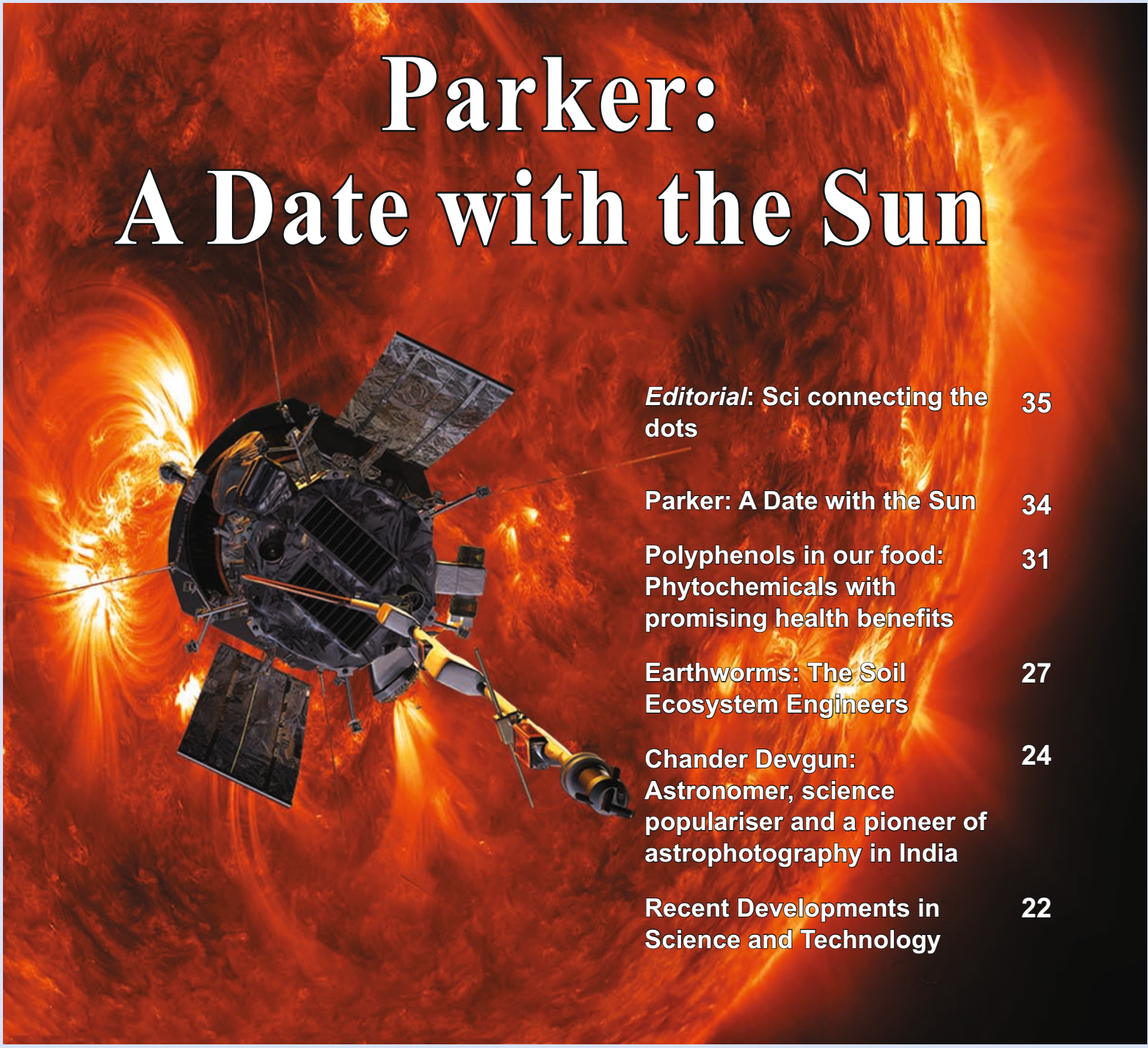
R.N. 70269/98
ISSN : 0972-169X

Postal Registration No.: DL-SW-1/4082/18-20
Date of posting: 26-27 of advance month
Date of publication: 24 of advance month

# DREAM 2047

October 2018 Vol. 21 No. 1 Rs. 5.00



# Parker: A Date with the Sun



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

EDITORIAL

# Sci connecting the dots

***Dr. T. V. Venkateshwaran***

With a gleam in eyes, bubbling with excitement, she held forty-one different types of the leaf collected during the nature walk. "I was able to identify more types of leaves than the others, look how varied they look like" excitedly says Bipasha Chakraborty student from Shri Shri Ravi Shankar Vidhya Mandir, Tripura.

She was one among the 60 students from four of the eight north-eastern states who attended the semi-finals of "Sci-Connect", a unique programme by Vigyan Prasar designed to sensitise young children in upper primary to secondary levels about science in daily life held at Gangtok. It took a tedious journey of three days to reach Gangtok from her remote village. On the way, she was injured, yet spiritedly she says "I have no regrets that I have to face small problems while coming here. I am thrilled that I am part of this competition," she says.

Ismotora Khatum, a class nine student from Assam, inspired by the programme, dreams of becoming a teacher and a researcher. She wants to do research but also communicate the joy of discovery to other children. She was a participant of semi-finals held at Aizwal, Mizoram between 28 and 30 August. Brikchana Karki from Government Girls Senior Secondary School, Sikkim, is keen to take part in the event next year. She says "it was great exposure and good learning experience".

Covering the entire North-East, states of Manipur, Nagaland, Tripura Sikkim, Arunachal Pradesh, Assam, Meghalay,a and Mizoram the sci-connect programme is executed through the various State Councils of Science and Technology. This year more than 9,000 students from NE registered to take part, a quantum jump from the 6,000 of last year.

Unlike the run-of-the-mill competitive contest, the aim is not just to award the talent but nurture curiosity and inspire them towards sciences. Thus the competitive test administered to all the 9,000 registered participants went beyond the school curriculum and included the content of select 35 films prepared by Vigyan Prasar on various aspects of science and technology. The video programmes covered a variety of topics ranging from biographies of eminent scientists S.N. Bose and J.C. Bose to 'how a radio telescope works', 'network theory', 'daytime astronomy', 'probability', 'calculus', 'Large Hadron Collider' and 'relativity'. The films were sent to all the schools registered under the respective state council to take part in the sci-connect.

Top 15 students from each NE state were selected as the state-level winner. They were invited to semi-finals held at Gangtok, and Aizwal held during August 2018. From both these semi-finals, eight teams consisting of 24 students have been selected. The finals are to take place during 3-5, October 2018 at Agartala. Top three winners will be awarded cash prize and trophy.

Sci-connect is one of the many innovative and creative programmes Vigyan Prasar organised with the aim to nurture and instil scientific temper. Sci Connect quiz and the side events like hands-on science, hosted around the event help raise scientific awareness and help them practice the method of science from their very young age. Moving beyond the resource-rich opportunity saturated metropolis, these programmes light a spark in villages and remote regions. Only with inclusive growth that Indian science can grow to the next level and inspiring children from diverse social, cultural, regional background becomes imperative. Kudos to the team that made this programme a success and thanks to all who made these possible.

Email: tvv@vigyanprasar.gov.in

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



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

# Parker: A Date with the Sun

*M.S.S. Murthy*

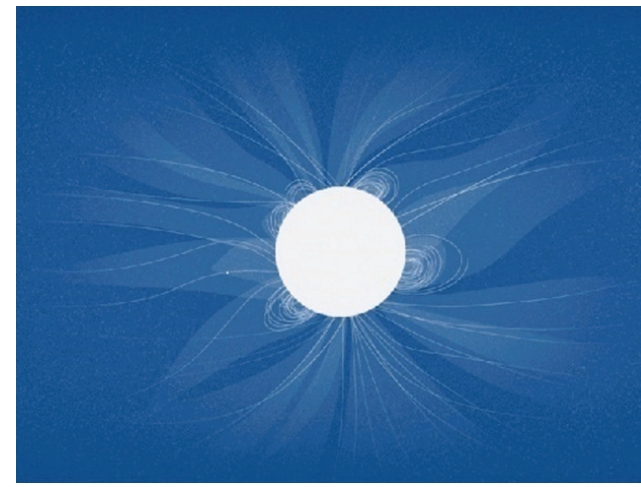
*Parker Solar Probe is a NASA robotic spacecraft en route to probe the outer corona of the Sun. About the size of a small car, it will travel towards the Sun's atmosphere at a speed of about 700,000 kmph, becoming the fastest human-made object. By November 2018, it will enter an orbit that approaches within 6.2 million km from the Sun's surface. During its seven-year lifetime, the Parker Solar Probe is expected to make 24 passes near the Sun to collect all the data astronomers need to develop deeper understandings of the dynamics that spark space weather events.*

On 12 August 2018, American space agency NASA embarked on a mission that was never before attempted– a mission to 'touch' the Sun. A spacecraft called *Parker Solar Probe* was launched from Cape Canaveral, Florida, USA to travel through the solar system and enter the Sun's outermost atmosphere, the corona.

