Fracking~messiah or menace?

METHANE POLLUTION IS REARING ITS HEAD AS THE NEW GREENHOUSE GAS THREAT, WRITES **S ANANTHANARAYANAN**

The last half century has seen humanity coming to grips with the harm caused by CO_2 emissions of burning coal for heat and generation of electricity. And the world is striving to adapt technology and lifestyles to undo the damage done. An apparent solution, but also a threat, is the maturing of methods to tap large underground reserves of natural gas that can partly replace coal as an energy source.

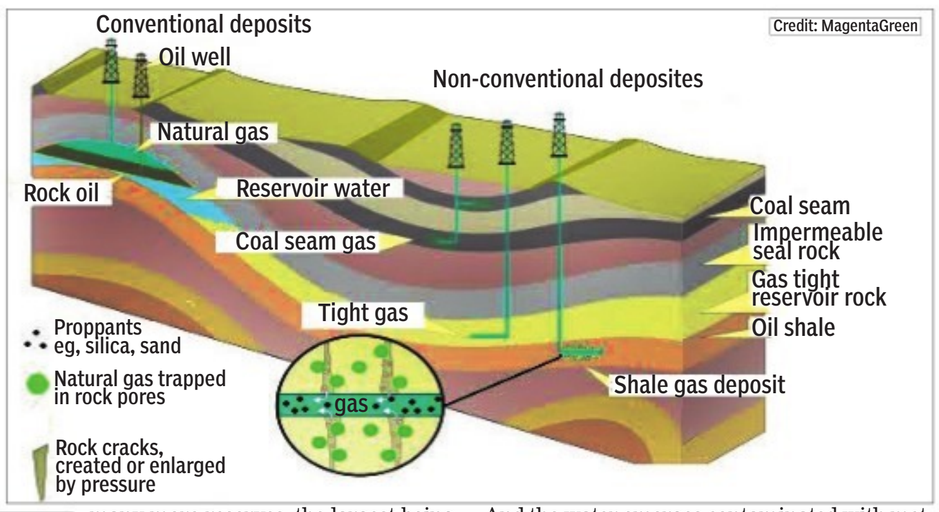
The journal *Science*, of the American Association for the Advancement of Science, has released a special issue, *The Great Gas Boom*, which discusses the "promise and the peril" of this resource that the USA is rapidly exploiting, but which some countries like France and Bulgaria and even some states in America have put on hold.

The earth's store of coal, natural gas and petroleum has arisen from vegetable matter buried and compressed over millions of years. The vegetable matter itself arose by fixing atmospheric CO_2 through photosynthesis. Photosynthesis uses the energy in sunlight to separate both the carbon in CO_2 as well as the hydrogen in H_2O (water), to create, with some oxygen, the basic carbohydrates like sugars and starches. When decomposed plant matter was buried and cut off from oxygen, and subject to bacterial action, oxygen content was further reduced and under intense pressure, hydrocarbons, which consist only of hydrogen and carbon, came about in the form of gas and petroleum. And in places where conditions were right, even hydrogen was removed and vegetable matter was reduced to just carbon, as deposits of coal.

Coal can thus be considered a hydrocarbon with the hydrogen content removed. Hydrogen removal can be likened to burning out the hydrogen part, which would release energy, and coal is hence left with less energy than hydrocarbons.

Another way of looking at this is to say that hydrocarbons are sources of more energy than coal. And the good part is that the additional energy comes from hydrogen, whose burning does not create CO_2. Tapping sources of underground hydrocarbons like natural gas thus amounts to getting hold of solar energy of past eons, stored in ways that are more than just carbon, so that we can power modern living without causing the environment as much damage as we are when we use energy derived from coal alone.

Hydrocarbons in underground reservoirs occur both in the liquid form of petroleum as well as in the form of natural gas. The extraction and refinement of petroleum, whose reserves are placed at around 200 billion tonnes, which is less than a fourth of reserves of recoverable coal, is a major industry and the price of oil is a vital factor in the global economy. And for natural gas, while this is also present along with oil deposits, there are also large reservoirs of just gas, mainly in Russia and West Asia. While the gas that is found with oil is usually flared and lost, except where there are local consumers, larger finds of natural gas have led to the laying of pipelines and power generation from gas at distances from the sources. But a further, equally large source of natural gas is in the reserves trapped in rock formations known as *shale*.




"We see this potential train wreck on the horizon," says Mark Brownstein of the Environmental Defence Fund, New York City.

