Chapter-11
QUARK THE ULTIMATE PARTICLES

How wonderful that we have met with a paradox. Now we have some hope of making progress.
(Neils Bohr)

11.01. INTRODUCTION

Our quest for ultimate particles did not end with subatomic particles described in chapter-9. In the second half of 20th century, we found another particle (quark) as the ultimate constituent of matter. These are smaller than proton-neutron of atomic nucleus. They were again found to occur in six types of three colours exchanging some mysterious force-carrying particles.

How did we find them?

11.02. STRANGENESS & EIGHTFOLD WAY

Symmetry is a special ordered state where lies musical sweetness and pleasantry. To us, it simplifies theories required to describe range of observation. Symmetry is reflected in conservation laws. All physical laws show translational symmetry. It means that experiments done in one space and time would predict results for that done in another space and time. The symmetry is described by conservation of momentum. We know about conservation of mass and energy. Isospin symmetry is observed in strong nuclear force. It is likewise reflected in isospin conservation.

When numerous subatomic particles had been discovered, scientists wondered why there would be so many? Are they really necessary for making matter of this world? Is it possible that there exists some more simplified form of matter, hidden within it? In the usual mode of thinking, scientists first tried to bring some order among varieties of particles. The effort was similar to Mendelayev's periodic table or to Linnaeus taxonomy.

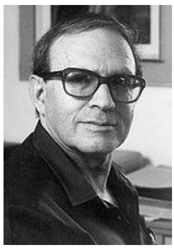
In Chapter-9, we have seen that Kayon was the first subatomic particle discovered, with a strange behaviour. It is produced by strong force and should decay via strong force. They decay strongly to produce pions in 10^{-23} sec. But the strange particles are living surprisingly a long life (10^{-8} sec). The Lambda particles live for long 10^{-10} sec. In the microworld, a life of 10^{-10} sec instead of 10^{-23} means a longer life of 10 million million seconds. That's a big life indeed! Thus, we find some subatomic particles behaving strangely; they are heavier than protons and have relatively long life though they are otherwise convertible to lighter particles. Two more strange particles, negative Xi (cascade particle) and sigma, were discovered shortly after the discovery of lambda.

To theorise this unique behaviour, Murray Gell-Mann of USA and Nishijima Kazuhiko and **T. Nakone** both of Japan, independently introduced in 1953 a new property of matter, *strangeness*. Some particles possess this property which is conserved in strong nuclear reaction wherein they are created. These strange particles are easily produced in high energy collision. Weak nuclear force work in decays but this does not conserve strangeness. The strangeness is expressed by quantum number, S, having only integer value. Proton, neutron and pion have no strangeness (S=0). These particles can produce strange particles only in pairs and so net value of strangeness becomes zero. This fact is described as **associated production** by Nishijima and Abraham Pais in 1952.

The Japanese physicist, **Nishijima Kazuhiko (**1926-2009) was graduated from Tokyo in 1948 and received Ph.D. from Osaka six years later. He worked at Osaka till 1959.

How to classify subatomic particles with properties like mass, charge, spin, isospin and strangeness? In 1961-62, a proposal for classification of hadrons, was made by the American physicist, Gell-Mann and the Israeli physicist Ne'eman.

Murray Gell-Mann was born in New York City in 1929. Graduated from Yale (1948), he joined MIT for Ph.D. Later he went to Chicago to study under Enrico Fermi and therefrom at CalTech in Pasadena (1956).



The Israeli physicist, **Yuval Ne'eman** (1925-2006) was four years senior to Gell-Mann. He began his study in engineering and later became interested in fundamental physics. While he was a military attache at the Israeli embassy at London, he simultaneously worked for his Ph.D. in this new field.

Gell-Mann's grouping according to strangeness, is known as *eightfold Way*. The term 'Eightfold' has been taken from Lord Buddha's Eightfold teachings. There is a kind of mathematical symmetry in the grouping of hadrons, labelled as **SU(3)**, meaning *special unitary group in three dimensions*. Particles are classified into families according to characteristics like electric charge, strangeness, rate of intrinsic spin. Each particle would fit then into a position in one of many families. Certain properties are conserved when these particles decay or interact. They would not violate law of conservation of electric charge and would conserve strangeness.

