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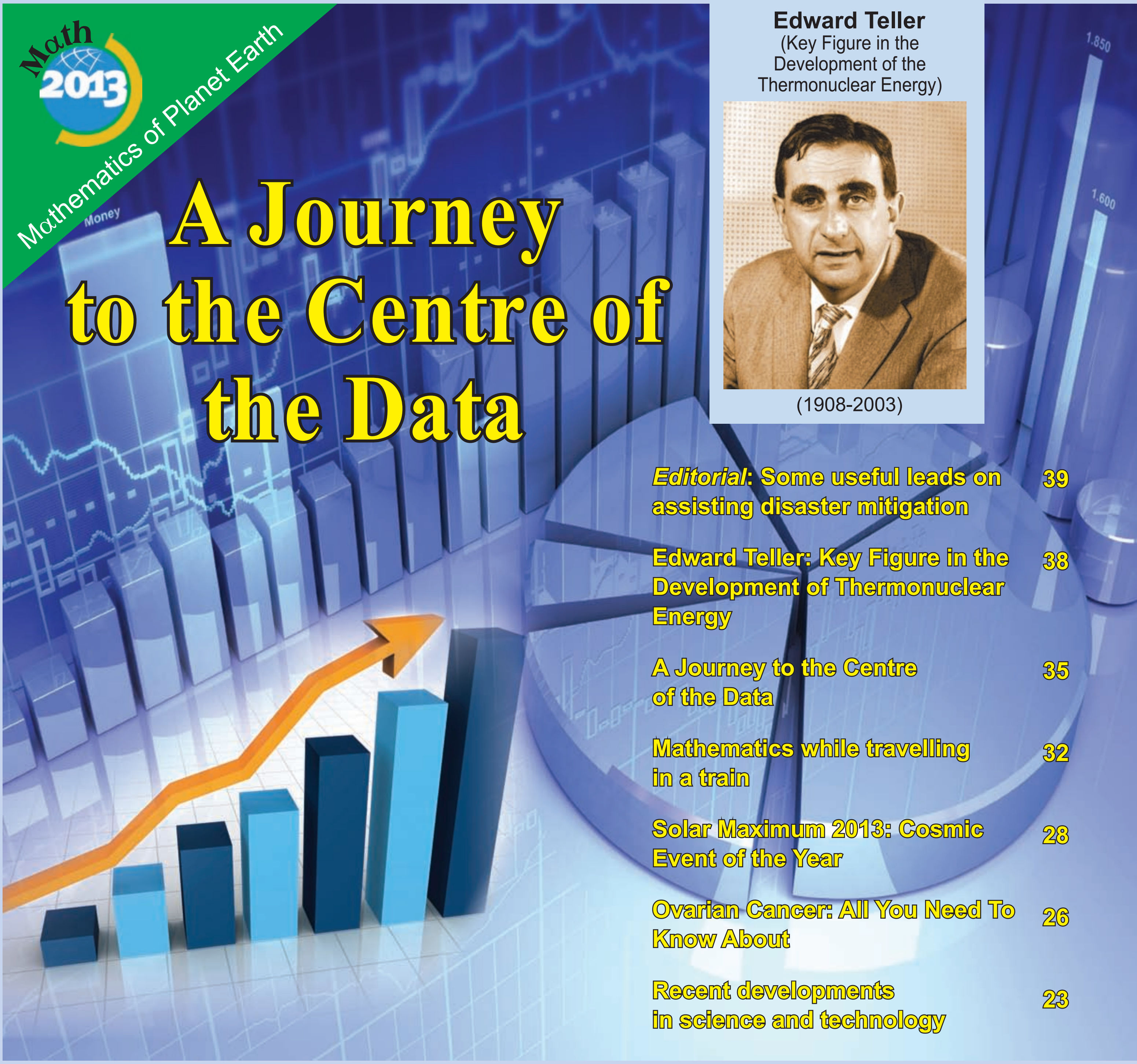

A Journey to the Centre of the Data

Edward Teller
(Key Figure in the Development of the Thermonuclear Energy)

(1908-2003)

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

Some useful leads on assisting disaster mitigation

Dr. R. Gopichandran

Vigyan Prasar salutes the tenacity of purpose shown by all the rescuers post-disaster in Uttarakhand recently. This salutation is however tempered with grief due to the vicissitudes faced /endured by the survivors and the agony of fellow citizens who have lost their belongings/livelihood/loved ones. Post-disaster recovery and rehabilitation are long drawn processes. India has consistently revealed her abilities to recover rapidly form comparable circumstances in the past. This time too she will rise up to the challenges.

The aim of this note is to help dedicated and enthusiastic communicators who tackle impacts of calamities at the grass roots level in Uttarakhand and for those set to launch on similar initiatives. Help in this context is about presenting some credible and useful sources of information that can guide development and implementation of communication strategies as part of disaster management.

Before I go any further, I wish to indicate that the Ham Radio initiative at Vigyan Prasar has been active during the recovery phase post-disaster in Uttarakhand. Our colleague Shri Sandeep Baruah used the facilities based in Vigyan Prasar to connect with and enabled further communication with the involvement of Ham Radio volunteers in Uttarakhand. The benefit of Ham Radio operations in the short wave – high frequency bandwidth helped overcome challenges posed by several other modes of communication. Baruah is of the considered view that large numbers of ready-to-use Ham Radio related kits are needed immediately so that they can be handed over to volunteers along with adequate and appropriate training to deliver. This will suitably complement other modes of large-scale communication in disaster situations. Thanks to NDTV, Hindi channel for highlighting the importance of this approach recently.

Some of the important sources of useful information on disaster management related activities are:

- A snapshot on India's large scale institutional mechanisms (1);
- Gender sensitive approaches with case examples by the Brookings Institute (2);
- Leadership exhibited by communities/individuals to develop locally adapted solutions as presented by the Climate and Development Knowledge Network (3); and
- The Human Development Report 2010 of the UNDP that presents a comprehensive analysis of interplay of determinants of vulnerability (4).

These are in addition to the valuable resources that can be accessed through the Prevention Web. (5)

The scale and diversity of impacts wreaked by the recent disaster should only strengthen the resolve to communicate sector/thrust area-specific science and technology-based mitigation and adaptation strategies of direct relevance to recovery and rehabilitation. The special emphasis has to however be on the phenomena, causes, individual and synergistic influences, predominant, tangible and underlying principles, natural and artificially induced changes and institutional mechanisms to develop locally adapted solutions. These are truly useful windows of opportunity to enable larger scale transitions to sustainable development guided by empirical evidences; going far beyond subtle mind-set-based targets of communication. The importance of well-informed action cannot be overemphasised in this context. Communication on these aspects on a priority basis and actions enabled thereof will also will also enhance the credibility of communicators, clearly going beyond clichéd rhetoric.

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Edward Teller

Key Figure in the Development of Thermonuclear Energy

Dr. Subodh Mahanti
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"Edward Teller did not avoid controversy in a life filled with superb science, invention, and human drama. Istvan Hargittai's honest account is the first balance reading we have of the character and achievements of this remarkable, thrice-exiled scientist, the father of hydrogen bomb."

Roald Hoffman, Nobel laureate while commenting on the biography of Teller written by Istvan Hargittai

"Edward Teller was one of the great physicists of the twentieth century. His career began just after the key ideas of the quantum revolution of the 1920's were completed, opening vast areas of physics and chemistry to detailed understanding. Thus, his early work in theoretical physics focussed on applying the new quantum theory to the understanding of diverse phenomena. Later, he made key contributions to statistical mechanics, surface physics, solid state and plasma physics. In many cases, the ideas in these papers are still rich with important ramifications."

S. B. Libby and M. S. Weiss in *Edward Teller's Scientific Life,* Lawrence Livermore National Laboratory, 2004

"Teller is often referred to as the 'father of the hydrogen bomb'. Insofar as he made the initial proposal in 1942, worked longest on the project, and campaigned most vigorously for its completion, the description is accurate. If, however, the phrase is taken to mean that bomb exploded in 1951 was Teller's own design, the description is misleading."

A *Dictionary of Scientists,* Oxford University Press, 1999

Edward Teller is often referred to as the 'father of hydrogen bomb', though he himself did not like the title. He is also referred to as 'Master Bomb Maker' and 'Statesman of Science'. Teller was one of the great scientists of the twentieth century and at the same time one of the most controversial scientists. He evoked extreme views. To his admirers he was the hero of the Cold War and to his detractors he was the evil personified.

The Gamow-Teller theory of weak interactions or selection rules for beta decay, the Lyddane-Sachs-Teller relation, the Jahn-Teller effect and theorem, Goldhaber-Teller resonance, the "BET" (Brunauer-Emmet-Teller) equation of state, the Ashkin-Teller generalisation of the Ising Model, Poschl-Teller exemplar of anharmonic quantum mechanics, and MR^2T^2 (N. *M*etropolis, A. W. *R*osenbluth, M. N. *R*osenbluth, Augusta H. *T*eller and Edward *T*eller) algorithm are examples of Teller's significant scientific contributions. The Gamow-Teller theory of weak interaction was Teller's first important contribution in nuclear physics. Initially it had to compete with an alternate theory proposed by Enrico Fermi. However, Fermi's theory proved to be wrong. The Gamow-Teller theory became the basis for a unified theory of weak interaction. Teller's elucidation of the Jan-Teller Effect in 1933 is often considered as his most important scientific contribution. His works on diamagnetism, level crossings, many-body valence bases, and dissipation of sound are of present significance.

Edward Teller

Teller was an inspiring teacher and mentor. He was known for his personal warmth, generosity and openness. Many of his students and young collaborators became famous in their fields. Nobel laureate Maria Goeppert-Mayer acknowledged Teller as an important mentor. Teller favoured a strong defence policy. He also called for the development of advanced thermonuclear weapons and continued nuclear testing. He was a strong proponent of an anti-ballistic missile shield. He worked on and campaigned actively for the Strategic Defence Initiative (SDI) or "Star Wars" as it was popularly called. He described his ideas on SDI in his book *Better a Shield than a Sword* (1987). The SDI project was abandoned in 1993.

Edward Teller (the native form of his name was Teller Ede) was born on 15 January 1908 in Budapest, Hungary (then one of the important cities of the Austro-Hungarian Empire). Hungary became an independent nation after the First World War demolished the Empire. His father Max Teller was a lawyer and his mother Ilona Teller was a pianist. Teller entered the Minta gymnasium at the age of nine and he graduated from the Gymnasium in June 1925.

Young Teller was a mathematical prodigy. He could calculate in his head large numbers such as the number of seconds in a year. He wanted to study mathematics but his father thought that the prospect of getting a job after studying mathematics was not good. Finally it was decided that Teller would study chemical engineering. In 1926 Teller left Budapest for Karlsruhe in Germany to study chemical engineering at the Karlsruhe Technical University. Teller later recalled: "My father said I couldn't make a living that way, so we compromised, a little painfully, on chemistry. But I cheated. I studied chemistry and mathematics. After two years, my father gave up and told me to study what I wanted."

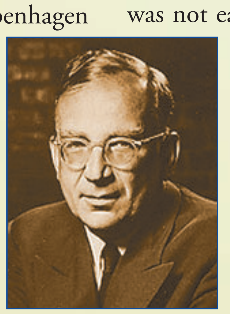
Arnold Sommerfeld

In April 1928, Teller was transferred to Munich University to pursue his academic interest under Arnold Sommerfeld. At Munich, a streetcar accident cost Teller his right foot. He had to be fitted with prosthesis. After his recovery he went to the University of Leipzig to work under the supervision of Werner Heisenberg as Sommerfeld had gone abroad for a year. Heisenberg was just six years older than Teller, but at such an early age he had attained world fame in physics and had gathered a number of students around him, namely Friedrich von Weizsacker, Lev Landau, Felix Bloch, Friedrich Hund, Rudolph Peierls, J. H. van Vleck, and Robert Mulliken all of whom later became great physicists. In 1930, he obtained his PhD in physics from the University of Leipzig. His PhD thesis described one of the first accurate quantum mechanical treatments of the hydrogen molecular ion. After his PhD he joined the University of Gottingen as research associate. However, he could not settle in Germany permanently as Adolf Hitler's Nazi regime came to power and started implementing racial policies. Hitler was particularly against the Jewish community.

