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Fields Medal 2014

For the love of math

Artur Avila Manjul Bhargava

Martin Hairer Maryam Mirzakhani

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

Valuable snapshots on citizen science

Dr. R. Gopichandran

This is a follow up editorial on this topic. The objective of the present editorial is to highlight a classic recent publication in the field of Citizen Science. It is "New Visions in Citizen Science" by Anne Bowser and Lea Shanley, Woodrow Wilson Center, November 2013 accessed on 22 July 2014 from http://www.wilsoncenter.org/sites/default/files/NewVisionsInCitizenScience.pdf. It is a must-read for practitioners in the field of science and technology communication because of the holistic perspective it provides to understanding the relevance of this approach.

The authors reveal the significance of collaboration with a large number of citizens, especially to gather precise data for a wide variety of applications. These could assist scientific research and in the process also create and strengthen a stake for citizens to influence knowledge development and consolidation. They cite instances wherein citizens record observations about air quality, occurrence and distribution of organisms in water bodies, enable emergency responses and help interpret hazards, in addition to tackling challenges in public health.

It can be inferred from the insights of the authors that:

1. Of equal importance is the need to assess the influence of enabling circumstances to sustain the relevance and appropriateness of such citizen-centred approaches through safeguards. These could pertain to the quality and usefulness of large-scale data and such related aspects as legal and institutional mechanisms that acknowledge their roles. From a public policy point of view it is essential to recognise the individual and synergistic impacts of these determinants. This has implications for ownership and validation that could also stand the tests of consistency.
2. Such aspects as intellectual property rights, procurement regulations and liability are also equally important.
3. Innovative approaches that are locally adapted to harmonise and tackle the challenges stated are needed to optimise output through citizen engagement. These could result in appropriate capacity building of all stakeholders to comprehend their preparedness and the motive of common good.
4. A community of practitioners could guide documentation, interpretation and communication for effective knowledge sharing. These could be locally established experts/institutions, only to enhance local relevance and ready acceptance. Best practices with respect to the above stated could be shared in this process.

The councils of science and technology in the respective states could be useful focal points for these exercises and establish a local context to knowledge enrichment and applications. Science clubs could be useful facilitators in this process.

Yet another classic reference is the UNEP Year Book 2014 - Emerging issues update: Realising the potential of citizen science. This reference too was accessed on the same day as the above cited from http://www.unep.org/yearbook/2014/PDF/chapt6.pdf. The update mentions testing of natural phenomena and development of technology as useful spin-offs through the citizen science initiative. These provide opportunities to understand a wider range of direct livelihood benefits and in several cases also enrich traditional knowledge systems. Missions of the Government of India, especially on environmental and health related aspects, can use well designed tools to gather location-specific information periodically. This approach is also aligned with India's approaches for citizen participation through institutions at the grassroots level and mechanisms for engagement steeped in principles and values of democracy.

The paper "Links and Distinctions Among Citizenship, Science, and Citizen Science" by Caren B. Cooper from http://democracyeducationjournal.org/cgi/viewcontent.cgi?article=1070&context=home focusses on democratisation of science with reference to science education and with a special focus on students. Trends and convergence with public participation in scientific research are discussed with implications for decision-making processes and creating a milieu for growth of interest in science. The author emphasises the need to recognise heterogeneity in opinions, values and basis of inferences; yet upholding the credibility of science based insights.

Email: r.gopichandran@vigyanprasar.gov.in

Editor : R Gopichandran
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 : info@vigyanprasar.gov.in
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For the love of math

Dr. Shubashree Desikan
E-mail: shuba.desikan@gmail.com

This year, the International Mathematical Union (IMU) awarded four mathematicians the highest honour in mathematics – The Fields Medal. Let us walk with them a while.

Mathematics is a subject that all at once inspires awe, some fear, frowns and smiles, but whatever be the emotion it evokes in a person, it is a branch of study that forms the backbone of much of the science and technology we practise and enjoy today. It is not too much of a stretch to say that mathematics forms the language of sciences today.

From left to right: Fields Medallists Artur Avila, Manjul Bhargava, Martin Hairer, Maryam Mirzakhani and Rolf Nevanlinna prize winner Subhash Khot. Photo is from ICM Website.

It is a well-known fact that the best and most striking achievements in the sciences are awarded the Nobel Prizes. Achievements in mathematics, on the other hand, are not recognised by Nobel Prizes. The highest honours in the field of mathematics are the Abel Prize and the Fields Medal. This year, four mathematicians were awarded Fields Medals for their work in advancing the frontiers of mathematics. These four mathematicians are Brazilian Artur Avila; Canadian-American Manjul Bhargava, who is of Indian origin; Austrian Martin Hairer, and Iranian Maryam Mirzakhani.

The Fields Medal, officially known as International Medal for Outstanding Discoveries in Mathematics, is a prize awarded by the International Mathematical Union (IMU) once every four years at the International Congress of Mathematicians (ICM), which met this year (2014) at Seoul in South Korea. A minimum of two and a maximum of four mathematicians not over 40 years of age may be awarded at each congress.

Many firsts

What is interesting this year is that there have been many firsts in the tradition of the ICM.

- Maryam Mirzakhani is the first woman ever to have been awarded the Fields Medal since its inception in 1936. Not only that, she is also the first Iranian to have got it.
- Brazil, with its string of World Cup soccer titles, got its first Fields Medallist, this year, in Artur Avila.
- No other person of Indian origin has won this prize before Manjul Bhargava.
- As if to add to all this, Ingrid Daubechies of Princeton University is the first woman to preside over the executive committee of the IMU at its latest session.
- To cap it all, the prizes were awarded by South Korea's first woman president, Park Geun-Hye.

Artur Avila

The prizes this year show you how diverse talents, varied approaches, choices of subject, differing personalities, multiple cultures and wide-ranging backgrounds can produce mathematicians of the highest calibre who can not only produce stunning results but go on to win the highest honour in mathematics. In many cases, the medallists are globe-trotters, working in more than one place and travelling across the world to collaborate and carry on their work.

Artur Avila

Artur Avila is Brazil's most famous mathematician of the present times. The 35-year–old mathematician received the Fields Medal for his outstanding contributions to dynamical systems theory which have "changed the face of the field," according to the citation. He divides his time between CNRS in France, where he holds the position of research director, and Brazil's National Institute of Pure and Applied Mathematics (IMPA) at Rio de Janeiro, where he is a fellow.

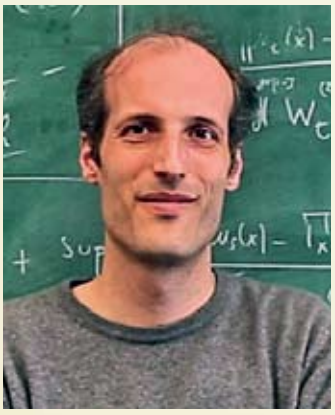
Avila had always been brilliant in mathematics, but found other subjects difficult and because of that had trouble staying in one school. His talent was first discovered and nurtured by his schoolteacher Luiz Fabiano Pinheiro. On his suggestion, Avila started attempting to win the Mathematics Olympiad when he was just13 years old. He actually did win the gold medal when he was just 17. The Olympiad was conducted in Brazil by the IMPA in Rio and once he got introduced to mathematicians there, he started to work on research-level

problems when he was still in high school. In collaboration with Welington de Melo and Mikhail Lyubich, he has worked on a wide class of dynamical systems – those arising from maps with a parabolic shape, known as unimodal maps, and proved that if one chooses a map like this at random, the result will be stochastic or regular. Another great work of his is on "weak mixing," another aspect of dynamical systems.

Manjul Bhargava

Manjul Bhargava

To those who have seen a famous picture of Nobel Laureate Richard Feynman playing the bongo, here is a mathematician who plays the *tabla*. This year's Fields Medalist Manjul Bhargava was born in Canada and is now working at Princeton University in USA. Bhargava is a multifaceted personality interested in Sanskrit poetry as well as Indian classical music and can virtually play with mathematics. His Indian roots were important to him then, as now, and he frequently visits institutes at Bangalore, Hyderabad and Mumbai to interact with students and faculty there. He has learnt to play the tabla from Ustad Zakir Hussain, the maestro. Manjul Bhargava's mother, Mira Bhargava, is a mathematician and was his first teacher of math and music – his two great loves.



