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Evaluating the claims of ancient Indian achievements in science

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ORTHODOX , value-neutral dispassionate study of the workings of nature that we broadly call sciences is under a threat as never before. The pattern of scientific research in India that the greats of Indian science set up after independence is being systematically questioned in today's India. One of the axioms of the post-independence formulation was that modern science and technology (with a forward outlook to its utilization) was the way to the future. For this, both research in science and technology (S&T) was crucial and was well supported, but its path was left to the judgement of scientists with guidance from international scholarship. This has served the nation well. Today, there is hardly a field of international research where India does not have some expertise of value. However, having spread ourselves thin, it also means that most research requires international exposure to nourish itself. This too was reasonably well served. Today, scientists working in contemporary science have deep connections with the world scientific community. This is good for Indian and international science, but to people with blinkered vision this also makes Indian scientists stooges of Western science who are not Indian enough in their patriotism and commitment.

Paradigm of shift in Indian science

Today, the entire paradigm of Indian science is under review. As India begins to grow and the generation that fought for independence gives way to the post-independence generation, various questions are being asked about the fundamental assumptions of S&T and its future. As research in pure science becomes more and more complex, its direct applicability is reduced, except in terms of the technological needs of science itself. With a few weak bridges and tenuous links between scientific research and industrial technology, questions are being raised about the country affording financially intensive research programme with international collaboration.

Another major paradigm of Indian science was that we took the model for growth from Max Planck Institutes in Germany. This meant basing fundamental research in specialized institutes, while universities focused on teaching. This is also being increasingly questioned, as universities become more self-confident and assertive, and their talented staff demand research infrastructure. Teaching institutes with core research strength are being increasingly created. This augers well for the nation.

However, more severe is the intellectual challenge to the attitude of science and scientists. Fringe groups that harp on unreal-

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istically fantastic achievements of the past constitute the most aggressive challenge to contemporary science. Men and women, trained in sceptical rationalist approach to studying nature in all its aspects, are unwilling to accept any claims of past glory without critically evaluated evidence and are proving to be the strongest challenge to these groups who wish to glorify our past beyond logic and reason.

In recent months, these groups that considered scientists trained in classical objective and axiomatic thinking as decadent representatives of the West and worse, are beginning to find voice. To them these men of critical studies are dangerous propagandists of counter culture that will not glorify our past for its own sake. In a markedly regressive step, they are reinventing (often literally) new 'evidence' of past glories of Indian S&T. They demand that our past achievements, significant in their own right, should be exaggerated way beyond their natural boundaries. In this, the scientists trained in modern axiomatic methods are considered more a nuisance or impediments than collaborators. They are being increasingly looked at as enemy combatants. These scientists, aware of significant success paths that have led to those discoveries, know that these claims of past successes were not achievable in the earlier periods.

Modern scientists and ancient sciences

Many of the scientists who are willing to read the past literature appreciate both its glory and its limitations. But as the fringe nationalistic groups who wish to go beyond these logical explanations, try to forcefully occupy the main stream dialogue on India's past, they are not willing to accept limitations imposed by logic. The great seers of the past were supposed to be all-seeing and all-knowing, period. There may be no evidence that they knew electromagnetism or thermodynamics, which are crucial steps that lead to quantum mechanics, but the fringe groups would want us to believe that they knew of quantum mechanics and even aerodynamics. Similarly, all rational studies of ancient literature and modern sciences firmly put a timescale of human evolution, but the fringe groups, with limited patience for logic and rationality would like to completely redefine the timescales, simply out of a false sense of pride.

One of their many arguments is that, not being present at these times gone by, scientists of today cannot fathom the capabilities of these ancient people. This shows a lack of understanding of the nature of evolution of science. So, it is worth reviewing how scientists judge historical science.

Evaluating the past and judging what our ancestors achieved is easier than most people would imagine. The most common approach to getting a timeline is that of direct dating of the archaeological remains with residues of human activity. Today's technology is so advanced that a few milligrams of such residues is sufficient to produce reasonably accurate results. This kind of study will tell you that the anatomically modern human arose about a million years ago and then, about one lakh years ago, the humans spread to different parts of the world, gradually dominating all landscapes. It is also universally accepted that modern humans arose in Africa and spread to the rest of the world from there, even as they mated with other local Humanoids. The accuracy of the numbers depends on how far back you are going, but broadly the sequence seems clear.

Human evolution and growth of our understanding of nature

The best evidence for human entry into the Indian subcontinent is around 70,000 years ago. We continue to come across sites where humans made various tools and left behind other residues, and they show a gradual increase in sophistication with time. By about 7000-10,000 years ago, they began to take up farming in a serious way and settled down. At this stage they began to build large stone structures in different parts of the Indian subcontinent, including the Harappan Civilization. This story is fairly incontrovertible, except for a few fine points here and there. Note that the timelines of the migration of human beings from Africa, and the evolution of human settlements and technologies does not allow the claims being made for the antiquity of ancient Indian civilization.

However, the entire evidence for the early habitation by Sanskrit speakers in India is literary and there are few, if any, archaeological sites that can be directly associated with early Sanskrit speakers. In this case, therefore, there is a fair scope for error. However, two criteria are used to date them. One is that languages are not constant and consistent. After all, my own grandfather had a completely different vocabulary compared to mine—if you do not believe me, pay attention to the agonizing that Oxford English Dictionary goes through every year. Since language evolves, it is also possible to date ancient documents. For example, if I see an English essay that uses 'Thou' or 'Thine', it is certainly several decades and probably hundreds of years old. The other method is to look for records of astronomical clues, internal dating of family trees, etc. as well as description of animals, and flora and fauna to pin down the place where the writing occurred and the period during which it happened. One can then use the description of technology to create a logical timeline—in general, technologies become more advanced with time. This can be used as a consistency test.

In recent decades, genetics of humans, animals and plants has proved invaluable in understanding the movement and mixing of people and their migratory pattern. The genetics of languages can also provide other supporting evidence.

From the Ashokan period, we get monuments that can be dated by the above method and they provide direct evidence and written material of the human activity in the historic period.

The scaffolding of science

However, when extreme claims are made, there are other arguments that can be brought to bear upon the matter under discussion. Most importantly, no field of science today has arisen in isolation. To reach quantum mechanics, we had to learn about thermodynamics, atomic physics and electromagnetic theory in its full mathematical complexity to realize that the problem of stability of atom required a new kind of physical law.

Similarly, to get to the stage of aeroplane, we needed to understand the dynamics of air and wind, its movement, measure air pressure and its difference when it went over a curved surface compared to a flat surface. Bernoulli's principle did not arise in vacuum and Wright brothers could not have even imagined an aircraft without a 100 years of industrial revolution and deep understanding of metal, internal combustion engine and so on. Interplanetary travel required the understanding of distances between planets, a firmly established heliocentric idea of the organization of the solar system. Extremely powerful engines that could lift objects out of the gravity of the Earth (and hence a good understanding of gravity itself) and a basic mathematical foundation in calculus to get there. Experimental facilities, test facilities, manufacturing facilities all go hand in hand for this kind of a capability to arise.

Similarly, for genetic engineering, we need to understand life at the molecular level. For this, one needs to know that the smallest objects are molecules made of atoms. We need to know that there is only a small variety of atoms that provides the entire variety of the universe. We need to understand the centrality of carbon in life and so on, which in turn needs an understanding of the periodic table of elements. We need to understand atomic physics and chemistry for which we need X-ray, optical and infrared devices and photographic plates that can take spectra of lights from atoms and allow us to create a mathematical theory about how biology works. This needs to be further supported by microscopy and other devices to understand and create molecules of various complexities and manipulate them to understand how they interact.

After a century or more of such studies, one begins to realize how heredity is based on the information provided to a foetus through the very process of conception. We then need to isolate these cells in extremely clean and low-temperature environment, and then study and manipulate them. Only several decades of such studies can give us the basic rules of genetics. Manipulating these genes to make composite life-forms is an order of magnitude more complex. We need to first understand how genetic information is actually read and executed. We need to understand the consequences of removing or replacing some genes from one life-form into the life cycle of another life-form. This again requires huge amount of resources and time, not to mention a rigorous educational system and sophisticated laboratories. It also needs a group of people devoted exclusively to the purpose of unravelling the mysteries of genetics. In fact, modern genetics has taken inputs from physicists, chemists and biologists to accomplish what it has. So far, there is no evidence, either archaeological or in the literature of the existence in the past of such a group of people or facilities needed for this.

Similarly, nuclear weapons arose after we had understood the uniqueness of atoms, interaction of atoms and the nature of energy coming from unstable nuclei. We needed technologies to isolate atoms of specific materials in sufficient quantities. Even then, pure uranium will not instantly give you an atom bomb, since the neutrons emitted by a uranium atom may or may not go and hit another uranium atom. To achieve sustained fission, the core of uranium has to be compressed in a specialized compression technology to make an atom bomb. This requires highly evolved metallurgy and other infrastructure, not to mention complex mathematics. And atom bombs are certainly not light enough to be put on an arrow head or be deployed by individual humans.

Also, implicit to all this is that electricity is crucial to the entire process. It provides the most convenient and versatile source of energy which can be converted into other forms. There is absolutely no evidence that our ancients knew how to generate and use electricity.

Most importantly, the language of science is not Sanskrit, it is mathematics. While most sciences begin with descriptive recording of their work, true and rapid progress comes only after these results are put in mathematical format, allowing generalization and cross-applications. We have no evidence of such a transition in the past. Most modern developments in science would not have arisen without several important mathematical tools that are now routinely applied to science. Even the best works in Indian mathematics stop at the limiting value theorem that came up in the Kerala School between the 14th and 16th century AD. While *Rig Veda* deals with large numbers in powers of ten, the classical *beej ganita* is of much later origin and was not the language of ancient seers.

Even if one is willing to ignore all this, it is also worth asking what happened to all these wonderful technologies and capabilities? How is it that these technologies were lost? Why was there no precise documentation of the technologies? What were the cataclysmic events that destroyed all traces of these technologies? Why is there even no legend or myth of their destruction? If foreign invasion is the reason, then would not the invading forces be keen on using these abilities for furthering their ambitions of subjugating the entire world? Is it not inconceivable that anyone would destroy such potent weapons and technologies?

Reflections on education

The arguments of the fringe group also raise questions about the educational system and scientific temper being imparted to young minds. Clearly, the very fact that irrational ideas hold sway over such a large group is a major failure of our educational system. When a medical doctor specializing in sex change operations quotes the example of Shikhandi (a transgender in the Mahabharata) as an example of sex change operations in that period, it raises questions about the scientific temper of the Indian psyche. Clearly, we also do not seem to emphasize timeline and logical sequencing in the study of history. History is not so much about dates as about the sequence of growth of human civilization.

So when one talks of whether a particular technology was known to our ancestors or not, one must sit back and pause. Consider the amount of other knowledge that led to a particular insight into the working of nature, and satisfy yourself and convince others that this entire scaffolding of knowledge existed at the period being discussed. The evidence can be in the form of reliable documents in appropriate language, evidence of experimental facilities, evidence of technological competence as well as mathematical competence. Without this evidence, all claims are simply fantasies of an untrained mind. It is worth bearing in mind that none of these claimants of the technology of the past has made a single prediction stating that a particular technology will be the next one to be found and that the ancient literature defines how to reach this unattained technology. While it can be suggested that the early scientists did not fully understand the potential of their capabilities, later commentaries should have been more predictive of the consequences of the technologies. At least the modern readers of these texts should be able to make predictions based on these ancient formulations.

The shrillness of debate

When evaluated in light of these powerful stable and sustainable arguments, attempts at making grandiose claims of past achievements are self-defeating. Further, they destroy the credibility of the entire system and serious scientific studies of India's past get discredited in light of these efforts. These attempts drag down more than just themselves. They bring down the morale of the contemporary scientists and divert attention and resources away from modern science and technologies. As the 102nd Indian Science Congress recently debated the true scientific capabilities of ancient Indian seers in a session 'Science in Sanskrit', on other forums claims have been made that ancient Indians could make interplanetary voyages. This is difficult to accept, when they had no detailed knowledge of geography beyond the Indian subcontinent. The idea that the earth was spherical was not even considered in India until AD 500, when Aryabhata proposed the idea of heliocentric solar system. As a result, fundamental issues like the deeply perceptive studies of these ancient scientists in mathematics and astronomy that changed the world are not receiving attention. Indeed a stage has come where even those pointing out demonstrably impressive achievement do not find a decent audience. Contemporary scientists see ghosts of ultranationalists in them and ultra-nationalists do not find them committed enough. In this hazing, our entire ancient heritage is being condemned by the heretics.

