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Seventy-five Years of Nuclear Fission

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

Ten important strands of S&T Communication

Dr. R. Gopichandran

The International Public Communication of Science and technology (PCST) Conference in May 2014 in Brazil saw more than 500 registered participants from about 50 countries and all continents. Deliberations at the Conference centred on the forms, functions, applications, impacts, tools and cross-cutting methodologies of science and technology communication. Of these, ten important cross cutting strands and related challenges call for significant and focussed attention. They include the need to:

I. Enhance visibility in the public domain and perception, of the role played by science.

II. Focus on "how science works", going beyond knowledge of facts and evidences of applications.

III. Strengthen methods to impart learning on (public) practice of science.

IV. Ensure political engagement and social inclusion through focussed S & T communication and devise methods to synergise public and democratic processes into decision making duly recognising the challenge on expecting pubic to make choices with prevailing levels of uncertainty.

V. Diagnose the evolution of S & T communication in a country/culture-specific context aligned with local relevance.

VI. Understand the "hardest to reach out to" and the means of engaging such stake holders, recognising the skills they possess to comprehend and understand messages.

VII. Synthesise science and development perspectives to gain greater attention in the political agenda.

VIII. Highlight "inclusion" as a "collective identity", recognise the difference between scientific knowledge and belief in the context of inclusion and most importantly, tackle challenges when "public does not want to be included" in some contexts and define parameters of such social inclusion.

IX. Engage public on "risk governance" and resolve risk/value conflicts, especially with growing inclement weather and environmental systems.

X. Develop indicators of impacts of S & T communication, recognising challenges due to continued poor quality reporting of goals and impacts of S & T communication initiatives expected to be achieved.

The overarching objective is to increase confidence/understanding of choices and the ability to diagnose "where we are and how do we go ahead" and help stakeholders communicate better. The theme of the Conference, namely, 'science communication for social inclusion and political engagement' appeared to be aligned with India's constitutional perspective on scientific temper and her initiatives through the recent STI Policy 2013. Initiatives in India should suitably integrate the ten focal areas stated above to strengthen the framework of goals, approaches, tools and techniques and indicators of success/challenges. This also creates the context to develop

1) A compendium on "Practices and Impacts of S & T Communication: An Indian Perspective". This is essential to showcase India's efforts with empirical evidences, understanding of the unfinished agenda and the location specific approaches to optimise impacts. A compendium of this nature is conspicuous by its absence. This can be expected to help establish the much needed academic and action-programme linkages for the mutual benefit of several countries experiencing comparable challenges in S&T communication.

2) A 5-year programme on "Capacity building for focused S & T communication", especially for the benefit of middle-level in-service practitioners on a priority basis. This is to rapidly build on inherent strengths, only to deliver expeditiously aligned with her missions.

3) Create a community of practitioners whose expertise can strengthen public engagement and the twin (S & T) popularisation and action-oriented goals. This will help sustain inputs for policies, plans, programmes and projects.

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Seventy-five Years of Nuclear Fission

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Four hundred and odd nuclear power reactors around the globe producing electricity to light up homes and turn the wheels of industry; thousands of radiation therapy machines giving a new lease of life to cancer patients; new methods of diagnosing diseases, which otherwise were not possible; an impressive stockpile of MAD nuclear weapons..... The list can go on. The one discovery that spurred these and many more technologies – the discovery of the fission of uranium nucleus just completed 75 years on 22 December 2013. The path for this discovery was neither short, nor was it an accidental one. But it demanded persistent hard work, refinements in experimental techniques and boldness to depart from conventional thinking.

The modern alchemy

One can trace back the roots of this discovery to the grand old man of modern physics, Lord Rutherford. In the late 19th and early 20th century, he not only delivered the final blow to Dalton's theory of indivisibility of atoms but also carried out path-breaking experiments in which one type of element got converted to another type of element – the modern version of alchemy. For example, he directed a beam of alpha particles (helium nuclei) at nitrogen atoms to produce oxygen atoms;

$$^{14}N + {}^{4}He = {}^{17}O + {}^{1}p.$$

The nitrogen nucleus absorbed an alpha particle and then rearranged itself to an oxygen nucleus, throwing out a proton. These were termed as 'nuclear reactions' or 'nuclear transmutations' as against chemical reactions in which the elements remain unchanged.

Later Ernest Walton and John Cockcroft, using their newly designed particle accelerators, accelerated charged particles to very high energies to bombard a variety of target elements to produce a range of nuclear transmutations.

Two common features of all these early transmutation experiments were that the target elements were generally the lighter elements in the Periodic Table and the transmuted element was a naturally occurring stable element, just about next to the target element in the Periodic Table. On account of the positive charge of the bombarding particle, this type of reactions did not succeed in bringing about transformation of heavy elements. The high positive charge on the nucleus of these elements repelled the bombarding particle and prevented it from penetrating the nucleus.

Probing with neutrons

Then came the neutrons. James Chadwick from England, following the lead provided by Walther Bothe and Herbert Becker in Germany and Joliot-Curie in France, discovered a highly penetrating radiation when alpha particles from radium bombarded finely powdered beryllium. He postulated that these radiations constituted particles with neutral charge (zero) and mass almost equal to that of protons, which he called neutrons.

Ida Noddack. She was the first to speculate that uranium nucleus may break when bombarded with neutrons.

Enrico Fermi, an Italian scientist was quick to grasp the advantage of neutrons in transmutation experiments. Because they did not have any net charge, they could penetrate the target nucleus more readily. He used a finely powdered mixture of radium and beryllium tightly sealed in a glass or metal capsule as the neutron source. He also discovered that if the neutron source was embedded in a paraffin block, the neutrons were slowed down and became more effective in bringing out transmutations.

Fermi and colleagues irradiated practically all the elements in the Periodic Table. In most cases the target nucleus captured the slow neutron to become a radioactive isotope (similar to artificial radioactivity previously discovered by Joliot and Frederic Curie), which decayed, by beta particle emission, to a stable element one higher in the Periodic Table. They were particularly interested in knowing what would happen if uranium, the heaviest naturally occurring element in the Periodic Table, is irradiated with neutrons. Would it generate 'transuranium elements'?

By irradiating uranium with slow neutrons, Fermi and his associates discovered four radioactive products. After studying the decay characteristics of the radioactive products, three of them were found to be the isotopes of uranium (since there were only three known isotopes) and the fourth one was mistakenly thought to be a transuranium element – an element with atomic number 93. But there was no chemical proof and not everyone was convinced. It was even suggested that the fourth element was an isotope of protactinium – a decay product of uranium.

Ida Noddack, a German chemist, had different ideas. She wrote, "It is conceivable that when heavy nuclei are bombarded with neutrons, these nuclei could break down into large fragments, which are essentially isotopes of known elements, but not the neighbours of the irradiated elements". However, the break-up of uranium nucleus on absorption of a neutron to lighter elements was unthinkable at that time. Everyone was looking for elements beyond uranium. And also she did not provide any theoretical basis for her speculation. So her comments were mostly ignored.

Around the same time the French scientists Irene Curie and Paul Savitch performed neutron irradiation of uranium and identified some products as thorium and actinium – elements below uranium, not above, in the Periodic Table. They also detected a radioactive product with 3.5-hour half-life, which appeared to be a rare earth, but not actinium. It co-precipitated with lanthanum but not with any suspected transuranium element, and had chemical properties similar to lanthanum. That was a puzzle. For lanthanum (atomic number 57 and atomic weight 139) is a medium-mass

Lise Meitner and Otto Hahn in their laboratory

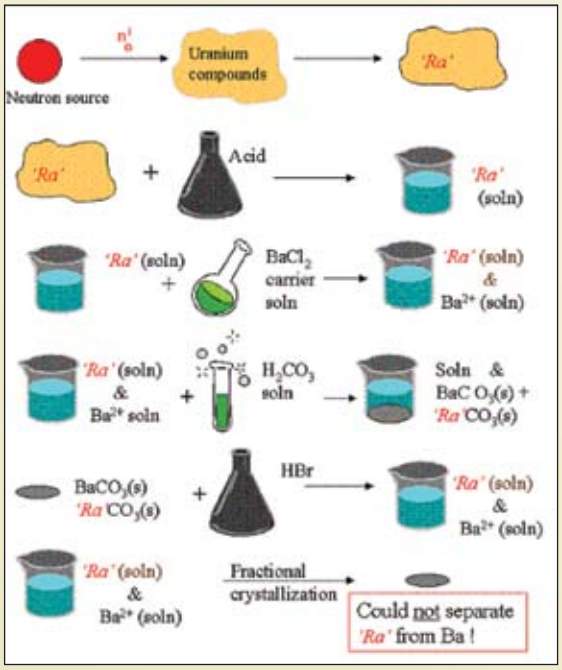
element in the Periodic Table rather than a heavy one.