Martin Hairer

It was a difficult decision for Bhargava to choose between music and mathematics. He decided to be a mathematician, because he could envisage being able to pursue music while being a mathematician. Growing up in Canada, he used to spend months away from his regular school to visit his grandparents in Jaipur, where he attended the local school and learnt Hindi and Sanskrit. With a mind that could grasp math and patterns quickly, he was able to appreciate the common threads in all these.

Bhargava likes to take up simple longstanding problems in number theory and look for elegant solutions and powerful methods that offer deep insight. One major, famous and early work of his is in generalising the Gauss Composition Law to higher degree polynomials. Further, the work he has done on elliptic curves along with Arul Shankar and also Christopher Skinner has found a mention in the citation for the prize. Elliptic curves in mathematics have been applied in cryptography, among other things. When asked about applications of mathematics, and in particular, elliptic curves, Bhargava says, "they were exciting and central to number theory well before … applications were found; but it was inevitable that [applications] would be found, given their fundamental nature. That is why elliptic curves have fascinated me! They are so fundamental in both pure and applied mathematics. Beyond advancing the subject of number theory in general, a heightened understanding of elliptic curves also has important implications in coding theory and cryptography."

Martin Hairer

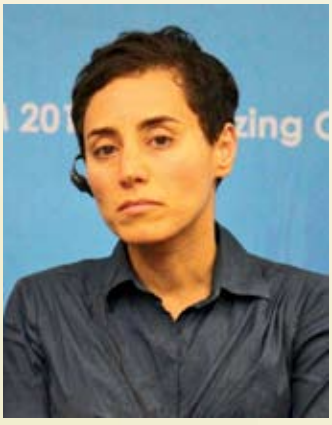
Thirty-eight years old and known for his keen mathematical intuition, Martin Hairer, who now works at the University of Warwick in UK, is fluent in French, German and English. Hailed a miracle worker, Prof Hairer's talents coexist with an admirably down-to-earth nature, according to Natalie Wolchover who writes about him in *Quanta Magazine*. He is also keenly interested in computer programming and had come up with an award-winning sound editing program called *Amadeus.*

Hairer was born in Switzerland and grew up in Geneva. His father Ernst Hairer is a mathematician. Being precociously intelligent, Martin topped his class from his childhood. He used to play with calculators that could program and at the age of 14, he developed a program for solving ordinary differential equations. He could not have known then that he would be going on to do great work in stochastic partial differential equations.

Prof. Martin Hairer was awarded Fields Medal for his contributions which led to a new understanding of Stochastic Partial Differential Equations (SPDE). Ever since Newton, it has been our scientific culture to describe changes, motion, and evolution of things around us in terms of PDEs. Examples include motion of planets and fluids, which can be modelled by deterministic PDE. In contrast to this, consider the evolution of stock market prices or the motion of suspended particles inside a fluid or the spread of a colour dye in a turbulent fluid. We see in them wild fluctuations whose source is uncertain, not easy to describe. The so-called random Stochastic PDEs are appropriate to model such situations. One such model known as KPZ equation (introduced by Kardar, Parisi, Zhang in 1986 in physics literature) has been studied by Hairer. It describes the evolution of rough interfaces between two media: imagine snowflakes or the advancing fronts of forest fires in their small details. He has introduced and exploited a gem of a notion called 'Regularity Structures' which extends the classical Taylor series of smooth functions to non-smooth objects. In this endeavour, inspiration came from recent developments in Rough Path Analysis.

Maryam Mirzakhani

Here is one Fields Medallist who had no intention of becoming a mathematician in her early years. When growing up, she was a voracious reader and read many novels, especially influenced by *Lust for Life,* based on the life of the famous artist Vincent Van Gogh, which gave her a great ambition to do something great. But in her first year at middle school, in Teheran, she did pretty badly in mathematics, perhaps because she had a teacher who was very discouraging. In the second year, however,



Maryam Mirzakhani

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The chronicle of arsenic

Pradip Kumar Sengupta
E-mail: sengupta_pradip@yahoo.com

Arsenic is a very common name in the modern world. Since discovery of its presence as a toxic substance in groundwater, the name 'arsenic' has become a matter of grave concern for the people living in the alluvial plains of Bangladesh and some parts of India and other countries. Millions of people are victim of arsenic toxicity. Before this phenomenal appearance of arsenic in our drinking water, this element was known only to chemists and geologists and to some extent to metallurgists. But if we look into the history we will find the emphatic presence of arsenic and its compounds in various turning points of human culture and history. It had been used both for good and bad purpose for several centuries. In our history, literature, and business arsenic was in existence with its all vices and virtues.

Origin of arsenic

Arsenic is an element found in nature in rocks, soil, water and air—in fact, it is one of the most common elements on Earth. According to cosmic abundance its place is

Arsenopyrite (FeAsS)
(source: wikipedia)

20. Arsenic is rarely found in native form. Arsenic minerals are very common and are found primarily in igneous and metamorphic rocks. In sedimentary rocks and alluvium it is generally found as minor sulphide or oxide minerals associated with other mineral grains.

According to geochemists the primary compound of arsenic is arsenic hydroxide which in favourable environment becomes arsenic sulphide due to its high affinity towards sulphur. The first mineral thus formed is orpiment (As_2S_3). (The name orpiment has come from the word auropigmentum, which means powder of gold.) The carbonation of arsenic sulphide minerals, including orpiment and realgar (As_2S_2), is an important process in leaching arsenic into groundwater under anaerobic conditions..

Discovery of arsenic

Natural occurrence of arsenic minerals had been known since antiquity. Aristotle in the 4th century BC makes reference to a mineral named sandarach (arsenic trisulphide). In the 1st century AD, Pliny stated, "Sandarach is found in gold and silver mines." By the 11th century three species of arsenic minerals became known to us – the white, yellow and red – which are arsenic ferrosulphide (arsenopyrite), arsenic trisulphide (orpiment) and arsenic disulphide (realgar), respectively. But as an element it was unknown till 13th century.

The 13th century German philosopher and theologian Albertus Magnus has been given the credit as discoverer of metallic arsenic. However, his documentation is considered vague. In 1649, German physician and pharmacologist Johann Schroder clearly reported the preparation of metallic arsenic by reducing arsenic trioxide with charcoal. Thirty-four years later, the French chemist Nicolas Lemery also observed that metallic arsenic was produced by heating arsenic trioxide with soap and potash. By the 18th century the properties of metallic arsenic were sufficiently known to classify it as a semi-metal.

In 1641 a German physician named Johann Schroder wrote in his pharmacopeia that arsenic is generated if arsenic oxide is burnt with charcoal. In late 18th century a number of compounds of arsenic were prepared in the laboratory and people became aware of the multifarious chemical properties of the element.

Arsenic appears in three allotropic forms: yellow, black and grey; the stable form is a silver-grey, brittle crystalline solid. It tarnishes rapidly in air, and at high temperatures burns forming a white cloud of arsenic trioxide.

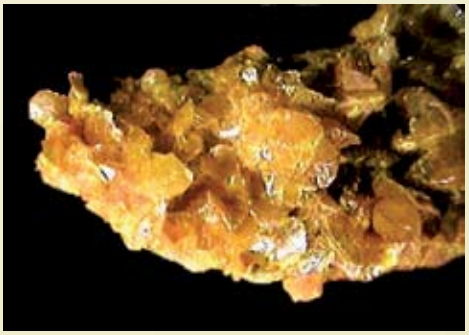
Arsenic toxicity

Arsenic has been a cause of mortality throughout the world and a highly preferred poison by killers. The associated problems of arsenic poisoning include heart, respiratory, gastrointestinal, liver, nervous, and kidney diseases. The carcinogenic effect of arsenic arises from the oxidative stress induced by arsenic. Arsenic's high toxicity naturally led to the development of a variety of arsenic compounds as chemical weapons, such as dimethylarsenic chloride. During World War I some arsenic poisons were employed as chemical warfare agents. This threat led to many studies on antidotes and an expanded knowledge of the interaction of arsenic compounds with living organisms. One result was the development of antidotes such as British anti-lewisite.

