A tribute to the great cartoonist R. K. Laxman

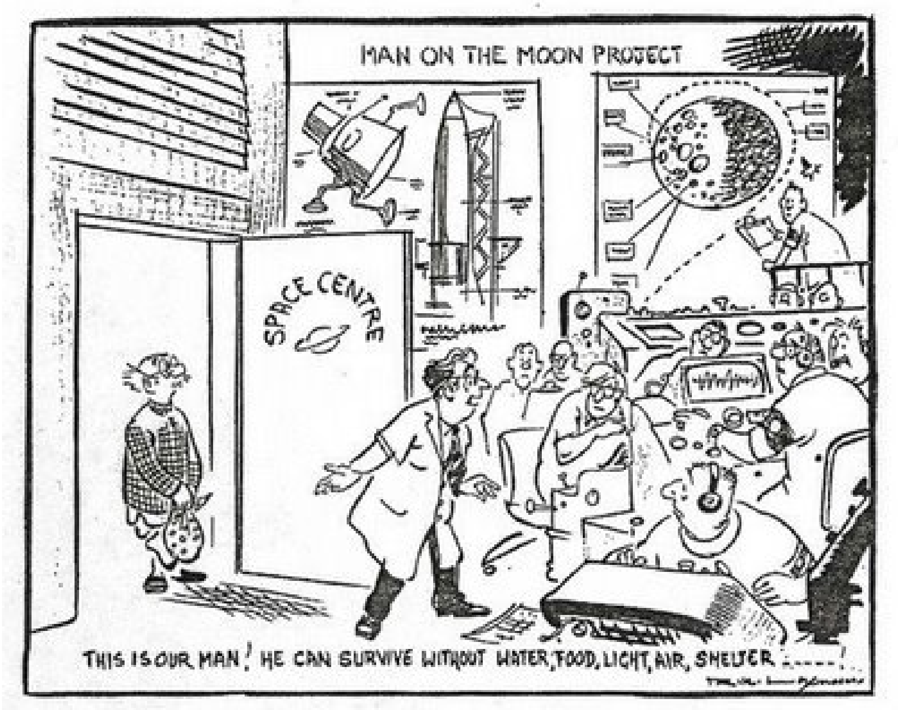
R. K. Laxman, who breathed his last on 26 January this year, was a cartoonist par excellence. He had the unique ability to see the absurd element in most situations, and to translate that into visual humour with his inimitable style of caricature. Political hypocrisy was Mr. Laxman's favorite target. His perspective for looking at the world was through the eyes of the common man. With this view, he created the famous character, The Common Man, who was the star of the daily cartoon strip "You Said It," in the Times of India.

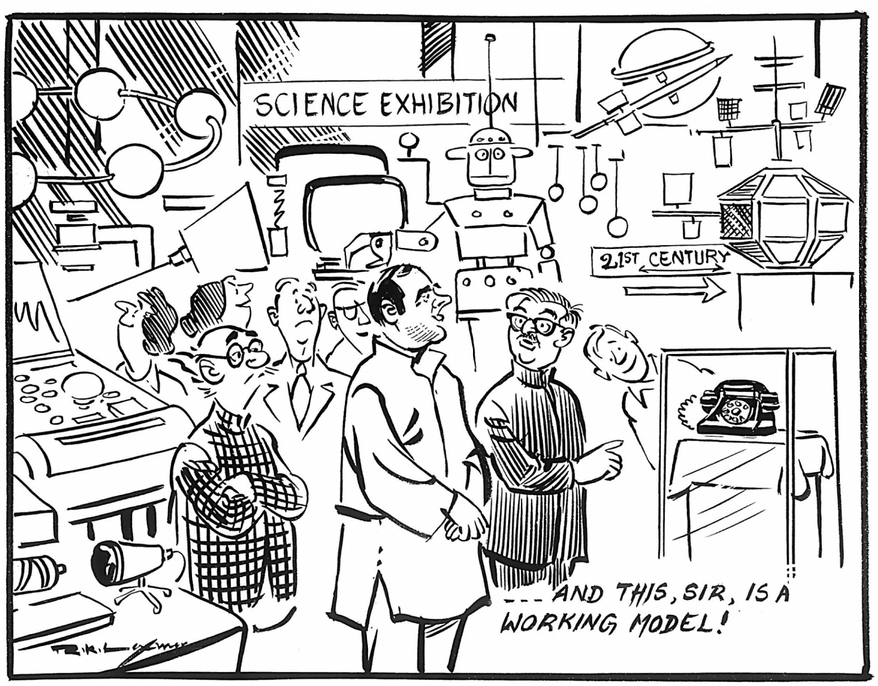
But very few know that he had an avid interest in science, and was the first science cartoonist in India. It is not easy to make a serious subject a subject of laughter. This he did with consummate ease and insight. His science cartoons were published in the magazine "Science Today," which were later compiled into a book titled "Science Smiles." Some of these cartoons were also reprinted in the magazine "Resonance" published by the Indian Academy of Sciences.

In this issue we publish a few science cartoons by Laxman as a tribute to the great cartoonist.

There must be life on the planet Earth, professor. I see mushrooms of smoke, rockets flying, explosions, bullets ...

Homage


MAN ON THE MOON PROJECT
SPACE CENTRE
THIS IS OUR MAN! HE CAN SURVIVE WITHOUT WATER, FOOD, LIGHT, AIR, SHELTER ......!


SCIENCE EXHIBITION
21ST CENTURY
--- AND THIS, SIR, IS A WORKING MODEL!

Opinions of Great Scientists

We publish excerpts from the interviews given by three eminent scientists on issues of current interest

Faith and belief should not be mixed with science — Nobel Laureate Dr. Venkatraman Ramakrishnan[1]

Professor Venkatraman Ramakrishnan

Nobel Laureate Dr. Venkatraman Ramakrishnan expressed strong views on recent events in the arena of science in India. In an interview published by The Hindu (March 20, 2015), he said "There is no room for political, personal or religious ideologies in science. Science is about investigation based on facts and experiments." He also referred to the happenings in the 102nd Indian Science Congress, Mumbai, "I heard that some nonsense was spouted at the Indian Science Congress by people who are ideologically driven" he said. "What was astonishing to me is that the Indian science establishment did not speak out instantly and strongly about it. That needs to happen. I don't have a problem with any government, including the current one. However, governments and scientists in India need to ensure that politics and religious ideology do not intrude into science. They belong to separate spheres and if they are not kept separate, it is science in India and the country as a whole that will suffer."

In another interview televised by NDTV on March 20, 2015, the interviewer posed a question regarding the recent remarks by Prime Minister Mr Narendra Modi "··· the fact that Karna was born outside his mother's womb showed that genetic sciences existed in those times" and "...we worship lord Ganesha, there must have been a plastic surgeon who got an elephant's head on a human body and began the practice of plastic surgery." In reply, Prof. Ramakrishnan commented that "faith and belief should not be mixed with science". "Modern science is evidence based. It is based on experiments and logical reasoning. In fact it is the opposite of faith. The motto of the Royal Society reads 'Nullius in verba' in Latin for 'Take

[1]Prof. Venkatraman Ramakrishnan is an Indian-born structural biologist, who shared the 2009 Nobel Prize in Chemistry with Thomas A. Steitz and Ada E. Yonath, "for studies of the structure and function of the ribosome". He has recently been elected as the President of the prestigious Royal Society, London,

nobody's word for it'. That is, you don't take anybody's words as truth, you have to look at facts, data and confront them. I think this is a very healthy attitude and it has advanced science tremendously in the last 350 years. When it comes to matters of religion, belief, etc., they are matters of personal faith and the two spheres should not be mixed." Responding to questions on improvement of science education in India, he said "Even though English is the international language of science and at higher levels English is very much required, at the school level good science books should be made available in the regional languages since a large number of students learn through the regional languages. The quality of books in the regional languages and the teaching and training is very important."

Professor Stephen Weinberg

Nonsense to say modern science existed in ancient Greece or India — Steven Weinberg[2]

Q: Many people believe that much of modern science already exists in ancient texts or teachings of their respective religions. In India, for example, the Hindu rightwing claims that many scientific and technological achievements of modern times like the aircraft, nuclear bombs, plastic surgery, etc were discovered 3,000 to 10,000 years ago. Is that possible?

A: It is nonsense to suppose that modern scientific and technological knowledge was already in the hands of people thousands of years ago. Though much has been lost, we have enough ancient texts from Greece, Babylon, India, etc to show not only that early philosophers did not know these things, but that they had no opportunity to learn them.

Q: What is the difference in the 'science' of ancient times and modern times?

A: We have learned to keep questioning past ideas, formulate general principles on the basis of observation and experiment, and then to test these principles by further observation and experiment. In this way, modern physical science (and to an increasing extent, biological science as well) has been able to find mathematical laws of great generality and predictive power. Our predecessors in the ancient and medieval world often believed that scientific knowledge could be obtained by pure reason, and where they understood the importance of observation, it was passive, not the active manipulation of nature that is characteristic of modern experiment.

Further, their theories of the physical world were often muddled with human values or religious belief, which have been expunged from modern physical science.

Q: Why did modern science arise in the

[2]Prof. Steven Weinberg is a Nobel-winning physicist, who is often called one of the most influential living scientists in the world. He has done seminal work on particle physics and has written several popular books on science. He talks to Subodh Varma of Times of India about the tension that exists between religious belief and science.

17th century? Why not earlier or later?

A: It is impossible to say why the scientific revolution occurred precisely when and where it did. Still, we can point to several developments in former centuries that prepared the ground for the scientific revolution.

One was the Renaissance of the 15th and 16th centuries, which led to an increased concern with the real world and a turning away from scholastic theology. Another was the invention of printing with moveable type, which made it possible for the books of scientists such as Copernicus and Galileo to circulate rapidly throughout Europe.

Looking further back, we can point to the growth of universities from the 13th century onward. Although these grew out of schools associated with Christian cathedrals, they became havens for secular scientific research, for Buridan and Oresme at Paris, for Galileo at Padua and Pisa, and for Newton at Cambridge.

Despite stupendous advances in science, its acceptance still seems to be limited in society. In fact, you have publicly taken on antiscience lobbyists like climate change deniers or anti-evolutionists...

There are few people today who will deny the value of science, but there are many who are terribly confused about the content of scientific knowledge. They think that it is still an open question whether evolution through natural selection is responsible for the origin of species. It is good to keep an open mind, even about the conclusions of experts, but there comes a point at which issues become settled. It is silly to keep an open mind about whether the Earth is flat.

Q: Does a person have to abandon religion in order to become a scientist?

A: Certainly not. There are fine scientists (though not many) who are quite religious. But there is a tension between science and religious belief. It is not just that scientific discoveries contradict some religious beliefs. More importantly, when one experiences the care and open-mindedness with which scientists seek truth, one may lose some respect for the pretensions of religion to certain knowledge.

Q: You have earlier written about the 'beauty' of science. What does that mean?

A: By seeking scientific knowledge over many centuries, we have developed a sense of the sort of scientific principle that is likely to describe nature, and we have come to think of such principles as beautiful, in the same way that a designer of sailboats develops a sense of the sort of design that will sail well, and comes to think of such sailboats as beautiful. There is no simple prescription for the beauty of a scientific theory, but it surely includes rigidity, the property that the details of the theory cannot easily be altered without destroying the consistency of the theory.

Did India Discover the Pythagoras Theorem? — An interview with Prof. Manjul Bhargava[3]

The Pythagoras theorem 'should either be an Egyptian theorem if you look at the standard of just having an idea about it, an Indian theorem if you're looking for a complete statement of it, or a Chinese theorem if you're looking for the proof of it,' Fields Medal winner and Princeton University Professor Dr Manjul Bhargava told Mr. P Rajendran of Rediff.com.

"It's really a subtle question—where the Pythagorean theorem first originated," says Dr Manjul Bharagava, winner of the Fields

[3]Prof. Bhargava, a Professor at the Princeton University, USA, is a Fields Medal winning mathematician. Interview by P Rajendran for Rediff.com in New York. Reprinted from rediff.com, January 9, 2015.

Medal, the world's top prize in mathematics, when asked about the controversy over the claims of Indian origins of the theorem by Dr Harsh Vardhan, India's minister of science and technology.

