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Fractals: Nature's Versatile Code



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

Valuable resource platforms on the dynamics of science communication



Dr. R. Gopichandran

The objective of this editorial is to present a set of extremely important web based information/ knowledge resources on the dynamics of science communication. The websites¹⁻⁶ indicated in the following serve this purpose. In this context I wish to also propose it will be quite useful to:

i. Undertake a reality check on science communication methods used in our country. It is likely a large volume of outputs are produced for the benefit of end users/receivers of such of information. Science communication theories can be tested for their robustness and newer paradigms could emerge. These have to be assessed for the impacts they exert and sustainability of the form and function of communication strategies. It is with the bottom line that the unique strengths communicators can be strengthened to deliver better. This will benefit institutions and individuals in carrying on with their tasks; yet with greater zeal and focus. Local level linkages with national missions can also be reinforced. Most importantly, communication strategies have to be aligned with enabling circumstances that transform intent into action at the individual and collective levels.

Jucan & Jucan¹ present interesting insights on these aspects. Timm *et. al*⁶ discuss the unique location specific strategies with the Arctic region as a case example.

ii. Showcase India's competence in science communication (as an outcome of the reality check) for the benefit of countries with comparable circumstances of science communication. This is also an important aspect of bilateral and multilateral communication reporting. South-South linkages that will exploit India's excellence can be valuable routes for this purpose. A logical milestone over time can be India's partnerships for locally adapted communication across South-East Asia and further on.

iii. Not oversimplify science communication any more, especially when our country is increasingly exposed to the vagaries of climate change, natural and man-made disasters and related socio-political challenges/agendas. We need to go beyond a superficial communication focus on the method of science to engage with people on local level action that strengthen mitigation and adaptation outcomes. This is because of the cross-cutting influence of the thrust areas I have stated on sustainable development.

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Fractals: Nature's Versatile Code



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Have you ever wondered about Nature's typical pattern formations that we see around us? A piece of rock often follows the overall shape of a mountain or the twigs of

So, Euclidean shapes cannot accurately define all natural patterns. But there is a clue hidden within the nature's pattern formation strategy. If one can identify the



Fig 1. Natural fractals: (a) cross sectional view of cabbage, (b) fern, (c) flower

a tree resemble the overall structure of the tree. In most cases each small part of an object appears to replicate structure of the whole, possessing symmetry across scale. Nature abounds with shapes which repeat themselves at many different sizes. Even they possess a remarkable invariance under the changes of magnification. For instance, if a small portion of the given image (Fig. 1) is magnified, it resembles the whole image. If from that magnified portion another small portion is again magnified the result is the same. In this way, if selected portions of the previous ones are repeatedly enlarged then the final image is very similar to the structure of the original one. This property of objects, where magnified subsets look like the whole and to each other, is known as 'self-similarity'.

Now let's look at another question. The shapes and dimensions of most of whatever you see around, you can analyse with the knowledge of Euclidean geometry. Their shapes may be spherical, cubical, cylindrical or any other combinations of them. But the shape all objects cannot be described by a particular geometrical figure. For example, shapes of all clouds are not spherical, mountains are not all conical in shape, and coastlines are not gentle curves.

small subset within the pattern as well as the procedure of repetitive arrangement then a structure can be developed which is very similar to the original one. But remember, the dimensional analysis of the structure will not give an integral value such as one-, two- or three-dimensional structure concept. And that structure is called a 'fractal'.

So, fractal is a geometric pattern that is repeated at every scale and so cannot be represented by classical Euclidean geometry. Each small part of the pattern replicates structure of the whole, possessing symmetry across scale. Anything that appears random and irregular may be a fractal. Fractal shapes

possess no characteristic sizes; they are self-similar and independent of scaling. They are the result of a construction procedure or algorithm that is often recursive and provide a suitable description of many natural shapes, whereas Euclidean shapes, described by simple geometric relations are not suitable for accurate description of natural shapes.

A simple illustration of how fractal patterns develop is the 'Von-Koch snowflake curve' named after the mathematician Helge von Koch (Fig. 2). In the figure, a simple line segment (used as the initiator) is divided into three equal parts and the middle segment is replaced by two equal segments forming part of an equilateral triangle. So the units of the next figure are $\frac{1}{3}$ times the original line and each is repeated 4 times.

At the next stage each of these 4 segments is replaced by 4 new segments which are $\frac{1}{3}$ times smaller than the previous one. This process is repeated 6 times to yield the final curve. As the number of iterations increases, the curve gets smoother. Here, we get scaling factor $s = \frac{1}{3}$. Number of self-similar parts at each iteration is $n = 4$. So we obtain the fractal dimension $D = 1.26$. ($D = \log n / \log 1/s$) Keeping D constant, if n and s are changed, new curves will be generated.

Now, by varying D , different fractal curves can be generated. An important factor to note is that, as D approaches from 1.26 to 2, the curves progress from being line-like to filling much of the plane (for a three-dimensional object the fractal dimension lies between 2 and 3). A comparative study in D for different types of generated curves is shown in fig. 3a to 3d.

The iterative procedure can be used for a given mathematical expression also. Such an expression generated by French mathematician Gaston Julia can be used to create mathematical fractals. By changing the value of a constant C , different types of

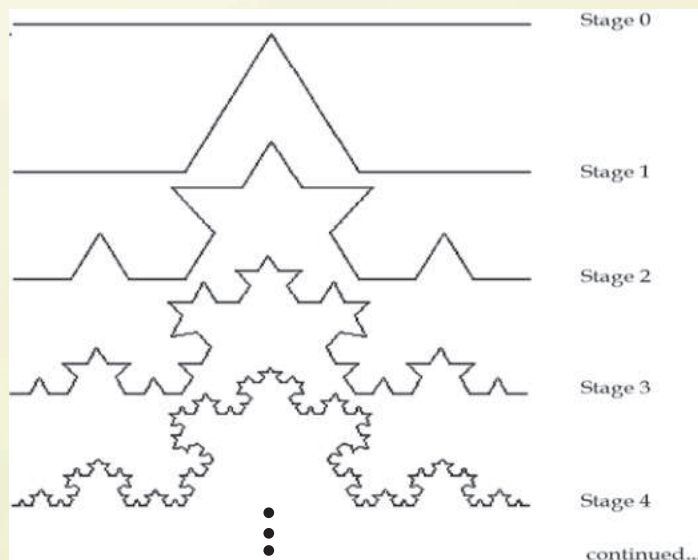


Fig. 2. An iterative or recursive procedure for generating a Von-Koch snowflake curve.

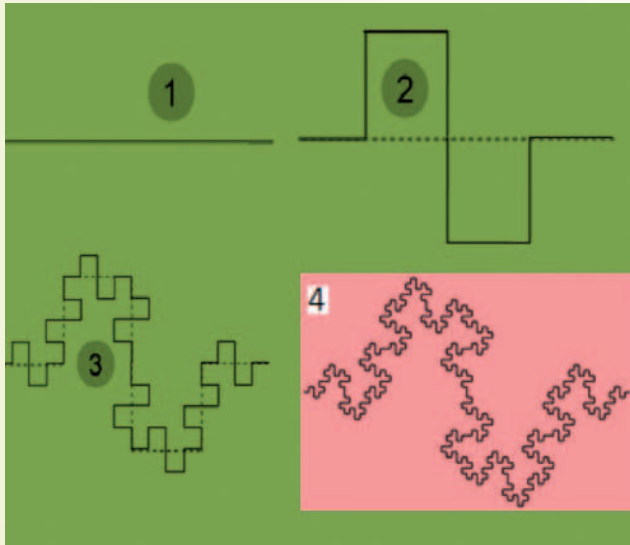


Fig 3a: Minkowski sausage: Curve 1 is initiator and curve 2 is generator. Here $n = 8$, $s = 1/4$. So, $D = 1.5$ and the curve 4 is generated after 8 iterations.

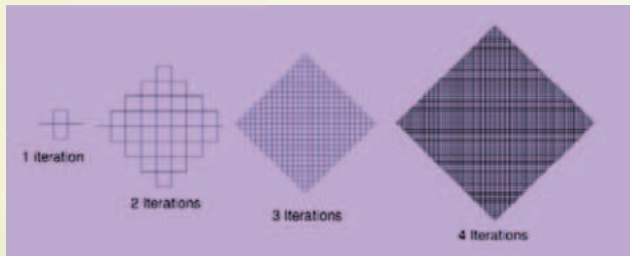


Fig. 3b. Space-filling Peano curve. Here $n = 9$, $s = 1/3$. Hence $D = 2$. Here initiator is a straight line and after first iteration the generator is developed.

