CHAPTER IV

A HYPOTHETICAL FRAMEWORK IN FIVE DIMENSIONS

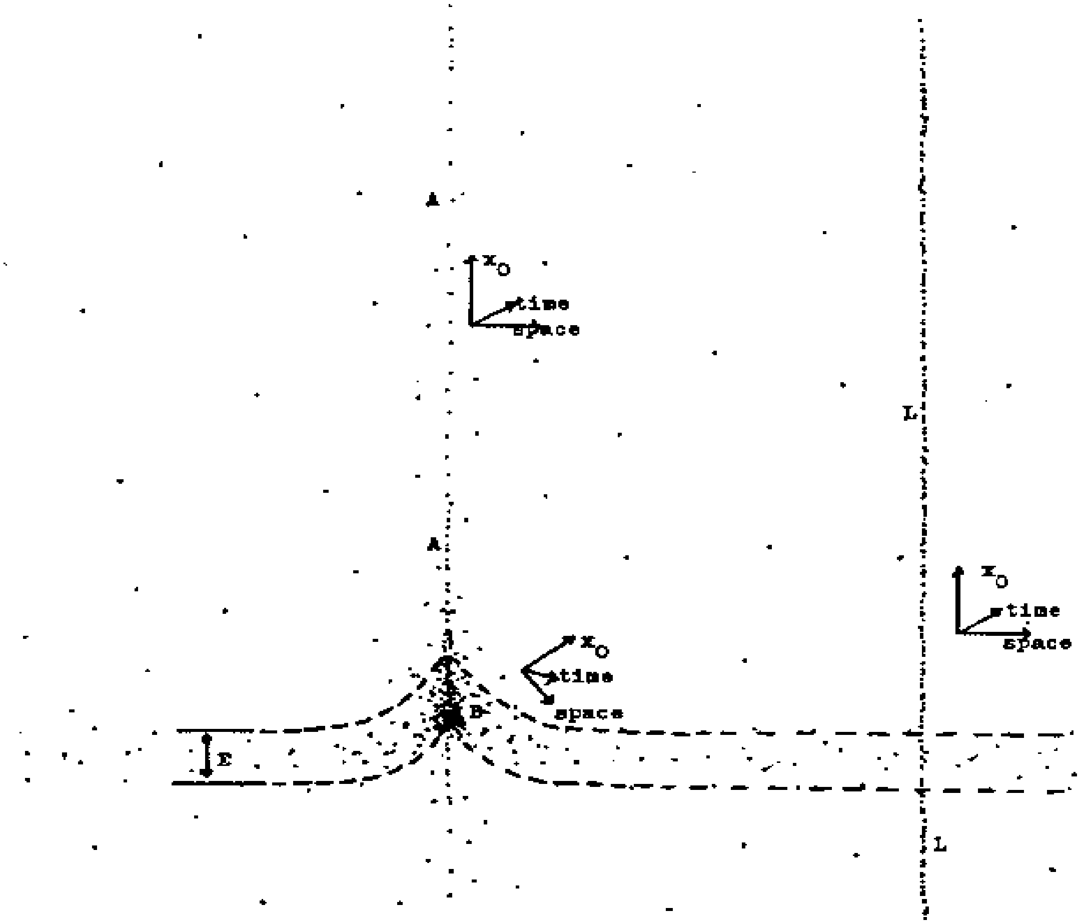
The following work is based upon the assumption that our four-dimensional space-time continuum is extrinsically curved in an embedding continuum of five dimensions. Unlike other five-dimensional theories, this theory assumes that the fifth dimension is non-material, but nonetheless real in a physical sense. It is pure field. In order to account for the materiality of our normally perceived existence, each mathematical point of our common four dimensions of space-time extend continuously in the direction of the fifth coordinate. Rather than taking the position of other theorists to explain away the fifth dimension to account for the four-dimensionality of space-time, the experimental and experiential evidence for the four-dimensionality of space-time is taken for granted yielding the assumption that there is a small, almost negligible 'effective width' in the direction of the fifth coordinate.

Our space-time would then appear as a sheet with the dimensions of space and time curved in the fifth dimension. This sheet forms the arena for all physical phenomena, i.e., material collisions and interactions, with a small exception (as will be shown shortly). The width of the sheet is constant and is thus, negligibly small, defined by a small constant. This constant defines our four-dimensional structure, giving it its uniqueness, and is thus called the 'constant of definition.' However, it must be remembered that the continuity of the field in the fifth dimension is paramount, so that the 'constant of definition' seemingly gives us a thin sheet, while actually the component in the fifth direction can be considered to have a nearly infinite or comparatively large extension for all practical purposes. The 'constant of definition' and its relation to the fifth coordinate give the complete field in five dimensions its basic properties.