Otto Hahn, working at the Kaiser Wilhelm Institute of Chemistry, Berlin, Germany had a long career in radiochemistry under Lord Ramsey of England and had developed sensitive chemical methods to separate and purify minute quantities of radioactive materials. He, along with his physicist colleague Lise Meitner, had discovered an isotope of protactinium in 1917. Since one of the products in Fermi's experiments was suspected to be an isotope of protactinium, naturally it attracted their attention. So they repeated Fermi's experiments. Between 1934 and 1938 they had found at least 10 radioactive products of uranium bombardment with neutron. Among them four were (again mistakenly) identified as transuranium elements with atomic numbers 93 to 96.

Fritz Strassmann

Here we have to digress a bit. In the late 1930s Germany was in a political turmoil. Adolf Hitler had seized power and the Nazis had the upper hand. It had become impossible for Lise Meitner, who had a Jewish ancestry, to continue in Kaiser Wilhelm Institute and had to leave Germany. She migrated to Sweden and took up a research position in the Nobel Institute for Physics, Stockholm. However, she maintained correspondence with Otto Hahn and continued to advise him on their joint research.

Meanwhile, Hahn along with a young chemist Fritz Strassmann continued his investigations on the uranium bombardment with neutrons and found another radioactive product with properties similar to those of barium. However, again it was out of question to imagine at that time that barium with atomic number 56 would be formed during irradiation of uranium with neutrons. Since radium and barium belong to Group 2 elements in the Periodic Table and have similar properties, Hahn and Strassmann assumed these new products to be isotopes of radium. Hence, barium was used as a carrier to separate the suspected radium isotopes. In the final analysis, to separate the radioactivity from the carrier barium for further characterisation the mixture was subjected to 'fractional crystallisation'. But, however much they tried, they were unable to separate the two. Various other types of separation techniques also failed, though those techniques were known to separate barium and radium isotopes. Hence, they were forced to conclude that the suspected radioactivity was nothing but a radioactive isotope of barium, implying that barium was formed as a consequence of neutron bombardment of uranium. However, they were not sure of the physical basis of the process. Barium had an atomic mass 40 percent less than that of uranium. No previously known methods of radioactivity or transmutations experiments could account for such a large difference in the mass of the product nucleus.



Hahn and Strassmann adopted several chemical methods to separate the suspected radium component from the carrier barium.

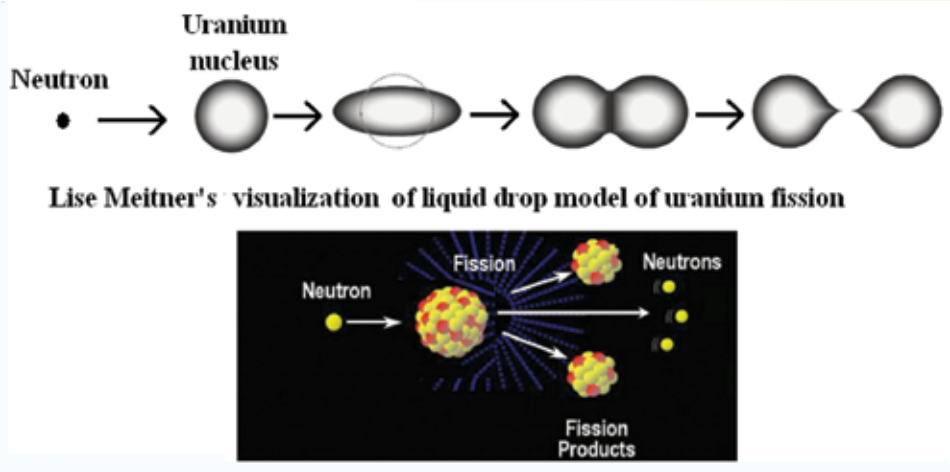
The liquid drop model

On 22 December 1938, Hahn and Strassmann sent a manuscript for publication to the German science magazine *Naturwissenschaften*, reporting that they had discovered barium as one of the products of bombarding uranium with neutrons. Around the same time Hahn also sent a letter to Lise Meitner describing the results of the chemical separation techniques which proved that some of the products were isotopes of the element barium. Was the uranium nucleus "bursting" under neutron bombardment? He was not sure.

When Meitner received the letter, her cousin Otto Robert Frisch, also a physicist working with Niels Bohr at Copenhagen was visiting her for Christmas. They pored over the contents of Hahn's letter to find an explanation to the puzzling results. In the beginning Frisch was sceptical about the chemical techniques and conclusions. But Meitner was confident about Hahn's ability as a radiochemist and the methods he used to separate the unknown products from barium. But then how does one explain the presence of barium?

Otto Robert Frisch. He experimentally demonstrated the process of fission

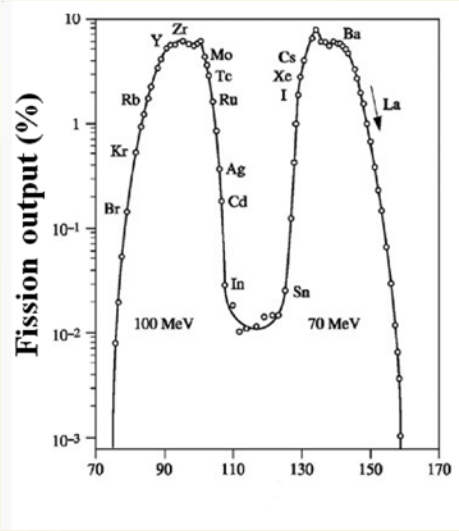
Sometime earlier, Russian physicist George Gamow and Niels Bohr had proposed that nuclei of heavy elements like uranium, containing large number of protons and



neutrons are less tightly bound than nuclei of lighter elements and hence may behave like a liquid drop. Meitner visualised that just as a liquid drop can fragment into smaller drops when disturbed, a uranium nucleus, after absorbing a neutron would wobble, become more unstable, elongate and start pinching at the middle to finally break into two parts of approximately equal mass with their atomic numbers somewhere in the middle of the Periodic Table. She estimated that the resulting two nuclei repel each other and gain a total kinetic energy of about 200 million electron volts (MeV). This is a huge amount of energy compared with the energy released in radioactive decay (maximum about a few Mev) and chemical reactions (only of the order of a few eV).

Where does this energy come from? Meitner had the answer. She worked out that the total mass of the products formed by the breakup of uranium nucleus would be slightly lower than that of the original uranium nucleus plus neutron. This small difference, according to Einstein's equivalence of mass and energy ($E=mc^2$) could account for the energy released.

Thus, Meitner and Frisch could correctly interpret the results of Hahn and Strassmann to mean that on absorption of a slow neutron the uranium nucleus (atomic number Z=92) splits into two lighter fragments. If one of them was an isotope of barium with Z=56, the other was krypton with Z=36 making the total atomic number 92; in the process energy of about 200 MeV is also released. Barium and krypton are not the only fragments. Depending upon the internal structure and to some extent chance, it could be any pair of elements in the middle of the Periodic Table with the total atomic number being equal to 92, like $_{36}Kr/_{56}Ba$, $_{37}Rb/_{55}Cs$, $_{38}Sr/_{54}Xe$ and so on. Since they inherit excess neutrons (more than what the stable elements in the middle



Mass of the fisson product

of the Periodic Table generally possess) from the uranium nucleus, their mass could vary from 90 to 100 and from 130 to 140. Hence, they are highly unstable and pass over to stable isotopes with the emission of beta particles in one or more steps. Thus, a large number of radioactive elements would be generated. Hence, many of the radioactive products reported after bombarding uranium with neutrons in the previous experiments, which were wrongly labelled either as transuranium elements or the decay products of uranium were actually radioactive species generated in the breakup of the uranium nucleus. Presence of lanthanum in the experiment of Curie and Savitch could also be explained.

Thus, here was a new type of nuclear transmutation, much different from any known till then. In view of its similarity with cell division in biology, Frisch named it "nuclear fission"

