

Science and Metaphysics

A discussion on
**Consciousness
and Genetics**

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Transcendences in physics and their implications to consciousness

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Abstract

The way science has developed in the past four hundred years, it has become the traditional role of physics to explain all natural phenomena at the most fundamental level. In this endeavour concepts like space, time, matter, mass, particle, radiation, wave, energy, causality drawn from everyday experience are suitably defined, quantified and incorporated into mathematical equations formulated to represent the underlying physical explanations. In these formulations, the guiding and restricting role of laws of nature discerned from varieties of experience are taken into account. Verification of the predictions and falsifications, the key factors in scientific methodology have been responsible for the successes achieved. It has happened in the history of science that many of these concepts originally derived from experience, have had to be radically modified and transformed and even transcended (going beyond limits of normal human experience) to explain newly discovered phenomena, as well as those that defied explanation in the old framework, in the domain of physical sciences themselves.

The concepts of four dimensional space-time continuum, equivalence of mass and energy, the dependence of the rate of flow of time on the velocity of the moving frame of reference, the equivalence of curvature of space and mass, and of force and acceleration which were all ushered in by the special and general theories of relativity and the concept of vacuum as the ultimate substratum that is the very source of all constituents and forces of nature as highlighted by quantum theory, are some of the typical examples of such transcendences in physics dictated by new experimental results. These aspects will be elaborated in this presentation with a view to emphasize that in the efforts to resolve the problems of Consciousness in terms of neuronal correlates and the associated physico-chemical processes, transcendences of some of the physical and biological concepts, may be required. In the same way as the 'spin' parameter of individual particles (integral or half-integral of \hbar) controls the behaviour of large assemblies of these particles to obey either the Bose-Einstein or Fermi-Dirac Statistical distributions only, and also determine the very structure of elements in the periodic table and their properties, there may be very sensitive bio-parameters at the cell or sub-cell levels which may influence the group behaviour of bundles of neurons that could lead to emergence of consciousness and its many ramifications.

1. Introduction

The real and crucial problem of consciousness which has been outstanding and unexplained for several centuries, and which in recent years has been termed 'the hard problem of consciousness', is to explain the subjective experiences like cognition, recognition, feeling, sensation, thought, emotion etc. in terms of the physico-chemical activities of the brain. Recent developments in the field of neurosciences have provided elaborate and minute details of these processes in the various cortices of the brain, in the hundreds of billions of neurons that spread out from the brain to the various organs of the body, in the sensors that interface with the external world, in the glial and other cells in the brain, in the bloodstream, in the endocrinal and immunological systems and so on. While a variety of techniques have contributed to the vast store of knowledge that has accumulated over the centuries, in recent decades employment of newer non-invasive techniques, like CATSCAN, PET, fNMR, magnetic encephalograph, lasers,

and computer-coupled micro-electrodes, have provided much higher spatial- and time-resolutions for mapping ongoing processes in different locations of the body. These processes themselves, being chemical, physical, electro-chemical, or electro-magnetic, fall well within the framework of science and therefore of proper interpretation.

It has to be emphasized that all physical processes in nature are, in the final analysis, quantum processes. However, not all require the use of sophisticated quantum mechanical analysis and can be treated in the classical framework. The general rule in this regard is that if the 'action' involved in the process under consideration is large compared to the action defined by the Planck constant h , then classical approximation is adequate and works. There is, however, need for caution. There are many instances in which subtle influences of a quantum nature influence gross phenomena in a major way, especially if the macro-processes are the combined results of large assemblies of micro-quantum units.

In the history of life sciences, it has become clear that the detailed mode of functioning of many of the organs of human and animal bodies, like the heart, liver, lung, kidney and so on, can be fully explained in terms of physics and chemistry and there is no need to go beyond them either in terms of concepts or forces. In most of these cases, even classical physics and chemistry are adequate. However, when it comes to explaining the processes that go on in the brain and its accessories leading to consciousness, as hoped for by most scientists, it soon becomes apparent that normal concepts and procedures of explanation are hopelessly inadequate and that some kind of transcendences of these are absolutely essential. Such Transcendences (going beyond the limits of normal experience) have taken place several times in the past in the field of the physical sciences itself. The following are a few typical illustrations of such happenings.

2. Space-time continuum

Space and Time are two important concepts drawn from our daily experience. These are very different kinds of experiences. In our minds, space is characterized by emptiness and as a plenum for matter to occupy. Time is something that flows

independent of us. In Newtonian dynamics, space and time are independent of each other. Time is universal and the rate of flow of time is the same everywhere and is independent of motion. All these ideas underwent a radical change, when Einstein introduced his special theory of relativity to explain the experimental fact that the velocity of light is independent of the motion of the source or observer as dictated by the famous experiments of Michelson and Morley. Einstein stated "we can do away with the ether; the velocity of light may be regarded as a constant of nature independent of the motion of the source or observer. But, we have to give up our conventional ideas of space and time". According to him, "the Laws of Science should be the same for all freely moving observers no matter what their speed". Formulating the special theory of relativity he stated:

- (i) There is no absolute time; space and time have to be fused into four-dimensional space-time continuum
- (ii) Space contracts and time dilates in a moving medium – the extent depends on the velocity
- (iii) Idea of simultaneity has no longer any meaning.

