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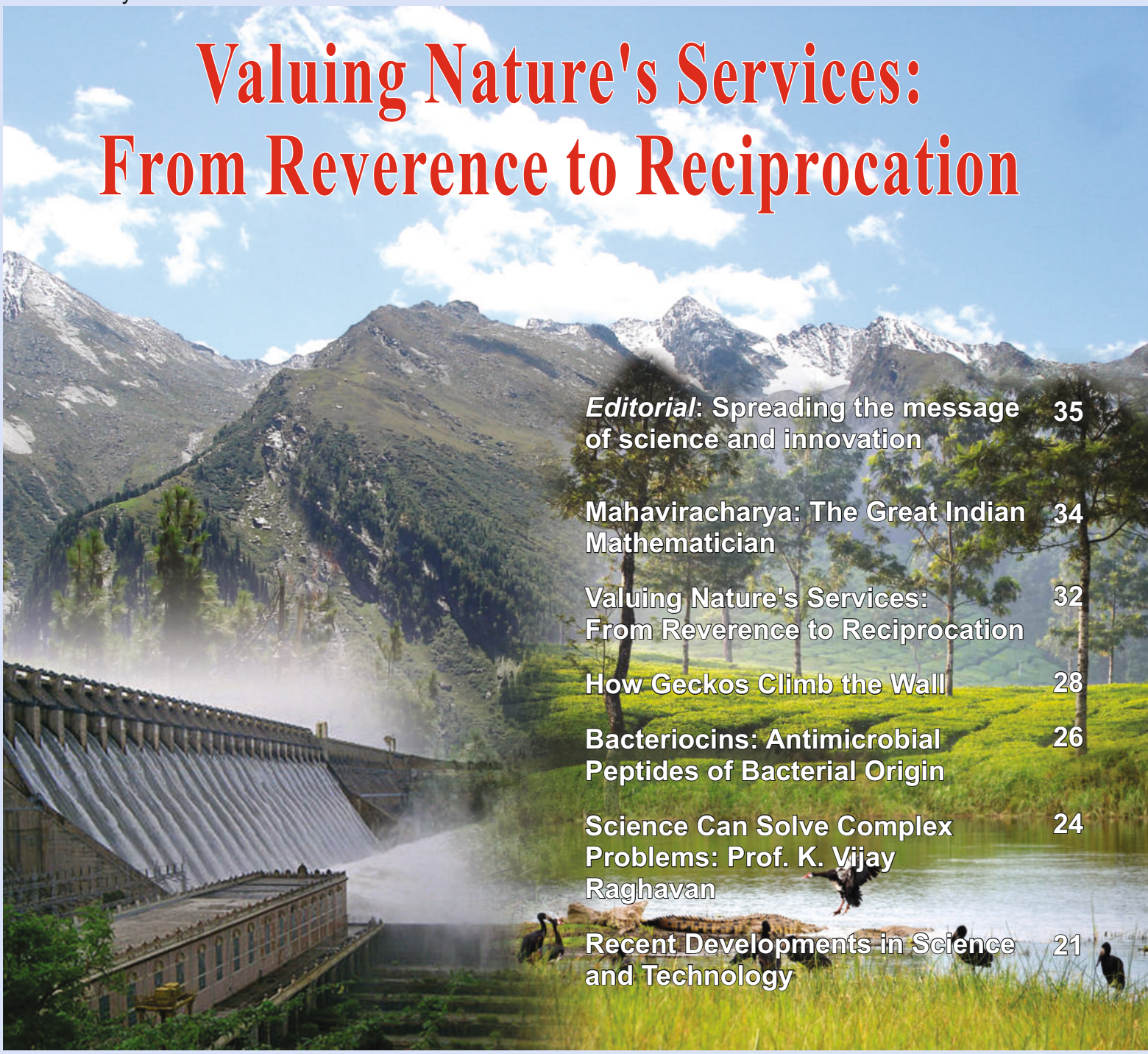

Valuing Nature's Services: From Reverence to Reciprocation

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

EDITORIAL

Spreading the message of science and innovation

Chander Mohan

Vigyan Prasar (VP) has been in the forefront of communicating and popularising science since its inception and various channels and formats of media have been utilised to reach out to people literally in every nook and corner of India. Being an Autonomous Organisation of the Department of Science and Technology (DST), our services and expertise, particularly in organising exhibitions or expos, have lately also been harnessed by DST. Our autonomous structure gives us an edge, specifically with regards to meeting tight deadlines. What started as a trickle last year has now turned out to be torrent that has brought laurels to both the parent and the offspring!

I am tempted to use this space to blow our trumpet a bit and take you through some of the more significant events that we either participated in or organised on behalf of DST in the past few months. The latest was the Meet the Press of Dr. Harsh Vardhan, Hon'ble Minister of Science and Technology and Earth Sciences, on 7 June 2018, which was held in National Media Centre. A set of posters, designed and developed by VP to exclusively showcase the societal connect of DST were prominently displayed in the foyer of National Media Centre, the venue of the Press Meet. These posters, which were highly appreciated by the media fraternity, were hand-picked by experts from a collection that had earlier been displayed in a month-long exhibition that was set up by various wings of the Ministry of Science & Technology (S&T), Ministry of Earth Sciences (ES), and Ministry of Environment, Forest & Climate Change (EFCC) in the sprawling lawns of the residence of Hon'ble Minister of S&T, ES and EFCC. VP was assigned the responsibility to highlight capabilities and achievements of DST and its Autonomous Organisations through a judicious mix of posters, prototypes and audio-visuals.

The exhibition reflected the initiatives and innovations which were chiefly of societal importance and impacted the masses, particularly the youth, women, disadvantaged sections of society and so on. Innovations from National Innovation Foundation (an Autonomous Institute of DST) such as a modified boiler and condensate heat recovering system, bamboo splint-making machine, manual waste lifting and dumping cart, multipurpose food processing machine, natural water cooler, cow dung pot and log making machine, mosquito destroyer, etc., were highlighted along with technologies, tools, and techniques developed under the support from various Divisions of DST, specifically Science for Equity, Empowerment and Development (SEED) Division. Some of the prominent prototypes exhibited included *Surya Jyoti* (micro-solar dome), *Jal TARA* filter, Sanitary napkin incinerator, Solar water and space heating system for high-altitude dwellings, Waste-to-weave green technologies, and Head harness to reduce drudgery in lifting weights in the agriculture fields, at construction sites, etc. Colourful and informative posters to emphasise flagship programmes of DST, *viz.*, INSPIRE-MANAK Award for meritorious high school students, Knowledge Involvement in Research Advancement through Nurturing (KIRAN) for women, and Technological Interventions for Disabled & Elderly (TIDE) were also put up. The exhibition was visited by many dignitaries, parliamentarians, media persons and also witnessed by thousands of students from local schools and public at large.

A fortnight-long exhibition on the occasion of *Swachhata Pakhwada* was organised to showcase the technologies that have been developed in the country to address the challenging areas in sanitation and cleanliness. The exhibition was organised in the premises of Technology Bhawan, Head Quarters of DST and was inaugurated on 7 May to highlight technologies developed over the years with the support from DST. Vigyan Prasar, Department of Biotechnology (DBT), Biotechnology Industry Research Assistance Council (BIRAC), Technology Information, Forecasting and Assessment Council (TIFAC), Technology Missions Division (TMD), Science for Equity, Empowerment & Development (SEED), Indo-U.S Science and Technology Forum (IUSSTF), National Entrepreneurship Board (NEB), and National Innovation Foundation-India (NIF) participated in the exhibition which also got rave reviews from visitors from all walks of society. In short, VP has now acquired the requisite expertise in designing, developing, displaying and directing expos on diverse themes at short notice.

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Mahaviracharya: The Great Indian Mathematician

Anuj Kumar Jhankal

Mahāvīra was the first mathematician in the world who had given the concept of Least Common Multiple (LCM) known as Niruddha. His book Gaṇitasārasaṅgraha proved influential to other mathematicians in India and the world. It is rightly said that before Mahāvīra, mathematics in India was in the clutches of Jyotisha due to religious rituals. Mahāvīra gave the subject a form, an independent edge, and existence.

