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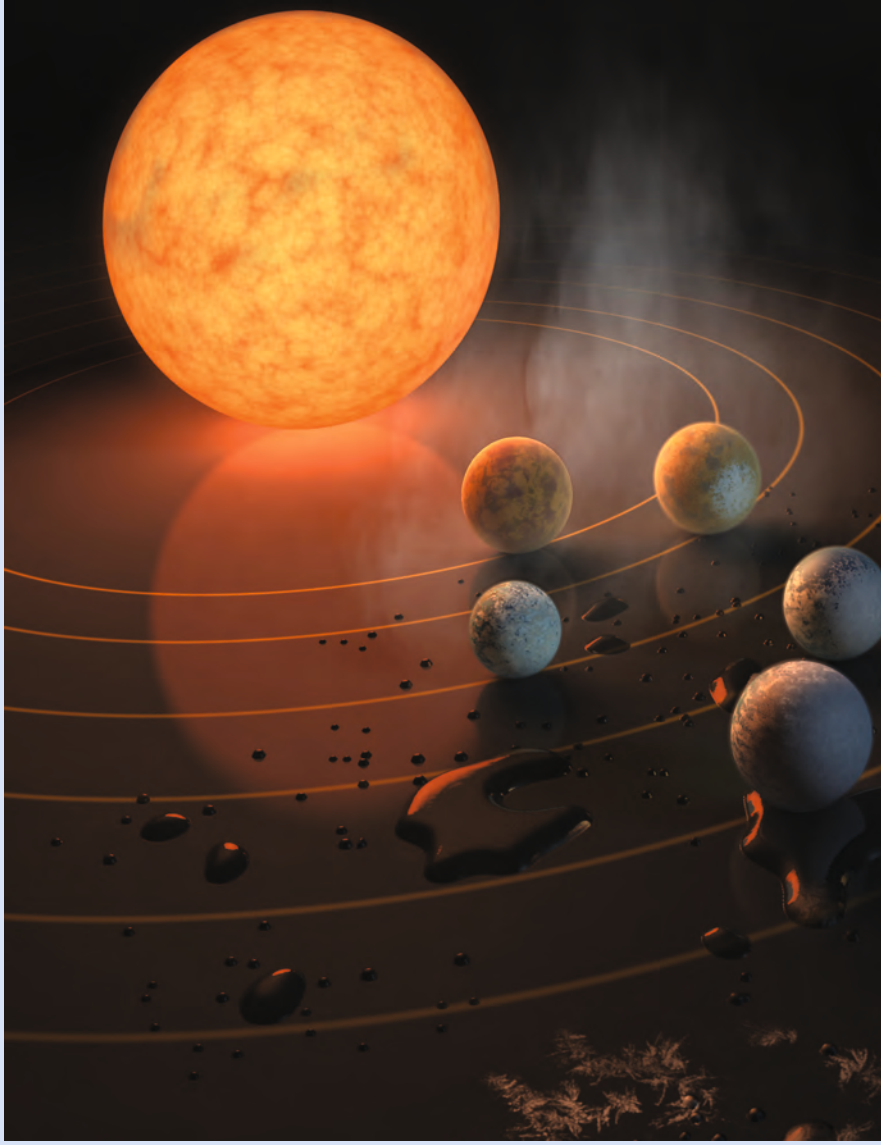
Exoplanet Hunting: Are We Alone in the Universe?



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

The 105th Indian Science Congress

Chander Mohan

The focal theme for 2018 Indian Science Congress (ISC), which was held in Manipur University during 15-20 March 2018, was "Reaching the Unreached through Science and Technology". In 2017, Hon'ble Prime Minsiter (PM) in his inaugural speech, had observed that "some of these important challenges are in the key sectors of clean water and energy, food, environment, climate, security, and healthcare... and need to keep an eye on the rise of disruptive technologies and be prepared to leverage them for growth... clearly assess the challenges and opportunities for our technology readiness and competitiveness." "This year", he observed, "the time is ripe to redefine 'R&D' as 'research for the development' of the nation – that is 'R&D' in the real sense. Science is after all, but a means to a far greater end – of making a difference in the lives of others, of furthering human progress and welfare." He added, "Science and technology could help facilitate "ease of living" for the people. Referring to the focal theme of this year's congress, he said, "scientific knowledge should be applied to solve day-to-day problems in various sectors such as housing, malnutrition, clean energy and elimination of diseases.Thus, ISC endeavoured to take these views to the next level.

A team of media professionals from the India Science Wire (ISW) of Vigyan Prasar (VP), DST, attended the 105th session of the Science Congress. The team produced 12 stories, in Hindi and English, which had 42 republications by various media both print and web media portals. Further, 35 live tweets were issued from ISW Twitter handle which had a total tweet impression of 23,012 while Facebook posts attracted a reach of 15,300. The presence of ISW was not confined to reporting and disseminating information, but also played the role of 'agenda setting'. Of late, ISC coverage in mainstream media had got primarily confined to covering inaugural address by Hon'ble PM, but with intervention of ISW, coverage this year got widened by including little-known aspects of ISC like Women's Science Congress, Pride of India expo, Kishore Vigyanik Sammelen and so on, which were organised by the Department of Science & Technology (DST) and Vigyan Prasar (VP). Stories released by ISW encouraged other media to explore these aspects.

Rashtriya Kishore Vaigyanik Sammelan, organised every year along with ISC, offers a unique opportunity for the young students in the age group of 10-17 years from all over the country, to improve the scientific treatment and expand their innovative talents in the field of S&T. Around 7,000 children participated in this year's ISC, and a science model competition was also held for them for the first time. The main aim is to let child scientists from the school system as well as from out of school to exhibit their creativity and innovation to solve problems they experience locally using the method of science.

Women's Science Congress, another initiative of DST at ISC, once again provided a forum for about 1,100 women scholars, scientists and students from across the country to explore more and engage in science. Through this platform, more young women get inspired to be a part of scientific community by engaging themselves in active research. The Science Congress is also a step towards their capacity building for experimenting ideas and share their research outcomes.

The Pride of India (PoI) Expo, organised on the occasion was a major centre of attraction. Apart from delegates, students and residents of the town also thronged it to get a glimpse of India's achievements in S&T domain. The expo was a hub of new ideas, innovations and products encompassing the entire canvas of scientific world. Indian Space Research Organisation, Department of Atomic Energy, Council of Scientific and Industrial Research, Indian Council of Agricultural Research, and Indian Council of Medical Research, besides DST, had put up their expos. The expo was designed to act as a platform for interactions between scientific fraternity and the academia, on the one hand, and entrepreneurs and students, on the other. A key attraction of this year's Expo was the "Vigyan Jyot" or Flame of Knowledge, aimed at popularising science among the youth and motivating them to take up science as a career. The DST pavilion, put up by VP, showcased its efforts to create and foster India's strengths in S&T and also displayed R&D initiatives realised through its autonomous institutions, which was adjudged the best innovative pavilion.

Email: chander.m@nic.in

Editor : Chander Mohan
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 : rnath07@gmail.com
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Exoplanet Hunting: Are We Alone in the Universe?

M.S.S. Murthy

Recently astronomers have discovered that seven planets are orbiting a Jupiter-sized dwarf star named TRAPPIST 1a. At least three of the seven planets are known to be located within the so called "habitable zone" from the star, triggering the hope of detecting life outside our solar system. The planetary system is located at about 40 light years from the Earth, in the constellation of Aquarius. Are we one step closer to answering the question: Are we alone in this universe?

23 February 2017 was a big day for astronomers. They were celebrating the discovery by America's NASA of seven exoplanets orbiting a dwarf star. Though the discovery of star-planets systems other than our solar system is no longer new, this was particularly exciting because for the first time so many planets were found orbiting a single star. Even more exciting was the announcement that at least three of the seven planets are known to be located within the so called "habitable zone" from the star, triggering the hope of detecting life outside our solar system. The discovery was reported in the science journal *Nature*, in a paper authored by 30 astronomers from across the Atlantic!

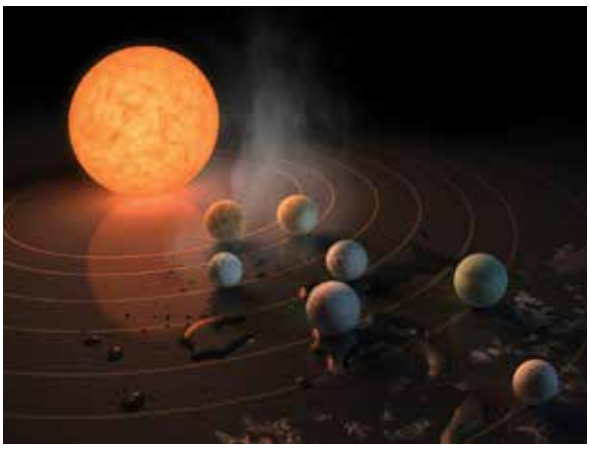


Fig.1. An artist's impression of the seven planets orbiting a dwarf star (Credit: Nature)

What are exoplanets?

An exoplanet is simply a planet orbiting a star outside the solar system. The Milky Way galaxy is known to harbour billions of stars and it is possible that many of them, like our Sun, may have planets orbiting them. The first exoplanet was discovered in 1992 by an American astronomer, wherein the planet was orbiting a pulsar–a neutron star. Later in 1995 a giant planet was found orbiting one of the main sequence stars (stars that generate energy through hydrogen fusion in their core) called 51 Pegasus, further confirming that planets are not unique to our solar system.

How are exoplanets discovered?

