

# CASSIOPEIA'S ToE

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## Baryons and Leptons

What are baryon number and lepton number? First of all they are conserved counts of fundamental fermions – particles of  $\frac{1}{2}$  integer spin. Being fermions puts them in the category “matter” as opposed to integer spin fundamental objects, which are in the category of “force”.

Wherever there is a conservation law, there is corresponding symmetry under transformation, and Baryon number can be thought of as the conservation of “charge” corresponding to the QCD Lagrangian being invariant under U(1) transformations. There are five charges (and conserved currents) invariant under U(1) in the Standard model. Three of them are Baryon Number, Lepton Number and Hypercharge. (These may be accidental symmetries of the Standard Model, but they are symmetries none-the-less.) The Standard Model fails to tell us how the universe arrived at its current imbalance of baryons and leptons over their anti-particles.

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In Field Theories with local gauge symmetry and an exactly conserved quantity (like electric charge), there should be a corresponding long-range gauge field with a massless gauge boson. However, no such field (interaction) is known that corresponds to conservation of Baryon Number (or Lepton Number)

So Baryon number conservation is considered an accidental global symmetry. It is allowed to be broken through the electroweak chiral anomaly. And there are Grand Unification Theories that permit proton decay and Baryon and Lepton number violations at extremely high energies.

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In the Standard Model, there are 3 generations (mass levels) of fermion particles in the Lepton Family (leptons interact Weakly but not Strongly) as well as 3 generations of Quarks (which interact both Weakly and Strongly). Flavour is a term used to refer to the particles of each group. The electron, muon, and tau and their corresponding neutrinos are the 6 flavours, of Leptons. And while, each flavour is not by itself universally conserved, the total count of Leptons is conserved – this is Lepton Number.

Similarly, Baryon number is the count of quarks (divided by 3 since each quark baryon number is  $\frac{1}{3}$ )

And in our wormhole view, we can let this number be a count of the (spin-1/2) wormholes between Fields (that is wormholes connected to more than one Field). But spin becomes a major factor in this count since all bosons connect to more than one Field as well. It will turn out to be necessary to let spin be a property of the wormhole (or at least of the vibrational mode that causes the wormhole).

Lepton Number is a count of fermion wormholes (spin-1/2) that connect the gravity Field with the weak Field— one such wormhole per lepton. Anti-leptons have the directionality of that wormhole reversed. So a wormhole and an anti-wormhole cancel each other out and conserve Lepton Number ( $T_3$ )

Similarly Baryon Number is a count of fermion wormholes that connect the gravity Field with (BOTH Weak and) the Strong Fields. Since all quarks couple to the weak interaction, all baryons also have a weak I-spin number.

QFT requires that each generation be an irreducible representation of  $SU(2)$ , so we should use different Fields to represent each generation. In the case of the electron, muon, and tau, they all couple to the Weak Field and can transform into each other through the path of neutrino emission and an intermediate W-boson state.

(SIDE NOTE)

The neutrino oscillations indicate that neutrinos have mass, but the mechanism by which they gain this mass suggests a Majorana term – which would violate Lepton number in units of 2.

If we started with equal numbers of protons and antiprotons, and if antiprotons could decay into leptons, it would explain the current balance in the universe and perhaps also explain the equality of electric charge between the electron and the proton. (my own idea)

## Generations

What is the difference between electrons and muons and taus?

In the Standard Model, each flavor is a  $U(1)$  symmetry, and the trio is  $U(1) \times U(1) \times U(1)$

If we extend the Standard Model to include neutrino masses, flavor violations are “allowed” but extremely suppressed to the point of “not happening”.

In the wormhole visualization, we will represent that the difference lies entirely in their coupling to the Higgs Field. And this fact requires us to represent each generation in their own field. Perhaps the lightest is only the fundamental frequency connecting to the Higgs Field while the second and third generations

include the 2<sup>nd</sup> and 3<sup>rd</sup> harmonic respectively as well as the fundamental frequency.