Einstein's theory led to the very important consequence that Mass and Energy, two distinctly different concepts till then, were equivalent and related by the equation $E=mc^2$.

Einstein went further and developed the general theory of relativity which had more drastic consequences. Space is no longer Euclidean, and space-time becomes increasingly curved in the presence of mass and energy. While in Newtonian theory, gravitation is a force, in Einstein's general theory the gravitational laws describe the relation between the mass of the gravitating body and the structure of the field around it. In fact mass itself can be looked upon as curvature of the space-time continuum.

3. Action at a distance

Let us consider the case of Newtonian dynamics ushered in by Newton more than three hundred years ago. On the basis of observations on the motion of bodies on earth, he framed his famous laws of motion and extended them to explain the laws of planetary motion that had been enunciated by Kepler. According

to Newton, the force between the sun and the earth that kept the earth in its orbit was proportional to the product of their masses and inversely proportional to the square of the distance between them. However, he did not clarify how this gravitational force was transmitted between the two objects, which were so far away from each other. The basic concepts used in Newtonian dynamics, force, mass, and distance, were all familiar concepts and derived on the basis of everyday experience (anthropomorphic) of the common man in his daily transactions. There was a 'ring' of familiarity about them. However, there were aspects which created problems in fuller understanding. One, of course, was the source of this gravitational force and the other was the 'action at a distance'. Till then, the impression in the minds of common men was that for force to act, spatial contact between the two bodies involved was essential. Action at a distance meant, in this case, transmission of force without any physical matter between them. Newton was aware of this problem. He had no answer. He is reported to have said 'God only knows'!

The same problem of action at a distance was encountered in the fields of electricity and magnetism, though in these cases the distances were of much smaller magnitude. Faraday introduced the idea of magnetic and electric fields, without specifying the physical contents of these fields. Subsequently, the vague concept of 'ether' was brought in to explain these various fields. Maxwell who developed the electro-magnetic theory tried hard to explain the propagation of electro-magnetic waves in terms of the elastic properties of the ether, but did not succeed. The concept of ether was later abandoned since it conflicted with experimental results on the velocity of propagation of light which had been identified as comprising electro-magnetic waves. It is interesting to point out here how sometimes the relation between cause and effect gets wrongly identified and misplaced. Maxwell thought that the elastic properties of the ether were somehow responsible for the propagation of electro-magnetic waves. Later theories showed that the elastic properties of any medium are the result of the electro-magnetic interactions of the constituents of the medium.

The action at a distance and the propagation of electro-magnetic waves could be tackled only in the framework of the new quantum field theories and relativity theories. These theories

required a total transcendence in the old and familiar concepts of space, time, causality, force, particle, wave etc. This was much more radical and far-reaching in consequences than the paradigm shift that happened in just moving from a Geocentric to a Heliocentric system.

4. Quantum tunneling

In the discovery of radioactivity, almost towards the end of the 19th Century, something very strange had been observed – emission of α -particles from very heavy nuclei like uranium. To come out of the nucleus, the α -particle had to overcome a huge potential barrier. The particle did not have the energy to do this. Yet occasionally it did come out. There was no explanation in terms of the classical ideas. This is where the dualistic wave/particle ideas of quantum mechanics which were just being developed came in handy. By treating the α -particle as a wave and solving the corresponding Schrödinger wave equation, the probability of finding the particle outside the nucleus was calculated and found to be finite. This meant essentially occasional penetration of the α -particle through the potential barrier. In this explanation one had to give up the conventional idea of the “trajectory” of the particle defining its precise location in space and time, at every instant.

What is interesting and intriguing is that the same physical entity, namely the α -particle is registered by the Geiger counter as a particle and it leaves the track of α particle in a cloud chamber. But for understanding its penetration through the potential barrier, it has to be regarded as a wave. This wave/particle duality has to be built into the explanation of the phenomenon. This duality has other ramifications too. Light which we considered as an electromagnetic wave also has this dual character. Depending on the experimental set up it can be seen as a wave or as a particle (photon). In phenomena like interference, diffraction or polarization, light behaves like a wave. In phenomena like the photoelectric effect, or the Compton effect, light behaves like a particle. The particular mode of light to be seen depends on the choice of the observer. This raises the question, how can objective reality become subject dependent? How can the same entity be an extended object like a wave and

an extremely compactified point-like object, a particle? Apart from the deep philosophical implications, such dual aspects as far as scientists are concerned, focus attention on the necessity of evolving a proper scientific framework in which such apparently contradictory features that go against common sense and experience are resolved.