When we look at the night sky, a countless number of stars are seen. Even though many of them are much bigger and brighter than our Sun, they appear only as specs of light since they are too far away from us. Any planet orbiting such a star will be much smaller and fainter and hence cannot be seen directly. Powerful telescopes, both ground-based and space-based have to be used. But even then, astronomers have to employ indirect methods to detect and study those orbiting planets. Prominent among these techniques are 1. Radial velocity and 2. Transit photometry.

Radial Velocity: Generally we say that a planet orbits the star. But it is not really true. Just as the star pulls the planet gravitationally, so also the planet pulls the star, though with a weaker tug. Because

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

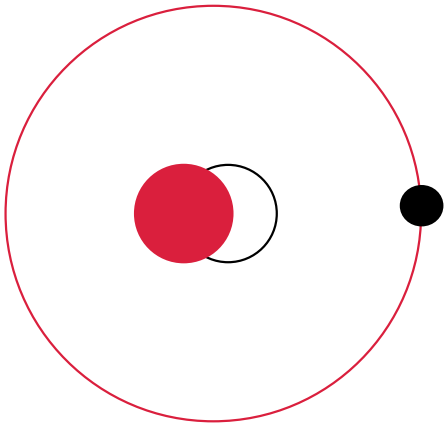


Fig.2. A star-planet system orbiting a common centre of mass

of their mutual gravitational pull, both the star and the planet orbit around their common centre of mass– also known as 'barycentre'. As a result the star moves over a small circular path. If the plane of the orbit is in the line of sight of an observer on Earth, then the star's radial velocity appears to vary as it moves towards or away from the Earth. It is known that when a source of light moves towards or away from the observer, the frequency/wavelength of the light changes. When the source approaches the observer, the frequency shifts towards the blue region of the spectrum (known as blue shift) and when the source moves away, the shift is towards the red (red shift). This is known as Doppler Effect. So by measuring the frequency shift in the star light, it is possible to detect perturbations in its radial velocity and conclude the presence of another body that may be causing the perturbations. By using telescopes equipped with high-sensitivity spectrometers as in HARPS (High Accuracy Radial velocity Planet Search) in the La Silla Observatory in Chile or the HIRES (High Resolution Echelle Spectrometer) at the Keck Telescope, hundreds of exoplanetary systems have been discovered using the radial velocity method.

Since the extent of gravitational force exerted by a planet depends upon its mass, the radial velocity method can also be used to estimate the mass of the planet. However, the mass thus estimated depends upon the inclination of the plane of orbit as seen by the observer. For the same reason, it is easier to detect huge planets by this method. Smaller, Earth-size planets are hard to detect since they create only small wobbles in the star's orbit.

Transit Photometry: When a planet crosses in front of a star disc as seen from the Earth, it is known as a 'transit'. In 2012 many on the Earth would have watched the transit of Venus as a dark spot moving across the bright solar disc. We may not be able to actually see a planet transiting its parent star in all cases. However, as the planet transits the star, it blocks a little bit of the star light. That means the star will look a little bit less bright than otherwise. Thus, by observing how the brightness of the star changes, one can infer not only the presence of a planet, but also figure out the size of the planet. More than one planet transiting at the same time produce multiple dips in the light curve, which can be further analysed to identify the individual planets. By studying the time between the transits, it is also possible to find out how far away the planet is from its star. This will also tell us what would be the temperature on the surface of the planet. Closer is the planet to its star, greater is the chance of detecting it by transit photometry.

Another advantage of transit photometry is that it is possible to study the atmosphere, if any, of the transiting planet. When the star light passes through the atmosphere of the planet, some of the chemical elements present there may absorb light of specific wavelengths. These appear as dark lines in the star spectrum. Thus by carefully analysing the stellar spectrum by high resolution spectrometers attached to a telescope it is possible to detect the chemical elements present in the planet's atmosphere.

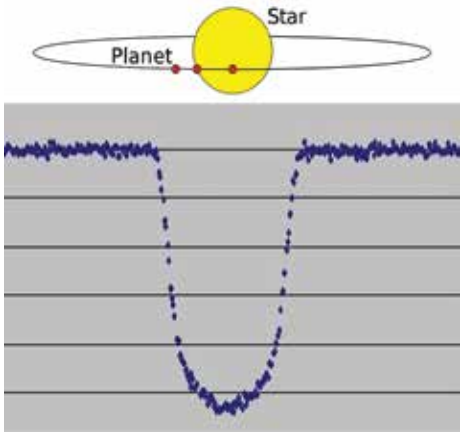


Fig.3. A planet transiting its star and the resulting dip the starlight as seen by observer on Earth. The dip is exaggerated (Credit: Wikipedia)

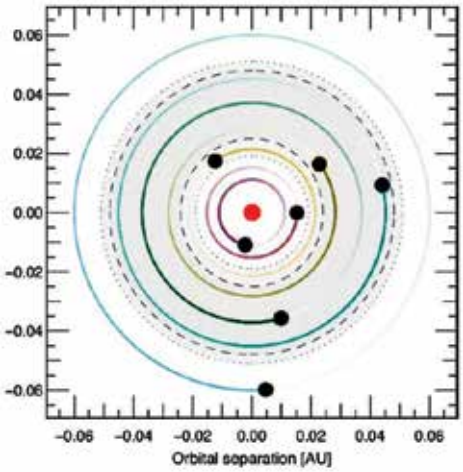


Fig.4. Orbits of seven planets around the cool star TRAPPIST 1a. The shaded areas and the dashed circles represent habitable zones around the star under various assumptions.

Then there are other methods like Direct Imaging, Reflection/ Emission Modulation, Gravitational Microlensing, Pulsar Timing (when a planet is orbiting a pulsar), and so on. However, since false positives are possible in every method, an exoplanet discovered by one method is always confirmed by employing the other methods. Also by combining data from different methods many more features of the planets can the estimated. For example, by combining data on mass of the planet (as determined by the radial velocity) with the size of the planet (as estimated by the transit photometry), astronomers can estimate the density of the planet and then speculate on its internal structure– whether it is rocky, icy or gaseous. It is astonishing how, sitting several light years away, astronomers can accrue vital information about these other planetary systems!

The French, European and American space agencies operate several space-based and ground-based observatories to look for exoplanets. Of these the *Kepler* spacecraft, launched by the America's NASA in 2009 designed to probe exoplanets by using transit photometry has been the most successful. According to one estimate, as of May 2017, a total of 3,621 exoplanets have been discovered and confirmed in 2,712 planetary systems.

Continued on page 28

Identifying Genes that Control Our Body Clock

Biman Basu

For a long time it was not known how this biological clock of every living organism actually works, till a trio of American scientists – Jeffrey C. Hall of the University of Maine, Michael Rosbash of Brandeis University in Waltham, and Michael W. Young of Rockefeller University in New York, USA – were able to unravel the mystery. They discovered that body's internal clock is controlled by certain genes. They were awarded the 2017 Nobel Prize in Physiology or Medicine, "for their discoveries of molecular mechanisms controlling the circadian rhythm".

It has been known for long that every living organism – from the tiniest bacterium to plants, animals and human beings – have an have an internal biological clock known as the circadian clock that controls activities like the sleep-wake cycle, hunger cycle, hormonal cycle and much more. (The term circadian is derived from the Latin "*circa diem*" meaning "approximately a day".) These regular cycles are controlled by the day-night cycle caused by the Earth's daily rotation around its axis.

Very often the term biological clock is used interchangeably with circadian rhythms. However, though related, they are not one and the same. In fact it is biological clocks that produce circadian rhythms and regulate their timing.

The biological clock is generated by about 20,000 neurons that form a structure called the 'suprachiasmatic nucleus' (SCN), which is a tiny region of the hypothalamus in the brain. These neurons receive signals from the eyes. Besides light, exercise, hormones, and medications also affect the SCN and the setting of the circadian clock.

Circadian rhythms are synchronised with the Earth's rotation by daily adjustments in the timing of SCN, following the exposure to light which indicates the time of the day. When it is dark at night, the eyes send a signal to the hypothalamus that it is time to feel tired. The brain, in turn, sends a signal to our body to release melatonin hormone, which makes us feel drowsy. The onset of secretion of melatonin occurs about two hours before natural sleep time and peaks during the middle of the night. That is why the circadian rhythm tends to coincide with the cycle of daytime and night-time.

Any disruption in the internal clock or when there is a mismatch between this internal "clock" and the external surroundings can affect the organism's wellbeing and lead to serious disturbances in normal activity. A common example is the 'jet lag' experienced by air travellers after crossing several times zones because of a shift in the day-night hours at their new destinations. They tend to feel sleepy and stay awake at the wrong hours at the new time zone. In the short term, body clock disruption affects memory formation, but in the long term it increases the risk of diseases, including type-2 diabetes, cancer and heart disease. Jet lag can have a profound effect on sleep and alertness.

Physiology or Medicine laureates. (l to r) Michael Rosbash, Jeffrey C. Hall, and Michael W. Young (Credit: nature.com)

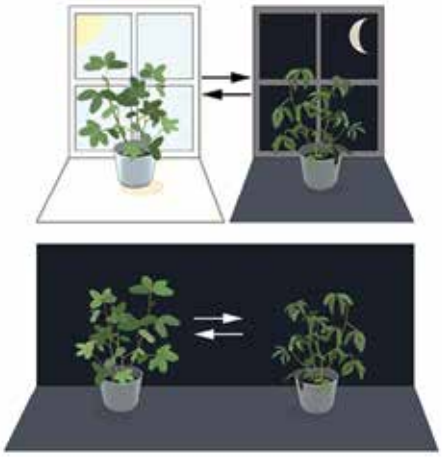
The author is a former editor of the popular science monthly *Science Reporter*, published by CSIR, He is a winner of the 1994 'NCSTC National Award for Science Popularisation'. He is the author of more than 45 popular science books. Email: bimanbasu@gmail.com

For a long time it was not known how this clock actually works, till a trio of American scientists – Jeffrey C. Hall of the University of Maine, Michael Rosbash of Brandeis University in Waltham, and Michael W. Young of Rockefeller University in New York, USA – were able to unravel the mystery. They discovered that body's internal clock is controlled by certain genes. They were awarded the 2017 Nobel Prize in Physiology or Medicine, "for their discoveries of molecular mechanisms controlling the circadian rhythm".