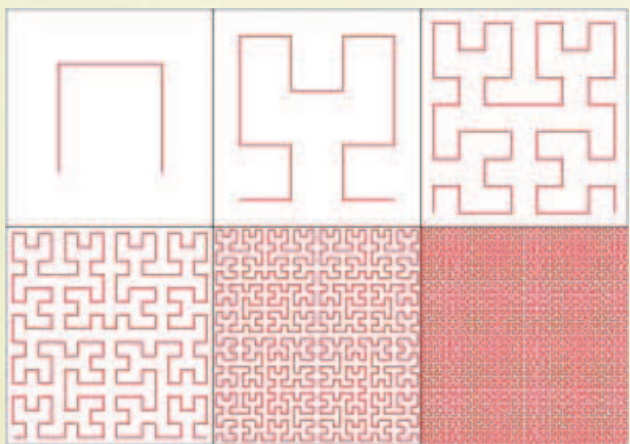


Fig. 3c. Hilbert curve after six iterations. Here $n = 4$, $s = 2$. Hence $D = 2$

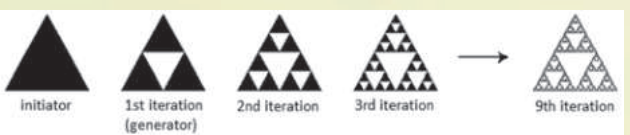


Fig. 3d. Sierpinski gasket generated after 8 iterations. Here triangle is the initiator, $s = 1/2$, $n = 3$, hence $D = 1.585$

Julia sets can be generated as shown in Fig. 4.

If you were wondering about the utility of these curves because they do not resemble any natural shapes, you may not be right. The idea of fractal geometry was developed by many of the past mathematicians between 1870 and 1900 and it was used to develop several mathematical monsters without any practical application. But the turning point came in 1967, when the French mathematician Benoit Mandelbrot nourished it with his new ideas and published his famous paper entitled ‘How long is the coast of Britain?’ He coined the word ‘fractal’ from the Latin ‘*fractus*’ meaning irregular, to describe the shapes of objects with fractional dimensions. He discovered the occurrence of fractals everywhere, from which he gathered his works and published a book, first in French (1975) and then in English, titled *The Fractal Geometry of Nature* in 1982. Mandelbrot demonstrated his ideas of the use of fractal images, and stunning fractal designs and landscapes produced by his colleagues Richard Voss and Alan Norton at IBM’s Thomas J. Watson Research Center in New York generated a keen interest in this area.

All the fractals that you have just seen just are composed of several scaled down and rotated copies of them. The Von-Koch snowflake curve, Sierpinski gasket, and Julia sets fall into this category because whole sections can be obtained by applying a non-linear iterated map to an arbitrary small section. The drawback of this method is that this type of fractal image does not tally

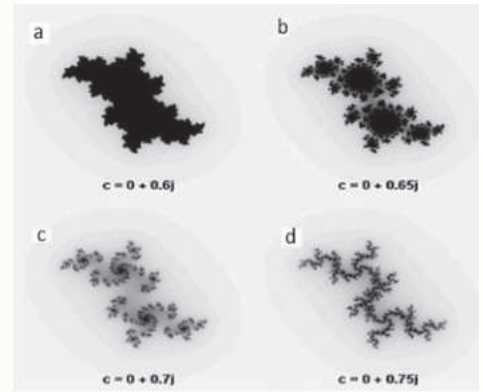


Fig. 4. Different Julia sets (a, b, c, d) are developed by varying C

with the real-world images. They are called ‘deterministic fractals’. If you can add an additional element of randomness in the recursive structure, the generated fractals can simulate natural phenomena. They are not self-similar as in the previous case, but are self-similar in a statistical sense and are called ‘random fractals’. You can also change the scaling factor from portion to portion of a pattern, i.e., say, a certain volume is filled up by a number of balls of different radii. For example, if we want to generate a non-uniform von-Koch snowflake curve (as discussed earlier) the division distributes the mass of the object (i.e., scaling factor) among the line segments non-uniformly and the linear mass density in the Koch curve varies. Also the mass density among the several segments of a unit mass generates more variations depending upon the number of iterations and the entire collection is known as a ‘multifractal’ (Fig. 5).

Now you may be getting interested in developing fractal images. For this you would need a proper algorithm suitable for your selected structure and by applying recursive program in your computer you may simulate your chosen structure. You can judge the fractality (the quality of being fractal or subdivided) of a given pattern also. Fractals are found to be used or likely to be applicable in different aspects of science and technology. Let us have a brief idea about that.

To analyse several growth processes:

The formation of structures developed by complicated interactions could be analysed by the emerging theory of fractal geometry. To follow the random behaviour in physical systems, a new model is proposed which is based on aggregation technique. Aggregates

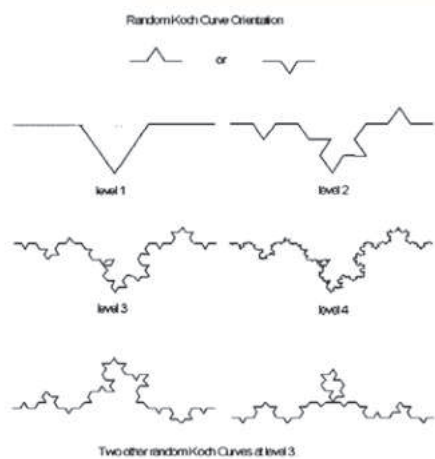


Fig. 5. A non-uniform (multifractal) Von Koch curve

are objects, made of small elementary units (monomers) sticking together to form a larger structure (e.g., matter irreversibly combines to form dust, soot, dendrites, etc.). Diffusion limited aggregation (DLA) is such a fractal growth mechanism which can explain the patterns formed due to the colloidal aggregates, flow of fluid through a solid matrix, or growth mechanisms of crystals resembling complicated fractal structure. Fractals also occur in the motion of air bubbles in oil, in the deposition of ions on electrodes or in electrical discharge phenomenon which can be explained successfully by aggregation technique. In a porous medium the local porosity often exhibits spatial variations. These variations can be characterised by a multifractal spectrum, as long as suitable scaling characteristics are present.

Fractal image coding: The most popular use of fractal geometry is found in the field of image compression. Specific classes of fractals can be used for digital image compression. Basic rule of this method is that, using any original discrete image specified by an array of pixels, a computer can construct a fractal image – a coded image – which is both visually close to the original one but has a digital representation requiring fewer bits than the original image

Fractals in biological aspects: Fractals have also created interest in the field of medical science. At the microscopic level one can examine the biological tissues, the backbone of protein molecules, tumour growth or bacterial growth with the help of fractal geometry. Any growth may possess

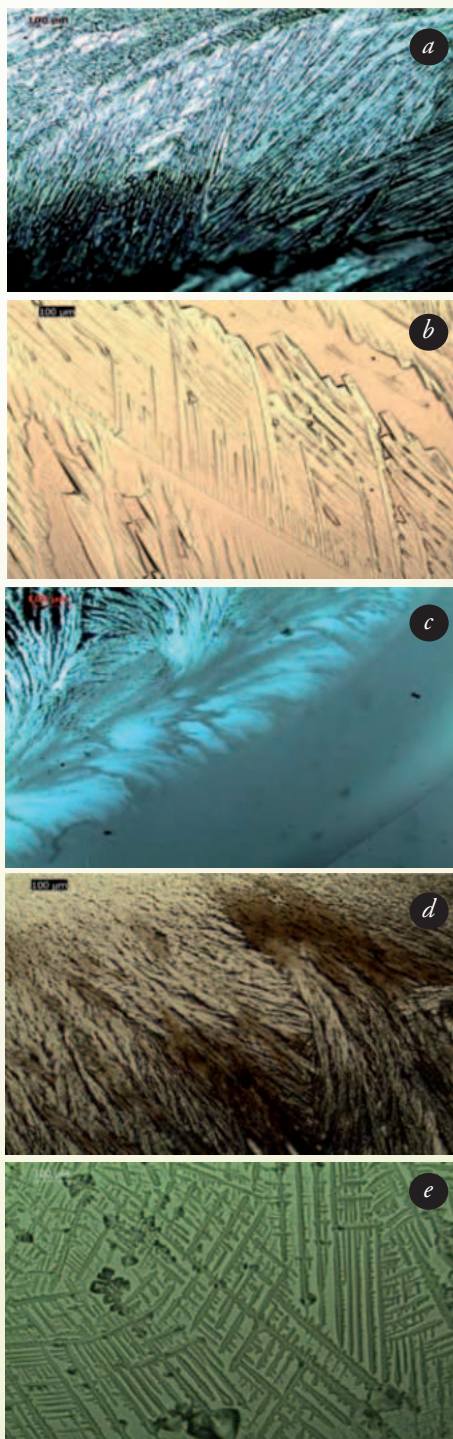


Fig 6. Several patterns are obtained under different conditions showing fractal nature: patterns are formed by the evaporating drying droplet at 28°C with humidity 38% (droplet volume is 20 microlitre, diameter < 1 cm) on different substrate and are investigated by polarizing microscope Leica DM750 under optical resolution 100 µm. Droplets are formed from (a) 5% aqueous solution of CuSO_4 (on quartz surface), (b) 7% aqueous solution of CuSO_4 (on glass surface), (c) 3% aqueous solution of CuSO_4 with gelatin (on quartz surface), (d) 5% aqueous solution of CuSO_4 with gelatin (on glass surface), (e) 5% aqueous solution of KCl (on glass surface). Fractal dimension analysis of the observed patterns is under investigation.

a repetitive arrangement from portion to portion. If you can generate the initiator, then under a particular recursive algorithm (which are the characteristic of that chosen pattern) that growth pattern can be simulated. In this way complicated structures can be analysed more easily.

