long-term changes in the climate due to human activities.

Global warming, a major factor for Climate Change, is considered to have started in 1712. It was then that the steam engine became available, ushering in the Industrial Revolution. In 1885, Karl Benz built an internal-combustion engine motor car pumping more greenhouse gases into the atmosphere. In 1938, Guy Callender, a British, concluded that the Earth's temperature had risen in the previous century, mainly due to atmospheric CO₂ rise.

While these were significant steps in the history of Climate change, the significance of the phenomenon came to the fore in 1972, with the first UN Conference on Environment, held at Stockholm. By 1975 global warming became a household term when US scientist Wallace Broecker explained how human race was disturbing the climate by generating about 70 million tonnes of carbon dioxide every year.

Realizing the need for a concerted action, all the nations came together to address the issue. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was constituted to collect evidences related to Climate Change. In 1990 the IPCC presented 1st Assessment Report, concluding that the Earth's temperature had risen by 0.3 to 0.6°C

CLIMATE CHANGE:



from the previous century due to human activities. That set the stage for the Earth Summit which was held in Rio de Janeiro where the first agreement was reached for stabilization of greenhouse gases in the atmosphere. Developed Nations agreed to reduce their emission to the levels of 1990.

In its Second Report, submitted in 1995, IPCC concluded that humans were changing the Earth's climate. It meant that if Climate Change was to be halted or slowed down in its track, humans need to change their behaviour. Therefore, in 1997, an agreement was reached at Kyoto, Japan to reduce emissions of greenhouse gases. Developed nations, excepting the US, pledged to cut

greenhouse gases emissions by 5% between 2008 and 2012. In 1998, global warming and El Niño caused a temperature rise of 0.520°C compared to the 1961 and 1990 mean. The IPCC concluded that the Earth's temperature increase in 20th century was mainly due to burning of fossil fuels and also it was likely to be the highest during the last millennium. By 2008 the atmospheric CO₂ reached 380ppm from 315ppm in 1958. IPCC's Fourth Report published in 2007 concluded that man-made greenhouse gases were responsible for Climate Change.

Global Warming

Climate Change and global warming are now synonymous. Global warming indicates increase in the Earth's surface temperature while Climate Change includes global warming and other changes due to rise in the atmospheric greenhouse gases. Joseph Fourier had described this phenomenon to be responsible for the warm atmosphere. Due to that the average temperature of the Earth remains about 15°C. If the greenhouse effect becomes stronger, the Earth's temperature rises, resulting in Climate Change, including Earth's warming, changes in precipitation, droughts, floods, intense storms etc.

Greenhouse Gases

Common greenhouse gases in the atmosphere are water vapour, CO₂, methane, nitrous oxide, ozone and certain halogen containing gases, produced naturally as well as by humans. Greenhouse gases in the Earth's atmosphere are presently higher than ever before. Concentrations of CO₂, methane and nitrous oxide are at the highest levels in the past 800,000 years.

Thermal power plants are major greenhouse gases contributors as most of them burn coal. Most motor vehicles utilize fossil fuels, adding greenhouse gases. Huge quantities of plastics reach landfills and oceans, releasing methane and CO₂ on decomposition. Forests and coral reefs are important sinks for CO₂. But these are being destroyed for various reasons.

About 90% of aerosols come from natural sources; the rest from fossil fuels and biomass burning. Chemical fertilizers release nitrous oxide from soil. Cattles generate methane during food digestion. Also, rice fields generate methane, adding to the global warming.

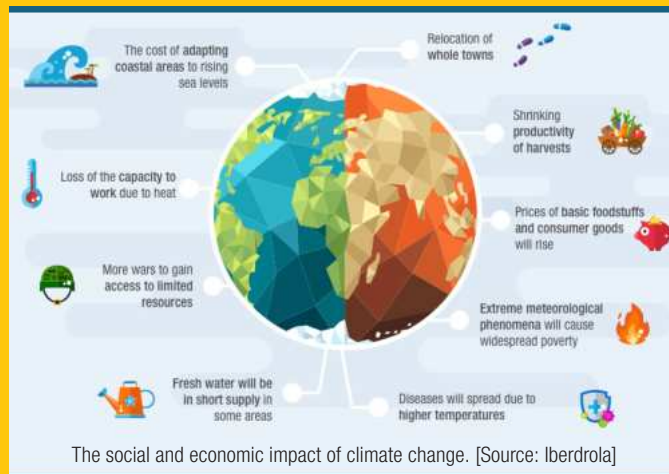
Kyoto Protocol and Beyond

The Stern Review Report published in 2006 warned that Climate Change could cause drop in global GDP by up to 20% by 21st century end. Climate Change could affect hundreds of millions of people globally through water scarcity, food shortages, diseases, and environmental degradation. In 2006 carbon emissions reached 8 billion tonnes/annum, the highest ever in the history of Earth. In 2012, the Arctic ice reached its lowest level since 1979. In 2013 the mean concentration of CO₂ crossed 400 ppm and touched 417.6ppm in May 2020.

Impacts of Climate Change

Climate Change can have various impacts. Most of the world will have higher average temperatures. But certain regions will turn colder. Some regions will become drier while others may receive more than usual rain or snow. Storms, droughts and floods will be more frequent. The trouble is, at present, it is not possible to predict which regions will experience what. Summer in Indian cities is turning hotter and more humid, as indicated by data collected between 1951 and 2010 at 283 weather stations. Indians may face the wrath of heat-waves, as even 0.5°C rise in summer can substantially increase heat-related deaths.

