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The Short-Range or "Particle" Forces

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Abstract

The strong force is responsible for the binding of compound atomic nuclei and the binding of quarks in the class of heavy composite particles, the hadrons. Hadrons consist of baryons (containing 3 quarks) and mesons (containing quark-antiquark pairs). The weak force is responsible for the creation, destruction, and transformation of single, unpaired elementary particles (quarks and leptons). Both forces are to be understood in terms of energy, charge, and especially symmetry conservation. The strong force conserves whole quantum units of charge and achieves "least bound energy" nuclear configurations; the weak force ensures the invariance of all conserved parameters in elementary particles during the creation, destruction, or transformation of single, unpaired particles.

Introduction: The Particle Spectrum

The energy forms of our Universe are generally divided into two types (always a dichotomy!), the bosons and fermions (free and bound forms of electromagnetic energy - light and matter). These are distinguished on quantum mechanical grounds, bosons having integer spins (0,1,2) and fermions having half-integer spins (1/2, 3/2) - in units involving Planck's energy constant. Bosons can superimpose their energy upon one another, fermions cannot, obeying Pauli's "Exclusion Principle" (photons can pile up to any energy, electrons remain individually distinct). The field vectors of the forces are bosons - photons, gravitons, gluons, IVBs (Intermediate Vector Bosons) - and are massless except for the IVBs. The particles which constitute atomic matter are fermions - leptons, quarks, neutrinos - and are massive (apparently neutrinos have a tiny mass). The field vectors of the weak force fall between these classes, as massive bosons or force carriers; for this reason they are given the awkward name of "Intermediate Vector Bosons" (IVBs) (see: "The Particle Table").

In the particle spectrum we will generally be discussing the fermion class of particles (the constituents of atomic matter), in addition to some short-range boson field vectors (mesons, gluons, and IVBs). Fermions themselves are subdivided into two sections, the leptons and hadrons. Hadrons include any particles containing quarks: of these there are only two kinds, the mesons, which contain quark-antiquark pairs, and the baryons, which contain three quarks, the latter familiar to us as protons and neutrons. Leptons do not contain quarks; they include the electron and its neutrino, and similar but heavier "family members" (quarks also exist in 3 "families" of 6 related particles of various discrete and quantized masses). Leptons are the only truly elementary fermions; hadrons are not elementary, as they contain sub-units bearing fractional charges, the quarks. Our primary interest is the spectrum of elementary leptonic particles and its relationship to the quarks. (In more familiar terms, how are electrons and neutrinos related to protons, neutrons, and mesons?)

Leptons and Leptoquarks

The leptonic spectrum of elementary particles consists of only three known massive members, the electron, muon, and tau. These particles are identical except in terms of mass (and a conserved charge known as "number" or "identity"), the electron being the lightest, the tau the heaviest. Each is accompanied by its own neutrino, a (nearly) massless particle. There is, as always, a corresponding set of antiparticles and antineutrinos. The neutrino carries the "identity" charge of its massive leptonic partner. "Identity" charge, otherwise known as "number" charge, is a strictly conserved charge of elementary particles; its origin as a symmetry debt as well as the practical significance of the leptonic particle series as alternative charge carriers of electric and identity charge, is fully discussed in "Symmetry Principles of the Unified Field Theory". Neutrinos are the "bare" or explicit form of lepton number or identity charge, which is also carried in "hidden" or implicit form by all massive leptons (including the hypothetical leptoquark). (See: "The Weak Force Identity Charge".)

A fourth member of this leptonic spectrum is thought to exist, the hypothetical and very massive "leptoquark". This particle forms the bridge between the leptons and quarks. My personal view of this primordial particle is that it formed as a sort of "fractured" heavy lepton. One possible "rationale" for breaking an elementary particle into three parts (which became the quarks) is that a composite particle can absorb much more energy than an elementary one, as its internal parts can be squeezed together like a set of compressible springs (against the resistance of Pauli's Exclusion Principle). The increasing mass of the elementary leptonic spectrum is therefore explained on the pragmatic grounds of absorbing or "packaging" energy ever more efficiently in the early moments of the Big Bang, when the Universe contained very little space but a lot of energy. The leptoquark is the ultimate energy absorber, compactor, or energy "package".

Of course, almost any amount of energy can be stored in the momentum of a massive particle - also a useful feature for preventing the gravitational collapse of the early Universe. However, an even more compelling reason to create a composite primordial particle is that such a particle can arrange its internal quark sub-units to produce an overall condition of electrical neutrality - like the neutron. Electrical neutrality is a necessary precondition for symmetry-breaking among particle-antiparticle pairs during the "Big Bang", otherwise matter-antimatter annihilations between electrically charged particles cannot be avoided. The primordial mass-carrying, symmetry-breaking particle must therefore be a composite, electrically neutral particle - an electrically neutral leptoquark or its analog.

When the leptoquark is fully compressed by the external pressures of the Big Bang, it is in every respect a heavy lepton, the heaviest member of the leptonic particle spectrum. But when the pressure is relieved, its quarks spring apart from mutual repulsion, and the particle becomes a heavy baryon (hyperon). This is why the leptoquark is the bridge between the leptonic and quark series.

As a fractured elementary particle, the baryon must be held together by permanently confining internal forces, the strong force carried by "gluons", exchanged between the "color" charges of the quarks. For quantum mechanical and symmetry conservation reasons, the baryon cannot be allowed to fly apart; given the absence of antimatter there would be no way to cancel, neutralize, or annihilate the partial charges of its sub-elementary fragments. Permanent confinement to a "virtual" elementary charge state of whole quantum charge units is the only possible solution. Although a "virtual" lepton in terms of electric charge, the baryon cannot undergo leptonic decay because of its explicit and conserved color charge (neutrinos do not carry color charge). If the quarks are fully compressed again, however, the color charge vanishes (the symmetry principle of "asymptotic freedom" - (Politzer, Gross, and Wilczek, 2004 Nobel Prize)) and this obstacle is removed. "Proton decay" can then go forward (via the "X" IVB) with the emission of a leptoquark neutrino. (See: "The Origin of Matter and Information".)

We owe the stability of the proton to the unthinkable energy densities of the cosmic forge in which it was produced. Like Frodo's ring, the proton can only be destroyed in the furnace which created it. Proton decay is probably commonplace today only in the interiors of black holes. (See: "The Half-Life of Proton Decay and the 'Heat Death' of the Universe".)

