EXHIBIT

Science in 2019: A Look at What We've Achieved

December 2019

8 January 2019:

The First Commercial Quantum Compter

IBM Q System One™, the world's first integrated universal approximate quantum computing system designed for scientific and commercial use, was launched this year by the company to tackle problems that are too computationally complex for classical systems to handle.

The 20-qubit system designed by IBM scientists, enclosed in a 9x9x9 feet airtight glass cube, is the first of its type and marks a milestone in the development of commercial quantum computing systems.

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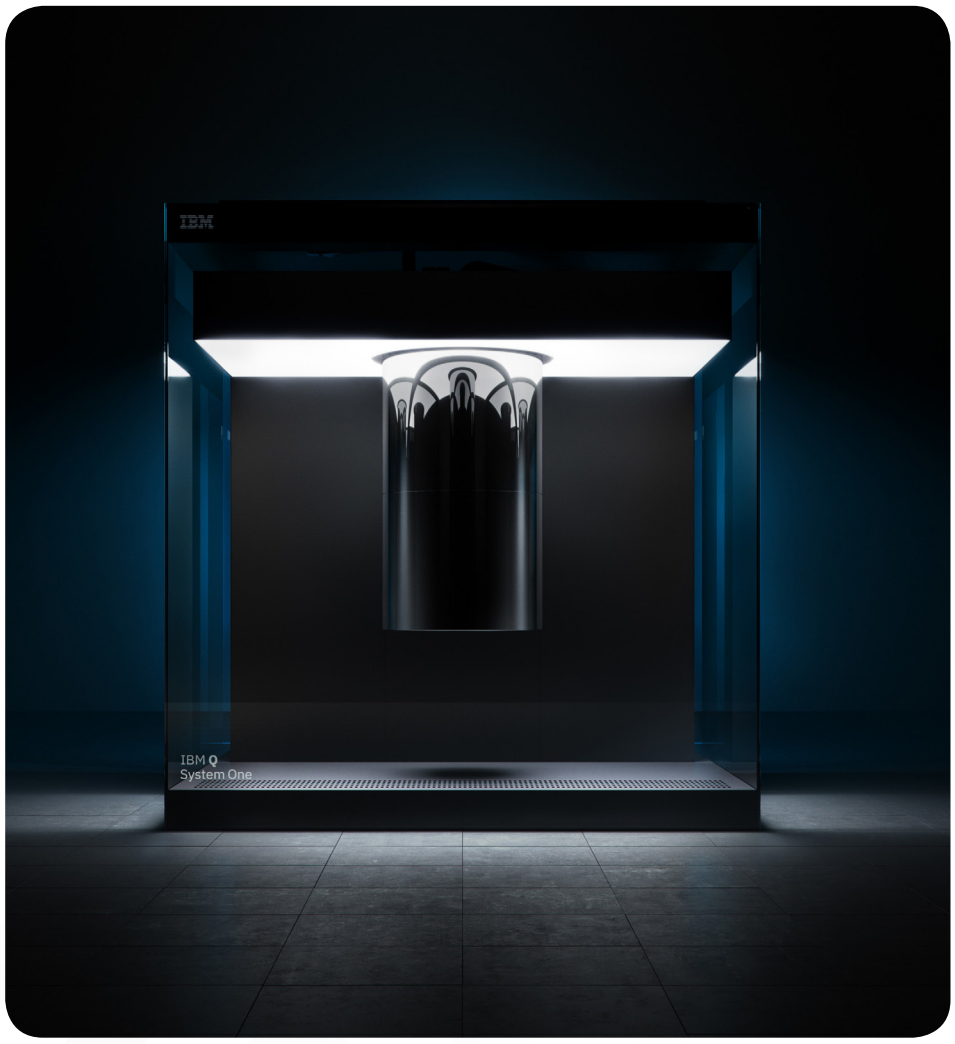