Dr Vardhan, a surgeon by training, made the claim at the 102nd Indian Science Congress in Mumbai, which also hit headlines for claims that included assertions of ancient inter-planetary flight, of herbal pastes being used on the feet to find underground water, ways to use dung with herbs and egg white to make natural plastics, and the performance of reconstruction plastic surgery 3,500 years ago.

The Pythagorean theorem, which could be tested in a more evidence-based model, states that the square of the hypotenuse of a right triangle is the sum of the squares of its two legs. (usually framed as $a^2 + b^2 = c^2$), where and c is the length of the hypotenuse, and a and b are the lengths of the two other sides. It is credited to Pythagoras of Samos, a mathematician, philosopher and religious leader.

"It depends on what you mean (where the Pythagorean theorem first originated)," says Dr Bhargava, the Brandon Fradd professor of mathematics at Princeton University, adding that there are different levels of knowledge of the theorem.

"One is the one that originates in 2,500 BC in Egypt," he adds. "There's no statement of the theorem anywhere, but there is some knowledge that seems to be indicated of it because there are (Pythagorean) triples (when the length of the three sides are whole numbers, such as 34, and 5)."

While these are not written down, these ratios that satisfy the theorem can be seen in structures there.

"These numbers that come up in 2,500 BC are like 3, 4, 5 and 5, 12, 13 — some small triples that show some knowledge," says Dr Bhargava. "These could easily have come by trial and error or coincidences. There's no written evidence. There's a big probability that they had knowledge of it, but there's no hard evidence; it's more speculation." If the idea was just that "there's some inkling that something like the Pythagorean theorem is true, that definitely goes back to 2,500 BC," he says.

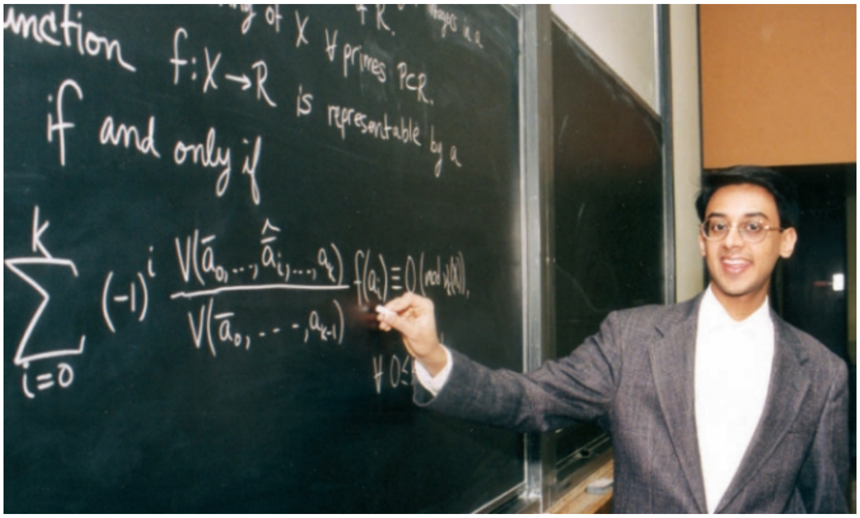
According to Dr Bhargava, "The first systematic systems of listing $a^2 + b^2 = c^2$ happens in the Plimpton tablets, which happen in about 1,800 BC (in Mesopotamia, or the modern-day Arab world). That shows a systematic understanding of producing solutions to that equation. That shows much more likelihood of knowledge of the Pythagorean theorem in a more general framework. But again there's no written statement of the theorem."

He agrees that the very large triples seen on the tablets suggest that a good understanding of the idea is more likely.

"I would guess they had a knowledge of the Pythagorean theorem," Dr Bhargava says, adding, "If you're looking for hard scientific evidence, it's completely conceivable that they were just looking at algebraic solutions to the equation $a^2 + b^2 = c^2$ without any geometric connection because there's no... picture, no reference to any triangle. it's just an abstract equation: $a^2 + b^2 = c^2 \cdots$ There's not clear evidence that geometry was behind what they were doing – although it's entirely possible."

"These are the difficulties with history — because we don't have a complete record of what they knew, we just have a little glimpse. But $a^2 + b^2 = c^2$ comes naturally for number theorists, even when they're not thinking about triangles."

Arguing again that there are different standards for empirical evidence, Dr Bhargava says, "If you're happy with a systematic solution to the equation that come up in the Pythagorean theorem even though



Professor Manjul Bhargava at Princeton. Photo courtesy: The Bhargava family

there's not a complete statement, one would say it came up with the Babylonians in Mesopotamia around 1,800 BC."

"Another standard would involve," he adds, "the requirement of a document that explicitly states the Pythagorean theorem — the geometric theorem. That first occurs about 800 BC in India in the Shulba Sutra of Baudhayan."

*"There's the first explicitly written theorem that ways that if you have a right triangle, the square of the length of the hypotenuse is the sum of the square of the length of the two legs. That is written for the first time as a theorem for a general triangle in the Shulba Sutra of Baudhayan... At least, that's the first recorded instance."

"In that sense, if you want hard scientific evidence, it's accurate to say that the Pythagorean theorem was first (recorded) in India in about 800 BC. Another standard could go beyond a mere statement," says Dr Bhargava.

"One can go further than that — which is the standard that mathematicians often use — that while it's nice to have the explicit statement but if there's no proof well, then, maybe they (the ancient culture being studied) didn't know it," he says.

"The Shulba Sutras do contain proofs in some special cases and contain numerical proofs in general, but the first actual rigorous proof of the Pythagorean theorem that's on record originates in China — after the Shulba Sutra."

"So in China in school textbooks they often call it the Gougu theorem. And that was first given in a Chinese manuscript some years later (the Zhou Bi Suan Jing, the material for which dates back to sometime between the 1046 BC and 256 BC)."

"So maybe the statement of the theorem went from India to China, but the actual proof – the complete, rigorous proof — was given in China, at least as far as written records go. That's why the Chinese ... (named) the Pythagorean theorem after the person who first proved it (and) who was in China."

According to Dr Bhargava, all these layers of information suggested the question of who discovered the theorem is not a well-defined one.

"It depends on what standard you are

using," he says. "But a very natural one for the common people is, well, where was it first stated explicitly. And for that India is the correct answer and it's certainly reasonable to say the Pythagorean theorem originated in India. But if you want to be really rigorous and (ask) who first totally understood even the proof of that then it would naturally be the Chinese."

Dr Bhargava feels there is something to draw from the discussion.

"The Pythagoras theorem is clearly the wrong name; that's clear," he says, laughing. "Pythagoras clearly stated it way after it was stated in India. It is not clear that he proved it at all. From neither perspective — the statement or the proof — is the 'Pythagorean theorem' a correct name."

"It should either be an Egyptian theorem if you look at the standard of just having an idea about it, an Indian theorem if you're looking for a complete statement of it, or a Chinese theorem if you're looking for the proof of it," he adds.

Dr Bhargava agrees that nomenclature can be driven by more chauvinistic needs.

"I think sometimes some nationalism, if it inspires them (students) to go into that subject and do well, it's OK as long as it's not false. And all these countries have a thoroughly legitimate claim to say the Pythagorean theorem is invented there. And they are all correct, depending on what standard they implement." □

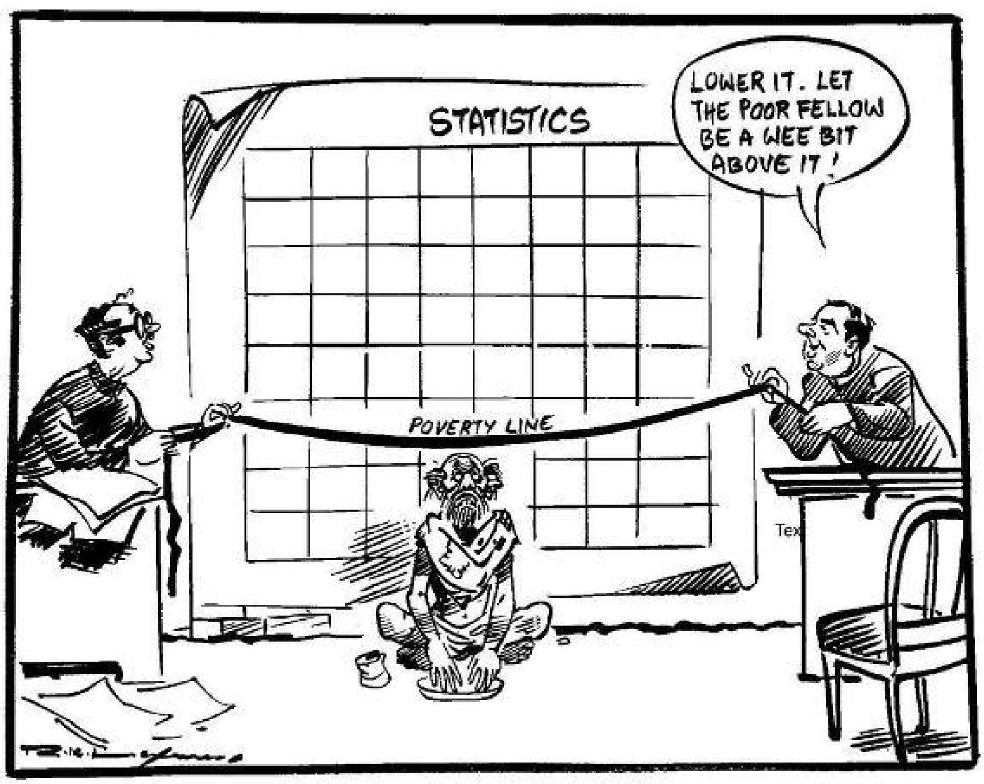


Image Courtesy: The Times of India

25 Years of Hubble Space Telescope

P. N. Thankachan*

HUBBLE SPACE TELESCOPE (HST) was one of the most magnificent instruments man had ever made. The present day knowledge of our universe is largely due to the HST. HST was launched into orbit in 1990. Till 2011, it had performed one million observations, and about scientific papers were published using these data. Thousands of galaxies have been discovered by the HST. Now we understand that our universe has more than 10000 crores of galaxies like our Milky Way galaxy, which has almost 10000 crores of stars.

Since the time of Galileo, telescopic observation about the objects in the sky have shaped our understanding of the universe. In the 19th century, William Hershel discovered many objects in the sky with the aid of a telescope. Larger and larger telescopes were built in different countries, which enabled us to look deeper into space. But the Earth-bound telescopes had a problem: the light from the distant objects has to travel through air to reach the telescope, and this blurs the image. To minimize this effect, observatories were built atop mountains, but that also had its limits.

The idea of a space-based telescopes was, for the first time, put forward by an American scientist Leyman Spitzer. In his paper 'Astronomical advantages of extra-terrestrial observatory' (1946), he explained the possibility of installing a 10" telescope in space with the help of the then rocket technology. His aim was sky observation without the hindrance of the atmosphere. In 1962, there was a positive development and in 1965, a project headed by Leyman was started.

The 'Pillars of Creation' nebula photographed by the Hubble Space Telescope

In 1966, the Orbit Astronomical Observatory (OAO) was launched, but failed due to battery complaints. In 1968, OAO2 was successfully launched and till 1972, it provided many useful data.

The HST was launched on April 24, 1990. But the first pictures sent by HST were blurred. It was found that the 2.4 m diameter mirror in the HST had a problem known as chromatic aberration. Then a historic mission to repair the mirrors in the HST at the height of 570 km from the Earth was taken, and in 1993 engineers were sent in the space shuttle 'Endeavour' to repair the mirrors.

Within months of the repair, the HST recorded a magnificent celestial event—the

*Prof. Thankachan is with the Department of Electronics, Rajiv Gandhi Institute of Technology, Kottayam, Kerala.

The Hubble Space Telescope in orbit.

comet Shoemaker Levy 9 breaking into the fragments and plunging into the Jupiter.

When it was launched, the HST had three aims: To study the rate of expansion of universe, to obtain authoritative knowledge of the galaxies, and to study the inter-galactic gas clouds.

