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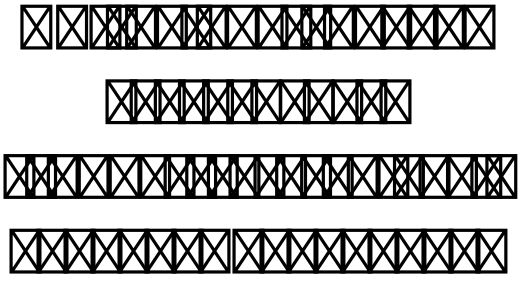


What does it take to keep a bicycle upright and moving, without crashing?

Humans have been riding bicycle-like machines for close to 200 years, beginning with the Draisine or "velocipede" in 1817.

While riding and balancing a bicycle can seem simple and effortless, the actual control process used by a human rider is still somewhat of a mystery. Using mathematical equations, researchers have explained how a bicycle without a rider can balance itself and have identified the bicycle design features critical for that to happen.

However, the stability – that is, the ability to remain balanced – of a bicycle with a rider is more difficult to quantify and describe mathematically, especially since rider ability can vary widely. My colleagues and I brought expert and novice riders into the lab to investigate whether they use different balancing techniques.

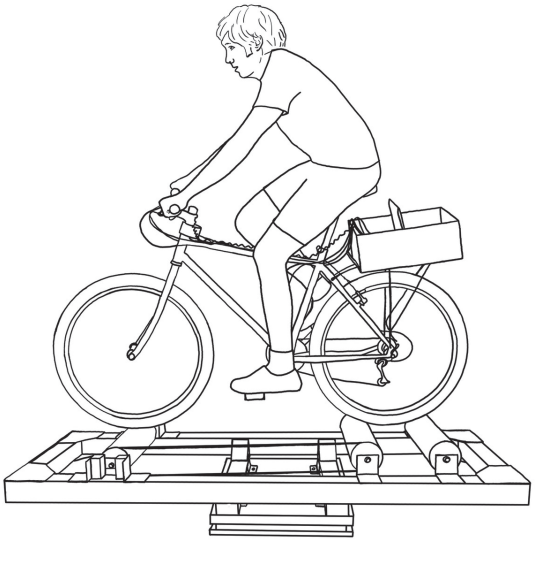
The physics of staying upright on a bicycle

A big part of balancing a bicycle has to do with controlling the center of mass of the rider-bicycle system. The center of mass is the point at which all the mass (person plus

bicycle) can be considered to be concentrated. During straight riding, the rider must always keep that center of mass over the wheels, or what's called the base of support – an imaginary polygon that connects the two tire contacts with the ground.

Bicycle riders can use two main balancing strategies: steering and body movement relative to the bike. Steering is critical for maintaining balance and allows the bicycle to move to bring the base of support back under the center of mass. Imagine balancing a broomstick on one hand – steering a bicycle is equivalent to the hand motions required to keep the broomstick balanced. Steering input can be provided by the rider directly via handlebars (steering torque) or through the self-stability of the bicycle, which arises because the steer and roll of a bicycle are coupled; a bicycle leaned to its side (roll) will cause a change in its steer angle.

Body movements relative to the bicycle – like leaning left and right – have a smaller effect than steering, but allow a rider to make balance corrections by shifting the center of mass side to side relative to the bicycle and base of support.



Steering is absolutely necessary to balance a bicycle, whereas body movements are not; there is no specific combination of the two to ensure balance. The basic strategy to balance a bicycle, as noted by Karl von Drais (inventor of the Draisine), is to steer into the undesired fall.

Newbies versus pros

While riders have been described using mathematical equations, the equations are not yet useful for understanding the differences between riders of different ability levels or for predicting the stability of a given rider on a given bicycle.

Therefore, the goal of my colleagues' and my recent work was to explore the types of control used by both novice and expert riders and to identify the differences between the two groups. In our study, expert riders identified themselves as skilled cyclists, went on regular training rides, belonged to a cycling club or team, competed several times per year, and had used rollers for training indoors. Novice riders knew how to ride a bicycle but did so only occasionally for recreation or transportation and did not identify themselves as experts.

Cain SM, Ashton-Miller JA, Perkins NC (2016) On the Skill of Balancing While Riding a Bicycle.CC BY

Cain SM, Ashton-Miller JA, Perkins NC (2016) On the Skill of Balancing While Riding a Bicycle.CC BY

We conducted our experiments in a motion capture laboratory, where the riders

rode a typical mountain bike on rollers. Rollers constrain the bicycle in the fore-aft direction but allow free lateral (left-right) movement. They require a bicycle rider to maintain balance by pedaling, steering and leaning, as one would outdoors.

We mounted sensors and used a motion capture system to measure the motion of the bicycle (speed, steering angle and rate, roll angle and rate) and the steering torque used by the rider. A force platform underneath the rollers allowed us to calculate the lateral position of the center of mass relative to the base of support; that let us determine how a rider was leaning.

We found that both novice and expert riders exhibit similar balance performance at slow speeds. But at higher speeds, expert riders achieve superior balance performance by employing smaller but more effective body movements and less steering. Regardless of speed, expert riders use smaller and less varying steering inputs and less body movement variation.

We conclude that expert riders are able to use body movements more effectively than novice riders, which results in reducing the demand for both large corrective steering and body movements.

Mysteries remain

Despite our work and that of others in the field, there is still much to be learned about how humans ride and balance bicycles. Most research, including ours, has been limited to straight line riding, which only makes up a fraction of a typical bicycle ride.

Our work reveals measurable differences between riders of different skill levels. But their meaning is unclear. Are the differences linked to a higher risk of crashing for the novice riders? Or do the differences simply reflect a different style of control that gets fine-tuned through hours and hours of training rides?

Ideally, we would like to identify the measurements that quantify the balance performance, control strategy and fall risk of a rider in the real world.

With such measurements, we could identify riders at high risk of falling, explore the extent to which bicycle design can reduce fall risk and increase balance performance, and develop the mathematical equations that describe riders of different skill levels.

Stephen Cain, Research Investigator in Department of Mechanical Engineering, University of Michigan

Did you know bicycles have been around for about 200 years? But these "people-powered" vehicles didn't always look the way they do today. Let's check out the history of the bicycle with its most significant dates and changes.

1817 - Barn Karl von Drais from Germany invented a "Running Machine." It had a bicycle-like frame and two wheels. However, instead of peddling this contraption, the person would do a glide-walk.

1860's - the "Boneshaker" was invented. It had an iron frame and wooden wheels. It also had pedals and cranks on the front wheel. It got its name from the shaky ride it provided.

1870's - this was the first model to be an official "bicycle." It had a big wheel on the front. This allowed the rider to go further with one pedal-push. In addition, it had rubber tires, which made it more comfortable to ride.

1885 - John Kemp Starely took the bicycle design and made it better. He added a chain to make pedalling easier and both tires were the same size.

1888 - inventor, John Boyd Dunlop took the hard rubber wheels and filled them with air. This made the ride less bumpy and easier to manoeuvre.

1920's - bicycle makers began to develop smaller versions for children to ride.

1940's - the kickstand was added to the bike frame.

1960's - the racing bicycle was introduced. It had lower handlebars, a lighter frame, narrow tires and different speeds.

1980's - the more rugged mountain bike became popular. These had knubby

tires, a durable frame and flat handlebars.

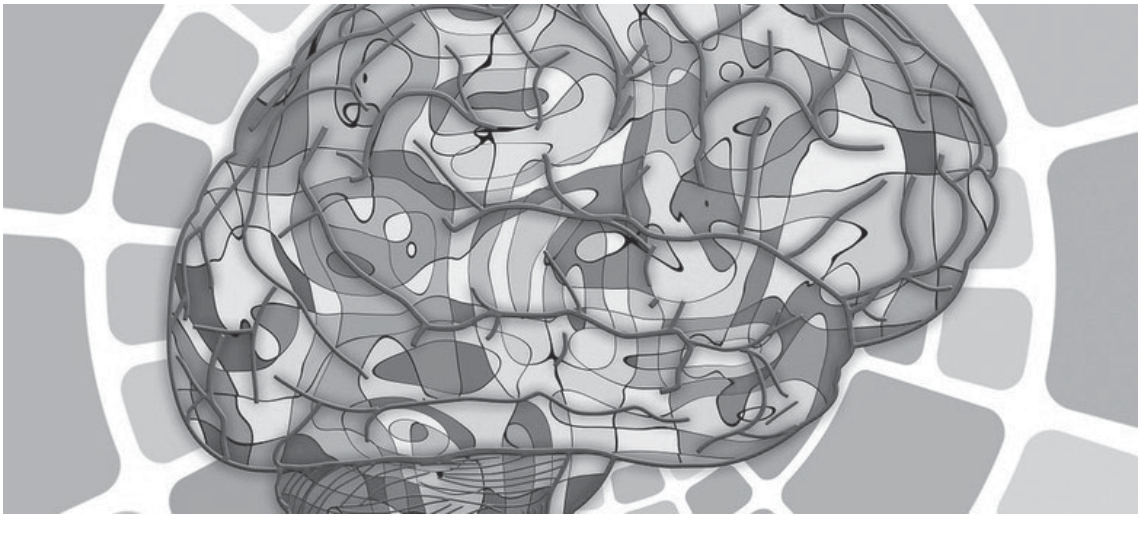
Today - bicycles come in a variety of styles. Big or small, bikes are here for all.

Ponder This: People in China depend on bicycles a lot. How many bikes are used in China today? Find out if you are right in More Freaky Facts.

Along with just about every other aspect of real or imagined differences between the sexes, the idea that your biological sex will determine the sex of your brain – and so your behaviour, aptitudes and personality – has a long and controversial history. The idea that a man's brain is "male" and a woman's brain "female" is rarely challenged.

The latest neuroscientific techniques employed to measure and map those brain structures and functions which might distinguish the two sexes are discussed in a recent special issue from the Royal Society examining the differences between male and female brains. But among the papers is one that directly questions the very concept upon which the others are broadly based, boldly stating that there is no such thing as a male or a female brain.

One of the authors, Daphna Joel, had previously published a study of structures and connections in over 1,400 brains from men and women aged between 13 and 85, in which no evidence was found of two distinct groups of brains that could be described as either typically male or typically



female. Brains were more typically unique "mosaics" of different features – something more correctly characterised as a single heterogeneous population.