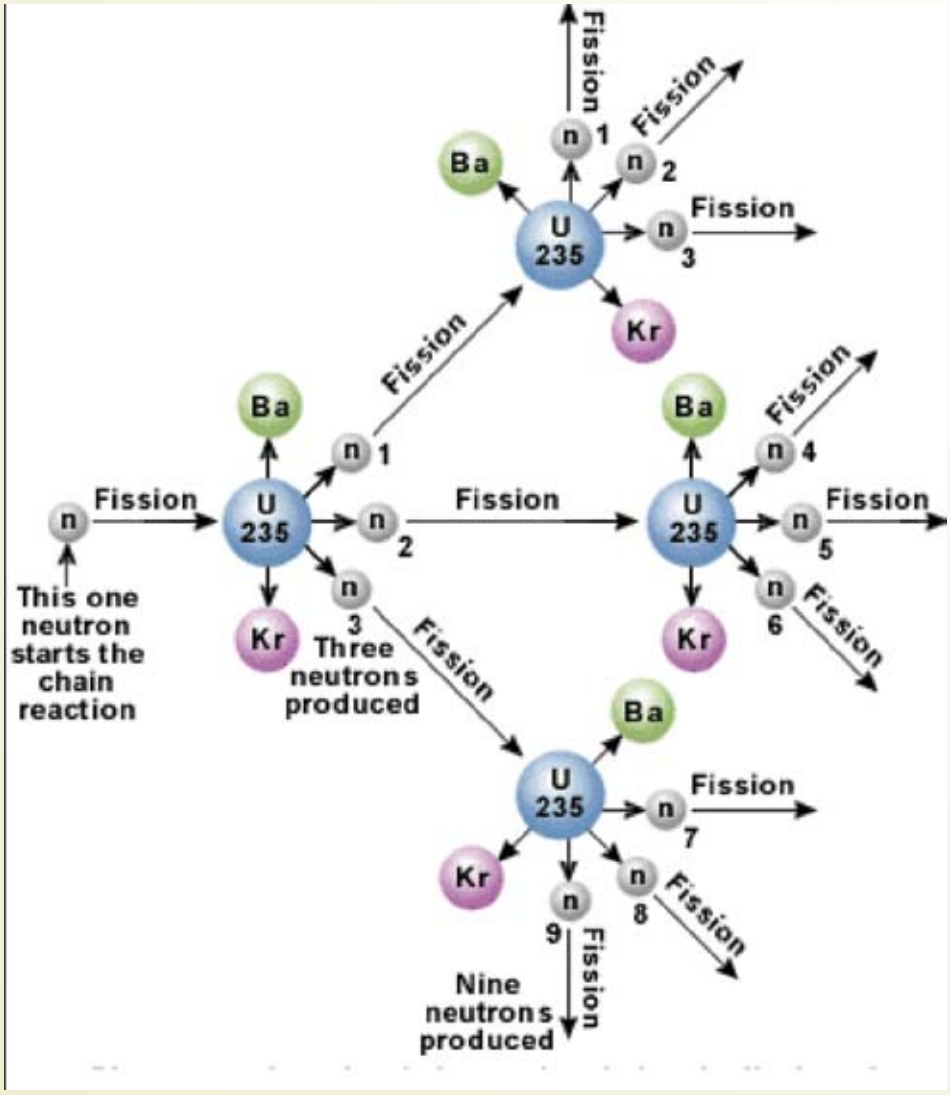
On 16 January 1939, Meitner and Frisch fine-tuned their arguments and sent a manuscript to *Nature.* Frisch went back to his laboratory and performed experiments to provide conclusive physical evidence for fission. He lined an ionisation chamber with uranium, irradiated it with a neutron source kept outside and recorded huge ionisation pulses caused by the recoiling fission fragments.

A chain reaction

When Frisch discussed the results of Hahn and Strassmann with Bohr, he was astonished. Bohr carried the news of uranium fission to USA where he was attending a conference at Princeton. The discovery was so unexpected and sensational that it immediately caught the attention of other scientists, resulting in a tremendous outpouring of scientific papers from all over Europe and USA confirming the fission process and revealing many of its properties

Though the energy released in a fission reaction was large (about 200MeV) compared with radioactive decay and chemical reactions, by itself it was not enough for any practical applications. The Hungarian physicist Leo Szilard suggested that if a fission chain reaction could be set up, the enormous amount of energy released can be harnessed for military and civilian purposes. The prerequisite for such a chain reaction was that fission of each uranium nucleus should release more than one neutron, which in turn can induce more fission in more uranium nuclei, and so on. Though Hahn and Strassmann had already noted that more neutrons may be set free in a fission process, F. Joliot in 1939 experimentally established that, on the average, each fission resulted in about 2.6 neutrons.

Leo Szilard, the man who thought of the fission chain reaction



Fission chain reaction with Uranium-235 nucleus. It need not be Ba/Kr pair all the time.

What followed next – the construction of the first reactor (popularly known as the Chicago Pile-1) based on controlled fission chain reaction (1942), the first atomic bomb tested in New Mexico (July 1945), USA, destruction of Hiroshima and Nagasaki by dropping of uranium-235 and plutonium-239 bombs (6 and 9 August 1945), cold war and nuclear arms race, etc. – are all part of history now.

At the end of World War II, Otto Hahn was suspected of working for the German nuclear energy project to develop atomic bomb. In 1945 Hahn and nine other prominent German physicists were taken into custody by the Allied Forces and interned at Farm Hall, near Cambridge, England from 3 July 1945 to 3 January 1946. While they were there, ironically, they learnt about the bombing of Hiroshima and Nagasaki. Hahn was despaired that his discovery led to the death and suffering of millions of innocent Japanese.

In November 1945, while he was still in detention, the Royal Swedish Academy of Sciences announced that Otto Hahn had been awarded the 1944 Nobel Prize in Chemistry "for his discovery of the fission of the heavy atomic nuclei". He could not participate in that year's ceremony, but did so in the December 1946 function.

Like many Nobel Awards, this also had its share of controversy. Many felt that Lise Meitner should have been awarded the Prize along with Otto Hahn. Hahn's initial conclusions were couched in cautious words because the idea that a uranium nucleus could be broken up had not occurred to anyone (except to Ida Noddack, which was any way largely ignored). Until then neutron bombardment products were considered to be close to the parent atom in atomic number. Hahn himself explains, "our over-cautiousness stemmed primarily from the fact that as chemists we hesitated to announce a revolutionary discovery in physics". Lise Meitner provided the necessary theoretical explanation of his discovery. About this she herself wrote, "Surely Hahn fully deserved the Nobel Prize in Chemistry. There is really no doubt about it. But I believe that Otto Robert Frisch and I contributed something not insignificant to the clarification of the process of uranium fission – how it originates and that it produces so much energy and that was something very remote from Hahn. For this reason I find it a bit unjust that in newspapers I was called a "Mittarbeiterin'(co-worker) of Hahn in the sense that Strassmann was."

Hahn received many honours for his discovery. Among them were also honorary memberships of the Indian Academy of Sciences (Bangalore) and National Academy of Sciences, India (Allahabad).

Dr M.S.S.Murthy retired as a senior scientist from the Bhabha Atomic Research Center, Mumbai in 1997. He is a popular science writer and authored a number of books. ■

Biological weapons: a real threat

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Organisms have been used as warfare agents for ages to dislodge and dismantle the socio-political fabric of so-called enemy zones by terrorist organisations. This form of terror tactics is called "bioterrorism". It involves the deliberate release by a rogue state of harmful, virulent, pathogenic organisms or their by-products into the environment that cause panic, horror, and social instability along with political restlessness in a so-called enemy zone. Bioterrorism is evolving and organising to become more dangerous than other terrorist threats. It is a threat a real threat to every nation that loves freedom.

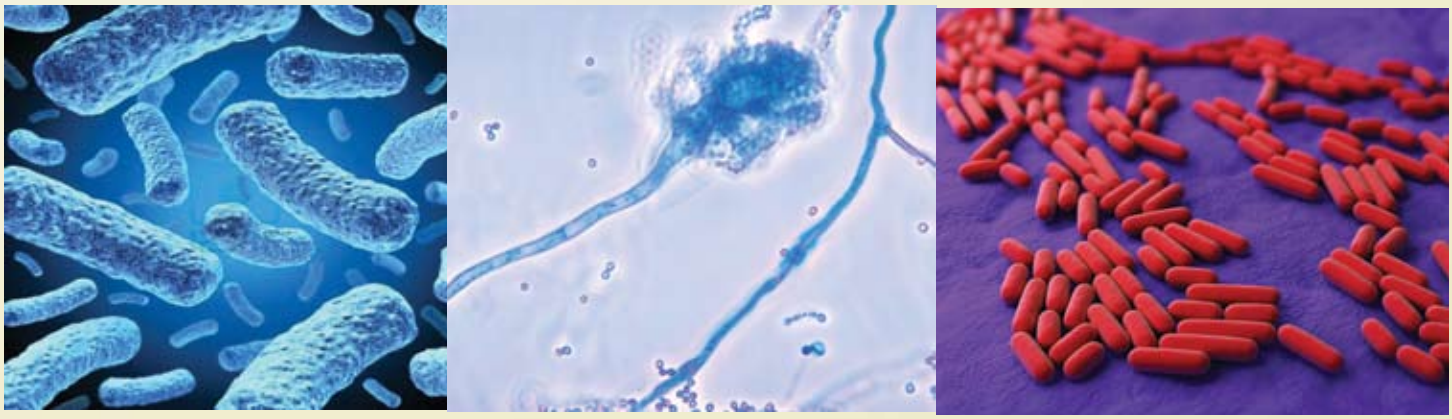
Any lethal and harmful living organism/ pathogen or its product such as a bioactive substance, secondary metabolite, pheromone, hormone, or a secondary messenger that can be delivered by conventional warheads or even civilian means or through natural vectors such as insects can serve as a potential warfare agent in bioterrorism. Highly contagious lethal pathogens belonging to any group of living organisms such as bacteria, viruses, prions, protozoans and fungi can pose greater danger than nuclear or conventional weapon technology because of their broad and unlimited geographical target area and potential to spread indefinitely. Bioweapons may be disseminated by various methods, including through aerosols, through specific blood-feeding insects, or food and water contaminants. Hence, these are also called as poor man's atom bombs. These weapons are highly effective, easy to deliver and self-perpetuating. They can be deliberately used to spread diseases that generate terror and horror in the masses. The rapid expansion of biosciences and biotechnology worldwide needs to be looked into in the context of bioterrorism.

