R.N. 70269/98
ISSN : 0972-169X

Postal Registration No.: DL-SW-1/4082/12-14
Date of posting: 26-27 of advance month
Date of publication: 24 of advance month

Vigyan Prasar

DREAM 2047

April 2013 Vol. 15 No. 7 Rs. 5.00

Taming the limitless

Satish Dhawan
(A Scientist Extraordinary with a Social Commitment)

(1920-2002)

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

Premise of S & T Communication: Preparedness of stakeholders

Dr. R. Gopichandran

The objective of this editorial is to help emerging specialists/ practitioners and institutions engaged in science and technology communication know about some interesting insights on the process and the logical framework that drive such efforts. In this context, I am inspired, particularly by the arguments of Nisbet and Scheufele (2009). They clearly define three important interrelated considerations in the design and delivery of communication interventions. Firstly, there is need for a holistic understanding of the preparedness of stakeholders to comprehend messages that are delivered, duly recognising their knowledge base, values and perspectives, regarding the issues deliberated on. Secondly, this understanding will help develop communication processes that are inclusive and do not even inadvertently alienate receivers of such information. Thirdly, policy decisions that impinge on the use of science and technology are also probably driven by the political context, values and tradeoffs with respect to costs, benefits and risks. This therefore implies a larger link between the perceptions of individuals and the enabling environment for action at the collective level.

Much as sustainable development features high on the agenda of countries, as in India too, policies and plans have to duly recognise diverse perspectives and the need to harmonise approaches, goals and outcome. Importantly, this approach of stakeholder engagement is evident in the consultation processes related to development and implementation of several public policy instruments in India. Communication strategies that enable this harmonisation for a consensus are central to the success of the processes and outcome of participation.

The fourth consideration highlighted by Nisbet and Scheufele (*op.cit*) is the stakeholder's own perspective about the implications of the message received for action. Receivers of such information ask if scientific knowledge communicated (depending on the context) actually works and whether scientists have paid adequate attention to diverse knowledge on the topic of concern. Public also reportedly examines if scientists have taken the specific developmental considerations of all stakeholder groups, while articulating options for management, with implications for immediate, medium and long-term periods. Importantly, they appear to ask if such enabling circumstances as institutional mechanisms including regulations and the extent which they will be exerted have also been defined.

UNESCO (2013) through a recent snapshot of its initiatives in the science, technology and innovation interface re-emphasised the interrelatedness of social dimensions and emerging knowledge systems on technological progress and sustainable development. This resonates with the views of Nisbet and Scheufele (*op.cit*) on the premise that scientific knowledge is advanced through inclusive decision-making enabled through dialogues and involvement of all stakeholders in the decision-making process. The snapshot refers to the process of debates and emerging perspectives in the interface of science, knowledge and society that the 2013 event of the World Science Forum (WSF) in Brazil is eagerly anticipated to enable further consolidation. It will be useful to follow these events to know about the emerging dynamics of science and technology communication with special reference to sustainable development.

1. Nisbet MC and Scheufele DA 2009 What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany* **96** (10) 1767 – 1778 Accessed on 11 3 2013 from http://climateshiftproject.org/wp-content/uploads/2012/01/NisbetScheufele2009_WhatsNextforScienceCommunication_PromisingDirectionsLingeringDistractions_AmericanJournalBotany.pdf
2. UNESCO 2013 UNESCO Science for peace and development. 51p. UNESCO, Paris. Accessed on 11 3 2013 from http://unesdoc.unesco.org/images/0021/002197/219756E.pdf

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Tel : 011-26967532; Fax : 0120-2404437
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website : http://www.vigyanprasar.gov.in

Published and Printed by Dr. Subodh Mahanti on behalf of Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi - 110 016 and Printed at Aravali Printers & Publishers Pvt. Ltd., W-30, Okhla Industrial Area, Phase-II, New Delhi-110 020 Phone: 011-26388830-32.

Satish Dhawan

A Scientist Extraordinary with a Social Commitment

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"The dream of Dr Sarabhai was shaped into reality by Prof. Satish Dhawan. After he took charge of ISRO from 1972, Prof. Dhawan structured and nurtured ISRO with a space profile and his work led to many significant accomplishments and benefits from a number of remote sensing and communication satellites. The Polar Satellite Launch Vehicle accomplished the feat of launching multiple satellites for India and other countries in different orbits in a single mission."

APJ Abdul Kalam in *Ignited Minds: Unleashing the Power within India* (2002)

"Dhawan had a very intense feeling of technology and, more significantly, an exceptional depth of understanding of its relation with the society. His concern was to make space technologies like remote sensing and communication relevant to the society. He knew that if this had to become a reality, he had to institutionalise their implementation."

K. Kasturirangan in *Resonance*, October 2003

"He (Satish Dhawan) went on to become a great scientific leader in India, building a space research organisation that grew to be a spectacularly successful technology development enterprise. But Dhawan combined his nationalist commitment to big science with a deep love for little science. I learnt from him how to do research even when one did not have all the equipment needed. His laboratory was full of beautiful little 'gizmos', as the he called them, and we jointly added some more to the collection, including a simple but effective one dollar box camera for fast recording of oscilloscope traces, some of which ended up in a paper in the *Journal of Fluid Mechanics*."

Roddam Narasimha in *One Hundred Reasons to be a Scientist* (2005)

Satish Dhawan shaped India's space programme by translating Vikram Sarabhai's dream into reality. His role in shaping the country's space programme is enough to make him one of the most influential personalities in post-independence India. However, Dhawan's pre-eminent role in the development of science and technology in the country goes much beyond the confines of India's space programme. He made very significant but multi-dimensional contribution to scientific research, science education, development and training of S&T manpower, S&T policy formulation and implementation and building of S&T institutions and transforming the existing ones. He did all this with a deep sense of social commitment and keen awareness of present and future requirements of the country. He was widely regarded as the conscience of the scientific community. He was a great inspirer of people.

Dhawan was one of the most eminent researchers in the field of turbulence and boundary layers. He carried out pioneering experiments in rural education, remote sensing and satellite communications. His efforts led to the development of operational systems like INSAT, India's telecommunication satellite system, the Indian Remote Sensing Satellites (IRS), and the Polar Satellite Launch Vehicle (PSLV).

Satish Dhawan

Dhawan advocated the need of accurate weather prediction, which, he believed could substantially improve India's economy. It is said that perhaps 'Dhawan was India's first champion of numerical weather prediction'.

Dhawan was the longest serving director of the Indian Institute of Science (1962-1981), one of the premier scientific research and educational institutions in the country. He was the Chairman of the Indian Space Research Organisation (ISRO) from 1972 to 1995) and Chairman of the Indian Space Commission from 1972 to 2002. It was because of Dhawan, who took great pains to establish close interfaces with the multiple users, that the Indian space programme has attained the important status in the country's development.

Dhawan was a great inspiring leader. He readily took the responsibility of failures of people working under him and allowed them to take the credit when there were successes. It was not that he was not disappointed at failures, but he would not show it to others. Every time he would analyse the causes for the failure in depth so that it does not repeat again. He considered the institution more important than the individual and always endeavoured to create collective decision-making structures. He was an original thinker. He had a deep sense of humour. He was a deeply compassionate human being. He avoided publicity.

Dhawan's most important contribution was as a teacher. In fact, he primarily considered himself a teacher. His role as a teacher was not confined to his class rooms. APJ Abdul Kalam, the former President of India and an important contributor to India's space programme, who worked closely with Dhawan wrote: "The unique feature of his teaching was that he created a spirit of

research and inquiry in me, taught me how to design without giving me the design. He enriched my design capability by following through implementation and test phase, just by asking more and more questions and making me find the answers from them. This enriched my self-confidence in taking up future design problems."

Dhawan was born on 25 September 1920 in Srinagar, Jammu & Kashmir. His father was a civil servant of undivided India and retired as Resettlement Commissioner of the Government of India. He studied at the Punjab University in Lahore (now in Pakistan). He had a combination of academic degrees. From Punjab University, Lahore he obtained BA in Mathematics and Physics and MA in English Literature. In 1943, he moved to the USA where he first attended the University of Minnesota, Minneapolis and completed a Bachelor of Engineering degree in Mechanical Engineering in 1945. In 1947, he obtained a Master of Science in Aerospace Engineering and Aeronautical Engineer's degree from the California Institute of Technology (Caltech). From Caltech he also obtained a double PhD in Mathematics and Aerospace Engineering under the supervision of Hans W. Liepmann (1914-2009), an American engineer known for his numerous contributions in fluid mechanics covering a wide range of problem areas.


Hans W. Liepmann

Commenting on the work done by Dhawan for his PhD thesis, Roddam Narasimha wrote: "For his PhD thesis he invented an ingenious method of directly measuring friction drag on a surface by letting a small strip of it—about a millimetre wide—float, and measuring its effective deflection against the resistance of a spring by electronic methods, using a null technique. These results appeared in various books of the time, including the first edition of the English translation (from German published in 1955) of Schlichting's book *Boundary Layer Theory*, the first on the subject. They have been faithfully reproduced in the many editions the book has gone through over the last fifty years, including the eighth edition published in 1999."