''बहुभिर्प्रलापैः किं त्रैलोक्ये सचराचरें यत्किंचिद्वस्तु तत्सर्वं गणितेन विना नहिं''

[*Gaṇitasārasaṅgraha*, Chapter 1 Verse 16]

Mathematics was holds a high importance since the Vedic time. Mathematics (*Ganita*) along with astronomy was included in (*Jyotis sastra*), often associated with the astrological knowledge. Mathematicians Āryabhaṭa, Varāhamihira, Brahmagupta, Bhāskara-I, Mahāvīra, Bhāskara-II, gave expansive and clear shape to many branches of mathematics. This period (AD 400-1200) is often known as the golden age of Indian mathematics. All these mathematical works were assembled in Sanskrit in the form of *shlokas* (verses) or *sutras* (formulae) in order to help students master them easily. This was superseded by prose narratives by many scholars so that the subject could be understood thoroughly.

Mathematicians of ancient India were chiefly well informed scholars in *Jyotisha* or Astronomy. Mahaviracharya (or Mahāvīra, AD 800-870) occupies a special place among all. Mahāvīra was born in Mysore (now Mysuru) and as a young man became intimate with mathematics of southern India. He had written a book of mathematics known as *Gaṇitasārasaṅgraha* (or *Ganita Sara Samgraha*, AD 850). Mahāvīra's *Gaṇitasārasaṅgraha* compiled in prosodic Sanskrit is the largest work belonging to the ancient period. It is a landmark in the history of Indian mathematics. It is an epitome of all mathematic known at the time of writing the *Gaṇitasārasaṅgraha*, setting right the ambiguity in mathematical concepts and cleansing the ideas already known. It contains 1,131 *shlokas* and about 1,000 problems and is presented in nine chapters and compiles all mathematical knowledge of mid-9th century India. It presents the bulk of knowledge which we have of Jaina mathematics and also lends an account of the work of those who developed this mathematics. In the introduction to the work, Mahāvīra admitted with modesty that what he had done was only selecting some relevant material as much as possible by searching and researching into the mighty ocean of mathematics. These mathematicians included Āryabhaṭa, Brahmagupta and Bhāskara-I.

In his own words:

With the help of the accomplished holy sages, who are worthy to be worshipped by the lords of the world ... I glean from the great ocean of the knowledge of numbers a little of its essence, in the manner in which gems are picked from the sea, gold from the stony rock and the pearl from the oyster shell; and I give out according to the power of my intelligence, the Sara Samgraha, a small work on arithmetic, which is however not small in importance.

As a text, the nine chapters of *Gaṇitasārasaṅgraha* contain elementary arithmetic operations, measuring units, measurement of weight and length of gold-silver ornaments, area and volume of various

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bodies, etc. Elementary algebraic equations of one variable were used for distribution of property, purchase-sale transactions, etc. The nine chapters of the *Gaṇitasārasaṅgraha* are:

Terminology: In this chapter, measurement units for space, time, grains, silver-gold, and land are defined. Names of operations in arithmetic, general rules in regard to zero, positive and negative quantities, the names of notational places and qualities of an arithmetician are also given.

The imaginary numbers were not identified until 1847 by Cauchy in Europe. Mahāvīra was the first mathematician in the world who made a very significant remark on the square root of negative number. He said:

''ऋणयोर्धनयोघाते भजने च फलं धनम्
ऋणं धनर्णयोस्तु स्यात्स्वर्णयोर्विवरं युतौ
ऋणयोर्धनयोर्योगो यथा संख्यमश्णं धनम्
षोध्यं धनमश्णं राषेः ऋणं षोध्यं धनं भवेत्
धनं ऋनर्णयोर्वर्गो मूले स्वर्णे तयोः क्रमात् ऋणं
स्वरूपतोश्ष्वर्गो यतस्तस्मातन्न तत्पदम्।।''

[*Gaṇitasārasaṅgraha*, Chapter 1 Verse 50-52]

It means "The squares of positive as well as negative numbers are always positive and the square roots are positive and negative respectively of these quantities. A negative number is a non-square by its nature because there is no real square root of it" This is the first clear recognition of an imaginary number in mathematics which had to wait for several centuries for recognition.

Basic Arithmetical Operations: This chapter deals with the numeral terminology, symbols, numbers in metric and non-metric scale notion, numbers without denomination, etc.

Fractions: This chapter deals with the following subtopics: multiplication, division, squaring, square root, cubing, cube root of fractions, summation of fractional series in progression, etc.

Mahāvīra was the first mathematician in the world who had given the concept of Least Common Multiple (LCM) known as *Niruddha* in those days, which is as follows:

''छेदापर्वतकानां लब्धानां चाहतौ निरुद्धः स्यात्
हरहृत निरुद्धगुणिते हारांषगुणों समो हारः''

[*Gaṇitasārasaṅgraha*, Chapter 3 Verse 56]

It means "The *Niruddha* or LCM is evaluated by product of common factors of all denomination and their quotients respectively. The new numerators and denominators obtained as products of each original numerator and denominator by the quotient of *Niruddha* divided by the denominator give fractions with same denominator"

Miscellaneous Operations: This chapter deals with the miscellaneous problems on fractions and also includes distribution amongst the relatives. Mahāvīra used the term *Ekanshak Bhinna* for fractions whose numerator is 1 representing a sum of 1 as: $1 = 1/2 + 1/3 + 1/3^2$…..n. This type of fractions were used in AD 1127 and known as 'Egyptian fractions'.

Rule of Three: This chapter deals with the method to find the fourth quantity if three are already known.

Mixed Problems: This chapter deals with the rules about of mixing copper with gold for making ornaments, rules of interest on capital, etc.

Mahāvīra was the first mathematician in the world who gave the concept of Combination.

The original text as follows:

''एकाद्येकोत्तरतः पदमूर्ध्वाधर्यतः क्रमात्क्रमषः
स्थाप्य प्रतिलोमघ्नेन भाजितं सार''

[*Gaṇitasārasaṅgraha*, Chapter 6 Verse 218]

It means "The quotient of product of number in descending order starting from a number *n* (total objects) to (*n*-*r*+1) divided by product of numbers in ascending order starting from 1 to a number *r* (choice) is the result"

Calculations of Areas: This chapter deals with calculations relating to the measurement of areas. Rules of finding areas of rectangle, square rhombus, parallelogram, etc.

Calculations of Excavations: This chapter deals with calculations regarding excavation. Calculations relating to piles of bricks and operations relating to the work done with saws in sawing wood are the two topics that are discussed in this chapter.

Calculations of Shadows: The last chapter has been devoted completely for the calculations relating to shadows.

Unquestionably, Mahāvīra, who contributed to a fuller and better organisation in mathematics, was the only one in the history of mathematics in India was acknowledged abroad too. He won repute among Indian mathematicians because of his establishment of terms for concept such as imaginary numbers, lowest common multiple, combination, equilateral and isosceles triangles, rhombus, circles and semicircle, solution of algebraic equations and their applications in practical life of humankind. His book *Gaṇitasārasaṅgraha* proved influential to other mathematicians in India and the world. It is rightly said that before Mahāvīra mathematics in India was in the clutches of *Jyotisha* due to religious rituals. Mahāvīra gave the subject a form, an independent edge and existence.

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Valuing Nature's Services: From Reverence to Reciprocation

Dr. Anjali Uniyal & Dr. Gopal S. Rawat

Payment for Ecosystem Services (PES)is a mechanism to identify, conserve and manage the benefits humans derive from Nature. It includes paying back to the ecosystems or its conservators by the users of the ESS to maintain it. Since 1997, nearly 1million hectares of forest in Costa Rica have been part of the PES programme at one time or another, and forest cover has now returned to over 50 per cent of the country's land area, from a low of just 20 per cent in the 1980s. In India, Bohl (a small village) in the lap of Dhauladhar mountain range presents the first example of PES.