Common biological warfare agents

Bacterial agents	*Bacillus anthracis* (anthrax), *Franciscella tularensis,* (Tularemia), *Brucella suis* (Brucellosis), *Coxiella burnetti* (Q fever)
Viral agents	Venezuelan equine encephalitis virus (VEE), Yellow fever virus
Toxins	Botulinum toxin, Staphylococcal enterotoxin
Anti-plant agents	*Pyricularia oryzae* (rice blast), *Puccinia graminis tritici (*wheat rust)

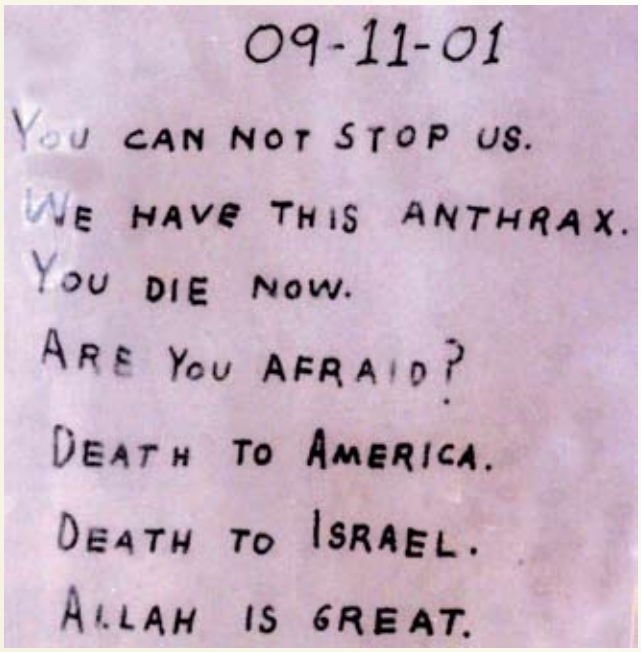
Bioterrorism is not a new or novel form of terror tactic. It has been there with many nations and organisations from time immemorial. The strategic use of bioweapons, their delivery systems and the range of organisms being used to cause terror has improved. The history of bioterrorism dates back to Roman Civilisation. The first recorded use has been on Tartar soldiers at the besieged Crimean city of Kaffa where soldiers were inflicted with the plague pathogen. It continued on into the 14th century where the bubonic plague was used to infiltrate enemy cities, both by instilling the fear of infection in residents, in hopes that they would evacuate, and also to destroy defending forces that would not yield to the attack. In the 15th century, smallpox virus was used on contaminated clothing to defeat South American and Native American forces. Attempts to use anthrax were directed at animal populations during World War I.

In 1995, a small Japanese terrorist group launched a terrorist attack using poisonous nerve gas in a Tokyo subway station that killed 12 and affected more than 5,000. The response of Japanese emergency services successfully prevented a higher mortality. Russia always had an offensive bioterrorism strategy. During the cold war, Soviet Union was accused of attempting the recombination of the venom-producing



Organisms used as bioweapons Bacteria, Aspergillus, Bacillus anthrax

genes from cobras and scorpions with DNA of harmless bacteria. Such agents if delivered as respiratory aerosols could make thousands of people paralytic. In the 1980's Iraq made substantial efforts to develop and stockpile large amounts of biological weapons. In the United States a biological terrorism attack occurred in 2001 when letters laced with infectious anthrax were delivered to media offices and the U.S. Congress.


09-11-01
YOU CAN NOT STOP US.
WE HAVE THIS ANTHRAX.
YOU DIE NOW.
ARE YOU AFRAID?
DEATH TO AMERICA.
DEATH TO ISRAEL.
ALLAH IS GREAT.

Many analysts rank cultured and genetically engineered biological organisms as the most dangerous of all existing weapons technologies, with the potential for producing more extensive and devastating effects on human populations than even nuclear weapons. Recombinant DNA technology has broadened the scope of modified strains of microbes which if released in the environment can cause mass destruction. There is also a possibility that genetic engineering may produce a weapon that is unique and can only be protected against with a unique vaccine. Minor molecular adjustments may produce a more toxic, fast acting, and stable biological agent. These two examples of potential developments in biological warfare may give bioweapons a great deal more utility, especially on the battlefield. There is also some speculation that a toxic agent could be produced that would target only a specific genetic makeup, giving an attacker the capability to discriminate among age, gender, racial or behaviour groups as target sets. Experts are of the opinion that ready availability of DNA and protein sequence data from natural pathogens, together with advances in transgenic and transformation technologies, might facilitate the development of bioengineered weapons by those with more sinister intentions.

The use of bioweapons for the purpose of economic sabotage against national agricultural and livestock industries is a potentially serious threat to biodiversity. Not only do bioweapons have direct effects on the genetic diversity of domesticated plants and animals, there is also the potential for both direct and indirect consequences on plant and animal populations. Agriculture, particularly in many developed countries, has several characteristics that make it vulnerable to attack with genotype-specific weapons. Typically it employs mono-cropping of large acreages with genetically identical cultivars, and high-density husbandry of genetically inbred animal strains. These agronomic practices reduce the genetic variability that makes populations resistant and susceptible to diseases.

Although the production of biological weapons for bioterrorism is a cheap and cost-effective technology, the economics involved in combating the threat is vast. Man-made or natural infectious outbreaks could decimate the global economy. Killing efficiency of biological weapons is more than any other conventional warfare agents. One gram of toxin can kill millions of people. Purified strain of botulinum toxin in a single missile warhead could affect an area of 3,700 sq. km, which is 16 times more than any conventional weapon. Reports from various countries suggest that every country would have to spend a huge chunk of money for developing strategies to combat this threat.

Awakening, awareness and understanding the gravity of threat is the need of hour. Government agencies, non-government organisations and laboratories across the globe are gearing up to fight back. Novel detection techniques are being designed. Bioinformatics and nanotechnology has answers to many queries and potential solutions to offer for efficient detection and surveillance systems. Coordinated efforts from policy makers, biologists, military, and defence laboratories can help mitigate and minimise the risk of bioterrorism. Moreover, we need to develop and fund specific research programmes aimed at addressing the threat of biological weapons, rather than hoping that some magic wand will do the job.

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Letter to editor

Forgetting S.N. Bose

With reference to the letter of Dr. B.N. Dhawan (Dream 2047, May 2014), as an author, while I do admit and regret the inadvertent lapse on my part, I would like to point out that articles have already been published in Dream 2047 that amply bring out the monumental work of S N Bose. In particular, I would like to quote the following two of my articles: i) "Bosons: The birds that flock and sing together" (Dream 2047, January 2002) and ii) "It's a Higgs boson!" (Dream 2047, September 2012). The first article is a popular account of the life and times of S.N. Bose, Bose-Einstein Statistics, bosons, and the subsequent progress till the beginning of the present century. I admit it is rather old, but the second article is fairly recent and gives a brief life-sketch of S.N. Bose and his work, but with emphasis on the Standard Model and the Higgs boson discovered in 2012 at LHC.

Both the articles are available on the VP website.

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Conservation of wetlands and waterbirds: an ecosystem approach

Vaithianathan Kannan

S. Kannan

Wetlands cover 6.4% of the Earth's surface and 3.4 % of the Indian landmass. India, with its annual rainfall of over 130 cm and varied topography and climatic regimes, support and sustain diverse wetland habitats. Natural wetlands in India occur as high-altitude Himalayan lakes, flood plains of major river systems, wetlands of the arid and semi-arid regions, coastal wetlands such as lagoons, backwaters and estuaries, mangrove swamps, coral reefs and marine wetlands. India is a nation of extraordinary diversity, the second largest in Asia and the seventh largest country on Earth. The resources of aquatic habitats are vast but little-known. They can be collectively called 'wetlands'.

A perennial river that flows through Eastern Ghats at Chitalaikona Andhra Pradesh (Photo credit: V. Kannan)

Wetlands have been defined as 'lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water'. As habitats and ecosystems, wetlands provide services and products far in excess of the approximately 6% of the Earth's surface that they cover. Wetlands are distinct ecosystems, with characteristic vegetation adapted to soils that are saturated with water, either permanently or seasonally. They constitute unique biotic communities involving diverse plants and animals that are adapted to shallow and often dynamic water regimes. They are among the richest of ecosystems, harbouring a plethora of flora and fauna. They also provide a number of ecosystem services such as water retention during dry periods (thus keeping the water table high and relatively stable), flood mitigation during periods of flooding, catchment for nutrient-rich soils, etc. Wetlands benefit people by providing clean water and opportunities for fishing, agriculture, recreation and tourism. Wetlands also play an important role harbouring and supporting biodiversity – as waterbird habitats and breeding grounds for invertebrates, fish, etc. They provide drought-refuge for several species of waterbirds, many of them found in seasonal wetlands such as swamps.

