1.2 - Outline and Summary

This article attempts to unify all of the electromagnetic, weak, strong and quantum gravitational interactions; and to account for all of the fundamental particles and symmetry groups that may exist in nature, including the phenomenological flavor, color and generation groups. While we have indicated possible experimental avenues by which some of the results developed here may be verified, the emphasis is predominantly theoretical. From one vantage point, this may be summarized as an attempt to determine precisely, the unique high energy gauge groups and their interrelationships, which are both necessary and sufficient, without anything superfluous, to describe all of the known particles and interactions which exist in nature, at all energies. That is to say, this article attempts to specify precisely, that particular set of gauge groups which nature does in fact follow, from among all of the possible gauge groups which might be mathematically feasable, but which for one reason or another are not in complete accord with the actual phenomenology of nature. Crucial in this approach is the decomposition of the real observed fermions and vector bosons, into a proposed (smaller) set of complex particles which are designated as preons. These preons bear a relationship to real particles that is very similar to the relationship that complex spinors bear to real spacetime, insofar as it is possible to decompose four real spacetime dimensions into two complex spinor dimensions, retaining all information provided by classical spacetime physics, yet providing new insights into spacetime that would tend to be overlooked if one did not consider spinor decomposition. This reduction of four real elements down to two complex ones is an important simplification of spinor calculus It is for this reason that repeated reference is made to the monographs by Penrose and Rindler,[-1.13] which empasize very heavily the fundamental importance of spinors, in developing a deeper and simplified understanding of ordinary spacetime physics.[-1.14]

Aside from the current introductory section, Section 1, this article contains a very large section 2, consisting of subsections 2.1 through 2.14. In fact, it would be perfectly possible to divide these materials into two seperate sections, one containing 2.1 through 2.8; and the other containing the remaining 2.9 through 2.14. The former sections 2.1 through 2.8, with exceptions noted below, essentially provide a review of established spacetime physics, with emphasis on the Dirac wave equation and its various solutions. By and large, much of this material is covered by any good introduction to the Dirac equation[-1.15], and would presumably comprise an important component of any graduate or perhaps undergraduate curriculum in theoretical physics. As such, with exceptions noted below, it is possible for the reader with a direct interest in grand unification and gauge theory to skip over most of sections 2.1 - 2.8, and to begin with section 2.9. Sections 2.9 through 2.14, comprise the majority of the new material developed in this article, and are devoted exclusively to various aspects of grand unification. These are elaborated in greater detail below.