Vikram Sarabhai

In 1951, Dhawan joined the Department of Aeronautical Engineering of the Indian Institute of Science, Bengaluru (then Bangalore). His initial appointment was as Senior Scientific Officer, but within four years he became Professor and Head of the Department, and in 1962, at the age of 42, he became the youngest Director of the Institute. He transformed the Institute and brought in young faculty both from within the country and abroad, started new departments and encouraged to initiate work in newer areas, for example, in atmospheric sciences. Dhawan was a star attraction in the campus right from the day he joined the Institute. Roddam Narasimha, an eminent scientist and one of the most successful students of Dhawan, wrote: "Dhawan brought to the Institute an element of youthful freshness, modernity, earnestness and Californian informality that captivated the students and many colleagues. In short, he was a star on the campus."


Indian Institute of Science, Bangaluru


JRD Tata

After the sudden death of Vikram Sarabhai in December 1971, Smt. Indira Gandhi, the then Prime Minister of India, invited Dhawan to take the reins of India's space programme. At the time the offer was made, Dhawan was in USA on sabbatical leave and he was teaching a course at Caltech. He told the official of Indian Embassy that he would not be able to return to India without finishing the course, and further, without consulting his present employer, that is, IISc, it would not be possible for him to give a final answer. R. Choski, Chairman of IISc Council and JRD Tata, the President of the institute's court told Dhawan, whom he met after coming back to India, that IISc had no objection to his taking up the assignment offered by the Prime Minister.


Smt. Indira Gandhi

Dhawan met the Prime Minister Smt. Indira Gandhi and told her that he would be willing to take up the assignment but he would like to put up the following two conditions: (i) He should be allowed to continue as Director of IISc, and (ii) the headquarters of India's space programme should be located in Bengaluru. The Prime Minister accepted both the conditions and Dhawan took up charge of India's space programme in September 1972. He became Chairman of

the newly established Space Commission, Secretary to the Department of Space, and Chairman of ISRO. It may be noted that the Space Commission and the Department of Space were established on 1 June 1972. Since the time of Dhawan all the three posts are simultaneously held by a single person.

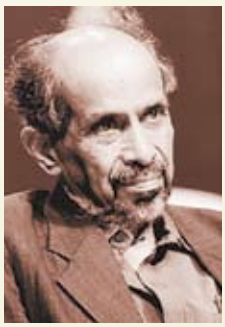

K. Kasturirangan

K. Kasturirangan, former Chairman of ISRO and a close associate of Dhawan has pointed out that Dhawan selected Bengaluru as the headquarters of India's space programme for strategic reasons. He wrote: "Dhawan was a person who could think well ahead. It was his strategic decision that kept the Headquarters of Indian Space programme in Bangalore, not because he wanted to run the space programme even as he continued his academic administrator's role as Director of the Indian Institute of Science but because he knew that Bangalore had several advantages. The city could accelerate satellite building activities, which had just been taken up, using the institutions, National Aeronautical Laboratories (now called National Aerospace Laboratories) and industries like Hindustan Aeronautics and Bharat Electronics. Besides its salubrious climate that facilitated the fabrication of satellite systems, the academic, industrial and research ambience of the city were decidedly advantageous."

He saw to it that he himself was not in charge of the major projects (he only chaired the *Aryabhata* Project Management Board) but ensured that works and responsibilities are properly delegated. N. Gopal Raj, a regular commentator on India's space programme wrote: "He (Dhawan) believed the institution was bigger than the individual and sought to create collective decision-making structures. Under him, the Department of Space and the Indian Space Research Organisation developed effective ways of assessing growth strategies for the future and monitoring the progress of the ongoing projects. Project management methods allowed work to be coordinated across different groups and work centres within ISRO, and even in industry and academic institutions."


APJ Abdul Kalam

APJ Abdul Kalam, commenting on Dhawan's management style, wrote: "I learned an important lesson in management from Prof. Dhawan when I was appointed Project Director SLV-3 in 1972 to design, develop and launch the first satellite launch vehicle to inject *Rohini* into near-earth orbit. This was that, when a Project Director is appointed, the whole organisation—including the Chairman ISRO—works for his success. It is a lesson that has been of abiding value all through the other projects I have worked on."


Roddam Narasimha

Dhawan continued to do research in his laboratory and to interact with fellow scientists. Highlighting Dhawan's attachment to 'little' science, Roddam Narasimha wrote: "While doing all the high technology and big science at ISRO, he never forgot how crucially important 'little' science was, and ceaselessly promoted it, especially with young people. Indeed, he indulged in it himself whenever he could; the only book he wrote (to my knowledge) is a little gem on bird flight, which grew out of a lecture he gave first at the Academy, and then at many other places across the country (especially, by his insistence, at those off the beaten track, like Jammu and Guwahati). I still remember how he took a busy break from running his space empire to work on the Academy lecture, drawing his own diagrams and doing his own sums."


K. R. Narayanan

Dhawan had a deep sense of social commitment. For him the mere economic benefit accruing from science and technology was not enough. He expressed his concern for the entire segment of the society. His comments on ISRO's effort in identifying and delineating 13 types of wasteland in the country as pointed out by Kasturirangan are worth quoting. When Kasturirangan showed him the maps prepared for reclaiming the lands for agricultural and other uses Dhawan said: "…this is all very good and these maps are very useful to develop this country. But do you know that wastelands in our country are not a waste? There are tribals and others who depend on the produce of these so-called wastelands. If you start water recharging and improve the water availability in these lands to improve the vegetative cover, the whole place may look very promising to prospective developers. Then these tribals will be disturbed and there will be no system to protect them." For him a technology had no use if it did not serve the common person (*aam admi*). He strongly believed that the chief objective of science and technology should be to serve the country and its people.

Dhawan's fascination for nature was contagious. Natural phenomena around him always made him curious. Like a true scientist in the tradition of Archimedes, Galileo, Newton, Raman and many others, he had an inner urge to unravel or the understand the mysteries of nature. He was fascinated with birds and birds' flight. He once wrote: "Whenever my work related to the country's space programme became a little taxing, I went to see the birds of SHAR—and came back feeling happy and invigorated." He was not simply contented by observing birds flight. His consistent and painstaking observations evolved into a serious research problem and which led to the outstanding contribution in the field of aeronautics. In this context it is worth quoting KRY Simha: "It is remarkable that Raman and Dhawan studied nature to enrich their respective professions to help launch Bangalore to a premier position in world science and technology. Bangalore is rapidly losing a lot of her charming gardens, lakes and birds except for some dashing green barbets and some sparkling sunbirds. But the charming spirit of Dhawan will continue inspiring students, teachers, naturalists and environmentalists besides aerospace scientists and engineers."

Among the awards received by Dhawan are: Padma Vibhushan (India's second highest civilian award, 1981), Indira Gandhi Award for National Integration

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Taming the limitless

The other day I watched a documentary film titled 'Journey to the edge of the Universe'. The film was written by the famous British astronomer Nigel Henbest and writer Billie Pink and it was directed by Yavar Abbas. It documents a spectacular space journey from the Earth to the edge of the Universe. It had many interesting and mind-boggling facts about the Universe. After watching the film, I was fascinated and absorbed with the facts and figures about the Universe and many other questions also came to my mind. How big is our Universe? Is it infinite? How was the Universe created? How did the time begin? Is infinity just an abstract idea? Does it define the beginning and end of the Universe?

The next day was a Sunday. My uncle was reading the morning newspaper and I was eagerly waiting for him to finish the reading. Probably uncle could guess my curious and restless look. He put aside the paper, smiled and said, 'My dear Googol, you seem to do a lot of scribbling on your notebook – what's the matter?'

'Uncle, will you please explain me the concept of *infinity*? Yesterday I saw a documentary and the concept would help me understanding our Universe,' I said.

'Well Googol, *infinity* is a concept of something that is unlimited, endless and without bounds. The concept of infinity intrigued human minds for thousands of years. Both mathematicians and physicists struggled for centuries to define and understand the concept of infinity. '

'Please elaborate it.'

'In mathematics, infinity is often wrongly treated as if it is a number to measure or count extremely big things. However, one should understand that infinity is not the same sort of number as the real numbers – it is rather a concept. There is no way you can reach infinity through an extremely large number. Whatever big number you may consider, there exists another number which is bigger than the one you considered.'

Georg Cantor
(1845 - 1918)

'That is why it is said that the number line never ends and it is extended to the infinity.'

'It's precisely so. The concept of infinity was explained using the set theory by Russian-born German mathematician Georg Cantor in 1874. Cantor provided conclusive proof that defined the nature of infinity.'

'Uncle, please tell me how I can understand the concept of infinity.'

'Let me explain. Consider a set of *all positive even integers* {2, 4, 6, …….up to infinity}, denote it by 'A'. Consider another set of *all positive odd integers* {1, 3, 5, ….. up to infinity}, denote it by 'B'. In his way grouping numbers or any objects is called *set*. Hence 'A' and 'B' can be called set A{2, 4, 6,…….up to infinity} and set B{1,3,5….. up to infinity}. We need to check whether both sets have the equal numbers of elements. As both the sets are extended to infinity we will not be able to count the number of elements in each set. However, there is a way to check whether set A and B have same number of elements. The element '2' is set A and element '1' in set B are the *corresponding elements*. That is, both numbers are the first element in respective series. Similarly, the numbers '4' in set A and '3' in set B are corresponding elements. In this way you can go on forever. This is known as *one-to-one correspondence*, and it allows us to compare any two sets without ever needing to count how many terms are there in either of them. In this case, you will always find two corresponding elements for both sets A and B. Therefore sets A and B have equal number of elements. Now, here is a question for you Googol:

> The concept of infinity intrigued human minds for thousands of years. Both mathematicians and Physicists struggled for centuries in defining and understanding the concept of infinity.