In turn, we all lose our national heritage and national pride. No one wins. The ultra-nationalists who seem to think that a lie repeated a thousand times becomes truth—do no good to their professed desire to have Indian scientific achievements appropriately recognized. It also does not help the contemporary scientists who feel hounded by these fringe elements. Even on forums for rational evaluation of past sciences, they feel intimidated out by these shrill voices.

The true Indian contribution to science

It is not that Indian achievements were not significant for their own period, as an editorial by Narasimha (Narasimha, R., Curr. Sci., 2015, 108, 471- 472.) pointed out that even the most casual visitor to Indian science will feel impressed by the works of Aryabhata and his collaborators, or of the zinc smelters of the past. They will also be impressed by the work of the Kerala School of Mathematics or of the secular approach of a large fraction of literature in Sanskrit with its intricate arguments on the working of the world. To that one must add the exacting architecture from the Harappan towns to the Taj Mahal and the rockets of Tipu Sultan. The list is both impressive and large.

For example, it is known in learned circles that the Pythagorean triplets were also discovered by Indian mathematician and the earliest reference goes back to *Sulba Sutra* possibly pre-dating Pythagoras. In fact, the Greeks were probably the last of the Great Civilizations of the past (Egypt, Mesopotamia, India, China and Greece) to come up with the realization of Pythagorean triplets and all the other civilizations had realized this well before the Greeks. So there is no doubt that Indians knew of the Pythagoras theorem before the Greeks learnt it. But when such an assertion is also mixed with claims of invention of *vimanas* that could undertake interplanetary journey, both the earlier claims get discredited. Those who set out to restore the glory of India's past do more damage to it. So, for example, the session of the Indian Science Congress on 'Ancient Sciences through Sanskrit' could have looked like:

(1) Nyaya-Vaisheshika system: Scientific approach to understanding the working of nature in ancient India. They are two of the six core schools of logic which derive their roots from Vedic literature. These schools of thought were fairly advanced and complex in their explanation of nature and the working of the physical world. They divide the knowledge about a system into seven parts (*padartha*): dravya, guna, karma, samanya, vishesha, samayaaya and abhaava. This provides an interesting approach and several new insights into understanding the property of matter and

material that did not invoke God or religion in any way. These were studies in the best rationalist traditions.

(2) Yoga and Ayurveda: Ancient India's approach to health and illness. This combination of self-discipline, exercise and plant-based medicine with a holistic approach to life and health has resulted in novel thinking. Its approach to health and healthcare continues to attract students from all over the world. Combined with Yoga, this healthcare system was analytical, rational and practical. Evolution of the system led to an equivalent of modern-day plastic surgery as the system evolved.

(3) Indian philosophy of science: The philosophy behind Indian approach to nature has not been fully understood due to lack of any systematic study. Within these secular philosophies lie some truly insightful ideas about humans and their interaction with environment and the working of nature. These go beyond the arguments of the Nyaya-Vaisheshika system and discuss a whole set of issues related to logic, reason and doubt. Beyond that, they are far more inclusive in discussing human exploitation of and respect for nature.

(4) An overview of Indian mathematics from the Vedas to the Kerala School: Indian mathematics has been justly recognized as being far-reaching and complex with a variety of ideas from number theory to second-order algebraic equations and the concept of limiting value.

(5) Astronomical ideas in Indian texts: Indian astronomy was both accurate and pragmatic. Without the love for circles that bogged down some of the work in Greek astronomy, the Indian astronomers were free to derive equations which gave good fit to the movement of planets. This resulted in creating the first sine and cosine tables and early trigonometry. The method employed to calculate eclipses and records of transits of planets all make a rich tapestry of study of astronomy in India. From Aryabhata's encyclopaedic work on astronomical calculations to Varahamihira's defining of syllabus for astronomy and clarification of various concepts, the achievements of Indian astronomical texts are astounding.

(6) Eclipse and planetary conjunctions: Mahurats, tithis, calendar, eclipses, and planetary conjunctions were an important part of Indian astronomy and panchang-making. The manner in which vyatipada (a conjunction of Sun and Moon at Rahu) that would produce an eclipse was calculated makes a fascinating subject in its own right.

And if the topic was made wider with ancient Indian sciences, topics such as architecture and technologies of Harappan civilization and the technological marvel of the Taj Mahal or rockets of Tipu Sultan and more can be added. The science of temple architecture of India could also have been included as it is a sensitive and scientifically well designed architectural work.

A session with these contents would have left behind a healthy legacy of Indian science in the minds of all participants and the world as a whole. It is probably important to realize that the most competent speakers on these subjects are people trained in dispassionate evidence-based method in scientific studies and have critically evaluated and found the gems of Indian science that should make all of us proud.

Reflections on the consequences of the present debate

However, in the extreme claims of the fringe elements, Indians stand to lose the most. It means that a rational and realistic study of India's past is now a much maligned field, which no rationalist scientist or citizen will attempt.

Equally importantly, the rationalist scientists will find their own work space squeezed as they begin to deal with a government that is influenced by parochial consideration. Pure excellence will give way to committed excellence—an oxymoron idea. There is no such thing as committed excellence. You cannot see white colour while wearing blue sunglasses. Some may be able to deduct the possibility of white colour where they see uniform bright blue, but most will live under the impression that the world is blue. The result is that those who can see other shades will be outcast, forced to find companionship only amongst those who do not wear sunglasses, or go away to places where sunglasses are not a norm (or worse, start wearing sunglasses themselves). We will all be poorer for it and our reputation will take a plunge from which we will be hard pressed to come back.

So what should we do? For one, the fringe groups need to be exposed for what they are. This will require a concerted effort and scientists will have to shed their traditional shyness. We will have to educate people as to why the claims of the fringe groups are nonsense without appearing to be ignorant or condescending of the past. For this, scientists will have to arm themselves with a better understanding of the true achievements of the past, and then step forward and take on the fringe groups who are well-organized, well-funded, shrill and increasingly tolerated, if not encouraged by the powers that be. This will be a distraction, but the battle is for the soul of the nation, no more, no less. A battle is not far, and it will be brutal, hard and long. It will have to be fought on every forum and every place, from Indian Science Congresses to the newspapers and public forums. But those who care for the soul of India and desire a rational nation to emerge will have to join the battle.

Early History of the Earth

The Breakthrough Science Society had published a Bengali book "Vivartan Yuge Yuge" (Evolution through Ages) in 1999 to present an outline of the evolutionary process in all forms of matter in a single book. This is an updated version of the original chapter from that book which concerned with the evolution of the Earth, with incorporation of some additional material. Translated by Mr. Prabir Sengupta.

WHAT DOES THE EARTH look like! If you have a look from space, it is like a sphere. Not an exact sphere though. The North and South poles are slightly flattened giving it more of a resemblance to an orange. The diameter of Earth through its centre from N-pole to S-pole is 12714 km while that from East to West is 12757 km.

Scientists have classified the area near the surface of the Earth into four inter-connected geo-spheres which are termed as the lithosphere, hydrosphere, biosphere, and atmosphere. The names of the four spheres are derived from the Greek words for stone (litho), air (atmos), water (hydro), and life (bio). All living and nonliving material on or near the surface of the Earth are classified to be in any of these four spheres.

The lithosphere is the outermost solid, rocky layer covering the entire planet. It covers the entire surface of the Earth from the top of Mount Everest to the bottom of the Mariana Trench.

The hydrosphere is made of everything water—such as oceans, rivers, lakes, rain, snow, and ice caps. Around 75% of the Earth's surface is covered by the ocean which holds 97% of the Earth's water. The remaining 3% is fresh water out of which 3/4th is solid and exists in ice sheets.

Atmosphere of the Earth is the cushion of air that surrounds the solid crust of the Earth. The atmosphere extends as far as 1600 kms above the surface of Earth. Nitrogen makes up about 78% and oxygen about 21% of the gases present in Earth's atmosphere. The lower part of the atmosphere is called troposphere where all the weather conditions like cloud, wind and storms take place.

The biosphere is the region of Earth where life exists. Most of the planet's life is found from 3 m below the ground to 30 m above it and in the top 200 m of the oceans and seas. It includes all the biomes and ecosystems around the planet.

Humans have been ever curious about what lies beneath deep below the surface. The realms of science fiction and literature have portrayed vivid imagination though ages. From Dante's Divine comedy, Edgar Allen Poe's narratives of Arthur Gordon Pym to Jules Verne in his fiction of the mercurial journey through the volcanic vent, the list can go on and on. The subterranean fantasy has fired imagination of the marvel superhero comics from the 1960's. The 20th century fox movies, the famous Ice Age series explores the concept in its Dawn of the Dinosaurs sequel. But what really lies deep below! Let's now get ready to dig deep and sail into a fascinating journey to the centre of the Earth.

It would have been easiest if we could drill a tunnel from N-pole to S-pole through the

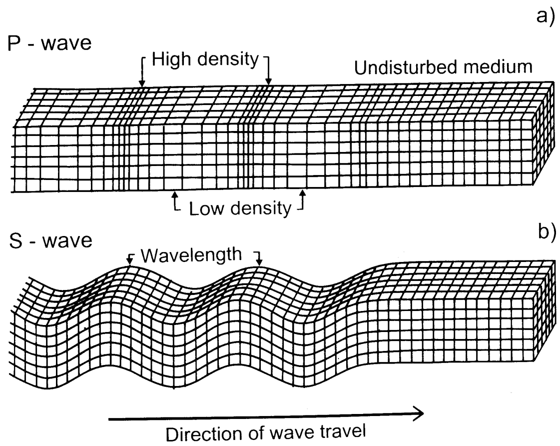

Figure 1: The nature of the P-wave and S-wave.

Earth's centre and send a probe through it. However, it is easier said than done. The deepest borehole that had been drilled till date is Kola Superdeep Borehole in Kola peninsula, Russia, which reached a depth of 12262 m. More than 99 percent of the distance to Earth's centre still lay beneath the drill bit.

If the inner Earth is so remote and inaccessible, how can we learn anything about it? Geo-scientists gather clues from meteorites, rocks, earthquake waves, and Earth's magnetic field and use those indirect methods to decipher the code to the Earth's interior. The secrets buried inside our planet are mostly revealed by recording and studying seismic waves which are caused by things like earthquakes or explosions. There are three components of seismic waves—shear waves (S-wave), which won't travel through liquid; pressure waves (P-wave), which move through both liquid and solids and surface waves (Love waves and Rayleigh waves) which travel along the surface and responsible for all earthquake-related destruction. P- and S-waves travel through the interior of the Earth. Depending on what material they travel through, seismic waves speed up, slow down, or disappear. The arrival times of different types of seismic waves around the world provide clues to the composition and structure of the inner Earth. These waves show that the Earth is primarily made from five layers: the inner and outer core, the lower and upper mantle, and the crust. By observing the behaviour of these waves, seismologists have determined the depths of the boundaries between Earth's major layers.

The inner Core is a big metal ball made mostly of iron and a bit of nickel with a thickness of about 2500 km. It extends from the centre to about 5150 km depth and is at a temperature of 5000 degree to 7000 degree Celsius. However the inner core is so deep within the Earth that it is under immense pressure. So much pressure that, even though it is so hot, it is solid. The inner core is the hottest part of the Earth and its temperature is equivalent to the surface temperature of the sun!

The outer core extends from a depth of 5150 km to 2890 km with a temperature ranging between 4000 degree to 5000 degree Celsius and is made of iron and nickel. The outer core is liquid and it rotates around the inner core. This rotation of liquid outer core against a solid inner core creates the dynamo effect which is responsible for the Earth's magnetic field. This magnetic field goes way out into space and makes a protective barrier around the Earth that shields us from the stream of charged particles that are ejected by the sun, called the solar wind.