From the perspective of the continuous field in the direction of the fifth coordinate, we can say that the portion of the field within the constant width of the four-dimensional continuum represents the densest or strongest field concentration in the fifth direction. Only when a specific field density along the fifth coordinate is reached, can it be said that matter, in the form of a four- dimensional particle, occupies that portion of the five-dimensional field. A dense area of the field causes the sheet to curve in the fifth dimension, or more accurately it corresponds to the curvature of the sheet itself. Since the four-dimensional space-time continuum has a width in the fifth dimension, the curvature forms areas of even denser field as a cusp on the underside of the curve. The curve must remain smooth at the point of the cusp so the field closes on itself increasing the field strength even more, while restricted by the 'constant of definition,' thus forming a stable particle. This action has, in General Relativity, been interpreted as a singularity in the field, but the 'constant of definition' allows us to do away with the singularity at the point of the cusp. The width characterized by the constant of definition can also be said to determine the effective range of the fifth dimension, in that it acts as a constraint for the mechanical properties of matter, as well as the arena (but only in a special sense) for electromagnetic phenomena to take place.

There is a well-defined symmetry about the point of the cusp in normal space-time. At this point, a line of symmetry is formed as a dense cross-section in the fifth direction, just as a line of greater density forms the curvature in the space-time continuum. This line of symmetry intersects the sheet at the center of mass of the elementary particle. The importance of the line of symmetry in the fifth direction will become more evident when the photon is taken into consideration.

The photon has no extension in normal three-space, but exhibits properties similar to those exhibited by particles with mass even though it is a massless particle. In other words, the photon has energy without mass as opposed to material particles that have a mass equivalent to energy. Thus, for a photon there will be no field density change in the spatial direction and no curvature is evident, but there is a dense region that would amount to an infinitely extended line along the fifth coordinate. A photon is its own line of symmetry in the fifth direction. Such a structure for the photon has many implications. A diagram representing the structure of the photon as well as an elementary particle follows.



This diagram is a means of visualizing the space-time curvature in the fifth coordinate, x_o, with the time coordinate passing into the page. The curvature of space follows the densest part of the field as represented by the dots. The dots are not meant to represent, in any way, a particle nature of the field. B represents the cusp in the field, where the density is the greatest as the curvature doubles on itself due to the effective width, E, of the space-time continuum. A is the line of symmetry defining the wave-particle nature of matter, while L is the representation of a photon in the field structure. The photon, L, has a cross-sectional width in the 'sheet' of space-time, which gives the photon its particle-like characteristics. the dotted line shown above, which outlines the curvature or the 'sheet' of space-time, is not part of the field, but merely a way of depicting the idea of an effective width of the space-time 'sheet' in the fifth dimension.

All of 'normal' physics is based on interactions between matter, photons and energy and their respective relationships, where matter in its simplest form corresponds to elementary particles. In its interaction with matter, a photon can have an energy of 'hf,' where h is Planck's constant and f is the frequency of the light particle. This energy allows the photon to exhibit matter-like characteristics. The interaction of photons with matter is merely that which is represented in the fifth dimension as happening within the 'effective width' of the space-time sheet. The constraint of our physical reality to the sheet alone, as defined by the 'constant of definition,' is related directly to the quantity 'hf.' Interactions between particles will follow the same scheme. In other words, particles normally interact with each other only within the sheet as mechanical collisions. Particles and various fields also interact wholly within the sheet. However, an interaction between matter and light, which exhibits the wave nature of light, corresponds to an interaction between the line extending along the fifth coordinate, representing a photon, and the line of symmetry of the particle, which also extends along the fifth coordinate. Reactions within the 'effective width' of the space-time continuum represent particle interactions and interactions that take place outside of the ‘effective width’ of the sheet represent wave interactions whether they are particle-particle, particle-wave or wave-wave interactions.

Any experiment such as a single or double-slit experiment, can, by the nature of the apparatus, emphasize one or the other type of interaction resulting in our recognizing light either as a wave or particle from our limited four-dimensional perspective. Wave-particle duality is a consequence of the five-dimensional extension of each mathematical point of our space-time continuum in the fifth direction. The constant of definition, being related to 'hf' for a photon, must also be related to matter in the same way. Material objects which are stationary with respect to some observer exhibit no relative frequency, f, which is to say that they have an undefined relative wavelength according to DeBroglie's equation, $\lambda = h/mv$. This is to say that they are constrained by the 'effective width' of space-time in the fifth direction. So, the 'constant of definition' must also be proportional to h with respect to material particles. In this manner, Planck's constant is reduced to a field property of the five-dimensional structure.