Arsenic in history

Arsenic compounds and metallic arsenic has been used by people since long. Realgar and orpiment were most popular. Beautiful women used orpiment powder as a cosmetic for its golden colour. Artist Senini wrote, "Arsenic is golden but it is poisonous. As a pigment it is closest to gold. But it cannot be used for fresco and tempera because it turns black after a few days."

Orpiment was also found in a bag near the mummy of Tutankhamen, which proves that the compound was also adored in ancient Egypt. Orpiment used to be imported from Persia, Armenia and Asia Minor. Egyptians used to prepare bronze by mixing arsenic with copper and tin. Arsenic was also used in mirrors.



Orpiment (As_2S_3) (source: wikimedia)

The use of arsenic as a medicine goes back to antiquity. Plinny wrote, realgar can be used for dressing wounds. Besides it is a medicine for sores and skin ailments. If it is

Crystalline Realgar (As_4S_4) (source: wikipedia)

taken with turpentine oil it cures asthma. Orpiment was also used as a medicine for warts and swelling. In the 16th century a Swiss-German scholar named Paracelsus pioneered the use of chemicals and minerals in medicine. He wrote that an ointment containing powder 18 toads dried in Sun, mixed with white and red arsenic, pearl, coral and other precious gemstones and herbs prevents plague if applied on throat.

In India arsenic was in use since the time of Buddha. In *Charak Samhita*, orpiment appears under the name *harital* and realgar as *monohshila* . Arsenic element has different names in different regions. In Sanskrit it is called *sankh*, in Hindi *sankhiya*, and *senko bish* in Bengali. In Indian medical science it is stated that "if properly processed *harital* cures bronchitis, and hysteria. It also improves body heat and appetite. It is also a cure for leprosy. If unprocessed *harital* is taken it may lead to death."

Arsenic as a poison

Use of arsenic as a poison is very old. Aristotle in 340 BC described it as a cattle killer poison. The *Chinese Encyclopaedia of Medicine* of 16th century AD described arsenic as a pesticide and rat killer poison. Till 19th century arsenic trioxide was a favourite weapon of professional killers.

Chronic arsenic poisoning with the symptoms of peripheral neuritis broke out among beer drinkers in an epidemic form in the county of Lancashire in England in 1900. Beer was found contaminated with arsenic, varying from 0.01 to 0.3 grain or even 1.4 grains per gallon, and derived from impure sulphuric acid used in the manufacture of glucose and cane sugar required for brewing it.

Commercial Arsenic Poison (Source http://www.toptenz.net/wp-content/uploads/2008/09/arsenic.jpg)

If we look into the pages of history we shall find that several political murders had been committed using arsenic. One of the best examples is the death of Napoleon on the island of St. Helena in South Atlantic where he was poisoned with arsenic. In ancient England arsenic candles were very popular weapon for poisoning anybody slowly. Arsin gas is emitted from arsenic candle which is highly toxic. George Wythe (1726-1806), a signer of the Declaration of Independence and the first official law professor in the United States, was poisoned by his grand-nephew George Wythe Sweeney, with arsenic to claim an inheritance.

Modern uses of arsenic

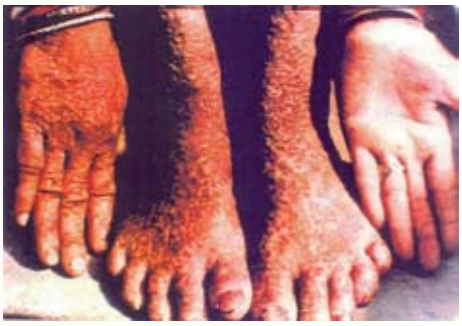
With passing time scientists discovered beneficial properties of arsenic. From 1860 until the introduction of DDT and other organic pesticides inorganic compounds of arsenic remained as the dominant pesticides. But widespread contamination of soil gave rise to public resistance to use of arsenic in agriculture. Arsenic chemicals such as monosodium methyilarsonate (MSMA) are typically used for control of grassy weeds such as crabgrass in fields.

Metallic arsenic is used mainly in the making of alloys, in combination with lead and copper. Trace quantities of arsenic are added to lead-antimony grid alloys used in acid batteries. Exceedingly high pure arsenic metal is used in the electronics industry, primarily in the form of gallium or iridium arsenide to form semiconductor compounds. It is used for making LEDs.

Arsenic in literature

Arsenic is a favourite fictional murder weapon, due to its reputation for being odourless, colourless, and virtually undetectable by the victim. Director Franz Capra's 1944 film *Arsenic and Old Lace* is good example of this.

In Gustave Flaubert's debut novel Madam Bovary the heroin Emma committed suicide by consuming arsenic. *A Rose for Emily* by William Faulkner is another example of appearance of arsenic in literature. There are more examples in Bengali literatures also. In *Chander Pahar*, the great adventure novel by Bibhuti Bhushan Bandyopadhyay, presence of arsenic in stream water is mentioned. In *Jagat*, a Hindi Novel by Rahi Masoom Reza, a death from arsenic poisoning came at a turning point of the novel.



Skin lesion due to arsenic poisoning from groundwater (Courtesy: Amitabha Sengupta)

Arsenic in ground water

Arsenic poisoning still remains a public menace. Arsenic contamination of the ground water in Bangladesh and in West Bengal, India, is a major public health problem today. It is often due to naturally occurring high concentrations of arsenic in deeper levels of ground water. Arsenic poisoning was first identified in the early 1980s in West Bengal, India, where health officials linked an outbreak of skin lesions to groundwater pumped from shallow wells. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water. It is estimated that every day, more than 100 million people are exposed to arsenic-contaminated drinking water in Bangladesh, Cambodia, China, India, Myanmar, Nepal, Pakistan and Vietnam. In the Ganges Delta, the affected wells are typically more than 20 metres and less than 100 metres deep. Extraction of large volumes of ground water for irrigation is believed to be a major factor for the rising arsenic contamination of ground water. Indian scientists have developed simple techniques of making ground water arsenic free which can go a long way in tackling the arsenic problem.

Pradip Kumar Sengupta is a hydrogeologist and after retirement from government service he works as an independent researcher on water resource management and volunteers as a science communicator.

Charismatic carambola

Dipanjan Ghosh

Sreeparna Ghosh

Abstract

Carambola is a fruit tree native to India. The fruit is memorably tasty as well as rich in vitamins and anti-oxidants. It is specially

Figure 1: A carambola (Averrhoa carambola) tree in the fruiting season.

used as ayurvedic medicines from the time immemorial.

The fruit of carambola, commonly known as '*kamrakh*' or '*kamranga*' shares a kinship with our sociological texture and heritage. It even finds mention in the Ramayana. Also known as 'star fruit', it is botanically known as *Averrhoa carambola* Linn. It belongs to the family Oxalidaceae. Carambola is known under different names in different languages of our country. In Assamese it is known as '*kordoi*', in Bengali and Oriya, it is '*kamranga*', in Gujarati and Hindi, it is '*kamrakh*', in Kannada, it is '*kaparakshi hannu*', in Malayalam, it is '*chaturappuli-vairappuli*'. In Marathi and Konkani, carambola is known as '*karambal*'. In Tamil, it is known as '*thambaratham*' and in Telugu, it is '*ambanamkaya*'.

Carambola is believed to have originated either in Sri Lanka or in Moluccas of Indonesia, but it has been commonly grown in China, India, Malaysia and Taiwan for centuries. It is rather popular in Australia, Brazil, Caribbean Islands, Central and South America, Hawaii, Mexico, Peru, Philippines, tropical West Africa and Zanzibar. In many parts of the world, carambola is cultivated more as an ornamental plant than for its fruits.

The carambola plant is basically grown in tropical and sub-tropical climate although mature trees can tolerate freezing temperatures for short periods and sustain little damage below 0°C. Besides, it thrives even up to an elevation of 1200 m, particularly in the Himalayan foothills. The carambola tree needs rich loamy soil for faster growth. In addition it requires good drainage and cannot withstand flooding.

Carambola is a slow-growing, deciduous, small to medium-sized tree with much branched trunk and bushy rounded crown (Figure 1). The tree grows rapidly and produces fruits at the age of 4-5 years. At maturity, the carambola plant reaches 6-9 m in height.

