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~~Non-~~Conceptual Revolution of the 20th Century Leading to one Grand Unified Concept - the Quantum Vacuum

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Be it on the basis of common sense or on the basis of most rigorous science, the understanding and explanation of all phenomena that we experience near us, far away from us or inside us, depend on a variety of concepts and the relations between the concepts.

Some of the oldest concepts which have been in use in normal parlance of people and for which one has evidence even from the scriptures that date back to thousands of years, are space, time, matter, mass, heat, light, force, energy, vacuum, causality, etc. They continue to keep the same meaning in their usage in daily life even to-day. However, these concepts also became part of science about four hundred years ago during the time of Bacon, Descartes, Newton, Galileo the founders of modern science. Concepts were gradually quantified; units introduced to enable meaningful measurements of high accuracy with instruments developed for the specific purposes. New concepts like velocity, acceleration, momentum, kinetic energy, potential energy etc. were also introduced. Most importantly this helped in mathematical formulation of the results of observation and prediction of new results, embodying operating principles of nature figured out through experience, sometimes intuition. In a sense the scientific methodology got initiated at this stage.

With the introduction of more and more sophisticated instruments systematic studies on the properties of matter, heat, light, sound, etc., resulting in increased knowledge for the explanation of which of many new concepts like molecules, atoms, entropy, refraction, diffraction, interference, spectral lines, acoustic waves, light corpuscles, light waves and so on had to be postulated. These concepts dominated the fields of Mechanics, Heat and Thermodynamics, Optics and Acoustics. These became the most prominent subjects of experimental and theoretical studies till the end of the 19th century. Yet another field that came into prominence during this period was the subject of electricity and magnetism following the classic experiments of Farady, Oersted, Ampere,

Coulomb and others. A grand synthesis of all this work in the field of electricity and magnetism was achieved by Maxwell and led him ^{to} the recognition of the existence of electromagnetic fields in space, strangely moving with the same velocity as that of light. This fortuitous coincidence with the velocity of light led to the identification of light as an electromagnetic wave. Subsequently Hertz produced EM waves of longer wave length in the laboratory.

The concept of field (magnetic, electric and electromagnetic field) introduced in this context presented right from the beginning a serious ontological problem. A wave amplitude could be a mathematical entity but since the EM wave also transmitted energy it had to be a physical entity. Maxwell tried to identify the EM-waves as 'ether waves', but did not succeed. We shall come back to the question of 'field' again later.

Towards the final years of the 19th century a new concept "particle" as a fundamental entity burst forth into prominence and has reigned supreme in the field of physics since then. The role of particles at the fundamental level became evident through the detection of the emission of the "alpha-particle" by uranium nucleus first and later detection of other particles - X-rays, electrons, and protons in the study of phenomena associated with discharge tubes. The electron turned out to be the particle responsible for electric current, the proton the particle in the nucleus of atoms and X-rays - the particle of electromagnetic radiation called the 'photon'. The EM wave/particle (photon) signaled the beginning of acquaintance with another new feature - the same entity being both a wave and a particle - (a transcendence beyond common sense) - the complementarity principle advanced by Niels Bohr.

Space and Time

Till the advent of Special Relativity in 1905, space and time had been regarded in complete conformity with common sense, as autonomous, independent of the external surroundings and their movements. In fact Newton in his *Principia* had said: "Absolute Space", in its own nature without relation to anything external always remains similar and immovable and similarly "Absolute Time" in its own nature flows equably without relation to anything external. This absolute nature of space and time was torpedoed completely by

the special and general theories of relativity. Time became a dynamical entity which could stretch or contract and even stop as for example near a black hole or a singularity. The clock rates depended on the state of motion and on the curvature of space in which they are located. This also meant that we have to give up the concept of a "universal present moment". What is present moment in one location can be past or future in other locations. A meter stick travelling with a high velocity will shrink in its length and the extent of shrinkage depends on the velocity. Such changes in the concepts of space and time were necessary to explain the experimental fact that the velocity of light was a constant, independent of the motion of the source or observer. This straight away contradicted the common sense notion of addition of velocities which had become a law in Newtonian Dynamics. According to Einstein the three dimensional Euclidean space and the one dimensional forward moving time should be fused into a new concept of *space-time* having four dimensions. The geometry of this four dimensional ~~space-time is non-Euclidean~~ and its ^{Special} peculiar properties are responsible for ~~the special~~ ^{Several} features observed in the three dimensional non-Euclidean space and unidirectional time, ~~in which all our observations and experiments are carried out.~~

Arthur Eddington put this transformation in a transparent and lucid way as long as in 1920's:

"The four dimensional world is no mere illustration. It is the real world of physics. An observer on the earth sees and measures an oblong block, an observer in another star contemplating the same objects finds it to be a cube. Shall we say the oblong block is the real thing and the other observers must correct his measures to allow for his motion? All appearances are accounted for if the real object is four dimensional and the observers are measuring different three dimensional appearances or sections and it seems impossible to doubt this true explanation."