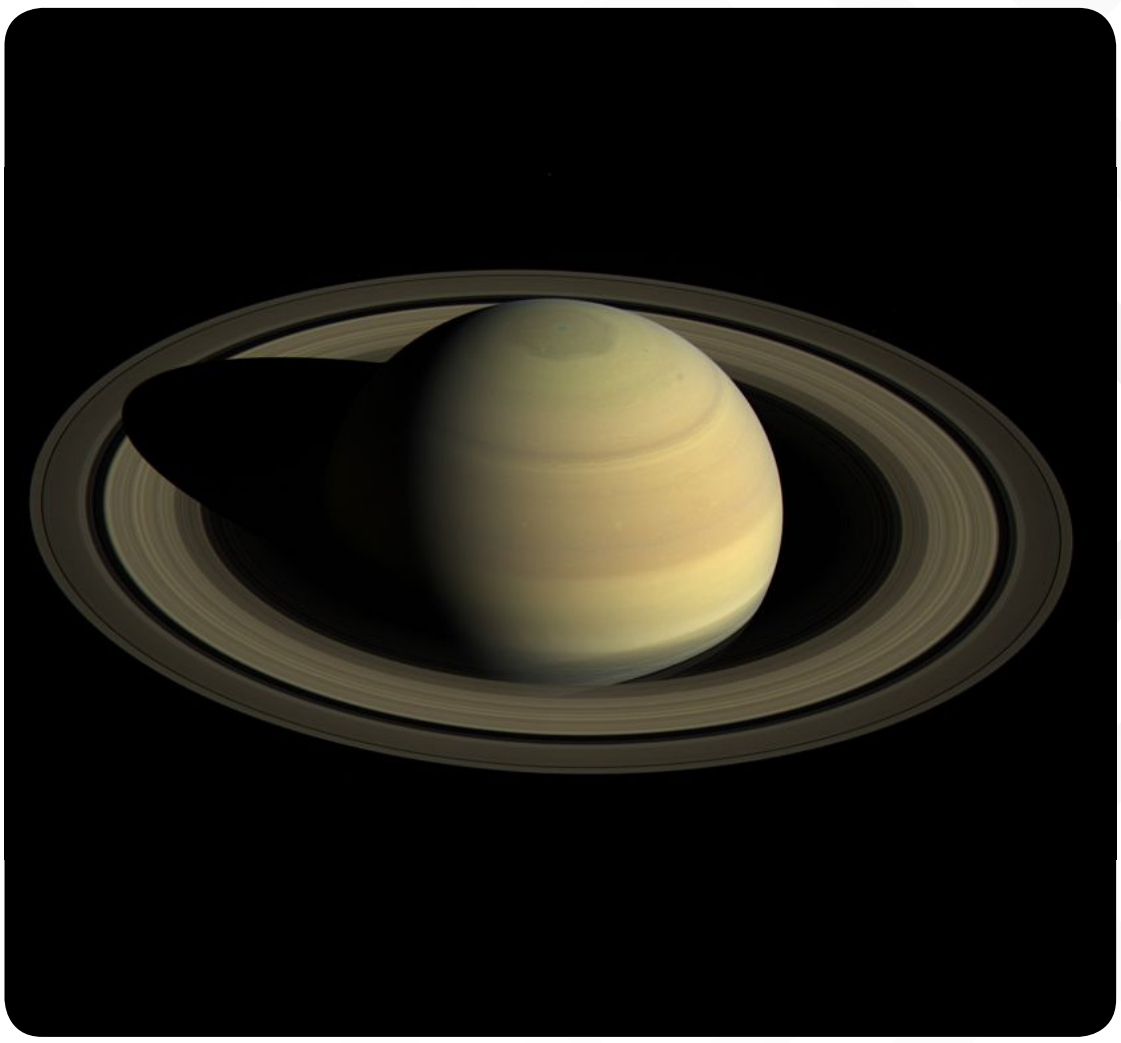

17 January 2019:

Day length on Saturn Determined

Christopher Mankovich and his colleagues have succeeded in finding the length of a day on Saturn. The conventional method of using the planet's magnetic field to measure its period of rotation could not be used in the case of Saturn because of the near-perfect alignment of its magnetic field with its rotation axis. Instead, using data collected by NASA's Cassini mission, scientists have been able to pin the exact length of a day on Saturn to 10 hours, 33 minutes and 38 seconds. The rotation of the planet alters its gravitational field, thus creating oscillations, which are reflected as waves in its rings. These oscillations cause ring particles in their orbit to slowly build up energy that gets carried away in the form of an observable wave. These waves were then studied to aarrive at this measurement.

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19 January 2019:

AI Identifies Unknown Human Ancestor

By combining deep learning algorithms and statistical methods, investigators have identified, in the genome of Asian individuals, the footprint of a new hominid who cross-bred with its ancestors tens of thousands of years ago. Until now, the existence of the third ancestor was only a theory that would explain the origin of some fragments of the current human genome; however, deep learning has made it possible to make the transition from DNA to the demographics of ancestral populations. This algorithm has learned to predict human demographics using genomes obtained through hundreds of thousands of simulations. This paves the way for applying it to answer other questions in biology, genomics and evolution.

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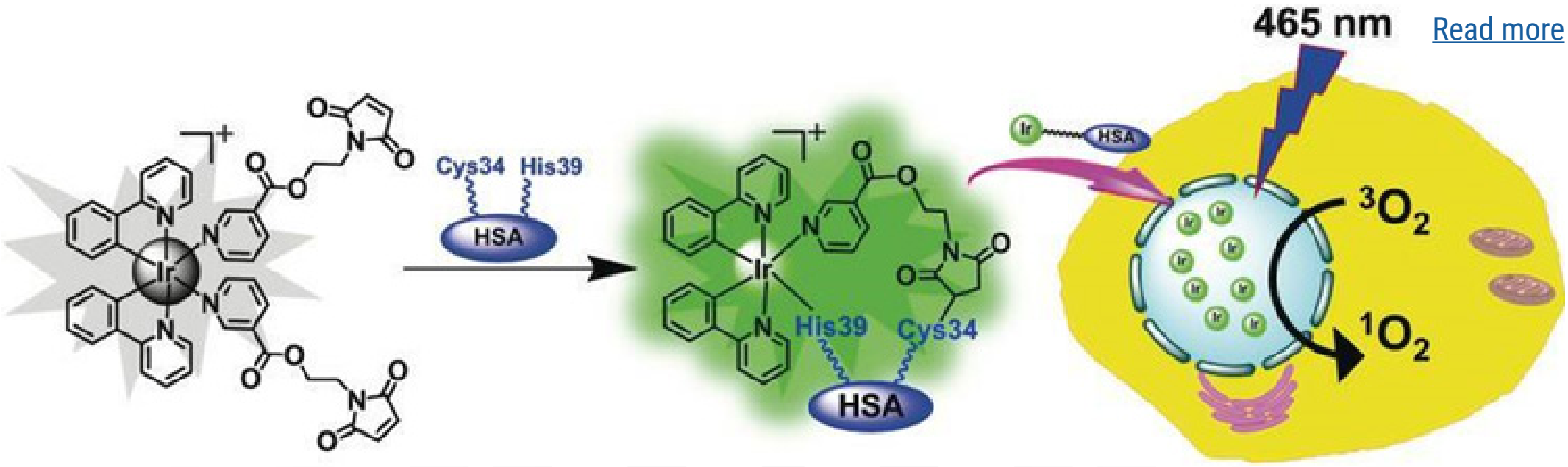
3 February 2019:

Photodynamic Cancer Therapy

WHO statistics show that one in six deaths worldwide is due to cancer. Last year alone, it took over 9.5 million lives. Scientists across the world have been trying to develop new methods to treat cancer. A promising development in cancer treatment is Photodynamic therapy, in which a certain iridium-coated compound, attached to albumin, is used to penetrate the cancer cells right into their nuclei. The compound's photosensitive nature allows it to convert the cells' oxygen into a lethal form, killing cancer cells from the inside while leaving the healthy cells surrounding it intact.