Traditionally, wetlands have been viewed as wastelands, breeding grounds for mosquitoes and opportunities for land reclamation and dumping sites. Many wetlands have already been lost or degraded through activities such as draining, filling and clearing. This has resulted in a dramatic decline in both the availability and quality of wetlands and their availability to waterbirds. However, in recent years the various services offered by wetlands have started receiving global conservation attention and wetlands have been recognised as important areas for conservation.

Wetlands are unique biotic communities involving diverse plants and animals that are adapted to shallow and often dynamic water regimes. Wetlands are among the richest of ecosystems – a term used to define the concept of a biological system that with its increasing physical and chemical components forms a functional and self-sustaining entity. The value of the world's wetlands are increasingly receiving due attention as they contribute to a healthy environment in many ways. They retain water during dry periods, thus keeping the water table high and relatively stable. During periods of flooding, they mitigate flood and trap suspended solids and attached nutrients.

Waterbirds

The term 'waterbird' refers to bird species dependent on aquatic habitats to complete

A wetland nearby Chennai and along the margins the human settlements at the backdrop of wetlands in Chennai a potential threat (Photo credit: S. Ramanathan)

Agricultural wetlands also serve as a feeding habitat for species like Black-tailed godwits (Photo credit: V. Kannan)

parts of their life cycles that may include feeding, breeding, nesting and moulting. Waterbirds are adapted to living in habitats ranging from freshwater to marine habitats and their adaptations vary depending on their environment. Common adaptations include webbed feet, bills and legs adapted to feed in water and the ability to dive into water to catch prey. Common waterbirds include ducks, geese, swans, grebes, loons, storks, herons, egrets, ibises, spoonbill, cormorants, pelicans, flamingos, cranes, rails, crakes, coots, moorhens and kingfishers. Out of 310 Indian wetland species 130 (42%) are migrant and 173 are resident. Of the 173 resident species, 53 species are permanent residents, 38 are partial residents and part winter migrants and 50 undertake local migrations depending on water conditions.

Wetland birds play a significant cultural and social role in local communities as well as being an important component of wetland ecosystem. These birds have figured throughout history in human culture, serving as sources of food, ornamentation, in folklore, or as totem figures. Even today, many serve as symbols of cultural identity, conservation organisations, environmental programs or locales. They have long attracted birdwatchers from across the country for scientific or recreational purposes or aided in livelihoods such as the seabird flocks leading anglers to their catch.

Spectacular in their form or in their congregations, such as those observed for flamingos in Mumbai, waterbirds represent a unique habitat and beauty of the natural world at its best. They constitute a natural resource of great intrinsic, human, and ecological value. Despite their value, or perhaps because of it, waterbirds have not always fared well at the hands of humans. Some waterbirds continue to be threatened by human activities. People sometimes look upon waterbirds with disfavour when nesting or roosting congregations fight and make noise, which conflict with aesthetic standards in urban and suburban environments. Public disaffection towards waterbirds, warranted or not, may be among their greatest long-term threats.

Wetlands serve as a staging habitat for migratory species like the Pacific Golden Plover (Photo credit: V. Kannan)

An analysis of threatened wetland birds indicates that of a total of 242 species, 82 species are in Asia of which 39 are in India. The Painted Stork (*Mycteria leucocephala*), darter (*Anhinga melanogaster*), Spot-billed pelican (*Pelecanus philippensis*), Lesser Adjutant (*Leptoptilos javanicus*), and the Indian skimmer (*Rynchops albicollis*), which were formerly found throughout much of south and south-east Asia are now rapidly declining in abundance. The Pink-headed Duck (*Rhodonessa caryophyllacea*), a globally threatened species, has probably disappeared from India. In addition, the habitats of waterbirds are also at risk due to human as well as natural threats such as coastal development or coastal erosion, industrial run-off into wetlands, etc.

An ecosystem approach for conservation

Biologically, wetlands play a vital role in releasing nutrient-rich sediments and vegetative matter into rivers, which helps feed fish, and many animals that live in other habitats use wetlands for migration or reproduction. Wetlands help to counterbalance the effect of human activities on rivers by rejuvenating them and surrounding ecosystems. Unlike most other habitats, wetlands directly improve other ecosystems. Because of its many cleansing benefits, wetlands have been compared to kidneys. Wetlands are vital to the health of all other biomes and to wildlife and humans everywhere.

The ability of wetlands to recycle nutrients makes them critical in the overall functioning of Earth. No other ecosystem is as productive or as unique in this conversion process. However, wetlands are also one of the most threatened habitats of the world. Wetlands in India, as everywhere else, are facing

Mangrove vegetation in a coastal wetland (Photo credit: V. Kannan)

Blooming beauty in a freshwater wetland (Photo credit: V. Kannan)

increasing anthropogenic pressures. Rapidly expanding human population, large-scale changes in land use, unchecked development projects and improper use of watersheds have all caused a substantial deterioration in their condition Several wetlands have been lost to industrial, agricultural and other urban developments.

Human activities cause wetland degradation and loss by changing water quality, quantity, and flow rates, increasing pollutant inputs and changing species composition as a result of disturbance and the introduction of non-native species. A wetland's characteristics evolve when hydrologic conditions cause the water table to saturate or inundate the soil for a certain length of time each year. Any change in hydrology can significantly alter the soil chemistry and plant and animal communities. Although wetlands are capable of absorbing pollutants from the surface water, there is a limit to their capacity to do so. The primary pollutants causing wetland degradation are sediments, fertilisers, human sewage, animal waste, pesticides and heavy metals.

Many Asian waterbird species that are dependent on wetlands, either directly or indirectly are also under threat. Studies have shown that 42% of the waterbird populations are disappearing at an alarming rate not only in India but also in the world. The provision of feeding and roosting habitat is very important for migratory species. Some of these birds migrate thousands of kilometres in search of wetlands. In recognition of the significance of wetlands for many trans-equatorial species of migratory waterbirds, several wetlands have been identified as being internationally significant under the Ramsar Convention.

Humans use the rivers as a potential fishing area (Photo credit: V. Kannan)

The destruction of wetlands which serve as nesting and feeding grounds has forced waterbirds to compete for diminishing resources. Clearing and degradation of fringing and littoral wetland vegetation reduces waterbird breeding success as a consequence of the loss of habitat and protection from predators. It is therefore important to have a good understanding of the ecological needs of the waterbirds which use the wetland or may be attracted to it, in order to provide suitable habitat for these species. Waterbirds and other migratory birds are some of nature's most magnificent resources. Their conservation is a critical and challenging endeavour to all who value nature.

Wetlands are important for many reasons, they acts watersheds, help prevent flooding by holding water much like a sponge and filter, and also purify the surface water. They also play a key role in a number of global processes, from climate change to coastal protection. Wetlands are also habitats for wildlife that simultaneously provide opportunities for human recreation, such as birdwatching, hunting, fishing, and hiking. Besides celebrating the 'World Wetlands Day' on 2 February every year we need to ensure their existence to protect waterbirds and also benefit humans. Wetlands are real crossing points where nature and human culture have come together for hundreds of generations.

More recently, waterbirds are being considered as indicators of wetland quality that can inform scientists and decision makers about the regional biodiversity and for evaluating habitat restoration efforts. The protection of the threatened waterbirds is particularly a difficult conservation challenge due to the number of threats and drivers that need to be managed for their conservation. Focussing on actions to limit threats to wetlands, the waterbird habitat, directly envisions the wellbeing of waterbirds – a two-in-one approach.

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The dangers of hyponatremia

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All of us in this generation are cautious about our intake of common salt because a high sodium level in the blood is supposed to raise the blood pressure leading to a host of other problems. So we try to reduce the intake of common salt. However a lesser known condition called hyponatremia (low sodium in blood) poses a greater threat to our lives.

Hyponatremia refers to abnormally low sodium levels in the blood. Sodium is essential for many body functions including maintenance of fluid balance, regulation of blood pressure and normal functions of the nervous system. Sodium ion is an electrolyte and it helps to regulate the amount of water in and around our cells.

Hyponatremia is an electrolyte disturbance in which the sodium ion concentration in the plasma is lower than normal. The normal serum levels in the blood are between 135 and 145 m mol/L (millimoles per litre). The condition becomes severe when sodium level falls below 125m mol/L.

Sodium ion is a cation (positive ion) and it cannot cross the cell membrane from the interstitial space into the cell because the charged sodium ions attract up to 25 water molecules around them, creating a large polar structure that is too large to pass through cell membrane.

Clinical signs and symptoms

Most patients with hyponatremia are asymptomatic; that is, do not show any symptoms of the condition. Symptoms usually do not appear till the sodium level drops below 120 m mol/L. In cases of severe hyponatremia , neurological and gastrointestinal symptoms predominate. The risk of seizures and coma increases as the sodium level falls. Difficulty in respiration is also one of the symptoms seen in hospitalised patients. Muscle weakness, restlessness, fatigue, confusion and convulsions are also some of the serious symptoms.

The probable causes of fall in sodium levels are:

1) Prolonged period of exercise
2) Prolonged sweating
3) Severe vomiting or diarrhoea
4) It can also be caused by overhydration by drinking too much of water. Water tries to enter the cells causing them to swell (oedema). When this occurs in the brain, it is referred to as cerebral oedema which is dangerous.
5) Being on a low-sodium diet.