The work of the three Nobel laureates showed that like a switch, light can turn off and turn on genes that control the molecular structure of biological clocks. Changing the light-dark cycles affects the sleep-wake cycle by speeding up, slowing down, or resetting biological clocks as well as circadian rhythm. Besides determining the sleep-wake cycle, circadian rhythms influence hormone release, body temperature, metabolism and other functions.The work of the three laureates explains how plants, animals and humans adapt their biological rhythm so that it is synchronised with the Earth's revolutions.

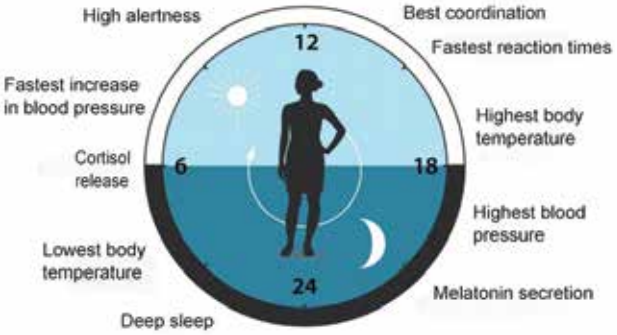
The three laureates used fruit flies (*Drosophila melanogaster*) as a model organism, and isolated a gene that controls the normal daily biological rhythm. They showed that this gene encodes a protein that accumulates in the cell during the night, and is then degraded during the day. Subsequently, they identified additional protein components of this machinery that revealed the mechanism governing the self-sustaining clockwork inside the cell. Misalignments in this clock, they said, might play a role in medical conditions and disorders, as well as the temporary disorientation of jet lag that travellers experience when crisscrossing time zones.It is now recognised that biological clocks function by the same principles in cells of all multicellular organisms, including humans.The team's discoveries also helped explain the mechanism by which light can synchronise the clock.

Early work on circadian rhythms was initiated by Jeffrey Hall who was at Brandeis University from 1974, where he took an early interest in the biology of circadian rhythms in fruit flies. His initial work showed that



The leaves of the mimosa plant open towards the Sun during day but close at dusk (top). But studies during 18th century demonstrated that the leaves continue to follow their normal daily rhythm, even when kept in constant darkness (bottom), indicating the presence of some kind of an internal clock. (Credit: nobelprize.org)

a specific gene played an important role in regulating the rhythm of courtship cycles of male fruit flies. In the 1980s, working in collaboration with his Brandies colleague Michael Rosbash, a neuroscientist, he isolated a section of DNA called the 'period'



The circadian clock anticipates and adapts our physiology to the different phases of the day. Our biological clock helps to regulate sleep patterns, feeding behaviour, hormone release, blood pressure, and body temperature. (Credit: nobelprize.org)

gene, which had been implicated in the circadian rhythm.

With the gene identified, the researchers then aimed at figuring out how the 'period'gene fits into a biological clock. The first clue came when Hall and Rosbash discovered that the levels of the protein encoded by this gene (called PER) changes in a 24-hour cycle, suggesting that the variation might somehow communicate time information to the rest of the cell. Subsequent work by themshowed how abundance of the PER protein peaks at night and then declines during the day. The researchers gradually pieced together a model in which the accumulation of PER serves as a signal that blocks expression of the gene that encodes it. This type of negative feedback loop would become a prevailing theme in the study of circadian rhythms, as researchers identified additional loops and clock proteins over the years.

But to have this effect, the protein would have to reach the genetic material in the cell nucleus, and no one was able to figure out how it got there. In 1994, Michael Young, working at Rockefeller University, independently discovered aclock gene called 'timeless'. He showed that when the protein encoded by the 'timeless'gene bound to the protein made by the gene 'period', they were able to enter the cell nucleus. He further identified a third gene, 'doubletime,' which appeared to control the frequency of the oscillations over a 24-hour period.They both affect the stability of PER.

Together these discoveries laid the groundwork for other researchers to map similarly essential circadian genes in mice and other animals. They provided insight into how a periodic fluctuation in levels is adjusted to more closely match a 24-hour cycle. It is now recognised that biological clocks function by the same principles in cells of all multicellular organisms, including humans.The medical relevance of these findings became apparent as it was found that changes in these clock genes are associated with a series of sleep disorders in humans.

While all three laboured to isolate the period gene, publishing was something of a race. While Hall and Rosbash collaborated as colleagues, Young was working on the puzzle independently. Both teams reported their findings in 1984. According to the scientists, "The medical relevance of these findings has become apparent as it was found that changes in these clock genes are associated with a series of sleep disorders in humans. There are strong indications that some forms of depression are linked to the control of circadian rhythms."

Diabetes Education in India: Need of the Hour

Richa Saxena

A diabetes patient not only has to visit a diabetes specialist for adjusting his or her insulin dose and medications, but he may have to also visit other specialists such as a cardiologist if he is a heart patient, an eye specialist for diabetic eye disease or retinopathy, nephrologist for kidney disease and a podiatrist for diabetic foot disease, etc. Implementation of diabetes education programmes and access to medical services under one roof will help numerous patients to manage the disease better. With a burgeoning diabetes population in our country, introduction of diabetes education programmes is the urgent need of the hour.

In spite of taking insulin injections and diabetes medications as prescribed by the treating physician, people suffering from diabetes still struggle to control blood sugar levels with poor health outcomes and a rapidly rising incidence of life-threatening diabetes complications. Diabetes mellitus is not a disease like cold and flu which can be treated by merely popping pills. It is a disorder which lasts a lifetime and requires self- management through proper education and skill development.

There is need to sensitise government and policy makers to address this escalating health problem by introducing diabetes education programmes throughout the country. The importance of diabetes education is still not understood by many medical professionals as well as the government.

Diabetes patients in most parts of India are unable to manage their disease well due to poor access to good quality medical services, which are only available to those living in large metro cities. Implementation of diabetes education programmes and access to medical services under one roof need to be provided as diabetes patients have to visit more than one specialist for managing diabetes complications. For example, a diabetes patient not only has to visit a diabetes specialist for adjusting his or her insulin dose and medications, but he may have to also visit other specialists such as a cardiologist if he is a heart patient, an eye specialist for diabetic eye disease or retinopathy, nephrologist for kidney disease and a podiatrist for diabetic foot disease, etc. The importance of diabetic foot clinics cannot be ignored due to an increasing number of non-traumatic foot amputations among diabetes patients every year. Due to lack of awareness about diabetic foot problems or due to non-availability of a podiatrist or foot care specialist in their region, diabetes patients often suffer from serious foot complications that may begin as a minor injury and lead to a non-healing foot ulcer/sore, which when left untreated may lead to amputation.

Running to different specialists takes a toll on diabetes patients as they need to invest much time, energy and money in visiting several specialists for various complications. If all these services are provided under one roof, then it will surely lead to better compliance and ensure regularity in visiting the doctors. Moreover, a diabetes patient is more likely to take his condition seriously if he is educated about diabetes and its complications during his visits to the physician's office. This will save considerable time and other resources as he will receive diabetes education during his visits to the physician.

The cost of managing diabetes poses significant financial burden on the patient. This in turn discourages the patients, especially those belonging to lower socioeconomic group, from taking their condition seriously as they cannot afford to buy expensive medications, insulin

Richa Saxena is currently working as a freelance nutrition and health writer. Previously she worked in Dr. Reddy's Foundation for Health Education and Wockhardt Hospitals, Hyderabad. Email: 2rd.richa@gmail.com

injections and blood glucose monitoring strips. The government needs to take steps in providing diabetes medicines and other supplies at subsidised rates to ensure greater affordability.

Increase in stress due to time constraints and commuting problems only discourage the patient from visiting the physician regularly. Moreover, due to lack of awareness about diabetes self-management, in spite of adhering to the doctor's prescription, diabetes control suffers. This lowers a patient's confidence in the doctor's ability to treat diabetes leading to much frustration and lack of motivation to manage the disease.

On the other hand, some people with diabetes are often concerned about managing their disease condition, but lack of education only leaves a patient helpless and clueless as they look for someone who could help them make complex daily decisions about diabetes management. Here, a diabetes educator can play a vital role in serving as a facilitator to help diabetes patients modify their behaviour and empower them with the necessary skills to manage diabetes on a daily basis. A diabetes educator not only guides the patients towards better diabetes control but also provides emotional comfort as diabetes patients often suffer from depression and psychological issues which remain unaddressed due to a doctor's busy schedule.

Psychological counselling of diabetes patients is an important aspect as it leads to better compliance and improved patient well-being. Screening for depression among diabetes patients helps in timely treatment of depression which can affect diabetes control immensely. A patient who has sound knowledge of diabetes is better equipped to handle crisis situations arising due to diabetes. For example, hypoglycaemia or low blood sugar is often seen in patients who are treated with insulin. Only if a patient knows how to recognise the symptoms of hypoglycaemia and how to treat it when it actually happens, will he be able to save his life from this acute complication which can be potentially life threatening, if left untreated. Moreover, timely detection and treatment of acute complications of diabetes can reduce the chances of hospitalisation, thereby contributing to significant healthcare savings.

The key to controlling diabetes is education. Through education patients can successfully keep diabetes away.