Werner Heisenberg

In 1934, Teller left Germany with the help of the Jewish Rescue Committee. From Germany he went to England and after a brief stopover in London he went to Copenhagen, where he worked with Niels Bohr for a year. At Bohr's Laboratory he came in contact with George Gamow. From Copenhagen Teller again moved to London while Gamow went to George Washington University. In 1935, Teller went to the USA to join George Washington University at the invitation of Gamow. In Washington, Teller worked with Gamow till 1941 when he joined the top secret Manhattan Project commissioned for developing the atom bomb before Hitler's Nazi regime achieved it in Germany. Nuclear fission was discovered by the German scientists Otto Hahn, Fritz Strassman and Lise Meitner in 1939. This opened up the possibility of releasing energy by splitting the atom, which could be converted into the most destructive weapon ever known to humanity. Teller and many other physicists, who were forced to leave Germany and other countries under Germany's influence because of Adolf Hitler's anti-Jewish policies, became deeply concerned over the possibility that this most dangerous weapon might fall in the hands of Hitler. They were more concerned because of the fact that Germany's nuclear programme was headed by none other than Heisenberg. Leo Szilard, a friend of Teller persuaded Albert Einstein to bring this possible danger to the attention of the then US President Franklin Roosevelt. It was Szilard who prepared the famous letter for President Roosevelt informing him of the discovery of fission and the possibility of nuclear bombs. Szilard decided to get the letter signed by Einstein, then the most celebrated scientist of the world. Teller accompanied Szilard when the latter visited Einstein at his summer home on Long Island. It is said Teller went there because Szilard could not drive a car. Teller later joked that he began his career in nuclear physics as Szilard's chauffeur. He also recalled that it was not easy to locate Einstein. He wrote: "It was a little difficult to find Einstein. Several inquiries failed to elicit the whereabouts of this obscure personage. In the end we asked a young girl not yet 10 years of age, with two fairly long braids, who responded positively to an inquiry about a nice old gentleman with plenty of white hair." There is no consensus on whether President Roosevelt actually read the letter. Apparently the President was satisfied with the summary made for him by Alexander Sachs, who had taken the letter signed by Einstein to the President.

Niels Bohr

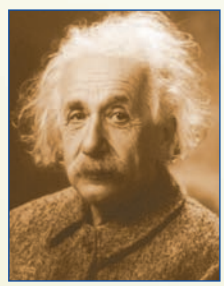


George Gamow

Leo Szilard

Whatever might be the case, an official Advisory Committee on Uranium was established which ultimately led to the creation of the Manhattan Project (then the most stop secret project) with the objective of developing atom bomb. The project formed the greatest collection of America's best scientific talent into a productive team.

After becoming part of the Manhattan Project, Teller first worked with Enrico Fermi in Chicago and then moved to Berkeley to work with J. Robert Oppenheimer. From Berkeley Teller moved to the isolated Los Alamos Scientific Laboratory secretly established in New Mexico. It was at Los Alamos where the first atom bomb was produced under the leadership of Oppenheimer. The atom bomb was successfully tested at Alamogordo in New Mexico in 1945 and weeks after the first successful test two atom bombs destroyed the Japanese cities Hiroshima and Nagasaki, which forced Japan to surrender, marking the end of the Second World War. It may be noted that Germans were far behind from producing the bomb. Teller's most important contribution to the development of the atom bomb was his calculation that a nuclear explosion would destroy a limited area and it would not continue indefinitely destroying the Earth as thought by some scientists.



Albert Einstein

J. Robert Oppenheimer

As early as 1940 Teller was thinking beyond the atom bomb. It was Enrico Fermi who had originally suggested that the fusion of hydrogen atoms might create even more powerful force than splitting atoms. Teller found Fermi's idea worth pursuing. However, Oppenheimer, the director of the Los Alamos Laboratory was not in favour of developing hydrogen bomb that involves fusion of hydrogen atoms. After the end of the Second World War, Teller left Los Alamos laboratory and started teaching at Chicago University in Illinois. During his stay at Chicago he did research work and collaborated with Enrico Fermi (on the capture of negative mesons in matter), Maria Goeppert-Mayer (on the origin of chemical elements) and Robert Richtmyer (on the origin of cosmic rays).

Teller revived the idea of producing hydrogen bomb after the erstwhile USSR tested its first atom bomb in 1949. Teller argued that the USA needs the hydrogen bomb for its defence and the then US President Harry Truman accepted Teller's suggestion. Teller went back to Los Alamos and started working on the hydrogen bomb. Finally Teller and Stanislaw Ulam came up with a design that would work. Teller was not chosen as head of the project. The first hydrogen bomb was successfully tested in the Pacific Ocean in 1952.

Stanislaw Ulam

Teller was convinced about the inevitability of the hydrogen bomb and he pursued it doggedly. Teller himself termed the development of the hydrogen bomb as 'the work of many people.' There is no doubt that he was the driving force behind the production of H-bomb. *The Economist* wrote: He (Teller) believed the development of H-bomb was inevitable. That may be true, but Teller pushed the inevitability forward. Perhaps more than anyone else, he pushed its "sweet technology". He was a patriot; more than that, he was imbued with a fierce sense of patriotism that seems to be characteristic of immigrants who have totally and gratefully embraced America. His native Hungary suffered fascist rule in the years before the Second World War and communist rule afterwards."

Towards the end of his professional career Teller was excommunicated by the scientific community because of his testimony against Oppenheimer. It is believed that this was because of Teller's views on the suitability of Oppenheimer from security point of view in handling top secret security projects. Teller reportedly said: "I feel that I would like to see the vital interests of this country in hands which I understand better, and therefore I trust." The US Atomic Energy Commission suspended Oppenheimer's security clearance following a recommendation of special panel constituted by it. It was to be decided whether he was a security risk and a formal enquiry began. This led to the cancellation of Oppenheimer's security clearance. It may be noted that Oppenheimer's relatives including his wife were communists and he himself was associated with communist organisations in Berkeley in the 1930s.

Teller was deeply hurt by the desertion by fellow scientists with whom he interacted and worked. Teller once said:" If a person leaves his country, leaves his continent, leaves his relatives, leaves his friends, the only people knows are his professional colleagues. If more than 90 percent of these men then come around to consider him an enemy, an outcast, it is bound to have an effect. The truth is it had a profound effect. It affected me, it affected Mici (his wife); it even affected her health."

Teller was appointed Director Emeritus at the Lawrence Livermore National Laboratory and Senior Research Fellow at the Hoover Institution, and both these positions were held by him till his death.

Teller authored/co-authored a number of books including *The Structure of Matter* (with Francis Owen), John Wiley and Sons, New York, 1949; *Our Nuclear Future* (with Albert T. Latter), Criterion Books, New York, 1958; *The Legacy of Hiroshima*, (with Allen Brown), Doubleday and Co., New York, 1962; *The Reluctant Revolutionary*, University of Missouri Press, Columbia, 1964; *The Constructive Uses of Nuclear Explosives* (with Wilson K. Telley and Gary H. Higgins), McGraw Hill, New York, 1968; *Great Men of Physics* (With Emilio G. Segre, Joseph Kaplan, Leonard I. Schiff), Tinnon-Brown, Los Angeles, 1969; *Critical Choices for Americans: Power and Security* (with Hans Mark and John S. Foster), Lexington Books, Lexington, 1976; *Nuclear Energy in the Developing World*, Mitre Corporation, Metrek Division, McLean, 1977; *Energy from Heaven and Earth*, W. H. Freeman and Co., San Francisco, 1979; *Better a Shield Than a Sword*, Free Press/MacMillan, New York, 1987; *Conversations on the Dark Secrets of Physics* (With Wendy Teller and Wilson Talley), Plenum Press, New York, 1991; and *Memoirs: A Twentieth-Century Journey in Science and Politics* (with Judith Shoolery), Perseus Publishing, Cambridge, MA, 2001.

He won several honours and awards including Albert Einstein Award of the Lewish and Rosa Strauss Memorial Fund (1958), Harrison Medal of the American Ordance Association (1955), Enrico Fermi Award of the US Atomic Energy Commission (1962), Harvey Prize of the Technical Institute of Israel (1975), the US National Medal of Science for 1982, Shelby Cullom Davis Award (1988), Fannie and John Hertz Foundation Award (1988), Presidential Citizens Award (1989) by the US President Ronal Reagan, Order of Banner with Rubies of the Republic of Hungary (1990), Middle Cross with the Star of the Order of Merit of the Republic of Hungary (1994), a Magyarsag Hirneveert Dij, the highest official Hungarian government award (1998), the US Department of Energy Gold Award (2002), and the Presidential Medal of Freedom by the US President George Bush, Jr. in 2003.

Teller died on 9 September 2003 in Stanford, California.

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(The article is popular presentation of the important points on the life and work of Edward Teller in the existing literature. The idea is to inspire the younger generation to know about EdwardTeller. The source consulted for writing this article has been listed. However, the sources on the Internet have not been individually listed. The author is grateful to all those authors whose writings have contributed to writing this article. The author is also grateful to the sources from which the illustrations/photographs have been reproduced.)

A Journey to the Centre of the Data

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Last week, the results of the Board examinations were announced. Our school reportedly did very well. Our teachers were encouraging us to do better than our seniors. I was quite perplexed though. It is true that I could see many jubilant and triumphant faces, but I also could not miss out some sombre and sad faces in the background. It was apparent that they did not fare as they had expected. I was wondering if they did not do well, the school surely did not do well at least for some students.

One evening I expressed my confusion to my uncle.

'Googol, you are right to some extent. If we consider those few unfortunate students, yes, the school did not do well based on the performance of those selected few. But taking into account the performances of all the students, we can say that the school on average did well.'

'Uncle, I did not understand how I can account for all individual students and still speak about the school as a whole. Could you please explain this to me?'

'Googol, this is where the statistical principles come into action – to draw out meaningful information from the data. Let me give you a simple example. Suppose the driver of your school bus logs in the time of your school journey time every day on his log book. Now if someone is interested to know the journey time to your school, it will not be a good idea to present several years of the log books. There should be something that should represent the whole dataset by a specific acceptable value. In statistical parlance, this is explored using summary statistics or descriptive statistics of the data.'

'From my experience, I can say that the journey time is 30 minutes. But, some day it is shorter when it takes 25 minutes, while some other day it is much longer when it takes 40 minutes.'

'Yes Googol, you are getting the idea.'

'I am still thinking how we can represent the whole dataset by a single value?'

'Well, it's not important that we have to represent the whole data with a single value, but we can capture the essence of the data using a variety of concepts of statistical theories – one of them is the central tendency of the data.'

Arithmetic mean refers to a central value of a set of numbers. It is the most common form of measurement of central tendency.

'What is it?'

'In statistics, a measure of *central tendency* is a concept that reflects the central value of the data. Statistically speaking, any data can be assumed to follow a *theoretical probability distribution*, and a measure of central tendency focuses on the centre of the distribution.'

'What are the different measures of central tendency?'

'Arithmetic Mean (AM) is one of the measures of central tendency.'

'Uncle, please tell me more about the arithmetic mean.'

'*Arithmetic mean* refers to a central value of a set of numbers. It is the most common form of measurement of central tendency. It is calculated as *the sum of the values divided by the number of values.*'

'Yes, I heard about that. Is it also called average?'

'Yes, in general, the arithmetic mean is also called *average* or the *mean* in short.'

'Tell me more about calculating the arithmetic mean.'

'Well, let's consider we have a *set* of four values: {2, 5, 3, 6}. For illustration purpose, assume the set represents our data. As I have told you earlier, to obtain the arithmetic mean of a set of values, you have to add all values and then divide the sum by the number of values. Now Googol, could you figure out the arithmetic mean of these four values?'