The basic subgroups of SU(3) consist of 8 or 10 members. Protons, neutrons and other spin ½ baryons fall into the group of eight. Nine short-lived resonance particles with spin $^3/_2$, fall in a group of ten though its tenth member was not then discovered. That the grouping was a success, appeared from the predictive power of the classification for this very tenth member.

In July 1962, at international conference at CERN, two resonance particles, negative and neutral Xi-star, were announced by scientists from Los Angeles University. Gell-Mann and Ne'eman realised that two Xi-stars would complete the new decupet of the Eightfold Way. The family contained four resonance (the deltas) with no strangeness and three sigma-star resonance with 1-unit of strangeness. The newly discovered Xi-star resonance fit there with 2-unit strangeness. Hence the tenth member having 3-unit strangeness was missing.

Like Mendelayev's table of elements, prediction emerged that the new tenth particle should have -ve charge with strangeness -3, and mass around 1680 MeV. The particle was discovered later in 1964 at Brookhaven National Laboratory of NY. It was named **omega$^-$** (ω^-) having a mass around 1686 MeV. Its anti-particle, the **anti-omega$^-$**, was discovered seven years later. Gell-Mann was honoured with Nobel Prize in physics in 1969 for his discovery of strangeness and 8-Fold Way.

11.03. THREE QUARKS

Physicists won't be happy unless they could explain why baryonic particles would come in so many numbers? Why SU(3) symmetry would apply to them? They were not content with the order of 8-fold Way. Is it possible that there are some more-fundamental particles that build up this whole range of baryon class? Earlier we have seen how some hundred elements were found to be made from three simple fundamental particles i.e. electron, proton and neutron. Is it possible that numerous baryons would be made up with something simpler like that?

Around 1963-64, Gell-Mann and Zweig observed that most basic subgroups of SU(3) consist of only three things. They independently put up a bold suggestion that baryons might be composed of smaller and more fundamental sub-baryonic particles. Gell-Mann was then working at CalTech. His Jewish colleague, **George Zweig** (b1937), was born in Moscow, USSR but then came to USA. He was a graduate from Michigan (1959) and moved to CalTech to work under Richard Feynman.

Zweig named those hypothetical fundamentals, 'aces'. In 1963, he went to CERN and published his views an year after. Gell-Mann named it **quark**. The term was taken from James Joyce's Finnegan's Walk – 'Three quarks for Muster Mark'. Gell-Mann's name survived.

Quarks are taken as point-size particles like leptons, without any structure. Initially two quarks had been proposed, **up** (*u* or q_u) and **down quark** (*d* or q_d), having fractional charges +2e/3 and -e/3 (or simply +2/3 and -1/3) respectively. A proton with positive charge, is structured with 2 up and 1 down quark in a combination of *udu* or $q_uq_dq_u$. Net charges would come down to +1. A neutron having zero charge, would be made up with 2 down and 1 up quark in the combination of *dud* or $q_dq_uq_d$. Here net charge would be then 0.

neutron (n^0) = d (-1/3) u (2/3) d (-1/3)
proton (p^+) = u(2/3) d (-1/3) u (2/3)

When lambda^0 (λ^0) was discovered with some other strange and heavy baryons in the octet grouping, Gell-Mann proposed that there should be a third one, **strange quark** (*s* or q_s), having charges +2e/3. The lambda^0 then would have a quark structure of *dus* or $q_dq_uq_s$ with strangeness -1.

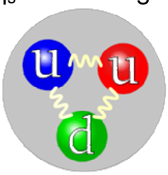


Fig:11.1. A proton, composed of two up quarks and one down quark. (The color assignment of individual quarks not important, only that all three colors are present.)

Quarks are spin½ matter. In order to form proton or neutron, also having ½ spin, three quarks have to align themselves in such way that two quarks would cancel each other's spin and leave a net spin value of ½. Spin of three quarks may also align themselves in such way that net value of spin comes out to be $^{3}/_{2}$. In case of short-lived-resonance states of delta (Δ), there may occur four combinations, *uuu*, *uud*, *udd*, and *ddd,* having charges +2e, +e, 0 and -e respectively. But these all are in theories. Where they really exist?

