Section III, Chapter 8

The Multifamily Conundrum

The Two Extra Families

Despite the successes of the standard model physicists are still haunted by a major puzzle that echos Rabi's consternation over the origin of the muon over half a century ago. This is the enigma of why three families of fundamental particles exist when only one; the 1st, will suffice to build the universe as we know it. The two extra families seem superfluous, and while they are embraced by the standard model, that model simply has no explanation for them.

Of course, the question arises as to whether more families of fundamental particles exist. But, there are compelling reasons to believe that only three families of matter exist. Two independent lines of evidence persuasively fix the number of additional families beyond the first family at exactly two. The first line of evidence came from experiments conducted at CERN and SLAC to evaluate what is called the resonance curve produced from many thousands of Z_0 decays. This curve is traced by plotting the number of Z_0 events detected in the collision debris versus the energy at which the detection occurs. A bell shaped curve is normally the result. The precise shape of this curve is very sensitive to the specific number of families of matter that exist. A steep curve indicates at most two families of matter, while a shallow curve implies as many as four families. The observed curve was exactly halfway between these two extremes. After processing all the data the five teams of experimenters between the two facilities arrived at an average value for the number of neutrino varieties to account for their observed data of 3.09.

For more information on these experiments the interested reader should refer to: "The Number of Families of Matter", by Gary J. Feldman and Jack Steinberger, Scientific American, February, 1991.

The second line of evidence comes from astronomical observations of the relative abundance of helium to hydrogen. Since these two elements constitute the bulk of matter extant in the universe their ratio largely determines the overall ratio of neutrons to protons. The relative abundance of these two nucleons is in turn sensitive to the rate at which the universe cooled in its early history. That cooling rate is influenced by the number of neutrino species, and the observed 3 to 1 ratio of hydrogen to helium favors a maximum of three neutrino types.

What characteristics distinguish members of the different families? Except for mass, the only difference between siblings from one family to the next lies in their lifetimes. All members of the 1st family are known to be stable, although recent extensions of the standard model predict the decay of the proton in an astronomically long time frame (see Decay of the Proton, Scientific American, June, 1981). Unlike the 1st family, most of the particles comprising the 2nd and 3rd generations exist only briefly in high energy physics experiments. However, there are two particles in the higher generation groups which display an exception to this rule. These are the muon neutrino - the 2nd generation cousin to the electron neutrino, and the tau neutrino - the third generation cousin to the electron neutrino. As far as is known these two neutrino varieties, along with their antiparticles, are stable with indefinite lifespans like all 1st generation particles. This is quite curious, and as we shall see this anomaly, along with other factors, provides the basis of a theory that might well explain the existence of the two additional families of matter, and why there are just two extra families and no more. To understand the connection, we must first briefly recap the history of some theoretical ideas in particle physics that emerged during the infancy of quantum mechanics.

The Monopole Connection

In the late 1920's the remarkable British physicist Paul Dirac deduced from a relativistic equation describing the electron's properties, that nature should allow a symmetry relating the electron to a positively charged twin. Within 5 years the existence of the positron was confirmed, and Dirac went on to predict that an antimatter twin should accompany other particles, and these were duly confirmed.

Dirac was also one of the first physicists to explore the possibility of another symmetry transformation - the existence of magnetic monopoles. A magnetic monopole, by definition, is an isolated magnetic charge, either north or south, and entails the transposition of the roles of the electric and magnetic fields as seen in ordinary matter. Speculation about the existence of monopoles can be traced back for centuries, but it was Dirac who first suggested a theoretical underpinning for their existence. He demonstrated that the quantitization of electric charge would be required if monopoles existed. Readers who may be interested in the details of his theoretical argument should refer to the article "Superheavy Magnetic Monopoles" in the April, 1982 issue of Scientific American by Richard A. Carrigan Jr., and W. Peter Trower. The legacy of the Dirac monopole today lives on in the form of the GUT monopole, postulated in various grand unified theories. GUT monopoles are expected to possess enormous mass, on the order of 10^{15} proton masses. As such, their creation could only have occurred in the early stages of the universe's evolution, when temperatures (and therefore energies) were high enough for such massive particles to form.

