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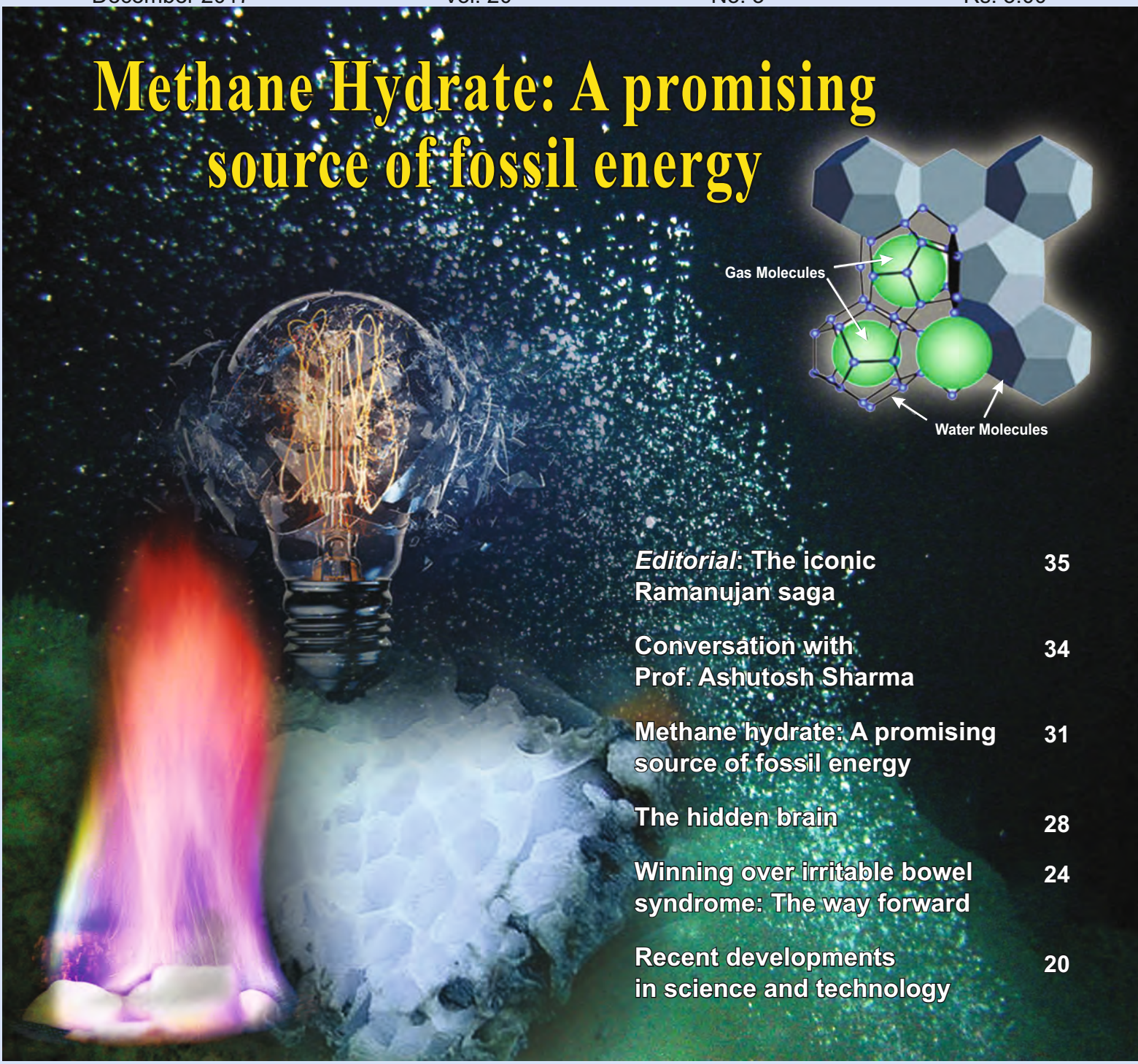

... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

EDITORIAL

The iconic Ramanujan saga

Chander Mohan

National Mathematics Day is celebrated across India on 22 December to create awareness about the great legacy of Srinivasa Ramanujan. The work of Ramanujan continues to inspire mathematicians all over the world. From a humble background, Ramanujan rose to the pinnacle of mathematical superiority that shaped 20thcentury. His mathematical identities and theorems opened up new possibilities and contributed immenselyto the frontier areas of mathematics in the present century as well. Recently, a group of American researchers proved a theorem contained in a letter Ramanujan wrote from his deathbed in 1920. The letter outlined several new mathematical functions that had never been heard of before, together with a theory. Well-known Mathematician Ken Ono of Emory University said, "For people who work in this area of math, the problem has been open for 90 years … Ramanujan's legacy, it turns out, is much more important than anything anyone would have guessed when Ramanujan died."

Born on 22 December 1887 in the town of Erode in Tamil Nadu, Ramanujan emerged from extreme poverty and began his journey to become one of the most influential mathematicians of all times. During his childhood, Ramanujan cultivated his love for Mathematics without any support. Ramanujan was born in a poor family during British colonial rule of India. While at school, he came across a book entitled *A Synopsis of Elementary Results in Pure and Applied Mathematics* by George Shoobridge Carr. This book had a great influence on Ramanujan's career. G.H. Hardy (1877 – 1947), an eminent English mathematician wrote about the book: "He (Carr) is now completely forgotten, even in his college, except in so far as Ramanujan kept his name alive." While working on the problems in the book, he discovered many other new formulae and provided results which were not there in the book. He jotted the results down in a notebook and during 1903 to 1914 he had compiled three notebooks. Later, these notebooks opened up new possibilities in frontier areas of mathematics.

Much of Ramanujan's mathematics falls in the domain of number theory— the purest realm of mathematics. During his short lifetime, Ramanujan independently compiled nearly 3,900 results, mostly identities, and equations. He stated results that were both original and highly unconventional, such as the Ramanujan prime and the Ramanujan mock theta function, and these have inspired a vast amount of further research in mathematics.

National Mathematics Day (NMD) provides an opportunity to recollect the great life and works of Ramanujan. Schools, colleges, and research institutes should take this opportunity to plan events that highlight mathematics in research and its applications in cutting-edge technology and in daily life. Appreciation for Mathematics needs to be developed among general people, particularly among students. Science students need to understand that without a firm mathematical base, research would not yield substantial result. India is in a path of rediscovering itself– rising to take leadership in science and technology in the present century. Let us join hands to inspire aspiring young Indian students to break their bonds of intellectual confinement and soar the way that Ramanujan did.

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Conversation with Prof. Ashutosh Sharma

Dr. Meher Wan

Prof. Ashutosh Sharma is a renowned academician and scientific administrator. His field of research is highly interdisciplinary, which spans a wide range spanning nanotechnology thin polymer films nanocomposites and devices in energy, health and environment functional interfaces micro/nanomechanics of soft matter nano-patterning and nanofabrication colloid and interfacial engineering biomaterials and biosurfaces wetting and adhesion. He is a recipient of numerous honours and awards including the inaugural Infosys Prize in Engineering and Computer Science, TWAS Science Prize of the World Academy of Sciences, Bessel Research Award of the Humboldt Foundation, J.C. Bose Fellowship, Bhatnagar Prize, Homi J. Bhabha Award of UGC, The Syed Husain Zaheer Medal of INSA, Distinguished Alumni Awards of IIT Kanpur and SUNY Buffalo, and the Lifetime Achievement Award of the Indian Science Congress. Prof. Ashutosh Sharma is an elected Fellow of Indian National Science Academy, Indian Academy of Sciences, The National Academy of Sciences, India, Indian National Academy of Engineering, The World Academy of Sciences (TWAS), and Asia-Pacific Academy of Materials. He has been an associate editor of several reputed journals like *ACS Applied Materials and Interfaces.* His other interests are ancient history and philosophy, poetry and art. Prof. Ashutosh Sharma is the Secretary, Department of Science and Technology, Government of India since January 2015.

Meher Wan (MW): Let us start with the question. For last few years, Indian scientists and technologists were in news. Whether it is about the participation of Indians in detection of gravitational waves or success of ISRO! What is your feeling about the progress of India in science and technology currently?

Prof. Ashutosh Sharma (Prof. A. Sharma): There are lots of interesting good things which are happening, if we look at some quantitative indicators. We see the rate of growth of scientific publications is about 14% in India *vs.* about 4% globally. We are now at number five or six in the world in terms of number of publications. If you extrapolate from the rate of growth then we should really move up to 3rd position by around 2022 or little bit later. At seventy-fifth year of our independence, we should be in a respectable situation in the world. India has made great strides in the field of space. Many of our strategic sectors have greatly benefited from the growth of science and technology in the country.

Prof. Ashutosh Sharma

At the same time, if we look at another indicator of growth, for example, the growth in the budget of scientific departments like DST, DBT, who support our scientists across labs, across universities, IITs, IISERs everywhere. In DST only, our budget has nearly doubled in the last four years so that we are able to support more scientists, more schemes, by bringing new schemes. The list is actually very long and consists of several new schemes and programs. As you can imagine, if you double the budget in four years, this is accompanied by a similar expansion in the activities that can be undertaken.

MW: What are the fields where we have done remarkably well?