## Sun-Earth relationship

It is not just the life-sustaining light and warmth that we receive from the Sun. An invisible stream of solar material consisting of charged particles, high-energy electromagnetic radiation, and strong magnetic field lines, known as 'solar storm' continuously buffet the Earth's upper atmosphere and the protective magnetic field. This bombardment generates what astronomers call the 'space weather', which can have far reaching effects on human activities. They range from the fascinating display of coloured lights called auroras at the poles to harmful effects like disrupting communication signals from GPS and satellites, radiation exposure to astronauts during interplanetary missions, and even damage to electricity grids. Though astronomers have been studying space weather for nearly six decades now, there are still a number of questions for which definite answers are not available. The *Parker Solar Probe* is designed to collect firsthand information on solar storm by plunging into the area of the Sun where it is actually generated. Though there is nothing much that man can do to interfere with this ferocious natural phenomenon, a better understanding of some of these aspects will help to develop measures to protect the symbols of modern human civilisation.

Basically, the Sun is a big ball of gas made of 95% hydrogen, 4.5% helium and the remaining small part contributed by various heavier elements from lithium to iron.During its formation the Sun's core got highly compressed due to gravitational force, producing tremendous pressure and heat. As a gas heats up, the atoms break apart into constituent parts – the positively charged



*Closed magnetic field lines loop back to Photosphere. Surrounding are the open field lines reach into corona and beyond. Credit: NASA*

Dr M.S.S.Murthy retired as a senior scientist from the Bhabha Atomic Research Center, Mumbai in 1997. He is a popular science writer and authored a number of books. Email: mssmurthyb104@gmail.com

nuclei and the negatively charged electrons, turning it into what is called plasma. Under those conditions, four protons (nuclei of hydrogen) undergo nuclear fusion reaction to form a helium nucleus, releasing energy in the form of gamma radiation and neutrinos. Astronomers estimate that every second the Sun burns about 600 million tons of hydrogen in nuclear fusion, releasing a tremendous amount of energy.

The energy produced in the Sun is transported outward first by the process of diffusion. But at some point in the outer 20% of the radius of the Sun, diffusion becomes ineffective, and the energy is transported by convection. Here, as in a pot of boiling water, buoyancy carries columns of hot plasma to the surface, where it gets cooled and sinks back again to continue the process. From here on the energy appearing as light and heat, radiates all over into the space. This bright surface, called the photosphere, is what we normally recognise as the Sun. Above the photosphere exist two layers of solar atmosphere– the chromosphere and the corona. However, the density of the solar plasma in these areas is so small that light from the particles cannot be seen in the bright background of the photosphere. But during a total solar eclipse, when the Moon completely covers the photosphere, the chromosphere looks like a red ring and the corona appears as white crown with plasma streamers spreading around.

## The mystery of coronal heating

While the density of the solar plasma decreases rapidly as we move out from the core to the photosphere and beyond, the temperature varies in a dramatically different pattern. It is our daily experience that as we move away from the source of heat, the temperature decreases. This is also what happens across the inner layers of the Sun. While the core is sizzling with a temperature of about 15 million degree Celsius, the photosphere cools to about 5,700 degrees. However, based on spectroscopic measurements of the dim light from the corona, astronomers have found it to be simmering at 1.2 million degree Celsius, more than 200 times that of the photosphere. This high temperature of the corona means that it is heated by something other than the conduction from the photosphere. Astronomers have not yet


*Dr. Eugene Parker (seated front), a pioneer in solar physics, after whom the solar probe is named, watches the launch. Credit: NASA*

been able to explain satisfactorily this strange phenomenon, known as 'coronal heating'.

## The birth of solar storm

The first space weather event recorded in history was on 1 September 1859. Richard Carrington and Richard Hodgson, two British amateur astronomers, while routinely observing the Sun, noticed two flashes of intensely bright light near a group of sun spots– areas of intense magnetic field on the Sun's surface. Though the flashes lasted only for less than 60 seconds, a day later colourful auroras, which normally are seen only at the poles, were also visible in tropical latitudes. That is not all. Telegraph wires, the hi-tech stuff of that time, suddenly shorted out in United States and Europe, igniting widespread fires.

Though the actual cause of these effects on Earth was not known at Carrington's time, astronomers realised that it was associated with the intense solar activity seen the previous day. Since Carrington's time, a number of such events, which came to be known as 'space weather' have been observed, though none of them as serious as the one of 1859. It is now common knowledge that the Sun operates on an 11-year cycle of activity and solar flares occur more often during the Sun's peak activity– episodic ejection of material and magnetic flux from the solar surface. However, not all of them are of the same severity and not all are directed towards the Earth. NASA regularly records these events in its space weather program, some of which have been responsible for major electrical disturbances and satellite failures. The one that occurred in 1989 cut out electric power to an entire Canadian province. With the high dependence of the present-day

### The state-of-the-art heat-shield

Since the corona reaches a temperature of more than a million degrees Celsius, the biggest challenge in the construction of the probe was to keep it from burning out. How much heat wouldthe *Parker Solar Probe* experience when it is closest to the Sun? To answer this question, one has to differentiate between the concepts of temperature and heat. In space, the temperature can be thousands of degrees without delivering significant heat to an object close by.Temperature means how fast the particles are moving, whereas heat means the total amount of energy the particles transfer to an object they encounter. Particles may be moving fast (that is high temperature), but if there are very few of them, an object encountering them will not experience much heat. Compared to the visible surface of the Sun (photosphere), the average density of particles in the corona is so low that it will have very few of them. Hence, the spacecraft will experiencea temperature of only about 1,400 degrees Celsius.

However, even this is too high and to withstand it the *Parker Probe* makes use of a heat shield made up of an 11.5-cm-thick carbon composite foam material sandwiched between two carbon fibre sheets of 2.4 metres and painted white to reflect sunlight. The shield is tested to withstand a temperature of 1,650 degrees Celsius, keeping the instruments safe at a temperature of 30 degrees Celsius.

civilisation on artificial intelligence, internet and wireless communications, astronomers are of the opinion that if an event of that size occurred today, it would lead to damages costing about two billion dollars, fuelling chaos everywhere and may take as long as 10 years for the world to recover.

In 1958, Eugene Parker, after whom the present solar probe is named, proposed that the corona sizzling with more than 1.2 million degrees Celsius heats up the solar particles (electrons, protons, and alpha particles), which then overcome the Suns' gravity and expand outwards beyond the Sun. A year later, the Soviet spacecraft *Luna*-1 detected solar particles in space. Three years later NASA's *Mariner*-2 spacecraft identified two distinct streams of solar storm: a slow stream travelling at approximately at 250 kmph, and another fast one blowing at supersonic speed of 750 kmph.

## The Indian Solar Mission

The Indian Space Research Organisation (ISRO) is also planning to launch a solar mission, '*Aditya*-L1' during 2019-2020. However, it is programmed to observe the Sun from a distance of about 1.5 million km from the Earth (or almost 148 million km away from the Sun) from the Lagrangian point L1. *Aditya*-L1will carry six scientific payloads from different institutions in the country to perform a variety of measurements:

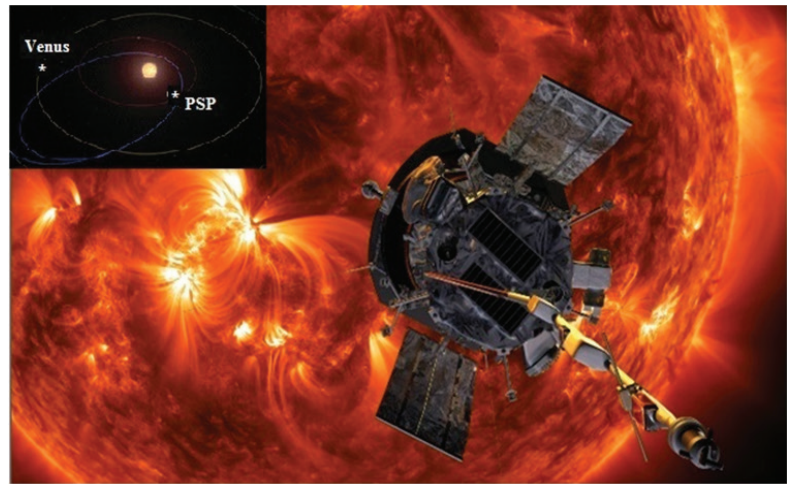
- Magnetic field measurements of corona to study the dynamics and origin of coronal mass ejection, a process in which a huge amount of solar material (energetic charged particles) is thrown out of the Sun into space.
- Image photosphere and chromosphere in near-ultraviolet radiation and measure solar irradiance variations.
- Measure the properties of solar strom particles– their distribution and spectral characteristics.
- Make measurements to understand composition of solar strom and its energy distribution.
- Monitor X-ray flares to study the heating mechanism of the corona.
- Observe the dynamic events in the solar corona and provide an estimate of the energy used to accelerate the particles during eruptive events.
- Measure the magnitude and nature of the interplanetary magnetic field.

ISRO says, "With the inclusion of multiple payloads, this project also provides an opportunity to solar scientists from multiple institutions within the country to participate in space based instrumentation and observations. Thus, the enhanced *Aditya*-L1 project will enable a comprehensive understanding of the dynamical processes of the sun and address some of the outstanding problems in solar physics".

