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An Antarctic Mystery: Physical Spectacles of the Frozen Continent

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

EDITORIAL

Disseminating Science effectively over the Net

Chander Mohan

After months of concerted efforts of the small but sprightly team of Vigyan Prasar, which entailed dogged pursuits of several stakeholders, sometimes for days at a stretch, for credible and current information, there appeared the proverbial silver lining after ominous-looking dark clouds of uncertainty got swept away. On the eve of my last official engagement as Director, Vigyan Prasar, these *Sheros* & heroes, rolled out the much-awaited 'India Science, Technology, and Innovation' (ISTI) Web Portal (www.indiascienceandtechnology.gov.in). If that was the cake, the icing followed almost immediately afterwards with the advent of 'India Science', (www.indiascience.in) a first-of-its-kind national Science & Technology Channel on the Internet or OTT (Over The Top). I could not have asked for a better and more apt a present on my superannuation from government service on the last day of July 2018. Their relentless pursuits and focussed attention resulted in this double accomplishment, which I can proudly claim as some of the biggest achievements or steps forward in the relatively short but smart history of Vigyan Prasar as not just an Autonomous Organisation of Department of Science and Technology but also as its extension or outreach wing.

We are arguable calling it a soft launch, given the dynamic and ever-changing nature of such ventures. The India Science Channel currently has limited content; and it will be our continuous endeavour to keep adding more content as we move forward and also 'up the ante' in time to come. We are gearing up to not just keep up the pace but move forward with firmer and surer steps with every passing day. The Channel is intended to sport a 24-hour scheduled playlist, as well as a video-on-demand (VOD) spread and we also plan to introduce LIVE webcasts in due course. The ISTI Portal, on the other hand, is a unified online platform that entices and encourages participation in science, technology and innovation, or the triad of development, by helping researchers, scientists, academia, students and other stakeholders seek and find vital information related to scientific research in institution and laboratories in India. It will also help them share not just expertise and experiences but facilities and infrastructure as well. We shall strongly and stringently monitor these two platforms from the perspectives of both back-end technology as well as content (quantity and quality). In our pursuit to make these two sites better and richer, we seek your feedback which shall help us in fine-tuning the products and make these accessible to anyone who has Internet connectivity. Expect more from us……Jai Hind!

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An Antarctic Mystery: Physical Spectacles of the Frozen Continent

Felix Bast

The poles experience polar summers and winters, two extraordinary phenomena occurring nowhere else in the world. During polar summers, the Sun never sets, so it is full time "day". During polar winters, the Sun never rises; it is the darkness that prevails for many months. Antarctica is the most inhospitable continent on Earth; it is the coldest, driest and windiest. Antarctica is considered the largest desert in the world.

An Antarctic Mystery is a famous two-volume novel by the French writer Jules Verne, written in 1897. Depicting the nautical adventure to Kerguelen Islands, southern Indian Ocean, I had read this book during my school days. This novel implanted a subconscious seed within me, to long for a long and adventurous voyage to Antarctica. I was fortunate to be part of 36th Indian Scientific Expedition to Antarctica (ISEA) and I visited both the Indian research Stations in Antarctica, 'Bharati' and 'Maitri', aboard m/v *Ivan Papanin* – an eventful expedition lasting four-months in early 2017. While *An Antarctic Mystery* is a work of fiction, this article is not; it narrates a number of bizarre physical phenomena, optical illusions, eerie geographical features and much more that one can experience in Antarctica.

We left the Port of Cape Town, South Africa on 27 December 2016, and in next one week's time, we progressively headed south by crossing the celebrated southern latitudes, roaring forties (40°S), furious fifties (50°S) and screaming sixties (60°S)– the *de facto* boundary of Antarctica. By then, we could see numerous small blocks of the floes – floating masses of ice pieces in various shapes– all around the ocean. The temperature of surface water measured, to my surprise, minus 1.8°C. Salt in the seawater brings down the freezing point to minus 2.8°C (the same reason many cities in the higher latitudes sprinkle salt on the roads during winter to melt the fallen snow), an immensely cold water indeed. Man overboard (a person falling to sea from the ship) in these waters would mean instant death from hypothermic shock and cardiac arrest, no matter whether he is wearing a lifejacket or not. We approached the continent on southeast direction and could increasingly spot icebergs – a few enormous ones too, especially on our starboard side (right side of the ship). The size of floes progressively got larger, and the sound of these floes hitting on the hull of our ship produced a distinct loud "bang" on iron, a sound remarkably similar to those in warzones depicted in World War movies.

As we crossed the Antarctic Circle (66.5°S), the floes were replaced by drift ice, also known as pack ice– a contiguous layer of white, floating and mobile ice sheet on the sea surface. The thickness of this ice sheet was quite small at first, about a metre, which increased as we approached the continent. The sight of our ship moving through this pack ice was quite remarkable; almost every one of us was gathering either at the bow or the terrace above the bridge, relishing the scene, and capturing it with our cameras. As the hull hit these ice sheets, cracks would appear on the sheet at random locations; not exactly at the point of collision. Being an ice class vessel, our ship could easily sail through the pack ice without any trouble. After cruising through the pack ice for a while, perhaps an hour or so, the ship suddenly smashed on a sheet of ice with a jerk and a loud bang and stopped. This sheet of ice, called fast ice (or landfast ice–sea ice that is "fastened" to the coastline, to the sea floor along shoals or to grounded icebergs), is a lot thicker than the pack ice, so that ship couldn't easily break it to sail through. Unlike pack ice, the fast ice

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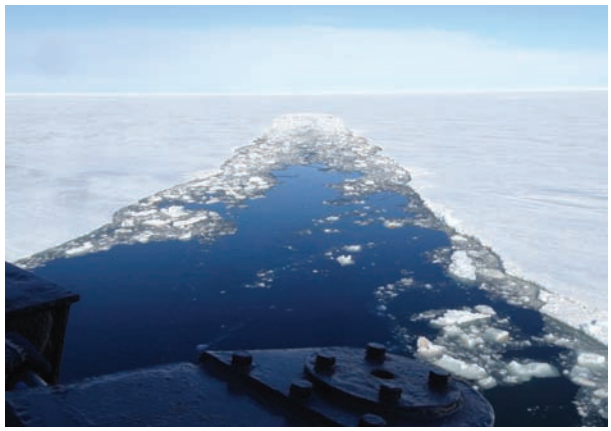

Fig.1. Ice-breaking on the fast ice in Antarctic Ocean. Image taken from the bow of ship, revealing the semi-triangular shape of ship's hull at the point of hit at the fast ice. (Felix Bast © 2017)

is not a 'drifting' sheet of ice; it is stationary, as the sheet is attached to the shore, and could be 2-3 metres in thickness. Fast ice is so thick that there are runways for airplanes and driveways for snow vehicles built over fast ice sheets in Antarctica. One can ride ice scooters –called 'skidoos'– a joyful mode of transportation quite often used by the members at the station during winters, over it. For short distance transportation of cargoes, sledges are often towed behind the skidoos.

After the initial bang, the ship would reverse-sail several ship-lengths, perhaps 5-6 times the length of the ship, and then, with full throttle, would smack the fast ice sheet once again, breaking the ice for a few more metres. This strenuous process, known as 'ice breaking' would be repeated for the next couple of days. If you stand at the bow, the ship's reverse sail would reveal the last hit it made on fast ice-that would appear as a pointed semi-triangular-shape of ship's hull, with the shape filled up with broken masses of ice of various shapes (Fig. 1). I could see in those broken masses a distinct haziness of extreme chill– as if you are looking at the pellets of dry ice (the solid CO_2) at a temperature of minus 78°C. I would stand by the ship's bow looking at these, fancying lifting one of these hazy white blocks, like the hazy blob of Orion nebula you could see through a telescope. These spongy white lumps, a few centimetres across, are called *Shuga*, as I would learn later. It was at this time that I experienced that feeling of total pin-drop silence so typical of Antarctica. That was the moment I felt for the first time I have arrived in Antarctica– the frozen continent.

Amongst those Shuga, I spotted yet another mystery, the blue ice! Blue ice (Fig. 2) has a spellbinding azure hue that you won't find anywhere on Earth other than polar areas. Blue ice forms when layers of snow, accumulated over the glacier, compresses that squeeze the air out of the ice, to make them very hard and dense. The blue colour is because strained oxygen-hydrogen (O-H) bonds of ice molecules absorb the red light, and the blue light gets reflected back; the same reason why a large mass of water– such as the ocean– appears blue. Over the course of my stay in Antarctica, I would see some massive icebergs and glaciers having conspicuous blue ice formations within; it would appear as a shimmering sapphire, or as if the ice is internally illuminated with a potent deep blue light, a very magnificent spectacle indeed.