Which one is a bigger set – the set of the *even natural numbers* or the set of *all the natural numbers*?'

'Apparently it seems that the set of all natural numbers is twice as big as the set of all even numbers. That is, set N{1,2,3,4…… up to infinity} looks bigger than set E{2,4,6,8….. up to infinity}, as half the natural numbers are even. However, if I consider one-to-one correspondence as you have explained, then both the sets N and E seem to be of equal size, as both will go forever! Well, I am not sure what would be the correct answer.' I said.

'You are going to the right direction. In a *finite set* of natural number, say in first 100 natural numbers, there will be 50 even numbers. Hence number of elements in a finite set of E will be half of a finite set N. However, if we consider two *infinite sets*, then one-to-one correspondence will go on forever and we have to conclude that both sets are equal in size!' Uncle explained.

'It sounds logical now. I think that this now explains that an *addition* of infinity with infinity will give infinity,' I said.

'Yes. Not only addition, *multiplication* of infinity with infinity will also give infinity,' uncle said.

'What about division? If we divide infinity by infinity what will happen?' I wanted to know.

'It's very good question Googol. As you have seen that the rules of algebraic operation cannot be extended to any operations of infinity. This is more complicated for the rule of division. The *division* of infinity by infinity is called *undefined*. Let us consider an example. The infinity is also represented by the mathematical symbol ∞ and therefore let's try to write an expression as the following:

$$\frac{\infty}{\infty} = \frac{\infty + \infty}{\infty} \quad \textit{which would mean that:} \quad \frac{1}{1} = \frac{2}{1} \; x$$

'You can see this is not a valid operation,' uncle explained.

'Uncle, is there any concept of negative infinity?' I wanted to know.

'A *negative infinity* in mathematics is negative of infinity, where infinity by default is *positive infinity*. Mathematically, if x is a real number then $-\infty < x < \infty$ i.e. *minus infinity* is less than any real number, and infinity is greater than any real number.' Uncle explained.

'What will happen if we subtract infinity from infinity?' I wanted to know.

'Mathematically this is similar to adding infinity to negative infinity, i.e., $\{\infty + (-\infty)\}$. This is again a situation which cannot be defined. Infinity is not a fixed number, hence *subtraction* of infinity from infinity ($\infty - \infty$) is also *undefined*. Remember, adding infinity to infinity will give infinity because adding two boundless quantities will always give another boundless quantity. However, the same rule is not applicable in case of subtraction, as subtracting one boundless quantity from another may result in zero, or positive, or negative values depending on which boundless, positive or negative infinity is bigger. Moreover, infinity cannot be quantified with a number, hence subtraction will be meaningless,' uncle explained.

Dividing "infinity" with "infinity" is not possible. Similarly, subtracting "infinity" from "infinity" is also not possible. Both cases are undefined.

'Uncle, extending the concept of infinity to the real world, or Universe, I was wondering if our Universe is truly infinite,' I wanted to know.

'As per the definition of infinity, our Universe cannot be infinite, although we can only observe a finite fraction of the whole Universe.'

'I have read that the Universe has no edge and that it is expanding.'

'A space with no edge does not necessarily mean that it belongs to an infinite space. Cosmologists have long sought to discover whether infinity exists in our physical Universe. However, it seems an infinite Universe will not be able to justify some of the observable physical phenomena about our Universe. One such observation is the expansion of the Universe. Einstein's theory of General Relativity shows how the amount of matter in the Universe determines the curvature of space. A curved space with no edge does not have to be infinite; however, it can still expand in all the directions.' Uncle explained.

A space with no edge need not necessarily be infinite. Cosmologists have long sought to discover whether infinity exists in our physical universe.

'If the Universe is expanding forever, does it not make the Universe infinite?' I wanted to know.

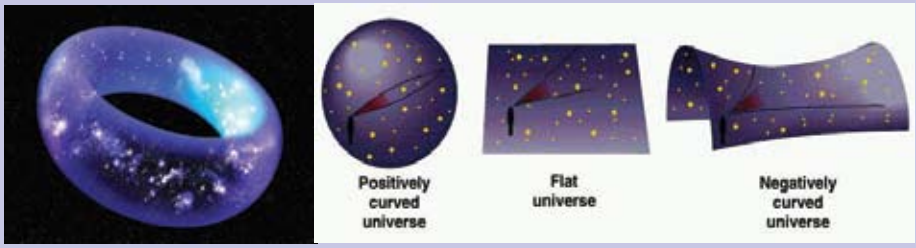
'If you know the expansion pattern, then you will realise that the expansion of the Universe is not uniform throughout the time. The Universe has been expanding for about 13.7 billion years. Initially it accelerated and then due to the gravitational pull it decelerated. However 8 billion years later, it started accelerating again. In an infinite Universe, these changes would not have been possible.'

'What about the black hole? I have heard that the density of black hole is infinite. Does it mean that the black hole is an example of physical reality where infinity exists?' I wanted to know.

'We need to use the concept of infinity in calculations, equations, theories and approximations to describe the physical world around us. Often infinite series used for unbounded functions and equations describing physical phenomena may involve infinite quantities. However, Physicists often require that the end result be physically meaningful. In quantum field theory infinities arise which need to be interpreted in such a way as to lead to a physically meaningful result, a process called *renormalisation*. However, there are some theoretical circumstances where the end result is infinity. One such example is the singularity in the description of black holes. Some solutions of the equations of the general theory of relativity allow for *finite mass distributions of zero size*, and thus *infinite density*. This is an example of what is called a *mathematical singularity*, or a point where a physical theory breaks down. This does not necessarily mean that

Mathematical singularity is a point where a physical theory breaks down. This does not necessarily mean that physical infinities exist; it may mean simply that the theory is incapable of describing the situation properly.

Finite Universe



Doughnut- shaped Universea

The idea that the Universe is finite and relatively small, rather than infinitely large, first became popular in 2003, when cosmologists noticed unexpected patterns in the cosmic microwave background (CMB) – the relic radiation left behind by the Big Bang.

The CMB is made up of hot and cold spots that represent ripples in the density of the infant Universe, like waves in the sea. An infinite Universe should contain waves of all sizes, but cosmologists were surprised to find that longer wavelengths were missing from measurements of the CMB made by NASA's Wilkinson Microwave Anisotropy Probe.

Cosmologists have suggested various 'wrap-around' shapes for the Universe: it might be shaped like a football or even a 'doughnut'. In each case, the Universe would appear to be infinite, because one would never physically reach its edge – if you travelled far enough in any direction you would end up back where you started, just as if you were circumnavigating the globe.

Source: Nature | Published online 23 May 2008

physical infinities exist; it may simply mean that the theory is incapable of describing the situation properly.'

'Hmm, it seems that Physicists still have to investigate a wide range of complex and multifarious phenomena and theories. I have another question. The concept of infinity signifies the unbounded – does it necessarily mean that it is about bigger than the biggest only? What about the other side of the story: smaller than the smallest quantity?' I wanted to know.

'Smaller than the smallest is known as *infinitesimal*. In this context let me tell you a famous paradox involving both infinity as well as infinitesimal. It is known as *Zeno's first paradox*. Zeno (490–430 BC) was a Greek philosopher and created a set of philosophical problems. Zeno's first paradox purports to show that the motion is impossible because if you want to walk from one point to another you must first cross half the distance, then half the remaining distance, then half the remainder and so on. For example, if the two points are one kilometre apart you will first reach 1/2 km from start, then 3/4 km from start then 7/8 km and go on. After you have taken *N* steps of the journey you will cross a distance equal to $(1 - 1/2^N)$ km. No matter how big the *N* is, you will never reach your destination, and there will always be an "infinitesimal" distance left. Therefore Zeno stated that motion is nothing but an illusion.'

> Mathematics can tackle an abstract concept like "infinity" in describing real life problems and provide possible solutions.

'This is very interesting! However, if *N* is infinity, then I will be able to reach my destination. It is amazing – does it mean infinity exists?' I wanted to know.

'As I have mentioned earlier also, infinity is a concept. In order to describe our physical world with mathematical equations we need to know the meaning of infinity very clearly.'

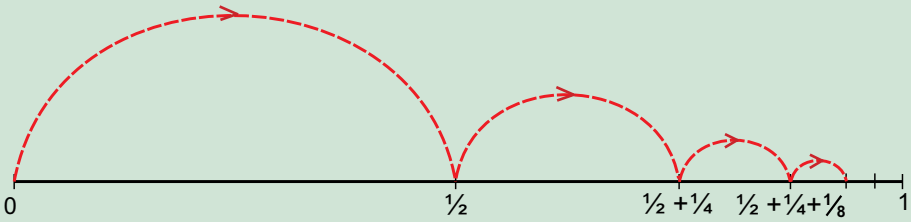
'Uncle, I remember receiving an email from one of my friend which stated the tortoise and hare story in a different form; it concluded that if the tortoise starts ahead of the hare, it will surely win the race, irrespective of the how fast the hare can run compared to the tortoise. I think this is also similar to Zeno's paradox.'