In summary, the elementary leptonic particle spectrum consists of 3 known members, the electron, muon, tau, and a 4th hypothetical leptoquark, each with its own neutrino (and corresponding antiparticles). They form an energy-absorbing series, each useful at a particular energy density of the early Universe. The heavy leptoquark is the champion energy-absorber with its internal set of compressible quarks. The quark mass spectrum (up, down; strange, charm; bottom, top) has the same energy-absorbing utility as the leptonic series. When, during the Big Bang, the leptoquark finds itself without an annihilation partner (due to the asymmetric decay of electrically neutral leptoquark-antileptoquark pairs - the fundamental weak force asymmetry), its quarks expand as the external pressures of the Big Bang are relieved by the expansion and cooling of the Cosmos (due to the entropy drive of free energy - light's intrinsic motion). Once the quarks have expanded under their mutually repulsive electrical and quantum mechanical forces, the conserved color charge becomes explicit and leptonic decay via the leptoquark neutrino is no longer possible - neutrinos do not carry and hence cannot cancel color charge. The game is over - the leptoquark is trapped - it must leave its symmetric state in Heisenberg virtual reality and enter the 4th dimension of real time as a heavy baryon (hyperon), cascading downward to its lowest energy state, the proton. As it descends in energy, it produces the elementary leptons (via the "W" IVBs) it needs to balance its leptonic unit of electric charge. Such decays are mediated by the IVBs, and they are the only way single leptons are produced as a permanent, net, reaction residue, which is why we find exactly one electron for every proton in the Universe. (See: "The Particle Table".)

Baryons and Quarks (strong force)

The triumph of Nature's energy compaction mechanism is the baryon with its three quarks. In its primordial form this particle is the leptoquark. The model I use for the leptoquark is the "fractured" elementary lepton: baryons (and their precursors, leptoquarks) are elementary, leptonic particles which have been fractured into 3 parts under the great pressures of the initial moments of the Big Bang. The baryon is simply a leptoquark with its quarks expanded and the color or strong force which binds them explicitly revealed. The compacted leptoquark is the highest energy member of the leptonic elementary particle spectrum, with its quarks so tightly compressed that the color charge is implicit, not yet exposed. Hence all particles (baryons and leptons) are leptonic or elementary in their origins, which is why they carry exactly the same unit charges and interact so freely. This is also why we anticipate the existence of leptoquark neutrinos - which in turn are likely "dark matter" candidates.

The "utility" of fracturing an elementary particle into three parts, or "quarks", is twofold: 1) it becomes possible to arrange the internal, partial electric charges of the quarks into an electrically neutral configuration, as in the neutron (electrical neutrality is an essential precondition for the symmetry-breaking production of matter in the "Big Bang"; 2) the fractured particle becomes a much better energy absorber, since its quarks can be compressed, soaking up energy like a set of internal springs. The entire leptonic spectrum of increasing mass (including the quark series) is primarily useful for its energy- absorbing and storage capacity at different stages of the Big Bang, when all the energy of the Universe was confined to a very small spatial volume: much better to store energy as particles rather than waves under these extremely spatially cramped conditions. In fact it seems likely that the Universe could not have begun as a singularity without such an inherent capacity to compactly package its enormous energy content. The particles absorb and dampen the violence of the initial blast (perhaps preventing damage to the dimensional structure of spacetime), just as the mass and inertial momentum of a mountain absorbs the energy of an underground nuclear explosion. Furthermore, massive particles produce a gravitational field of negative energy which exactly cancels their positive "rest mass" energy, allowing the Cosmos to be born in a state of zero net energy and charge (due to the presumed initial balance between matter and antimatter).

Massive particles can also store an unlimited amount of energy as momentum and kinetic energy, a feature of particular utility in preventing the formation of a cosmic black hole rather than a "Big Bang". Another rationale for mass is the benign character of the entropy drive of bound energy, time. Unlike the vitiating "velocity c" (the spatial entropy drive of free energy), the intrinsic motion of time ("velocity T" - the historical entropy drive of bound energy) does not readily dissipate the energy content of mass. Whereas light fully participates in the expansion and cooling of its spatial conservation domain, matter does not similarly participate in the expansion and decay of its historic domain of information (see: "The Time Train"). Matter formed in the Big Bang still contains almost all of its bound energy content, whereas light formed at the same time has cooled to nearly absolute zero, worthless for any work application. The Universe would be a dull place indeed if at least some of its energy content, in the beginning, had not been stored as mass or bound electromagnetic energy in matter for future use. (See: "Spatial vs Temporal Entropy".)

Quarks have a special significance, for without quarks there would be no material Universe. Ordinary leptons are produced and decay symmetrically in particle-antiparticle pairs. There is no escaping the annihilation reactions required by their opposite electrical charges. But this is not true of particles containing quarks, because the quark combinations can sum to electrical zero, as in the neutron. This possibility provides an avenue of escape from the all-compelling electric charge, a window of time in which one member of a neutral leptoquark-antileptoquark pair can undergo a leptonic decay (similar to proton decay), leaving the other pair member without an annihilation partner. If the remaining partner does not also self-destruct immediately, its quarks will expand, the color charge will become explicit, and its neutrino, which cannot cancel color charge, will be unable to consummate a leptonic decay. The leptoquark is consequently trapped in time; its quarks will expand fully as the external pressure allows, and it will become a "real" high-energy baryon ("hyperon") rather than a virtual leptoquark. The hyperon so formed will "cascade" to the ground state proton (via the "W" IVB), producing electrons, mesons, and neutrinos as alternative charge carriers when necessary to balance the electric, color, or identity charges of the various intermediate products, stages, and interactants of the decay pathway. (See: "The Origin of Matter and Information"; see also: "The Higgs Boson and the Weak Force IVBs".)

Leptoquarks can undergo leptonic decay (with the aid of leptoquark neutrinos, the ambient pressure of the Big Bang, or via the "X" IVB) while their quarks are so tightly compressed that the color charge vanishes (the symmetry principle of "asymptotic freedom"). Protons can do the same if their quarks are compressed tightly enough (to "leptonic size"), summing their internal color field to zero, a process requiring enormous symmetrically applied pressure, probably available today only in the interiors of black holes (or via the weak force "X" IVB). The stability of the proton is a testament to the enormous pressures under which it (in the form of a leptoquark) was created.