One of the important observations made by the HST is known as 'Hubble deep field'. in such an observation, a segment of the sky is observed continuously for 10 days. In 1995, the HST found 3000 galaxies in an angle of 2.5 arcs in the direction of the constellation Ursa Major. 'Deep field south' was another observation which too revealed a large number of galaxies. The clear images taken by HST also helped to pinpoint distant supernovae of a special type that astronomers uses to measure distances. This allowed the astronomers to measure the distances of even more distant galaxies, or peer back further in the history of the universe. This led to the momentous discovery that our universe is not only expanding, but also accelerating.

Another important discovery in astronomy that the HST helped to make was that almost every galaxy contains a black hole at the centre. It also appears that the black hole mass is intimately connected to the galaxy mass.

The 1995 mission to fix the spherical aberration problem was only the first of five missions to service the instrument. Subsequent service missions to repair the telescope and to upgrade it occurred in February 1997, December 1999, March 2002, and May 2009. During the 1997 service mission a spectrograph and an IR camera are added to the telescope. In 2007, a new spectrograph and a Wide Field Camera were installed. The HST has the ability to see in multiple wavelengths, including infra-red, visible and ultra-violet ranges.

To mark the 25th anniversary of the launch, a snapshot of the famous 'Pillars of Creation' in Eagle Nebula was taken last year. The first time the 'Pillars of Creation' was snapped in 1995. □

Mitigating Devastation by Floods

Sabyasachi Maiti *

A rainy morning of Bengal usually starts with sad news of flood casualties. Even in the 21st century, societies with ultra-modern developments are still unable to overcome this curse of nature. Natural calamities like tsunami, cyclone, earthquake, forest fire etc. are still capable of causing extensive devastation. These are still not in our control. Advances in science have given mankind a deeper understanding of the laws that guide the natural phenomena, but in our country we are still a long way off from proper monitoring that could somewhat mitigate the devastating effects of natural calamities. Developing countries like India and others in southeast Asia are still unable to utilize fully the advances in science and technology for this purpose. Among the natural calamities flood is very common in Bengal. Every year, floods cause huge loss of human life, cattle, food grains and homesteads. Although globally many early warning tools are available, here their use is often limited, and there is a general lack of awareness about such early warnings. It is important to bring about cooperation between scientists, public and government officials and policy-makers for integrated flood management. Rising above all superstitious beliefs, or personal benefits, floods must be looked upon as large-scale events, and every aspect of water movement from source to sink in every zone must be scientifically investigated.

*Dr. Maiti is in the faculty of the Geology and Geophysics Department, IIT Kharagpur.

'What is flood?', 'Why does Bengal face it frequently?', 'Can any measure be taken by the state or the people to prevent it?', 'Is this man-made?' Many controversies appear about Bengal floods. With talks of climate change floating around, we keep blaming our climate also. However, with all the arguments and counter-arguments, we actually overlook both the role of nature and our social responsibility to prevent disasters due to floods. Let us start with a simple definition of flood. Flood is overflow of water from its natural channel causing submergence of surrounding land and habitats. Although flood occurs due to seasonal excess of water flow caused by heavy rainfall, and/or tidal surges, tsunamis, bursting of glacial lakes etc., unplanned damming of river channels, reduction of floodplain areas by unscientific intervention and unplanned agricultural activities also can trigger flood situation. Floods can be dangerous in two situations: 1) when sudden rush of water from high elevation occurs, and 2) when restricted flow of water creates water-logged or stagnant situations for a long period of time. Frequent floods without abnormal rainfall usually occur due to our negligence, lack of awareness and improper interaction between local people and public officials. Its devastation can be definitely minimized with cooperative participation.

Mutual cooperation is possible only when we think about nature beyond our textbooks. The definition of natural drainage, geomorphologic creation of natural levee, natural flood protection- - lessons about

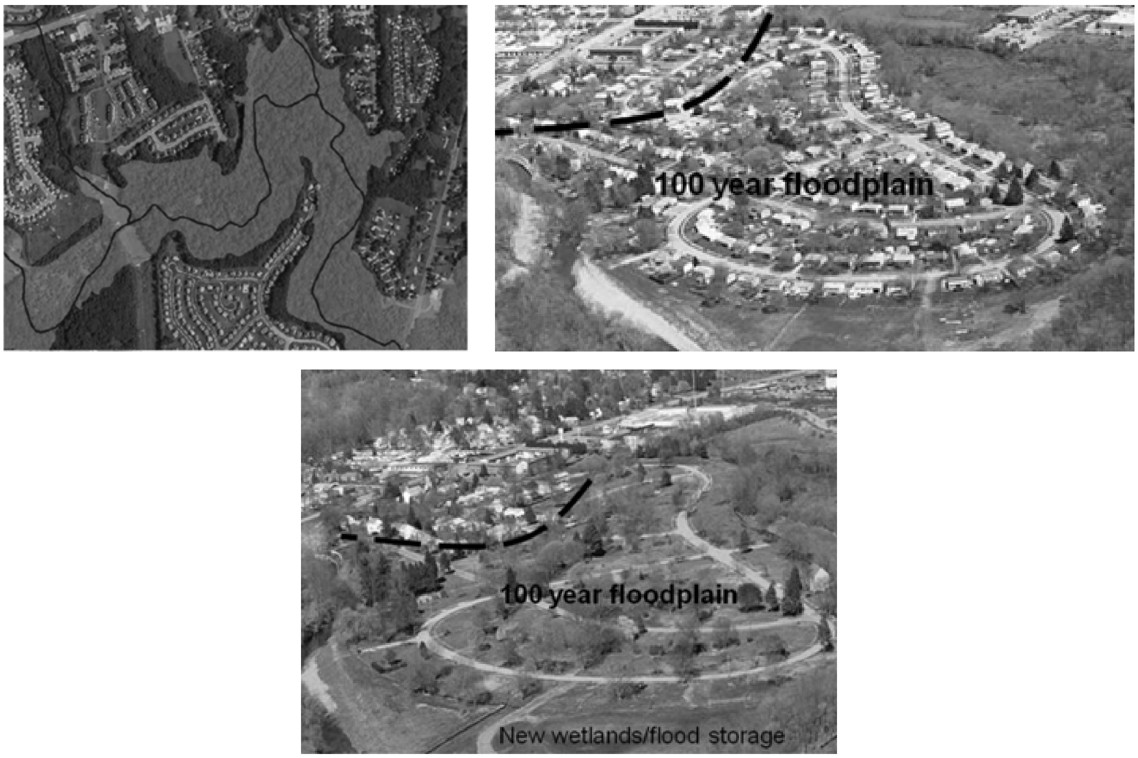


Figure 1: a) Regional view of flood-prone area with demarcated 100 year flood plain; b) Zoomed area falls with 100 year flood plain area; c) The areas after completion of evacuation and natural rehabilitation for flood water storage/ wetland

all of these are available in school text-books. In brief these can be summarized as follows. In natural drainage system, the fluvial geomorphology has three important flood controlling components, known as natural levee, flood plain and natural scarp. Natural levees are elongated ridges of sediments that are built up by river action along the river banks; floodplains are the areas beyond the natural levee where the water overflows from the channel during periods of high discharge and the flood water deposits the sediments on the floodplains; natural scarps are steep walls bounding the river channel. Among these three, natural levee is the first stage of protection from a river overflowing its banks; it is naturally built up during seasonal events of floods. Flood plain is the area of river valley where it can play freely with seasonal, annual or decadal changes of river course; if the river is allowed this play the area beyond the flood plain is protected. Natural scarp also offers protection from high level of water. All these three geomorphic features are present in most of the drainage systems. A few abnormalities may happen due to tectonic movements or sudden changes in river course. However, school children today can hardly visualize what these look like. The reason is simple; because most of the components are forcefully occupied and modified by buildings, agricultural fields, sand mining, unplanned local dams etc.

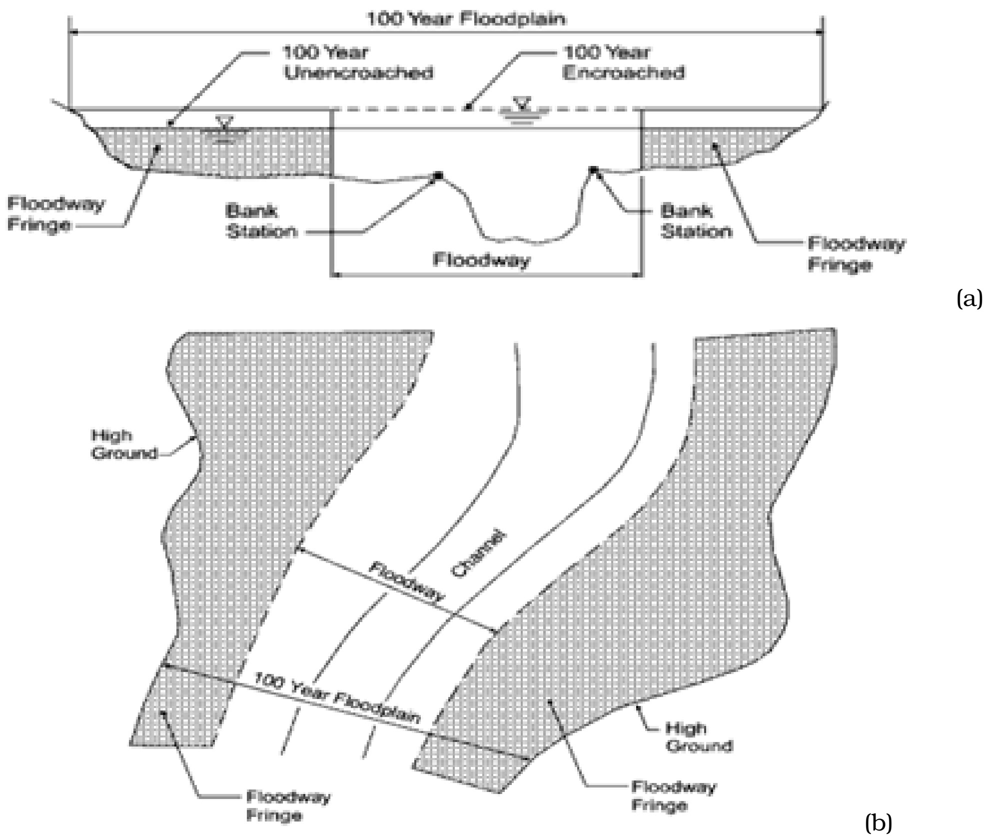


Figure 2: 100-year flood plain: (a) cross section, and (b) top view.

Flood in rural Bengal refers to riverside flood, which occurs frequently in each monsoon season. Even, West Bengal's capital Kolkata is often waterlogged during this time. Most of the time, immediate prevention strategies of the Government irrigation department are erection and repairing of embankments, construction of pumping stations in waterlogged areas and local attempts of irrigation diversion. Although such costly initiatives are undertaken for cities and business areas, rural areas are often neglected. As a result, we never had permanent solutions for this huge flood water flow, which ultimately reaches the oceans. All through the years after independence, we never applied a systematic and well-coordinated line of action in which flood protection and water-harvesting are properly taken care of from the entire source to sink areas. This knowledge is known as integrated watershed management. It is not right that we don't have any scientific information or knowledge to do that. But most of our knowledge is confined in textbooks, scientific publications, and project submission reports only. Now is the time to remedy this by bringing scientists in a loop with Government officials and public. The arrangement may be looked upon as a triangle where each of them is linked with the two others.

Figure 3: Elevation and relocation of a flood-prone home on the Delaware Bay.

Strength of mutual cooperation between public and Government for flood mitigation can be discussed for the following case study in Glenville floodplain, USA. The local people were participated after giving their own lands to city planner. The flood plain area was partially evacuated and all other utilities (e.g., roads, electricity, pipelines etc.) were disconnected and demolished to give free flow of flood water, and to ensure proper diversion of channel water towards detention ponds. However, these kinds of non-structural measurements are successful for small city or village level where ensuring evacuation and relocations are less complex. Other non-structural methods are Elevation, Floodwalls, Levees and Berms, Buyout/Acquisition, Dry Flood Proofing, Wet Flood Proofing, Flooding Warning etc. These measurements are cost- effective and easy to implement with participation of Government officials and stakeholders. In contrary, Structural measurements are very costly to implement and maintain. In long-run unmanaged initiative can also exaggerate flood situations. Following are few examples of structural measurements, viz., Dams, Reservoirs, Floodwalls, Levees, Channels, Straightening, Clearing and snagging, Closure structures, Bridge modifications, Conveyance modifications, Pumping, Channel diversions, Beach Nourishment etc. These measurements are more appropriate for cities with large population where relocations are impossible. However, before adopting any particular type of flood protection measurement, a regional planning with demarcation of 100 years flood situations, flood prone areas, existing resources (ecological, economical and socio-political), elevated or protected zones, and risk assessments are important. Many countries implement flood regulations, flood insurance, building codes for flood prone areas and frequent mock-drills of flood situations. Such implementations are possible when public and Government officials are ready to accept scientific investigation, spatial analysis of management decisions openmindedly beyond any political or personal benefit.