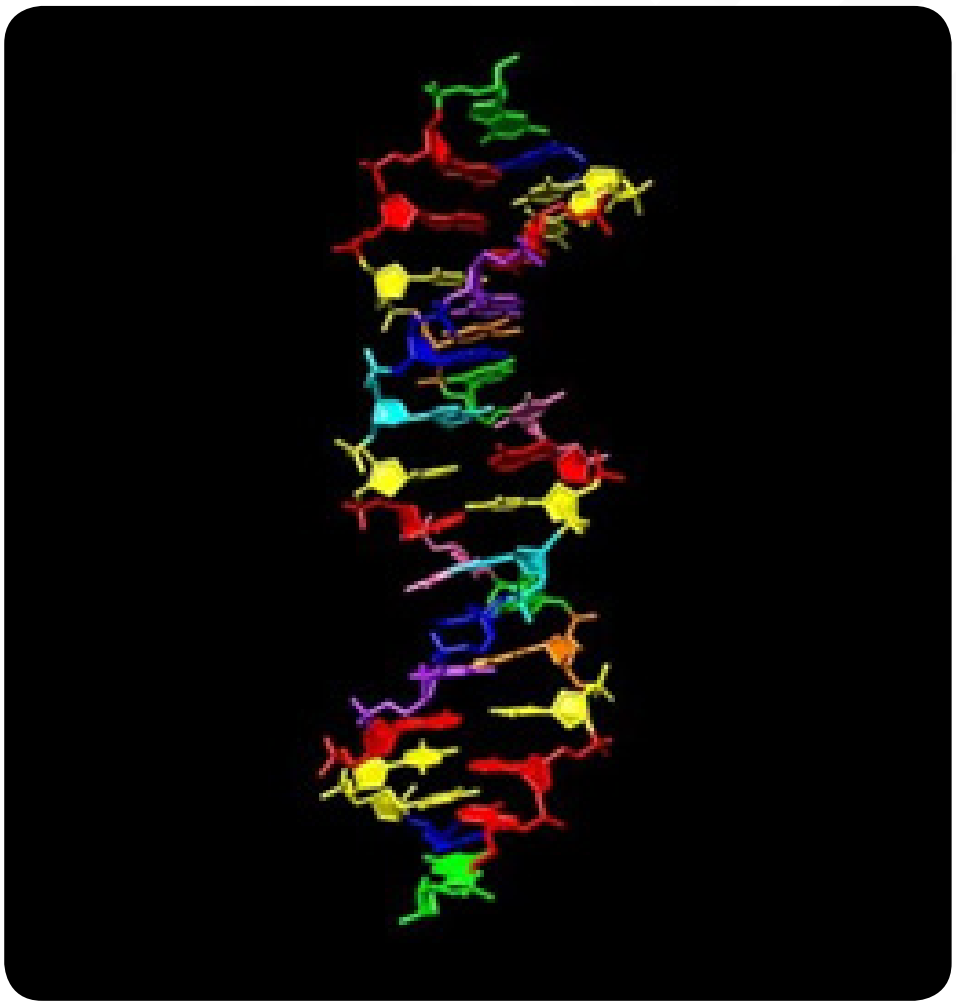
[Read more]

20 February 2019:

FarFarOut Discovered

'FarFarOut' is the nickname of the newly discovered trans-Neptunian object. This object was found at a distance of 100 AU (15 billion km) from the sun, becoming the farthest observable object of our solar system. A team of scientists trying to find direct evidence for the hypothetical Planet Nine, found an object almost 400 km wide outside the orbit of the previously known farthest object, 'FarOut'. This new object triggers the need to find the orbits of such icy worlds which would provide us with insights into our solar system's extreme frontier.

[Read more]



22 February 2019:

Hachimoji DNA and RNA

Researchers Hoshika et al. have developed an "alien" DNA called Hachimoji DNA, from eight building block letters, expanding the genetic code from four, thus doubling the information density. The extra building blocks are P and B (analogues of purine), and Z and S (analogues of pyrimidine). These duplexes form P-Z and B-S pairs. The new system meets all the requirements for Darwinian evolution, and can be transcribed to Hachimoji RNA. It also satisfies Schrödinger's physical condition: the blocks can replace each other without disrupting the helix. It expands the scope for molecular structures that might be capable of supporting life, both in terrestrial and extraterrestrial habitats.

[Read more]

6 April 2019:

Marsquake

Fifty years after Apollo 11's astronauts deployed the first seismometer on the surface of the moon, data from NASA's InSight (placed on Mars) seismic experiment has given researchers the opportunity to compare marsquakes to moon and earthquakes. Scientists concluded that the ongoing cooling of the planet's interior is causing the crust to contract, accumulating stress. This stress is released by a break in the crust.

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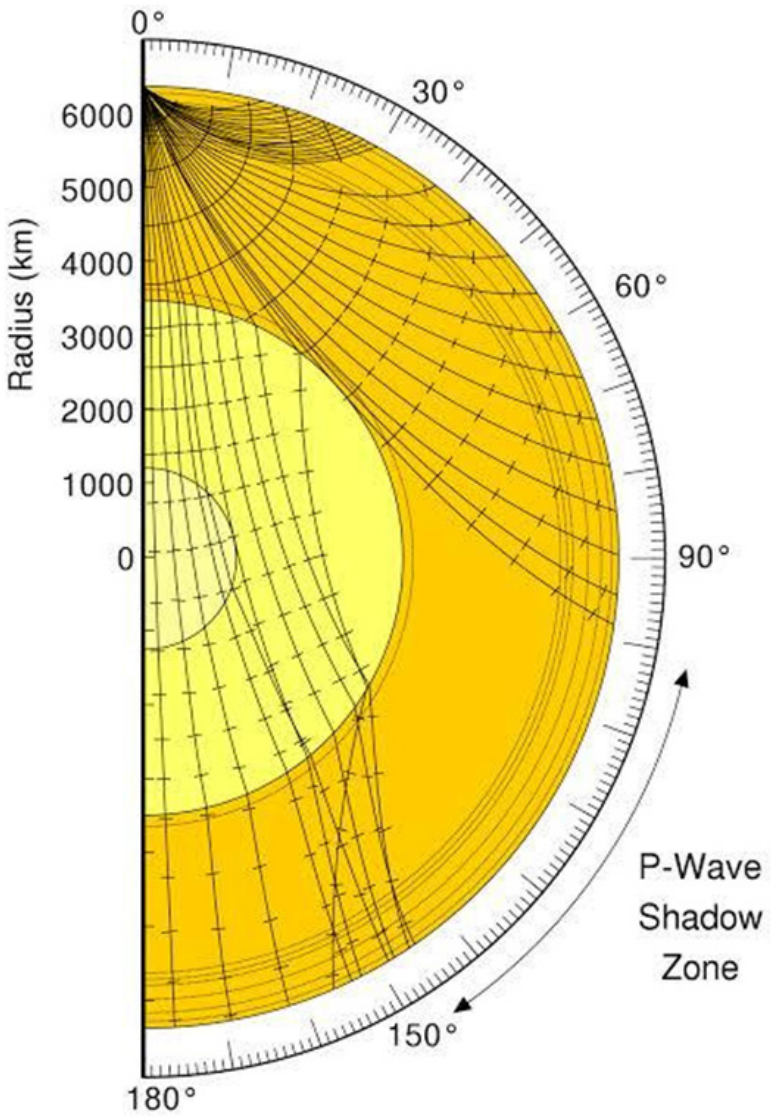

