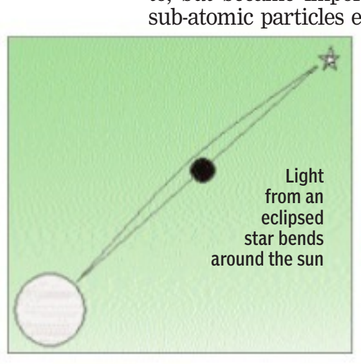
A hundred years of relativity

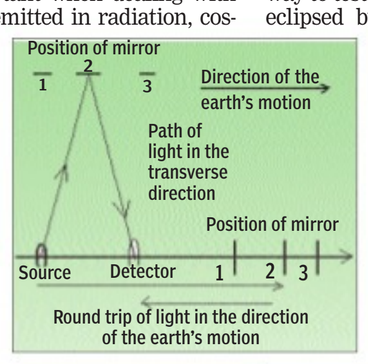
IT WAS IN NOVEMBER 1915 THAT ALBERT EINSTEIN PRESENTED TO THE WORLD HIS NEW FORMULATION OF SPACE, TIME AND GRAVITY, WRITES **S ANANTHANARAYANAN**

In two earlier path-breaking papers — the first "On the electrodynamics of moving bodies" in June 1905 and the second in September, "Does the inertia of a body depend on its energy content?" — Einstein set out the so-called "Special Theory of Relativity", which deals with motion and energy. Then in a 1915 paper, "Explanation of the Perihelion Motion of Mercury from General Relativity Theory", he extended the theory to include the force of gravity and applied the theory to a problem that arose in planetary motion as worked out by Newtonian mechanics. The two discoveries have since affected and dominated every possible area in science.

Interest in the subject arose from the discovery that the speed of light was independent of the state of motion of its source. As the earth, in its orbit around the sun, moves through space at a high speed of 30 km a second, the time for light to reach a mirror and back, in the direction of the earth's orbit should be different, compared to sideways. Experiments, however, repeatedly shown this not to be the case, but that the conventional rule of addition of velocities had to be changed when speeds grew very high.

Einstein thought the reason for this oddity may be that the concepts of distance and time, based on ordinary experience, ignored the time that light took to reach us whenever we made an observation or a measurement. By integrating this fact into the way a distance or an interval of time was seen from reference points that were in relative motion, Einstein developed a world-view that was not in three dimensions, like the physical world which changes with time, but one where time was equally an additional dimension. And in this four-dimensional description, he worked out how the measurements made from different reference points were related.





The relationship, in fact, implied that moving observers found lengths to shrink and time also to move slower. The effect, of course, was miniscule and undetectable at speeds that we are used to, but became important when dealing with sub-atomic particles emitted in radiation, cosmic rays, or in collisions of such particles and so on. It is only by incorporating this kind of working that the now vast area of high energy physics can be understood and the effects have been verified in a great number of ways. Another result of the new view of nature was that the energy of motion in moving objects manifested as increase in the mass of the object, miniscule at ordinary speeds, of course. And then, that mass and energy were equivalent, and the ratio was the square of the velocity of light! This is the famous $E=mc^2$ relation and there can be no end to relating how basically the equivalence has driven the progress of science.

The General Theory

The view developed so far about light, radiation, lengths, time and mass was without considering the force of gravity that acts between masses. The theory developed was hence of the special case where gravity was ignored and the next development was of the general case, where gravity was also considered.

In the existing world-view, interactions considered were basically electromagnetic and the rules to deal with electromagnetism had been exactly and elegantly formulated. Einstein attempted a similar description of the gravitational effect of a massive body. The relativistic rules for acceleration of objects, with the changes in measures of length and time and masses as the speed changed, which were available, were now linked with gravitation by considering the force of gravity to be the same thing as acceleration. This can be understood in terms of a weightless astronaut in a spaceship. If the spaceship were accelerated in some direction, the astronaut would not be able to distinguish between what he feels and a force of gravity.

Using this kind of thinking and much abstract mathematics, Einstein created a framework in which what the presence of a mass did was to distort the shape of the four-dimensional continuum of space and time. Such distortion would cause straight-line movement to seem curved, along the contours of space itself. And using this method of working, he was able to exactly explain an anomaly in the orbit of Mercury. Einstein himself also proposed another way to test this assertion — that a star that was eclipsed by the sun should still be visible, because light would bend due to the sun's gravity!