The concept of the magnetic monopole leads quite naturally to an intriguing speculation. If, as Dirac proposed, monopoles should exist as a result of a quantitization condition, then might not analogues of Dirac monopoles exist outside the immediate domain of the electromagnetic field? As already noted, the weak force is understood to possess two quantitized weak color charges analogous to electric charge in QED. But the weak charges differ in one very significant way from their electromagnetic counterpart. The field around an isolated electric charge extends out to infinity falling off in intensity by the inverse square of the distance. In contrast, the field emanating from a weak purple or orange charge extends only to a distance of about 10^{-16} cm.

For Dirac monopoles to be created topologically from a elementary electric charge, would require essentially reining in the the far flung lines of electric force going out to infinity, and realigning them in a dipole configuration. Similarly, the original dipole magnetic field of the spinning particle would also need to be retracted from an infinite dispersal and restructured into an isotropic, or hedgehog configuration with all magnetic force lines pointing radially outward. When this exercise is performed the topologies of the electric and magnetic field lines of the original particle are essentially interchanged, and a pair of magnetic monopoles results, possessing opposite magnetic charge. Since there is no net magnetic charge, this quantity is conserved in the transformation. In the original Dirac theory a "tail" connects the two monopoles, but recent mathematical advances have dispensed with this undesirable appendage.

If the lines of force emanating from a charged particle were finite instead of infinite, intuitively one might expect less energy would be required to reconfigure them into a monopole configuration. Just this condition, of course, characterizes the weak field whose influence extends only to a range of 10^{-16} cm. If a secondary magnetic type field is associated with the weak field, possessing the same restricted range, then concievably quantitized weak magnetic monopoles might be produced in copious quantities at relatively low energies. If so, why have they not been detected yet?

The answer may be that they have. Concievably, here may lie the explanation for the muon neutrino and tau neutrino (see figure 2 below). Since the electron neutrino is itself a quantitized unit of weak charge, it could be that its heavier cousins the muon neutrino (v_μ) and tau neutrino (v_t) constitute quantums of weak magnetic pole charge - one corresponding to the weak magnetic north monopole, and the other the weak magnetic south monopole. The respective antiparticles of the muon neutrino and tau neutrino could simply correspond to the antimonopoles. Thus, these neutrinos may in reality constitute south/antisouth and north/antinorth weak magnetic monopole sets. To establish a convention we will assign the south/antisouth monopole set to the v_μ and $\bar{\nu}_\mu$ and the north/antinorth monopole set to the v_t and $\bar{\nu}_t$. It should be emphasized that this choice for the time being is purely arbitrary, we could just as easily have chosen the reverse assignments (see figure 3 below).

The stability of the v_μ and v_t makes sense in this context, as the weak monopoles would constitute elementary quantum particles whose annihilation could only occur by a chance meeting with their antimatter counterpart. But, since the interaction cross sections of these weakly charged particles are vanishingly small this process should be extremely rare. Also, assuming these are the lightest particles carrying this charge these neutrinos could not decay into any other particle.

How does the concept of weak magnetic monopoles fit into the observed multifamily particle structure? To understand this we must first delineate the role of the weak color charges in particle interactions. As stated, two weak color charges characterize the weak force in the

Effective range of electro-magnetic field.

Effective range of electro-weak field.