In telecommunication: A new application is fractal-shaped antennae that greatly reduce the size and the weight of the antennas. The benefits depend on the fractal applied, frequency of interest, and so on. In general, the fractal parts produce 'fractal loading' and make the antenna smaller for a given frequency of use. Practical shrinkage of 2-4 times is possible for acceptable performance.

Besides, fractals are used in geographical mapping (i.e., to provide a simple solution of capturing the enormous detail and irregularity of landscapes, coastlines, etc.), galactic clustering, or even in determination of fluctuation in economic system. In surface physics, fractals are used to describe the roughness and to predict the morphology of surface growth. Fig. 6 shows different types of growth mechanisms, like crystal deposition on solid substrate, viscous fingering, nature of crack formation, effect of colloidal solvent on crystal growth mechanism, etc. The images were obtained at Jadavpur University, Kolkata, where patterns formed under different conditions and different morphologies are investigated in the lab of condensed matter physics research centre.

In general we can say we have fractals around us. Different types of structures as we find in nature like leaf and petal structures, seashells, broccoli, lightning bolts, ice crystals, spreading of viscous fluid over a solid substrate, electrochemical depositions – all follow fractal designs. Fractal design in molecular level may lead to new approaches in material science and nanotechnology and theoretical treatments at multiple scales and levels. Besides developing fascinating and wonderful fractal images, researches may also go on to find solutions of different types of problems (like structures, growths, etc.) using fractal geometry.

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Beware of the Selfie Syndrome



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Mobile phones have become a ubiquitous mode of interpersonal communication today. As a result, communication is becoming faster and more frequent compared to letters of olden days that took days in transit. A recent report of the Internet and Mobile Association of India and Indian Market Research Bureau reveals that use of rural mobile internet use expanded by 93% in 2014 with 306 million mobile internet users by 2015. Social media is now considered as the future of communication. This new media makes the transfer of text, photos, audio, video, and information in general among internet users almost instantaneous. The number of self-portrait photos posted online has grown rapidly as a function of the simultaneous growth of social networking and smart phone use in our country. These self-shot photos are called 'selfies'. The most common places for posting selfies are blogs, social networking sites such as Facebook, and photo sharing websites, such as Instagram. The act of taking selfies with a mobile phone, placing the subject center-stage, has exploded in popularity in recent years, and even world leaders like Britain's Queen Elizabeth II, our Prime Minister Narendra Modi, and U.S. President Barack Obama have joined in.

What is a selfie?

Selfie is commonly defined as a self-portrait posted online on a social networking site such as Instagram, Twitter, Facebook, etc. In other words, a selfie is a self-portrait, typically a photograph taken with a digital camera or mobile phone held in the hand or supported by a selfie stick and posted online. With the advances in mobile technology like smart phones and tablets, the process of taking selfie has become easier.

Selfie syndrome

The American Psychiatric Association (APA) has coined the term 'selfitis' for a mental

disorder characterised by an obsessive compulsive disorder of clicking selfies. The disorder manifests itself in three stages:



Taking a selfie

borderline, acute, and chronic. Selfie is no more an amusing or funny hobby but a mental disorder or an obsession to project self-image. Many psychologists believe that selfitis may be partly the result of past bullying, a broken relationship, strained family bonding, or low self-esteem.

Broadly, selfie syndrome can be divided into three categories, namely 'border-line selfie', 'acute selfie', and 'chronic selfie' respectively. In case of border-line selfie, the user takes minimum of three photographs per day and does not post it on social media whereas in case of acute selfie the user takes at least three photographs per day and posts them immediately on social media. But in case of chronic selfie, the user takes a minimum of six photographs per day and posts them immediately on social media.

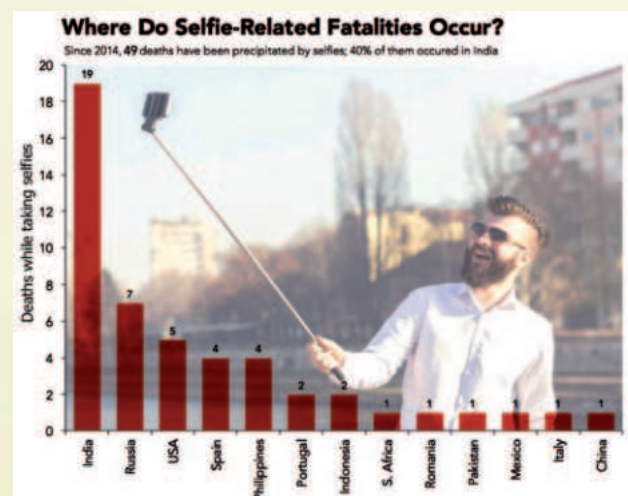
Selfie - a mental problem

Researchers have found that the propensity to take selfies is associated with two psychological problems

known as narcissism and psychopathy. Clicking self-photos is mainly associated with narcissism that measures inflated self-image (often motivated by underlying insecurity), while psychopathy involves a lack of empathy and impulsive behaviour. Studies have shown that selfie syndrome may affect the communicative ability, namely linguistic competency, psychological competency, and cognitive competency of students and affect their motivation to learn. The danger is that selfitis is spreading its tentacles very rapidly among teenagers and college going students which may lead to a serious mental catastrophe waiting for us to break out shortly.

Selfie deaths

But more dangerous is the reckless manner of taking selfies that is leading to unavoidable deaths worldwide, a majority of them in India. India accounted for 40% of the deaths (19 out of 49) since 2014 caused due to accidents while taking selfies, according to a *Washington Post* report. Three college students died in Kosi Kalan near Mathura, while trying to capture a self-portrait in front of a speeding train in January last year. In March, seven youths who were out celebrating a friend's



Countrywise selfie-related deaths (Credit: Zachary Crockett; Data via Google News Archives, Wikipedia)



*A guide for taking 'safe selfies' published by the Russian government after a series of selfie-related deaths.
(Credit: https://mvd.ru/safety_selfie)*

birthday died when their boat capsized as they were attempting to take a selfie. A Japanese tourist in Agra died in September after he succumbed to head injuries from slipping on the Taj Mahal's stairs as he tried to take a selfie. An engineering student in Namakkal, Tamil Nadu was killed when the rock he was standing on while taking a selfie cracked plunging him into a 18-metre-deep ravine. Two students lost their lives in Sundernagar, near Rajkot, by drowning in the Narmada canal while trying to take selfies. Selfie-related deaths have continued in 2016 as well, with two people being killed near the Bandra-Worli Sea Link in Mumbai by drowning. The number of selfie deaths is growing with each passing day, especially in India and there is urgent need to take corrective steps.

Selfie and social cohesion

From cultural point of view, the 'selfie' exposes a very basic human desire – to feel noticed, appreciated and recognised. Selfie has also inspired a spate of risk taking and offensive public behaviour, pushing the boundaries of safety and decorum, whether by dangling from a skyscraper or posing with live explosives. It is argued that selfies affect young people negatively and may lead towards more fragile social interactions that deter social cohesion badly.

Selfie safety

Selfies are officially more deadly than sharks. Several governments and regulatory bodies

have now begun treating the selfie as a serious threat to public safety, leading them to launch public education campaigns reminiscent of those against smoking and drinking of the past. For instance, Mumbai police has identified 16 'no-selfie zones' in the city to combat the menace. Internationally, 'no selfie' zones has been declared by several countries; they include the Garoupe beach in France, Mecca in Saudi Arabia, Lakeshore in California, and Pamplona in Spain, to name a few. In Russia, the government agencies are keeping a close watch on selfie education through rigorous selfie safety campaigns and a pictorial guide for taking 'safe selfies' has been published by the Russian government in the style of the common traffic signs, after

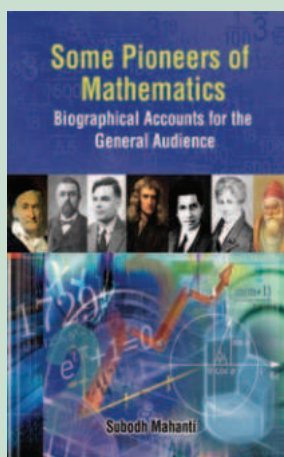
a series of selfie-related deaths. It is high time that similar campaigns are launched in India as our country boasts one of the largest populations of youth (550 million) in the world who use smart phones and mobile phone internet access.

Conclusion

In today's highly networked world, the number of social networking sites offering avenues for faster communication is rapidly increasing. This has created a wave of growing internet consciousness among teenagers and adults who use social network sites frequently in order to take advantage of opening their world to friends and introduce themselves to others by sharing their photos as selfies. Therefore selfie education and selfie consciousness is very much required to keep our burgeoning youth population from the syndrome of selfitis for which necessary guidelines and follow-up action need to be framed in the interest of curbing the menace in our country.

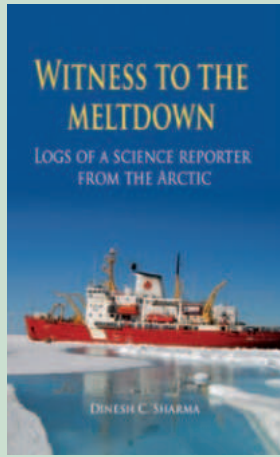
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Dangers of Consanguineous Marriage



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Consanguinity is a Latin term (*con* = shared, *sanguis* = blood) used to describe the relationship between couples who share at least one common ancestor. Consanguineous marriage is the union of individuals having a common ancestor. It is nothing but inbreeding. Information on consanguineous marriage and its outcome is scarce or even unavailable. These marriages are culturally and socially favoured in many cultures and constitute 20 to 25% of all marriages.