Earth's mantle is thought to be composed of silicate rocks with more calcium, magnesium and iron. It has different temperatures at different depths. The temperature is lowest immediately beneath the crust and increases with depth. The highest temperatures occur where the mantle material is in contact with the heat-producing core. This steady increase of temperature with

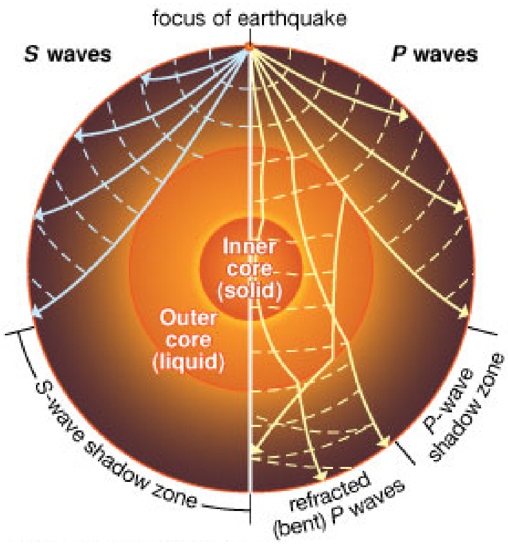

Figure 2: Seismic waves travelling through the Earth's body tell us about the structure of its interior.

depth is known as the geothermal gradient. The geothermal gradient is responsible for different rock behaviours and these differences in rock properties are used to divide the mantle into two different zones. The upper mantle extends up to 670 km and attains a temperature of around 1400 degrees. Rocks in the upper mantle are comparatively cooler and brittle and they break under pressure which releases energy and produces earthquakes. The lower mantle extends from 670 km to 2890 km depth. The temperature attained is around 3000 degree Celsius near its contact with the upper core. The rocks in the lower mantle are hot and soft like a jelly (but not molten) and instead of breaking they flow when subjected to pressure. The uppermost layer of the mantle and the crust act together as a rigid, brittle shell and together they are called the lithosphere which means the "sphere of rock". The upper mantle is divided into lithospheric mantle and asthenosphere. The asthenosphere is softer, has a small amount of melting of rocks and is capable of flowing over a long time range under stress.

The crust is the thin outer layer of the Earth where we live. It varies from around 5 km thick under the ocean floor to around 70 km thick under Fold Mountains on land with an average thickness of around 40 km. The land crust also called the continental crust is made up of rocks that consist primarily of silica and alumina and hence called the "sial" while the one under ocean floor is primarily composed of silica and magnesium and hence known as "sima". These two different types of crust are made up of different types of rock. The thin oceanic crust is composed primarily of basalt and the thicker continental crust is composed primarily of granitic rocks. The low density of the thick continental crust allows it to "float" in high relief on the much higher density mantle below.

As you go deeper into our planet, the conditions of pressure and temperature steadily increase. The rocks become hotter and denser the deeper you go. The weight of all the overlying rocks causes the increase in pressure. Much of the heat is created by the decay of radioactive elements mainly occurring in the mantle; in addition there is the residual heat from the time of the planetary accretion and the core formation. Because the interior of the Earth is hot and under great pressure, it transfers much of its internal heat to the cold universe outside. Most of the heat is transferred by a mechanism called convection. Convection is the process by which hot materials rise, move laterally, cool, and then descend in a cycle. Within the Earth, irregular convection cells within the mantle transfer heat from the core to the surface of the planet. This mechanism is the driving force behind both heat transfer and the global processes of plate tectonics.

The Discontinuities

When an Earthquake occurs, the seismic waves spread out in all directions passing through the Earth's interior as well as on its surface. Seismic stations located at increasing distances from the Earthquake epicentre record seismic waves that have travelled through increasing depths in the Earth. Seismic velocities depend on the material properties such as density, rigidity, and also on temperature and pressure of the media through which seismic waves pass. Seismic waves travel more quickly through denser materials and therefore generally travel more quickly with depth. Anomalously hot areas slow down seismic waves and they move more slowly through a liquid than a solid. Molten areas within the Earth slow down P waves and stop S waves because their shearing motion cannot be transmitted through a liquid. Partially molten areas may slow down the P waves and weaken S waves. Sudden changes in seismic velocities and other wave properties at depth are known as seismic discontinuities which help us in determining the boundaries between different layers within the Earth.

In 1909, a Croatian geophysicist named Mohorovicic found that the velocity of seismic waves (P wave) shows a sudden jump from average 6 km/s to 8 km/s while penetrating through the outer shell of the Earth. This suggests a change in composition. The zone, which is believed to be 500 m thick, is present at varying depth from 5 to 10 km below ocean floor to 80 km below fold mountain belts with an average depth of 35 km round the globe. This zone is marked as the boundary between crust and mantle and is named as Moho or Mohorovicic discontinuity.

The boundary between the lithosphere and the asthenosphere at around 100 km depth shows an abrupt decrease in seismic wave velocities due to the presence of small amounts of molten material. The asthenosphere contains rock which exhibits ductile plastic behaviour and extends from depths of approximately 100 km, its base is not well defined, and in some regions to approximately 700 km. This zone is also known as Low Velocity Zone (LVZ), though the two are not exactly the same. The asthenosphere is the layer between the lithosphere and the upper mantle. At around 410 km, the intense pressure of overlying material causes the silicate minerals to transform into higher density atomic arrangements. This results in a steady increase of the seismic wave velocity. The boundary between the upper and lower mantle is a transition zone extending from 410 km to 660 km.

At about 2900 km due to the liquid nature of the outer core, the P-wave velocities abruptly decrease as the waves move into material of much lower density and S-waves are not transmitted. This zone marks the boundary between lower mantle and outer liquid core and is known as Gutenberg discontinuity.

At approximately 5150 km, due to the solid nature of the inner core, P-wave velocities abruptly increase as the waves move into material of higher density. This is the Inner Core–Outer Core boundary and is called Lehman Discontinuity.

The Big Onion

We have seen so far that the Earth is layered like an onion and the composition/structure changes with depth. A simplified generalization is that as we go deeper, the material gets denser. But how did this density layering happen!

Our solar system formed from the solar nebula which under gravitational forces evolved to a protoplanetary disc. With time the central part developed into the proto-sun and the remainder into a number

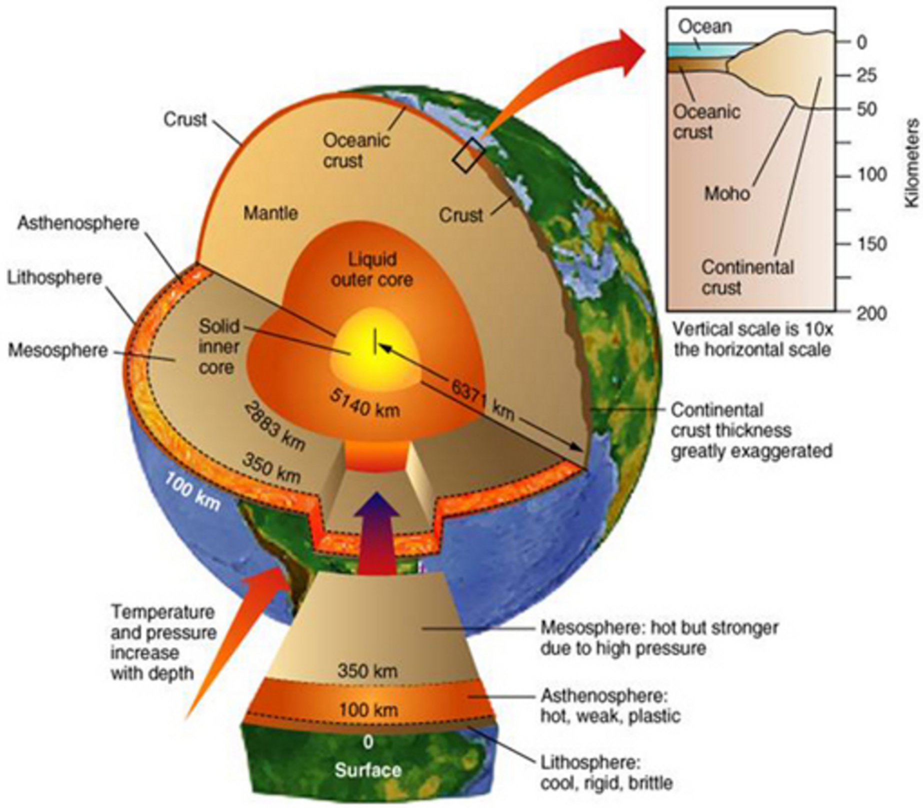

Figure 3: The structure of the Earth's interior.

of concentric rings. "Dust" particles of refractory materials concentrated in the inner rings, while "ice" particles of volatile material concentrated in the outer rings. The material in the rings began to accrete through collision and eventually by about 4.6 billion years ago planetesimal bodies which were more than about 1 km diameter were formed. Through continuous collisions the planetesimals grew progressively larger to give rise to protoplanets upto a few thousand kilometres in diameter, and ultimately to planetary bodies almost the same size as today's planets. For the terrestrial planets the process is thought to have been completed within about 100 million years.

When they first developed the large planetesimals and protoplanets were of fairly homogeneous composition. However as they formed they began to heat up, the source of heat being the energy of collisions and the decay of radioactive elements. In bodies whose temperatures rose sufficiently to cause partial melting, dense iron rich melt sank to form the core surrounded by a silicate mantle. The process is called planetary differentiation. As the core formed the release of the gravitational energy, the radioactive decay and the continued collisions heated up the planetary body even more, and eventually led to the formation of an outer layer of molten mantle.

At this early age the Earth's surface

was being continuously bombarded by meteorites. It has been suggested that at about 4.53 billion years ago, a Mars-sized protoplanet collided with the Earth. Under the force of impact the colliding body disintegrated and a large part of the Earth's mantle was blasted away. A ring of debris formed around the Earth which accreted to form the Moon. The Earth was at this time covered with a layer of molten material, the magma ocean, with small crusts of solidified basalt floating about, which were short-lived. Gradually the Earth cooled enough to form solid rocks to form at the surface. This was the Hadean eon which extended from 4.5 to 3.8 billion years.

No rocks of this period have been found on the Earth, but their evidence is found in the presence of 4.4 billion years old detrital grains of the mineral zircon in the later sedimentary rocks. During this time outgassing of the Earth's mantle through volcanic eruptions led to the formation of the primitive atmosphere of the Earth. The principal volatile components were water vapour, methane, carbon dioxide, sulfur dioxide, nitrogen and hydrogen. The comets and meteorites colliding with the Earth might also have contributed volatile components, notably water vapour, to the primitive atmosphere. At this time the Earth had probably cooled enough to have liquid water at its surface. 3.9 to 4.0 billion years was a period of intense meteorite bombardment on the Earth, which had broken up and remelted the original solid rocks forming the crust, thereby explaining their absence today. The oldest rock found on the Earth is the 4.03 billion years old Acasta Gneiss from Canada.

The Young Earth

By 3.8 billion years, the beginning of the Archaean eon, the Earth had cooled enough to form continental and oceanic crusts, with volcanoes poking up above the oceans which were likely to be of acidic composition; large bodies of sedimentary rocks were also formed. First life appeared in the oceans quite early in the Archaean, probably by 3.5 billion years. The early life forms were prokaryotes, bacteria or archaea. Photosynthetic organisms appeared by 2.7 billion years and with their appearance the oxygen content of the atmosphere started to rise.

By the end of the Archaean eon at 2.5 billion years, the beginning of the Proterozoic eon, about 80% of the present day continental crusts had formed, life had colonized the oceanic depths and the shallow marine realms, oxygen content of the atmosphere started to rapidly rise. Plate tectonics had commenced and collisional mountain belts were forming. The Proterozoic is a period of transition to the modern world. Continental crust continued to be formed, but at a slower rate. By the middle of the Proterozoic more than 90% of the Earth's continental crust had formed. Stable continental cratons came into being along with well defined collisional orogenic belts.

Plate tectonic processes led to the formation of supercontinents and their break up. The supercontinent Rodinia was formed through collisional amalgamation of continental blocks at 1 billion years. It started to break up at about 800 million years and a new short-lived supercontinent Pannotia came into existence at about 570 million years, which broke up at 550 million years. The oxygen content of the atmosphere continued to rise and by the end of the Proterozoic the oxygen content was nearly the same as today's atmosphere. The increase in oxygen had a profound effect on life which could become more complex. Eukaryotic organisms appeared definitely by 1 billion years but probably much earlier. A great leap forward in complexity of organisms occurred perhaps as early as 620 million years and certainly by 565 million years when several types of multicellular organisms constituting the Edicaran fauna appeared. A global ice age set on towards the end of the Proterozoic. The oceans froze and the lands were covered by glacier, so that the entire Earth was covered by snow, the so-called snowball Earth. But life survived and when ice vanished life expanded into new environments and new species such as the Ediacaran fauna evolved.

The onset of the Phanerozoic eon is marked by the appearance of diverse organisms with hard shells, known as the Cambrian Explosion of life. The Phanerozoic eon is the time of evolution of a myriad life forms, progression of life from the sea to land, assembling of the continents into a single supercontinent Pangaea and its subsequent break up to their present day configuration. Some aspects of the Earth's evolution during the Phanerozoic is discussed below.