5. The Dirac sea: (The quantum mechanical vacuum)

When Dirac formulated the quantum mechanical equation for a relativistic electron, and solved it, he was surprised to find solutions that corresponded to both positive and negative energy states of the electron. The normal practice was to treat the negative energy solutions as 'unphysical' and just ignore them and consider only the positive energy solutions. Dirac just did not do that. He transcended the normal practice and tried to interpret the negative energy states in a bold unconventional way. He assumed that all the negative energy states of the electron, an infinite number of them, are completely filled in 'empty space' in which we see the movement of the electrons which have positive energy states. If however one of the electrons in the negative energy states makes a spontaneous transition due to fluctuation to a positive energy state then a 'hole' is created in the sea of negative energy states and this 'hole' behaves like a particle of opposite charge, namely positive charge, and if the energy available due to fluctuation is sufficiently large, then there is manifestation of two particles – an electron and a positron (as the hole is called). This pair creation happens more easily if a quantum of energy in the form of a photon is deposited into this Dirac vacuum or empty space. The positron is regarded as the 'anti-particle' of the electron. Right in the beginning, Dirac thought that this positively charged particle may be the proton itself which however has a mass widely different from that of the electron. Soon it became clear that, even for theoretical reasons, the particle has to be the positive counterpart of the electron itself. Around the same period, without being aware of these theoretical developments in England, Carl Anderson in USA, discovered in cosmic rays a particle which had a positive charge and the same mass as the electron. This is undoubtedly Dirac's positron. This whole development brought about awareness of

many new aspects of nature. One, of course, is the existence of the anti-particles, the other is the revolutionary idea of the Dirac vacuum as the plenum in which all the negative energy states are filled and with which we cannot normally interact, the third is that all other particles can have such seas of negative energy states with the possibility of anti-particles being produced under suitable conditions. Though many of these ideas of infinite negative energy states etc. have undergone transformation in later years, in terms of field theoretical concepts the substance of Dirac's idea of vacuum or empty space as the plenum from which all fundamental particles emerge under favourable conditions stands. Dirac says: "All matter is created out of some impereptible substratum – Nothingness, unimaginable, and undetectable. But it is a peculiar nothingness out of which matter is created".

This new insight on empty space, the quantum vacuum or Dirac Sea has very significantly influenced subsequent developments in the field of elementary particle physics, cosmology, solid state physics etc. The creation and annihilation of particle-antiparticle pairs due to fluctuations in the Dirac Sea, a process that continuously goes on, opened up several interesting ways of understanding hitherto unexplained phenomena. How is the electrostatic force between the proton and the electron (for example in the hydrogen atom), negotiated though the empty space in between? The action at a distance problem that we raised earlier. This is now explained in terms of the exchange of virtual particles (virtual in the sense that they cannot be observed directly in any particle detectors) – the pairs of electrons and positrons, and their annihilation products – photons, being exchanged between the proton and the electron. This new concept of "exchange forces" in a sense replaced the old ideas of force drawn from daily experience. Is there evidence for such a phenomenon? Yes. This too was established, though indirectly through the detection of the altered radiation from the hydrogen atom itself. The electrons from the virtual pairs would move towards the positively charged proton and the positrons towards the electron of the atom. This would result in a reduction in the effective force between the proton and the electron., and would change the frequency of radiation emitted. In the case of other much shorter range nuclear forces the particles and anti-particles that were exchanged, were not the photons, but various other types of

mesons of much heavier mass. The essential point to note is that there was a transcendence again in the very notion of force; and how it was negotiated.

In the field of cosmic ray studies (cosmic rays are very high energy particles that come from the depths of space), a very spectacular phenomenon is encountered. Occasionally more than a billion particles are incident almost simultaneously over tens of square kilometres at mountain altitude or sea level. These showers contain all kinds of fundamental particles – electrons, positrons, photons, nucleons, anti-nucleons, hyperons etc. The most intriguing thing is that these billions of particles owe their origin to the incidence of just one kind of high energy particle at the top of the atmosphere. Where were these particles before they manifested? The answer is in the extended Dirac vacuum. The primary particle in its collision with an air nucleus, first produces a large number of secondaries which start moving down. The production of these mesons, nucleons etc. is essentially a mining out from the excited vacuum region of the collision, sufficient energy being put in by the collision process. Some of the secondaries spontaneously decay into other particles. The remaining suffer further collisions as they move down and repeat the same process and produce more secondaries and this cascade of nuclear interactions continues down the atmosphere. Among the decay products, there are high energy photons which create electron-positron pairs. These electrons and positrons radiate high energy photons which give rise to more pairs of electrons and positrons. It is this cascading in the atmosphere that results in the production of billions of particles, all culled out from their hide-out, the quantum mechanical vacuum. The phenomenon itself is a gross one with billions of particles that are sampled and recorded in instruments like scintillation counters, cloud chambers etc. But the entire process involving the creation of so many particles is quantum mechanical in nature. Such an outcome could never be explained in the classical framework. The phenomenon, when analysed in terms of high resolution timing devices, beautifully demonstrates some of the relativistic effects like time dilation, increase of mass with energy etc. The chief point to be noted is the dominant role of empty space or vacuum in the whole process, which would never have figured in any classical treatment of the problem.