Sections 2.1 through 2.8, by and large, provide a basic review of the Dirac wave equation and its various solutions and symmetries. Particular emphasis is placed upon the connection of the Dirac equation to the metric equation of classical spacetime physics $ds^2=g_{uv}dx^u dx^v$, and we attempt to demonstrate how all of the significant features of the Dirac equation, in one way or another, can ultimately be traced directly back to this classical metric equation. Heavy use is made of covariant notation, and it is assumed that the reader has had at least a good introduction to special and general relativity, and is thereby comfortable using covariant equations. -1.16 These sections 2.1-2.8 were developed with two main objectives. First, these sections are intended to serve as a basic introduction to the Dirac equation, albeit from a relativistic standpoint that starts by assuming, as given, the general validity of the classical spacetime metric in second order, given above. The Dirac equation itself, from a classical standpoint, may be regarded simply as a first order representation of the metric equation, of the form $ds = \gamma^u dx_u$, where the connection to the second order metric is established simply by defining the symmetric combination $g_{uv} = \frac{1}{2}\left(\gamma_u\gamma_v + \gamma_v\gamma_u\right)$, in the usual manner. (See eqs. (2.1)-(2.2) and (2.7)-(2.10), infra.) Everything else thereafter, can ultimately be traced back to this initial set of classical equations. This provides an extremely simple way to percieve the Dirac equation and its various solutions and symmetries, and it also sets the spacetime foundation for the subsequent discussions of grand unification. Second, these sections are intended to provide a primary introduction, in the context of spacetime physics, to what are called "quantized degrees of freedom." For the Dirac equation, particle spin, which can be "up" or "down," provides a particularly important example of what may be referred to as a "spacetime" degree of freedom, insofar as this is ultimately traceable to the classical spacetime metric equation, in first order. This concept is very useful whan we begin to consider grand unification, and it is applied in a wide variety of different situations. For example, there is a well known "flavor" degree of freedom called "weak isospin," which is very similar to spin, and which can be either "up" or "down," (or zero) for any particular flavor of elememtary particle. It is this degree of freedom which is part and parcel of weak interaction theory, and, if one ascribes to "isospin up" and "isospin down" the same sort of significance that is ascribed to "spin up" and "spin down" in ordinary spacetime physics, a-la Penrose and Rindler, then it is quite straightforward to decompose the four real Bose particles A^u, W^{+u}, W^{-u}, $Z^u(=W_0{}^u)$ of the Weinberg-Salam electroweak theory into two complex "preonic" states, $\Uparrow$ and $\Downarrow$ for isospin up and down, in a way that is very similar to the decomposition of four real spacetime dimensions ct,x,y,z into two complex spinor states, $\uparrow$ and $\downarrow$ for spin up and down. While electroweak theory may thereby be summarized by two preons (this is the main point of Section 2.9), it is possible as shown in sections 2.10 to 2.14 to extend electroweak theory to encompass all other particles and interactions as well, simply by (carefully) increasing the number of fundamental complex preons. Sections 2.7 and 2.8, which develop the notions of ordinary spin in spacetime, provide the "template" upon which the isospin decomposition of electroweak theory is to be based; and these sections, in turn, find their basis among the degrees of freedom of the Dirac equation, as discussed in sections 2.1-2.6. Other examples of (non-spacetime) degrees of freedom include electrostatic Coulomb charge Q (which is a flavor freedom) and the color degrees of freedom associated with strong interaction quantum chromodynamics. The replication of fermionic generations is due to yet another set of "generation" degrees of freedom. Thus, sections 2.1 through 2.8, in short, provide a basic introduction to the Dirac equation in such a way as to emphasize connections with the classical covariant metric equations of spacetime, and to provide a basis for future discussion of particle phenomenology in the context of spacetime physics. Additionally, these sections provide an introduction to quantized degrees of freedom, with particular emphasis on particle spin, in such a manner as to provide a basis for later discussion of the very similar isospin degree of freedom in electroweak theory, and of additional degrees of freedom such as electrostatic charge, color and generation freedoms. These are all vital to grand unification.