A price tag for everything that we buy from market indirectly tells us about its economic value. People value all those goods and services for which they pay, yet give little thought to their source or origin. Have we ever thought who the provider of all these goods and services is? The silent supplier of all these goods and services is Nature**.** In fact, Nature – an amalgam of diverse ecosystems like mountains, forests, rivers, grasslands, etc. – supports the survival of humans. Ecosystems not only provide us "*roti, kapda aur makan*" but also regulate soil fertility, genetic diversity, decomposition, exchange of gases, flow of water, and nutrient cycle. These services are known as Ecosystem Services (ESS) or Natures' services. The term "Ecosystem Services" was first coined by American biologists of Stanford University, Paul and Anne Ehrlich in 1981. We the human beings are voracious users of Natures' services, but have we ever paid back to Nature? Have we ever thought of a price tag for fresh air, fresh water, fertile soil or aesthetic services?

Humans appeared on Earth around 200,000 years ago. Since then Nature has helped *Homo sapiens* develop from a hunter-gatherer to modern humans with all sorts of gadgets and an intelligent brain! Primitive humans lived in forests, hunted animals and collected plants for survival. Rivers – a perennial source of water – provided humans a reason to settle and practise agriculture. Most civilisations, whether it was Mesopotamian or the Indus valley, developed in the lap of fertile river valleys. The Egyptian civilisation flourished because of the Nile River in an otherwise dry landscape. Himalayan rivers provide water and fertile soil to the downstream plains making it the food bowl of India. Forests serve as carbon sink and climate regulator. Humans have also developed green technologies such as bio-fuels, hydropower, geothermal and tidal energy based on Natures' services. On one hand our dependency on ESS is increasing, on the other hand, their backbone – the ecosystems – are degrading due to increasing population, carbon footprints, global warming, desertification, etc. Shift from 'need' to 'greed' has threatened the sustenance of ecosystems. The focus of modern society is on money making; it is least concerned about the invaluable ecological services of Nature. Thus what is critical for life goes unnoticed and unpaid for.

Our ancestors had recognised the value of Nature and its services long back during the Vedic Period. The four *Vedas* have hymns devoted to natural entities. *Rig-Veda* mentions life being made up of five elements of nature *viz., prithvi, jal, agni, vayu* and *aakash* and have been

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revered as God. It was their vision, that we are still able to reap the ESS of Nature.

Reverence – the ancestors' way of valuing nature

The adage **"***Prakiti rakshito rakshitah"* means "survival of life is possible only if the Nature is protected". It laid the foundation of respecting Nature in the form of rituals, festivals, and regulations. Sometimes the messages of conservation were veiled and sometimes as part of daily chores. Offering only tips of doob grass (*Cynodon dactylon*) in prayers might perhaps be to protect its regenerating part. Importance of the Sun (the prime source of energy) was very well understood by our ancestors, it is why the *Gayatri* mantra is full of praise for the Sun. As per *Guru Granth Saheb* 'Air is the guru, water is the father, and earth is the great mother of all'. Jain scripture "*Acharanga Sutra"* preaches 'Nature is to be protected in all ways'. Following these principles, one would stop destroying environment and conserve it for generations to share. Trees have been worshipped since time immemorial; the Ramayana, says, "*Vanesmin maamke nityam putrvat parirakshite*", which means people protected trees just like their own children. Some plants such as the mango (*Mangifera indica*), banana (*Musa paradisica),* banyan (*Ficus benghalensis*), bel (*Aegle marmelos*), tulsi (*Ocimum tenuiflorum*), amla (*Phyllanthus emblica*), etc., were considered abode of God/spirits and to harm them was regarded a sacrilege. Later, the medicinal importance of these plants has been identified. Felling of peepal (*Ficus religiosa*) trees was once looked upon as a terrible sin, maybe because of its ecological significance. Plants such as neem (*Azadirachta indica)* and coconut (*Cocos nucifera*) were adopted as the emblem of their states by the ancient Tamil kingdoms. Religious and social customs have also valued Nature's services (Fig.1). Most of the alpine flowers such as brahmakamal (*Sasurrea obvallata*), bhutkeshi (*Selinum vaginatum*) and kedarpatti (*Skimmia laureola*) were collected only after a local festival called "Nanda-Ashtami" (in mid-September) in Uttarakhand. Ecological reason behind this restriction was that most of the alpine flowers would have shed their seeds by then and collection of herbs would not harm their regeneration. So this ritual helped in proper dispersal of seeds and conservation of alpine herbs.

Fig.1. Under the sacred tree
(Photo by: Anjali Uniyal)

Another way of valuing trees has been their protection as sacred groves. A sacred grove is a forest or a bunch of trees, devoted to a local deity. These groves are regarded as the abode of Gods and hence conserved over generations (Fig.2). In Western Himalaya, Bhojbasa and Chirbasa near Gaumukh were named after the rich forests of Bhojpatra (*Betula utilis*) and chir (*Pinus wallichiana*), respectively. Deodar (*Cedrus deodara*) – "Tree of God" is closely linked with Shiva and a temple is generally found near a deodar forest. Sacred groves are still prevalent in Uttar Kannada and parts of Himalaya (in Himachal alone there are about 5,000 sacred groves). These represent some of the best old growth forests in India having immense ecological value as carbon sink and climate regulator.

Not only plants but the significance of water and air for life was also well known. The *Rig-veda* identifies five forms of water: Rain water (*Divyah*), natural spring (*Sravanti*), wells and canals (*Khanitrimah*), lakes (*Svayamjah*), and rivers (*Samudrarthah*). Our tradition of pilgrimage on river-banks and their confluences *(prayag*) recognises the purifying quality of water. Ancient Indians were very particular to maintain the purity of water. Scriptures such as *Manusmriti* and *Padma Purana* stresses 'the person who pollutes water of ponds, wells or lakes goes to hell'.

Forest management by our ancient rulers also signifies the invaluable services of Nature. Kautilya's *Arthasastra* depicts the sustainable use of forests for the economic development of Mauryan Empire (3rd and 4th century BC). A team of well-aware foresters led by a superintendent was responsible for the upkeep of forests and collection of wood. The revenue generated from forests was named as "Lion's share". Forests were duly rewarded by providing complete protection against any anthropogenic damage, following stringent laws. The forests in Maurayan era were classified according to their ecological services as Elephant forests, *Tapovana*, *Amod-pramod vana*, forests

Fig.2. A sub-alpine grove in the Himalaya
(Photo courtesy: Dr. Sanjay Uniyal)

for the sports of common man, and *Upvanas*. Realising the importance of elephants for army, dense forests that fulfilled the needs of the elephants, known as "Elephant forests", were exclusively set apart. "*Amod-pramod van*" was the forest exclusively for sports and game hunting by kings. There were "*Tapovans*" for ascetics and hermits. Last but not least, the brightest part of Mauryan forest policy was the economic uplift of villages. *Upvanas* comprised of small forests/groves, and botanical gardens/orchards around villages. They fulfilled the needs of fodder, fuel wood, timber, etc.

Afforestation and maintenance of pasture land was an important part of village development. Pasturelands were classified accordingly for browsers and grazers. Dried marshy lands and land between cultivated plots were planted with fragrant and medicinal herbs. Wastelands were reclaimed with valuable aromatic species. Not only plants, some animals such as elephants, some game birds and fishes also got protection against all kinds of molestation. Killing of a tiger/lion was not valued as a status symbol. This attitude discouraged wanton destruction of wild life in that era. Edicts of the great Asoka also refer his water management system, creation of botanical gardens and prohibition of cruelty to animals. The primeval ways helped in the conservation of ecosystems and their services for the present generation. Our ancestors' way of valuing and paying back Nature through reverence slowly vanished when the Industrial Revolution increased materialistic demands in the late 18th Century.

GDP – the commercial way of valuing nature in the past era

The Industrial Revolution led to the growth of urban sprawl and increased population growth. At its dawn in the mid-1700s, the world's human population grew by about 57% to 700 million. Increasing demands altered the use of natural resources from sustainable to unsustainable, conservation to market-oriented and long-term values to short-term gains. Gross Domestic Product or GDP values for goods and services replaced reverence for Nature.