6. The spin parameter and its large scale influence

In addition to the mass and charge of the elementary particles, another important parameter that was first discovered in the analysis of the hyperfine structure of spectral lines emitted by excited atoms of elements is the spin parameter which again is a quantized parameter. The spin angular momentum in terms of $(h/2\pi)$ units can be half-integral, integral or 0 and not any other value. What is most interesting is that the particles with half-integral spin electrons, protons etc. obey in large assemblies one kind of statistical behaviour (Fermi-Dirac distribution) and the integral spin particles obey quite a different statistical behaviour (Bose-Einstein). These features have tremendous influence on certain gross phenomena involving these particles. In fact the structure and properties of elements in the periodic table depends on the half integral character of the spin of the electrons and the Pauli Exclusion Principle. The influence of such parameters on macroscopic effects can be seen from the following examples. It is known that 99.9% of all matter that we come across on the earth is just empty inside. You can ask the question then: If this is so, why does not my hand go through the table, for example? There is no classical way of understanding this. The explanation depends on the quantum mechanical exclusion principle. There is lot of excitement in astronomy nowadays regarding condensed objects like white dwarfs, neutron stars, black holes etc. The factors governing the very formation of these objects and their properties depend on the spin parameters of the electrons, the protons and the neutrons that constitute the hydrogen and other elements of the stars.

There is yet another principle, Heisenberg's uncertainty principle, of tremendous importance in the quantum world, with major consequences in the everyday world that we are familiar with. The principle states that 'one cannot measure an object's position and momentum precisely and simultaneously'. A further elaboration of this principle that turned out to be significant was that it is not only a question of inability to measure, but also that these parameters do not have very precise values themselves; they fluctuate within the limits of the uncertainty principle - $\Delta P \Delta x \geq h/4\pi$ and $\Delta E \Delta t \geq h/4\pi$ where ΔP , Δx , ΔE , Δt are the uncertainties in position, momentum, energy and time interval of

action. This principle provides for departure in the sacrosanct principles of conservation of energy and of momentum. There could be a departure in energy conservation by ΔE in a process which proceeds in time less than $h/4\pi\Delta E$. In nature such allowances are made use of, for example, in spontaneous decays of some of the fundamental particles.

7. Conclusions

From the few examples given above (and many more which we have not presented here), it becomes apparent that many of the simple concepts originally introduced into physical explanations like space, time, causality, force, energy etc. have had to undergo considerable modification in terms of their implications and some have even transcended into the realm beyond normal human experience. These changes were forced by the discovery of new experimental results. We may remind ourselves that in the framework of the special theory of relativity, space and time are fused into the space-time continuum; flow of time, spatial intervals and even mass became functions of velocity; mass and energy become equivalent. In the framework of general theory of relativity, space becomes non-Euclidean, curvature of space becomes equivalent of mass (one a geometrical property and the other a physical quantity). In the light of quantum mechanics, the wave-particle complementarity has to be accepted and even vacuum, which was originally conceived in classical physics as empty space (absence of all matter and radiation) becomes the very source of all the fundamental particles – the ultimate constituents of all matter, radiation and force. The concept of force gave way to exchange of virtual particles and anti-particles. The example we have given of a very high energy particle cascading through nuclear and electromagnetic forces into more than a billion particles of different properties is a clear illustration of the very dominant role that this so-called vacuum can play in creation, and in the destruction of matter and antimatter in extremely short intervals of time.

Though all this is in the realm of inanimate matter, it is equally relevant to animate matter as well, since the ultimate composition of animate matter is not different and has its origin in inanimate matter. In the development of organisms from the unicellular