## Solar magnetism – the driving force

The mystery of the coronal heating and the occurrence of solar storms both seem to be intimately connected with each other and driven by the complex solar magnetic field lines. Like Earth, the Sun also rotates on its axis. With this, the plasma in the inner layers of the Sun also rotates, producing a powerful magnetic field, by what is known as the 'dynamo effect'. Since the Sun is a ball of gas and not a solid mass like the Earth, it rotates faster at the equator and slower towards the poles. Due to this differential rotation highly tangled loops of magnetic field lines, anchored to the solar surface at both ends are formed at the equatorial region. Some of them may extend all the way to the corona. At other regions the magnetic field lines may anchor at only one end and stretch far into the space, creating a highway for solar material to escape, forming the fast component of the solar storm. These regions are correspondingly called the closed and the open corona.

Plasma travels with its own magnetic field lines entrapped in the material. Under normal conditions, the magnetic field lines do not break or merge with other field lines. But sometimes as field lines get close to each other, they short-circuit and reconnect with their neighbours into new configurations. In the process, the stored magnetic energy is converted into heat and kinetic energy that sends solar particles streaming along the field lines to constitute the slower component of the solar storm, which may later switch to open magnetic field lines to reach the outer space.




*An artist's impression of Parker solar probe approaching the Sun. (Inset: The closest distance that the solar probe approaches the Sun in comparison with the orbit of Venus). Credit: NASA*

There are many conflicting theories explaining the details of these processes like the origin of the slow component, the mechanism of coronal heating, etc. However, current efforts to test these theories based on data obtained through satellites orbiting in the near-Earth space are hindered by the great distance between the point of measurement and the origin of these events. "It takes about four days to travel 150 million kilometres and reach the near-Earth space where solar plasma is studied. During this long journey the plasma may mix with other particles zipping through space and lose its defining features" says Lina Tran of NASA's Goddard Space Flight Center. Hence, astronomers feel that getting closer and tracing the solar storm back to its source would provide more reliable data.

*Continued on page 25*

# Polyphenols in our food: Phytochemicals with promising health benefits


*Dr. G. Hithamani and Dr. K. Srinivasan*

*For the past two decades, epidemiological studies and associated meta-analyses strongly suggest that long-term consumption of diets rich in plant polyphenols, especially flavonoids, offer protection against development of degenerative diseases such as cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases. Thus, polyphenols have now become the subject of increasing scientific interest because of their possible beneficial effects on human health.*

For the past two decades, epidemiological studies and associated meta-analyses strongly suggest that long-term consumption of diets rich in plant polyphenols, especially flavonoids, offer protection against development of degenerative diseases such as cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases. Thus, polyphenols have now become the subject of increasing scientific interest because of their possible beneficial effects on human health.

We all know about the importance of nutrients in our daily food — that proteins, fats, carbohydrates, and micronutrients like vitamins and minerals are essential for good health. We also know how much of each of these nutrients and micronutrients we need to consume daily to be healthy and how to avoid their deficiency, and what foods we have to eat to get enough of them. In recent years, another class of non-nutrient, nevertheless important ingredients in our food, called '*nutraceuticals*' are being talked about. The best-known among them are 'polyphenols', valued as antioxidants and with other beneficial properties. Polyphenols are essentially phytochemicals (chemical substances obtained from plants), often found in the fruits and leaves and are believed to protect the plants. Unlike vitamins, polyphenols are not sensitive to oxidation or light, and keep well inside the foods we eat, even after cooking.

The word 'Polyphenol' is a generic term derived from the Greek word *polus*, (to mean 'many'), and 'phenol' refers to an aromatic ring with a hydroxyl group attached. Polyphenols are abundantly-occurring natural molecules with proven antioxidant properties. Plants produce these molecules as secondary metabolites to get protection from invading pathogens and also under the conditions of stress, such as UV exposure, excess water, salinity, and changes in temperature. Polyphenols also significantly contribute to pigmentation in plants, and provide protection against predators, thereby called 'phytoalexins'. In food, polyphenols contribute to the bitterness, astringency, colour, and flavour.

The important dietary sources of polyphenols are fruits, vegetables, tea and seed coat of grains (Fig.1). Fruits like grapes, apples, pear, cherries and berries contain polyphenols up to 200-300 mg per 100 g fresh weight. The products manufactured from these fruits also contain polyphenols in significant amounts. Typically a glass of red wine or a cup of tea or coffee contains about 100 mg polyphenols. Cereals, dry legumes and chocolate also contribute to the intake of polyphenols. Cloves (15.2 g/100 g) stand first among 100 top ranked foods containing polyphenols. Polyphenols exist in soluble free or esterified/etherified form as well as in insoluble bound form attached to cell wall components.

Dr. G. Hithamani is a Research Fellow at CSIR - CFTRI, Mysore. Dr. K. Srinivasan retired as Chief Scientist at CSIR - CFTRI, Mysore has been active in science popularisation through articles related to food, nutrition, and health. E-mail: ksri.cftri@gmail.com

## Chemistry of polyphenols

Polyphenols represent a group of chemical substances, structurally characterised by the presence of one or more phenol units. With more than 8,000 polyphenolic compounds currently known, these can be divided, depending on their basic chemical structure, into at least 10 different classes. Polyphenols are broadly classified as phenolic acids, flavonoids, lignans, and stilbene. The flavonoids constitute one of the most important groups, with more than 5,000 compounds described. In nature, phenolic compounds are usually found conjugated to sugars and organic acids.

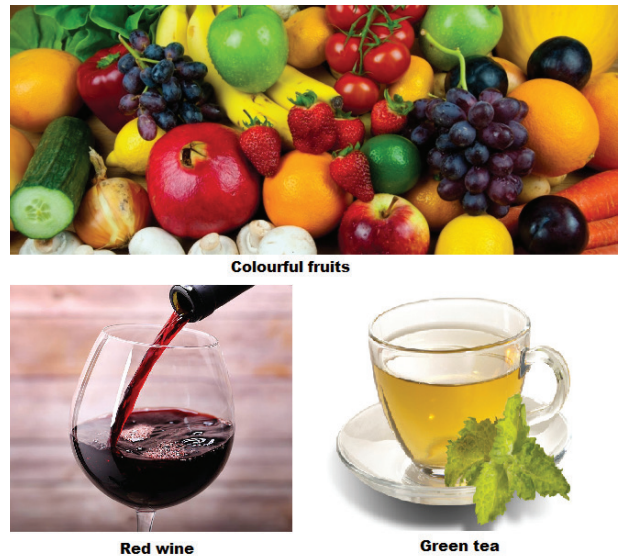



*Fig.1. Rich sources of antioxidant polyphenols*

## Phenolic acids

Phenolic acids are widely distributed aromatic secondary plant metabolites that account for one-third of our dietary polyphenols. There are two classes of phenolic acids: derivatives of benzoic acids (hydroxybenzoic acids) and derivatives of cinnamic acid (hydroxycinnamic acids). Compared to hydroxybenzoic acids, hydroxycinnamic acids are more commonly found, mainly in bound form as glycosylated or esterified derivatives. Hydroxybenzoic acids are found in microbes while hydroxycinnamic acids are found in plant cell walls and lignin Cereals and millets contain hydroxycinnamic acids. Gallic acid is extensively found in tea, tea leaves may contain up to 4.5 g/kg fresh weight of gallic acid.

## Flavonoids

Flavonoids are the largest and most extensively studied group of polyphenols. Flavonoids are further classified into seven major subgroups - flavonols, flavones, flavanols, flavanones, flavanonols, anthocyanidins, and isoflavonoids. Among these, flavones, flavonols, and flavanones are the most abundant naturally occurring flavonoids. Around 5,000 flavonoids have been identified in plant kingdom.

Together with carotenes, flavonoids are also responsible for the colour of fruits, vegetables, and herbs. The daily intake of the flavonoids constitutes about 2/3 of the total intake of dietary polyphenols. Green and black tea contains about 25% flavonoids. The most-consumed flavonoid is quercetin, and the richest sources are apple, onion, and tea. Other important sources of flavonoids are citrus fruits, pomegranates, berries, grapes, cocoa, coffee, olive oil, walnuts, and peanuts.

Isoflavones are found mostly in legumes, but soybeans are the principal human dietary source. Soy isoflavones can reduce blood cholesterol and can help to prevent osteoporosis. Symptoms of menopause are known to be alleviated by soy flavonoids. The most important flavanols are catechins which are found in plenty in tea; other sources include red wine and chocolate. Flavanones are abundantly found in citrus fruits contributing to the distinctive flavour. The other sources include chick peas, cumin, licorice, peppermint.

Anthocyanins are pigments found in red fruits such as cherries, plums, strawberries, raspberries, blackberries, grapes, red currants and black currants. Anthocyanins often occur in a complex mixture.

## Lignans

Lignans are polyphenols associated with dietary fibre. Plant lignans occur in the form of glycosides and are considered to be one of the several classes of phytoestrogen. Even though widely distributed, lignans are relatively less studied.