If oceans continue becoming warmer, water volume will expand. Faster melting of ice and snow will add more water. The net result will be a rise in the sea level posing direct threat to the coastal areas and islands, affecting millions of people. Average global sea level rise was 1.7 mm/year from 1901 and 2010,



between 1971 and 2010 it was 2.0 mm/year and between 1993 and 2021 the rise was between 2.8 and 3.5 mm/year. A harbinger of such danger was felt in 2017, when a large chunk of ice, more than a trillion metric tons, broke away from the Antarctic Peninsula. About a third of the Antarctic ice shelf may collapse with Earth's warming. Their melting will add water to the oceans and greater sea level rise. It is predicted that by the end of the 21st century more than 95% of the ocean area may rise, affecting 70% of coastlines.

Sea level rise is already visible along the Indian coasts. Estimated rise is between 1.06 to 1.75mm/year and Bengal coast is recording the maximum. In the Gulf of Kutch, the rise ranges between 0.4 to 2 mm. Submergence of coastland and destruction of the ecosystems have been reported for about 10,000-km stretch in Sundarbans. In Chennai, Kolkata and Mumbai the low lying areas are showing faster erosion damaging coral reefs and wetlands. In Odisha fields close to the sea coast eroded and submerged. Several million Indians living close to the sea may have to move inland causing population issues.

Impacts on Agriculture

Climate Change will make it difficult for crops to thrive in their own habitats. Various crops require different degrees of rainfall. Due to Climate Change, rain patterns may change causing crop failures. India, the second largest producer of rice and wheat, will be affected

the most. A rise between 2 to 4°C can bring down rice yield substantially. The International Rice Research Institute has predicted about 20% yield reduction for every 1°C rise in temperature. A rise of about 2°C can reduce wheat crop in most places. In India wheat contributes more than 35% of the total grain production. Climate Change can reduce production by 10-40% by the end of the current century. Brazil, China, parts of Africa and south-east Asia also

are likely to suffer. Obvious outcome will be food shortages.

Rainfall anomaly can cause devastations. For example, heavy rainfall claimed at least 100 lives in Sri Lanka during May, 2017. Some places received a year's rainfall in just 24 hours. Floods and landslides caused heavy losses. Large areas such as Uttarakhand in India face flash floods regularly. With changing climate, flash floods can be frequent or more severe or both.

