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The New Great Rush to the Moon

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A visionary science fiction writer**
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... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

Smashing Particles to Understand the Universe

In a few months from now, the newest and the largest particle accelerator, the Large Hadron Collider (LHC) would go into operation at the European Organization for Nuclear Research, better known by its acronym CERN. This gigantic scientific instrument is situated 100 metres underground near Geneva, where it spans the border between Switzerland and France. This would be the largest and the most complex particle accelerator in the world installed in a tunnel of 27-km circumference, or a ring of about 4.3-km in radius. The particles would be guided by thousands of cylindrical magnets supercooled to -271.3°C , close to absolute zero! When operational, two beams of sub-atomic charged particles, 'hadrons' – protons or heavy ions – would travel in opposite directions around the tunnel at 99.99 per cent of the speed of light, picking up energy in each lap.

Some of the particles moving in opposite directions would crash into each other at four intersection points at an energy never before reached in a particle accelerator. The maximum energy of the protons would be 7 TeV (tera-electronvolt). This implies the corresponding energy of 14 TeV when they collide head-on! Incidentally, 1 TeV of energy is the energy an electron gains when it accelerates through a potential difference of 1 trillion volts. Further, when the two beams collide, they would generate temperatures more than

100,000 times at the heart of the Sun, concentrated within a minuscule space. As a result of the violent collisions, these particles would be transformed into packets of energy, which would in turn condense back into various intriguing types of particles – some of them never even seen before! Huge detectors and equipment spaced along the tunnel will observe the spray from the collisions for analysis by scientists from all over the world. Incidentally, the largest of the set-up, ATLAS (A Toroidal LHC Apparatus), has a detector which is seven stories tall; while the heaviest, CMS (Compact Muon Solenoid), is heftier than the Eiffel Tower! How much is the cost of LHC? Over 5 billion US dollars!

How did it all begin? Over a century ago, in late 1800s, physicists believed that the essential business of science was finished, and that no more fundamental discoveries were expected! The future of truths of physics was to be looked for in the sixth place of decimals! There was perfect order in the Universe, as governed by the Newtonian mechanics with atoms as the foundation of matter. And that the atoms were indivisible. But, beginning in 1895, strange things started happening. Discovery of X-rays, radioactivity, and the discovery of electron established that the atom was not indivisible after all. Einstein's Special Theory of Relativity, followed by the General Theory completely revolutionized the way we

looked at nature. Now we had a space-time fabric in which no two events could be said to be simultaneous. Matter bends space and space directs how the matter moves. Energy and mass are interchangeable. Light behaved both like a wave and a particle. In 1911 Ernest Rutherford announced that atoms are mostly empty space, their mass concentrated in a tiny nucleus orbited by electrons.

Today we know that molecules are made of atoms. Atoms are made of particles called protons, neutrons, and electrons. Protons and neutrons are made of even smaller particles called quarks and gluons. Protons and neutrons are called hadrons, and this is how the LHC gets its name. How about quarks? Are they fundamental or made of yet smaller particles? We do not know! True, electrons are believed to be fundamental particles, as of now. Over the years, physicists have worked out a mathematical model that describes the known fundamental particles that make up matter (classified as 'fermions') and the particles that transmit the forces (classified as 'bosons' after Satyendranath Bose who proposed them). It is called the 'Standard Model', and summarizes the present picture of the field of elementary particle physics. It includes the electroweak theory of weak forces (encountered when a nucleus decays through emission of electrons) and the electromagnetic forces (encountered

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Arthur Charles Clarke

A Visionary Science Fiction Writer

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“As far as the future is concerned, any political or sociological prediction is impossible. The only area where there is any possibility of success is the technological future.”

Arthur C. Clarke

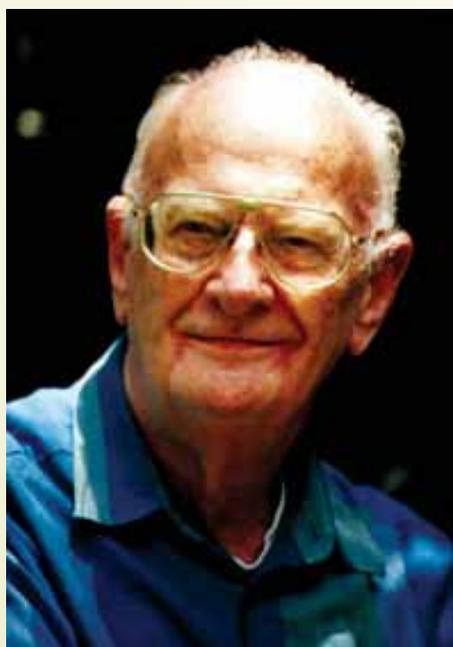
“Somewhere in me is a curiosity sensor. I want to know what’s over the next hill. You know, people can live longer without food than without information. Without information you would go crazy.”

Arthur C. Clarke

Arthur Charles Clarke’s achievements were unique. His works, which ranged from scientific discovery to science fiction, and from technical application to entertainment made a global impact. He had the uncanny ability to see the future. Clarke was a science fiction author, inventor, and futurist.

Clarke’s most important contribution was his idea that geostationary orbits would be ideal telecommunications relays. He also suggested that V2 rockets could be used to launch communication satellites. He proposed this idea in a paper privately circulated among the core technical members of the British Interplanetary Society in 1945. The concept was described in a paper titled “Extra-Terrestrial Relays — Can Rocket Stations Give Worldwide Radio Coverage?” published in *Wireless World* in October of that year. It is not clear whether this article was actually the inspiration for the modern telecommunications satellite. John R. Pierce of Bell Labs arrived at the idea independently in 1954. Pierce who was actually involved in the *Echo* satellite and *Telstar* projects is reported to have said that the idea was “in the air” at the time and it was certain to be developed regardless of Clarke’s publication. However, Clarke described the idea so thoroughly that he is regarded as the originator of the idea. Clarke himself was not very optimistic about the probability of his idea being realised in his lifetime. Clarke’s speculation realised 25 years later. The first commercial

geostationary communication satellite, *Intelsat 1 Early Bird* was launched on 6 April 1965. In 2002, the geostationary orbit had over 300 satellites. If he had patented his idea he would become a billionaire. The



Arthur C. Clarke

first draft of Clarke’s 1945 article is now in the Smithsonian Institution, USA. The geostationary orbit 36,000 kilometres above the equator is officially recognised by the International Astronomical Union as the “Clarke Orbit”.

Clarke in his novel *The Fountains of Paradise* introduced the concept of Space Elevator to a larger audience. In this novel Clarke describes how engineers construct a space elevator on top of a mountain peak

in fictional island country *Taprobane*. Clarke believed that ultimately his concept of space elevator would be his legacy, more so than geostationary satellites, once space elevators make space shuttles obsolete.

Clarke was one of the grandmasters of science fiction. He is placed with the best-known science fiction writers like Isaac Asimov and Robert A. Heinlein. His most known science fiction works are: *Childhood’s End*, *Rendezvous with Rama* and *2001: A Space Odyssey*. His novel *2001: A Space Odyssey* was made into a film of the same name by Stanley Kubrick. Following the release of *2001*, Clarke became much in demand as a commentator on science and technology, especially at the time of the *Apollo* space program. The fame of *2001* was enough to get the Command Module of the *Apollo-13* craft named ‘Odyssey’. Clarke also wrote a number of non-fiction books describing the technical details and societal implications of rocketry and space flight.

Clarke is often regarded as one of the chief prophets of space age. He predicted that commercial space travel would one day be a routine affair. He took part in media coverage of three *Apollo* mission – *Apollo-11*, *Apollo-12* and *Apollo-15*. He served as the first Chancellor of the International Space University formed by Peter Diamandis (1989-2004). Some of his fictional and non-fictional books related to space are: *Interplanetary Flight* (1950); *Prelude to Space* (1951); *Sands of Mars* (1951); *The Exploration of the Moon* (1954);



Communication satellite

The Young Traveller in Space (1954); *The Challenge of the Spaceship* (1958); *Man and Space: Life Science Library* (1967); *The Coming of Space Age* (1967); *2001: A Space Odyssey* (1968); *The Promise of Space* (1968); *The Space Dreamers* (1969). In his book *Exploration of Space* (1952), Clarke wrote: "We stand now at the turning point between two eras. Behind us is a past to which we can never return ... The coming of the rocket brought to an end a million years of isolation ... the childhood of our race was over and history as we know it began." It is interesting to note how Clarke described the immensity of space. He wrote: "To obtain a mental picture of the nearest star, as compared with the distance to the nearest planet, you must imagine a world in which the closest object to you is only five feet away – and there is nothing else to see until you have travelled a thousand miles."

In his book, *Profiles of the Future* (1962) Clarke attempted to project the future. The book was based on the essays that Clarke wrote in various magazines predicting future inventions and ideas. The theme of these essays "was one of ultimate possibilities, rather than achievements to be expected in near future." The theme is reflected in the subtitle of the book, "An Inquiry into the Limits of the Possible". The book did not discuss medical and biological developments in detail.

In *Profiles of the Future* Clarke described his most famous three Laws. The First Law states: "When a distinguished but elderly scientist states that something is possible he is almost certainly right. When he states that something is impossible, he is very probably wrong."

The Second Law states: "The only way of discovering the limits of the possible is to venture a little way past them into impossible."

The Third Law states: "Any sufficiently advanced technology is indistinguishable from magic."

After formulating the above three laws, Clarke had written, "Since three laws were sufficient for both the Isaacs – Newton and Asimov – I have decided to stop here." However, he continued to invent more laws.

Clarke was born on 16 December 1917 in the coast town of Minehead, Somerset, England to Charles Wright Clarke and Nora Mary Clarke (nee Willis). He was eldest of four children of his parents. His father, who was a farmer, died in 1931. At the time of his father's death Clarke was fourteen years old. His mother gave riding lessons to earn extra money to maintain the family.

Clarke became interested in science at an early age. The young Clarke was an avid reader of the works of H. G. Wells



H.G. Wells

and Jules Verne. He constructed his first telescope at thirteen. With the help of his self-made telescope, he mapped the Moon. As a boy he enjoyed stargazing and reading science fiction magazines. He studied at Huish's Grammar School, Taunton. As he was unable to afford a university education, he took up a job as an auditor in the pensions section of the Board of Education.