Such a mosaic of features cannot be explained in purely biological terms; it is a measure of the effect of external factors. This is true even at the most fundamental level. For example, it can be shown that a "characteristically male" density of dendritic spines or branches of a nerve cell can be changed to the "female" form simply by the application of a mild external stress. Biological sex alone cannot explain brain differences; to do so requires an understanding of how, when and to what extent external events affect the structure of the brain.

Neuroplasticity

The notion that our brains are plastic or malleable and, crucially, remain so throughout our lives is one of the key breakthroughs of the last 40 years in our understanding of the brain. Different short- and long-term experiences will change the brain's structure. It has also been shown that social attitudes and expectations such as stereotypes can change how your brain processes information. Supposedly brain-based differences in behavioural characteristics and cognitive skills change across time, place and culture due to the different external factors experienced, such as access to education, financial independence, even diet.

The importance of this to the male/female brain debate is that, when comparing brains, it's necessary to know more than just the sex of their owners. What kind of brain-altering experiences have their owners been through? Even a path as mundane as school, university and a nine-to-five career will meld the brain in different ways to those with different experiences.

Clearly this is important when any kind of

brain differences are being measured and discussed, particularly when it is the influence of a biological variable (sex) on a social variable (gender) that is being studied. But it's surprising how infrequently this is incorporated into the design of studies, or acknowledged in how results are interpreted. Understanding how much the brains being examined are entangled with the worlds in which they exist must be part of any attempt to try and answer the question of what, if anything, separates male and female brains.

A new approach

Perhaps the mounting evidence that brains can't be neatly divided into sex-based groups will prompt a game-changing alteration in how we approach this issue.. What is really meant by a "sex difference"? Taken straightforwardly, one would assume a "difference" implies the two groups measured are distinct. That the characteristics true of one are almost always not true of the other, that it's possible to predict characteristics based on sex or vice versa, or that knowing to which group an individual belonged would allow you to reliably predict their performance, responses, abilities and potential. But we now know that this simply doesn't reflect reality.

On a wide range of psychological measures, it's clear that the two sexes are actually more similar than different, despite oft-repeated stereotypes or anecdotal assertions. In parallel with the findings that brains are a mosaic of features, repeat analyses of more than 100 different behavioural and personality traits believed to be characteristic of one sex or the other have demonstrated that they don't fall into two distinct groups, but are best allocated to a single group. The researcher's conclusion, delivered with a wry smile, can only be that men are not from Mars nor are women from Venus: we are all from Earth.

The whole issue of male/female differences in the brain and the implications for male/female differences in any sphere – normal or abnormal behaviour, ability, aptitude or achievement – is really important to clarify. In the US, the National Institutes of Health recently mandated that, where appropriate, sex of the test subjects should be a variable in any research it funds. It's time to move on from the simplistic dichotomy of looking for what makes male and female brains different, and instead approach the issue through the probably more meaningful and potentially revelatory question: what makes brains different?

Gina Rippon, Professor of Cognitive NeuroImaging, Aston University

K.Sampath,
Scientist (Retd.), DRDO

This story describes about the birth of new hypothesis and experimental science, fall of old thought, testing deductions, openings for new field of exploration and new techniques.

Characters of this story: **Galileo 1564 – 1642, Artisans, Learned men, Evangelista Torricelli 1608 – 1647, Blaise Pascal 1623 – 1662, Perier – Pascal's Brother-in-Law, Otto Von Guericke 1602 – 1686, Robert Boyle 1627 – 1692, Thomas Hobbes (1588-1679), Franciscus Linus 1595–1675), Denis Papin (1647-1712) and others.**

For centuries, people have been aware of the fact that to drain a liquid out of a barrel there should be an opening neighborhood of the bottom and one at the top. Out of the lower opening comes the liquid, air goes into the upper one.

Likewise, we can suck up the water in a tube, close the top opening with finger, the water will not run out until the finger is removed; this is the principle of the pipette. Similar observations have been discussed even before the time of **Aristotle.**

Now we do understand the role of atmospheric pressure in these two cases. But from the period of **Aristotle** to the **Middle Ages**, the reason assigned to this phenomenon was in terms of a FULL UNIVERSE - the assumption that the nature abhors vacuum and air has to enter to move the liquid and the vacuum should not be there. The same principle was invoked to explain to suck up water into a tube or to lift water in a suction pump.

However, this explanation seems to have satisfied the philosophers for generations. **Galileo** in 1638 wrote more or less, that the suction pump could not raise water more than a certain height. His explanation was based on a **poor analogy** between breaking of a column of water and the breaking of a long wire. **It is worth noting that even scientist Galileo missed the opportunity to make still another great contribution to the advance of science. It is not uncommon even the great people sometimes fail to grasp the nature.**

Yes, a suction pump cannot raise water beyond 34 feet; this phenomenon was brought to the attention of Galileo by a workman. It is astonishing, that the limit of the ability of a pump to raise water has not been discussed or found earlier than that in Galileo's treatment. Those who thought about the subject attributed this to mechanical imperfections; indeed the system of plungers and valves was very crude as the technology was also not well developed.

People operated mines and pumps, and also smelted ores; they were improving the

practical arts by endless cut-and-try experimentations. **There was no occasion or meeting point to discuss and apparently a gulf separated artisans and learned men for centuries.**

No doubt there was such a vast gulf even in our country, because of lack of means of fast communication and also people wanted to keep the art as secrets to themselves. Everyone had to re-invent the wheel. Progress of science can take place only by exchanging, communicating and interacting, disseminating the ideas and experimental facts and not by keeping the knowledge as secret.

James .B. Conant says that "There were the professors and the learned men at princely courts who developed mathematics, deductive reasoning, and the embryo science of mechanics. Experimental science began when these two streams of human activity converged". And also, he said Experimental Science "can be thought of as an activity which increases the adequacy of the hypothesis and theory that are related to certain types of perception and which lead to certain types of activities. It is one extension of common sense".

Concepts are developed by observation, thinking and experimenting, arranging, correlating, imagining and analyzing data of the phenomenon. One can reason out the phenomena by ordering the events and relations logically.

Alas! Galileo missed the boat; but his pupil Torricelli found it! Torricelli laid down in 1644, some general but precise ideas, about the atmosphere and atmospheric pressure. At some date he wrote that the reason for the limit of about 34 feet beyond which water would not arise in suction pump might be a measure of the atmospheric pressure. He said that if the earth were surrounded by a " sea of air " and if air had weight, there would be an air pressure on all objects submerged in this sea of air exactly as there is water pressure below the surface of the ocean or lake or pond. Then a deduction followed from this hypothesis with the experimental confirmation**. Here an appropriate analogy helped him in the formulation of his new hypothesis.**

Deduction

A column of water of 34 feet high is sustained by the presence of the atmospheric pressure; then he thought and employed mercury, which is fourteen times as heavy as water, should be held up only 34/14 or 2 3/7 feet; he created a tube approximately one meter long, sealed at the

The Torricellian Experiment

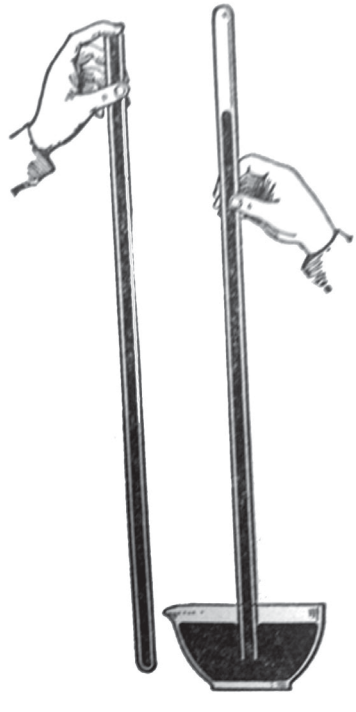
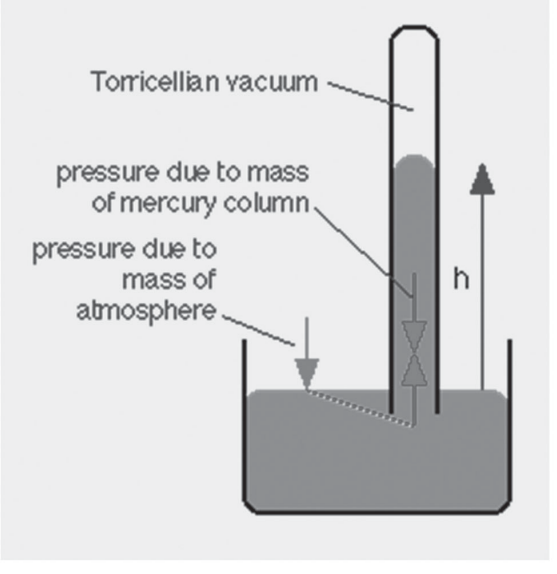
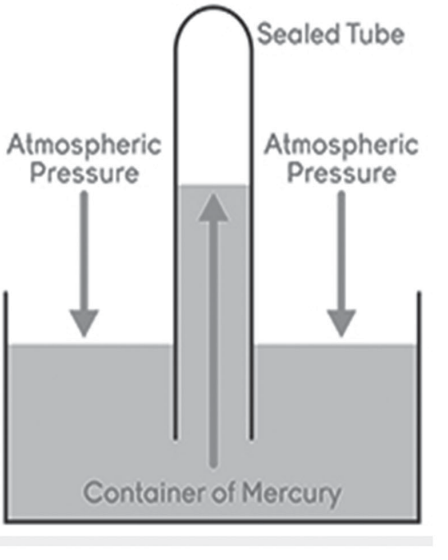


Fig 1

top, filled it with mercury, and set it vertically into a basin of mercury. The column of mercury fell to about 76 cm, leaving Torricellin vacuum above. This is something which can be tested and it was. **Torricelli performed this classic experiment somewhere around 1640.** The discovery of the principle of the barometer has brought him fame ("Torricellian tube", Torricellian vacuum"). The torr, a unit of pressure used in vacuum measurements, is named after him.

Fig 2





Thus **Torricelli** invented a new instrument, tested the validity of one deduction from his hypothesis and also produced vacuum and disproved the Aristotelian concept that nature abhors vacuum.