Prof. A. Sharma: If you look at simply the number of publications, then areas like material science and engineering, and engineering sciences in general have done quite well. In nanotechnology also, we are at number three in the world. There are many areas, where we are at number three or four and certainly in top five in areas like materials science, nanotechnology, engineering, possibly biotechnology also, but I don't have the exact numbers. At the same time you see that these are the classic areas which are based on knowledge domains rather than application domains. Materials can be applied in many different areas. Another thing that is happening in Indian science is that, one looks at not only the growth in the knowledge domains but also the growth that happens in terms of application domains. There are several new programs, for example, related to clean water, not just purifying water but also looking at conservation of water, recycling of water, harvesting of water, etc. Similarly, in renewable energy and clean sources of energy, to give you some idea, there is inter-ministerial-mission on clean coal for power, wherein DST is a good contributor in terms of basic R & D. It is called 'Advanced

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Super-Critical Coal Use Power Plant', which is aimed at increasing efficiency of coal use and reducing emission.

MW: What is your perspective to fulfil the technological needs of India in 21st century?

Prof. A. Sharma: Classically, if you look at science, it focusses either on materials or on mechanics; but the third aspect of science is manufacturing. Mechanics would help you understand how things happen. If we want to know what we need in order to make something, materials would get you there. But finally the last mile connectivity is provided by manufacturing, which is also a science. So, we have started a new program in manufacturing science. I give you one example: There is a new program called 'scientific waste management', particularly focussing on three aspects, namely 1. Biomedical hospital waste; 2. Plastic polymer waste; and 3. e-Waste. The e-waste is something new and when unorganised sector deals with it, they cannot do a scientific job of re-processing or recycling. The end users or common public might not have any understanding of science and technology, or what is an appropriate method suitable for Indian conditions or Indian mix of solid waste, which may be very different from other places because we do not sort solid waste. We have made a compendium of appropriate solid waste management technologies, which has now gone to all municipal corporations in the country. The important point is, if you just import some technology without understanding what appropriate technology is for our local conditions, then it would not be as efficient, and it may not be successful also. We should not just import the technology; we should develop it with understanding of our conditions.

MW: Innovation is a much talked about word these days! What role is DST playing for empowering innovations?

Prof. A. Sharma: We are doing very well in basic sciences. The next question is: Can we convert some of that to technology? And finally can we take that technology to a startup so that there is a business plan, finished product, which can go to the society? In terms of innovation or in terms of technology connect, going from basic science, there are a lot of new things which are happening. For example - there are five technology research centres which are coming up and these are very good in basic science. Each of the centres is funded at a cost of over 100 crores in the DST institutions that are good in basic science.

For last 30 years, DST has helped establishing more than 100 technology business incubators which incubate about 2,000 companies/startups. It is planned that in the next three years, we would more than double the number of companies to nearly 5,000. This would be hugely benefit our students and young researchers who wish to get into that space. There are lots of good success stories coming out from these already.

For researchers, there is a separate component of giving a grant up to ₹10 lakh to make a good prototype, even to see whether this makes a sense or not before going for a startup. There are lots of students who have recently graduated and want to have startups, but they need to support themselves, so there is a fellowship while in struggling phase before get seed funding. During that period they need to sustain themselves, so there is a seed funding up to `1 crore for good companies that are incubating.

The program that we have started last year is called NIDHI – "National Initiative for Developing and Harnessing Innovations", which is really an umbrella program which is made up of different components like fellowship, prototyping, training, mentoring, seed funding, patenting and so on.

Science and technology is not exclusively for DST, but the fruits of the science can permeate other ministries if we work together. To give an example, there is a 'Railways Technology Mission' that we are working together. We are looking at redesigning wagons to carry more loads or having cleaner fuel like methanol for use in engines. There is 'Electrical Mobility Mission' with Department of Heavy Industries, for redesigning vehicles for electric propulsion.

Similarly, there are several others. IMPRINT is another example that has DST as a major partner with MHRD. In the IMPRINT program, many of the scientists would focus on certain areas like nanotechnology, advance materials and so on. Another example is a new program called MANAK. MANAK program basically is an idea of taking innovation to school kids, where we introduce the idea of innovation at an early age starting from class six. This year, we are reaching out about 4-5 lakh schools. Each of these schools holds an internal competition to generate top two ideas to start with; that is about 10 lakh ideas overall. There are many more similar programs for boosting innovations nationwide.

MW: It is said that the necessity is the mother of invention. A country like India has innumerable necessities in every field; still we are not innovating enough in global comparison. Does it mean that we don't understand the necessities of our own country or we don't have courage to tackle them?

Prof. A. Sharma: Actually, it is somewhat cultural. There are two aspects to it; there has to be a clear path for commercialisation of ideas. Here comes the role of National Innovation Foundation; they have scouted something like a basket of 2 lakh appropriate ideas which deal with local problems. You can go to farmers, talk to women, children and everybody. There are good ideas. The next thing is that they have to be scaled up; they have to be commercialised. The products have to reach society at large. It is not that the base of the innovation is weak but the progress beyond has weaker links. Part of that problem is related to culture on both sides, industry on the one side and scientists who generate ideas on the other. This connect is not very strong, so industry is often at risk and they are not into new things, and so on. So, awareness has to be generated by scientists who take a more active role in connecting or taking the stuff there. More of it is happening now through startups and through linkages with industry. A few things are changing but that need to change at a faster rate.

Again, when you train young people about the gospel of innovations, it would take another 10 years before these kids actually grow up and have a greater participation in innovations I often illustrate this by saying that invention and innovation complete the circle of science. An invention that all scientists are engaged in converts resources into knowledge. Invention is knowledge. On the other hand, innovations convert knowledge into new resources and opportunities. If you only had the forward link and not the reverse link, it's not a circle and it is not sustainable. Thus sustainability requires that you produce something and it produces back. Sustainability of knowledge requires both invention and innovation. Society gains more confidence in science if we translate knowledge to innovations; people say science is doing great things for us. Everything that we see around us is value

generation through the knowledge.

MW: What is the current status of industry-academia relationship in India?

Prof. A. Sharma: We should really be counted as a power in the area of science and technology innovation in the next 10 years. There is synergy between economic growth and the growth in science and technology. As our industry grows, it is able to put in more in R&D and in risk taking. The countries that are good in innovation, their industries make money by using knowledge. It turns into knowledge economy. When that happens, there is a greater linkage between industry and the knowledge generators because industry remains competitive through knowledge and can continuously update it. A whole lot of industrial sector in India right now is not in that phase. Certainly, I think it's going to change in a big way.

In both applied and basic sciences, research could be incremental or it could be having profound impact. This is how we should start thinking about things, not in terms of whether it is applied or basic rather whether it is profound or simply and incremental. The question is whether it is making any impact in the respective area?

MW: In the next 20 or 30 years, where do we aim to be in the field of science and technology?

Prof. A. Sharma: I will talk about India because science in a sense is global. In the earliest part of science, when science was just rising with industrial revolution, things were not specific and focussed. The silos of knowledge became narrower and deeper with time. There was a second change which happened in science. We were thinking science only in terms of these silos, like saying here is physical chemistry, here is organic chemistry, here is condensed matter physics, synthetic biology, etc. But the real problems are not the problems of one subject alone. Thus, problem-solving activity requires interdisciplinary and multidisciplinary groups and co-operations and even going beyond. If you consider a problem of water purification, you need material science, maybe nanotechnology; you need some engineering ideas, design; and finally you are not going to do it in your lab but you are going to package it, you have a good design for it with aesthetic aspects. Finally, you would need socio-economic as well as political dimensions to it. Unless you bring all of these together as a package, you are not going to solve the problem, whether cleaning Ganga or anything else.

MW: We always talk about world-class scientists but we don't talk about world-class teachers!

Prof. A. Sharma: We do talk about world-class teachers and we need more of them. I give you an example - there is a new program that we have just put in, the portal is now open, and it's called VAJRA. Under this scheme, we would have 100 of top scientists and professors around the world visiting India and become an adjunct faculty in one of our institutions for collaborative work. They would also co-guide PhD students. Physically, they may spend 1-3 months here, but today you can also do research remotely. So, they would become integrated in our educational and research system. In next 5 years, the target is to have 1,000 of these scientists and professors in any given year, interacting with students of our IITs, universities, R& D labs and so on.

We have also started a new scheme at school level which is called TARE – "Teacher Associate for Research Excellence". We will give fellowship to teachers and will connect them physically with nearby R&D labs or central universities, IITs, IISERs etc. where they can find mentorship and resources to continue their work and learnings. On weekends, evenings or whenever they can find time, they can work remotely with these labs and the groups to keep their scientific interests and contributions alive. It will also reflect in better teaching practices. Teacher who is more motivated, happier in doing the work for which he is being trained, will convey that happiness and sense of fulfilment. So this is another way to enhance the quality of ours teachers in this space.

There are other schemes and of course, we have had Ramanujan Fellowships, INSPIRE Fellowships, Ramalingaswami Fellowships, etc. These are also mechanisms for retaining good people and attracting good people from abroad until they find a permanent job. This is for 5 years, so during that time one can do research, one can get paid like an assistant professor. Then one can look for a permanent job. There is also another scheme called 'Early Career Grant', which basically means for the first time setting up his/her lab by a young person. It would be easier to get your first grant with not as much hassle, which is the whole purpose of the scheme.

MW: As you have mentioned, the DST is doing much for education, research and development. What does DST want from young researchers and scientists in response of support which DST is providing to them?