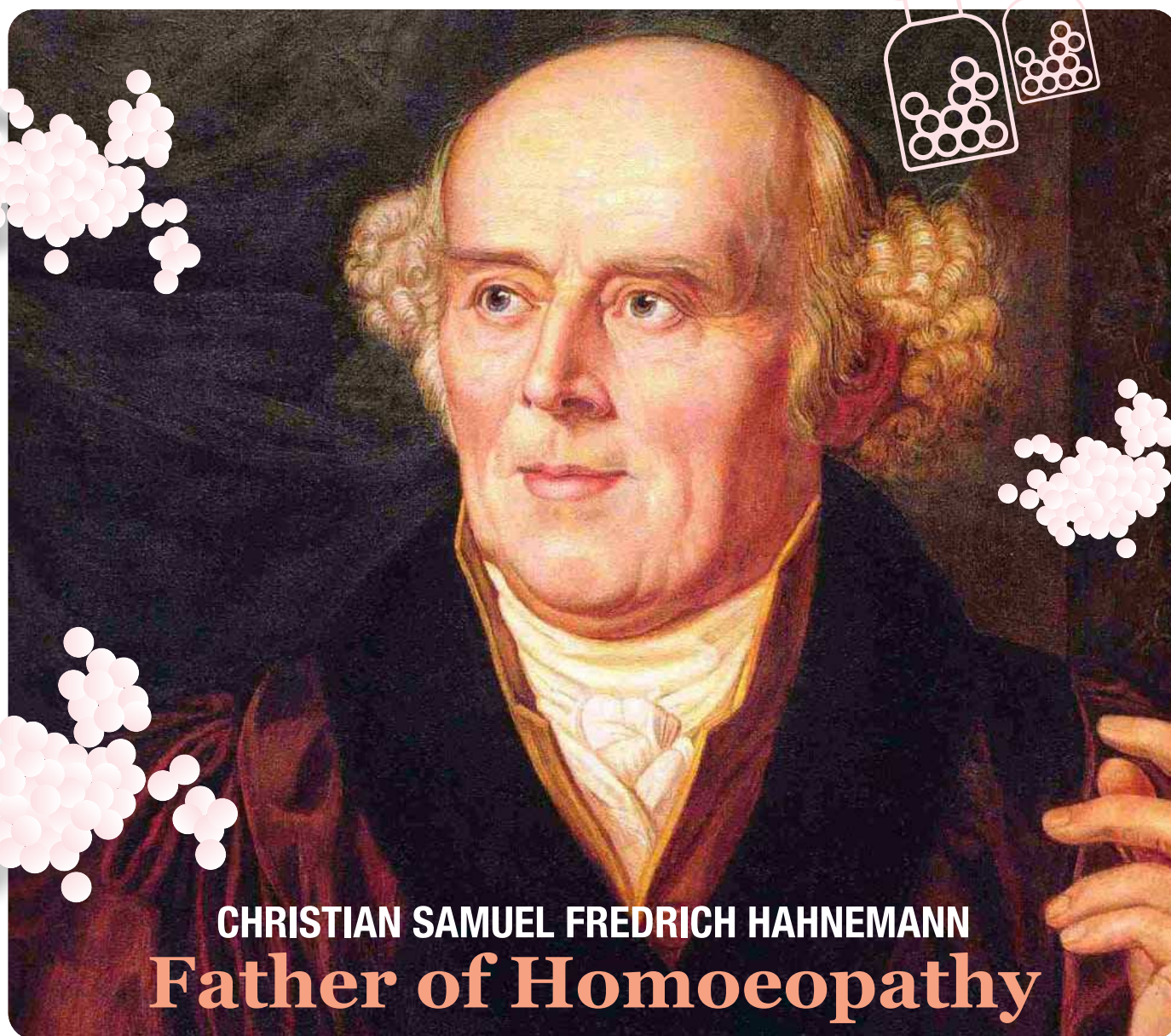
Innovations

In India, farmers are preferring crops such as millets, which tolerate higher temperatures and drought. Another possibility is Quinoa (*Chenopodium quinoa*). It grows even in drought conditions. Food and Agriculture Organization (FAO) has selected it as one of the crops for food security in the next century. About 500 farmers in Doda district (J&K) are growing lavender to replace maize and as a result getting up to four-fold income.

Global Warming and Climate Change are here for sure. They can't be reversed, but surely their progress can be halted or slowed with concerted action by individuals as well as nations. The World Environment Day is the occasion for all of us to remind ourselves of our role in this and play it honestly.

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CHRISTIAN SAMUEL FREDRICH HAHNEMANN Father of Homoeopathy

April 10 is marked with golden letters in the history of Medical Science. In 1755, Dr Christian Samuel Fredrich Hahnemann, Father of homoeopathy was born on that day. The credit for discovering Homoeopathy goes to him who introduced to the world the Law of Similarity between drug and disease and the Law of Dynamization, an alternative philosophy of medicine.

Principle of similarity was known to Hippocrates, but credit for following it astutely to develop it to a method goes to Dr Hahnemann. He argued that there are principles and laws which govern the practice of medicine. He talked about

the Vital Energy, which was ridiculed at that time, but homoeopaths relate that to the present Immune System theory. He invented Homoeopathy as a safe and sure system of medicine that is both gentle and curative. The word Homoeopathy is derived from Greek words Homoeo meaning similar and Pathos meaning suffering. Dr Hahnemann was a German MD who was of the opinion that if the vital force is deranged one becomes sick, which later on manifests itself in the form of symptoms. After many years of practice, he was neither satisfied nor convinced of the effectiveness of the existing medical practices which so often did more harm

than good to the patients. He realized that drugs had been prescribed on patients without proper knowledge of their actions and reactions, and they only dealt with symptoms and not with the disease itself. He believed that drugs did least for the individual suffering. He sought for a method which would be safe, gentle and effective. He believed that human beings have a capacity for healing themselves and that symptoms of diseases reflect the individuals struggle to overcome the forces antagonistic to life. He also believed that the physician's work was to discover and stimulate the 'vital healing force of the nature'. The key principle of

this medical approach is *similia similibus curentur*. Homeopaths generally refer this as Like be treated with likes.

Dr Hahnemann and his followers were convinced of his theory that a drug can produce all those symptoms which it is used to cure for, if given to a healthy human in substantial doses. He developed this theory while translating Cullen's *Materia Medica*. He and his followers carried out experiments on themselves over a long period during which they took small doses of various reputed poisonous or medicinal substances, carefully noting the symptoms those drugs produced. Patients suffering from similar symptoms were then treated with these substances or drugs and that's how Homoeopathy came into existence.

Having thus established the principle of Similarity, he worked to establish the smallest effective dose for he realized that this was the best way to avoid the side-effects. He surmised that the more similar remedy was diluted the more active it became. While dissimilar were ineffective. He called his method Potentization and the serial dilutions as Potencies to indicate their power. This was a paradox. That less of a substance could be more effective was unacceptable to the scientific thought of that time. Hahnemann and his followers were ridiculed, but homoeopathy has survived and today a changing outlook in medicine renders the concept of infinitesimal acceptable to many. This is emerging as Nano pharmacology.

Centuries have passed. But, the Principles of Homoeopathy remain the

HOMOEOPATHY IN INDIA

Homoeopathy was introduced in India the early 19th century. It flourished in Bengal at first, and then spread all over India. In the beginning, the system was extensively practised by amateurs in the civil and military services and others. Mahendra Lal Sircar was the first Indian who became a homoeopathic physician. A number of allopathic doctors started homoeopathic practice following Sircar's lead. The 'Calcutta Homeopathic Medical College', the first homoeopathic medical college was established in 1881. This institution took on a major role in popularising homoeopathy in India. In 1973, the Government of India recognised homoeopathy as one of the national systems of medicine and set up the Central Council of Homeopathy (CCH) to regulate its education and practice. Now, only qualified registered homoeopaths can practice homoeopathy in India. There are over 200,000 registered homoeopathic doctors currently, with approximately 12,000 more being added every year.