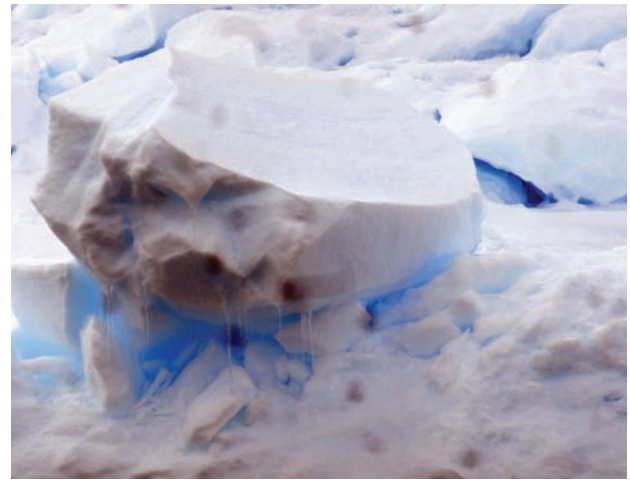

Fig.2. Blue ice. (Felix Bast © 2017)

When we crossed the Antarctic Circle (66.5°S), another physical spectacle was waiting for me, the polar summer. Antarctica is in the southern hemisphere, and the seasons in the south are diametrically opposite to those we see in the north; winter in the north would be summer in Antarctica. We crossed the Antarctic Circle on 4 January 2017 (Earth's perihelion, when it is closest to the Sun).It was the middle of winter in India, but in Antarctica, it was the mid-summer.

The position of the Antarctic Circle, like the Arctic Circle, is not fixed; as of 17 August 2017, it is located 66°33′46.8′north of the Equator. Its latitude depends on the Earth's axial tilt, which fluctuates within a margin of 2°over a 40,000-year period, due to tidal forces resulting from the orbit of the Moon. Consequently, the Arctic Circle is currently drifting northwards at a speed of about 15 metres per year.

Owing to the same axial tilt, places within 23.4° of both the poles experience polar summers and winters, two extraordinary phenomena occurring nowhere else in the world. During polar summers, the Sun never sets, so it is full time "day" (midnight Sun) that lasts for many months. During polar winters, the Sun never rises; it is the darkness that prevails for many months. At the South Pole, the Sun rises and sets only once in the whole year, during the equinoxes; in 2017 sunrise will be on the vernal equinox, 23 September, while the subsequent sunset will be on the autumnal equinox, 21 March 2018. September equinox is called autumnal in the northern hemisphere, while it is vernal in the southern hemisphere. March equinox is called vernal in the northern hemisphere, while it is autumnal in the southern hemisphere. In the South Pole, there will be six months of continuous sunlight (summer) between September and March, followed by six months of complete darkness (winter) between March and September.

Antarctica is the most inhospitable continent on Earth; it is the coldest (minimum temperature as low as minus 102°C at Dome-A), driest and windiest. Strong katabatic winds(winds caused by the downward motion of cold air) blow from the interior of the continent towards the Southern Ocean, with speeds up to 327 km/h (technically a "hurricane"). The ice valleys at the interior of the continent are 'the breeding grounds" of these katabatic winds that often turn into gales. Almost 98% of the continent is covered with permanently frozen kilometres-thick (average thickness is 1.9 km) ice sheet that contains 90% of world's ice. This ice, if you melt, is freshwater (not saltwater); the ice sheets of Antarctica (Fig. 3) are estimated to contain 70% of our planet's freshwater reserves.

Fig. 3.Author at Dalk Glacier, Antarctica. Ice axe and crevasse-probing stick are visible. Felix Bast © 2017

Ironically, Antarctica is considered the largest desert in the world, owing to the scanty precipitation that it receives. Some parts of Antarctica had had no rain or snow for the last 2 million years! In recent times, effects of global warming are becoming apparent in Antarctica, with accelerated melting of glaciers, changes in the distribution of plants and break-up of ice sheets. Occurrences of warm winds have intensified in Antarctica, increasingly forming massive sastrugi (parallel wave-like ridges caused by winds on the surface of hard snow, especially in Polar Regions) and melting the glaciers. One such a wind is the "foehn wind", which is a warm dry wind.

Antarctica is home to more than 400 subglacial ("below glaciers") freshwater lakes that are buried deep underneath the ice sheet. Lake Vostok (250km long and 40km wide) is the 7th largest lake in the world), lying 400 metres below Vostok station of Russia (Antarctica's largest). Many of these lakes are not frozen, thanks to the geothermal effects of the underlying rock bed. Subglacial lakes are considered to be 'time capsules', as they preserved the remnant of habitats when the continent began to freeze. These lakes are interconnected by the subglacial network of 'secret rivers'. One such secret river flows through the valleys of Gumburstev Mountains, which lies underneath the ice sheet. The river is so bizarre that the water "flows" uphill, or 'backwards', like a capillary action, or like liquid nitrogen flowing against gravity. This is because the kilometres-thick ice sheet pushes the lake like a syringe piston, allowing the water to pump-up through narrow conduits inside the ice against the gravity.

There are nine glacial meltwater streams (rivers) in Antarctica, with Onyx River (32km long, flowing near McMurdo station) being the largest among them. The lowest accessible point in Antarctica is Deep Lake at Vestfold Hills, which is 50m below sea level. This lake is extreme hypersaline; with salinity almost equal to that of the Dead Sea. This high salinity brings down the freezing point of water; even at minus 20°C Deep Lake is not frozen.

Fig.4.The Blood Falls (Photo: twentytwowords.com).

Scientists have detected life (few species of Haloarchaea, salt-loving archaeobacteria) in this extreme environment of a double whammy: low temperature and hypersalinity. As the conditions at places like these resemble the extremities of young Earth around 3 billion years ago –at the time when life probably originated– these microbes in the deep lake provide clues on the life's origin and how life could potentially develop on other planets. Alternatively, these life forms might suggest the very last Martians that survived on Mars or the final vestige of life on Earth. At Taylor Glacier in McMurdo dry valley, there is a famous 'five-storey' waterfall, known as the Blood Falls (Fig.4), which originates at the centre this glacier and falls into Lake Bonney. The water is from Brine Lake buried deep within the glacier. The red or crimson colour of the water– which is almost three times more saline than seawater– comes from iron and unique iron oxidising microbes. Iron is picked up from the underlying bedrock, and this iron-rich brine oozes through fissures inside the glacier at high pressures and gets oxidised before falling as a 'blood fall' to enthral we humans!

We were based at Bharati Station (Fig. 5), Larsemann Hills– India's newest and most sophisticated Antarctic research station– for the first 45 days of our stay in Antarctica. In the glaciers of Larsemann Hills, I observed various corrugated surface patterns of the ice sheet carved by the wind–most were in the shape of rhombus, several crevasses and melt water patches. I saw sastrugi everywhere (Fig.6). The melting of troughs of waves by the wind action formed these wave-like features, as I would learn later. At Bharati, the first brief night happened by the end of January, and since then nights started increasing quite rapidly. We left Bharati by the end of February, for another long voyage approximately 3,500 kilometres westward of the same continent,

Fig. 5.Ship m/s Ivan papanin docked on Antarctic Fast ice, with Bharati station in background. Two ball shaped 'radomes' housing radars for satellite communication are also visible. Felix Bast © 2017

towards our second stop, Maitri station–India's oldest Antarctic station still under operation.

As the ship approached the Princess Astrid Coast, around 80 km north of Maitri station, I could increasingly spot frazils–slushy icy formations in the super-cooled sea surface that flows with water with intact waves (of course, waves cannot form if the sea surface is frozen completely, for example, floe, pack ice or fast ice). Frazil ice is indeed the first stage in the formation of sea ice. I also found thin greasy translucent surface layers of sea that flows with water; as if we were sailing through an electrophoresis gel slab; these are indeed called grease-ice; the second stage of sea ice formation. At several locations I could spot several round formations in the frazil; pancake ice–as these are called. The pancakes indeed resembled the real pancakes, with a diameter around 1 m. And there were *Nilas* too– similar to pack ice, but very thin (up to 10 cm in thickness) that bends around waves and swells.

Fig. 6.Sastrugi and Queen Maud Land, Antarctica, aerial photo. Felix Bast © 2017

By the time we reached Maitri Station in March 2017, it was already the onset of long Antarctic winter with shrinking day lengths. The March night sky at Maitri was splendid. As Antarctica remains the most unpolluted place on Earth, in both air pollution and light pollution, you can get some of the clearest views of night sky from here. I could see Orion nebula within the Orion constellation towards northeast, as clear as a blob of haziness and our own galaxy the Milky Way extending in North-South direction with clarity unmatched anywhere; no super high-resolution images can measure up the clarity I saw. Right overhead is the Southern Cross (Crux)– a prominent constellation famous for its inclusion in the Australian flag.

Before the start of the expedition almost everyone had agreed that the southern lights, or Aurora Australis, would be visible only during the mid-winter in Antarctica, which is around July-August, so we will be missing it. While the wintering teams would get ample chance to watch the aurora during the whole of winter, a few of us staying in the summer huts were lucky enough to spot the first aurora at Maitri on the night of 6 March 2017 (Fig.7). Watching the live aurora was a breathtaking, unforgettable experience that we had at Maitri. The news of aurora sighting disheartened some of the winterers next morning, who were furious about why we had not informed them over the radio!