Prof. A. Sharma: No, DST does not want anything directly from youth. They should look out for a career; not just a job but a profession. While doing that they can also contribute to society in whatever aspects in the field they are trained, whether by doing good science, by doing innovation, or by doing whatever they are good at doing.

MW: You are a decorated professor who is running a well-equipped lab in IIT, producing PhDs, editing reputed journals. What was the motivation force behind joining science administration?

Prof. A. Sharma: First thing you said well decorated, it is a wrong term to use and unfortunately when we keep emphasising that point about decorations, lot of scientists are actually mislead into competing for it. The decorations are good, they keep us happy for a day or two, but beyond that they have very little value. Scientific community as a whole should not too pay much attention to these decorations because it can prevent us doing good science in many cases. I can tell you that from my personal experience, this happiness lasts not more than a day. The person who gets recognition/award will keep doing what he/she was doing earlier, but those who are excluded in the process get demotivated, many times very deserving people. There are both positive and negative in all of these decorations, we must understand that very well.

Now, coming to the question why I moved to Delhi after doing a lot of science, this was not an easy decision, I thought about it for around six months and fortunately there was time to think about it. I have said to myself, look! I have done a lot of science, now let us see how the science translates or knowing about the processes of science how it translates in to helping the people to do better. I thought, can the stuff that I have learnt for my whole life, bring some change on the table? As a scientist, it is not possible to do anything in that direction or there is very limited scope. So that was the fundamental reason to try this out.

MW: It was very nice to talk to you. Thanks a lot, Professor.

Prof. A. Sharma: My Pleasure too.

Methane hydrate: A promising source of fossil energy

M.S.S. Murthy

Methane hydrate is one of the most promising sources of fossil energy. Experts estimate that there is two to three times as much carbon stored in methane hydrates as there is in all other forms of fossil fuels such as coal, natural gas and petroleum. Krishna-Godavri Basin in the Bay of Bengal has highly enriched and one of the most comprehensive methane hydrate deposits in the world. It is required to develop suitable methods for safe and economical extraction of methane gas from these newly discovered reservoirs

In late July 2016, newspapers carried big headlines that a team of scientists from India, USA and Japan have discovered a large, highly enriched and one of the most comprehensive methane hydrate deposits in the world along the Krishna-Godavri Basin in the Bay of Bengal. This is expected to open up a new source of energy to meet the country's ever growing demands.

Methane, also referred to as 'natural gas', is the combustible part of the compressed natural gas (CNG) and is delivered from gas wells or during crude oil production. It burns, combing with oxygen, releasing carbon dioxide and energy. Though burning methane also produces carbon dioxide, compared with other fossil fuels like coal and petrol it is much less per unit amount of energy released. Hence, it is still an attractive source of energy.

Combustible ice

Locally, methane gas is produced due to the metabolism of anaerobic bacteria found in rotting organic matter. Often the gas has been detected in municipal solid waste dumps containing discarded foodstuff and other biodegradable materials. On the geological scale, millions of years ago, the decaying remains of plants and animals built up into thick layers, sometimes mixed with sand and silt, on the ocean floor. Over eons they sink deeper and deeper. Anaerobic bacteria found in ocean sediments break down the organic matter to crude oil and a mixture of gases like methane, ethane, propane, isobutene, nitrogen, carbon dioxide, hydrogen sulphide, etc. In due course, the gas molecules, being light, work

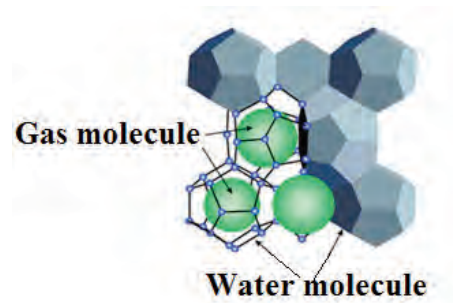

Fig.1. Structure of gas hydrate

Fig.2. Methane hydrate, also known as combustible ice

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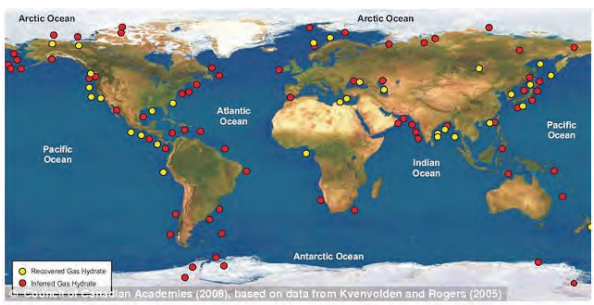
their way up where it is much cooler. At a depth of about 500 to 1,000 metres below the seabed, under the influence of low temperature (0 to 20 degrees Celsius) and high pressure (about 50 atmospheres), water crystallises to a cage-like structure around gas molecules (figure 1) forming what is known as 'gas hydrates'. Since methane forms the major gaseous component of these hydrates, they are also called 'methane hydrates'. A similar process occurs in the permafrost in arctic regions, about 2,000 metres below the ground surface.

Generally, below the methane hydrate stability zone (GHSZ), which contains highly concentrated dense layers of the hydrate, the temperature is quite high. Therefore methane gas, rising from greater depths in the sediment, collects here as free gas. Thus, in nature methane exists not only as free gas, but also as solid, icy crystalline structure. At normal temperature and pressure, methane hydrate separates into water and methane gas, which can be burnt on exposure to oxygen; hence, the name 'combustible ice' (figure 2).

Experts estimate that there is two to three times as much carbon stored in methane hydrates as there is in all other forms of fossil fuels such as coal, natural gas and petroleum. In a typical sample of methane hydrate, 5.75 moles of water holds 1 mole of methane gas. Taking their density and molecular weight into account, this works out to about 169 litres of the gas per litre of methane hydrate. On combing with oxygen, it burns releasing carbon dioxide, water, and 891kjouls of energy per mole (16 grams). Hence, with the dwindling resources of conventional fuels, many countries are prospecting for methane hydrate deposits in their continental margins.



Inferred ● and confirmed ● methane hydrate deposits around the world

Fig.3. Methane hydrate deposits around the world

The Indian Scene

According to a report by Alpana Singh and Bhagwan D. Singh of the Birbal Sahni Institute of Palaeobotany, Lucknow, published in *Current Science* (25 June 1999), the Indian deep sea shores may hold about 7.5 trillion metric tons of methane hydrate in an area of 80,000 square kilometres.

Methanehydrate exploration and research activities in India started in 1997 under the National Gas Hydrate Project (NGHP) in association with Oil and Natural Gas Commission (ONGC), Oil India Limited (OIL), Indian Oil Corporation (IOC), National Institute of Oceanography (CSIR-NIO), National Geological Research Institute CSIR-NGRI),and National Institute of Ocean Technology (NIOT).

The occurrence of significant quantities of methane hydrate was established in the Krishna-Godavari, Mahanadi and Andaman basins in an expedition conducted in 2006 (NGPH-1). However, not all deposits are amenable to extraction of methane gas with the present technology. Studies have revealed that hydrate deposits at high concentrations in permeable sand-rich matrix allow a more easy flow of gas and hence are suitable for extraction.The present expedition known as NGPH-2, started in 2015 with the collaboration of United States and Japan has recently reported discovering highly concentrated, coarse-grained sand-rich methane hydrate deposits in Krishna-Godavari Basin along the eastern coast.

Techniques for Exploration

Prospecting for methane hydrate under the ocean is done in many stages, using technologies

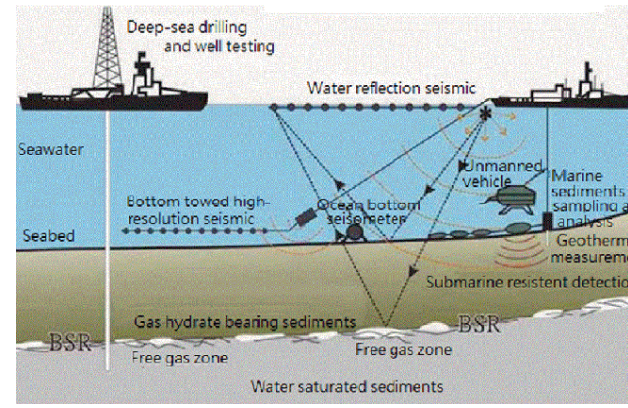


Fig.4. Various methods of detecting methane hydrate deposits under sea: Reflections of seismic waves, submarine detection seismographs, geothermal measurements, deep-sea drilling, well testing.

already in vogue in natural gas and oil industries, with suitable modifications. In the present case, first a computer simulation was done to determine the marine areas with potential for hydrate reservoirs. The program took into account many variables such as the

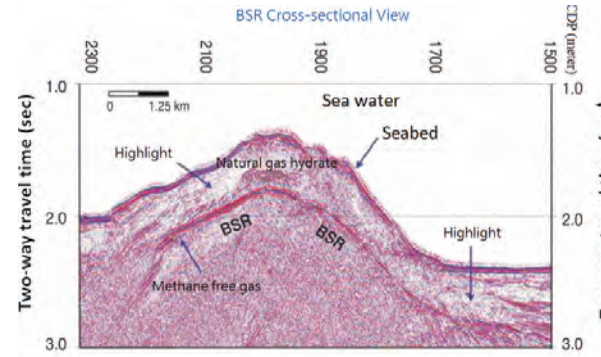


Fig.5. A typical seismic image of methane hydrate-bearing sediment under the sea.

magnitude of the plankton sedimentation, the thickness of sedimentation and the special environmental conditions such as temperature and pressure required for methane hydrate formation. The simulation suggested areas for further exploration with the Japanese deep sea-drilling research vessel *Chikyu*. These explorations were both of geophysical and geothermal nature.