'Indeed it is. Let me explain. Let the tortoise start 1 km ahead of the hare. The hare can run at twice the speed of the tortoise. Both start the race at the time. You might think that the hare, running twice as fast as the tortoise, would overtake it at the 2-km mark. However, when the hare reaches 1 km. the tortoise has already done (1 + ½) km; when the hare reaches the 1½ km, the tortoise has reached (1 + ½+ ¼) km and so on. Apparently the hare would never be able to reach the tortoise, leave aside crossing it!'

'But uncle, still the truth is that it would never happen in the domain of the physical reality! The hare will definitely overtake the tortoise! Isn't it so?'

'Definitely the hare will overtake the tortoise exactly the way you can always move from one point to another, irrespective of what paradoxes conclude. That is where mathematics will come to your rescue. After N steps, the hare reaches a distance $(2 - 1/2^N)$ from the starting position. At the same time the tortoise reaches a distance $(2 - 1/2^{N+1})$. If *N* tends to infinity, the paradox is resolved. Note how mathematics can tackle an abstract concept like infinity in describing a real life problem and therefore providing a solution.' Uncle explained.

'Uncle, it was fascinating to know the complex concept of infinity and its wider perspectives. Thank you very much for explaining all these.'



Zeno's first paradox: if you want to walk from one point to another you must first cross half the distance, then half the remaining distance, then half the remainder and so on. So you will never arrive at the destination.

India's Water Man: Rajendra Singh

(Interview based on the discussion of the senior scientist of Vigyan Prasar, B.K. Tyagi with *Jal Purush* Rajendra Singh)

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Living on the motto: 'Water is life' and dedicating his life to the cause of 'water conservation' Rajendra Singh, well known as *Jal Purush*, was born on 6 August 1959 in village Daula in Bagpat, Uttar Pradesh. He made Alwar, Rajasthan, his centre of activity. Today, he is known in the country as *Jal Purush* and 'Dandi of Rajasthan'. In 1975, he founded an NGO, called 'Tarun Bharat Sangh', in the village Kishori-Bhikampura in Thanagazi Tehsil situated in district Alwar, Rajasthan. The area of the Sangh's work remains basically confined to Rajasthan, Madhya Pradesh, Gujarat and Andhra Pradesh. As part of rainwater harvesting activity in 850 villages, the Sangh has constructed 4,500 check dams and *johads* (rainwater storage tanks). Also, many dying rivers were revived. In 2001 he was honoured with the Ramon Magsaysay Award and in 2005, he received the Jamna Lal Bajaj award.

B.K. Tyagi of Vigyan Prasar interacted with Rajendra Singh to learn about the important work done by him on water and nature conservation. Here are excerpts of the discussion.

VP: Rajendraji, how did it start – the saga of a common man becoming *Jal Purush*?

RS: I was involved with the work of distributing medicine and imparting education to village children in a village called Gopalpura, when 72-year-old Mangu Meena told me "You seem to be well meaning…. but not doing the *chokha* or noble work. When we can really afford, we will send our children to Delhi for education. *Chokha man* is one who does the work no one else can do".

VP: What was that *chokha* or noble work?

RS: He told me that the Sun steals our water…. you just stop it. At first, I did not understand what actually he meant by the Sun stealing the water? Then he told me that the water Nature provides us through rain gets dried up due to the heat of the Sun…. this is pure and simple theft. I started thinking how this theft can be stopped. This seemed to me a very difficult task, but Mangu Kakasaid he would tell me the way to stop it. .

VP: Did Mangu Kaka teach you water science?

RS: Mangu Kaka told me that he would have himself done it but the village had been split up and there was no unity.

Jal Purush Shri Rajendra Singh

He did not know how to express his ideas; but he said that when it rained in the past, the water percolated through the roots of the trees and grass to the interior of the Earth. The Sun was then not able to steal water from beneath the ground. The science of water immediately occurred to me. His knowledge left me totally flabbergasted.He took me to a *johad* – a rainwater storage tank – to the north of his village and said that in the past, the rainwater used to get stored in *johads* and this stored water finally percolated down to the well beneath it. Then I asked him how this water percolated down to the well because I was not aware of the science behind it. I realised that he was not talking nonsense; there was same logic in what he said. Gradually, I understood everything and then I realised that the traditional knowledge is present in people whom we regard as illiterate. Actually, they possess knowledge about Nature. I learnt everything through their knowledge.

VP: You are talking of which village?

RS: I am taking of village Gopalpura in district Alwar, Rajasthan.

VP: What were those inspiring factors that turned you into *Jal Purush*?

RS: When I was twelve years old I have had the occasion of reading/understanding Mahatma Gandhi. Right from my childhood this belief became firm in my mind that if you have to make the country better it cannot be done banking on the knowledge of others. This betterment can come only through our own knowledge. This knowledge is lying scattered in our country. It is essential to understand this first, and then on the basis of that knowledge we will have to prepare the models of development.

VP: So, ultimately it is Gandhian view, basically indigenous…?

RS: Of course, indigenous and self-reliant; which means doing own work with our own hands, using ideas from our own brain and from perspiration of our own body. This is called self reliance …. This is what is called Gandhigiri.

VP: But, how did the Gandhian view become amalgamated with water?

RS: We shall have to understand the basic mantra behind this. Water does the work of production, it does not perform the task of transformation. You may install anything, anywhere…. the production will take place. Water is at the root of production. Water brings prosperity and greenery that brings down the Earth's fever and sets the weather's temperament. But to do that we need moisture and it comes from the water drops in the clouds. That is, our production, environment and even industries are, in one way or the other, connected with water. If we suffer from fever we will take paracetamol. But, for bringing down the fever of the Earth we need greenery and water. Therefore, I worked towards bringing water and greenery.

VP: So, how did you make the basic mantra of water the social issue?

RS: When I went to Gopalpura village, the youth of that village were indifferent and they evaded work. The

village got totally desolated. Not only Gopalpura, I witnessed thousands of nearby villages. Those villages had old people and children. Helplessness, unemployment and disease – all these three maladies were part of their lives. It occurred to me that the mission for which I came here could be completed with the help of the local youths only. But, the youth force was missing. However, I got myself involved with the work related to water. The initial four years were very difficult. In a way, learning from Mangu Kaka only, I was carrying out my work. But the local people had no trust in me. They thought I could be a terrorist from Punjab or a dacoit from Dhaulpur. They feared that I may elope with some young girl of the village. There were no young boys there. An atmosphere of mistrust prevailed. But, after seven years, when a pond was constructed, this mistrust got converted into trust. You will be surprised to know how the local youths got involved with the work on their own. They started 'resource mapping' of their village on their own volition. There were discussions on sites for water trapping, the quantity of water that could be trapped, and how it could be done.

VP: Did your work bring about some social change there?

RS: You see, I did not do any miracle; it was a small task which I undertook. But, as soon as there was water in Gopalpura village hundreds of youths returned from the city and started cultivation. In a way, that amounted to reverse migration. Their faith in me grew and the reverse migration increased the faith in my work that whatever I was doing was right. It occurred to me that the road I was treading was the road to sustainable development. Neither any destruction nor any distortion or displacement was associated with this development.

VP: What are your views on the present model of development?

RS: The physical development that is taking place now-a-days, starts with displacement. First, the displacement of soil takes place, then it causes displacement of the minds of people, and ultimately the displacement of people themselves. With this the displacement of greenery takes place, the trees are cut; the moisture of the soil, grass, animals everything get displaced in the process. So, what we call development actually starts with displacement. There is distortion in this development and spoilage in it, and such development ultimately leads to destruction…… The present development has led to increase in droughts and floods. We will have to adopt that path of development which takes care of greenery and moisture. I am simply looking for old ways and things and working towards their sustenance and management on which depends the sustainable path of prosperity.

VP: Tell us something about your childhood; was it different from that of other children?

RS: It is not that I was very good or sensible in my childhood, but I was very naughty. Besides games and studies I used to play lot of pranks…. But there was always something new or creative in what I did. I was particularly fond of sitting with elderly people, talking to and trying to befriend them. So, I was not different but was a common child…. as common as a child of a farmer can be.

A restore water body

VP: When you resigned from your job for joining the water mission, what was the reaction of your family?

RS: All of them became very angry. The angriest of them all was my wife. She did not speak to me for a year… then she came to terms realising that I had gone mad. But, if I now look at my public life where people give me recognition, my wife has the greatest contribution in that.

VP: How much cooperation did you receive from your family?

RS: I realised that my wife had a right to be angry with me, but she remained in my house with my mother. She wanted to showcase her anger and the biggest thing inherent in her anger was that she wanted to indicate that I was drifting from a protected future (job). Perhaps she had no trust in me then. But, when she was convinced that I will be able to tolerate all odds then the greatest step she took was that she started living with me in that desolate, tormenting place. When my son started studying I could never spare a minute for him. But my wife always gave me the moral force that I needed. She was instrumental in making my son an 'ideal' son.

VP: And your son….?

RS: You will be glad to know that after completing his studies my son got a job. Then one day I asked him for whom and why he wanted to continue with his job. He became a little serious and after a few days he resigned from his job. Now he works with me and he is carrying out my work further. So, I am now free and lead a carefree life.

VP: There is a conflict between development and natural resources. If it continues then in the next 10-20 years will the situation become worse?