amoeba to the multi-billion-celled man, evolution based on the cardinal principles of natural selection and survival of the fittest is a subsequent phase to cosmological evolution, perhaps, beginning with the Big Bang as most popularly believed in scientific circles. These cosmological and creation theories of the universe and its variety of constituents have brought about the recognition of one very fundamental fact that, in the ultimate analysis, all this has arisen out of one substratum, call it quantum mechanical vacuum or four-dimensional space-time continuum or something equivalent, and this substratum has come into existence endowed with very specific properties, now discerned by physicists. Not all the properties of this substratum are known yet. In addition, the laws of nature have to be what they are, and so also the constants of nature. This being the case at the most fundamental levels of explanation, the possibility opens up that a similar situation may prevail in the living world also and explanations of fundamental questions like life, consciousness may in some sense be hidden in the as-yet unrecognised aspects of vacuum. In as much as the nuclear constituents throw up from the vacuum the virtual particles that mediate nuclear forces and the charged particles throw up the particles that mediate electromagnetic forces, it is conceivable that something similar may be happening during neuronal excitations, electronic tunneling from synapses, release of neurotransmitters etc. Since the consequence we are expecting from such processes is the emergence of consciousness, clearly this has to be a kind of transcendence that leads to very different type of cause-effect relation. In this context one may point out the following example, in the familiar field of chemistry. The three elements Carbon, Nitrogen and Oxygen combine differently to produce alcohols, sugars and fatty acids whose properties are very different. What is different is only the physical spatial structure of each brought about by the electromagnetic forces mediated by the virtual particles created in the intermolecular spaces. While the individual molecules do not show distinct properties, in large assemblies these properties 'emerge'. The whole is more than its constituents!

It may also be appropriate to remind ourselves of the cascade phenomenon – emergence of a billion particles through nuclear and electromagnetic cascades by the incidence of just one particle of very high energy – creation, decay and annihilation of particles under the supreme role of the underlying vacuum.

The notion that science and metaphysics are two different themes which cannot have issues of common concern has changed with the new and different ways of understanding science, technology, philosophy and spiritual traditions. A rich literature exists on the philosophical understanding of the complexity of consciousness, especially in the Indian wisdom traditions. Scientists are also rather excited about the emergence of new insights into many outstanding issues in the life sciences. In recent years particularly, molecular genetics has caused waves through the Human Genome Project and raised, rightly or wrongly, great hopes as well as great fears.

A dialogue between scientific and metaphysical traditions has now not only become relevant but also imperative in the modern context where we are often confronted with dilemmas in defining values - whether they be scientific and technological developments and innovations, societal and communal health, or moral and spiritual explorations. This volume is a collection of invited papers on the frontiers of science and metaphysics, with special reference to the themes of consciousness and genetics.

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Abstract. The way science has developed in the past four hundred years, it has become the traditional role of physics to explain all natural phenomena at the most fundamental level. In this endeavour concepts like space, time, matter, mass, particle, radiation, wave, energy, causality drawn from everyday experience are suitably defined, quantified and incorporated into mathematical equations formulated to represent the underlying physical explanations. In these formulations, the guiding and restricting role of laws of nature discerned from varieties of experience are taken into account. Verification of the predictions and falsifications, the key factors in scientific methodology have been responsible for the successes achieved. It has happened in the history of science that many of these concepts originally derived from experience, have had to be radically modified and transformed and even transcended (going beyond limits of normal human experience) to explain newly discovered phenomena, as well as those that defied explanation in the old framework, in the domain of physical sciences themselves.

The concepts of four dimensional space-time continuum, equivalence of mass and energy, the dependence of the rate of flow of time on the velocity of the moving frame of reference, the equivalence of curvature of space and mass, and of force and acceleration which were all ushered in by the special and general theories of relativity and the concept of vacuum as the ultimate substratum that is the very source of all constituents and forces of nature as highlighted by quantum theory, are some of the typical examples of such transcendences in physics dictated by new experimental results. These aspects will be elaborated in this presentation with a view to emphasize that in the efforts to resolve the problems of Consciousness in terms of neuronal correlates and the associated physico-chemical processes, transcendences of some of the physical and biological concepts, may be required. In the same way as the 'spin' parameter of individual particles (integral or half-integral of h)

controls the behaviour of large assemblies of these particles to obey either the Bose-Einstein or Fermi-Dirac Statistical distributions only, and also determine the very structure of elements in the periodic table and their properties, there may be very sensitive bio-parameters at the cell or sub-cell levels which may influence the group behaviour of bundles of neurons that could lead to emergence of consciousness and its many ramifications.

1. Introduction

The real and crucial problem of consciousness which has been outstanding and unexplained for several centuries, and which in recent years has been termed 'the hard problem of consciousness' is to explain the subjective experiences like cognition, recognition, feeling, sensation, thought, emotion etc. in terms of the physico-chemical activities of the brain. Recent developments in the field of neurosciences have provided elaborate and minute details of these processes in the various cortices of the brain, in the hundreds of billions of neurons that spread out from the brain to the various organs of the body, in the sensors that interface with the external world, in the glial and other cells in the brain, in the bloodstream, in the endocrinal and immunological systems and so on. While a variety of techniques have contributed to the vast store of knowledge that has accumulated over the centuries, in recent decades employment of newer non-invasive techniques, like CATSCAN, PET, fNMR, magnetic encephalograph, lasers, and computer-coupled micro-electrodes, have provided much higher spatial- and time-resolutions for mapping ongoing processes in different locations of the body. These processes themselves, being chemical, physical, electro-chemical, or electro-magnetic, fall well within the framework of science and therefore of proper interpretation.