During the Second World War he served in the Royal Air Force. He started

as a Corporal. On 27 May 1943 he was commissioned as a Pilot Officer (Technical Branch). He was promoted Flying Officer on 27 November 1943 as a radar specialist. He was mostly involved in the early warning radar defence system. Clarke spent most of his service time working on Ground Controlled Approach (GCA). He was released from the active service with the rank of Flight Lieutenant. After the war he could afford to have a university education. He earned a first-class degree in mathematics and physics at King's College, London.

In the post-war years, Clarke was associated with the British Interplanetary Society. In its early days members of the Society used to meet in Clarke's apartment. He served as its chairman twice.

Clarke moved to Sri Lanka in 1956 and lived there till his death. When he came to Sri Lanka, it was known as Ceylon. Clarke held citizenship of both the UK and Sri Lanka. Commenting on his adopted country Clarke once wrote: "The island of Ceylon is a small universe; it contains as many variations of culture, scenery, and climate as some countries a dozen times its size. What you get from it depends on what you bring; if you never stray from your hotel bar or the dusty streets of westernized Colombo, you could perish of fulminating boredom in a week, and it would serve you right. But if you are interested in people, history, nature, and art – the things that really matter – you may find, as I have, that a lifetime is not enough." (*The View from Serendip*, 1977). He was pained to see the conflicts between Tamil rebels and the Government. He wrote: "I've been living in Sri Lanka for 50 years, and half that time I've been a sad witness to bitter conflict that divides my adopted country, and dearly wish to see a lasting peace established in Sri Lanka as soon as possible."

Clarke was an avid scuba diver and a member of the Underwater Explorers Club. Living in Sri Lanka afforded him the opportunity to visit the ocean year-round. With his friend Mike Wilson he filmed the Great Barrier Reef of Australia, which later formed the basis of his novel *The Deep Range* (1957). Clarke once said: "I now realise that it was my interest in astronautics that led me to the ocean. Both involve

exploration, of course, but that's not the only reason. When the first skin-diving equipment started to appear in the late 1940s, I suddenly realised that here was a cheap and simple way of initiating one of the most magical aspects of space-flight – weightlessness.”

Few science fiction writers could match Clarke's breadth, versatility and penetrating intellect. With his background in physics and mathematics and his dedication to “hard,” fact-based science fiction, Clarke became scientists' favourite sci-fi writer. His writings have influenced astronauts. Neil Armstrong had seen the Clarke and Kubrick's depiction of a lunar base in “2001” just a year before he became the first man on the Moon.

Clarke's first professional science fiction work appeared in 1946 in the science fiction magazine *Astounding Science* (May 1946 issue). The story was titled “Rescue Party” and it was written in March 1945. He wrote his first science fiction novel, *Prelude to Space*, in 1947, but it was published in 1951. It has been reported that he wrote his first novel over a period of three weeks. His first novel to be published was *Against the Fall of Night* (1948). In 1948, Clarke wrote *The Sentinel* for a competition organised by the BBC. It was a story about man's contact with sentient life. Clarke's story was not selected. However, it proved to be a turning point in his career. This formed the basis for his most famous work *2001: A Space Odyssey* and its subsequent sequels. Clarke's work is marked by an optimistic view of science empowering mankind's exploration of the solar system. One of the central themes in Clarke's fiction was the “spiritual” rebirth and the search for man's place in the universe. In *Rendezvous with Rama* Clarke touched the question, “What is the meaning of life?” *2001: A Space Odyssey* traces the evolution of man and humanity's quest for existential answers, symbolised by the unearthly monolith. In the sequels, which followed the first *Odyssey* Clarke showed how technological progress allowed to reveal some of the secrets behind the monolith. Isaac Asimov in his memoir published in 1994 wrote: “Arthur and I share similar views on science fiction, on science, on social questions, and on politics. I have

never had an occasion to disagree with him on any of these things, which is a credit to his clear-thinking intelligence.”

In 1975, the Government of India donated Clarke his first satellite dish. He used the link ‘on several occasions, including millennium eve, to address the world he helped to envision half a century ago’.

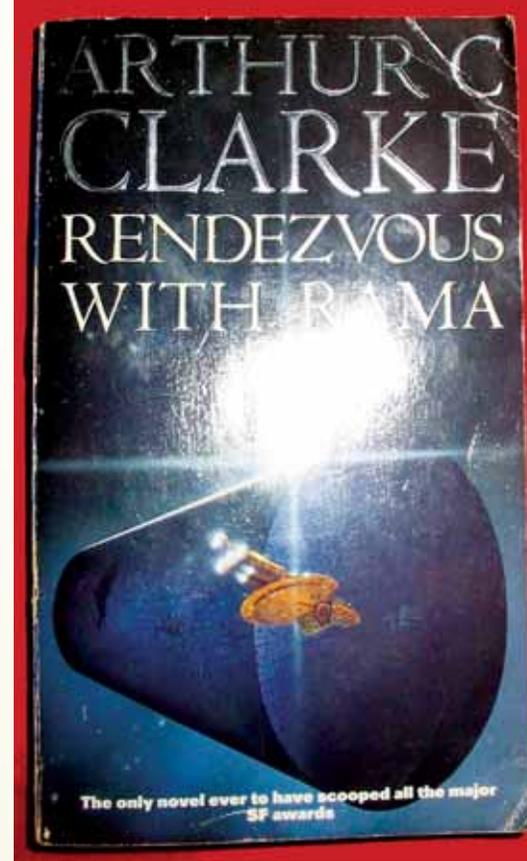
Clarke was not much impressed with organised religion. He had said: “The rash assertion that ‘God made man in His own image’ is ticking like a time bomb at the foundation of many faiths.” He again wrote: “and as the hierarchy of the universe is disclosed to us, we may have to recognise this chilling truth: if there are any gods whose chief concern is man, they cannot be very important gods.” In an essay entitled “Credo” published in 1991 Clarke proposed a belief system of his own by distinguishing between two views of God. Alpha, who rewards good and evil in some vaguely, described afterlife, and Omega, “Creator of everything...a much more interesting character and not so easily



Isaac Asimov

dismissed.” Clarke wrote: “No intelligent person can contemplate the night sky without a sense of awe. The mind-boggling vista of exploding supernovae and hurtling galaxies does seem require a certain amount of explaining.”

Clarke was a Fellow of the Royal Astronomical Society. He received all of science fiction's major awards including the Hugo, Nebula and John W. Campbell awards. The Science Fiction Writers of



Cover page of one of Clarke's book

America named Clarke a Grand Master in 1986. For his work as a science populariser and science fiction prophet he was given the Lindbergh Award in 1987. In 1989, Clarke was appointed Commander of the Order of the British Empire (CBE) “for services to British cultural interests in Sri Lanka”. The same year he became the first Chancellor of the International Space University, serving from 1989 to 2004 and he also served as Chancellor of Moratuwa University in Sri Lanka from 1979 to 2002. On 26 May 2000 he was made a Knight Bachelor “for services to literature” at a ceremony in Colombo. The award of a knighthood had been announced in the 1998 New Year Honours, but investiture of the award had been delayed, at Clarke's request, because of an accusation, by the British tabloid *The Sunday Mirror*, of paedophilia, which was, however, found to be baseless by Sri Lankan police and retracted by the paper soon after. Clarke's health did not allow him to travel to London to receive the honour personally from the Queen, so the United Kingdom High Commissioner to Sri Lanka invested him as a Knight Bachelor at a ceremony in Colombo.

In 2003, Sir Arthur was awarded the Telluride Tech Festival Award of Technology where he appeared on stage via a 3-D



Jules Verne

hologram with a group of old friends which included Jill Tarter, Neil Armstrong, Lewis Branscomb, Charles Townes, Freeman Dyson, Bruce Murray and Scott Brown. In 1986, Clarke received the *Vidya Jyothi* (Light of Science) award from the President of Sri Lanka. On 14 November 2005 Sri Lanka awarded Clarke its highest civilian award, the Sri Lankabhimanya (The Pride of Sri Lanka), for his contributions to science and technology and his commitment to his adopted country.

An asteroid, 4923 Clarke, has been named in Clarke's honour. A species of ceratopsian dinosaur discovered in Inverloch in Australia was named after him as *Serndipaceratops arthurclarkei*. Clarke was the Honorary Chairman of the Institute for Cooperation in Space, founded by Carol Rosin. He served on the Board of Governors of the National Space Society, a space advocacy organisation originally established by Wernher von Braun. Clarke was a distinguished vice-president of the H. G. Wells Society. In 1980 he was Vikram Sarabhai Professor at Physical Research Laboratory in Ahmedabad. In the 1980s Clarke was a presenter of the television series *Arthur C. Clarke's Mysterious World* (1980) and *World of Strange Powers* (1985). He lectured widely in Britain and in the United States. Until 1982 Clarke had been writing his books using a typewriter.

In 1994, Clarke was nominated for a Nobel Peace Prize by law professor Glenn Reynolds.

In 1986, Clarke provided a grant to fund the prize money (initially £1,000) for the Arthur C. Clarke Award for the best science fiction novel published in Britain in the previous year. In 2001 the prize was increased to £2001, and its value now matches the year (e.g., £2005 in 2005). In 2005 he lent his name to the inaugural Sir Arthur Clarke Awards – dubbed “the Space Oscars” established by the Washington D.C.-based Arthur C Clarke Foundation. The Arthur C. Clarke Lifetime Achievement Award recognises “an individual, a group or an entity that exemplifies the values and accomplishments of Sir Arthur's life. The award honours substantial and enduring contributions that relate the sciences and arts in meeting the challenges of contemporary life and the needs of tomorrow.”