RS: You mean to say that in the next 10-20 years everything will get polluted, nobody will survive, everything will become topsy-turvy? It has already started. Today, the whole Earth is ailing; all the rivers have become polluted. Now, this has started affecting our health and body. People of my age group get afflicted with heart problem and cancer. When the overall health of a country is not good its economic system and its 'natural resources' cannot remain sound. This means that now the 'natural resources' are dwindling fast. The government reports sometimes claim that the 'green cover' is increasing, but the government never says that the natural resources, which are necessary for life, are deteriorating at an alarming pace. All rivers have been converted into drains be it Narmada or Yamuna. All have become polluted. The river Yamuna that flows through the National Capital Delhi, where all the 'power' of the country is centered, is most polluted. It is indicative of the fact that where there is power or where there is education, there is also maximum pollution. Education and power seem to have become the highest scale for measuring pollution. Where more power exists or where there is more education, the natural resources are most polluted.

VP: How can it be salvaged?

RS: The solution is very simple. Despite saying so much dismal things prevailing in India, when I look at the solution…. then I can see a silver lining in the cloud. The seeds of hope are there. Therefore, even after losing so much, our hopes are running high. The solutions are really simple. Can't we make a law which forbids people discharging the sewage water of municipality into rivers? If such a law is made that no sewage water would be discharged into any river the water of which is used for drinking purposes, the root cause of the problem would be removed.

VP: How can that water be put to practical use?

RS: The sewage water of the city after being cleansed can be fed to trees, fields meant for agriculture or horticulture or it can be discharged into the old canal system. The river should have only that water that flows into it from its origin. This is not a very costly affair. But, for implementing this, the government should have strong determination and will. If the Government of India is dead determined that the sewage water of municipality would not be allowed to be discharged into rivers, then a solution can be achieved.

VP: Today, the problem is not limited to water alone. The soil and air are in a deteriorating state too.

RS: The soil pollution is due to the chemicals used in agriculture. These are very dangerous. To stop this pollution we will have to encourage what is known as 'organic farming'. In this kind of farming there is less consumption of water and so the water pollution will also be least. So far as industries are concerned it must be ensured that no industry has a right to spread pollution at any cost. At the same time, the pollutants from the industry must be recycled and reused. For example, the sugarcane industry used to be the most polluting of all. But, in the new 'sugar cane model' there is facility for making electricity and acid from the waste materials of the industry. So, all those materials that created pollution earlier can now be used for beneficial purpose. The industries with no provision of recycling should not be allowed to run, they should be closed down immediately.

VP: What is the reason that despite having laws for all these the pollution is still increasing….?

RS: For spreading pollution no criminal case is made in our country, it comes under civil case. As a result, the cases drag on with no punishment forthcoming. Our judiciary has become toothless. We have very weak laws. If we provide teeth to the laws that can straightway punish the guilty then a deterrent can be put against spreading pollution. This means that in the context of pollution there must be provision for punishment or imposition of heavy penalty.

VP: To implement solutions suggested by you how is it that there is lack of political will? After all, we are all facing these threats.

Shri Rajendra Singh at work site

RS: Look, India is an independent democratic country. But its character has now changed in the sense that it has become a 'corporate-driven democracy'. In such a democracy, the corporate has a role that can tilt all the good decisions taken in its favour. When spreading pollution becomes a criminal offence in India then it would be possible to send the corporate leaders to prison. For this, strong political will is needed.

VP: You have a Gandhian view. Has it relevance for the youth?

RS: Yes, today's youths are coming to terms with this view. They also want to work in this direction. It has acceptability on a very large scale and this is increasing. So, I want to say that if by the end of the second decade of the 21st century this view becomes a little stronger and we are able to make them (youths) realise, and after this realisation if they have the desire to do something on their own then change is inevitable.

VP: What is your view about social sites and media? Can an idea or viewpoint be propagated through them?

RS: In the modern context, I consider media and Facebook, Internet, etc., very much useful. But I am not able to say in detail about them because I do not use them much. That is my weakness and limitation. But, I know that through them my colleagues have done very big work. In the second decade of 21st century the media can sow the seeds of a new revolution. All the youths connected with me are using this media. It has great potential. I do use a laptop. My job becomes much simpler by their use. But I am not used to them. I get a natural feeling by planting trees and sowing the seeds.

VP: In the context of work, how do you keep yourself updated?

RS: All my colleagues are young and they keep me updated. I sit with them and not alone. They use information technology. Through their help I carry forward my work. They do their work on advice from me. I do it with their help.

VP: Are you satisfied with your work?

RS: Look, for all achievements in life, we try to achieve something by keeping a goal. So, to keep my energy intact and to keep myself young and fresh I daily try to achieve on the motto: 'every day I can achieve something.' The morning encouragement fills me and charges me with energy the whole day. And, at night when I retire to bed, I look back to see what more I could have done today!

VP: Is this a continuous process?

RS: Absolutely… one does not get instant satisfaction. It is a continuous process. This is called the process of continual change. In this process you have to do something every day and every moment. You simply do not stop even after achieving something. This simply fills a new energy in you. So, you keep on continually achieving more and even more.

VP: In the present context how do you see the future of our natural resources?

RS: I feel that if, within the next few years, the youths of the country come forward, the rivers that have been virtually converted into drains can be revived within the next twenty-five years' time. The greenery of the mountains that has been eroded can be restored back. The only necessity is that the

realisation must dawn on them (youths).

VP: Today we free exchange of information and news through media and the Internet. How else can our youth be made to realise?

RS: I had told you initially that ours is a 'corporate-driven democracy'. Media is considered to be the fourth pillar of democracy. So, it has a very important role. But if this pillar works for them (corporates), in order to checkmate, the youth of the country will have to come forward. And in this context, only those who have realisation of things to come can help the youth identify the issues.

VP: What is the role of science journalism in environmental conservation and management of natural resources?

RS: Its role is to identify the right issue and to carry it forward.

VP: What message would you like to give to the science clubs of Vigyan Prasar and science communicators at large?

RS: I think that science is the basic foundation of our life. When we have certain necessities of life, then in order to fulfill them we make inventions. In other words, the necessity is the mother of invention. Therefore, the necessity becomes the mother and 'science' comes to the rescue as science gives the perception. When this perception comes, especially to the youths, students and teachers then they are able to identify the ground realities and difficulties of life. Their unification would lead to the process of identification of issues. The science emerging out of this realisation or perception would be the real science which would encourage conservation and boosting of resources rather than their exploitation, as it is happening today. So, I feel that the science magazines, the Science Centres meant for creating scientific temper, and 'science exhibitions' all can do a lot in this direction.

VP: Do we have role models today who can infuse perception in children?

RS: Look, role models exist even today. But appreciating and understanding them and following their ideas and principles is what is lacking now. When I was a young boy we were inspired to follow the ideas and principles of all great role models spread across villages to all parts of the country. Nothing of this sort is passed on in the school education today. If somebody does good work then people look at his pocket. If he possesses lavish money then people think where that money has come from. So, this is our tendency…… nobody is trying to search for goodness. So, when the effort to search for goodness dies out then the creativity of the country and of the youth vanishes.

VP: Rajendraji. Many, many thanks to you for sharing your thoughts with us.

(Translate by Abhas Mukherjee)

Continued from page 36 (**Satish Dhawan**: A Scientist Extraordinary with a Social Commitment)

(1999), Distinguished Alumnus Award, Indian Institute of Science, Bengaluru and Distinguished Alumnus Award, California Institute of Technology (1969)

Dhawan died on 3 January 2002 at the age of 81.

K. R. Narayanan, the then President of India, in his message on the death of Dhawan said: "India's space programmes owe to a great extent its spectacular growth and high level of maturity to the stewardship and visionary leadership of Prof. Dhawan."

The launch centre of the Indian Space Research Organisation in Sriharikota, Andhra Pradesh, has been named after Satish Dhawan, Today it is one of the best known names among the Spaceports of the world today.

As mentioned earlier Dhawan was a pioneering researcher in the field of fluid mechanics, he was a great teacher and he made India's space programme as one of most successful enterprises but he also emerged as a conscience of the scientific community. Roddam Narasimha wrote: He (Satish Dhawan) was, most of all, the undeclared but widely accepted moral and social conscience of the scientific community. He was a great man." CNR Rao, a doyen of modern Indian science and who was persuaded to join the IISc by Dhawan said: "Satish (Dhawan) was the moral conscience of the academic community in India." This was the uniqueness of Dhawan.

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(The article is a popular presentation of important points on the life and work of Satish Dhawan available in the existing literature. The idea is to inspire younger generation to know more about Dhawan. The author has given sources consulted for writing this article. However, the sources on the Internet have not been individually listed. The author is grateful to all those whose writings have contributed to writing this article.)

The Warming Earth

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The Earth is heating up and humans are responsible for it. According to the Intergovernmental Panel on Climate Change (IPCC), 97% of scientists agree that the average temperature of the Earth is rising. They have adequate scientific proof of that.

According to a paper published in the October 2012 issue of *Current Science*, assuming that use of fossil fuels and emission of greenhouse gases continue at the current rate, mean warming in India is likely to be in the range 1.7–2°C by 2030s and 3.3–4.8°C by 2080s relative to pre-industrial times.

