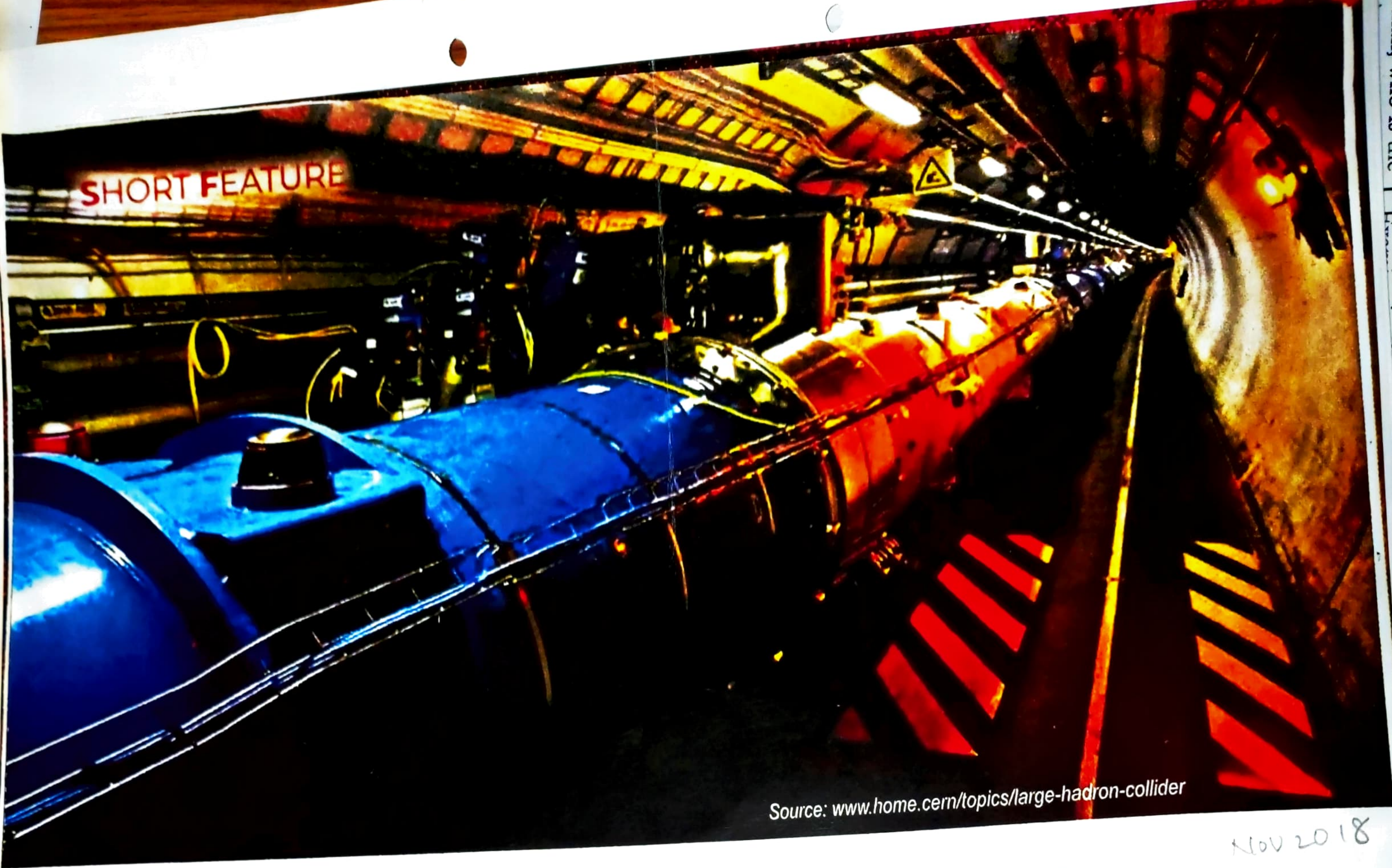

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The World beyond Protons, Electrons & Neutrons

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EVERYTHING in the universe is made up of atoms. But what is an atom made of? Subatomic particles – Protons, Electrons and Neutrons, right? But there is a world beyond them.

While trying to understand this concept, I came across a colouring book which gave me a beautiful insight into this subject. This colouring book is a product of the ATLAS (A Toroidal LHC ApparatuS) experiment by CERN – the European organisation for nuclear research. It starts with the introduction of the first animated character Bob who is a Physicist looking for answers to two questions: 'What are we made of?' and 'What happened at the beginning of the universe?'

Then comes the second animated character Betty who is an Engineer, involved in building particle detectors. Particle detectors are like giant microscopes. The book describes the particle detector such that even a child can visualize it. It says, "The particle detector is longer than 3 school buses, taller than 3 Giraffes and heavier than Eiffel tower." The Large Hadron Collider (LHC) is the world's largest and most powerful particle detector.