The Heisenberg Uncertainty Principle can be applied directly to this structure even though the structure is derived directly from the fundamental nature of the field rather than the quantum. If we assume any type of extension in the fifth dimension while curvature in this fifth direction is connected with the concepts of mass or energy, we should be able to apply the Uncertainty Principle in either of its forms

$$\Delta x \, \Delta p \geq h/4\pi$$

$$\text{or} \quad \Delta E \, \Delta t \geq h/4\pi \,.$$

In these equations there is an implied indeterminant in the new structure due to the relation of the mass and energy to the fifth component or direction in the field. In other words, since a particle cannot be localized in the field along its space and time dimensions, we cannot localize our four-dimensional continuum in a five-dimensional structure to a greater degree of accuracy than is allowed by Planck's constant. The Heisenberg Uncertainty Principle is merely an alternate way of stating that we cannot localize the particle within the average stationary portion of the sheet since its field is spread across the fifth dimension along its line of symmetry. Once again, the 'constant of definition' has been related directly to Planck's constant.

The Heisenberg Uncertainty Principle is normally interpreted in a probabilistic sense. This can also be extended to the five-dimensional structure. If we consider a particle along its wave-particle line of symmetry, it can be seen that there is a probability that the particle can be located anywhere in the fifth dimension, since it has a component or a field density value all along the symmetry line. The particle, if it can be called such within the five-dimensional perceptive, is actually located at all points along this line of symmetry simultaneously, but there would be a greater likelihood of finding the particle where its density is greatest, or within the boundaries of the 'effective width.' of the sheet relative to the whole sheet. It is least probable to find the particle at any large distance from the sheet along the symmetry line in the fifth direction. The density along the line of symmetry thus corresponds to a location of the particle within the overall five-dimensional structure. In this way, the volume of the concentrated field corresponding to the particle serves a purpose similar to that of the function in quantum mechanics.

The application of the Heisenberg Uncertainty Principle has other consequences that are related directly to Special Relativity within this new expanded space-time framework. Suppose a material particle is moving with a very high relative velocity and during an attempt to localize it to a point within the four-dimensional sheet. According to the Uncertainty Principle, the momentum must be indistinct which would correspond to a non-localization of the particle along its wave-particle symmetry line in the fifth dimension. According to the Special Theory of Relativity, there would be an increase in the mass of the particle such that, $m = m_0/[1-v^2/c^2]$, where m is the measured mass and m_0 is the rest mass. This change in mass must cause a change in the local curvature with respect to the observer localizing the particle. Further, when the velocity of the particle approaches the velocity of light, the particle will have effectively Lorentz-Fitzgerald contracted to nothing as well as having very nearly attained pure wave characteristics according to quantum mechanics.

These physical circumstances directly imply that the particle's density in the fifth dimension spreads more evenly along the wave-particle line of symmetry, even as its length in one dimension of normal space has diminished or contracted. Its momentum becomes less distinct in the sense of quantum mechanics, because it is spread over the fifth dimension and the probability of its being observed within the 'effective width' decreases proportionately. As the particle approaches the velocity of light, it has contracted to nothing (it has no spatial extension in the direction of motion) and has spread out evenly in the direction of the wave-particle symmetry line. It has become light-like in its characteristics such that it has become very nearly a line in the direction of the fifth dimension. As the velocity increased and the particle spread along the fifth coordinate, it has gained more wave-like properties according to DeBroglie's equation. So, once again there is a correspondence between the line of symmetry and the concept of wave/particle duality as well as the function and the line of symmetry. However, we now have a much closer philosophical correspondence between Special Relativity and the Heisenberg Uncertainty Principle. This correspondence occurs in such a way that Relativity and Uncertainty appear as two different aspects of the same physical event. Their quantity and units are different, but their quality is the same from the perspective of five dimensions. The correspondence of these two seemingly incompatible principles is unique and unprecedented in physics.

We now come to a new concept of inertia and its relation to mass. Inertia is normally defined as the resistance of matter to an acceleration (in Newtonian physics), while mass is related to curvature in the space-time continuum (in Einsteinian physics). In this five-dimensional structure, an acceleration in four-dimensional space-time will correspond to a change or field variation along the fifth direction as described above, however, there is always the case for relative velocities, where there is always an infinite extension in the fifth dimension. Inertia is no more than the interaction of the five-dimensional component (along the whole length) to the adjacent field as extended in the fifth dimension.