'Let me figure it out. I have to add all values first, that gives (2 + 5 +3+ 6) = 16. Now I have to divide the sum by number of values which is 4. So the arithmetic mean of the set {2, 5, 3, 6} is 16/4 = 4.'

'That's correct, Googol. The calculation of the arithmetic mean is exactly the same whether we have four values or one million values. For a set of large number of values, a calculator or computer will do this job for you in fraction of a second.'

'Tomorrow I will calculate the arithmetic mean of age, height and weight of my 10 friends.'

'Yes, for any variables like age, height, weight where the data are continuous in nature, you can calculate the arithmetic mean. A variable is said to be a *continuous variable* when it can take any values in a *continuum*. For example, you can measure the weight of your friend in kilograms. But you may be interested to measure it with much higher precision, if at all possible with a weighing balance having higher precision. In that case, you may measure the weight of your friend in grams or may be in milligrams!' Uncle smiled.

'I understand that the arithmetic mean is a very common measure of central tendency.'

'You are right, Googol, the examples

of arithmetic means are used everywhere. In fact, most often when we speak about the mean, we do generally imply the arithmetic mean. This is a very simple measurement to compute and comprehend. For example, your teacher must have calculated the arithmetic means of the scores of all students in the class for different subjects. That would give her the idea about how on average the class is performing on a specific subject.'

'Uncle, I have now realised that the arithmetic mean is very simple and easy to understand, but is there any problem with this particular central tendency measurement as a summary statistic?'

'It's a good question, Googol. To understand this, you should remember that the very basic premise of central tendency is to present the central value of the data which the arithmetic mean does in most circumstances. But it's not always the case. Let's come back to our previous set of four values {2, 5, 3, 6}. Now if we have another value 100 in this set, what will be the arithmetic mean of this set of values?

'Let me try this one out, uncle. The set of values we have: {2, 5, 3, 6, 100}. Hence, the arithmetic mean is: (2 + 5 + 3 + 6 + 100)/5 = 116/5 = 23.2'

'You got it right, Googol. Now tell me what do you feel about this measurement of arithmetic mean as the central tendency for the set of those five values?'

'I'm finding it not-so-obvious to consider 23.2 as a central value of the set {2, 5, 3, 6, 100}.'

'That's exactly the point. To be precise, it's clear that the arithmetic mean 23.2 does not even belong close to four values in the set. It would therefore be unreasonable to consider 23.2 as an ideal candidate to represent the central tendency of our data set. So the arithmetic mean is not the ideal solution here.'

'I feel that a different kind of central tendency measurement will solve this conundrum.'

'Yes and that is called median. The *median* is another measure of central tendency which is the *exact central location* or the *middle value* in a set of values. The median *partitions the data exactly in two equal half* where 50% or half of the data are lower than the median value and the rest 50% or half of the data are above the median value.'

The *median* is another measure of central tendency which is the *exact central location* or the *middle value* in a set of values.

'And how do we calculate the median?'

'To calculate the median, there are three steps. First, we have to arrange the values in the set in *ascending order* or the lowest to highest values. In the second step, we have to find out the *middle location* of the set of values. Finally, the median is *the value at that middle location*. Well, why don't you try to find out the median of the five values that we have just considered.'

'Right, uncle, let me give it a try. Our set of values is: {2, 5, 3, 6, 100}. First, we have to arrange these values in ascending order. The set from the lowest to highest will be: {2, 3, 5, 6, 100}. Then, we have to find out the middle location of the set of values. There are five values; so the middle location will be the value at number three. Finally, the value in the third location of the ordered set of data is the median. Hence the median of the set of values {2, 3, 5, 6, 100} is 5.'

'That's correct, Googol. I hope that you would also now appreciate that the median is a sensible representation of the central tendency in this dataset.'

'Yes, I can see it now. The median has partitioned the data exactly into two halves - half of the values are below 5 and half of the values are above 5.'

'As you have noted that the median is not influenced by arbitrary high values in the dataset like the arithmetic mean. Statistically speaking, the median is of central importance in *robust statistics*, as it is also the most resistant statistic, having a breakdown point of 50%. As long as no more than half the data is contaminated, the median will not give an arbitrarily large result.'

'Uncle, I was just thinking how we can estimate the median when we have even number of values in a set, for example, we have an additional 9 in our set: {2, 3, 5, 6, 9, 100 }.'

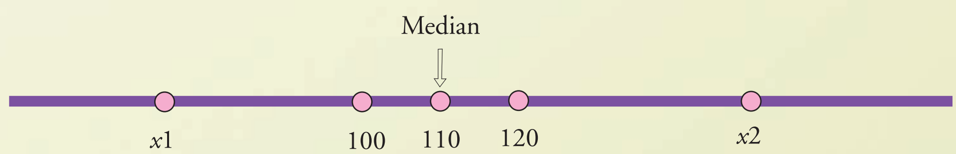
'Yes, for *odd number* of values in a set, it is easier to find the location of the median which is simply $(N+1)/2$ where N is number of values in the set. For example, for a set of 5 values, the median is located at the (5+1)/2 or the 3rd position of the ordered data. For *even number* of values, we cannot get a single location, but we fix on two central locations and the median is the *arithmetic mean of the values at these two locations*.'

'Right, that means for the set of values {2, 3, 5, 6, 9, 100}, the two central locations are third and fourth. So the median will be the arithmetic mean of the values at these locations which is: (5+6)/2 = 5.5.'

'That's a right answer, Googol. Mathematically, when N is even, computer calculates those locations as: *floor*($N/2$) and *ceiling*($N/2$). The functions *floor*(x) means that you need to take the largest integer which is not greater than x and *ceiling*(x) means that you need to take the smallest integer which is not less than x, and in our formula of the location, $x = N/2$.'

'I appreciate it now why the median is a useful measurement of the central tendency of the data.'

'Let me give you an insight into the concept of the mean and the median using the number line. For example, in the number line we have a set of five values where three values are 100, 110 and 120. Other two values X1 and X2 where X1 is less than 100 (i.e. X1 < 100) and X2 is greater than 120 (X2 > 120). Now the estimate of median of the set of these five values will be 110 irrespective of the values of X1 and X2. However, if X1 is close to 100 and X2 is much greater than 120, then the mean will be more influenced by X2. On the other hand, when the value of X1 is much less than 100 and X2 is closer to 120, the mean will be more influenced by X1. So the mean is influenced by extreme values at either end.



"Uncle, could you please give me some real life examples where the median is the most sensible measure of central tendency of the data.'

'As you may have realised by now, whenever we come across extreme values in the data, the median would be appropriate. Many policy and financial matters are involved with the median. A simple example is the annual income of people. If it is of interest to know a summary statistic of the annual income of people in a region, it is not ideal to estimate the mean, as few persons with very high incomes will distort the picture. In that case, a median will give you the exact idea which will tell us that 50% of the population in the region earns less than the median while other half earns more than the median. That is the reason that often the summary statistic on salary of an organisation is given by the median salary value rather mean salary value.'

The *mode* is the value that has the highest frequency in the data.

'Is there any other measurement of the central tendency of the data?'

'Another central tendency measurement is called the mode. The *mode* is the value that appears most often in a set of data. Or in other words, the mode is the value that has the highest frequency in the data. It is important in some circumstances as the mode identifies the value that is most likely to be sampled.'

'Please explain this further, uncle.'

'Continuing our simple example, suppose if we have a new set of values as: {2, 6, 3, 5, 6, 9, 100, 6, 3}. Googol, could you find out the mode of this set of values?'

'Well, let me decipher it. The mode is the value that appears most frequently and here the values 2, 5, 9 and 100 appear only once, 3 appears twice and 6 occurs thrice. So the mode of the set {2, 6, 3, 5, 6, 9, 100, 6, 3} is 6.'

'That's correct, Googol. The mode can be calculated not only for the variables that are measured numerically, but it is also applicable to the categorical variable. A *categorical variable* is a variable that can take on one of a limited, and usually fixed, number of possible values. For example, the variables season may take six values, month (12 values), gender (two values), etc.'

'Yes, I realise now that it is easy to count the frequency for categorical variable, like how many boys and girls are there in my class.'

'The mode is logically easy to comprehend when values are *categorical or discreet* in nature (i.e., the data are measured by simple counting). Here, the mode is simply the value that takes the highest frequency. However, the mode is also valid for the continuous type of data like age, height or body weight. As we discussed before, these variables can take values in a continuum and so the same principle of highest frequency is not readily applicable. In statistical term, if you draw the curve of the underlying theoretical distribution of the continuous data, the mode is the value where the curve shows its peak. Also note that the mode is not necessarily unique since the maximum frequency may be attained at different values.'

'Uncle, please give me an example of the mode.'

'The mode is an important measure of central tendency in many situations. Imagine a business is selling different types of a food item like biscuits, and it may be of interest to know which brand is selling the most. This is identified by the mode. Similarly, some shoe sizes are most common in the population and therefore the mode of the shoe size is important for the manufacturer or the business.'

'I see that the statistical principle is important at every part of our life. Do we have more measures of central tendency than the mean, the median, and the mode?'

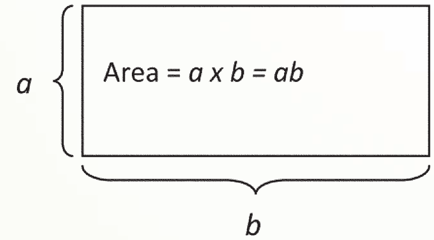
'Well, there are several other measurements. But two other common measurements are the geometric mean (GM) and the harmonic mean (HM).'

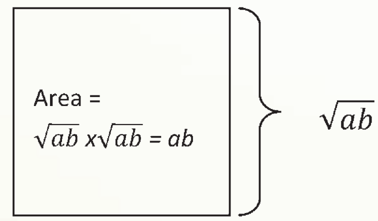
'What is a geometric mean?'

'In mathematics and statistics, the *geometric mean* is another type of mean or average, which indicates the central tendency of a set of values represented by the product of their values. The geometric mean is defined as the *n*th root (where *n* is the number of values in a dataset) of the product of the values. For instance, the geometric mean of two values, say 2 and 8, is just the square root of their product; that is, $\sqrt[2]{2 \times 8} = 4$. Mathematically, the geometric mean of a set of *n* values $\{x_1, x_2, x_3, \ldots .. , x_n\}$ can be expressed as: $\sqrt[n]{x_1 \times x_2 \times \ldots \ldots \times x_n}$.'

'The calculation of the geometric mean is quite complicated.'

'A simple concept of the geometric mean can also be understood in terms of geometry. The geometric mean of two numbers, *a* and *b* is the length of one side of a square whose area is equal to the area of a rectangle with sides of lengths *a* and *b*. This concept can be readily extended to more than two-dimensional scenario to account for more than two numbers.' Uncle explained.





'When is the geometric mean a sensible measurement of central tendency of the data?'

'The geometric mean is often used for a set of values that are meant to be multiplied together or are exponential in nature, such as data on the growth of the human population or interest rates of a financial investment. In those circumstances, the geometric mean is an essential measurement to capture the central tendency of the data. Note here that the geometric mean applies only to positive values as real numbers cannot represent the root of a negative number.'

'You have also mentioned about the harmonic mean. What is a harmonic mean?'

'In mathematics and statistics, the *harmonic mean* (sometimes also called the *subcontrary mean*) is appropriate for situations when the average of rates is desired. Mathematically, the harmonic mean of a data set $\{x_1, x_2, x_3, \ldots .. , x_n\}$ is given by:

$$HM = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3} + \ldots\ldots + \frac{1}{x_n}}$$

For example, for a set of three values {3, 4, 5},

$$HM = \frac{3}{\frac{1}{3} + \frac{1}{4} + \frac{1}{5}} = \frac{3}{(20 + 15 + 12)/(3 \times 4 \times 5)} = 3.8298$$

'And where can we apply the harmonic mean?'

