

# Quark–Lepton Families and Irreducible Anomaly-Free Sets in Flipped Trinification

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We develop a model-independent framework to construct **quark–lepton families** in flipped trinification,  $SU(3)_C \times SU(3)_L \times SU(3)_R \times U(1)_X$ , for arbitrary charge embedding. The approach identifies and classifies **Irreducible Anomaly-Free Sets (IAFS)**—minimal fermion multiplet combinations that cancel, by themselves, all gauge and mixed anomalies:  $[SU(3)_{L,R}]^3$ ,  $[SU(3)_{L,R}]^2 U(1)_X$ ,  $[SU(3)_C]^2 U(1)_X$ ,  $U(1)_X^3$ , and  $\text{grav}^2 U(1)_X$ . We show how Standard-Model families arise as unions of a small number of IAFS and derive general constraints relating family replication to color, recovering well-known 331-like non-universality as a limiting case. For each IAFS we provide electroweak-viable charge assignments, discuss the scalar content needed for the sequential breaking  $SU(3)_L \times SU(3)_R \times U(1)_X \rightarrow SU(2)_L \times U(1)_Y$ , and outline renormalizable Yukawa structures that generate realistic quark and lepton masses (including right-handed neutrinos) while controlling exotic states. The classification maps directly onto phenomenology, predicting patterns for extra neutral currents ( $Z'/Z''$ ), exotic quark/lepton charges, residual discrete symmetries, and typical flavor textures. Our results provide a modular “building-block” toolkit to engineer flipped-trinification models from **quark–lepton families** and their **irreducible anomaly-free** combinations, clarifying which embeddings remain compatible with current collider and flavor constraints.

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