Extension of atmospheric pressure and its confirmation

Blaise Pascal and his contemporaries knew the phenomena connected with water pressure. The pressure below the surface of the water in a reservoir depends on the depth. A creature like fish rising from the bottom of ocean towards the surface will be fleeing regularly diminishing pressure. Pascal felt the same phenomenon should be observed in the atmosphere. Torricelli barometer to measure the pressure was available.

The second deduction by Pascal thus is "if the earth is surrounded by a sea of air and if air has weight, the pressure of the air will be less on the top of a mountain than at the foot". (Birth of Pascal's law- sea of air, exerts press equally on all sides) It was to be determined using the Torrecellian column as the measure of the atmospheric pressure. Performing the experiment on the top of the Puy-de-dome and at the foot, the observed height will be less in the first instance than in the second, only when no other factors have influenced the pressure in the mean time or the height of mercury column.

Blaise Pascal's brother-in law **Perier** carried out the experiment and he took every precaution not to have any other variable

enter into his experiment.

He further reported that the repetition of the experiment on the top, gave the same result at different points on the summit, some sheltered, some in the open and one carried out when cloud carrying rain drifted over the summit. An observer stationed at the bottom has been meanwhile watching one tube during the entire time; he had found that the mercury level remained unchanged.

Otto Von Guericke (inventor of vacuum pump) constructed a water barometer and built the first machine for pumping air out of a container. He could get his results only when he started to pump air as well as water from an enclosed container and finally achieved pumping out air alone. **He also realised that a spherical metal container was necessary to stand the resulting atmospheric pressure.**

Guericke demonstrated the force of air pressure with historic experiments. He had joined two copper hemispheres of 51 cm diameter (Magdeburg hemispheres)) and pumped the air out of the enclosure. Then he engaged a team of eight horses onto each hemisphere and showed that they were not able to separate the hemispheres. When air was again let into the enclosure, they were easily separated. Thus Guericke disproved the hypothesis that nature abhors vacuum.

Other research

Guericke applied the barometer to weather prediction and thus prepared the way for meteorology. He invented the first electrostatic generator.

After hearing the new pump and method of producing vacuum, **Boyle** saw the possibility of testing still another deduction from the Torrecellian conceptual scheme. James .B. Conant says that Boyle's combination of logic & imagination represents a pattern repeated by many successful investigators in the last 350 years.

Some philosophers had an imagination to see that a new instrument made possible the testing of an important point; further they could see such new instruments were also instrumental for research in new areas.

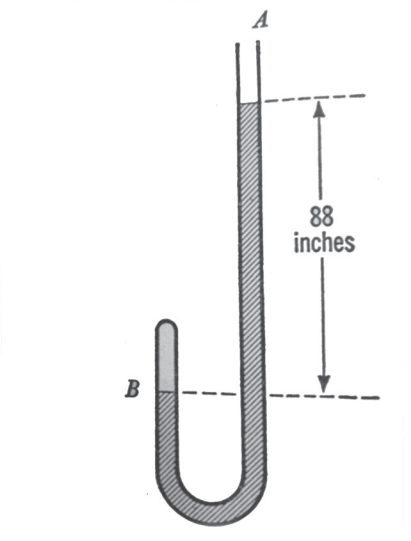
Boyle modified Von Guericke's pump so that he could introduce the lower part of the Torrecellian barometer into the vessel to be evacuated. Then, as he worked the pump and withdrew the air from above the mercury reservoir, the mercury column fell. He was able to evacuate the reservoir to a pressure of something less than one-thirtieth of the original pressure. When air was admitted into the receiver the mercury column rose to the usual height.

Von Guericke's pump, the several models of Boyle's "Pneumatical engine"and Torricelli's barometer showed how fundamental new devices are opening new fields for experimentation. Experimental observations alone are not sufficient to be called as an advance in science. There is a chain of arguments or reasoning which is an essential element that **links or connects** the experimental data to a broad idea.

Whenever a new idea is proposed, that is always received with an opposition accompanied by doubts and is not easily accepted by the peers. Some accepted that the space at the top of the tube was empty, while others felt that it was occupied by something that had filtered through the mercury or glass or that it contained a vapor drawn out of the metal itself.

The fact emerged is, that vacuum indeed can be produced. But there were some philosophers who still believed that the nature

abhors vacuum. Thomas Hobbes and Franciscus Linus were belonging to this category. Linus said that an invisible membrane holds the mercury column in the Torrecellin tube; he named this membrane as Funiculus.



Franciscus Linus said that the funiculus could not sustain a column of mercury more than 29.5 inches high to account for constant height of the barometer at sea level. Boyle immediately built a" J" tube with one short and one long leg. He filled it with mercury to make the difference in levels about 88 inches. Boyle then sucked with his mouth on the opening and the mercury in the tube rose considerably and showed that the Franciscus Linus hypothesis of invisible membrane is false!

There were numerous other such instances.

Boyle's important experiment with his Air pump was the transmission of sound in a vacuum.

Boyle's exploration with new Techniques

Boyle demonstrated the fact that a candle would not burn in vacuum; but gun powder would.

By rotating two surfaces against each other in an evacuated vessel and quickly admitting air Boyle found that the objects to be warm. He concluded that, in the absence of air, generation of heat by friction would take place.

Boyle also showed that using the diminished pressure a liquid can be distilled at temperature much below its normal boiling point. Only in 19th century distillation in vacuum came into existence. The chemists started adopting this procedure regularly.

The concept of vacuum and its application is important for instruments such as x-ray tubes, radio tubes, cyclotrons and for complicated physical and chemical equipments. These are possible because of the art of producing good vacuum conditions.

Foundation of modern vacuum technology was laid at the start of the 20th century. The vacuum technologies play significant role in the development of groundbreaking innovations and as well as the production of products of everyday use such as microchip production, the coating of CDs, DVDs and the development of laser technology etc.

Vacuum technologies also play an important role in the frontier of R&D related to fundamental research space, nanotechnology and high energy physics. Over and above without vacuum technology there is no Large Hadron Collider (LHC).

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Tokomak Energy aims to build mini-nuclear reactors and announces target of producing electricity by 2025 and feeding power into the grid by 2030

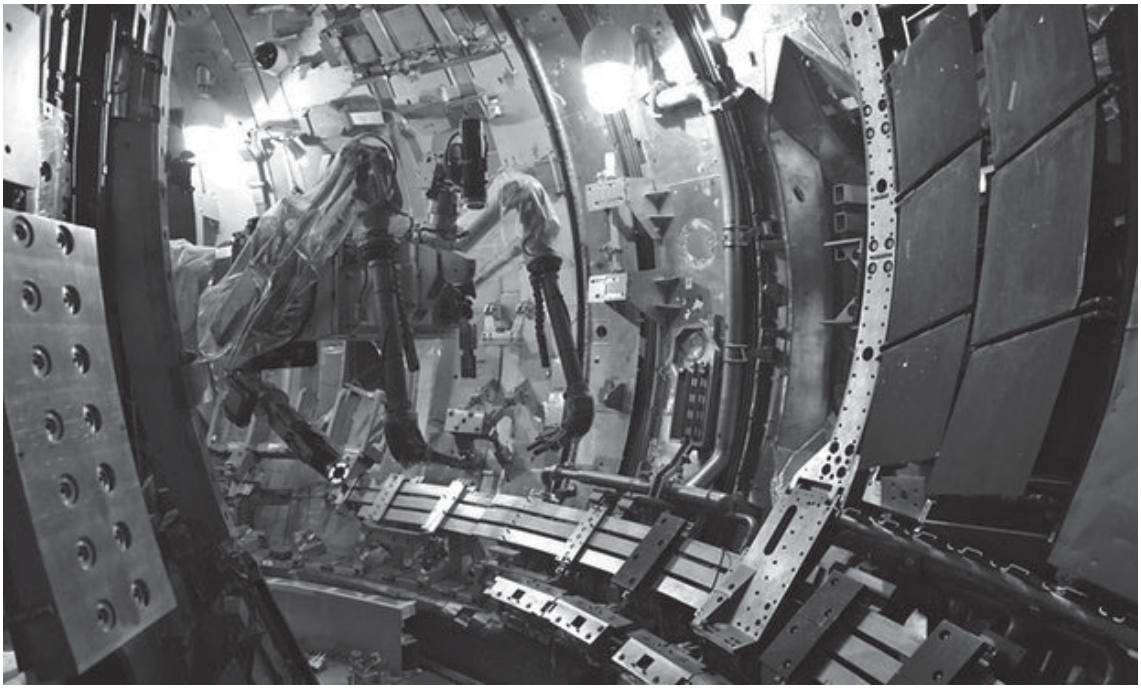
Nuclear fusion reactor simulator

Nuclear fusion involves two atomic nuclei joining to make a large nucleus. Energy is released when this happens. A fusion reactor simulator, like the one above at Culham Centre for Fusion Energy, Abingdon, Oxfordshire, helps to study fusion in conditions approaching those needed for a power plant. Photograph: Haydn Denman/ Alamy

Nuclear fusion needs a "Wright brothers" moment, to convince the world of its promise of unlimited clean and safe energy and so unlock significant private investment, according to a physicist whose says his company is closing in on that goal.

David Kingham, the chief executive of Tokamak Energy, has announced his company's target of producing its first electricity by 2025 and feeding power into the grid by 2030, as well as investment from the UK's Institution of Mechanical Engineers.

Harnessing the nuclear energy which powers the sun has long been touted as the ultimate solution to the challenge of powering the world while halting climate change. But, as fusion sceptics often say, the reality has stubbornly remained a



decade or two away for many years.

"If we make exciting progress relatively quickly, with relatively modest funding then we'll get to a Wright brothers' moment in fusion and suddenly people will realise it is going to be possible," said Kingham, whose company is a spin off from the UK's national fusion lab at Culham near Oxford.

"That will unlock lots of investment around the world to solve some of the big challenges, like the lifetime of materials, that you don't need to worry about at the moment but you do need to worry about if you are going into mass production."

The company is up against North America-based companies backed by Amazon's Jeff Bezos and Paul Allen, Microsoft's co-founder, in the race to make a breakthrough.

Tokamak Energy's aim is to develop a nuclear fusion device just a few metres wide which uses high-temperature superconductors to create the magnetic field to contain the fusion plasma, with small reactors mass produced later. In November, the UK government announced £250m in funding for small modular reactors, most of which currently focus on conventional nuclear fission.