'In situations involving rates and ratios, the harmonic mean provides the truest average. In physics, computer science,

Continued on page 29

Mathematics while travelling in a train

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Introduction

In the year 2012 we had observed the National Year of Mathematics. As a part of the commemoration the author had taken part in many programmes targeted towards allaying the fears about mathematics and in the process had interacted with many students, teachers, and guardians. It was observed that there exists a lot of fear psychosis about mathematics in the mind of the young learners. Often, more than the learners it is the guardians who suffer from such a fear psychosis and their wards cannot escape the contagion. So it was felt that one of our prime objectives should be to spread awareness about the fact that mathematics is a way of life.

Indeed mathematics has pervaded into our overall existence in many ways. In the world of science it is the language of all explanations ranging from the microcosm to the macrocosm. However, the common man should be made to realise that mathematics is a way of life. In our daily household chores, we have to undertake a good bit of accounting, time budgeting, all of which are dependent on mathematics. The subject has been applied to a significant extent in the design and construction of the house we live in, preparation of the furniture we use and so on. Incidentally quite a good bit of the subject can be learnt while travelling in a train. Through this article we shall present some examples.

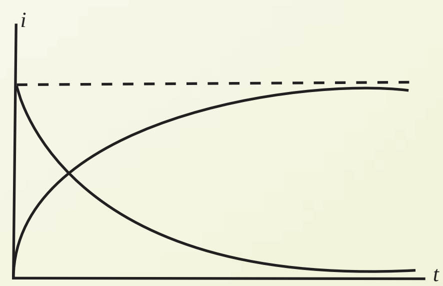
Asymptotism

It may appear that we are beginning our journey with a difficult concept. The very word 'asymptotism' may sound unfamiliar. But an unfamiliar word does not essentially mean that the concept would be difficult. As a matter of fact, the objective is to allay the misgiving that the concept is difficult. It will be indeed dealt in a very simple manner.

Let us visualise the railway tracks. They are parallel. Stand on a railway track where it goes absolutely straight; that is, it does not curve or bend. Make sure that no train is coming from either side. If you stretch your view to the furthest point possible the rails will give an appearance that they are meeting. If you keep moving ahead, the point where they had been appearing to meet will move further and further. Parallel lines do not meet ever. We say that they meet at infinity. This brings out the concept of asymptotism. It becomes quite significant in various studies, conspicuous among them being the cases of exponential growth and decay, which we come across in electric circuits having inductance and capacitance.

Current in an electric circuit having inductance (L) and resistance (R) grows to a steady value theoretically in infinite time after the switch is put on. Similarly, it goes to zero also in an infinite time after the switch is put off. The same happens with charge in a circuit having a capacitor (C) and a resistance (R).

Fig. 1. *Growth and decay of current in an L-R Circuit*



Refer to Fig.1 which represents the variation of current (i) with time (t) during its growth and decay in an L–R circuit. In Fig. 1, i approaches a steady value i_o in infinite time. The curve never meets the line i=i_o, but keeps approaching it, almost like two parallel tracks. Similarly while decaying, i keeps approaching the value 'zero', and the curve meets the t-axis at t=∞. Similar are the situations in respect of growth and decay of charge with time in C-R circuits. Other significant examples are the phenomenon of radioactive decay (Fig.2) and of course the normal distribution curve (Fig.3).

Fig. 2. *Radioactive decay (N is the number of atoms at time t)*

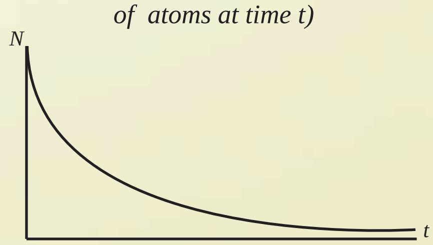
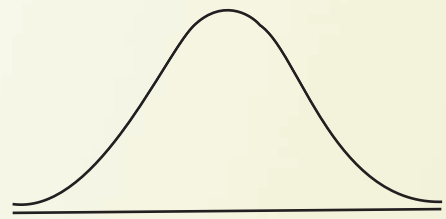


Fig.3: *The normal distribution curve*



In Fig. 2, we see that the number of atoms reduces to zero again at t=∞. The curve approaches the t-axis asymptotically. Similarly in Fig.3, we find that the tails of the normal distribution curve approaches the x-axis (the negative side at minus infinity and the positive side at plus infinity). The approach in either case is asymptotic. The reader may please not misconstrue that the technicalities of these graphs (Figs. 1-3) are being explained here. The idea is to bring home the concept of asymptotic approach by observing the parallel structure of two railway tracks.

Measurement of speed

How about measuring the speed of train while travelling in it!

Many a reader must have given it a try. The vertical posts which you come across while travelling in a train are placed 100m apart. So these provide a very handy tool for measuring the average speed. Suppose you start your stopwatch (in your mobile phone) exactly when it crosses a post and stop it when it crosses the next post. If the time recorded is 9.92 seconds then the average speed is $\frac{100}{9.92}$ metres per second, i.e., 10.08 metres per second or 36.29 km per hour. If the time recorded is 5.06 seconds then the speed is 19.76 metres per second or 71.15 km per hour. Thus you can assess whether or not the train is travelling with uniform speed. If it is accelerating or decelerating you can make an attempt to determine the value of its acceleration and deceleration as the case may be. Most importantly, if you know the distances between the stations you can figure out whether or not you will be able to reach your destination in time, or if the train is running late then what is the extent of delay and so on. I have assigned to many learners one problem related to average speed, which states that a train travels from a station *A* and goes to a station *B* with a speed of 50 km per hour and returns from *B* to *A* with a speed of 60 km per hour. Then what is its average speed for the journey? The answer that I generally get is 55km per hour which is the arithmetic mean (AM) of 50 and 60. A careful calculation will establish that the AM is not the right answer. If the distance between *A* and *B* is *x* in km, then the time taken respectively for the onward (*A* to *B*) and return (*B* to *A*) journeys are $\frac{x}{50}h$ and $\frac{x}{60}h$ respectively. So the average speed, which is determined as the total distance travelled by the total time taken, works out to be

$$\frac{2x}{\frac{11x}{300}} \text{ km per hour}$$

$$= \frac{2x}{\frac{11x}{300}} \text{ km per hour}$$

$$= \frac{600}{11} \text{ km per hour}$$

It is interesting to note that if the onward and return journey speeds are respectively '*u*' and '*v*' then the average speed is given by

$$\frac{x+x}{\frac{x}{u}+\frac{x}{v}} = \frac{2x}{x\left(\frac{1}{u}+\frac{1}{v}\right)}$$

$$= \frac{2uv}{u+v}$$

which is the harmonic mean (HM) between *u* and *v*. Thus train travel provides quite an illustrative example the of the HM.

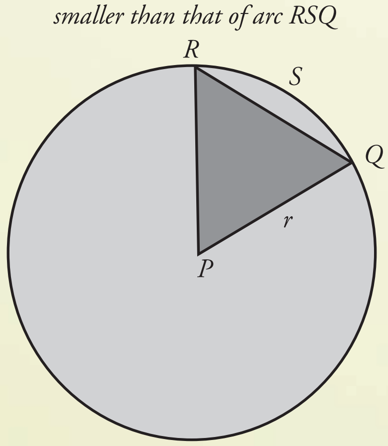
Having discussed the above examples, let us try to explain something which you must have observed while travelling in a train. When the train moves in a particular direction anything stationary outside seems to move in the backward direction with the same speed. This is because of relative motion of the outside landscape with respect to the train. In other words, relative to the passenger sitting in the train, any stationary object seems to move backward with a speed equal to that of the train. Now if you stretch your view far off into the landscape you will find that the objects have a tendency to turn, again in a sense opposite to the motion of the train. Objects lying close by, like a tree will seem to turn with a higher angular speed than those lying far off, like a hill, which will seem to turn with a low angular speed. As a matter of fact the apparent angular speeds of the objects progressively diminish as you stretch your sight away from the train. How do you explain this observation?

Now, whenever an angular motion gets linked with some kind of a linear motion, the relation that becomes operative is, linear speed = (angular speed) × (radial distance). You may recall that for a uniform circular motion, the linear speed = (angular speed) × (the radius of the circle). In the instant case, the relative linear speed of the entire landscape is the same, its magnitude being equal to the speed of the train. So, linear speed remaining fixed, the angular speed becomes inversely proportional to the distance of the object from the train. Hence the angular speeds of the objects diminish progressively as their distances from the train increase.

A simple lesson in geometry

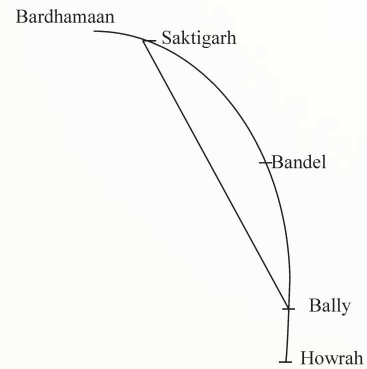
We have come across the word 'chord' in geometry. Basically a student learns about it while studying about a circle. It is the shortest distance between two points on the circumference of a circle. How does it become relevant in connection with train travel? The word 'chord' is not only applicable to a circle. It applies to any curve.

Fig 4: Length of chord RQ is smaller than that of arc RSQ



In Fig.4 we see that *RQ* is the chord of a circle and we know that its length is smaller than the arc *RSQ*. When we travel in a train say from Howrah to Bardhamaan, we often hear a passenger say that the chord line turns from the Bally station. There is nothing wrong in saying that, as indeed the Howrah-Bardhamaan Chord line gets separated from the Howrah-Bardhamaan Main line at Bally, giving the impression that the chord line bends. But this impression in the mind of the passengers is created by the adjective 'Main' in Main line. They feel that the Main line goes straight and the Chord line becomes curved which is not true. The Main line goes northward up to Bandel and then turns west, the total distance between Howrah and Bardhamaan being 105 km (Fig.5). The chord line, as the name suggests, is straight and is the shortest distance between two points on a curve and connects Bally and Saktigarh, making the total distance between Howrah and Bardhamaan via the Chord line only 95 km, which is 10 km less than what we have along the Main line. Thus the word, 'Chord' in railway parlance is a contribution of geometry.

Fig 5: The Main and the Chord lines between Howrah and Bardhamaan



The same holds for the Grand Chord line between Asansol (actually Sitarampur) and Mughal Sarai. The distance along the Main line between Asansol and Mughal Sarai (via Patna) is 555 km, whereas along the Grand Chord line (via Gaya) which effectively gets separated from Sitarampur is 461 km, which is 94 km less.

A lesson in modulo

Now, let us take up another example related to travel by train. Suppose you have got a reserved berth in a 3-tier compartment. Before boarding the train you might be interested to know the position of the berth; that is, whether it is lower, middle, upper, side lower or side upper. Now, in a particular cubicle there are eight berths. In the first such cubicle, 1 and 4 are the lower berths, 2 and 5 the middle and 3 and 6 the upper, 7 is side lower and 8 is side upper. Thus it is a problem of 'Modulo 8'. The outcome is given in the Tabular Form below:

Berth No.	N Modulo 8	Position of berth
N	1 or 4	Lower
	2 or 5	Middle
	3 or 6	Upper
	7	Side lower
	0	Side upper

Thus, if the berth number is '29', we work out 29 modulo 8 and as 29 = 8 × 3 + 5 the value of modulo is '5'. So the position of the berth is 'middle'.

For a 2- tier coach, since each cubicle contains six berths, it will be a problem of *N* modulo 6, as there is no provision of a middle berth. If the modulo is 1 or 3 it is a lower berth, if 2 or 4, it is an upper berth, if 5, it is a side lower berth and if '0', then a side upper berth. Thus we see that by way of application of arithmetic we can arrive at the exact conclusion regarding the position of the berth. If the berth number is again '29' and 29 modulo 6 is 5, here it will be a side lower berth.