An article by Ajoy Kumar Ghosh in PubMed [PMID: 20471616 DOI: 10.1016/j.homp.2009.10.001]

same. Hahnemann's homoeopathy is often termed as both Science and Art. As the basis of disease understanding is philosophical and the application of medicine is an art. The medicines in the form of small tiny pills or colourless liquids withstood the test of more than 230 years. The principle of Individualisation speaks of holistic approach in health, disease and treatment by taking into consideration of the sick individual at physical, mental, social and spiritual levels. This concept is now emerging even in biomedicine as personalized medicine (theranostics) as an important factor of diagnostics and therapy of long-term diseases.

Dr Hahnemann believed in integrating the individual with his sufferings. Accordingly, a person's mind, emotions, impulses, likes and dislikes, sensations, aversions, mania, and fear and phobias cannot be ignored when treating diseases. Dr Hahnemann said

pathology recognizes nothing but the man's body and the mind is the key to the man. Century later, after Sigmund Freud's dramatic introduction of the psychoanalysis physicians realized the relation between the mind and physical illness. Homoeopathy considers it better to treat the sick person rather than the disease alone. It believes that though the disease may be the same, each patient may react in a different way and as such produce symptoms which are peculiar to the person. A homoeopath takes into considerations all the symptoms of the case which reflects the patient's individuality and prescribes a remedy which produces the identical group of symptoms in the Drug Proving. Homeopathic remedies are used by many for viral diseases, different forms of allergic conditions, skin disorders, behavioural problems and several chronic long-term diseases. Its strength also lies in its effectiveness on certain clinical conditions for which there is less treatment in other medical systems.

Scientific validity of the principles postulated by Dr Hahnemann in early 18th century are getting validation with the advancement of science. It is said that he was ahead of his time in terms of knowledge and wisdom. Dr Hahnemann's story is a significant chapter in the development of modern medicine from the ancient healers.

DRUG PROVING

Drug Proving, also termed as Homoeopathic Pathogenetic Trial (HPT), is a process in which drug substances are put into trial on healthy human volunteers and their pathogenetic effects are observed, noted and compiled as the first step to introduce the drug in the Homoeopathic *Materia Medica*. Proving of a drug substance is a unique process in Homoeopathy. Unlike conventional medicine where animal experimentation forms the basis of evaluation of drug pathogenesis, homoeopathic medicines are proved on healthy human volunteers, including controls, from both sexes and age group between 18-60 years. In India, the Central Council for Research in Homoeopathy, since its inception in 1978, has adopted the Drug Proving Research Programme as one of its primary research areas where the Council has focused on proving of indigenous drugs and fragmentarily proved drugs.

Source: Central Council for Research in Homoeopathy

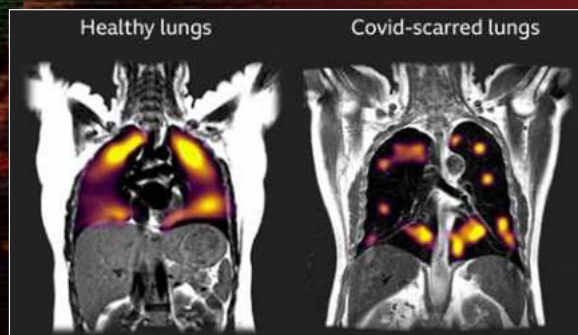
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COVID, Oxygen, SpO2 and Oximeter

The SARS-CoV-2 virus in the droplets that we inhale finds a welcome home in the lining of the nose. The surface of the cells that form the lining of the respiratory tract, called epithelial cells, are rich in the cell-surface receptors, a type of proteins called angiotensin-converting enzyme 2 (ACE2). Typically, this receptor which helps regulate blood pressure, binds with a part of the viral spike protein called the receptor-binding domain (RBD). The virus, then, takes a foothold grabbing onto the ACE2 receptor, and enters the cells. Once inside, the virus hijacks the cell's machinery, reproducing myriad copies of itself. The viral copies emerge from the infected cell and invade new cells.

As the virus multiplies and more and more cells are invaded by the virus, the immune system works in overdrive. If not controlled in the initial stages, the virus marches into the alveoli of the lungs.



In the scarred lungs, on the right, there are much larger areas of darkness, representing parts of the lungs that are having difficulty transporting oxygen into the blood stream (Image: Oxford University)

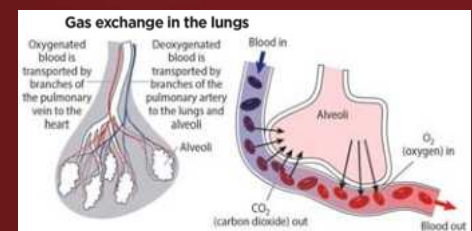
Alveoli are lined with a single layer of cells, also rich in ACE2 receptors. Once these cells are infected, alveoli are destroyed, and the virus can enter the bloodstream. White blood cells react to the virus and infected cells and release inflammatory molecules called chemokines. More immune cells are summoned to target and destroy the virus-infected cells.

Alveoli became stuffed with fluid, white blood cells, mucus, and the detritus of destroyed lung cells. Clogged alveoli

make it harder, at times even impossible, for you to breathe. As fluid collects inside the lungs, they carry less oxygen to your blood. That means your blood may not supply your organs with enough oxygen to survive. The patient would gasp for breath. If the oxygen level steadily falls down, the patient might suffer hypoxia.