10 April 2019:

Powehi Gets Photographed

This year saw humanity setting its eyes on an image of a black hole for the first time. The black hole that was imaged is the supermassive black hole M87*, also named Powehi, located nearly 53 million light-years away. The feat was achieved using the Event Horizon Telescope (EHT). The EHT is composed of many radio observatories and radio telescope facilities around the world, working together to produce a virtual high-sensitivity, high-angular-resolution telescope with an effective aperture equal to the diameter of the Earth. In April 2017, the EHT collected data on M87* and it took nearly two years of data-processing, simulations and calculations to produce the now-iconic image.

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12 April 2019:

The World's First Malaria Vaccine

RTS, S/AS01 (trade name: Mosquirix) is the culmination of nearly three decades of research. It is the world's first vaccine that is proven to provide young children with partial protection from malaria. The efficacy of the RTS,S vaccine was established in a Phase 3 clinical trial that concluded in 2014. The vaccine is designed to prevent the parasite (*Plasmodium falciparum*) from infecting the liver, where it matures, multiplies and re-enters the bloodstream. WHO, in association with other public health organisations, has launched a pilot implementation program this year to vaccinate children in three African countries: Ghana, Kenya and Malawi.

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15 May 2019:

E. coli with Synthetic DNA

In a milestone for synthetic biology, scientists at the Medical Research Council Laboratory of Molecular Biology in Britain succeeded in rewriting the DNA of the bacterium *Escherichia coli*, bringing down the number of codons from 64 to 61. This was done by modifying the genome such that it only required 61 codons to produce all the amino acids the bacterium needs. Instead of using six codons to make serine, it used just four and had two stop codons instead of three. The new bacteria, called Syn61, had longer, rod-shaped bodies and reproduced slowly, but thrived.

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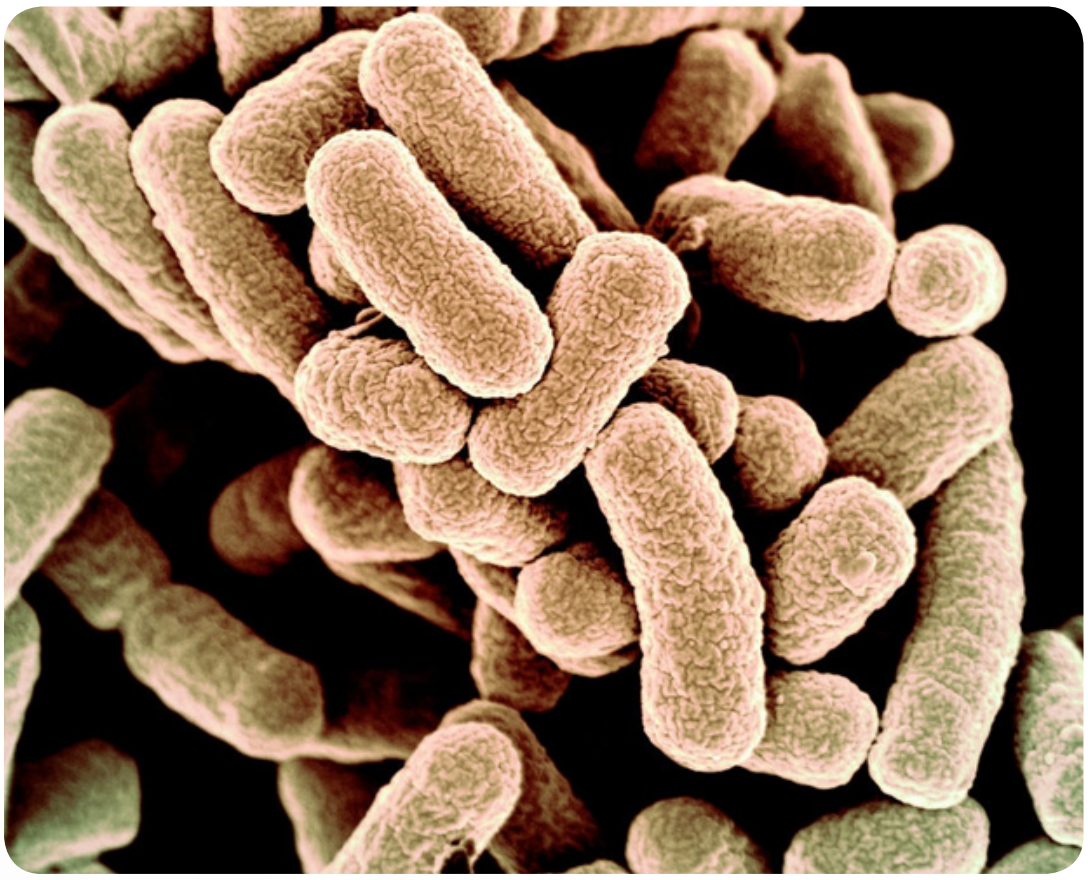