The geophysical explorations generally employ seismic methods to characterise areas under the seabed. Air guns attached to the bottom of the ship produce acoustic waves that penetrate the seabed, from where they are reflected differently from different layers. Acoustic waves pass faster through the dense hydrate depths than through the lighter free-gas zone below and also reflect less from

Fig.6. Scientists making measurements on sediment cores recovered during the NGHP-2 expedition. (Inset) A typical core sample.

the hydrate zone than from the free-gas zone. Acoustic receivers mounted on long cables called streamers towed behind the ship record the reflected waves to produce a high-resolution image of the sea floor.

The interface between the two zones which results in strong reflection of the acoustic waves is known as the 'Bottom Simulating Reflector' (BSR). Hence, whenever a BSR is detected in the acoustic tests, it indicates the presence of methane hydrate sedimentary layers. Thus by analysing the reflected acoustic signals the dense gas hydrate zone and the underling free gas zone can be mapped. The geothermal methods trace the temperature variations to estimate the depths in the seabed where methane hydrate can exist in stable structures.

When once mapping is complete, drilling units are lowered from the research ship and sediment cores are retrieved from hundreds of metres from below the seabed. The long cores are then cut into smaller sections for the quantitative analysis of methane hydrate contained in them. During the expedition,drilling has been done at about 20 sites and from these it is estimated that about 1,894 trillion cubic metres of coarse-grained sand-rich deposits of methane hydrate exist in these areas.

Extracting the methane gas

Several international companies are working to develop safe and economical methods for extraction of methane from the hydrate deposits. The production of methane from methane hydrate is fundamentally different from the production of oil and natural gas, which flow naturally through the pores in the reservoirs into the wells. A hydrate, on the other hand, is a dense, cold solid and has to be first dissociated to release the gas.

Since methane hydrate occurs at low temperature and high pressure, the obvious methods to release the gas are either to raise the temperature (heating method) or to lower the pressure (depressurisation method) to a point where the hydrate breaks down. In the heating method, hot water is pumped to the deposits through a well, thus raising its temperature. The released gas can be pumped out. However, flooding the deposits with hot water requires immense energy input, which makes it uneconomical.

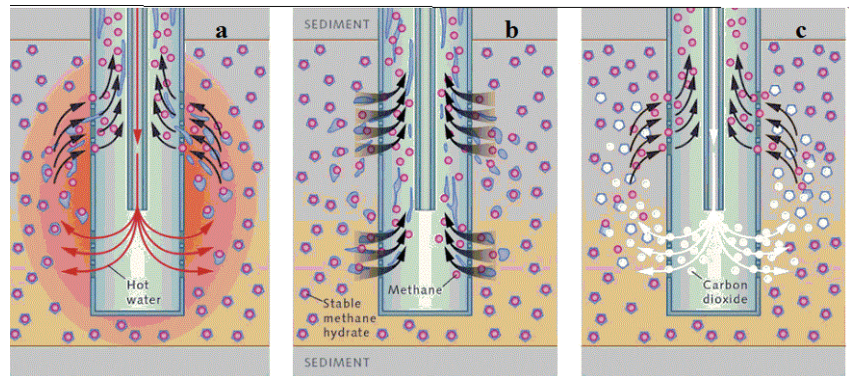


Fig.7. Methods of extracting methane from hydrate deposits: (a) Heating; (b) Depressurisation; (c) Carbon dioxide exchange.

High pressure prevails in the deposits because of the overlaying water and sediment loads. Drilling a well into the deposit and pumping out the water reduces the pressure and liberates methane gas. However, depressurisation also releases, along with the gas, sand, which soon clogs the well and the pump. The Japanese have developed filters to prevent this from happening and have successfully extracted methane gas from test wells over a period of one week.They plan to start a large-scale pilot production in 2018. However, some of the dynamics of the procedure, like the pressure created by the released gas and the endothermic nature of the hydrate bonds inhibit the continuous flow of gas, which is essential for economic industrial production.

A third method is to inject carbon dioxide into the hydrate deposit. Like methane, carbon dioxide also forms hydrates, with a stronger bond with the water molecule. Therefore, when the hydrate deposit is infused with carbon dioxide, it replaces methane in the water molecular cage. It has been observed that the exchange takes place more readily when the carbon dioxide is introduced into the reservoir as a warm super critical fluid. The method has the advantage that the carbon dioxide released from other fissile fuel burning can be used for this purpose. This not only sequesters one of the greenhouse gases but also provides structural stability to the seabed, which otherwise may collapse when emptied of methane. The Germans are actively pursuing this method.

Which of these or a combination of these will be suitable for industrial production of methane gas from the hydrate deposits, has to be ascertained for each site, depending on its geological parameters. The next step in the Indian expedition is to develop suitable methods for safe and economical extraction of methane gas from these newly discovered reservoirs along the coast lines.

The hidden brain

Govind Bhattacharjee

We often boast of other animals being inferior to human beings in evolutionary terms since our brain sizes are far greater than that of most animals. Nothing can be farther from the truth. Evolutionary success has very little relationship with the brain size. Larger brains have not replaced smaller brains, but have only added to them, increasing the complexity of brain structure. The increased complexity was not the objective of evolution but a by-product of its endless experiments over endless millennia. It was only a coincidence that mammals were favoured with this complexity.

"If the human brain were so simple that we could understand it, we would be so simple that we couldn't."

Emerson M. Pugh in *"The Biological Origin of Human Values"*

The human brain is an incredibly complex and awesome apparatus with its multitudes of folds and overlapping structures. It has tremendous power to gather and process all the sensory data for taking appropriate decisions. Brain is an excellent miniature system that is capable of the most sublime thoughts while requiring very little power to function, thanks to its highly sophisticated molecular and cellular architecture, which is a marvel of evolution. With billions of intricate neural connections squeezed within its small volume, thehuman brain is often compared to a gigantic telephone network, a computer or the internet; but all these analogies are inappropriate to capture the human brain's complexities. The brain does not work on the basis of any operating system or a central processing unit. It only has a superbly efficient neural network – a learning machine where memory and thoughts are distributed throughout its volume rather than being concentrated in a central area like the CPU of a computer. It does not even compute very fast, but it is an amazingly efficient learning machine – many times more efficient than the most powerful supercomputers of our day. It learns new tasks astronomically fast, and can learn even from its mistakes. But its immense complexity becomes simpler to grasp if we consider the evolutionary processes that created such an incredibly complex and efficient leaning machine.

An average human brain contains about 100 billion nerve cells or neurons packed within a volume of about 1300 cc within the skull. Within the brain, the neurons appear grey and are hence known as 'grey matter'. The brain is the major component of our central nervous system and weighs about 1.4 kg. It is divided into two distinct hemispheres, which are called the left and right cerebral hemispheres. The two cerebral hemispheres are joined together by a bundle of fibres called the *corpus callosum* through which they communicate with each other.

The outer layer of the brain is called the cerebral cortex, or more specifically the

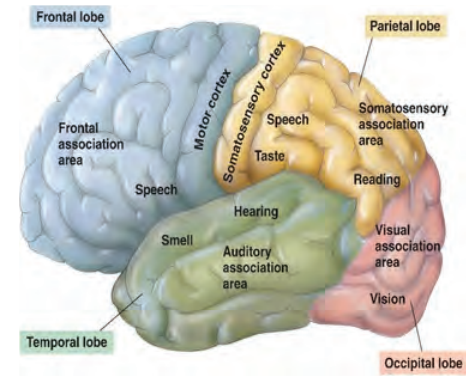


Fig.1. Areas of the brain

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neocortex, neo meaning new to indicate that this is the newest part of the brain as it evolved. Cortex is the wrinkled outer covering of the brain. The cerebral cortex, which is only about 3 millimetres thick, plays a key role in cognition – in our memory, attention, perception, awareness, thought, language and consciousness. Each hemisphere of the cerebral cortex is divided into four sections called lobes: frontal, parietal, temporal, and occipital lobes. The frontal lobes are located in the forehead at the front of the brain. This area controls all higher functions of the brain, namely planning, personality, memory, language, problem solving and complex decision making. Broca's area, which controls the production of speech, is also located within the frontal lobe. The frontal lobe contains a motor cortex that controls the motor functions, i.e., movement of the body's voluntary muscles, by sending commands to the peripheral nervous system. The frontal lobe possibly played a key role in our bipedalism, the essential human function. Our upright posture may not have been possible before the development of the frontal lobe. The front part of the frontal lobe is known as the prefrontal lobe and is believed to be associated with many of our higher cognitive behaviours like planning and decision-making. Damage to the prefrontal lobe results in the person losing the essential attributes that make us human, namely ambition, empathy, foresight, morality, social life and sense of dignity, while retaining all other cognitive abilities intact. For this reason, this area is often referred to as the 'seat of humanity'.

The temporal lobes, which are located just behind the temples of the head, contain the primary auditory cortex and the auditory association area. The left temporal lobe also contains the Wernicke's area involved with the comprehension of language. The parietal lobes lie at the top and back of the brain and house the somatosensory cortex that processes the sensory signals from different parts of the body – cells at the top receiving information from the bottom of the body and so on. In particular, it is responsible for the sensation of touch, pain and temperature, spatial perception, and distinction of size, shape or colour. The occipital lobes lie at the back of the brain at the base of the cortex and process the visual information from the eyes in the primary visual cortex and the visual association area.