## Stilbenes

Stilbenes are often found in the non-edible tissues of plants. However, the major dietary sources of stilbenes include grapes and peanuts with smaller amounts found in berries, red cabbage, spinach, and a few herbs. Resveratrol is one of the best studied stilbenes from grapes and red wine.

## Occurrence in nature

Polyphenols by and large are present in plants. Larger polyphenols are often concentrated in leaf tissue, the epidermis, bark layers, flowers and fruits. High levels of polyphenols in some woods can explain their natural preservation against rot. Structurally, phenolic compounds vary from simple molecules such as phenolic acids and are highly polymerised compounds, such as pro-anthocyanidins (tannins), which occur in plants and are common in many foods (fruits, vegetables, cereal grains) and beverages (wine, beer, teas). The most common phenolic compounds in human diet are phenolic acids, flavonoids and tannins.

## Polyphenols in traditional medicine

Many herbal teas which are advocated for human wellness contain soluble polyphenols, and their efficacy is often attributed to astringent tannin substances. Pomegranate, a rich source of polyphenols, is extensively used in traditional remedies. Red wine, which is rich in polyphenols, especially resveratrol, has been associated with the prevention of cardiovascular diseases and cancer. There is epidemiological evidence that resveratrol can protect against the negative effects of consuming excess calories. *Indian gooseberries (Emblica officinalis)*, commonly known as *amla*, have traditionally been used in the *Ayurvedic* medicine for enhancing general vitality and cognition, to relieve anxiety and promote longevity. Although there is very limited human evidence, it appears to be promising in the management of blood glucose in both healthy persons and diabetics. Most of these actions are attributed to gooseberry's antioxidant properties,

which are partially derived from not only high ascorbic acid content but also from a large amount of phenolic tannin compounds. Turmeric, by virtue of its polyphenolic bioactive constituent curcumin, is the earliest anti-inflammatory drug known in the indigenous system of medicine in India, and is traditionally used for wound healing.

## Health benefits of polyphenols

For the past two decades, epidemiological studies and associated meta-analyses strongly suggest that long-term consumption of diets rich in plant polyphenols, especially flavonoids, offer protection against development of degenerative diseases such as cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases. Thus, polyphenols have now become the subject of increasing scientific interest because of their possible beneficial effects on human health. These molecules are very good antioxidants and may neutralise the destructive reactivity of undesired reactive oxygen/nitrogen species produced as by-products during metabolic processes in the body. The involvement of reactive oxygen species (ROS) in the aetiology of these degenerative conditions suggests that these phytochemicals showing antioxidant activity may contribute to the prevention of these pathologies. Several studies have demonstrated the antioxidant activity exerted by polyphenols, as flavonoids, especially regarding the scavenging of various oxidising species, such as superoxide anion, hydroxyl radical and peroxyl radicals.

Specific polyphenols from plant species (Fig.2) have been actively studied as potential treatments for various metabolic diseases. For example, resveratrol from red wine, curcumin from turmeric, and quercetin from different sources have all been studied as potential therapeutic agents. Several studies focussed on food polyphenol content have shown the beneficial effects of grape seeds, coffee, and cocoa. There is evidence of the role of polyphenols as protective agents against cardiovascular disease and hypertension, certain forms of cancer, including breast, esophageal, gastrointestinal, lung and skin cancer, Type 2 diabetes, aging, and inflammation..

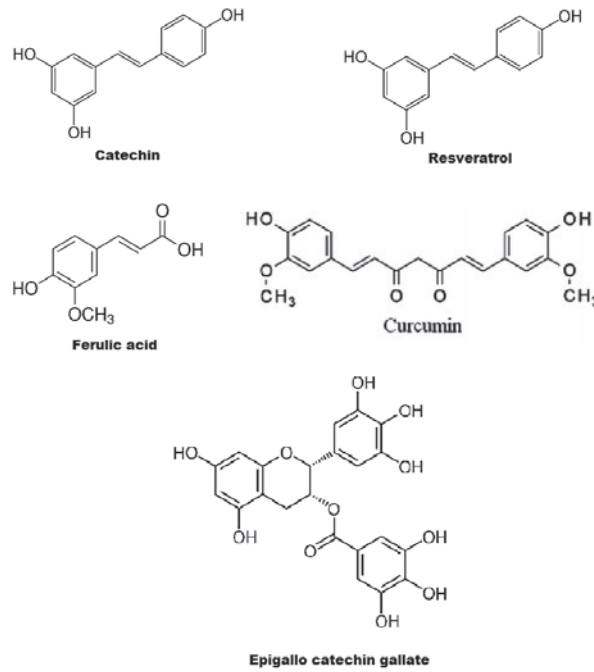



*Fig.2. Structure of some popular polyphenols*

Several beneficial effects of turmeric and its polyphenolic constituent – curcumin, which imparts yellow colour for this spice, have been experimentally documented. Turmeric and curcumin have been studied as possible ameliorative or preventive agents for major health problems, namely diabetes, cardiovascular disease, inflammatory disorders, and cancer.

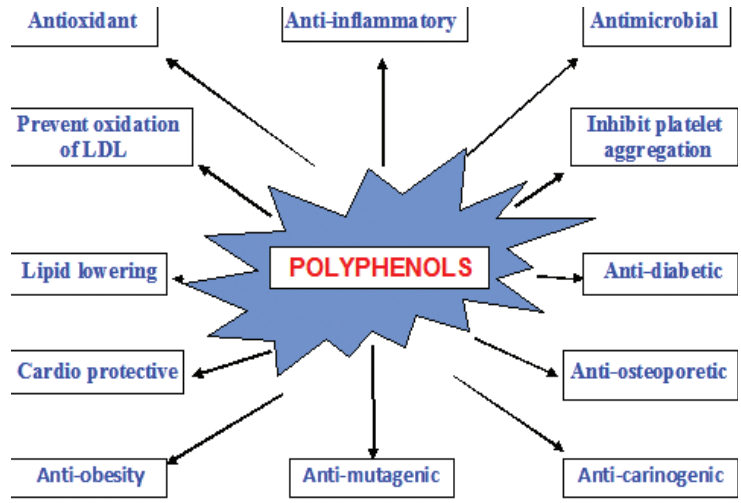



*Fig.3. Multiple health effects of polyphenols*

The anti-inflammatory potential of curcumin has been experimentally and clinically validated. Animal studies have revealed that curcumin lowers the incidence and severity of arthritis and also delay the onset of arthritis. Dietary curcumin has been found to be an effective lipid lowering agent and to effectively prevent the incidence and severity of cholesterol gallstone disease. The anticancer potential of curcumin has been evidenced by both preclinical and clinical studies. Some of the health beneficial functions of polyphenols are briefy described Fig.3.

## Antioxidant activity

Polyphenols are recognised as natural antioxidants and hence have an important role under oxidative stress. The antioxidant properties of polyphenols are mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors and singlet oxygen quenchers. Consumption of polyphenol-rich foods is useful in lowering the risk of oxidative stress-related diseases.

## Anti-cancer activity

A number of polyphenols including quercetin, catechins, isoflavones, lignans, flavanones, ellagic acid, resveratrol, and curcumin are proved to be effective against oral, abdomen, duodenum, colon, liver, lung, breast and skin cancers. Polyphenols are found to act as protective agents either by reducing the number of tumours or their growth. Intake of tea is protective against skin cancer, colorectal cancer and also prevents oral cancer in smokers by reducing smoking-induced DNA damage and cell growth inhibition. Consumption of polyphenol-rich fruits, vegetables and red wine reduces the incidence of colorectal cancer. Green tea is associated with a decreased risk of advanced prostate cancer.

## Anti-osteoporosis activity

Polyphenols reportedly exert physiological effects against osteoporosis (a condition in which

bones become weak and brittle). Flavonoids present in plant-based foods supports the bone health in humans. In a study on 3,160 women participants in the UK, dietary intake of anthocyanins and flavones showed their positive association with hip and spine bone mineral density. Reactive oxygen species play a key role in the aging process, and greatly contributes to osteoporosis. Green tea polyphenols have shown their osteo-protective effects by decreasing oxidative stress, increasing the activity of antioxidant enzymes, and decreasing the expression of pro-inflammatory mediators in rodent models.