As the high energy baryon (hyperon) decays to its ground state (the proton), it brings into existence (via the "W" IVB) something else that is unique - single leptons, whose electric charges (which of course are the same as the baryon's own leptonic charge), can be used to balance the proton's electric charge. Hyperon decay (including neutron "beta" decay) is the only pathway through which single, permanent, massive leptons can be created, which is why there is exactly one electron for every proton in the Universe (other reactions can produce single, charged leptons (as in meson or muon decays) but they are always balanced by antiparticles somewhere in the reaction chain, and so are not permanent).

The baryon's quarks must be permanently confined in a simple sense because the baryon is derived from an elementary leptonic ancestor and it must continue to exhibit a unit elementary or leptonic charge. The baryon must be a "virtual" elementary particle, in terms of charge, if it cannot be a "real" one. If the baryon were to actually fly apart, there is no available quantum unit of charge which could cancel, neutralize, or annihilate the partial, sub-elementary charges of its quarks, a disaster for symmetry conservation. The only solution is to permanently confine quarks to combinations which sum to whole quantum units of charge, the leptonic charge units. This task of confinement is accomplished by a field of force carriers called gluons, massless field vectors of the strong force which travel with intrinsic motion c, although wholly confined within the baryon. Thus we find that "keeping up appearances" is important even at the level of elementary particles.

The quark spectrum, like the leptonic one, is useful in a practical sense for absorbing energy. We do not know why it displays the particular pattern it does (3 "families" of paired quark "flavors"); in our present state of knowledge it is, and may remain, a "given condition" of our Universe. Certainly we can understand that these are resonant energy forms of one another, but that does not help us to understand why they display this pattern rather than some other. We have to accept the fact that we live in a conserved, organized Universe, and that in consequence we will observe order and pattern of some sort, but why that pattern has its particular form may not be explicable beyond Occam's principle of the simplest system sufficient for the task (of primordial symmetry-breaking). Perhaps the most reasonable guess is that the three families of quarks and leptons are related to the three dimensions of space - the spatial metric is reflected in the particle metric, because particles are originally formed from an interaction (mediated by the weak force) between the energy of light and the structure of metric spacetime. In such a scenario, the simple leptons would be related to the time dimension and the much more complex quarks to the spatial dimensions. (It has also been suggested that the three "family" structure of the elementary particles is necessary (for technical reasons of quantum mechanics) to produce the asymmetry which characterizes the weak force decay responsible for the creation of matter during the "Big Bang".)

Gluons (strong force)

Gluons are the field vectors of the strong force. Gluons are massless, traveling between the three quarks of a baryon at velocity c. Each gluon is composed of a color x anticolor charge, which it carries from one quark to another. There are three "colors": red, green, blue, and corresponding anticolors (not real colors, just names of convenience). Each quark carries a color charge, which interacts with the color charges carried by the gluon. The interaction changes the quark color; the quark emits a new gluon, which carries a new color combination to another quark, changing its color, and so on ad infinitum. The constant interchange via gluons of color charges between quarks is the binding mechanism of the strong force. Almost all the mass of a baryon is due to the binding energy contained in the gluon field, not in the quarks themselves. (See: "Getting Your Quarks in a Row" by Brian Hayes; *American Scientist,* Nov. - Dec. 2008, pages 450-454.) The standard model of the strong force ("quantum chromodynamics") was worked out by Gell-Mann and Zweig, Han and Nambu, and others, in the mid nineteen-sixties. See *Inward Bound* by A. Pais, 1986, Oxford, for a full recounting of these discoveries.

Conversely to the long-range "particle" forces, electromagnetism and gravitation, the strong force grows stronger with increasing distance rather than weaker, the type of force one experiences when stretching a rubber band. Although this type of force has an explanation in terms of a "round-robin" exchange of virtual gluons traveling at velocity c between quarks, involving energy conservation within the temporal limits of virtual or Heisenberg space, we can understand this force more easily from the point of view of symmetry conservation. As the quarks expand, their partial charges become more exposed to the outside world and hence more of a threat to charge conservation (symmetry conservation), since (given the absence of antimatter) there is no quantum unit charge which can cancel, neutralize, balance, or annihilate the quark partial charges. Charge-symmetry conservation requires these partial charges to be kept close enough together that they effectively sum to whole quantum unit (leptonic) charge values - insofar as the long-range electrical force is concerned - the "outside world". This requirement will define the limits of the spatial volume occupied by the baryon, and the maximum distance between quarks. Hence symmetry/charge conservation and quantum mechanical constraints both conspire to create the strong force, permanently confining quarks via a field of virtual gluons. The strong force has exactly the character one would expect if an elementary particle were fractured into 3 parts, but nevertheless required to remain a "virtual" elementary entity in terms of whole quantum (leptonic) units of charge, as seen by the outside world (via the long-range electromagnetic force).

While the strong force, quarks, gluons, and color charges may seem very complex, they are undoubtedly the simplest system which is sufficient to break the symmetry of the primordial elementary (leptonic) particle-antiparticle pairs. Simply fracture an elementary leptonic particle into three parts so that its partial charges can arrange themselves into electrical neutrality, and the strong force must follow of necessity. This only sets the stage for symmetry-breaking however, and what is still not clear is how or why the weak force asymmetry is arranged - other than by the obvious requirement of the "Anthropic Principle" (the Universe must be so constituted that it allows our existence).

The most important aspect of the color charge is its composition. Gluons consist of color x anticolor charges in every combination; therefore the field in total sums to zero. The field can be physically summed up by forcing the quarks together. When the quarks are fully compressed, the original leptonic elementary particle is recreated and the need for the confining color charge vanishes (the limit of "asymptotic freedom" - Politzer, Gross, Wilczek: 2004 Nobel Prize in Physics).

It requires tremendous energy, symmetrically applied, to force the quarks together against their mutually repulsive electrical and quantum mechanical forces. It is just this resistance to compression that makes baryons such excellent energy-absorbers, and so useful for "packaging" and compactly storing the free energy content of the early Universe. (Other reasons for converting free electromagnetic energy to bound electromagnetic energy include the negative energy of gravity associated with mass, and the storage of energy in a form which is not subject to the vitiating entropy drive of free energy, gauged by "velocity c".)