Descartes' rule of signs

As we know, there are umpteen numbers of trains between New Delhi/Delhi and Mughal Sarai. The author has also travelled many a time up to Howrah or Patna and en route he has crossed Mughal Sarai. Every train crosses River Yamuna almost immediately after leaving New Delhi/Delhi and again at Naini. Now trains like Rajdhani Express (to Howrah, Patna, Guwahati), Kalka-Howrah Mail, and Sampoorna Kranti Express do not cross River Ganga before reaching Mughal Sarai, which is on the southern side of the Ganga. But Poorva Express (via Varansi) does cross the Ganga at Varanasi and goes to Mughal Sarai, which is on the southern side of the Ganga. So, how does it happen that the trains which do not cross the Ganga and the one that does, both remain on the same side; that is, the southern side of the Ganga at Mughal Sarai? This question had baffled the author and he could find the answer once the Poorva Express coming from New Delhi was unusually late, by more than 10 hours, due to some serious disruption on the track. As per normal schedule the train covers the stretch between Allahabad and Mughal Sarai during night and it is generally not possible

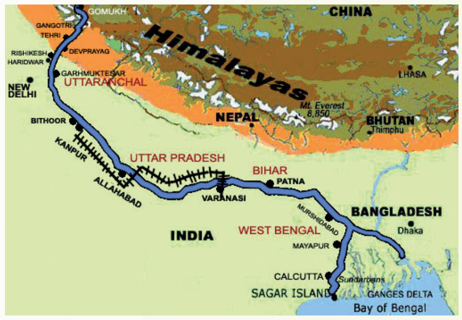


Fig.6. The railway track has been shown with reference to the flow of Ganga. The track crosses the Ganga from south to north at Phaphamau and north to south at Varanasi.

to identify landmarks on the way. Due to the inordinate delay mentioned above the stretch was covered during day time and the author discovered that after leaving Allahabad the train crosses the Ganga from south to north at Phaphamau and again crosses the same river from north towards south at Varanasi before reaching Mughal Sarai (See Fig.6). The crux of the matter is that Poorva Express crosses the Ganga twice while the other trains named above do not cross it at all. Two is an even number, the situation would have been the same, if it had crossed the Ganga any number of times, provided the number is even. Now, we will see that there is a subtle link of the situation described above with the Descartes' rule of signs. Let us explore that.

Descartes' rule of signs provides a way for determining the maximum number of real positive and negative roots of a polynomial equation, in one variable, $f(x) = 0$, by counting the number of times that the signs of its real number coefficients changes when the terms are arranged in descending order of powers. For example, let us consider the equation.

$$2x^5 + x^4 - 3x^3 + 4x^2 - x - 1 = 0 \qquad (1)$$

The signs of the coefficients when the terms are arranged in the descending order of power are:

$$+ \quad + \quad - \quad + \quad - \quad -$$

So, the number of changes is three. Hence, there can be at most three positive real roots. For determining the number of negative real roots, we have to change $+x$ to $-x$ so that the polynomial becomes,

$$-2x^5 + x^4 - 3x^3 + 4x^2 - x - 1 = 0$$

Hence, the number of changes is two. So the maximum possible number of real negative roots is two.

Rene Descartes (1596-1650), a French philosopher and mathematician has given

Rene Descartes

Isaac Newton

Carl Friedrich Gauss

the rule without any proof in *La Geometrie* (1637). Sir Isaac Newton (1642-1717), the famous English physicist and mathematician restated the rule in 1707. However, the earliest known proof was given by the French mathematician Jean-Paul de Gua de Malves (1713-1785), in 1740. But it was the famous German mathematician, Carl Friedrich Gauss (1777-1855), who had made the first real advance in 1828 and extended the rule to state that in cases where the number of real positive roots in less than the maximum; that is, the total number of changes of signs, then the deficit would always be an even number. Hence, for the example given by Eq.1, there can either be three positive roots or one positive root, but it cannot have two positive roots. Similarly, the number of real negative roots will either be two or zero, but not one.

Likewise for the equation,

$$x^4 - 3x^3 + 6x^2 - 12x + 8 = 0\,, \qquad (2)$$

The number of changes is four, and the number of real positive roots are two (i.e., four minus two). It can be verified that these roots are x = 1, $x = 2$, Changing + x to - x the equation becomes,

$$x^4 + 3x^3 + 6x^2 + 12x + 8 = 0, \qquad (3)$$

So, there is no change in sign and hence there are no real negative roots.

But Eq. (2) is a four-degree equation. So it should have four roots. Out of them there are 'two' real positive roots and 'nil' real negative roots. So, what about the remaining two roots! These are imaginary roots and it can be verified that those roots are x= 2j, x = –2j, where j = $\sqrt{-1}$.

Now, the feature of the rule which has links with train travel is the one which emerged out of Gauss' extension of the rule, that is the number of real roots of the polynomial equation, $f(x) = 0$, be it positive or negative, is equal to the number of changes of sign in $f(x)$ or $f(-x)$ as the case may be or less than that by an even number.

Now, let us look carefully into Eq.1. The final term

$= f(0) = -1$, so $f(0) < 0$.

in such case the number of changes is bound to be odd.

Some examples are:

$+ \quad + \quad + \quad + \quad -$ (1 change)

$+ \quad + \quad - \quad - \quad -$ (1 change)

$+ \quad - \quad + \quad - \quad +$ (3 changes)

$+ \quad - \quad + \quad - \quad + \quad -$ (5 changes)

Again in Eq.2, $f(0) = 8$, that is $f(0) > 0$, and the number of changes of sign is four as shown below:

$+ \quad - \quad + \quad - \quad +$ (4 changes)

If $= f(0) > 0$, then the number of changes is always even as evident from the following examples:

$+ \quad - \quad - \quad - \quad +$ (2 changes)

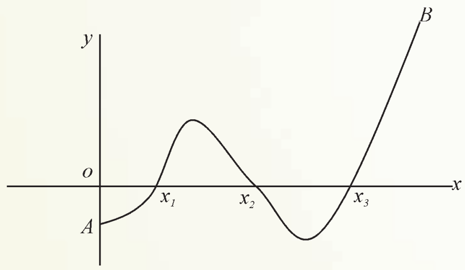
$+ \quad + \quad + \quad + \quad +$ (0 change)

$+ \quad - \quad + \quad - \quad + \quad - \quad +$ (6 changes)

Now, refer to Fig. 7. It shows two co-ordinate axes, x and y.

The roots of the equations $f(0) = 0$ are the points on the x-axis $(y = 0)$, where the curve, $y = f(x)$ cuts it. If $f(0) < 0$, as in case of Eq. 1, it means that the curve meets the y-axis at a point like A, which is below the x-axis. In order to have a positive real root it has to cut the x-axis somewhere.

Fig. 7. The curve cuts the x-axis at $x = x_1, x_2, x_3$



Now, for higher values of x, $f(x)$ is highly positive because of the first term. This means that the curve goes up to that point, like B, high above the x-axis for higher values of x. Before that it has cut the x-axis once say at $x = x_1$. If it cuts it again at $x = x_2$ $(x_2 > x_1)$, then for values of x, greater than x_2 it goes below the x-axis. So, in order to come up it has to cut the x-axis again at $= x_3$ $(x_3 > x_2)$. Thus it cuts the x-axis thrice. It establishes also that the curve cuts the x-axis once or thrice. If it ought to have been more than the number of cuts would have been five, seven, nine, … times; that is, odd number of times.

For Eq. 2. $f(0) > 0$. And again for higher values of x, $f(x) > 0$. So, corresponding to $x = 0$, the curve will remain above the x-axis and again for remaining above it has either not to cut the x-axis and if at all it cuts it would be doing so two, four, six, eight,…… times; that is, even number of times.

The remarkable feature in each case is that when the curve is on one side (that is either above or below) of the x-axis, then in order to be again on the same side the number of times of crossing the x-axis is always two, four, six,….; that is, an even number. This idea gets reflected when we look for the routes of the trains from Allahabad to Mughal Sarai. Both are on the southern side of the Ganga. Now, let us draw an analogy between the x-axis and the Ganga and between the curves and the routes of the trains. As mentioned, there are two kinds of trains. One that does not cross the Ganga; that is, in other words the number of times it crosses the river is 'nil', and the other kind that crosses the Ganga twice and not once.

Thus we see that train travel, in particular the laying of the tracks with reference to the flow of rivers encountered by them on the way, provide a subtle but a crucial link to the Descartes'rule of signs.

Acknowledgement

The author wishes to acknowledge the contribution made by Sri. Madhav Kumar in preparing the figures but for which the article would not have been complete.

Dr. C. K. Ghosh, Director, NCIDE, IGNOU, New Delhi

Continued from page 33 (A Journey to the Centre of the Data)

and finance, the harmonic mean is often used. In data involving rates or ratios, the nice property of the harmonic mean is that it gives equal weight to each data point whereas the arithmetic mean gives higher weights to higher values than lower values.'

'Uncle, thank you so much for explaining the importance of several measures of central tendency of a dataset. It was really fascinating to know how myriads of data points are so articulately and beautifully represented by these measures of central tendency which then tell us so much about the meaningful features of the data.'

'Yes Googol, this is the very first step of capturing the essence of data using statistical techniques.'

'Uncle, after this discussion, I am now feeling that it is not really so disappointing to be an average in the class.'

'And why do you think so, my dear Googol?'

'Well uncle, I was taking the cue from the concept of the arithmetic mean. If all students in a class are around the mean, then everyone is more or less an average student. If everyone tries to be better than the average, the mean will also get better and an average student would still be average even if he or she performs better.'

'Googol, that does make sense, both statistically and philosophically!' Uncle quipped.

Solar Maximum 2013:
Cosmic Event of the Year

Bhaswar Lochan
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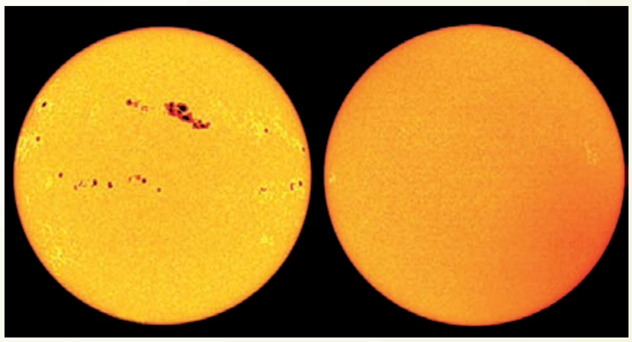
2013 CE is going to be a very fascinating year for solar science enthusiasts and heliophysicists alike. This year the solar maximum is coinciding with the maximum of solar magnetic cycle known as the 'Hale cycle'. This coincidence will bring more solar flares, more coronal mass ejections, more geomagnetic storms and more auroras than we have experienced in quite some time. The approaching maximum represents an unprecedented opportunity to understand the physics of the solar cycle and its effects on Earth.

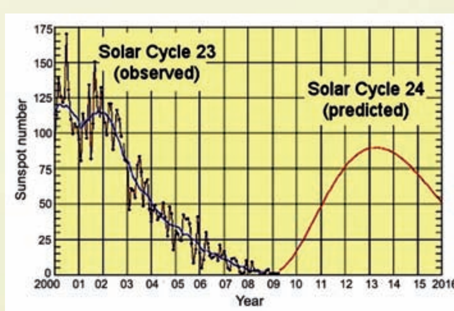
In 325 BCE the Greek scientist Theophrastus discovered sunspots very first time showing that Sun is neither steady nor featureless. Since then the sunspots visible with a simple projection of Sun have been well documented. Over the last three hundred years the number of sunspots has regularly waxed and waned in an approximate 11-year cycle, called the 'solar cycle' equivalent to 11 Earth years. This sunspot cycle is a very useful instrument to mark the changes on Sun. The Earth years in which the minimum number of sunspots occurs are called 'solar minimum' while the years having maximum number of sunspots are described as 'solar maximum'. Currently our star Sun is going through a solar maximum, and the peak of the on-going cycle is predicted to fall in middle to late of 2013 CE.

Though solar cycles have been observed for centuries, it was actually in late twentieth century when scientists began to understand the reason behind these cycles. They determined that the sunspots were actually a magnetic phenomenon and the entire Sun was magnetised with north and south magnetic poles like a magnetic bar. As the Sun does not have a solid crust like our Earth these poles in the Sun's interior remain constantly on move. The magnetic material inside the Sun therefore is constantly stretching, twisting and crossing as bubbles up to the surface. Over time, these activities eventually lead to the complete reversal of the poles. This polar flip – north becomes south and south becomes north is the genesis of the solar cycle.