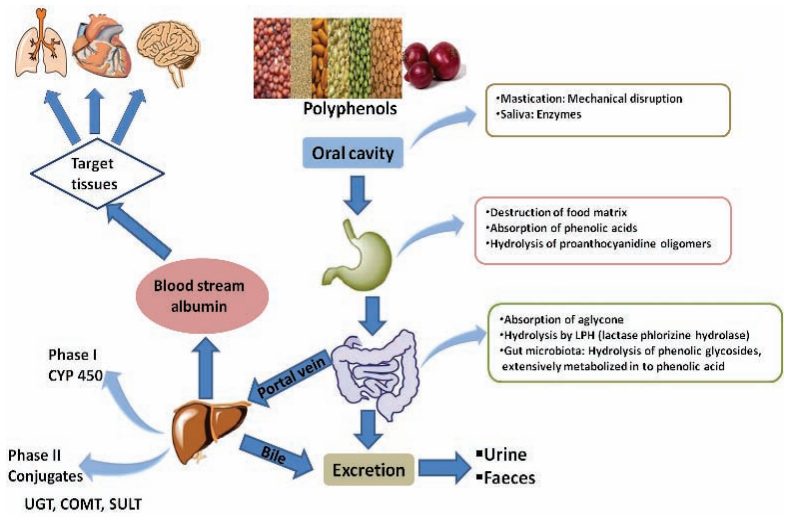



*Fig.4. Bioavailability of polyphenols*

## Anti-inflammatory activity

Reactive oxygen species react with proteins resulting in amino-glycated end products (AGEs). AGEs are involved in triggering obesity and insulin resistance, diabetes mellitus Type 2 and inflammation. Curcumin, the polyphenol found in turmeric, has attracted considerable interest in recent years due to its high medicinal potential particularly regarding oxidative stress and inflammation.

## Antidiabetic activity

Dietary polyphenols reduce intestinal absorption of carbohydrate, modulate the enzymes involved in glucose metabolism, improve β-cell function and insulin action, and stimulate insulin secretion. These properties of dietary polyphenols together with their antioxidant and anti-inflammatory properties are known to contribute to its hypoglycaemic (glucose-lowering) effect. Quercetin, a flavonoid found in onion has been found to be a strong anti-diabetic compound. Quercetin has the ability to protect against the alterations in diabetic patients during oxidative stress, lipid peroxidation and inhibition of oxidative stress during diabetes.

## Anti-obesity effect

Polyphenols in combination with polysaccharide is potential in treating obesity. Several cell cultures, and animal and human studies confirm the anti-obesity potential of green tea catechins, particularly epigallocatechin gallate.

## Antimicrobial activity

Phenolic compounds of *Ginkgo biloba* plant exhibit inhibitory activity against several bacteria such as *Escherichia coli* (food poisoning), *Enterobacter aerogenes* (infections due to multi-drug resistance), *Pseudomonas aeruginosa* (sepsis), *Salmonella enterica* serovar Typhi (typhoid), *Shigella dysenteriae* (diarrhoea and dysentery), *Staphylococcus aureus* (skin infections), *Streptococcus pyogenes* (skin and pharynx infections), and *Vibrio vulnificus* (cellulitis or septicemia). Coumarin, a phenolic compound is effective in suppressing the bacterial strains *E. coli, E. aerogenes*, *Salmonella typhimurium* and *S. infantis,* which are in involved in gastroenteritis.

## Bioavailability of polyphenols

The biological properties of polyphenols may depend on their absorption in the gut and their bioavailability. Only polyphenols that are released from the food by the action of digestive enzymes and bacterial microbiota in the large intestine are bioaccessible and their eventual metabolism governs their bioavailability (Fig.4). Bioavailability of polyphenols in humans is influenced by numerous factors such as variation in food matrix and method of food processing employed, and presence of other dietary factors. For example, thermal treatment of food material can disrupt the cell wall allowing the release of polyphenols to become bioavailable, however, the same treatment would degrade polyphenols and bring down total content of the same from the food. Physical nature of the food also influences the bioaccessibility and bioavailability of these compounds.

## Conclusion

In view of the beneficial role of plant derived polyphenols in human health, their liberal daily intake in the range of 500 to 1,000 mg through consumption of fruits, vegetables and whole grains is considered optimal. Consumption of fruits and vegetables at the recommended quantity of about 400 g per day and regular consumption of cereal grains that are good providers of antioxidant polyphenols keep one healthy and degenerative diseases at bay.

# Earthworms: The Soil Ecosystem Engineers

*Dr. Jyotsna Devi*

*Earthworms are unique among soil invertebrates as they bury organic debris, mix organic and inorganic matter in their excreta and modify the structure of the soil through their burrow systems. Therefore the earthworm is considered as the leader in revitalisation of the soil. It can be regarded as a soil biotechnologist and a solid waste manager.*

Earthworms have always been regarded as friends of the farmers because they have a very positive effect on the physical, chemical and biological parametersof the soils. They consume large quantities of organic litter or waste andconvert them into manure, which is used as valuable compost, known as 'vermicompost'. Their importance in nutrient cycling, soil structure, soil health including soilfertility, productivity, agriculture, and their application in organic waste management is well established.

An earthworm is a tube-shaped, segmented worm found in the phylum Annelida. It is up to 36 cm long and weighs up to 11 g. Colour ranges from light purple to brownish, with the underside being slightly paler. Earthworms are a common sight on sidewalks after rain. They crawl across our sidewalks and live in our home gardens and fields. Some earthworms live in burrows in the soil. They are known to tunnel as deep as 2 m during periods of dryness or in winter. Children play with them in villages and biology students dissect them in high school. Many people use them as fish bait. Hence they are also known as angleworms. Earthworms provide a principal food source for various wildlife including birds, reptiles, insects, and moles. They cannot see or hear, but they are sensitive to both light and vibrations.

Structurally, the first thing that is noted about earthworms is that their body is segmented, appearing as a series of aligned adjacent rings (about 150) called annuli. Internally, each of these segments is separated by septa or partition wall. The number of segments is fairly consistent within a species and can be useful for identification. Because the body is segmented in this fashion, most earthworms can survive losing some backportions of their body to predation or injury, and many can regenerate the lost sections. These segments are covered in setae, or small bristles, which the worm uses to move and burrow. The worm's first segment contains its mouth.

Internally, earthworms are complex, having most major organ systems. Some internal organs, including the excretory organs, are duplicated in each segment. Between segments 32 and 37 is the clitellum, a slightly bulged, discoloured organ that produces a cocoon for enclosing the earthworm's eggs. The body is tapered at both ends, with the tail

Dr. Jyotsna Devi is Principal Scientist, Horticultural Research Station, Assam Agricultural University, Kahikuchi, Guwahati, PIN - 781017
Email: jtsndevi@gmail.com

end the blunter of the two. They lack either an internal skeleton or exoskeleton, but maintain their structure with fluid-filled chambers that function as a hydrostatic skeleton. Circumferential and longitudinal muscles on the periphery of each segment enable the worm to move. Similar sets of muscles line the gut, and their actions move the digesting food toward the worm's anus.

The circulatory system consists of three major blood vessels running the length of the worm. While not having a true brain, earthworms have a ventral nerve cord that runs the length of the worm, a network of nerves that control the muscles.

Most earthworms are omnivores, feeding on both decaying and live plant matter, fungi, bacteria, and microscopic animals. For most species, decomposing plant matter is the primary food source, although most of their nutrient needs are supplied by microorganisms ingested at the same time. Earthworms also ingest large amounts of soil, sand, and tiny pebbles. It has been estimated that an earthworm ingests and discards its own weight in soil every day.

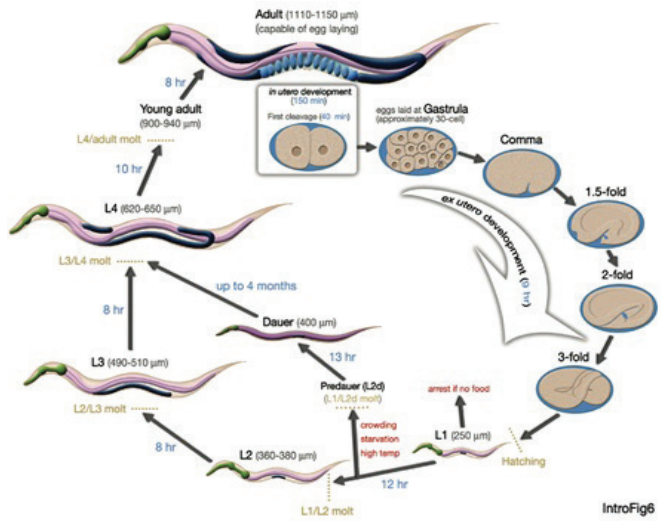
About 3,000 species of earthworms exist in the world. In India, more than 500 species have been identified till date. Most of these are indigenous earthworms, which mean they belong to our soils.

Earthworm species are generally categorised environmentally as being epigeic, endogeic, and anecic. Epigeic species live in organic litter near the soil surface and generally have a short life cycle and high fecundity. These earthworms are most often used commercially for composting. Anecic species form permanent burrows, spend much of the day in the mineral horizon, but come to the surface to forage on litter and plant debris, often at night. The night crawlers that many are familiar with are anecic worms. Endogeic species live in the dark, rich topsoil layer and seldom come to the surface, so these are infrequently encountered by humans.

Earthworms are hermaphrodite, which means that both male and female reproductive organs are present in every worm, yet self-fertilisation is not feasible. Most species copulate and reproduce by cross-fertilisation.