The Theory of Everything in Geology

In the early 16th century as man started exploring and mapping Earth with more and more precision, a stark resemblance was observed between the boundaries of continents that are far apart from each other and separated by oceans. Abraham Ortelius, a Dutch geographer and map maker suggested as early as in 1596 that Americas were torn away from Europe and Africa and "The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three [continents]". In 1858, geographer Antonio Snider-Pellegrini made two maps showing his version of how the American and African continents may once have fit together and then later separated. Sir Charles Lyell, the revered British geologist and main proponent of the "present is the key to the past" concept wrote in his book, Principles of Geology, that "Continents, therefore, although permanent for whole geological epochs, shift their positions entirely in the course of ages".

However, it was in 1912 that the idea of moving continents was seriously considered as a full-blown scientific theory called Continental Drift, introduced in two articles published by a 32-year-old German meteorologist named Alfred Lothar Wegener. He contended that all continents were joined together as a super-continent and around 200 million years ago it began to split apart. In support of his theory, Wegner put forward the evidences of similar plant and animal fossils and rock formations in different continents which are now separated by large oceans. However, Wegner's theory was denounced largely at that time, partly because he was not able to provide a mechanism of how the continents actually moved in time and space.

Despite much opposition during initial years, the continental drift theory started getting support and opened up a debate that raged in the geological circle across the world for next four decades. It was only in late 1950's that first evidences came in from study of paleo-magnetism of rocks that suggested the Earth's magnetic north and south poles reversed through time and more importantly the relative position of the magnetic north pole also varied through time. This apparent polar wandering baffled the scientists. The only logical explanation, if you don't believe that the north pole has danced all around the globe in geological time, is to accept that the continents had moved (shifted and rotated) relative to the north pole, and each continent, in fact, shows its own polar wander curve.

The second piece of evidence came in

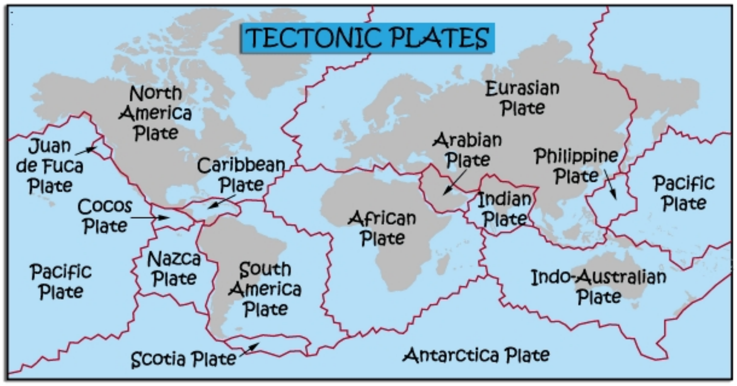

Figure 4: The major plates in the Earth's crust.

early 60's from data on the bathymetry of the deep ocean floors which gave evidence of sea-floor spreading along the mid-oceanic ridges and magnetic field reversals published between 1959 and 1963 by a number of workers like Heezen, Dietz, Hess, Mason, Vine & Matthews, Morley etc.

Harry Hess, a 2nd world war veteran who was posted in the Pacific fleet, had mapped thousands of km of deep sea topography through his sounding gears (echo sounding) during and post World War 2. After carefully analysing the data, he proposed a groundbreaking hypothesis in 1962 that proved vitally important in the development of plate tectonic theory. Hess theorized that the ocean floor is at most only a few hundred million years old and significantly younger than the continents. This represents the time it takes for molten rock to ooze up from volcanically active mid-ocean ridges, spread sideways to create new seafloor, and disappear back into the Earth's deep interior at the ocean trenches. This recycling process, later named as seafloor spreading, carries off older sediments and fossils, and moves the continents as new ocean crust spreads away from the ridges. Supporting Wegener's theory of continental drift, Hess explained how the once-joined continents had separated into the seven that exist today. The continents don't change dramatically or move independently, but are transported by the shifting tectonic plates on which they rest. Hess also theorized that because the continental crust is lighter, it does not sink back into the deep Earth at trenches as does the oceanic crust. Instead, the lighter rocks are scraped off the descending ocean crust and are piled into mountain rages at the trenches' edge. He also incorporated the idea proposed by the Swiss geologist Emile Argand in the 1920s that mountain belts are created when two continents collide.

The plate tectonics theory proposes that the outer rigid layer of the Earth called the lithosphere is divided into a couple of dozen "plates" that move on the Earth's surface relative to each other. This rigid, brittle shell of the Earth lies on top of asthenosphere, the hot, plastic interior of the Earth. Within the asthenosphere, there are convection cells which bring heat from the Earth's interior out to the surface. These convection cells move very slowly, about 10 cm a year.

When the rising convection cells reach the base of the lithosphere they split the overlying lithosphere and the two halves move away from one another creating a divergent boundary; the molten mafic material from below rises up to fill the space and solidifies to create new oceanic lithosphere. As the newly created lithosphere moves away from the divergent boundary it cools and the density increases. Where the convection goes down, the denser lithosphere bends and goes down below the lighter lithosphere forming a subduction zone (convergent boundary). Plates are destroyed (remelted at depth) at the subduction zones. Because oceanic lithosphere is created and destroyed so easily, ocean basins are young and the oldest we have is only about 200 million years old. Continents, on the other hand, are composed of lighter rocks which do not subduct and hence are more or less permanent. The oldest continental fragment we have found till date is about 4.0 billion years old. The divergent boundaries are regions of tension where rift structures are formed, and the convergent boundaries are regions of compression where mountain belts are formed. In addition to these two there is another type of plate boundary where the two plates move sideways with respect to one another; these are transform faults with strike slip motion. The forces that drive the movement of the plates are slab pull (gravity driven sinking of denser plate at subduction zone) and ridge push (lateral pressure of the intruding magma at the divergent boundary). The movement of plates has caused the formation and break-up of continents over time including occasional formation of super-continents that contain most or all of the continents, and has also given rise to the major mountain belts and volcanoes of the Earth.

It is generally agreed that there are eight "major" plates today namely the African, Antarctic, Eurasian, North American, South American, Pacific, Indian and Australian. There are also dozens of smaller plates, the seven largest of which are the Arabian, Caribbean, Juan de Fuca, Cocos, Nazca, Philippine Sea and Scotia. A plate may be an ocean basin alone, or a continent alone, or a combination of ocean basin and continent.

The current motion of the tectonic plates is today determined by remote sensing satellite data sets calibrated with ground station measurements.

Amazing facts on Plate Tectonics

Plate tectonics has been responsible for many of the features that we find on the surface of the Earth today. In the final stage the Appalachian Mountains were made by the collision of the North American and African plates. The seismic and volcanic activity of the West Coast of the United States is produced by the grinding of the Pacific and North American plates against each other. The "ring of fire" around the Pacific, corresponding to regions of high volcanic and seismic activity is caused primarily by the subduction of the Pacific, Nazca and Cocosplates. The Dead Sea in Israel is part of a rift system produced by plates that are pulling apart in that region. The Himalayan Mountains were formed and are still growing as a result of the Indian plate burrowing under the Eurasian plate and raising its edge.

And in next the 50 million years or so, plate tectonics will drastically reshape the face of the Earth. Based on projections of current plate motions, scientists have predicted that

- Portions of California will separate from the rest of North America.
- Australia will become linked to Asia.
- A sliver of Africa east of the East African rift will separate from the main continent.

A Brief History of Science
Part 10: The Revolution in Biology

Soumitro Banerjee*

WHILE IDEAS IN PHYSICS and many other branches of science were undergoing great advancements in the 17th and 18th centuries following the advent of mechanical materialism and the ideas of causality and determinism, in biology the transition from observation to understanding happened much later. There were a few factors contributing to this, but the main factor was that, in the language of the eminent biologist Theodosius Dobzhansky, "nothing in biology makes sense except in the light of evolution." And the world was not yet ready to welcome the idea that biological species do evolve.

First, the belief that reigned supreme in the western world was that all the species on Earth were created by God and they have remained the same ever since. The belief was supported by the apparent empirical observation that biological species do not change. Cows give birth to cows, and horses give birth to horses and this goes on generation after generation. Even though some changes take place in each cow through the course of its life, nobody had seen the species changing. So the idea of fixity of species resulted from this empirical observation—the experience of people over generations. This is called the error of empiricism. And, one cannot advance much in biology with the idea of fixity of species.

Yet, the opening of the mind's eye in course of the Renaissance prompted people to look closer at the things around them, including living beings. Observation and study of nature started afresh. But since religious beliefs were still very strong in this period, people viewed the study of nature as an attempt to understand the mind of God in creating the different forms of living matter. For example, the English naturalist John Ray (1627-1705) was the first to introduce a classification of plants, but his discourses on the subject were titled "The wisdom of God manifested in the works of the creation". There were also discussions in the Church circles about the natural world, and aimed at integrating it with religious beliefs. Many books were written based on the idea of this "natural theology". Conceptually this did not advance biology much, but observational data started accumulating out of which biology would grow in the later years.

The philosophical foundation for any investigation was provided at that time by the Aristotelian system of formal logic, which, as we have seen in earlier issues, wanted to describe "things as they are", not things in the process of change and development. Therefore, naturalists of the period collected samples and described living beings "as they are". The philosophical basis of their study prevented them from noticing

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Carl von Linnaeus (1707-1778)

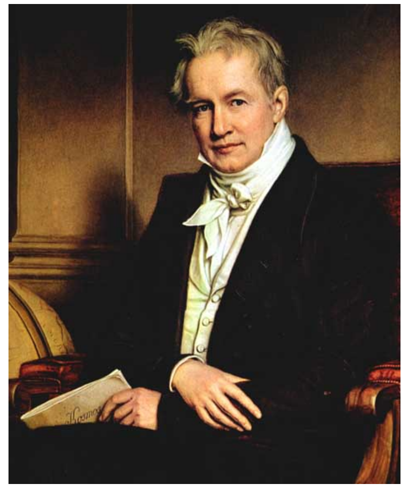
the clues that would later give rise to the idea of biological evolution.

But still, important works were done in this period. A case in point was the eminent Swedish biologist Carl von Linnaeus (1707-1778), who systematized the study of the biological world. He introduced a hierarchical system of classification consisting of seven levels (namely Kingdom, Phylum, Class, Order, Family, Genus and Species). He introduced a system of nomenclature based on similarity of the external morphology and behaviour of different forms of life. In this system the name of a species is preceded by the name of the genus (for example the scientific name of the wolf is *Canis lupus*—*Canis* is the genus and *lupus* is the species). We still follow this system of nomenclature. Yet, Linnaeus did not believe in evolution and was only studying the different species "as they are" and was categorizing them. This systematization itself contained hundreds of clues that pointed to the fact of evolution, but Linnaeus failed to see these because of his religious beliefs.

But evidence was accumulating. From much older times, people have been finding fossils of animal bodies, but dismissed them as the "unsuccessful creations of God". Fossils were also found at odd places—for example, fossils of marine animals on top of mountains, which demanded explanation. As explorers made voyages to distant lands, they found animals and plants that were not found in Europe. There was no mention of these life forms in any of the sacred books; no mention of how and when *these* were created. And when mining started on large scale, people started finding more and more fossils—and it became apparent that the number of different life forms found in fossils outnumbered the life forms that exist today. So "God's unsuccessful creations" theory came into question: If a creator makes more mistakes than correct ones, there is reason to doubt his wisdom. In any case, it was increasingly being felt that the genesis theory of the Bible was inadequate in explaining the multitude of life forms and fossils that were being found. But for a long time the age-old beliefs lingered and naturalists were reluctant to accept that species do change.

As an example, take the case of the eminent French naturalist Georges Buffon (1707-1788), head of the *Jardin du Roi* (Royal Gardens) in Paris. He was a person of great knowledge and wide-ranging interests. He wrote a 32-volume treatise on natural history which was immensely influential in shaping the thoughts of scientists for the next two generations. It was he who first conjectured how the solar system may have been created. It was he who pointed to the importance of comparative anatomy in understanding biology, and hinted at the possibility of transformation of one species into another with closely related anatomical features. But he saw these changes as "degeneration" from the original

Georges Cuvier (1769-1832)



Alexander von Humboldt (1769-1859)

forms created by God, and declared that he does not believe in evolution of species!

Another eminent naturalist, Georges Cuvier (1769-1832) followed up the idea of comparing the anatomy of different species to establish relations between them. For example, he studied the anatomy of the Indian elephant, the African elephant, mammoth fossils, and the fossil of an elephant-like animal found in America (now we know it as the mastodon). He showed that these are distinct but related species, the last two being extinct. He carefully studied fossils found in different strata of rocks and showed that many animals had lived in the past and became extinct after some time. But through this he did not conclude that species change. Rather, guided by his religious belief, he concluded that there have been many epochs of catastrophic floods, resulting in mass extinction of species and subsequent re-creation by God in multiple genesis events.