According to the Scripps Institute of Oceanography, the concentrations of the chief greenhouse gas, carbon dioxide, in the atmosphere – as observed in September 2012 – was 391 parts per million (ppm). The International Energy Agency (IEA) warns that without drastic action to reduce emission by 2017, possibility of limiting the concentration to 450 ppm will be lost completely. Without this, the target of the United Nations Climate Change Conference, fixed in 2010, to limit warming to 2°C by 2011 above pre-industrial levels will not be met. An analysis of the carbon emission limits required to satisfy future representative concentration pathways of greenhouse gases, published in *Geophysical Research Letters* in 2011, shows that meeting this target is impossible since it requires an immediate curb on emissions accompanied with carbon sequestration.

Global surface temperature has increased by about 0.2°C every decade in the past 30 years. This was the rate predicted in the 1980s in initial global climate model simulations with transient greenhouse gas changes. The rise is most pronounced in the Western Equatorial Pacific than in the Eastern Equatorial Pacific over the past century, says a paper published in *Proceedings of the National Academy of Sciences* (*PANS*) in July 2006. According to the paper, in India, the mean maximum temperature has increased by 0.7 degrees between 1901 and 2003. This increase is more pronounced during post-monsoon and winter season than in the pre-monsoon and summer season and is more marked in north India than in the southern part of India.

Greenhouse gas emisions impact monsoons and other weather systems

Why this rise in temperature?

There are many reasons for the rise in the Earth's temperature. Change in the Sun's output, continental drift, volcanic eruptions, change in the Earth's tilt, ocean currents and concentration of greenhouse gases being the more significant of them. So, how are scientists so sure that the marked rise in temperature over the last century is due to emission of greenhouse gases?

The scientists ran mathematical models to measure climate change over the last hundred years with only natural influences from the Sun and also from volcanic eruptions, and again with the additional influence of increase in carbon dioxide concentration over the last century. It was found that the temperature increase graph in the latter case matched the actual temperature increase over that period. This gave the scientists confidence that the rise in temperature was actually due to increase in carbon dioxide concentration from human activity.

But how does the increase in carbon dioxide level lead to temperature increase? Carbon dioxide – like some other gases consisting of two component atoms like water vapour, methane and nitrous oxide – is a heat-trapping gas. It consists of two atoms of oxygen loosely bound on two sides of a carbon atom. The bonds between the carbon atom and the oxygen atoms are loose enough to allow it to vibrate by absorbing infrared radiations on exposure to the Sun's rays. Subsequently, the vibrating molecules emit the radiation and it is absorbed by a neighbouring molecule. The transfer of heat energy from one molecule to the next keeps the heat from escaping to space and causes the 'greenhouse effect'. In contrast, other major components of the atmosphere like nitrogen and oxygen have tightly bound molecules and cannot absorb such radiation and hence do not have the capacity to trap heat.

How did we find out?

Now, let us track how carbon dioxide was identified as the main culprit in this story. Way back in 1753, Joseph Black, a French-Scottish physician and chemist, discovered

Carbon dioxide emissions are from everywhere, as from this brick kiln

carbon dioxide while looking for the properties of a gas produced when limestone was treated with acid. In 1827, Jean-Baptiste Fourier, a French mathematician and physicist, was searching for the answer to the question: how the Earth, despite its distance from the Sun, remained warm enough for life to exist. He suggested that an atmospheric effect existed that kept the Earth warmer than it would be otherwise. He used the analogy of a greenhouse to describe this heating effect.

More than three decades later, Irish physicist John Tyndall carried out research on radiant heat and the absorption of radiation by gases and vapours including CO_2 and H_2O and showed that carbon dioxide and water vapour are heat-trapping gases. In 1896, Swedish chemist Svante Arrhenius suggested that carbon dioxide emissions from the burning of coal would trap heat in the atmosphere and lead to global warming.

As a result, from the late 1950s, David Keeling, Professor at the Scripps Institute of Oceanography at the University of California, took up the task of measuring carbon dioxide (CO_2) levels on a mountain-top in Hawaii. This centre of measurement at Mauna Loa was later converted into a laboratory.

Frequent and regular measurements of the atmospheric carbon dioxide (CO_2) concentration were combined with readings taken at the South Pole, and in other locations. Over the next decade, these measurements confirmed that levels of CO_2 in the atmosphere were rising year-on-year. In 1967, an early computer simulation suggested that global temperatures might increase by more than 4°F (1.22°C), depending on CO_2 levels.

The link between carbon dioxide emission and temperature rise was established over the next two decades through improved climate models. The first climate conference was held in 1979. It called on governments "to foresee and prevent potential man-made changes in climate". In 1987, an ice core from Antarctica revealed an extremely close link between carbon dioxide levels and temperature going back more than 100,000 years.

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established through the joint efforts of the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to assess the existing knowledge about the climate system, the impact of climate change, and possible ways forward.

Scorched earth... climate change causes permanent states of drought in some areas in the world

While scientists all over the world carry out research on the various aspects of climate change, the IPCC brings them all together to bring about a consensus among countries on the current state of knowledge and the way forward on the basis of that. It does not carry out research or monitor climate-related data or other relevant parameters.

The First Assessment Report of the IPCC was brought out in 1990. In response to this report, United Nations' General Assembly convened a series of meetings that culminated in the adoption of the United Nations Framework Convention on Climate Change (UNFCCC). As a result a treaty, famously known as the Kyoto Protocol, was signed by several countries with the goal of reducing carbon dioxide emissions over the years. It set global targets for reduction of carbon dioxide emissions.

What needs to be done to reduce carbon dioxide emission?

As burning of fossil fuels like diesel and petrol is the largest source of carbon dioxide, reduction in use of fossil fuels can cut down the emissions substantially. This can be done through energy efficiency across industries, buildings and appliances, use of fuel-efficient cars, responsible driving, and greater use of public transport.

Apart from this, renewable sources of energy like solar, wind and hydropower can be an effective alternative to fossil fuels. Countries are in the process of updating their technology, policies and regulations to implement this change.

We on our part can play a significant role in reducing emissions by decreasing our personal energy consumption. We can save energy at home by turning down our heating or cooling requirements. We can also opt for energy saving appliances. Energy usage in travel can be reduced by using more energy efficient modes of transport. It will require commitment and discipline to curb global warming in the long run.

(The author is senior science and environment journalist writing for scidev.net)

Gall stones

Diagnosis and Treatment Options

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Strange though it may seem, a large majority of people with gall stones in whom the stones are diagnosed by accident through ultrasound do not develop any symptoms. Even when they are followed, only 1–2 per cent of them grow symptoms or complications related to their gallstones for each year that goes by. Even over a period of twenty years, only about 1 in three patients with gall stones suffer difficulties, while a large two-thirds of patients remain symptom-free.

The writing is crystal clear: unless gallstones trouble you, you let them be! Yes, they may carry some risks and could stir up complications in some people, but the risk is so small, that unless you have symptoms and your surgeon feels that you must undergo gall bladder removal surgery, you shouldn't worry your head about them.

When to Seek Medical Help?

Of those, who suffer difficulties due to their gall stones may either suffer an acutely inflamed gall bladder, a condition called acute cholecystitis, or experience severe repeated attacks of colicky pain, due to chronic cholecystitis.

There are other risks too, even if small. A gall stone could slip into the main bile duct which carries bile to the intestine, block it, and cause jaundice. In others, the stone can swell the pancreas and produce pancreatitis. Rarely, long-standing gall stones may trigger a cancer in the gall bladder. The odds of developing these serious complications are so low, that unless there is a good reason, you do not need to go under the scalpel.

The gall bladder needs to be removed only when gall stones produce an acute or chronic inflammation in the gall bladder or a complication develops. In any case, repeated attacks of inflammation lead to scarring in the gall bladder wall, and make it a liability since it loses its function.

If you're diagnosed with gall stones and develop recurrent or intense abdominal pain, do not delay contacting your doctor. A general surgeon, or laparoscopic surgeon is best.

Red flags

If you were to develop yellowing of the skin or a fever during a gall stone attack, consider these as the red flags. Seek medical help immediately. Do not delay.

What the Doctor Can Do?

Symptomatic gall stones produce swelling or inflammation in the gall bladder. Over time, as the inflammation becomes chronic, the gall bladder loses its function. If that be the case, it is best taken out.

Surgeons nowadays prefer the laparoscopic method to remove the diseased gall bladder. This modern scar-less peephole surgery is just a one-day affair, and you can generally be back at work within a week.

Medicines do not yield any benefit in the treatment of gallstones. In any case, a shrunken, non-functioning gall bladder serves no useful function in the body.

Identifying the stones

If your doctor suspects you have gallstones, you'll probably undergo one or more of the following tests to identify the stones:

Ultrasound

This is a painless procedure that lasts only about 15 minutes. You must go for the test after at least 12 hours of overnight fasting.

A simple ultrasound test can detect stones in the gall bladder with about 95 per cent accuracy, but it is much less accurate in detecting stones that have passed into the bile ducts.

Ultrasound also provides several other important points of information for the surgeon. Such as whether a person has any polyp (a tumor protruding from the mucous lining of the gall bladder), the diameter of the common bile duct, or any abnormalities in the liver tissue.

Infrequently, a patient with typical attacks of biliary pain may not have any gall stones, or may only have sludge. Should such patients suffer recurrent attacks of colic and the ultrasound were to show the presence of sludge on two or more occasions, it may work best if they were to have their gall bladder removed.