## Life cycle

During mating two earthworms are bound together by sticky mucus while each transfers sperm to the other. After copulation, the clitellum (a thickened glandular and non-segmented section of the body wall near the head in earthworms) secretes a structure called a 'cocoon'. Cocoons are small, spherical, translucent structures which separately pick up eggs and sperm deposited by the other earthworm. Fertilisation of the ova occurs within the cocoon. After that, the cocoon hardens to give protection to the developing eggs. Within 24 hours after



IntroFig6

the worms mate, the cocoon is deposited in the soil. The cocoons can lay dormant for an extended period of time until conditions are just right. In about two to three weeks, the cocoons hatch and release 1 to 5 white and transparent young earthworms, which are 2.5-4.0 cm long. The entire cycle from cocoon to cocoon takes about 50 to 60days in most local varieties of earthworms. The life expectancy of major Indian earthworms is about a year during which period they produce several offspring.

When earthworms grow up, formation of segments take place. Segments look like rings around their bodies and a fully grown worm has between 120-170 segments. When earthworms are about two to three weeks old, they begin to form clitellums (which are organs that allow them to pass sperm to other earthworms). At around this age, they are able to mate with others and produce offspring. At around six weeks old, they become fully matured and do not grow further. It is estimated that earthworms can live for several years based on the specific species. For example, *Lumbricusterrestris* usually live four to eight years.

## Ecological importance

Earthworms have various important ecological roles. They ingest decomposing plant matter and then expel it in a more broken down form. Thus they speed up the decomposition process. The organic piles of waste left after digestion by earthworms are termed casts or castings. Worm castings typically have higher microbial activity and higher concentration of plant-available nutrients than the original material and therefore earthworms aid in nutrient cycling. Endogeic worms ingest large amounts of soil as they burrow, digest the organic matter contained therein, and then expel the mineral component back into the burrow. Additionally, activity of anecic worms moves organic matter from the soil surface deeper into the soil profile. Tunnelling by earthworms helps break compaction which improves aeration and water infiltration in the soil profile. This way casting and other organic residues from earthworms improve soil structure. The casts are rich in nutrients, growth promoting substances and beneficial soil micro flora, and have properties of inhibiting pathogenic microbes.

## Economic importance

The earthworm is one of nature's leading "soil scientists". The worms can turn common soil into superior quality by facilitating the amount of air and water that get into soil. They break down organic matter and when they eat, they leave behind castings that are an exceptionally valuable type of fertiliser. In this way they make a healthier soil which improves/enhances plant growth and agricultural productivity. For this reason worms are viewed as a gardener's friend and their presence and activity in gardens is generally encouraged.

## Vermicomposting

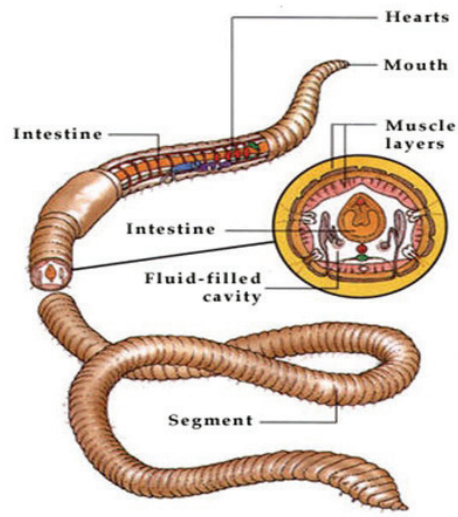
Compost is simply decomposed organic matters.Vermicomposting is

an easy method of preparing enriched compost that the plants can assimilate by recycling agricultural wastes with the use of earthworms. There are two methods of vermicomposting,namely'Bed method' and 'Pit method'. In bed method, composting is done on the *pucca/kachcha* floor by making bed (200 cm×60 cm×60 cm) of organic mixture, while in the pit method, composting is done in the cemented pits of size 150 cm×150 cm×90 cm..The unit is covered with thatch grass or any other locally available material. However, pit method is not preferred due to poor aeration, water-logging at bottom, and high cost of production.Species of earthworms used for vermicomposting are *Eiseniafoetida* (red earthworm), *Eudriluseugeniae* (night crawler), *Perionyxexcavates*, etc. Red earthworm is preferred because of its high multiplication rate.

## Process of vermicomposting

Acool, moist and shady site away from direct sunlight should be selected as vermicomposting unit. Shading is necessary as earthworms shy away from strong light. Beds of partially decomposed material of size (200 cm×60 cm×60 cm) should be made. Each bed should contain 150-200 kg of raw material (cow dung and chopped dried leaves/grasses in the proportion of 3:1) and the number of beds can be increased as per raw material availability and requirement.

Red earthworm (1,500-2,000 numbers) should be released on the upper layer of bed and water should be sprinkled immediately after the release of worms. Beds




should be kept moist by daily sprinkling of water and by covering with gunny bags/ polythene. The raw material should be turned once after 30 days for maintaining aeration and for proper decomposition.

The compost gets ready in 45-50 days. The finished product would be3/4th of the raw materials used. When raw material is completely decomposed it appears black and granular. Watering should be stopped as compost gets ready. The compost should be kept over a heap of partially decomposed cow dung so that earthworms could migrate to cow dung from compost. After two days, compost can be separated and sieved for use. As a preventive measure, the floor of the unit should be compact to prevent earthworms' migration into the soil.The level of nutrients in compost depends upon the source of the raw material and the species of earthworm. A fine worm cast is rich in nitrogen, potassium and potassium besides other elements like calcium and magnesium.

Awareness of the problems caused by excessive use of chemicals inagriculture in the form of fertilisers and pesticides, has led to the search for alternatives to chemical farming, namely organic farming. The common objective of organic farming is to avoid the application of chemicals that damage both living organisms and the surroundings, and harness instead the energies of natural agents to make agriculture highly productive, while at the same time retaining the fertility of the soil and the health of the land.

Earthworms are unique among soil invertebrates as they bury organic debris, mix organic and inorganic matter in their excreta and modify the structure of the soil through their burrow systems. Therefore the earthworm is considered as the leader in revitalisation of the soil. It can be regarded as a soil biotechnologist and a solid waste manager. ■

# Parker: A Date with the Sun *(Continued from page 32)*

## The *Parker Solar Probe*

So the key is to get closer to the Sun, where the events actually originate. And *Parker Solar Probe* is designed to do just that. About the size of a small car, it will travel towards the Sun's atmosphere at a speed of about 700,000 kmph, becoming the fastest human-made object. By November 2018, it will enter an orbit that approaches within 6.2 million km from the Sun's surface (nearly 143 million km from Earth).

The solar probe carries four instrument suits to make a number of measurements on various of parameters: the magnetic fields and how they change over time; take 3-D pictures of the electric fields at high frequencies; count the abundance of particles– electrons, protons and alpha particles in the fast and the slow components of the solar storm and measure their properties such as velocity, density and temperature to understand where they come from, how they get accelerated and how they move out of the Sun to the interplanetary space; and image the corona and the solar storm before the spacecraft flies through them.

During its seven-year lifetime, the *Parker Solar Probe* is expected to make 24 passes near the Sun to collect all the data astronomers need to develop deeper understandings of the dynamics that spark space weather events. This will help them forecast the space weather events more accurately so that suitable precautionary measures can be taken to protect astronauts, satellites, communication systems and power grids. Astronomers also hope that understanding the Sun will also help them understand other sun-like stars, which can potentially foster habitable environments for life to exist, but too far to reach– a step for the search for intelligent life elsewhere.

Scientists are not the only ones who are taken along this adventure. NASA had opened it for public participation from all over the world, inviting them to send their names to the Sun! Along with the instruments to make the measurements, *Parker Solar Probe* also carries a microchip containing the names of more than 1.1 million participants who signed up. The author is one of them. ■

# Chander Devgun: Astronomer, science populariser and a pioneer of astrophotography in India

*Dr. Mila Mitra*

*As an observational astronomer, Shri Devgun has conducted and led many eclipse viewing expeditions. He was witness to 16 solar eclipses, 51 lunar eclipses and transits of Mercury and Venus for which he had led student expeditions to Russia, China and Hongkong. He was a renowned astrophotographer, specialising in wide-field landscape astrophotography. His image of comet Hale-Bopp in 1997 was showcased on NASA website.*

Chander Devgun, well-known astronomer, astrophotographer and science communicator, passed away on 29 July 2018 in New Delhi. He was a pioneer in popularising astronomy in India, and has been deeply committed to spreading astronomy to the masses and to students. He was the co-founder and president of SPACE (Science Popularisation Association of Communicators and Educators), an NGO engaged in spreading scientific temper through astronomy. He was an amateur astronomer with more than 25 years of experience in observational astronomy, telescope making, and astrophotography. He has done pioneer work in Dobsonian telescope making in India, and spearheaded the telescope making concept for schools in late 1990s under the guidance of Late Dr. Nirupama Raghavan, former Director of Nehru Planetarium, New Delhi.

*Chander Devgun*

As an observational astronomer Shri Devgun has conducted and led many eclipse viewing expeditions. He was witness to 16 solar eclipses, 51 lunar eclipses and transits of Mercury and Venus for which he had led student expeditions to Russia, China and Hongkong on behalf of SPACE. He also spearheaded the Vamana Project to measure the distance to the Sun, during Venus transit of 2012. Under his guidance SPACE has been a pioneer in introducing astronomy as a subject in the form of a co-curricular activity in the Indian education system at school level. SPACE has done strong brickwork to create a foundation for astronomy by running astronomy-based workshops all over India.