Fig.3. Timber logging during colonial period in the Himalayas (Photo courtesy: www.Fao.org)

Exploitation of land, air and water aggravated with the accelerating industrial and population growth. Exponential growth in population led to exponential requirements for resources, energy, food, housing and land, as well as increase in waste by-products. Land requirement for urban development, railways, roads, agriculture and industries led to excessive deforestation. As per the UN Food and Agriculture Organisation (FAO), during the colonial period, timber trade formed the backbone of many industries and forest products were extracted just like coal and gold from mines. Forest management focussed on production of timber and resin trees (Fig.3) and eliminated ecologically important species such as oak. Many Non-timber forest products (NTFPs) such as paper/plywood, gums/resins, cane/rattan, drugs, spices/condiments and herbs further added to the value of revenue. Management policy also favoured plantation owners, who were mostly from Europe. They were given a free hand to destroy natural forests to make way for tea, coffee and rubber plantations to meet Europe's growing need.

Though forest dwellers were deprived of their right to hunt, the Kings and British officials continued big game hunting. Hunting of wild animals was seen as a sport and considered prestigious. This led to the extinction of many wild species in India during the British era (Fig.4). All the regulations and forest laws framed by the British focussed only on enhancing the GDP and commercial valuation of forests. Ironically, conservation of ecologically important species was lacking. Water, which was once a prime input for agriculture, became an essential part of upcoming industries. Hydroelectric power in late 19th century led to the construction of more big dams (Fig.5) all over the world without consideration of their adverse impacts. Rivers became an economic resource instead of an ecological entity. The smoke and industrial effluents coming out from different industries not only polluted the air but also degraded the quality of water. The concentration of carbon dioxide in the atmosphere increased and the level of biological oxygen demand (BOD) in water bodies also increased. The spiritual connection to water and water bodies that our ancestors had maintained

Fig.4. Big game hunting during British period (Photo courtesy: www.thoughtco.com)

Fig.5. Dam construction for hydro-power (Photo-courtesy: http://climatenewsnetwork.net)

faded with time. On one hand, a rise in GDP reflected the economic growth in the industrial era, on the other hand erratic climatic conditions, global warming, incidence of acid rain, ozone layer depletion, increased pest attacks, and extinction of wild species revealed a decline in the ESS. This raised concern among ecologists all over the world. Rachel Carson in her revolutionary book *Silent Spring* in the middle of 20th century highlighted the negative impact of humans on Natures' services.

PES - a reciprocal way of valuing nature in the modern era

Payment for Ecosystem Services (PES) is a mechanism to identify, conserve and manage the benefits humans derive from Nature. It includes paying back to the ecosystems or its conservators by the users of the ESS to maintain it. First step in the implementation of PES is to estimate a value for the ESS that an ecosystem provides for human use, as it is done in a goods market. The exchange value or 'price' associated with the ecological goods is regarded as 'natural capital', which was first coined by E.F. Schumacher in 1973 in his book *Small is Beautiful.* Natural capital revolves around the idea that global economy is dependent on the ESS that Nature provides. Valuation of ESS gained momentum after the combined ESS of the Earth was worked out by Australian ecological economist R. Costanza in 1990s as US$33 trillion, which is nearly twice the global Gross National Product (US$18 trillion) at that time. Value of the ESS and the impact of ESS degradation on human wellbeing were well recognised. This initiated the Millennium Ecosystem Assessment (MA) in the year 2001 which classified ESS into four types: (i) Provisioning (supply of natural products such as food, timber, fuel etc.; (ii) Regulatory (maintenance of air/water quality, climate, sequestration of carbon, recycling of waste and control of agricultural pests/disease); (iii) Supporting (involving ecosystem functioning such as soil formation, photosynthesis, and provision of habitat); and (iv) Cultural (that quantifies the aesthetic/spiritual and educational benefits that accrue from nature). Some of them have direct use while others have non-use values; hence their estimation involves different methods like market price valuation, preference to pay, cost of replacement/damage control, etc.

Economic valuation can be accounted for in policies so that ecosystems are paid back in the form of conservation and sustainable management. As most of the ESS are not traded in the markets; a regulatory agency integrates the link for PES between beneficiary and the suppliers. PES has helped in the revival of various ecosystems across the world. Since 1997, nearly 1 million hectares of forest in Costa Rica have been part of the PES programme at one time or another, and forest cover has now returned to over 50 per cent of the country's land area, from a low of just 20 per cent in the 1980s. In the Himalaya, Nepal government has initiated PES for the trading of carbon credits. In India, Bohl (a small village) in the lap of Dhauladhar mountain range (North-West Himalaya) presents the first example of PES. The upstream villagers (the suppliers) have conserved a forest patch which forms the recharge zone of Bohl spring (Fig.6). The spring is the only source of pure water for the downstream town, for which Palampur Municipal Council (PMC, the beneficiary) pays a sum of Rs.10,000 per year to the villagers for the conservation and management of the upstream forest (Fig.7). This has not only maintained the flow of drinking water but also improved the socio-economic status of the villagers.

Fig.6. Forest conserved for spring recharge in the Dhauladhar Mountains (Photo by: Anjali Uniyal)

Fig.7. Payment for Ecosystem Services in the Dhauladhar Mountains (Photo by: Anjali Uniyal)

To bring back the status of degraded ecosystems, money matters in the modern era. Reciprocation may have taken place of reverence, but it is also true that one cannot put a price tag for the immense services Nature provides to us. Therefore, we should always behave the way our ancestors did; behave as if Nature's services are invaluable. "O Earth! Let me not hit your vitals" (*Atharvaveda*).

How Geckos Climb the Wall

Anirban Roy

Among the diverse animals that we see around us, gecko's unique ability to climb any wall surface is a matter of interest for the zoologists. A lizard climbing the wall is a very common sight to observe, but the unique biophysical aspects of their habit is worth it to be studied in more details. Scientists have concluded that four different biophysical forces are responsible for Gecko's strange adhesiveness to any surface.

Among all the members of the lizard family, geckos are considered to be climbers of supreme expertise. Geckos are lizards belonging to the infraorder Gekkota and suborder Lacertilia. Geckos are found in warm climates throughout the world. The size of the members typically range from 1.5 cm to 60 cm. Geckos differs from other lizards since most geckos lack eyelids and instead bear transparent membranes, which they often lick to maintain a moist condition for their eyes. There is a fixed lens within each iris which gets enlarged in darkness to allow more light to enter the eyes. Apart from having highly specialised vision, geckos are considered expert climbers. House geckos are an intricate part of households because they feed upon insects, including mosquitoes.

Green leaf gecko (Jonad, 2010)

It is often asked: What helps geckos climb any vertical surfaces with ease, what is the role of electric charges in the climbing process, why geckos cannot climb on surfaces coated with Teflon and many more.

It is estimated that for tokay gecko (of average weight of 43 g and average footpad area of 227 mm^2) the total clinging force with which the animal sticks itself to vertical surfaces amounts to about 20 Newtons. The basic credit for geckos's climbing skills has been bestowed upon the presence of millions of tiny hairs on their toes called 'setae'. Setae is a latin word for bristles; every seta terminates in the form of thinner hair-like structures with flat caps at the end called spatulae. The Gecko footpad areas are covered with millions of setae with density up to 5300 mm^2. The combination of seta and spatulae promotes a large surface area to the gecko feet, as compared to its body size. It is estimated that a mature gecko with all its setae in contact with the surface can potentially support up to 132-kgweight. The geckos employ the force not only to cling to any vertical surface, but also to attach to the body of its mate.

Aristotle–called the 'Father of Biology'– was the first biologist to comment upon the geckos's extraordinary climbing ability by saying that it has the capability to "run up and down a tree anyway." In 1984, it was suggested that electrostatic force of attraction could play a role in the climbing process. After 16 years of study, in 2000,

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Setae (top) and spatula (bottom) of gecko feet.