Figure 2: For its beautiful pink flowers, carambola is cultivated more as an ornamental plant than for its fruits.

Figure 3: Both (b) ripe and (a) unripe star fruits are full of vitamin C and anti-oxidants.

Leaves are spirally arranged, alternate, exstipulate, 15-20 cm long, and pinnately compound.

Flower are borne on axillary cymes in small clusters. Each flower (Figure 2) is pedicallate, small, 6mm wide, pink in colour with purple streaks.

The carambola tree flowers throughout the year, with main fruiting seasons from April to June in sub-tropical regions and from October to December in tropical regions. The fruit (Figure 3) is showy, about 6-15 cm long and up to 9 cm wide. The fruit has 5-6 prominent longitudinal ridges running down its sides. Thus slices cut in cross-section resemble the form of a star (Figure 4). Hence, the popular cognomen 'star fruit' is conferred to carambola.

The fruit skin is thin, smooth, waxy and usually green but turns light orange-yellow when ripe. The flesh is juicy, crisp as well as translucent, light-to-dark yellow in

colour and does not contain any fibre. The fruit has a more or less oxalic acid odour and the flavour ranges from very sour to mildly sweetish. Moreover, there are two main types of star fruit, the small tart type has a higher acid content and the sweet type contains a lower amount of organic acids. However, the so called sweet variety of carambola rarely contains more than 4 per cent sugar. Each fruit can have 10-12 thin, flat, light brown seeds, about 6-13 cm long and enclosed in a gelatinous aril.

Food value

In most of the South Asian countries and Australia, carambolas are produced throughout the year. In the USA, the fruit is found all the year, but the main harvesting season starts from September and continues up to November. In India, carambolas are available mainly from September to January. The fruits naturally fall to the ground when fully ripe. However, for marketing and shipping, fruits are hand-picked in quite an early stage.

The carambola fruit contains considerable amount of nutrients and dietary supplements. Biochemical analyses have revealed that 100 g of edible portion of carambola fruit contains carbohydrates 9.38 g, proteins 1.04 g, lipids 0.33 g and dietary fibres 2.80 g. The same amount of fruit tissue provides 31KCal or 128kJ of energy. The star fruit is rich in almost all the essential amino acids with alanine, lysine and serine in good quantity. The fruit is also full of vitamins, especially vitamin C and various minerals including potassium. Moreover, the juice of the star fruit has also shown antimicrobial activity against some pathogenic bacteria such as *Escherichia, Klebsiella, Pseudomonas*, and *Staphylococcus*. Green fruits as well as ripe fruits of carambola contain moderate to high level of organic acids like oxalic acid, tartaric acid, malic acid, α-keto glutaric acid, succinic acid and fumaric acid.

Ripe carambolas are eaten out of hand, sliced and served in salads or used as garnish on avocado or seafood. A dish may be made of chopped unripe fruits combined with horseradish, celery, vinegar and spices after seasoning. Carambolas are also cooked in puddings, tarts, stews and curries. In addition, the ripe or unripe fruit pulp is used to make jams, jellies and pickles.

In conventional cuisines worldwide, carambolas are used in various ways. In Australia, the unripe sweet variety of carambola is cooked as a vegetable. In China, carambolas are cooked with fish whereas in Thailand, sliced as well as boiled green fruits are cooked with shrimp. In Malaysia, star fruits are often stewed with sugar and cloves, alone or combined with apples. In India, the entire fruit is chopped into pieces to form chutneys. In Philippines, unripe carambolas are eaten dipped in rock salt. The ripe fruits are sometimes dried in Jamaica for future use.

Figure 4: Thin slices of fruit, cut in cross-section, resemble the form of a star.

Carambola fruit juice is served as a cooling beverage. In Taiwan, the fruit extracts are used to prepare syrup. In Hawaii, the juice of sweet variety is mixed with gelatin, sugar, lemon juice and boiling water to make sherbet. In India also, the fruit extract is mixed with small amount of citric acid and a pinch of potassium metabisulphite to make a soft drink.

Therapeutic uses

The rural and aboriginal people of the tropics have been using different parts of the carambola tree in various disorders for years. For instance, the carambola is believed to have a beneficial effect in the treatment of eczema in Brazil. In Cambodia, a paste prepared from crushing leaves and flowers is used against dermatitis as well as in relieving pains. In China, crushed leaves and shoots are poulticed on the warts of chicken pox, itching and also to cure ringworm infection.

In *Ayurveda*, carambola is prescribed as a diuretic to treat kidney and bladder complaints. Dried fruits or juice act as febrifuge to reduce fever. The fruit is also said to subdue biliousness, diarrhoea, and flatulence. Dried slices crushed in a little water can be taken to counteract piles problem.

Star fruit has certain other traditional applications. The fruit extract increases the saliva secretion, and hence acts as an appetizer if administered before taking a meal. The fruit is also used to overcome hangover, caused by excessive indulgence in alcohol. The flower is applied as a vermifuge. Also fresh seeds contain a substance which promotes lactation in pregnant women as well as stimulates blood flow in the pelvic areas and uterus.

But there is a word of caution. The oxalic acid present in the carambola fruit can be a harmful for individuals suffering from renal calculi and kidney failure. Besides, the juice of carambola fruit may show some inhibitory effects on some medicines and cellular enzymes.

Dipanjan Ghosh is a teacher by profession, well-known popular science writer and one of the Editors of the journal '*Indian Science Cruiser*' published from Kolkata. E-mail: dpanjanghosh@gmail.com

Sreeparna Ghosh is a conservation activist and is associated with Ecocampers, a Bardhaman-based NGO engaged in nature conservation. She is also a popular science writer. E-mail: zeenaghosh@gmail.com

Homeopathic medicine: Reality or a placebo?

Papiya Nandy
Email: pnandy00@gmail.com

Homeopathy is the third-most commonly used system of healing in the world and has been practised for more than two centuries, mainly because of its easy availability, low cost, and negligible side effects. But its acceptability is still on the borderline of reality and placebo. Mainstream scientists treat it as an outcast, blaming the curing power as nothing but placebo effect, even though there is ample evidence of millions of people having been cured by homeopathy.

Some very interesting observations about this medicine system are the following:

(a) Contrary to allopathic medicines, homeopathic medicines are said to be more potent at higher dilutions (potency 1C means dilution 10^2)

(b) A large number of homeopathy practitioners have their basic degree in allopathy, and

(c) Even the most sceptic ones use homeopathy on a regular basis.

Then why this step-motherly attitude to homeopathy? Perhaps the reason behind this is the lack of adequate research to explain how homeopathy really works. Also it is very subjective – the same medicine for one particular ailment may not work for two different persons; the personal history matters a lot.

One question usually raised about homeopathy relates to the extremely high dilutions used. As Avogadro number is 6.02×10^{23}, at dilutions used in homeopathy, the initial solute is virtually no longer present beyond 12C (that is, dilution by a factor of 10^{24}) of a homeopathic medicine. However, the fact that these medicines are said to be active even at extreme dilutions (dilution factor even beyond 10^{400}) has drawn the scepticism and curiosity of the scientists leading to the popular belief that perhaps these medicines have only a placebo effect. To decipher this apparently strange effect, several hypothesis, mostly of speculative nature have been forwarded, ranging from liquid memory and clathrate formation to quantum mechanics, relativity, etc

One typical operation used in making of homeopathic medicines is repeated shaking or 'succussion' of the solution of the drug in alcohol. It has been found that such repeatedly shaken extremely dilute solutions or 'very low molarity repetitive succussed diluted liquid' (VLMRSDL) of which a homeopathic medicine is an example, has its properties modified significantly from the original liquid. The change in properties is reflected in the measured values of NMR, UV spectroscopy, dielectric behaviour, electrical conductivity, and heat of mixing. The change in properties of the diluted solution may be taken as indicative of some effect of the solute even at high dilutions.

One of the necessary conditions for diluting a homeopathic medicine is "succussion", which is shaking the mixture a measured number of times after each dilution. At the time of Hahnemann, the founder of homeopathy, the process was manual, but is now done mechanically. Could it be that the size of the drug particles changes with dilution and succussion?. Is it possible that succussion is converting the bulk drug into a nano form?

