Comments on The Second Creation

Dave 10/20/20 - 11/10/20

"The formulation of the Standard Model is one of the great achievements of the human intellect—one that rivals the genesis of quantum mechanics. It will be remembered—together with general relativity, quantum mechanics, and the unravelling of the genetic code—as one of the most outstanding intellectual advances of the twentieth century" { Silvan Schweber, Science historian, 1997}.

On Cosmic Rays (chapter 9):

The most common **primary** cosmic ray particles from outer space are the proton at 89% followed by roughly 10% alpha particles and a 1% balance made up of nuclei from other stellar-synthesized elements up to iron – or rarely up to lead. We may also find neutrons electrons and neutrinos. High-energy primary particle coming from space collide with nuclei in the upper atmosphere to generate a spray of particles which later interact in their turn. **Few "if any of the primary radiation survives at sea-level."** *{…Consider that 14 psi pressure means that 14 pounds of atmosphere lie above every square inch, or a **ton** is above every square foot—can cosmic rays punch through that?}.*

Among the **secondary** particles are more protons, neutrons, positive and negative pions, and positive and negative kaons. Some of the pions and kaons decay into muons and neutrinos. **"Muons dominate the charged particle spectrum at the Earth's surface"** (about 75% muons and 25% electrons and positrons). "150 muons are striking every square meter of the Earth every second."

The AMS on the International Space Station {Sam Ting Spectrometer, CERN}: Early results confirm an unexplained excess of high-energy positrons in Earth-bound cosmic rays," and positron fraction peaks at a maximum of about 16% of total.

"EAST-WEST EFFECT:" our book didn't mention that cosmic rays tend to come from the west. This is due to the Lorentz Force F=qv× B where the Earth has a magnetic north pole near its geographic south pole so that the B field points up near the equator. Then a velocity v radially inwards crosses B-up to give F to the right—from west to east. This implies that the charge on the rays is mostly positive {q > 0}.

On the first modern quantum mechanics paper:

Steven Weinberg said, "I have tried several times to read the paper that Heisenberg wrote on returning from Heligoland" and "have never understood the motivations for the mathematical steps in his paper." "Perhaps we should not look too closely at" it.

{Understanding **Heisenberg's** ''magical'' paper of July 1925: A new look at the calculational details Ian J. R. Aitchisona) Department of Physics, }
http://www.mat.unimi.it/users/galgani/arch/heisenberg25amer_j_phys.pdf

We just read a whole **chapter 7** on how the tiny **Lamb Shift** was measured between the $^2s_{1/2}$ and $^2p_{1/2}$ hydrogen levels. Why? Hans Bethe discussed this new shift in 1947 at Shelter Island and wrote a three page non-relativistic calculation for it on a return train trip. Freeman Dyson called this article "a turning point in the history of physics," Dirac said "the most important calculation in physics for decades," and Feynman said "the most important discovery in history of QED." It showed the power of mass renormalization to sidestep infinities and made the correction tangible.

Ref. [Maclay] G. Jordan Maclay, "History and some aspects of the Lamb Shift," Physics 2020 *covered 95% of the Lamb effect.*

P 204 The 1956 "Theta-Tau" mystery particles of identical mass decay to 3 pions versus 2 pions with implied parity + and - 1. But the parent K meson only has -1 parity -– ? Solution: parity P is not conserved in weak interactions. This eventually led to the Yang&Lee Nobel prize. The old names "$\theta-\tau$" are now called K^o_{long} and K^o_{short} – two mesons that oscillate into each other with time. K mesons have a strange quark and a light quark. If a 'u' is replaced with a bottom quark, b, the 60 year old θ-τ problem is repeated with this new neutral strange meson (called B^o_s).

Fermi's idea for beta decay (pg. 241) was that just as an electron can radiate a photon, let a nucleon radiate an electron-neutrino pair. The "Fermi constant," G_F, for this process can be measured from the decay $^{14}O \rightarrow {}^{14}N^* + e^+ + \nu_e$. It was eventually seen that G_F was proportional to $1/M_W^2$ – so, it is tiny because the mass of the W is big (80 GeV).

Neutrinos do not have a charge and do not participate in the strong interaction that exists in all nuclei. Thus, neutrinos typically pass through normal matter unimpeded and undetected.

Fermi theory is Not renormalizable and breaks down crudely near $1/\sqrt{G} \sim 290$ GeV.

What is the neutrino electron cross section? 10^{-42} cm^2

For typical neutrinos produced in the sun (with energies of a few MeV), it would take approximately **one light year of lead** to block half of them. {10^{-44} for 1 MeV neutrinos). Ref: https://cds.cern.ch/record/677618/files/p115.pdf Introduction to Neutrino Physics 85 pages.