In 1919 CE, the American scientist George Ellery Hale, who was a pioneer in demonstrating the strong magnetisation of sunspots, showed that the sunspots of a new sunspot cycle after a minimum of solar activity, appearing in high latitudes, were of opposite magnetic polarity in the northern and southern hemispheres. As the cycle progresses, the mean latitude of sunspots in each hemisphere steadily decreases and new sunspots appear closer to the equator without change in their magnetic polarities. However, the magnetic polarities of sunspots forming in the next sunspot cycle reverse. This rule is now known as 'Hale's Law' and the corresponding cycle comprising of two sunspot cycles spanning twenty-two years is called the 'Hale Cycle'.



The Sun near solar maximum in March 2001 showing a large number of sunspots (left), and near solar minimum in January 2009, with hardly any sunspot visible (right).



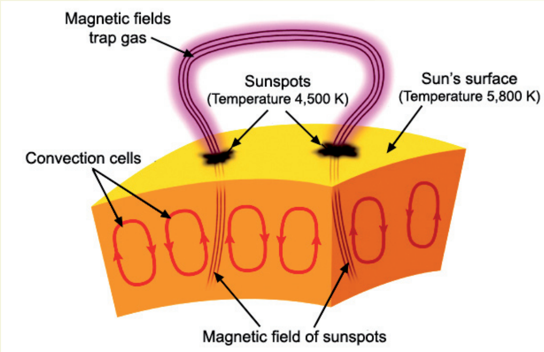
Graph showing the rising and falling number of sunspots over a solar cycle. The red curve at right shows the projected numbers.

Effect of Solar Maximum

The magnetic field of the Sun encompasses its atmosphere up to the corona and also solar winds. Its spatial and temporal variations lead to a host of phenomena collectively known as solar activity. All of solar activity is strongly modulated by the solar magnetic cycle, since the latter serves as the energy source and dynamical engine for the former. This solar activity rises and falls with an 11-year cycle that affects us in many ways. The amount of total solar irradiance, the radiating energy emerging from the Sun and incident on Earth's upper atmosphere, varies in a defined manner throughout eleven-year cycle of sunspots. It increases by almost 0.1% at solar maximum in comparison with the solar minimum. Increased solar activity includes increases in extreme ultraviolet and x-ray emissions from the Sun, which produce dramatic effects in the Earth's upper atmosphere.

Effect on communication: Sky wave modes of communication, i.e. radio communication, works on refracting signals from the ionosphere of the Earth. During solar maximum the number of ionised particles in the ionosphere increases considerably due to increased number of solar photons and cosmic rays. This potentially affects propagation of radio waves in a complex way to hinder the regular operations of marine ships, aircraft communication, and short-wave broadcasting.

Effect on Terrestrial Climate: There is growing realisation among the scientists that the solar maximum has a significant effect on terrestrial climate too. According to a report issued by NASA, the long-term and short-term variations in solar activity are going to affect global climate. It says while the variation in luminosity over the 11-year solar cycle amounts to only a tenth of a per cent of the total output, such a small fraction is still important. "Even typical short term variations of 0.1% in incident



Sunspots are associated with extremely strong magnetic fields and always appear in pairs.

irradiance exceed all other energy sources (such as natural radioactivity in Earth's core) combined. Of particular importance is the Sun's extreme ultraviolet (EUV) radiation, which peaks during the years around solar maximum. Within the relatively narrow band of EUV wavelengths, the Sun's output varies not by a minuscule 0.1%, but by whopping factors of 10 or more. This can strongly affect the chemistry and thermal structure of the upper atmosphere, eventually translating into a considerable impact on the regional climate.

Effect on spacecraft and space communication: During a solar maximum there occurs a sudden eruption of intense high-energy radiation from the Sun's surface caused by explosions on its surface. The coronal mass ejections (CME) associated with these solar flares produce a radiation flux of high-energy protons, sometimes known as solar cosmic rays. These can cause radiation damage to electronics and solar cells in satellites. The solar proton events also can cause single-event upset (SEU) events on electronics. At the same time, the reduced flux of galactic cosmic radiation during solar maximum decreases the high-energy component of particle flux. If astronauts on a space mission are above the shielding effect produced the Earth's magnetic field, the radiation from a CME could be dangerous to humans; many future mission designs therefore incorporate a radiation-shielded "storm shelter" for astronauts to retreat to during such a radiation event.

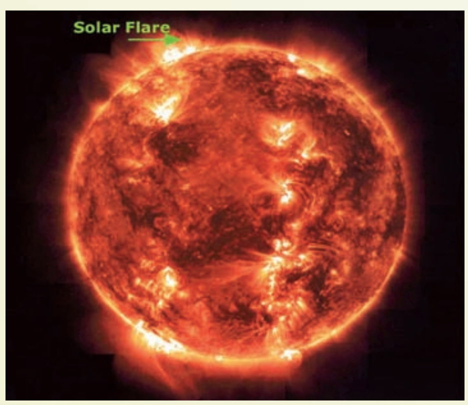
Moreover, the associated atmospheric heating increases both the temperature and density of the atmosphere at many spacecraft altitudes. The increase in atmospheric drag on satellites in low-Earth orbit can dramatically shorten the lifetime of these valuable assets.

Effect on terrestrial organisms: Though there are no conclusive evidences that the solar maximum causes effects on the life on our planet, some researches indicate the possibility of its effects on health of living beings. This is a field of active research.

Impact of Solar Maximum 2013 on Earth

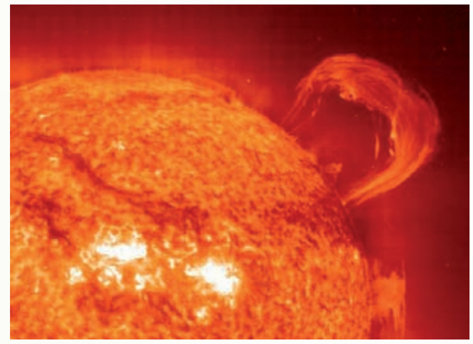
NASA is predicting that the coming solar maximum could produce very energetic solar flares and coronal mass ejection. These events have the potential to cause significant damage to our power grids due to overheating as well as our orbiting satellites. Researchers at NASA believe it could damage mobile networks, air craft navigations, disable stock markets, banks and traffic controls. Even domestic appliances like televisions, refrigerators or computers could also be affected by this event.

Studying the patterns some scientists are predicting this maximum to be on the line of the solar maximum that occurred in August-September 1859. Known as 'Carrington Effect' due to its discovery of by British astronomer Richard Carrington,



Solar flares like these (upper and bottom left) and other phenomena that occur at solar maximum can wreak havoc on telecommunication and satellite-dependent industries (Credit: NASA)

shortly after the Sun reached solar maximum in 1859, it experienced a significant increase in sunspot activity as well as a sequence of intense solar flares. The largest solar flare on record during the maximum was then observed. The result of the flare was a coronal mass ejection that sent charged particles streaming toward Earth, reaching



During high solar activity the Sun blasts streams of hot, ionised gas into the solar system. These eruptions, called coronal mass ejections or CMEs pose a potential threat to astronauts or satellites if aimed at Earth.

the atmosphere only 18 hours after the ejection. This is startlingly quick given that the trip normally takes several days. The auroras produced as a result of this super geomagnetic storm could have been seen up to the Caribbean islands and the most advanced communication system of those times telegraph services were badly hit for a long time.

How prepared are we?

In modern times the effect of solar maximum could throw life out of gear. Though solar flares generated due to solar maximum is unable to put life on the Earth at risk, according to studies conducted by US's National Research Council these flares could cause a damage of one to two trillion dollars. It is therefore essential to be prepared for the event in view of our heavy dependence on global satellite networks and modern communication technology for our daily chores, to avoid any serious damage. NASA, National Oceanic and Atmospheric Administration (NOAA), and the European Space Agency (ESA) are jointly keeping track round–the-clock on the activities of the Sun using various probes like SOHO and Solar Dynamic Observatory to identify any possible dangerous solar storm generation or coronal mass ejection event to issue advance warning.

Effect on India: The effect of solar maximum is expected to be limited up to higher latitudes and India is likely to be less affected by the coming event in terms of power grid failures and similar events. The Udaipur Solar Observatory keeps track of solar activity in India and will be in a position to issue warnings in case of any eventuality.

Ovarian Cancer
All You Need To Know About

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"Adversity draws men together and produces beauty and harmony in life's relationships, just as the cold of winter produces ice-flowers on the window panes, which vanish with the warmth."

—Oliver Wendell
The Journals of Søren Kierkegaard

Much the size of an almond and found on either side of a woman's lower abdomen (pelvis), the paired ovaries are a vital part of a woman's reproductive system. They stock her eggs, and produce the female sex hormones estrogen and progesterone, which give her the loveliness and charm of femininity, and are a key to her finding the joy of motherhood.

Newborn girls have a supply of about 150,000 immature eggs, which are present in their ovaries even before birth. With a rise in the levels of female sex hormones at puberty, which trigger the start of her monthly menstrual cycles, the eggs begin to mature. Each month, their body prepares to procreate. The cycle continues until sometime between the ages of 45 and 55, when their ovaries decide to step into a semi-retirement. They cut back the production of female sex hormones and stop producing and releasing mature eggs, thus signalling menopause.

While performing these duties, and even after hanging up their boots, the ovaries can be besieged by a number of difficult diseases. Of them, the most dreaded are the cancers. Most common between the ages of 40 and 70, they sometimes run in families and are more common in women who have never been pregnant. These cancers can be of many kinds, each running its own course, and must be managed depending on their type and stage of severity.

But before we delve into the specifics of ovarian cancers, let's first understand what exactly a cancer is.

Understanding Tumours and Cancer

The building blocks of the human body that make up the tissues and organs are called cells. Cancer begins in cells. In the normal course, cells grow and divide to form new cells depending upon the needs of the body. When cells grow old, they die, and new cells take their place. Sometimes, this orderly process goes wrong. New cells form when the body does not need them, and old cells do not die when they should. These extra cells can form a mass of tissue called a growth or tumour. These growths or tumours can be benign or malignant.

Benign tumours

Benign tumours are not cancer. They do not invade the tissues around them and do not spread to other parts of the body. Generally, they can be removed and if once cleared well, usually do not grow back. For this reason, they are rarely life-threatening.

Malignant tumours

Commonly referred to as cancers, malignant tumours are generally far more serious than benign tumours. They can invade and damage nearby tissues and organs. Cells from malignant tumours can spread to other parts of the body. Cancer cells spread by breaking away from the original (primary) tumour and entering the lymphatic system or bloodstream. The cells invade other organs and form new tumours that damage these organs. The spread of cancer is called metastasis. For this reason, they may be life-threatening. Malignant tumours often can be removed, but sometimes they grow back.

Ovarian Cysts: Benign and Malignant

Cysts are common in the ovaries. They may be found on the surface of an ovary or inside it. Classically, a cyst contains fluid. Sometimes, however, it also contains solid tissue. Most ovarian cysts are benign (not cancer), and go away with time.

Sometimes, a doctor will find a cyst that does not go away or that gets larger. The doctor may order tests to make sure that the cyst is not cancer.

Types of Ovarian Cancer

The type of ovarian cancer a woman has is determined by the type of cell where her cancer begins. The key types of ovarian cancer are:

Cancer that begins in the cells on the outside of the ovaries

Called epithelial tumours, these cancers begin in the thin layer of tissue that covers the outside of the ovaries. Most ovarian cancers are epithelial tumours.

Cancer that begins in the egg-producing cells

Called germ cell tumours, these ovarian cancers tend to occur in younger women.

Cancer that begins in the hormone-producing cells

These cancers, called stromal tumours, begin in the ovarian tissue that produces the hormones estrogen, progesterone and testosterone.

The type of ovarian cancer a woman has helps determine her prognosis and treatment options.