While sections 2.1 through 2.8 are therefore fairly standard in their exposition of the Dirac equation, aside from the emphasis on covariance and upon quantized degrees of freedom, there is one important area in which these sections introduce new material of a fundamental character, and this relates to the chiral Dirac matrix $\gamma^5 \equiv i\gamma^0\gamma^1\gamma^2\gamma^3$. In particular, the fact that the four Dirac matrices $\gamma^0,\gamma^1,\gamma^2,\gamma^3$, which are readily associated with the four spacetime dimensions ct,x,y,z, can be multiplicatively combined to form a fifth linearly independent matrix γ^5, provides strong motivation to directly associate this matrix with a fifth dimension of spacetime, which is referred to as the "chirality" dimension. In fact, once this fifth-dimensional viewpoint is adopted, it becomes clear that the <u>seperate</u> consideration of spacetime and chirality requires a great deal more effort than does the <u>combined</u> consideration of spacetime and chirality into a single five dimensional spacetime/chirality manifold which includes γ^5, and which is described by equations which are covariant in five dimensions, rather than the usual four. This consolidation of chirality with spacetime into a five-dimensional covariant manifold is just as significant, in its own way, as the consolidation of space and time into a single covariant four-dimensional manifold, as first recognized by Minkowski,[-1.17] based upon the special theory of relativity,[-1.1] and later incorporated into the general theory.[-1.19] The five-dimensional metric has signature diag $(g_{uv}) = (1,-1,-1,-1,1)$, see eq. (2.18)(a) infra, and so is not unlike the early five-dimensional "cylinder" models of Kaluza-Klein;[-1.20] though it does not appear that any of the five-dimensional models proposed to date clearly recognize the fundamental and compelling connection between a fifth dimension, and the chiral γ^5 matrix that is unavoidably introduced by the Dirac equation, into any discussion of spacetime physics, particularly for spin half particles which require the Dirac, as opposed to the Klein-Gordon wave equation. By recognizing clearly the elevation of "chirality" to a spacetime dimension on a par with space and time, many aspects of modern particle theory which in four-dimensions may seem somewhat ad-hoc or obscure, are seen to become quite clear and natural once a five-dimensional approach has been adopted. For example, the experimental necessity of recognizing fundamental asymmetries under certain interactions as between left and right handed chiral projections, defined by way of the chiral operators $\frac{1}{2}(1 - \gamma^5)$ and $\frac{1}{2}(1 + \gamma^5)$ respectively, which was first recognized theoretically by Lee and Yang with respect to weak interaction parity non-conservation, is easily regarded in a five-dimensional approach to have its geometric source in certain asymmetries of the chiral fifth dimension. In four dimensions only, the necessity of giving careful consideration to each of the left and right handed projections may not appear quite so obvious or compelling. In addition, whereas the energy vector E^u for any given particle, in four dimensions, is given by the energy E^0 and three components of linear momentum E^1, E^2, E^3 which are all related to the invariant rest mass m, for a free particle, by $mc^2 = \gamma^u E_u$, u=0,1,2,3, the five dimensional energy vector E^U, U=0,1,2,3,5 introduces an additional component E^5 which must also be given a physical interpretation, and which is now presumably related to the (five dimensional) invariant rest mass M, according to $Mc^2 = \gamma^U E_U$, covariant in five dimensions. This additional component E^5 is most naturally regarded as an imaginary contribution to the particle rest mass, ie., as a particle width Γ which is connected to particle lifetime τ by $\Gamma = 1/\tau$.[1.21] Consequently, to properly specify the "position" and "momentum" of a particle in five dimensions, it is necessary in addition to energy and momentum, to specify the particle width, or lifetime. Without knowing the lifetime, the mere specification of energy and momentum does not suffice to precisely determine the invariant rest energy of a particle, and thereby leads to uncertainties in predicting the future behavior of that particle. Thus for example, while it is impossible in four dimensions, given a large sample of radioactive material with known half-life, to predict precisely which individual particles will undergo decay in a specified time frame, (though aggregate predictions can of course be made with considerable accuracy) the five dimensional approach presupposes the specification of a precise lifetime for each particle, in connection with the fifth component E^5 of the five-dimensional energy-momentum-chirality vector.

Consequently, what is uncertain in four dimensions can perhaps be made more certain in five, with the ultimate consequence that perhaps, after all, God really does not play dice! The initial development of chirality as a fifth dimension of spacetime takes place in Section 2.1. Consequently, this section is advised even for the reader who is otherwise uninterested in reviewing the Dirac equation. In Section 2.4, it is shown further how the chiral fifth dimension brings about consideration of left and right handed fermionic projections unavoidably, as soon as one begins to consider certain symmetries, particularly hermitian conjugacy, of the Dirac equation in five covariant dimensions. As the consideration of chiral symmetry and asymmetry is an important part of later discussion of grand unification (it is already important, even in electroweak theory alone) Section 2.4, along with the following Section 2.5 are also advisable for the reader with a primary interest in grand unification. In brief, these two sections, among other things, serve to define in a five-covariant manner, the various finite symmetry operators P, C and T for parity, conjugation and time reversal respectively, along with an axial finite operator A that is connected directly with the chiral fifth dimension; and also, the left and right handed chiral projections. The geometric interpretation of the chiral dimension, and of closely related issues involving possible modification to the physics of "uncertainty," is not directly pertinent to grand unification, and is therefore not elaborated in depth herein. The author does plan to address these fundamentally important questions, either in a subsequent draft of the current article, or in a seperate paper on the geometric and kinematic interpretation of the chiral fifth dimension.