First evidence of reality of quarks came around 1968-1972 from studies at SLAC that was capable of producing high-energy electrons for collision.

The basic idea of the experiment was like this. If the proton is singular elementary particle, the lightweight electrons fired at it, would bounce off with nearly the same energy. Very little energy would be consumed in the recoil of massive proton. But if the proton is made up of quarks, the result would be different. The quarks inside proton are in constant motion and the fired electrons may find a very energetic quark or a quiscent quark. If electrons encounter such an energetic quark, the bounced-off electron would record higher energy than average in the spectrometer. If the quark is slower, the scattered electron's energy would also come lower. Thus energies of scattered electron recorded in the spectrometers, would give a direct measure of energies of quarks that electrons encountered. Realities would be proved by such indirect evidences.

In experiments from 1966-1972, the giant End Station-A of SLAC, indicated that energies of scattered electrons varied. The variation in energy distribution and the rate of arrival of scattered electrons in the spectrometers positioned at different angles, showed that proton consists of three quarks. Similar experiment was carried out at CERN using neutrinos, instead of electrons. Experimental results from these two were compared and a final conclusion was reached to declare that a proton is really made up by three quarks.

In this way, a theoretical conjecture was proved correct by experimental results. For this, **Jerome Isaac Friedman** (b1930) and **Henry Way Kendall** (1926-1999) of MIT and **Richard Edward Taylor** (b1929) of SLAC were awarded 1990 Nobel Prize in Physics.

Quarks too have antiparticles. A quark combines with an antiquark to form a meson. For example, pion comes in three varieties. Positive pion with charge +e, is formed by $u\underline{d}$, and negative pion by $d\underline{u}$ while neutral pion is a quantum mixture of $u\underline{u}$ and $d\underline{d}$.

When electron and positron collide at high energies, they would annihilate each other into pure energy. Soon this energy would recreate matter particles. The new particles might be electron-positron or muon-antimuon or quark-antiquark. The new-born quark-antiquark would fly into opposite directions and would cluster into pions, kayons and protons. This would happen within 10^{-23} sec and so we would practically observe a jet of particles consisting mainly of pions.

In the Mark J detector at the PETRA positron-electron collider at DESY laboratory near Hamburg, such jets of particles had been observed. To scientists, that was the nearest thing to seeing a quark. Scientists agree upon such seeing.

With this discovery, we go farther down into the scale of our microworld. Quarks are presently most fundamental particles that build all atomic particles.

Table:11.1. spin-$^1/_2$ baryons octet

strangeness						mass (MeV)
0		n^0 (udd)		p^+ (uud)		
	940					
-1	Σ^- (dds)		Σ^0 (uds), Λ		Σ^+ (uus)	
	1385	sigma				
-2		Ξ^- (dss)		Ξ^0 (uss)		
	1321?	Xi				

Table:11.2. spin-$^3/_2$ baryons decupet

strangeness					mass (MeV)
0	Δ^- (ddd)	Δ^0 (udd)	Δ^+ (uud)	Δ^{++} (uuu)	1232
	delta				
-1	Σ^- (dds)	Σ^0 (uds)	Σ^+ (uus)		1385
	sigma				
-2		Ξ^- (dss)	Ξ^0 (uss)		1530
	Xi				
-3			Ω^- (sss)	1672	
	omega				

Let us recall now the whole picture.

The material world began with just 92 varieties of indivisible atoms. Very soon those indivisible atoms, had been found divisible into nucleus and electron. Then the nucleus was ruptured open into proton and neutron. We had a trio of particles, making all those 92 varieties of atoms. Lately, two of the atomic particles have been broken down further into more minute particles, quarks. Does not our knowledge go deeper with respect to age and consequent scientific-technological development? If so, question remains whether these quarks are divisible further. Where it will end in our search for fundamentals?

Scientists say that there are theoretical evidences that we are very close to the knowledge of ultimate particles. Some hope that micro-world would then emerge simpler with electron-like light point-size particles of very low mass. Others think that it would be like strings.