Shale gas

Shale consists of flakes of rock formed from the compaction of fine grains of clay, minerals or quartz. It occurs where the original material had more than one per cent of carbonaceous content and the characteristic of shale is that it occurs in sheets that can be prized apart, although the sheets are well compacted at great depths below the earth's surface. Shale gas is natural gas that is trapped between rock layers in shale formations. Very large reserves of shale gas have been discovered and exploited in the USA since a century and there are many more reserves, the largest being in China. As the USA and China are major importers of petroleum, shale gas use has impacted the oil market, apart from being a replacement for coal.


Sherry Vargason can ignite her kitchen faucet.

But the extraction of shale gas presents its own set of problems. In the case of a bore into the earth for water or for oil, the liquid that is contained in the rock formation flows into the bore and collects for being pumped out. But with shale gas, shale does not allow gas to flow and it is not possible to collect gas just by a borehole entering a shale formation. The way to access shale gas has hence been from natural fractures in the shale, or, in recent times, by artificially creating extensive fractures around the bore hole, a method called *fracturing* or *fracking*.

Early methods of fracking used explosives but the current method is *hydraulic fracking*, where water is forced into the bore hole, which bends horizontally, under very high pressure. The high pressure is able to overcome the pressure of the load of soil above the shale and water enters between the sheets of shale to release the gas. The water used is mixed with sand or other mineral particles, called *proppants*.

The special issue of *Science* recounts that fracking in the USA was first tried in Kansas nearly 70 years ago and has now grown into a booming industry with thousands of bores drilled, largely in Pennsylvania, Texas and Louisiana. Shale gas now accounts for 40 per cent of the natural gas produced in the USA and is growing. The use of coal is falling and America has reduced its level of CO_2 and is positioning itself as an exporter of natural gas.

The downside

On the downside, there are controversies galore. For one, there is the huge quantity of water used, some 15 million litres for one well, says Erik Stocksad, author of one of the pieces in *Science*. And the water emerges contaminated with methane, the chief component of natural gas, and has to be put away (in many cases, it is reused to frack another well). Next, the fear of contamination of aquifers feeding supplies of drinking water. And then the evidence of leakage of methane gas from bores as well as from pipelines that distribute shale gas. Methane, whose molecular structure has a carbon atom surrounded by four hydrogen atoms, is like a spring-loaded flywheel among molecules, and has a high capacity to absorb heat.

This makes methane a potent greenhouse gas many times worse than CO_2, and it is felt by many that injecting methane into the atmosphere would negate the benefits of reduction in the sion of CO_2. Another serious consideration is that promoting shale gas, with its limited benefits, if any, would take away from the urgency of the need to limit CO_2 emissions.

There are even fears that fracking could lead to seismic disturbance and earthquakes. In defence of fracking, experts say the pressures at the great depths at which fracking happens would seal any larger cracks in the rock so that there is no danger to drinking water supplies. Studies with tracers injected into six commercial wells have shown no trace of contamination leaks, the *Science* article says. On the other hand, it says leakage from the casing of the wells is a real risk, with documented instances. One of the articles even displays a picture of Sherry Vargason of Pennsylvania showing water from a faucet that bursts into flame when a match is applied! Experts, however, defend themselves by saying that there is no clear evidence of the leaks having been caused by fracking as seepage of methane could happen because of natural geologic faults. And also that as gas companies gain experience, the risk of leaks are coming down.

But the controversy rages, with communities regrouping to contain what is considered dangerous manipulation of the natural balance. In the meantime, one team is "documenting water quality along the border between frack-free New York and frack-heavy Pennsylvania… and gas companies are funding their own vast surveys of pre-drilling water quality — even if only to defend themselves against post-drilling lawsuits", says the *Science* article.

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Is there life down there?

Another interest in pumping water into shale formations is to discover the nature of micro-organisms that these isolated crevices of the earth might harbour. Writing in the special issue of Science, Elizabeth Pennisi describes the work of researchers Paula Mouser and Shikha Sharma.


Paula Mouser and Shikha Sharma.

While analysing carbon isotopes in the water from aquifers and also fracking wells, Sharma noticed that the water flowing out "had a very different signature" than the water that was sent in, and the data suggested the presence of ancient, methane-producing organisms. Paula Mouser, working independently, had also seen evidence of salt tolerant organisms in fracking wells. The two have now got together and plan, later this year, to collect the original water from the wells, when they are bored, and before fracking water is pumped in, "to get a full sense of what's down there".

Energy companies also have an interest in the nature of micro-organisms, as these could cause corrosion of equipment or toxic contamination of the gas or even consumption of the methane before it reaches consumers.