One way of finding that out is to study the effect of the diluted medicines on cell membrane, which is undoubtedly the site of action of all medicines. The function of the cell membrane is to protect the integrity of the interior of the cell by allowing certain substances such as drugs, etc., into the cell, while keeping other substances out. The knowledge of interaction between drug and cell membrane is crucial for explaining the drug activity, selectivity and toxicity.

We decided to study how these drugs penetrate the membrane and whether there is any correlation of this penetration with the potency of the homoeopathic drug. For this study we chose two homoeopathic drugs.

The complexity of the biological membrane necessitates the use of artificial membrane. In the study liposomal membrane made of a synthetic lipid was used. To study the change in membrane fluidity (the inverse of viscosity of the lipid bilayer of a synthetic lipid membrane) caused

Homeopathy is the third-most commonly used system of healing in the world.

by drug-membrane interactions, a standard fluorescent probe molecule was incorporated within the liposomal membrane. This particular probe acts as a reporter molecule of the fluidity of its microenvironment.

In consultation with homeopathy doctors, the first drug tried was *Aconitum napelles*, a hydrophobic material of plant origin, prescribed by homeopathic doctors mainly for high fever, dry skin and other different ailments. It was observed that with increase in potency (i.e., further dilution followed by succussion), the membrane fluidity decreased, suggesting more penetration of the drug into the membrane. This can be taken as an indirect evidence of decrease in size of the initial aggregated structure of the drug, leading to nanoparticle formation of lower dimension and thereby facilitating enhanced membrane penetration.

The second drug tried was *Cuprum metallicum*, a hydrophilic material, derived from pure metallic copper, which is extensively used to treat spasms, cramps, etc. Here again the effect of the drug on membrane fluidity was found to be a function of potency. However, here the drug interacts with the membrane differently. Being ionic in nature, the drug alters the fluidity profile of the liposomal membrane interior. At lower dilution of the drug (6C or 10^{12}), the change in fluidity was found to be more while at higher dilution the change in fluidity of the membrane moiety was less.

Thus it was found that in both the cases the fluidity of the microenvironment of the fluorescent probe changes with the potency (degree of dilution) of the drug. The result can be interpreted at the molecular level, based on drug-lipid interaction.

For *Cuprum metallicum*, the size of the drug particles was measured using Dynamic Light Scattering method and was visualised using High Resolution Transmission Electron Microscopy. The average size of the drug particle for potencies 6C, 30C and 200C were found to be 16 nanometres (nm), 1.6 nm and 0.62 nm respectively, showing that the size distribution of the drug indeed decreases with increase in potency.

Thus from the above observations it can be concluded that homeopathic medicines are indeed more potent at higher dilutions because of the drug particles attaining the size in the nano range, which then facilitates their permeation through the cell membrane thereby enhancing the desired effect

Papiya Nandy is Director, Jagadis Bose National Science Talent Search, Kolkata/ Formerly Professor of Physics and Emeritus Fellow, Jadavpur University, Kolkata.

Continued from page 33 **(For the love of math)**

she had a more encouraging person to teach her and her performance improved sky-high. She was all set to be a star. Erica Klarreich writes in *Quanta Magazine* that Maryam Mirzakhani and her friend Roya Beheshti literally demanded of the principal of their school that she arrange problem-solving classes for them, so that they could take part in the International Mathematics Olympiad. The principal stood by them and ensured that they got the coaching they asked for. She was not deterred by the fact that never before had Iran fielded a girl student in the Olympiad.

In 1994, Mirzhakhani won a gold medal in the Olympiad. After getting her BSc from Sharif University of Technology in Teheran, she went on to do her PhD at Harvard University, where she worked with Fields Medallist Curtis McMullan. Now 37 years old, she is a professor at Stanford University in USA. She is described as a mathematician who loves to "chew" on a problem slowly and seeks out deep problems that take a long time to solve.

Her important work is in the field of geometry and dynamical systems. She was noticed first for her work in hyperbolic geometry and her most recent work has been in dynamical systems. Her work in geometry has to do with counting the number of geodesics on a hyperbolic surface. A geodesic is a curve whose length cannot be shortened by deforming it. A theorem called "the prime number theorem for geodesics" estimates that the number of closed geodesics having a length less than some bounding value L would grow exponentially. Mirzakhani considered what would happen to the prime number theorem for geodesics if you only take into account simple geodesics. That is, geodesics that do not intersect themselves.

Now, these hyperbolic spaces may have "handles" on them which define the "genus" of the surface – for example, a coffee-cup-shaped surface has one "handle" and its genus is one. You may think of surfaces with any value of genus, g = 1,2,3… Associated with every one of these spaces is a moduli space which has (6g – 6) dimensions. Mirzakhani's work establishes a link between counting problems of simple closed geodesics on a single surface to volume calculations on the moduli space. This further leads to an understanding of a conjecture made by physicist Edward Witten. Mirzakhani along with Alex Eskin and Amir Mohammadi has also done some breakthrough research in understanding dynamical systems on moduli spaces.

Dr. Shubashree Desikan is an Assistant Editor with The Hindu *newspaper.* *She would like to thank Prof. Srikrishna Dani of IIT Bombay and Prof. M. Vanninathan of TIFR Centre for Applicable Mathematics, Bangalore for their encouragement and useful inputs. The articles in* Quanta Magazine *were also useful and informative in compiling this article.*)

Generic medicines – Myths and reality

Dr. Guru Prasad Mohanta
Email: gpmohanta@hotmail.com

Celebrity actor Amir Khan's advocacy of generic medicines in a popular television programme, Satyamev Jayate, received wide attentions of all sections of society. But, there is still a lot of reservations among the stake holders, especially patients and the doctors on the subject

Medicines are usually available under two names: a generic name and a brand name. In a strict sense, these terminologies are slightly different in USA and in India. In USA there is only one brand for a particular drug molecule. This is the innovator's brand and no one else is allowed to market this drug molecule within the patent protection period. On expiry of patent, marketing of the molecule under its generic name is allowed. There may be several generic versions of the branded one. Generic name is the common name of the drug molecule. The generic versions must have equivalent properties and action similar to the innovator's brand and are interchangeable.

Medicines are usually available under two names: a generic name and a brand name

'Medicines are usually available under two names: a generic name and a brand name. There have been different public perceptions about brands and generics.'

India did not have product patents, but only process patents prior to 2005. This favourable patent provision allowed the Indian pharmaceutical companies to produce a drug molecule by a different process and market it as a brand of their choice. Thus in India we have several brands of the same drug molecule available in the market. They are not brands in true sense, as they are not marketed by the innovator. Hence they are called 'branded generics'. These branded generics can be viewed as brands. Thus we have several brands and several generic products of the same drug molecule unlike one brand and several generic versions in USA.

A common example is that of paracetamol, a medicine for reducing fever. Paracetamol is a generic name and is available in India in several brands or proprietary names like Crocin, Calpol, Metacin, Pyregesic, Dolo, etc. The price of this common medicine varies widely. There are more variations in the price for other life-saving drugs. It is not possible for anyone including doctors, who prescribe; or chemists, who sell; to identify any deficiency in the quality of medicines It is solely the responsibility of the manufacturers to ensure the quality of their products.

'The biggest myth is that generics are inferior in quality and hence they are cheaper. But this is not necessarily true.'

There have been different public perceptions about brands and generics. Many doctors and chemists feel that the two do not have the same quality. The biggest myth is that generics are inferior in quality and hence they are cheaper. But this is not necessarily true. Often either the doctor or the chemist decides what medicine a customer should buy and often both are influenced to promote a particular brand over others. Brand building and marketing costs add to the price of a brand. There is no inferior quality in medicines. The medicines available in the market are tested before being released to ensure quality. The quality is maintained as per medicine standard specified (in Pharmacopoeia). On the other hand, there are frequent reports of quality issues in many brands. At one time it was reported that leading paracetamol brands did not qualify in 70% of quality parameters. It is interesting to note none of these companies contested these findings/results of a consumer organisation. One can see the list of brands which failed in quality tests on the website of the Central Drug Standard Control Organisation: http://cdsco.nic.in.