Flavour is the term used to distinguish different quarks. Three types of quark mean three flavours. As a general rule, baryons are made up of three quarks while mesons of one quark and one anti-quark :

baryon = qqq and **meson = $q\underline{q}$**

Soon the quark model was found in conflict with Pauli's exclusion principle, since two fermions cannot exist in the same quantum state. In particles like Δ^-, we have quark formation as *ddd* and in Δ^{++} as *uuu*. It means that the spin of at least one quark have to be same in nature. But that is not permissible as per Pauli's principle. To overcome this difficulty, a new property of matter was introduced.

It appears so easy to explain intricate and complex behaviour of Nature – just import a new characteristic if known properties are not enough! But again what else can be done to know the unknowns, if that was ordained by Nature itself? In order to build a comprehensive model, we are to improve our ideas and import new characteristics.

11.03. COLOR OF QUARK

The American physicist **Oscar Wallace Greenberg** of Maryland University indicated in 1964 about possibilities of different varieties of para-quark. He noticed that three similar quarks in Omega-minus (Ω^-) and some other hadrons would have to possess a new property, named **color**. The term 'color' has nothing to do with the colour of flowers and clouds. It is just a property of color charge.

The Japanese-American physicist **Yoichiro Nambu** (b1921) of Chicago and **M.Y. Han** of Syracuse University, worked together in 1965 to understand this new property. Each quark would occur in three varieties of color, **red**, **blue** and **green**. Here again 'red' etc mean simply characteristics. Three quarks with three color for each would make nine color-quarks. There should also be three anticolors to make antiquark. Hence quark-antiquark would come in eighteen varieties.

The particle Omega-minus (Ω^-) then may be taken as a combination of three strange quarks with same spin but of different color. A combination of three colors would make things white or colorless. Color charges appear to be conserved. This idea explains how hadrons occur in two groups of baryon and meson. Mesons are made up of quark of one color and anti-quark of another appropriate color to make it colorless. Baryons are made of three quarks of three colors to make it colorless. A single quark or a 4-member quark is not possible as they would not be colorless.

Table:11.3. spin-0 meson octet

strangeness						
+1		K^0 (ds)			K^+ (us)	
0	π^- (ud)		η (uu)	η1 (dd) π^0 (ss)		π^+ (ud)
-1		K^- (us)			K^0 (ds)	

Table:11.4. spin- 1 meson octet

strangeness						
+1		K^0 (ds)			K^+ (us)	
0	π^- (ud)		η (uu)	η1 (dd) π^0 (ss)		π^+ (ud)
-1		K^- (us)			K^0 (ds)	

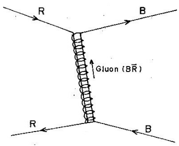
11.04. CHROMODYNAMICS

In 1970, three Harvard physicists, Sheldon Glasshow, **John Iliopoulus** (b1940) and **Luciano Maiani** (b1941), proposed a fourth quark, named **charm quark**. The observation of neutral current in neutrino experiments in 1973 and discovery of J/psi particle in 1974, strengthened the idea of fourth quark.

An analogy can be observed between colors of hadrons and charges of atoms. In atom, charges of constituents balance in overall charges. In the same way, colored quarks in hadrons balance themselves to make it colorless. Nuclei can be formed from colorless protons and neutrons, in the same way molecules are formed from neutral atoms. There appears that colour may be the source of force between quarks, in the same way, charge is the source of electro-magnetic force between charged particles. Such analogies prompted development of quantum field theory of strong force.

In 1971-72, Murray Gell-Mann and Fritzsch developed the field theory. The theory became known as **quantum chromo**dynamics or **QCD**, in line with the first field theory, quantum electro-dynamic theory or QED. **Harald Fritzsch** (b1943) was born in Zwickeu of Germany. He was professor of Max Planck Institute in Munich.

According to this theory, a quark may change its color by emitting a field quanta, named **gluon**. The emitted gluon is then absorbed immediately by another quark and the color of the recipient quark would change. Gluons also carry color and interact with each other. They are massless like photons. The color force between quarks forming nuclear particles, is the origin of nuclear force between nucleons. Nuclear power is the process by which energy from color forces between quarks are extracted.