Plasmas are well understood, meaning that containing the ultra-hot gas is the major obstacle. "It is essentially an engineering and technical challenge now," said Kingham. Copper magnets and regular superconductors, which operate at near absolute zero, require too much energy. So Tokamak Energy is using high-temperature superconductors, though these still operate at -200C.

The plasma needed for fusion energy reaches an extraordinary temperature: 100mC, hotter than the core of the sun. But Tokamak Energy's third prototype, currently under construction, aims to reach 15mC in the next 12 months and 100mC by the end of 2017.

The company is the world's only private venture developing tokamaks, a Russian acronym for "toroidal chamber magnetic field". Being private keeps the focus on the engineering, Kingham said, whereas the £1bn-a-year public programmes often focus on the science.

The biggest fusion project in the world is ITER, a collaboration of 35 nations aiming to build a huge fusion reactor in southern France, with magnets weighing about the same as a Boeing 747. It should complete construction in 15-20 years, and deliver 500MW of power, about the same as today's large fission reactors. But it has been hampered by delays.

Tokamak Energy is far from alone in backing small fusion reactors, with rivals including Lockheed Martin's famous Skunk Works team, who in 2014 said they would produce a truck-sized fusion plant in a decade but attracted criticism for providing few details.

Others in the field include Tri Alpha Energy, which harnesses particle accelerator technology and is backed by Allen, General Fusion, which uses a vortex of molten lead and lithium to contain the plasma and is backed by Bezos, as well as Helion Energy, First Light Fusion and the University of Washington's Dynomak.

"To a certain extent, we can learn from them and they can learn from us," said Kingham. But he argues that the spheroidal

Nuclear fusion

In physics, nuclear fusion (a thermonuclear reaction) is a process in which two nuclei join to form a larger nucleus, thereby giving off energy. Nuclear fusion is the energy source which causes stars to "shine", and hydrogen bombs to explode.

Any two nuclei can be forced to fuse with enough energy. When lighter nuclei fuse, the resulting nucleon has too many neutrons to be stable, and the neutron is ejected with high energy. Most lighter nuclei will return more energy that it requires to cause them to fuse, making the reaction exothermic, generating net power.

The opposite case, heavy nuclei with too few neutrons, is also unstable and leads to nuclear fission. Unlike fusion however, fission reactions require so little extra energy for very heavy nuclei that they occur all the time on their own. This is not the case with fusion, where the lowest mass nucleon, hydrogen, still requires considerable energy to fuse.

The total energy contained in a nucleus, the so-called binding energy, is considerably greater than the energy that binds the electrons to the nucleus. Thus the energy released in most nuclear reactions is much larger than that for chemical reaction. For example, the ionization energy gained by adding an electron to hydrogen is 13.6 eV. Compare that to the energy being released in the D-T reaction shown to the right, which at 17 MeV is over 1,000,000 times greater.

magnetic tokamak his company is developing, based on work at the Culham lab, is closer to the scientific mainstream. “We are dealing with known unknowns, but perhaps others are dealing with unknown unknowns,” he said.

Tokamak Energy has convinced a range of bodies to back them with £15m of funding, including Oxford Instruments, the company that pioneered MRI scanning, and the state-backed Innovate UK. The company was also named a technology pioneer by the World Economic Forum in 2015, allowing them to forge links with major energy companies, while a paper by the company in Fusion Energy on small fusion reactors is the journal’s most downloaded paper.

The latest investor is the Institution of Mechanical Engineers. Dr Jenifer Baxter, head of energy and environment at the institution, said: “The institution’s Stephenson Fund was inspired by the original statement of purpose of the Institution, set out by founder George Stephenson in 1847, to ‘give an impulse to invention likely to be useful to the world’.”

“Small-scale nuclear fusion could revolutionise our future and is exactly the sort of technology Stephenson was referring to,” said Baxter. “If successful, the work of Tokamak Energy, could be the cornerstone technology to enabling sustainable economic growth in a world facing the twin challenges of climate change and growing world population.”

International team of astronomers witness the elusive shock breakout after sifting through three years of data collected by Nasa's Kepler space telescope

The final violent death throes of a star has been seen with visible light for the first time and provided a fresh mystery for astronomers.

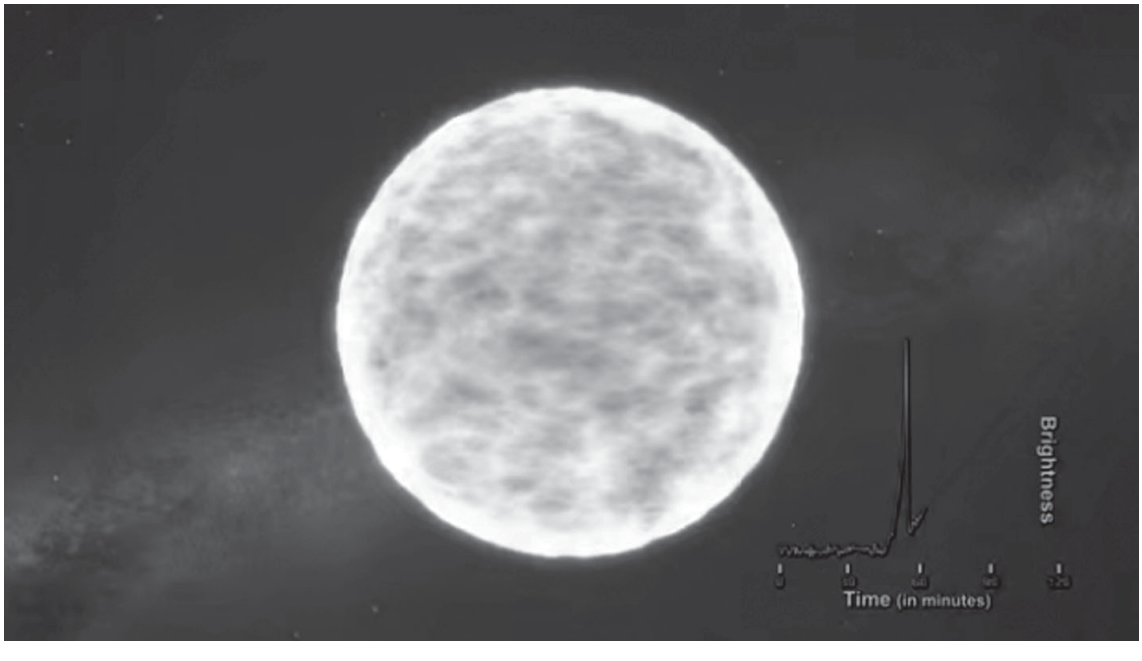
Scientists think shock breakouts – a shockwave and flash of light that rocks a massive star just before it explodes into a "supernova" – allow the stars to finally explode, spewing out all the heavy atoms that exist in the universe.

But actually watching that process occur and seeing how it progresses has proved elusive, leaving scientists guessing about exactly how it happens.

By sifting through three years of data collected by Nasa's now half-broken Kepler space telescope, an international team of scientists have now seen the elusive shock breakout occur. The problem is, it seemed to happen in only one of two exploding stars observed.

In data collected in 2011, they found two supernovae begin, potentially capturing the crucial moment. However only one star seemed to have the shockwave. An author on the paper, Brad Tucker from the Australian National University, said that was a mystery. He said the shockwave was thought to ripple across the surface and actually allow the supernova to explode.

"We've always thought that this is the physical mechanism that allows the star to blow up," he said. "So gravity collapses the



core down, and once the pressure is too much, you create a neutron star or sometimes a black hole, the rest of the energy rebounds and causes the star to blow up.

"It's been this fundamental thing that we've always thought occurs but we've never seen it take place."

Tucker said it had been seen by chance with x-ray telescopes before, but not in great detail.

The fact one of the supernova they saw with Kepler had the shock breakout and one didn't, means there's something to learn, he said.

Since the one where they didn't see the shockwave was a bigger star – about 500 times the size of Earth's sun – it could mean it wasn't strong enough to escape the star's gravity. "It could mean that the shockwave happened but it didn't have enough oomph to get out," he said.

Tucker said it was also possible that something like dust was blocking the view of the shockwave or, because it was further away (2,000 times further than the smaller one), it was just fainter and they missed it.

"It's telling us something but we just don't know what it is," he said.

"That is the puzzle of these results," said Peter Garnavich, an astrophysics professor at the University of Notre Dame in Indiana. "You look at two supernovae and see two different things. That's maximum diversity."

The shock breakout itself lasted only about 20 minutes, so catching the flash of energy was a milestone for astronomers, where things usually happen on the timescale of years, centuries or millennia.

"In order to see something that happens on timescales of minutes, like a shock breakout, you want to have a camera continuously monitoring the sky," said Garnavich. "You don't know when a supernova is going to go off, and Kepler's vigilance allowed us to be a witness as the explosion began."

Tucker said that as they push through more data from the Kepler missions, they will almost certainly see more of these events. He said from 500 galaxies they watched in the original Kepler mission, they found six supernovae, including these two. Kepler's second mission – called K2 – aims to watch 5,000 galaxies, so should increase the odds, he said.

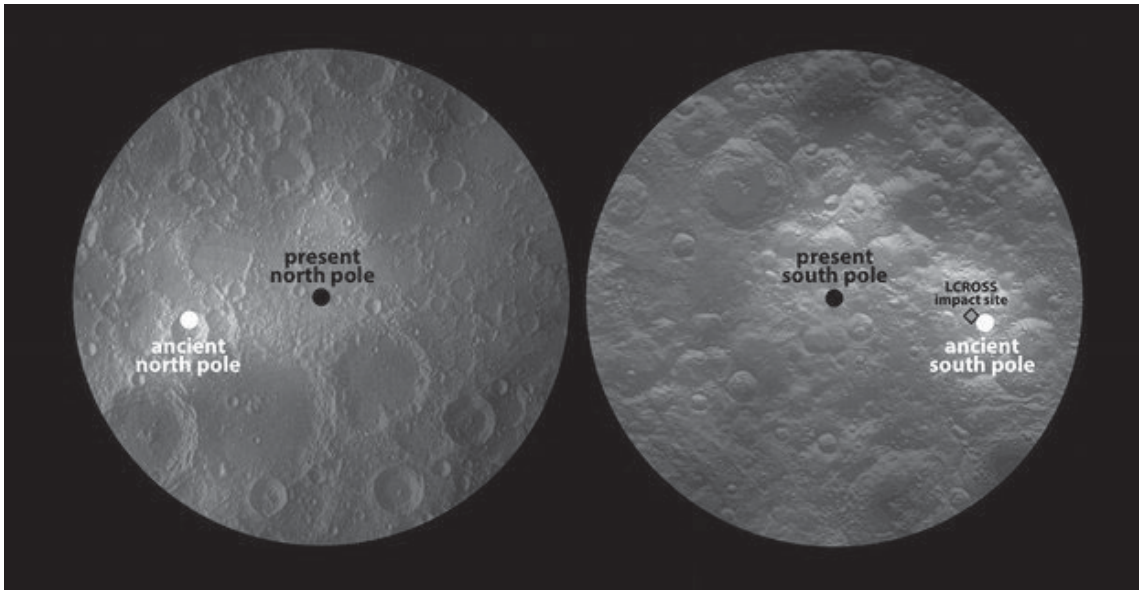
"While Kepler cracked the door open on observing the development of these spectacular events, K2 will push it wide open observing dozens more supernovae," said Tom Barclay, director of the Kepler mission at Nasa Ames. "These results are a tantalising preamble to what's to come from K2."