Sodium level decreases when the accumulation of total body water becomes greater than the body's accumulation of electrolytes (sodium and potassium); that is, there is excess of water relative to the plasma sodium (salt level in the blood).

Older adults usually become ill with hyponatremia due to age related causes that affect the way the body handles the balance of sodium and water such as:

i) Taking certain medications such as diuretics, antidepressants and pain medications
ii) Changes in kidney function
iii) Kidney failure
iv) Heart failure
v) Having high level of antidiuretic hormone which causes water retention
vi) Urinating less frequently
vii) Hypothyroidism
viii) Addison's disease (affecting adrenal gland)

Possible complications

In severe cases hyponatremia can lead to:

i) Decreased consciousness, hallucinations or coma,
ii) Brain herniation (water inside the skull produces pressure that moves the brain tissue), or
iii) Death

Treatment

Hyponatremia is corrected by slow administration of normal saline and intravenous administration of fluids and electrolytes. The serum sodium is not allowed to rise by more than 8 m mol/L in 24 hours. Sudden increase of sodium level may lead to severe neurological disorder.

Pharmaceutically, drugs called vasopressin receptor antagonists can be used. A new class of "vaptan drugs" have been developed.

Acute severe hyponatremia (less than 125 m mol/L) usually associated with neurological symptoms such as seizures need to be treated urgently because of the high risk of cerebral oedema.

Prevention

Keeping the water and electrolyte balance can prevent low blood sodium. For athletes, it is very important to drink the right amount of water during exercise. Athletes should also consider drinking of rehydration beverage containing electrolytes. Players and those who exercise more should drink fluids containing electrolytes (not only water).

Accurate diagnosis of the cause, pathogenesis and chronicity (the condition of being chronic) and monitoring during treatment are the critical parts of the management of severe hyponatremia. Frequent monitoring of the patient is absolutely essential in order to ensure optimal chances of recovery. ■

Of Anal Fissures —
Causes, Home Remedies, and Treatment

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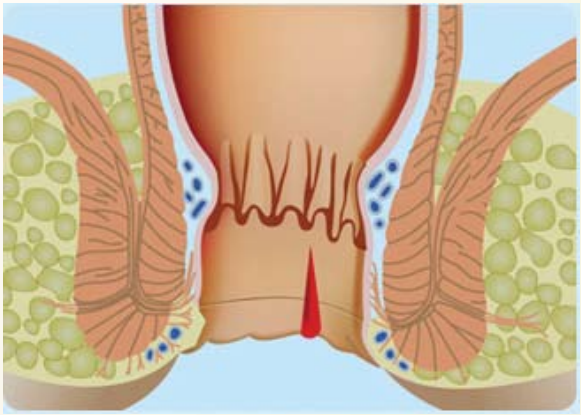
Stretching and tearing of the rim of the back passage or anus can occur when a person passes particularly hard stools. Even though this tear is usually small, often less than a centimetre in size, it can be exquisitely painful. This is because the anus is very sensitive. The pain tends to be worse when you pass stools and for an hour or so after passing stools. This condition is given the name of an anal fissure.



Anal fissures are common, both in adults and in children. They are not usually serious, but they are sore and can be distressing. In most people the fissure heals within 1-2 weeks or so, just like any other small cut of the skin. In such a situation, home treatments often work. The aim is to ease the pain until the fissure heals, and to keep the stools soft and easy to pass.

Some fissures, however, take longer to heal. A fissure that lasts more than six weeks is called a chronic anal fissure. Such a persistent fissure can be dealt effectively through a number of treatments—these include an ointment to relax the anal muscle, and surgery.

Tell-tale symptoms

Anal fissures can be recognised easily by their tell-tale symptoms:

Pain during a bowel movement

An anal fissure causes a sharp, stinging, or burning pain during a bowel movement. The pain, which can be severe, may last for a few hours.

Bleeding

Often an anal fissure will bleed a little. You may see a small spot of bright red blood on toilet tissue or a few drops in the toilet bowl. The blood is separate from the stool. Very dark, tarry stools or dark red blood mixed with stool indicates some other condition, possibly inflammatory bowel disease or a more serious condition. You should contact a doctor if you have any bleeding with bowel movements.

Itching and discharge

Fissures may itch. They also may cause a faint yellowish discharge.

Painless wound

Sometimes an anal fissure may be a painless wound that won't heal and that bleeds intermittently but causes no other symptoms.

Causes

Anal fissures are caused by a breach in the skin of the anal canal. Such damage or injury can take place in a number of situations:

Constipation

Constipation can make an anal fissure more likely to develop. You try to pass a hard stool, and may tear of the skin around the back passage.

Childbirth

In women, childbirth can also cause trauma to the anal canal. In about 1 in 10 cases, the fissure occurs during childbirth. Unattended deliveries are more likely to be accompanied by such damage.

Repeated diarrhoea

In some cases, an anal fissure may be caused by Crohn's disease, an inflammatory bowel disease that causes bloody diarrhoea, abdominal pain, fever, weight loss, and fissures or fistulas near the anus.

Direct trauma

Fissures can also be caused by digital insertion (as during an examination), foreign body insertion, or anal intercourse.

Key predisposing factor

Since many people get constipated or have diarrhoea without getting anal fissures, many experts believe there is some other cause of anal fissures. Some people may have excessive tension in the two muscular rings—the so-called sphincters—controlling the anus. The external anal sphincter is under your conscious control. But the internal anal sphincter is not under your control. This muscle remains under pressure, or tension, all of the time. A fissure may develop if the resting pressure of the internal sphincter becomes too high, causing spasm and reducing blood flow to the anus. Once a tear has developed, pain when passing stools, increases the anal tone (the tendency to constrict) further. This high resting pressure can also keep a fissure from healing. This makes the symptoms worse and a vicious cycle sets up, worsening the fissure.

Diagnosis

Most doctors can diagnose an anal fissure by your typical symptoms and by examining the skin around your back passage (anus). Usually, the doctor can see the fissure by gently separating the buttocks.

A doctor may use a gloved finger (digital rectal examination) or a lighted instrument (anoscope) to examine the fissure. But if the fissure is extremely painful, the doctor will usually wait until it has begun to heal before performing a rectal exam or using an anoscope to rule out other problems. A topical anaesthetic may be used if an immediate examination is necessary.

During an exam, a doctor can also find out whether another condition may be causing the fissure. If you have several fissures or have one or more in an area of the anus where fissures usually do not occur, you may have another condition such as inflammatory bowel

disease, syphilis, a suppressed immune system, tuberculosis, HIV infection, or anal cancer. Most fissures occur along the midline, the top or bottom of the anus.

Treatment options

Simple home treatments

In most people, anal fissures heals within a week or so, just like any other small cut or tear to the skin. The treatment aims to ease the pain and to keep the stools soft whilst the fissure heals.

Easing pain and discomfort

Warm baths

Warm baths are soothing, and may help the back passage to relax which may ease the pain.

Numbing creams and ointments

A topical medicine is one that you apply directly to the affected area. Topical anaesthetics work by desensitising (numbing) the skin, which in the case of an anal fissure, will help ease the sharp and severe pain you may experience when passing stools.

Lidocaine is the most commonly prescribed topical anaesthetic. It either comes in the form of a gel or an ointment. Lidocaine is usually only used for one to two weeks because the fissure should start to heal within this time. It is usually applied shortly before passing a stool. You should only use this for short periods (up to 5-7 days). If you use it for longer, the anaesthetic may irritate or sensitise the skin around the anus.

Steroid cream

A cream or ointment that contains steroid medication may be prescribed by a doctor if there is a lot of swelling (inflammation) around the fissure. Steroids reduce inflammation, and may help to reduce any swelling around a fissure. This may help to ease any itch and pain. You should not use it for longer than one week at a time.

Ablution

Wash the anus carefully with water after you go to the toilet. Dry gently. Don't use soap whilst it is sore as it may cause irritation. It is important to avoid causing pain or irritation during ablution.

Toilet paper

If you use baby wipes, do not use products that contain fragrance or alcohol. This could lead to discomfort or itching. If you use toilet paper, use a soft brand if possible and avoid rubbing the area too hard.

Pain-killers

Painkillers such as paracetamol or ibuprofen may help to ease the pain. Do not however use any **painkiller** that contains codeine. They are a common cause of constipation.

Avoid constipation and keep the stools soft

Eat plenty of fibre

You should increase the amount of fibre in your diet. Foods high in fibre include:

- wholegrain bread
- brown rice
- oats
- beans
- grains
- seeds
- fruit and dried fruit
- vegetables
- natural unprocessed foods

Have lots to drink

Adults should aim to drink at least two litres (10-12 cups) of fluid per day. You will pass much of the fluid as urine. However, some is passed out in the gut and softens the stools.

Fibre supplements and laxatives

If a high-fibre diet is not helping, you can take fibre supplements (bulking agents) such as *ispaghula* husk, methylcellulose, or bran. Methylcellulose also helps to soften stools directly which makes them easier to pass.