Benefits of diabetes education

1. Improved quality of life.
2. Enhances patient's ability to cope with the emotional stress of diabetes.
3. Helps patient understand the gravity of the disease.
4. Better A_1C levels (indicator of average blood-glucose concentration) due to improved glucose control.
5. Reduction in medical expenditure leading to significant healthcare savings.
6. Prevents or delays long term complications of diabetes.

During diabetes education sessions, interaction between diabetes patients has many benefits. Patients learn a lot by sharing their experiences and provide emotional support to each other. This encourages active participation in diabetes management, helps in problem solving and motivates many patients to take charge of diabetes in a proactive manner when they hear about success stories of diabetes patients who are well-informed and empowered with the skills.

Diabetes management should not be limited to visits to a physician, but the patient must actively be involved in managing diabetes through self-care behaviour. Each diabetes patient must assume the responsibility of looking after his health. This is possible only when the patient is involved in diabetes management plan wherein a diabetes educator serves as a coach to educate the patient about self-care behaviours such as:

Learning to inject insulin correctly in the body - Early initiation of insulin leads to better diabetes control. Patients with diabetes often have apprehensions about starting insulin injections. They often feel punished for not being able to manage diabetes and may have a sense of failure when asked to initiate insulin treatment. Lack of confidence also prohibits many patients from taking insulin as injecting insulin needs proper guidance and practice. Diabetes education helps patients learn how to inject insulin in a correct manner and also removes any fears they may have regarding insulin injections.

Monitoring blood glucose at home using a glucometer - Monitoring blood sugar at home not only helps to prevent any casualty arising due to acute complications of diabetes such as low blood sugar and ketoacidosis, but also helps a patient in achieving his target blood sugar levels.

Recording blood sugar readings in a logbook for future reference - Blood sugar readings taken at different points of time during the day give a clear picture of how well a person is managing his diabetes. The readings recorded in a logbook enable the healthcare team (doctor, nurse, and dietitian, and diabetes educator) along with the patient to make any changes in the diabetes treatment plan.

Learning to interpret blood sugar readings to adjust insulin dose - Unless the patient is taught how to interpret the blood sugar readings, the patient will not be motivated to check and record glucose readings. Once the patient learns how to adjust insulin dose according to blood sugar readings, he will be able to prevent

fluctuations in blood glucose levels arising due to improper insulin dose.

Balancing food intake and activity to manage blood sugars - Home monitoring of blood glucose also helps a patient actually see the effect of food and activity levels on blood sugar. The patient can lower or increase food intake depending on activity levels which may vary on a day-to-day basis. On days with higher activity levels, food intake can be increased or insulin dose can be lowered to prevent low blood sugar levels. Blood sugar monitoring also helps in controlling portion sizes of food and gives the patient more freedom to enjoy a variety of foods in his diet including the ones he relishes as an occasional treat.

Treating acute complications of diabetes to avoid hospitalisation - Acute complications of diabetes mellitus such as hypoglycaemia and ketoacidosis can become life threatening if ignored and left untreated and may require hospitalisation. Through patient education, one can learn to recognise the symptoms and treat the condition on time which saves one from hospitalisation.

Preventing long term complications of diabetes by achieving target blood glucose levels - With optimal blood glucose levels, one can prevent or delay long-term complications of diabetes (cardiovascular disease, retinopathy, neuropathy and nephropathy), especially when diabetes patients are imparted education about diabetes self-management soon after diagnosis. Those who have long-standing diabetes and have developed complications also benefit from achieving target blood glucose levels as it retards further progression of the disease complication.

Sick day management - Diabetes patients must not neglect diabetes during an episode of illness such as cold, flu or diarrhoea. Blood-sugar monitoring is even more important during illness as blood glucose levels tend to be high during fever or illness. Prolonged diarrhoea can lead to low blood-sugar which again needs proper dietary management and blood-glucose monitoring to prevent low blood glucose and dehydration arising from untreated diarrhoea**.** Hence, diabetes patients need to be educated about sick day management rules as negligence during illness can result in acute complications of diabetes.

India leads the world in diabetic population but lags behind in diabetes education. With a burgeoning diabetes population in our country, introduction of diabetes education programmes is the urgent need of the hour. Since diabetes mellitus is incurable, it has to be managed successfully by actively involving the patient in the treatment plan. This is possible only when the patient is well-informed about diabetes and is motivated enough to take charge of his diabetes through self-care behaviour.

Thus, a patient-centred approach to diabetes management empowers the patient with the necessary survival skills and enables him to make informed decisions about managing diabetes as he learns to use his discretion in decision-making process on a daily basis. Since each patient's needs are different, a highly individualised diabetes management plan needs to be devised with the help of the patient along with the diabetes care team. This will not only enable him to control diabetes better but also help in preventing long-term complications arising due to poor diabetes control. Implementation of a diabetes education programmes in India will help in managing diabetes more effectively which will considerably reduce healthcare expenditure and improve productivity leading to economic growth. ■

Exoplanet Hunting: Are We Alone in the Universe? ..... *(Continued from page 33)*

The TRAPPIST 1a System

The present excitement is around the discovery by transit photometry, of the first known system of seven Earth-sized planets around a single star known as *TRAPPIST 1a*, by NASA's *Spitzer* Space Telescope launched in 2003. The planetary system is located at about 40 light years from the Earth, in the constellation of Aquarius, which astronomers think is relatively close to us! The seven planets have been named as *TRAPPIST*-1b, 1c, 1d, 1e, 1f, 1g, and 1h with orbital periods ranging from 1.5 to 12.35 Earth days. With support from as many as six ground-based observatories, the *Spitzer* team has measured the size, mass and density of the planets. Five of these–1b, 1c, 1e, 1f, and 1g –have size similar to that of Earth, while the other two are intermediate in size between Mars and Earth. Furthermore, at least three of these planets are rocky and located in the habitable zone– an area around a parent star where the rocky planet is most likely to have the right temperature and liquid water conducive to life. NASA summarised the importance of the discovery by announcing, "The discovery sets a new record for the greatest number of habitable-zone planets found around a single star outside our solar system. All these seven planets could have liquid water– key to life as we know it – under right atmospheric conditions... and highly conducive for life to exist".

TRAPPIST 1a itself is a small, Jupiter-sized star, about 8% of the mass of our Sun. It is not massive enough initiate sustainable nuclear fusion in its core and hence glows in red. Being about 2,000 times fainter than our Sun, it is classified as a dwarf ultra-cool star. Because of the low mass of the star, the planets orbit closely to the star and hence are warmed gently (temperature in the range of 0 to 100 degrees Celsius), raising the hopes of supporting life even if it is in its rudimentary form.

What Next?

The *Spitzer* team believes that similar dwarf stars could host Earth-sized planets in tight orbits making them "promising targets" in the search for extra-terrestrial life. Meanwhile, astronomers will be busy finding out if the *TRAPPIST 1a* planets could have atmosphere and contain traces of gases which are by-products of life. Gases like carbon dioxide, oxygen, methane are released to the atmosphere during the respiration of animals, plants and microorganisms. Hence, traces of these gases in the planetary atmosphere may indicate the existence of life in some form. James Webb Telescope, expected to be launched by NASA in 2019 will attempt to detect these chemical fingerprints of life in the *TRAPPIST 1a* planets' atmosphere. It will also analyse the planets' surface temperature to assess their habitability and take us one step closer to answering the question: Are we alone in this universe? ■

The Legendary Stephen Hawking

Susheela Srinivas

We don't know whether it was a cosmic scheme of things or an uncanny coincidence, but Stephen Hawking was born exactly 300 years after the death of Galileo and died on the day Einstein was born exactly 139 years ago. Whatever may be the links; Hawking, the acclaimed scientist, theoretical physicist and thinker, contributed immensely to the field of cosmology and earned a well-deserved place on par with the stalwarts.

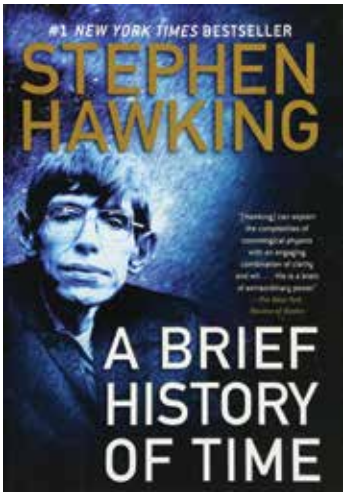
The rare debility that afflicted his body bound him to his wheelchair, perhaps, but his brilliant mind roamed freely all over the universe, deciphering its concepts and seeking answers to many complex questions that have been plaguing humankind for centuries.

From the age of 21 to his last breath at 76, Hawking was immersed in cracking the code of the universe, lecturing the science fraternity, predicting the future of space technology and finding path-breaking strategies for space travel, in collaboration with scientists, universities and agencies.

Not content with unparalleled heights in research alone, he was eager to share the puzzles of the universe with all. The numerous books he penned during his lifetime are a testimony to this zeal. As an author of several science books, his attempt to disseminate complex theories and present them in simple terms for all to understand is remarkable.

His first book, *A Brief History of Time* (1988) remained a bestseller for 237 weeks: a unique record for a science book. It has been reprinted with updates including further research since then. His books continue to be significant not just for the scientific community but the general reader as well, as they provide logical reasonings to our existence.

Self-admittedly an agnostic, Hawking freely discussed the concept of God as the originator of the universe but chose to remain on the scientific side of the argument. His illustrious life spanning 76 years has seen trials, tribulations and triumphs.



Early days

Born to Frank and Isobel Hawking on 8 January 1942 in Oxford, England, Stephen was their first born followed by two sisters and an adopted brother. The family lived in Highgate, London, where he attended school. His father was a medical man and often travelled to East Africa to conduct his researches on tropical medicine. His mother educated in Oxford worked as a secretary.