It has to be emphasized that all physical processes in nature are, in the final analysis, quantum processes. However, not all require the use of sophisticated quantum mechanical analysis and can be treated in the classical framework. The general rule in this regard is that if the 'action' involved in the process under consideration is large compared to the action defined by the Planck constant h , then classical approximation is adequate and works. There is, however, need for caution. There are many instances in which subtle influences of a quantum nature influence gross phenomena

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2. Space-Time Continuum

Space and Time are two important concepts drawn from our daily experience. These are very different kinds of experiences. In our minds, space is characterized by emptiness and as a plenum for matter to occupy. Time is something that flows independent of us. In Newtonian dynamics, space and time are independent of each other. Time is universal and the rate of flow of time is the same everywhere and is independent of motion. All these ideas underwent a radical change, when Einstein introduced his special theory of relativity to explain the experimental fact that the velocity of light is independent of the motion of the source or observer as dictated by the famous experiments of Michelson and Morley. Einstein stated "we can do away with the ether; the velocity of light may be regarded as a constant of nature independent of the motion of the source or observer. But, we have to give up our conventional ideas of space and time". According to him, "the Laws of Science should be the same for all freely moving observers no matter what their speed". Formulating the special theory of relativity he stated:

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3. Action at a Distance

Let us consider the case of Newtonian dynamics ushered in by Newton more than three hundred years ago. On the basis of observations on the motion of bodies on earth, he framed his famous laws of motion and extended them to explain the laws of planetary motion that had been enunciated by Kepler. According to Newton, the force between the sun and the earth that kept the earth in its orbit, was proportional to the product of their masses and inversely proportional to the square of the distance between them. However, he did not clarify how this gravitational force was transmitted between the two objects, which were so far away from each other. The basic concepts used in Newtonian dynamics, force, mass, and distance, were all familiar concepts and derived on the basis of everyday experience (anthropomorphic) of the common man in his daily transactions. There was a 'ring' of familiarity about them. However, there were aspects which created problems in fuller understanding. One, ofcourse, was the source of this gravitational force and the other was the 'action at a distance'. Till then, the impression in the minds of common men was that for force to act,

spatial contact between the two bodies involved was essential. Action at a distance meant, in this case, transmission of force without any physical matter between them. Newton was aware of this problem. He had no answer. He is reported to have said 'God only knows'!

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The action at a distance and the propagation of electro-magnetic waves could be tackled only in the framework of the new quantum field theories and relativity theories. These theories required a total transcendence in the old and familiar concepts of space, time, causality, force, particle, wave etc. This was much more radical and far-reaching in consequences than the paradigm shift that happened in just moving from a Geocentric to a Heliocentric system.

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What is interesting and intriguing is that the same physical entity, namely the α -particle is registered by the Geiger counter as a particle and it leaves the track of a particle in a cloud chamber. But for understanding its penetration through the potential barrier, it has to be regarded as a wave. This wave/particle duality has to be built into the explanation of the phenomenon. This duality has other ramifications too. Light which we considered as an electromagnetic wave also has this dual character. Depending on the experimental set up it can be seen as a wave or as a particle (photon). In phenomena like interference, diffraction, polarization, light behaves like a wave. In phenomena like the photoelectric effect, or the Compton effect, light behaves like a particle. The particular mode of light to be seen depends on the choice of the observer. This raises the question, how can objective reality become subjective dependent? How can the same entity be an extended object like a wave and an extremely compactified point-like object, a particle? Apart from the deep philosophical implications, such dual aspects as far as scientists are concerned, focus attention on the necessity of evolving a proper scientific framework in which such apparently contradictory features that go against common sense and experience are resolved.

5. The Dirac Sea: (The Quantum Mechanical Vacuum)

When Dirac formulated the quantum mechanical equation for a relativistic electron, and solved it, he was surprised to find solutions that corresponded to both positive and negative energy states of the electron. The normal practice was to treat the negative energy solutions as 'unphysical' and just