As for the distinct topics elaborated in Sections 2.1 - 2.8, section 2.1 introduces the "classical" Dirac equation in five-dimensions, emphasizing the close connection of the Dirac equation, to the metric equation of spacetime. Section 2.2 introduces the notion of "quantized degrees of freedom," and focuses specifically upon the particle/antiparticle and spin-up/spin-down degrees of freedom of the Dirac equation in five dimensional spacetime and chirality. Section 2.3, which is fairly standard, involves the determination and labelling of the various spinor eigensolutions of the five-dimensional Dirac equation, and reviews the high and low energy approximations for these solutions. Sections 2.4 and 2.5 as noted above, develop the various finite symmetry operators C,P,T,A along with the left and right handed chiral projection operators, by considering the symmetry of the five dimensional Dirac equation under the various operations of hermitian conjugation, (ie., conjugate transposition) and under the seperate operations each, of conjugation and transposition. Section 2.6, which seeks to elaborate more clearly the conjugate relationship between particle and antiparticle spinors, and to introduce Feynman diagrams, contains some limitations that will be addressed in a subsequent redraft of this article. So long as the reader has a basic working knowledge of Feynman diagrams and their rules for construction, this section may be safely skipped without impact upon later discussion. Section 2.7, which introduces the various s,t,u scattering channels for future reference, in a standard manner, is also concerned with the various polarization states, both real and virtual, of massive and massless vector Bosons. In many ways, this is the first subsection which is developed with an eye specifically toward preonic grand unification, as the decomposition of the allowable covariant polarizations for a spin 1 particle into its spin $\frac{1}{2}$ components, is quite similar to the preonic decomposition of the electroweak vector bosons A^u, $W^{\pm u}$, Z^u into their "isospin $\frac{1}{2}$" complex components. This discussion is carried further into Section 2.8, which, in direct preparation for discussion of preonic grand unification, examines in depth the complex spinor decomposition of the four (chirality aside) real spacetime dimensions ct,x,y,z into the two complex (Argand) spinor dimensions spin up, $\uparrow$, and spin down, $\downarrow$. This summarizes sections 2.1 through 2.8 which, as indicated previously, may be regarded somewhat independently of the remaining sections beginning with 2.9.

Section 2.9, which is the first section dealing with grand unification per-se, is a somewhat unconventional review of the electroweak theory of Weinberg and Salam. While most reviews of this subject tend to focus on such topics as spontaneous symmetry breaking, the ephasis here is placed particularly upon the particle phenomenology of Electroweak theory, which is comprised of the four vector bosons A^u, Z^u, W^{+u}, W^{-u}. These four particles, which are to be regarded as real Bose particles, can in fact be decomposed into a set of two complex "isospinor" states, isospin-up and isospin-down, which are dubbed as "preons," in very much the same way that the four real dimensions of spacetime may be decomposed into a set of two complex "spinor" states, spin-up and spin-down. These complex preons are just as important to acquiring a deeper understanding of real elementary particles, as are complex spinors to aquiring a deeper understanding of real spacetime. This is again why the importance of "spinors and spacetime," as elaborated by Penrose and Rindler, cannot be overemphasized, as it applies with equal force to "preons and particles." Section 2.10 further reemphasizes the importance of complex preons in acquiring a deeper and simplified understanding of real particles.