This new view of inertia leads to a new understanding of Mach's Principle. It has been assumed that the 'constant of definition' guarantees a specific and constant width (or constraint) to the four-dimensional continuum along its five-dimensional component, which determines the unique four-dimensional sheet within the five-dimensional continuum. This must hold true in all local portions of space and time to be complete. There are no holes (discontinuities) in the sheet where the width is less than the amount needed to meet the density required by the 'constant of definition.' Therefore, in areas where there is no local matter to contribute directly to the field, all material particles which constitute all of relative space-time must contribute to determine the proper 'effective width' in the fifth direction. In other words, the effective width of that portion of the sheet that would normally correspond to the vacuum of deep space is the sum product of the individual curvatures of all the material particles in the universe. The 'constant of definition' is therefore dependent on the total amount of matter and energy in the universe, as then Planck's constant must be. By the redefinition of inertia, it has been shown that all of matter and energy not only affect local matter and energy within the sheet of the four-dimensional continuum, but over the whole of the five-dimensional extension of the field. Even though the four-dimensional sheet of the continuum is unique to one particular frame of reference (the inertial frame of the observer), another frame of reference with a different relative velocity will have its own unique view of the four-dimensional space-time continuum, thus its own inertial reference frame or relative view of the sheet.

We can now return to the concept of light as a straight line perpendicular to the four-dimensional continuum, extended across the fifth dimension and a representation of electromagnetism in this five-dimensional structure. No explanation has ever been given for the mechanism of the constancy of the velocity of light with respect to all relative velocities in a four-dimensional space-time structure. The constancy of the speed of light is a fundamental assumption of Special Relativity such that it has never been deduced from basic principles. Given two particles or observers moving at constant relative speed, both will interact with light waves from the same source and both measure the light waves to have an equivalent velocity of c, but different frequencies due to their own relative velocities. Since each of these particles (observers) has its own frame of reference system in which it interacts with the light waves or photons, we can deduce that the differences in frequency are a result of the relative change of orientation of inertial frames of reference along the fifth coordinate. Frequency must be related to the relative position in the fifth dimension indirectly in some manner, which has already been stated, by relating the five-dimensional component to wave characteristics of matter and photons. The constant velocity of light is also related to the 'constant of definition,' since both particles (observers) have this factor in common with light waves. Therefore, no matter how great the relative velocity between any observers, the velocity of light between them and any light source will remain the same since light is represented as an extended line in the fifth dimension. The velocity of light is both infinite, in that it can be approached but never reached by material objects, and finite in that the interaction between material bodies and light waves within the confines of the 'effective width' of the four-dimensional sheet is constant.

Light is, of course, an electromagnetic phenomenon and the consideration of light given above can be extended to explain the electromagnetic field. Electromagnetic phenomena, by experiential observation, are strictly four-dimensional in character, while according to the General Theory of Relativity; gravitational phenomena are (when we assume extrinsic curvature in an embedding space) due to a higher dimension in which the four-dimensional space-time is curved. Assume now a charged particle that is stationary with respect to a magnetic field detector. As long as the particle remains stationary, the detector can find no presence of a magnetic field due to the particle. However, if the particle begins to move relative to the detector, a current is induced in the detector, showing that a magnetic field has been generated due to the relative motion of the particle. Electromagnetic phenomena are constrained to the four-dimensional sheet. In the case where both a charged particle and detector move with a constant relative velocity, they have different inertial frames due to a relative separation in the fifth dimension. Or, rather, their average field positions along their respective lines of symmetry have changed. The detector will note a magnetic field around the moving charged particle which is proportional to the particle's speed and this magnetic field must be a product of the relative separation of the particle and detector in the fifth direction which is also proportional to their relative speed, while the electrical field associated with magnetism is constrained to the four-dimensional sheet. Magnetism arises in this case, due to the constraint of the electrical field to the space-time continuum, while the material source of the charge changes its five-dimensional component generating a magnetic field.

The space-time structure in five dimensions, as outlined here, has a great deal of versatility and application. Although the hypothetical structure has not been completed and a mathematical structure has not yet been derived, areas of application for this hypothesis have already suggested themselves. In this unification, nuclear forces are a direct result of the curvature of space-time. As the continuum curves, a cusp forms causing the density of the field to increase in all dimensions. This corresponds to nuclear forces, as opposed to an acceleration due to gravitational forces, which corresponds to a shortest path along the curvature. A rigorous treatment of the characteristics of the continuum in the vicinity of the cusp, as a function of time, could possibly lead to stability conditions for elementary particles, while considerations of binding between two or more elementary particles in this framework could lead to the stability conditions for atomic nuclei. A field theoretic solution for the tunneling effect, as expressed in the quantum theory, could also be developed from this hypothesis.