Scientists' participation is important in many ways. They are responsible for studying natural river flow from source to sink, considering various types of habitats, natural resources and socio-economic activities. They must define various modes of management strategies for different zones based on their location values. Hard protection for each and every part of the river banks would actually make the river floodprone and devastating. Lastly, based on their defined strategies, they must install and guide different modes of early warning systems and codes for different locations. Similarly, Government officials can play important roles by diminishing the gaps between the scientists and the public. They must initiate participatory learning and awareness about warning system, evacuation strategies for the public, including school children, the aged and the infirm. Finally, great responsibilities lie with the local public who are most important to locally maintain regional watershed management strategies. The Government must make serious efforts to educate the public on the various aspects of flood control and disaster mitigation. Schoolchildren and college students can take initiative to make the local people aware about the hazardous effects of unplanned construction and mining. Here a significant change may be required in our primary education system. We must give due emphasis on real life issues rather than rote learning of theories for examinations only. We must adopt the culture of honouring the skill acquired through practice and theory. Integration and respect for society and social responsibilities are best strategy for facing the challenges of tackling any natural calamity.

We human beings are social; we are sustained by social interactions; thus our destiny in this world will be defined by — 'how social we are?' Finally, the flood disaster is preventable if we are socially conscious. □

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Evolution of Cell—the Unit of Life

This is the translation of a chapter from the Bengali book "Bibartan Juge Juge" (Evolution through ages)

EVERYTHING IN NATURE is composed of some basic units or "building blocks". The structural and functional unit of life is the "cell". All life forms are composed of these simple building blocks called cells.

The term "cell" was first coined by the English scientist Robert Hooke (1635-1703) in 1665 while observing the structure of a cork under a microscope. He found contain honeycomb-like chambers — which he termed as "cell". But the role of a cell as structural unit of life was established much later. Around the year 1838, two German scientists Matthias Schleiden (1804-81) and Theodor Schwann (1810-1882) in their book "Cell Theory" proposed that the body of all plants and animals living on Earth is made up of a single or a large number of cells. After this recognition of cell as the unit of life, people started investigating its structure, nature, and evolution, which still continues to this day.

How small or large is a cell exactly? How does this unit of life look like? True, most of them are so small that they cannot be seen through our naked eyes. Generally their diameter varies from 1 to 100 micrometer (micrometers) [1 micrometer = 1/1000,000 m]. Normally our eyes are incapable of distinguishing things smaller than 0.2 mm in diameter. That is why almost all cells are not separately visible unless we take the help of a high quality optical microscope. Simple optical microscopes have magnifying power of about 2 micrometers, i.e., they can magnify an object to 200 times its actual size. With such a microscope, almost all types of cells, and their inner structure can be clearly studied. Electron microscopes have magnifying power of 0.5 nanometers (1nm = 1/1000,000,000 m), which makes them the best instrument available for studying the finer details of internal structure of a cell.

After the discovery of advanced microscopes and different physical processes of separating the different parts of a cell, called organelles, scientists got involved in revealing the mysteries of internal cell structure. Their prolonged investigation ultimately led to the conclusion that, there are two types of cells — prokaryotes and eukaryotes, because in spite of a few similarities between a bacterial cell (prokaryote — ill defined nucleus) and a well developed plant or animal cell (Eukaryote — well defined nucleus), there are fundamental differences.

Footprint of early cells

We know that the study of fossils is one of the best methods of finding the traces of evolution of life. The fossilized forms of microscopic organisms that indicate the first signs of life are termed as 'microfossils'. The oldest microfossils found so far are approximately 350 million years old. These ancient microfossils are very small in size (1-2 nanometers in diameter) and all of them are unicellular, lacking any special intracellular structure. Scientists also observed that these simple microfossils surprisingly resemble a unicellular organism present now in plenty everywhere in nature, which are termed as microbes or bacteria. Scientists named this simple type of cells as prokaryotes. In Greek, the word prokaryote means 'before kernel" or prenucleus or without nucleus.

Presently, the bacteria found in our surrounding environment are called eubacteria. These bacteria are different from the fossilized bacteria. Naturally so, because the living environment of eubacteria is totally different from that of the earliest bacteria.

Well, can we get some idea about the early bacteria by studying the present living bacteria? Yes it is possible! There are places similar to pre-life conditions on earth—like hot water springs, craters of volcanos on sea beds where temperature is very high, salty marine waters etc. These environments are considered to be unfavourable for life. On studying bacteria growing in these unfavourable conditions it is found that the cellular structure and metabolic activities of bacteria in these regions differ from that of the eubacteria living in natural moderate environment. These types of prokaryotes (bacteria) are termed as archae-bacteria. Many of these organisms are anaerobic (respire in the absence of oxygen). They die in the presence of oxygen. Hence we can conclude that the present archae-bacteria (that survive in oxygen starved regions) are similar to the fossilized bacteria.

Later the research of scientists especially that of Dr. C. R. Woese of the University of Illinois led to the following conclusions.

1. The prokaryotic cells originated from ancient cells,

2. This prokaryotic cell group bifurcated into two separate lines — one of which represents archae-bacteria, the other, eubacteria.

3. All the present bacteria or the cells of prokaryotic group draw their lineage from these two lines.

Figure 1: Microfossils: Bacteria on fossil rock surface.

One typical member of eubacteria group (prokaryotic type) is the cyanobacteria which are able to photosynthesize. They are believed to exist approximately 280 million years ago. Their ability of photosynthesis proves that cellular metabolism first started in prokaryotic cells, which, in course of evolution gave rise to structures necessary for the development of multicellular organisms. Oxygen evolved as a result of their photosynthetic activity, which slowly made the environment suitable for the origin of eukaryotic cells.

Fossil evidence indicates that there were no multi-cellular organisms or eukaryotes before 150 million years. That means the Earth was ruled by simple unicellular bacteria for half its lifetime, approximately for 200 million years.

The Footsteps of New Cells

It was observed that the ancient microfossils that evolved after 150 million years ago had more complicated structure in comparison to the cells existing before that time. In size these cells were quite large (60mm diameter), and were provided with intercellular chambers. Cell wall was well organized and organelles surrounded by intercellular membranes were also present. These new cells are designated as Eukaryotic (true karyotic / true nucleus) cells. Thus we see that cells of prokaryotic group carry the signs of primordial evolution. And eukaryotic cells show signs of an advanced phase of evolution.

The appearance of well-defined and stable cell membrane is another distinctive feature observed in the effort to explain evolution of cells. It is the link between acellular biomolecules and multicellular plant and animal forms. All cells have a distinctive membrane called the cell membrane. This helps them maintain their separate existence from the surrounding environment. These membranes are called semi-permeable membranes; they are semi-solid in structure and allow movement of molecules selectively. The cell membrane maintains connection with the extra-cellular environment as well as with the neighbouring cells. Cell membranes contain several respiratory enzymes and carrier proteins. The inner part of the cell that is surrounded by the membrane is called cytoplasm.

Let us now delve a little into the structural features of the prokaryotic and eukaryotic cells. This will help us understand the case in point about the evolution of cells better. The explanation of the structural details and complexities will help us appreciate the internal structure of cells and their evolutionary development.

Structure of Prokaryotic cells

Prokaryotic cells are much smaller in size compared to eukaryotic cells. (1.25×1.2 to 1.5×4.0 micrometers). These are mainly spherical or rod shaped, although there are also some bacteria of other shapes. We have to keep in mind that all prokaryotic organisms are unicellular. Often a large member of cells, sometimes more than hundred in number, remain as a group shaped in the form of a garland. All forms of eubacteria, archaebacteria and blue green algae like Nostoc, Oscillatoria, etc., belong to this group. All prokaryotic cells have the following general characteristics :

- They have semi-permeable cell membrane described earlier.
- Cytoplasm is devoid of any organelles separated by membranes.
- There is no nucleus. Instead, the DNA molecules are scattered in a particular region of the cell.
- The liquid matrix of the cytoplasm i.e., cytosol contains a large member of ribosomes (500 to 50,000 in number). These small ribosomes are the protein factories of the cell.

Apart from the above characteristics, a few prokaryotic cells also have some special features. For example, most of them possess cell wall outside their cell membrane. The only exception is Mycoplasma, which lack a cell wall. In case of eubacteria, this cell wall is composed of a substance called peptidoglycan which is a polymer of sugar and amino acids that forms a mesh-like layer. Its main function is to provide rigidity to the cell and to check abnormal swelling. In some bacteria the cell wall is surrounded by a jelly-like polysaccharide layer, commonly named as capsule. Many

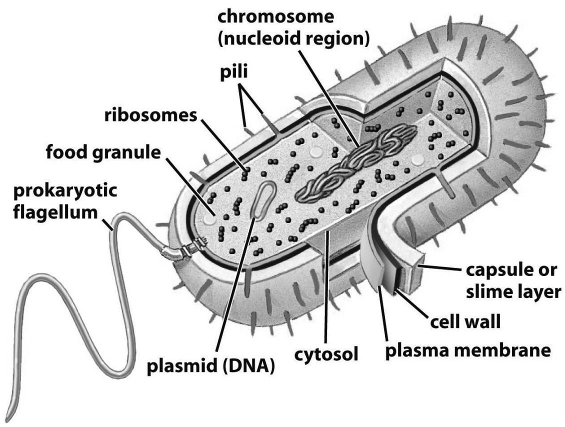

Figure 2: Structure of prokaryotic cell.

disease-causing bacteria contain this capsule by means of which they can avoid the attacks of white blood cells — our body"s defense mechanism.

In case of photosynthetic bacteria like cyanobacteria, a portion of the cell membrane extends and is folded heavily resulting in the formation of inter-cytoplasmic membrane that stores the photosynthetic pigment bacterio chlorophyll and other accessory materials. These cell organelles have a special significance in understanding the course of evolution of photosynthetic cells. In some bacterial cells this type of inter-cytoplasmic membrane is termed as mesosome, which helps in cell division and in reactions that produce energy.

Certain types of bacteria possess one or more whip-like organs of locomotion made of a protein flagellin. These are known as flagella. With these flagella they can swim in aquatic environment. Also there are fine thread-like structures called pili or fimbriae present on the surface of bacteria, which help it to attach to surfaces or to other bacteria. Bacteria can even exchange their genetic material by their sex pili.

Now it is time to sum up details regarding prokaryotic cells. They are of two types: archae-bacteria (those living in extreme conditions) and eubacteria (all the bacteria living in moderate conditions). Among eubacteria, the mycoplasma and cyanobacteria have a few unique characters different from the regular bacteria and therefore there is a special mention.

Structure of Eukaryotic Cells

Other than bacteria and blue green algae, all advanced plant, animal, and fungal cells are called eukaryotic cells. Eukaryotic cells are highly developed, well organized, and larger in size (diameter 8 to 100 micrometers). Like prokaryotic cells, these cells also have cell membrane, cytoplasm and ribosome. But they differ from prokaryotes in having different organelles (like nucleus, mitochondria, endoplasmic reticulum, Golgi-body, lysosome, plastid, and vacuole) separated by intra-cellular membranes. Also, there are ribosomes, centrioles, microtubules, etc., that are not surrounded by membranes. Not all eukaryotic cells contain all of these organelles. But each of them has some specific functions which they perform wonderfully to maintain the function of the living body.

In the eukaryotic cells, the complexity is seen both in structure and function. The nucleus, the mitochondria, endoplasmic reticulum, Golgi complex and plastids (in plant cells) are membrane bound cell organelles, each of which have a specific function.

Nucleus is the key organelle containing the genetic material DNA and proteins. The DNA along with proteins form thread like chromatin network which during cell division condenses into chromosomes. Every species has a fixed set of chromosomes.