Experiments have confirmed that the subatomic particles are not indivisible but they can be further divided into 17 elementary or fundamental particles. These 17 elementary particles can be grouped into three major categories: quarks, leptons and bosons.

The question that arises is: what is the role of these elementary particles? Quarks and leptons constitute matter and so are called matter particles whereas the bosons build up force and hence are termed force particles.

Quarks are the fundamental constituents of matter. They are of six types: up quark, down quark, top quark, bottom quark, strange quark, and charm quark. They combine to form composite particles called Hadrons. The Hadrons are of two types: Baryons and Mesons. The Baryons are made up of three quarks and the mesons are made of one quark and one antiquark.

The most common examples of baryons are protons and neutrons. The up quarks and down quarks build up the protons and neutrons. An Up Quark (UQ) carries a charge of +2/3 and a Down Quark (DQ) carries a charge of -1/3. So, we can see, even protons and neutrons could be broken down into smaller units.

A proton is made up of two up quarks and one down quark. Hence its resulting charge is +1 (+2/3+2/3-1/3).

Elementary Particles

Matter Particles			Force particles	
Quarks	Leptons		Bosons	
Unitary	Charged	Neutral	Vector bosons	Scalar bosons
1. Up	7. Electrons	10. Electron Neutrino	13. Photon	17. Higgs Boson
2. Down	8. Muons	11. Muon Neutrino	14. W boson	
3. Top	9. Taus	12. Tau Neutrino	15. Z boson	
4. Bottom			16. Gluon	
5. Strange				
6. Charm				

(Charge of 1UQ=+2/3; Charge of 1 DQ=-1/3; 1 Proton=2 UQ + 1 DQ =+2/3+2/3-1/3=+1)

A neutron is made up of one up quark and two down quarks. Hence its resulting charge is 0 (+2/3-1/3-1/3).

(Charge of 1UQ= +2/3; Charge of 1 DQ=-1/3;1 Neutron=1 UQ + 2 DQ = +2/3-1/3-1/3=0)

Leptons do not undergo any strong interaction with other particles but they are observed during beta decay. Leptons are of six types and are grouped in two categories: charged leptons (electrons, muons and taus) and neutral leptons or anti-leptons (electron neutrinos, muon neutrinos and tau neutrinos). Electrons are the most stable type of leptons. The other types of leptons – muons and taus – also exist but they are very high energy particles and are not stable. Hence, they transform to their lower energy states, the electrons. Neutral particles called neutrinos also exist.

During beta decay, a difference of energy, momentum, and angular momentum was observed between theorized and observed values of initial and final particles. In 1930, Wolfgang Pauli said that a particle called electron neutrino might be causing this change. This was confirmed by Clyde Cowan and theorize the existence of anti-neutrinos but nothing has been confirmed yet.

Quarks and leptons both complete the picture of the atom. So why do we need another set of particles? Imagine a game of chess. You have all the pieces but you do not know how to play the game. Will you be able to play? No. Hence, we require a set of rules or a set of particles governing the interactions of these particles. Such particles are called bosons – the man behind bosons was Sir Satyendra Nath Bose.

Bosons are also called force particles as there is a boson 'causing' every fundamental force. Bosons are of two types: vector boson and scalar boson. There are four vector bosons: photons, W boson, Z boson, and gluon. Photon (not proton) is the boson responsible for electromagnetic interaction. We commonly know it as the 'particle of light' which is nothing but an electromagnetic wave. W and Z bosons are responsible for the weak nuclear interaction or the force which binds the nucleus and the electrons. Gluons (derived from the word 'glue') are responsible for the strong nuclear interaction or the force that binds the protons and neutrons.

Even after the discovery of so many elementary particles, there was something which was missing. Physicists were trying to complete the puzzle. In July 2012, a scalar boson called the Higgs Boson was discovered. ATLAS was involved in this discovery. The 'Higgs Boson' is like that golden piece of the jigsaw puzzle without which the world of elementary particles would be incomplete. The behavior of Higgs Boson with other particles is still a mystery to be solved.

These particles are responsible for imparting mass to other particles. Imagine a network of vertical and horizontal lines and a lot of different sized marbles moving in between those. Such is the stationary network of Higgs bosons with a variety of particles moving in between them. A photon passes through this network very fast and does not interact with it much; hence it has very less mass. Contrary to this, quarks are very slow. They interact with this network more and hence gain more mass.

And what about the most fundamental force, gravity! Scientists are still not quite clear how to accommodate this force in the standard model. They have conceptualized a particle called 'graviton' which they say is responsible for gravity but they are not quite sure. These 17 elementary particles and graviton together complete the picture of the atom and its interactions as per the standard model of particle physics.

Physicists have been trying to delve deeper into this subject but this is a study that gives birth to more questions rather than answering the existing ones.

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