Other than the stones and sludge, some patients may also develop typical biliary symptoms due to cholesterolosis (caused by the accumulation of cholesterol in the gall bladder lining).

Computed tomography (CT)

A CT scan of the abdomen can sometimes reveal gall stones that contain high levels of calcium. In addition, during a gallbladder attack, the gall bladder may appear thickened on a CT or ultrasound scan.

Radionuclide scan

A small amount of a radioactive tracer material is administered intravenously, followed by a scan of the gall bladder to see if the tracer material gains access to the gall bladder. If it doesn't, a stone is likely blocking the opening of the gall bladder or cystic duct.

Magnetic resonance cholangiopancreatography (MRCP)

If a bile duct is found to be blocked, and the ultrasound fails to identify the exact position of the gall stones, a specialised imaging test called magnetic resonance cholangiopancreatography, may be most useful. It is a non-invasive test that requires a person to lie still in a machine carrying large magnetic field.

Endoscopic retrograde cholangiopancreatography (ERCP)

Infrequently, a patient may also require a more difficult procedure called the endoscopic retrograde cholangiopancreatography. This test allows the doctor to take pictures of the bile ducts.

A flexible tube with an attached camera (endoscope) is threaded through the upper digestive tract to the opening of the common bile duct. Through a catheter located inside the tube, contrast agent (dye) is injected into the common bile duct, outlining the bile ducts so they can be seen on X-ray film. If a stone is discovered in a duct, it usually can be extracted immediately with tools attached to the endoscope.

Blood tests

Elevated levels of certain substances, including bilirubin, alkaline phosphatase and the aminotransferases, suggest a bile duct obstruction.

Treatment options

Usually, the best treatment for gall stones is to do nothing more than watch and wait. This is almost always recommended if a person has 'silent stones' that typically don't cause any symptoms or other problems. Silent stones often are discovered by accident, during diagnostic testing for another health condition.

If a person has one or more gall bladder attacks, the treating doctor will probably recommend surgery, unless the candidate has other health problems that make surgery too risky.

Elective surgery

The best treatment for a person with symptomatic gall stones is to undergo a planned elective surgery. While awaiting surgery, they would do well to avoid large meals and fat in the diet. Diabetic persons should undergo surgery quickly because they are at higher risk of developing complications. If a woman is pregnant and has gall stones which continue to give trouble despite dietary control, the best course is to undergo surgery during the second trimester.

Two ways of doing surgery

There are two ways in which a diseased gall bladder can be removed:

Open surgery

This approach, in which the gallbladder is removed through a large abdominal incision, is used only occasionally today. The doctor may recommend open surgery if the gallbladder walls are thick and hard, or if a person has scar tissue from earlier abdominal operations. Recovery typically entails a week's stay in the hospital, followed by about 3 weeks at home.

Laparoscopic surgery

The vast majority of gall bladder surgeries are now done by making two or more peephole incisions in the abdomen instead of one large one. The surgeon creates room to examine the abdomen by filling it with carbon dioxide. The gas is injected by means of a tube that's inserted through an incision a half-inch to an inch long, near the navel. One or more small incisions are made to insert surgical instruments. One instrument contains a scope to view the gallbladder. Another is equipped with a laser or electric cutting device to remove the gallbladder.

Laparoscopic surgery ordinarily requires only an overnight hospital stay. Recovery time also is shorter because the surgeon doesn't cut through the abdominal muscles, which require a long time to heal. Additional advantages include less post-operative pain and less scarring.

Conversion to an open surgery

Some patients taken for laparoscopic surgery may be best served by an open procedure if the surgeon is unable to view important structures due to the existing inflammation. This conversion rate has been found to be between 4 and 35 per cent, being higher in the setting of acute cholecystitis than with chronic cholecystitis. Increased patient age, male gender, obesity, and thickened gallbladder wall (>4 mm) are the other factors predicting the need to convert to an open surgery.

Results of surgery

Surgery to remove the gall bladder, called cholecystectomy, is generally safe and effective. It offers excellent long-term results for patients with symptomatic gall stones. About 90 per cent of patients are rendered symptom-free after the surgery. For patients with atypical symptoms or painless dyspepsia, that is, fatty food intolerance, flatulence, belching, or bloating, the percentage of patients experiencing relief of symptoms is a little less.

Non-surgical options

The treating doctor may recommend one of these treatments if a person has complications or other health problems that make surgery inadvisable. The major disadvantage of these non-surgical alternatives is that gallstones usually redevelop.

Bile salt tablets

Bile salt tablets dissolve cholesterol stones over several months or years. However, they don't work on pigment stones. Most doctors prefer the medication ursodiol (Udiliv) because it's one of the safest and seems to have the fewest side effects, mainly occasional, mild diarrhoea. Ursodiol works only on stones containing large amounts of cholesterol and no detectable calcium, and when the cystic duct leading to the gallbladder is open, allowing bile to enter and exit normally.

The disadvantage of ursodiol is that its effects are not permanent. Gall stones tend to recur in at least half of people taking ursodiol within 10 years after treatment, unless the medication is continued indefinitely. In addition, ursodiol is expensive.

Sound wave therapy

Known as extracorporeal shock wave lithotripsy, this treatment is more effective and more commonly used for kidney stones than gall stones. It sends high-frequency sound waves through the abdominal wall to break up gall stones. The person then must take ursodiol tablets to dissolve the stone fragments.

Shock wave therapy works best on single stones less than 12 mm in diameter. Consequently, only 5 per cent to 10 per cent of people with gallstones are good candidates for this therapy, and its use remains experimental. Like other treatments in which the gall bladder is left in place, the stone recurrence rate is high without long-term ursodiol treatment.

Life without a gallbladder

Most people who have surgery to remove their gall bladders get along well without them. The liver continues to make enough bile to digest fat in a healthy diet. But instead of being stored in the gall bladder, bile flows out of the liver and empties directly into the small intestine.

You don't need to change your eating habits after surgery. However, with bile flowing more frequently into your small intestine, you may experience a greater number of bowel movements and your stools may be softer. Many times, though, these changes are only temporary. Over time, your intestines usually adjust to the effects of surgery.

Quack remedies

Many patients with gall stones, who do not wish to come under the scalpel, fall a prey to quack remedies. The tricks adopted by charlatans are most ingenious: some give half a bucket of magic potion to drink and then make you vomit out stones (as if it is that easy!), while others give fanciful packets with contents that're only best known to them. Others even advocate a dip in a particlar pond! You should not fall for any of these tricks. Follow the scientific way of treatment. Believe me, these charlatans, when diagnosed with gall stones themselves, never prefer their own method of treatment, and come rushing to seek the help of a surgeon!

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Recent developments in science and technology

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Source of cosmic rays discovered

Cosmic rays were discovered more than 100 years ago, but their origin had remained a mystery till recently. Cosmic rays are mostly extremely energetic pieces of atoms: protons, electrons, and atomic nuclei which have had all of the surrounding electrons stripped during their high-speed (almost the speed of light) passage through the Milky Way galaxy. About 90 per cent of them are protons. During their journey across the galaxy, the electrically charged particles are deflected by magnetic fields. This scrambles their paths so much that it is no longer possible to point back to their sources in the galaxy. So the source of cosmic rays can be determined only by indirect means. A new study by an international team of more than 160 researchers using observations from NASA's Fermi Gamma-ray Space Telescope now provides the first clear-cut evidence of production of some of the fastest-moving matter in the universe by the expanding debris of exploded stars. This discovery, reported in the journal *Science* (15 February 2013 | doi: 10.1126/science.1231160), is considered a major step toward understanding the origin of cosmic rays.

Fermi Gamma-ray Space Telescope

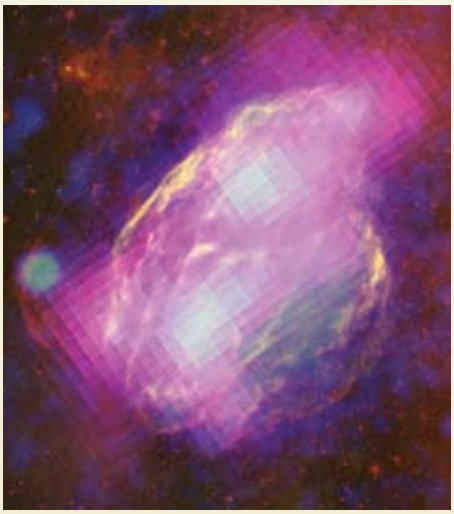
The researchers made use of the fact that accelerated protons, through a variety of mechanisms, can lead to the emission of gamma rays, the most powerful form of light and a signal that travels to us directly from its sources and can be detected. The Fermi Gamma-ray Space Telescope is specifically designed to look for gamma rays coming from space. It includes two scientific instruments – the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). The LAT is an imaging gamma-ray detector which detects photons with energy ranging from about 30 million to about 300 billion electron volts (30 MeV to 300 GeV). Since its launch in 2008 the LAT has been mapping gamma rays of such high energies emitted from supernova remnants. The recent Fermi results concern two particular supernova remnants, known as IC 443 and W44, which are expanding into cold, dense clouds of interstellar gas. These clouds emit gamma rays when struck by high-speed particles escaping the remnants.