Fig.7. Aurora australis. Felix Bast © 2017

Virtually every night since then, between 10:30 and 12:30, the spectacular celestial fireworks–sans sound– was clearly discernible towards southeast of the station, for the jubilation of whole station. Perhaps the Antarctic silence would then seem to you deafening, and you would long for a background score at least; perhaps Handel's 'music for the royal fireworks' might sound best. "Now most of the sky was covered with swinging, swaying curtains which met in great whirl overhead: lemon, yellow, green and orange"–exactly the same as in the description by the celebrated British explorer Apsley Cherry-Garrard in his beautiful book *The Worst Journey in the World: Antarctic 1910-1913*. On the night of 13 March 2017, the day back home our families and friends celebrated Holi–the festival of colours – we watched the stunning aurora, the variegated Holi colours straight from the heavens. My feeling then has no words in English; perhaps the closest would be 'wabi-sabi' in Japanese; appreciation of beauty which is imperfect, impermanent and incomplete.

Auroras form as charged particles emitted by the Sun during solar flares collide with the particles (gases) of our atmosphere in Earth's magnetic field. In a common bar magnet that we used in school (and prodigies among us attempted to make perpetual motion machines out of them!), the magnetic force is strongest near poles, and that explains why auroras are seen only near the poles. These atomic collisions excite electrons in atoms of gases in the Earth's atmosphere. Like us, super-exited electrons jump too; they jump from lower energy level to the higher level. After a while, the electrons fall back to the lower energy level (again, like us). Various studies have found excitement from a major lottery win falls back to the earlier state within one year! There is a name for it in cognitive psychology: "Hedonic treadmill".The difference of energy is emitted as photons (light). The wavelength of these photons (that is, the colour) depends on which atom is excited; collisions with oxygen produce red and green auroras while that with nitrogen produce pink and purple auroras. Intensity of these auroras depends on the strength of Earth's magnetic field, which changes every single day, as well as that of the solar flares. The solar cycle– increase and decrease in

Continued on page 19

The Anthropocene: Are We In A New Epoch in the Geological Time Scale?

Pradip Kumar Sengupta

During the Holocene epoch, modern humans evolved and enjoyed a stable climate through about 11,700 years. Holocene is the age of development of human civilisation as well as the age of land use change, agriculture and mining. Although Holocene epoch is still continuing, geologists believe that a new epoch 'Anthropocene' is required to be recognised to mark starting of a new epoch. If the Anthropocene epoch is officially accepted, there will be a change in the geological time scale.

The 35th International geological congress 2016 held in Cape Town, South Africa, had a special session to discuss on the impact of the human species on the Earth's system. In that session held on 29 August 2016, experts recommended that a new geological epoch, which may be called the Anthropocene, needs to be declared. However, the concept of Anthropocene is not new and a similar term was used first by Soviet scientists in 1960 to refer to the Quaternary, the most recent geological period marked by the appearance of humans on Earth. Ecologist Eugene F. Stoermer gave a different view and used the term to mark human impact on Earth's atmosphere. In 2008, the Stratigraphy Commission of the Geological Society of London arrived at a resolution that there is merit behind recognising a distinct geological epoch separated from Holocene to mark the human signature on the ecology and geological processes on Earth.

While on the topic of Anthropocene, I would like to share an interesting story from the March 2011 issue of the *National Geographic* that stated:

The word "Anthropocene" was coined by Dutch chemist Paul Crutzen about a decade ago. One day Crutzen, who shared a Nobel Prize for discovering the effects of ozone-depleting compounds, was sitting at a scientific conference. The conference chairman kept referring to the Holocene, the epoch that began at the end of the last ice age, 11,700 years ago, and that—officially, at least—continues to this day.

"Let's stop it, " Crutzen recalls blurting out. "We are no longer in the Holocene. We are in the Anthropocene." Well, it was quiet in the room for a while. When the group took a coffee break, the Anthropocene was the main topic of conversation. Someone suggested that Crutzen copyright the word.

The official recognition of Anthropocene is still pending. But, geologists, ecologists and environmental scientists believe that there is scope for identification of human impact on Earth from geological records that may separate Holocene from Anthropocene.

The word Anthropocene is derived from two Greek words *anthropos* (meaning "human") and *-cene* from *kainos* (meaning "new" or "recent"). Accordingly, Anthropocene refers to a new era marked by widespread human activity on Earth as manifested in changing the management of Earth systems and processes in different physical environments on local to global scales.

What is an epoch?

Epochs form part of the geological timeline of the Earth. All 4.6 billion years of the Earth's life time are split into Eons, Eras, Periods, Epochs and Ages. These divisions are not arbitrary; they reflect major changes in the dominant conditions and forms of life on Earth. Each division is identified by major and minor episodes in the Earth's history as marked by appearance or extinction of organisms

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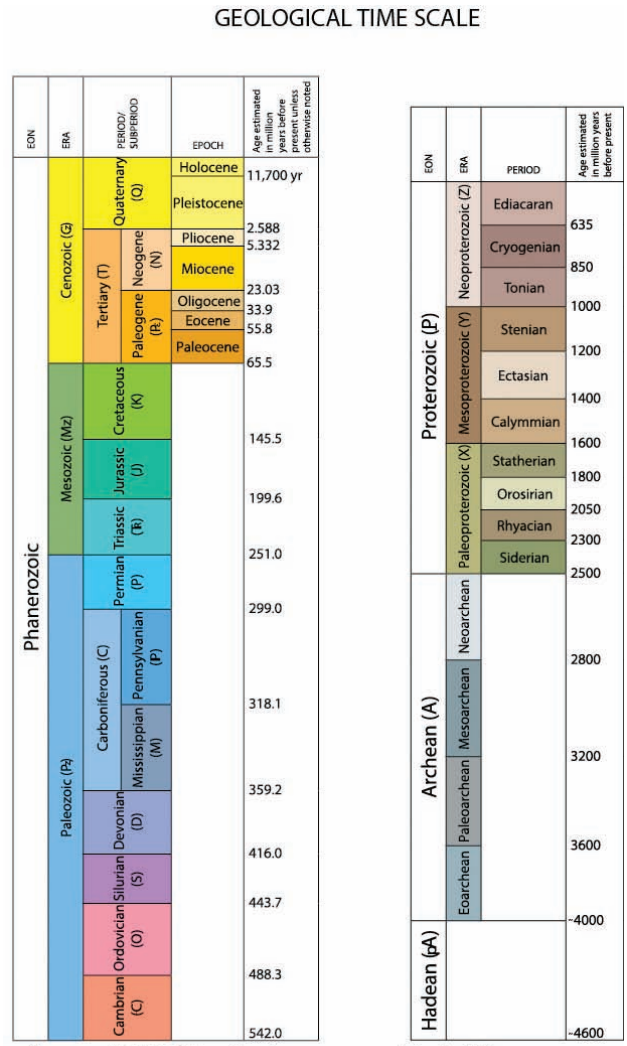
and tectonic or meteoritic activities. The time period since Earth's origin is divided into four Eons namely, Hadean, Archaean, Proterozoic, and Phanerozoic. Phanerozoic Eon is divided into Palaeozoic, Mesozoic and Cenozoic Era. Cenozoic Era that started about 66 million years ago is further subdivided into the Paleogene, Neogene and Quaternary periods. Quaternary period has two epochs: Pleistocene and Holocene. Currently we live in the Holocene epoch of the Quaternary period in the Cenozoic era of Phanerozoic eon.

The Phanerozoic Eon

The current Eon is the Phanerozoic, which started some 540 million years ago. In this Eon major diversification of life took place and almost all species of the animal and plant kingdom evolved. Some of them are still living and some have disappeared from Earth leaving their marks as fossil records. The major episode in this Eon are the emergence and break-up of Gondwanaland, formation of the Deccan Trap, rise of major mountain ranges like the Himalaya, Rocky and Andes , and evolution of present day continents.



Source: USGS, http://pubs.usgs.gov/gip/141/

Figure 1. Geological Time Scale (Source: United States Geological Survey)

What happened in the Quaternary period?

The Quaternary period started about 2.5 million years ago (Mya), marked by the onset of Northern Hemisphere glaciation. Over this short time period, there has been relatively little change in the distribution of the continents due to plate tectonics. Geological records of this period are very prominent and major geological changes include emergence of great lakes, formation of recent alluvium deposits, periodical rising and falling of sea levels and formation of a land bridge between Asia and North America which facilitated migration of human ancestors from Asia to America. The Toba super-volcano in Indonesia erupted around 74,000 years ago and at least 2,800 cubic kilometres of volcanic material was ejected during this super-eruption. The ashfall extended through Arabian Sea in the west to the South China Sea in the east.