Shri Devgun has been at the helm of various international/national level projects in astronomy. He was the National coordinator for UN based 'World Space Week' programme in India to promote astronomy among public and in that role has helped initiate many events in India for the public. He has also been the national coordinator for the 'Asteroid Day' project in India on behalf of SPACE. The project aims at making people aware of the dangers posed by near-earth objects. He has initiated highly acclaimed programmes like the All India Asteroid Search Campaign (AIASC) for students to discover asteroids and the Great India Star Count program to measure light pollution. Earlier, he led project 'Khoj' to find the central meridian for IST in India. He regularly presented astronomy in the media, and was in fact, on three TV channels talking about the 27-28 July lunar eclipse, the day prior to his passing away.

Dr. Mila Mitra is a Science Communicator based in New Delhi and has been a long associate of Shri Devgun. Email: Mila.mitra@gmail.com


*Polar star trails over Jantar Mantar by C.B. Devgun*

*Jantar Mantar in unique projection by C.B. Devgun*

He was a renowned astrophotographer, specialising in wide-field landscape astrophotography. His image of comet Hale-Bopp in 1997 was showcased on NASA website. His image of a lunar eclipse against the backdrop of the Shanti Stupa in New Delhi was released as a special postal cover and was selected as Picture of the Day in 'Astronomy Picture of the Day' (APOD) website.

Shri Devgun has trained legions of students and mentored them to follow astronomy. Aman Arora, the first student who discovered an asteroid said, "He has inspired generations of students and his methods of teaching are unparalleled". Dr. Patrick Miller, Director, International Astronomical Search Collaboration, recollected, "Chander and I often spoke of ways to introduce astronomy to interested students throughout India. He never stopped his search for ways to do this, sharing his passion for astronomy with students and teachers."

*Lunar eclipse phases over Shanti Stupa in New Delhi by C.B. Devgun as featured in 'Astronomy Picture of the Day' (APOD) and also released as postal cover.*

As president of SPACE Foundation, Shri Devgun has promoted astronomy outreach in numerous ways – through public lectures and by conducting sky observation sessions, accompanied by stories about the skies for the public, at NGOs and at orphanages. He has conducted heritage walks and been a part of the Expert Committee for restoring the Jantar Mantar in New Delhi.

Shri Devgun had received many awards in science communication and teaching. He will always be remembered as an astronomer and astrophotographer par excellence who inspired and mentored many and passionately spread scientific temper. Students and the astronomy community in India deeply mourn his passing. ■


*C.B. Devgun receiving the Vipin Joshi Smarak Samiti National level Award for teachers in 2016.*

*M31 Andromeda galaxy by C.B. Devgun*

# Recent Developments in Science and Technology

***Biman Basu***

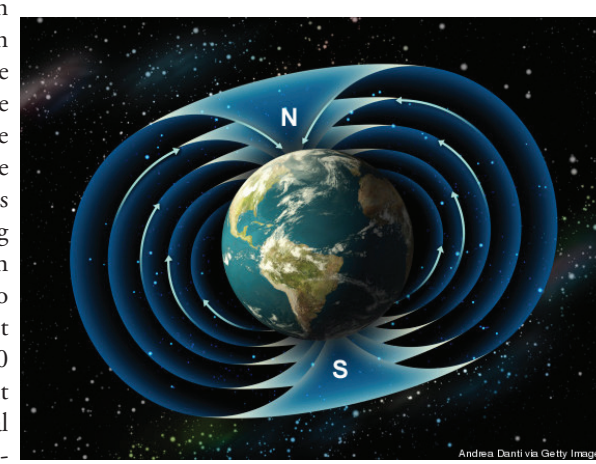
*A reversal of Earth's magnetic poles has several effects. During the process of reversal, the strength of Earth's magnetic field weakens gradually, which may have several consequences, especially on our modern networked society. Modern electronics – both on Earth's surface and in orbit – may be at high risk of interference and jamming by particles and radiation, knocking out the global communication network thus posing new challenges to our civilisation.*

## Earth's magnetic poles may flip faster than believed earlier

Our Earth behaves like a huge bar magnet with North and South poles, which become manifest when we use a magnetic compass. The compass needle aligns itself with the magnetic north and south poles. The Earth's magnetic field that surrounds the planet from all sides is vital for the survival of life on this planet as it protects us from the energetic radiations coming from space, especially from the Sun. The Earth's magnetic field also serves to deflect most of the solar wind, whose charged particles would otherwise strip away the ozone layer that protects the Earth from harmful ultraviolet radiation.

It has been known for a long time that the Earth's magnetic poles are not fixed but keep changing position over time and occasionally even reverse polarity – turning the magnetic North Pole into the magnetic South Pole and vice versa. When this happens, the directions shown by the compass needle also reverses. According to geologists, on average such reversal occurs every 2,00,000 to 3,00,000 years; the last time it happened was around 7,80,000 years ago. However, recent research by an international team of scientists led by Chuan-Chou Shen of National Taiwan University, Taipei, has shown that geomagnetic pole reversals can happen at much shorter intervals – as short as just 144 years (*Proceedings of National Academy of Sciences*, 20 August 2018. https://doi.org/10.1073/pnas.1720404115). The researchers believe that another polar flip could happen soon.

The researchers arrived at this conclusion by radioisotope dating of stalagmites in old limestone caves in southwestern China, several of which were still magnetised. A 76-mm-long core of stalagmite they examined covered approximately 16,000 years. By analysing the magnetic properties of the single layers, the scientists discovered two phases with a weaker magnetic field, one between 1,05,000 and 1,03,000 and another between 98,000 to 92,000 years ago. The team discovered that, 98,000 years ago Earth's magnetic poles




*Recent research has shown that Earth's magnetic poles may flip faster than believed earlier.*

The author is a former editor of the popular science monthly *Science Reporter*, published by CSIR, He is a winner of the 1994 'NCSTC National Award for Science Popularisation'. He is the author of more than 45 popular science books. Email: bimanbasu@gmail.com

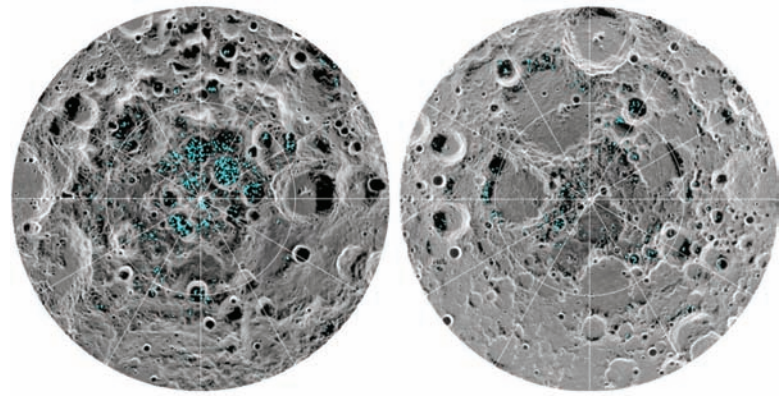
underwent a sudden reversal within what may have been just a century, during which the magnetic North Pole "moved" from Alaska in the north to a spot in the Antarctic Ocean in the south. What is most surprising is the speed of this almost complete reversal – apparently just 144 years.

They have other reasons too. First, the Earth's magnetic field is roughly 10 percent weaker today compared to when records first began 175 years ago, meaning the poles are more prone to shift. Second, the magnetic poles are moving increasingly faster. The magnetic north pole currently sits under the arctic ice to the north of Canada, and every year it moves some 50 kilometres towards Siberia. The most compelling reason is that a reversal in the Earth's magnetic field is long overdue.

A reversal of Earth's magnetic poles has several effects. During the process of reversal, the strength of Earth's magnetic field weakens gradually, which may have several consequences, especially on our modern networked society. A weakened magnetic field would allow more energetic particles and radiation to penetrate Earth's atmosphere. According to the researchers, even during a complete reversal, the magnetic field doesn't just vanish completely. Residual magnetism still offers some protection and Earth's atmosphere alone is sufficient to protect life from the most harmful effects of space radiation. However, in the modern age, such a reversal could spell trouble for many devices that we have come to rely on. Modern electronics – both on Earth's surface and in orbit – may be at high risk of interference and jamming by particles and radiation, knocking out the global communication network thus posing new challenges to our civilisation.

## Water ice confirmed on Moon

In November 2008, when India's first lunar probe *Chandrayaan*-1 reached the Moon, it made the first discovery of the presence of water molecules on the lunar surface. Ten years later, a detailed study of the *Chandrayaan*-1 data by a team of scientists led by Shuai Li of the University of Hawaii and Brown University has confirmed for the first time the presence of water ice in Moon's polar regions. However, there are differences from hemisphere to hemisphere. Ice is more abundant in the south, where it is found principally at the bottoms of permanently shadowed craters; in the north, the stuff is more widely, and thinly, dispersed. The researchers spotted a distinctive signature of water ice in the reflectance spectra gathered by *Chandrayaan*-1's M3 instrument (*Proceedings of the National Academy of Sciences*, 20 August 2018. DOI: 10.1073/pnas.1802345115). Before this finding, there was "no direct evidence to show there is surface exposed water ice on the Moon". The previous studies relied on modelling and indirect evidence.