Risk Factors

The cause of cancer of the ovary is not known, but certain factors may increase a woman's risk of developing ovarian cancer. These risk factors include:

Inherited gene mutations

A small percentage of ovarian cancers are caused by an inherited gene mutation. The genes known to increase the risk of ovarian cancer are called breast cancer gene 1 (BRCA1) and breast cancer gene 2 (BRCA2). These genes were originally identified in families with multiple cases of breast cancer, which is how they got their names, but women with these mutations also have a significantly increased risk of ovarian cancer.

Another known genetic link involves an inherited syndrome called hereditary non-polyposis colorectal cancer (HNPCC). Women in HNPCC families are at increased risk of cancers of the uterine lining (endometrium), colon, ovary and stomach.

Family history of cancer

Women who have a mother, daughter, or sister with ovarian cancer have an increased risk of the disease. Also, women with a family history of cancer of the breast, uterus, colon, or rectum may also have an increased risk of ovarian cancer.

If several women in a family have ovarian or breast cancer, especially at a young age, this is considered a strong family history. If you have a strong family history of ovarian or breast cancer, you may wish to talk to a genetic counselor. The counselor may suggest genetic testing for you and the women in your family. Genetic tests can sometimes show the presence of specific gene changes that increase the risk of ovarian cancer.

Personal history of cancer

Women who have had cancer of the breast, uterus, colon, or rectum have a higher risk of ovarian cancer.

Increasing age

Though an ovarian cancer can occur at any age the risk increases as a woman advances in her age. Most women are over age 50 when diagnosed with ovarian cancer.

Never having been pregnant

Older women who have never been pregnant have an increased risk of ovarian cancer.

Menopausal hormone therapy

Some studies have suggested that women who take estrogen by itself (estrogen without progesterone) for 10 or more years may have an increased risk of ovarian cancer.

Dismiss the talcum

Scientists have also studied whether taking certain fertility drugs, using talcum powder, or being obese are risk factors. It is not clear whether these are risk factors, but if they are, they are not strong risk factors.

Understanding the significance

Having a risk factor does not mean that a woman will get ovarian cancer. Most women who have risk factors do not get ovarian cancer. On the other hand, women who do get the disease often have no known risk factors, except for growing older. Women who think they may be at risk of ovarian cancer should talk with their doctor.

What are the symptoms?

Ovarian cancer rarely produces symptoms in the early stages, although there may be symptoms similar to those of an ovarian cyst, such as irregular periods. But, as the cancer grows, symptoms may include:

- Pressure or pain in the lower abdomen (pelvis), back, or legs
- A swelling in the abdomen
- Nausea, indigestion, gas, constipation, or diarrhoea
- Feeling very tired all the time

Less common symptoms include:

- Shortness of breath
- Feeling the need to urinate often
- Unusual vaginal bleeding (heavy periods, or bleeding after menopause)

Very often these symptoms are not due to cancer, but only a doctor can tell for sure. Any woman with these symptoms must see her doctor.

How is it diagnosed?

If a woman has a symptom that suggests ovarian tumour, her doctor must find out whether it is due to benign tumour, cancer or to some other cause. For this, the doctor may ask about her personal and family medical history. She may have one or more of the following tests:

Physical exam

The doctor would check her general signs of health. The doctor may press on her abdomen to check for tumours or an abnormal buildup of fluid (as cites). A sample of fluid can be taken to look for ovarian cancer cells.

Pelvic examination

The doctor feels the ovaries and nearby organs for lumps or other changes in their shape or size.

He or she also inserts a device called a speculum into the vagina. The speculum opens the vagina so that the doctor can visually check the vagina and cervix for abnormalities.

Blood tests

The doctor may order blood tests. The lab may check the level of several substances, or biomarkers, including CA-125. CA-125 is a protein found on the surface of ovarian cancer cells and some healthy

tissue. Many women with ovarian cancer have abnormally high levels of CA-125 in their blood.

However, a number of noncancerous conditions also cause elevated CA-125 levels, and many women with early-stage ovarian cancer have normal CA-125 levels. For this reason, a CA-125 test isn't usually used to diagnose or to screen for ovarian cancer, but it may be used after diagnosis for monitoring a woman's response to ovarian cancer treatment and for detecting its return after treatment.

Ultrasound

The ultrasound device uses sound waves that people cannot hear. The device aims sound waves at organs inside the pelvis. The waves bounce off the organs. A computer creates a picture from the echoes. The picture may show an ovarian tumour.

For a better view of the ovaries, the device may be inserted into the vagina (trans-vaginal ultrasound).

Biopsy

A biopsy is the removal of tissue or fluid to look for cancer cells. Based on the results of the blood tests and ultrasound, the treating doctor may suggest surgery (a laparotomy) to remove tissue and fluid from the pelvis and abdomen. Surgery is usually needed to diagnose ovarian cancer.

Although most women have a laparotomy for diagnosis, some women have a procedure known as laparoscopy. The doctor inserts a thin, lighted tube (a laparoscope) through a small incision in the abdomen. Laparoscopy may be used to remove a small, benign cyst or an early ovarian cancer. It may also be used to learn whether cancer has spread.

A pathologist uses a microscope to look for cancer cells in the tissue or fluid. If ovarian cancer cells are found, the pathologist describes the grade of the cells. Grades 1, 2, and 3 describe how abnormal the cancer cells look. Grade 1 cancer cells are not as likely as to grow and spread as Grade 3 cells.

Spread of Ovarian Cancer

Ovarian cancer can invade, shed, or spread to other organs:

How it may invade

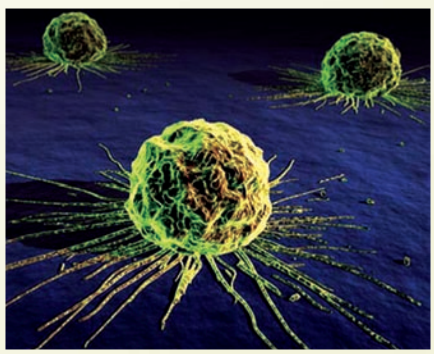
A malignant ovarian tumour can grow and invade organs next to the ovaries, such as the fallopian tubes and uterus.

Shedding into the abdomen

Cancer cells can shed (break off) from the main ovarian tumour. Shedding into the abdomen may lead to new tumours forming on the surface of nearby organs and tissues. The doctor may call these seeds or implants.

Spread to distant organs

Cancer cells can spread through the lymphatic system to lymph nodes in the pelvis, abdomen, and chest. Cancer cells may also spread through the bloodstream to organs such as the liver and lungs.



When cancer spreads from its original place to another part of the body, the new tumour has the same kind of abnormal cells and the same name as the original tumour. For example, if ovarian cancer spreads to the liver, the cancer cells in the liver are actually ovarian cancer cells. The disease is metastatic ovarian cancer, not liver cancer. For that reason, it is treated as ovarian cancer, not liver cancer. Doctors call the new tumour "distant" or metastatic disease. ■

(Next month: Ovarian Cancer—Staging and Management)

Recent developments in science and technology

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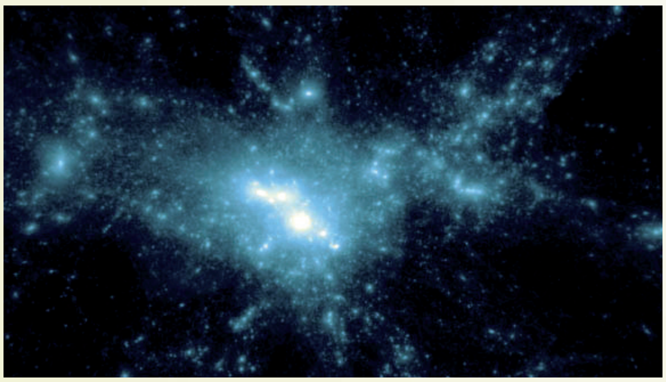
Simple theory to explain dark matter

It is now generally accepted by astrophysicists that visible matter that we can see as stars, galaxies and clouds gases in space constitutes only 5% of the universe. The rest is accounted for by dark matter (27%) and dark energy (68%). Dark matter came to the attention of astrophysicists when it was found that there are discrepancies between the mass of large astronomical objects determined from their gravitational effects, and the mass calculated from the "luminous matter" they contain: stars, gas and dust. The existence of dark matter was first proposed in the 1930's to explain discrepancies in the rotational rate of galactic clusters. Scientists hypothesise that dark matter cannot be seen in telescopes because it does not interact very strongly with light and other electromagnetic radiation. But the true nature of dark matter still remains a mystery.



This computer simulation visualises dark matter halo (Credit: Heidi Wu/Oliver Hahn/Risa Wechsler/Ralf Kaehler/Kavli Institute for Particle Astrophysics and Cosmology)

What we do know about dark matter is that it is not in the form of stars and planets that we see. We also know that it is not in the form of dark clouds of normal matter, matter made up of particles called baryons. Finally, dark matter is not antimatter, because we do not see the unique gamma rays that are produced when antimatter and matter annihilate on coming in contact. Currently, the most common view is that dark matter is not baryonic matter, but that it is made up of other, more exotic particles like axions (a postulated low mass chargeless particle with small interactions) or WIMPS (Weakly Interacting Massive Particles). Now there is simpler explanation available for dark matter. In a recent paper, theoretical physicists Robert Scherrer and Chiu Man Ho from Vanderbilt University, Tennessee, USA, propose that dark matter may be made out of a type of basic particle called the 'Majorana fermion' (*Physics Letters* B, 11 June 2013 | doi: 10.1016/j.physletb.2013.04.039).

We know that all fundamental particles in nature can be divided into one of two categories – Fermions or Bosons. Fermions, named after the Italian physicist Enrico Fermi, are particles that obey the Fermi-Dirac statistics, while bosons, named after the Indian physicist Satyendranath Bose, obey the Bose-Einstein statistics. A Majorana fermion, also referred to as a Majorana particle, is a fermion that is its own antiparticle. It was hypothesised by Italian theoretical physicist EttoreMajorana in 1937. The term is sometimes used in opposition to a Dirac fermion, which describes fermions that are not their own antiparticles. No elementary fermions are known to be their own antiparticle, though it is possible that the neutrino may be a Majorana fermion. By contrast, it is common that bosons such as the photon are their own antiparticle.

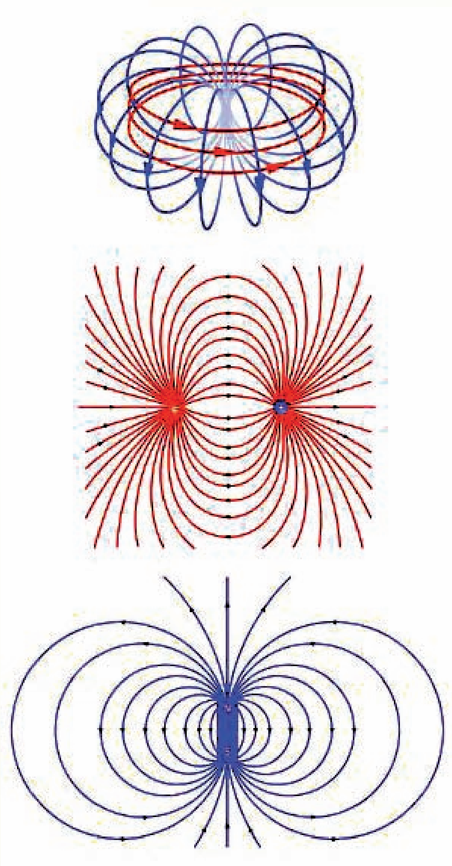
Majorana particles are unique in that they possess a rare, doughnut-shaped type of electromagnetic field called an 'anapole'. Its magnetic field loops in on itself, confined to a doughnut shape, instead of forming north and south or positive and negative poles, the way ordinary matter does. This field gives Majorana particles properties that differ from those of particles that possess the more common fields possessing two poles (north and south, or positive and negative) and explains why they are so difficult to detect. Since the existence of a magnetic anapole was predicted in 1958, it has been observed in the magnetic structure of the nuclei of caesium-133 and ytterbium-174 atoms. Although Majorana fermions are electrically neutral, fundamental symmetries of nature forbid them from acquiring any electromagnetic properties except the anapole.