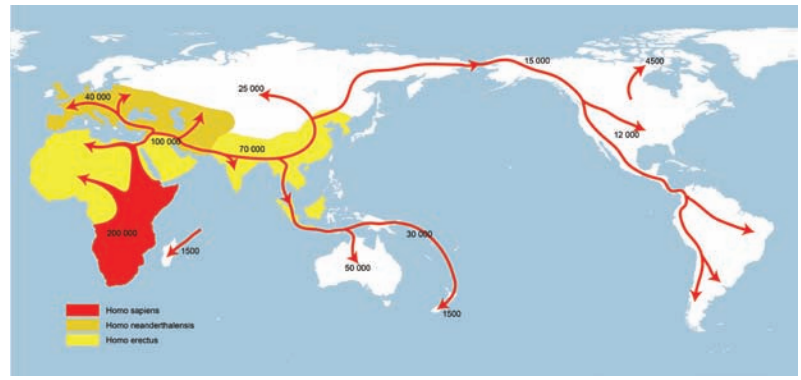


Figure 2. A map of early human migrations by NordNordWest (Source: Wikimedia Commons)

The Quaternary represents the time during which recognisable humans existed. The first hominids to appear on Earth were *Homo habilis* about 2.5 Mya. About 1,00,000 years ago *Homo sapiens* or modern humans started migration from Africa and settled in Europe, Asia and America. At the time of the Toba eruption, the Earth was shared by three other human species, the Eurasian *Homo neanderthalensis,* the *Homo erectus*, and the dwarf *Homo floresiensis.*It is believed that *Homo floresiensis* (nick-named Hobbits) had evolved from *Homo erectus*. Like *Homo sapiens,* all of these human species were also hunter gatherers and stone tool makers. It is not evident from existing records that *Homo erectus* and the *Homo floresiensis* knew the use of fire. Toba eruption caused a sudden cooling of the Earth as the atmosphere was covered by suspended ash and gases. Last traces of Hobbits that were found in Indonesia are believed to be 50,000 years old. Some scientists also suspect human (*Home sapiens*) hands behind the extinction of Hobbits.

The Neanderthal man and the Hobbits became extinct about 40,000 years ago and modern humans, the *Homo sapiens* took over the control of the Earth. The human impact on biodiversity was prolific in the late Quaternary when almost 70 % of all large mammals became extinct due to over-hunting. This started about 50,000 years ago till the closing of the last ice age, i.e., the closing of the Pleistocene and beginning of the Holocene epoch.

The Earth experienced several episodes of climate change and periodical ice age and warm climate during the Quaternary era. The Earth's current epoch, the Holocene, started at the end of the last ice age, around 11,700 years ago.

Holocene Epoch

During the Holocene, modern humans evolved and enjoyed a stable climate

through about 11,700 years. Holocene is the age of development of human civilisation as well as the age of land use change, agriculture and mining. The major events in the human history that changed the Earth during the Holocene as sourced from the website 'Welcome to the Anthropocene' are:

- 11,000 years ago, farming began almost simultaneously in South west Asia, North China and South America
- Between 11,000 and 9,000 years before present, humans domesticated cattle, dogs, sheep and goats in South-west Asia.
- 9,500 years ago, first large urban settlement in Anatolia, Turkey.
- 8,000 years ago, extensive farming and large-scale ecological effects of agriculture in Asia and Europe started.
- 6,500 years ago, rice cultivation started and the effect is manifested in generation of methane, a potential greenhouse gas.
- 3,500 years ago, the first wheel was invented in Mesopotamia, but was not used for transportation.
- 50 BC, signs of soil quality change due to intensive farming became apparent.
- AD 1439, a major advancement of civilisation occurred with the invention of the printing press that led to dissemination of science and literature to a wider section of people.
- 1492 to 1800, the era of colonisation that resulted into global mixing of animal and plant species and diseases.
- 1534 and 1687, period marked by new scientific inventions and development of modern science in mathematics, physics, biology and astronomy. A major event during this period is beginning of coal mining and using it as a major source of energy.
- 1712, the first commercial steam engine started operation
- 1760, Industrial Revolution started.
- 1804, world population reached one billion.
- 1859, mineral oil exploration and exploitation started.
- 1913, the first motor car is developed.
- 1945, the Atomic Age begins.
- 1950 is termed as the year of great acceleration when many new materials were introduced in human life, one of which is plastic.
- 2011, world population reaches 7 billion.
- 2014, atmospheric carbon dioxide reaches 400 ppm that indicates that the Earth system has overstepped a major threshold of the planetary boundaries.

Figure 3.Late Pleistocene landscape of Northern Spain. By Mauricio Antón (Source: Wikimedia Commons)

Why do we need a new epoch?

Way back in the 1870s, an Italian geologist named Antonio Stoppani proposed that the Earth has stepped into a new era, which he labelled the Anthropozoic. Stoppani's term was ignored on the ground that it was unscientific. During Stoppani's time, the Earth system indicators were neither identified nor measured. But, when Paul Crutzen uttered the name 'The Anthropocene', only a few years back, it struck a chord. The scientific community welcomed the new term as it is evidenced by measurable human impacts on the world. The term Anthropocene has become a lot more obvious because human population has roughly quadrupled. The pattern of human population growth is defined by biologist E.O. Wilson as, "more bacterial than primate-like." Moreover, four of nine planetary boundaries have now been crossed; biodiversity loss is phenomenal, atmospheric carbon dioxide has reached to 400 ppm. Since the mid-20thCentury, the Earth has so profoundly changed that the Holocene must give way to a new geological epoch.

Box1 : Planetary boundaries

In 2007 Johan Rockström of the Stockholm Resilience Centre proposed the idea of planetary boundaries which he published in his first landmark paper on the topic in 2009. He identified nine Earth-system processes that are affected by human activities. These processes are: (1) climate change, (2) biodiversity loss, (3) biogeochemical processes, (4) ocean acidification, (5) land use, (6) freshwater use, (7) ozone depletion, (8) atmospheric aerosols, and (9) chemical pollution. He also indicated control variables and boundary values of the variables that indicate safe limits and threshold values.

Geological evidences of the Anthropocene

For marking a geological age and its boundary there must be some evidences on Earth that will indicate to the future geologists that a geological epoch has ended and a new epoch has started. They should find it in the sedimentary layers. For example, the Gondwana age is marked by plant fossils of Glossopteris and the Jurassic is marked by dinosaur fossils. Geologists are considering the following markers as evidences of the Anthropocene:

1. Radioactive elements dispersed across the planet by nuclear bomb tests.
2. Plastic pollution of soil and sediments in current rivers and sea.
3. Soot or black carbon from power stations that left a permanent layer of airborne particulates in sediment and glacial ice.
4. Bones left by the global proliferation of the domestic chicken.
5. High amount of nitrogen and phosphorous in our soils.

Fitting the Anthropocene in geological time scale

The starting point of Anthropocene has still been a matter of controversy. There are two schools of thoughts. One suggests that an early Anthropocene started long back when land use change had started. Others argue differently. The major idea of identifying the Anthropocene as a separate entity thrives on the long and complex relationships of humans with the Earth's ecosystems. The major suggestions in favour

Continued on page 25

Food Binders

K. Masilan and Lidiya Wilwet

Binders are liquid or dough-like substances that harden by a chemical or physical process and bind fibres, filler powder and other particles added to it. Binders are used in different kinds of food products. Binders increase yield, improve the emulsion stability, improve the fibre content, reduce the fat content, improve the texture, bring desirable flavour,bring desirable juiciness, and tenderness.

Introduction

A binder or binding agent is any material or substance that holds or draws other materials together to form a cohesive whole mechanically, chemically, by adhesion or by cohesion. In a more narrow sense, binders are liquid or dough-like substances that harden by a chemical or physical process and bind fibres, filler powder and other particles added to it. Food binders add volume, flavour, texture and firmness to recipes. Binders are used in many different kinds of food, particularly in meat and fish products.

Classification

Binders can be classified according to their chemical nature, namely (1) Carbohydrates such as corn, soya, tapioca, wheat, sorghum, and rice; (2) Proteins such as milk protein, caseinate, transglutaminase (enzyme binder),egg powder; and (3) Hydrocolloids such as gelatin, collagen, xanthan gum, carrageenan, and alginate.

Carbohydrates

Examples of carbohydrate food binders include potato starch, flour, eggs and tapioca flour. Potato starch is a fine starch that has minimal nutritional value and contains very small amounts of protein or fat. Potato starch makes an ideal food binder because it has a neutral taste, clear colour, high binding strength, long texture and a minimal tendency to foaming or yellowing. Potato starch contains approximately 800 ppm phosphate bound to the starch; this increases the viscosity and gives the solution a slightly anionic character, a low gelatinisation temperature (approximately 60°C) and high swelling power. Manufacturers commonly use potato starch as a food binder in potato chips, hot dogs, pastry, breads, instant soups and pre-packaged grated cheese. Additionally, manufacturers use potato starch to add texture and volume to many food products including packaged desserts.

Flour is another commonly used food binder. Flour adds volume, texture and taste to food recipes. You can use flour as a binder to make both savoury and sweet dishes. You can bake, fry, boil and steam flour to produce different food textures. Mainly two types of flours are widely used as food binders,

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namely oat flour and sorghum flour.

Oat flour has several applications in food industry, namely it is used as texture and flavour enhancer during the production of chicken sausage. Similarly the addition of oat flour increases water holding capacity as well as it yields 5% increase in protein content in some burgers. Likewise, the incorporation of oat flour increases the cooking yield in meat *kofta* as well as chicken *kofta*. Notably, the addition of oats increases the emulsion stability of chicken meat patties.