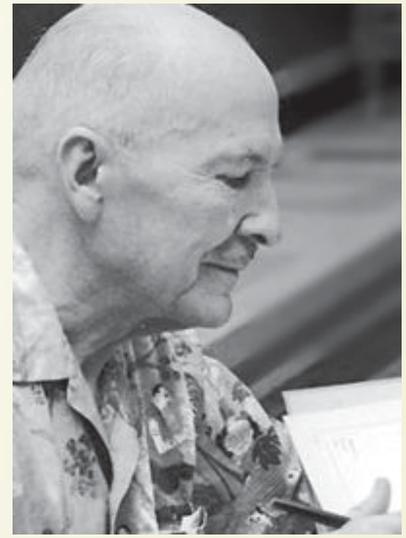
The Arthur C. Clarke Innovator's Award recognises “initiatives or new inventions that have had recent impact on or hold particular promise for satellite communications and society, and stand as distinguished examples of innovative thinking.”



Neil Armstrong

In 1962 Clarke had a severe attack of polio. In 1988 he was diagnosed with post-polio syndrome and needed to use a wheelchair most of the time thereafter. He died in Colombo, Sri Lanka on 19 March 2008 after suffering from breathing problems.

There are a number of important works on Clarke. Among these are: *Arthur C. Clarke: A Critical Companion* by Robin Anne Reid (1997); *Arthur C. Clarke: The*



Robert A. Heinlein

Authorised Biography by Neil McAleer (1992); *Clarke's Odysseys* by Peter Stockill (1990); *Arthur C. Clarke: A Primary and Secondary Bibliography* by David N. Samuelson (1984); *Arthur C. Clarke* by E. S. Rabkin (1979); *The Space Odysseys of Arthur C. Clarke* by G. E. Slusser (1978) and *Arthur C. Clarke*, ed. By J. D. Olander and M. H. Greenberg (1977).

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(The article is a popular presentation of the important points on the life and work of Arthur C. Clarke available in the existing literature. The idea is to inspire the younger generation to know more about Arthur C. Clarke. The author has given the sources consulted for writing this article. However, the sources on the Internet are numerous and so they have not been individually listed. The author is grateful to all those authors whose works have contributed to writing this article.)

The new Great Rush to the Moon

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There has been a renewed interest in exploration of the Moon in the past few years and a number of space missions are planned by various countries during this decade. The Indian Space Research Organisation is planning to send an orbiter mission to the Moon in summer of 2008 for remote sensing. The main motivation for the future missions is to resolve some of the uncertainties regarding the formation and early stages of chemical evolution of the Moon, which can be clearly defined now in view of the vast database on chemical, geological and chronological aspects that has become available as a result of forty years of study of the samples re-

turned from the Moon and detailed chemical and mineral maps prepared based on data obtained by several orbiter missions. Let us see how much we know about the Moon so that scientific objectives of the future missions can be clearly formulated.

The intellectual quest for the Moon began eons ago when humans first learnt to comprehend nature and correlate celestial phenomena. But serious study of our nearest celestial neighbour began only after the Russian satellite *Sputnik* demonstrated in 1957 that the space around and beyond the Earth can be explored. This was followed by a series of orbiting, landing and sample-return missions to the Moon by the former Soviet Union and USA. The *Surveyor* landings provided the first analysis of lunar samples, and

unmanned *Lunokhods* and lunar rovers explored large areas of the Moon. The *Apollo* manned missions by USA provided the opportunity for direct exploration of the Moon by humans and for conducting sophisticated experiments on the lunar surface. As a result of these missions, lunar samples from nine

used for space vehicles. Last year, two orbiters have already been sent, eg. Japan's *Selene* (now christened *Kaguya*) was launched in September 2007 and China's *Change'E-1* in October 2007. They are currently in orbit and will stay there for about a year. *Chandrayaan-1* and USA's *Lunar Reconnaissance Orbiter* (*LRO*) are scheduled for 2008. Plans are already being made by Italy, UK (*Lunar Exploration Orbiter, LEO*), Germany (*Moon lite*) for missions in the near future, and additionally Russia may revive its earlier plans of sending *LunaGlob* penetrator-orbiter mission. In addition ESA's *MoonNEXT* mission is currently being designed. Thus in the next four or five years several mis-

sions to Moon are expected, in addition to the Lunar-Rover-Lander mission (*Chandrayaan-2*) by ISRO. We examine here the rationale of this great rush to Moon.

Origin of the Moon

The main problem about the Moon is the mystery of its origin. What is this mystery? Simply stated, how did our Earth come about acquiring such a large satellite, which in many ways resembles the composition of the Earth's mantle? Planetary satellites are either captured objects, as is the case with the two satellites Phobos and Deimos of Mars, or are formed by 'co-accretion' with their parent planet. Some of the satellites of the outer planets Jupiter, Saturn and Uranus, may have formed by this process. But in

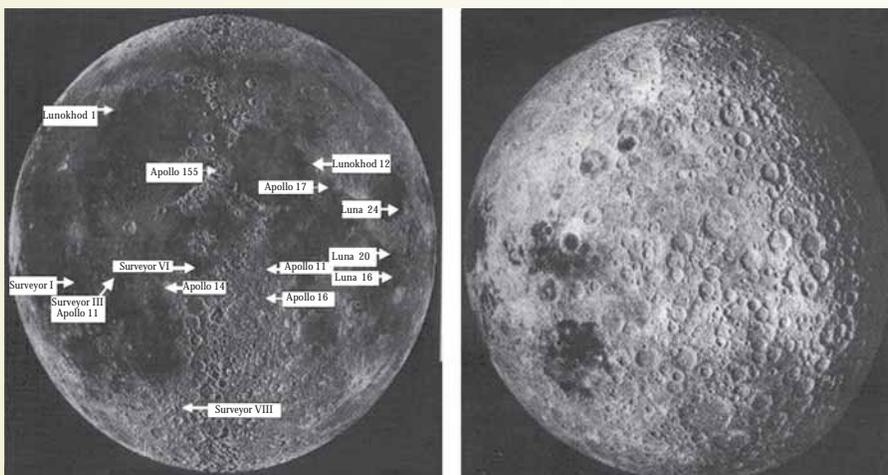


Fig. 1. Earth-facing and far side pictures of the Moon showing various lunar landing sites. These include the unmanned *Surveyor* and *Lunokhod* sites and the *Luna* and *Apollo* (manned landing) sites from where the samples were brought back to Earth. The far side picture was taken by *Apollo-16* (Photo credit: NASA).

well-documented sites became available for study and the past four decades have seen an all-out effort to understand the origin and evolution of the Moon based on the laboratory analyses of these rocks. Much has been learnt about the astronomical, physical, chemical, isotopic, geological and chronological aspects of the Moon, but new questions have emerged which demand fresh efforts to resolve. In spite of the large database, the mystery of the origin of the Moon remains unsolved. With the development of new technology, there is renewed interest in lunar exploration in many countries.

The first mission to moon of this century, *SMART-1* was sent by the European Space Agency in 2003 to try out electrical propulsion technology, in stead of chemical propellants commonly



Fig. 2. According to the giant impact hypothesis, the Moon was formed out of debris ejected when a Mars-sized body collided with Earth about 4.5 billion years ago.

case of Earth and Moon, co-accretion is ruled out as they do not have the same bulk composition (and density). The high ratio of the mass of the Moon to that of the Earth ($M_M/M_E = 0.012$) compared to that for other satellite-planet systems (less than 0.001), and its low density (3.34 g/cm^3 compared to 5.52 g/cm^3 for Earth) makes the Moon an enigmatic object. These observations led the American chemist Harold Urey and others in the pre-*Apollo* era to propose that the Moon is a captured object. With myriads of objects going around in the solar system, capture is indeed a very probable process. Recent space missions have shown that even small asteroids have captured objects orbiting around them. The results of analysis of rocks brought back by *Apollo* astronauts, which indicated similarity of the composition of the Moon with the Earth's mantle, however, argued against such a simple capture. The Moon, thus, does not fit either mode of formation.

Absence of satellites in case of the three inner planets Mercury, Venus and Mars (the two small Martian satellites Phobos and Deimos are re-

cently captured objects and would not last long enough to be considered as permanent satellites) indicates that satellites do not form as a natural consequence of planetary formation process. The co-accretion, fission, capture or collisional ejection models should have worked as well on Venus (since Venus is in many ways similar to the earth), if not on the much smaller Mercury or Mars, but obviously have not. Therefore, the Moon must have become the Earth's satellite in a very special way.

At present, the most acceptable hypothesis involves collision of a massive body (about tenth of Earth's mass)

with the Earth before it was fully accumulated, ejecting large amount of earth material in circumterrestrial orbit, which accumulated to form the Moon. This explains most of the dynamic, astronomical, physical, chemical, isotopic and chronological data and is known as the 'giant impact' hypothesis.

The ages of various components present in lunar rocks and dust give information on the timing and processes responsible for their formation. For example, dating of the highland rocks allows us to determine the solidification age of the lunar crust. Ages of impact-generated brecciated rocks and melts define the period of large impacts on the Moon. Ages of basaltic fragments in lunar soils and volcanic glasses give the span of basaltic volcanism on the Moon.

Based on detailed work, the oldest crystallisation age of a crustal rock is found to be 4.4 billion years for one of the *Apollo-16* rocks. One may therefore infer from the available data that the Moon was formed by 4.55 billion years ago, within 100 million years of the formation of the solar system and at about the time when the Earth was almost formed, and that the crust of the Moon cooled and solidified by 4.46 billion years ago. The ages of breccia rocks, formed due to major impacts, range between 4.26 and 3.85 billion

years ago. The ages of breccia rocks, formed due to major impacts, range between 4.26 and 3.85 billion

Table 1. Chronology of the major lunar events with respect to formation of solar system

Formation of solar system (oldest meteorite)	4566 million years
Giant impact on the Earth and formation of the Moon	around 4550 million years
Formation of magma ocean	4530 ± 20 million years
Solidification of lunar crust	~4400 million years
Heavy bombardment by large planetesimals	4250–3850 million years
Mare volcanism	3800–3200 million years

years but clustering of their ages in a 100-million-year period around 3.85 billion years ago suggest an epoch of intensive bombardment of the Moon between 3.8 and 3.9 billion years. The oldest volcanic basalts are dated at 4.3 billion years and the age distribution indicates that volcanism continued, off and on, for about 1000 million years or so. Since 3.2 billion years ago, there has been only occasional small volcanic episodes on the Moon and none has been identified during the last 800 million years. Based on the distribution of ages and chemical composition, a sequence of major events on the Moon has been constructed. These are listed in Table 1. The emerging scenario is that the Moon was formed close to the Earth, about 4.5 billion years ago and was at least partially molten immediately afterwards. This led to the separation of the crust and possibly the core and was followed by a period of large impacts on the Moon and subsequent episodic eruption of basaltic lava which filled most of these impact basins.