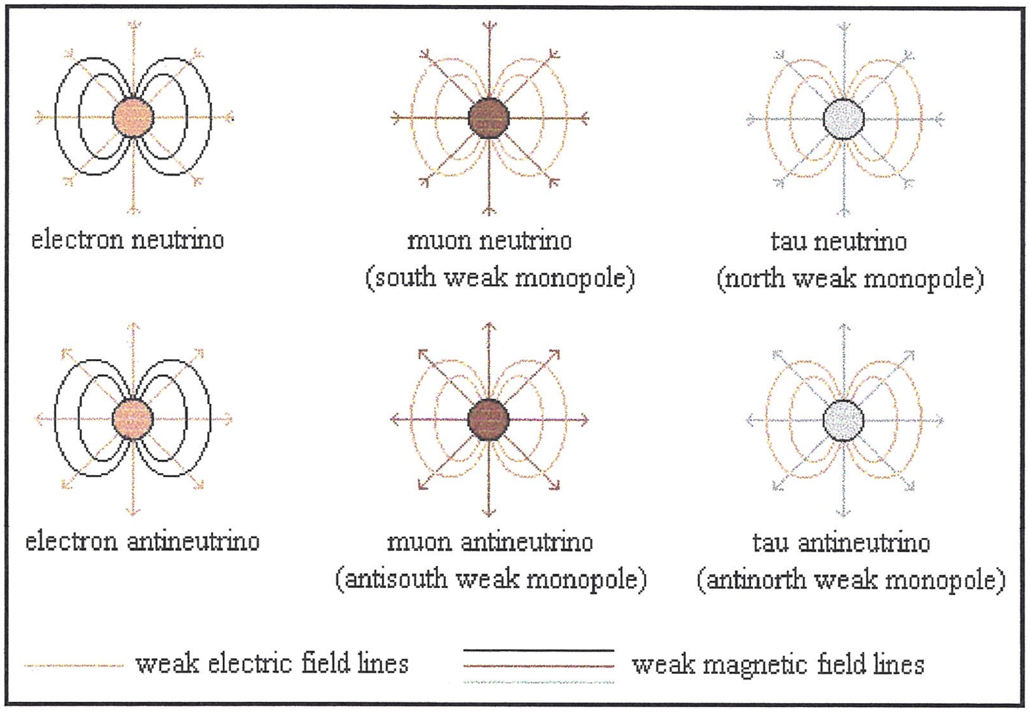
Monopoles

While the classical Dirac monopole and its successor - the modern GUT monopole - are calculated to possess enormous mass (10^{15} GeV, for the latter), it may be that the restricted range of the weak force (10^{-16} cm.) dramatically reduces the energy required to topologically restructure its field into a monopole configuration. This implies a much smaller mass for the resultant particles, perhaps in fact, the masses observed in the muon neutrino and tau neutrino.

Figure 2

standard model. These weak color charges can only be transformed by the action of either a ±W. Additionally, only left-handed particles and right-handed antiparticles carry weak color charge.

A good example of these features of the weak force is illustrated by the decay of the neutron. Figure 1, on page 58, shows neutron decay (beta decay) at three different resolutions. The left most drawing shows the neutron decaying into a proton, electron, and electron antineutrino. At a finer detail (middle) we see the quark composition of the hadrons, and also that the emission of the electron and electron antineutrino is mediated by a W^-. In the right most



The Neutrinos

The muon neutrino and tau neutrino are unique among the higher generation particles in that they are stable. It's speculated that these siblings of the electron neutrino are in actuality quantums of weak magnetic charge; weak field analogues of Dirac monopoles. In Dirac's original theory the north and south magnetic monopoles are antiparticles of one another. Here, it is proposed that the 2nd and 3rd generation neutrinos correspond to weak magnetic pole/antipole sets. The separate colors used to represent the weak north and weak south magnetic charges underlines the distinct identities of the v_{μ} and v_{t}.

Figure 3

diagram we see that the original weak orange charge of the neutron's left-handed d quark is transformed via the W^- into weak purple charge and coupled to the proton's left-handed u quark. Additionally, the W mediates the transfer of orange charge to the electron antineutrino, and the coupling of antipurple charge to the left-handed electron.

It's important to emphasize that neutron decay is entirely a 1st generation process; that is, only 1st generation particles are involved. But, what happens if we attempt to illustrate the decay of a higher generation particle by the same method, showing the weak color charges before and after the decay? These transitions are also mediated by the weak force. Can we assume the weak color charges present in the 1st generation particles are simply paralleled in their higher generation siblings, thus leading to the same weak color charge transitions? Perhaps not. Intuitively, one suspects that the 'flavors' of the higher generation particles are in some way connected to their weak color charges.