This test was not immediately tried, both because Einstein's paper was in German and translations were not readily available, and also because of World War I. But in 1919, immediately after the war, Sir Arthur Eddington and Sir Frank Dyson organised expeditions to South Africa and Brazil to photograph the star field during a total solar eclipse that was expected in May. The pictures did show images of stars that should have been hidden behind the sun's disc and the news was sensational — Einstein's prediction had been proved.

It was the victory of a German in a field that had been dominated by Newton, an Englishman, and the verification was by English scientists — a triumph of science that eclipsed, in turn, the humdrum exchanges of post-war reconciliation.

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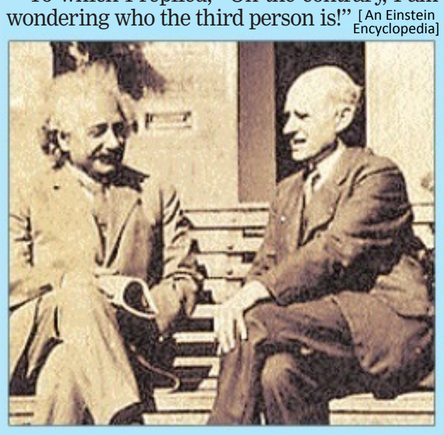
Comprehending the theory

The Theory of Relativity is reputed to be particularly abstruse and difficult. Astrophysicist S Chandrashekhar recalls an anecdote that Sir Arthur Eddington related, "After discussion (at the Royal Society) Ludwik Silberstein came up to me and said, 'Well Professor Eddington, you must one of the three people in the world who understands relativity."

I said, "Oh, I don't know…." To which Silberstein said, "Professor Eddington, don't be modest."

To which I replied, "On the contrary, I am wondering who the third person is!" [An Einstein Encyclopedia]

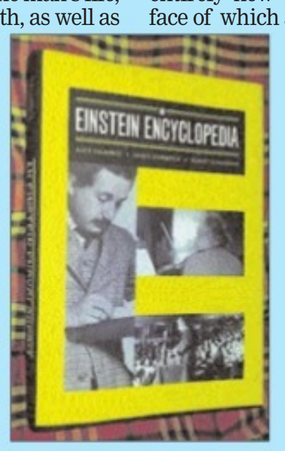


Einstein with Sir Arthur Eddington.

An Einstein encyclopedia

Einstein quit Germany and Europe and moved to the USA in 1933. He joined the Institute for Advanced Study in Princeton, New Jersey, and was part of the institute till 1945, but had an office in the premises till he died in 1955. It seems proper that the Princeton University Press has brought out a collection of facts, history, people and science, covering "the personal, scientific and public spheres of Einstein's life" to mark the centenary of his celebrated 1915 paper.

The book is a veritable museum of the man's life, quite literally from his birth to his death, as well as a curating of the wide sweep of his work. About the person, the book recounts his early years, his schooling and university days, his work in the patent office, where he was a "technical expert", his personal life, his family, his illustrious and magnificent career and, finally, an intimate account of his last days. About his career and work, the book is a swift tour of the coming of age of physics itself — the background, the foundations that led to his famous reformulation of space and time, the extension to include the force of gravity, which is, in fact, a giant leap by itself, and the pivotal role of his work in all developments in science since then. Einstein's first important work, in fact, was in clarifying ideas of the "quantum", or the discrete packets in which transfer of energy took place. The discovery of the equivalence of mass and energy, soon after, led to the advances in quantum mechanics, which is the way nature behaves at very small dimensions, and the ability to manipulate atoms and molecules in a way that could not have been imagined.



His work on the nature of the force of gravity, which was not merely refinement of the laws found by Newton, but was a new way of looking at mass, enegry and space, led to discoveries that even Einstein could not have imagined — neutron stars, black holes, galactic dynamics, gravitational lensing, the Big Bang, the expanding universe, an entirely new understanding of cosmology, in the face of which anything before the time of Einstein is almost relegated as primitive.