Yet scientific information was pouring in from all sides. The German explorer Alexander von Humboldt (1769-1859), travelled extensively in South as well as North America in the first decade of the 19th century and collected an immense volume of scientific information related to botany, geology and meteorology. He travelled through the Amazon and the Andes, documented the lives of several native tribes, discovered and studied many new species of animals (including the electric eel) and plants. His memoirs published over the next two decades contained very rich scientific information that enriched biological knowledge significantly.

Naturalists in this period were grappling with the question of being able to explain the immense variety of living organisms.

Philosophy opens the door

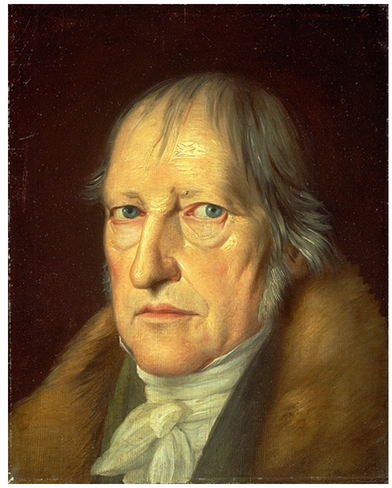
In this situation, philosophers took the first plunge. Immanuel Kant (1724-1804), whom we have met earlier in our discussion on causality, proposed that everything in the material world is in a state of “flux” (the word “evolution” had not been coined at that time). He even envisioned that the solar system itself had come into being through such an evolutionary process. He proposed a hypothesis that the solar system originated from a primeval nebula. This, after a lot of modification and enrichment by subsequent generations of scientists like Laplace, is still the accepted theory today.

Picking on the idea that everything in nature is continuously undergoing changes, the German philosopher Georg Hegel (1770-1831) in his book "Science of Logic" pointed out that changes in nature do not proceed in linear progression, as uniformly gradual changes. Slow quantitative changes are in fact punctuated by qualitative changes; things proceed from "being" to "becoming". Water freezes to ice, seeds germinate to saplings, nitrogen and oxygen upon reacting give rise to substances with new properties—he cited these as examples of such qualitative changes. When such a qualitative transformation happens, the entity becomes a new entity, *negating* its earlier existence. According to Hegel, the Kantian "flux" or changes in nature need to be understood in terms of both the quantitative changes as well as the qualitative transformations. But in spite of providing this vital clue to understanding nature, he stood rooted on the concept of an "Absolute Idea"—the primary all-inclusive entity whose external representation is nature or material world—and fell prey to idealism.

However, with these developments in philosophy, the idea of evolution was, so to speak, in the air. It remained for the scientists to prove its reality with hard data, and to work out how it actually happens.

The backlash of natural theology

The believers of natural theology were keenly noticing the threat of the new idea. Various lines of argument trying to refute the idea of evolution were formulated in this period. But the most powerful attack came from the English clergyman William Palley (1743-1805). In the year 1802 he published a book titled "Natural Theology, or Evidences of the Existence and Attributes of the Deity collected from the Appearances of Nature". His argument was as follows.



Georg Hegel (1770-1831)

Suppose you are walking along a forest path, and you come across a piece of rock. That would not raise any question in you, because there is nothing extraordinary about it. But if you come across a watch lying on the forest path, it will surely raise a question—because upon examination of the object you would notice the intricate mechanism. You would conclude that it is indeed extraordinary to find such an object on the forest floor, because, clearly, it is a product of conscious design.

Paley then took the argument forward by citing the extraordinary mechanisms that make a living body work, and argued that these must be the products of conscious design. He particularly cited the eye as an example of intelligent design. And, he said, if there is a design, there must be a designer. *That* designer of the natural world, according to Palley, is God.

It took the genius of Darwin to conclusively put an end to all these ideas in circulation with an alternative materialistic

James Hutton (1726-1797)

Charles Lyell (1797-1875)

explanation supported by testable evidence. But, as we'll see, even Darwin was influenced by natural theology in his early years.

Does the Earth change?

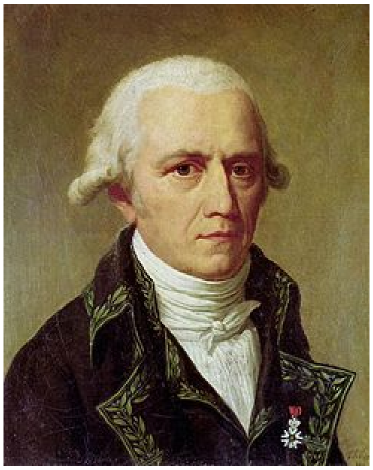
Kant's assertion about the ever-changing nature of the world encouraged the Scottish geologist James Hutton (1726-1797) to investigate if the Earth itself has undergone such changes. He found not only that the mountains, rivers and seas have changed over time, but also that the time taken for the changes to take place is much longer than what was supposed in the Biblical genesis belief. He explained the features of the Earth's crust by means of natural processes over geologic time scale. Through observation and carefully reasoned geological arguments, Hutton came to believe that the Earth's surface is perpetually being formed, and forwarded the crucial argument that the history of the Earth could be determined by understanding how processes such as erosion and sedimentation work in the present day. Hutton's work established geology as a proper science, and thus he is often referred to as the "Father of Modern Geology".

The English geologist Charles Lyell (1797-1875) worked further to unearth the history of the Earth, and published a 3-volume monograph titled "Principles of Geology", which was a compendium of the knowledge of geology in his time. It also popularized Hutton's idea that the Earth was shaped by the same processes still in operation today. It is this book that later proved crucial in the development of Darwin's theory of evolution [1].

Lamarck: A theory of evolution takes birth

The French naturalist Jean Baptiste Lamarck (1744-1829) first tried to propose a theory of biological evolution in the year 1809. According to Lamarck, the process of evolution is essentially the process of morphological change of the organs belonging to the members of a

[1] Darwin carried the first volume in his Beagle voyage, and acquired the other two volumes by post during the course of the journey.



Jean Baptiste Lamarck (1744-1829)

species, resulting in the transformation of a section of one species into another. Why do the organs evolve? Because of the influence of the environment on individual organisms. An organism may face a change in the environment to which it is adapted — which may happen on account of climatic change or migration to a different location. A change in the environment causes changes in the needs of organisms living in that environment, which in turn causes changes in their behaviour. Altered behaviour leads to greater or lesser use of a given structure or organ; a more frequent and continuous use of any organ gradually strengthens, develops and enlarges that organ, and gives it a power proportional to the length of time it has been so used; while the permanent disuse of any organ imperceptibly weakens and deteriorates it, and progressively diminishes its functional capacity, until it finally disappears. This rule—that use or disuse causes structures to change—Lamarck called the "First Law" in his book *Philosophie Zoologique*. Lamarck's "Second Law" stated that all such changes were heritable. The result of these laws was the continuous, gradual change of all organisms, as they became adapted to their environments.

Lamark's theory had great impact on his contemporaries. First, it stated that evolution of species is a fact. Second, it pointed to the course of evolution: According to Lamarck it proceeded from the simple to the complex, from the lower to the higher, and so it is a progressive process. Third, he proposed a plausible causal mechanism—evolution guided by "need to change" in response to the change in environment. Evolution, according to him, was an entirely natural process that does not require any divine intervention.

Darwin: The grand synthesis

This was the intellectual climate when Darwin was a young man. On the one hand, the philosophical ground for studying the biological world as a body of ever-changing living matter had been created; on the other hand the belief in a Biblical genesis was still very strong. However, the doubts about the genesis theory had been sown by the development in geology (which showed that the Earth was much older than supposed in the genesis stories), and the observational facts regarding the ever-changing nature of the world coming in from all quarters. The fact of evolution had also been forcefully propounded by Lamarck. But at the same time, the idea of a creation event had been further strengthened by the "intelligent design" argument, and most scientists studying the natural world were trying to strike a compromise between science and theology.

When Darwin boarded the HMS Beagle in 1831 for the arduous 5-year journey across the globe as a resident naturalist, he was a devout Christian and believed the Biblical genesis theory. His job was to study the flora and fauna of the places the ship visited—which he did remarkably well. He collected thousands of specimens and dispatched them in crates to England for study and classification by professional biologists. He carefully took notes of what he observed. And by the time he returned to England in 1836, he had become doubtful about the idea of Biblical genesis.

He started carefully analyzing the data he collected, and by March 1837 he was convinced that transmutation of species was a reality. But as yet he had not found the mechanism of evolution. In his autobiography, he explained "It was evident ··· that species gradually become modified; and the subject haunted me. But it was equally evident that neither the action of the surrounding conditions, nor the will of the organisms (especially in case of plants), could account for the innumerable cases in which organisms of every kind are beautifully adapted to their habits of life." Thus, in his search for a mechanism of evolution, he was convinced, early on, that Lamarck's theory does not provide a satisfactory explanation.

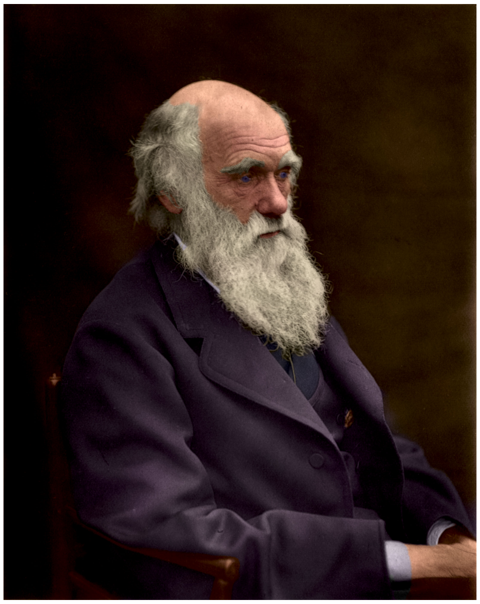
In 1838 he was able to formulate a plausible hypothesis that could be subjected to tests. Then, what he did was surprising: He did not think of publishing his idea; instead, he worked intently for no less than twenty years testing his hypothesis using the evidence from different areas of biology and geology. He prepared a preliminary 35-page sketch of his argument in 1842, and then expanded it to a 230-page "essay" in 1844. But he was not yet satisfied with his theory and was not ready for its publication (though he instructed his wife Emma to publish it in case of his death). In the meantime he continued accumulating facts and details in support of his theory.

This "silent" mode of working came to an abrupt end when he received a letter from a naturalist named Alfred Russel Wallace who, while working in the Malay Archipelago, had come to similar conclusions on the mechanism of evolution. Darwin showed the letter to his scientist friends Charles Lyell and J D Hooker. They suggested that extracts of Darwin's essay of 1844 and a letter addressed to Prof. Asa Gray of Boston, in October 1857 and Wallace's paper be read jointly at the Linnean Society meeting on July 1, 1858 — thus recording Wallace as a co-discoverer of the theory. After that, at the insistence of Lyell and Hooker, he wrote up the book '*On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*'. When it was published in 1859, it went on to change the course of scientific history.

It is not possible to present a detailed account of Darwin's theory in the scope of this article. This has already been published in some earlier issues of Breakthrough, which are available in the archives of www.breakthrough-india.org (see, for example, "Darwin and the Theory of Evolution", Vol.12, No. 1, October 2006). Here we present a very brief outline of his argument.

Darwin noticed a few "clues" in his studies of the natural world. First, that within every species there are variations: no two organisms are the same. Second, that every organism exists in two types of struggle for existence: (a) the intra-species struggle for the limited resources like food, and (b) the inter-species struggle with the enemy (e.g., deer-tiger) or competing (e.g., tiger-leopard) species. Third, that in every species far more individuals are born than can survive in the struggle and can reach maturity. Only a handful of successful individuals can produce offspring.

On the basis of these clues he built his theory of natural selection: variation means different physical characteristics, and in a given natural environment some characteristic features may give survival



Charles Darwin (1809-1882)

advantage. These organisms are, therefore, better adapted to their environment. Out of the millions of individuals that are born in a given generation, the ones that carry the advantageous physical traits are "selected by nature" to produce the next generation. Thus the advantageous physical characteristics get transmitted and the disadvantageous ones get eliminated. This mechanism allows the average physical characteristics of a species to change over generations, and new species to emerge. True, the process was slow, but as Hutton and Lyell had shown, the Earth was old enough to account for the necessary time for this evolutionary mechanism to work.

