Gaining and Losing a Direction: Lepton Capture and Neutrino Capture in the Simplex Patterns

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Abstract

In IDWT a particle is a pattern of identical portions occupying the lattice points of a simplex: n levels in d bound directions, with S(n, d) = C(n + d − 1, d) portions. Every such pattern is exactly a stack of patterns one direction smaller. The two members of each weak pair differ by one bound direction: down-type quarks (three) and up-type quarks (four); neutrinos (five) and the electron and muon (six). A weak transition is a pattern gaining or losing that direction: it becomes the pattern it is a layer of, or it drops onto one of its own layers. The shapes decide which transitions exist; the masses decide which way they run. Run downward in mass they are decays and lepton captures. Run upward, with energy supplied from outside, they are the reverse of decay: neutrino capture, in which a neutrino gains its sixth direction and becomes the charged lepton whose layer it is. It completes that lepton's stack of layers with portions taken from the matter it hits, and the mass of the new lepton is paid by the target and the impact. The layers also order the flavor content of the neutrinos: the first neutrino is a layer of the electron, the second and third are not, and the electron-flavor neutrino is the flavor dominated by the first mass state with the smallest share of the third, as measured.

1. The patterns

Particle	Depth d	Level n	Count C
down	3	1	1
strange	3	4	20
bottom	3	16	816
up	4	3	15
charm	4	20	8,855
top	4	72	1,215,450
neutrino 1	5	10	2,002
neutrino 2	5	15	11,628
neutrino 3	5	22	65,780
electron	6	13	18,564
muon	6	35	3,838,380
tau	10	23	64,512,240

The bound directions are built in blocks: the three observed directions, the fourth direction, and hidden pairs. Down-type quarks bind the observed three; up-type quarks add the fourth; neutrinos bind five; the electron and muon bind six; the tau binds ten. The bottom quark's mass sits between 16 and 17 levels (the flavor paper); its 16-level pattern is used here. The three neutrino patterns are the three mass states.

2. Every pattern is a stack of the next smaller patterns

For every depth d and level n,

$S(n, d) = S(1, d - 1) + S(2, d - 1) + \ldots + S(n, d - 1)$.

A d-simplex with n levels is cut, parallel to one of its sides, into n slices, and the slices are the $(d - 1)$-simplices with 1, 2, …, n levels. These are the pattern's layers. A pattern of depth $d - 1$ is a layer of a pattern of depth d exactly when its level is at most the larger pattern's level.

Quark layers. Up (three levels) is a stack of tetrahedra with 1, 2 and 3 levels: its first layer is the down quark. Charm (twenty levels) is a stack of tetrahedra with 1 to 20 levels: its first layer is down and its fourth is strange.

Lepton layers.

Charged lepton	Its five-direction layers	Neutrinos among them
electron, 13 levels	1 to 13 levels	neutrino 1 (10 levels)
muon, 35 levels	1 to 35 levels	neutrinos 1, 2 and 3 (10, 15, 22 levels)

The first neutrino is the tenth layer of the electron. The second and third neutrinos, with 15 and 22 levels, are larger than the electron's 13 and are not among its layers. All three are layers of the muon. The tau is ten-dimensional, so its layers are nine-dimensional; the neutrinos sit inside its five-direction faces, which have 23 levels.

3. Two directions of one transition

A weak transition connects a pattern and a layer of it, one direction smaller.

- **Losing a direction:** the pattern drops onto one of its layers.
- **Gaining a direction:** a layer becomes the larger pattern it belongs to.

The shapes decide which transitions exist. The masses decide which way a transition runs on its own. Gaining a direction lowers the mass in down → up and raises it in neutrino → electron, so the direction gained or lost carries no sign of its own. In every observed quark decay the mass falls, while the count rises in two and falls in two:

Decay	Count	Mass
down → up	1 → 15	4.70 → 2.16 MeV
bottom → charm	816 → 8,855	4,186 → 1,273 MeV
charm → strange	8,855 → 20	1,273 → 92.9 MeV
top → bottom	1,215,450 → 816	172,600 → 4,186 MeV

Beta decay is the down quark gaining the fourth direction and becoming the up quark whose first layer it is. Charm to strange is the charm quark losing the fourth direction and dropping onto its fourth layer.

4. Losing a direction in the lepton sector: lepton capture

A charged lepton bound to a nucleus can drop onto one of its neutrino layers, while an up quark in the nucleus drops onto its down layer:

charged lepton + up → neutrino + down.

Charge is conserved: $-1 + 2/3 = 0 - 1/3$.

- **Electron capture.** An inner electron is absorbed by a proton, which becomes a neutron, and an

electron neutrino leaves; for example $^{7}Be + e^{-} \rightarrow {}^{7}Li + \nu_e$. The electron loses its sixth direction and drops onto its tenth layer, the first neutrino.

- **Muon capture.** A muon in a muonic atom is absorbed the same way, $\mu^{-} + p \rightarrow n + \nu_\mu$. The muon drops onto one of its neutrino layers; it has all three.

These run on their own when the nucleus can absorb the energy, as decays do.

5. Gaining a direction: neutrino capture, the reverse of decay

A neutrino at rest cannot gain a direction: every charged lepton is far heavier. When the neutrino brings energy from outside, it can. It gains its sixth direction and becomes the charged lepton whose layer it is, while a down quark in the target gains the fourth direction and becomes an up:

neutrino + down → charged lepton + up.

Charge: $0 - 1/3 = -1 + 2/3$. This is beta decay with the neutrino moved to the incoming side: in beta decay the down gains the fourth direction and a lepton pair is created; in neutrino capture the down gains the fourth direction and the incoming neutrino gains its sixth.