The book has a large division about Einstein's colleagues and contemporaries, which reads as a Who's Who of physics in the first half of the century. And then there is the section that describes Einstein's role in shaping concepts in physics, time and space, simultaneity, causality, relativity and quantum mechanics, statistical mechanics.

The authors are Alice Calaprice, renowned author of books on Einstein, Daniel Kennefick, professor of physics and author of books on the Theory of Relativity, and Robert Schulmann, an authority on the writings by and about Einstein. While the book is informative and full of interest for the lay reader, it cites extensive references and sources, including an annotated bibliography, which could enthrall the specialist.

CRACKING THE CODE

TAPAN KUMAR MAITRA DELVES INTO THE PROCESSES BY WHICH GENES ARE EXPRESSED

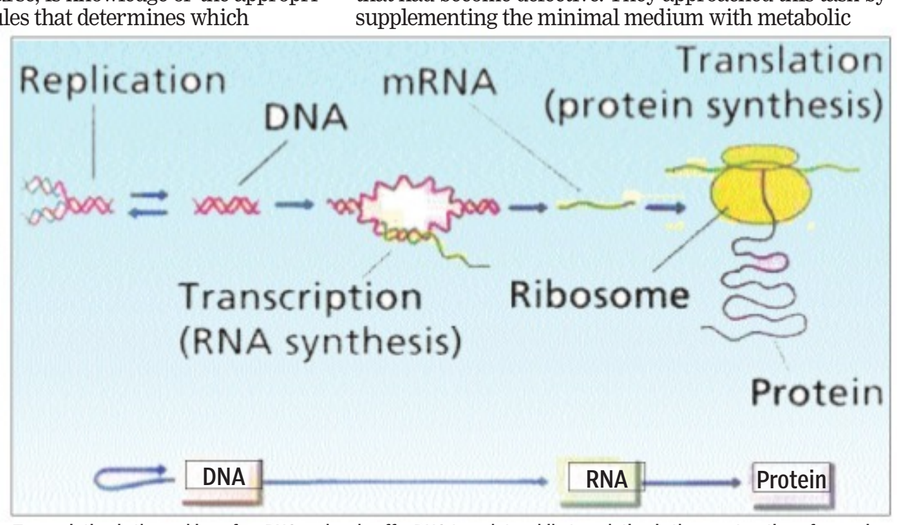
The essence of gene expression lies in the relationship between the nucleotide base sequence of DNA molecules and linear order of amino acids in protein molecules. This relationship is based on a set of rules known as the genetic code. The cracking of that code was one of the major landmarks in 20th century biology.

During the flow of information from DNA to RNA via proteins, it is easy to envision how information residing in a DNA base sequence could be passed to mRNA through the mechanism of complementary base pairing.

But exactly how does mRNA pass its "message" to a protein? To the uninitiated, the message is just a series of nucleotides in an mRNA molecule, with no obvious meaning. But given access to the genetic code, anyone can convert the sequence of purine and pyrimidine bases in the mRNA into a string of amino acids, and the message becomes recognisable as a polypeptide.

Thus, a nucleotide base sequence can contain information for guiding protein synthesis but it must be translated into an amino acid sequence to make sense. What is needed, of course, is knowledge of the appropriate code—the set of rules that determines which nucleotides in mRNA correspond to which amino acids. The encoded message can then be translated into proteins the cell can use.

Until it was cracked in the early 1960s, the genetic code was a double secret. Before scientists could figure out the exact coding relationship between the base sequence of a DNA molecule and the amino acid sequence of a protein, they first had to figure out if such a relationship existed at all. That awareness arose from the discovery that mutations in DNA can lead to changes in proteins.



Transcription is the making of an RNA molecule off a DNA template while translation is the construction of an amino acid sequence (polypeptide) from an RNA molecule. Although originally called dogma, the idea has been tested repeatedly with almost no exceptions to the rule being found.

The link between gene mutations and proteins was first detected experimentally by George Beadle and Edward Tatum in the early 1940s using the common bread mold, *Neurospora crassa*. Neurospora is a relatively self-sufficient organism that can grow in a minimal medium containing only sugar, inorganic salts and the vitamin, biotin. From those few ingredients, neurospora's metabolic pathways produce everything else the organism requires. To investigate the influence of genes on these metabolic pathways, Beadle and Tatum treated a neurospora culture with X-rays to induce genetic mutations. Such treatments generated mutant strains that had lost the ability to survive in the minimal culture medium although they could be grown on a complete medium supplemented with a variety of amino acids, nucleosides and vitamins.