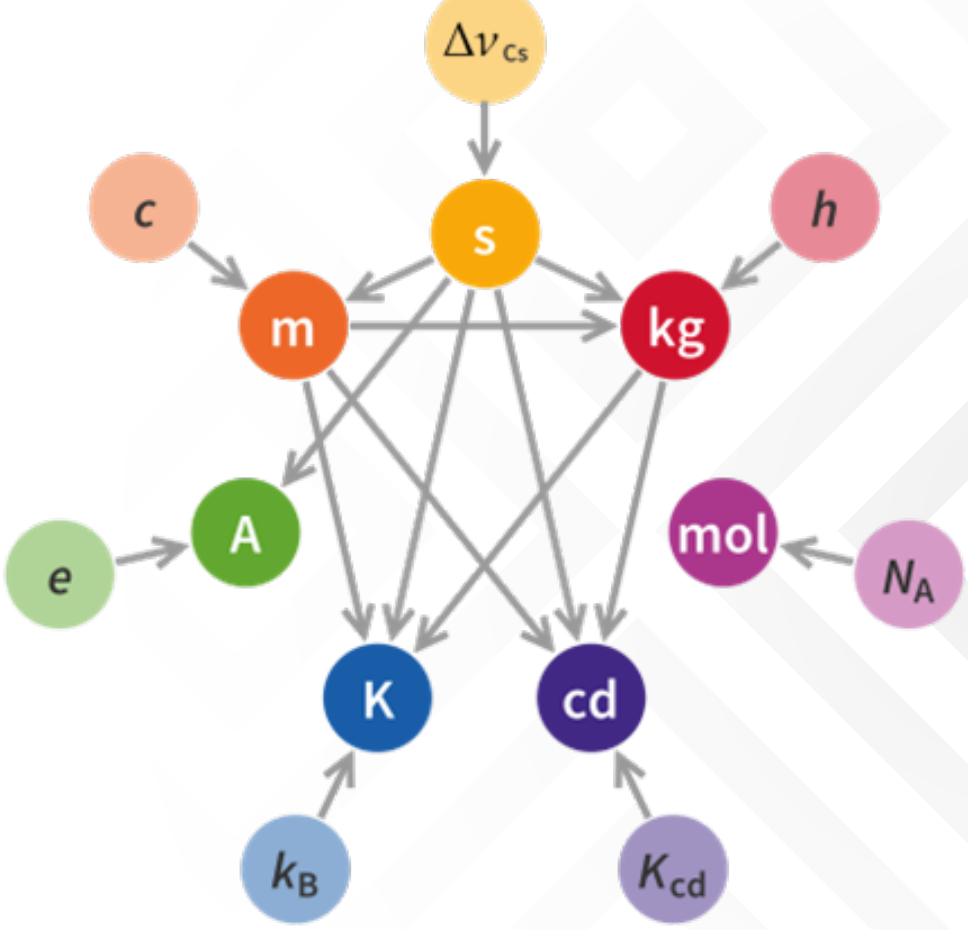

20 May 2019:

SI Units Redefined

The SI base units were redefined, effective from the 144th anniversary of the Metre Convention. This decision was followed by a series of experiments which were done to measure the physical constants to a higher accuracy relative to the old SI definitions, in order to set exact numerical values for the Planck constant (h), the elementary electric charge (e), the Boltzmann constant (k), and the Avogadro constant (N_A).

The international prototype of the kilogram was retired, definitions of kilogram, ampere and kelvin were replaced, and the definition of a mole was revised.

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17 June 2019:

3D Printed Biological Tissue

3D printing of biological tissues has always involved the usage of microscale scaffolds for providing a structure for the cells to divide. Eventually, the host material biodegrades, leaving behind only the bio-tissue. Though successful, this method has detrimental drawbacks. The new method uses a block of hydrogel made up of microbeads; the stem cells are deposited by the printing nozzle and are held in place by the microbeads. Once the printed tissue has reached maturation, it can be easily removed from the matrix. This has been used to 3D print a cartilage ear and a rodent-sized femur.

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13 July 2019:

Proof of Quantum Entanglement

One of the most famous ways to prove quantum entanglement is to break the Bell Inequality, which was set up by the late physicist John Bell, and was done by researchers from the University of Glasgow. Particles that are entangled at the quantum level share one or more properties that persist even at large distances. The team used two entangled photons and separated them, after which, they had one of the photons move through a filter that caused a phase transition of any desired angle. They proceeded to image the other photon and observed a phase change in it (corresponding to its partner), though it had not been passed through the filter. This was visualised by the researchers and presented as the first visual proof of quantum entanglement.

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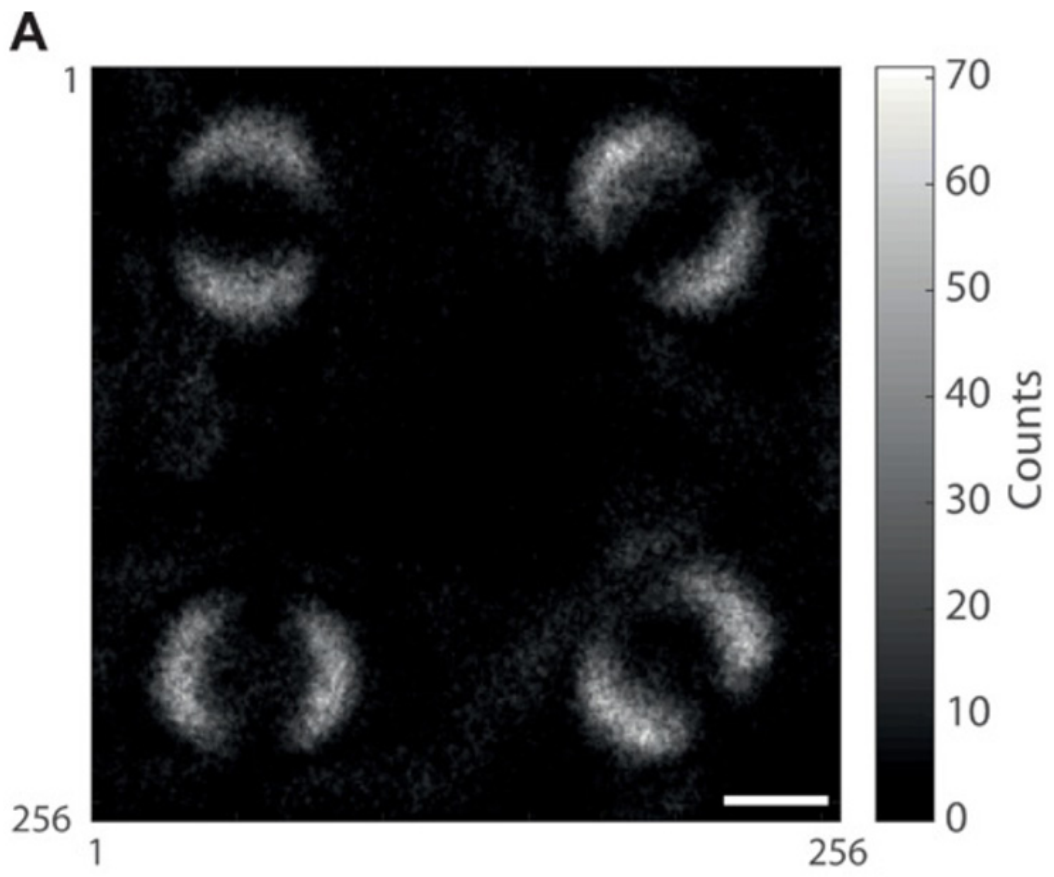