When the quarks are fully compressed to "leptonic size", the color charge vanishes. This is the leptoquark configuration; the particle is now actually a heavy lepton with only an implicit color charge and it can undergo leptonic decay via the "X" IVB, with the emission of a leptoquark neutrino. During the Big Bang, such decays by neutral anti-leptoquarks isolated their leptoquark partners whose quarks subsequently separated, producing heavy baryons (hyperons), and through their decay, the neutrons, protons, and leptons of the expanding and cooling Universe.

Gluons have been compared to "sticky light". They are no doubt aspects of the electromagnetic field, photons modified in some way to attract each other and the quarks. Gluons must have been produced during the partitioning of the compressed electromagnetic wave packet that was the mass of the original lepton. It is not hard to imagine that as these partitions (quarks) were pulling apart, each produced a particle-antiparticle charge pair (the three colors and anticolors of the gluon field), for reasons of symmetry conservation mentioned above (the quantum mechanical requirement for unit charges). Just as a baryon may be derived from a "fractured" elementary lepton, so a gluon may be derived from a "fractured" photon, splitting the field vector of the primordial leptonic electric charge. Both the fractional charges of the quarks and the fractional gluon field vectors remain permanently hidden from view, as if Nature were ashamed of what she had done.

But how does one get a 3 component color field out of an electrical dipole? One of the colors (green) is apparently neutral, so the color field components can be represented (in terms of electrical analogs) as (+1, 0, -1), with the charges of the anti-colors reversed. Green-antigreen is completely neutral (0 x 0), leaving the 3 x 3 color x anticolor matrix with only 8 active gluons rather than 9, as is indeed believed to be the case. (See: "Proton Decay and the 'Heat Death' of the Universise".)

The Strong Force - Two Expressions

The strong force has two structural levels of expression, quite different, one (discovered by Gell-Mann and Zweig, 1964) between quarks within the individual baryon (mediated by a gluon exchange field), and another (discovered much earlier by Yukawa, 1934) between individual baryons within a compound atomic nucleus (mediated by a meson exchange field). While the internal baryon level of the strong force consists of an interaction among three quarks carrying 3 "color" charges ("red, green, blue") exchanging a color-carrying gluon field, the strong force at the compound nuclear level consists of an interaction between two or more baryons carrying 2 quark "flavor" charges ("up, down"), exchanging a flavor-carrying meson field. The gluon field is composed of virtual color-anticolor charges, and the meson field is composed of virtual flavor-antiflavor charges, so the analogy is complete, except that the gluon field is massless while the meson field is massive. The massless gluon field nevertheless produces a short-range field because unlike photons, the gluons attract each other (gluons have been compared to "sticky light").

Two particle charges unique to the quarks, "flavor" and "color", each produce a version of the strong force, expressed at different structural levels of the nuclear material. The color version of the strong force is expressed within the baryon, producing absolute quark confinement, while the flavor version of the strong force is expressed between baryons in a compound atomic nucleus, producing a very powerful (but not absolute) binding of baryons within the nuclear boundary.

The role of the color charge is to protect charge invariance, charge conservation, and symmetry conservation by maintaining the integrity of whole quantum charge units, hence explaining the absolute character of the confinement of quark partial charges. The role of the flavor charge is also symmetry-keeping, but with respect to energy states rather than charge, which is a more variable function (since energy can be conserved in many forms - as mass, light, heat, linear and angular momentum, nuclear binding energy, chemical binding energy, kinetic and potential energy, magnetic and electrical energy, sound, etc.) The flavor charge contribution in the strong force meson exchange field is to reduce the amount of bound energy (mass) contained in the baryon ground state as far as possible, while not violating the absolute parameters of charge conservation (electric charge, color charge, baryon number charge, spin).

It is the fact that we have two ground state flavor charges (up-down), that allows us to have two ground state baryons (neutron and proton), which can share their virtual meson fields and so bond together by reducing their total bound energy content. Because neutrons spontaneously decay into protons (half-life of about 15 minutes), and protons, given a sufficient energy boost, will revert to neutrons, we see that these two particles are in a real sense simply differently charged versions of one another. This close "family" relationship (as demonstrated by these weak force transformations) is the basic reason why these particles can form a combined "resonance" or "superposition" - the "nucleon" (as demonstrated by strong force bonding).

It is remarkable what a variety of compound atomic nuclei can be produced by the exchange of a simple meson particle-antiparticle pair between proton and neutron (92 natural elements plus hundreds of isotopes). Another remarkable fact is that it requires the input of gravitational energy (as in the stars) to force these nucleons into such close proximity that they will actually bond. They will not bond spontaneously (unlike the gluons), but require some additional external coercion. Hence the nucleosynthetic pathway conversion of bound to free energy is actually the role of gravitational symmetry conservation, not actually an "agenda" of the flavor charge, although we can see symmetry conservation as a role of their combination (flavor charge plus gravitational force). As we have seen, the gravitational force is produced by the time dimension or historical entropy drive of matter. Therefore, the stellar conversion of bound to free energy is ultimately a consequence of the temporal entropy drive of matter, eroding and vitiating the energy content of atoms via gravity. Entropy increase and symmetry conservation work hand in hand.

Flavor charges apparently exist to quantize and regulate, scale, or "gauge" the mass of the several types of quark. The function of quantized flavor charges is to ensure that the mass of quarks is invariant no matter when or where they may be created. The partial or fractional flavor charges of the quarks are not strictly conserved, whereas the "number" or "identity" charges of the leptons (including the leptoquark) are strictly conserved. Therefore we should not refer to leptonic charges as "flavor" charges, but as either "number" or "identity" charges. A (hypothetical) number charge is associated with the leptoquark (and carried in its "bare" form by a leptoquark neutrino), but no number or identity charges are associated with the sub-elementary quarks themselves (there are no neutrinos associated with individual quarks).

The color charge of the strong force clearly has an "agenda" of quark confinement in the service of symmetry and charge conservation, through the protection of whole quantum charge units. The flavor charge of the strong force also has a (less obvious) agenda of symmetry conservation, but not through charge conservation, rather through the release of bound to free energy by funding the energetic mechanism of the nucleosynthetic pathway.