Use of sorghum flour as a food binder improves the taste and quality of low-fat beef burgers, increase in the emulsion stability of chicken nuggets, and also provides higher cooking yield in chicken patties.

Tapioca flour is another food binder used in many desserts because it thickens at a lower temperature than corn starch and remains stable when frozen. Finely ground tapioca flour is used as a food binder to make pie fillings. Also tapioca flour is used to produce a dessert's glossy finish that makes the product look more appetising. Tapioca flour improves the emulsion stability and texture in some burgers. Further, you can use tapioca flour as a binding agent to thicken soups, stews, and sauces. Recipes for many baked goods specifically call for tapioca flour because this binder provides a chewier texture than other types of food binders.

Proteins

Egg is food binder commonly used in cooking. Eggs coagulate, emulsify, add texture and colour to recipes and manufactured food products. As a binder, eggs can turn a liquid food into a semi-solid or solid. The coagulation binds ingredients together supporting the formation of structures during the baking process. Egg-powder (protein-based binder) improves physico-chemical and organoleptic properties (properties that can be sensed by sense organs) of meat nuggets.

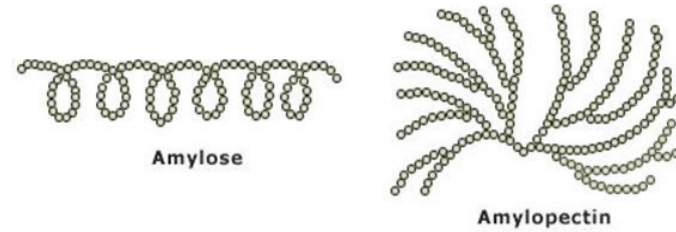
Food texture can be manipulated by the addition of hydrocolloids (substances which form a gel in the presence of water) in processed food products. As a definition, 'hydrocolloid' means particles of 10 to1000 nanometre (nm) in diameter dispersed in water as a continuous phase. Alternatively, the term refers to poly saccharides and proteins which are used in a variety of industrial sectors, including foods, to control and regulate such a colloidal state. Hydrocolloids exhibit multiple functionalities in foods, including thickening, gelling, water holding, dispersing, stabilising, film forming, and foaming and have been used as a texture modifier in almost every kind of processed food products, including mayonnaises, dressings, dessert jellies, ice creams, and many others. Food polysaccharides are obtained from various natural sources; agar and carrageenan come from seaweeds, guar gum and locust bean gum from plant seeds, pectin from citrus or apple peels, xanthan gum and gellan gum from microorganisms, and chitin and chitosan from animals

Beta-glucan (carbohydrate) and carrageenan (hydrocolloid) are used together for increasing the flavour and emulsion stability of chicken patties and chicken nuggets. Likewise, it also increases the water holding capacity of chicken *kofta* and also increases the nutritional quality of chicken sausage.

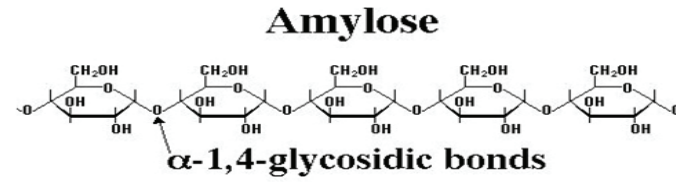
Mechanism behind food-binding properties of starch

Characteristics of starch:

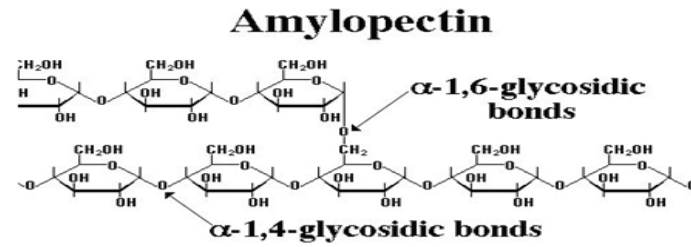
- Starch is a polysaccharide.
- It has two components, namely amylose (20-30%) and amylopectin (70–80%),which constitute the structure of the compound.



Because of tightly packed structure, amylose is more resistant to digestion than amylopectin and is therefore called 'resistant' starch.



Amylose is a linear molecule comprising of 1,4 linked alpha-D-glucopyranosyl units. There is a small degree of branching by 1,6 alpha linkages. Smaller of the two polysaccharides making up starch,



amylopectin is a highly-branched molecule comprising both 1,4 linked and 1,6 linked alpha-D-glucopyranosyl unit branches non-randomly distributed in clusters. When put in cold water, starch granules absorb a limited amount of water. At higher temperatures (usually higher than 65°C) irreversible swelling of starch granules may occur, known as 'gelatinisation'. Gelatinisation temperature depends on several factors such including the source, namely, plant species, mutant variety, and granule size. Surface coating with lipids leads to starch-lipid interaction, which alters the gelatinisation temperature. Increased translucency and increased viscosity may be observed during gelatinisation.

Mechanism behind food-binding properties of proteins

Proteins can be used as a food binder both at high temperature and cold temperature. Fish protein can be used as a binder at high temperature. During preparation of fish paste by heating fish muscle at 90°C for 30 min, the muscle protein undergoes gelling at the temperature of 40°C and hence starts improving the mechanical and functional properties of fish paste. This is followed by the endogenous transglutaminase (TGase) catalysing the formation of

covalent bonds between adjacent proteins and thus improving the gel structure further.

Cold temperature food binding involves the aggregation of myofibrillar proteins (rod-like units of a muscle cell) without the denaturation/ aggregation which occurs during heating. Transglutaminase (TG) present in proteins shows activity even in cold temperatures below 4°C. This property is important when binding raw meat under refrigeration condition to produce restructured products. In cold binding, aggregation is mostly due to the TG activity

Mechanism behind food binding properties of food hydrocolloids

Gelation is an important functional property of food hydrocolloids and hence used as a texture modifier. During heating, molecules in solid state change to gel phase.The molecules in double-helix shape change into loose coils. On absorbing water, it gives a gel-like appearance. On cooling, the molecules revert back to the double-helix structure.

Carrageenan, a hydrocolloid used in foods, binds water during the thermal processing of meat products and becomes a gel on cooling. It is an excellent water absorber. The temperature of swelling and gelling depends on the carrageenan type and the ionic environment.

Gelatin is a water-soluble protein and hydrocolloid. As a food binder, it can give desirable viscosity and bondage. Most edible gelatin gels liquefy at an extremely low temperature (28°C). Gelatin is one of the rare proteins known to have good foaming properties. Gelatin solution cooled to 10°C has the consistency of thick egg-white

Alginates are used as hydrocolloid in foods. Sodium alginate is a cold binder and its efficiency can be improved by adding a low concentration (1g/kg) of calcium chloride ($CaCl_2$). At higher concentrations (10g/kg), $CaCl_2$ reduces the binding capability of alginate.

Conclusions

Binders are used in different kinds of food particularly in meat products. The functions of binders include: (i) Increasing yield, (ii) improving the emulsion stability,(iii) improving the fibre content (iv) reducing the fat content,(v) improving the texture,(vi) bringing desirable flavour,(vii) bringing desirable juiciness, and(viii) bringing desirable tenderness. Commercial binders in food products include (i) oat flour,(ii) sorghum flour,(iii) β-glucan and carrageenan,(iv) corn flour(v) egg powder, (vi) legume flour, and (vii) tapioca flour.

Starch is a polysaccharide and has two components, namely amylose(20-30%) and amylopectin(70–80%). At higher temperatures (usually higher than 65°C) irreversible swelling of starch granules known as 'gelatinisation' occurs.

Food binding due to protein occurs at both low temperature as well as high temperature. Carrageenan, gelatin and alginate are important hydrocolloids used as binders in food. ■

The Anthropocene: Are We In A New Epoch in the Geological Time Scale? *(Continued from page 28)*

of an early Anthropocene are:

1. Beginning of use of fire.
2. From the beginning of large-scale agriculture in various parts of the world between eight and five thousand years ago. (Proposed by U.S. geologist William Ruddiman).

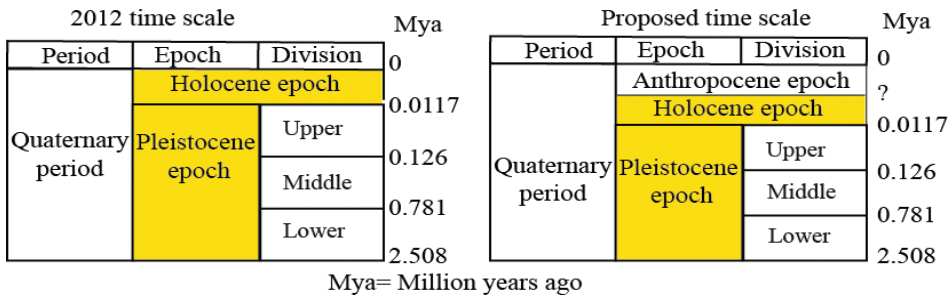


Figure 4.The existing and proposed geological time scale.