The formation of the lunar crust early in its history indicates that, soon after its formation, the Moon had an ocean of molten lava, the magma ocean, in which the low-density crust, containing aluminum-calcium silicates floated and crystallised. How much of the Moon was molten is still not certain. Mineral compositions and assemblages of the lunar rocks show that most of the rocks formed at shallow depths and only a few of them formed at 40 to 50 km depth.

Models of formation of the solar system and the origin of the Moon

There are several ways in which a Sun-like star with orbiting planetary bodies can form from a molecular cloud. However, experimental evidence related to the early formative stages of our solar system is quite sketchy and is sufficient to define only a few basic constraints. The picture that is emerging indicates that the solar system

formed from a rotating, cold, dense molecular cloud which contracted and collapsed about 4.6 billion years ago. There is some evidence that the collapse of the nebula was triggered by shock waves from nearby supernovae explosions. The contracting nebula became hot and the central mass evolved to become the Sun. The peripheral gas and dust, as a result of early cooling processes, led to grain formation which collapsed into a protoplanetary disc. Grain aggregation resulted in the formation of larger objects which eventually accumulated into 100-1000-km size planetesimals. The planetary material went through these stages quickly – within about a million years. Melting and internal differentiation of large planetesimals into crust, mantle or core occurred within a few million years due to heat supplied by radioactive decay of ^{26}Al , which was present in adequate quantity at that time. Runaway gravitational accretion formed a number of bodies with 1000 to 2000 km radius within time scales of 100,000 years, but formation of planets like the Earth took a longer time – a few tens of million years.

According to the planetary formation scenario, several such planetesimals, some as large as Mars, existed in the early solar system. Deviations of planetary orbits from solar equatorial plane and of rotational axes from orbital planes suggest that the planets did not only form from a myriad of small grains randomly or orderly oriented but major addition of rotational and orbital angular momentum also occurred, due to a few large-body collisions during the terminal stages of planetary formation. Collisions of planetesimals with protoplanets should have been highly probable during this period.

Giant impact hypothesis

The giant impact or collisional ejection hypothesis for the formation of the Moon takes into consideration all the post-*Apollo* data. According to this hypothesis a giant body, about a tenth of the mass of Earth (the impac-

tor), travelling at a velocity of about 5 km/s had a grazing impact with the early Earth before that latter was fully formed. To match the density and composition of Moon, it is speculated that the Earth and the giant impacting body were already differentiated into a metallic iron core and silicate mantle at the time of impact. As the impactor collided with the Earth, its metallic core separated from the mantle and accreted onto the Earth, increasing its iron content and density. The mantle of the impactor and ejected Earth material formed a disc orbiting around the Earth, which quickly accreted to form a partly molten Moon. The giant impact hypothesis, in a way, can be considered as an impact-induced fission of the Earth. The clinching evidence that Moon largely contains Earth material came from similarity of oxygen isotopic ratio in Moon and Earth rocks.

It is postulated that an off-axis collision would have imparted much of the Earth's angular momentum to the debris created from such an impact. A huge amount of energy was released due to collision, so that the interface attained a temperature of about 5500 K and a pressure of 600–700 bars, and a dense hot plume of vapour was formed. This model explains in a natural way the obliquity of the Earth, lack of volatiles on the Moon, similarity of the Moon's composition to Earth's mantle, and its low density, and is consistent with the presence of many large bodies during the formative stage of the early solar system. However, the timing of the impact after core formation makes it a very special event.

Recent computer simulations indicate that the Moon could have formed by impact on the nearly fully formed Earth. After the impact, it would have taken only about 24 hours to form the proto-Moon and the associated disc in orbit around Earth and the Moon would have formed quickly thereafter in a period of days. If this model is correct, then chance rather than destiny has played an important role in formation of the Moon, and it

was a catastrophic and the rarest of the rare events that gave the Earth its large satellite.

Some unresolved problems in lunar science

The giant impact hypothesis, though able to explain most of the observations, appears to be *ad hoc*. It also considers only two bodies in isolation, a large impactor and the Earth, whereas some debris from previous collisions on the Earth and several moonlets may have already existed at the time of the terminal giant impact. Their role in the formation of the Moon remains to be ascertained. The computer simulations also indicate that as much as 70% of the Moon should be made of material from the impactor which is not consistent with the observed chemical and isotopic composition. There are also questions related to the magma ocean. The extent of magma ocean is not known, although there are indications that less than half of the Moon was involved. The question whether the Moon has a core or not, and its size and composition, has been extensively debated, but there are no seismological observations which can provide a direct and conclusive answer.

Some of the problems stated above can be resolved by study of long cores from selected sites on the Moon. Long cores through the bedrock can provide information about stratigraphic relations, composition of the lunar interior and heat flow (which depends on the radioactive content). A soil core going to the bedrock can provide insight into the nature of the solar activity (solar wind, heavy nuclei, and solar energetic particles) way back in time when the lunar crust had just formed. The 2-m long *Apollo-15* core represented roughly 1 billion years of records and therefore extending it to 4.5 billion years may not be difficult. However, taking long cores through soil or bedrock may pose challenging technical problems. It is, therefore, necessary to explore scientific

programmes that are realisable and inexpensive.

One of the important questions is related to presence of water in the permanently cold polar regions of the Moon, inferred from the neutron data obtained by the *Lunar Prospector*.

Scientific objectives for future missions

Orbiting missions

Remote sensing of the Moon is a powerful technique for geochemical mapping. The light incident from the Sun in ultraviolet to infrared range is reflected in different proportions at different wavelengths by various minerals present on the lunar surface and therefore reflectance spectroscopy can be used as a powerful tool to map minerals on the Moon. X-rays from the Sun, produced in occasional solar flares, incident on the Moon produce fluorescent X-rays, characteristic of various elements present in the surface soil and rocks of the Moon. These fluorescent X-rays lie in the sub KeV to 10 KeV range for the most abundant elements. Thus X ray spectroscopy can be used to map various elements, magnesium to iron present on the lunar surface. Natural radiation (α , X- and γ rays) coming out of rocks of the Moon can be used to determine the distribution of radioactive elements like U, Th and K. These radiations can be measured by γ -, X-ray and γ -ray spectrometers. A useful approach for orbiting missions would be simultaneous chemical and mineralogical mapping with high spatial resolution using the various spectrometers mentioned above. The objectives for such missions could be: (1) Multispectral imaging to determine distribution of various minerals having different spectral response so as to map the central peak regions of large craters, to understand the composition of the lunar interior and the composition of ejecta as a function of distance from large impact basins. (2) X-ray mapping in 0–10 keV region for elements like Mg, Al, Si, Ca and Fe. (3) Mapping in the

hard X-ray– γ ray region (10–250 keV) for measuring U and Th. This region has not been studied so far and contains several γ -ray lines of interest like the 46.5 keV line of ^{210}Pb , produced in the decay chain of gaseous radon, occurring in the uranium series, and 238.6 and 241.9 KeV lines of ^{212}Pb and ^{214}Pb occurring in the thorium series.

The objective of an orbiter mission should be to prepare a high-resolution 3D atlas in the visible/UV, near IR regions, and to superimpose X- and γ ray maps and study some areas of specific interest related to crustal inhomogeneity, presence of water, and the bulk composition of the Moon.

Landing missions

Landing missions with geophysical sounding (conductivity, composition, seismic studies, etc.) can resolve many questions related to the existence and dimensions of the core, presence of water and chemical composition, particularly of some unexplored areas on the far side. If water is found, then measurement of the deuterium/hydrogen ratio will provide crucial answers to the source of water, whether it is juvenile, cometary, asteroidal, or was formed by interaction of solar wind hydrogen.

Sample return missions

Much, particularly chemical and isotopic composition and chronology, can be learnt if samples from some critical areas of the Moon can be brought to the Earth for laboratory analysis. Interesting areas from this point of view are on the far side of the Moon, the South Pole Aitken basin and the north and South Pole regions. These will also provide ground truth for interpretation of multi-spectral images from the *Clementine* and other future remote sensing missions.

Adapted from a paper published in Current Science.

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Understanding High Blood Pressure



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Much a bane of the modern civilization, hypertension or high blood pressure is a major killer disease. Its numbers vary between different countries, regions and ethnic and social groups, but globally, it is estimated to affect more than 1 billion people. The condition afflicts both men and women, and though the numbers increase strikingly with age, teens and children are not spared its wrath. The modern push-button age has put everybody at risk.

Medical researchers have mapped several risk factors that contribute to this abominable rise in blood pressure. Most of them are intimately interwoven with the modern ways of life. The growing fetish for ever-increasing automation, little physical activity, fast and processed food, and increasing stress have raised an epidemic of high blood pressure that is sweeping through not just the Western world but across all continents.