Matter

Another important concept that has dominated the field of science as well as philosophy is 'Matter', which is the dominant perceptible constituent of nature. The first classification of matter is animate and inanimate namely living

and non-living. The chemists 17th century onwards have established that all matter on the earth consists essentially of 92 elements, hydrogen to uranium and spectroscopic studies of the stars have revealed that the same elements constitute the stars also. All animate matter too comprises of the same elements; only the molecular structures of the long organic molecules are different.

A very exciting finding of the 20th century was that all elements consist of the same three particles protons, neutrons and electrons. A further significant revelation was that the protons and neutrons consist of three fundamental particles namely Quarks. Thus to-day we can say that all matter in the universe consists of quarks and electrons. Besides the protons, neutrons and electrons, a large number of other short lived particles were discovered in cosmic rays and at high energy accelerators. Among all the particles there are two categories - those that have half integral ($1/2, 3/2$) spin and those with integral spin ($0, 1, 2$) spin. The former are called Fermions since they obey Fermi-Dirac statistics and the latter are called Bosons since they obey Bose-Einstein statistics.

Thus in the matter of matter a great synthesis, simplification and unification has been achieved in the 20th century. The next question is about the forces that bind the quarks into protons and neutrons, and the protons and neutrons into the various nuclei to form atoms and molecules and the forces that bind matter to matter to form the universe.

Force Fields

It is now well known that four different types of forces operate in nature. They are (1) the gravitational force, (2) the Electro-magnetic force, (3) the Nuclear or Strong force and (4) the Weak or Radioactive force. The concept of gravitational force was introduced by Newton through the famous equation $F_G = G (m_1 \times m_2) / r^2$, where m_1 and m_2 are the masses of any two objects and r is the distance of separation and G is the universal gravitational constant. This is the equation that provided the explanation of the famous Kepler's ^{laws on} elliptical orbital motions of Planets. The other famous equation of Newton is $F_1 = M \cdot a$ where m is the inertial mass and 'a' is the acceleration.

Newton had no idea how the gravitational force was generated and how it acted at a distance. This action at a distance' problem remained unanswered for

four centuries till Einstein came on the scene, with his General Theory of Relativity. According to this theory, the space around any massive object gets warped and the extent of warp depends on the mass of the object and the distance. Using the Principle of 'least resistance paths', Einstein was able to replace the idea of Gravitational Force in Newtonian physics by introducing space and time as dynamic players giving a new mechanism for the operation of Gravitational action. This eliminated the action at a distance problem.

According to quantum field theory, every elementary particle - the quarks and anti-quarks leptons, electrons, muons, neutrinos and tau-meson and their anti particles, are represented by quantum fields which not only give the probability of finding the particle at any given space and time, but also are the repository of other properties like spin, mass, charge of the particles. These properties manifest themselves in interactions with the force fields. The force fields are the electromagnetic field, the gluon field and the gauge boson fields which are the fields corresponding to the photon, gluon, and W^\pm , Z^0 whose exchange mediate the electromagnetic, strong and weak interactions. According to the standard model of particle physics, which incorporates all these features, it became necessary to introduce one more field, known as the Higgs Boson field for two specific purposes : (i) the very short range of the weak interaction ($<10^{-17}$ cm) indicated that the mass of the particles (W^\pm , Z^0) that mediate the force had to be in the range of 100 GeV. The standard theories, however, indicated that these should have zero mass like the photon. The 100 GeV mass range was confirmed by experiment. To give this mass to the W^\pm , Z^0 , the new field namely Higgs Field was introduced as part of the quantum mechanical vacuum field similar to the case of other fields of the standard model. (ii) The second purpose which the Higgs Boson served was to give masses to all particles which have non-zero mass - all the quarks, leptons. The most familiar particle, the electron gets its mass when the electron field interacts with the Higgs Field. The mass is not given once and for all. It has to keep on interacting with the Higgs field as long as it exists wherever it is. The Higgs theory does not give the strength of the coupling constant of interaction. It has to be adjusted with the experimental determination of the mass of the electron. The same is the case with all other particles. The theory could also not give the mass of the Higgs particle itself. Since 1970's the Higgs particle has been searched for, at all particle accelerators

Fermi Lab, CERN etc. It was clear that the mass exceeded the maximum mass they could produce. On the basis of various considerations the particle physicists came to the conclusion that Higgs mass may be in the range 100-150 proton masses. A new accelerator known as the Large Hadrons Collider (LHC) at CERN was built at a cost of about 10 billion dollars through international collaboration.