Mitochondria is a rod shaped cell organelle, also called the "powerhouse of the cell" because it synthesizes ATP (Adenosine

Tri-phosphate) the energy rich molecule that drives all life processes like respiration, photosynthesis, growth, etc. In simpler words, this organelle provides energy for keeping the cell active! Mitochondria has its own DNA but no nucleus!

Plastids are variously shaped cell organelles found only in plant cells. When they have coloured pigments in them, they are called chromoplasts. Red coloured pigment containing chromoplast is called rhodoplast found in red algae, similarly green coloured pigment containing chromoplast is called chloroplast, which we see in all green plants. When there are no pigments in plastids, they are called leucoplasts meant for storage. Plastids help in photosynthesis. Chloroplasts have played a key role in evolution because they have, through the process of photosynthesis, produced oxygen that later became the gas which dominantly supported both plant and animal forms. This organelle also has a DNA of its own but no nucleus.

Endoplasmic reticulum provides the skeletal network within the cells and help in protein synthesis because some part of it has ribosomes, help in lipid and sterol synthesis. Golgi complex is sac-like and helps in packaging and transfer of synthesized nutrients. Lysosomes are vesicles or bubbles which are membrane-bound and contain enzymes called lysozymes which help in digestion of foreign particles. They are also called the "suicide bags" of the cells, because they cause cell death in special conditions. Vacuoles are membrane bound and are present majorly in plant cells.

In plant cells the prime functions of the vacuole are — (i) to store food material (ii) to keep various excretory substances separate from cytoplasm and to release them outside the cell whenever necessary, and (iii) to help in pollination by attracting pollinating insects through the pigment anthocyanin.

Apart from the above mentioned cell organelles, a bunch of thin elongated fibres are distributed through the cytoplasm of the entire eukaryotic cell. These microfilaments, made of the protein 'actin", sustain the characteristic shape of a cell. Another type of filament called microtubule made up of the protein 'tubulin", actively participates in forming a special type of fibres that facilitate the movement of chromosomes during cell division. Microtubules also help in the movement and locomotion of a cell.

Other than all these major cell organelles, various non-living materials or intercellular substances like glycogen granules, starch granules, oil droplets, etc., are also spread over the cytoplasm of any cell. All these intercellular materials are utilized to reserve food particles and to release energy through oxidation when necessary.

Evolution of eukaryote from prokaryote

Microfossil analysis and comparative studies of recent prokaryotic and eukaryotic cells have indicated that eukaryotic cells have originated from prokaryotic cells in course of evolution. Out of the several evidences supporting this hypothesis, perhaps the strongest is the observation of symbiosis of two or more prokaryotic cells producing greater functionality. Moreover, critical structural analysis of chloroplast and mitochondria shows that their sizes are very similar to those of prokaryotic cells. These organelles contain certain nucleic acids which help them to produce specific proteins that can be utilized for their own construction. They have a relative independent existence. Again these are not outside the control of the core nucleus, because most of the proteins are synthesized from the nuclear DNA molecule.

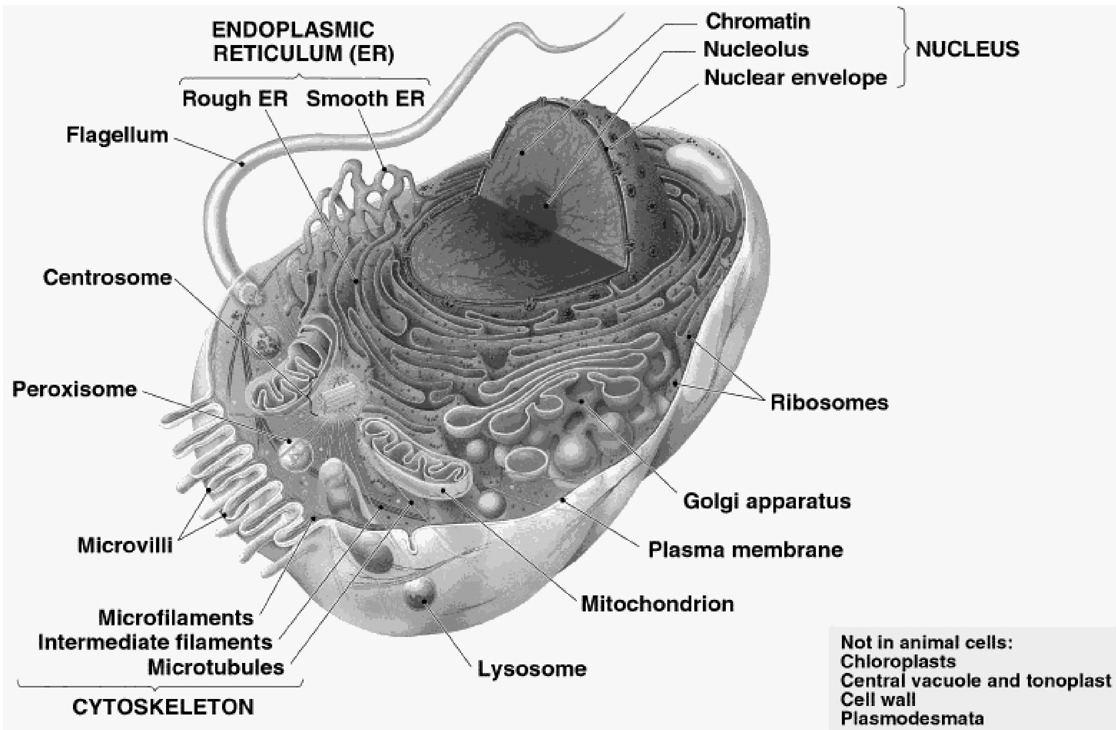

Figure 3: Structure of eukaryotic cell.

According to this theory, at some point in the past some energy producing self-living bacterium started living inside another prokaryotic cell. This symbiotic relationship proved mutually beneficial for both the organisms, as it enabled certain functionalities which were impossible for each one individually. Thus this form was naturally selected. In course of evolution this association of two or more prokaryotic cells got transformed into a eukaryotic mitochondrion. In a similar manner photosynthetic bacteria got transformed into chloroplasts in course of evolution.

Multicellular Life

From the above discussion it is clear that the eukaryotic cell has much greater structural and functional complexity in comparison to the prokaryotic cell. The division of the eukaryotic cell into chambers separated by membranes is an important event in the evolutionary pathway. This chambering added the power of certain specific functions to some cell organelles, which enabled a cell to acquire specific characteristics. Some of these specially featured cells started to live together forming a colony. Later on, these colonies having specific collective features may have evolved along different pathways to give birth to advanced multi-cellular organisms through cell tissue organ differentiation. □

The translations of the other chapters published earlier can be found in the website http://www.breakthrough-india.org /archive.html

A Brief History of Science
Part 9: The Development of the Ideas of Causality and Determinism

Soumitro Banerjee*

IN THIS INSTALLMENT of the essay, instead of proceeding chronologically following the discoveries in specific periods in history, we shall deal with two concepts that are central to the whole of science. We shall see how these concepts evolved, and to trace the development all the way to the modern age, to arrive at the modern understanding of these concepts.

Causality

Causality is one of the central doctrines in science. Much of science bases itself on the premise that nothing happens without a cause. Scientists look for the reason behind every event. When an apple falls from a tree, they ask why did it come down? When they see the moon moving around the Earth, they ask why does it do so? When they see someone ill, they look for the reason behind the disease. All such investigations start from a question that the scientist forms in his mind, and the question mostly concerns the cause of various things we see around us.

Even though causality is such a crucial issue in science, it has been subject to intense controversy among scientists and philosophers on the question of what constitutes a cause for an event. Both the definition of 'cause', and the way of knowing whether A and B are causally linked have changed significantly over time. In order to develop a clear idea about the modern concept of causality, we have to work step by step through the course of the history of evolution of the idea of causality.

Aristotle's causality

The idea that there is a cause for every event was based on man's day-to-day experience, and naturally the initial formation of the idea took place in the early human society. In fact, all human actions are based on some understanding of causal relationship. Tigers *cause* death, and so keep away from tigers. The little seed *causes* the tree of the future, and so you plant the seed where you want the tree to be. Such mundane day-to-day actions of man also depended on some rudimentary concept of causality.

As far as we know, the idea first took a well articulated and concrete form in ancient Greece. We find a rather refined expression of the idea of causality in the writings of the prominent Greek philosopher Aristotle. He defined four types of causes behind every event: material cause, formal cause, efficient cause, and final cause. Consider a bronze sculpture, and ask what is the cause behind it? Aristotle says that the cause can be searched in

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four different ways. First, it is made of bronze. Hence the material, bronze, is a cause in the sense that the sculpture would be impossible if the bronze were not there. This is the material cause. Second, the sculpture has a form, and the sculptor had that *form* in mind when he worked on the bronze. This is the formal cause. Third, the sculptor is the external agency that acted in order to produce the sculpture. Hence the sculptor is also a cause—the efficient cause. The final cause is that for the sake of which a thing exists, or is done—including both purposeful and instrumental actions. The final cause, or teleos, is the purpose, or end, that something is supposed to serve.

The last one, the final cause, had an obvious religious leaning. So, during the advent of the middle age, the Church establishment latched itself to it, and saw divine hand as the "final cause" behind everything that happens. It became the default Church philosophy and was taken as the theoretical grounding behind the scholasticism practised throughout the middle age, only to be overthrown at the advent of Renaissance.

During the renaissance, this concept of causality came under scrutiny as scientists of that period no longer accepted the authority of Aristotle and refused to take his ideas as infallible truth. We notice a change in their idea of causality by the way they pursued their science, that is, the way they looked for the cause behind different natural phenomena. But in this period we do not see any focused treatment of the subject in the writings of the scientists. Only in Galileo's writings we see a rejection of the idea of final cause.

Hume's causality

In the 18th century, the Scottish philosopher David Hume (1711-1776) offered a full discourse on the problem of causality in his famous book *A Treatise of Human Nature*. Hume freed the idea of causality of religious orientation, and made it stand on an empirical ground. He found worthless the medieval scholars' appeals to the power of God to cause things to happen, since, as he said, such claims give us "no insight into the nature of this power or connection" (1978 edition, p. 249). Instead, he proposed an idea of causality that could be tested. According to Hume, two events A and B can be said to be causally connected if they satisfy three criteria:

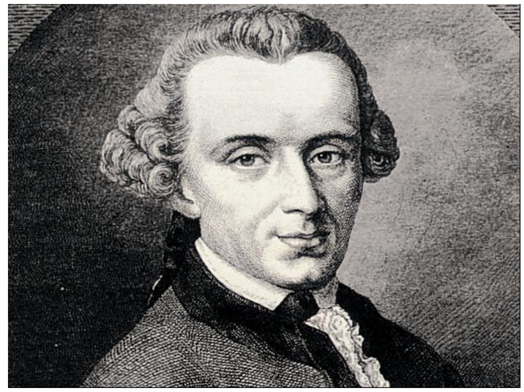
David Hume (1711-1776)

- *Precedence*: A must precede B in time;
- *Contiguity*: A and B are contiguous (that is, not widely separated) in space and time;
- *Constant conjunction*: A and B always occur together.

By secularizing the notion of causality and by making it testable, Hume made an enormous contribution to the advancement of human thought. Much of the development of post-Newtonian science follows the path shown by Hume.

Yet, his definition of causality had important flaws. Indeed, one could erroneously conclude "day causes night," because the occurrence of day and night follow all the criteria set by Hume. One problem of Hume's criterion of precedence was pointed out by the eminent German philosopher Immanuel Kant: If a lead ball rests on a cushion and makes a dent, it is clear that the dent is caused by the pressure of the ball. Yet, the resting of the ball and appearance of the dent occurs simultaneously, not one after the other. Had Hume said "an effect cannot precede the cause," this logical problem would not occur. The criterion of contiguity follows from common sense: If a person is found murdered, the investigator should look for the cause in the immediate vicinity, not one hundred miles away. But the tides in the Sunderbans are caused by a distant object—the moon—and hence the cause is not contiguous with the effect in space. The criterion of constant conjunction also has similar problems. It is known that quinine cures malaria. Yet, if you administer quinine to a hundred malaria patients, 95 may recover and 5 may not. If we were to follow Hume, we could not conclude that quinine causes cure of malaria.