Gas exchange in lungs

Like a tree diverge out from trunk, branch and twig, the lungs also branch out into bronchi, bronchioles, and air sacs called alveoli at the terminal end of bronchioles. The bifurcating tree structure of the lungs is so extensive that together the lungs



Through the mechanism of diffusion, O_2 and CO_2 are exchanged between the air and the pulmonary capillaries in alveoli.

contain approximately 2,400 kilometre of airways, about the distance of Chennai from Delhi. The total surface area of 300 to 500 million alveoli in the lungs is about 100 square meter, roughly the size of a tennis court. The walls of these alveoli are just one cell in thick. They are crisscrossed with tiny pulmonary capillaries blood vessels.

Oxygen circulation

Haemoglobin in the blood and myoglobin in the muscles are oxygen-carrying proteins. These proteins have an iron-containing group called 'heme'. Typically, there is about 12 to 20 gram of haemoglobin in every 100 ml of blood. The Fe^{2+} in the haemoglobin can reversibly bind with O_2 . Oxygen is a nonpolar molecule in which, due to the distributional arrangement of electrons, induces dipole. Fe^{2+} exerts a weak ion-induced dipole attraction and binds to O_2 . Once in the blood, the oxygen is bound to haemoglobin in red blood cells, taken through the pulmonary vein to the heart, pumped into the systemic vascular system and, finally, brought to all the body cells. Oxygen absorbed by the haemoglobin in lungs is transported by blood to tissue

Can one rely on the smartphone SpO2 sensors?

The simple answer is No. For computing the SpO2 levels, the beam of probe light has specific wavelengths of red and infrared. However, the smartphone cameras have regular white or yellowish flashlights. Therefore, they may not give adequately reliable readings.



myoglobin in various parts of the body. Ultimately the oxygen reaches the mitochondria and used in the production of energy.

In muscles, the oxygen pressure is low. Myoglobin, found in the muscles, attracts the oxygen and takes it away from the haemoglobin in the blood. Therefore, as the oxygen-rich blood reaches muscles, oxygen is released, and the saturation of the haemoglobin drops to about 50%. The concentration

of oxygen in the mitochondria, where fuels are burned to release energy, is even lower than myoglobin. Hence, the oxygen from the fully saturated myoglobin is transferred to the cell via mitochondria.

In short, the haemoglobin picks up oxygen in the lungs, circulates through the bloodstream. The myoglobin in the muscles and tissues absorb the oxygen from the blood. Myoglobin then delivers it to the mitochondria, where it is used to oxidize fuel molecules.

What is SpO₂?

SpO₂ is oxygen saturation in our blood. This measures the ratio between the oxygen-carrying haemoglobin (oxyhaemoglobin) and the haemoglobin not carrying oxygen (Deoxyhaemoglobin). In

COVID-affected person, if the infections spread unchecked, the lungs will be damaged, and the oxygen saturation of the blood will fall. By keeping watch of the SpO₂ levels, one can seek medical help at an appropriate time. Low levels of SpO₂ can result in severe symptoms known as hypoxemia. Moderate hypoxemia results in fatigue, light-headedness, numbness and tingling of the extremities and nausea. Bluish spots may appear in the skin. Further reduction in the oxygen levels would turn into hypoxia or low oxygen levels in the tissue, which is life-threatening.

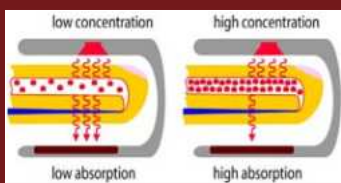
A pulse oximeter is used to measure the SpO₂ levels in the blood. When the pulse oximeter is placed on a finger, it measures the pulse rate and the oxygen saturation levels. The normal range of saturation is between 94 per cent and 100 per cent, indicating a healthy level of haemoglobin carrying oxygen through the blood. If the measure is less than 90%, then one should seek immediate medical help.

HOW DOES A PULSE OXIMETER WORK?



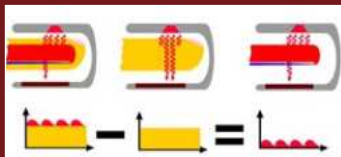
The pulse oximeter has a light-emitting diode (LED) and a sensor. It fires a small beam of light through the blood in the finger and measures the light received on the other side.

The ratio of absorbance of red and infrared light gives an indication of the relative concentration of oxyhaemoglobin and deoxyhaemoglobin. This tells us about the oxygen saturation in the blood.



Less oxyhaemoglobin in the blood means less absorbance of red light; more of it means more absorbance. Therefore, by measuring the absorbance of red and infrared the amount of oxyhaemoglobin and deoxyhaemoglobin in the blood can be measured.

Without knowing if the finger is fat or thin, the measurement could lead to error. Further, blood is not a neat red liquid but contains various irregular objects such as red cells. These objects will scatter the light and hence reduce the transmission.



Pumped by heart, the blood flows in pulse. Measurement of the absorbance during the presence and absence of the blood enable us to differentiate between the absorbance due to tissue and the absorbance due to oxygen saturation in the blood.

The oxyhaemoglobin absorbs more infrared light than red light. The deoxyhaemoglobin absorbs more red light than infrared light. This property is manipulated to measure the relative abundance of oxyhaemoglobin and deoxyhaemoglobin in the blood. The LEDs emit red light, with a wavelength of 650 nm and the invisible infrared light, with a wavelength of 950 nm. The sensor at the other end measures how much of the light passes through or absorbed. The relative absorbance of red and infrared light indicates how much oxyhaemoglobin and deoxyhaemoglobin are present in the blood.