Anapoles are difficult to detect because particles with familiar electrical and magnetic dipoles interact with electromagnetic fields even when they are stationary, but particles with anapole fields do not. They must be moving before they interact and the faster they move the stronger the interaction. As a result, anapole particles would have been much more interactive during the early days of the universe and would have become less and less interactive as the universe expanded and cooled.

The anapole dark matter particles proposed by Ho and Scherrer would have annihilated in the early universe just like other proposed dark matter particles, and the left-over particles from the process would form the dark matter we see today. But because dark matter moves so much more slowly, and because the anapole interaction depends on how fast it moves, these particles would have escaped detection so far.

Transistors without semiconductors

The invention of the solid-state transistor by William Bradford Shockley, John Bardeen, and Walter Houser Brattain in 1947 revolutionised electronics by doing away with the bulky, fragile and power-guzzling electronic tubes. Since then with advancement in technology the size of transistors has been shrinking fast. Today's electronic devices hold up to a few billion transistors on a single 'chip'. This has not only made possible the vast reduction in the size of electronic gadgets but has also greatly increased their versatility. A modern mobile phone can do much more in a much shorter



A comparison of an anapole field with common electric and magnetic dipoles. The anapole field (top) is generated by a toroidal electrical current. As a result, the field is confined within the torus, instead of spreading out like the fields generated by conventional electric (middle) and magnetic (bottom) dipoles. (Credit: Michael Smeltzer, Vanderbilt University)

time than a room-sized computer of the 1960s.

The pace of miniaturisation of transistors is often described by what is known as the 'Moore's Law', an observation made in 1965 by Gordon Moore, co-founder of Intel, that the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. Moore predicted that this trend would continue for the foreseeable future. Most experts, including Moore himself, expected Moore's Law to hold for at least another two decades. But that may not be possible because transistors based on semiconductors can get small only up to a point. At the rate the current technology is progressing, in 10 or 20 years, it won't be possible to make them any smaller. Also, semiconductor-based transistors have another disadvantage: they waste a lot of energy in the form of heat.

Now researchers have come up with a new material as the base of future transistors that won't use any semiconductor. Physicist Yoke Khin Yap of Department of Physics, Michigan Technological University in collaboration with scientists from the Oak Ridge National Laboratory, USA has created a transistor using a nanoscale insulator with nanoscale metals on top. To make the transistor, they first made virtual carpets of boron nitride nanotubes (BNNT), which happen to be insulators and thus highly resistant to electrical charge. Then, using lasers, the researchers placed quantum dots (QDs) of gold as small as three nanometres across on the tops of the BNNTs to make QD-BNNT composites that behaved like transistors.

When the researchers fired up electrodes on both ends of the QDs-BNNTs at room temperature, something interesting happened. Electrons jumped very precisely from gold dot to gold dot, a phenomenon known as 'quantum tunnelling'. According to the researchers, "One-dimensional arrays of gold quantum dots (QDs) on insulating boron nitride nanotubes (BNNTs) can form conduction channels of tunnelling field-effect transistors" (*Advanced Materials* 17 June 2013 | doi: 10.1002/adma.201301339). They could demonstrate that tunnelling currents can be modulated at room temperature by tuning the lengths of QD-BNNTs and the gate potentials. In effect, Yap's team had made a transistor without a semiconductor. When sufficient voltage was applied, it switched to a conducting state. When the voltage was low or turned off, it reverted to its natural state as an insulator.

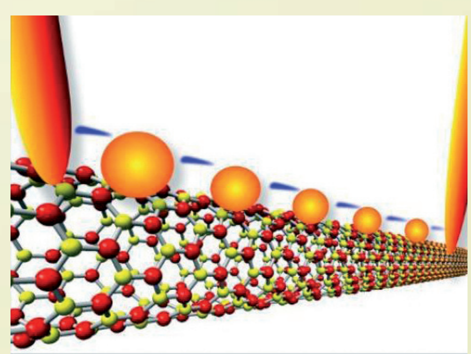
The main advantage of the system was that there was no 'leakage'; no electrons from the gold quantum dots escaped into the insulating BNNTs, thus keeping the tunnelling channel cool. In contrast, silicon is subject to leakage, which wastes energy in electronic devices and generates a lot of heat.

According to the researchers, theoretically, these tunnelling channels can be miniaturised into virtually zero dimensions when the distance between electrodes is reduced to a small fraction of a micron, thus making transistors smaller than ever possible using semiconductors.

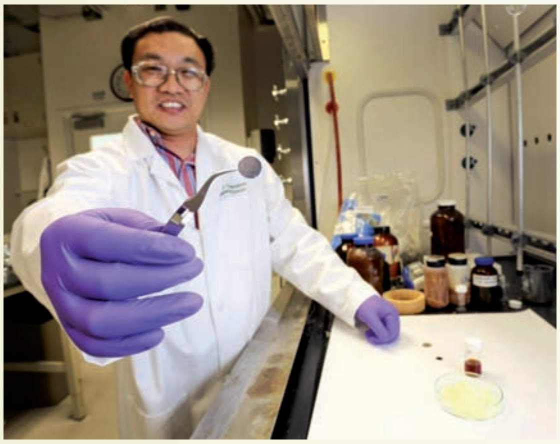
Lithium-sulphur batteries are safer and longer-lasting

Today we have ultra-fast means of telecommunication and versatile portable electronic devices that bring the world to our fingertips anywhere and at any time. But no matter how high-tech these gadgets are, they still need electric power provided by the humble battery for sustenance. Batteries have evolved much over the years. Lithium-ion batteries have replaced the basic carbon-zinc and alkaline ones, which are still used in flashlights and TV remotes. As electronic gadgets become increasingly high-tech, scientists scramble to create batteries that are small, inexpensive and long lasting, and lithium-ion batteries appear to fit in ideally. But recent incidents involving fire risk in lithium-ion batteries in Boeing *Dreamliner* aircraft had raised doubts about the safety of lithium-ion batteries. Although the issue has been resolved, scientists are looking for better and safer alternatives.

Now, a team led by Chengdu Liang at the Oak Ridge National Laboratory, USA has designed and tested an all-solid lithium-sulphur battery with approximately four times the energy density of conventional lithium-ion technologies that power today's electronics. Theoretically, sulphur-lithium battery chemistry can have an energy density (watt-hours per gram) that is 10 times that of conventional lithium-ion batteries. In small-scale testing, sulphur-lithium has been shown to have an energy density that is four times that of lithium-ion. Using the new technology the Oak Ridge researchers were able to maintain a capacity of 1200 milliamp-hours per gram (mAh/g) after 300 charge-discharge



Electrons flash across a series of gold quantum dots on boron nitride nanotubes. Michigan Tech scientists made the quantum-tunnelling device, which acts like a transistor at room temperature, without using semiconducting materials. (Credit: Yoke Khin Yap graphic)



Researcher Chengdu Liang holding the new all-solid lithium-sulphur battery developed by an Oak Ridge National Laboratory which has the potential to reduce cost, increase performance and improve safety compared with existing designs. (Credit: Oak Ridge National Lab)

cycles at 60 degrees Celsius. For comparison, a traditional lithium-ion battery cathode has an average capacity between 140-170 mAh/g. The new battery design, which uses abundant low-cost elemental sulphur, also addresses flammability concerns experienced by other chemistries. Another advantage is that sulphur cathode is a lot cheaper than the lithium-based cathode normally used in a lithium-ion battery. Sulphur, by virtue of being a by-product of petroleum processing, is available almost free.

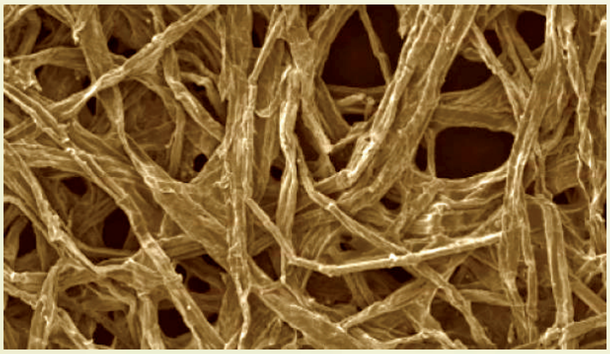
Scientists had known about the potential of lithium-sulphur batteries for decades, but failed to develop long-lasting, large-scale versions for commercial applications. The main obstacle was the need to use liquid electrolytes. On one hand, the liquid helped conduct ions through the battery by allowing lithium polysulphide compounds to dissolve. On the other, the same dissolution process caused the battery to prematurely break down. The Oak Ridge team overcame these barriers by first synthesising a never-before-seen class of sulphur-rich materials that conduct ions as well as the lithium metal oxides conventionally used in the battery's cathode. The researchers then combined the new sulphur-rich cathode and a lithium anode with a solid electrolyte material, also developed in the same lab, to create an energy-dense, all-solid battery (*AngewandteChemie*International Edition, 4 June 2013 | doi: 10.1002/anie.201300680).

"Our approach is a complete change from the current battery concept of two electrodes joined by a liquid electrolyte, which has been used over the last 150 to 200 years," says Liang, the lead author of the paper. He further adds that the new all-solid lithium-sulphur battery has the potential to reduce cost, increase performance and improve safety compared with existing designs. The new battery would also be more environmentally friendly compared to current designs because,"not only does sulphur store much more energy than the transition metal compounds used in lithium-ion battery cathodes, but a lithium-sulphur device could help recycle a waste product into a useful technology".

The new design will offer portable cost effective power storage device and is likely to bring about a paradigm shift. According to the researchers, this technology if commercialised, would mean an electric vehicle could easily have a 600-km to 1,000-km range on a single charge. This would likely bring a major change in buyer acceptance and possibly reduce the sometimes prohibitive purchase price.

Now, a battery made of wood

In a parallel development, researchers Liangbing Hu, Teng Li and colleagues of the University of Maryland, USA have come up with a battery made from a sliver of wood coated with tin that shows promise of becoming a tiny, long-lasting, efficient and environmentally friendly energy source. The scientists built the battery by using a very thin piece of wood, which they say is "a thousand times thinner than a piece of paper," coated with tin. And, instead of lithium, which is found in many rechargeable batteries, they chose to use sodium to make it eco-friendly. But since sodium does not store energy as efficiently as lithium, the new battery is not suitable for use in cell phones or laptops. However, its low cost and inexpensive materials would make it ideal for storing huge amounts of energy quickly, such as at wind farms or solar energy installations (*Nano Letters*, 29 May 2013 | doi: 10.1021/nl400998t).



Wood fibres are flexible and absorbent. A sliver of wood coated with tin could make a tiny, long-lasting, efficient and environmentally friendly battery.

The idea of using wood came from the fact that wood fibres are very good at storing liquid electrolytes as they can swell and contract many times over; that is, they are flexible and can last long without rupturing. Wood fibres from trees are supple and naturally designed to hold mineral-rich water, similar to the electrolyte in batteries. So the researchers made use of the soft and mesoporous (material containing pores with diameters between 2 and 50 nanometres) wood fibres as a new platform for low-cost sodium-ion batteries. Existing batteries are often created on stiff metal bases, which are too brittle to withstand the swelling and shrinking that happens as electrons are stored in and used up from the battery.

During testing the researchers noticed that after charging and discharging the new battery hundreds of times, the wood ended up wrinkled but intact. Computer models showed that that the wrinkles effectively relax the stress in the battery during charging and recharging, so that the battery can survive many cycles. In fact, this new battery has been tested and can handle over 400 charging cycles with a capacity of 339 mAh/g. Researchers hope to increase this figure further as they perfect the design.Sodium-ion batteries have a theoretical capacity as high as 847 mAh/g.

The researchers say the wood-based sodium-ion batteries are unlikely to become available any time soon as theirs is just a working prototype. However, it does bode well for the future of low-cost and environmentally friendly rechargeable battery technology. And such developments are especially important when the world is slowly shifting towards green power generation that requires high energy storage solutions. ■