Cosmic rays are mostly protons, which give rise to gamma rays when they encounter interstellar material. High-energy electrons also produce gamma rays, but by different mechanisms called bremsstrahlung and inverse Compton scattering. The problem was cosmic ray protons and electrons give rise to gamma rays with similar energies and it was difficult to know which mechanism is involved. Since cosmic rays are mostly protons it was necessary to know which gamma rays were produced by protons. There is one step involved when gamma rays are produced by protons – production of neutral particles called pions, which in turn decay into gamma rays. After analysing four years of data, the Fermi scientists found a distinguishable feature in the gamma-ray emission of both supernova remnants. They detected the characteristic pion-decay feature in the gamma-ray spectra of the two supernova remnants, IC443 and W44, with the Fermi Large Area Telescope, which provided direct evidence that cosmic-ray protons are indeed accelerated by supernova shockwaves.

According to Elizabeth Hays, a member of the research team and Fermi deputy project scientist, "Now we have conclusive proof that supernova remnants, long the prime suspects, really do accelerate cosmic rays to incredible speeds." In other words, supernovas are indeed the source of cosmic rays.

Kepler discovers smallest exoplanet

Mercury, with a diameter of 4,879 km is the smallest planet of our solar system. NASA's Kepler space telescope has now discovered what is claimed to be the smallest planet outside the solar system – much smaller than Mercury – in a star system called Kepler-37. This is a remarkable discovery as far as exoplanets (planets orbiting stars other than the Sun) are concerned because most of the hitherto discovered exoplanets are much larger than our Earth – some as large as Jupiter. Till date, 861 planets have been discovered outside our solar system. The first exoplanets found to orbit a normal star were giants. As technologies have advanced, smaller and smaller planets have been



The W44 supernova remnant. Fermi's LAT detects GeV gamma rays (magenta) produced when the gas is bombarded by cosmic rays, primarily protons. (Credit: NASA/DOE/Fermi LAT Collaboration)

The line-up compares artist's concepts of the planets in the Kepler-37 system to the Moon and planets in the solar system. The smallest planet, Kepler-37b, is slightly larger than our Moon, measuring about one-third the size of Earth. (Credit: NASA/Ames/JPL-Caltech)

discovered, and Kepler has shown that even Earth-size exoplanets are common. The newly discovered planet, designated as Kepler-37b, is about the size of our Moon (*Nature*, 20 February 2013 | doi:10.1038/nature11914). Its small size made its detection a challenge for Kepler scientists.

The research team used data from NASA's Kepler space telescope, which was launched in 2009 to look for Earth-like planets. It continuously measures the brightness of more than 150,000 stars every 30 minutes. When a planet transits, or passes in front of a star from the spacecraft's vantage point, the light from the star dims slightly, revealing the size of the transiting planet relative to its star.

Identified by studying nearly three years of high-precision data from the Kepler spacecraft, the new planet is estimated to be about the size of the Earth's moon. It is one of three planets orbiting a star designated Kepler-37, about 210 light-years from Earth in the constellation of Lyra. The host star Kepler-37 belongs to the same class as our Sun, although it is slightly cooler and smaller. Owing to its extremely small size and highly irradiated surface, Kepler-37b is very likely a rocky planet with no atmosphere or water, similar to Mercury.

In order to determine the size of the transiting planet accurately, the size of the star must be known. So, the researchers first studied the oscillations or slow vibrations of the host star to learn about its size. The bigger the star, the lower would be the frequency, or 'pitch' of its vibration. The team found the mass of Kepler-37 to be about four-fifths or 80 per cent of our Sun. This information allowed the main research team to better measure the three planets orbiting Kepler-37, including Kepler-37b, the smallest one.

All three planets orbit the star at less than the distance of Mercury from the Sun, which means they are very hot, inhospitable worlds. Kepler-37b orbits the host star every 13 days at less than one-third Mercury's distance from the Sun. The estimated surface temperature of this smouldering planet is more than 430°C, enough to melt zinc. It is almost as hot as Mercury. Of the other two planets, Kepler-37c is slightly smaller than Venus and orbits the host star every 21 days, while Kepler-37d is twice the size of Earth and orbits the host star in 40 days.

The latest finding could have implications for some wider discoveries. According to the researchers, "while a sample of only one planet is too small to use for determination of occurrence rates, it does lend weight" to the idea that small planets are far more common than large ones.

Biodiversity protects against diseases

Biodiversity is the diversity of plant and animal life in a particular habitat. This includes genetic diversity within and between species and of ecosystems. Biodiversity is important for several reasons. Although we may not readily appreciate it, biodiversity provides us with many of the things that sustain our lives. Recent research has shown that richer biodiversity offers higher protection against diseases, at least to amphibians. A study by Pieter Johnson, an ecologist and evolutionary biologist at the University of Colorado Boulder, USA, and his team has found that the richer the assortment of amphibian species in a pond, the more protection that community of frogs, toads and salamanders has against a parasitic infection that can cause severe deformities, including the growth of extra legs (*Nature*, 13 February 2013 | doi:10.1038/nature11883).

According to the study, the chance of a frog getting infected by a parasitic worm that causes limb deformities is less if it lives among a diverse array of pond mates that can also be infected. The results showed that ponds with half a dozen amphibian species had a 78 per cent reduction in parasite transmission compared to ponds with just one amphibian species. The findings support the idea that greater biodiversity in large-scale ecosystems, such as forests or grasslands, may also provide greater protection against diseases, including those that affect humans. For instance, a larger number of mammal species in an area may curb cases of Lyme disease (a bacterial infection that is spread to mammals by infected ticks), while a larger number of bird species may slow the spread of West Nile virus that is spread by mosquitoes.

Over the past decade, a growing number of studies have reported negative correlations between host biodiversity and disease risk, which suggested that biodiversity conservation could promote human and wildlife health. But no definitive correlation between biodiversity and disease was available, mainly because organisms differ widely in their ability to maintain and transmit infections, and the order in which communities assemble in an ecosystem could not be ascertained. Solidly testing these links with realistic experiments has proven very challenging in most systems. Researchers had to struggle to design comprehensive studies that could establish the possible connection between disease transmission and the number of species living in complex ecosystems. Part of the problem was the enormous number of organisms that may need to be sampled, and the vast areas over which those organisms

Deformed frog with extra legs caused by trematode worm infection.

may roam.

Johnson and his team designed the study in a novel way – studying smaller, easier-to-sample ecosystems, surveying a total of 345 wetlands over a period of three years. The researchers visited hundreds of ponds in California, recording the types of amphibians living there as well as the number of snails infected by the pathogen *Ribeiroia ondatrae* – a trematode worm that infects the tadpoles of various frog, newt, and salamander species, often causing deformities. Snails are an intermediate host used by the parasite during part of its life cycle.

By collecting data from hundreds of ponds and thousands of amphibian hosts, Johnson's group was able to provide a rigorous test of the biodiversity-disease link, which has relevance to a wide range of disease systems. According to the researchers, by revealing a consistent link between species richness and community competence, these findings highlight the influence of biodiversity on infection risk and emphasise the benefit of a community-based approach to understanding infectious diseases.

Carnivorous plants glow to lure prey

Plants are known to use a wide range of techniques to attract pollinating insects. They include colourful flowers, tasty nectar, even mimicry. Carnivorous plants, which acquire most of their nutrients by capturing ants, insects and other arthropods through their leaf-evolved biological traps, attract insects for food. These plants also use a variety of methods to attract their prey, not least of which are their flowers. Some carnivorous plants even have appendages that mimic flowers in looks and scent in order to fool insects into coming close. A team of Indian researchers have now reported a new prey capture mechanism in some species of carnivorous plants. The scientists from the Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala, have found the existence of distinct blue fluorescence emissions in some species of pitcher plants (*Nepenthes*, *Sarracenia*), sundews (*Drosera*), butterworts (*Pinguicula*), Venus flytrap (*Dionaea muscipula*), and bladderworts (*Utricularia stellaris*). When the capture spot was masked by coating a non-fluorescent extract, the prey capture was drastically reduced (*Plant Biology*, 5 February 2013 | doi: 10.1111/j.1438-8677.2012.00709.x). According to Sabulal Baby, member of the research team, the distinct blue emissions were so far not known in carnivorous prey traps.

The pitcher plant Nepenthes khasiana glows blue to attract insects. (Credit: Rajani Kurup, Anil J. Johnson, Sreethu Sankar, and Sabulal Baby)

The team discovered the distinct blue fluorescence on the inner sides of Venus flytraps, and on the lids, interior pitcher tubes and peristomes (upper rims) of pitcher plants when exposed to ultraviolet radiation at 366 nm. The researchers found that these alluring blue emissions gradually developed with the growth of the prey traps and diminished towards their death. According to the researchers, to potential prey, the blue fluorescent rings emitting from the pitcher plants' upper rims may make attractive landing pads. Since these fluorescent emissions would also be perceptible in low-light conditions, they could also attract nocturnal prey.

To test the significance of blue fluorescence as a prey-attracting device, the team "masked" the blue rims of Indian pitcher plants (*Nepenthes khasiana*) growing in the botanic gardens by coating them with a non-fluorescent extract. The result was a drastic reduction in the plants' prey capture success over the 10-day period when their blue emissions were hidden, thus indicating that blue fluorescence acts as a "very significant signal" in attracting prey. According to the researchers, the discovery of the plants' blue fluorescence in UV light conditions provides "a new understanding of prey capture in carnivorous plants and also of plant-animal interactions."