Section 2.11 is the first section devoted to grand unification. Utilizing the preonic approach now developed for two-preon electroweak theory, (which by the way, is closely related to the fact that the gauge group of electroweak theory is SU(2)xU(1)) one increases from two to four the number of available preons; and at the same time, one utilizes the simple gauge group SU(4) (later to be SU(4)xU(1)) to engage in the full classification of these four preons, whereby the already developed "isospin-up" and "isospin-down" preons of electroweak theory are now to be associated with the explicit SU(2) subgroup of SU(4). Whereas the 2 electroweak preons can be utilized to compose 2x2=4 real flavors of Boson, of which $\frac{1}{2}(2)(2+1)=3$ are conjugally independent particles (W^{+u} and W^{-u} are mutual antiparticles), the 4 preon theory elaborated here now allows one to compose 4x4=16 real flavors of particle, both Fermion <u>and</u> Boson, of which $\frac{1}{2}(4)(4+1)=10$ are conjugally independent. Similarly, whereas the electroweak subgroup SU(2)xU(1) introduces two diagonalized matrices and hence two linearly independent quantized degrees of freedom, namely weak isospin I^3 and hypercharge Y, the SU(4) group, without the U(1) factor, contains three diagonalized matrices, and hence three linearly independent degrees of freedom, which include both of Y and I^3, along with baryon number B. And, whereas electroweak theory provides for one (chiral symmetric) degree of freedom which "sits across" the other two, namely the electrostatic charge $Q=Y+I^3$, the four preon extension using SU(4) without U(1) provides for two (chiral symmetric) degrees of freedom sitting among all of I^3, Y and B; namely Q defined as above, and lepton number L defined (for left handed chiral projections only) by $L = B - 2Y$. Quark number, Q_u, is a third (chiral symmetric) degree of freedom which (for left handed particles only) may be defined by $Q_u = 3B$. (See eqs. (2.275), infra) There are however, a number of very important limitations upon the theory at this point. First, whereas the sixteen flavors of real particle provided to this point include the four electroweak vector bosons A^u, W^{+u}, W^{-u}, Z^u along with four colorless strong/ hyperweak (high energy) interaction vector bosons and eight left handed fermions $(u,d,\nu,e)_L$ and their antiparticles, the theory at this point still fails to account for any of the right handed chiral projections $(u,d,\nu,e)_R$ and antiparticles. Nor does the theory at this point begin to account for the three allowable colors of quark and certain hyperweak bosons, or for the nine ($9=8 \oplus 1$) bi-colors of strong interaction gluon; though partial progress is made insofar as quark number $Q_u = R + G + B$ (See eq. (1.1)) is now defined for left handed projections. While the identification of quark number Q_u for left-handed fermions signifies a somewhat limited unification of the electroweak and strong interactions, there is also nothing said to this point of quantum gravitation. And of course, nothing is developed to this point which might serve to explain the observed multiplicity of fermionic generations.