However, such measurements would be marred by the variations in the thickness of the fingers from one to another. The tissues in a thin finger absorb less light than a fatter finger.

During a measurement, the thickness of the finger or scattering property of the blood will not change. However, as the heart pumps the blood, the blood flow pulsates. That is the abundance of the blood increase and decrease over the period. And luckily, arterial blood is the only thing throbbing in the finger. Everything else is non-pulsating. Any "changing absorbance" must therefore be due to arterial blood.

Pulse oximeter is very susceptible to errors. If the probe is not placed correctly or the patient moves the oximeter, the measurement might be corrupted. Therefore, patients must rest their fingers on a surface and place the pulse oximeter to measure. Further, factors such as movement, temperature, or nail polish can impact the accuracy.

Hypoxia

When the whole body or a region of the body is deprived of adequate oxygen supply at the tissue level, it results in a condition known as hypoxia. Severe hypoxia causes twitches, disorientation, hallucinations, irregular heartbeat and eventually death.

During hypoxia, in a tissue, the ATP production is halted. Without ATP, no energy would be available for the tissue to function, say make the heart tick and brain neurons twitch. The organism will soon lose consciousness and will die if oxygen is not quickly restored. Oxygen depletion for a more extended period results in cells death, gangrenous necrosis of tissue and eventually death of the organism. Different tissues have varied tolerance to hypoxia. The tissue survival time of the brain is less than 3 minutes, whereas the kidney and liver can survive up to 15-20 minutes. Hair and nails can survive without oxygen replenishment for several days.

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SCIENCE OF CYCLING: An unsolved mystery

To emphasize and advance the use of the bicycle as a means of fostering sustainable development, strengthening education, including physical education, etc. UN declared June 3 as World Bicycle Day.

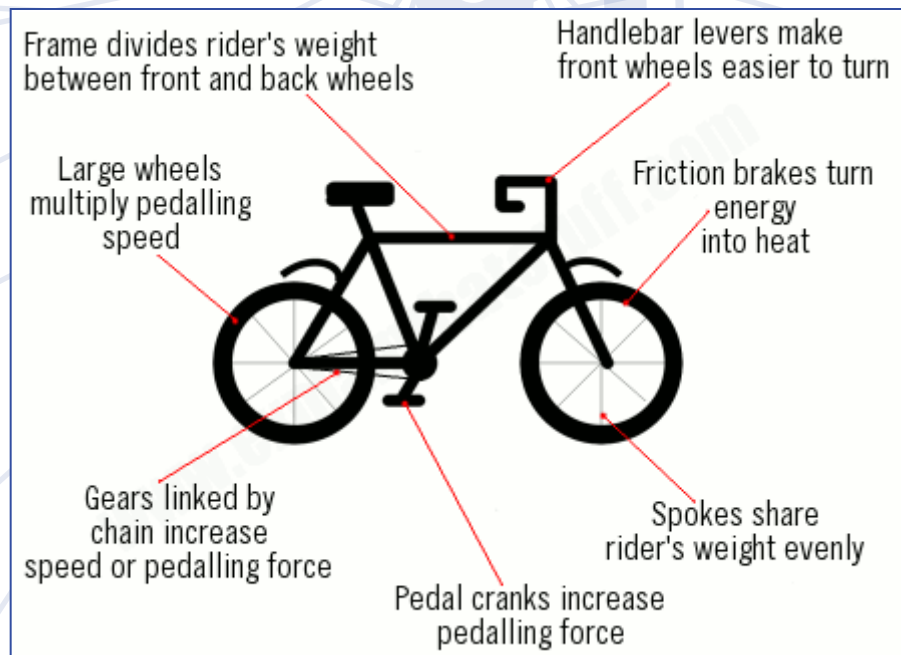
If we had to pick the greatest machine of all time, for its sheer simplicity, we would pick the bicycle as a perfect example of how scientific ideas can be harnessed in developing practical applications of technology. Cycles are one of the quick, efficient, cost-effective, and pollution-free modes of local transportation that is also good for health. They are able to do that because they very efficiently convert the muscle power of our bodies into kinetic energy (energy of movement). Harnessing the power from our muscles in an amazingly effective way, a bicycle can convert around 90 per cent of the energy we supply at the pedals into kinetic energy that powers us along; in comparison, a car engine converts only about a quarter of the energy of fuel into useful power besides creating lot of pollution in the process.

The role of bicycle

In scientific terms, a bicycle can magnify force or speed. It is also a machine in the sense that it converts energy from one form (muscular energy) into another (the kinetic energy of bicycle). The frame does not simply support the rider: its triangular shape (often two triangles joined together to make a diamond) is carefully designed to distribute the rider's weight. Although the saddle is positioned much nearer to the back wheel, the cyclist leans forward to hold

the handlebars. The angled bars in the frame are designed to distribute the weight more or less evenly between the front and back wheels. The technology for designing durable, flexible, cost-effective parts of bicycle like: frames,

like machines for nearly two centuries and while riding and balancing a bicycle may appear simple and effortless, the actual control process used by a rider is still somewhat of a scientific mystery. Using mathematical equations,



Courtesy: www.explainthatstuff.com

wheels/tires, gears, brakes, etc., is well-developed and understood and need not to be discussed here.