Highgate was an area where the academics and scientific community lived, and this influenced his upbringing. As a child, Stephen was often fascinated by mechanical and electrical toys. One of his prized possessions was an electric train bought by his father from America when he was five years old. As he writes, he liked to take things apart out of curiosity to learn and wanted to control them.

Hawking received a scholarship at Oxford where he pursued his graduation, and, later proceeded to Cambridge for research. Here, inspired by the famous Indian scientist Jayant Narlikar's work (having done a summer course with him), Hawking applied to work with Fred Hoyle (Narlikar was his protégé), the well-known British astronomer who supported the steady state universe theory. However, fate willed otherwise, and he was not offered a position with Hoyle. Finding cosmology and gravitational theory based on Einstein's theory of relativity interesting, Hawking began his research at Cambridge.

Could it be a big bang?

In the 1960s, the widely accepted theory on the origin of the universe as advocated by Fred Hoyle was the steady state theory, according to which the universe existed as we find it today without a beginning or an end. The galaxies were forever being created as the universe expanded.

It was also the time when Roger Penrose, another famous British mathematician, presented the existence of

Susheela Srinivas is an engineer, popular science writer, and columnist. Email: sushsri@gmail.com

cosmological singularity: point of infinite density and space-time curvature which was theorised in Einstein's general theory of relativity and would exist when massive stars collapsed upon themselves.

Taking off from here and working backwards, in 1966 Hawking submitted his dissertation paper where he conjectured that the universe could have originated from a singularity, but exploding outward. The present state of the universe is an outcome of an event of a point of infinite density and infinite space-time curvature exploding outward and expanding. He presented mathematical calculations to support his arguments. Also, his theory answered why the galaxies were found to be ever moving away from each other.

For the next decade, Hawking continued his research to support his theory further, this time collaborating with Penrose. The result is the big bang theory as we know it today: A situation in the beginning when the concept of space and time were non-existent, and from where the universe began expanding into the world as we witness today.

The scientific fraternity began taking notice of his theory. This was also the time when the steady-state universe theory failed to qualify in experimental tests and hence Hawking's theory gained momentum.

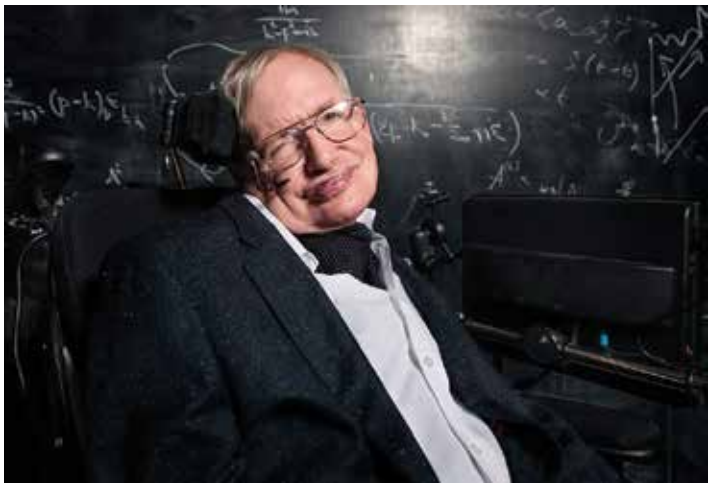
In recognition of his work

During the 1970s physicists were equipped with two theories on cosmological factors: One was Heisenberg's uncertainty principle stating that 'empty' space is not devoid of particles — as appears to be understood— but consists of matter-antimatter pairs which are rapidly separating and combining to ultimately crash and annihilate, all in an infinitesimally short time which is beyond measurement.

The other was that black holes were stars that collapsed on themselves into gravitationally intense bodies trapping everything at their centres such that even light could not escape. Anything that enters the fringe of this centre called the event horizon is lost forever. Accordingly, it was understood that black holes never emit light, never shrink and are continually gaining mass as they draw more and more matter from surroundings.

During this time, two physicists from the then Soviet Union working on the energy of spinning black holes showed that such a system would emit particles which carried some of the momenta of the black hole and can escape away from the system sapping some of the energy. If such a situation continued, eventually the black hole would cease to spin.

Intrigued, Hawking began working around these theories with the intention of testing, repeating and refining them. What emerged from his theoretical calculations surprised him and the world. What he found can best be described in his own words, and



as written in *A Brief History of Time*: "I found, to my surprise and annoyance, that even non-rotating black holes should apparently create and emit particles at a steady rate. In fact, some of those particle pairs must appear perfectly positioned with one negative-mass antimatter particle separated onto one side of the event horizon and the other positive-mass matter particle separated onto the other side."

He further explained that these pairs would move away sufficiently and begin to stream from the surface of event horizons, causing emissions from the event horizons. The radiation was named 'Hawking radiation" in his honour.

This discovery changed the way the world viewed black holes: as a wall that gobbled up matter that rapidly decayed over time, streaming particles into space by laws of thermodynamics and quantum theory. The first black holes emerging out of extreme pressures of a growing universe would have shrunk enormously and hence would be streaming out powerful radiations (Hawking radiation). Eventually, they would explode.

Not deterred by disability

Hawking's constant companion from the age of 21 was his debilitating motor neuron disorder medically known as Amyotrophic Lateral Sclerosis (ALS), also known as Lou Gehrig's disease. Like anybody subjected to devastating news, he was in shock initially. In his memoir – *My Brief History* - he confesses, however, that the prospect of an early death urged him to work incessantly in his intellectual pursuits. Over time, the disease ultimately paralysed his body forcing him to a wheelchair and in need of constant care. He also considers himself lucky as the disease did not affect his mind.

As he gained prominence as a cosmologist, he toured the world on his wheelchair. Highly technical modifications to his support equipment became a signature part of him: An advanced electrical wheelchair, his life-support system attached to it and a rare computer which detected the movement of a single functioning cheek muscle and synthesised his words to speech. With the help of this system, he could choose words on his computer and compile speeches, lectures and even write. Almost all his works we access today are derived from this system.

Hawking spent nearly five decades as a thinker and cosmologist, delivering insightful observations of the universe and theorising its nature of origin. It is but natural that he was conferred highest accolades and positions, in the league of Sir Isaac Newton, Charles Darwin, Rutherford and J.J. Thomson.

The death of this legendary cosmologist on 14 March 2018 is a huge loss to cosmology and the world at large; the void may remain for a long time to come. As one of the rare geniuses of the latter half of the twentieth century, Hawking left a legacy of theories: an amalgam of the existing and newfound wound together and envisioned to be working in ways to define our origins — all in more perceptible terms. ■

Crisp and CRISPR: Designing our Descendants



Jayashree Das, Pritha Dey and Pradipta Banerjee

Genetic modification is a gradual process that takes hundreds of thousands of years perfecting an organism to adapt to its environment. However, with the cutting edge-technology available to us today, changing a genome may take few hours to weeks, giving rise to the basic question of all: is it safe? The questions seem never-ending; is the gene-editing man playing God? Or is this another honest attempt at eliminating darkness?

The term "Designer babies" includes children whose characteristics have been tampered with by chemical modification of their genetic material while in the womb. The resultant offspring are said to be "designer" babies because the genetic alteration in the zygote stage is done through technology and is a far cry from being "natural". Genetic modification, even though it sounds frightening, is a regular course of action that forms the basis of evolution, a gradual process that takes hundreds of thousands of years perfecting an organism to adapt to its environment. However, with the cutting edge-technology available to us today, changing a genome may take few hours to weeks, giving rise to the basic question of all: is it safe?

Advancement in science and technology has taken man forward in great leaps and bounds in uncovering the secrets of Nature. But sometimes the fine line between uncovering its secrets and respecting its boundaries becomes hazy. This has wide implications that may range from a sense of euphoria and achievement to that of fear and an impending catastrophe. Some believe that venturing into *terra incognita* or unknown lands is a risky step at this nascent state of biotechnology, incurring Walt Kelly's famous statement about Nature being destroyed by relentless progress "We have met the enemy and he is us". However, some scientists see a silver lining and seek refuge in the fact that there is no true knowledge without taking chances. They argue that editing the genome at the zygote stage may fend off genetic defects which would have otherwise crippled the baby. Even though scientifically sound, the ethical attributes of the phenomenon remains an ever-argued issue.

The social and ethical conundrum

The situation remains tangled because of differing laws and opinion of different countries. For example, germ line modification of DNA is considered illegal in countries like the UK while being marginally considered in the US. Some bioethicists have maintained that designer babies are technically a commodity and should be subjected to market regulation. Some parties believe that whether legal or not, interfering with evolution may have severe consequences on genome stability, while some others lament the socio-economic rift created between parties who can afford to have designer babies and those who cannot. Several religious groups, as expected, vehemently oppose such new endeavours in science as they believe it goes against the norms of their religion and are a threat to the laws of Nature.

Humanitarian issues also factor in this respect. For example, if one were to find out that they were made as a replica of another or created for a particular purpose or that their destiny was charted out before they

Jayashree Das is HOD-in-charge, Department of Biochemistry, Dayananda Sagar Institutions, ShavigeMalleshwara Hills,Kumarswamy Layout, Bengaluru-560078. Email: jayashreedas26@gmail.com
Pritha Dey has completed her BSc in Biochemistry from Dayananda Sagar Institutions, Bengaluru - 560078. Email: prithadey81@yahoo.in
Pradipta Banerjee is Assistant Professor of Biochemistry at the School of Basic and Applied Sciences, Dayananda Sagar University, Bengaluru - 560078. Email: pradipta.banerjee@dsu.edu.in

were born, would such a person be normal? It should be kept in mind that, though specifically designed before their birth, such individuals would still be humans, endowed with all biochemical and physiological systems, as well as emotions. However, the very fact that the designed human in question has no biological parents or siblings, or a family for that matter, of his or her own could, of course, be a cause for emotional instability such as severe depression.