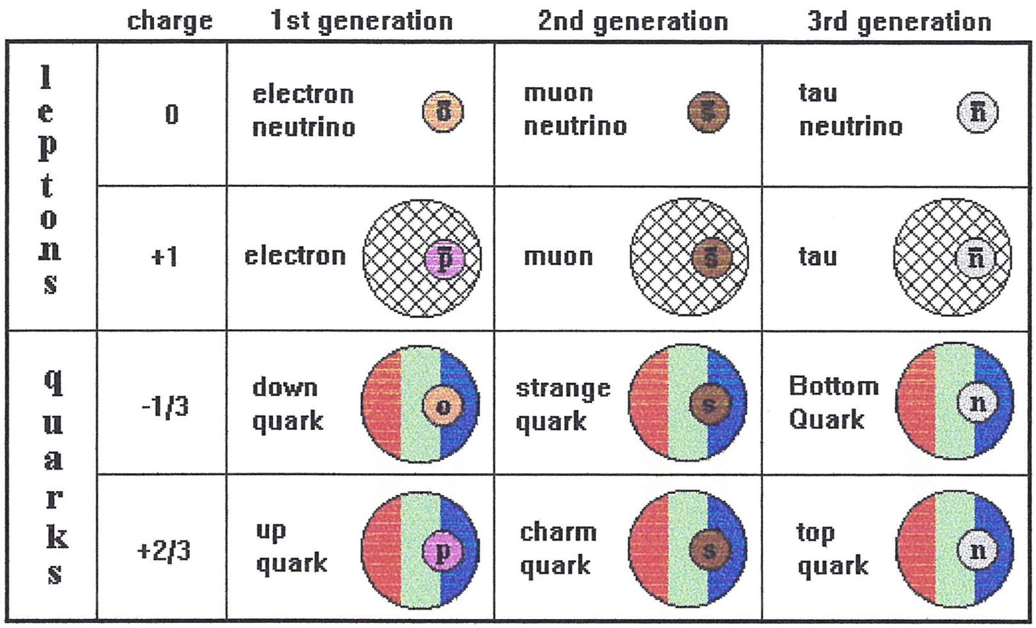
The weak monopole concept provides just such a connection. In so doing it establishes an explanation for the limit of two extra families, and other phenomena unique to the weak interactions. To accomplish this requires making a crucial assumption about the nature of 2nd and 3rd generation particles. That assumption, simply stated, is that the 1st generation weak color charges are replaced in the higher generation particles with new color charges corresponding to the charges associated with the weak magnetic monopoles. This simple assumption has powerful and far reaching consequences as we will see.

Putting the Pieces Together

Remember that the proposed weak monopole family structure consisted of a south/antisouth monopole set and a north/antinorth monopole set corresponding to the $\nu_{\mu}/\bar{\nu}_t$ and the set $\nu_t/\bar{\nu}_t$ - the 2nd and 3rd generation neutrinos, respectively. It then logically follows that strangeness and charm in the 2nd generation quarks, and muonness in 2nd generation charged leptons is a manifestation of either a south or antisouth weak monopole charge substituting for one of the 1st generation weak color charges. Likewise, 3rd generation quarks and charged leptons must arise from the substitution of 1st generation weak color charges by a north or antinorth weak monopole charge. Figure 4 lists the assignments of weak color charge, including the newly proposed weak magnetic monopole color charges.

What about the number of extra families and the process of associated production of quarks? Since there are only two poles in a dipole field the limit of two additional families is automatically established. Then, since the pole charges exist in matter-antimatter sets this accounts for the phenomena of associated production in quarks, and the conservation of lepton number in the 2nd and 3rd generations. Virtually all higher generation flavors are produced in associated production. For example, when a particle carrying one unit of strangeness is produced in a high energy collision it is always created in accompaniment with a particle carrying one unit of antistrangeness, so that the net amount of strangeness is the same before and after the interaction. Associated production must then simply reflect the conservation of weak magnetic pole charge. Exactly the same process occurs with regards to higher generation lepton production. Muons are always produced in pairs of opposite electric charge and family number, or in association with a neutrino carrying the opposite family number value. Again, pair production of opposite weak magnetic pole charges must be the explanation.