A laxative such as lactulose or a macrogol laxative may sometimes be suggested. You can buy these at pharmacies or get them on prescription.

Toileting

Don't ignore the feeling of needing to pass stools. Some people suppress this feeling and put off going to the toilet until later. This may result in bigger and harder stools forming that are more difficult to pass later.

Medications

An anal fissure will usually heal within 1-2 weeks in most people. However, it can take longer to heal in others. Even if it has lasted six weeks, and has become chronic, there is still a reasonable chance that it will heal on its own without treatment. However, treatment can help to heal the fissure as quickly as possible.

The plan of treatment is: One, to relax the tone of the muscle around the anus. This allows a good blood flow and enables the fissure to heal as quickly as possible. Two, keep the stools soft and easy to pass.

Glyceryl trinitrate ointment

If your symptoms do not start to improve after a week, you may be prescribed a medicine called glyceryl trinitrate (GTN). GTN works

by expanding nearby blood vessels, which helps to increase the blood supply to the site of the fissure. The increase in blood supply should enable the fissure heal more quickly.

GTN also reduces anal pressure. This should help reduce the pain. It comes in the form of an ointment and is applied directly to the anal area, usually every 12 hours.

GTN is not suitable for use by pregnant or breastfeeding women. It is also unsuitable for children. Headaches are a very common side effect of this type of medicine. Approximately 50 per cent of people using GTN will experience a headache. Some people may also feel dizzy or light-headed after using GTN.

You will usually have to use GTN ointment for six to eight weeks, or until your fissure has completely healed.

GTN ointment may help in some, but not all, cases. Studies have shown that, for people with a chronic anal fissure, about 6 in 10 fissures healed with GTN treatment compared to about 5 in 10 that healed with no treatment. So, the effect of GTN ointment is modest, but may well be worth a try.

Calcium channel blockers

Calcium channel blockers are a type of medication usually used to treat high blood pressure (hypertension). However, they have also proved useful in treating cases of anal fissures in some people. Topical calcium channel blockers work by relaxing the sphincter muscle and increasing the blood supply to the site of the fissure.

Topical calcium channel blockers are also not free of side effects. These may include headache, dizziness (particularly when standing up from a sitting or lying position), and itchiness or burning at the site when you apply the medication. However, these side effects should pass within a few days once your body gets used to the medication.

There is no evidence that calcium channel blockers are more effective than GTN, so they tend only to be used in people unable or unwilling to take GTN.

Botulinum toxin

Botulinum toxin is a relatively new treatment for anal fissures. It is usually used if other treatments have failed. A powerful poison, it is quite safe to use in small doses. In cases of anal fissure, an injection of the toxin can be used to paralyse the sphincter muscle. This eases the muscle spasm, helps reduce pain and allows the fissure to heal.

Botulinum toxin is an effective treatment in the short to medium term, with three out of four people remaining symptom-free for six months after treatment. Further treatment may be required in the long-term, as around half of people experience a return of their symptoms within three years.

Surgery

When simpler measures fail, surgical techniques may be used to treat an anal fissure. The success rate with surgery is very high: at least 9 in 10 cases are cured.

Internal sphincterotomy

An internal sphincterotomy involves removing a section of the sphincter muscle. This helps to reduce the tension in the muscle, preventing further spasms of the sphincter and allowing the anal fissure to heal.

An internal sphincterotomy is a relatively straightforward operation that can be performed using a local anaesthetic on a day patient basis, which means you will not have to spend the night in hospital.

An internal sphincterotomy is an effective treatment with a good track record of success. Around 95 per cent of people who have this type of surgery will experience healing of their anal fissure.

Complications

As with any operation, there is a risk of complications. After this operation, around 1 in 10 people will experience bowel incontinence after having surgery due to damage to the anal muscles. This means they will lose some control of their bowel movements. However, it is usually a mild type of incontinence where the person is unable to prevent themselves from passing wind, and they may also experience some mild soiling.

The symptoms of incontinence usually improve in the first few months after surgery and resolve within two months. However, in around 1 in 200 cases the incontinence is permanent.

Fissurectomy

A fissurectomy is the surgical removal of an anal fissure, along with the surrounding tissue. Fissurectomies are not as widely used as internal sphincterotomies because they do not treat the underlying causes. Therefore, a fissurectomy may not prevent anal fissures from recurring in the future.

However, a fissurectomy rather than a sphincterotomy may be a recommended treatment option for children because removing a section of the sphincter muscle at an early age could cause permanent incontinence.

Advancement anal flaps

Advancement anal flaps involve taking healthy tissue from another part of your body and using it to repair the fissure and improve the blood supply to the site of the fissure. This is often recommended to treat cases of chronic anal fissure, which have occurred as a result of pregnancy or other injury to the anus.

Risk of recurrence

Some people seem prone to anal fissures happening again. Up to half of people who have a chronic anal fissure successfully treated with GTN ointment will have one or more recurrences at some future time. These people generally have higher-than-average pressure (tone) of the muscle around the anus. They are more likely to tear the rim of the anus if it is stretched. However, a further course of GTN ointment can be used to help to heal any future fissure. Surgery may be an option if recurrences are frequent.

Prevention

If you have had one anal fissure, after it has healed you have a higher-than-average chance of having another one at some future time. The best way to avoid a further fissure is not to become constipated by using simple common sense measures. Take a high-fibre diet, plenty of fluids, and observe all other precautions that reduce the risk of harder stools.

Recent developments in science and technology

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Lightning storms linked to the Sun

Scientists have found a link between activity on the Sun and lightning storms on Earth. Researchers led by Christopher Scott in the Department of Meteorology at the University of Reading, UK have found a correlation between increased lightning storms on Earth and streams of high-energy particles beaming out of the Sun. The researchers have found that for up to 40 days after high-speed solar winds – travelling at more than three million kilometres per hour – hit the Earth's atmosphere, there is a significant increase in lightning rates across northern Europe (*Environmental Research Letters*, 15 May 2014 | doi: 10.1088/1748-9326/9/5/055004).

Scientists have found a link between activity on the Sun and lightning strikes on Earth.

Apart from light and heat, the Sun also emits a constant stream of hot plasma known as solar wind, which travels through the solar system at extremely high speeds. The solar wind consists of mostly electrons and protons with energies usually between 1.5 and 10 keV. It arises out of the hot solar corona, which is the outermost layer of the solar atmosphere. The solar wind does not blow with a constant force – it speeds up and slows down depending on the Sun's activity, and its power can rise and fall. The researchers found that more lightning strikes occur when the solar wind is at its strongest.

Thunderclouds become electrically charged from the collisions of microscopic ice particles in their midst, and from air currents that push the negative and positive charges apart. The air is a good insulator, which keeps the electrons from jumping back and neutralising the electrostatic charges. But if a pathway of ionised air molecules is formed that can act as a conductor between different parts of a cloud, or between the cloud and the ground, the result is a lightning bolt.

It has been known earlier that cosmic rays from space facilitate lightning by ionising air, which is an electrical insulator. According to the researchers, the solar wind has its own magnetic field, and as high-speed solar-wind particles travel through space, they can lead to localised strengthening of the magnetic field, which pushes some of the particles to even higher speeds. These so-called 'solar energetic particles' – unlike other those that travel at slower speeds – have enough energy to penetrate Earth's magnetic field and to travel through the atmosphere, down to the altitudes where thunderclouds form. At the same time, the number of solar particles reaching Earth increases by 6 per cent. If solar particles ionise the air in the same way as cosmic rays, the net effect should be an increase in the number of free electrons leading to a massive discharge. This would in turn increase in frequency of lightning strikes during a peak in solar wind strength.

To test this idea, the research team compared data from NASA's Advanced Composition Explorer (ACE) spacecraft, which measures energetic particles in the solar wind, with lightning rates seen between 2000 and 2005, as measured by monitoring stations for the UK Met Office. In the 40 days after a blast of solar wind, the UK saw an average of 422 lightning strikes. By contrast, there were 321 strikes on average in the 40 days before a blast.

According to the researchers, since the solar wind peaks regularly and its cycles are monitored by spacecraft like ACE, it should be possible to predict dangerous storms. They further add that if a thunderstorm is coming, meteorologists might be able to use data on the solar wind to predict how severe a storm is going to be.