SPECIFIC SEQUENCE

ONCE CONSIDERED AN ODDITY OF NATURE, PROTEIN SPLICING HAS NOW BEEN DETECTED IN DOZENS OF DIFFERENT ORGANISMS, PROKARYOTES AS WELL AS EUKARYOTES, SAYS **TAPAN KUMAR MAITRA**

After polypeptide chains have been synthesised, they often must be chemically modified before they can perform their normal functions. In prokaryotes, for example, the *N*-formyl group located at the N-terminus of polypeptide chains is always removed. Moreover, the methionine to which it was attached is often removed also, as is the methionine that starts eukaryotic polypeptides. As a result, relatively few mature polypeptides have methionine at their N-terminus, even though they all started out that way.

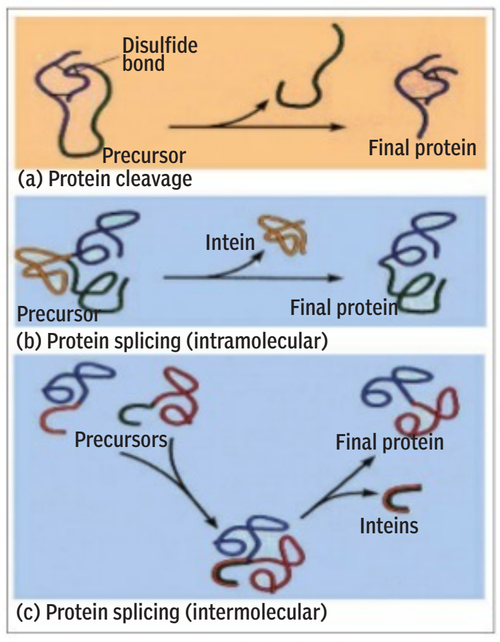
Sometimes, whole blocks of amino acids are removed from the polypeptide. Certain enzymes, for example, are synthesised as inactive precursors that must be activated by the removal of a specific sequence at one end or the other. The transport of proteins across membranes may also involve the removal of a terminal *signal sequence,* and some polypeptides have internal stretches of amino acids that must be removed to produce an active protein. For instance, insulin is synthesised as a single polypeptide and then processed to remove an internal segment; the two end segments remain linked by disulfide bonds between cysteine residues in the active hormone.

Other common processing events include chemical modifications of individual amino acid groups — by methylation, phosphorylation or acetylation reactions, for example. In addition, a polypeptide may undergo gly-cosylation or binding to prosthetic groups. Finally, in the case of proteins composed of multiple sub-units, individual polypeptide chains must bind to one another to form the appropriate multi sub-unit proteins or supra-molecular complexes.

In addition to the preceding post-translational events, some proteins undergo a relatively unusual type of processing called *protein splicing*, which is analogous to the phenomenon of *RNA splicing*. Intron sequences are removed from RNA molecules during RNA splicing, and the remaining exon sequences are simultaneously spliced together. Likewise, during protein splicing, specific amino acid sequences called *inteins* are removed from a polypeptide chain and the remaining segments, called *exteins*, are spliced together to form the mature protein.

Protein splicing is usually intramolecular, involving the excision of an intein from a single polypeptide chain by a self-catalytic mechanism. However, splicing can also take place between two polypeptide chains arising from two different mRNAs. For example, in some photosynthetic bacteria, a sub-unit of DNA polymerase III is produced from two separate genes, each coding for an intein-containing polypeptide that includes part of the DNA polymerase sub-unit. The two polypeptides are brought together by binding between their intein segments, and an inter-molecular splicing reaction then joins the two polypeptides together, accompanied by intein removal.

In some cases, the inteins removed by protein splicing reactions turn out to be stable proteins, exhibiting their own biological functions (usually endonuclease activity). Once considered an oddity of nature, protein splicing has now been detected in dozens of different organisms, prokaryotes as well as eukaryotes.



Some polypeptides are synthesised as inactive precursors that must have amino acids removed to produce an active protein; (a) protein cleavage is one mechanism that can be used to remove a stretch of amino acids from a polypeptide chain. For example, the protein hormone insulin is synthesised in an inactive precursor form (proinsulin) that is converted to the active hormone by enzymatically removing a long internal section of polypeptide. The two chains generated by removing this internal section remain connected by disulfide bonds between cysteine residues. Parts (b) and (c) illustrate the alternative mechanism of protein splicing, in which amino acid sequences called inteins are removed from one or more precursor polypeptides and the resulting polypeptide segments are spliced together to create a continuous polypeptide chain.