12 August 2019:

Interstellar Iron in Antarctic Snow

A research team in collaboration with the Technical University of Munich (TUM) has discovered Iron-60 for the first time in Antarctica snow. Scientists confer that Iron-60 in the Antarctica snow originates from the interstellar neighbourhood; for example, from an accumulation of gas clouds in which our solar system is currently located.

There are no natural terrestrial sources for the Iron-60 isotope contained therein; it originates exclusively as a result of supernova explosions or through the reactions of cosmic radiation with cosmic dust.

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15 August 2019:

Synthesis of Cyclo[18]carbon

Cyclo[n]carbons, which are carbon allotropes consisting n carbon atoms linked covalently in a ring, have enticed chemists for many years. A team of researchers from the University of Oxford and IBM research, Zurich has synthesised and characterised a pure ring of 18 carbon atoms for the first time. The team generated cyclo[18]carbon on an inert surface at extremely cold temperatures—about 5 K (-268°C). The high reactivity of the cyclo-carbon has opened up new alleys for synthesising other carbon allotropes and carbon-rich structures which can eventually be used as elements for molecular electronics.

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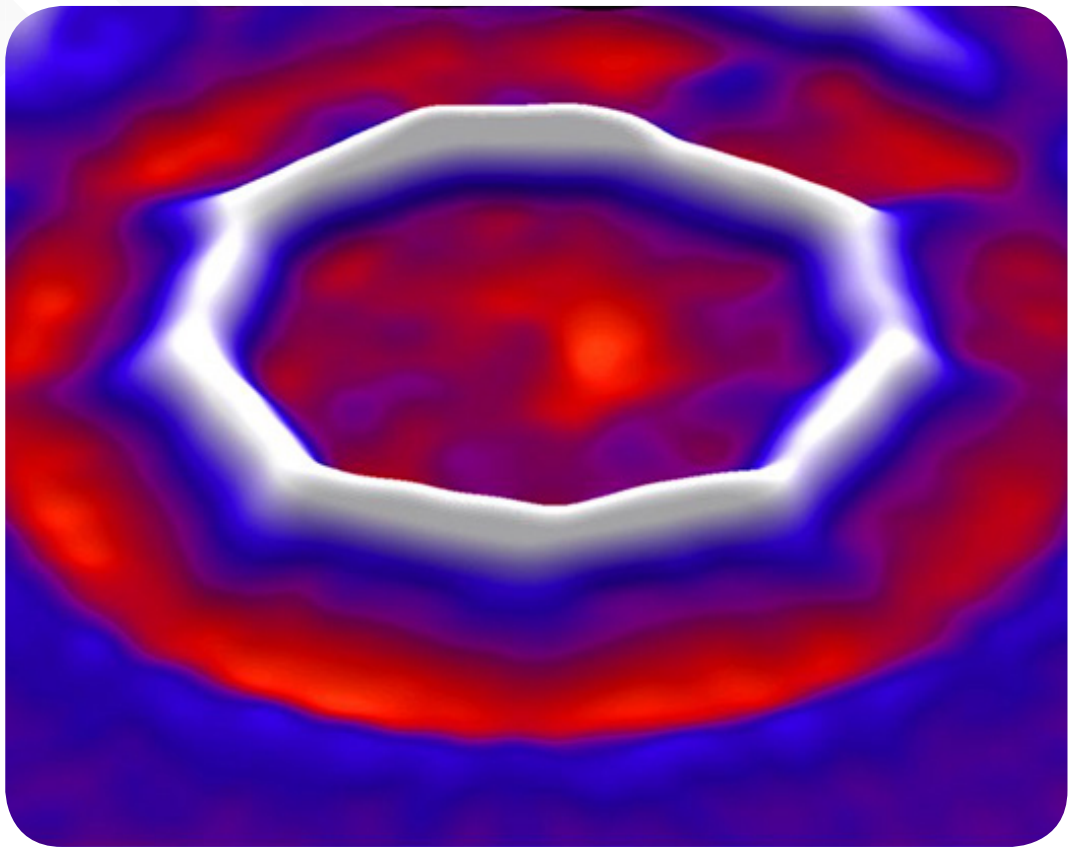

9 September 2019:

The Answer to 42, and possibly life!

The Diophantine equation, a classic in mathematics, is a polynomial equation whose solutions are constrained to be integer values. A challenge put forth in 1954, which demanded a third-degree trinomial version of the Diophantine equation to have solutions for every number between 1 to 100, was finally put to rest this year. Only two numbers stood resilient: 33 and 42, the latter of which proved to be the most challenging of all. It took 500,000 computers (The Charity Engine) over a million computational hours to arrive at the solution, whose digits are of the order of 10^{16} (negative integers are allowed). Many a hitchhiker is grateful for this feat!

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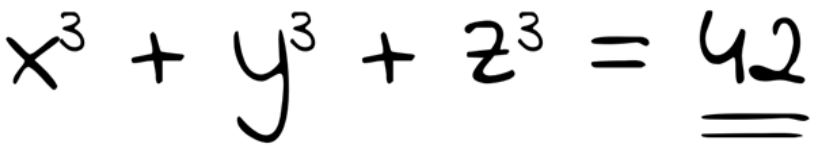

20 September 2019:

Global Climate Strikes

A series of general strikes aimed at demanding action against global climate change were held from 20th September, which was three days before the United Nations Climate Summit. The protests took place in 150 countries and were a part of the 'School Strike for the Climate' movement, inspired by Swedish climate activist Greta Thunberg. About 6 million people participated in the protests, and it has been reported to be one of the most significant climate strikes in world history.