The miracle of the strong force (at the compound nuclear level) is of course the 92 elements of the periodic table (and their many isotopes). These exist only because the proton and neutron can coexist as a "doublet", a paired bound state of nuclear matter which achieves in its combined form (the "nucleon") a state of lower bound energy than either partner could alone. The origin of this miracle goes back to the paired quark families and the ground state "up, down" flavor pairs. Why do quarks come in paired families, anyway? The pairing phenomenon is also seen in the lepton families as they pair with neutrinos, and in the pairing of quark families with lepton families, of meson and gluon charge-anticharge pairs, of matter and antimatter, and even of space and time. The ultimate source of all this pairing is probably electrical, originating with the dipoles of both electric and magnetic fields in the primordial source of cosmic energy, light. When light interacts with the metric of spacetime to produce particles (during the Big Bang), the electromagnetic dipole of light, the tripole of space, and the quadrupole of spacetime are carried into the structural fabric of particles. (See: "Nature's Fractal Pathway".)

Nucleons

The "nucleon" is a combined state of both the proton and neutron, a resonance or superposition of these particles. Because in the combined state the baryons can share their load of "parasitic" virtual mesons, a significant reduction of their total bound energy is possible. This reduced energy is the "binding energy" of the atomic nucleus released in nuclear fusion. The quark composition of the proton is "uud+", while that of the neutron is "udd". The exchange of a (virtual) meson particle-antiparticle pair, ud+ or ud- (antiparticles underlined), changes a proton into a neutron and vice versa. If two protons and two neutrons combine, they can position themselves at the corners of a tetrahedron in which all partners are equidistant. In the tetrahedral configuration meson exchange is especially efficient, as each proton has two equidistant neutrons to play the round-robin exchange game with, and vice versa. This 4-baryon tetrahedron is the alpha particle or helium nucleus, an especially tightly bound and favored nuclear configuration (the "brick" of the nucleosynthetic pathway), and it is easy to see why. The exchange of mesons between neutron and proton is exactly the "sharing of differences" that epitomizes the third stage of the General Systems model. It leads directly to the 4x3 tetrahedral bonding of the alpha particle (4 nucleons each of 3 quarks), and thence to the carbon atom - 3 alpha particles each of 4 nucleons; and so on up the nucleosynthetic pathway in alpha particle increments. (See: "The Fractal Organization of Nature".)

The "nucleon" can also be imagined as a state of higher symmetry than either the proton or neutron alone - the analog of a force unification symmetry state, but expressed at the particle level. This symmetry state was originally given the name of "isospin" symmetry or "isotropic spin" symmetry, and was conceived as a global symmetry state for which meson exchange formed the local symmetry "current" or field vector, and the proton and neutron were the local derivatives.

"Isotropic spin" symmetry or "isospin" symmetry leaves the strong force unaltered when protons and neutrons are interchanged. The name derives from assigning a completely imaginary state of "spin" to the nucleon ("up" for the proton and "down" for the neutron). This theoretical spin state is isotropic (invariant) insofar as the strong force is concerned, whether it is in the up or down "phase". "Global" isospin symmetry was understood as a natural consequence of "local" strong force meson exchange between the nucleons. When the quark model was developed by Gell-Mann and Zweig, the "up" and "down" designations were retained for the ground state quark flavors. The superseded isospin model was then applied to the actual (rather than virtual) weak force transformations of neutrons to protons. The weak force is also a short-range force with massive field vectors, the IVBs. Also like the strong force, meson exchange occurs in weak force baryon transformations, but is mediated by the much more massive IVBs. (See: "The 'W' IVB and the Weak force Mechanism".) (See: Robert Oerter: *The Theory of Almost Everything*. Penguin (Plume) 2006.) (See: James Trefil: *The Moment of Creation*. Macmillian (Collier) 1983.)

Local gauge symmetry is epitomized in the neutral, quiescent nature of the cold, crystalline, ground state of atomic matter, the state we normally occupy that is so life-friendly. Because it is our normal, habitual state, we become thoroughly accustomed to it and forget how remarkable it really is. The heavy elements of which we are composed are very strange particles indeed: the nuclear material is composed of baryons containing 3 colored quarks confined by a massless gluon field exchanged at velocity c. Baryons in turn consist of two kinds, protons and neutrons, bound (in compound atomic nuclei) by a virtual meson field exchanged between baryons, which reduces them both to a common denominator of least bound energy - the androgynous "nucleon". This fantastically complex nucleus is in turn surrounded by a cloud of electrons bound to the nucleus (and each other) by a massless field of exchanged photons. These electric and magnetic fields will allow the creation of molecules and a further hierarchy of chemical structure, information, and complexity.

Nor is this all: these particles and fields are surrounded by (and engender) clouds of virtual particles which contribute to the interactions and total bound energy. Elementary particles carry various conserved charges such as electric, color, identity, and spin, including partially conserved charges such as the local quark "flavor" charges. There are neutrinos associated with each elementary particle (neutrinos function as alternative charge carriers for "identity" or "number" charge); and while all charges are balanced by alternative charge carriers rather than antiparticles, antimatter is abundantly present in the gluon and meson fields, and in the clouds of virtual particles. The photon is its own antiparticle. The whole atomic complex is set within the regulatory metric and entropic fields of spacetime and gravitation, and subject to the exotic transformation fields of the weak force IVBs which can create, destroy, or transform elementary particles, and elevate portions of the material system above the ground state of electromagnetic symmetry to a higher level of force unification (electroweak force unification or even the GUT symmetry level).

The incredible complexity of matter beggars our understanding, and yet in its ground state it is perfectly well behaved and predictable (in its gross characteristics), a benevolent condition necessary to our evolution and survival. The meson field of the strong force succeeds in reducing the energy level of most heavy atomic nuclei to a quiescent ground state. Radioactive decay is not a common phenomenon in our ordinary elements - one has to look rather hard to find it, as the Curies discovered. The local activity of the meson field provides us with a non-radioactive spectrum of stable heavy elements capable of producing and sustaining life - which itself is a whole new level and hierarchy of biological information and complexity, built upon the electron shell and delicate bonding chemistry of carbon atoms and water molecules. At the top of this biological order, humans are building an entirely new information domain of abstract and symbolic thought patterns, imagination, languages, culture, and mechanical and technological systems. (See: "The Fractal Organization of Nature".)