Broca's and Wernicke's areas together with the pathway between them called *arcuate fasciculus*,which is actually a bundle of axons, primarily control our ability to use language, even though language may be distributed in other areas as well, just as these areas may be used for other brain functions also. We know this from the examination of patients in whose brains these areas somehow got damaged, say due to a stroke, leading to a condition known as *aphasia*. In Wernicke's aphasia, also called fluent aphasia, a person has the ability to speak fluently using grammatically correct sentences just like any other normal individual, except that nothing that he says makes any sense at all. They can produce sound and speech that has no meaning. Broca's aphasia is almost the complete opposite of Wernicke's aphasia – here the patients cannot speak fluently, but whatever they speak has meaning. They have problem is speaking but not in understanding, because their Wernicke's

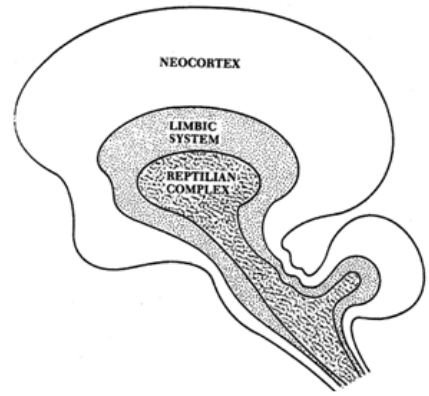

Fig.2. A schematic representation of the Triune Brain Model of Dr. Paul MacLean[14]

areas are intact. In some cases the pathway *arcuate fasciculus* can also be damaged, in which case patients can speak fluently about things that make perfect sense, but lose their ability to repeat words or sentences they have spoken, or to recollect something from memory.[1]

An efficient model for understanding the brain in terms of its evolutionary history is the famous 'Triune Brain Theory'developed by Dr. Paul MacLean of the National Institute of Mental Health, USA in the early 1970s based on his experiments with squirrel monkeys.[2] According to this theory, three distinct brains emerged successively in the course of evolution that now co-inhabit the human skull. First of these is the reptilian brain, also known as the reptilian complex or the R-complexwhich surrounds our midbrain. This is the oldest of the three

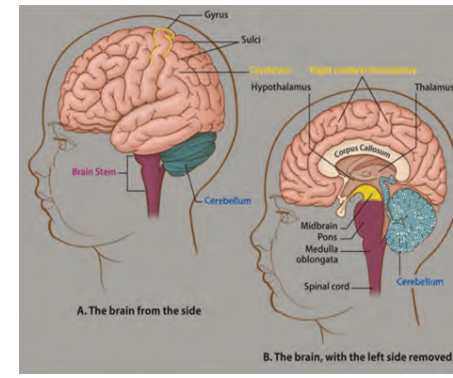

Fig.3. (A) The brain from side; (B) The brain with the left side removed

and controls body's vital life-sustaining functions such as heart rate, breathing, temperature and balance. We share it with all reptiles and mammals.

The earliest structure of the brain to evolve several hundred million years ago was the brain stemandcerebellum (meaning 'little brain').Brain stem is an extension of the spinal cord that contains the medulla oblongata, which regulates breathing and heartbeats, and the pons('bridge') that provide the pathways for sensory and motor impulses to and from the cerebral hemispheres. The cerebellum plays a prominent part in coordinating our muscular movements, neuromuscular control and our reflexes – all its functions are unconscious, involuntary and automatic.

It was in 1970 that Dr. MacLean first noticed that the cerebellum, the brain stem and the basal ganglia[3] that together constitute the back and centre part of our brain are almost identical to the brain of reptiles. The

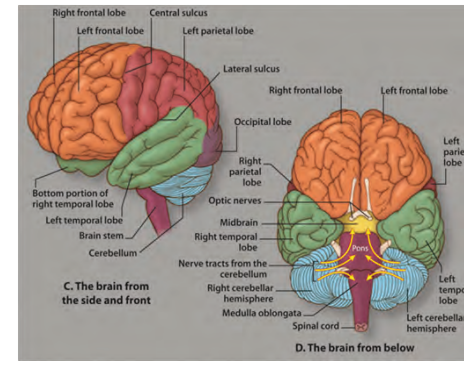

Fig.4. (C) The brain from the side and front; (D) The brain from below

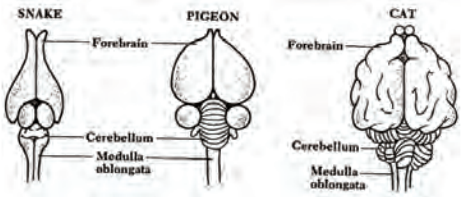

Fig.5. Schematic diagram of the Brains of Reptile, Bird and Mammal. Cerebellum and Medula Oblongata are parts of the hindbrain.

R-complex is essential for our survival; it regulates our eating, digestion, heartbeat, sleeping, sexual behaviour, reproduction and the 'fight or flight' instinct. This is the oldest structure in the brain that can be traced back to about 500 million years. Reptiles and amphibians have a cerebrum that works very similar to the R-Complex, which is the signature evolution has left within our brain from the time mammals were evolving from reptiles and amphibians.

As reptiles evolved into mammals, the brain necessarily increased in size and complexity as new structures evolved to control and coordinate the increased complexities and activities of mammalian life. The mammalian brain is similar to the limbic system that lies within the neocortex, in the centre of the brain surrounding parts of the reptilian brain and is prominent among animals that live in social groups like the apes. These social groups with their complex dynamics of behaviour would need a sophisticated limbic system to distinguish between potential enemies, allies and rivals. The limbic brain, which emerged in the first mammals about one hundred and fifty million years ago, is capable of storing memories of behaviours that produced pleasant and unpleasant experiences, and is thus responsible for emotions in human beings. It is the seat of our value judgments which influences our behaviour, often unconsciously. In the paleocortex and limbic system, the brain has indeed preserved the memories of our evolution from reptiles and mammals as shown in Fig.5. These three parts of the brain do not operate independently, but have numerous neural interconnections through which they interact. The neural pathways from the limbic system to the cortex are especially well developed. We share the limbic system with other mammals though not fully with the reptiles.

The main structures of the limbic brain shown in Fig.6 are the hippocampus, the amygdala, and the hypothalamus. Within each hemisphere of brain is located a thalamus that relays the incoming sensory signals to appropriate areas of the brain for processing. Below it lies the hypothalamus, which controls hunger, thirst, the circadian rhythm, anger, pleasure and emotions. The largest structure of the limbic system is the hippocampus which plays a large role in processing our short-term memories into long-term memory. The amygdala controls our fear and aggression, and is also involved in emotion and memory. Electrical stimulation of the amygdala in animals causes extreme fear or frenzy.

It is believed that altruistic behaviour originated in the limbic system. Mammals and birds are the only living beings that

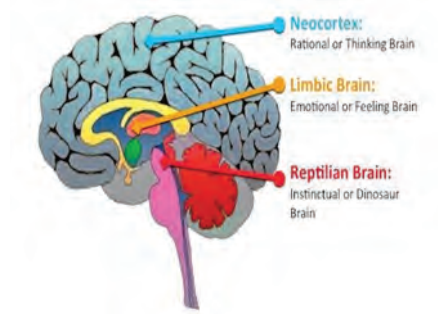

Fig.6. The limbic brain[8]

harbour and display affection towards their young offspring and care for them. The relatively larger capacity for information processing among the mammalian brains owes its roots to this distinction. As Carl Sagan observed, "Love seems to be an invention of the mammals." The pituitary gland, the pea-sized gland known as the 'master gland', which dominates the human endocrine system and controls the growth, development and functioning of all other endocrine glands, is an essential part of the limbic system. The olfactory cortex related to smell is among the oldest parts of the limbic system and played the most vital part in evolutionary progression of mammals in identifying food, predators (also preys), mates, and in sexual behaviour.

Finally, we have the third layer of the brain in thecerebral cortex, the outermost layer of the brain with its two large cerebral hemispheres, which is responsible for the development of human language, abstract thought, imagination and consciousness. Most of our cognitive abilities spring from here. The neocortex, the latest evolutionary structure within the cerebral cortex, governs our higher cognitive behaviour and our immense learning abilities. It makes up about 80 percent of the total brain-mass and is most developed among humans. As it evolved gradually, it became progressively more and more wrinkled, the wrinkling allowing the cortex to develop much larger surface area, and hence more neurons to accommodate within the small space available inside the skull. At birth, the cortex forms a smooth covering over the structures of the brain, but as it increases in size and complexity over a period after birth, it becomes more and more wrinkled, finally reaching a total surface area of about 2,800 square centimetres in a fully grown adult. The increase in wrinkling of the cortex is known as *corticalisation* and is the real measure of human intelligence. This increase in the folds of the cortex has been a major evolutionary factor that enabled a better coordination and organisation of the complex behaviours in higher primates and humans. Neocortex undoubtedly is the seat of abstraction, reasoning, analysis and symbols. It is the seat of mathematics, arts and music. It is responsible for our humanness, even though the higher primates and some cetaceans like dolphins and whales also have well-developed neocortex.