On the other hand, what is expected of a society that finds out that a person living among them has been specifically designed to be intelligent, powerful or brutal or poetic? Are we as humans really ready to accept such an individual? If history is any lesson it has always been that a newer immigrant is perceived as more of a threat than a welcoming hand, particularly so if the incursion poses a threat to the bread-winning population of the society.

The science behind it all

So how do we modify the genome of a baby in the womb? Genes are in fact specific regions in a long chain of nucleic acids which holds the information for sequential joining of amino acids in order to synthesise a protein. There are 64 known codes and they are grouped as triplets. Each triplet is called a codon. Each codon comprises a sequence of three nucleotides and specifies a particular amino acid(for example, AUG, which stand for Adenine, Uracil and Guanine, codes for methionine) and many such amino acids are linked together to form protein molecules, the building blocks of life. Modification of a gene involves changing the sequential arrangement of nucleotides. The new sequence codes for different amino acids to be incorporated in the protein chain. The resulting protein may perform a different function leading to changes in cellular activity.

This change in gene expression can be performed with surgical precision with the help of a newly found set of genes known as CRISPR (clustered regularly interspaced short palindromic repeats) and CRISPR-associated proteins (Cas). The protein Cas9 is an endonuclease, a type of enzyme that recognises and breaks down polynucleotide strands at a specific site within the given stretch of nucleic acids.

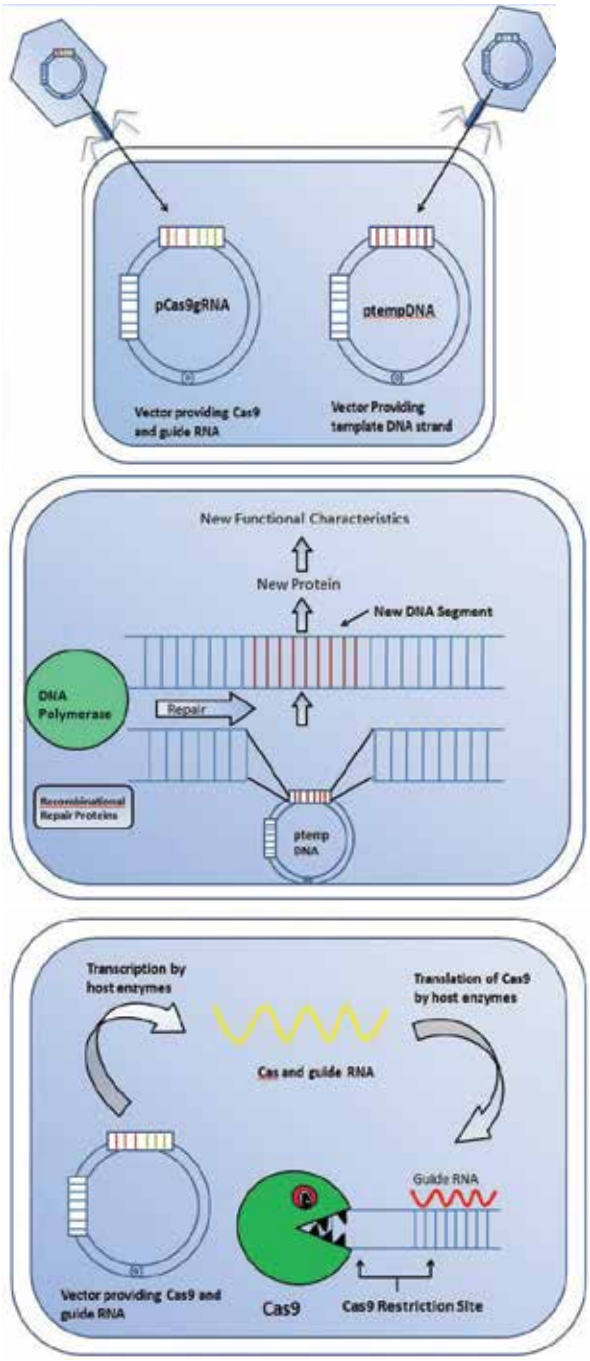


Fig. 1. Utilisation of Cas9-CRISPR system for genome editing in the embryo (Credit: Banerjee et al. 2016)
a) Insertion of two plasmids in the host embryonic cell through viral transfection. Both vectors contain an origin for replication, a marker to ensure the success of transfection and a suitable gene of interest. The first vector, pCas9gRNA is a plasmid containing the gene for Cas9 and a guide RNA that can bind to the host defective gene to be replaced. The second vector, ptempDNA contains a corrected copy of the gene to be replaced, the template.
b) The host enzymes synthesise the Cas9 nuclease and the gRNA from the first vector. The gRNA binds with the gene to be replaced and Cas9 makes a double stranded cut.
c) Cellular repair proteins insert the template DNA from 2nd vector.

At the heart of this gene editing system, the steps of which are shown in Fig. 1, lies the triad consisting of Cas9 nuclease, a guide RNA, and a template DNA. The stretch of genes coding for Cas9 enzyme and a guide RNA is integrated into a vector and injected into the host cell, usually a stem cell taken from an embryo. A second vector containing the template DNA (the corrected copy of the gene to be replaced) is also injected into the same host cell. Once inside the cell, host protein synthesis components create Cas9 protein and guide RNA from the first vector. The guide RNA molecule directs it towards the stretch of DNA to be replaced, where Cas9 makes a double-stranded break. This triggers a chemical alarm signal leading to the recruitment of repair proteins at the broken site. During DNA repair, the cell is forced to integrate a newly introduced template at that site instead of the original sequence. This template is supplied by the corrected copy of DNA from the second vector. Thus, during the repair process, a corrected gene sequence is inserted in place of the mutated segment. Even though it sounds like something from science fiction, such modification of the genome of human embryos with the help of CRISPR has been carried out with some levels of success.

So what's next?

In theory, gene editing sounds wonderful (Fig. 2). Even if it does not create a race of super people, can it be really safe to assume that it is a boon? Here are some plausible speculative scenarios which may help decide the effectiveness of human genetic editing.

Disease resistance: An age of utopia

Medically speaking, diseases – heritable or otherwise – can be prevented from occurring in such altered humans. Certain diseases such as Klinefelter's, Turner's and Huntington's syndromes are genetic in nature, inherited from parents via transmission of specific genes. If the mutated set of genes is removed and replaced with the normal gene cluster, then these diseases would no longer be expressed in the progeny. Even if a child does not inherit such specific disease-causing genes from its parents, it may carry a deadly mutation that may trigger diseases like cancer or autoimmune diseases in course of time. In that case, the genetic composition of an unborn child can be determined, mutations can be identified and the entire defective gene set can be replaced, thereby reducing or even eliminating the possibilities of unwanted phenotypic expression. This would imply disease-resistant, disorder-free future progenies that can say a final goodbye to deadly ailments like AIDS and cancer.

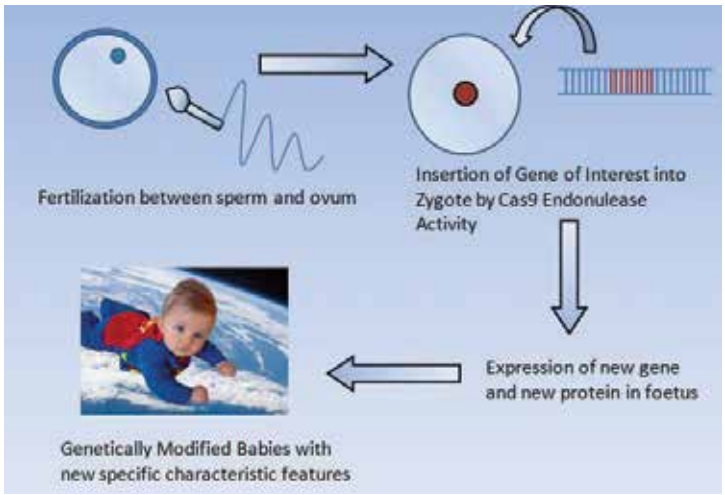


Fig. 2. Hypothetical scheme for creation of designer babies through genome editing. The photograph used in the figure is taken from public domain.

Soldiers and warmongers, a new crusade?

Theoretically, babies could be designed using CRISPR such that they possess greater strength and stamina than others. On reaching maturity and after training, these specially created humans may turn out to be more gritty than usual. Though this may prove useful in warfare, it would also create an undue advantage of one over others. Such super-people may be created so precisely that they would be made solely for war and violence, increasing their values for destructive actions. In terms of combat, the demand for specially designed soldiers may increase exponentially and it may even be that the editing of genes in unborn children is forced upon the parents.

Explorers of the unknown

For centuries, mankind's dream of travelling through space and reach the boundaries of the observable universe has remained unfulfilled. Today, even if the path to space seems clear enough, the problem of sustaining life outside the Earth's atmosphere remains as a solid roadblock to this lofty goal. If humans with altered metabolism amenable to cryo-freezing(freezing by cooling to extremely low temperature) are genetically engineered, they could be cryo-preserved and transported through space over millions of light years to other celestial bodies or even galaxies. On reaching the destination, the cryo-preserved humans could be rejuvenated by thawing and the altered metabolism could be activated to suit the foreign climate so that exploration and research could be conducted successfully.

A roomful of Einsteins: Does God really play dice?

Let us suppose we have a room full of geniuses like Einstein and Newton, or at least a room full of people with artificially enhanced intelligence. Would that trigger the establishment of a million new theories and laws or concepts beyond our imagination? Would that give us deeper insight into the mysteries of the galaxies and beyond? Or would that just create a huge commotion in the room due to the clash of egos? Most probably, one would not acknowledge the ideas of others and as a result, instead of delivering new theories, no progress would be made at all. This gets us thinking whether engineering more intelligent babies through gene editing would actually be of any use, provided of course, we do find genes and their expressions that would have a direct effect on intelligence.