However, it is known that consanguineous marriage leads to higher levels of mortality, morbidity and congenital malformation in the offspring due to the greater probability of inheriting a recessive gene. The increase in recessive or deleterious traits due to consanguineous marriage leads to reduced fitness of a population, which is called 'inbreeding depression'.

Genetic diversity is more important in a population and inbreeding erodes that. Nevertheless consanguineous marriage remains the choice of a large part the population in many countries in North Africa, West Asia and South Asia. There may have been a historic reason for that. People lived in small communities for generations and finding a partner completely unrelated to them was next to impossible. Consanguineous marriages are preferred across all ethnic and religious groups to varying degrees. The major reasons for a preference for consanguineous marriages are socio-cultural rather than any perceived economic benefits either in the form of consolidation of family property or smaller and less expensive dowries.

Each of us inherits two copies of a gene, one from the mother and another from the father. Each copy of the gene could be different. The copy that is expressed in physical forms such as shape of nose, colour of eyes and hair, etc., is said to be dominant

while the one that is not expressed but is present is said to be recessive. A person may possess both dominant genes (homozygous dominant) or one dominant and one recessive gene (heterozygous dominant), or both recessive genes (homozygous recessive).

Most of the genes that we carry are either beneficial or neutral in character; otherwise we would not survive. We also possess genes with potential to have a negative impact on our health. These genes



are recessive which can be expressed only if they can work together with a similar recessive gene. The recessive form of an allele cannot be expressed in the presence of a dominant allele. (An allele is either of a pair of alternative forms of a gene that can occupy the same fixed point on a particular chromosome and that controls the same character.) Recessiveness refers to a trait, hence even if one possesses a recessive allele which is deleterious, it cannot express its effect on its own. The individual will only be the carrier of that allele. The recessive alleles are so rare that it is unlikely a random reproductive partner will carry it and there is always a 50- 50 chance that the individual won't pass on its deleterious recessive alleles.

With inbreeding, however, the family members share an unequal percentage of their genes. To cite an example, let's assume two cousins who carry recessive genes responsible for a dangerous disease, marry and have four

children. Since both the parents are carriers of the deleterious allele, there are three possible consequences. Of the resultant offspring, one may inherit both dominant alleles (homozygous dominant), one may inherit one dominant and one recessive allele (heterozygous and carrier of deleterious allele), and yet another may inherit both the recessive alleles (homozygous recessive) that would suffer from the dangerous disease. Thus as a result of inbreeding, in a single generation the risk of this dangerous disease would hypothetically jump from 0.1 % in the general population to a whopping 25% for the children of this particular inbreeding couple. In other words, bringing together of two alleles of a recessive trait is possible only through union of closely related couple or consanguineous union.

Consanguineous marriage may sometimes be beneficial also. If one of the two has genes for better mental capability and the other has genes for better physical capability, the offspring are likely to get both these qualities instead of just one or the other

Consanguineous marriages integrate multiple facets of human adaptation: economic, cultural and genetic. It provides many socio-economic benefits. Inbreeding increases the speed of selection of beneficial recessive and co-dominant alleles. Long-term practice of interbreeding has resulted in a marked elimination of many deleterious genes. For example, in populations endemic with malaria, the prevalence of consanguineous marriages and the frequency of alleles protective against malaria are both very high. Thus consanguinity could theoretically increase the relative fitness of a population under specific ecological condition; sometimes the overall genetic benefits may even exceed genetic costs of inbreeding.

Consanguineous marriage has been quite common among the royal families.

Many people including scientists, writers, and film directors are also known to have consanguineous marriages. Charles Darwin, the naturalist, married Emma Wedgwood, his first cousin. Three of his ten children died before the age ten, three other children who had married left no children. The analysis of a sample of twenty-five families related to Darwin and belonging to four consecutive generations does show a statistically positive association between child mortality and consanguineous marriage. Albert Einstein the scientist, H.G. Wells and Edgar Allen Poe the writers, Samuel Morse the inventor of telegraph, and David Lean the film director were all married to their close relatives.

All Hindu marriages continue to be contracted within caste boundaries and *gotra* are also observed. *Gotra* means clan and also refers to an unbroken male line from a common male ancestor. Marriage does not occur between a man and a woman of the same *gotra*. In North India among Hindus, marriage between biological kin is prohibited for approximately seven generations on the male side and five generations on the female side. But South Indian Hindus strongly favour marriage between first cousins. Sikhs almost follow Hinduism and Buddhists favour first-cousin marriage. The Zoroastrians of Iran had their own marriage customs that included consanguineous marriages.

Looking into the legal aspects, some countries with civil legislation restrict consanguineous marriage. Marriage law (1981) of The Peoples of Republic China prohibits marriage between couples related as first-cousins or closer. But first-cousin marriages are legal in countries like UK and Australia. In the US, only in some states first-cousin marriage is a criminal offence.

Consanguineous marriage brings in homozygous recessiveness in a population. This appearance of homozygosity may be the reason for several of the diseases like Cystic fibrosis, Tay-Sachs disease, sickle cell anaemia, etc. Cystic fibrosis is one of the most common recessive genetic diseases. It is a progressive life-long condition in which the glands that produce mucus, sweat and intestinal secretions do not function properly. Thick mucus accumulates in the lungs, leading to breathing difficulty and infection. It also affects digestion and the affected males are infertile.

Tay-Sachs disease is a rare inherited

disorder that progressively destroys nerve cells in the brain and spinal cord at four or six months of the child. The affected child experiences seizures, vision and hearing loss, intellectual disability and paralysis. An eye abnormality called Cherry-red spot in the retina is characteristic of this disorder.

Sickle-cell anaemia is a serious disease in which body makes sickle-shaped red blood cells. These cells contain abnormal haemoglobin (haemoglobin-S). These cells are stiff and sticky and tend to block the blood flow in the blood vessels. In sickle-cell anaemia the cells usually die after 10 to 20 days. The bone marrow cannot make new cells fast enough to replace the dying ones. People who inherit haemoglobin-S gene from one parent and a normal gene from the other parent have a condition called Sickle-cell trait. They do not have this disease but they become resistant to malaria. Sub-Sahara Africans carry this gene. Thalassaemia is inherited in an autosomal recessive fashion. This is caused by the weakening and destruction of red blood cells. People suffering from this disease make less haemoglobin which results in anaemia. They get overload of iron that damages heart, liver and endocrine system. Thalassaemia can make the bone marrow expand resulting in abnormal bone structures.

Albinism results from inheritance of recessive genes. This congenital disorder is characterised by the complete absence of melanin pigments in the skin, hair and eyes. It is also associated with vision defects such as photophobia, astigmatism, etc. Phenylketonuria (PKU) is characterised by non-functioning of phenylalanine hydroxylase resulting in mental retardation.


Consanguinity may also lead to epilepsy and increase the incidence of blinding disorder called retinitis pigmentosa, etc. Though a good number of cases of genetic disorders due to recessive lethal alleles are known, there is no single known case due to dominant lethal alleles. Dominant lethal alleles are always expressed resulting in death and never get passed on, as the individual does not live to reproduce. Recessive lethal alleles persist because they can be carried without exhibiting their lethality in a heterozygous condition.

Variety is the spice of life and to have variety new genes need to be introduced in the offspring. But new genes are rather meagre in consanguineous marriages when compared

to marriages between unrelated couples. Not many people are aware of this. Increasing public awareness about consanguinity could be achieved by providing proper education and training to primary health care workers on all health and social issues related to consanguinity. Health care providers and genetic specialists could consider both negative impact of consanguineous marriage in terms of increased genetic risks to the offspring, as opposed to the potential social and economic benefits. In populations that are highly endogamous (marrying only within the clan), genetic counselling and screening could be offered with consideration of the genetic disorders that occurs with high frequency in that specific population. While counselling, specific questions addressed to the couple could help in eliciting the presence of a genetic or hereditary disorder in the family.

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Lotus Effect - An Epoch-making Discovery



Dr. Vidyanath Jha

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Human beings are capable of explaining the hidden mysteries of nature by applying their analytical mind. Modern instruments have



Fig. 1: Round drops of water over a lotus leaf

made it possible to explain the scientific processes behind many old philosophical maxims coined by ancient scholars.

Discovery of the “Lotus Effect” is an example that refers to the property of self-cleaning property of lotus leaves as a result of very high water repellence (Fig. 1). After the invention of the scanning electron microscope it became possible to see the details of microscopic objects of the dimension of a nanometre (10^{-9} metre). This led to the discovery of the basic concept of lotus effect by the German botanist Wilhelm Barthlott (Fig. 2). This discovery was a milestone in biophysics.