Steve Howell, project scientist for Nasa's Kepler and K2 missions, said: "All heavy elements in the universe come from supernova explosions. For example, all the silver, nickel and copper in the earth and even in our bodies came from the explosive death throes of stars. Life exists because of supernovae."

That's not quite as poetic as the way US astronomer Carl Sagan famously put it:

The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff.

The findings have been accepted for publication in the Astrophysical Journal.



The unexpected locations of the ice patches on the moon's surface has led scientists to believe that the moon may once have spun on a different axis

Huge volcanic activity over three billion years ago appears to have altered the tilt of the Moon, according to new research.

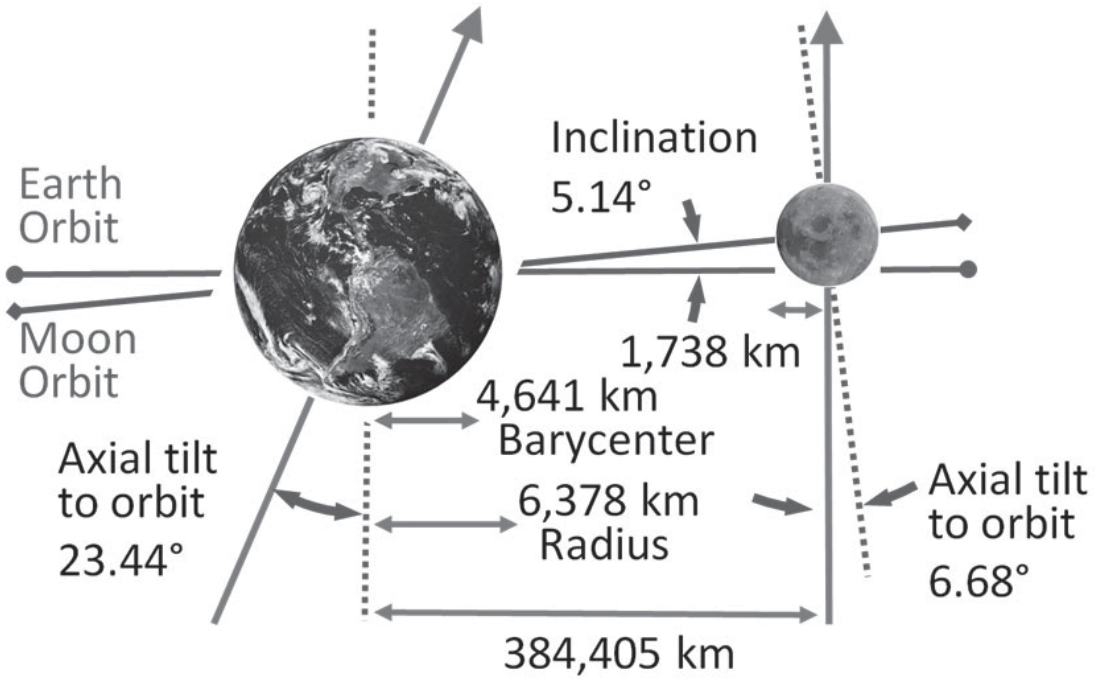
Scientists concluded that the celestial body may have once spun on a different axis after studying its north and south poles, and finding that lunar ice was deposited in unexpected locations.

"The discovery of ice on the poles of the moon was probably one of the most significant discoveries in lunar science ever," says Dr Ian Garrick-Bethell from the University of California, who was not involved in the study. "This goes one step further."

The researchers concluded that the moon's axis of rotation is now 5.5 degrees different from what it once was as a result of volcanic activity, which stemmed from a region of hot rock lurking deep beneath its surface.

Orbiting the Earth at an average distance of 385,000km, the moon boasts some of the coldest spots in the solar system, with temperatures at its poles reaching below -240 C.

The revelation came after a US and Japanese research team took a fresh look at data collected by the Lunar Prospector neutron spectrometer in the late 1990s. Such data had previously been used to map the presence of hydrogen deposits on the lunar surface and, because water is rich in hydrogen, had led scientists to conclude that



they were made of ice.

But scientists had been puzzled by that fact that deposits of hydrogen didn't tally with what would be expected from current lunar temperatures.

The latest research suggests two of these deposits are not only offset from the moon's current axis by around 5.5degrees each, but are diametrically opposite to each other. That, the authors of the new study conclude, suggests that these deposits mark "palaeopoles" - former north and south poles where ice formed billions of years ago.

This change in lunar tilt, the researchers suggest, could have been triggered by change in volcanic activity more than 3.5 billion years ago - a period when a region on the near-side of the moon known as the PKT erupted with the lava flows that formed the large, dark expanses of basalt visible from Earth.

As the mantle deep within the moon heated up, it expanded and decreased in density. According to models created by the authors of the new study, that could have been enough to change the moon's tilt. "It is like taking a football and removing a chunk out of one side - that would change how the football would spin in the air," said James Keane, one of the researchers from the University of Arizona.

As the volcanic activity dwindled, the moon was eventually left with its current tilt of 1.54degrees. "The moon cools very, very slowly so even though there is not enough heat to cause volcanism today there is still excess heat in the region," said Keane. "Presumably if the moon had an infinite amount of time to cool off we would predict it would go back to that original pole."

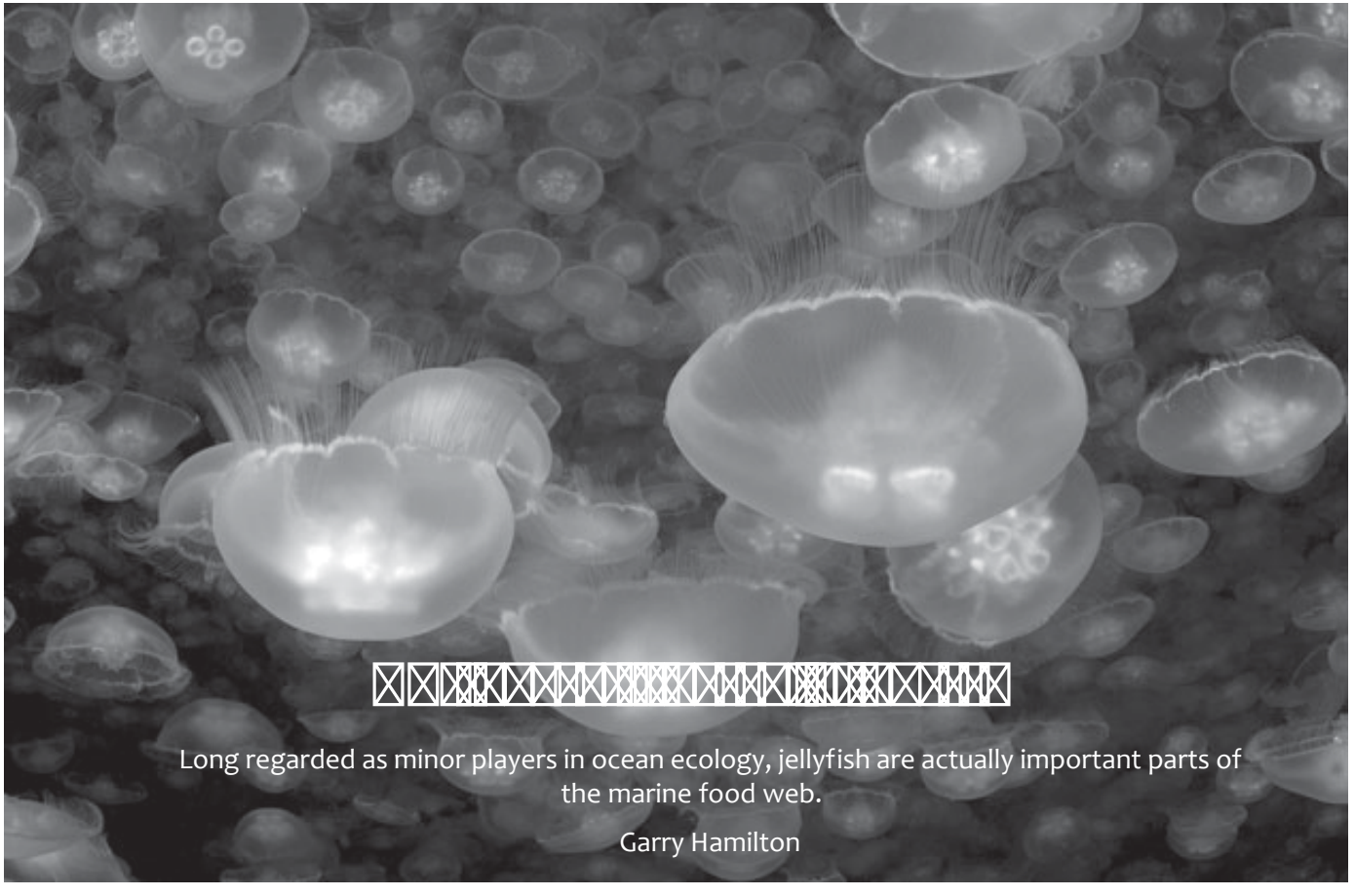
Published in the journal Nature, the research offers fresh insights into the moon's

turbulent past, but it also heralds a new set of questions. As Garrick-Bethell points out, the Lunar Prospector data can only tell scientists about the presence of hydrogen. "We don't know the physical nature of that hydrogen deposit," he said. "We think it is ice - we don't have any idea what kind." What's more, the hydrogen deposits could have caught the sun's rays, while impacts from asteroids might have been expected to have eroded the ice. "There's a whole bunch of mysteries there," said Garrick-Bethell. "Are these ice deposits really billions of years old? How could they have survived that long? It's amazing."