Such observations suggested that the neurospora mutants had lost the ability to synthesise certain amino acids or vitamins and could survive only when such nutrients were added to the growth medium. To determine exactly which nutrients were required, Beadle and Tatum transferred the mutant organisms to a variety of different growth media, each containing a single amino acid or vitamin, which was added as a supplement to the minimal medium. This approach led to the discovery that one mutant strain would grow only in a medium supplemented with vitamin B_6 while a second one would grow only when the medium was supplemented with the amino acid argi-nine and so on. A large number of different mutants were eventually characterised, each impaired in its ability to synthesise a particular amino acid or vitamin.

Because amino acids and vitamins are synthesised by metabolic pathways involving multiple steps, Beadle and Tatum set out to identify the step in each pathway that had become defective. They approached this task by supplementing the minimal medium with metabolic precursors of a given amino acid or vitamin rather than with the amino acid or vitamin itself. By finding out which precursors supported the growth of a particular mutant strain, they were able to infer that, in each mutation, a single enzyme-catalysed step leading to the synthesis of a specific compound was disabled. There was, in other words, a one-to-one correspondence between each genetic mutation and the lack of a specific enzyme required in a biochemical pathway. From those findings, Beadle and Tatum formulated the one gene-one enzyme hypothesis, which stated that each gene controls the production of a single enzyme molecule.

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'A pretty amazing thing'

'VOICE TRANSPLANTS' JUST GOT ONE STEP CLOSER, SAYS **STEVE CONNOR**

Human vocal cords have been grown in the laboratory for the first time in a development that could one day lead to "voice" transplants for people who cannot speak because of a permanently damaged larynx. Scientists said the bio-engineered vocal cords grown from individual cells produced sounds similar to those made by the human voice box when warm, moist air was passed over them to make them vibrate.

Dr. Nathan Welham, right, and his team in the Welham Lab at the Wisconsin Institute for Medical Research.

They believe it may be possible to generate a variety of synthetic vocal cords that can be used "off the shelf" for transplant operations to suit the individual needs of different patients who cannot speak. At present there are limited treatment options available for people with a larynx damaged by cancer or other disorders because of the highly specialised nature of the vibrating cells of the vocal cords.

Speech is generated by passing air over the vocal folds — commonly called vocal cords — within the larynx. The folds consist of two flexible bands of muscle lined with delicate, moist tissue called mucosa that vibrate hundreds of times per second to produce sound — much like the vibrating strings of a violin.

The scientists recreated the mucosal tissue of the vocal cords using healthy cells taken from patients who'd had their larynxes removed for unrelated reasons, as well as from a human cadaver. These cells were cultured in the laboratory for about 14 days when they grew around a bio-engineered "scaffold" to mimic the three-dimensional structure of the mucosal lining within human vocal cords.

The two types of cells used in the procedure — fibroblasts and epithelium cells — assembled themselves naturally into different layers just like they do within human vocal cords, the scientists found. To test whether these synthetic vocal cords functioned normally, they transplanted them into larynxes removed from dead dogs. They then blew warm, moist air through them to compare the sounds they made to those made by natural vocal cords.

In a study published in the journal *Science Translational Medicine*, the researchers report that the sounds produced by the synthetic vocal cords were similar to those made naturally — although without the additional modulation produced by the throat, mouth and tongue. "Voice is a pretty amazing thing, yet we don't give it much thought until something goes wrong," said Nathan Welham of the University of Wisconsin-Madison, who was one of the leaders of the research project. "Our vocal cords are made up of special tissue that has to be flexible enough to vibrate, yet strong enough to bang together hundreds of times per second. It's an exquisite system and hard thing to replicate," he said.

The scientists also transplanted small samples of the synthetic human vocal cord into mice and found that they were not rejected by the immune system, raising hopes that they could one day be used in transplant operations. "Part of the advantage of using an engineered tissue is that we can customise the size and make the tissue to fit the defect, and also fit the size of the vocal fold in the male or female or child that would be the recipient," Dr Welham said. "If we are able to store these or have them ready for off-the-shelf therapy, then they're much more readily available perhaps than trying to match donor and recipient and timing things as is done for solid organ transplantation."