Other misperceptions include: switching over to generics is risking life; generics take longer time to act; generics are not safe; generics are not as potent as brands; generics are not regulated like brands and hence risky; brands are better because they are prescribed by doctors; and many others. All these perceptions are far from the truth. There are no different quality standards for brands and generics. They are therapeutically exchangeable. They are also equally regulated. The only difference is marketing strategies and price. Often the same company produces both brand and generic products

Paracetamol is a generic name and is available in India in several brands or proprietary names like Crocin, Calpol, Metacin, Pyregesic, etc.

but sell at substantially different prices.

The Government of India and the Medical Council of India have been urging doctors to prescribe medicines only by their generic names. The generic name is same throughout the world. The generic name is also known as International Non-proprietary Name (INN) and is designated by the World Health Organisation. The central and state governments are promoting generics in public hospitals through procurement under generic name and prescribing. There are a few centrally sponsored Jan Aushadhi Stores in the country that sell generic medicines only and many are reported to be not functioning properly. The Government of Kerala, Rajasthan, and Andhra Pradesh have initiated several measures to make the generic medicines available at private outlets for the benefit of the public. Medicines usually constitute 75% of the healthcare costs.

> 'The generic name is also known as International Non-proprietary Name (INN) and is designated by the World Health Organisation.'

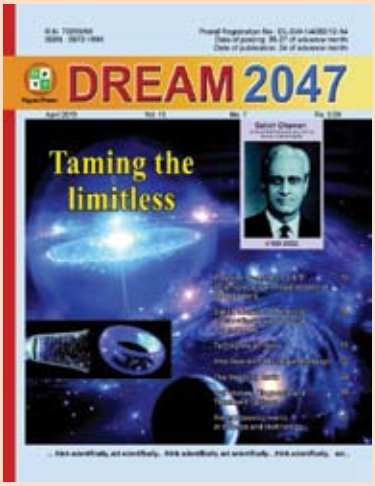
Often brand names create problem for the consumer. A particular brand may not be available at all places. Sometimes, a brand name may lead to confusion too. For example, Lona is a brand name for clonazepam, anti-epileptic medicine. Lona is also the name of a low-sodium salt recommended for hypertensive patients. This brings confusion both in the minds of patients as well as chemists. The Government should promote generic medicines not only through establishing generic medicine stores but also by ensuring the quality of these medicines through periodic quality checking and publishing such results. This would build public trust/confidence on generics and help them minimise the expenditure on medicine. When medicines are prescribed by generic names but sold at different prices, then financial interests may be the determining factor for the chemist to sell a particular company's product. Here consumers must exercise their rights to buy the medicine of their choice. But they also need to keep themselves updated on the medicines and their prices.

Dr. Guru Prasad Mohanta is a Professor of Pharmacy at Annamalai University has a passion to educate the common man on safe and effective use of medicines. He is a columnist in newspapers and magazines on issues related to health and medicine.

Dream 2047

Articles invited

Vigyan Prasar invites original popular science articles for publication in its monthly science magazine *Dream 2047*. At present the magazine has 50,000 subscribers. The article may be limited to 3,000 words and can be written in English or Hindi. Regular coloumns on i) Health ii) Recent developments in science and technology are also welcome. Honorarium, as per Vigyan Prasar norm, is paid to the author(s) if the article is accepted for publication. For details please log-on to www.vigyanprasar.gov.in or e-mail to dream@vigyanprasar.gov.in



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For students of the classes 8-10

HINDI ESSAY COMPETITION

Topic: Malaria–A Challenge and its remedial measures

In this national competition, 25 best essay entries will be awarded with tablet computers, trophy and certificates. In addition, one year subscription for two popular science magazines 'Dream 2047' and 'Vigyan Pragati' will also be given.

Last Date: October 31, 2014

This Hindi essay competition is being organised by Vigyan Prasar, DST, Govt. of India and CSIR-Open Source Drug Discovery (OSDD) on national level. The proforma and terms & conditions for this competition can be downloaded from the websites of OSDD or Vigyan Prasar:

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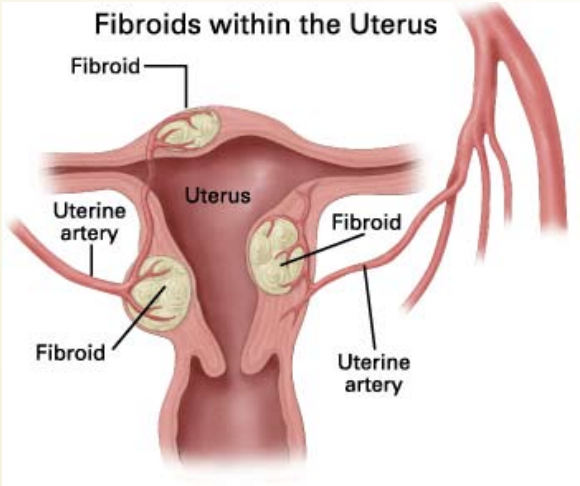
Vigyan Prasar
A-50, Institutional Area,
Sector-62, Noida - 201 309

Treatment options in uterine fibroids

Dr. Yatish Agarwal
e-mail: dryatish@yahoo.com

Uterine fibroids are benign growths which develop in or just outside a woman's womb. They crop up from the uterine muscle cells, depend on oestrogen and progesterone hormones, and therefore, occur during a woman's childbearing years.

Most uterine fibroids are harmless, and do not cause any difficulties. They tend to shrink and gradually fade away once you breeze past menopause. However, some fibroids can be painful, some can produce pressure on the neighbouring organs, and others can bleed heavily and lead to anaemia, while a few can interfere with fertility and pregnancy.

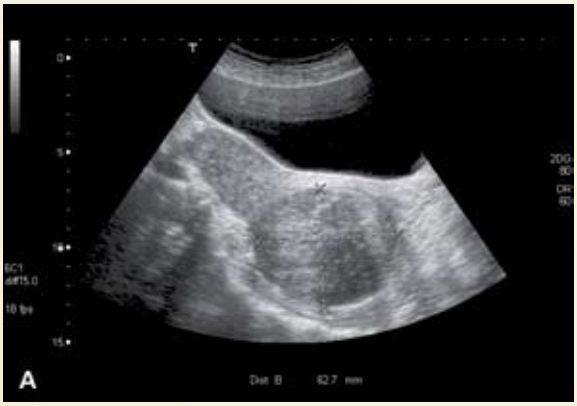


If you have a fibroid which is giving you a problem, talk with your doctor. Many treatment options exist. The blood supply to fibroids can be cut off, fibroids can be surgically removed, the entire uterus can be removed, or medicine can temporarily shrink fibroids. The choice will depend on whether you have severe symptoms and whether you want to preserve your fertility.

Lines of Treatment

The line of treatment in uterine fibroids is guided by the severity of symptoms, the age of the affected person, and her personal choice.

Women who have mild or no symptoms can do without any treatment, whereas a young woman wanting to raise a family and facing infertility due to a fibroid may require fibroid surgery. Some women also do well with medications.



Watchful waiting for minimal symptoms

Many women with uterine fibroids experience no signs or symptoms, or only mildly annoying signs and symptoms that they can live with. If that's the case for you, watchful waiting could be the best option. Fibroids aren't cancerous. They rarely interfere with pregnancy, unless they are multiple or situated close to the uterine outlet. They usually grow slowly — or not at all — and tend to shrink after menopause, when levels of female reproductive hormones drop.

If you are nearing menopause, watchful waiting may be the best option for you, depending on how tolerable your symptoms are. Past menopause, once the hormone levels drop, most fibroids shrink and symptoms subside on their own.

Managing fibroids causing infertility or pregnancy problems

If you have fibroids, there is no way of knowing for certain whether they are affecting your fertility. Fibroids are a cause of infertility in a small number of women. Many women with fibroids however have no trouble getting pregnant.

If a fibroid distorts the wall of the uterus, it can prevent a fertilised egg from implanting in the uterus. This may make an *in vitro* fertilisation less likely to be successful, if the fertilised egg doesn't implant after it is transferred to the uterus.

Surgical fibroid removal, called myomectomy, is the only fibroid treatment that may improve your chances of having a baby. Since fibroids can grow again, it is best to try to become pregnant as soon as possible after a myomectomy.