Lotus leaves and flowers have minute bumps on their surface that are covered with



Fig. 2: Wilhelm Barthlott – the discoverer of lotus effect

wax and thus repel water. Liquid water falling on a lotus leaf, instead of wetting the surface, moves in the form of round drops and makes

it clean by capturing the dirt particles on it. It is on account of this factor that lotus is held as emblem symbol of purity. The original research paper of Wilhelm Barthlott was published in the journal *Planta* under the title- “The purity of sacred lotus or escape from contamination in biological surfaces” (Vol. 202, pages 1-8, 1997). In this paper he made a mention of the reference to the self-cleaning property

of lotus leaves found in ancient Sanskrit texts of India. The *Padmapatramivambhasa* maxim, as inscribed in the classical text *Srimadbhagavadgita*, suggests the adoption of a lifestyle that follows the principle of unattachedness towards the vicissitudes of life in a way similar to the non-wetting properties of the lotus leaves .

Besides lotus (*Nelumbo nucifera*), the self-cleaning property is also found in a few other plant species belonging to the genera *Colocasia*, *Alocasia*, *Musa*, etc. Leaves of banana (*Musa* spp.) show this property in their young stages that gradually diminishes when they get mature (Fig. 3).

Lotus effect lessens the onslaught of fungal and other diseases on these plants as

fungal spores, conidia, etc., fail to germinate for want of moisture. The crystalline wax found on lotus leaf is present as microreliefs, which are laden with air. Water droplets over lotus leaf get round-shaped on account of surface tension and make a contact angle of more than 90° . This prevents their spread. Dirt particles present over the surface are made to stick to the moving droplets on the surface. Less surface free energy (the energy which has to be expended in order to increase the

size of the surface) on lotus leaf further adds to its superhydrophobicity (an effect where roughness and hydrophobicity combine to generate unusually hydrophobic surfaces, causing water to bounce and roll off). The surface wax has bumps of 5 to 9 micrometres which are lashed with nano branches of 124 nm (Fig. 4).

Evolution of the characteristic of



Fig. 3: Round drops of water over a young banana leaf

self-cleanliness in animals and plants, on account of hydrophobicity, has spanned over millennia and this provides them with an adaptation to withstand extreme environmental situations. This has opened up the possibility of extraction of water from air and of solving a number of technological and biomedical problems.

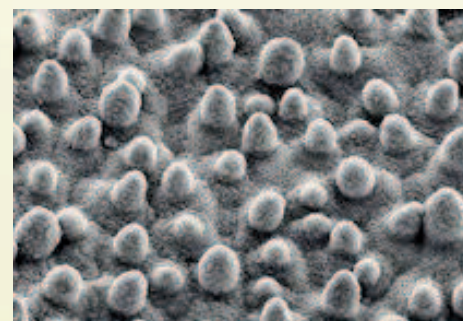


Fig. 4: Minute bumps over a lotus leaf

Scientists have also discovered an insect called *Stenocara gracilipes* (commonly known as Namib Desert Beetle) that collects water from desert fog, based on the basic principle of lotus effect. This beetle takes up a position pointing its head to the ground. The wing portion thus lying above helps the

condensation of the desert fog into water droplets that fall into its mouth part (Fig. 5). The capacity of water collection in this beetle is virtually on account of presence of waxy bumps on the wings that are of hydrophobic nature. Scientists at the Massachusetts Institute of Technology in USA have developed a system similar to one found in Namib Desert beetle that is effective in de-capacitating germs lying on surfaces that are likely to cause contamination.



Fig. 5: A Namib Desert Beetle collecting water from desert fog

The property of superhydrophobicity is also found in butterfly and dragonfly that are unable to clean their wings like some other insects. An insect called *Gerris remigis* (popularly called water strider) can move rapidly over water surface. Scientists have found its leg having several appendages that are laden with invisible hairs called microsetae, forming a unique hierarchical structure through their orientation at inclined angle of 20° . This makes them superhydrophobic. This discovery in the field of microfluidics could help the manufacture of aquatic robots in near future (Fig. 6).

In view of the imminent drinking water crisis in several parts of the globe, scientists have launched a campaign to discover new sources of water. MIT scientists



Fig. 6: *Gerris remigis* moving swiftly over water surface.



Fig. 7: Roofs of modern houses cast with Erlus Lotus tiles

have made a superplastic that collects water through incorporation of both hydrophilic and hydrophobic properties. This device includes a polymer that has a surface charged both positively as well as negatively. It is impregnated with small silica particles and has a wax film with fluorinated silane coating that makes water droplets drop easily. This new technique is quite effective for collecting water in foggy deserts. Scientists are on way to developing a bactericidal water purification system with this process.

The principle of lotus effect now finds practical applications in different walks of life including solar energy and transport and communications. Solar panels face the problem of deposition of dust particles. A dust cover of 4 gm/m^2 over a solar panel causes a loss of up to 40% in efficiency. Scientists are of the opinion that a paint based on lotus effect can help make maintenance less costly.

Modern houses and their walls can be kept clean by using paints based on lotus effect. A tile called 'Erlus lotus', developed recently in Germany, helps solar disintegration of organic dirt deposited over its surface that is washed off during the first rains (Fig. 7). A Munich based company that produces this tile has been honoured with Materialica Design Award.

Lotus effect has its implication in meat industry as well. A slicing machine developed on this principle makes pieces of accurate weights. This has done away with the problem of weighing aberrations. Teflon is used as coating material to achieve



Fig. 8: A slicing machine developed on this principle.

the effect. Another characteristic of this machine is that it does not require periodic replacement of its blade that maintains its sharpness and is also resistant to corrosion (Fig. 8).

Wilhelm Barthlott is a leading researcher in the field of technical interfaces of biological sciences. This discovery has brought forth a new concept in materials science and has opened up ways for development of superhydrophobic bio-inspired surfaces. Annual value of commercial products based on lotus effect in the field of biophysics has now crossed the range of ten crore dollars. Economic importance of self-cleaning surfaces is growing day by day.

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Dietary Fibre: Indispensable for Good Health



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Fibre is that edible part of plants which passes undigested through the large intestines. Fibre is present only in plant foods. It is mainly classified into soluble and insoluble fibre depending upon its solubility in water and its varying roles within the body. Even though it does not contribute any nutrients to our body, fibre has some very important role to play in prevention and management of certain diseases.

Let us see what fibre does inside our body. Fibre's role is not just limited to maintaining a healthy digestive system to prevent constipation, but it also helps in weight management, modulation of blood glucose in type-2 diabetes, prevention of heart disease, and reducing the incidence of certain types of cancers.

Fibre resists digestion and absorption in the small intestine as our body does not have the required digestive enzymes. As it passes through the gut, it may get fermented by the action of intestinal bacteria resulting in formation of short-chain fatty acids and some gases like methane, carbon dioxide and hydrogen. Some of these short-chain fatty acids get absorbed in the intestine to yield energy and help to keep the intestinal wall healthy, thus preventing various types of intestinal disorders.

Fibre and constipation

Fibre is mainly associated with relieving constipation. Constipation is a condition resulting in the passage of hard stools. This condition can make a person feel bloated and sluggish. Due to chronic constipation, people often feel lethargic and fatigued. Though constipation is often taken lightly, it can become serious as it increases the chances of colon cancer. It can also reduce appetite and limit food intake. Sometimes constipation

can also result in flatulence (gas formation) which can be quite unpleasant and a source of discomfort. It affects the general well-being and mood of an individual, affecting daily life. The type of fibre that prevents



Whole grains, fruits and vegetables are good sources of fibre in our diet

constipation is known as insoluble fibre as it does not get dissolved in water. Insoluble fibre, due to its water holding capacity, absorbs water from the intestinal walls and adds bulk to the faecal matter. In simple words, inside the large intestine, fibre swells up due to water absorption and increases the stool volume making it soft and eases the passage of stool through the gut. This helps in preventing constipation as fibre also reduces the transit time (time taken by the faeces to

pass through the intestines) by stimulating contractions in the intestinal walls.

Diverticulitis and colon cancer

Insoluble fibre helps in preventing constipation and thus wards off colon cancer and diverticulitis (inflammation of intestinal wall with the formation of pouches). When we consume low-fibre diets, then the gut struggles to get rid of all the undigested waste products. This causes a strain on the intestinal walls which can sometimes cause development of small pouches in the colon called diverticulae. This condition is medically known as diverticulitis and is common in old age. Hence, high-fibre diets increase the bulk as well as result in softer mass which reduces the pressure

on intestinal walls and aids in contractions of intestinal walls to speed up the passage of stools.

There is some evidence that suggests fibre's role in reducing the risk of colon cancer. Faecal matter is acted upon by bacteria in the intestines leading to the formation of cancer-causing substances or carcinogens. In the long run, constipation can lead to colon cancer, because the longer the faecal matter remains in contact with the intestinal walls, the greater will be the chances of producing carcinogens which may stimulate cancer formation in the colon. Since fibre speeds up the passage of stools in the intestines, less time is available for bacteria to act upon the faecal matter reducing the time carcinogens remain in contact with the intestinal walls. This way, fibre helps to sweep away cancer causing substances reducing the risk for colon cancer.