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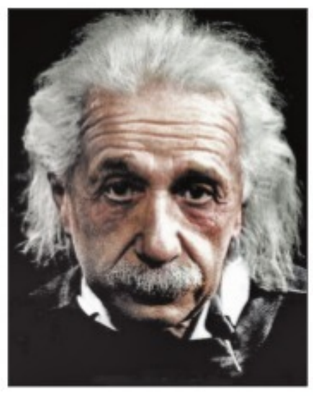
Demystifying space & time

EVEN A CENTURY LATER, ALBERT EINSTEIN'S GENERAL THEORY OF RELATIVITY CONTINUES TO FORM THE BEDROCK ON WHICH NEWER THEORIES ARE BUILT, WRITES **KALIKA PRASAD DASGUPTA**

Though Michael Faraday discovered electromagnetic induction in 1831, Danish physicist Hans Christian Oersted had demonstrated earlier how an electric current flowing through a wire loop produced a magnetic field. His discoveries, which simply originated from observations in laboratories, were the backbone for the invention of electric generators. These phenomena of electro-magnetism were elegantly propounded in mathematical terms by James Clerk Maxwell and were elaborated through laboratory experimentations by Heinrich Hertz. This formed the point of departure for Albert Einstein, who wanted to extend earlier observations in a more profound way and independent of any frame of reference. It was the genesis of his Special Theory of Relativity (1905), originally called "On Electrodynamics of Moving Bodies".

However, even after that the application of relativity to gravity was Einstein's most daunting problem. He followed the path set out by Carl Friedrich Gauss and Bernhard Riemann who had revealed the concept of "symmetry with congruence" in their theory of curved surfaces based on the principles of René Descartes. From the Big Bang to everything thereafter, cosmology today owes its roots to a single scientific concept — Einstein's General Theory of Relativity. With his new theory of gravity, Einstein upended the accepted concept of a rigid immutable space and time and, finally, physics had to accept a dynamic cosmos.



Throughout the autumn and winter of 1915, Einstein tirelessly worked on his General Theory, which explained the apparent anomaly in Mercury's orbit that defied Newtonian mechanics — the planet's perihelion, the point of its orbit nearest the sun, is advanced by 43 seconds of arc per century. In Einstein's final theory, gravitation was not treated as a force of attraction between bodies and the same was untenable in a relativistic universe explained in terms of field theory.

Einstein's gravitational field equations (1912 - 1915) governing space-time curvature are 10 non-linear partial differential equations with tensor quantities. This theory, *inter alia*, explains gravitational red shift, whereby light passing close to a heavy object such as a planet will redden. His theory of curved space near massive planetary bodies such as the sun also explained the deflection of light along a curved path.

Einstein's equations also suggested that the universe was expanding. It contradicted the concept of a static universe as advanced by Fred Hoyle and JV Narlicar in the 1960s, though earlier, at the end of the 1920s, American astronomer Edwin Hubble had demonstrated that the universe was really expanding. Einstein's field equations later provided the mathematical foundations of the Big Bang theory and the origin of the universe.

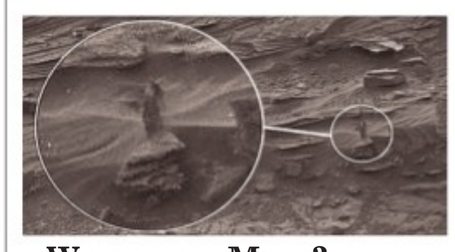
In a sense, Einstein was one of the founders of quantum theory, though he did not cherish the concept of its uncertainty principle. His Nobel Prize was not for his relativity principle but for his 1905 paper on the quantum nature of light. In mid-1924, taking up ideas from Satyen Bose in Dhaka and Louis de Broglie in Paris, he predicted that atoms might club together in a single entity. This is not an ordinary crystal or molecule, but an accumulation of similar atoms bonded together like a conglomeration in a slow moving laser beam. Such a condensate can exist at temperatures close to absolute zero and was called the Bose-Einstein Condensate. Special Relativity rules out the reversal of time by travelling faster than light; however, General Relativity allows for an extraordinary condition of space-time called a "wormhole".

An object might enter at one end, proceed by a route outside the known universe and come out at the far end of a wormhole in a quite different place and/or time. In particular, an excursion like that allows a return to an earlier time.