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23 October 2019:

Quantum Supremacy

Confirming the rumours that had been floating about in 2019, Google published a paper in Nature, claiming that they have achieved quantum supremacy. In quantum computing, quantum supremacy is the goal of demonstrating that a programmable quantum device can solve a problem that classical computers practically cannot (irrespective of the usefulness of the problem). Google says that its 54-qubit Sycamore processor was able to perform a calculation in 200 seconds that would have taken the world's most powerful supercomputer 10,000 years. Although researchers at IBM dispute these claims, it is a historic first.

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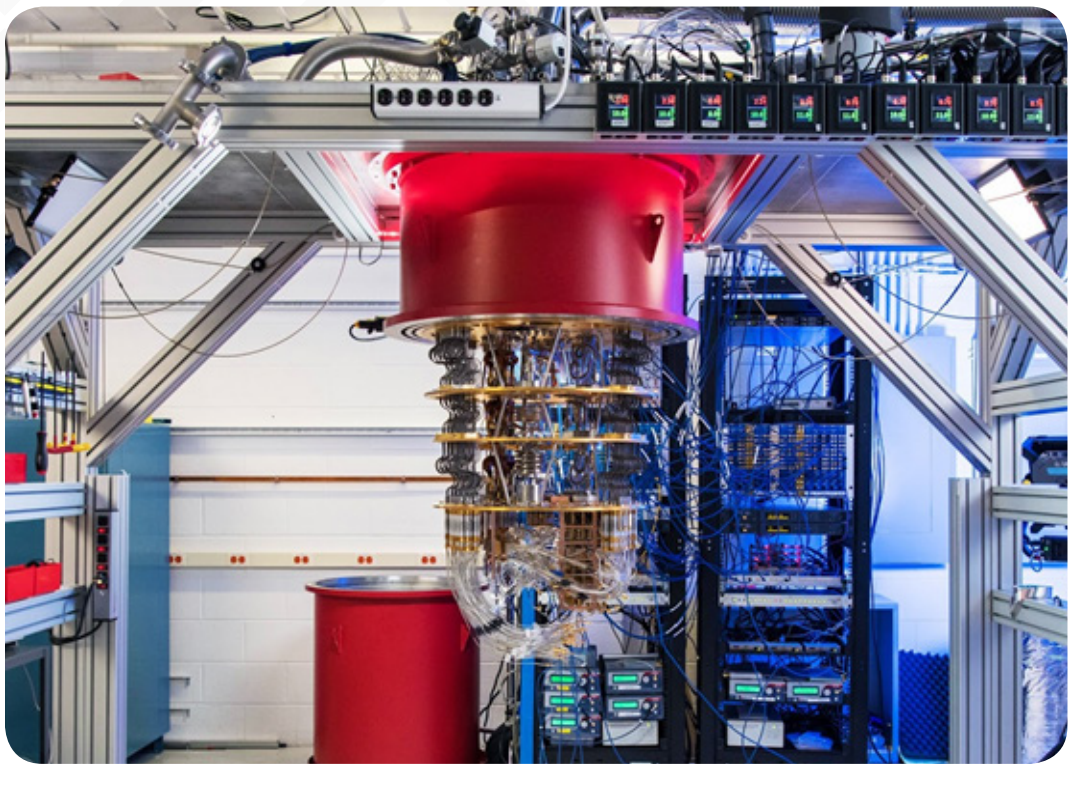

18 November 2019:

Titan Gets Mapped

The first map showing the global topography of Saturn's largest moon, Titan, has been completed and it reveals a dynamic world of dunes, lakes, plains, craters and other terrains. Rosaly Lopes, a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, California, and her colleagues produced the map using radar and visible-light images from NASA's Cassini mission, which orbited Saturn from 2004 to 2017. What makes Titan interesting is that it is the only planetary body in our solar system other than Earth which is known to have a stable liquid on its surface, which is a mixture of methane and ethane.

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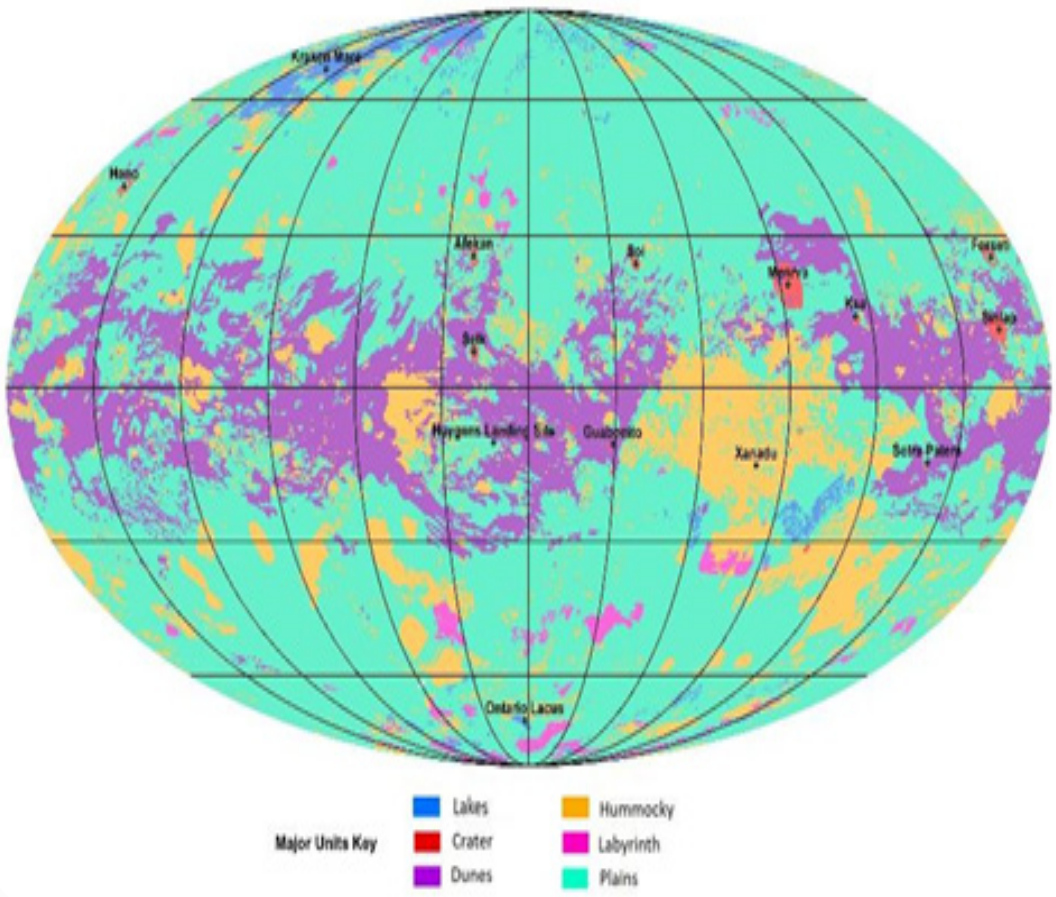