Fibre and heart disease

High cholesterol levels can trigger heart disease. Soluble fibre

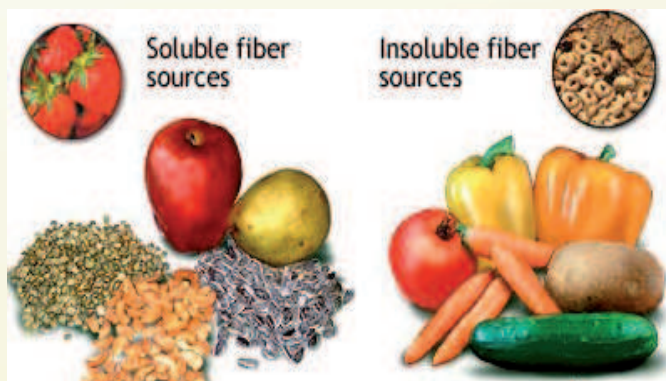


Dietary Fibre is an integral part of a healthy diet

dissolves in water to form a viscous gel. When consumed through foods, soluble fibre swells up in the digestive tract and delays the passage of food through stomach and intestines. It therefore, slows down the process of digestion and absorption. Cholesterol is required for the formation of bile. Bile is a juice formed in the liver and stored in the gall bladder. It is released during digestion, especially for its role in the digestion of fats in the diet. After fat digestion, bile is recirculated till required for fat digestion again. When soluble fibre is taken through the diet, it binds with the bile and cholesterol and facilitates its excretion. In this way cholesterol from blood is removed for new bile formation thus lowering blood cholesterol levels. Soluble fibre is known to reduce cholesterol levels by reducing the risk for heart disease.

Fibre and type-2 diabetes

Soluble fibre, as discussed earlier, absorbs water and swells up to form a viscous gel-like substance. This fibre delays gastric emptying, so that food remains longer in the stomach resulting in slow absorption of nutrients from the intestines. We know that food, especially carbohydrates in food are broken down to glucose and this glucose gets absorbed from



Both soluble and insoluble fibre have different roles to play in our body.

the intestines into the bloodstream, raising blood sugar levels. Since the rate of glucose absorption affects the insulin requirement and insulin sensitivity (how efficiently insulin lowers blood glucose levels), soluble fibre slows down glucose absorption thus reducing insulin requirement and improving insulin sensitivity. In simple terms, soluble fibre in the diet helps regulate blood sugar levels and avoids any spikes or fluctuations in blood glucose. This way soluble fibre in the diet helps to manage diabetes better.

Fibre and weight management

Fibre plays a significant role in weight management. High-fibre foods tend to be lower in calories, and impart a feeling of fullness. Fibre reduces hunger pangs as it stays in the stomach for longer periods, delaying digestion and reducing frequent cravings for food. High-fibre foods not only are lower in calories but also increase volume thereby increasing satiety and reducing hunger. Hence, fibre helps in maintaining weight and energy balance, but how effective it is in reducing body weight is still an unanswered question.

Which foods are good sources of fibre?

Insoluble fibre which helps in relieving constipation and prevents certain intestinal disorders, is mostly present in wheat bran, whole grain cereals like whole wheat flour, brown rice, whole wheat bread and pasta, etc. It is also found in mature vegetables like lady's finger, carrots, beans and leafy greens like spinach, coriander, fenugreek, cabbage, etc., in pineapples and the skin of fruits like apple, etc. It is also present in legumes and whole pulses like chickpeas (*chhole*), horse gram (*chana*), peas, etc., and nuts and oilseeds like flaxseed (*alsi*).

Soluble fibre helps in managing cholesterol, diabetes and weight. It is present in oat bran in the form of beta-glucan, guar gum present in guar beans, fenugreek (*methi*) seeds, psyllium husk (*isabgol*), fruits containing pectin (used for making jellies), viz., citrus fruits like oranges, limes, guava, pear, apple (the inner fleshy portion), melons, plums and peaches, legumes like kidney beans (*rajmah*), certain vegetables like onions, bottle gourd, pumpkin, etc., the slimy fluid of lady's finger called mucilage is also a soluble fibre.

How to increase fibre in the diet?

- Instead of fruit juices, go for whole fruits (with skin and seeds)
- Instead of refined cereals like *maida*, *suji/rava*, go for whole wheat flour, broken wheat porridge, oats, etc. Whole wheat bread and brown rice

is better than white bread and white polished rice, which have a low-fibre and vitamin content.

- Have at least three servings (300 gm) of vegetables including leafy greens like spinach and fenugreek (*methi*) leaves and two servings (200 gm) of fruits daily to meet the fibre requirements.
- Use whole pulses (with the husk), beans like *rajmah*, *chhole* and *chana* than split dals.
- Add leafy green vegetables like spinach, fenugreek and coriander to *dals*. This not only increases the fibre content but also makes *dal* more nutritious.
- Have salads with meals. Salads are an easy way to increase fibre in diet. Adding sprouted whole green gram (*moong*) and horse gram (*kala chana*) to salads increases protein content too.

Precautions while introducing/increasing fibre-rich foods in the diet

- Fibre is essential for maintaining good health, but excess of anything is bad for health. This goes well for fibre too. Too much fibre can reduce the absorption and increase excretion of minerals like iron and calcium from the intestines leading to their deficiencies.
- Increasing fibre in the diet too quickly can lead to abdominal discomfort, flatulence (gas) and sometimes diarrhoea too. Hence, fibre must be added slowly to the diet and should not be taken in large amounts, especially if already on a low-fibre diet.
- When taking fibre-rich foods, always increase fluid intake as fibre works well only when adequate water is present in the diet. Increasing fibre intake without increasing fluids can cause stools to become hard and in turn lead to constipation.
- Fibre should be obtained through natural food sources instead of fibre supplements as natural sources of fibre provide other nutrients like vitamins and minerals too.

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Stress Incontinence: Tests and Treatments



Dr. Yatish Agarwal
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Even though the symptoms of stress incontinence, the loss of bladder control, a common and embarrassing problem are tell-tale with occasional leak of urine when a person coughs, sneezes or laughs, your doctor might order a battery of urodynamic tests, which are used to assess the function of your bladder. You must, however, know that these tests are not that necessary in most women with uncomplicated stress urinary incontinence.

Tests of bladder function

Measurements of post-void residual urine

If there is concern about your ability to empty your bladder completely, particularly if you are older, have had prior bladder surgery or have diabetes, a test of your bladder efficiency may be needed. To measure the residual urine after you have voided, a specialist may use an ultrasound scan, which translates sound waves into an image of your bladder and its contents.

Measuring bladder pressure

Some people might require cystometry, a test that measures the pressure in your bladder and in the surrounding region during bladder filling. A catheter is used to fill your bladder slowly with warm fluid. Tests of your bladder leakage will be done during the filling to check for stress incontinence.

This procedure may be combined with a pressure-flow study, which tells how much pressure your bladder has to exert in order to empty completely.

Voiding Cysto-urethrography

Radiologists can take images of the bladder as it functions. Video urodynamics uses imaging to create pictures of your bladder as it is filling and emptying.

The procedure is simple. Sterile fluid mixed with a contrast agent that shows up on X-rays is gradually instilled in your bladder by a catheter, and subsequently X-ray images are recorded. The images are taken when your bladder is full, and as you urinate to empty your bladder.



Cystoscopy

This is an examination of the bladder and urethra using a scope inserted into the bladder. This procedure is usually completed in the office.

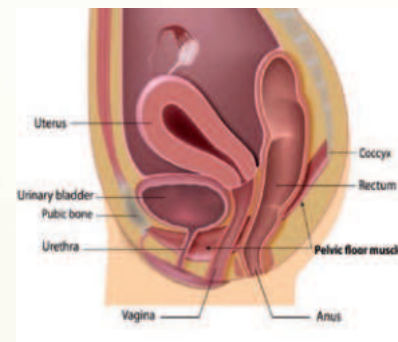
You and your doctor should closely discuss the significance of doing the tests and how they might impact your treatment strategy. In most cases, a detailed history and a careful physical examination can identify the problem of stress incontinence without doubt.

Treatments

Measures You Can Take

Strengthen your pelvic floor muscles

Simple pelvic floor muscle strengthening exercises, known as Kegel exercises, can work wonders to strengthen your pelvic floor muscles and urinary sphincter. Your doctor or a physical therapist can help you learn how to do them correctly. Just like any other exercise routine, how well Kegel exercises work for you depends on whether you perform them regularly.



To get started:

Find the right muscles. To identify your pelvic floor muscles, stop urination in midstream. If you succeed, you've got the right muscles. Once you've identified your pelvic floor muscles you can do the exercises in any position, although you might find it easiest to do them lying down at first.

Perfect your technique. Tighten your pelvic floor muscles, hold the contraction for five seconds, and then relax for five seconds. Try it four or five times in a row. Work up to keeping the muscles contracted for 10 seconds at a time, relaxing for 10 seconds between contractions.

Maintain your focus. For best results, focus on tightening only your pelvic floor muscles. Be careful not to flex the muscles in your abdomen, thighs or buttocks. Avoid holding your breath. Instead, breathe freely during the exercises.

Repeat three times a day. Aim for at least three sets of 10 repetitions a day.

Caveat. Don't make a habit of using Kegel exercises to start and stop your urine stream. Doing Kegel exercises while emptying your bladder can actually lead to incomplete emptying of the bladder — which increases the risk of a urinary tract infection.

Make healthy lifestyle changes

Quitting smoking, losing excess weight or treating a chronic cough will lessen your risk of stress incontinence as well as improve your symptoms.