R+ (BŔ) → B ; B - (BŔ) → R

Fig:11.2. quark colors changing by emitting gluon. Red quark (R) changes into blue quark (B) and vice versa, by exchanging gluon (BŔ). (source:*The Primeval Universe* of Narliker, p/136)

Protons and neutrons are bound together in nucleus by exchange of force-carrying particles (pions) that carry strong force. The strong force between quarks is carried by another boson, **gluons**, having rest mass 0 and spin-1. Physicists think that **gluon force is the real strong force**. Strong interaction is something like side-effects of the gluon force. We cannot get a single gluon as it has a color. This makes almost impossible to get a gluon free.

The strong nuclear force has one peculiar property, called **asymptotic freedom**. Due to this, the force between quarks become stronger when quarks move apart. This prevents an individual quark to exist independently. In close range, the force remains weaker. What happens when quarks try to move apart? More gluons appear on the scene and each contribute to the net force to prevent separation. In close range, less gluons appear and consequently less force is built up. At infinitely close range, quark may behave freely. Gluons are like the most patriotic citizen, free to fight among themselves in peacetime, but stand united against any separation of its country. At high energies, the strong force gets weaker. Quarks and gluons should behave then like free particles. Thus at asymptotically short distances or at high energies, quarks are expected to behave like free particles. That's an interesting kind of freedom permitted within a range. Try to move away from the closely-knit community, you are vehemently opposed to do it.

We may observe tracks of free quarks in photographic plates when proton and anti-proton are made to collide at high energy. Experiments in this regard are being arranged in three major accelerators at Fermilab, SLAC and CERN.

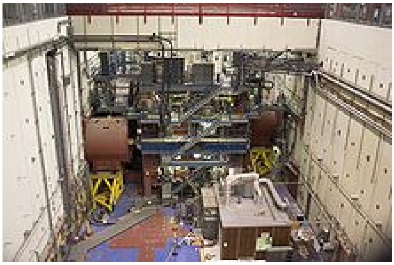


Fig:11.3. Brookhaven National Laboratory & SLC pit and detector.

Brookhaven National Laboratory (**BNL**) is located in Long Island, New York established in 1947. The Tevatron was built in 1982 at **Fermilab** near Chicago. The synchroton was converted into proton-antiproton collider where 1000 GeV (1 TeV) energy can be attained. In 6.5 km long circular tunnel, streams of proton and anti-proton would collide in head-on collision with the total energy of 2TeV to break up into particles. There is another collider called Stanford Linear Collider (**SLAC**) at Stanford of California. Here electron and positron streams collide in linear accelerators at 45-50 GeV.

The Large Electron-Positron Collider (**LEP**) at **CERN** of Geneva, can raise the energy level at 200 GeV total. Electron and positron streams are made to collide in a 27 km long elliptical tunnel. At CERN, the existing LEP is under further development into Large Hadron Collider (**LHC**). Here proton and antiproton would collide at 10 TeV per beam. Its operation would begin in 2008. The USA planned to manufacture one Super-conducting Super-Collider (**SSC**) to make it ready by 2000. With an elliptical underground tunnel of 87 km long, it will have 10,104 magnets weighing 41,500 ton energy level to the tune of 20 TeV per beam.

11.05. J/psi PARTICLE & CHARM QUARK

In November 1974, Samuel Ting as the leader of Brookhaven National Laboratory and Burton Richter of Stanford, working independently, found a new elementary particle, named **J/psi** (**J/Ψ**) particle.

Samuel Chao Chung Ting (b1936) was born at Michigan, graduated from Michigan (1956), got MS in 1960 and Ph.D. two years later. Then he joined nuclear research centre at CERN, followed by Columbia University and MIT. **Burton Richter** (b1931) was from Stanford where he joined in 1956 as research associate after some months at Brookhaven. He was born at Brooklyn of NY and studied in MIT.

Actually Brookhaven named the new one, J-particle while Stanford team, psi-particle. As both are one and the same, it was later renamed J/psi particle to honour both. The particle should be made of quark and anti-quark. As its mass is around 3.7 GeV, it cannot be built up by up, down or strange quark. So there must be a fourth quark, heavier than up-down-strange quarks, as predicted in 1970 by Glasshow, Iliopoulus and Mariani. The J/psi particle thus confirmed the fourth quark, **charm**. Within some days, Richter's team found at Stanford Positron Electron Asymmetric Ring collider, (SPEAR) of SLAC, evidence of another particle, called **psi-prime** (**Ψ′**). It was just below 3.7 GeV with relatively long life. Ting and Richter shared the Nobel Prize in 1976.