The Intermediate Vector Bosons (IVBs) (weak force)

The IVBs are unusual in that unlike all other field vectors of the "standard model", they are massive. It is the great mass of the IVBs that makes the weak force "weak", that is, slow to act. This is because the energy to produce these massive bosons must be borrowed, and the more energy required, the more difficult it is to borrow it. The "W" and "Z" are about 81 and 91 times heavier than the proton, respectively, and the hypothetical "X" is presumed to be very much more massive still.

The IVBs are probably metric particles, that is, particles composed entirely of the dimensional metric bound into a dense and specific configuration. Their mass is derived entirely from the binding energy required to deform and hold the metric in their own particular way. The IVBs apparently act by engulfing particles within their unique geometry, which brings reactants very close together so they can interact in ways they could not in ordinary, extended space. In this regard the IVBs are like metric catalysts, and resemble the "strings" of string theory. The IVBs are evidently derived from the dense metric of the early Universe, when the reactions they now rarely produce would have been a commonplace of that primordial energy-dense environment. The mass of the IVBs recreates a primordial force unification symmetric energy state, as gauged by the Higgs boson (in the case of the "W" IVBs, the "electroweak" force unification era as it existed during the "Big Bang"). All transformations originating with the electroweak force unification symmetry state or era can therefore be reproduced by the "W" IVB. (See: "The Higgs Boson and the Weak Force IVBs".)

A basic function of the IVBs is to form a bridge between real particles and the virtual particle "sea" of the vacuum; the IVBs thus make available all the electric, number, color, and flavor charges of the virtual particle "sea", so that "real" particles can use them to accomplish transformations and decays, and to materialize and dematerialize as necessary. The IVB is essentially acting like a human "spirit medium" or priest, bridging the gap between the manifest and unmanifest worlds. It is the "magical" ability of the IVBs to contact, catalyze, and materialize the virtual particle "sea" that is their distinguishing characteristic and that requires their unique structure and mass.

The role of the (hypothetical) "X" IVB is to compress the quarks of a baryon so tightly within its dense metric that the color charge self-annihilates, producing a leptoquark. The "X" IVB reproduces the primordial force unification symmetric energy state of the "GUT" era, as it existed during the "Big Bang", as gauged by an appropriate Higgs boson ("Grand Unified Theory" or strong force plus electroweak force unification era). (See: "Table of the Higgs Cascade".) With no color charge, the leptoquark can decay like any other heavy lepton. Proton decay is rare because the mass of the X is so great; the great mass of the X is due to the great energy required to compress the quarks sufficiently to vanish their color charges (the principle of "asymptotic freedom"). The role of the IVBs is to bring real particles and virtual particle-antiparticle pairs into a sufficient proximity, enabling real particles to exchange their conserved charges and energy with the alternative charge carriers of the virtual leptonic and/or meson field, thus manifesting aspects of the virtual field, and so facilitating the decay of the "real" particles to lower bound energy states. (See: "The 'W' IVB and the Weak Force Mechanism".)

The weak force only creates particle "singlets" - isolated particles of matter without antimatter partners. Charge and symmetry conservation require charge invariance over time - elementary particles created today must be the same in all respects as those created in the "Big Bang". The weak force mechanism satisfies this criterion by recreating the original energy-dense environmental conditions (via the huge mass of the IVBs) in which the elementary particles in question were first created.

The most significant feature of the massive IVBs is that they recreate the original conditions of the energy-dense primordial metric in which particles were first created and transformed during the early micro-moments of the "Big Bang". This recapitulation ensures that the original and invariant values of charge, mass, and energy are handed on to the next generation. The IVB mass not only provides a "safe house" where charge and energy transfers can take place, it simultaneously ensures that the appropriate alternative charge carriers are present.

There is a crucial difference between the electromagnetic creation of particles via particle-antiparticle formation, and the weak force transformation of existing particles to other elementary forms. In the case of particle-antiparticle pair creation, there can be no question of the suitability of the partner for a subsequent annihilation reaction which will conserve symmetry. However, in the case of the transformation of an existing elementary particle to another form, alternative charge carriers must be used, since actual antiparticles can only produce annihilations. But how is the weak force to guarantee that the alternative charge carrier - which may be a meson, a neutrino, or a massive lepton - will have the correct charge in kind and magnitude to conserve symmetry at some future date in some future reaction, with an unknown partner which is not its antiparticle? Furthermore, the quark charges are both partial and hidden (because they are "confined"), and the number charges of the massive leptons and baryons are also hidden (because they are "implicit") - they have no long-range projection (such as the magnetic field of electric charge) to indicate to a potential reaction partner the relative condition of their energy state.

These problems are all solved by a return to the original conditions in which these particles and transformations were first created, much as we return and refer to the Bureau of Standards when we need to recalibrate our instruments. The necessity for charge and mass invariance in the service of symmetry, charge, and energy conservation therefore offers a plausible explanation for the otherwise enigmatic large mass of the weak force IVBs. The IVB mass serves to recreate the original energy-dense environmental conditions in which the reactions they now mediate took place, ensuring charge and mass invariance and hence symmetry, charge, and energy conservation regardless of the type of alternative charge carrier that may be required, or when or where the new elementary particles may be created. (See: Global-Local Gauge Symmetries of the Weak Force.)

In the dimensional realm we have seen that space, created by the intrinsic motion of light, is also the entropic conservation domain of light, establishing (via the inertial forces of the metric) the rate of propagation of electromagnetic waves, the symmetry of the dimensional metric, and conserving free energy within a defined dimensional framework. Space also accommodates the additional energy conservation requirements of bound energy through the addition of a 4th dimension, time (an alternative, primordial entropy drive for matter, creating history). The forces of gravitation and inertia, the intrinsic motions of light and time, demonstrate these dimensional conservation properties to our physical senses. (See: "Spatial vs Temporal Entropy".)

But spacetime is also the conservation domain of particles. The fact that a dimensional framework exists (time and historic spacetime) to conserve the energy accounts of matter implies that a corresponding particle framework, a particle "metric", must also exist embedded in the structure of spacetime. The inherent capacity of space and light to accommodate and conserve the dimensional aspects of mass (via time and gravitation) implies also that space and light have an inherent capacity to produce massive particles, and vice versa. Each capacity implies the latent presence of the other: why otherwise should either exist?

For a further discussion of the weak force in its full energy spectrum, see: "The Higgs Boson and the Weak Force IVBs".