The antineutrino version runs the quark side the other way. An antineutrino gains a direction and becomes a positron while an up quark drops onto its down layer:

antineutrino + up → positron + down.

These are the charged-current processes by which the neutrinos were first detected:

Process	Gains or losses	Threshold	First observed
$\bar{\nu}_e + p \rightarrow e^{+} + n$ (reactor antineutrinos)	antineutrino gains a direction; up loses one	1.806 MeV	Reines and Cowan, 1956
$\nu_e + {}^{37}Cl \rightarrow e^{-} + {}^{37}Ar$ (solar neutrinos)	neutrino gains a direction; down gains one	0.814 MeV	Davis, Homestake, 1968
$\nu_\mu + n \rightarrow \mu^{-} + p$ (accelerator neutrinos)	neutrino gains a direction into the muon; down gains one	about 110 MeV	Lederman, Schwartz and Steinberger, 1962
$\nu_\tau + N \rightarrow \tau^{-} + X$	neutrino gains a direction into the tau	about 3.5 GeV on a nucleon at rest	DONUT, 2000

The geometry is the same in every row: the incoming neutrino is a layer of the charged lepton it becomes. Neutrinos are also detected without gaining a direction, by neutral-current and elastic scattering, in which the neutrino stays a neutrino.

5.1 Where the new portions come from

A neutrino becomes a charged lepton by taking on portions from the matter it hits. The electron is a stack of thirteen five-direction layers, and the first neutrino is its tenth. Becoming the electron means building the rest of that stack around it:

Layers of the electron	Portions
layers 1 to 9	3,003
layer 10, the first neutrino	2,002
layers 11 to 13	3,003 + 4,368 + 6,188 = 13,559
whole electron	18,564

Each portion carries the unit of the family it is bound in. In the neutrino the 2,002 portions carry the neutrino unit, and the whole neutrino weighs less than an electronvolt. In the electron all 18,564

portions carry the lepton unit, 27.53 eV, which is the electron's mass divided by its count. Becoming the electron therefore means adding 16,562 portions and binding all 18,564 at the lepton unit: 511 keV, less the neutrino's own mass.

That mass is paid by the matter that is hit and by the impact:

- **A free neutron.** In $\nu_e + n \to e^- + p$ the neutron becomes a proton and gives up 1.293 MeV of mass. That covers the electron's 511 keV with 0.782 MeV to spare, which leaves as motion. The capture has no threshold: an impact of any energy completes it.
- **A proton.** In $\bar{\nu}_e + p \to e^+ + n$ the target gains mass instead: the neutron is 1.293 MeV heavier than the proton. The impact must supply that and the positron's 511 keV, together with the recoil: the threshold is 1.806 MeV.
- **A bound nucleus.** For chlorine-37 the nucleus that is hit must gain the mass difference of argon-37 over chlorine-37, and the threshold is 0.814 MeV.

Below the threshold the impact cannot pay for the new lepton and nothing happens. So a neutrino turns into the lepton because it is already a layer of that lepton. It completes the pattern with portions taken from what it hits, and the target's change of mass and the energy of the impact pay for binding them.

6. Which neutrinos fit which leptons

The neutrinos that interact with a charged lepton are flavor states, mixtures of the three mass states. The layers say which mass states each charged lepton holds directly:

Charged lepton	Neutrino layers held directly
electron	neutrino 1 only
muon	neutrinos 1, 2 and 3

The measured electron row of the lepton mixing matrix is the one dominated by a single mass state, the first, with the smallest share of the third:

Flavor	Share of mass state 1	Share of mass state 2	Share of mass state 3
electron	0.68	0.30	0.022
muon, best fit	about 0.11	about 0.43	about 0.46
tau, best fit	about 0.21	about 0.27	about 0.52

At three standard deviations the muon row spans 0.05 to 0.28, 0.18 to 0.50 and 0.40 to 0.61, and the tau row 0.06 to 0.29, 0.20 to 0.52 and 0.37 to 0.58.

The electron flavor holds mostly the first neutrino, the one the electron has as a layer, and least of the third, the largest; the ordering follows the levels $10 < 15 < 22$. Its second and third components are reached through a corner: the first neutrino is a corner of the second and third, at the same depth. The muon holds all three as layers, and its flavor state has large shares of the second and third. The tau holds all three inside its five-direction faces, as it would any five-direction pattern of up to 23 levels, so the shapes do not separate the muon and tau rows.

7. Summary

Every simplex pattern is a stack of the next smaller patterns, and the two members of each weak pair differ by one bound direction. A weak transition is a pattern gaining or losing that direction. The shapes decide which transitions exist; the masses decide their direction. Losing a direction gives the decays and lepton captures. Gaining a direction with energy supplied gives neutrino capture, the reverse of decay, by which the neutrinos were first detected. The neutrino completes the charged

lepton with portions taken from the target, and the target’s change of mass and the impact pay for binding them. The same layers order the flavor content of the neutrinos: the first neutrino is a layer of the electron, and the electron-flavor neutrino is the flavor dominated by the first mass state.

8. Open items

- The magnitudes of the lepton mixing. The electron captures and emits the electron-flavor state, which holds 30% of the second mass state and 2.2% of the third, though only the first is its layer. The corner overlaps 2,002/11,628 and 2,002/65,780 give 0.17 and 0.030 for the second and third shares, against the measured 0.30 and 0.022.
- The difference between the muon and tau rows.
- The tau differs from its neutrino by five directions, not one; its transitions are not a single gain or loss.