*The image shows the distribution of surface ice at the Moon's south pole (left) and north pole (right), detected by NASA's Moon Mineralogy Mapper (M3) instrument. Blue represents the ice locations, plotted over an image of the lunar surface, where the grey scale corresponds to surface temperature (darker representing colder areas and lighter shades indicating warmer zones). The ice is concentrated at the darkest and coldest locations, in the shadows of craters. This is the first time scientists have directly observed definitive evidence of water ice on the Moon's surface. (Credits: NASA)*

The researchers used data from NASA's Moon Mineralogy Mapper (M3) instrument carried aboard *Chandrayaan*-1 to identify three specific signatures that definitively prove there is water ice at the surface of the Moon near the lunar polar regions within 20 degrees of both poles. The M3 was uniquely equipped to confirm the presence of solid ice on the Moon. According to the researchers, the M3 instrument collected data that not only picked up the reflective properties expected from ice, but was able to directly measure the distinctive way its molecules absorb infrared light, so it could differentiate between liquid water or vapour and solid ice. The M3 data showed "very unique" chemical fingerprints of water ice in craters at the Moon's north and south poles. Most of the newfound water ice lies in the shadows of craters near the poles, where the warmest temperatures never reach above minus 157°C. Because of the very small tilt of the Moon's rotation axis, sunlight never reaches these regions. According to the researchers, previous observations had indirectly found possible signs of surface ice at the lunar south pole, but these could have been explained by other phenomena, such as unusually reflective lunar soil.

The researchers say, "With enough ice sitting at the surface – within the top few millimetres – water would possibly be accessible as a resource for future expeditions to explore and even stay on the Moon, and potentially easier to access than the water detected beneath the Moon's surface". However, the abundance and distribution of ice on the Moon are distinct from those on other airless bodies in the inner solar system such as Mercury and Ceres, which may be due to the unique formation and evolution process of our Moon, the researchers say.

The next step would be learning more about the lunar ice, how much of it is there, how it got there and how it interacts with the larger lunar environment. Future missions already being planned by NASA and ISRO may try to address these questions in order to learn more about our closest celestial neighbour.

## There is no safe level of alcohol drinking

It has been known that alcohol drinking is not good for health, but there have also been reports appearing off and on claiming beneficial effects of certain alcoholic drinks such as beer and wine or harmlessness of drinking in moderation. But a new scientific study concludes there is no safe level of drinking alcohol. The study was

part of the annual Global Burden of Disease (GBD), which assessed alcohol-related health outcomes and patterns between 1990 and 2016 for 195 countries and territories and by age and sex. The study found that in 2016, nearly 3 million deaths globally were attributed to alcohol use, including 12 percent of deaths in males between the ages of 15 and 49 (*The Lancet*, 23 August 2018. DOI: 10.1016/S0140-6736(18)31310-2).

*Recent research shows there is no safe level of alcohol drinking.*

According to Dr. Emmanuela Gakidou of the Institute for Health Metrics and Evaluation at the University of Washington, Seattle, USA and the senior author of the study, "Our findings are consistent with other recent research, which found clear and convincing correlations between drinking and premature death, cancer, and cardiovascular problems. Zero alcohol consumption minimises the overall risk of health loss".

The study used 694 data sources on individual and population-level alcohol consumption, along with 592 prospective and retrospective studies on the risk of alcohol use. More than 500 collaborators, including researchers, academics, and others from more than 40 nations contributed to the study. According to Max Griswold, senior researcher and lead author, "With the largest collected evidence base to date, our study makes the relationship between health and alcohol clear – drinking causes substantial health loss, in myriad ways, all over the world".

The study found that alcohol use patterns vary widely by country and by sex, the average consumption per drinker, and the attributable disease burden. Globally, more than 2 billion people were current drinkers in 2016; 63% of them were male. In 2016, the study found, eight of the leading 10 countries with lowest death rates attributable to alcohol use among 15- to 49-year-olds were in the Middle East: Kuwait, Iran, Palestine, Libya, Saudi Arabia, Yemen, Jordan, and Syria. The other two were Maldives and Singapore.

Conversely, seven of the leading 10 countries with highest death rates were in the Baltic, Eastern European, or Central Asian regions, specifically Russia, Ukraine, Lithuania, Belarus, Mongolia, Latvia, and Kazakhstan. The other three were Lesotho, Burundi, and Central African Republic. The good news is India does not figure anywhere.

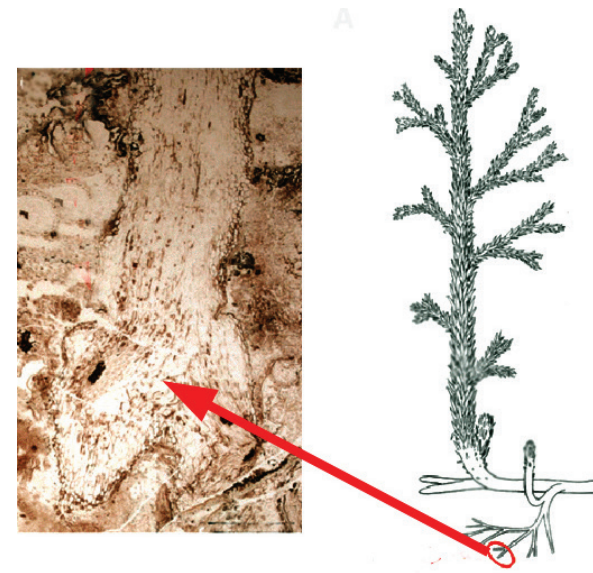
"There is a compelling and urgent need to overhaul policies to encourage either lowering people's levels of alcohol consumption or abstaining entirely," says Gakidou. "The myth that one or two drinks a day are good for you is just that – a myth. This study shatters that myth." *Lancet* Editor Richard Horton says, "We now understand that alcohol is one of the major causes of death in the world today. We need to act now. We need to act urgently to prevent these millions of deaths. And we can."

## Origin of plant roots in land plants

Plants and vegetation are crucial for the Earth's ecosystem. Yet till recently little was known about the origin of roots – one of the three fundamental organ systems of vascular plants which play a crucial role in anchorage, symbiosis, and nutrient and water uptake in plants. This was because of the fragmentary nature of the fossil record that obscures the origins of roots and makes it difficult to identify when the sole defining characteristic of extant roots, namely the presence of root caps covering new root tips, appeared. Recent research has brought to light a transitional root fossil from the earliest land ecosystem that sheds light on how roots have evolved (*Nature*, 22 August 2018; DOI: 10.1038/s41586-018-0445-z). The findings suggest that plant roots have evolved more than once, and that the characteristics of roots developed in a step-wise manner – with the central root organ evolving first and the root cap subsequently coming later.

Roots can be characterised by a few specific attributes. Roots are multicellular organs characterised by special features including gravitropic response, which makes them grow downwards into the ground, branching, and forming root hairs and protective root caps which protect the growing root tips. Roots were an early development in plant life evolving on land during the Devonian Period, 416 to 360 million years ago.

The current research primarily involved microscopic study of the oldest known plant ecosystem preserved in the 407 million-year-old Rhynie chert. (Chert is a sedimentary rock composed of microcrystalline quartz, the mineral form of silicon dioxide.) The study was conducted by Dr Sandy Hetherington and Professor Liam Dolan – both of Oxford's Department of Plant Sciences and Magdalen College Oxford. Says Dr Hetherington: "The level of preservation in the Rhynie chert is truly remarkable – it never ceases to amaze me that I am able to examine the cellular organisation of plants that were growing 407 million years ago. It provides an exceptional window into life on the terrestrial surface at that time."



*Micrograph of longitudinal section of the rooting system of A. mackiei showing dichotomous branching. Notice there is no root cap.*

The defining feature of modern-day plant roots is the meristem – a self-renewing structure that is covered by a cap at its apex. Root meristems are hard to spot in the fragmentary fossil record, which can make it challenging to unearth the evolutionary origin of roots.

Through microscopic study of the Rhynie chert, the authors found evidence of root meristems belonging to the lycopsid plant *Asteroxylon mackiei*. Lycopsids (commonly known as club mosses) are the oldest group of living vascular plants (those with tissues that internally move water and minerals) whose lineage branched off early, before the other higher plants evolved. The researchers were able to build a 3D reconstruction of the fossil meristem.

Surprisingly, the fossil analysis revealed that the meristems of *A. mackiei* lacked both root hairs and caps – they were covered instead by a continuous layer of surface tissue. This structure makes these roots unique among the vascular plants. The authors suggest that these roots are a transitional step towards modern, rooted vascular plants, which came later. The discovery suggests that plant roots were built up step-by-step during the course of plant evolution.

This research, however, does not tell us where root caps came from. As mentioned above, the root cap is important for protecting the root as it pushes through the soil and it is the site where roots detect gravity. Only further research may show how the ancient roots managed without a cap to provide these functions and from where root caps came. ■