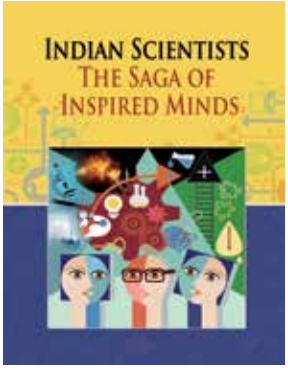
Why Y? Deciding sex

Sex determination has always been a heated subject of debate the world over, especially in India. Whether parents should be allowed to know the sex of their unborn child is a question still under scrutiny. This further raises the query whether giving parents the liberty to decide the sex of their child would lower foeticide rate or cause a dangerous imbalance in the sex ratio of future generations.

Conclusion

The questions seem never-ending; is the gene-editing man playing God? Or is this another honest attempt at eliminating darkness? When all is said and done, are we truly fit to judge the activities of science? As age progresses and the gene-editing technologies bring us even closer to obtaining designer babies, it looks like we would have to take a leap of faith. – "The one who understands both the known and unknown experiences eternity"–*Isha Upanishad*.

Vigyan Prasar book on Indian Scientsist released



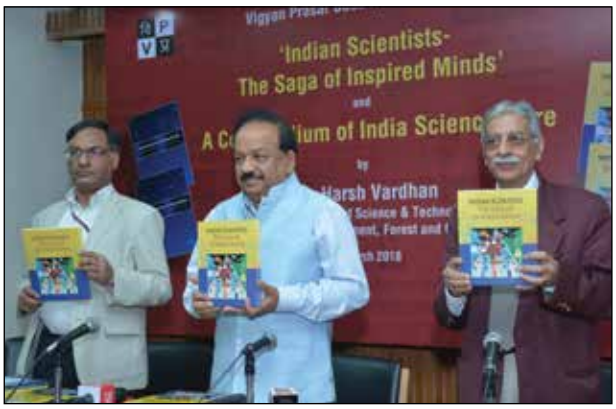
Advancements in science and technology that shape the world are the result of the dedication, zeal and sacrifice of scientists who toil to make the discoveries, inventions and innovations. Such dedication and sacrifice can be inspiring for the youth and public at large. There are many Indian scientists who have proven their scientific excellence and brought repute to our nation. Vigyan Prasar has recently brought a book on Indian scientists titled *Indian Scientists: The Saga of Inspired Minds* in which inspirational moments of 54 stalwarts of science have been featured. The book narrates many events in the lives of these scientists which may be inspiring for the young generation and help them to take up science as a career, do research and serve society with their discoveries and inventions. Quotes and opinions of associates and family members of the scientists included in this book make it unique. In this context, this book is different from other biographical collections of Indian scientists available in public domain.

The book was released on 12 March 2018 by the Union Minister for Science & Technology, Dr. Harsh Vardhan, along with Secretary, DST, Prof. Ashutosh Sharma and Director, Vigyan Prasar Shri Chander Mohan, at the India International Centre Annexe, New Delhi. Both English and Hindi editions of the book were released at the function.

After releasing the book, Dr. Harsh Vardhan said that the lives and contributions of the scientists featured in this book had changed the scientific destiny of our country. He was very much hopeful that such books could inspire and motivate Indian youth to carry forward the scientific legacy left over by Indian scientists. He said common man will also be inspired by the vision and leadership of the scientists covered in this book. He added that through this book, scientific awareness can be created, which will definitely serve the inclusive development of the country.

During this event, Dr. Harsh Vardhan read out a few passages from the book which are inspirational moments of the scientists. He emphasised that he would request Ministry of Human Resource Development to include the book in school curriculum or ensure that it was made available to students all over the country.

Dr. Harsh Vardhan also interacted with associates and family members of



some of the scientists featured in the book who were present at the venue. They included Prof. Krishna Mishra, Honorary Professor, Indian Institute of Information Technology-Allahabad, Prof. S.V. Eswaran, Retd. Professor, Department of Chemistry, St. Stephens College, Delhi University, both were research scholars of Dr. T.R. Seshadri; Shri Kartikay V. Sarabhai, son of Vikram Sarabhai and Founder Director, Centre for Environment Education; Dr. Tushar Purushottam Prabhu from Indian Institute of Astrophysics, a student of astrophysicist Dr. Vainu Bappu; Arun Bhatnagar, former IAS officer and grandson of Dr. Shanti Swaroop Bhatnagar; and S.P.K Gupta, biographer of Dr. Yellapragada Subbarow. The chapters of this book are written by the well-known popular science writers Biman Basu, Subodh Mahanti, Sukanya Datta, T.V. Jayan, Hasan Jawaid Khan, T.V. Venkateswaran, and Rintu Nath.

Prof. Ashutosh Sharma, Secretary, DST considered the publication as an exceptional book on Indian scientists which focussed on the nonlinear processes and inspirations of scientists rather than on the final product. What made them tick? What were the underlying creative processes and tensions? How were the eureka moments arrived at?

Director, Vigyan Prasar, Chander Mohan in his address said that Vigyan Prasar always tries to communicate those aspects of science which play a crucial role in our daily life. Publishing popular science books is one of the major programmes of Vigyan Prasar. He expected this book will receive great attention from the young minds and common readers apart from scientists and academicians.

On this occasion, Dr. Harsh Vardhan also released a compendium of science news articles and features syndicated by India Science Wire (ISW) during 2017. The compendium included 425 original news stories in English and Hindi produced by India Science Wire and published in Indian mass media. These news articles highlight some of research work done in Indian research laboratories, academic institutions and universities. More than 150 delegates, scientists, teachers, science writers and media persons attended this function.

(Report by: Dr. Manish Mohan Gore)

Recent Developments in Science and Technology

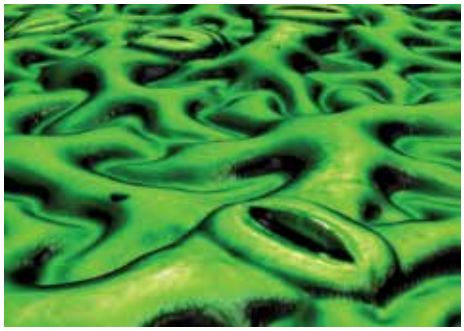
Biman Basu

Scientists have recently discovered egg cases of the deep-sea fish Pacific white skates near hydrothermal vents, which throws new light on how deep-sea creature adapt to their not-so-friendly environment. The team believes that the fish use the warm water near the vents to speed up the typically years-long incubation time of their eggs. Pacific white skates are fishes that lack hard, bony material in their skeletons; they have a skeleton of cartilage. They are among the deepest-dwelling skates in the ocean, living more than 3,000 metres below the surface and preferring rocky parts of the seafloor

Scientists engineer crops to reduce water consumption

Water is an essential requirement for growing crops and currently almost 90 per cent of global freshwater is consumed in agriculture. Yet, production still needs to dramatically increase to feed the ever-growing world population and with the growing water scarcity that seems difficult. But there is hope. For the first time, scientists based at the Institute for Genomic Biology (IGB), University of Illinois at Urbana-Champaign, USA, have managed to reduce water consumption by crops by almost 25 per cent without affecting yield, by altering the expression of just one gene that is found in all plants. To engineer the plants, the researchers increased the levels of a photosynthetic protein called PsbS, which is a key part of a signalling pathway in the plant that relays information about the quantity of light. By increasing PsbS, the plants get the signal that there is not enough light energy for the plant to photosynthesise, which triggers the stomata to close since carbon dioxide is not needed to fuel photosynthesis. The genetic modification thus tricks the plants into partially closing their stomata, the microscopic pores in the leaf that allow water to escape, thereby preventing loss of water.

Stomata are the gatekeepers to plants: When open, carbon dioxide enters the plant to fuel photosynthesis, but at the same time water is allowed to escape through the process of transpiration. Partially closing of the stomata allows less water to escape through transpiration while allowing carbon dioxide to enter the plant for photosynthesis. In this way, the researchers could improve the plant's water-use efficiency – the ratio of carbon dioxide entering the plant to water escaping – by as much 25 per cent, without significantly sacrificing photosynthesis or yield. In field tests with tobacco plants, the researchers found that when water is limited, these modified plants grew faster and yielded more than their non-modified counterparts (*Nature Communications*, 6 March 2018 | DOI: 10.1038/s41467-018-03231-x). The research is part of the international research



Engineered plants conserve 25 percent more water by only partially opening their stomata, allowing less water to escape through transpiration while carbon dioxide enters the plant to fuel photosynthesis. (Credit: Jiayang Xie, Katarzyna Glowacka, Andrew D. B. Leakey)

project Realising Increased Photosynthetic Efficiency (RIPE) that is supported by Bill & Melinda Gates Foundation, the Foundation for Food and Agriculture Research, and the U.K. Department for International Development.

According to the researchers, crop yields have steadily improved over the past 60 years, but the amount of water required

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

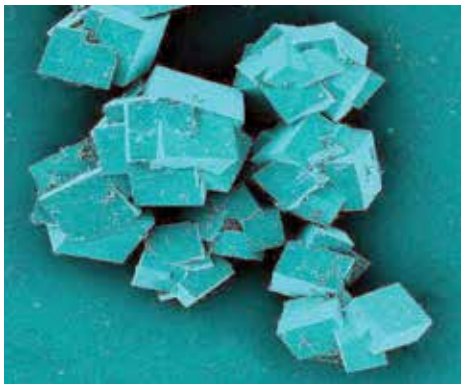
to produce one ton of grain remains unchanged – which led most scientists to assume that this factor could not change. But the recent research shows that it can be done. Normally, four factors can trigger stomata to open and close: humidity, carbon dioxide levels in the plant, the quality of light, and the quantity of light. The present study is the first report of hacking stomatal responses to the quantity of light.