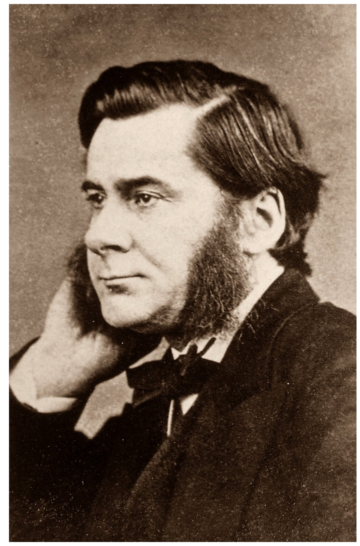
A few features of his theory are noticeable. First, it is a completely materialistic theory that calls for no divine hand or conscious design to produce the complicated organisms or body-parts that we see today. Second, it is a causal theory that clearly states the connection between the cause (environment) and the effect (change in organisms). Yet, unlike all causal theories science had seen so far, it, at base, is a probabilistic theory. The variations that take place are random, and from among all the variants natural selection chooses the form best adapted to the environment. A given physical characteristics gives an organism only a higher *probability* of survival, and only when viewed at the species level—with millions of individuals—does it become a causal mechanism governing the process of evolution.

Darwin himself threw light on his transition from a believer in "intelligent design" to a strict materialist. "The old argument of design in nature, as given by Paley, which formerly seemed to me so conclusive, fails, now that the law of natural selection has been discovered" Darwin wrote in his Autobiography. We can no longer argue that, for instance, the beautiful hinge of a bivalve shell must be made by an intelligent being, like the hinge of a door by man. There seems to be no more design in the variability of organic beings and in the action of natural selection, than in the course which the wind blows. Everything in nature is the result of fixed laws."

Convincing the world

Even though obtaining evidence for his theory was a two-decade long endeavour, convincing the world about the fact of evolution and its materialistic mechanism proved to be an uphill task. Given the dominance of religious sentiments in peoples' minds, it is understandable that *The Origin of Species* created quite a furore. Darwin had spared only a few sentences to simply state that all species, including man, was subject to natural laws, and the origin of the human race could be traced in a similar manner. The implication enraged the devout Christians who saw his theory as a blasphemous attempt to unseat God.

Darwin was a shy and reclusive man and did not want to take part in any debate. Fortunately, a few very competent professional biologists came forward to defend and to popularize his theory. A public debate was organized at the Oxford University Museum on 30 June 1860, in which Bishop Samuel Wilberforce took the side of the Church and Thomas Henry Huxley took the side of Darwin's theory of evolution. The debate is best remembered today for a heated exchange in which Wilberforce supposedly asked Huxley whether it was through his father's side or his mother's side that he claimed his descent from a monkey. Huxley is said to have replied that he would not be ashamed to have a monkey for his ancestor, but he would be ashamed to be connected with a man who used his great gifts to obscure the truth. Because of his staunch defence of Darwin's theory Huxley was popularly referred to as Darwin's "bull dog".



Thomas Henry Huxley (1825-1895)

With passage of time it became clearer that the theory fits all observations and provides a consistent rational explanation of the past and present variations in the organic world. Slowly people in larger numbers became convinced about the truth of the theory, and it found general acceptance. But the struggle between science and anti-science is far from being over (See Box-1).

It is notable that Darwin avoided any direct attack on religion, and differed from the approach of some science activists of his day. For example, Edward Aveling, a professor of biology and a serious campaigner in favour of Darwin's theory, used to mount frontal attack on religious beliefs to propagate atheistic views citing Darwin's theory. When he sought permission to dedicate his book "The Students' Darwin" to Darwin, the latter declined the offer. Darwin wrote, "though I am a strong advocate for free thought on all subjects, yet it appears to me (whether rightly or wrongly) that direct arguments against Christianity and theism produce hardly any effect on the public, and freedom of thought is best promoted by the gradual illumination of men's minds which follows from the advance of science. It has, therefore, been my object to avoid writing on religion, and I have confined myself to science." The science activists of today may also have something to learn from Darwin's views.

Darwin's method of investigation

What method did Darwin adopt in his investigations? In his time, two prominent methodological issues were in vogue: the inductive doctrine propounded by Bacon, and the deductive doctrine propounded by Descartes (see Part 5 of this series, published in January 2014). Most biologists in Darwin's time adopted the Baconian approach. Bacon had noted that in his time the minds of most investigators were obscured by religious beliefs, and the preconceived notions and prejudices prevented

Box-1: Evolution theory in school education

Even though Darwin's theory of evolution is now a scientifically accepted theory, and can be understood and appreciated by high school students, in many countries—even advanced ones—it is either not taught or is taught along with creationism. In the states of Georgia and Alabama of the United States, the biology textbooks must have a sticker that says "This textbook contains material on evolution. Evolution is a theory, not a fact, regarding the origin of living things. This material should be approached with an open mind, studied carefully, and critically considered." In the state of Kansas, there is no mention of evolution, the age of the Earth, etc., in the school curriculum so that evolutionary theory would not appear in state-wide standardized tests and it is left to the local school districts in Kansas whether or not to teach it. In the state of Pennsylvania, the Dover Area School Board voted in 2004 that a statement must be read to students of 9th grade biology mentioning intelligent design. And in the state of Texas, the Texas Education Agency (TEA) director of science curriculum Christine Comer was forced to resign in 2007 over an e-mail she had sent announcing a talk given by an anti-intelligent design author, because the TEA "must remain neutral" on the issue of evolution!

In the member states of the European Union, even though both creationism and the theory of evolution are taught in most schools, the Council of Europe has taken a firm stand. On October 4, 2007, it is to be appreciated that the Parliamentary Assembly of the Council of Europe (PACE) adopted its Resolution 1580 titled *The dangers of creationism in education.* The resolution observed that "The war on the theory of evolution and on its proponents most often originates in forms of religious extremism closely linked to extreme right-wing political movements," and urged member states to "firmly oppose the teaching of creationism as a scientific discipline on an equal footing with the theory of evolution and in general the presentation of creationist ideas in any discipline other than religion."

them from reaching correct conclusions about the working of nature. So he had recommended that one should collect information about various aspects of nature *without any prior idea in mind*, and should adopt inductive logic in deriving general conclusions about them. Even though Darwin said that he also adopted a similar approach, he actually didn't.

Instead, faced with a question, he would first look for the primary clues, would then form *hypothesis* on that basis, and then would meticulously plan *directed observations* that would prove the hypothesis to be either true or false. Thus, when he started methodical investigation after returning from the Beagle voyage, he always had a very clear idea about what he was looking for. So Darwin actually did not follow the Baconian recommendation that observations should not be guided by hypothesis.

Pointing out the problem of undirected observation, he wrote "A man might as well go into a gravel pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service." He underscored the importance of hypothesis in guiding empirical research by indicating what is worth observing and what evidence to seek. He says about his own method of research "I cannot avoid forming one hypothesis on every subject." Through his own work Darwin showed that, if the hypotheses are constructed on a scientific basis (and not on the basis of preconceived notions and unfounded beliefs), these may become very powerful tools that guide systematic observation and help to reach correct conclusion. This is a very important point in the method of science, to which we shall return later.

The second point is that he never accepted something as true only because it appeared to him to be true. He always subjected his ideas to very strict tests. He would examine and re-examine his own database, and would explore all the possible alternative explanations. Only when it was evident that the other theories failed to offer satisfactory explanation of the question at hand, he would allow himself to conclude in favour of his hypothesis. Still he kept open the possibility that he might be proved wrong. This reflected a firm determination to guard against any kind of subjective bias.

Another aspect of his scientific personality is worth mentioning. Many scientists have a tendency to take note of only the arguments and facts favourable to his/her theory and disregard (or at least give less importance to) the ones that do not support the theory. But Darwin attached great importance to any contrary facts and objections that seemed to go against his theory. He made appropriate note of these and mentioned them in his book in full; and honestly expressed his inability to answer them with complete satisfaction. He did not try to ignore or bypass them.

For example, his theory vitally rested on the premise that there are variations within each species. His theory pointed to the way the variations unfavourable to adaptation in a given environment are eliminated by natural selection. One may thus conclude that variations would reduce with time, which is not supported by observation. He could not answer the question "How do new variations originate?" (it could be answered only after the development of genetics), but he clearly mentioned it in *The Origin of Species*.

"I had ··· followed a golden rule, namely that, whenever a published fact, a new observation or thought came across me, which was opposed to my general results, to make a memorandum of it without fail and at once; for I had found by experience that such facts and thoughts were far more apt to escape from memory than favourable ones" he wrote in his Autobiography. "Owing to this habit, very few objections were raised against my views which I had not at least noticed and attempted to answer."

After Darwin

Darwin's work opened a gate that had been closed for a long time: to understand the biological world in the light of evolution. Biology advanced in leaps and bounds in the century following the publication of *The Origin of Species*. Before Darwin, scientists had collected and recorded observations of lakhs of species, devised data bases to understand them, but the interaction, inter-relation, dependence on each other was poorly understood. Darwin interlinked the lakhs of species and uncovered the law governing the living world.

Yet, it is clear that Lamarck and Darwin proposed very different mechanisms of the evolutionary process. Who was right? Much of biology in the later years concerned resolution of this puzzle, which came only after we understood the molecular mechanisms of heredity and evolution. With the development of molecular biology and genetics, some improvisations, some factual additions and deletions, and further enrichment have taken place. But the basic theory of evolution as proposed by Darwin stands vindicated. We shall come to that chapter of the history of science in a later issue.

(To be continued)

Materialist Philosophy in Ancient India

Subrata Gouri *

A POPULAR BELIEF is prevalent in our country that this land was a place for development of spiritualism and idealistic view of philosophy. It is further believed that our *munis* and *rishis* used to be so engrossed in thoughts of *moksha* and the other world that they did not find any time for thinking about the present world of things; though in *purushartha*, it is true that *artha* and *kama* are concerned with worldly affairs subservient to *dharma* but *moksha* remained the ultimate object of life.

But a critical study of history of the philosophical thoughts clearly reveals that there was a rich tradition of materialist philosophy in our country from ancient time. In fact, a majority of the schools of philosophy that flourished in our country reflected materialistic views. But the ruling class and their standard bearers had tried to suppress these materialistic views. They even destroyed many valuable writings belonging to materialistic philosophies. On the contrary, they always upheld and patronized the idealist views. This tradition is still going on today. So it is necessary to highlight and uphold the materialistic philosophy that existed in our country.

Before entering into the main subject, I would like to point out the basic difference between the two great camps of philosophical thoughts i.e., materialism and idealism. I would like to refer to the Marxist philosopher Friedrich Engels in this context. He defined these two philosophical currents as follows: "The great basic question of all philosophy ··· is that concerning the relation of thinking and being. The answers which the philosophers gave to this question split them into two great camps. Those who asserted the primacy of spirit to nature ··· comprised the camp of idealism. The others, who regarded nature as primary, belong to the various schools of materialism."

In European philosophy the first who fully asserted the primacy of spirit to nature was Plato. He worked out his theory of ideas in conscious opposition to materialism. He wrote, "Why this dispute about reality is a sort of battle of gods and giants? The giants are the materialists. The gods are of course the idealists." The idealists of our country also expressed the same view. They too worked out their philosophy in opposition to materialism. Their idealism moreover was for them the philosophy of the gods or *Devas*, while materialism was the '*Upanishad*' or 'secret knowledge' of the demons or the *Asuras*.

The clearest expression of this is to be found in a legend of the Chhandogya *Upanishad*. *Indra* and *Virocana*, the representatives of *devas* and *asuras* respectively approached *Prajapati* for the knowledge of the true self. *Prajapati* asked them to look at their own images on a pan of water and they saw their own bodies 'corresponding exactly to the hair and finger nail'. This knowledge of the Self being the body proved sufficient for *Virocana*. But Indra felt dis-

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satisfied and came back to *Prajapati* to be instructed in the idealist philosophy which therefore became the philosophy of *Devas*.

Thoughts of the pre-historic stage was materialistic

So it is clear that the struggle between materialism and idealism lasted for thousands of years. But when did this struggle start? In this article we shall not enter into a detailed discussion, but anthropological studies have clearly shown that the thoughts of the early humans were materialistic in nature. Idealism came afterwards after the division of the society into classes. So it is natural that this would be reflected in the early civilization. Thoughts of the early human society on this land were materialistic.

We had two traditions—Vedic and non-Vedic. Both the societies reflect the common features of existence of materialism particularly in the early part of it.