With respect to Mach's principle, it was stated that the 'constant of definition' still allowed for a five-dimensional width even when no local matter was present which must therefore be due to the contribution of all matter and energy in the universe. In like manner, when there is an interaction between material particles that are different field sources, such as in the potential barrier or tunneling effect, and the fields of these different sources combine in such a way as to meet the 'constant of definition,' a new particle may appear to have tunneled past the potential barrier. More detailed explanations for both of these phenomena, the stability of particles and nuclei as well as the tunneling effect, are left for the later mathematical development of this theory.

This theory is unique in several respects:

(1) As it stands, it is completely philosophical, whereas the five-dimensional theories of the past have been criticized for lack of a coherent philosophical or pre-theoretic view of the fifth dimension.

(2) It unifies gravitation, quantum mechanics, electromagnetism and the nuclear forces as well as giving new insight into Special Relativity.

(3) Although this theory is original and independent of the past theories, it either combines or parallels features of some of the previous theories.

(4) Instead of making an assumption regarding the fifth dimension and then proceeding to explain why we don't experience it, this theory is built upon the assumption that our experiences are correct, therefore leading to the assumption that the fifth component is too small to be of any consequence (effectively) under normal conditions.

(5) It explains the source as part of the field. With respect to the four-dimensional continuum, the sources of the field are not singularities.

The main criticism of previous five-dimensional theories can be summarized such that they lacked any philosophical, intuitive or pre-theoretic framework. These criticisms undermine any possibility that there could indeed be a real fifth dimension, which we do not normally experience, although its influence may be felt indirectly. Any pre-theoretic concept or perception of the fifth dimension would more than likely be found in areas that seem paradoxical when considered within a four-dimensional space-time structure. This doesn't mean that the fifth dimension should be used as a dumping ground for any anomalies or strange phenomena, real or imagined, that can't be otherwise explained, but it at least suggests a place to begin a scientific search for the effects of the fifth dimension in our four-dimensional world.

Many theorists have worked on and/or suggested that the quantum world could best be explained in terms of a fifth dimension. This supposition was confirmed within the context of this new theory of the fifth dimension since the 'effective width' of the four-dimensional sheet is proportional to Planck's constant. This new theory is incomplete at present. This initial development of the theory was only meant to illustrate the possibilities that assuming a real fifth dimension has for developing a complete theory of physical reality. The hypothesis upon which this theory was constructed is a product of some of the paradoxes in physics that seem to warrant further explanations, so philosophical rather than mathematical explanations seemed preferable to precise mathematical deductions. It is also possible that this hypothesis may act to complement and supplement other five-dimensional theories that were built on purely mathematical formalisms without philosophical content.

This theory has added advantages when compared to older five-dimensional theories. It goes further in its dealings with forces other than gravitation and electromagnetism, which Kaluza's theory dealt with exclusively as did almost all other theories. This theory more closely approximates those extensions of Kaluza's theory that sought to include an explanation of the quantum within the five-dimensional field structure. It also goes further in resolving a problem that is basic to all field theories, the reduction of the source of the field to the field itself. A particle need no longer be regarded as a singularity of the field. In effect, this fact makes it unnecessary to allow for the discontinuity of singularities in the continuous field. This theory also represents the culmination of Einstein's goal of representing a particle as a non-singular curve in the four-dimensional continuum. The theory is non-dualistic, in that the field and the source of the field are not separate things. The source of the field in four-dimensional space-time is just a denser portion of the field in five-dimensional space-time. This theory is also total, in that it seeks to explain all fields as aspects of one single field and complete only in that it allows nothing to exist but the single field, which corresponds to the five, dimensions of space-time. It does not allow the field to breakdown at singular points. Although the theory is total and complete in a philosophical sense, this theory is far from being finished or completed in a practical sense, and, when it is finished, it may well run into serious problems as have other theories. Its philosophical qualities do not make it less susceptible to criticism than the other five-dimensional theories.

Several features of this theory can also be found to coincide with features inherent in other theories, even though this hypothesis was derived independently. The concept of representing light as a line extending in the fifth direction had already been used by Wang and Cheng.[1] The notion of a five-dimensional density corresponding to the Ψfunction of quantum theory, corresponds to the five-dimensional volume which Wilson equated to the Ψfunction.[2] Even the basic deduction of a thin-sheet which models our four-dimensional space-time has been used to some extent by Klein.[3] The concept of a thin 'sheet' also dates back to Clifford and his followers.