Section 2.12 begins to address some of these limitations. First of all it is noted, if one wishes to account for the observed chiral asymmetry of the weak interaction as first proposed in the context of parity non-conservation by Lee and Yang, and at the same time, if one wishes to ensure that the strong and electromagnetic interactions remain chiral symmetric (which implies that parity is conserved), it turns out that it is absolutely mandatory for one to revise the SU(4) gauge group so as to include a U(1) factor, ie., one must now utilize the gauge group SU(4)xU(1). The U(1) factor for SU(4) introduces an additional diagonalized generator which is proportional to the 4x4 unit matrix, and thereby adds a fourth linearly independent quantized degree of freedom. As the gauge group of U(1) is abelian, and as the electromagnetic and weak interactions, and to some degree (without color) strong interaction is already accounted for by SU(4), it seems quite compelling to associate this fourth degree of freedom with quantum gravitation, so as to avoid the introduction of yet a fifth interaction. Without the U(1) factor for SU(4), which is to say without quantum gravitation, it becomes impossible to reconcile the chiral asymmetry of the weak interaction with the chiral symmetry of the electromagnetic and strong interactions. Hence, quantum gravitation is required to explain all that is known about chiral symmetry and asymmetry. Oddly, the quantum gravitational interaction, like the weak interaction, appears to be chiral asymmetric, as a consequence of this reconcilliation. However, whereas the only real chiral projections which couple through weak interactions are left-handed, it appears as though the only real particle projections which couple through quantum gravitation are right-handed. With the introduction of quantum gravitation, one is now able to account for both left and right handed chiral projections of the real fermions (and Bosons -1.22) by considering both left and right handed projections of the same four preons. The two preons of electroweak theory turn out to be chiral asymmetric, as might be expected, while the two additional preons introduced in going from SU(2)xU(1) to SU(4)xU(1) turn out to be chiral symmetric. These two additional preons also happen to be the sole carriers, individually, of both quark number (= R + G + B) and of lepton number (which is regarded at high energies as a fourth color); and this too, is a consequence of quantum gravitation. For reference, we should note that these four preons are referred to simply as A,B,C and D. The C and D preons are defined simply to be the isospin up and down preons of electroweak theory, while the A and B preons are defined respectively as the sole carriers of quark number and (anti)lepton number. With G used to designate the degree of freedom associated with quantum gravitation, one now acquires four (chiral nonsymmetric) degrees of freedom G, I^3, Y, B, along with three (chiral symmetric) degrees of freedom which sit among them, namely $Q=Y+I^3$ as usual, along with quark number $Q_u = G + 3B$ and lepton number $L = B - 2Y - G$, see eqs. (2.305) infra. These somewhat modified relationships which account for the quantum gravitational degree of freedom G, apply both to left and right handed chiral projections, ie., they obey chiral symmetry. For left handed real particles only, G=0, which results in the simplified relationships discussed earlier. For right handed particles however, $G \neq 0$ necessarily. Consequently, the introduction of quantum gravitation is most readily viewed as an attempt to describe both quark number and lepton number (and electrostatic charge) according to relationships which are chiral symmetric; while at the same time accounting for the established chiral asymmetry of the weak interaction. To this point, while both left and right handed chiral projections may now be accounted for, and while quantum gravitation is itself also accounted for, there are still two important limitations on the theory as developed to this point. First, we are still utilizing a colorless strong interaction, and second, there is still no discussion of the repetition of the fermionic generations.

In Section 2.13, the primary concern is the discussion and introduction of quantum chromodynamic color, still within a single generation of fermions. Noting that the "A" preon is the exclusive carrier of quark number $Q_u = R + G + B = 1$; and that the "B" preon is the exclusive carrier of (anti) lepton number $L = -1$ which is at high energies a fourth (anti) color, it now becomes apparant that the A preon, which carries quark number, must therefore be the carrier of color as well. Consequently, the A "flavor" of preon is now considered to itself exist in one of three "color" states, namely, A_R, A_G, A_B, defined in strict accord with established Q.C.D. theory. Lepton number, as a high energy fourth color, is already carried by the $\bar{B}$ preon, which we now redesignate as $\bar{B}_{\bar{L}}$. With the addition of a tri-colored A preon, the total number of preons required to account for both flavor and color within a single generation is raised from four to six, namely, $A_R, A_G, A_B, B_{\bar{L}}, C, D$. The high energy gauge group of color is chosen to be SU(4)xU(1) which, in conjunction with high energy flavor SU(4)xU(1) discussed earlier appears at first to introduce a total of eight preons and eight linearly independent degrees of freedom. However, there is an important overlap between the flavor and color groups. Because each of quark number Q_u and lepton number L may be constructed by linear combination from both of the flavor and color groups, it is possible to reduce what are seemingly eight degrees of freedom between both flavor and color, down to only six combined degrees of freedom. This in turn, reduces what are seemingly eight independent preons, down to six, namely, three colors of A, and B,C,D. With these 6 preons, one can now compose 6x6=36 distinct flavor/color combinations of real particle within a single generation, of which $\frac{1}{2}(6)(6+1) = 21$ are conjugally independent. Included among the 36 are the four electroweak bosons A^u, W^{+u}, W^{-u}, Z^u, the $9 = 8 \oplus 1$ bi-colors of gluon, six colored hyperweak vector bosons (including antiparticles), one newly predicted neutral hyperweak boson designated $X_0{}^u$ which is quite similar to the Z^u ($=W_0{}^u$) of electroweak theory, and all sixteen flavor/color combinations of quark and lepton within a single generation, including antiparticles. Reducing out conjugate states, this amounts the the eight flavor/color combinations of fermion $(u,d)_{R,G,B}$ and (ν,e). Accounted for also, are both left and right handed chiral projections. All that remains unaccounted for at this point, is the replication of fermionic generations. In order to provide a basis for discussing generation replication properly, it is necessary to develop the strong neutral current phenomena in the same manner that the electroweak neutral current is developed. This is done by ensuring that the high energy color group SU(4)xU(1) breaks down below grand unification energies to the SU(3)xU(1) color group of low energy Q.C.D., including the singlet state. It is in this process that a new super-massive neutral hyperweak vector boson $X_0{}^u$ acquires its mass and definition and, as shown in the subsequent section, it is this boson, and only this boson, which is able to mediate the decay of leptons <u>across</u> generational boundaries, rather than strictly within a single generation. Of course, because the X_0^u has a mass which is determined by the scale at which grand unification takes place, it is virtually impossible to produce this particle in the labaratory with current technology. Consequently, there has been no observation to date of Cabibbo mixing among leptons,(though this phenomenon is well established among quarks) and no detection of any neutrino rest mass, and of a right-handed chiral component for the neutrino.