Shed extra weight. If you're overweight — your body mass index (BMI) is 25 or higher — losing excess kilos can help reduce the overall pressure on your bladder and pelvic floor muscles. Moderate weight loss may markedly improve your stress incontinence. Talk to your doctor for guidance on weight loss.

Add fibre to your diet. If chronic constipation contributes to your urinary incontinence, keeping bowel movements soft and regular reduces the strain placed on your pelvic floor muscles. Try eating high-fibre foods — whole grains, legumes, fruits and vegetables — to relieve and prevent constipation.

Don't smoke. Smoking can lead to a severe chronic cough, which can aggravate the symptoms of stress incontinence. Smoking is also associated with a drop in your oxygen-carrying capacity, a factor thought to increase the risk of an overactive bladder. And smoking is associated with bladder cancer.

Make scheduled toilet trips

Your doctor might recommend a schedule for toileting—bladder retraining—if you have mixed incontinence. More frequent voiding of the bladder may reduce the number or severity of urge incontinence episodes.

Regulate fluid consumption

Your doctor might make some recommendations about the amount and timing of fluids you consume during the day.

Since caffeinated and alcoholic beverages act as dietary irritants that affect your bladder function, and tend to make you urinate and leak more frequently, you may be asked to avoid them, especially on days you really don't want to be bothered by leakage. This may significantly improve your symptoms.

Take good care of your skin

Prolonged contact with wet clothing can cause skin irritation or sores. Keep your skin dry by changing your garments when they're wet and applying a barrier cream if your skin is frequently wet.

Sexuality and incontinence

Leaking urine during sexual intercourse can be upsetting, but it doesn't necessarily have to get in the way of intimacy and enjoyment. Talk with your partner. As difficult as this may be initially, be upfront with your partner about your symptoms. A partner's understanding and willingness to accommodate your needs can make your symptoms much easier to handle.

Empty your bladder beforehand

To reduce your chances of leakage, avoid drinking fluids for an hour or so before sex and empty your bladder before intimacy starts.

Try a different position

Altering positions may make leakage less likely for you. For women, being on top generally gives better control of the pelvic muscles.

Do your Kegels

Pelvic floor muscle exercises (Kegel exercises) strengthen your pelvic floor muscles and reduce urine leakage.

Be prepared

Having towels handy or using disposable pads on your bed may ease your worry and contain any leakage.

Medical Treatments

Being incontinent is never the norm as you age. Treatments are usually available to significantly reduce the effects of incontinence on your life. Stress incontinence can often be cured.

Find a doctor who's willing to work with you to determine the best way to treat your incontinence. Your doctor may recommend a combination of treatment strategies to end or lessen the number of incontinence episodes.

Devices

Certain devices designed for women may help control stress incontinence, including:

Vaginal pessary

A specialised urinary incontinence pessary, shaped like a ring with two bumps that sit on each side of the urethra, is fitted and put into place by your doctor. It helps support your bladder base to prevent urine leakage during activity, especially if your bladder has dropped (prolapsed). This is a good choice if you wish to avoid surgery. A pessary will require routine removal and cleaning. Pessaries are used mostly in people who also have pelvic organ prolapse.



Urethral inserts

This small tampon-like disposable device inserted into the urethra acts as a barrier to prevent leakage. It's usually used to prevent incontinence during a specific activity, but it may be worn throughout the day. They are, however, used only in rare cases.

Surgery

Surgical interventions to treat stress incontinence are designed to improve closure of the sphincter or support the bladder neck. Surgical options include:

Injectable bulking agents

Synthetic polysaccharides or gels may be injected into tissues around the upper portion of the urethra. These materials bulk the area around the urethra, improving the closing ability of the sphincter. Since this intervention is relatively noninvasive, it may be appropriate to consider before other surgical options. However, it is not a permanent repair. Multiple injections are required for most people.

Retropubic colposuspension

This surgical procedure — done laparoscopically or by abdominal incision — uses sutures attached either to ligaments or to bone to lift and support tissues near the bladder neck and upper portion of the urethra. This is often used in combination with other procedures to treat a woman with stress incontinence, who also has a bladder that has dropped down.

Sling procedure

This is the most common procedure performed in women with stress urinary incontinence. In this procedure, the surgeon uses the person's own tissue, or synthetic material (mesh) to create a sling or hammock that supports the urethra. Slings are also used for men with sphincteric leakage.

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Recent Developments in Science and Technology



Biman Basu

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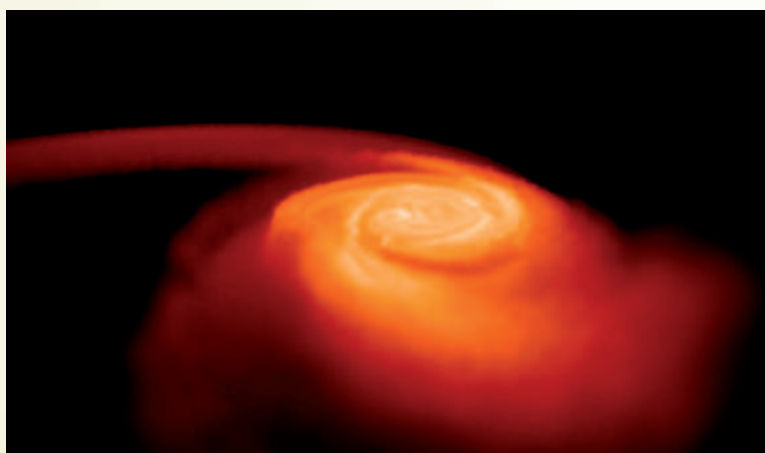
Gold on Earth came from neutron stars

The origin of heavy elements like gold, mercury, platinum, uranium, etc., has remained a mystery for a long time, mainly because these elements cannot be produced in stars in course of their evolution by a process known as 'stellar nucleosynthesis'. Only elements up to iron are formed in this process. Elements heavier than iron are believed to be produced in supernovas – violent explosions that mark the end of massive stars. On becoming a supernova, the star releases very large amounts of energy as well as neutrons, which allows elements heavier than iron, such as uranium and gold to be formed and expelled out into space. Our Sun is believed to have been created from debris thrown out by an earlier supernova explosion and that is why we have heavy elements like gold existing on Earth.

However, new research shows that most of the heavy elements like gold, for example, may have been created by an entirely different process – collision of neutron stars. Neutron stars are ultra-dense objects – collapsed cores of stars that have exploded as a supernova. They are typically about 20 km in diameter, but with masses ranging between 1.18 and 1.97 times that of the Sun. But most are 1.35 times the mass of the Sun, with all the matter crammed together by the force of gravity so tightly that even the atoms have collapsed into neutrons. As a result, the density of a neutron star is so large that a teaspoon full of neutron-star material would weigh on Earth about 5 billion tons!

According to astronomers, most neutron stars wander through space in isolation, but many pair up, as remnants of binary stars. As a binary pair they can orbit each other for a billion years, before

gradually drifting closer and closer and spiralling together till they catastrophically merge. When two neutron stars collide and



This illustration depicts two neutron stars colliding. As they merge, the stars eject material into space at 10 to 50 percent the speed of light. Mergers of these kinds of stars are thought to be the source of gold and other heavy metals found throughout the universe. (Credit: Stephan Rosswog, Jacobs University Bremen)

merge, most of the material collapses to form a black hole. It also causes a brief gamma-ray burst – outshining its own galaxy – and produces some debris, including gold and other heavy elements. Some of the material is spewed into space. A single event of neutron star collision is estimated to produce about 20 Earth-masses worth of gold!

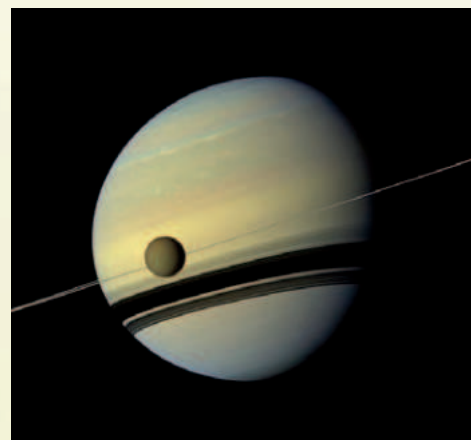
But this kind of violent merger is not a frequent occurrence at the galactic level. According to astronomers, such a neutron-star collision is likely to happen in the Milky Way galaxy about once every 100,000 years. But the universe contains many billions of galaxies and so astronomers doing an all-sky survey will occasionally see one of these rare gamma-ray bursts. In fact, they did detect such an event in June 2013 – a gamma-ray burst from the collision of two neutron stars, about 3.9 billion light-years away. The gamma-ray burst was detected by NASA's *Swift* satellite. But the final answer about the origin of heavy metals was still not forthcoming.

Recently, researchers from the Michigan State University in USA, working with colleagues from Technical University

Darmstadt in Germany, have succeeded in simulating the production of heavy elements in both supernovae and neutron-star mergers. Their work shows that the neutron star merger route is most probable for production of the heavy elements (*Physical Review Letters*, 25 March 2016 | DOI: 10.1103/PhysRevLett.116.121101).