Another puzzle lies in the fact that the scientists found two distinct palaeopoles, rather than a continuous path that might have been expected from a gradual change in the tilt of the moon.

Professor Ian Crawford, a planetary scientist from Birkbeck University, said the study was "persuasive". But he believes that to confirm the theory scientists should embark on developing a new series of instruments to probe the surface of the moon. "I think there is a very strong case for soft landing one or more spacecraft in these localities and drilling to depths of a few metres to confirm the presence of subsurface ice," he said, adding that understanding ice deposits on the moon could prove a valuable resource in future space explorations.

Keane also believes the palaeopoles could yield further insights. "It might be a primordial sample of water ice, which we don't have on the Earth," he said. That, he believes could offer scientists a chance to crack an abiding conundrum: where the Earth's water came from. "This might be a place right in our backyard where we could go and sample that water and try to answer those questions," he said.



Long regarded as minor players in ocean ecology, jellyfish are actually important parts of the marine food web.

Garry Hamilton

Jennifer Purcell watches intently as the boom of the research ship Skookum slowly eases a 3-metre-long plankton net out of Puget Sound near Olympia, Washington. The marine biologist sports a rain suit, which seems odd for a sunny day in August until the bottom of the net is manoeuvred in her direction, its mesh straining from a load of moon jellyfish (Aurelia aurita). Slime drips from the bulging net, and long tentacles dangle like a scene from an alien horror film. But it does not bother Purcell, a researcher at Western Washington University's marine centre in Anacortes. Pushing up her sleeves, she plunges in her hands and begins to count and measure the messy haul with an assuredness borne from nearly 40 years studying these animals.

Biology on the high seas

Most marine scientists do not share her enthusiasm for the creatures. Purcell has spent much of her career locked in a battle to find funding and to convince ocean researchers that jellyfish deserve attention. But she hasn't had much luck. One problem is the challenges that come with trying to study organisms that are more than 95% water and get ripped apart in the nets typically used to collect other marine animals. On top of that, outside the small community of jellyfish researchers, many biologists regard the creatures as a dead end in the food web — sacs of salty water that provide almost no nutrients for predators except specialized ones such as leatherback sea turtles (Dermochelys coriacea), which are adapted to consume jellies in large quantities.

"It's been very, very hard to convince fisheries scientists that jellies are important," says Purcell.

But that's starting to change. Among the crew today are two fish biologists from the US National Oceanic and Atmospheric Administration (NOAA) whose research had previously focused on the region's rich salmon stocks. A few years ago, they discovered that salmon prey such as herring and smelt tend to congregate in different areas of the sound from jellyfish1 and they are now trying to understand the ecological factors at work and how they might be affecting stocks of valuable fish species. But first, the researchers need to know how many jellyfish are out there. For this, the team is taking a multipronged approach. They use a seaplane to record the number and location of jellyfish aggregations, or 'smacks', scattered about the sound. And on the research ship, a plankton net has been fitted with an underwater camera to reveal how deep the smacks reach.

Scientists with the National Oceanic and Atmospheric Administration use a plane to survey swarms of moon jellyfish, which show up as curvy white streaks in an arm of Puget Sound, Washington.

Correigh Greene, one of the NOAA scientists on board, says that if salmon populations are affected in some way by jellyfish, "then we need to be tracking them".

From the fjords of Norway to the vast open ocean waters of the South Pacific, researchers are taking advantage of new tools and growing concern about marine health to probe more deeply into the roles that jellyfish and other soft-bodied creatures have in the oceans. Initially this was driven by reports of unusually large jellyfish blooms wreaking havoc in Asia, Europe and elsewhere, which triggered fears that jellyfish were taking over the oceans. But mounting evidence is starting to convince some marine ecologists that gelatinous organisms are not as irrelevant as previously presumed.

Fisheries: Eyes on the ocean

Some studies show that the animals are important consumers of everything from microscopic zooplankton to small fish, others suggest that jellies have value as prey for a wide range of species, including penguins, lobsters and bluefin tuna. There's also evidence that they might enhance the flow of nutrients and energy between the species that live in the sunlit surface waters and those in the impoverished darkness below.

"We're all busy looking up at the top of the food chain," says Andrew Jeffs, a marine biologist at the University of Auckland in New Zealand. "But it's the stuff that fills the bucket and looks like jelly snot that is actually really important in terms of the planet and the way food chains operate."

A mass of mush

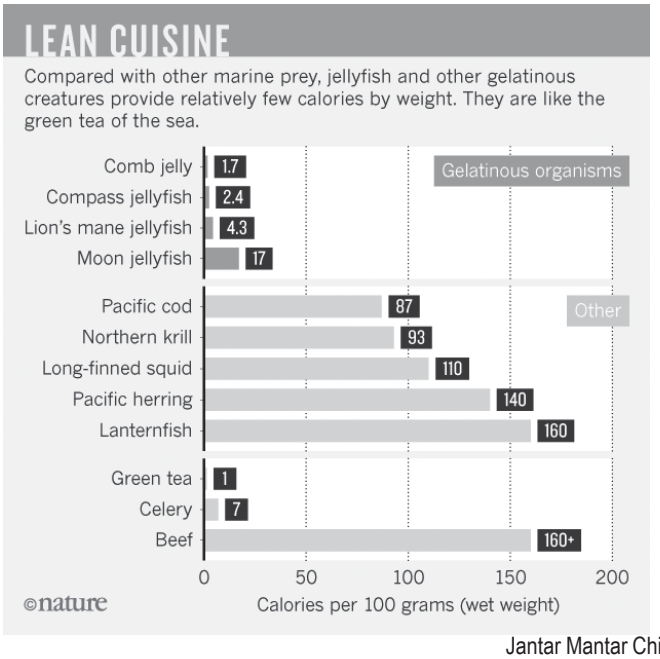
The animals in question are descendants of some of Earth's oldest multicellular life forms. The earliest known jellyfish fossil dates to more than 550 million years ago, but some researchers estimate that they may have been around for 700 million years, appearing long before fish.

They're also surprisingly diverse. Some are tiny filter feeders that can prey on the zooplankton that few other animals can exploit. Others are giant predators with bells up to two metres in diameter and tentacles long enough to wrap around a school bus — three times. Jellyfish belong to the phylum

Cnidaria and have stinging cells that are potent enough in some species to kill a human. Some researchers use the term jellyfish, or 'jellies' for short, to refer to all of the squishy forms in the ocean. But others prefer the designation of 'gelatinous zooplankton' because it reflects the amazing diversity among these animals that sit in many different phyla: some species are closer on the tree of life to humans than they are to other jellies. Either way, the common classification exists mainly for one dominant shared feature — a body plan that is based largely on water.

Why a jellyfish is the ocean's most efficient swimmer

This structure can make gelatinous organisms hard to see. Many are also inaccessible, living far out at sea or deep below the light zone. They often live in scattered aggregations that are prone to dramatic population swings, making them difficult to census. Lacking hard parts, they're extremely fragile.



"It's hard to find jellyfish in the guts of predators," says Purcell. "They're digested very fast and they turn to mush soon after they're eaten."

Sources: J. Spitz et al. J. Mar. Sci. 67, 909–915 (2010); T. K. Doyle et al. J. Exp. Mar. Biol. Ecol. 343, 239–252 (2007)

For most marine biologists, running into a mass of jellyfish is nothing but trouble because their collection nets get choked with slime. "It's not just that we overlooked them," says Jonathan Houghton at Queen's University Belfast, UK. "We actively avoided them."

But over the past decade and a half, jellyfish have become increasingly difficult to ignore. Enormous blooms along the Mediterranean coast, a frequent summer occurrence since 2003, have forced beaches to close and left thousands of bathers nursing painful stings. In 2007, venomous jellyfish drifted into a salmon farm in Northern Ireland, killing its entire stock of 100,000 fish. On several occasions, nuclear power plants have temporarily shut down operations owing to jelly-clogged intake pipes.

Jellies on the rampage

Ocean 'calamities' oversold, say researchers

The news spurred scientists to take a closer look at the creatures. Marine biologist Luis Cardona at the University of Barcelona in Spain had been studying mostly sea turtles and sea lions. But around 2006, he shifted some of his attention to jellyfish after large summer blooms of mauve stingers (Pelagia noctiluca) had become a recurring problem for

Spain's beach-goers. Cardona was particularly concerned by speculation that the jellyfish were on the rampage because overfishing had reduced the number of predators. “That idea didn't have very good scientific support,” he says. “But it was what people and politicians were basing their decisions on, so I decided to look into it.”

For this he turned to stable-isotope analysis, a technique that uses the chemical fingerprint of carbon and nitrogen in the tissue of animals to tell what they have eaten. When Cardona's team analysed 20 species of predator and 13 potential prey, it was surprised to find that jellies had a major role in the diets of bluefin tuna (Thunnus thynnus), little tunny (Euthynnus alletteratus) and spearfish (Tetrapturus belone)2. In the case of juvenile bluefins, jellyfish and other gelatinous animals represented up to 80% of the total food intake. “According to our models they are probably one of the most important prey for juvenile bluefin tuna,” says Cardona.

Jellyfish in the food web

At the bottom of a fjord in Norway, an underwater camera captures hagfish, crabs, lobsters and other creatures consuming dead jellyfish. Courtesy: Andrew K. Sweetman

Some researchers have challenged the findings, arguing that stable-isotope results can't always distinguish between prey that have similar diets — jellyfish and krill both eat phytoplankton, for instance. “I'm sure it's not true,” Purcell says of the diet analysis. Fast-moving fish, she says, “have the highest energy requirements of anything that's out there. They need fish to eat — something high quality, high calorie.”