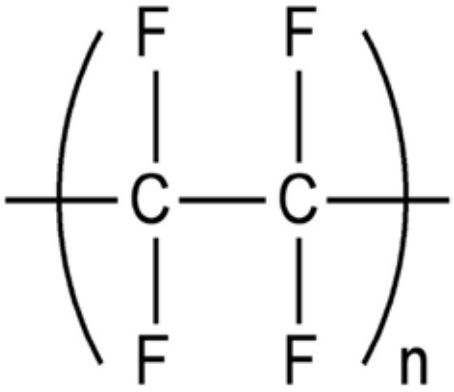
Robert Full of the University of California, Berkeley, USA confirmed the immense role played by Van der Waal's forces in gecko's climbing ability. The setae on gecko feet were studied using Atomic Force Microscope (AFM),which confirmed the presence of the setae.

The setae and its corresponding spatulae, apart from providing large surface area, promotes Vander Waal's forces.Named after its discoverer Johannes Diderik Van der Waals, this force of attraction exists between any two molecules in contact with each other. This force arises due to distortion of electric cloud. It is the combined force of atoms, molecules and other intermolecular forces that are caused by fluctuating polarisations of nearby particles. When particles of a positive or negative charge are in close proximity, they can have an effect on the polarisation of nearby particles. When the gecko places its feet on the wall surface, the numerous spatulae get spread on the surface in contact. The negatively charged ions on the feet orient themselves in accordance with the positively charged wall molecules and an attractive force develops between the large number of spatulae and the molecues of the wall. Since the gecko feet is covered by millions of spatulae, a considerable strong contact force develops which helps the animal to remain stuck to the wall.

Along with the Van der Waal's force of attraction, capillary forces play an important role in assisting the gecko to climb any surface. A fresh experiment was done with tokay gecko when it was allowed to climb a "dry" vertical surface, sprayed with water. It was observed that the animal was unable to climb the wall surface when additional water was trickled. It was later concluded that the gecko feet is hydrophobic in nature and addition of water has significantly reduced the adhesive force that was in action on a dry surface. In terms of physical science, it was the mere absence of the capillary force that resulted in the gecko failing to climb the wall. Capillary force (or capillary action) is that particular virtue of liquids and with the help of which liquids can flow through narrow spaces against the force of gravity. In a separate experiment, the gecko was totally immersed in water which was found to reduce the adhesive forces by 20% of its original value. This experiment eliminates the possiblity of hydrogen bonding playing any role in the gecko adhesion since hydrogen bonding does not decrease with water. Therefore, it was suggested that in ambient air condition and capillary forces play a dominant role in gecko adhesion wherein in presence of subtle moisture, Van der Waal's forces play its role. Gecko's attactive force was markedly influenced by surface hydrophobicity and presence of water.

A third component of force was also introduced to substantiate the gecko

House gecko



Monomer of Teflon

adhesion– static electricty and frictional force. Static electricity produced by friction causes attraction of hair– a common observation in our day-to-day life. Static charges in the wall causes the setae of the gecko to get attracted and the frictional force that arises due to the irregularities in the wall helps the animal to get hold of the vertical surface. The force of friction is imperative for letting the gecko move along the wall surface with ease. In 2011, *Journal of the Royal Society Interface* came up with a new finding – gecko footprints showed the presence of phospholipid residues. Phopsholipid residues are two-layered lipids present in cell memebranes with one layer being hydrophillic and the other layer hydrophobic. The gradual sticking and leaving the wall surface is largely the contribution of the phospholipid layers whose exact mechanism is yet to be established. Therefore, four different biophysical forces are coming into account to explain the gecko's strange adhesiveness to any surface.

It has been observed that inspite of such extraordinary climbing skills, geckos cannot climb surfaces coated with Teflon. Chemically, Teflon is polytetrafluoroethylene, which is the combination of carbon and fluorine. Fluorine itself is highly electronegative and easily attracts electrons towards itself. Due to this chemical nature of Teflon, the gecko cannot instill the Van der Waal's force and therefore find it difficult to stick to Teflon.

Among the diverse animals that we see around us, gecko's unique ability to climb any wall surface is a matter of interest for the zoologists. A lizard climbing the wall is a very common sight to observe, but the unique biophysical aspects of their habit is worth it to be studied in more details. ■

Bacteriocins: Antimicrobial Peptides of Bacterial Origin


Ashwini Kumar Dubey and Yogesh Kumar

In view of the growing resistance to antibiotics by various pathogenic microbes the attention of biomedical scientists has been drawn towards the use of bacteriocins as a promising substitute for conventional antibiotics. There are a number of advantages of using bacteriocins. One of the major advantages is that the natural microbiota of the human body is not harmed much by these protein-like molecules as compared to the traditional antibiotics.

While working on *Escherichia coli* strains, the Belgian microbiologist Andre Gratia in 1925 found that one strain of the bacterium inhibited the growth of other strains. This inhibition was due to the bactericidal effect of a protein-like antimicrobial agent, which was later termed as bacteriocin. More than ninety-nine percent of all known bacterial species produce bacteriocins or antimicrobial peptides/proteins (AMPs) and a large number of bacteriocins produced by both gram-positive and gram-negative microorganisms have been characterised till date. The bacteriocin discovered by Andre Gratia was termed as colicin since it was produced by *E. coli.* Colicin could not be used on humans because of its narrow spectrum of antimicrobial activity.

Action of bacteriocins

Bacteriocins inhibit the pathogens by different modes of action, viz., bactericidal, bacteriostatic, or lytic mode. In general, the bacteriocins are known to have antimicrobial potential against closely related species. However, a number of bacteriocins have been reported to have antimicrobial activity against a wide variety of gram-positive and gram-negative microorganisms. A few of bacteriocins are known to have antifungal, antiviral, anti-tumour and spermicidal activity as well.

Bacteriocins with a wide spectrum of activity may find application in various fields: agriculture, food, and medicine. However, extensive use of bacteriocins on a large scale can also cause bacterial cells to develop resistance to them. Usually the bacteriocins' producer strain is immune to its secreted bacteriocins because of the immunity protein in its cell membrane encoded by an immunity gene. If the immunity gene is taken up by a sensitive cell then the sensitive cell would also become resistant to a particular bacteriocin protein. The sensitive bacterial species can also develop resistance against bacteriocins by spontaneous mutation.

Classes of bacteriocins

Bacteriocins are considered a diverse group of protein-like antimicrobial substances released extra cellularly by almost all bacterial species in its milieu to compete with other closely related species. These protein-like substances are categorised into five classes: Class I, II, III, IV and V to facilitate the understanding of their structure-function relationships based on their mode of action, amino acid sequence, molecular size, heat resistance and host ranges.

Class I bacteriocins are smaller peptides (less than 5 kDa) that contains modified amino acids such as lanthionine

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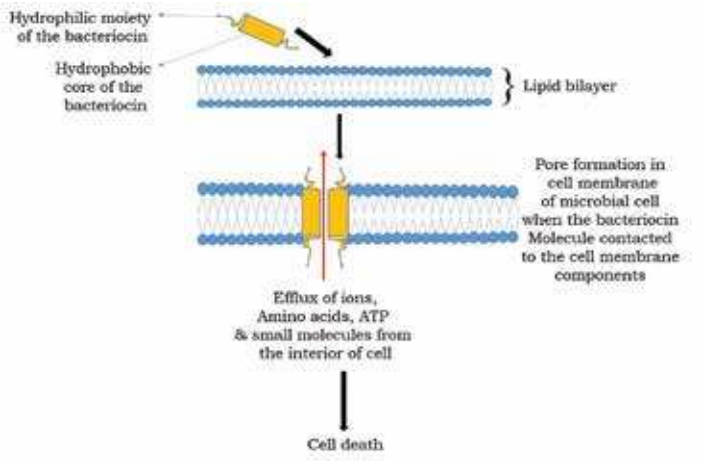
and beta-methyl lanthionine whereas Class II bacteriocins are heat-stable small peptides (less than 10 kDa) active against *Listeria* and do not contain modified amino acids. Class III bacteriocins are heat-labile proteins with larger sizes (greater than 10 kDa) and Class IV bacteriocins are cyclic peptides which are known to have resistance to proteases. The fifth class of bacteriocins, Class V are complex bacteriocins which consist of proteins/ peptides with the carbohydrate or lipid moieties bound to it.