Such parallels with the ideas of other scientists have two specific advantages. Just as Bergmann only decided to publish (9 years later) a theory that he and Einstein had developed after he read of Jordan's plan to publish a similar theory dealing with a non-constant fifteenth variable, the fact that some of the ideas in my own theory parallel other's ideas seems to lend some credence to this new approach to the five-dimensional field. This theory could not be totally devoid of physical worth since others have developed similar theories, but then again, the fact that others have had similar ideas is not proof of their validity. These parallels also hint that the mathematical structures of those other theories may have a direct bearing on the future mathematical development of this new theory. In the sense that this new theory, as here stated, is completely philosophical, it may also be possible to apply the basic concepts expressed here to other theories, thus extending them beyond the inherent mathematical limits. A great deal of freedom can be gained in developing the mathematics for this theory, as along as the philosophical ideas thus far developed are not destroyed or ruined by the strictures of some mathematical systems of logic.

CONCLUSION

The development of five-dimensional unified field theories can be regarded as having had a role in a much larger conceptual development within the history of science. Throughout this thesis, the five-dimensional (and hyper-dimensional) theories have been portrayed as a continuous development, beginning with Riemann and the development of Non-Euclidean geometries and proceeding to the present. There have been allusions to the part played by these theories in the overall development of newer concepts of space, time and dimension, but the five-dimensional development has been the main topic considered. The role of Kaluza has also been stressed as the originator of the modern idea of a five-dimensional unified field concept. He put forward a theory which was simple and straightforward, finding a limited success but never really popular. Kaluza's role has been very important, but in the overall conceptual development of space, time and dimension, many other people had as important or greater roles than did Kaluza. This thesis has been written with the five-dimensional theories playing the main role in the modern development of our concepts of space and dimension, but in essence the case is actually reversed in an overall historical picture with the five-dimensional theories playing a secondary role to the development of the concepts of space, time and dimension.

Kaluza's work can also be seen as a primary focal point wherein the speculations of the latter half of the nineteenth century on the dimensionality of space and General Relativity were synthesized into a common worldview. The early hyper-dimensional concepts, pre-relativity hypotheses with no substantial theoretical basis, were built on mathematical implications, suggestions and speculations. During the period when these new ideas were first voiced, the seeds of more modern attitudes toward the hyper-dimensional theories were sown. These early attitudes influenced the later attitudes toward Kaluza's theory and the general acceptance or lack of acceptance of the five-dimensional hypothesis. The earlier attitudes were represented by work of Clifford, Mach and Zöllner, who represented the attitudes of acceptance of the hypothetical curvature as a legitimate picture of reality, the empirical backlash to curvature and hyper-dimensionality and the sometimes pseudo-scientific aspects relegated to the five-dimensional theories which caused the scientific community to look upon the theories skeptically and with disfavor, respectively.

It is not known to what extent Kaluza had any knowledge of these previous ideas or how much they may have directly influenced him, but they did serve to create a scientific atmosphere where the concept of hyper-dimensionality was certainly not unknown, and therefore may have influenced Kaluza indirectly. This same scientific atmosphere, which was already primed to accept General Relativity and possibly the five-dimensional theory when Kaluza came upon the scene, influenced the work of other scientists, such as Nordström, Einstein and Kasner, but the popularity of the quantum theory stole the thunder from these theories. When the development of the hyper-dimensional is studied within this greater historical context, the significance of Kaluza's contribution to science and human thought may seem somewhat diminished, but it cannot truly detract from the fact that he was the originator of the first such theory. The development of a five-dimensional theory was inevitable and if not developed by Kaluza, it would have evolved in one form or another. However, the particular form that the five-dimensional theory did take was due to Kaluza alone.

After Kaluza brought together the notions of hyper-dimensionality and General Relativity, a slow continuous growth of extensions and modifications, as well as independent theories, took place. These new extended theories and ideas kept the concept from disappearing from science altogether after the initial criticisms of Kaluza's theory. Some of the criticisms were serious and valid, others were based on questionable and inconsequential, but they took their toll on the acceptance and popularity of the theory. One very interesting facet of this story is the relation of Einstein to the development of the five-dimensional concept. Einstein, probably more than any other single individual, has done more to shape our present scientific view of the world than Newton, or perhaps even Pythagoras and the ancient Greek philosophers. Yet his role and attitude in this particular matter is somewhat of an enigma. He must have known of Nordström's five-dimensional theory of 1914, but in 1919 he encouraged Kaluza to continue his own five-dimensional theory since he thought it a completely original idea. Then, in 1922, he stated that Kaluza's idea brought us no closer to the truth of the problem, while still later, in 1926, he recommended Kaluza for a better academic position on the basis of Kaluza's work on the five-dimensional theory. Still later, in 1931, 1938 and 1941, Einstein put forward his own five-dimensional theories, in collaboration with other scientists, as modifications of Kaluza's theory. It would seem that Einstein's enthusiasm for the concept waxed and waned as both time and science progressed, although Einstein's changing opinion of the five-dimensional theories was probably more a matter of his inherent caution than his lack of acceptance of the geometry that Kaluza had put forward. Einstein summed up his attitude toward the five-dimensional hypothesis in 1936.