Virtual Particles

The manifest world of particles is but the 4-dimensional, explicit, "real" expression of this 2-dimensional, implicit, "virtual" potential of space to produce matter (the elementary particle analog of Plato's realm of "ideal forms"). It is like the metric of spacetime, inherent in the structure and conservation function of light, but expressed in terms of particles rather than waves. This is the particle spectrum of spacetime (the virtual particle "sea" or "zoo"), a spectrum whose full extent we are still exploring with our accelerators.

Ordinarily, this spectrum is expressed only virtually, in the production of particle-antiparticle pairs of different types; if we could identify all the allowed types of virtual particle-antiparticle pairs, we would know what the full particle spectrum is that spacetime is prepared to produce and conserve. Of course, we only see the ones that become real, including those we succeed in producing in our accelerators. But the "vacuum" (spacetime) is at all times full of these virtual pairs, in greater or lesser abundance and duration depending upon the energy required to produce them. It is this background of virtual particles which I refer to as the embedded particle "metric", "sea", or "zoo" of spacetime (the Heisenberg-Dirac "vacuum sea" of virtual particle-antiparticle pairs).

As far as we can tell from the "real" particles which come from the virtual "sea" of spacetime, only a very few particle types are allowed and produced - the particle spectrum is quantized and quite limited, as we have seen in the preceding section. We have identified this particle spectrum as the leptonic spectrum (or series) of elementary particles. This embedded particle spectrum is simply a "given condition" of our spacetime - we can no more explain its form or energy parameters than we can explain the magnitude of c or Planck's constant of energy. But we can learn something about its range and characteristics, depending upon how complete our theories are, how powerful and/or sensitive our instruments are, and what instruments and theories we choose to use. It is only in this century that we have become aware of the virtual particle spectrum embedded in the vacuum, or made much progress in identifying its range in terms of "real" particles; the "top" quark has been found only recently (Fermilab 1994), although long suspected; the "X" IVB particle, the leptoquark (and its neutrino), still exist in theory only. A host of other hypothetical particles may also be present, like fish deep in the vacuum "sea" waiting to be discovered: among others, the particles of supersymmetry and string theory; the "Higgs" boson; and the particles comprising the notorious "dark matter" and "dark energy" of cosmology - if any of these actually exist. The high-energy vacuum of spacetime is like the Earth's ocean depths - we still don't know what is in there. (The leptoquark neutrino (which may be quite heavy) is my choice as a likely candidate for "dark matter".)

We are usually unaware of the virtual particle-antiparticle background of space, just as we are usually unaware of the dimensional metric. We become aware of the dimensional metric through gravitation, time, velocity c, and the inertial forces associated with accelerated motion, and we become aware of the particle "metric" through high-energy physics experiments, radioactivity and "cosmic rays", and because we and the world are made from a materialized portion of it. Of course, one awareness is dependent upon the other - we are aware of the dimensional metric because it affects the massive particles we are made of. What we are usually not aware of is that the universal system is a conserved and integrated whole - particle and dimensions alike. Particles are as much a part of spacetime as light; indeed, particles are made from light (a long-standing hypothesis also proved experimentally only recently - at SLAC). Matter is an asymmetric form of light, 1/2 of a symmetric particle-antiparticle pair, the energy of light brought to rest in the conserved form of an elementary particle.

So long as particles remain as particle-antiparticle pairs, they simply continuously annihilate one another and never intrude into the "real" world of 4-dimensions (we are 4-dimensional chauvinists - the 2-dimensional world is quite real, but it is so symmetric and quantized at such an energy level that we cannot experience it. Light is as close as we get to it, but we only see light when it, too, becomes bound and part of our 4-D world. Our thoughts and dreams are perhaps the only 2-dimensional "virtual" reality we physically experience). Note the grand analogy (awaiting exposition) between the manifestation of 2-D virtual particles via the massive weak force IVBs and the manifestation of 2-D thoughts via our hard-won social comprehension and implementation of natural law. In this we compare the "hard" mathematical structure of natural law plus a formal social structure, to the massive quantum-mechanical mechanism of the weak force and IVBs. (See: "A General Systems Analysis of the Creative Process in Nature".)

Particle Creation (weak force)

The difficult problem is how to bring a single particle of matter (rather than a particle-antiparticle pair) out of the virtual world of 2-dimensions and into the "real" world of 4-dimensions. The problem is one of conservation: the raw energy, the symmetry, and the entropy of free energy must all be conserved in such a transformation. The raw energy of light is conserved as the mass and momentum of particles. Symmetry conservation takes the form of conserved charges (and spin); unless the particle is electrically neutral to begin with, there will have to be electric charge conservation; a gravitational location charge will inevitably be engendered, ushering in the time dimension (conserving entropy and causality); if quarks are involved, there must be a color charge; and finally there must be an "identity" charge (carried by a neutrino), informing spacetime as to the particular type of particle created. (See: "The Origin of Matter and Information".)

An especially difficult problem is that all elementary particles, whether created today or eons ago in the "Big Bang", must be exactly the same in mass, charge, and all other respects - for obvious reasons of energy, symmetry, and charge conservation. It is this problem of charge and mass invariance in the creation and transformation of elementary particles that requires the hugely massive IVBs of the weak force (as scaled by the Higgs boson) to recreate the primordial energy-dense environmental conditions in which these elementary particles originated. Only in this way can they be exactly reproduced, anytime, anywhere, regardless of entropy, the passage of time, the expansion of the Cosmos, etc.

During the Big Bang, the weak force "X" IVB brings (electrically neutral) leptoquarks into the 4th dimension of real time. As these particles cascade downward via the "W" IVB to their ground state (the proton), they bring other single leptons (alternative charge carriers) into existence as required to balance electric charge. The ordinary leptonic field (below the mass energy level of the leptoquarks) functions as an alternative charge carrier for the massive quark field, which in its absence could not manifest, as quarks could, in that case, only balance their charges with antiquarks, resulting in "mutually assured annihilation". The identity of every elementary particle is conserved as an antineutrino (or neutrino) as it is created. All elementary matter particles in the Universe today have a conserved identity in spacetime in the form of an antineutrino. For baryons, this is the antineutrino of the antileptoquark whose decay forced matter leptoquarks to become "real" (the proportion of these asymmetric decays to symmetric particle-antiparticle annihilations is thought to be roughly one in ten billion). I suggest a possible reaction pathway in "The Particle Table"; (or see: "The Origin of Matter and Information"). Since all particles are elementary in their origin (including baryons because of their derivation from leptoquarks), all particles have a conserved identity (and through gravitation, a known location and mass) in spacetime. Finally, through historic spacetime, all events are permanently recorded so long as the Universe does not collapse in a "Big Crunch". (See: "A Spacetime Map of the Universe".)