But Cardona stands by the results, pointing out that stomach-content analyses on fish such as tuna have found jellyfish, but not krill. What's more, he conducted a different diet study that used fatty acids as a signature, which supported his earlier results on jellyfish, he says. “They're probably playing a more relevant role in the pelagic ecosystem of the western Mediterranean than we originally thought.”

Fish live beneath Antarctica

Researchers are reaching the same conclusion elsewhere in the world. On an expedition to Antarctica in 2010–11, molecular ecologist Simon Jarman gathered nearly 400 scat samples to get a better picture of the diet of Adélie penguins (Pygoscelis adeliae), a species thought to be threatened by global warming. Jarman, who works at the Australian Antarctic Division in Kingston, reported in 2013 that DNA analysis of the samples revealed that jellyfish are a common part of the penguin's diet. Work that has yet to be published suggests the same is true for other Southern Ocean seabirds.

“Albatrosses, gentoo penguins, king penguins, macaroni and rockhopper penguins — all of them eat jellyfish to some extent,” says Jarman (see 'Lean cuisine'). “Even though jellyfish may not be the most calorifically important food source in any area, they're everywhere in the ocean and they're contributing something to many top-level predators.”

And some parts of jellyfish hold more calories than others. Fish have been observed eating only the gonads of reproductive-stage jellyfish, suggesting a knack for zeroing in on the most energy-rich tissues.

Jeffs now suspects that these crustaceans, which support a global fishery worth around US$2 billion a year, depend heavily on this relationship. "What makes the larvae so successful in the open ocean," he says, "is that they can cling to what is basically a big piece of floating meat, like a jellyfish or a big salp, and feed on it for a couple of weeks without exerting any energy at all."

Through DNA analyses, researchers are also discovering more about how jellyfish function as refuges in the open ocean. Scientists have long known that small fish, crustaceans and a wide range of other animals latch on to jellyfish to get free rides. But in the past few years, it has become clear that the hitchhikers also dine on their transport.

In the deep waters of the South Pacific and Indian oceans, Jeffs has been studying the elusive early life stages of the spiny lobster (Panulirus cygnus). During a 2011 plankton-collecting expedition 350 kilometres off the coast of Western Australia, he and his fellow researchers hauled in a large salp (Thetys vagina), a common barrel-shaped gelatinous animal. The catch also included dozens of lobster larvae, including six that were embedded in the salp itself. DNA analysis of the lobsters' stomach glands revealed that the larvae had been feeding on their hosts.

Large masses of moon jellyfish float along the surface in an inlet near Olympia, Washington.

Where did they go?

Researchers are starting to recognize that jellyfish are important for other reasons, such as transferring nutrients from one part of the ocean to another. Biological oceanographer Andrew Sweetman at the International Research Institute of Stavanger in Norway has seen this in his studies of 'jelly falls', a term coined to describe what happens when blooms crash and a large number of dead jellies sink rapidly to the sea floor.

In November 2010, Sweetman began to periodically lower a camera rig 400 metres to the bottom of Lurefjorden in southwestern Norway to track the fate of this fjord's dense population of jellyfish. Previous observations from elsewhere had suggested that dead jellies pile up and rot, lowering oxygen levels and creating toxic

conditions. But Sweetman was surprised to find almost no dead jellies on the sea floor. “It didn't make sense.”

He worked out what was happening in 2012, when he returned to the fjord and lowered traps baited with dead jellyfish and rigged with video cameras. The footage from the bottom of the fjord showed scavengers rapidly consuming the jellies. “We had just assumed that nothing was going to be eating them,” he says.

Back on land, Sweetman calculated that jelly falls increased the amount of nitrogen reaching the bottom by as much as 160%. That energy is going back into the food web instead of getting lost through decay, as researchers had thought. He's since found similar results using remotely operated vehicles at much greater depths in remote parts of the Pacific Ocean. “It's overturning the paradigm that jellyfish are dead ends in the food web,” says Sweetman.

Such discoveries have elicited mixed responses. For Richard Brodeur, a NOAA fisheries biologist based in Newport, Oregon, the latest findings do not change the fact that fish and tiny crustaceans such as krill are the main nutrient source for most of the species that are valued by humans. If jellyfish are important, he argues, it is in the impact they can have as competitors and predators when their numbers get out of control. In one of his current studies, he's found that commercially valuable salmon species such as coho (Oncorhynchus kisutch) and Chinook (Oncorhynchus tshawytscha) that are caught where jellyfish are abundant have less food in their stomachs compared with those taken from where jellies are rare, suggesting that jellyfish may have negative impacts on key fish species. “If you want fish resources,” he says, “having a lot of jellyfish is probably not going to help.”

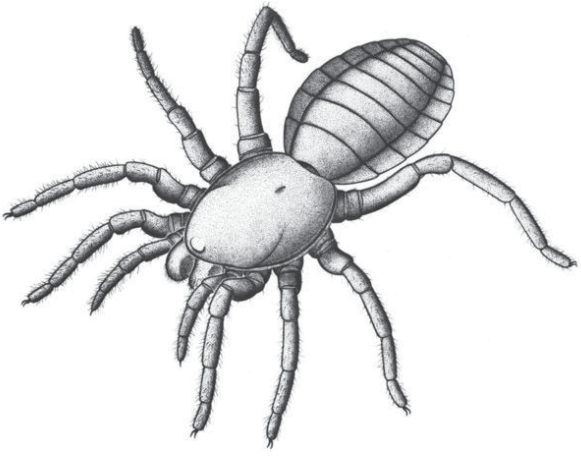
The spy who loved frogs

But other researchers see the latest findings as reason to temper the growing vilification of jellyfish. In a 2013 book chapter8, Houghton and his three co-authors emphasized the positive side of jellies in response to what they saw as “the flippant manner in which wholesale removal of jellyfish from marine systems is discussed”. As scientists gather more data, they hope to get a better sense of exactly what role jellyfish have in various ocean regions. If jellies turn out to be as important as some data now suggest, the population spikes that have made the headlines in the past decade could have much wider repercussions than previously imagined.

Back in Puget Sound, Greene is using a camera installed on a net to gather census data on a jellyfish smack. He watches video from the netcam as it slowly descends through a dense mass of creamy white spheres. At a depth of around 10 metres, the jelly curtain finally begins to thin out. Later, Greene makes a crude estimate. “Two point five to three million,” he says, before adding after a brief pause, “that's a lot of jellyfish.”

A more careful count will come later. Right now there's plenty of slime to be hosed off the back deck. Once that's taken care of, the ship's engines come to life. The next jellyfish patch awaits.

Jonathan Webb



Scientists say a 305 million-year-old fossil is the closest relative to "true spiders" ever discovered - but is not itself a spider.

Easily pre-dating the dinosaurs, the 1.5cm creature lived alongside the oldest known ancestors of modern spiders but its lineage is now extinct.

The specimen was dug up decades ago in France but never identified, because its front half was encased in rock.

Now, researchers have made a detailed reconstruction using CT scans.

Their findings are reported in the journal Proceedings of the Royal Society B.

"This fossil is the most closely related thing we have to a spider that isn't a spider," said first author Russell Garwood from the University of Manchester.

Now christened Idmonarachne brasieri, the arachnid was among "a box full of fossils" that Dr Garwood's co-author Paul Selden, from the University of Kansas in the US, had borrowed from the Museum National d'Histoire Naturelle in Paris in the 1980s.

It originally came from a rich region of fossil-bearing deposits near Montceau les-Mines, in eastern France.

"By CT scanning it, you can actually extract the full front half of the animal from the rock, to try and better understand its anatomy," Dr Garwood told BBC News.

First of all, as well as the animal's eight spidery limbs, he and his colleagues spotted some imposing jaws. These confirmed that it was a new species and not one of the more distant cousins of spiders known from the same period.

It also lacked the tail-like appendage of the older, similarly long-extinct arachnid family that included Attercopus, living some 80 million years earlier. Those earlier critters could produce silk, probably to line their burrows or make a trail to follow home, but did not have the spinnerets that allow spiders to weave webs.

As such, Dr Garwood explained, the new arrival I. brasieri fills a gap - having spider-like

legs and jaws but still lacking spinnerets.

"Our creature probably split off the spider line after [Attercopus], but before true spiders appeared," he said.

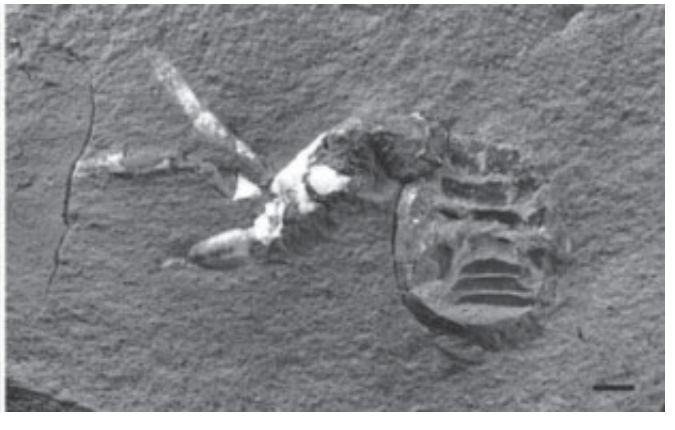
"The earliest known spider is actually from the same fossil deposit - and it definitely has spinnerets. So what we're actually looking at is an extinct lineage that split off the spider line some time before 305 million years ago, and those two have evolved in parallel."

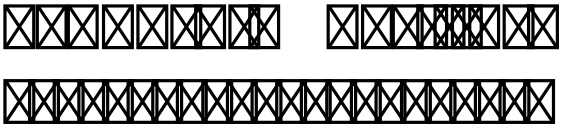
To confirm that the extinct critter definitely lacked spinnerets, the team switched from a regular laboratory CT scanner to using the high-powered X-rays of the Diamond synchrotron in Oxfordshire.

"We had to consider the fact they could have fallen out, and just left a hole in the abdomen," Dr Garwood said. "You need a quite high-resolution scan to be able to spot that distortion."

With all the evidence in place, the team was able to name their discovery. They chose to commemorate a colleague: Martin Brasier, an Oxford palaeobiologist who died recently in a car accident.

"He was a very supportive academic," said Dr Garwood.





Dozens of Japanese scientists and engineers are scrambling to save a satellite - and more than a quarter of a billion dollars of investment - tumbling out of control in space.

Hitomi, meaning the pupil of the eye, was launched last month.