Science of cycling

People have been making use of bicycle-

researchers have tried to explain how a bicycle without a rider can balance itself and have identified the bicycle design features critical for that to happen. The ability of a bicycle with a rider to remain balanced is more difficult to quantify

and describe mathematically, especially since the rider's ability can vary widely.

The science behind the motion of the cycle (balancing) is still a great mystery. Man has made tremendous progress in understanding science and developing technology and is looking for mysterious dark matter and the inexplicable accelerating expansion of the universe, but the bicycle represents a far more embarrassing hurdle in the accomplishments of physics. Most people appreciate the bicycle as an extraordinary machine without understanding the science behind it. If a riderless bike is pushed and let roll freely at high enough speed, it can withstand pushes from the side. It will wobble a little, but quickly recover. In the conventional analysis, this is because the gyroscopic force of the front wheel, its mass and the spontaneous turn of the handlebars all act together to keep the bicycle rolling forward. This has something to do with the gyroscopic effect, the force that keeps a spinning top upright. The mathematical analysis of bicycles also suggested that this is what that keeps a moving bike on its wheels. But although the equations were written down in 1910, physicists always had nagging doubts about whether this was the whole story.

The most definitive analysis came exactly a century later which involved an experimental bicycle that had all its gyroscopic effects cancelled out by a system of counter-rotating wheels. It turned out that taking into account the angles of the headset (the set of components on a bicycle that provides a rotatable interface between the bicycle fork and the head tube of a bicycle frame) and the forks, the distribution of weight and the handlebar turn, the gyroscopic effects are not enough to keep a bike upright. Thus, what makes the cycle stand upright is still not known. Scientists are not taking up the project of finding answer to "what keeps a bike upright" because it does attract much attention as people always go by practice to ride the bicycle. However, once we are able to discover exactly how these contraptions work, it might be possible to come up

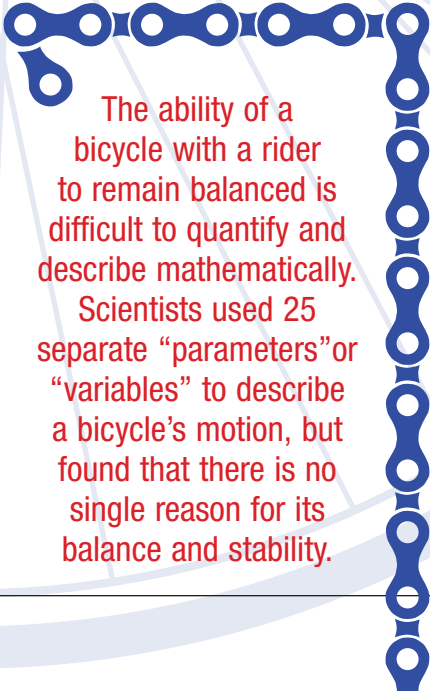
with bold new designs of bicycle, but nobody is desperate for that to happen.

In an age where we have worked out the history of the cosmos and the secret of life, it is rather surprising that the humble bicycle keeps our feet on the ground. Scientists have been puzzling over what makes bicycles balance since they were invented, back in the 19th century. In 2007, a group of engineers and mathematicians announced they had finally cracked the mystery with a set of incredibly complex mathematical equations that explain how a bicycle behaves. It turned out that gyroscopes are only part of the story. People often say that it is virtually impossible to fall off a bicycle because its spinning wheels make it behave like a gyroscope; but, unfortunately, it is not quite that simple. According to these scientists, who used 25 separate "parameters" or "variables" to describe every aspect of a bicycle's motion, there is no single reason for a bicycle's balance and stability. A simple explanation to cycle balancing does not seem possible because the action and reaction are coupled by a combination of several effects including: gyroscopic precession, lateral ground-reaction forces at the front wheel, ground contact point trailing behind the steering axis, gravity and inertial reactions from the front assembly having centre-of-mass off of the steer axis, and from effects associated with the moment of inertia

matrix of the front assembly. In simple terms, it is partly to do with gyroscopic effects, partly to do with how the mass is distributed on the front wheel, and partly to do with how forces act on the front wheel as it spins.

The centre of mass is the point at which all the mass (rider plus bicycle) can be considered to be concentrated and it is well understood by now that major part of balancing a bicycle can be controlled through the centre of mass of the rider-bicycle system. During straight riding, the rider must always keep the centre of mass over the wheels or the base of support. Bicycle riders can use two main balancing strategies: steering and body movement relative to the bike. Steering/paddling is critical for maintaining cycling balance and allows the bicycle to move to bring the base of support back under the centre of mass. Body movements of the rider relative to the bicycle-like leaning left and right-have marginal effect compared to steering, but it allows a rider to make balance corrections by changing the centre of mass side-to-side relative to the bicycle and base of support. Finally, it can be summarised that steering, and not body movement, is absolutely necessary to balance a bicycle and there is no specific combination of the two to ensure balance. The basic strategy to balance a bicycle is to steer it to prevent undesired fall.

Despite much research work in the field, there is still much to be learned about how humans ride and balance bicycles. Most research has been limited to straight-line riding, which only makes up a fraction of a typical bicycle ride. Ideally, there is a need to identify the measurements that quantify the balance performance, control strategy and fall-risk of a rider in the real world. With deep understanding of the science of cycling, it will be possible to identify riders at high risk of falling and explore the extent to which bicycle design can reduce fall-risk and increase balance performance.