> Here we must mention particularly the five-dimensional theory of Kaluza and Klein. Having considered this possibility very carefully, I feel that it is more desirable to accept the lack of internal uniformity of the original theory (the General Theory of Relativity), because I do not think that the totality of the hypotheses at the basis of the five-dimensional theory contains less arbitrary features than does the original theory.[1]

In this statement, Einstein admitted that he was not willing to give up the original theory of General Relativity, which was assured of success, even when it could not establish a single field representation of electromagnetism and gravitation. Nor would he abandon the original structure of space-time as expressed in General Relativity for another theory that was unproven, even if it was geometrically valid and simple. Einstein thought that a combination of geometry and experience together could offer the only valid and simple description of nature, as long as neither geometry nor experience was considered *a priori* at the expense of the other. He saw the value of the geometry of

Kaluza's theory, but was leery of the theory, its possibilities and implications because of its lack of empirical support. This explanation of Einstein's attitude is also evident in his later statement that hyper-dimensional theories must account for the *apparent* four-dimensionality of space-time. Here the word apparent is significant when trying to second-guess Einstein's motivations regarding the five-dimensional concept. By using the word apparent, Einstein may have been indirectly suggesting that any five-dimensional theory would have to consider a real fifth dimension rather than using the assumption as a mathematical ploy to develop a formalism devoid of physical content. Einstein may have been willing to accept Kaluza's geometry, but within his philosophy of nature whereby geometry cannot be had at the expense of experience, he could not regard the geometry without some striking physical phenomena to demonstrate the hypothesis. In this respect, Einstein was far more liberal than the rest of the scientific and academic communities, so it is easy to see why nearly all others neglected or rejected the concept of a higher-dimensional space.

When the various criticisms are studied in detail, it is obvious that they all reduce to one element alone, the standard objection to assuming the existence of a fifth dimension when we only seem to experience four dimensions of space-time. Why, then, should we bother with five-dimensional theories at all? If a five-dimensional theory could supply the simplest geometrical picture of our world while accomplishing a successful unification of forces without *violating* common experience, then it should be accepted at its face value until a better theory can be developed. If a five-dimensional theory were to predict new phenomena which were later found to exist, then the theory could hardly be denied. So far this has not been the case.

One form that this basic criticism took is the criticism of the condition of cylindricity. All five and higher-dimensional theories must have some prerequisite equivalent to this condition. If a five-dimensional continuum is assumed, some condition or constraint, which I will call a condition (or constraint) of definition, must be imposed on the field structure to uniquely '*define*' our four-dimensional space-time continuum. Without such a condition or constraint, our space-time would be meaningless and indistinct within the fifth dimension, cast adrift and lost on a vast ocean of a newer and higher dimension. Examples of the condition of definition range from Kaluza's condition of cylindricity, to the projective condition, the closed space of Einstein and Bergmann or the laminated sheets theorized by Podolanski. I chose what I thought to be a more realistic condition in my 'constant of definition,' which defines the 'effective width' or thickness of the four-dimensional sheet in the fifth direction. Since some condition of definition is required of all five-dimensional theories, any criticism of the particular condition of any theory is actually a criticism of the basic assumption of a fifth dimension. The basic difference between the various five-dimensional theories reduces to the particular form that any condition of definition takes and the resulting structure built upon it.

During the course of this investigation, two fundamental questions have been kept in mind: Why does the five-dimensional concept seem to be a natural extension of the concept of curvature? And, if it is such a natural extension, why has it not been exploited more fully? The naturalness of the five-dimensional hypothesis as an extension of relativity theory is based on the popular notion (or misconception in the minds of many) that a curve must occur in a dimension of higher number than the dimension of the surface that is curved. In the case of extrinsic curvature this may well be true, but in the case of intrinsic curvature no such higher-dimensional embedding space is necessary. There is no physical reason to assume an extrinsic curvature with an embedding space to describe our world as a whole, unless we find some striking physical phenomenon that cannot be explained and has not been previously incorporated into another theory. But again, there is no logical or other legitimate scientific reason to exclude the five-dimensional hypothesis unless bias is considered.