Pore formation in bacterial cell by bacteriocin

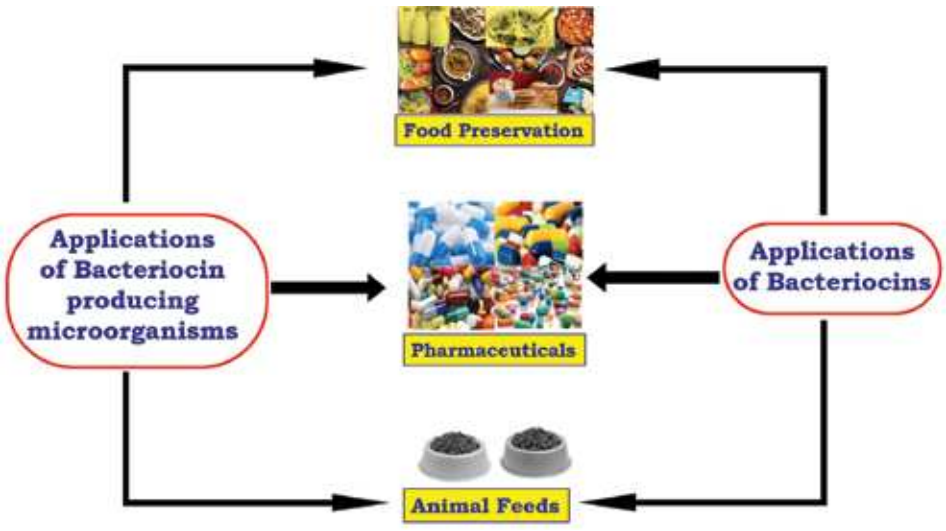
Bacteriocins are different from antibiotics

Unlike antibiotics, which are secondary metabolites, bacteriocins are protein-like molecules which are synthesised by the process of translation on the ribosomes involving messenger RNA. Antibiotics are known to have a wide spectrum of activity whereas bacteriocins have a narrow spectrum of activity, mainly against closely related species. Regarding their mode of action, antibiotics mostly act by targeting either the cell wall or the intracellular milieu of target cell whereas most of the bacteriocins act by creating pores in the cell membrane of target cell resulting into the leakage of cellular contents outside the cell and eventually resulting in the death of the microbe.

Applications of bacteriocins

In view of the growing resistance to antibiotics by various pathogenic microbes the attention of biomedical scientists has been drawn towards the use of bacteriocins as a promising substitute for conventional antibiotics. The bacteriocins from the lactic acid bacteria, which are *generally regarded as safe* (GRAS) microorganisms for its host, are found to be active against various microbes including human pathogens and thereby can be used in the treatment of various infectious diseases as an antibiotic complement and also in food preservation for the management of food spoilage and food-borne pathogenic microorganisms. Food can be supplemented with *ex situ*-produced bacteriocin preparations, or by inoculation with the bacteriocin-producer strain under conditions favouring production of the bacteriocin *in situ.* The bacteriocins produced by probiotic strains of lactic acid bacteria inhibit the growth of harmful pathogens *in situ* in the gut and thereby modulate the gut microbial flora.

There are a number of advantages of using bacteriocins. One of the major advantages is that the natural microbiota of the human body is not harmed much by these protein-like molecules as compared to the traditional antibiotics. Subsequently, in the gut, these substances are degraded to simple amino-acids products that are easily metabolised. The US Food & Drugs Administration (US-FDA) had approved Nisin, a Class-I bacteriocin produced by *Lactococcus lactis* with a wide spectrum of activity, as a food additive for direct use in foods. It has been also approved as GRAS status by World Health Organisation, Food and Agriculture Organisation, and the European Union. Nisin is available commercially in several countries. The other bacteriocin approved by FDA is pediocin produced by *Pediococcus acidilactici*, which is on the market in Europe and USA under the name ALTA2431. ■



Applications of Bacteriocins

INTERVIEW

Science Can Solve Complex Problems: Prof. K. Vijay Raghavan

Navneet Kumar Gupta

Developing our own basic sciences act as insurance for the unforeseen problems of the future. If we can guess our future problems right, it can help us plan for solutions. Therefore, basic science is not only about what you are learning, but also about building a foundation for your future solutions. To think that you can erect the Mount Everest without building mountain ranges would be a folly.

Professor K. Vijay Raghavan is a renowned academician and science administrator. A fellow of the Royal Society, he has made his mark as a former secretary of the Department of Biotechnology. He has also worked as the Director of the National Centre for Biological Sciences (NCBS). He was recently appointed as the principal scientific advisor (PSA) to the Government of India. In this capacity Prof. Vijay Raghavan's task would be to build and advance scientific missions across the country, which would entail envisaging and implementing multi-disciplinary and multi-institutional projects in strategic and technological as well as in other relevant socio-economic fields. Shri Navneet Kumar Gupta of Vigyan Prasar caught up with Prof. Vijay Raghavan to talk about the role of science in the national development. The following are excerpts from the interview.

Navneet Kumar Gupta: How did you become interested in science?

Prof. K. Vijay Raghavan: My father was in the Air Force, which gave me a chance to visit various parts of the country from my childhood. One of my early friends had a keen interest in science, literature and architecture. We would roam around the streets of Daryaganj in Delhi on the bicycle to collect chemicals and then experiments at home, although, many of those chemicals are no more easily accessible in the market now. These amateur ventures attracted me to the world of science. My grandparents gave me science magazines to read. Books related to science came at a premium in those days. However, there were some good libraries. Later, I studied at IIT-Kanpur. It was a totally different atmosphere. This is how science became inseparable from my life.

NKG: Most people identify science with space or defence sectors in this country. But you chose life sciences for research. As Secretary of the Department of Biotechnology, you took this stream to the masses. Do you feel the necessity to popularise the achievements in other fields of science?

Prof. K. Vijay Raghavan

Prof. KVR: The applications of space science are in abundance these days. However, the space sector has been the nation's pride since independence. Every

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rocket soaring into the sky boosts the morale of our citizens. Some sectors are indeed jewels of the country. But, India must have a distinguished place in other disciplines of science as well. Although, some of these fields are bit intricate, we have made significant strides in some of them. For example, we have conquered diseases like chickenpox and polio through effective vaccination and improved our maternity health. We have been able to double the life-expectancy since independence. We should strive to increase it to 75 by 2022, the year when we celebrate our 75th Independence Day. Such achievements should also get highlighted among the people.

NKG: What is the role of vernacular in popularising science in India?

Prof. KVR: The question of language is not merely restricted to communication in this regard. It has become more of a colonial mindset. For instance, a student from a state like Jharkhand or Karnataka with no English school background is forced to learn this language to study science. There are many luminaries who have immensely contributed to science in their native languages. People in several countries like Sweden, Denmark and Netherlands learn science in their own respective languages. They are also taught English which becomes a medium for them to take their scientific work to the world. Scientists in these countries write research papers in English but their thinking is rooted in their own society and culture. Teaching science in native languages has tremendously benefitted these countries. I am not advocating the abolition of English but we should try to spread the message of science in our own languages.

NKG: Girls are excelling in science. But, their representation in research is still low. What needs to be done to change this situation?

Prof. KVR: This has several reasons. We see many girls till B.Sc. level. However, their percentage dips at the level of higher education. Our institutions of higher learning need to be more women-friendly. Work timings and age limit for female research scholars should be lenient. They should be provided with facilities like daycare. Women should also be allowed to look after their other responsibilities; even if it means a temporary halt to their research work. We need more female representation at higher posts and committees. Such steps can improve India's gender profile. Respect for women is deeply ingrained in our culture. Moreover, we are a democracy and our women are highly committed to their work.