As of now there are strong indications that at the LHC, a new particle with a mass of 125-6 GeV has been discovered and the particle is a boson. While this is strong evidence for the Higgs Boson, there is some doubt lurking because of the fact that the ratio of the different decay modes of the Higgs predicted by the theory is not agreeing with the experimentally observed ratio. The statistics is still small. Many believe that the Higgs has been discovered. This is certainly a great triumph for both theory and experiment and for the Standard Model, though ^{the model} it has still has to go a long way to be fully established. Even now values of many parameters in the model have to be put in by hand on the basis of experimental results and are not calculable by theory.

20th Century Astrophysics and Cosmology

In his book 'Cosmic Impressions' Walter Thirring describes the drama of creation of the universe as follows:

"A miniscule speck in an embryonic space field with an Ur-substance of dark energy with negative pressure was the beginning of it all. (1)

The repulsion it created swelled this tiny fragment of space, but the ~~U~~-substance regenerated itself everywhere so that more and more of this miracle stuff was formed. The repulsion grows beyond measure and the expansion became an explosion of unimaginable force, the big bang. It shot open the gates to the underworld over wider and let this matter come bursting forth. This matter developed into the particles we have today, all 10^{88} of them. It had energy and positive pressure so that it took over the reigns from the Ur-substance and slowed down the explosion. However, there was still enough momentum to continue expanding for another 10^{10} years. We are left with a pale reflection of the beauty of the underworld; its symmetry was crushed and destroyed in the big bang.

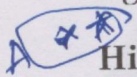
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The unified force was split into four forces which continued to be more and more alienated from one another."

Thus the concept of the "universe" itself changed drastically in the 20th century. Even in the year 1915, when Einstein completed his work on General Theory of Relativity which had implications to the nature of space, time and gravitation, and which time thousands of stars had been observed with small telescopes, there was still the impression that the universe is static - the stars were all in fixed locations, the only movements being that of Planets, Comets and Meteors. However, the solution to 'Einstein's first-verse' of his General Theory equations ^{showed} ~~should~~ that the universe was ^{not} static - another expanding or contracting. To save this embarrassment Einstein introduced a constant in his equation called cosmological constant (λ) ~~lambda~~ which Lemaitre interpreted as "exotic" form of energy that ^{and} uniformly and homogeneously fills all of space - the energy of space itself ^{that} has a gravitationally repulsive effect. However it so happened that in 1929. With the aid of the newly installed 100" telescope at Mount Wilson, Hubble made the astonishing discovery that the galaxies are running away from each other and the speed ^{increases} ~~in centre~~ with the increase in the distance between the galaxies. This discovery made Einstein remove ~~lambda~~ from his equation. The introduction of ~~lambda~~ ^{he} ~~had~~ ^{himself} called his 'greatest blunder.' Surprisingly ^{Recent} ~~discoveries~~ - that ~~the~~ the universe is not only expanding, but ^{also} accelerating at a rate higher than what was figured out before have resurrected 'lambda' - the cosmological constant.

The ^y ~~discovering~~ that the universe is accelerating was made only a decade ago. This came about by observations of the red ^{shifts} ~~ships~~ of a particular category of Super Nova ^e at very large distance from us. The ^{decrease} ~~decay~~ in ^{intensity} with distance was more than that expected ⁱⁿ the basis of ^{inverse} ~~invasion~~ square law of ^{intensity} variations. This acceleration is attributed to the repulsive force of a universal energy which has been called the "Dark Energy", perhaps the same as what we discussed above as the lambda introduced by Einstein ^{through} same differences ^{between λ and this energy} are ~~being~~ ^{being} claimed. This has also been identified as the universal Higgs Field energy which has all the properties required ^{for} ~~from~~ the explanation - repulsive gravitational force and constant energy density in to ^{new} ~~new~~ areas created by expansion of the universe. What is most intriguing about this dark energy is

that it becomes 70% of the total energy of the universe with another 25% of ⁴Dark Matter^h surrounding galaxies whose nature ^{is} also not known, leaving only 5% as the contribution from the well known baryonic and radiation ^{Contents} constant of the universe. The dark matter and the dark energy make their presence ^{felt... only} through gravitational action with known matter and energy. There is no other signature discovered yet.



Higher Dimensional Spatial Geometry and Physical Properties

All our observations and experiments are carried out in three dimensional space and one dimensional forward moving time with which we are all familiar. We have seen that because of the special properties of space and time, Einstein had to introduce the concept of four dimensional space-time and formulate^a his equations of General Relativity in four dimensions. Kaluza went one step further and showed that the Maxwell's equations fall out of Einstein's gravitational equations if he formulated the same in five dimensions. Klein pointed out that this fifth dimension could be an extremely curled up dimension of the size of Planck length ($\sim 10^{-33}$ cms). Though there were serious problems with Kaluza-Klein formulations, which were realized later, there were two important new insights that came out of this effort.