3. From the extinction of many large mammals in the late Pleistocene (mega fauna extinction)
4. From the European invasions of the Americas in the 1500s.
5. Beginning of the industrial revolution

In 2005, one of Australia's leading climate change scientists Will Steffen and others coined the term *Great Acceleration* to define the dramatic social-environmental changes that happened after 1950. They have shown in their article named 'The Trajectory of the Anthropocene: The Great Acceleration' that since 1950 there had been phenomenal change in both socioeconomic and natural systems. Great acceleration can be precisely identified by a sharp increase in world population, GDP, water consumption, energy use, fertiliser consumption, etc. The natural system also underwent changes as a result of increased atmospheric carbon-di-oxide concentration, surface temperature, ocean acidification, domesticated land and loss of tropical forests. The proponents of great accelaration suggest that 1950 should be the cut off year from when the Anthropcene should be counted.

When the Anthropocene epoch is officially accepted, there will be a change in the geological time scale. The last universally accepted geological time scale was released in 2012. If the Anthropocene is accepted, the quaternary period will be modified.

Conclusion

At the 35th International Geological Congress in Cape Town, scientists debated over two points: the cut-off year and the global markers of the Anthropocene. They have unanimously agreed that the Holocene is over and have further realised the need for the stratigraphic materials to mark the epoch. Two scientists, Simon Lewis and Mark Maslin assessed the anthropogenic signatures in the geological records necessary for recognising the new epoch. From their findings, two dates are under consideration – 1610 and 1964 – that may mark the beginning of the Anthropocene. ■

The Nipah virus and its impact on human health



Balwinder Singh, Kalyani Supriya and Rajeev Aggraval*

Nipah virus (NiV) infection is an emerging transmittable viral disease. There is no vaccine against this deadly virus for either humans or animals, but the risk of NiV infection can be avoided by taking proper precautions like isolating NiV patients, avoiding consumption of fruits bitten by birds and animals and avoiding toddy drinks collected from areas with a large bat population. Preventive measures should focus on direct eradication by mass culling of contaminated and in-contact pigs and antibody inspection of high-risk farms to prevent future outbreaks.

Nipah virus (NiV) infection is an emerging transmittable viral disease with a zoonotic origin that can be transmitted from animals to human and vice versa.The disease was first discovered in domestic pigs in the village of Sungai Nipah in Malaysia in 1998 and was recorded in Singapore in 1999. The deadly virus is asymptomatic; that is, shows no symptoms of the disease immediately after infection. It frequently infects animals such as pigs and fruit bats with incubation period of 5 to 14 days, and sometimes much longer–up to 45 days in a few cases. The virus has received scientific attention as cases of NiV infection rises continuously and a possible way to eradicate this problem still missing, making it a global issue.

Source

The route of the transmission of the virus varies, but most commonly the virus is found in the flying foxes or fruit bats of the Pteropus species (family Pteropodidae), which are a natural host of NiV. The virus is present in the urine, saliva and faeces of the bats. Nipah infection has been recorded in several species of domestic animals such as dogs, cats, goats, and horses. Due to its zoonotic potential, it can easily spread from fruit bats to other animals and to humans through bites or through contamination of fruits with excretions and secretions of bats. The molecular entity which causes Nipah virus problem is an RNA virus of the Paramyxoviridae family (Henipavirus genus), which is very closely related to the Hendra virus that caused a fatal disease formerly known as acute equine respiratory and neurological syndrome infection in

horses and humans which was first recorded in the Brisbane suburb of Hendra, Australia, in 1994.

Effects on human health

The infection by this deadly virus is an emergent issue and poses a huge challenge in India as well as worldwide. With increase in the numbers of cases scientists are vigorously working to identify and possible find a remedy for this deadly infection. The disease has various symptoms in humans. It starts with a headache, fever and then slowly progresses into drowsiness, disorientation, mental confusion, and maybe coughing. Shortly, it infects the central nervous system and respiratory system, and within 24-48 hours the patient goes into coma and potentially death.

Reports of outbreaks of Nipah virus infection show that two outbreaks occurred in 2001and 2007 in the state of West Bengal with a total of 50 fatalities. In 2018 there

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Table 1. Nipah virus outbreaks in India

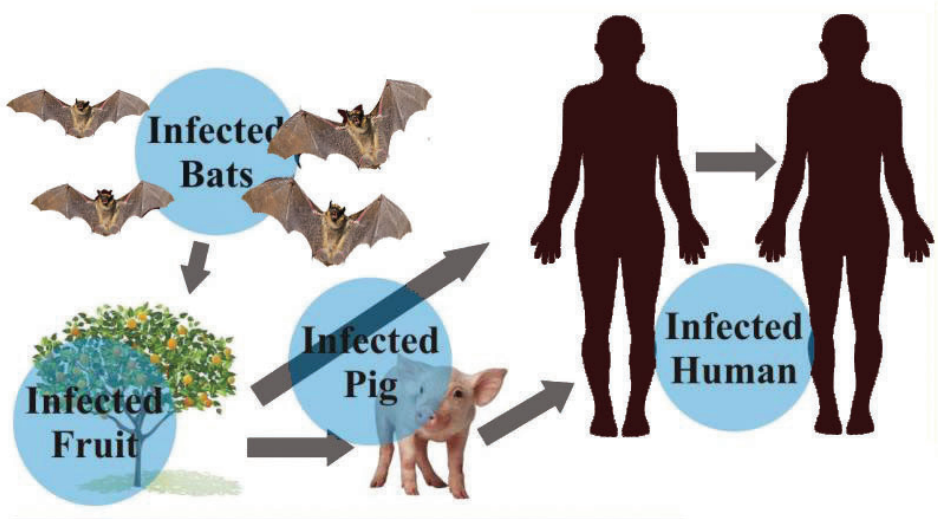
S. No.	Year/month	Location/district	Impact
1.	2001/ Jan-Feb	Siliguri (West Bengal)	61 cases and 45 fatalities
2.	2007/ March	Nadia(West Bengal)	5 fatalities
3.	2018/May	Village: Changaroth (Dist. Kozhikode, Kerala)	22 cases and 12 fatalities
4.	2018/ May	Nahan Town(District Sirmour, Himachal Pradesh)	8 dead bats found in Union School
5.	2018/May	District: Mangaluru(Karnataka)	2 fatalities
6.	2018/May	Telangana	2 fatalities

Table 2.Nipah virus outbreaks in Bangladesh

Sr. No.	Year/month	Location/district	Impact
1.	2001/ April-May	Meherpur	13 cases and 9 fatalities
2.	2003/ January	Naogaon	12 cases with 8 fatalities
3.	2004/Jan-Feb	Manikganj and Rajbari	42 cases and 14 fatalities
4.	2004/Feb–April	Faridpur	36 cases with 27 fatalities
5.	2005/Jan	Tangail	12 cases with 11 fatalities
6.	2005/Jan-Feb	Thakurgaon	7 cases and 3 fatalities
7.	2007/Feb -May	Kustia	8 cases and 5 fatalities
8.	2011/Feb	Hatibandha, Lalmonirhat and Dinajpur	46 cases and 26 fatalities
9.	2015/Feb	Nilphamari, Faridpur, Magura, Ponchoghor, Naugaon, and Rajbari	9 cases and 6 deaths

was a serious outbreak in Kerala which claimed 12 lives. Sporadic cases were also reported from Karnataka and Telangana in May 2018 (Table 1).

Between 2001 and 2015, nine outbreaks of Nipah virus were reported in Bangladesh, which claimed a total of 109 lives (Table 2).



Reasons behind NiV outbreaks

NiV has existed in bats for centuries and has not undergone any evolutionary change. So it is assumed that various ecological factors like human interventions such as rapid urbanisation, which interrupt the natural habitats of bats, may have contributed to the emergence of Nipah virus as a threat to humans. Changes in climatic pattern in the Indian subcontinentmay have also been responsible for triggering the spread of NiV infection in the region. In Malaysia and Singapore, transmission to humans has always been from direct contact with the excretions or secretions of infected pigs. However, in Bangladesh, NiV outbreaks suggested that transmission occurred from bats without an intermediate host by way of drinking of raw palm sap contaminated with bat excretion.

The identification and confirmation of the NiV infection is done by techniques such as the serum neutralization test, ELISA, and RT-PCR method. NiV is classified as a biosafetylevel-4 (BSL-4) agent, requiring the tests should be carried out in special labs to prevent its spread. There is no vaccine against this deadly virus for either humans or animals, but to reduce the risk of NiV infection, precautions should be taken while dealing with patients by wearing protective coverings and isolating the patient, avoid eating fruits bitten by birds and animals and avoid toddy drinks collected from areas where a large number of bats found. The treatment for NiV infection is limited to supportive care. Preventive measures should focus on direct eradication by mass culling of contaminated and in-contact pigs and on antibody inspection of high-risk farms to avoid future outbreaks. ■

Recent Developments in Science and Technology

Biman Basu

Presence of water ice in the polar caps of Mars has been known and there have been speculations about the presence of liquid water on the Red Planet, but without any confirmation. Now scientists have found evidence of the presence of a large reservoir of liquid water under Planum Australe– the southern polar plain on Mars. A lake of liquid water has been discovered some 1.5 kilometres below the polar ice cap.