NKG: The focus is increasingly on applied sciences these days. Does this mean that we might be ignoring the basic sciences?

Prof. K. Vijay Raghavan with Navneet Kumar Gupta during the interview

Prof. KVR: This is precisely why we need to understand the importance of basic science. One might argue the problems facing our nation justify paying more attention to the applied sciences. Many other countries are investing in basic sciences and we can take it from them, we can say. But this is a faulty premise. For one, borrowing technology from other countries compromises your sovereign autonomy. Second, developing your own basic sciences act as insurance for the unforeseen problems of the future. If we can guess our future problems right, it can help us plan for solutions. Therefore, basic science is not only about what you are learning, but also about building a foundation for your future solutions. To think that you can erect the Mount Everest without building mountain ranges would be a folly.

NKG: How justified is the opposition to projects like Neutrino Observatory?

Prof. KVR: The ground-level workers with scientific temper should establish a dialogue with the common masses in this context. Only a dialogue between the common man and the scientific community can solve such problems. This is the only way for a meaningful discussion on the utility of such scientific experiments.

NKG: Is India prepared enough for the climate change?

Prof. KVR: India has made some praiseworthy efforts in this regard. The erstwhile Ministry of Environment and Forest is now the Ministry of Environment, Forest and Climate Change. This indicates India is completely geared to tackle this menace. We are among the nations that fully understand the ramifications of this phenomenon and thus working to reduce its impact. India has taken several steps to reduce the emission of greenhouse gases. We are part of several international projects being implemented to deal with the problem. India is playing a pivotal role in initiatives like Mission Innovation and Solar Energy Alliance. We are moving fast towards the direction of clean energy and thus contributing effectively in saving the planet from the climate change.

NKG: Where do you see India in the world of science in 2030?

Prof. KVR: It is difficult to predict. Though, India has a lot of potential in every field. We are trying to encourage latest innovations in areas like nanotechnology, solar energy and infrastructure building. As the Prime Minister says, only working with all can ensure development for all. The scientists working in universities and other institutes should contribute more in solving our socio-economic problems. We can achieve a lot till 2030 if this happens.

(Translation: Deepak Sharma) ■

Recent Developments in Science and Technology

Biman Basu

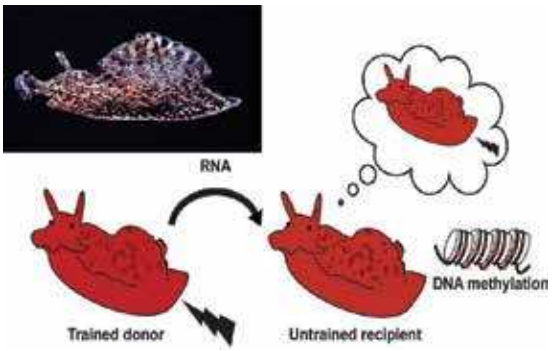
The seasonal migration of many species of birds is an ecological puzzle. There are about 10,600 known species of birds, and most don't migrate. But about 15 percent of bird species go on these exhausting annual journeys, commuting thousands of kilometres between their summer breeding grounds and the places they spend in winter. It has been a long-standing puzzle why some birds migrate but others don't. A recent study using computer simulation appears to provide a simple answer to the puzzle of bird migration.

Scientists succeed in transferring memory

Memory is one of the most complex processes of the brain. The term memory usually denotes the structures and processes involved in the storage and subsequent retrieval of information. The ability to store and retrieve memory is extremely important for a living organism to function normally. For decades, researchers have tried to pinpoint how, when, and where memories form. Long-term memory was thought to be housed within modified connections between brain cells. In the 1940s, Canadian psychologist Donald Hebb proposed that memories are made in the connections between neurons, called synapses, and stored as those connections grow stronger and more abundant. Experiments in the 1960s, however, suggested that RNA could play a role in making memories, though the work was largely written off as irreproducible. But memory was never considered a transferable commodity. A recent study with sea slugs by researchers of University of California-Los Angeles (UCLA) led by David L. Glanzman, however, show that memory can indeed be transferred from one animal to another in the form of RNA (*eNeuro* 14 May 2018 | DOI: 10.1523/ENEURO.0038-18.2018).

Like other invertebrates, sea slugs neither have a spinal cord nor one single brain. Instead they have a set of ganglia (groupings of neurons) that distribute the control of the various parts of the snail. Although this is a rudimentary brain, snails and slugs have more ability for associative thinking than most people give them credit for. Glanzman and his team worked with a species of sea slug known as the California sea hare (*Aplysia californica*).

Glanzman, who has been working on the cell biology of learning and memory for nearly 40 years, says most of the time he believed memory was stored at synapses. Meanwhile, memory-erasing research had been done on rats by researchers of Massachusetts Institute of Technology, Cambridge, USA, in 2014, which Glanzman and his colleagues wanted to replicate with the California sea hare. They found that the snail synapses built to "store" a memory were not necessarily the synapses that were removed from the neural circuits in the memory-erasing experiments. The studies suggested an alternative explanation: Memory storage may involve changes in gene expression induced by non-coding RNAs.



An illustration from Glanzman's paper shows the transfer of RNA from one snail to another. (Credit: David Glanzman/UCLA) (Inset) California sea hare (Aplysia californica).

For the experiment, Glanzman first

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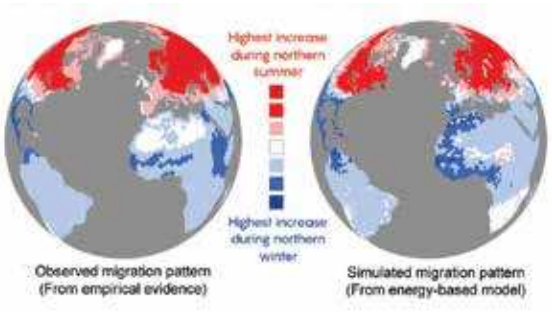
trained a few sea slugs by implanting wires into their tails and giving them a series of electric shocks every 20 minutes for a total of five shocks. The next day, the slugs went through the same shock session. The idea was to prime them to use what is called a 'defensive withdraw reflex'. The procedure sensitised the animals so that when Glanzman and his team later physically tapped these slugs on their tails, without electric shock, the creatures contracted their gills in a robust defensive action. Another set of slugs were not given any electric shock.

The researchers then extracted ribonucleic acid (RNA) from the nervous systems of both the shocked and non-shocked groups. They took this RNA and injected it into a third set of slugs that did not have to deal with any shocks or taps. Seven of these slugs got the shocked group's RNA and seven got the non-shocked group's RNA. Next, the team tapped these RNA-injected slugs on their tails. Those that had received the shocked group's RNA responded almost exactly like the shocked group, but those which were given the non-shocked group's RNA responded normally, thereby demonstrating a physical transfer of memory from the slugs that were given the electric shocks.

Mystery of bird migration solved

The seasonal migration of many species of birds is an ecological puzzle. There are about 10,600 known species of birds, and most don't migrate. But about 15 percent of bird species go on these exhausting annual journeys, commuting thousands of kilometres between their summer breeding grounds and the places they spend in winter. It has been a long-standing puzzle why some birds migrate but others don't. There is no obvious explanation for why some bird species are migratory and others are not. Big and small, the migrants come in all shapes, sizes and habits. Even within a migratory species, behaviours can vary wildly. A recent study using computer simulation appears to provide a simple answer to the puzzle of bird migration: It's all about energy efficiency. Although it may appear paradoxical, birds actually *save* energy by migrating. The study presents a model that explains, in a very broad way, the global distribution of birds. (*Nature Ecology & Evolution*, 8 May 2018 | DOI:10.1038/s41559-018-0556-9).



Researchers developed a virtual world with thousands of simulated bird species to test the idea that birds migrate to optimise their balance of energy supply and consumption. The species distribution patterns in the model closely resembled the distribution patterns of real birds in nature. The colours reflect the net increases in the number of species from migration. (Credit: quantamagazine.org)

Migrating birds, the researchers found, gain more energy from whatever is available at the destination than they expend getting there and back, or could find without making the journey. For birds which migrate from colder regions to warmer regions during winter, the energy cost of flying long distances is balanced out by the energy savings of being in a place (in the southern hemisphere) where, in summer, there are lots of mosquitoes, flies, insect larvae and other avian delicacies, and there is relatively little competition for food.