A larger cortex obviously houses a larger number of neurons, but more than the number what actually matters is the number of connections between these neurons that determines the responses to a given stimulus. Major elements of this network are the axons, dendrites and synapses. The fundamental element is of course the brain cell or the neuron. The brain and the spinal cord together constitute our central nervous system where the brain interprets and stores sensory information for sending orders to different parts of the body, and the spinal cord provides the pathway to carry messages from the brain to the peripheral nervous system, from where the parasympathetic and sympathetic nervous systems picks up signals that regulate the bodily functions respectively under ordinary conditions and under stress, and spending and saving energy.

It was not until the twentieth century that the neuron was recognised as the cell of the brain. Brain tissues look like a continuous jumbled mass – a reticulum – under the microscope, without any definite cell defining membranes that distinguishes cells in every other tissue. This reticular

theory of brain persisted well into the 20th century, till a Spanish neuroscientist, Santiago Ramon y Cajal, using a technique developed by the Italian anatomist Camilo Golgi of staining a few neurons so that they could be made to stand out in the jumbled morass that the brain appeared to be and studied individually, demonstrated that neurons were nothing but cells. That did not, however, convince Golgi, who remained a confirmed reticularist throughout his life. But the spectacular insight that Cajal gave into the working of the brain by suggesting that neurons were responsible for the movement and processing of information inside the brain was the beginning of modern neuroscience.

Cajal showed that although there exists a vast gulf of difference between the intelligence possessed by humans and insects or animals, such differences are not reflected in the structure of their neurons which remarkably looked similar, except for their numbers. As Cajal himself observed, "the quality of the psychic machine does not increase with the zoological hierarchy. It is as if we are attempting to equate the qualities of a great wall clock with those of a miniature watch."Human brain has about 100 billion neurons, compared to only a million neurons in the brain of honeybees, 20,000 in snails, and only 300 in the simplest worms. But humans do not possess any 'super-neuron'; neurons in all living beings operate more or less in the same way by sending and receiving electrochemical impulses, they have similar complex branched structure to facilitate communication with other neurons, and they are basically the same at the cellular level in every living thing. Golgi and Cajal received the Nobel Prize in Physiology or Medicine in 1906 for their work on structure on the nervous system, sharing the coveted Prize for the first time in history.

The neuron's complicated structure has evolved to enable them to perform the role of super-efficient messenger for receiving messages from and transmitting messages to other neurons. These messages are nothing but the electrical impulses generated within the cell by the action of the ions within and outside the cell membrane. The parts of the neuron that receives messages from other cells are called dendrites, which are like tendrils propagating from one end of the neuron; they are attached to the cell body or soma that contains the cell nucleus. Attached to the soma are the axons, which, like optical fibres, carry the messages to other neurons and are protected by the myelin sheath composed of fatty substances. Neurons, however, constitute only one tenth of the cells in the brain, the rest being the glial cells– grey fatty cells that support the neurons – providing insulation and delivering nutrients to them, producing myelin to coat the axons, and also cleaning up the wastes and removing dead neurons.

Each axon has several terminals to connect to the dendrites of neurons that receive messages; these terminals are fitted with tiny sac-like structures called synaptic vesicles which are filled with chemicals suspended in fluid; these chemicals are called neurotransmitters. An axon can connect to thousands of other neurons via their dendrites. The junction between two neurons consists of a minute gap – called the synaptic gap– across which neural impulses pass by diffusion of a neurotransmitter; this junction is called a synapse. Synapses act like gates, and regulate the flow of information, i.e., electrical impulses that travel along the axons, within the brain, which is unidirectional. Through the synapses, neurons connect to the incredibly complex and super-organised network of neurons that can process information and pass it down to all parts of the body via the bunch of nerves running through the spinal cord and reaching all parts of the body. Different structures and parts of the brain establish connections amongst themselves forming neural circuits that pass and process information back and forth, allowing the entire brain to work in unison, producing sublime perceptions or ideas.

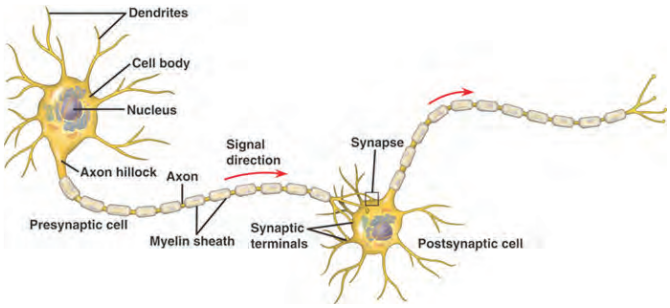

Fig.7. Structure of Neuron[15]

Billions of neurons inside the cerebral cortex thus create an amazingly intricate and astonishingly complex web of interconnections that account for the progressively complex of behaviour and sophisticated thinking among higher mammals and humans. Organisation of the vertebrate brain also shows striking similarity. All vertebrates have a forebrain, midbrain and hindbrain, and within these, neural systems that perform common functions, though different species have specialised areas within their brains to deal with the specific constraints and circumstances of their respective environments. In order to facilitate development of higher cognitive abilities, the structure in the human brain that has grown the most is the neocortex. Our superior ability to anticipate and plan for abstract reasoning have all resulted from a highly developed neocortex, in particular to the denser interconnections between the prefrontal cortex and the rest of the brain. The growth of neocortex was higher among the higher primates and humans; this might have been necessitated by the demands of growing complexity of their social lives which would include the ability to predict the behaviour of other individuals within the group. Natural selection would thus favour the development of areas in the cortex that are responsible for language and communication which improve the social skills.

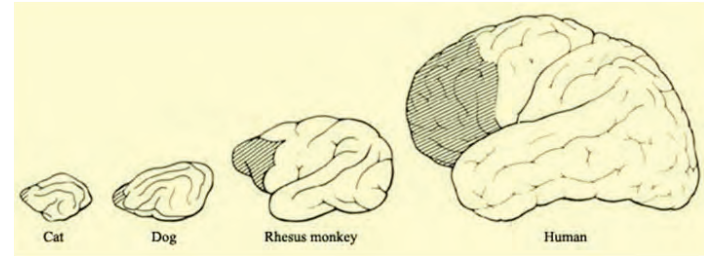

Fig.8. Relative sizes of the prefrontal cortex in animals and humans

Within the temporal lobe and prefrontal cortex of the brain lies a special class of nerve cells called 'mirror neurons', which fire not only when we perform some actions, but also when we watch someone else perform the same actions. These mirror

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Winning over irritable bowel syndrome: The way forward

Dr. Yatish Agarwal

Irritable bowel syndrome is a common problem which many adults suffer from. Even though irritable bowel syndrome is not a life-threatening condition, it can interfere seriously with the quality of life. A healthy diet, easing out on stress and regular physical exercise helps in reducing irritable bowel related problems. However, in case of moderate to severe problems you should consult a doctor

You're out with family and you've just finished a delicious meal at your favourite jaunt, when the familiar rumblings in your stomach begin. You excuse yourself and head for home, where you spend the next hour suffering through cramps and diarrhoea. Other times, you may battle uncomfortable constipation. Either way, your life suffers.

Irritable bowel syndrome is a common problem which many adults suffer from.It is often referred to as spastic colonbecause its symptoms are largely caused by spasm of the intestinal walls. The walls of the intestines are lined with layers of muscle that contract and relax, helping to move food from the stomach, through the intestines, to the rectum. Normally, the muscles contract and relax in coordinated rhythm. With irritable bowel syndrome, they function abnormally. They contract for a longer time, and with more strength than normal, causing pain. Food waste is forced through the intestines more quickly, producing gas, bloating and diarrhoea. Sometimes, the opposite occurs. Passage of waste slows, leading to hard, dry stools. Spasm of the intestines also causes them to produce more mucus with the stools.

Even though irritable bowel syndrome isnot a life-threatening condition, it can interfere seriously with the quality of life. If a person has a mild form, the condition may be only a minor inconvenience. At the other end of the scale, the pain and accompanying symptoms can seem unbearable. Most people have mild symptoms. Some people have moderate symptoms that are intermittent but can be disabling. A small fraction of people with irritable bowel syndrome have severe symptoms.

Steps you can take

Should you have only slight or temperate symptoms, and your family doctor or a gastroenterologist has made certain that your symptoms relate to irritable bowel syndrome, you might consider adopting some simple steps to improve upon your symptoms. Even though this will not cure you of the malady, yet you could participate in normal activities and fully enjoy life. The focus of self-care is tokeep things under controlthrough a two-pronged approach:

- Identify factors that trigger symptoms and take preventive steps to avoid them.
- Develop strategies to minimise symptoms

A healthy diet, easing out on stress and regular physical exercise are good starting points. They can keep your digestive system

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functioning smoothly, reducing the irritable bowel syndrome symptoms. Keep in mind, however, that your body may not respond immediately to changes in your daily habits. Instead, look for signs of gradual improvement. Your goal is to find long-term, not temporary, solutions.

Make changes in diet plan

Eat low-fat foods

Fat stimulates contractions of the large intestine, and this may aggravatethe irritable bowel syndrome symptoms. You don't need to avoid all fat, but if fat seems to worsen pain and diarrhoea, limit the amount you eat. The best way to reduce fat in your diet is to eat more plant-based foods. Plant foods — fruits, vegetables and foods made from whole grains — contain beneficial vitamins, minerals, cancer-preventing compounds (phytochemicals) and fibre.