- i. The electric and magnetic fields (vibrations of electric charge) observed in the (3+1) dimensions space is due to the geometrical patterns of higher dimensional space. Thus the concept of charge acquired a new ^{same angle.} aspect, similar to curvature of space replacing gravitational force in Einstein's theory
- ii. The additional dimensions could ^{be} of miniscule size \sim Planck length approximately 10^{-33} cms

angle

↔ Higher dimensional spaces can lead to more symmetries and therefore more conservation laws; and to more physical properties.

These ideas ^{has} ~~that~~ have been profitably incorporated in 'string theory' which ^{extended} ~~has~~ six additional dimension of Planck ^a size, in addition to the four ^{extended} normal space-time dimensions. →

→ four

In the multidimensional quantum mechanical theories the spatial patterns (Calabi-Yau spaces) ^{appear as} lead to the properties like mass, charge, colour charge, spin etc. which ^{are} regarded as hidden intrinsic properties in the old theories. Thus all these properties which we are familiar in 3+1 dimensional space which have distinctive character and serve different purposes are ~~all~~ just geometrical patterns in higher dimensional space! Since the space is nothing but the collection of many different quantum mechanical waves of energy, in a true sense all the material universe - its constituents and forces are ~~all~~ just manifestation of one reality namely 'energy' in the form of quantum mechanical vacuum.

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The Impact of these Concepts on Life Sciences

What about the animate part of the universe in the light of above?

If as most scientists believe that life and consciousness are also just physico-chemical activities of the bio-molecules and the neuronal chemicals and electrical pulses in the networks of neurons, then the ultimate explanation for these features also will naturally reduce to something similar to what is stated above for the acquisition of physical properties. However in establishing the relation between the physical properties and quantum mechanical waves in the vacuum, there was considerable help and insight from mathematics which so far is not available for biological processes at the fundamental levels yet. Considering the complicated nature of the issues connected with life and consciousness, it may be necessary to introduce ^{higher dimensions and} new wave functions in the vacuum endowed with special properties, that interact in the environments of the cells, cortices, neuronal networks etc. Such an approach will require more subtle level investigations in the bio-sciences both experimentally and theoretically. One has to go far beyond the molecular levels.

A chief objection to the use of quantum mechanical approaches to problems like ^{live} life and consciousness was that these phenomena require coherence and non-locality ^{effects} for long periods and at warmer temperature compared to the nano-scales and ultra low temperature environments in which laboratory experiments in which quantum ^{eff} efforts are produced and tested. However in recent years this objection ^{is} no longer valid, since some of the natural processes like the highly ^{efficient} effect photosynthesis in plants and bacteria turning

like

non-local effects

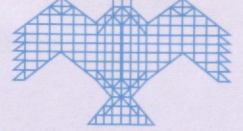
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sunlight^{ed} carbon-dioxide and water ^{into} organic material are taking place at atmospheric temperatures. Another remarkable phenomenon for which there has been no satisfactory explanation is the 'homing' of ~~birds~~ ^{birds over x distances} ~~our~~ long called, ^{was} has recently found explanation in terms of exotic quantum mechanical ^{effects} efforts taking place in the bird's eye, again at normal ~~atmosphere~~ ^{atmosphere} temperatures. Such magnetic field sensing has also been ^{noted} ~~nature~~ in some insects and plants. Philip Ball in his feature article ^{in Nature magazine} has called these developments as "The dawn of Quantum Biology". ^{migrated to}

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CAV Conclusion



A variety of concepts were introduced in the realm of Science for ~~ext~~ understanding and explaining the ~~observed~~ structure, contents, ~~processes~~ and processes in nature over the past several hundred years. As technology advanced the knowledge gained increased exponentially. It became necessary to introduce many more new concepts. At the same time it also became possible to unearth the intricate inner relations between what in the first instance appeared to be very different concepts and this led to unexpected synthesis. For example we have discussed in this paper how Space, time, matter and energy got synthesized as well as the different forces - gravitational, nuclear, electromagnetic and weak. The 20th century ~~top~~ physics is strongly pointing towards one ultimate concept namely quantum mechanical vacuum as the ocean of reality which is composed of waves of energy endowed with certain potential properties and whose spontaneous fluctuations are responsible for all creation and all activity that we see around us. This does not mean that we have understood everything that needs to be understood. This ocean can have the facility to have many more waves that may be needed to explain phenomena not understood yet or that will be ~~discovered~~ discovered in the future.