Magnetar puzzle solved

A magnetar is a magnetic star – a neutron star with magnetic fields more than 100

This artist's impression shows the magnetar in the very rich and young star cluster Westerlund 1. This remarkable cluster contains hundreds of very massive stars, some shining with a brilliance of almost one million suns. (Credit: ESO/L. Calçada)

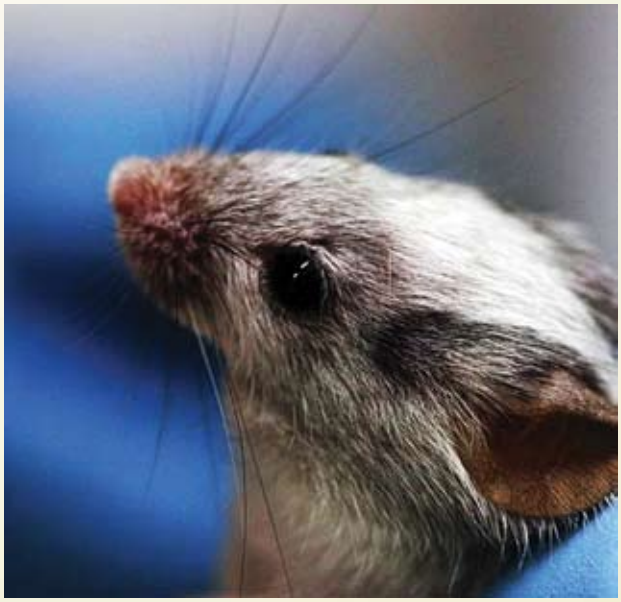
times stronger than those of neutron stars commonly known as pulsars. The field strength of a magnetar is one thousand trillion (10^{15}) times stronger than Earth's and is so intense that it heats the surface to 10 million degrees Celsius. The Westerlund 1 star cluster, located 16,000 light-years away in the southern constellation of Ara, hosts one of the two dozen magnetars known in the Milky Way. It is called CXOU J1647-45 and it has greatly puzzled astronomers.

Like all neutron stars, magnetars form as a result of a core-collapse supernova – the last dying stage of a massive star more than 40 times the mass of our Sun. They are about 20 km in diameter but extremely dense – having a mass of as much as one or two solar masses (a teaspoon of neutron star material would have a mass of about a billion tonnes). Normally, when a massive star collapses under its own gravity during a supernova explosion it forms either a neutron star (also known as a pulsar) or a black hole. Magnetars are an unusual and very exotic form of neutron star.

Magnetars are also known as 'soft gamma repeaters' (SGRs) because they emit bright, repeating flashes of soft (i.e., low-energy) gamma rays. Magnetar surfaces release vast quantities of gamma rays when they undergo a sudden adjustment known as a 'starquake' as a result of the huge stresses in their crusts. Magnetars were discovered in 1979, when a powerful blast of gamma rays swept through the solar system, and sent gamma ray detectors off the charts. Gamma ray detectors on nine spacecraft across our solar system recorded an intense radiation spike. The physical nature of these stars was a mystery for many years. In 1992, it was proposed that SGRs are magnetically-powered neutron stars; subsequent observational studies lent support to this hypothesis.

According to astrophysicists, magnetars are not powered by a conventional mechanism such as nuclear fusion or rotation, and till recently no plausible explanation for their existence was known. Astronomers now believe they have found the partner star of a magnetar for the first time which gives clue to its formation. This discovery helps to explain how magnetars form – a puzzle that had remained unsolved for 35 years.

Astronomers had earlier proposed an explanation of how magnetars are formed. They suggested that a magnetar is formed through the interactions of two very massive stars orbiting one another in an extremely compact binary system that would fit within the orbit of the Earth around the Sun. But, up to now, no companion star was detected at the location of the magnetar in the Westerlund 1 star cluster. So astronomers used the Very Large Telescope (VLT) at the European Southern Observatory's Paranal Observatory in Chile to search for it in other parts of the cluster. They hunted for runaway stars – objects escaping the cluster at high velocities – that might have been kicked out of orbit by the supernova explosion that formed the magnetar. One star, known as Westerlund 1-5, was found to be doing just that; it was the much sought after 'runaway star' that astronomers believe caused the formation of the studied magnetar. From the data gathered in relation to the magnetar in the Westerlund 1 star cluster, it is now believed that the rapid rotation and transfer of mass between binary stars is the key in the formation of the rare neutron stars known as magnetars.



Scientists have treated a genetic disorder in mice by using genome editing that corrects mutated DNA.

DNA 'edited' to cure liver disease

For the first time, scientists are able to 'edit' any part of the human genome with extreme precision using a revolutionary new technique called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats). The technique has been likened to editing individual letters on any chosen page of an encyclopaedia without creating spelling mistakes. It does this by using enzymes to target specific parts of the DNA database. According to the scientists who developed the technique, the technique makes it possible to make the most accurate and detailed alterations to any specific position on the DNA of the 23 pairs of human chromosomes without introducing unintended mutations or flaws. Using CRISPR (pronounced 'crisper'), researchers at the Massachusetts Institute of Technology, Cambridge, USA have cured mice of a rare liver disorder caused by a single genetic mutation. The findings offer the first evidence that this gene-editing technique can reverse disease symptoms in living animals (*Nature Biotechnology*, 30 March 2014 | doi:10.1038/nbt.2884). The technique is so accurate that scientists believe it will soon be used in gene-therapy trials on humans to treat genetic disorders such as sickle-cell anaemia, Down's syndrome and Huntington's disease.

Until now, gene therapy has had largely to rely on highly inaccurate methods of correcting a genetic defect using modified viruses that insert DNA at random into the genome – considered too risky for many patients. The new method, however, transforms genetic engineering because it is simple and easy and can be used to edit any desired part of the DNA molecule, right down to the individual chemical building-blocks or nucleotides that make up the genes.

The CRISPR technique relies on cellular machinery that bacteria use to defend themselves from viral infection. Researchers have copied this cellular system to create gene-editing complexes that include a DNA-cutting enzyme called 'Cas9' bound to a short RNA guide strand that is programmed to bind to a specific genome sequence, telling Cas9 where to make its cut. At the same time, the researchers also use a single-strand DNA template. When the cell repairs the damage produced by Cas9, it copies from the template, introducing new genetic material into the genome thus correcting the defect.

For the current study, the researchers

designed three guide RNA strands that target different DNA sequences near the mutation that causes tyrosinemia – a genetic disorder characterised by elevated blood levels of the amino acid tyrosine, a building block of most proteins. Type I tyrosinemia can lead to liver and kidney failure, problems affecting the nervous system, and an increased risk of liver cancer. It is a severe disorder of the liver caused by a defect in a gene that codes for an enzyme called FAH. Patients with this disease, which affects about 1 in 100,000 people, cannot break down the amino acid tyrosine, which accumulates and can lead to liver failure. Current treatments include a low-protein diet and a drug called NTCB, which disrupts tyrosine production.

In experiments with adult mice carrying the mutated form of the FAH enzyme, the researchers delivered RNA guide strands along with the gene for Cas9 and a 199-nucleotide DNA template that included the correct sequence of the FAH gene. Using this approach, the correct gene was inserted in about one of every 250 liver cells called hepatocytes. Over the next 30 days, those healthy cells began to proliferate and replace diseased liver cells, eventually accounting for about one-third of all hepatocytes. This was enough to cure the disease, allowing the mice to survive even after treatment with NCTB was discontinued.

Spider genome sequenced

For the first time ever, a group of Danish and Chinese researchers has sequenced the genome of a spider, which reveals that humans share certain genomic similarities with spiders. Unlike other arthropods whose genomes are very different compared to humans, spiders have longer introns and shorter exons similar to humans. (Introns and exons are parts of a gene of which exons are responsible for coding proteins.) The fact that the eight-legged crawling spider in some ways resembles humans is one of the surprising conclusions of the study. The mapping was done by an international team of researchers from the Aarhus University in Denmark and the Beijing Genomics Institute (BGI) in China (*Nature Communications*, 6 May 2014 | doi:10.1038/ncomms4765). The researchers worked with two types of spiders. One of these is a small velvet spider and the other is a tarantula. While the sequencing the velvet spider's genome has been successfully completed, there are still some unsolved gaps in the genetic map of the tarantula.

Spiders are the largest group in the arachnid class. All spiders have eight legs and they can be found in six continents. In fact, the only place where spiders have never been found is Antarctica. These creatures have successfully adapted to a wide range of habitats. However, scientists have been trying to gain a deeper understanding of these organisms and the newly mapped genome may be the key to unlocking many of the spider's secrets.

Velvet spider (Gandanameno kromme sp)

After the velvet spider genome was mapped, the researchers went even further and analysed the composition of the proteins produced by the spiders when they produce silk or secrete venom. The protein analysis further added to what is currently known about spiders.

Spider silk has long held the interest of both scientists and engineers due to its strength. According to the researchers, the new study may help unlock some of the secrets behind the strength of spider silk, which is said to be, weight for weight, at least five times as strong as steel wire. The analysis conducted by the researchers could also lead to possible industrial applications for spider silk and the development of stronger synthetic materials that could emulate the properties of natural spider silk. The new research may also unlock novel uses for spider silk in medicine and other fields of study.

The analysis of proteins secreted by the spider further added to what is currently known about spiders. It is well known that spider venom can be very dangerous for humans; further understanding of the venom could lead to more effective treatments for spider bites.

Leaving aside the similarities between human and spider genomes, gaining access to the completely mapped genome of a spider can revolutionise the way scientists understand spiders. Studying their genome can help scientists uncover a wealth of information about how spiders evolved and how they function. ■

Corrigendum

The article "Sir Asutosh Mukherjee: A mathematician par excellence" (Dream 2047 June 2014) was translated into Hindi by Shri Ramsaran Das, but the translator's name was mistakenly printed as Rupendra Sharma. The error is regretted.