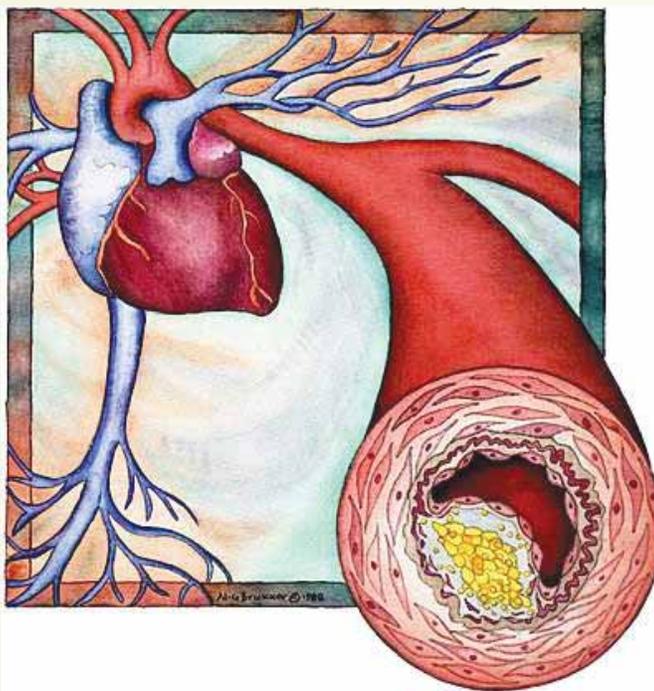
The Indian situation

Several surveys have probed into the prevalence of high blood pressure among people in India. The results reflect a worrying trend. The disease is on the rise, but the damage is more severe in those who dwell in cities, their lives far removed from the simple laws of nature. A study in Delhi and neighbouring rural areas of Haryana, found 25 per cent adult males and 28 per cent adult females in Delhi had high blood pressure. The numbers were about half this in rural Haryana, where 13 per cent adult males and 11 per cent adult females had elevated blood pressure.

Data from other parts of the country, including Jaipur, Bangalore, and

Mumbai, reflect a similar trend. And alarmingly, the problem is not just limited to the middle-aged and seniors, but is, increasingly, also being found in schoolchildren. Health surveys carried out in schools in Delhi have reported a growing number of cases of hypertension in young people.

It is a clear wake-up call for health planners of the country. Even as children tempted by make-believe



computer games, Internet, and television succumb to a lazy life, town planners and land mafia usurp playgrounds and natural parks, and fast-food corners and convenient stores contribute a high-fat high-calorie diet, the situation is rife for obesity, high blood pressure and diabetes among the country's young people.

Understanding high blood pressure

When your blood pressure stays persistently high—140/90 mm Hg or above—even at rest, you have high blood pressure. This condition is dangerous

because it makes the heart work too hard, and the force of its blood flow can harm arteries. This exposes to you several risks.

You are at an increased risk of a stroke, heart attack, heart failure, kidney disease, and blinding eye problems. You run a risk of premature death, and these complications can deal a crippling blow to your life. Even though you may live, your body systems may pack up, and you may feel very frustrated. If you wish to guard against such mishaps, you must treat blood pressure for life. Once it occurs, it usually lasts a lifetime.

Types of high blood pressure

Primary hypertension :

Most people with high blood pressure, about 95 per cent, have what is called primary or essential hypertension. This means that there is no single clear cause of it. You are however more likely to develop it if you are habitually physically inactive, eat a high-fat low-fibre food, are very

overweight, drink a lot of alcohol, or eat a lot of salt. These lifestyle factors contribute to high blood pressure, but it is still not precisely understood why these factors lead to the rise of blood pressure in some people and not in others. A genetic factor may be at play. Hypertension often runs in families, and you are more likely to be affected if your close relatives are too.

Secondary hypertension :

You may be among the other 5 per cent of people with high blood pressure who have what is known as secondary hypertension. This means your condition can be



starting you on any course of treatment. You may be asked to come back for repeat measurements over a number of weeks to check that the high reading is an ongoing problem and not a one-off. You may also need some tests, to see if high blood pressure is having an effect on the rest of your body. These may include:

- Analysis of your urine (protein in your urine may be the first sign of a kidney problem)
- Blood tests, to check the condition and working of your kidneys, amount of electrolytes in the body, and associated conditions and risk factors, including diabetes and cholesterol
- A chest X-ray, to identify any enlargement of the heart muscle
- An electrocardiogram (ECG), to look for any heart strain
- Eye check, to identify any change in blood vessels
- An ultrasound of the abdomen, to assess the kidneys, and look for any identifiable cause of high blood pressure

linked to a recognised cause. In fact, it may be a symptom of another underlying disease. Secondary hypertension can be caused by:

- Long-standing kidney disease
- Adrenal gland disease
- Narrowing of the aorta
- Use of oral contraceptive pills (rarely)
- Prolonged steroid treatment, use of decongestants, cocaine or amphetamines
- Liquorice (also in chewing tobacco)
- Sleep apnoea
- Pre-eclampsia of pregnancy
- Thyroid disease

blurred or impaired vision, nosebleeds or black outs. A headache caused by high blood pressure typically affects you in the morning. It is often limited to the back of the head and lasts two or three hours.

Some people only get to know about the disease once they have trouble with their heart, brain, or kidney.

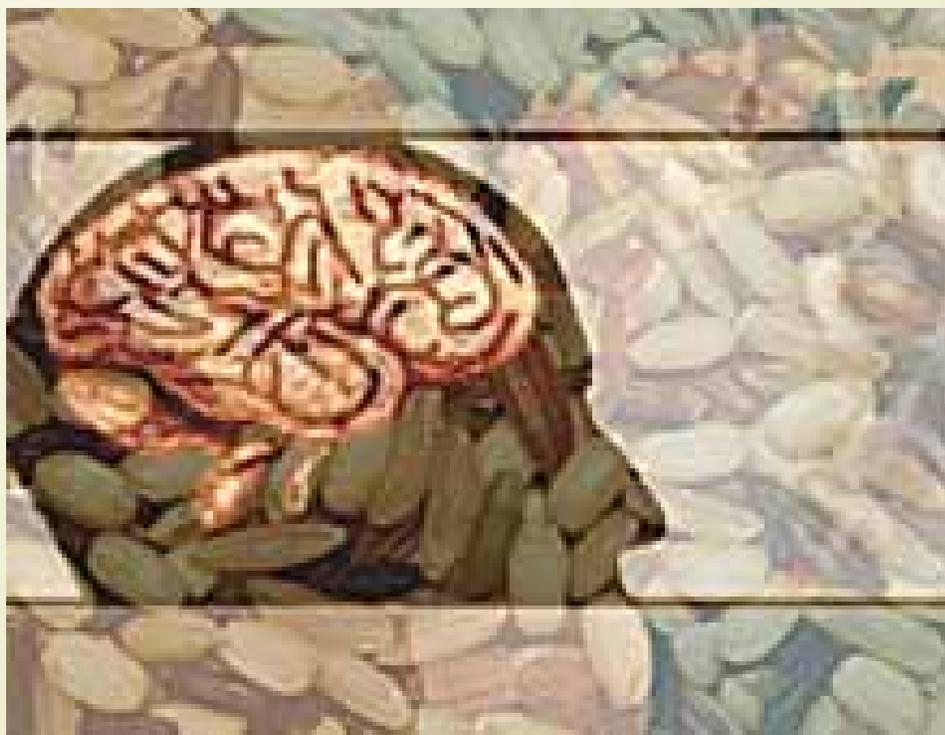
Diagnostic tests

Once you are diagnosed with high blood pressure, your doctor will give you a physical examination before

Getting to know about it

Most people with high blood pressure do not have any symptoms. In fact, you may not even know you have a problem: most people are diagnosed when they have their blood pressure taken as part of a physical examination. That is one good reason to have a regular check-up with your doctor, especially if you are over 40.

You may have heard that people with high blood pressure experience headaches and dizziness. However, in most cases, that is not so. Only people with severe high blood pressure or a rapid rise in blood pressure are likely to experience warning headaches,



Dangers

Since high blood pressure has no warning symptoms, it is often called the 'stealth killer'. Even at the highest levels, one may feel nothing. When high blood pressure is not detected and treated, it can cause a hardening of the arteries in the body, but especially those in the heart, brain, and kidneys. That is why people with high blood pressure have an increased risk of developing the following major illnesses:

- Narrowed coronary arteries, which may cause angina or heart attack
- Enlargement of the heart, which may lead to heart failure
- Small blisters (aneurysms) to form in the brain's blood vessels, which may cause a stroke
- Blood vessels in the kidney to narrow, which may cause kidney failure
- Eye problems
- Circulation problems in the legs, which could eventually lead to gangrene

In fact, high blood pressure plays a role in millions of deaths a year from these complications. If you have recently been diagnosed with the condition, you can escape the risk by treating it right from the start.

Treatment

If you have very severe hypertension, you may need to be admitted to hospital for initial treatment. But it is much more likely that your family physician or a cardiologist will provide the primary care. First, your doctor is likely to discuss the lifestyle changes that you need to make. You would be advised to lose any excess weight, get some regular moderate exercise, cut down on salt and alcohol, stop smoking, and have stress management or relaxation therapy. Each carries its own benefit. In fact, these measures may alone suffice if you suffer from a borderline hypertension.

However, if your blood pressure remains high, you may be prescribed one or more anti-hypertensive drugs. Several

exist. The drugs you are prescribed will depend on a number of factors, including their possible side effects, your other risk factors for heart disease and if you have any other illnesses. For example, if you have gout, diuretics stand excluded. It may take time to find the best treatment for you, balancing the benefits against any side effects. You must be patient, feel confident to discuss the situation with your doctor, and be committed to take necessary medication every day for a condition that may have no immediate symptoms.

Benefits of lowering blood pressure

The benefits of lowering your blood pressure are considerable. In clinical studies, anti-hypertensive therapy has been associated with a reduction in occurrence of stroke by 35-40 per cent, of heart attack by 20-25 per cent, and of heart failure by more than 50 per cent. This causes a significant improvement in the quality of life and adds many years to one's life.

Lifestyle changes to manage high blood pressure

Step to be taken	What's the target	Benefit (reduction in systolic blood pressure)
Weight reduction	Maintain normal body weight	5-20 mm Hg/10 kg weight loss
Healthy eating	Consume a diet rich in fruits, vegetables, and low-fat dairy products with a reduced content of saturated and total fat.	Up to 8-14 mm Hg
Cut down salt	Reduce salt consumption to less than 6 gm per day.	Up to 2-8 mm Hg
Physical activity	Carry out regular aerobic physical activity such as brisk walking at least 30 min per day, most days of the week.	Up to 4-9 mm Hg
Limit alcohol	Men should limit consumption to no more than 2 drinks per day, and women and lighter weight persons should take no more than 1 drink daily.	Up to 2-4 mm Hg
Stress relaxation	Change in attitude and actions, relaxation therapy, yoga, meditation, recreation, and vacation.	Lowering of chronic stress and possible reduction in blood pressure.
Stop smoking	Just quit.	Risk of angina, heart attack and stroke is significantly lowered.