The opposite also happens. Many species migrate to northerly breeding grounds in the summer, where resources can be more abundant for them and their young and there is not much competition for food. When winter comes, the cold kills off the food and they return to warmer climates.

In the model, migratory behaviour emerges as if driven by a global mechanism to redistribute birds more efficiently. It is not just animal instinct honed by evolution; it's the biosphere arranging birds in the most logical fashion. "There's just one rule and one mathematical model that explains the whole thing," said Marius Somveille, who did the research at Oxford University. The study used a computer model which created a simulated planet with similar climatic differences between regions (which is not the real one). The researchers then added virtual birds, and the estimated amount of "energy", or food, available in different regions. In the simulation, birds appear first in the tropics and gradually fill it up. The study used vegetation as a proxy for the energy supply in the environment.

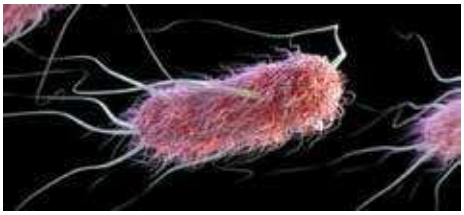
The model birds dispersed in a manner very similar to what happened in real life. The birds started off in the food-rich tropics, but growing competition forced some to start moving further afield. According to the researchers, "In our increasingly crowded virtual world, species progressively started exploiting more extreme pockets of seasonally available energy supply, often migrating longer distances". The model, they say, adds to our understanding of how Earth's plants and animals came to be distributed as they are. It could also be useful in predicting the future movements of other animals – to determine how they might migrate in response to global warming, for example.

Blood type affects severity of diarrhoea caused by *E. coli*

Diarrhoea is one of the most common health complaints, especially in many developing countries where there is lack of adequate sanitation. It is characterised by abnormally loose or watery stools and can range from a mild, temporary condition, to a potentially life-threatening one. Globally, an estimated 2 billion cases of diarrhoeal disease occur each year, and 1.9 million children under the age of 5 years, mostly in developing countries, die from it.

Diarrhoea can be caused by bacteria, viruses, or parasites, but diarrhoea caused by bacterial infection, especially *Escherichia coli* infection, is more common. Recent research led by researchers at Washington University School of Medicine in St. Louis, USA, has shown that a kind of *E. coli* most associated with "travellers' diarrhoea" and diarrhoea of children in underdeveloped countries of the world causes more severe disease in people with blood group A. The *E. coli* bacterium was found to release a protein that latches onto intestinal cells in people with blood group A, but not blood group O or B. The study was done in collaboration with investigators at Johns Hopkins University, the National Institutes of Health (NIH), and the US Naval Medical Research Centre.

Enterotoxigenic *E. coli* that produces a toxin in the intestine has been previously associated with millions of diarrhoeal cases that have resulted in deaths hundreds



People with blood group A are more likely to develop severe diarrhoea when infected with a kind of E. coli (shown in a computer-generated image above) than people with blood group O or B. (Credit: Alissa Eckert and Jennifer Oosthuizen/CDC)

of thousands, especially of children in underdeveloped countries. It primarily infects people living in or visiting developing countries but has also been associated with people who have been travelling to developing countries. People, who are infected with this bacterium, tend to suffer from fatal, cholera-like, watery diarrhoea. The symptoms vary so much that some people infected with the bacterium develop severe, cholera-like, watery diarrhoea that can be lethal, while others experience unpleasant symptoms but recover easily, and some don't get sick at all.

In the study, James Fleckenstein, Matthew Kuhlmann, Pardeep Kumar, and colleagues investigated whether blood type influences disease severity by looking at what happened to volunteers of different blood groups who were given to drink a cup of water laced with *E. coli* for five days to infect them. Those who had moderate to severe diarrhoea were treated with antibiotics. The disease comes on quickly, so anyone who was still healthy at the end of five days was unlikely to get sick later. Nonetheless, the remaining healthy participants also were given antibiotics to clear the bacteria before going home.

The researchers then studied blood samples from 106 volunteers and found that participants who had blood type A got sick sooner and more severely than those who had other blood groups. Eight out of ten volunteers in the study group developed diarrhoea that required treatment, as compared to another half of the volunteers with blood group B or O. It was found that the bacteria produced a specific protein which stuck to A-type sugars – but not B- or O-type sugars on intestinal cells. Since the protein also sticks to *E. coli*, it effectively fastens the bacteria to the intestinal wall, making it easy for them to deliver diarrhoea-causing toxins to intestinal cells (*Journal of Clinical Investigation*, 17 May 2018 | DOI: 10.1172/JCI97659). According to the researchers, the effect of blood group in people infected with this strain of *E. coli* was "striking and significant".

The researchers, however, caution that people with blood groups O and B need not be complacent because there are a lot of different species of bacteria and viruses that can cause diarrhoea. Basic hygiene – washing hands and purifying water – is the best protection against diarrhoeal diseases because it works against all kinds of organisms.

CRISPR-edited rice plants produce major boost in grain yield

Rice is a major staple food consumed by a large section of global population. Grown in more than a hundred countries, with a total harvested area of approximately 158 million hectares, producing more than 700 million tons annually, nearly 640 million tons of rice is grown in Asia, representing 90% of global production. Sub-Saharan Africa produces about 19 million tons and Latin America some 25 million tons. The world's largest rice producers by far are China and India. After China and India, the next largest rice producers are Indonesia, Bangladesh, Vietnam, Myanmar, and Thailand.

In the past, irrigation and fertilisers have helped raise cereal yields, but their full impact was realised only after the development of high-yielding varieties (HYVs). These semi-dwarf rice varieties were more responsive to plant nutrients and had shorter and stiffer straw that would not fall over under the weight of heavier heads of grain. They also matured more quickly and were insensitive to daylight length, thereby permitting more crops to be grown each year on the same land.

The first of these HYVs, named IR8, was released in 1966. Although rice yields have continued to rise on average across Asia since the Green Revolution era, annual growth rates are slowing. Moreover, total productivity has been declining, meaning that farmers now have to use higher amounts of inputs to obtain the same yields as before. On the other hand, using the population projections from the United Nations and income projections from the Food and

CRISPR-edited rice plants produce major boost in grain yield compared to conventional breeding methods.

Agricultural Policy Research Institute (FAPRI), global rice demand is expected to rise from 439 million tons (milled rice) in 2010 to 496 million tons in 2020 and further increase to 555 million tons in 2035, which may be difficult to achieve without a major breakthrough.

Now a team of scientists from Purdue University in USA and the Chinese Academy of Sciences has used CRISPR/Cas9 gene-editing technology to develop a variety of rice that produces 25-31 per cent more grain that would have been virtually impossible to create using traditional breeding methods. The team, led by Jian-Kang Zhu, a distinguished professor in the Department of Horticulture and Landscape Architecture at Purdue and director of the Shanghai Centre for Plant Stress Biology at the Chinese Academy of Sciences, made mutations to 13 genes associated with the phytohormone (plant hormone) abscisic acid, which is known to play roles in plant stress tolerance and suppression of growth. Of several varieties created as a result of the mutations, one produced a plant that had little change in stress tolerance but produced 25 per cent more grain in a field test in Shanghai, China, and 31 per cent more in a field test conducted on China's Hainan Island (*Proceedings of the National Academy of Sciences*, 21 May 2018 | doi.org/10.1073/pnas.1804774115).

The CRISPR/Cas9 technology allows plant breeders to quickly and accurately snip portions of DNA out of a sequence, editing the DNA code. In the present case, the method allowed Zhu's team to modify multiple genes at one time, something that would have taken decades to do with traditional breeding methods without a guarantee that the resulting plants would have the desired characteristics. ■