Hume had also argued that the notion of causality is a mental construct, not a property of nature. According to him, humans observe certain sequence of events repeatedly, and notice that certain events occur in contiguity, succession, and constant conjunction. This experience leads the mind to form certain habits: to make a "customary transition" from the cause to the effect. So instead of ascribing the idea of necessity[1] to a feature of the natural world, Hume took it to arise from within the human mind, when the latter is conditioned by the observation of a regularity in nature to form an expectation of the effect, then the cause is present.



Immanuel Kant (1724-1804)

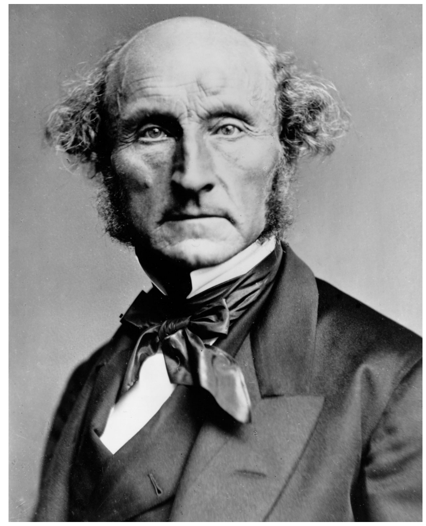
Kant's causality

Immanuel Kant (1724-1804) contradicted this position and asserted that we observe certain regularities in nature and construct causal connections, because such connections actually exist in nature. In his famous book *Critique of Pure Reason* (1787), he took the principle of causality to be required for the mind to make sense of the fact that certain sequence of events always obey a specific order in time. Whereas we can have the sequence of impressions that correspond to the sides of a house in any order we please, the sequence of impressions that correspond to water drops moving downwards in the Niagara Falls cannot be reversed: it exhibits a certain temporal order (or direction in time). This temporal order by which certain impressions appear can be taken to constitute an objective happening only if the later event is taken to be necessarily determined by the earlier one (i.e., to follow by rule from its cause).

It is ironic that in spite of taking this scientific position, Kant divided the world into

[1] In philosophy, the word "necessity" implies something that will necessarily happen, not in the sense of the word "need".

two types of entities: the knowables (things for us, or *phenomena*) and the unknowables (things in themselves, or *noumena*). He ascribed the principle of causality only to the phenomena. It took the scientific world quite some time to come to the realization that everything in the material world are knowable. We may not know everything at any given point of time. But science progresses on the basis of the confidence that everything is knowable, and the way to know what we don't know today is to look for the causes of every phenomena.



John Stuart Mill (1806-1873)

Mill's causality

Unlike earlier philosophers, who concentrated on conceptual issues, John Stuart Mill (1806-1873) concentrated on the problems of actually determining causal connections. Mill argued that causality could not be demonstrated without experimentation. His four general methods for establishing causation are:

1. *The method of concomitant variation*: Whenever A varies, if B varies in some particular manner (that is, if A goes up B always goes up or always goes down), then A is either a cause or an effect of B, or is connected with it through some fact of causation;

2. *The method of difference*: If an instance in which the phenomenon B occurs and an instance in which it does not occur, have every circumstance in common except one (say, A), then A is the cause, or an indispensable part of the cause of B;

3. *The method of residues*: Suppose a phenomenon A has many aspects (say, P, Q, R, and S) and through previous research it is known what can cause P, Q, and S. Therefore the residue in the phenomenon is R. Now, in the condition prevailing immediately before the occurrence of A, if there is some aspect which is known to be not a causative agent of P, Q, and S, then it may be the cause of R. Thus, the method is to subduct from any phenomena such part as is known by previous induction to be the effect of certain antecedents, and the residue of the phenomena is the effect of the remaining antecedents;

4. *The method of agreement*: If two or more instances of a phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon.

To illustrate, suppose one morning four patients report indigestion to a doctor. Upon investigation, the doctor finds that the four people spent the day in different circumstances, but all four of them went to a marriage party in the evening. The doctor would conclude that the indigestion is caused by something eaten at the marriage party. This is the method of agreement.

The doctor goes out and finds more people who went to the marriage party, but many of them did not fall ill. Upon questioning, he finds that the four patients ate dal, potato-chips, fish-fry, prawn curry, chicken curry, curd, and sweets, while the party-goers who did not fall ill ate most of the above but did not eat prawn curry. He would then conclude that the culprit is the prawn curry. This is the method of difference.

The doctor then investigates further by questioning the four patients. He finds that the patient A only tasted the prawn but did not eat much. He is feeling uneasy, but is not really ill. Patient B ate one serving of prawn curry and is ill. Patients C and D really liked the prawn curry and had extra helpings, and are severely ill. This would again point to the fact that the prawn curry caused the food-poisoning. This is the method of concomitant variation.

The doctor has years of experience, and knows that there are different manifestations of indigestion. He also knows which food items can cause which external symptoms. Only, he does not know the effect of consumption of stale prawn. Today the patients are complaining the usual symptoms of diarrhoea, and in addition they are complaining nausea. The doctor then concludes that the "residual" effect, nausea, is caused by the prawn which was not cleaned properly prior to cooking. This is an application of the method of residues.

These are mundane day-to-day examples. But a little reflection will reveal that all modern experimental designs to detect causality are based on one or more of these methods.

The modern concept of causality

After these seminal contributions, many other scientists and philosophers of science tried to enrich the idea in various ways. But the groundwork laid by these philosophers has continued to this day, with rectification of the shortcomings of their ideas.

First, out of Aristotle's four causes, only the material cause and the efficient cause are recognized by modern science. The formal cause has been included in the concept of efficient cause (in the sense that the form of the sculpture lies in the mind of the sculptor).

Second, out of Hume's propositions, the criterion of precedence is accepted with a small correction: Without going into debates about microsecond and picosecond separation between the cause and the effect, we simply say that the effect cannot precede the cause in time. The idea of contiguity could not stand ground in view of the exceptions cited earlier. The idea of constant conjunction had to be abandoned when it was recognized that a causative factor (say, a virus) may not always produce the effect (a disease) because of the influence of other factors. Hence the notion of constant conjunction has been replaced by statistical testing of causal connections.

Third, science has unequivocally rejected Kant's idea of "thing in itself" to be by nature unknowable. It has accepted his idea that phenomena in nature have objective causal connections, and that causality is not a mere mental construct. Science works by looking for these objective causal connections working behind the occurrence of every phenomenon in nature.

Fourth, modern science does not accept the idea of plurality of causes. Plurality of causes is a common sense opinion which means that a given effect or phenomenon may have been the result of multiple or alternative causes. This is not a scientific viewpoint. Modern science says that for every effect there is a single cause. If A and B together cause C, then A and B are not called causes individually; they are called “factors” affecting the phenomenon. The cause in this case encompasses both A and B. The immediate antecedent of C, the collection of all the conditions occurring immediately before the occurrence of C will be called the cause of C.

It is surprising to note that this idea was also first introduced by Galileo. As we have seen earlier, he was the main figure in the scientific renaissance of Europe, and was responsible for the introduction of the objective method in scientific pursuits, and for placing on a firm ground the heliocentric picture of the solar system. Naturally it is expected that he would have something to say about the problem of causality. However, we do not find a treatise of the subject in his writings. But in the book “Dialogue Concerning the Two Chief World Systems” we find glimpses of his thoughts and can piece together his position on the problem of causality.

In this book he states that “from one uniform cause only one single uniform effect can follow” (passage 515) and that “there is only one true and primary cause for one effect” (passage 488). He did not elaborate what he means by “uniform cause” and “uniform effect”, but he seems to oppose the idea of plurality of causes behind any effect. Further, he says “Thus I say if it is true that one effect can have only one basic cause, and if between the cause and the effect there is a fixed and constant connection, then whenever a fixed and constant alteration is seen in the effect, there must be a fixed and constant variation in the cause” (passage 517).

Thus, Galileo viewed cause as the set of necessary and sufficient conditions for an effect. If A and B are causes of C, then C will occur whenever both A and B occur; on the other hand, if only A or only B occurs, then C will not occur. C occurs if and only if both A and B occur, and so A and B put together constitute the cause of C.

It is a pity that this position of Galileo went unnoticed for a long time, and scientists went on arguing on what constitutes cause of an event, while they were actually trying to identify the “factors” included in the cause. For example, we now realize that the “operational causality tests” proposed by Mill are actually the ways to locate the “factors” included in the cause of a phenomenon.

Determinism

The idea of determinism was a natural outgrowth of mechanical materialism that developed following Newton’s work. In the Newtonian formulation, one can predict the motion of a body (say, a planet) by writing down the differential equation governing its motion, measuring the state (the position and the momentum) at an initial time, and solving the differential equations starting from that initial condition. Thus, the dynamical status of a body at any time can be predicted using the information about the dynamical status at an earlier time. This implied, in turn, that the state of a system is *determined* by the state at an earlier epoch.

Notice that this is a stronger statement than saying that the state of a system is *caused* by the state at an earlier epoch. It additionally implies that, given the existence of the factors causing the change of a system, the resulting state is uniquely determined by antecedent state. That is, given a specified way things are at a time t, the way things go thereafter is fixed as a matter of natural law.

Perhaps the most elegant definition of strict mechanical determinism was given by the famous French physicist Pierre-Simon Laplace in his book “A Philosophical Essay on Probabilities” (1814). Laplace said,

“We may regard the present state of

the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes."

Pierre-Simon Laplace (1749-1827)

This has come to be known as Laplace's "Demon," which, in possession of the information about the initial condition of all bodies in the universe, would be able to predict all events at all times in the future. How much information would be required for this, or how much computation power must the demon have—are all besides the point. The main point is that the future state *in principle* can be computed using the information of the initial state, which implies that the future state is *uniquely determined* by the initial state. In the language of Bertrand Russell, "The law of universal causation $\cdots$ may be enunciated as follows: given the state of the whole universe, every previous and subsequent event can theoretically be determined." This is the main assertion of mechanical determinism. In some scientific literature it is designated as "hard" determinism.

Probability

The idea of probability stands in sharp contrast to the above idea of determinism. The theory of probability developed out of gambling in the 17th century when mathematicians like Fermat, Pascal, Huygens and Bernoulli considered mathematical ways of predicting the outcome of games of chance. Where chance occurrences are involved, it was not possible to pinpoint the precise outcome, and so the mathematicians tried to work out the odds of getting a particular result. The theory of probability developed out of this effort.

For example, in a game of Ludo, the probability of getting a 'six' in a throw of die is $1/6$, because there are six sides of the die and they have equal probabilities of facing up when the die is cast. What is the probability of getting three sixes in three throws of the die? This is $1/6 \times 1/6 \times 1/6 = 0.00463$, by the law of multiplication of probabilities. Noticeable is the fact that you get the probability as a number, not as a nebulous concept like "what will most probably happen". And when you can quantify the probability as a number, you can do many things with it.

For example, when a pollen is released in water and is observed under a microscope, it is found to move in a zigzag fashion—a phenomenon known as the Brownian motion. Einstein explained it in terms of the random impacts of the pollen with water molecules, which are all moving at high speeds due to thermal motion. Since we do not know from which direction and with what velocity the next water molecule will collide with the pollen particle, we cannot say how it will move at the next instant. It depends on chance factors. But, using the rules of probability, Einstein managed to calculate the distance by which it is likely to move in a given amount of time. This was tested by experiment, and was found to be statistically true.

Thus, the theory of probability was making inroads into mainstream physics, especially in the field of statistical mechanics. But it was soon realized that the idea of determinism (as it was understood then) was at odds with the notion of probability. The motion of a tossed coin is governed by Newton's laws; and so if we know the exact condition of a coin toss, we should be able to calculate whether it will be head or tail when it falls to the ground. In that case we would not need to think in terms of probabilities. Similarly, if we know the exact position and momentum of all the water molecules in the drop of water, the conditions of each impact with the pollen can be calculated and the motion of the pollen can be exactly predicted. Thus, if everything is deterministic, we would not need the notion of probability at all.

Still, in practice why do we need the notion of probability? It is because of our lack of knowledge about the exact condition prevailing before an incident happens. The need for probabilistic understanding, therefore, stems from *our* lack of information. This is one interpretation of probability.

Thus, we see that the idea of mechanical determinism was in contradiction with the idea of probability. That is why, when the theory of probability was finding more and more acceptance in the description of physical phenomena, some people declared that determinism is dead.