Materialist thinking in the Vedic tradition

As we know that the Vedas are orally composed songs and eulogies composed by pastoral people before the advent of written script. They called themselves *Aryas* (Aryans) and were at some stage of barbarism[1]—and transmitted to the later generations by a method of sheer retentive memories and hence also called *Shrutis*, that which is heard. These immensely old oral compositions are traditionally called the *mantras*, one great division of the *Veda*, the other being the *brahmana*, which is in prose and is of later origin.

[1]Barbarism implies a society more advanced than the hunter-gather stage, practising animal husbandry and/or agriculture, but before the advent of reading and writing, and advanced societal organization like urban life.

The *mantras* come down to us in the form of four compilations or *Samhitas*, viz. the *Rigveda-Samhita, Samveda-Samhita, Atharvaveda-Samhita and Yajurveda-Samhita*. These are also often referred to simply as the *Rigveda, Samveda* etc. Of these, the *Rigveda* is the oldest and considered to be the foundation of all *vedic* literature. Since the people who composed the songs of *Rigveda* were in the stage of barbarism, it is natural that the thoughts inherent in the *Rigvedic* hymns and songs would be materialistic in nature. And we have seen exactly the same in the *Rigveda*. An actual reading of the *Rigveda* gives one the inescapable impression that like the songs and chants of the surviving pastoral people, these hymns, too were but the simple expressions of the everyday desires—the desire for cattle, food, rain, safety, victory, health and progeny. The desires were predominantly linked with worldly materials.

There is no doubt that the hymns and songs are full of extravagant praises for all sorts of deities or *Devas*. But who were they? They are often crassly human heroes, looting food and cattle for the tribesmen and sharing these out among themselves; sitting with them in their assemblies and addressed by them in endearing terms like friends or the best of friends—often they were simply natural phenomena and inanimate objects, even like the hill (*parvata*), the herb (*osadhi*), the trees (*vanaspati*), the forests (*aranyani*), the weapons like bow and arrows (*ayudha*). Sometimes again the deities are just the embodiments of purely these worldly desires, like the protection against abortion, 'the protection against consumptive diseases', 'the protection against nightmare'. A fascinating deity of this kind is *Pitu*, i.e., food. The barbarian poets with their healthy appetite praised him for being savoury and delicious and because he makes the body fat. In the general context of all sorts of traditional and modern claims attributing the highest spiritual wisdom to the *Rigveda*, these hymns to *Pitu* may be quoted here to show their materialist leaning:

'I glorify *Pitu*, the Great, the upholder, the strong, by whose invigorating power *Trta* (the famous) tortured the deformed *Vrtra*. Savoury *Pitu*, honeyed *pitu*, we welcome thee; become our, become our protector ···. Come to us, beneficial *Pitu*, a source of delight, a friend well respected and having no envy. Your flavours, *Pitu*, are defused through the regions, as the dust spreads through the regions, as the winds spread through the sky ···. The minds of the mighty gods are fixed, *Pitu*, upon you; by your active assistance (*Indra*) slew *Ahi*. O *Pitu*, the wealth which is associated with the mountains went to you; hear you, O sweet one, be accessible to our eating. And since we enjoy the abundance of the waters and the plants; — therefore, o body may thou grow fat. And since we enjoy *Soma*, thy mixture with boiled milk or boiled barley; — therefore, O body, may thou grow fat ···.' (Rg 1.187. Deity *Pitu*, Poet *Agastya*)

What do we find here? Anything spiritual or idealistic or simply material things?

One important deity was Sun or *Sabita*. The name of another deity was *Apangnapat*. He is the deity of water. Another important deity was *Agni* i.e., fire. Here there is no place for any supra-matter spiritual thoughts. So we can certainly say that though the later philosophers, particularly the Vedantic philosophers claimed Vedic support for their philosophies, according to the strictly Vedic tradition itself, philosophy, or for that matter, abstract thinking — was far from being the real purpose of the early compilations or *Samhitas*. Like all other primitive consciousness of the primitive societies, early Vedic consciousness was related to the strictly natural phenomena and forces, which they encountered in their daily life, i.e., they were worshiping nature.

The Mimamsa

We find two schools of philosophy based on the Vedic tradition i.e., *Purva Mimansa* or *Mimamsa* and *Uttara Mimamsa* or *Vedanta*. Among them *Vedanta* is the principal idealist philosophy of our land. But we find reflections of materialist thinking in *Mimamsa*.

At first let us look at the literature of *Mimamsa* Philosophy. The *Mimamsa-Sutra* is the source book of this system and it is a compilation of 2500 aphorisms attributed to a certain *Jaimini*. Though believed to be oldest among the *Sutra* works, it is impossible to be exact about its date, which could be between 300 BC and 200 AD. But the actual origin of the philosophy must have been older. Jaimini himself quoted a considerable number of his predecessors and the theoretical discussions concerning the rituals, the special theme of the *Mimamsa*, were already vigorously undertaken in the *Brahmana* literature, of which the *Mimamsa* was the direct outcome.

The earliest extant commentary on the *Mimamsa-sutra* was by *Sabara* and hence called *Sabara-bhashya*. The greatest *Mimamsakas* after *Sabara* were *Prabhakara* and *Kumarila*. Both of them worked on *Sabara-bhasya*, but there were sharp differences between them. The differences were strong, sometimes even fundamental. This resulted in splitting up of the *Mimamsa* into two schools called the *Bhatta* and the *Prabhkara* schools, after the names of these two exponents.

Now let us come to the subject matter of the *Mimamsa*. At first, we find that the *Mimamsa* forms the stock-example of how an orthodox system of Indian Philosophy is under no necessary obligation to admit the existence of God. Feeble and quite fanciful efforts are sometimes made by the modern scholars to prove that this orthodox philosophy par excellence could not possibly be atheistic. But it is true that *Jaimini* himself did not believe in God. *Sabara's* argument for the rejection of God is simply that there is no evidence of his excellence. Sense-perception does not reveal God and the other sources of knowledge are after all based upon sense-perception.

Here one point should be borne in mind that later philosophers, who believed in God, put forward newer arguments in favour of theism. So, later *Mimamsakas* had to wage determined struggle against them. For example, one important argument of the later *Nyaya-Vaisesikas* in favour of the existence of God was like this: everything which is made of parts, i.e., which is neither atomic nor infinite in magnitude, is of the nature of the effect, just as a pot is; and as an effect, it is in need of a course in the form of an intelligent agent, like the potter in the case of the pot. Everything in this world—or, the world as a whole—is made of parts; therefore it is of the nature of an effect and as such must be in need of a cause in the form of an intelligent agent. Considering the magnitude of the task this intelligent agent is supposed to perform, he must be conceived as omniscient, omnipotent, etc. i.e, is God. He creates the world from the atoms, the eternal material cause of the world, and periodically also destroys it.

Both Prabhakara and Kumarila came out sharply against this argument.

According to both Kumarila and Prabhakara, individual things of the world have their beginnings and ends; but this does not mean that the world as a whole is ever created or destroyed. Therefore, rejecting the idea of the periodic creation and dissolution of the world, both argued that there is only 'the constant process of becoming and passing away.' As for the cause of the individual things of the world, nothing more need to be assumed than what is actually observed, thus, for instance, the mundane parents rather than any extra mundane god are observed to be the causes of the offspring; why then assume anything more to explain their coming into being?

But why were the *Mimamsakas* so keen on rejecting the existence of God? The real clue to their atheism is to be found in their way of looking at the *Veda* and the *Vedic* deities. As already observed, the whole of the *Vedas* can be viewed by them as nothing but a body of ritual injunctions. At the same time, the *Vedic* texts mentioned all sorts of deities in connection with performance of the ritual. How then was the relation between the rituals and the deities to be conceived? Were the rituals mere acts of worship meant to please the deities so that they would grant the desired result? *Sabara* went into great details of the question and answered it with an emphatic 'No'. The deities had no substantive forms and as such could neither eat the oblations nor get pleased by them. Moreover there was no question of their granting the desired results because they had no real lordship over the worldly things that were desired by the performer of the rituals. Who then were the Vedic deities? *Sabara* in fact went to the extent of arguing that for a *Mimamsaka* there was no objection to viewing them as but mere names or sounds necessary for the ritual spells.

Sabara categorically asserted that the rituals were not acts of worship or propitiation. *Sabara's* elaborate discussion of the whole subject makes it quite clear that he was trying to draw a sharp distinction between the rituals as understood by the *Mimamsakas* and what is usually understood as the essence of religion. And since he argued that the rituals by themselves i.e., mechanically or by their own inherent potency and according to their intrinsic laws did not produce the results, it is quite evident that what he meant by the rituals was the magical acts as we know them today.

Here we should deal with one pertinent question: What is magic? George Thomson observed that magic rests on the principle that by creating the illusion that you control reality, you can actually control it. In its initial stages it is simply mimetic. You want rain, so you perform a dance in which you mimic the gathering clouds, the thunder-clap, and the falling shower. You enact in fantasy the fulfillment of the desired reality. In its later stages the mimetic act may be accompanied by a command, an imperative 'Rain!' But it's a command, not a request.'

It was of course quite natural for the *Mimamsakas* to take a magical view of the Vedic rituals. For they were after all the inheritors of the *Brahmana* tradition and the *Brahmanas* in spite of grafting upon the primitive rituals the later class interests of the priests, persisted in viewing the *Yajna* as essentially magic. However for the primitive magicians, there was no question of defending logically the efficacy of the magical acts. Actually there was no alternative before them for solving problems of life. This was the primitive consciousness of the early humans. As I already mentioned the *Mimamsa* is the outcome of the *Brahmana* tradition, which was linked with this primitive consciousness, and hence the clue to everything about the *Mimamsa* is to be sought in the assumption underlying the primitive magic. Hence, the reflection of the materialistic outlook was manifested in the *Mimamsa.*

We may now proceed to consider the refutation of idealism by the *Mimamsakas*. Kumarila explained the necessity for it from the *Mimamsa* point of view. If everything was *maya* or unreal (which our idealists believe), then neither the ritual acts nor the fruits thereof—in short nothing with which the *mimamsa* was basically concerned—could have any meaning; or if the world was like a dream, then instead of the strenuous undertaking in the form of ritual performances, people will prefer to fall asleep and enjoy pleasures in their dreams. Thus the incentive to refute idealism did not come from what we call a scientific urge. But it carried the *Mimamsakas* to develop strong philosophical considerations against the idealistic outlook.

We find long discussions by *Vrittikara*, one of the ancient *Mimamsakas*, refuting idealism. The later *Mimamsakas* i.e., Prabhakara and Kumarila refuted idealism in the same line as that of *Vrittikara*. There are so many arguments refuting the ideas of the various shades of idealism. But there is no scope of elaborate discussion for this document. So, only one argument of the *Mimamsakas* is being cited here.

According to idealism, idea is the source of everything, and there was nothing that could be called extra-mental. The object of knowledge was only a piece of knowledge itself i.e., an idea. The different forms perceived were only forms of knowledge and not of any hypothetical extra-mental object. To prove this the Indian idealist repeatedly cited the instances of the dreams and the sense-illusions: the elephant dreamt of, like the snake wrongly perceived as the rope, was after all only mental and there being no sure criterion to distinguish between the dreaming and the waking experiences, the objects perceived in the normal waking experiences too, were to be understood in the same way. The corollary was that all knowledge, because of their pretentious claim to reveal extra-mental were to be treated as false.

Contesting this position of the idealists, argued Vrittikara, what was perceived could not be a mere idea, nor forms perceived could be form of knowledge itself, because there was an objective coercion about the act of perception. In the presence of a piece cloth, one was bound to perceive the cloth and had no option to perceive a pot instead. Perceptions, thus, revealed the extra-mental objects and not thought itself. Besides, it was useless to argue that all perceptions were like the dream-experiences or the sense illusions, because dreams are eventually negated by waking experiences and illusions by correct perceptions that follow. When so negated, they were found to arise from defective causes; dreams from sleepiness, illusions from the want of proper illuminations, etc. But the normal waking perceptions were not so negated and were not found to arise from the defective causes. Thus, one of the strong idealistic arguments was refuted by the *Mimamsakas* on the basis of practice.

Materialist Philosophy outside the Vedic tradition

So far I have discussed on the materialist outlook reflected in the Vedic tradition, which is generally known as the mouthpiece of idealism in our country. But we also find bold and consistent materialist view in some schools of philosophy outside the Vedic tradition. The most important among them is *Lokayata*. The *Samkhya* system is also reflecting consistently materialist view, particularly in its older version. Other than these two systems, the *Nyaya-Vaisesikas* and the Buddhist philosophy also reflect the materialist outlook, though not consistently.