Meghalayan - A new chapter in Earth's history

On the basis of radiometric dating and other sources of evidence, it is now known that the Earth formed about 4.6 billion years ago. Geologic time is the extensive interval of time occupied by the geologic history of Earth. Geologic time is, in effect, that segment of Earth history that is represented by and recorded in the planet's rock strata.

The geologic time scale can be termed as the "calendar" of events in Earth's existence. It subdivides all time into slices or units of abstract time called eons, eras, periods, epochs, and ages. Each of these units of time is given a name based on stratigraphy, which is the correlation and classification of rock strata. The fossil forms that occur in the rocks provide the chief means of establishing a geologic time scale. One of the most widely used standard charts showing the relationships between the various intervals of geologic time is the International Chronostratigraphic Chart, which is maintained by the International Commission on Stratigraphy (ICS), the official keeper of geologic time. The most recent addition to the list is an age named after the north-eastern Indian state of Meghalaya.

Our current era is the Cenozoic, which is itself divided into three periods – Paleogene, Neogene, and Quaternary. We live in the most recent period, the Quaternary, which is again subdivided into two epochs: the current Holocene, and the previous Pleistocene, which ended 11,700 years ago. We currently live in what is called the Holocene, which began at the end of the last ice age, when glaciers started retreating. In that time, humans learned how to farm, built cities, and started launching rockets into space. The Holocene

Subdivisions of the Quaternary System

System/ Period	Series/ Epoch	Stage/ Age	Age (Million years)	
Quaternary	Holocene	Meghalayan	0	0.0042
		Northgrippian	0.0042	0.00833
		Greenlandian	0.00833	0.0117
	Pleistocene	'Tarantian'	0.0117	0.126
		'Chibanian'	0.126	0.781
		Calabrian	0.781	1.80
		Gelasian	1.80	2.58
Neogene	Pliocene	Piacenzian	Older	

In the geologic time scale, the Meghalayan is the latest age or uppermost stage of the Quaternary.

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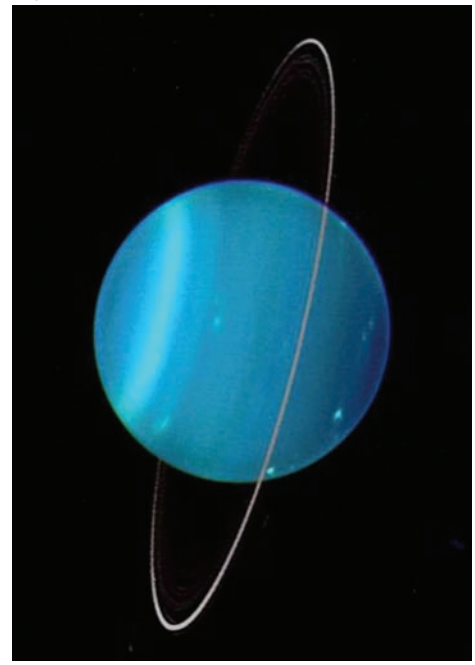
is further subdivided into three ages – the Greenlandian, the Northgrippian, and the youngest addition, the Meghalayan. The Greenlandianage runs from 11,700 to 8,200 years ago; the Northgrippan runs from 8,200 to 4,200 years ago, and finally, the Meghalayan runs from 4,200 years ago to the present. Thus the Meghalayan is the latest age or uppermost stage of the Holocene. The Meghalayan age was officially ratified by the International Commission on Stratigraphy in July 2018 along with the two others – the Greenlandian and the Northgrippian. Evidence of the 4,200-year climatic event has been found on all seven continents.

A portion of an Indian stalagmite that defines the beginning of the Meghalayan Age. (Credit: IUGS website)

According to geologists, around 4,200 years ago, a devastating drought lasting for at least two hundred years caused the collapse of civilisations around the world. It severely disrupted civilisations in Egypt, Greece, Syria, Palestine, Mesopotamia, the Indus Valley, and the Yangtze River Valley. Effects from the drought were felt around the world. Evidence of the prolonged drought has been found in stalagmites (rock formations that form on the floor of a cave due to the accumulation from ceiling drippings) in India, where the lack of monsoon rains is represented by changes in oxygen isotopes in the stalagmites. The clinching evidence came from a stalagmite found in a cave in Meghalaya in the form of chemical signatures, which provided the basis for naming the new geological age. To win a classification, a slice of geological time generally has to reflect something whose effects were global in extent, and be associated with a rock or sediment type that is clear and unambiguous. In the present case, the global nature of the drought, the permanent record visible in rock layers, and the lasting effects to life on Earth meant that this moment in history is enough to qualify as the beginning of a new geological age.

'Cataclysmic' collision tilted Uranus on its side

Uranus is unique among the planets of our solar system – its axis of rotation tilts 97 degrees from the vertical so that it lies almost in the orbital plane that makes the planet virtually "roll" on its side like a barrel as it goes round the Sun. Because of its tipped-over axis, Uranus' polar regions receive more heat from the Sun than do its equatorial regions. Another peculiarity of Uranus is that it spins in a direction opposite that of the other planets. Uranus also has a "very, very strange" magnetic field and is extremely cold, even though it "should" be warmer



With its axis of rotation inclined 97 degrees to the vertical, Uranus lies almost in the orbital plane that makes the planet virtually "roll" on its side like a barrel as it goes round the Sun.

Scientists have long pondered over the causes of Uranus' unusual tilt, but without any plausible answer. Now they seem to have found one: A major collision with another object in the distant past, as a new study has revealed. The study was carried out by astronomer Jacob Kegerreis and his colleagues at Durham University's Institute for Computational Cosmology in the UK. The study confirms that this collision with a huge object – which was almost twice the size of Earth – could have led to the planet's extreme tilt and other odd attributes.

To better understand how the impact affected Uranus' evolution, the team ran the first-ever high-resolution computer simulations of different massive collisions with the ice giant to try to work out how the planet evolved. They ran more than 50 different impact scenarios to see if they could recreate the conditions that shaped Uranus' evolution. The researchers suspect that the colliding object was probably a young proto-planet, made up of rock and ice. The research confirms a previous study which said that Uranus' tilted position was caused by a collision with a massive object during the formation of the solar system about 4 billion years ago. According to the simulations, the collision was strong enough to affect Uranus' tilt, but the planet was able to retain the bulk of its atmosphere. The simulations also suggested that debris from the colliding object could form a thin shell near the edge of the planet's ice layer and trap the heat emanating from Uranus' core. The trapping of this internal heat, the researchers said, could in part help explain the extremely cold temperature of the planet's outer atmosphere of minus 216 degrees Celsius. The simulations further show that the impact could have created molten ice and lopsided lumps of rock inside the planet, which could help explain Uranus' tilted and off-centre magnetic field (*The Astrophysical Journal*, 2 July 2018 | DOI: 10.3847/1538-4357/aac725).

Says Kegerreis, "Our findings confirm that the most likely outcome was that the young Uranus was involved in a cataclysmic collision with an object twice the mass of Earth, if not larger, knocking it on to its side and setting in process the events that helped create the planet we see today". According the researchers, the discovery could help us understand exoplanets outside our own

solar system. Uranus is similar to the most common type of exoplanets discovered so far and so researchers hope they can use the discovery to understand more about how those other worlds evolved and what they might be made of.

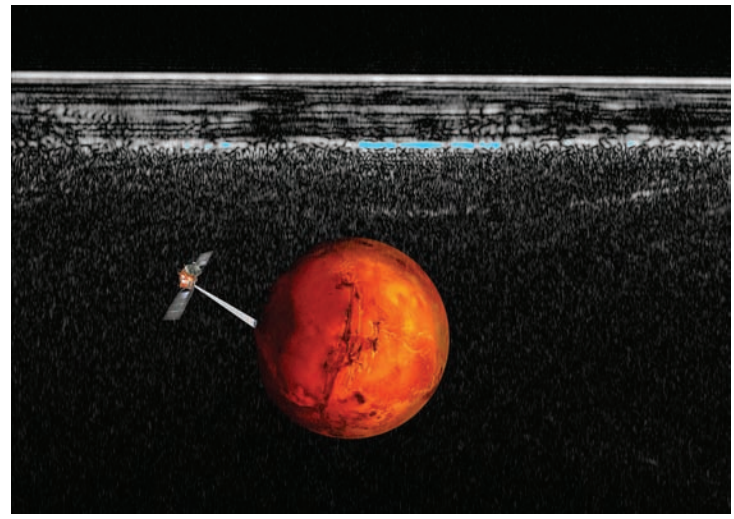
The research could also help explain the formation of Uranus' rings and moons. The impact suggested by the simulations could jettison rock and ice into orbit around the planet, which could have then clumped together to form the planet's inner satellites and perhaps altered the rotation of any pre-existing moons already orbiting Uranus, the researchers said.