ignore them and consider only the positive energy solutions. Dirac just did not do that. He transcended the normal practice and tried to interpret the negative energy states in a bold unconventional way. He assumed that all the negative energy states of the electron, an infinite number of them, are completely filled in 'empty space' in which we see the movement of the electrons which have positive energy states. If however one of the electrons in the negative energy states makes a spontaneous transition due to fluctuation to a positive energy state then a 'hole' is created in the sea of negative energy states and this 'hole' behaves like a particle of opposite charge, namely positive charge, and if the energy available due to fluctuation is sufficiently large, then there is manifestation of two particles – an electron and a positron (as the hole is called). This pair creation happens more easily if a quantum of energy in the form of a photon is deposited into this Dirac vacuum or empty space. The positron is regarded as the 'anti-particle' of the electron. Right in the beginning, Dirac thought that this positively charged particle may be the proton itself which however has a mass widely different from that of the electron. Soon it became clear that, even for theoretical reasons, the particle has to be the positive counterpart of the electron itself. Around the same period, without being aware of these theoretical developments in England, Carl Anderson in USA, discovered in cosmic rays a particle which had a positive charge and the same mass as the electron. This is undoubtedly Dirac's positron. This whole development brought about awareness of many new aspects of nature. One, ofcourse, is the existence of the anti-particles, the other is the revolutionary idea of the Dirac vacuum as the plenum in which all the negative energy states are filled and with which we cannot normally interact, the third is that all other particles can have such seas of negative energy states with the possibility of anti-particles being produced under suitable conditions. Though many of these ideas of infinite negative energy states etc. have undergone transformation in later years, in terms of field theoretical concepts the substance of Dirac's idea of vacuum or empty space as the plenum from which all fundamental particles emerge under favourable conditions stands. Dirac says: "All matter is created out of some imperceptible substratum – Nothingness, unimaginable, and undetectable. But it is a peculiar nothingness out of which matter is created".

This new insight on empty space, the quantum vacuum or Dirac Sea has very significantly influenced subsequent developments in the field of elementary particle physics, cosmology, solid state physics etc. The creation and annihilation of particle-antiparticle pairs due to fluctuations in the Dirac Sea, a process that continuously goes on, opened up several interesting ways of understanding hitherto unexplained phenomena. How is the electrostatic force between the proton and the electron (for example in the hydrogen atom), negotiated through the empty space in between? The action at a distance problem that we raised earlier. This is now explained in terms of the exchange of virtual particles (virtual in the sense that they cannot be observed directly in any particle detectors) – the pairs of electrons and positrons, and their annihilation products – photons, being exchanged between the proton and the electron. This new concept of “exchange forces” in a sense replaced the old ideas of force drawn from daily experience. Is there evidence for such a phenomenon? Yes. This too was established, though indirectly through the detection of the altered radiation from the hydrogen atom itself. The electrons from the virtual pairs would move towards the positively charged proton and the positrons towards the electron of the atom. This would result in a reduction in the effective force between the proton and the electron, and would change the frequency of radiation emitted. In the case of other much shorter range nuclear forces the particles and anti-particles that were exchanged, were not the photons, but various other types of mesons of much heavier mass. The essential point to note is that there was a transcendence again in the very notion of force; and how it was negotiated.

In the field of cosmic ray studies (cosmic rays are very high energy particles that come from the depths of space), a very spectacular phenomenon is encountered. Occasionally more than a billion particles are incident almost simultaneously over tens of square kilometres at mountain altitude or sea level. These showers contain all kinds of fundamental particles – electrons, positrons, photons, nucleons, anti-nucleons, hyperons etc. The most intriguing thing is that these billions of particles owe their origin to the incidence of just one kind of high energy particle at the top of the atmosphere. Where were these particles before they manifested? The answer is in the extended Dirac vacuum. The primary particle in its

collision with an air nucleus, first produces a large number of secondaries which start moving down. The production of these mesons, nucleons etc. is essentially a mining out from the excited vacuum region of the collision, sufficient energy being put in by the collision process. Some of the secondaries spontaneously decay into other particles. The remaining suffer further collisions as they move down and repeat the same process and produce more secondaries and this cascade of nuclear interactions continues down the atmosphere. Among the decay products, there are high energy photons which create electron-positron pairs. These electrons and positrons radiate high energy photons which give rise to more pairs of electrons and positrons. It is this cascading in the atmosphere that results in the production of billions of particles, all culled out from their hide-out, the quantum mechanical vacuum. The phenomenon itself is a gross one with billions of particles that are sampled and recorded in instruments like scintillation counters, cloud chambers etc. But the entire process involving the creation of so many particles is quantum mechanical in nature. Such an outcome could never be explained in the classical framework. The phenomenon, when analysed in terms of high resolution timing devices, beautifully demonstrates some of the relativistic effects like time dilation, increase of mass with energy etc. The chief point to be noted is the dominant role of empty space or vacuum in the whole process, which would never have figured in any classical treatment of the problem.

6. The Spin Parameter and its Large Scale Influence

In addition to the mass and charge of the elementary particles, another important parameter that was first discovered in the analysis of the hyperfine structure of spectral lines emitted by excited atoms of elements is the spin parameter which again is a quantized parameter. The spin angular momentum in terms of $(h/2\pi)$ units can be half-integral, integral or 0 and not any other value. What is most interesting is that the particles with half integral spin electrons, protons, etc. obey in large assemblies one kind of statistical behaviour (Fermi-Dirac distribution) and the integral spin particles obey quite a different statistical behaviour (Bose-Einstein). These features have tremendous influence on certain gross phenomena involving

these particles. In fact the structure and properties of elements in the periodic table depends on the half integral character of the spin of the electrons and the Pauli Exclusion Principle. The influence of such parameters on macroscopic effects can be seen from the following examples. It is known that 99.9% of all matter that we come across on the earth is just empty inside. You can ask the question then: If this is so, why does not my hand go through the table, for example? There is no classical way of understanding this. The explanation depends on the quantum mechanical exclusion principle. There is lot of excitement in astronomy nowadays regarding condensed objects like white dwarfs, neutron stars, black holes etc. The factors governing the very formation of these objects and their properties depend on the spin parameters of the electrons, the protons and the neutrons that constitute the hydrogen and other elements of the stars.