Lokayata

One interesting feature of the history of Indian Philosophy is that we do not find any original books or writings on materialist philosophy, particularly Lokayata, which was the most consistent materialistic philosophy in India. It is not the fact that there never existed any actual treatises of this system. Eminent writers like Tucci, Garbe and Dasgupta cite conclusive evidences to show that actual Lokayata texts were known in the ancient and early medieval times. But such texts have not reached our hands. Why? Mostly the idealists and their patrons i.e., the rulers destroyed it. Then what are the sources of our information of this materialistic philosophy? Mostly, the writings of those who sought to refute and ridicule it. In other words, Lokayata is preserved mainly in the forms of the *Purvapaksha*, i.e., as represented by its opponents.

But how old was this materialist philosophy? The author of the *Brahmansutras* designed two aphorisms specially to represent and refute this philosophy. In the Buddhist *Pitakas*, we come across not only the name *Lokayata* but also distinct references to the view that identified the body with the self. Along with the *Samkhya* and *Yoga*, the *Arthasastra* (4th Century BC) mentioned the *Lokayata*. The *Mahabharata* and the earliest Jain sources too mentioned this philosophy and even the *Upanishads* were not silent about materialism. Judging from all these, we can easily see that the materialist tradition in India is very old—probably as old as Indian philosophy itself.

Here another point is to be mentioned. The idealists always tried to malign the materialist philosophy in various ways. I would like to cite one such example. Lokayata was also termed as *Carvaka* at a later period, approximately eighth century AD. In the *Santiparva* of the *Mahabharatha* there was one Carvaka. After the great *Kurukshetra* war, as the Pandava brothers were returning triumphantly, thousands of Brahmins gathered in the city gate to bestow blessings on *Yudhistira*. Among them was *Carvaka*. He moved forward and addressed the king thus: "This assembly of Brahmins is cursing you for you have killed your kins. What have you gained by destroying your own people and murdering your own elders?" This outburst of *Carvaka*, abrupt as it was, stunned the assembled Brahmins. *Yudhisthira* felt mortally wounded and wanted to die. But then the other Brahmins regained their senses and told the king that this *Carvaka* was only a demon in disguise. And they burnt him, the dissenting *Carvaka*, to ashes.

So there was a conspiracy to associate the name *Carvaka* with this materialist philosophy. It was easy to convince the common people that this philosophy could not play any beneficial role for them. So, be alert and keep safe distance from it.

Now let us discuss about the content of the *Lokayata*. Directly opposing the view of the *Vedanta* which recognizes only *Brahman* or pure consciousness as real, the *Lokayatikas* did not admit the existence of anything but the four elements, i.e., '*Chaturbhuta*' — '*kshiti*' (earth), '*ap*' (water), '*tej*' (fire), '*varuna*' (air). According to Lokayata the elements themselves did not possess consciousness, still consciousness was viewed as emerging from them. How could that be possible? Just as rice and the other ingredients of producing wine did not by themselves possess any intoxicating quality, argued the Lokayatikas, yet when combined in a particular way, these caused the intoxicating quality to emerge. So did the material elements constituting the material human body, though themselves without consciousness, caused consciousness to emerge when combined in a particular way to form within the human body. It was surely one of the most significant things said by our ancestors to establish the primacy of matter over the spirit. Not only that, it also rejects the claim of the idealists that the soul can exist outside the human body.

The next important feature of the Lokayata is its insistence on the primacy of sense perception as the source of valid knowledge. It didn't rely upon inference from assumption or guessing as the source of valid knowledge. Here I want to mention about the attitude of argued the *Purandara*, who was himself a *Lokayatika* in this regard. His attitude to inference as summed up by Dasgupta was as follows: "*Purandara* ··· admits the usefulness of inference in determining the nature of all worldly things where perceptual experience is available; but inference cannot be employed for establishing any dogma regarding the transcendental world, or life after death or the law of *karma* which cannot be available to ordinary perceptual experience."

So the Lokayata did not reject all types of inferences. It rejected those inferences which had no relation to perceptual knowledge.

We know that the idealists of our country propagated the *Karma*-doctrine according to which the divine dispensation is not arbitrary but expressed itself as *karma*-law. The essence of the doctrine is of course simple. Every human action has its own inevitable results. A virtuous action results in something good, a vicious action in something bad. Therefore whatever you enjoy or suffer now is the result of your own past actions and the way you are now acting is going to determine your future. Such a doctrine has inevitably to lean on the conception of a trans-migratory soul. The idea of rebirth and the other world is linked with these concepts. We have seen that this idea was propagated so extensively that it did acquire a living grip on the minds of our millions. Even pronounced atheists like the Buddhists and the Jains laid supreme stress on the doctrine. In fact in their philosophy *Karma* became so important that it made God superfluous. In the general context of this traditional understanding of the law of *karma*, it is not of little significance to note that our materialists were by far the only philosophers to have vigorously rejected it. They had persistently advocated the *Svabhava-vada* or the doctrine of natural causation and the Jaina writer Gunaratna rightly saw in this denial of the law of *karma*. He cited examples according to which there is no such thing called *karma* at all, all the manifold world is to be explained by natural causes. Indeed, rejecting as they did the conception of a transmigrating soul it was only logical for our materialists to have rejected the law of *karma*.

Lokayata rejected the doctrine of the other world, which is related to the *Karma*-Law. Some ancient folk-lores depicting the views of the *Carvakas* were very interesting, which fought the doctrine of the other world with sarcasm. Some of them are as follows.

- If the *sraddha*[2] brings gratification to beings who are dead, then here, too, in the case of travellers when they start, it is needless to give provisions for the journey.
- If beings in heaven are gratified by our offerings in *sraddha* here, then why not give the food down below to those who are standing on the housetop?
- In the *Ramayana*, a certain *Jabali* tried to persuade *Rama* to give up the foolish ideas concerning the *Karma*-doctrine with similar verses:

  And the food by one partakes can it nourish other men? Food bestowed upon a Brahmin, can it serve our Fathers then? Crafty priests have forged these maxims, and with selfish objects say, 'Make thy gifts and do thy penance, leave thy worldly wealth and pray!

Such were the arguments of *Lokayatikas* or *Carvakas*, who upheld materialist view consistently.

Winternitz once observed that "it proved fatal for the development of Indian philosophy that the *Upanisads* should have been pronounced to be revelations." This is true particularly in the sense that it meant a divine sanction for the world-denying idealistic outlook, and as such this became the most serious obstacle to the development of the scientific spirit in Indian philosophy. No less fatal, however, had been the loss of our materialist texts. This has deprived us of a proper idea of our heritage of scientific thinking and has in consequence given idealism and spiritualism exaggerated importance in Indian philosophy. It is, therefore, important for us today to recover the relics of the *Lokayata* and, on the basis of careful examination of these, to re-construct the half-forgotten and half-distorted history of Indian materialism.

(To be continued)

[2] *Sraddha* is the ritual practised after a person's death.

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Organizational news

Workshops/Seminars on "Science in Ancient India: Myth versus Reality"

Over the past few months the *Breakthrough Science Society* concentrated on the organizational preparation to face the onslaught of the fringe groups who are trying to malign the true scientific heritage of India by projecting a false picture of India's past glory. An all-India workshop was organized in Kolkata on 23-24 May 2015 where the organizers from different states engaged in a threadbare discussion on the issues being raised. There were presentations on the developments in mathematics, astronomy, civil engineering and architecture, chemistry, and cultivation of materialism in ancient India, etc. A Council meeting was held during the workshop in which it was decided that similar workshops will be organized in the states and districts (wherever possible) to equip the science activists in the issues being debated. Accordingly the following programmes have been organized.

Jharkhand: A seminar on the subject was organised at Jamshedpur Graduate College on August 2, 2015. Dr Soumitro Banerjee, General Secretary, Breakthrough Science Society, was the main speaker. The other speakers were Dr. Usha Shukla, Principal, Graduate college, Dr Arunditi Roy, Dr Amitav Bose and Mr. Kanay Barik.

Odisha: A state level workshop was held at the Auditorium hall of Institute of Physics (IOP), Bhubaneswar on August 16, 2015. Prof Birendra Nayak, Retd. Professor of Mathematics, Utkal University inaugurated the workshop; Prof Ajit Srivastava, Institute of Physics, Bhubaneswar discussed the false claims made in 102nd Indian Science Congress; Prof Soumitro Banerjee, General Secretary of BSS thoroughly discussed the development of science in Indus Valley civilization and the Vedic period; and Prof Birendra Nayak discussed on the misnomer "Vedic Mathematics". Shri Biswabasu Das and Sri P. K. Rath were among the other speakers. More than 250 delegates from different parts of Odisha actively participated in the workshop.

Tamil Nadu: A State level workshop for the BSS organisers and activists was held at Theni, Tamilnadu on Aug 9, 2015. Prof S H Thilagar gave an overview of the workshop and its objectives. Dr R Venkatesan, Member, State Advisory Committee, BSS, presented a historical perspective of the development of science in ancient India. Shri Regurathipandian discussed about the myths that are being propagated. Ms Sugubala spoke on the distortions in science and history being introduced in school text books in some states.

West Bengal: In this state district-level workshops were organized in six districts. In the Purba Medinipur District the workshop was organized on 5th July, in which about 300 students, teachers, professors and science loving people participated.

The Kolkata district workshop was held on 26 July at the Darbhanga Hall of the Calcutta University. Prof. Amitabha Datta, former Professor of Jadavpur University and IISER Kolkata delivered the inaugural address, and Dr. Soumitro Banerjee, Dr. Radhakanta Koner and Mr. Subrata Gouri discussed the hotly debated issues.

Similar workshops were organized in the South 24 Paragana District on 12th July, in the West Medinipur and Purulia Districts on 19th July and in the Bardhaman District on 26th July.

Other programmes

Gujrat: The Universe Science Forum (USF), Ahmedabad, organised the following programmes:
July 4 – On the occasion of 81st Memorial Day of Madam Curie, a Film show and discussion on life struggle of Madam Curie.
July 11 – A documentary show and Photo Exhibition on the life struggle of Albert Einstein, at Government Primary School, Thaltej area, Ahmedabad.
August 2 – A discussion on the life struggle of Acharya P. C. Ray.
August 2 – A discussion was organised at the M.S. University, Vadodara, where Mr. Ayush and Mr. Fenil Soni spoke on the life and science of Acharya P. C. Ray.

Uttar Pradesh: A free medical camp was organized on June 17 in Allahabad at Fatehpur Bichhua (Tagore Town) jointly by *Breakthrough Science Society* and Medical Service Centre.

A weeklong summer camp was organized by BSS, Allahabad Chapter, from the 19th to the 25th of June at Loha Park of Allapur. Learning science through experiments, sky watch program, preparation of charts, anti-superstition shows, physical exercises and games were the various activities of the camp.

On the occasion of birth anniversary of Acharya Prafulla Chandra Ray, a program was organized on August 2 by the BSS, Allahabad Chapter.

Organizational News

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Jharkhand: On the occasion of the death anniversary of Madam Curie, a programme of Learning science through experiments and a discussion on the life history of great scientists was organised on July 4 by BSS Chaibasa unit.

Andhra and Telengana: On July 9, Madam Curie Memorial Day was observed in Hotline High School, Khairathabad, Hyderabad. On July 11, a program was organised to observe Madam Curie Day at Government High School, Mahaboobnagar, R.R. District.

Kerala: June 5 - World Environment Day was observed at Govt. HSS, Athiroor, Pathanamthitta, and at the Kavadiar HSS in Thiruvananthapuram.

June 9 - Astronmy club, Kottayam organised a presentation on Biodiversity of Western Ghats at Jawahar Balbhavan Kottayam by Shri Jessen T Das, Nature photographer.

August 6-18: The Hiroshima-Nagasaki Day was observed at 10 different places in the state.

Tamilnadu: BSS Madurai chapter organized Madam Curie memorial meeting at Thiagarajar college, on July 15, and at the Madura college on July 17.

Flood relief by IIT Kharagpur Chapter: Following the devastating flood in several districts of West Bengal, BSS IIT Kharagpur Chapter organised relief work among the affected people. In the first phase, about Rs 77,000 was collected in a span of only four days. On Aug 18, the team visited the remote villages namely Mohonpur and Radhabon near Panskura and Gopmahal Village in Ghatal area, and distributed mosquito nets, rice, dal, biscuits and baby food to the affected families. In the second phase the team visited Bargachhia of Howrah district, and distributed relief material worth about Rs. 36,000.