When a 2nd or 3rd generation quark decays to a 1st generation quark, it has always been assumed that the higher generation flavor is not conserved. But this cannot be true as the arguments advanced, so far, implicitly require the conservation of the higher generation quark flavors. When the weak color diagrams are worked out, it is seen that flavor conservation in higher generation decays is effectuated by the evolution of a neutrino pair. One of



<u>Origin of Higher Generation Quarks and Leptons</u>

Quantums of weak color charge are indicated by the small colored circles. The red/green/blue colors filling the larger circles (denoting the quarks), suggest the continuous interchange of strong color charges for a quark bound within a baryon (leptons do not carry strong color charges). The two weak color charges of the Standard Model (orange and purple) carried by all 1st generation left-handed particles are indicated with inscribed letters 'o' and 'p' (a bar over the letter indicates the weak color anticharge).

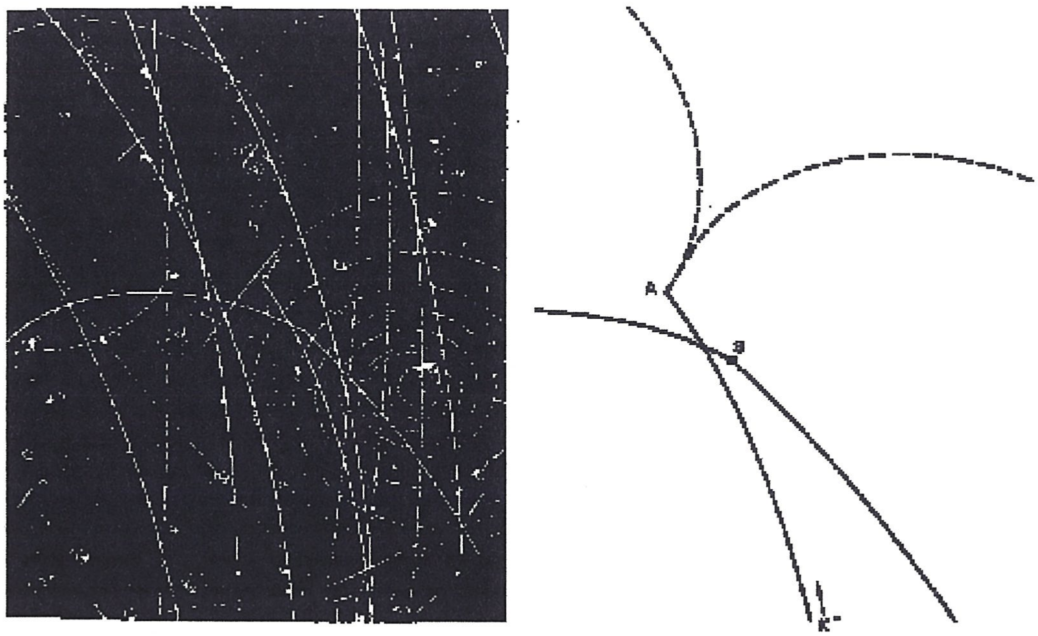
It's proposed that the 2nd and 3rd generations arise as a result of the substitution of the standard color charges with color charges corresponding to weak magnetic monopoles - brown for a weak south monopole, and grey for a weak north monopole. The muon neutrino and tau neutrino are postulated to constitute the weak monopoles themselves, identified with the inscribed letters 's' and 'n', respectively.

Figure 4

these neutrinos will always belong to the generation of the original quark, while the other will be an electron neutrino or antineutrino. It always works out that the two neutrinos have opposite helicity, thereby conserving the spin quantum number for the interaction. The higher generation quark 'flavor' then is simply the weak color charge associated with a weak magnetic monopole. Since the v_μ and v_t are the lightest particles carrying this weak color charge, ultimately the quark flavor must be transferred to one of them (or their antiparticles).