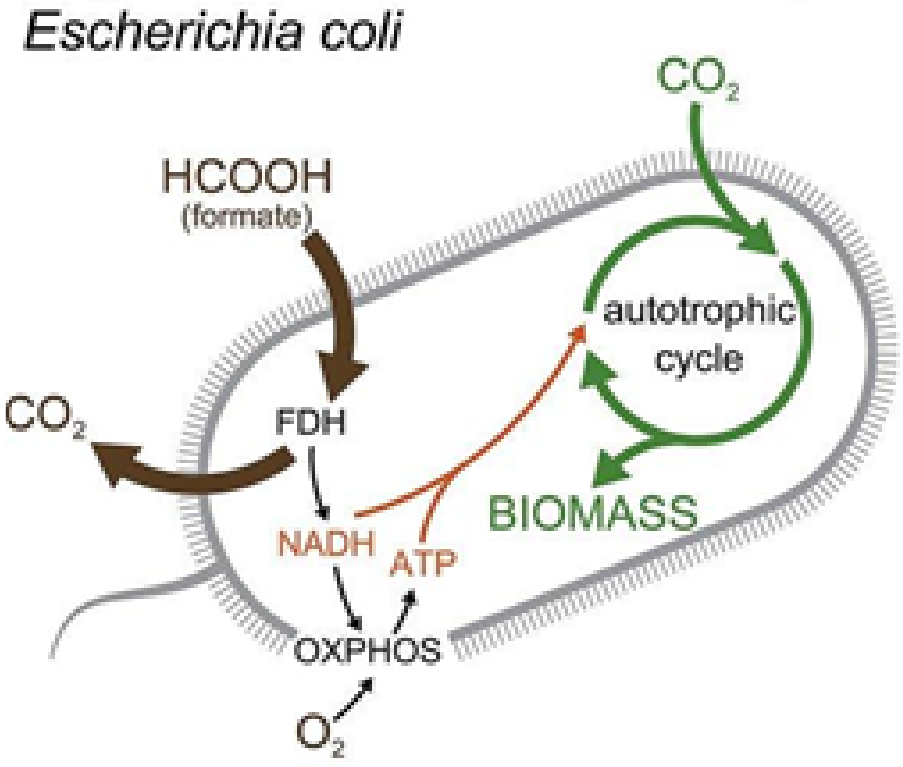

27 November 2019:

CO_2-Eating Bacteria

Researchers at the Weizmann Institute of Science, Israel, have genetically modified *E-coli* to consume carbon dioxide for energy instead of organic compounds. The research team used a technique called metabolic rewiring (also known as lab evolution) to transform the *E-coli*'s diet to make it consume CO_2. Two hundred days after genetic manipulation, the first cells capable of using CO_2 as their only carbon source emerged with CO_2 at concentrations about 250 times that of the Earth's atmosphere.

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28 November 2019:

The Coldest Reaction Ever

Researchers have performed the coldest reaction at temperatures millions of times colder than space. They also saw something nobody had ever seen—the moment when molecules interact. In such extreme temperatures—500 nanokelvin—the speed of two potassium rubidium molecules was reduced significantly, and the molecules were forced to linger in the intermediate stage for microseconds. This may seem short, but it was long enough for the team to investigate the phase (chemical reactions occur in femtoseconds). In the last two decades, scientists have used ultrafast lasers to detect and capture images of the reaction; it was almost impossible to capture the whole reaction until now. The ability to increase the reaction observation time offers alluring possibilities in almost every field of science.

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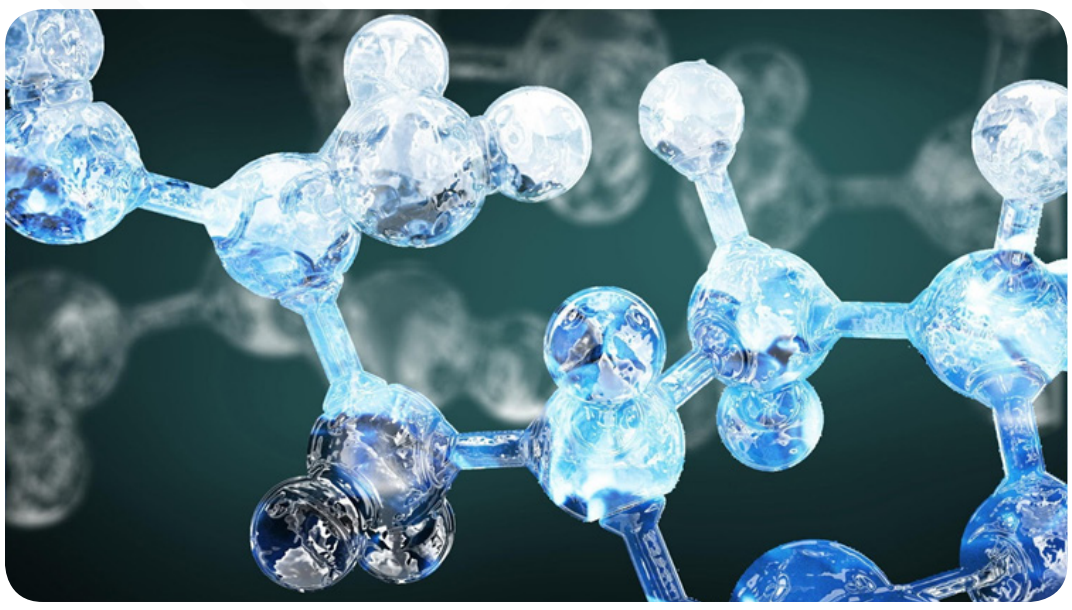

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