Check outfibre

For people with irritable bowel syndrome, dietary fibre can be either good or bad. High-fibre foods soften and speed passage of stool, reducing constipation. But in some people, fibre worsens diarrhoea, gas and pain. It may be that some people with irritable bowel syndrome are more sensitive to gases produced in the colon from fermentation of fibre.

The best approach is to gradually increase the amount of fibre in your diet over a period of weeks. If you continue to experience pain and diarrhoea, talk with a dietician about designing a low-fat diet that also includes reduced amounts of dietary fibre.

Drink plenty of liquids

Liquids can help relieve constipation and replace body fluids absorbed by fibre. Each day drink at least 8 glasses of fluids. Water is best. Beverages containing caffeine and alcohol cause you to urinate more. They also can worsen diarrhoea by stimulating or irritating your intestines. Avoid carbonated beverages because they can produce gas.

Avoid problem foods

If you find that certain foods aggravate your symptoms, don't eat them. Many people with irritable bowel syndrome notice an improvement in symptoms simply by excluding certain foods or beverages from their diets. If you have bothersome bloating or are passing considerable amounts of gas, your doctor may suggest that you cut out such items as carbonated beverages, vegetables — especially cabbage, broccoli, cauliflower,red peppers, and green onions — and raw fruits. Other common culprits are fatty foods, beans and other gas-producing foods, red wine, alcohol and caffeine. Some people may also have problems with wheat or milk.

Eat at regular times

Don't skip meals, and try to eat at about the same time each day. Scheduled meals help regulate bowel function and lessen symptoms of constipation and diarrhoea. That's because digestion stimulates the muscles in your colon to contract and move stool onward.

Some people find that eating frequent, smaller meals agrees with them better than eating three large meals a day. For others, especially people bothered by constipation, the opposite is true. To stimulate muscle contractions and passage of stool, they need to eat medium-sized to large meals.

Try curd, yoghurt and probiotics

Curd, yoghurt and probiotics contain "good friendly" bacteria that normally live in your intestines. It has been suggested that if you have irritable bowel syndrome, you may not have enough good bacteria and that adding probiotics to your diet may help ease your symptoms.

Recent studies suggest that certain probiotics may relieve symptoms of irritable bowel syndrome, such as abdominal pain, bloating, and diarrhoea and improve the quality of life.

Take these helpful hints

Ease out on stress

Worry, anxiety and other stressful emotions are a major cause of digestive upset. However, in people with irritable bowel syndrome, stress-related symptoms such as abdominal pain and diarrhoea tend to occur more frequently and severely. A vicious circle can develop: Your symptoms can increase your stress level, which causes your symptoms to worsen, which further increases your stress, and so forth.

If you wish to control your symptoms, learn how to relax. There are many methods of relaxation. Some people relax while listening to or performing music, or surrounding themselves with soothing aromas (aromatherapy). Others benefit from massage, yoga or meditation. Studies show that hypnosis also may reduce abdominal pain and bloating. A trained professional teaches you how to enter a relaxed (hypnotic) state and guides you through an imagery session during which you imagine your bowel muscles smooth, calm and still.

To help you get started, here are two simple relaxation techniques you can use when you begin to feel stressed:

Deep breathing

Most adults breathe from their chests. Each time you breathe in (inhale) your chest expands. Each time you breathe out (exhale) it contracts. To relax, breathe deeply from your diaphragm, the muscle that separates the chest from the abdomen. You can use deep breathing as your only means of relaxation or as a warm-up and cool-down method for other techniques.

Progressive muscle relaxation

This technique involves relaxing a series of muscles one at a time. First, raise the tension level in a group of muscles, such as a leg or an arm, by tightening the muscles and then relaxing them. Concentrate on slowly

letting the tension go in each muscle. Then move on to the next muscle group.

Dress appropriately

Avoid tight clothes like skin-tight jeans which tend to put unnecessary pressure on your tummy. Instead, opt to wear comfortable, loose-fitting clothing.

Soothe your tummy

Soak in a warm bath or lie down with a hot water bottle or heating pad on your abdomen to decrease abdominal pain. Be careful, however, not to burn your skin.

Go easy in the loo

Go to the bathroom as soon as you feel the urge, but don't hurry yourself. Allow adequate time for a bowel movement without straining.

Physical exercise can work wonders

Exercise helps decrease feelings of stress. It also stimulates the rhythmic contractions of the intestines, helping them to function normally. Exercise can relieve constipation and may alleviate symptoms of diarrhoea. It also can improve depression and make you feel better about yourself.

Aim for 30 minutes of moderate exercise most days of the week. If you've been inactive, begin slowly and gradually increase the amount of time you exercise.

Consider these over-the-counter medications

Certain non-prescription medications can help relieve your discomfort while you're taking steps to change your lifestyle. Depending on your symptoms, you may benefit with one or more of the following non-prescription products:

Antidiarrhoeal medications

Loperamide (Imodium) slows the rate at which food leaves your intestines, and increases intestinal water and ion (sodium) absorption to help solidify stool. Other antidiarrhoeal drugs, such as bismuth (Pepto-Bismol), also may relieve diarrhoea and the urgency to have a bowel movement. You need to be careful, however, not to use antidiarrhoeal medications too often or too long. Overuse can lead to or worsen constipation.

You might also experiment with peppermint tea (tea that contains peppermint oil). There's some evidence it helps relieve diarrhoea or gas accompanied by bloating.

Fibre supplements

To relieve constipation, begin with a natural fibre supplement such as Naturolax or Fybogel. They should help within 1 to 3 days. When taken regularly as directed, fibre supplements are generally safe and effective. As they're so absorbent, you must take them with plenty of water. Otherwise, they can become constipating — the opposite of what you want them to do.

Consider laxatives

If these measures donot help, you could ask your doctor about a laxative. There are several types:

Stool softeners

These are the most gentle products. They're sold over the counter under several brand names, including Cremaffin, Agarol and Dupholac.

Donot take mineral oil to help soften your stools and relieve constipation. It can block absorption of key vitamins.

Saline laxatives

These are relatively safe to use long-term and include the over-the-counter product Milk of Magnesia. It works by increasing water content in your stool.

Stimulant laxatives

The most powerful of laxatives, these products should be taken only when other measures fail to induce a bowel movement, and only after discussing their use with your doctor. Over-the-counter brand names include Dulcolax, Cremalax and Senade.

Caveat. Regular use of laxatives can aggravate constipation. You also can become dependent on laxatives for bowel movements if you take them for more than the time recommended by the manufacturer. Long-term use of stimulant laxatives may lead to chronic severe constipation. Talk with your doctor about the best use of these over-the-counter medications.

Medical treatment

If your symptoms are moderate to severe, you may need more help than lifestyle changes or over-the-counter medications can offer.

Prescription medications

Depending on your symptoms, your doctor may recommend one of the following medications:

Alosetron

This is the first medication approved specifically for the treatment of irritable bowel syndrome in women. Alosetron (Lotronex) is a nerve receptor antagonist that relaxes the colon and slows the movement of waste through the colon. It is especially useful if you have diarrhoea or alternating diarrhoea and constipation, rather than just constipation. The medication also helps relieve abdominal pain and cramping. Alosetron is safe and well tolerated for short-term use. Constipation is its only known side effect. Possible long-term side effects are unknown.

Lubiprostone

Lubiprostone works by increasing fluid secretion in the small intestine to help with the passage of stool. It is approved for women age 18 and older who have irritable bowel syndrome with constipation. Its effectiveness in men is not proved, nor its long-term safety. Common side effects include nausea, diarrhoea and abdominal pain. More serious side effects may include, fainting, swelling of the arms and legs, breathing problems, and heart palpitations

Smooth-muscle relaxants

Anticholinergic (antispasmodic) drugs such as hyoscyaminesulphate and dicyclomine may help relax intestinal muscles and relieve muscle spasms. However, these medications are not without some possible bothersome side effects, which include urinary retention, accelerated heart rate, blurred vision and dry mouth. It is thus best to use them sparingly, such as during a flare-up in symptoms.

Antidepressants

These medications are useful if your symptoms are severe enough to impair your daily function and cause depression or panic attacks. In addition to treating depression, the drugs help relieve abdominal pain and diarrhoea or constipation. Your doctor may recommend a tricyclic antidepressant or a

selective serotonin reuptake inhibitor.

The tricyclic agents amitriptyline, imipramine and doxepin are most frequently prescribed for depression and pain accompanied by diarrhoea. Tricyclic antidepressants may cause drowsiness, dry mouth and constipation.

The SSRIs fluoxetine (Prozac) and paroxetine (Paxil) often are recommended for depression and pain accompanied by constipation. In some people, SSRIs can cause nausea, cramping and diarrhoea.

Antidepressants must be taken regularly to be effective. These medications are generally prescribed only if you have chronic or recurring symptoms.

Antibiotics

Some people whose symptoms are due to an overgrowth of bacteria in their intestines may benefit from antibiotic treatment. Some people with symptoms of diarrhoea may benefit from rifaximin.

Counselling

This is a particularly important part of treatment if your condition is related to stress or anxiety. A health care professional who specialises in behavioural medicine, such as a psychiatrist or psychologist, can help you reduce stress and anxiety by looking at your response to life events, and then modifying that response.

You learn to identify stressful situations that cause your bowel reactions, and to develop strategies for dealing with them. For most people, counselling combined with medication works better than medication alone.

The Hidden Brain *(Continued from page 25)*

neurons are believed to have played a major part in the transmission of human culture and in shaping human social behaviour. In doing so, they may have played a major part in making the *Homo sapiens* what they are today.