Finally we arrive, in Section 2.14, at an examination of the multiplicity of fermionic generations. Noting that multiple generations are most readily observed for all fermions, ie., for all particles with fermion number F=1 or combinations thereof; and further, from prior discussion, that only the A and B flavors of preon have $F=Q_u+L=1$ (A has $F=Q_u=R+G+B=1$, L=0; B has F=L=1, $Q_u=R+G+B=0$) it becomes apparant early on that the four flavor/color preons $(A_R, A_G, A_B, B_{\bar{L}})$ (L=Lepton= fourth color at high energies) must in fact also be the carriers of the generation charges. The C and D preons, both with $F=Q_u=L=0$, are uninvolved in the fermion generation redundency, save for the fact that in many instances these are combined with A and B, which are involved. Experimentally, it is fairly clear that at least three such generations do exist in nature. From a theoretical standpoint, it appears most natural on the basis of preonic decomposition to suppose that there are in fact exactly four such generations in nature, and that the failure to observe such a fourth generation results, not from a limitation of nature, but from the limited ability of current experimental technology to attain sufficiently high energies of observation. Hence, development is carried out on the basis of a

four generation model, which can nevertheless be accomodated to any number of generations desired, though at the loss of certain symmetries that exist only for the four generational model. In particular, for four generations, introducing a proposed Υ generation in addition the the observed e, μ, τ generations, and utilizing the notion of "horizontal symmetry" first proposed by Pati and Salam[-1.23], each of the four preons $A_R, A_G, A_B, B_{\bar{L}}$ is horizontally replicated four times, which now leads to a total of sixteen flavor/color/generation combinations of A and B preon, that is, to $(A_R, A_G, A_B, B_{\bar{L}})_{e,\mu,\tau,\Upsilon}$. Added to the C and D preons which are not involved in generational mixing, one now arrives at a total of eighteen distinct flavor/color/generation combinations of preon, required to account for all known (and some currently unknown) flavor/color/generation combinations of real fermion and boson. The total number of distinct fundamental real particles is now raised to $18 \times 18 = (16 + 2) \times (16 + 2) = 256 + 64 + 4 = 324$, with $16 = 4 \times 4$ representing the sixteen distinct color/generation combinations of the A and B flavors of preon. (See (2.376) infra.) The 256 represents all flavor/color/generation combinations of gluons and hyperweak vector bosons, the 64 denotes fermions, and the 4 corresponds to the four A^u, W^{+u}, W^{-u}, Z^u of electroweak theory. Reducing out those particles that are related to one another by antiparticle conjugation, this yields $\frac{1}{2}(4)(4+1) \times \frac{1}{2}(4)(4+1) + \frac{1}{2} \times 64 + \frac{1}{2}(2)(2+1) = 100 + 32 + 3 = 135$ conjugally independent particles.
The 100 corresponds to gluons and hyperweak bosons, the 32 to fermions (four generations each of $u_R, u_G, u_B, d_R, d_G, d_B, \bar{\nu}, e$), and the 3 to the A^u, $W^{\pm u}$ and Z^u of electroweak theory. The reason for the factor $\frac{1}{2}(4)(4+1) \times \frac{1}{2}(4)(4+1) = 100$ as opposed to $\frac{1}{2}(16)(16+1) = 136$ is a result