Is there any evidence for neutrino emission in higher generation hadron decays, where none are expected? Indeed, there is. Figure 5 illustrates a lambda hyperon decay arising from the reaction $K^- + p \rightarrow \Lambda + \pi^0$. The lambda originating at point (A) travels in a straight line to (B), and because it is electrically neutral it is not deflected by the magnetic field. Visual inspection clearly suggests missing momentum at the vertex labeled (B). At this point the lambda with a strangeness of -1 decays into two visible particles - a proton and a negative pion, neither of which carries any strangeness. Neutrinos, of course, rarely interact with matter, so the absence of a visible track or tracks to account for the apparent missing momentum is understandable. Unfortunately, this image, like others of its kind was not available in a stereo photographic set, so that a precise and unambiguous accounting of momentum is not possible. However, out of a small sample of eight other bubble chamber photos of higher generation hadronic decays, six gave a tantalizing suggestion of missing momentum.

Finally, we come to the question of why the masses of siblings from one generation of quark or lepton to the next vary so enormously. Between the down quark and top quark there is a 12,000 fold increase in mass. Though not as extreme the mass differential between the electron and tauon is nearly 4,000 to 1. There is divided opinion whether all particle masses derive from their coupling to the hypothetical Higgs field, or if a prequark substructure is the ultimate source. The Higgs field postulated by Peter Higg's of Glasgow University is thought to permeate all of space and has the unusual property of possessing a broken symmetry in its lowest energy state.



Possible Missing Momentum

A neutral lambda originating at (A) decays into a proton and negative pion at (B). Careful measurement of the curvatures of these two charged particle tracks and their initial trajectories reveals missing momentum. The uncertainty in this measurement is the amount of displacement each track may possess in the camera axis, since this would skew the results. Six of eight other 2nd generation hadron decays revealed similar indications of momentum discrepancy. It is proposed that this apparent momentum shortfall is accounted for by the emission of a neutrino pair - one of which carries away the higher generation flavor. (photo courtesy CERN)

Figure 5

In the Weinberg-Salam electroweak theory the W and Z bosons and other particles acquire their masses through coupling to the Higgs field by varying degrees.

But there are equally compelling arguments to support the belief that the masses of the fundamental particles arise from an additional layer of structure. For sure, the mass spectrum observed between the three particle generations cannot be a direct function of the mass values of the proposed weak pole charges since the upper mass limits established for the v_μ and v_t are fractions of the masses of the 2nd and 3rd generation quarks and leptons. Instead these masses may derive from residual uncancelled mass-energy, if it is assumed that the weak charges constitute a component of some, as yet, unknown prequark substructure (prequark being used here in a generic sense to embrace a possible substructure to charged leptons as well).

The classical electron radius ($r_e = 2.8 \times 10^{-13}$ cm) precludes the possibility that the weak charges are the primary prequarks, since conservation of angular momentum in such a confined space demands energies in the multi-Gev range for such hypothetical prequarks. This is much greater than the energy needed to produce 2nd or 3rd generation particles. A secondary role for weak charges in a prequark substructure is not ruled out, but it implies a more complex substructure than envisaged in contempory prequark theories such as the Rishon model proposed by the Israeli physicist Haim Harari. Harari presents an excellent and highly readable exposition of his theory in the April, 1983 issue of Scientific American.

To summarize, the weak monopole hypothesis ties together virtually the entire gamut of weak force phenomena within a single conceptual framework (in chapter 7 we'll look at another weak force phenomena). Its principle physical consequence - the emission of a neutrino pair in higher generation hadronic decays - needs to be confirmed if the theory is to be validated. Should the concept turn out to be a correct description of real world physics, it automatically leads to a considerable simplification of the standard model. The concept also suggests a fruitful line of enquiry in probing higher energy regimes not yet attainable with existing accelerator facilities and ties directly into the field interchange hypothesis.

So by extending the field interchange concept to the components of the weak field we can explain one of the great puzzles of modern physics. If this explanation of the multiple families of matter can be experimentally confirmed it will lend additional support to the larger field interchange concept. This in turn will give further evidence to the reality of the UFO phenomenon.

In the next chapter we will look at how the concept of weak magnetic monopoles can resolve another puzzle of contemporary physics, the origin of parity and CP violation.