The five-dimensional theories as a group have been experimentally unsuccessful up to this time since no such physical phenomenon has been observed or predicted. Mach referred to this same situation, rather directly and colorfully, in his statement that "We have not yet found an 'accoucheur' who has accomplished parturition through the fourth dimension. If we should, the question would at once become a serious one."[2] In the absence of an event of this nature, the five-dimensional theory would only seem to be justified by an operational necessity represented by the unification of the field and quantum theories. Several theorists have noted that quantum theory offers the best chance for applying the five-dimensional hypothesis, while others have actively sought to include the quantum in a five-dimensional framework without using the quantum to define their own condition of definition.

I have attempted such a unification with my own theoretical structure. In the absence of any striking phenomena to force the acceptance of a five-dimensional theory on a skeptical academic community and an extremely conservative scientific community, the successful inclusion of the quantum as a part of the five-dimensional continuum would act to motivate and justify further research into the possibility of a five-dimensional universe. It seems that science must eventually answer the question 'Which is uglier and least acceptable, the non-geometrization of physics or the five-dimensional concept?' because a hyper-dimensional structure is implied by General Relativity in the eyes and minds of so many different scientists and there is so much for science to gain from the five-dimensional structure. A successful unification of quantum theory and General Relativity would definitely answer this question in favor of the five-dimensional concept. So, the operational necessity of developing five-dimensional theories rests in the possible success of these theories in explaining our physical reality. The main obstacle to utilizing a five-dimensional structure in physics is the prior bias demonstrated by many scientists and scholars.

The bias through which many would judge the five-dimensional concept could be traced to our predilection of a 3+1 dimensioned space with time, as we normally perceive the physical world around us. There exists no physical or mathematical proof that would restrict physical space to three dimensions or space-time to four. The most that can be said is that, in all known instances, the three-dimensionality of space seems to be the rule.

On the other hand, proofs have been offered that higher-dimensional spaces are in some cases just as legitimate (in a mathematical sense) as three-dimensional spaces. However, our psychological and physical make-up have lead to our inherent bias toward hyper-dimensional theories. Poincaré was probably the most radical supporter of the three-dimensionality of space, since he would have changed the basic laws of physics rather than accept the possibility of a hyper-dimensional space. Actually, his comments referred only to the concept of curvature, but it can be assumed that he would have been even less likely to accept a hyper-dimensional space since he so strongly supported the Newtonian view of a strictly Euclidean space. At the time that Poincaré's statement was made, the concept of intrinsic curvature had not yet evolved so any mention of curved space directly implied a higher embedding dimension. Dimensionality and curvature were synonymous before General Relativity. Einstein, critical of the radical view expressed by Poincaré, argued that Euclidean geometry could not be assumed *a priori*, but a combination of the simplest form of geometry and experience was necessary to decide our worldview. So, if the five-dimensional hypothesis would lead to the simplest overall explanation of physical phenomena, rather than the simplest geometry alone, then the hyper-dimensional theories would and should be the legitimate concern of serious scientific inquiry.

There are striking similarities between the arguments against four-dimensional spaces proposed in the last century and the five-dimensional space-times of the post-relativity era. This fact raises serious questions regarding the efficacy of the modern arguments and criticisms since the arguments of the last century were based on Newtonian principles and the arguments of today should be based upon a whole new concept of space and time according to the theories of relativity. If the arguments against the five-dimensional theories are the same or similar to those older arguments, could they also be mistakenly based on the older Newtonian concepts of space and time? It is quite possible that science still thinks in terms of a Newtonian worldview when it comes to space and time in spite of our relativistic training. If this is true, then the five-dimensional theories can never be taken seriously in a scientific and objective manner. This conclusion offers partial although circumstantial evidence that science needs to completely review the basic concepts of space and time independent of the five-dimensional theories, although the hyper-dimensional theories certainly emphasize this concept in science. Other evidence for the necessity of such a review can be found in both General Relativity and the quantum theory, no matter which philosophical interpretations of these theories are taken. In spite of advances made by science since the turn of the century, science still clings to semi-Newtonian concepts of space and time that do no justice to any of our present physical theories. The lack of serious consideration of Kaluza's theory and other such theories, which have met with some limited success, is further evidence of the need to find new meanings for space, time, space-time and dimensions as well as matter.

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Last Updated 22 December 1999

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