of the horizontal symmetry of the generations. Consequently, this symmetry reduces somewhat the number of fundamental particles. All of the remaining particles in nature, and all interactions, involve varying combinations, in one form or another, of these fundamental 135 conjugally independent particles and their interactions.

Finally, we should note those areas that are not explicitly developed here, but which are left for future efforts. It was noted at the outset, in Section 1.1, that the prediction of the Newton/Cavendish gravitational coupling G, and its associated mass scale of 1.22×10^{19} GeV., it an important prerequisite to the final validity of any theory which, as does the theory proposed, attempts to unify quantum gravitation with the remaining three strong, electromagnetic and weak interactions. In particular it is necessary, based upon the complete particle phenomenology of the theory, and upon low energy experimental coupling and related data, to arrive via the Gell-Mann renormalization group equation, with all higher order corrections considered, and within experimental errors, at a numerical value for the grand unified coupling including gravitation, which is equivalent with the <u>experimentally</u> based value of G, and its associated energy 1.22×10^{19} GeV. This is to be carried out in a manner similar to that utilized, for example, to arrive at a grand unification mass scale of $\approx 10^{15}$ GeV. for the Georgi-Glashow SU(5) model of the three non-gravitational interactions. While the theory developed here does provide a theoretical place for quantum gravitation and hence for the Newton coupling G, we have made no attempt herein to explicitly predict G from the model presented. If such a prediction were to be attempted, it would be necessary for this prediction to arrive at the same value of G which has long been known from experiment, $G = 6.67 \times 10^{-11}$ met^3/kg-sec^2, in order to independently validate that quantum gravitation is indeed incorporated properly into the present theory. This is the next logical step toward further development of the theory. Authors who have presented similar calculations for existing theories (such as Georgi-Glashow SU(5)) of the strong and electroweak interactions include Langacker,[-1.24] Weinberg[-1.25], and Halzen and Martin.[-1.26]

Also not explicitly developed here, is the geometric interpretation of the fifth chiral spacetime dimension, and closely related questions involving quantum mechanical uncertainty. One important area of chiral geometry involves the geometric interpretation of the Fermion rest mass for a given particle, see the Lagrangian (2.120).(3) infra and the discussion leading thereto. In fact, the geometric and dynamical interpretation of the chiral dimension poses questions of a most fundamental character, beyond those dealing specifically with grand unification. For example, if the particle width (inverse lifetime) is associated with the fifth component of the energy vector, E^5, then it would appear that the only particles in nature with a theoretically infinite lifetime, are precisely those particles for which the chiral energy component is equal to zero at all points along the particle worldline, $X^5 \sim \Gamma = 1/\tau = 0$. All particles with finite lifetime, ie., all particles which from a geometrodynamic perspective will eventually encounter a spacetime singularity, must of necessity possess a non-zero chiral energy component, $X^5 \sim \Gamma = 1/\tau \neq 0$, particularly at the time (event) of annihilation. Consequently, it appears that the chiral dimension might also offer some additional insights into the usual treatment of gravitational collapse in four dimensions. For the present at least, we leave these questions to the future.