Recent Developments in Science and Technology

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Reducing soot to control global warming

Global warming is a serious issue today and various measures are being suggested to control the rising temperatures around the globe. Reduction of greenhouse gas emission is one of them. A recent study published



Brown haze over India is created by soot from burning coal, wood, and biomass

in the online edition of *Nature* (23 March 2008) suggests that black carbon particles, commonly known as soot, may be as significant as carbon dioxide in contributing to global warming. Reviewing dozens of recent scientific studies the authors, Veerabhadran Ramanathan of the Scripps Institute in San Diego, California, and Greg Carmichael of the University of Iowa, USA, calculated that soot is the second largest contributor to global warming after carbon dioxide. According to them, sharply reducing the amount of soot in the atmosphere could help slow global warming and buy precious time in the long-term fight against climate change.

Soot is produced by burning coal, dung, wood and diesel. When it rises in the upper atmosphere, it traps the Sun's heat and blots out the light, raising the temperature at higher altitudes but

cooling the Earth below. Some 40% of soot comes from the same sources as greenhouses gases, notably the burning of coal and oil, and will only be reduced as quickly or slowly as economies become less carbon intensive. Remaining 60% of black carbon in the atmosphere comes from the more easily altered practices of burning biofuels and forests. According to the researchers, eight million metric tonnes of soot released into the atmosphere every year have created a number of "hot spots" around the world, contributing significantly to rising temperatures. The plains of south Asia along the Ganges River and continental East Asia are both such hotspots, in part because up to 35% of global black carbon output comes from China and India where

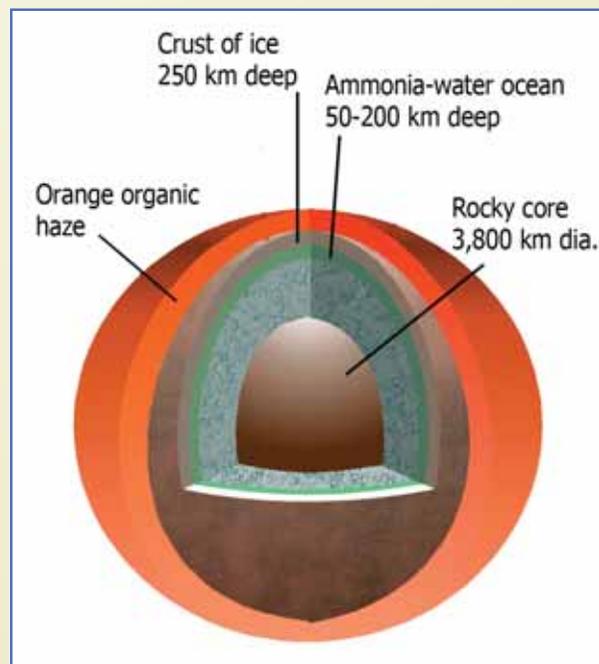
soot is blocking out up to a tenth of sunlight. Fine black soot settling on snow and ice – and thus trapping more of the Sun's heat – have also accelerated the melting of glaciers in the Himalayas and ice cover in the Arctic, two regions that have been hit especially hard by climate change in recent decades.

Unlike carbon dioxide, which lingers in the atmosphere for 100 years after it is released, black carbon has an atmospheric life cycle of approximately one week. Thus cutting back soot output would have an almost immediate effect. So, "Providing alternative energy-efficient and smoke-free cookers and introducing technology for reducing soot emissions from coal combustion in

small industries could have major impacts." Such measures could result in a 70-80% reduction in heating caused by black carbon in south Asia, and a 20-40% cut in China, according to the study. The authors caution, however, that soot reduction can only help delay unprecedented climate change, which is due primarily to CO₂ emissions.

Titan's underground oceans

Saturn's largest moon Titan has been springing many surprises ever since the *Cassini-Huygens* mission began to observe the moon in 2004. As Titan is covered with a thick atmosphere it is difficult to study its surface from Earth. Initial study of images sent back by *Cassini* suggested that Titan's surface was covered by a global ocean of hydrocarbons. Yet the first radar images of its surface, taken by the *Cassini* spacecraft in October 2004, together



Inside of Titan, showing water ocean below surface

with the data collected when the *Huygens* probe descended to Titan's surface in January 2005, showed most of the moon's surface to be solid. Since then, geological features such as dunes, channels, lakes, impact craters, and volcanic structures have been documented.

When *Cassini* observed the same features again in 2007 a startling discovery was made. All the major features showed a systematic drift, which has led researchers to conclude that Titan has an ocean buried below several tens of kilometres of ice (*Science*, 21 March 2008). Titan's low density suggests it is composed of a combination of water and rock. During the moon's early days, heat from its formation and the decay of radioactive material should have melted much of this water to create an ocean. Much of the ocean would have since frozen. But scientists suspect that a liquid layer up to 200 kilometres thick persists beneath an ice crust, probably aided by ammonia, which acts as an antifreeze, although hard evidence for such an ocean has been difficult to come by.

If the presence of an ocean is confirmed, Titan would be the fourth object in the solar system with a deep ocean, after the *Galileo* mission found such liquid layers in Jupiter's moons Ganymede, Callisto, and Europa. Large reservoirs of water – a condition for life to form and develop – may thus turn out to be a common feature in the solar system.

If Titan has an ocean beneath its surface, the possibility of life being present there cannot be ruled out. According to scientists, Titan may have provided especially good conditions for the development of life. Early in its history, liquid water may have been exposed to the surface, allowing complex carbon-containing molecules from the atmosphere to mix with the water and provide very good conditions for life to arise. But, it might have been difficult for this life to survive after the ocean was cut off from the atmosphere by ice.

Life ingredients from space

There have been several theories about the origin of life on Earth. Earlier it was believed that the first living cells might have appeared in water in the shallow seas of primordial Earth some

years ago. The researchers discovered that the meteorite, which fell at a place called Orgueil in France in 1864, may have come from a comet, rather than from an asteroid, as most meteorites do. What is of significance is that analysis of the



The Orgueil meteorite, which may have brought life-forming amino acids to Earth from space

3,500 million years ago, by the action of lightning on a mixture of gases like methane, ammonia and water vapour that made up Earth's atmosphere at that time. One recent theory suggested that life may have begun on Earth not on the surface but in the vicinity of deep-oceanic, hydrothermal vents, which are submarine hot springs with chimney-like structures often up to 55 metres tall that were first discovered in 1979. Hydrothermal vents represent discharges of hot, mineral-laden water, onto the ocean floor deep beneath the ocean surface that could have provided the ingredients and conditions for the first living cells to take shape.

According to a new theory proposed by researchers at Scripps Institution of Oceanography at the University of California, San Diego, USA, comets may have brought the type of fundamental ingredients necessary to help generate life on Earth (*Proceedings of the National Academy of Sciences*, 27 February 2007). The proposal is based on finding from the study of a meteorite that fell on Earth 136

meteorite has revealed the presence of simple amino acids like glycine and beta-alanine that could be the building blocks of the first living cells. Amino acids are the fundamental components of proteins and are synthesised in living cells. The researchers also analysed the sample's carbon isotope concentration and found that the amino acids were not derived from earthly contamination; rather they were formed without the help of biology, only chemical reactions.

Based on the unique amino acid composition within the Orgueil meteorite, the researchers were able to deduce information about the meteorite's past and inferred that it came from a comet. The amino acids, they say, were likely synthesised from components such as hydrogen cyanide, which have been recently observed in comets like Hale-Bopp. Thus, the paper suggests, the amino acids that helped generate life on Earth may have been delivered to Earth from space by meteorites that were derived from the remnants of comets. ■

Earthquake Tip-23

Advantages of Shear Walls in Seismic Regions

What is a Shear Wall Building

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called 'shear walls' (Figure 1) in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150 mm, or as high as 400 mm in high-rise buildings. Shear walls are usually provided along both length and width of buildings (Figure 1). Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation.

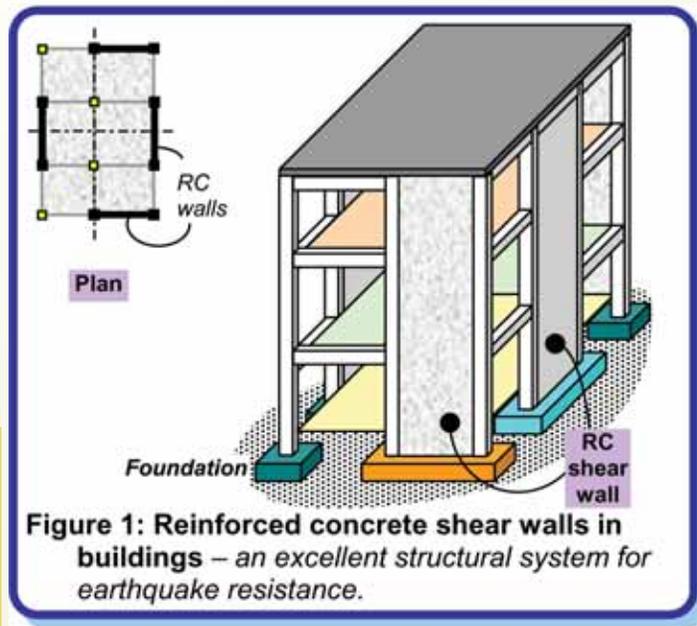


Figure 1: Reinforced concrete shear walls in buildings – an excellent structural system for earthquake resistance.

Advantages of Shear Walls in RC Buildings

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarised in the quote:

“We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls.”

- Mark Fintel, a noted consulting engineer in USA

Shear walls in high-seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing

earthquake damage in structural and non-structural elements (like glass windows and building contents).

Architectural Aspects of Shear Walls

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e., those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a 'moment-resistant frame') must be provided along the other direction to resist strong earthquake effects.

Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net cross-sectional area of a wall at an opening is sufficient to carry the horizontal earthquake force.

Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings (Figure 2). They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

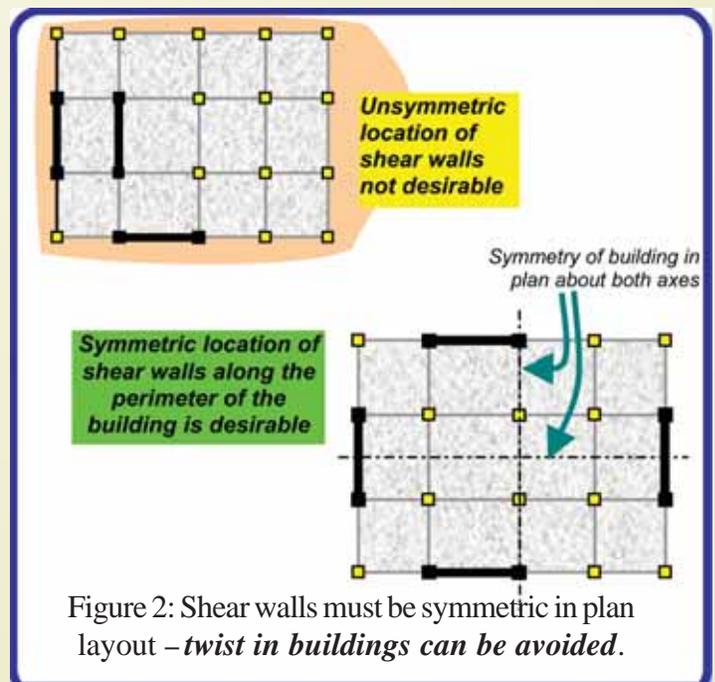


Figure 2: Shear walls must be symmetric in plan layout – twist in buildings can be avoided.

Ductile Design of Shear Walls

Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard 'Ductile Detailing Code' for RC members (IS:13920-1993) provides special design guidelines for ductile detailing of shear walls.

Overall Geometry of Walls: Shear walls are oblong in cross-section, i.e., one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used (Figure 3). Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces.

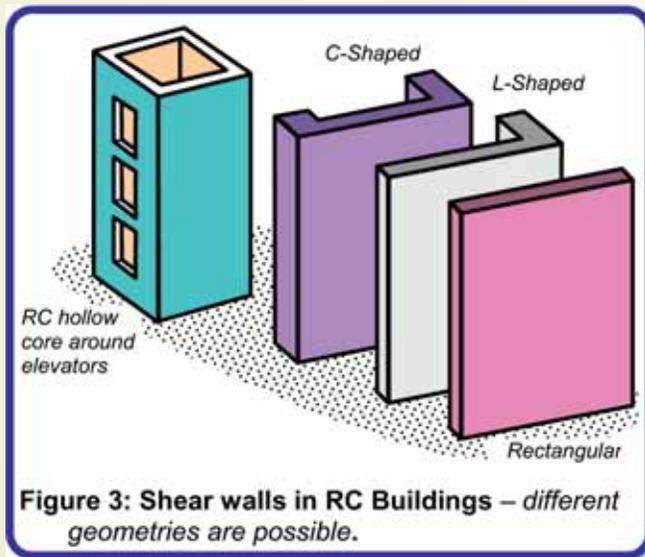


Figure 3: Shear walls in RC Buildings – different geometries are possible.

Reinforcement Bars in RC Walls: Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids (Figure 4a). The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called 'curtains'. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

Boundary Elements: Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall-end regions must be reinforced in a special manner to sustain these load reversals without losing strength (Figure 4b). End regions of a wall with increased confinement are called 'boundary elements'. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames (See IITK-BMTPC Earthquake Tip 19). Sometimes, the thickness of the shear wall in these boundary elements is also increased. RC walls with boundary elements have substantially

higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls without boundary elements.

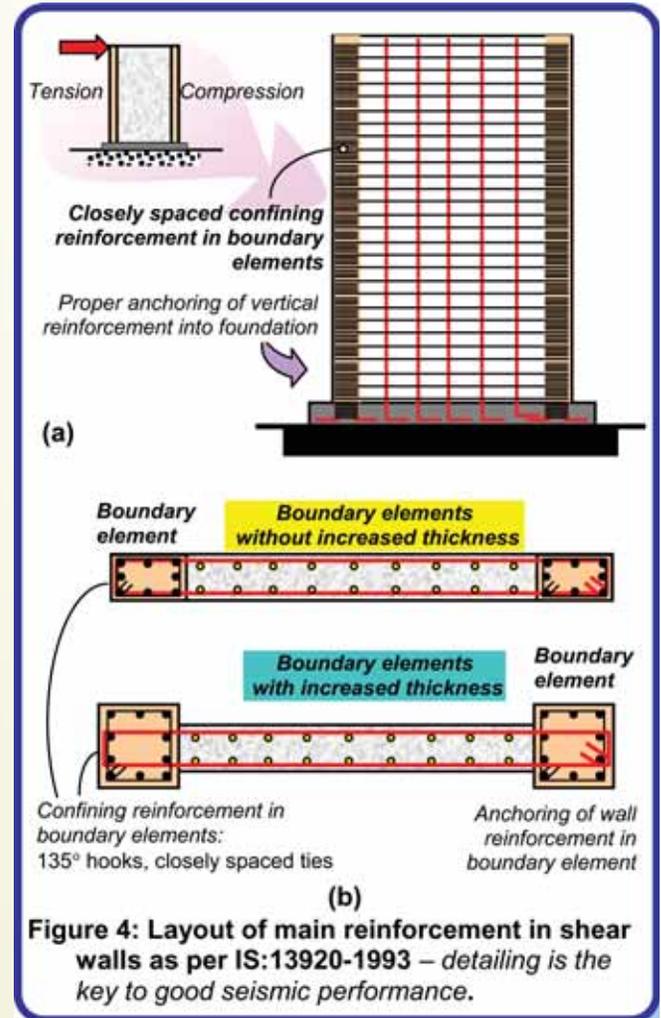


Figure 4: Layout of main reinforcement in shear walls as per IS:13920-1993 – detailing is the key to good seismic performance.

Related IITL-bmTpc Earthquake Tip

- Tip 6 : How Architectural Features Affect Buildings During Earthquakes?
- Tip 19 : How do Columns in RC Buildings Resist Earthquakes?

Resource Material

1. IS 13920, (1993), *Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces*, Bureau of Indian Standards, New Delhi.
2. Paulay, T., and Priestley, M.J.N., (1992), *Seismic Design of Reinforced Concrete and Masonry Buildings*, John Wiley & Sons, USA

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Sponsored by : Building Materials and Technology, Promotion Council, New Delhi, India

between electrically charged particles); and the quantum chromodynamic theory of strong forces (encountered within the atomic nucleus between protons and neutrons and which binds together quarks inside the protons and the neutrons). Particles that transmit forces between quarks are called gluons, while those responsible for beta decay (electron emission from nuclei) are the W and Z particles. In electromagnetic interaction, the particles transmitting force are the photons, while the ones responsible in gravitational interaction are called gravitons.

However, the Standard Model developed in 1960s and 1970s does not include answers to many basic questions such as how to unify electroweak forces with strong or gravitational forces. It cannot even explain mysteries of the Universe, answers to which have their roots in the world of fundamental particles. At the time of the Big Bang, the Universe had no dimensions at all. How did the Universe, infinitely dense at the time of the Big Bang, evolve into a vast Universe full of stars and planets we live in today? As the early universe expanded, energy should have condensed into equal amounts of matter and antimatter, which would then annihilate each other on contact, reverting to pure energy. Thus, the Universe should really be empty! But, there is more matter than antimatter and therefore we exist! Given the energy and the temperatures at which the LHC works, the experiments planned may help physicists understand why the Universe grew with just enough more matter than antimatter.

How about the dark matter? What is so 'dark' about it? Observations of the motion of distant galaxies indicate that they are subject to more gravitational force than their visible matter could possibly account for, implying existence of some exotic hidden matter in the mix. Where did this dark matter come from? A theory called 'supersymmetry' could possibly explain this. According to it,

every fundamental particle had a much more massive counterpart in the early Universe. Indeed, the electron might have had a massive partner that physicists refer to as the 'selectron'. Similarly, the muon might have had the 'smuon', and the quark might have had 'squark'. Many of those supersymmetric partners would be unstable. However, one kind of particles may have been just stable enough to survive till today without interacting with any other particles. Could they be dark matter? By smashing particles like protons at energies and temperatures that existed at the earliest moments of the Universe, the LHC could reveal the particles and forces that were responsible for everything that followed.

Predicted way back in 1960 by the University of Edinburgh physicist Peter Higgs, the Higgs boson is the only particle hypothesized in the Standard Model that has not been found in any experiment till today. Higgs boson is the key to the origin of the particle mass – and hence could perhaps explain how I weigh 70 kg! This is why it is also called the God particle! It is presumed to be massive compared with most subatomic particles – about 100 to 200 times the mass of a proton, and hence unstable. This is why one needs a huge collider like LHC to produce Higgs. LHC could create a small, compact bundle of energy from which a Higgs might spark into existence for a time long enough to be recognized. Finding it would be a big step for particle physics, although its discovery would not write the final ending to the story! Physicists believe that there must be a Higgs field that pervades all space; the Higgs particle would be the carrier of the field and would interact with other particles.

Until now, Fermilab in USA, the home of particle accelerator Tevatron, has been the frontier for particle physics research. It has found a few important particles, but it may not have enough energy to produce Higgs. When the LHC starts smashing particles, Europe will suddenly become the dominant location for particle physics. But, why

spend such huge money and brainpower over such accelerators and smashing particles? Computers we use today have become possible due to the development of microprocessors, and without the development of quantum physics, there would be no microprocessors, no computers, no internet, and no World Wide Web! It may be interesting to note that WWW was invented at CERN, by computer scientist Tim Berners-Lee. Remember the 2007 Nobel Prize for giant magnetoresistance discovered by two physicists independently in 1980s? They had no idea what it might lead to. But, their discovery proved to be crucial for making magnetized high data storage devices for computers and other consumer electronic items like iPods!