Saturn's rings are much younger than the planet

Till the thin rings of Uranus were discovered in 1977, Saturn was the only planet of the solar system with an ensemble of majestic rings. Saturn's large ring system was first discovered in the 1600s after the invention of the telescope. Scientists have generally assumed Saturn's rings and moons were born at the same time as the planet, about 4 billion years ago. That appears to be true for the large moons that are farthest away from Saturn, including Titan. But recent research shows



Saturn and its moon Titan appear in this image taken by the Cassini probe. Recent studies have found that the planet's rings and many of its moons may be only about 100 million years old. (Credit: NASA/JPL-Caltech/Space Science Institute)

that the rings and several smaller moons of Saturn may have formed only in the past few tens of millions of years. In fact, they may have come into being when dinosaurs were still roaming the Earth some 100 million years ago.

This startling fact came to light when researchers from the Search for Extraterrestrial Intelligence Institute (SETI) used data collected by NASA's *Cassini* mission to analyse the orbits of Saturn's moons using computer modelling in order to figure out when the satellites were born. Earlier, in 2012, French astronomers had discovered that tidal effects caused by Saturn's moons on the planet's fluid interior, are causing the rings, possibly made of frozen water and other liquids, to spiral quickly around the planet's orbit. Those findings suggested that the inner moons, and possibly the rings, formed much more recently than Saturn did. SETI researchers were trying to check up that hypothesis with newly analysed data and came to the conclusion that the planet's distinctive rings and inner moons were indeed formed a mere 100 million years ago.

While Earth has just one moon, the orbits around Saturn are clogged with as many as 62 moons. Those moons gravitationally pull at one another, gradually widening their orbits and moving further away from the planet. And when the moons line up just right, their orbits can get stretched or tilted. The researchers analysed the orbital data collected by NASA's *Cassini-Huygens* spacecraft, which reached Saturn and its moons in 2004. By modelling those shifts, a team led by astronomer Matija Čuk from the SETI Institute was able to analyse the history of Saturn's moons. They found that the orbits of Tethys, Dione and Rhea are "less dramatically altered than previously thought", implying that they have not been around long enough to alter each other's orbits. Change in the orbital tilt is typical of older moons. The researchers also came to the conclusion that the inner moons

may have formed during the Cretaceous Period, the last era of the so-called Age of Dinosaurs – around 230 to 66 million years ago.

According to the researchers, the inclination of the orbits of the moons in question should have been altered more than they have been by gravitational interactions, an indication that orbital changes have been few. And that, the researchers conclude, is evidence they must have formed recently (*The Astrophysical Journal*, 24 March 2016 | DOI: 10.3847/0004-637X/820/2/97). However, distant moons like Titan and Iapetus would have not formed at the same time as the younger moons and must have formed much earlier.

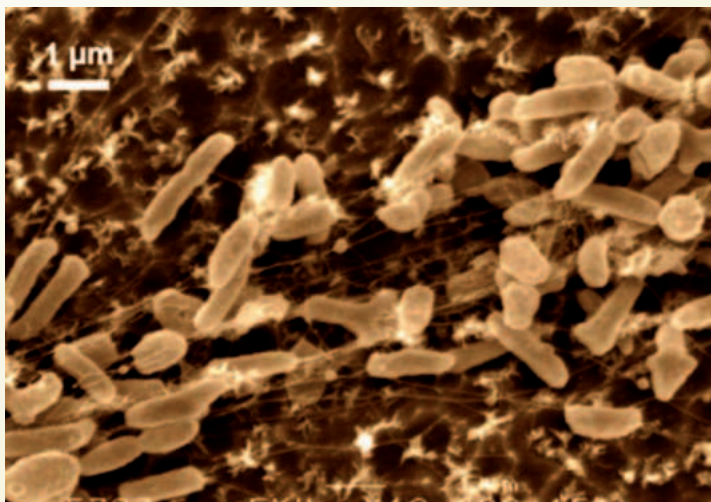
Plastic-eating bacteria can clean environment

Plastic pollution is a growing threat to our environment. Plastic pollution involves

the accumulation of plastic products in the environment that adversely affects wildlife, wildlife habitat, and humans. The main problem with plastics is that they are non-biodegradable; that is, they are not decomposed easily and remain intact for years. An estimated 311 million tons of plastics are produced annually worldwide; 90% of these are derived from petroleum. A large portion of these plastics is used for packaging such as drinking water bottles, but only about 14% is collected for recycling. Since they degrade extremely slowly, plastics constitute a major environmental hazard, especially in the oceans, where microplastics are a matter of major concern. One potential solution for this problem is the production of degradable plastics which can decompose easily in the environment. This may be useful in future but does not help to get rid of the plastics already in the environment.

Recently researchers have found bacteria that can fully degrade a widely used plastic commonly known as PET. A Japanese team, led by Kohei Oda from the Kyoto Institute of Technology and Kenji Miyamoto from Keio University, collected 250 samples of PET debris and screened for bacterial candidates that depend on PET film as a primary source of carbon for growth.

PET is a condensation polymer that is highly resistant to biodegradation. It is industrially produced by reacting either terephthalic acid or dimethyl terephthalate with ethylene glycol. Chemically known as polyethylene terephthalate, PET is a colourless polymer widely used for making bottles and containers for food. It is also used as fibre for making clothes. Human-made PET has been present in the natural environment for almost 70 years. Until recently, no organism was known to be able to decompose it. Scientists have now identified a bacterium called *Ideonella sakaiensis* that completely degrades and assimilates PET as its sole carbon source. When grown on PET, this strain produces two enzymes capable of hydrolysing PET and



False-colour scanning electron micrograph of plastic-eating bacteria *Ideonella sakaiensis*. (Credit: Shosuke Yoshida et al.)



Plastic pollution adversely affects wildlife, wildlife habitat, and humans.

the reaction intermediate, mono(2-hydroxyethyl) terephthalic acid.

The scientists identified this strain by screening 250 environmental samples at a PET bottle recycling site and confirmed that the bacteria are indeed responsible for degrading PET (*Science*, 11 March 2016 | DOI: 10.1126/science.aad6359).

Using genetic and biochemical analyses, they identified two key enzymes involved in PET breakdown although the degradation process is relatively slow. Complete degradation of a small PET film took 6 weeks at 30°C. Nonetheless, according to the scientists, the degradation of PET by *I. sakaiensis* bacteria may help in removing this plastic material from the environment in the long run. But if the terephthalic acid produced as a result of breakdown of PET could be isolated and reused, this could provide huge savings in the production of new polymer without the need for petroleum-based starting materials. Further research in this area will hopefully provide concepts and solutions for the degradation and recycling of other degradation-resistant plastic materials that are currently used and disposed of.

Nano-enhanced textiles clean themselves with light

Cleaning soiled clothes is always a messy affair. Scientists from the RMIT University in Melbourne and Queensland University of Technology in Brisbane, Australia have now developed a cheap and efficient way to grow special nanostructures directly onto textiles that can degrade organic matter when exposed to light. According to the scientists, when the nanostructures are exposed to light, they receive an energy boost that creates “hot electrons”. These “hot electrons” release a burst of energy that enables the nanostructures to degrade organic matter. The team is led by Rajesh Ramanathan of the NanoBiotechnology Research Lab at RMIT University. He says, “The advantage of textiles is they already have a 3D structure so they are great at absorbing light, which in turn speeds up the process of degrading organic matter” (*Advanced Materials Interfaces*, 23 March 2016 | DOI: 10.1002/admi.201500632).



The red colour indicates the presence of silver nanoparticles – the total coverage on the image shows the nanostructures grown by the RMIT team are present throughout the textile. (Credit: RMIT University)

The technique behind these self-cleaning textiles is quite interesting. It involves infusing copper and silver-based nanostructures into the fabric. Copper and silver-based nanostructures are known for their ability to absorb visible light. Because the nanostructure is metal-based it can absorb visible light, which excites the metal nanoparticles present on the surface. The work paves the way towards nano-enhanced textiles that can spontaneously clean themselves of stains and grime simply by being put under a light bulb or worn in the Sun. The treated fabrics when exposed to light break down organic matter such as stains from food products and oil that are

present on the cloth, making it clean. Sunshine, or even just a light bulb, could get rid of stains and grime.

The team of scientists found that by treating cotton fabric with certain solutions, these nanostructures were able to grow onto the textile within a span of half an hour. After drying, as soon as they are exposed to light, energy is released and the varied stain-forming organic compounds present on the fabric degrade and disappear. It was observed that the treated textile cleaned itself within just 6 minutes.

The benefits of self-cleaning textiles are plenty. Cleaning up clothes will become absolutely easy and hassle-free, saving both cost and time in the process, and leaving behind spotlessly clean clothes. The

nano-enhanced fabric is an apt solution to tackle the accumulation of day-to-day grime and pollutants on clothes that deteriorate quality and shelf life.

According to Ramanathan, so far they have only tested the technique on stains and had not yet started to test it on sweat. But they had tested some difficult organic compounds which successfully degraded in the process by just shining light on them.

Biman Basu is a former editor of the popular science monthly *Science Reporter*, published by CSIR. He is a winner of the 1994 ‘NCSTC National Award for Science Popularisation’. He is the author of more than 45 popular science books. ■

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 columns 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