The researchers warned, however, that there was still further research to be done before they would attempt a clinical trial on human patients.

THE INDEPENDENT

PLUS POINTS

More satellites?

Singapore will launch its first locally made commercial satellite next month from India — TeLEOS-1, weighing 400 kg, will be capable of taking photos at a ground resolution of up to one metre – what with the country "exploring different ways to expand its economy", according to Soo Chin Liew, principal research scientist at the remote imaging centre at the National University of Singapore. "Before, electronics was at the front end. Now, it seems like space is the next frontier. There are obvious benefits to creating a homegrown satellite — national pride, boosting the local economy, skills development to name some. But I think most countries in the region should stop making them because their massive price tag of hundreds of millions, even billions of dollars may not justify the expense relative to the benefits."

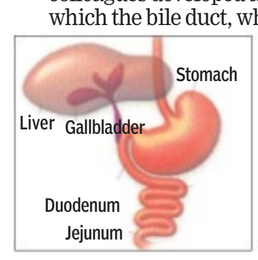
Many countries in Southeast Asia already have satellites that pretty much do the same thing: orbit earth and gather information in the same places. Sure, some satellites have a higher resolution and are better than others, but there are enough cheaper options in the region. Several organisations, including the National Aeronautics and Space Administration, provide an abundance of satellite images and data gathered throughout the world, free of charge.

"All these countries throwing up their satellites, it's ridiculous," Dinand Alkema, an assistant professor in earth systems analysis at the University of Twente in the Netherlands, said at the 36th Asian Conference on Remote Sensing held last month in Manila. "Satellites are incredibly useful, but what this region needs is coordination." That was a sentiment conveyed more than once at the conference.

SCIDEV.NET

Bile benefits

For obese patients undergoing a gastric bypass, such as the commonly used Roux-en-Y procedure, the surgery is extensive. "It basically changes the whole anatomy of the GI tract," says Naji Abumrad of Vanderbilt University. To scale down such procedures, he and his colleagues developed a new surgery in which the bile duct, which normally empties into the duodenum, is diverted farther down the small intestine to the ileum. In obese mice, this leads to weight loss, lower cholesterol, reduced blood sugar and increased energy expenditure — effects similar to those achieved with gastric bypass — without chopping up the intestine.



The new procedure also allows Abumrad to investigate some of bypass surgery's unexplained benefits. For example, the Roux-en-Y approach not only reduces the physical size of the stomach, diminishing food intake, it also improves metabolism and, in some patients, reverses type 2 diabetes independent of weight loss.

This common procedure to treat obesity shrinks the stomach and redirects the intestine to reduce calorie absorption. The duodenum, carrying digestive juices from the bile duct, is connected to the jejunum below where it has been connected to the gastric pouch. It has been suggested that these additional perks might be the result of increased recirculation of bile acids from the gut back to the liver. Bile acids, which are known to regulate metabolism and glycemic control, are mainly absorbed in the ileum region of the small intestine, hence the decision by Abumrad's team to reroute the bile ducts directly to this target. Sure enough, the mice that received bile-diversion surgery exhibited increased bile acid recirculation, as well as higher serum bile acids.

RUTH WILLIAM/THE SCIENTIST

Retirement for chimps

After downsizing its chimp research programme over the past several years, the National Institutes of Health will send its remaining animals to sanctuaries. "It seemed to me that it was time," NIH director Francis Collins told *Stat News*. "We have the information we need that keeping the animals in reserve was no longer justified."

Fifty chimps had been retained in case of a potential public emergency since 2013, when a bill was signed to retire all othe research. According to *The Washington Post*, in two years there had just been one request to study a chimp and the request was withdrawn. "It's time to say we've reached the point in the US where invasive research on chimpanzees is no longer something that makes sense," Collins said. Relocating the primates to sanctuaries will take time, and money. The *Washington Post* reported that the NIH will ask Congress for $3 million to support the animals' retirement.

KERRY GRENS/THE SCIENTIST