But, what is it that a big accelerator like the LHC expected to do, anyway? Accelerators are routinely used by physicists to study the smallest known particles – the fundamental building blocks of all things. LHC is expected to revolutionize our understanding, from the very small world deep within atoms to the vastness of the Universe. The experiments at the LHC are expected to answer fundamental questions like the origin of mass or the nature of the so-called dark matter. It could even give rise to new questions! Indeed, the experimental data using the higher energies reached by the LHC can push the frontiers of knowledge further ahead, helping us understand the fundamental laws of nature better, help confirm established theories, look beyond what we already know today; and also throw up new technologies as by-product. Even before LHC has started smashing the particles, the spin-off it has thrown up is the development of a technology - the Grid - that would make possible Internet 10,000 times faster than the present broadband connection; and allow data storage capacity over the Internet. On the "Red Button Day", both LHC and the Grid will be switched on at the same time.

□ Vinay B. Kamble

Sky Map for May 2008

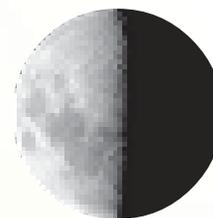
Full Moon



20 May

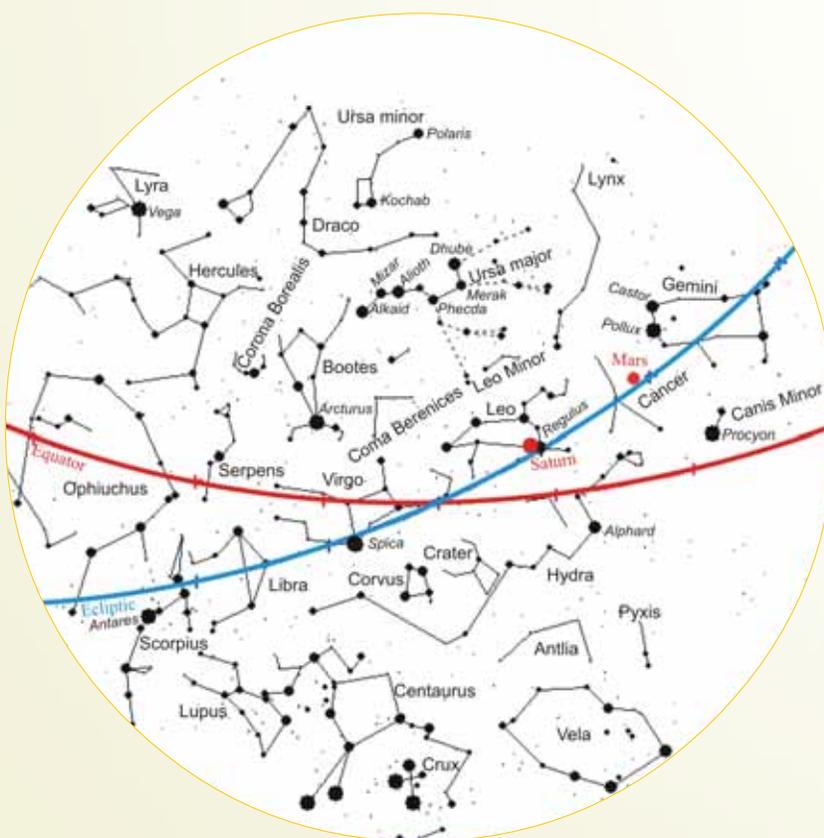
North

Moon - Last Quarter



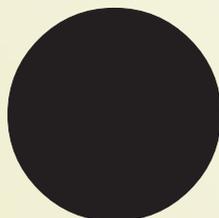
28 May

East



West

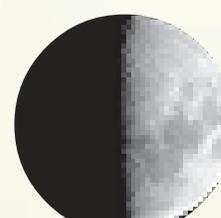
New Moon



5 May

South

Moon - First Quarter



12 May

The sky map is prepared for viewers in Nagpur (21.09° N, 79.09° E). It includes bright constellations and planets. For viewers south of Nagpur, constellations of the southern sky will appear higher up in the sky, and those of the northern sky will appear nearer the northern horizon. Similarly, for viewers north of Nagpur, constellations of northern sky will appear higher up in the sky, and those of the southern sky will appear nearer the southern horizon. The map can be used at 10 PM on 01 May, at 9:00 PM on 15 May and at 8 PM on 31 May.

Tips for watching the night sky :

- (1) Choose a place away from city lights/street lights
- (2) Hold the sky-map overhead with 'North' in the direction of Polaris
- (3) Use a pencil torch for reading the sky map
- (4) Try to identify constellations as shown in the map one by one.

Planet/Dwarf Planet Round Up:

- Mars** : In the constellation Cancer (*Karka Rashi*) up in the Western sky.
- Saturn** : In the constellation Leo (*Simha Rashi*) in the Zenith sky.

Prominent Constellations: Given below are prominent constellations with brightest star therein (in the parenthesis). Also given are their Indian names.

Eastern Sky : Corona Borealis, Hercules, Lyra (Vega), Ophiuchus, Serpens.

Western Sky : Cancer / *Karka Rashi*, Canis Minor (Procyon), Gemini (Castor, Pollux)/*Meethun Rashi*.

Southern Sky : Antlia, Centaurus, Corvus, Crater, Crux, Hydra (Alphard), Libra/*Tula Rashi*, Lepus, Scorpius (Antares), Pyxis, Vela.

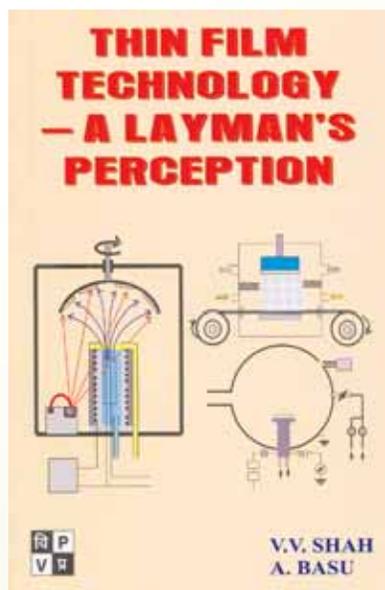
Northern Sky : Auriga (Capella), Draco, Lynx, Ursa Major/*Saptarishi*, Ursa Minor (Polaris) / *Dhurva Matsya (Dhurva Tara)*.

Zenith : Bootes (Arcturus), Coma Berenices, Leo (Regulus) / *Simha Rashi (Magha)*, Leo Minor, Virgo (Spica) / *Kannya Rashi (Chitra)*.

□ Arvind C. Ranade

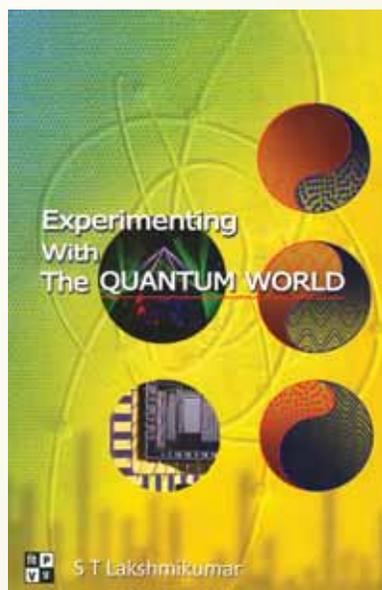
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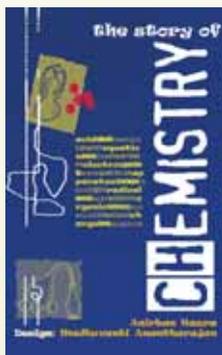
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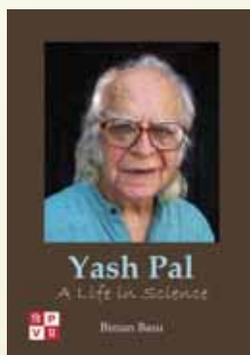


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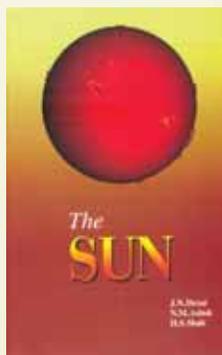
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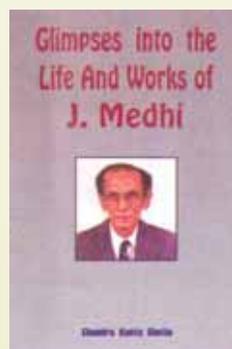
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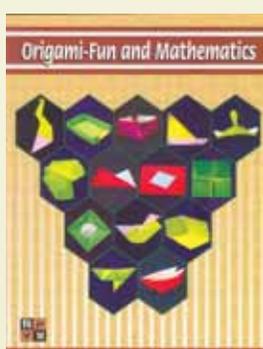
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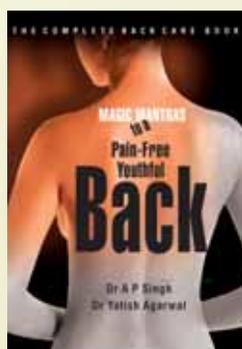
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Letters to the Editor

Science Journal par excellence!

I am pleased to note that *DREAM 2047* is becoming a popular science magazine *par excellence*. All the three issues which have come out in 2008 (January, February and March) contain information and material of high value and are most readable too. The editorials (e.g., the one on Monsoon) provide food for thought. Subodh Mahanti's biographies of scientists such as J C Ghosh, B C Guha and T R Seshadri are splendid. Biman Basu's "recent developments" column is timely and useful for students, teachers and scientists. The bi-lingual nature of the journal is most welcome. The layout is superb too!

Congratulations from a senior scientist and senior citizen!

Prof. (Dr.) C G Ramachandran Nair
Trivandrum

I am very grateful to Dr. V.B. Kamble and Vigyan Prasar for publishing a marvellous newsletter. I have been reading *DREAM 2047* regularly for two years. The editorials are thought-provoking. I am thankful to Dr. Yatish Agarwal for giving helpful health tips in *Mediscape*. I am expecting articles on science in our daily life. Why did you stop the series of articles "How many planets in solar system"? The efforts of Vigyan Prasar should reach schools, teachers and students; then only can we see a resurgence of science in the country.

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