Liquid water found on Mars

Presence of water ice in the polar caps of Mars has been known and there have been speculations about the presence of liquid water on the Red Planet, but without any confirmation. Now scientists have found evidence of the presence of a large reservoir of liquid water under Planum Australe– the southern polar plain on Mars. A lake of liquid water has been discovered some 1.5 kilometres below the polar ice cap. The discovery was made by a team of Italian scientists using three years' worth of data from the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument on the European Space Agency's *Mars Express* orbiter. According to the scientists who did the study, the potential lake is at least a few metres deep, and might be a fixed, steady feature of the subsurface. If confirmed, this would be the first-known reservoir of liquid water on present-day Mars which may provide a vital clue in the search for past or even present life on the Red Planet (*Science*, 25 July 2018 | 10.1126/science.aar7268 (2018).

"It's a very promising place to look for life on Mars," says Roberto Orosei, a planetary scientist at the National Institute of Astrophysics in Bologna, Italy, who led the study. "But we do not know for sure if it is inhabited." On Earth, similar 'subglacial' lakes are home to microbial life.

For the past 12 years the MARSIS instrument on-board the orbiting *Mars Express* has mapped the Martian underground using beams of low-frequency radar pulses, which can penetrate up to several kilometres beneath the surface. The radar pulses pass relatively unscathed through most substances, but reflect back up to the spacecraft each time they encounter boundaries between layers of different materials, such as the interface of ice and bedrock. That reflection is particularly strong at interfaces with liquid water, and shows up as a distinctively bright spot in visualisations of the data.



Artist's impression of the Mars Express spacecraft scanning Mars from orbit. The background shows the radar cross-section of the layers below Mars' south polar region as recorded by the MARSIS instrument; the blue layer denotes water.

Bright spots beneath Mars's southern ice cap were first detected in 2007. The Italian team reprogrammed MARSIS to employ a more intensive scanning mode and then surveyed Planum Australe 29 times with the instrument between 2012 and 2015. Every time the new MARSIS readings revealed a consistent 20-kilometre-wide bright spot nestled in a bowl-like depression beneath the ice cap in Planum Australe. The team then spent almost a year analysing the data, and another two years writing their paper and attempting to rule out non-aqueous explanations for what they had seen.

Scientists have found evidence that billions of years ago, Mars was much wetter and a more Earth-like place where water pooled in seas, carved enormous canyons and bubbled from hot springs. Many astrobiologists speculate that life may have had no difficulty getting started there. But then something went wrong that transformed the wet Mars into a desiccated orb of dried-up ocean-, river- and lakebeds. Robotic missions like the *Curiosity* still find surprising echoes of that bygone time, such as patches of water-ice frost forming on rocks as well as water droplets condensing like dew on a lander's leg. Mars-orbiting spacecraft have also glimpsed what might be rivulets of water flowing down sun-bathed crater walls at the height of Martian summer. Still, the water that once flowed across the Martian land had to go somewhere. Some of it was likely lost to space due to Mars's weak gravitational field, but scientists believe a significant fraction of the planet's aqueous inventory never really left and may have just frozen below ground. Now it appears not all of that buried watery wealth is frozen after all.

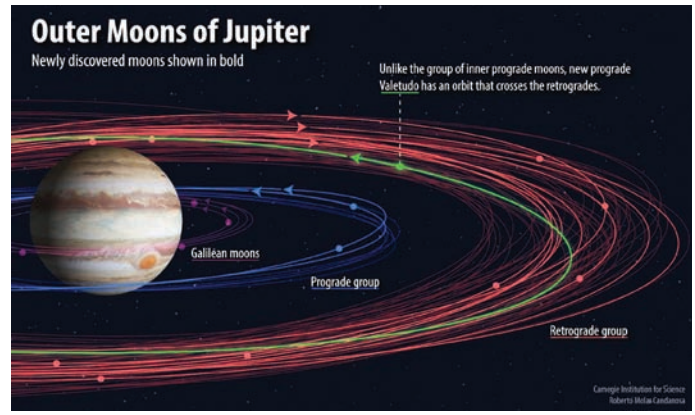
Jupiter gets 12 new moons

Jupiter is the largest planet of the solar system and it has the largest number of moons. Till recently, the total number of moons of Jupiter was taken to be 67. On 17 July 2018, the International Astronomical Union (IAU) announced the discovery of 10 new moons orbiting Jupiter. These along with two announced earlier in June 2017 bring the total number of Jupiter's known natural satellites to 79. Saturn, Jupiter's closest rival, has a mere 62 moons orbiting around it. The four largest of Jupiter's moons were discovered by the Italian astronomer Galileo Galilei using a small home-made telescope more than 400 years ago, in 1610. Later, over the years, dozens of moons were discovered using more powerful telescopes and space probes.

The discovery of the new moons came serendipitously. Astronomer Scott Sheppard of the Carnegie Institution for Science in Washington, DC, USA was looking for Planet Nine, a hypothetical planet many astronomers think should exist in the distant reaches of our solar system beyond Pluto. He and his team have been photographing the skies with some of today's best telescope technology, hoping to catch sight of this mysterious ninth planet. It so happened

that around mid-2017, Jupiter happened to be in an area of sky the team wanted to search for Planet Nine.

The Carnegie team used the Blanco 4-metre aperture (Blanco 4m) telescope located at the Cerro Tololo Inter-American Observatory in Chile. The telescope is ideally suited for spotting potential new moons because the camera installed on it can photograph a huge area of sky at once and also because it is particularly good at blocking stray light from bright objects nearby such as Jupiter that might wash out fainter ones. "It has allowed us to cover the whole area around Jupiter in a few shots, unlike before, and we were able to go for fainter objects than people have been able to go before," says Sheppard.



Jupiter's new moons (Credit: Carnegie Institution for Science)

When Sheppard's team turned the Blanco 4m telescope towards their search region here they expected find Planet Nine, several previously unidentified objects were spotted near Jupiter. The research team used other telescopes to follow up on these objects and confirm that they were orbiting Jupiter. All of the new moons around Jupiter are on average about three kilometres wide, which may be the reason why they had been left undiscovered until now, when scientists found them using incredibly sensitive telescopes. One of new moons turned out to be an oddball.

Jupiter's moons orbit the planet in broadly two groups. The moons closer to Jupiter, including the four Galilean moons, orbit Jupiter in the same direction as the planet's rotation, which astronomers call a prograde orbit. The outer moons move in the opposite direction – a retrograde orbit. But one of the newly discovered moons, which has been named Valetudo, moves in an unusual way. It is positioned where the outer, retrograde moons are, but it orbits Jupiter in the prograde direction. Sheppard says. "It's like it's going down the highway in the wrong direction."

According to the researchers, finding how the objects came to be formed and orbit around Jupiter could shed light on the formation of our solar system. For instance, the new moons are so small that they would be influenced by any gas and dust around the planet – the fact they have managed to survive suggests they formed after the rotating disk of gas and dust that surrounded the Sun formed into planets. ■

An Antarctic Mystery: Physical Spectacles of the Frozen Continent *(Continued from page 31)*

the number of sunspots– that completes once in every 11 years on average is the major factor that influences auroras though; the last peak happened in 2014 and the next peak expected in 2025.After returning from the Maitri, we could still see the aurora from our ship, very clearly indeed. I found yet another peculiarity of aurora; the camera (I was using Canon EOS 60D) captures it far better than our eyes, perhaps owing to the longer exposure time that I had set (around 2 seconds).


Fig.8. Sun dogs at Antarctica. (Ian Phillips at Casey Station © Australian Antarctic Survey)

During Antarctic winters when the temperatures slips below minus 40°C, blowing soap bubble would be a fun activity; the bubbles would instantaneously freeze into transparent ice balls, before breaking to three dimensional wafer-thin ice pieces. One can instantaneously generate cloud-like formation in air by sprinkling or splashing the boiling water; the steam sublimates to ice that would appear as cloud. The water droplets in the atmosphere naturally freeze to form 'diamond dusts'–tiny hexagonal ice crystals that glitter with sunlight (but does not cause fog). These ice crystals refract the sunlight to cause an extraordinary phenomenon called 'sun dogs'– two more suns appearing on either side of the sun, 22 degrees apart (Fig. 8). At times, these ice crystals also create an illusion called '22 degrees halo' with a ring around the sun at 22 degrees from the centre.

Then there is another phenomenon called "green flash"; just before the sunset you could see a green flash emanating from the Sun, sometimes appearing as a ray projecting skyward from the point of sunset. This green flash in fact happens everywhere on Earth, but hardly lasts for a second or two elsewhere, but in Antarctica it lasts for several minutes. This optical illusion is caused by refraction of sunlight, and is enhanced by the mirage. Due to the shorter wavelength, blue colour is expected to refract the most, but it will also be scattered out much faster (therefore sky, ocean, Antarctic blue-ice, etc., appear blue), rendering the green colour to our eyes. Antarctica amazes its visitors with so many optical illusions seen nowhere else on Earth! ■