It was designed to study energetic space objects such as supermassive black holes, neutron stars, and galaxy clusters, by observing energy wavelengths from X-rays to gamma-rays.

But time is now running out to save the mission.

What happened?

On Saturday, the US Joint Space Operations Center (JSpOC), which tracks space debris, detected five small objects around the satellite.

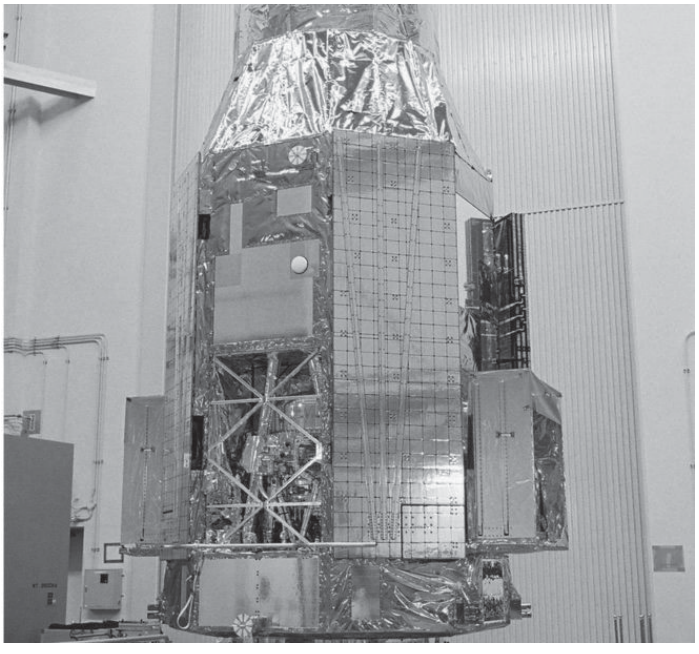
Ground control in Japan managed brief contact with the spacecraft after that, but then lost contact.

The satellite also appeared to show a sudden change of course, and observers on Earth have seen it appearing to flash, suggesting it may be tumbling.

The next day, JSpOC referred to the event as a "breakup", although experts have clarified that Hitomi may well be mostly intact.

What has happened to it?

The Japanese space agency (Jaxa) told the BBC it did not know right now, and that the agency was still trying to restore communications with Hitomi.



Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics, told Associated Press that two possibilities were that the spacecraft might have suffered a battery explosion or a gas leak, putting it into a spin and out of contact.

"To hear that they've run into this piece of bad luck, it's so very sad. I know enough about how the sausage was made to know that this could have easily have happened to us. Space is very unforgiving."

But Prof Goh Cher Hiang, project director of the satellite programme at the National University of Singapore, told the BBC that thanks to monitoring and backup systems, battery explosions were "very rare", and while a leak in the pressurised fuel tanks found on satellites could cause the trouble, "the designer of it can give us some kind of clue".

External factors could also be a reason, he added.

"It could also be from a collision with something in space, either from outer space or a man-made object already in space."

Small objects are not necessarily detected by ground radar, he points out, and with even tiny pieces a "collision can cause serious damage" because they are travelling so fast.

Satellites missing in action

Despite decades of practice, getting satellites into space in perfect working order is still tough.

A Russian defence satellite was lost last December after it failed to separate from the rocket carrying it to orbit

Nasa's Earth-observing satellite Glory did not make it into orbit in 2011, when the protective nose cone on its launcher failed to separate

In November last year, a US defence "nanosatellite" launched on a new type of rocket and learnt the hard way that being first is not always best, when it broke up after lift-off

In 2000, the rocket carrying Japan's Astro-E satellite crashed into the sea

Suzaku, Astro-E's successor, made it into

BBC. "But it's not impossible. It's the reason a

lot of people buy satellite insurance, just in case."

And "a complete failure of the operation", in which nothing can be salvaged of the original mission, is rarer still, especially for "reputable institutions" like Jaxa.

What now?

If it turns out to be impossible to save, it will create a financial black hole of its own. And the 31bn yen ($273m; £191m) it cost the Japanese government does not include instruments supplied by Nasa, the Canadian Space Agency, or the European Space Agency, either.

It will also be the third Japanese X-ray astronomy satellite to be lost or critically affected by malfunction. In 2000, the rocket carrying the Astro-E satellite crashed into the sea, and while its successor, Suzaku, made it into space, its main instrument was disabled by a helium leak in 2005.

But Jaxa has pulled off off seemingly hopeless space recoveries before. Its engineers managed to get the Akatsuki probe into Venus orbit in December last year after the spacecraft had been drifting in space for five years.

Is there reason for hope?

The fact that the agency still had contact with Hitomi for a period even after debris was spotted near the craft is seen by some as a hopeful sign, as it could indicate that it is not critically damaged. Its location is also roughly known.

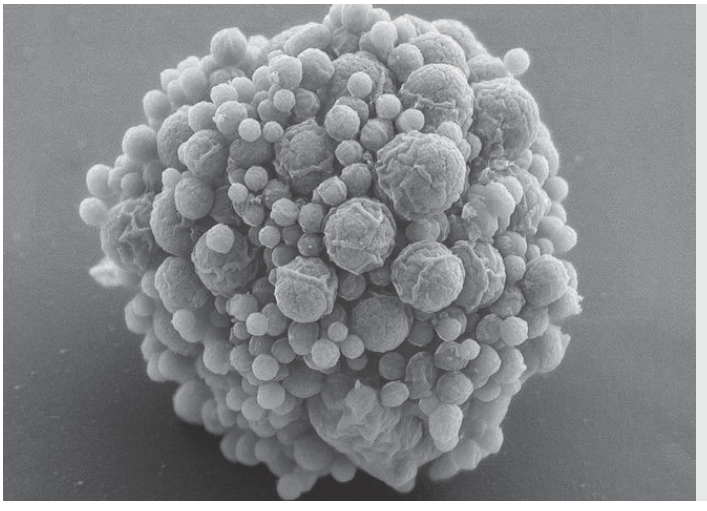
But a quick recovery will be essential. If the satellite is tumbling in space, as it is thought to be now, it may not be able to capture enough solar energy to power itself before a fix is found.

It all comes down to three things, Prof Goh says: "One, communications; two, power; and three, the computer. First you have to talk to the satellite."

If they can do that, Jaxa has a chance to work out what has gone wrong and how to fix it. But if that is impossible "then you are in trouble".

If it turns out to have been lost, it will be particularly unfortunate for those hoping to study black holes after the news last month that gravitational waves from the collision of two black holes had been detected.

Reporting by Simeon Paterson



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Jonathan Amos

Scientists have taken another step in their quest to understand the bare genetic essentials of life.

A team led by US research entrepreneur Craig Venter has created a semi-synthetic, functioning bacterium in the lab that has fewer than 500 genes.

This minimal number is lower than in any known free-living bug in nature.

The group says its investigations aim to push the boundaries of fundamental knowledge and could lead to novel means to make new drugs and other chemicals.

"Our long-term vision has been to design and build synthetic organisms on demand where you can add in specific functions and predict what the outcome is going to be," said Daniel Gibson, who is a co-author on a paper describing the latest work in Science Magazine.

"We think these cells would be a very useful chassis for many industrial applications, from medicine to biochemicals, biofuels, nutrition and agriculture," he told reporters.

Two-decade journey

The team reported its first semi-synthetic organism in 2010.

In that project, the scientists constructed in the lab the entire "genetic software" of Mycoplasma mycoides, a microbe that lives in cattle and other ruminants.

This artificial package of DNA was then transplanted into the cell of another Mycoplasma species that had been emptied of its genome, and "booted up". The engineered bug, dubbed Syn 1.0, duly started to divide.

In the new paper, Dr Venter and his colleagues report how they have now reduced the biochemical instructions in this organism to the bare minimum.

After a long series of trial and error experiments, the Mycoplasma microbe, now dubbed Syn 3.0, can operate on just 473 genes - about half the number found in the wild bug, and about 50 fewer than in the related Mycoplasma genitalium, which has the smallest set of genes in any independent organism known to science.

By way of comparison, more complex organisms such plants and animals can have many tens of thousands of genes driving their

biology.

Dr Venter and colleagues have been pursuing the idea of a minimal genome for 20 years. Their earlier studies suggested the rock-bottom number could be around 300. But in pinning down Sin 3.0's must-haves, the California-based scientists have found that the real number is higher.

Must-have component

They say they have now come to recognise the role of many "quasi-essential" genes - those needed for robust growth but not absolutely required for life. The filtering has also retained genes that perform vital functions in a kind of back-up to each other; thus, one or other of a pair of genes could be seen as superfluous, but one absolutely has to stay or the organism will die.

Dr Venter used an aviation metaphor: "If you know nothing about aeroplanes and you're looking at a Boeing 777, and you're trying to find out the function of parts just by removing them, and you remove the engine from the right wing - the airplane can still fly and land. So, you might say that's a non-essential component, but you won't discover the essentiality until you remove the second one.

"And that's what's happened over and over again in biology, where we would have what appeared to be a non-essential component until we removed its counterpart."

Of Syn 3.0's 473 necessary genes, 149 are a mystery - the team does not know their function, and experiments are underway to close that knowledge gap.

The scientists stress that this minimal genome applies only to their semi-synthetic organism. Context is everything. Other microbes will live in different types of environment, with different ways of operating.

A bug that powers itself via sunlight and photosynthesis will not have the same essential set of genes, for example, as an organism that processes methane to derive its chemical energy.

Starting position

Laurence Hurst is a professor of evolutionary genetics at the University of Bath, UK.

His team stated in 2006 that research on minimal genomes was underestimating what was essential in a cell.

"It was gratifying to see that our prediction that the minimal genome would be larger than previously predicted because of hidden essential genes is indeed borne out. These come about because there are often two routes to the same end," he told BBC News.

"Just as you can close a file on a computer by going to the menu bar and clicking 'quit' or going to the keyboard and typing 'command Q', so too genomes have two means to do the same thing. You can only get rid of one to retain functionality. As soon as one is lost the other becomes essential.

"Looking to the future, the claim is that this could lead the way to a new form of synthetic biology, in which genomes are designed rather than simply modified. The possibilities are exciting but whether this is the best and most cost effective route remains to be seen.

"A complete network analysis of how such a simple system works would, however, make for an excellent starting position to predict what modifications could be successfully incorporated."