After 1916, Einstein did not consider his theory to be the pinnacle of human knowledge. He felt the basic fields of nature, such as gravitation, electromagnetism and the like must be explained in a single theory, which would account for any phenomena occurring in nature, including quantum mechanics. For the rest of his life he worked tireless on this theory of unifying fields in a profound manner.

Since Einstein breathed his last, physics has propounded several similar cutting-edge theoretical endeavours, such as the String Theory and Super String Theory, which extended human knowledge to a trans-universal scale. As Richard Feynman suggests, there could be 11 universes in parity with 11 dimensions. It would be like Lord Krishna telling Arjuna that he knew 11 *rudras* that the latter was unaware of. But all such theories stem from Einstein's master theory, which turned 100, this year.

PLUS POINTS



Woman on Mars?

There's a mysterious, fey lady standing on Mars! Well, no, of course there isn't, but it looks uncannily like it in this photo from Nasa's Curiosity Rover. The image is totally legit, and one of thousands of Mars photos National Aeronautics and Space Administration collates online. For those desperate to believe, the images are best viewed sequentially — increasing in zoom — and you should start by turning on *The X-Files* theme music. The "sighting" was first picked up by indispensable UFO blog, UFO Sightings Daily, which claims the mass "looks like a woman partly cloaked".

Key questions: Why is she striking such a powerful pose? Isn't that a bit of a precarious place to stand? Where did she get those clothes? What does she do for fun? Did she understand the finale of *True Detective*?

The figure could be a Martian, or a statue from an ancient civilisation, or just a bit of rock. You decide. The dramatic claim is similar to that of Cydonia, the so-called "Face of Mars", and is down to our pareidolia — a psychological phenomenon involving a stimulus wherein the mind perceives a familiar pattern where none actually exists.

CHRISTOPHER HOOTON/THE INDEPENDENT

Predator or prey?

It is often said that the eyes are a window to the soul and now research suggests that their shape can be used to distinguish between predator and prey in the animal kingdom. A study by the University of California and Durham University found that animals with pupils shaped like vertical slits are more likely to be ambush-predator species such as cats and crocodiles.


The crocodile's vertically slitted eyes help it judge distance at low levels, allowing it to move snappily to take its prey at speed.

Meanwhile, plant-eating "prey" species such as sheep and goats tend to have horizontal, elongated "letterbox" pupils. And circular pupils are linked to "active foragers" — animals that chase down their prey rather than creeping up and ambushing them.

The analysis of 214 species, which appears in the journal *Science Advances*, suggests that there are good evolutionary reasons for these differing optical designs. Tests showed that eyes with horizontal-slit pupils offered an expanded field of view. Located on each side of the prey animal's head, they provide a panoramic visual display that improves its chance of spotting approaching danger. The slits also have the added advantage of limiting the amount of dazzling light from the sun, making it easier to see the ground.

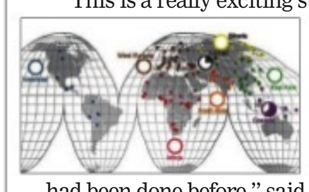
"The first key visual requirement for these animals is to detect approaching predators, which usually come on the ground," said the report's lead scientist, Professor Martin Banks of the University of California at Berkeley. "They need to see panoramically on the ground with minimal blind spots. Once they do detect a predator, they need to see where they are running. They have to jump over things."

TOM BAWDEN/THE INDEPENDENT

Human Diversity

Genetic differences among ethnically diverse individuals are largely due to structural elements called Copy Number Variants, according to a study published on 6 August in *Science*. Compared with other genomic features, such as Single Nucleotide Variants, CNVs have not previously been studied in as much detail because they are more difficult to sequence. Covering 125 distinct human populations around the world, geneticist Evan Eichler at the University of Washington in Seattle and an international team of colleagues studied the genomes of 236 people — analysing both SNVs and CNVs.

"The take-home message is that we continue to find a lot more genetic variation between humans than we appreciated previously," Eichler told *The Scientist*.



"This is a really exciting study of CNVs in worldwide human populations and has a much finer resolution than what had been done before," said Kirk Lohmueller, who studies human genetic variation at the University of California, Los Angeles, and was not involved in the work.

Classified as deletions or duplications, CNVs are genomic loci that can greatly vary in the number of copies, and are often located in regions of highly repetitive content, making them more difficult to sequence compared to SNVs. Thus far, the vast majority of human genome analyses — including from the Human Genome Project and the 1,000 Genomes Project —have focused on SNVs and CNV deletions; these studies largely overlooked CNV duplications because of technology limitations.

ANNA AZVOLINSKY/THE SCIENTIST