The J/psi and psi-prime particles probably possess some new properties that prohibit their rapid decay. They are built with charmed quark and charmed antiquark. When a charm combines with an anticharm, there would be no net charm and the particle would survive so long two quarks do not come close enough and move around each other. This new particle-binary is called **charmonium**. With high energy, the quark-antiquark form heavy particle which may move to lower energy state on radiating energy. The J/psi is the lowest energy state of charmonium. Latter is reckoned as the member of high energy particle world. Its long life further proves that strength of strong force diminishes as energy increases. At ultra high energy, the gap between electro-magnetic force and strong force would be reduced.

The up, down and strange quarks build baryons (protons, neutron, lambdas) and mesons (pions, kaons). The charmed quark may build with lighter quarks another class of **charmed baryons** and **charmed mesons**. In an experiment of electron-positron annihilation called, TASSO at the PETRA collider in Hamburg, three tracks were found due to decay of charmed meson, **D-star** (D^*). This D-star consists of a charmed quark and a down antiquark ($c\underline{d}$) and decays very quickly into a neutral **D-zero** with emission of a charged pion. The D-zero consists of a charmed quark and an up antiquark ($c\underline{u}$) and decays further in $5x10^{-13}$ sec into kayon and pion.

In 1975, **Gerson Goldhaber** (1924-2010) from Berkeley showed from data of electron-positron collision at SPEAR that the neutral charmed mason, D-zero, have a mass of 1.865 GeV. At the bubble chamber at SLAC, two charmed masons, one charged and one neutral, had been produced that left some visible tracks. In 1975, bubble chamber at Brookhaven observed decay of **charmed sigma particle**. (Source: 'The Particle Explosion' by Close, Marten and Sutton, Oxford University Press, 1987). Can this charm quark likewise build particles with strange quark also? Theoretically, yes.

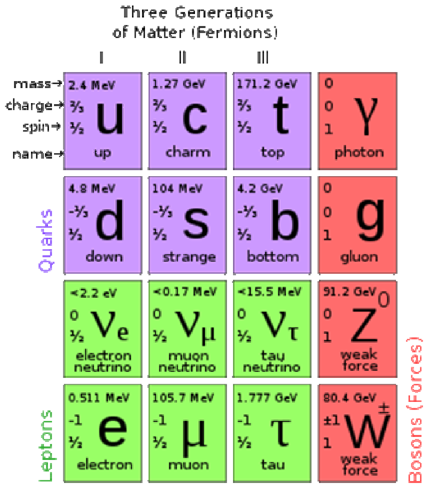
Table:11.05. elementary particles (spin ½)

charge	quarks	electro-magnetic	weak	QCD	gravity
+2/3	u c t	yes	yes	yes	yes
-1/3	d s b	yes	yes	yes	yes
leptons	ν_e ν_μ ν_τ	yes	yes	no	yes
	e^- μ^- τ^-	no	yes	no	yes

11.06. TOP & BOTTOM QUARK

The SLAC announced the existence of **tau-lepton** in 1975. In the previous year, the experiment was carried out by **Martin Parl** and his team on the Mark-I detector at the SPEAR electron-positron collider. It was confirmed from Hamburg next year.

The tau was electrically negative, 3500 times heavier than electron with an average lifetime of $3x10^{-13}$ sec. Its antimatter version contains positive charge. It is unaffected by strong force but takes part in electromagnetic and weak interaction. If the total energy of electron-positron collision is above 3.6 GeV, a tau and anti-tau would emerge. The negative tau decays into an electron and two neutrinos while positive antitau into a positive muon and two neutrinos. The tau and antitau may also produce a negative muon and a positron with neutrinos. With this discovery, we now have three pairs of leptons – electron and electron-neutrino, muon and muon-neutrino and tauon and tauon-neutrino



. Fig:11.4. Table of quarks and leptons.

Can we infer any symmetry between leptons and quarks? Perhaps, yes, scientists thought. There should occur three pair of quarks, though we had only two pairs.