The present research complements previous work, published in *Science* in 2016, which showed that increasing PsbS and two other proteins can improve photosynthesis and increase productivity by as much as 20 percent. Now, the researchers say they will apply their discoveries to improve the water-use-efficiency of food crops and test their efficacy in water-limited conditions such as during drought. They plan to combine the gains from these two studies to improve production and water-use by balancing the expression of these three proteins.

According to the researchers, the results show that increased PsbS expression allows crop plants to be more conservative with water use, which will help to better distribute available water resources over the duration of the growing season and keep the crop more productive during dry spells.

New efficient way to filter salt, metal ions from water

Exposure to common ionic pollutants, such as salt, heavy metal ions and toxic anions is a major concern throughout the world due to their potential impacts on human health and the environment. Recently, metal-organic frameworks (MOFs) with ion-exchange properties have attracted great interest with respect to the capture of diverse hazardous cationic and anionic species. Metal-organic frameworks are a class of crystalline materials that consist of coordination bonds between transition-metal cations and multi-dentate organic linkers. The structure of MOFs is characterised by an open framework that can be porous, with the largest internal surface area of any known substance. MOFs can be used for gas storage, purification and separation, as well as for catalysis and sensing applications. Recent research has shown that the absorption capacities of MOFs are considerably superior to conventional materials. These membranes have potential



A scanning electron microscope image of metal-organic frameworks, crystals that can separate lithium and salt from seawater (Credit: CSIRO)

to remove salts from seawater and separate metal ions in an efficient and cost-effective manner.

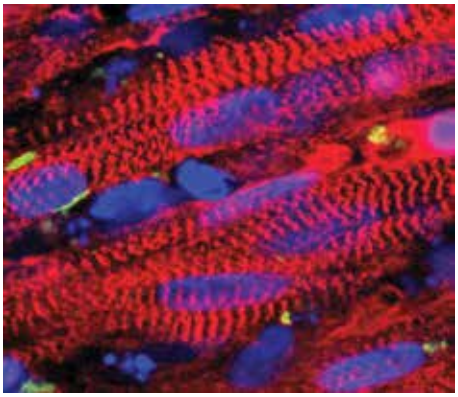
Researchers from Monash University in Melbourne, Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and Department of Chemical Engineering at The University of Texas at Austin, USA have developed a new technique to selectively filter ions from water using membranes made of MOFs. According to the researchers, the sponge-like crystals of MOF can be used to capture, store and release chemical entities; in this case, the salt and ions in sea water (*Sciences Advances*, 9 February 2018; DOI: 10.1126/sciadv.aaq0066). Currently, reverse osmosis is responsible for more than half of the world's desalination capacity, and the last stage of most water treatment processes, but the technique is expensive and energy-intensive. According to the researchers, with further development, MOF membranes have the potential to perform the dual functions of removing salts from seawater and separating metal ions in a highly efficient and cost-effective manner, offering a revolutionary new technological approach for the water and mining industries.

According to Huanting Wang of Monash University, a co-author of the paper, "We can use our findings to address the challenges of water desalination. Instead of relying on the current costly and energy-intensive processes, this research opens up the potential for removing salt ions from water in a far more energy-efficient and environmentally sustainable way."

The technique can also be used to recover rare elements such as lithium from waste water. Lithium-ion batteries are now the most popular power source for mobile electronic devices. However, at current rates of consumption, the rising demand is likely to require lithium production from non-traditional sources, such as recovery from salt water and waste process streams. According to CSIRO's Anita Hill, the research offers another potential real-world use for the next-generation material. "The prospect of using MOFs for sustainable water filtration is incredibly exciting from a public good perspective, while delivering a better way of extracting lithium ions to meet global demand could create new industries for Australia," she says.

Skin cells turned into muscle cells

Stem cells are undifferentiated cells of a multicellular organism which are capable of giving rise to indefinitely more cells of the same type, or to other kinds of cell by differentiation. Stem cells have the remarkable potential to develop into many different cell types such as skin, muscle, blood, bone, hair, etc., in the body during early life and growth. In addition, in many tissues they serve as a sort of internal repair system after an injury, dividing essentially without limit to replenish other cells as long as the person or animal is still alive. It was earlier believed that only embryonic stem cells obtained from embryos are pluripotent, meaning that have the property of growing into cells of different kinds; it was believed that adult cells do not possess this property. But later, scientists developed techniques to turn adult cells into 'induced' pluripotent



A stained cross section of the new muscle fibres. The red cells are muscle cells, the green areas are receptors for neuronal input, and the blue patches are cell nuclei. (Credit: Duke University)

stem cells, or iPS cells that can be coaxed to grow into any type of body cell. Induced pluripotent stem cells are derived from skin or blood cells that have been reprogrammed back into an embryonic-like pluripotent state that enables the development of an unlimited source of any type of human cell needed for therapeutic purposes. Now, for the first time, a biomedical engineering team at Duke University in USA. led by Nenad Bursac, has succeeded in growing functioning human muscle from induced pluripotent stem cells derived from adult skin cells, which holds promise for cellular therapies, drug discovery and studying rare diseases (*Nature Communications*, 9 January 2018 | DOI: 10.1038/s41467-017-02636-4).

In the present study, the researchers started with human induced pluripotent stem cells obtained from adult non-muscle tissues, such as skin or blood, and reprogrammed them to revert to a primordial state. The pluripotent stem cells were then grown while being flooded with a molecule called Pax7 – which signals the cells to start becoming muscle. As the cells proliferated they became very similar to – but not quite as robust as – adult muscle stem cells. While previous studies had accomplished this feat, till now nobody has been able to further grow these intermediate cells into functioning skeletal muscle.

According to Lingjun Rao, a postdoctoral researcher in Bursac's lab at Duke University, the key to their success was their unique cell culture conditions and 3-D matrix, which allowed cells to grow and develop much faster and longer than the 2-D culture approaches that are more typically used. Once the cells were well on their way to becoming muscle, Bursac and Rao stopped providing the Pax7 signalling molecule and started giving the cells the support and nourishment they needed to fully mature.

The results of the study show that after two to four weeks of 3-D culture, the resulting muscle cells form muscle fibres that contract and react to external stimuli such as electrical pulses and biochemical signals mimicking neuronal inputs just like native muscle tissue. The researchers also implanted the newly grown muscle fibres into adult mice and showed that they survive and function for at least three weeks while progressively integrating into the native tissue by growing blood vessels.

In the past, in order to develop cell therapies to correct and treat muscular dystrophies, researchers had to work primarily with animal models. The new development marks a major advance the field which has the potential to be used in the future for therapeutic stem cell transplantation.

Deep-sea fish uses hydrothermal vents as egg-incubators

Eggs need heat for incubation. But at ocean depths of a few kilometres, temperature drops to as low as 2.7°C that makes the incubation period of deep-water fish eggs pretty long – often up to a few years. Skates – diamond-shaped deep-sea fish that are related to sharks and rays – incubate their eggs for as long as four years or more, longer than most animals on Earth. The discovery of deep-sea hydrothermal vents in 1977 at the Galapagos Rift challenged our views of ecosystem functioning and fuelled new hypotheses about how life on Earth could have originated around these chemically reactive environments. Yet, the research conducted at these extreme and logistically challenging environments still continues to reveal unique biological processes. Forty years later, we now know that hydrothermal vent ecosystems exist in every ocean basin and they support rich communities and unique biological processes. An international team of researchers led by Pelayo Salinas-de-León of the Charles Darwin Research Station, have recently discovered egg cases of the deep-sea fish Pacific white skates near hydrothermal vents, which throws new light on how deep-sea creature adapt to their not-so-friendly environment (*Scientific Reports*, 8 February 2018 | DOI: 10.1038/s41598-018-20046-4). The team believes that the fish use the warm water near the vents to speed up the typically years-long incubation time of their eggs.

Bathyraja spinosissima, the Pacific white ray.

Pacific white skates are fishes that lack hard, bony material in their skeletons; they have a skeleton of cartilage. They are among the deepest-dwelling skates in the ocean, living more than 3,000 metres below the surface and preferring rocky parts of the seafloor,

The skates reproduce by laying groups of eggs encased in rectangular pods that resemble large and leathery pouches, made of collagen secreted from an oviduct. The water-permeable egg cases, whimsically known as "mermaid purses", are often washed up on beaches after the eggs have hatched. A study in 1980 had shown that inside the pods, the eggs incubate for years at a stretch – at least 1,500 days in waters where the average temperature is 2.7°C.

To learn more about how skates interact with their deep-sea environment, the scientists used a remotely operated underwater vehicle (ROV) named "*Hercules*," to survey in and around an active hydrothermal field in the eastern tropical Pacific near the Galapágos Islands, north of the Darwin Island. The researchers found 157 egg cases in the area and collected of the yellow-green egg-cases with the ROV's robotic arm. DNA analysis revealed that the egg cases belonged to the skate species *Bathyraja spinosissima*, one of the deepest-living species of skates that is not typically thought to occur near the vents. More than half of the observed egg cases were found within 20 metres of the chimney-like black smokers, the hottest kind of hydrothermal vents. The temperature recorded by the probe within 1 metre of active vent chimney was 4.52°C. The researchers believe that the warmer temperatures in the area could reduce the typically years-long incubation time of the eggs. While nesting behaviour that uses an active volcanic source to incubate eggs is known from a few species on land, it has never been seen in a marine environment before. This is the first record of a hydrothermal vent habitat serving as an egg-case nursery site, the researchers reported.