The complexity of the human brain has been the result of hundreds of millions of years of evolution. Starting with the reptilian brain, the limbic system or the 'mammalian brain', and neocortex or the 'thinking brain' had evolved over a period of 500 million years, but at each stage the brain had retained its older structures which were useful in fulfilling the fundamental needs of life. Thus instead of discarding these structures, evolution had adapted them, through a process of building expansions and extensions around the older structures, rather than rebuilding everything from the scratch. And sure enough, even the human foetus has retained the memory of such development. Brain of a human foetus also develops from inside out mimicking its evolutionary stages, starting with the neural chassis, which is the brain stem, then the R-complex and following it up with the limbic system, and finally the neocortex. Memory of our evolution goes into the depth of time, far deeper than the last two hundred and fifty thousand years since *Homo sapiens* had dwelt upon this Earth.

We often boast of other animals being inferior to human beings in evolutionary terms since our brain sizes are far greater than that of most animals, as if humans occupy some kind of a pride of place among all the animals. Nothing can be farther from the truth. Evolution has seen thousands of species of animals and birds and millions of species of insects succeed in the struggle for life, each species carving out a specific niche for itself in which it lives in perfect harmony with its surroundings to which it has successfully adapted itself despite their smaller brain sizes. Evolutionary success in fact has very little relationship with the brain size. Larger brains have not replaced smaller brains, but have only added to them, increasing the complexity of brain structure. The increased complexity was not the objective of evolution but a by-product of its endless experiments over endless millennia. It was only a coincidence that mammals were favoured with this complexity.

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Recent Developments in Science and Technology

Biman Basu

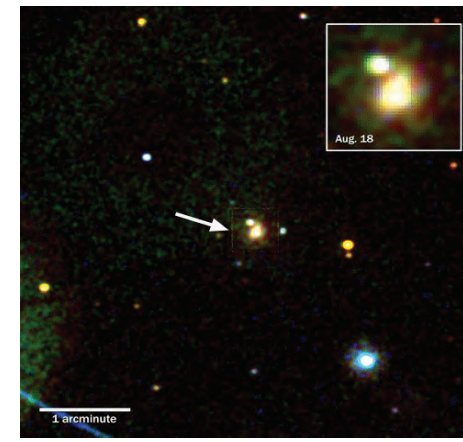
Gravitational wave due to collision of two neutron stars that took place some 130 million years ago reached Earth on 17 August 2017. In an incredibly collaborative effort, over 3,500 astronomers around the world worked with physicists to record the event. Along with gravitational wave, the collision produced a fireball called a kilonova, which was clearly visible in the Hubble observations. This event provides the first real evidence that light and gravitational waves travel at the same speeds.

Gravitational waves from neutron star collision detected

Ever since gravitational waves were first detected by the US-based Laser Interferometer Gravitational-Wave Observatory (LIGO) in September 2015, four similar events have been recorded by LIGO and its European counterpart Virgo. But a recent discovery made on 17 August 2017 beats them all. The origin of gravitational waves detected in the previous four events was the merger of black holes located billions of light years away. But the source of gravitational waves detected in the recent event was different – the merger of two neutron stars, which made it especially significant for astronomers. This is because the merger not only gave off gravitational waves but also radiation in electromagnetic wavelengths that could be detected from Earth. In fact, the event was simultaneously observed as gravitational waves as well as in multiple electromagnetic wavelengths – gamma rays and X-rays. For the first time in history, an astronomical phenomenon has been first observed through gravitational waves and then seen with telescopes.

In an incredibly collaborative effort, over 3,500 astronomers using 100 instruments on over 70 telescopes around the world and in space worked with physicists from the LIGO and Virgo collaboration to record the event. Observatories from the very small to the most well-known were involved. They included the *Hubble Space Telescope* and several other NASA and ESA space observatories, such as the *Swift*, *Chandra* and *Spitzer* missions. The significance of the event can be judged from the fact that till 16 October, more than 30 papers had been published in five journals –*Physical Review Letters*, *Science*, *Nature*, *Nature Astronomy* and *Astrophysical Journal Letters*.

Neutron stars are the crushed leftover cores of massive stars that long ago had exploded as supernovae. In the present case, two stars, located near each other in a galaxy called NGC 4993 in the constellation of Hydra, started out between 8-20 times the mass of our Sun, but after the supernova explosions, each was compressed to about 16 kilometres in diameter, being made up entirely of neutrons. These are stars that have extremely high densities– a teaspoonful of neutron star material would weigh 1



Swift's Ultraviolet/Optical Telescope imaged the kilonova produced by merging neutron stars in the galaxy NGC 4993 (arrowed) on 18 August 2017, about 15 hours after gravitational waves and the gamma-ray burst were detected. (Inset) Magnified views of the galaxy. (Credit: NASA/Swift)

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billion tons. After formation, the two neutron stars started spinning around each other in a cosmic dance until their mutual gravity caused them to come together and collide and merge, probably turning into a black hole. The stellar collision produced a fireball of astronomical proportions. The associated stellar flare, called a kilonova, is clearly visible in the Hubble observations.

The repercussions of that gigantic event arrived at Earth 130 million years later. As a result, while the merger took place 130 million years ago, signals from the event as gravitational waves designated as GW170817and gamma rays, reached Earth only on 17 August 2017. According to the scientists, this event has the most precise sky localisation of all detected gravitational waves so far. Further, this event provides the first real evidence that light and gravitational waves travel at the same speeds – near the speed of light – as Einstein had predicted 100 years ago.

A cataclysmic event like the merger of two neutron stars has interesting fallout in terms of synthesis of the heaviest elements of the periodic table. For decades, astronomers had debated the origins of the heaviest elements, which include precious metals, rare earth elements and basically everything on the bottom rungs of the periodic table, from platinum to plutonium. According to the scientists, "The collision of the two neutron stars produced 10 times of mass of Earth in gold and platinum alone. Think about how as these materials are flying out of this event, they eventually combine with other elements to form stars, planets, life … and jewellery."

Study finds pollution is deadlier than war, disaster, hunger

There was a lot of hue and cry about air pollution in the National capital caused by Diwali crackers and the Supreme Court had to issue directive to curtail sale of crackers during Diwali. But Diwali crackers are not the only source of air pollution neither is air pollution the only health concern. Water, soil and noise pollution are also areas of concern. It has been revealed in a recent study by *The Lancet* Commission on pollution and health that pollution is deadlier than war, disaster, hunger. The study found that environmental pollution – from filthy air to contaminated water – is killing more people every year than all war and violence in the world; more than smoking, hunger or natural disasters; more than AIDS, tuberculosis and malaria combined. According to the study, "Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 – 16% of all deaths worldwide – three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence.

Air pollution in Delhi. A recent study has found pollution to be a bigger killer than war, disaster, and hunger.

The financial cost from pollution-related death, sickness and welfare, the study found, is equally massive, costing some $4.6 trillion in annual losses – or about 6.2 percent of the global economy. *The Lancet* Commission study marks the first attempt to pull together data on disease and death caused by all forms of pollution combined.

It is most often the world's poorest who suffer, the study found. The vast majority of pollution-related deaths – 92% – occur in low- or middle-income countries, "where policy makers are chiefly concerned with developing their economies, lifting people out of poverty and building basic infrastructure". Environmental regulations in those countries tend to be weaker, and industries lean on outdated technologies and dirtier fuels. In wealthier countries where overall pollution is not as rampant, it is still the poorest communities that are more often exposed, the study found. The study attributed the present state of affairs to "decades of neglect of pollution and its harmful effects on people's health, the environment, and the planet both by governments and the international development community" (*The Lancet*, 19 October 2017 | http://dx.doi.org/10.1016/S0140-6736(17)32345-0).

The study found that one out of every four premature deaths in India in 2015, or some 2.5 million, can be attributed to pollution. Several other countries such Bangladesh, Pakistan, North Korea, South Sudan and Haiti also see nearly a fifth of their premature deaths caused by pollution. China's environment was the second deadliest, with more than 1.8 million premature deaths, or one in five, blamed on pollution-related illness, the study found.

The report says India has taken some recent actions, such as tightening vehicle and factory emission standards and occasionally limiting the number of cars on New Delhi's roads. But they have done little about crop burning, garbage fires, construction dust or rampant use of the dirtiest fossil fuels.

It goes without saying that pollution mitigation and prevention can yield large net gains both for human health and the economy. Air quality improvements in the high-income countries have not only reduced deaths from cardiovascular and respiratory disease but have also yielded substantial economic gains. *The Lancet* study found that, in the US, an estimated US$30 in benefits has been returned to the economy for every dollar invested in air pollution control since 1970, which is an aggregate benefit of $1·5 trillion against an investment of $65 billion.

The aim of *The Lancet* Commission on pollution and health is to raise global awareness of pollution, end neglect of pollution-related diseases, and mobilise the resources and the political will needed to effectively confront pollution. To advance this aim, the Commission has come out with six recommendations: (1) Making pollution prevention a high priority nationally and internationally and integrate it into country and city planning processes; (2) Mobilising, increasing, and focussing the funding and the international technical support dedicated to pollution control;(3) Establishing systems to monitor pollution and its effects on health; (4) Building multi-sectoral partnerships for pollution control; (5) Integrating pollution mitigation into planning processes for non-communicable diseases; and (6) Intensifying research on pollution and pollution control.