Predeterminism

But the view of strict determinism that evolved from mechanical materialism had even more serious problems. If the state of everything in the universe is uniquely determined by the state prevailing in the past, it implied that the present is predetermined by the past. That past, in turn, is predetermined by the even distant past. Thus, everything that is happening in the world now is fatalistically predetermined by the condition of the particles constituting the universe at a far distant past. Thus, mechanical determinism also implies predeterminism.

This is obviously an unacceptable position. If true, it would imply that the fact that you are now reading this article, the thoughts going on in your mind, the discussions that happened over a cup of tea—all these are the consequence of the positions and momenta of the particles of the universe a thousand years in the past. Obviously absurd.

What exactly went wrong?

Enter the quantum

Towards the early part of the 20th century, there was an explosion in physics. We came to know that the atom is not the smallest constituent of matter. We learned about the sub-atomic particles like the proton, neutron and electron. We learned that light has a dual character—in some situations it behaves as particle and in some situations it behaves as wave, producing interference and diffraction patterns. Then de Broglie showed that not only light has this dual character, *all* particles also behave like waves (for example, electrons also exhibit a diffraction pattern). He thus generalized that matter as such has dual character. Schrödinger found out the equation that these waves obey. Then Heisenberg told us that the position and the momentum of a particle cannot both be measured with infinite accuracy; if you measure one accurately there will be some uncertainty in the measurement of the other.

It is not possible to give a detailed account of these momentous developments within the scope of this article. So we will focus on the specific issue that concerns us here, namely, the status of determinism.

The basic formalism of quantum mechanics was developed in the 1920s and 1930s, but people have since been debating about its concept and implications. However, over the years many experiments have been conducted, and the predictions of quantum mechanics have always come out to be true. If we take a theory's ability to correctly predict the behaviour of things in different circumstances as its test for truth, we can say today that quantum mechanics has passed that test.

This has necessitated certain change in our mental picture of what a particle is. We often intuitively equate the character of a micro-particle with that of a piece of stone—only the former is small and the latter is big. The character of a piece of stone is that it is "localized", meaning that at any point of time it is at a definite position. It is "there" at a point, and it is "not there" at the other points. It now appears that we have to abandon this picture when we deal with micro-particles. They are, in some sense, "there" not just at a point, but over a range in space, much like a fuzz (see Figure 1). The extent of its being "there" varies from point to point, that is, the "density" is different at different points. And beyond a certain (small) range, this density is practically zero.

In classical mechanics, the "state" of a particle is given by its position and momentum, and if these (and the forces acting on the particle) are known, the future state become determined, and can be predicted using the laws of classical mechanics. In contrast, for micro-particles the state is not given by the position and momentum. Instead, it is given by a single complex number which has different values at different points in space and at different instants of time. This is called the wave-function, denoted by the Greek letter Ψ (psi). This wave-function determines the "density" at different points in space at any given time. When the particle interacts with something—another particle or a measuring instrument—the interaction always occurs locally, that is, at a specific point. The density actually specifies the probability of finding the particle at a given point in space at a given time, when such an interaction happens.

Figure 1: Left: the classical "point" picture of a particle, right: the quantum "fuzzy" picture.

This makes the probabilistic description inevitable in describing micro-particles. Earlier people believed that we have to take recourse to probability because of our lack of information, that is, we have to talk in probabilistic terms because we do not know where exactly the electron is located. In this view the electron has a definite position at every point of time, that is, there is a well defined trajectory; and only because we do not know it exactly we have to talk in terms of its probability of being at a specific location in space at a certain time. But now we realize that this picture is not correct.

The behaviour of the electron is *inherently* probabilistic; it is fundamental—something that is not born out of our inability to find its location. This means that the probabilistic description is objective, not subjective.

The same is true for its velocity also (scientists talk more in terms of the product of its velocity and its mass, that is, its momentum). The velocity of a particle also does not have a definite value. It is also distributed as a fuzz. The uncertainty principle says that the fuzziness of the position and the fuzziness of the momentum cannot both be arbitrarily small. If one has less fuzziness (that is, one is more localized) the other has more fuzziness. This has nothing to do with our inability to measure the position and momentum of the micro-particle. This property is not subjective. It is objective. This is how the particles actually are.

It may be noted that many authors write about the uncertainty principle in terms of the Heisenberg-Bohr interpretation. This interpretation talks in terms of *our* observation. How do we observe something? By shining light on it. So if we want to see an electron we would shine a light on it. But since the particle is so tiny, the light would disturb its position and momentum. If we want to observe the position more accurately, we have to shine a light with lower wavelength. Since lower wavelength means higher energy, that would disturb the velocity of the particle more strongly. According to Heisenberg and Bohr, this brought in the uncertainty in the position and momentum. Notice that the whole interpretation depends on *our* ability to observe. Hence there is a subjective element in it. In contrast, the modern interpretation of the uncertainty principle is objective, and does not depend on our ability to observe.

If we adopt this objective view of probability, its contradiction with determinism disappears, for now determinism has to be understood in terms of the probabilistic description. Determinism asserts that the future state is determined by the past state. In classical mechanics, the "state" comprises the values of the position and the momentum of the particle, which were expected to be determined by the state in the past. But in quantum mechanics, the state is given by the wave-function. So determinism would assert that the future wave-function of the particle should be determined by the past wave-function. This is exactly what happens, as the wave-function obeys the Schrödinger equation.

But the probabilistic description also says that the exact location of the particle is not given by the past. The past only determines the probability distribution. The particle could actually be at any place where the probability is non-zero.

If a quantum system is in state A, from there it could go to state B, C, or D. Which state it will actually go cannot be predicted with certainty. But the state A deterministically dictates the *probabilities* of going into state B, C, and D. The system transits to one of these states strictly following the law of probability. Because of the fundamentally probabilistic nature of the micro-particles, the problem of pre-determinism disappears.

Thus, if you sharply ask the question "Why do you need probabilistic description of physical phenomena?", there can be two types of answers. The first one will say that the world is strictly deterministic (in the sense that everything is determined uniquely by the preceding events), but since we do not know the values of all the variables, the best we can do is to obtain the probabilities of getting different end-results. If we knew all the variables and parameters needed for the prediction, and if we had the necessary computing power, we could have calculated the outcome with certainty. This is the stand of statistical mechanics, a very successful branch of physics.

The other answer to the question will be that nature is at a fundamental level probabilistic. For a given cause there can be multiple possible outcomes, and any of these could actually materialize. Our inability to predict which one will actually materialize is not due to our lack of information, but because it is unpredictable at a fundamental level. But the probability of each outcome is deterministically given by the cause. That is why scientists can calculate the probability of each outcome and check against experiment. This is the "objective" interpretation.

Both the interpretations are perfectly scientific, and necessary in specific circumstances. In the case of a coin toss, we need the probabilistic prediction because of our lack of information about the condition of the throw. Here the first interpretation prevails. In the case of a micro-particle, it is fundamentally impossible to predict the position. That is not due to our lack of knowledge of the initial position or momentum. But the probabilities of finding the particle at different locations is given by the wavefunction, which, in turn, is deterministically given by the earlier wavefunction and the forces working on the particle.

Now, if we add the "lack-of-information" interpretation of probability with strict mechanical determinism, we still have the problem of pre-determinism. Predeterminism disappears only if we add the objective interpretation of probability. It is in this sense that quantum mechanics has given us a more enriched version of determinism free from predeterminism.

Over the past 30 years another development has happened in classical mechanics which has shown why determinism should not imply pre-determinism. The development of chaos theory has shown that there are conditions under which a very minute difference in the initial condition of a system may lead to widely different future states. This does not require the participating bodies to be micro-particles: such situations occur in the motion of gross bodies, even in planet-size objects. Moreover, it has been found that such situations are not rare, and in fact, are quite prevalent in nature. And such tiny perturbations in the state of a system are always there in a natural system. Therefore, even though the system may evolve deterministically following the governing equations, the future state is not uniquely given. Here also the problem of pre-determinism disappears.

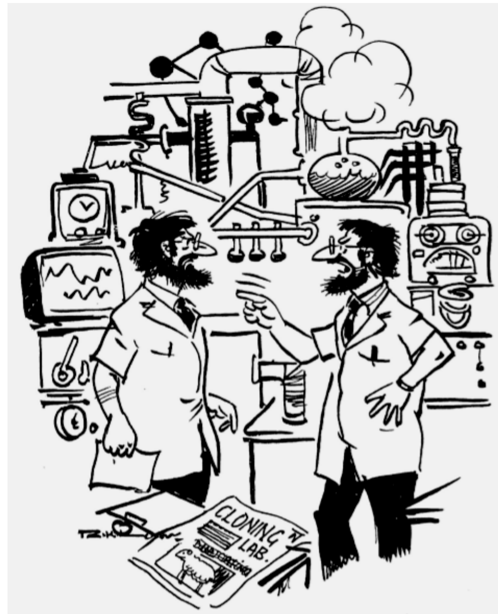
Conclusions

Both the ideas of causality and determinism are fundamental to modern science. But the content of these notions, and their technical meanings, have evolved over the years to take a modern form. And in the meantime we have seen scientists as well as philosophers pronouncing the demise of both in the light of certain discoveries in science. But when the initial mist is cleared, the recent developments have enriched our understanding of both of these concepts.

Planck felt that causality is a "heuristic" principle in the sense that it is futile to try to "prove" causality. Unless we believe there is a cause and effect relationship inherent in all events in the world, one can do no science—for the whole of science evolved out of our attempt to find the cause of things happening around us. Einstein was also of the same opinion.

The early idea of mechanical and strict determinism was flawed because it implied pre-determinism. But the idea was immensely influential and many eminent scientists erred when they placed determinism as contradictory to the idea of probability, and tried to defend determinism by repudiating probabilistic description of the microworld. Now we know that the probabilistic description is fundamental, and determinism and causality are not at odds with the notion of probability. In fact, when we understand causality and determinism in this light, these notions emerge as much more powerful in understanding the ways of nature. □

The earlier installments can be found in the website http://www.breakthrough-india.org /archive.html



That's what you say? I say I am the original and you are the duplicate · · · !

Organizational news

Breakthrough Science Society's Statement on Net Neutrality

28 April: The Breakthrough Science Society wholeheartedly supports the ongoing campaign to ensure 'Net Neutrality' in India.

As we all know, Net Neutrality is a principle that Internet Service Providers (ISPs) should treat all traffic and content on their networks as equal, without discrimination. The internet was created as an *open* platform, where anyone could set up and host their site anywhere, and be available across the globe. Tim Berners-Lee, a founding father of the Internet, has clearly articulated that the ISPs should *not* be allowed to favour one service over others. The openness of internet also means that the global community of internet users is free to use the internet in whatever form they choose—text, image, voice or video—without any discriminatory charges from the internet service providers based on the type of data.

The recent moves by Telecom companies (Telcos) like Airtel threaten to uproot these long-standing principles. These companies are trying to differentiate the internet by breaking the web into fast and slow lanes. They will offer faster download speeds to rich companies who pay them and will offer very slow speed for those who cannot pay.

Firstly, the 'Airtel Zero' deal between Flipcart and Airtel will inevitably lead, in course of time, to 'blocked sites and fast lanes'. It will also lead to Idea Zero, Vodafone Zero, Aircel Zero etc. and users will be restricted to few 'islands of data' as decided by the Telcos and not the entire 'universe' of the internet. The websites of the smaller establishments based on 'open and free' model (such as Wikipedia) will become very slow, and these ventures will be forced to get on one of the bandwagons to survive the brutal squeeze of the Telcos.

Secondly, the argument by the Telcos that they are losing revenue due to OTT (Over-the-top) applications like Skype, WhatsApp and Viber by citing reduced sms revenue is ill-founded as their revenue as well as profit margins due to data services have consistently increased. In any case, Telcos cannot be allowed to dictate the consumers' choice of technology. Hence, Airtel's move to charge extra for 'Voice on Internet Protocol' (VoIP) services like Skype and Viber over its mobile data network is highly condemnable.

We are happy that the Airtel-Flipcart deal was scrapped due to the massive outburst of anger against such privatization of internet. Even the Airtel's move to charge extra (about 5 times) for VoIP services led to a massive consumer backlash and we congratulate the consumers for successfully forcing Airtel to postpone the move, though it has not really been withdrawn.