Management of severe fibroid symptoms

If you have fibroid-related pain, heavy bleeding, or a large fibroid that is pressing on other organs, you can consider trying treatments that shrink the fibroid. Several medical treatments can be tried. Two surgical options also exist: you can opt for a surgical removal of the fibroid (myomectomy), or go for removal of the entire uterus (hysterectomy).

However, fibroids can grow back with all treatments, unless hysterectomy has been done. Myomectomy is therefore recommended only for women who have childbearing plans.

Treatment Options

Shrinking a fibroid with hormone therapy

To shrink a fibroid for a short time, hormone therapy with a gonadotropin-releasing hormone analogue (GnRH-a) puts the body in a state like menopause. This shrinks both the uterus and the fibroids. Fibroids grow back after GnRH-a therapy has ended.

GnRH-a therapy can help to shrink a fibroid before it is surgically removed. This lowers your risk of heavy blood loss and scar tissue from the surgery. It can also be used to provide short-term

relief as a "bridge therapy" if you are nearing menopause.

Medications : Medications for uterine fibroids target hormones that regulate your menstrual cycle, treating symptoms such as heavy menstrual bleeding and pelvic pressure. They don't eliminate fibroids, but may shrink them. Medications include:

Gonadotropin-releasing hormone (GnRH) agonists : Medications called GnRH agonists treat fibroids by blocking the production of estrogen and progesterone, putting you into a temporary postmenopausal state. As a result, menstruation stops, fibroids shrink and anaemia often improves.

Many women have significant hot flushes while using GnRH agonists. GnRH agonists typically are used for no more than three to six months because symptoms return when the medication is stopped and long-term use can cause loss of bone.

Progestin shots : A progestin shot (Depo-Provera) every 3 months may lighten your bleeding. It also prevents pregnancy. Based on different studies, progestin may shrink fibroids or may make them grow. This might be different for each woman.

Progestin-releasing intrauterine device (IUD) : A progestin-releasing IUD can relieve heavy bleeding caused by fibroids. A progestin-releasing IUD provides symptom relief only and doesn't shrink fibroids or make them disappear.

Birth control hormone pills : They can lighten menstrual bleeding and pain while preventing pregnancy.

Iron and vitamin supplements : Iron and vitamin supplements are an important part of correcting anaemia caused by fibroid blood loss.

Minimally invasive procedures

Certain procedures can destroy uterine fibroids without actually removing them through surgery. They include:

Uterine artery embolisation : Embolisation has become a first-line treatment for symptomatic uterine fibroids. Selective catheterisation and embolisation of both uterine arteries, which are the predominant source of blood flow to fibroids in most cases, is the cornerstone of treatment.

Small particles (embolic agents) are injected into the arteries supplying the uterus, cutting off blood flow to fibroids, causing them to shrink and die. This technique can be effective in shrinking fibroids and relieving the symptoms they cause. Complications may occur if the blood supply to your ovaries or other organs is compromised.

Myolysis : In this laparoscopic procedure, an electric current or laser destroys the fibroids and shrinks the blood vessels that feed them. A similar procedure called cryomyolysis freezes the fibroids. Myolysis is not used often. Another version of this procedure, radiofrequency ablation, is being studied.

Laparoscopic myomectomy : In a myomectomy, your surgeon removes the fibroids, leaving the uterus in place. If the fibroids are small and few in number, you and your doctor may opt for a laparoscopic or robotic procedure, which uses slender instruments inserted through small incisions in your abdomen to remove the fibroids from your uterus. Your doctor views your abdominal area on a monitor using a small camera attached to one of the instruments.

Robotic myomectomy gives your surgeon a magnified, 3-D view of your uterus, offering more precision, flexibility and dexterity than is possible using some other techniques.

Hysteroscopic myomectomy : This procedure may be an option if the fibroids are contained inside the uterus (submucosal). Your surgeon accesses and removes fibroids using instruments inserted through your vagina and cervix into your uterus.

Endometrial ablation and resection : This treatment only works for submucosal fibroids, which project into the uterine cavity. Performed with a specialised instrument which is inserted into the uterus, it uses heat, microwave energy, hot water or electric current to destroy the lining of your uterus, either ending menstruation or reducing your menstrual flow. Typically, endometrial ablation is effective in stopping abnormal bleeding.

Submucosal fibroids can be removed at the time of hysteroscopy for endometrial ablation, but this treatment does not work for fibroids which lie in the muscles of the uterus or in any other position.

Traditional surgical procedures

Options for traditional surgical procedures include:

Abdominal myomectomy : If you have multiple fibroids, very large fibroids or very deep fibroids, your doctor may use an open abdominal surgical procedure to remove the fibroids. Many women who are told that hysterectomy is their only option can have an abdominal myomectomy instead.

Hysterectomy : This surgery — the removal of the uterus — remains the only proven permanent solution for uterine fibroids. But hysterectomy is major surgery. It ends your ability to bear children. And if you also elect to have your ovaries removed, it brings on menopause and the question of whether you'll take hormone replacement therapy. Most women with uterine fibroids can choose to keep their ovaries. ■

Recent developments in science and technology

Biman Basu
E-mail: bimanbasu@gmail.com

Why is Mercury so metal-rich?

Although classified into two broad groups – rocky (or terrestrial) and gaseous – each of the planets of the Solar System is unique, having some characteristic not found in the others. Mercury is the smallest among eight planets of the Solar System and is smaller than our Moon. It is also the closest to the Sun. The origin of planet Mercury has been a difficult question in planetary science because its composition is very different from that of the other rocky planets and the Moon. Mercury has more than twice the fraction of metallic iron compared to any other rocky planet. In fact, its iron core makes up almost 70 per cent of its total mass; in comparison, Earth's iron core is just 32 per cent of its mass.

Till recently it was not known how Mercury got so much iron in its core and why its mantle is so thin. Many hypotheses have been suggested for the formation of Mercury, but none could explain how Mercury lost its mantle while retaining significant levels of volatiles (easily vapourised elements or compounds, such as water, sulphur and lead). Mercury has substantially more volatiles than our Moon, leading scientists to speculate that its formation could not have been the result of a giant impact ripping off the mantle, which has been a common popular explanation.

Now planetary scientists seem to found the answer. They have come up with a new hypothesis that involves 'hit-and-run' collisions between planet-forming bodies. According to them, when the planets were forming in the early Solar System, there were numerous solid bodies of various sizes that ultimately came together and accreted to form the rocky planets. According to them, Mars and Mercury are the last two remaining relics of the original population of such bodies. The researchers came to this conclusion by creating a statistical scenario for how planets could merge and grow from an original population of about 20 bodies that mostly merged together to form the two larger rocky planets Venus and Earth. The researchers say, although Mars and Mercury underwent collisions, they did not merge into the larger rocky planets because they were simply 'lucky'.

To explain the mystery of Mercury's metal-rich composition, Erik Asphaug of Arizona State University in USA and Andreas Reufer of the University of Bern in Germany developed the new hypothesis on the basis of computer simulations where proto-Mercury loses half its mantle in a grazing blow into a larger planet (proto-Venus or proto-Earth). This grazing collision, the researchers say, could have potentially stripped away proto-Mercury's mantle without an intense shock, leaving behind a mostly-iron body. One or two of these hit-and-run collisions can explain Mercury's massive metallic core and very thin rocky mantle (*Nature Geoscience*, 6 July 2014 | doi:10.1038/ngeo2189).

Mercury, one of the closest planets to our Sun, has long puzzled scientists with its unusual metal-rich composition. Now, researchers have discovered the possible origins of Mercury's unique composition. (Photo: NASA/JPL/Caltech)

According to Reufer, who performed the computer modelling for the study, "Giant collisions put the final touches on our planets. Only recently have we started to understand how profound and deep those final touches can be". The findings reveal not only how Mercury formed, but also a bit more about planet formation in general. This could tell scientists a bit more about planets in other galaxies and which ones might be more likely to host life.