The expectation was fulfilled in 1977 when scientists at Fermilab

under **Leon Max Lederman** (b1922) found a new meson called **upsilon**, of mass 9.46 GeV, spin-1 and short life of 10^{-20} sec. A year later, the DORIS electron-positron collider at Hamburg began production of **bottomnoium**, followed by Cornell Electron Storage Ring

(CESR) in 1979. This new meson upsilon proved the existence of bottom quark. It binds with its antiquark to form bottomonium**.** The upsilon particle (bb) is the lowest energy state of bottomonium. [Lederman was the director of Femilab since 1979.]

Evidence of the force-carrying particle, **gluon,** was found in the electron-positron collider at PETRA collider at Hamburg in 1979. When high energy electron and positron collide, the quark and antiquark would fly apart and produce two jets of hadrons. The separation of quark and antiquark might shake off one or more gluons in the process. If gluons happened to emerge with sufficient energy, it would produce its own jet of particles. Accordingly, three-jet occurrence was observed at PETRA collider, later at PET collider at SLAC and at L3 detector at CERN.

If the symmetry between lepton and quark really exists, there must be one more quark to pair with bottom quark. The sixth quark, even if undiscovered, has been named **top quark**. It is easier to propose a name but harder to prove its existence. The top quark remained elusive for quite some time. Groups of scientists raced to discover the particle. Finding the sixth member means a certain Nobel award. Fermilab announced on 26th April 1994 that they have found it. Two groups of scientists, D-zero and CDF, collected 17 and 45 records respectively and the data confirms the top quark.

Experiment at LHC (Large Hadron Collider) of CERN at Swiss-French border started on 10th September, 2008 but a cooling failure prompted shutdown for sometime. The cost of LHC is some $8 billion.

Two needle-thin proton beams would travel some 27 km almost at the speed of light at an average depth of 100 m below earth and would eventually made to collide. The collision would mimic conditions similar to Big Bang episode. Exotic particles to be produced as a result, would be detected by six detectors, three major and three minor ones, namely, Atlas, Alice, CMS & LHCB etc. It is expected to produce Higgs boson (refer Ch12). Mini blackhole may also result that would decay immediately. The existence of dark matter, extra dimensions, antimatter may also be detected.

The LHC after some initial failure started colliding at 7TeV energy (half the designed energy of LHC) on 30th March, 2010. The machine would then be upgraded to achieve 14TeV energy level.

CDF group of Fermilab made another important announcement on 8th February, 1996. They said that *quarks appear to have structures.* The team analysed data for four years before they declared it. According to a physicist of CDF group, there is 1% chance of error. If it comes out to be correct, our quest for fundamental particles will cross another level. The indivisible atom was broken in the last century, the nucleus was broken some decades ago, proton-neutrons were broken quite recently and now quark is going to be broken down into some other particles. When we would find the ultimate fundamental particle that builds our material world? We have no answer as yet.

11.07. REMARKS

Our Grand Nature at present abounds with low energy matter all around. Fundamental particles so far we have, are 36 quarks and 12 leptons bound by 4 forces carried out by 6 gauge bosons. The six quarks and six antiquarks having three colours, build all baryons and mesons of our world. In total we have 48 fundamental particles.

Our observable Nature is made up of two baryon particles (proton and neutron) and one lepton (electron). For these, only two quarks, two antiquarks and electrons are necessary. These baryons exchange force carrying particle mesons. Four fundamental forces are carried by gauge bosons which are photon, massive vector bosons, gluon and graviton.

There occur many more baryons and masons that can be observed in cosmic ray interactions or high energy particle collisions. They are all heavier particles making no observable matter anywhere in our world so far. What for do they exist if they do not form anything material in the real world?

Two quarks, two antiquarks and one electron are sufficient for our Nature. Do they exist somewhere else, in this Universe or in some other Universe hitherto unknown? Can it be like this that they are evolved states of our observable matter showing up at some energy level only?

We are not even sure how far we are away from the most fundamental particles. To us right now, quarks and leptons, are ultimate particles.

How these particles, if not fundamental, say nearly fundamental, were produced in the Universe? How they evolved in our times into what we observe in the form of atoms-molecules, elements-compounds, rocks and minerals?

We have solved numerous questions. We have numerous unresolved questions also. Science is not a magic to solve anything at one go. That's the reality of story of our Creation. If one is to absorb shy of such complex reality, the story of science is not for the person.