It is important to note that four countries—USA, Brazil, Holland and Chile—have already made Net Neutrality into a Law. A common thread that binds these four countries is that the Net Neutrality Law was an outcome of people-initiated movements. So, we have inspiring precedents.

It is equally important to note that people across the globe have already leveraged internet as a means of mass action against unjust policies. Social media-driven campaign has played an important role in mass movements such as the “Occupy Wall Street” movement, the Arab Spring and the anti-corruption movement in India. In fact, the awareness about the ongoing movement for Net Neutrality has reached millions mainly because of Net Neutrality!

So, it is heartening to see that the youth of the country and the scientific community have stood at the forefront of this successful campaign with over 10 lakh people demanding the Telecom Regulatory Authority of India (TRAI) to keep the internet free. We have made a great beginning, but, at the same time, we urge the people—especially the citizens of the internet—to remain vigilant, as the battle for Net Neutrality is far from over.

We are surprised that the Prime Minister Narendra Modi who waxes eloquent on ‘Digital India Initiative’ has not spoken up on this raging issue despite such a massive outpouring of anger. We strongly demand the Modi government not to unjustly favour the Telcos that will not only make internet access costlier but also curtail internet users’ right to information. Finally, we demand that Net Neutrality should be enshrined into a *Law*. □

Breakthrough Science Society’s statement on the unscientific claim by the Prime Minister Mr. Narendra Modi about the discovery of life in plants

7 April: The scientific community of India expresses grave concern at the false unscientific claims made by the honorable Prime Minister Mr. Narendra Modi at a meeting of the Ministry of Environment and Forests.

Addressing the State Ministers of Environment and Forests, he claimed that the existence of life in the plants was discovered in ancient India long before the discovery by Acharya Jagadish Chandra Bose, and that it was discussed in the Sreemad Bhagvat Gita and Mahabharata.

However, he didn’t care to place any evidence in favour of his claim. He also claimed that there is Param Atma or absolute soul in plants, and that is why Indian people worship plants. It can be referred here that a few months ago he made such wild claims about the existence of genetic engineering and plastic surgery in ancient India. We deplore that fact that, the Prime Minister of India, instead of spreading scientific awareness among the people, is constantly making such false and unscientific pronouncements.

It is known that science follows the objective method of studying nature through experimentation, observation, theory-building and hypothesis testing, and only by following this method, man has succeeded in reaching correct understanding of various natural processes including life. Acharya Jagadish Chandra Bose also made his fundamental contributions through experiments, where he demonstrated that plants can also respond to sensations and stimuli. The scriptures may and do contain many speculative ideas, but these cannot be taken as scientifically established truths. The response to stimulus is a natural process, and it provides no evidence of the existence of a Param Atma in the trees and plants. In science, there is no place for such speculations. Regarding the worship of plants it can be said that in ancient times people derived many benefits from trees and plants and they regarded the trees and plants as totem. Their worship was nothing but expressions of peoples’ wish to please the natural objects and forces for getting benefits out of them. There was no supernatural content in their prayer. The Breakthrough Science Society appeals to the scientists, educationists and science-minded people to raise their voice against such unscientific claims. □

Kerala State Science Conference

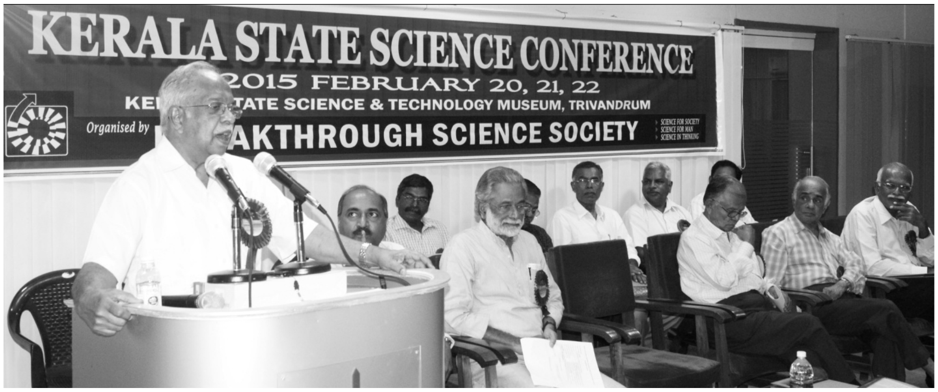
The Kerala chapter of Breakthrough Science Society organized a state level science conference from 20th to 22nd February, 2015, at Kerala State Science and Technology Museum, Thiruvananthapuram, with an objective of giving a thrust to the science movement in Kerala. The conference was attended by around 250 delegates.

Dr. Babu Joseph, former Vice-chancellor, Cochin University of Science and Technology inaugurated the conference in a function presided over by Sri. P Radhakrishnan, Former Deputy Director, LPSC, ISRO and Chairperson, Reception Committee. Citing the preposterous claims made in the papers on 'Ancient Aviation Technology' presented in the recently held 102nd Indian Science Congress, Dr. Babu Joseph in his inaugural address pointed out that certain forces were deliberately trying to distort the scientific methodology by presenting mythological stories as scientific truths. Dr. Balachandra Rao, Honorary Director, Gandhi Centre for Science and Human values, Bangalore, and Prof Dhrubajyoti Mukherjee, All India President, Breakthrough Science Society, also spoke in the inaugural session.

Dr. Babu Joseph delivered his keynote lecture on 'Light and Gravitation' in the subsequent session. Sri. P. Radhakrishnan, Former Deputy Director, LPSC, ISRO gave a talk on 'Cosmic Quest'. This was followed by a session on 'Learning Science through Experiments' conducted by Prof. C. P. Aravindakshan and a talk on 'Science and Culture' by Sri. G. S. Padmakumar, President, Breakthrough Science Society, Kerala Chapter. A public programme was organized in the evening in which Prof. Pappootty, a renowned science activist, delivered a popular lecture on the topic: 'Astrology vs Astronomy'. A sky-watching programme was also organized after the public lecture.

In the second day of the conference, Dr. Balachandra Rao made a presentation on the topic: 'India's Contributions to Astronomy and Mathematics in Ancient and Medieval Periods'. In the subsequent session Dr. S. Mahadevan, Professor, Molecular Reproduction, Development and Genetics (MRDG), Indian Institute of Science, Bangalore, delivered a lecture on 'Studying Evolution using Micro-organisms'. This was followed by a presentation on 'International Year of Light' by Dr. Godfrey Louis, Professor and Dean, Cochin University of Science and Technology.

In the afternoon, a session titled '100 Years of General Theory of Relativity' was organized in which Prof. K.P. Satheesh (Former Principal, Govt. Brannan College, Tellicherry) and Prof. Soumitro Banerjee (Professor, IISER, Kolkata and General Secretary, Breakthrough Science Society) were the main speakers. In the subsequent session Dr. Umesh R Kadhane, a member of the faculty of the Indian Institute of Space Science and Technology, Thiruvananthapuram made a presentation on the topic: 'Science Education and Being a Scientific Personality'. A panel discussion on the topic 'Science in Ancient India V Myth and Reality' was organized in the evening as a public programme. Dr. S. Mahadevan, Dr. Balachandra Rao, and Dr. Soumitro Banerjee were the speakers at this panel discussion moderated by Dr. V. Venugopal, Director, Netaji Centre for Socio-cultural studies.



Prof. Babu Joseph inaugurating the Kerala State Science Conference.

The third day of the conference was devoted to organizational matters, conducted by a presidium comprising Sri. G.S.Padmakumar, Prof. P.N.Thankachan, Prof. Francis Kalathungal and Dr. P.P. Rajeevan. Dr. Soumitro Banerjeee delivered the inaugural speech. Prof. P. N. Thankachan placed the organizational report. The conference also adopted resolutions on 'Drug policy', 'Science Education', 'Gadgil committee report, 'Energy and Environment policy' and 'Bill to prevent practice of black magic and other superstitions'. The delegates unanimously elected a new executive committee and a general council with Sri. G.S. Padmakumar as President and Prof. P.N. Thankachan as Secretary. Prof. Dhrubajyoti Mukherjee, All India President, Breakthrough Science Society delivered the concluding speech. The conference ended with a resolve to take the science movement in Kerala to a higher level.

Bihar: Workshop on Astronomy and Anti-superstition at Bhagalpur

Breakthrough Science Society, Bihar Chapter organized a Workshop on Astronomy and Anti-superstition on 21-22 February, 2015 at SMS Mission Sciences +2 School, Bhagalpur. Mr. Dinesh Mohanta (Member, All India Executive Committee, Breakthrough Science Society) was the chief guest. The workshop involved training of the participants in the art of anti-superstition campaign, and in skywatching using telescopes.

Andhra Pradesh and Telengana

National Science Day Celebration: A convention on the topic "Ancient Indian Science — A Dispassionate Study" was organized on the occasion of National Science Day on 28 February at the Stanley College of Engineering & Technology for Women, Hyderabad, Telangana. Prof. S. M. Ahmed, Professor in Hyderabad Central University and Scientist from ISRO was the chief-guest and Dr. P.L.Visweswar Rao, popular historian, was the main speaker. A book titled "Science versus Pseudo Science" was released.

Seminar at Anantapur: 25 March, 2015: Breakthrough Science Society in association with Dept. of Mechanical Engineering, JNTU College of Engineering (Anantapur) organised a seminar on "History and Development of Aviation Technology." Prof. H.S. Mukunda, an eminent scientist in the field of Aerospace engineering (IISc Bangalore) was the main speaker. Prof. H. S. Mukunda deliberated on the science behind flying and debunked the unscientific claims made by the author of *Vymanika Shastra*.

Science Camp at Hindupur: A science camp was organized by BSS, Hindupur Chapter on 26 April.

Tamilnadu

25 February, 2015 — A seminar on "Science to Common Man" and Chart Exhibition was held as part of observance of National Science Day in association with Bharathi Women's College, Chennai.

26 February 2015 — National Science Day Seminar was organized at the American College, Madurai

28 February 2015 — National Science Day was observed at the Dr. Ambedkar Government Arts College, Chennai.

Karnataka

The Karnataka Chapter of the BSS has developed Kannada subtitles for a movie on the life of Madame Curie. It was screened in 10 colleges in the districts of Chitradurga and Hosadurga in the month of January.

At Jagalur, a taluk in Davangere district, there was a discussion on scientific temper followed by a miracle busting show performed by Ms. Rajani. K. S. (State Unit member) and Mr. Manjunath. S. (Davangere District In-charge). Mr. G. Satish Kumar (State Convenor) conducted the discussion. Around 500 people participated in the event.

An expert talk was organised by the Gulbarga District Committee at PDA College of Engineering in the month of Feb, 2015 on the topic "Frugal engineering and Top ten technological trends – a social perspective".

Study class on the topic "Science in history—J.D.Bernal" is being organised every month since January in Bangalore.

West Bengal: Convention demanding anti-black magic bill

Kolkata, 28 February: On the occasion of National Science day (28 February, 2015), the Breakthrough Science Society West Bengal Chapter organized a March from College Square to the State Yuva Kendra, Moulali, demanding introduction of an anti-black-magic bill in the state. The March made the following demands. Claiming to have supernatural power and cheating people with such claim should be declared as illegal and punishable offence. Advertising such claims through print and electronic media should also be banned. Similarly, branding men/women as witch and accusing somebody of being possessed by ghost, and subjecting them to physical and mental torture should also be declared as punishable offence. Throughout Bengal a mass signature campaign was organized by BSS WB Chapter and around 23000 signatures have been collected. A delegation led by Professor Kartick Ghanta (Acting President of BSS WB Committee) submitted a memorandum to the Governor along with the signatures.

The March culminated at the State Yuva Kendra, Moulali, where a Convention was held with the same demand. Eminent science writers Mr. Asish Lahiri, Dr. Bhavani Prasad Sahoo, Mr. Subrata Gouri (Vice-President, BSS WB Committee) spoke on the occasion. The Convention adopted a resolution with this demand. The speakers appealed to the participants to strengthen this movement and to spread it to each and every corner of the state. Professor Dhrubajyoti Mukherjee presided over the session and urged upon the participants to continue the effort till the bill is passed in the West Bengal Legislative assembly.