Elephants have the strongest smelling power

Genetic studies often produce surprising results, as a recent study of olfactory genes in mammals has shown. An elephant's trunk is the most conspicuous part of its body, but there are no bones in it. A fusion of the nose and upper lip, the trunk is an elephant's most versatile tool – used for breathing, smelling, touching, grasping, lifting things, and producing sound. Elephants also use their sensitive sense of smell to forage for food and identify family members. Recent research by a team led by Yoshiihito Niimura of the University of Tokyo in Japan shows that elephants have the strongest sense of smell among all mammals – much sharper than even the sharpest police dog. The researchers came to this conclusion after studying the genes coding for olfaction (the power of smell) in 13 mammals. In the study, African elephants were found to be the best sniffers, possessing the largest number of genes associated with smell – as many as 1,948, which is five times more than in humans and more than twice that of dogs. The researchers did not examine the function of each gene, but the vast number of olfactory receptor genes in the African elephant suggests that its trunk has profound smelling abilities (*Genome Research*, 22 July 2014, doi:10.1101/gr.169532.113).

In the animal world, the sense of smell is critical to all mammals; they use it for

The African elephant's trunk is endowed with the strongest sense of smell among mammals.

sniffing out food, avoiding predators, finding mates and locating their offspring. Compared to the elephant's 1,948, horses have around 1,000 smell genes, rabbits around 750, and rats about 1,200. In comparison, humans have fewer than 400 and other primates like chimpanzees, even less. According to the researchers, given the size of their trunks and how important it is to their survival, it is probably not surprising that an elephant's nose is not only the longest in the animal kingdom, but also the most sensitive. So acute is the African elephant's sense of smell that they can distinguish between two tribes living in Kenya: the Maasai, whose young men enjoy spearing elephants, and the Kamba, who are farmers and usually leave elephants alone. In comparison, humans and other primates have a very poor sense of smell.

In the study, the researchers looked at the number of olfactory receptor genes in each mammal. These genes code proteins that reside in the nasal cavity and bind to odour molecules. Nerve cells then relay the information to the brain, which classifies the smell. The researchers started out studying a collection of olfaction genes known as the 'olfactory receptor repertoire' (OR repertoire) in 13 mammal species, from primates to elephants. Among this group they identified more than 10,000 different genes that code for scent receptors. Most animals had a nearly unique repertoire, with only three genes in common amongst all the species. But the researchers were surprised to find that the African elephant came out way ahead of every other studied species, with almost 2,000 genes that code for the sense of smell. Niimura says, "The functions of these genes are not well known, but they are likely related to the importance of smell to the poorly sighted African elephant in interpreting and navigating its environment".

According to the researchers, their study has shown that the common ancestor of all 13 mammals had 781 such genes. This indicates that the number of olfactory receptor genes has increased over time in elephants and rodents, while it has decreased in primates and humans. The primates in the study were found to have lost more than half of their olfactory receptor genes. Most notably, orangutans lost about 70 percent since the common ancestor lived about 100 million years ago.

Almost all dinosaurs probably had feathers

The *Archaeopteryx*, the primitive toothed bird of the Jurassic Period that had a long feathered tail and hollow bones, is usually considered the most primitive of all birds. Over the past two decades, discoveries in China have produced at least five species of feathered dinosaurs. But they all belonged to the theropod group of "raptor" dinosaurs, ancestors of modern birds. From these discoveries, scientists were able to conclude that at least the theropod group of dinosaurs was sporting bird-like feathers about 200 million years ago – 50 million years before the first bird-like animal, the *Archeopteryx*, came into existence.

But recent discovery of fossils of a 1.5-metre-long two-legged running dinosaur (ornithischian) dating from roughly 160 million years ago in Siberia suggests that feather-like structures on dinosaurs may have been even more widespread throughout the dinosaur world than was previously thought. The fossils were discovered by a team of researchers from Europe led by Pascal Godefroit of the Royal Belgian Institute of Natural Sciences. The dinosaur, named *Kulindadromeus zabaikalicus*, walked on its two back legs and was probably a plant eater. It also appears to have had three different

This illustration of Kulindadromeus zabaikalicus, a newfound feathered dinosaur, shows it in its natural environment. (Illustration by Andrey Atuchi)

types of feather-like structures covering large portions of its body. The fossils, which included six skulls and many more bones, greatly broaden the number of families of dinosaurs sporting feathers, indicating that feathers evolved from the scales that covered earlier reptiles, probably as insulation. In addition to its feathers, the *Kulindadromeus* also had scales, notably arched ones that appeared in rows on its long tail (*Science*, 25 July 2014 | doi: 10.1126/science.1253351).

Dinosaurs can be classified into three great evolutionary lineages. The theropods were primarily two-legged flesh-eating dinosaurs that ultimately gave rise to the birds. All dinosaurs with feathers till now known were theropods, which are evolutionarily closest to the birds on which feathers are normally found. The second group comprised the sauropodomorphs – mostly gigantic four-legged plant-eating dinosaurs with long necks such as the Diplodocus. Finally, there were the plant-eating ornithischians, which include everything else and came in a bewildering array of different body shapes, including armoured forms, those with horns and spikes and all manner of odd headgear, and were both two-legged and four-legged.

According to the researchers, the discovery of *Kulindadromeus* fossils adds a whole new dimension to understanding evolution of feathers, mainly because the three feather types found as imprints with the fossils are different from ones found on feathered dinosaurs or modern birds. Nobody knows for sure what these different feathers did, but one thing clear and that is, these dinosaurs could not fly. The recent discovery shows that the common ancestor of dinosaurs probably had feathers, and that all dinosaurs had some type of feather, just like all mammals have some type of hair.

How antioxidants can accelerate cancer

Antioxidants are substances that inhibit oxidation or inhibit reactions promoted by oxygen or peroxides. For decades, health-conscious people around the globe have been taking antioxidant supplements and eating foods rich in antioxidants, believing it to be one of the paths to good health and a long life and can prevent cancer. But clinical trials of antioxidant supplements have repeatedly shown that antioxidants cannot reduce cancer risk. Virtually all such trials have failed to show any protective effect against cancer. In fact, in several trials antioxidant supplementation has been linked with increased rates of certain cancers. In one trial, smokers taking extra beta carotene had higher, not lower, rates of lung cancer.

Antioxidant-rich foods or antioxidant supplements do not prevent cancer but may accelerate the growth of certain cancers.

Two researchers, Navdeep S. Chandel of the Feinberg School of Medicine at Northwestern University, Chicago and David Tuveson of Cold Spring Harbor Laboratory, New York have come out with an answer to why antioxidant supplements might not be working to reduce cancer development and why they may actually do more harm than good (*New England Journal of Medicine*, 10 July 2014 | doi: 10.1056/NEJMcibr1405701). Their inference is based on recent advances in the understanding of the system in our cells that establishes a natural balance between oxidising and anti-oxidising compounds. These compounds are involved in so-called redox (reduction and oxidation) reactions essential to cellular chemistry.

In our body, oxidants (substances that oxidise another substance) like hydrogen peroxide are essential in small quantities and are manufactured within cells. It is known that in large amounts oxidants are toxic, and cells naturally generate their own anti-oxidants to neutralise them. So it was presumed that increasing the intake of antioxidants could counter the effects of hydrogen peroxide and other similarly toxic "reactive oxygen species," or ROS. Since it is known that cancer cells generate higher levels of ROS to help feed their abnormal growth, antioxidants were supposed to be effective in countering cancerous growth.

In their NEJM paper Chandel and Tuveson propose that taking antioxidant pills or eating large quantities of foods rich in antioxidants may be failing to show a beneficial effect against cancer because they do not act at the critical site in cells where tumour-promoting ROS are produced, namely the mitochondria. According to them, supplements and dietary antioxidants may be accumulating at scattered distant sites in the cell, "leaving tumour-promoting ROS relatively unperturbed".

According to the researchers, therapies that raise the levels of oxidants in cells may be beneficial, whereas those that act as antioxidants may further stimulate the cancer cells, causing them to grow faster. Interestingly, radiation therapy kills cancer cells by dramatically raising levels of oxidants. The same is true of chemotherapeutic drugs – they kill cancer cells via oxidation.

The authors suggest that "genetic or pharmacologic inhibition of antioxidant proteins" may be a useful therapeutic approach in humans. The concept has already been tested successfully in rodent models of lung and pancreatic cancers. The key challenge, they say, is to identify antioxidant proteins and pathways in cells that are used only by cancer cells and not by healthy cells. The researchers propose new research to profile antioxidant pathways in tumours and adjacent normal cells in order to identify possible therapeutic targets. ■