The ability of a bicycle with a rider to remain balanced is difficult to quantify and describe mathematically.

Scientists used 25 separate "parameters" or "variables" to describe a bicycle's motion, but found that there is no single reason for its balance and stability.

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DR NANDIVADA RATHNASREE: The Star Communicator

Dr Nandivada Rathnasree, Director, Nehru Planetarium, New Delhi, a star communicator, breathed her last on May 9. I first met her in 2004. I had just joined Vigyan Prasar and my area of work was astronomy and space science communication. It was necessary to connect with people and institutions working in the field, and the first person I met was Dr N Rathnasree. That was just a beginning. Our association continued over the years. She invited me to join for the fortnight meeting with Amateur Astronomers Association of Delhi (AAAD) at the Planetarium. This was a tradition started by her predecessor Dr Nirupama Raghavan and she wholeheartedly took it forward. She was the mentor, guide, and teacher for many of the members of AAAD. She was so passionate about propagating scientific spirit that she hardly bothered for official timings and kept the planetarium open for amateur astronomers even after office hours. Once during the preparation of Total Solar Eclipse (TSE) of July 2009, she asked us to meet on weekends so that we can spend more time on designing and fabricating a solar projector. And she did get it done. It was the one we used during the Total Solar Eclipse.

Dr Rathnasree was also passionate about the landscape astrophotography at historical sites. She gave ideas and guided us to find such locations where astrophotography can be carried out. Indeed, on many occasions such photos found space in the foyer of the planetarium for all the people to see. Many passionate astrophotographers were born out of such workshops. She was very particular about acknowledging the source of every single effort which was in the public domain. She encouraged me to talk about projects that can be undertaken

through a small telescope. Dr Rathnasree was also a great experimentalist. During the International Year of Astronomy, in 2009, she suggested us to try out the Galileo scope, which was designed by International Astronomical Union (IAU) and made available to the public. Through the Galileo scope, we trained nearly 500 teachers and students for demonstration of the Total Solar Eclipse of 2009. The demonstrations that Dr Rathnasree gave from the studio went for extra 30 minutes to an hour. Such was her involvement in outreach programmes. The same Galileo scope was used later for projection of the Sun during the Annular Solar Eclipse of January 2010.

Dr Rathnasree's management skills also need a special mention. During Lunar Eclipse of 15 June 2011, a programme was organized at the lawns of Teen Murti Bhavan. The event was at midnight, but the crowd had assembled just after the sunset. She managed it in such a way that none of the over 2000 visitors during their stay felt any leisure time till the actual event. Five teams were formed to engage the crowd through the night. One team engaged the visitors in showing the night sky with constellations and bright stars; another was projecting the Moon through an LCD projector; the third team had 11-inch GOTO telescope to show the Andromeda Galaxy; the fourth focused on planets like Saturn, Jupiter and some of the Messier objects; and finally the fifth team was continuously providing feed and interviews to the media section. Dr Rathnasree was on the field throughout the night motivating the teams and people and finally ensuring that all members reached home safe and secure. She personally rang up all such members who forgot to inform her on reaching their homes.

During several programmes including Transit

of Venus (2012); Professional-Amateur (Pro-Am) meeting (2013); National Meet on Role of Planetarium in Science Communication (2013); Radio Astronomy Discovery (RAD@home, 2014); Astrophotography workshops (2017) and regular Popular Astronomy Talks she actively participated in communicating with the participants and helped them learn something new. Her extensive efforts in restoring the markings of Jantar Mantar's instruments like Samrat Yantra, Jai Prakash Yantra, Ram Yantra, Misra Yantra, etc. are known across the astronomy community. She was always passionate to show and demonstrate the working of these Yantras and had organized trips to Jaipur, Ujjain, and Delhi's Jantar Mantar. I had several opportunities during such excursions to be with her. In 2016, during the International Astronomy Olympiad, we held the astronomy festival in Bhubaneswar. She enthusiastically explained the workings of many traditional yantras to school children using various scale models of Jantar Mantar developed by amateur astronomers and also engaged them in several daytime activities. The students enjoyed the experience thoroughly.

She developed many shows for the planetarium and invited me to watch them. She was an extra-ordinary communicator and left her impression as one of the most creative, dynamic, and hard-working Directors of the planetarium. She customized many shows as per the need and interest of the visitors. Dr Rathnasree was a tremendous supporter of Vigyan Prasar in all its outreach activities. She helped us in the evaluation process of the Vigyan Prasar Network of Science Clubs to bring out bright and hardworking science club coordinators and encourage them in creating awareness about astronomy and other related scientific activities. Very recently, we were engaged in discussions on involving our science clubs spread across the country for preserving the heritage astronomy sites by hands-on demonstrations.

As recently as 17 April 2021, she actively participated in the demonstration of Occultation of Mars by the moon. She also planned to participate in the Zero-Shadow Day experiments of 24 April 2021 organized at Nehru Planetarium, Bangalore. But as she developed symptoms of COVID-19, she could not participate. Now, with her untimely demise, a large void is created in the astronomy outreach activities. May her soul rest in peace. The best homage we can give her is to continue the astronomy communication which she wanted all of us to do for the benefit of the people in general and students and teachers in particular.

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