There is yet another principle, Heisenberg's uncertainty principle, of tremendous importance in the quantum world, with major consequences in the everyday world that we are familiar with. The principle states that 'one cannot measure an object's position and momentum precisely and simultaneously'. A further elaboration of this principle that turned out to be significant was that it is not only a question of inability to measure, but also that these parameters do not have very precise values themselves; they fluctuate within the limits of the uncertainty principle – $\Delta P \cdot \Delta x \geq h$ and $\Delta E \cdot \Delta t \geq h$ where ΔP , Δx , ΔE , Δt are the uncertainties in position, momentum, energy and time interval of action. This principle provides for departure in the sacrosanct principles of conservation of energy and of momentum. There could be a departure in energy conservation by ΔE in a process which proceeds in time less than $h/\Delta E$. In nature such allowances are made use of, for example, in spontaneous decays of some of the fundamental particles.

7. Conclusions

From the few examples given above, (and many more which we have not presented here), it becomes apparent that many of the simple concepts originally introduced into physical explanations like space, time, causality,

force, energy etc. have had to undergo considerable modification in terms of their implications and some have even transcended into the realm beyond normal human experience. These changes were forced by the discovery of new experimental results. We may remind ourselves that in the framework of the special theory of relativity, space and time are fused into the space-time continuum; flow of time, spatial intervals and even mass became functions of velocity; mass and energy become equivalent. In the framework of general theory of relativity, space becomes non-Euclidean, curvature of space becomes equivalent of mass (one a geometrical property and the other a physical quantity). In the light of quantum mechanics, the wave-particle complementarity has to be accepted and even vacuum, which was originally conceived in classical physics as empty space (absence of all matter and radiation) becomes the very source of all the fundamental particles – the ultimate constituents of all matter, radiation and force. The concept of force gave way to exchange of virtual particles and anti-particles. The example we have given of a very high energy particle cascading through nuclear and electromagnetic forces into more than a billion particles of different properties is a clear illustration of the very dominant role that this so-called vacuum can play in creation, and in the destruction of matter and antimatter in extremely short intervals of time.

Though all this is in the realm of inanimate matter, it is equally relevant to animate matter as well, since the ultimate composition of animate matter is not different and has its origin in inanimate matter. In the development of organisms from the unicellular amoeba to the multi-billion-celled man, evolution based on the cardinal principles of natural selection and survival of the fittest is a subsequent phase to cosmological evolutions, perhaps, beginning with the Big Bang as most popularly believed in scientific circles. These cosmological and creation theories of the universe and its variety of constituents have brought about the recognition of one very fundamental fact that, in the ultimate analysis, all this has arisen out of one substratum, call it quantum mechanical vacuum or four-dimensional space-time continuum or something equivalent, and this substratum has come into existence endowed with very specific properties, now discerned by physicists. Not all the properties of this substratum are known yet. In addition the laws of nature have to be what they are, and so also the

constants of nature. This being the case at the most fundamental levels of explanation, the possibility opens up that a similar situation may prevail in the living world also and explanations of fundamental questions like life, consciousness may in some sense be hidden in the as-yet unrecognised aspects of vacuum. In as much as the nuclear constituents throw up from the vacuum the virtual particles that mediate nuclear forces and the charged particles throw up the particles that mediate electromagnetic forces, it is conceivable that something similar may be happening during neuronal excitations, electronic tunneling from synapses, release of neurotransmitters etc. Since the consequence we are expecting from such processes is the emergence of consciousness, clearly this has to be a kind of transcendence that leads to very different type of cause-effect relation. In this context one may point out the following example, in the familiar field of chemistry. The three elements Carbon, Nitrogen and Oxygen combine differently to produce alcohols, sugars and fatty acids whose properties are very different. What is different is only the physical spatial structure of each brought about by the electromagnetic forces mediated by the virtual particles created in the intermolecular spaces. While the individual molecules do not show distinct properties, in large assemblies these properties 'emerge'. The whole is more than its constituents!

It may also be appropriate to remind ourselves of the cascade phenomenon – emergence of a billion particles through nuclear and electromagnetic cascades by the incidence of just one particle of very high energy – creation, decay and annihilation of particles under the supreme role of the underlying vacuum.