The philosophers, the poets, and the shamans have known for a long time about the "virtual sea" in its most generalized spiritual and ideal context and meaning (the "Akashic Record" for one example); the scientists of today are investigating its narrowest, most literal, and most specialized aspect. Before we put too much emphasis on the machinery of particle physics, it is well for us to remember that neither "Truth" nor "Beauty" comes out of a particle accelerator, but only out of the abstracting, synthetic, and emergent communicative power of the minds, hearts, and souls of human beings.

Particle Decays (weak force)

The leptonic series of elementary particles - electron, muon, tau, and leptoquark, represent quantum steps or "rungs" in the particle spectrum or "ladder" of spacetime. Elementary particles can be created in these discreet energies but no others (analogously to the discreet quantum energy levels of electron orbital shells in atoms). Each step is distinguished by a corresponding neutrino, which is the (explicit) identity charge and hallmark of an elementary particle: there are no neutrinos associated with the sub-elementary quarks. The hypothetical leptoquark neutrino carries a single identity charge for all baryons; baryons must all return to the leptoquark configuration to decay (the color charge must self-annihilate - "in the limit" of "asymptotic freedom").

An analogous quantum spectrum or series characterizes the quarks; the quark series is of lesser significance than the leptonic one, for just as quarks are sub-elementary, so the quark spectrum is sub-elementary, and has no associated neutrinos. Because quarks can exist only as quark-antiquark pairs (the mesons), or triplets wholly confined within the baryons, they either annihilate each other (the mesons) or their transformations occur within the confines of the baryon. If their transformations require electric charge conservation, then a lepton or a charged meson must be extracted from the virtual particle "sea" by the weak force "W"; flavor transformations among the quarks of a baryon likewise require the services of the "W" IVBs to produce the necessary flavor charges from the mesons of the virtual sea. (See: "The Role of the "W" IVB in Weak Force Transformations".)

The decays of leptons are the simplest to understand (see reactions in "The Particle Table"). Suppose a tau decays into a muon, a favorable symmetry-conserving reaction since the muon is much lighter and the tau can convert a lot of bound energy to free energy in the process. One might think that this reaction would be fast and easy: the tau simply jumps to a lower quantum slot and becomes a muon, shedding excess energy in a flash of light.

But leptons are true elementary particles and their identities must be conserved, both for the tau, which must be destroyed, and for the muon, which must be created. The "W" repackages the tau mass energy into the muon, and produces a tau neutrino to conserve its identity charge. Likewise, a muon antineutrino must be produced to conserve (balance) the muon's identity charge (when the muon decays, the neutrino it releases will cancel this antineutrino). Apparently the "W" "bear hugs" both the tau and a muon-antimuon virtual particle pair so tightly that the tau's mass energy can flow to and materialize the muon at the same time it is annihilating with the antimuon, liberating both the tau's neutrino identity charge and the antimuon's neutrino identity charge in the process. The reaction takes a (relatively) long time because the "W" is so massive and therefore very difficult to produce.

A more complex weak force interaction occurs when a baryon decays from a neutron to a proton ("beta" decay); here an electron must be produced to carry the electrical charge difference. The "W" produces the electron and its antineutrino. The decay of a neutron to a proton is incredibly slow by the standards of particle physics (a half-life of 15 minutes - a trillion times slower than many other weak force decays), because there is barely enough energy difference between the neutron and proton to allow it, and the pathway is very complex, involving a virtual alternative charge carrier meson for the quark flavor transformation as well as the virtual electron-positron pair.

If no elementary particle is involved in a decay or transformation, if there is no leptonic identity to be conserved and no quark flavor to be supplied from the virtual "sea", then the IVBs are not involved in the interaction. There is one apparent exception: the "Z" (neutral) mediates weak force transformations in which two particles swap identities, or simply scatter (bounce) off each other - an electron and its neutrino, for example. In the case of the simple swap, a weak force interaction is nevertheless required because an elementary particle has both disappeared and been produced. This is a dangerous transaction from a conservation point of view, and so requires the safeguard of the structural confines of the IVB. In the case of simple scattering, the point is that the neutrino simply has no other way of interacting with matter except through the mediation of a weak force IVB - which is why it hardly ever does. What other types of particles are "out there" that interact even less frequently or perhaps not at all? These are among the "dark matter" candidates, known only by their gravitational influences, and the leptoquark neutrino may be one of them.

Summary

The derivation of quarks from the leptonic series via the "fractured lepton" model helps us to understand a number of important concepts: 1) the relationship of baryons to leptons - baryons are fractured, expanded leptons, which is why they carry exactly the same electrical charges as, and interact so freely with, leptons; 2) the origin of color charge, a virtual field of quantum-mechanically modified photons which acts to keep this "elementary" particle from coming apart, hence preventing a quantum-mechanical and symmetry conservation disaster; 3) the nature of the leptoquark, a fractured elementary lepton whose quarks have not yet expanded due to high external pressure, and consequently has no explicit color charge; 4) the nature of "leptoquark decay" - having no explicit color charge, electrically neutral leptoquarks can undergo leptonic decay via the "X" IVB, emitting a leptoquark neutrino; 5) the nature of proton decay, again via the "X" IVB, which must follow the leptoquark model, its quarks compressed to "leptonic size" until the color charge vanishes ("in the limit" of "asymptotic freedom"), then decaying with the emission of a leptoquark neutrino - a process that probably can occur routinely only in black holes in the present Universe; 6) why no neutrinos are associated with quarks - quarks are sub-elementary particles which have only a collective identity realized in the leptoquark and conserved as the leptoquark neutrino; 7) the triangular relationship between the strong force, weak force, and the leptoquark. Color and identity charge converge in the formation of the fractured leptonic particle that is the leptoquark and the ancestor of both the baryons and the leptons (strong and electroweak force unification at the GUT energy level).

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The Tetrahedron Diagrams (Text)
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The Hourglass or "Grail" Diagrams

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