{Fermi coupling constant $G_F/(\hbar c)^3$ =1.66 x10^{-05} GeV^{-2} [Page 202],. $\hbar c$ = 197MeV fm's = 0.197 GeV·fm's So G_F = 0.0076 GeV^3 fm^3 · 1.66 10^{-05} GeV^{-2} = 1.27 x10^{-07} GeV·fm^3.

P 208 On the Garwin Lederman 1957 muon experiment: The Downfall of Parity -50 years ago.
https://www.actaphys.uj.edu.pl/fulltext?series=Reg&vol=39&page=251

$\pi^- \rightarrow \mu + \nu_\mu$, $\mu \rightarrow e + \nu_e + \nu_\mu$,

Overthrow of parity says that muons have spin oriented in the direction of motion (natural polarization) https://fas.org/rlg/021557%20Garwin-Lederman-Weinrich.pdf+

Positrons from decaying muons only go forwards while electrons from μ-'s are only emitted in a backwards direction.

On the Wu/Ambler experiment: $^{60}Co \rightarrow {}^{58}Fe + e + \nu$. The nucleus has spin up in a **B** field, e^-'s go in opposite direction rather than an expected up and down hemispheres.

Repeat: $^{58}Co \rightarrow {}^{58}Fe + e^+ + \nu$. Positron e^+ 's go in same direction as S and B.

P 288 The Lederman, Schwartz, Steinberger experiment: AGS protons hit Beryllium→ pions → muons and muon neutrinos. Then ν_μ + matter → μ in a spark chamber (and not e's !) ⟹ muon-ness. Muon-ness is different from electron-ness, so we have 4 leptons (e, ν_e, μ, ν_μ). So, match this with 4 quarks, (u,d,s,c). The concept of charm explaining the absence of weak neutral currents is very difficult to grasp, p 292- very complex Feynman diagram.

Page 265: The phrase "Charge is a generator" can be confusing. *Charge is the source of electromagnetic field from which derive from potentials, A. The topic here is Quantum Electrodynamics beyond just Schrodinger "matter waves" (where charge might not be relevant). It depends on the given existence of a varying electromagnetic vector potential field A(x,t); that the wave function ψ(x,t) phase can be transformed to* $e^{iqA}\psi$ *if accompanied with a change in the derivative (made "covariant" to include the addition of A); and that A itself can be gauge transformed without affecting any field physics. It also assumes that all this can be put into a "Lagrangian, L(x,t)." Charge, q, is the source of a massless particle, the photon; and* the photon is the agent that ensures the gauge symmetry."

QED has a U(1) group symmetry which remains after the symmetry breaking of the electroweak theory $SU(2)_w \times U(1)_y \rightarrow U(1)_{EM}$. The U(1) Y refers to the gauge symmetry for Hypercharge, and its generator is the hypercharge operator Y. It transforms just like EM: Gauge transformation $\phi \rightarrow \phi' = e^{i\alpha(x)Y}\psi$, and covariant derivative $D_\mu = \partial_\mu - iYA_\mu$ (with a different type of field A).

Gell-Mann's "Eightfold Way" Page 267 Is slightly difficult and would be clearer if represented by quarks for each meson and baryon. That is, we now know the final SU(3) flavor foundation in terms of the lightest quarks like s u d; so re-do the diagrams using these in place of isotopic spin and strangeness. We did this when reading Facts and Mysteries of Elementary Particle Physics by Martinus Veltman back in 2012 (his page 230). On page 281 of our book we read: "larger representations are built up by fitting together an array of the smallest." {and the smallest is the SU(3) u d s triangle}. Veltman showed pictures of how the octets and deciplets are built from stacking triangles.

From a quark perspective, Isotopic spin is really "u-ness" (or "u-ness minus d-ness") with $I_{z\,uquark} = +\frac{1}{2}$. So d is not u and has $I_z = -\frac{1}{2}$ (reduced from proton being the triplet p = uud and n = udd) and is analogous to electron spin $s_z = +\frac{1}{2}$ and $s_z = -\frac{1}{2}$ for spin projections up or down in a z-direction (u or d – and see p 193). The charge of the u-quark is Q= + 2/3 and charge d is – 1/3 electron charge; so Q(uud) = 4/3-1/3 = +1 for p and Q(udd) = 0 .
Masses $M_u \sim 2.2$ MeV and $M_d \sim 4.7$ MeV are both very light (versus $M_{strange} \sim 96$ MeV and M charm ~ 1270 MeV).

By his early convention, strangeness S = -1 for the s quark (sort of like Ben Franklin arbitrarily selecting the electron charge to be negative – DC circuits might have been easier with a positive choice for electron-current flows).

On page 268, the Kaon K+ or k^+ meson is u with anti-s while the k^- is s and anti-u. On the middle plot, the Delta Δ++ is uuu while Δ- is ddd – triples are ok since each has a different "color" –*page 259 says that the* ***Δ*** *was discovered by Fermi* {NOTE that the isotopic spin is then + 3/2 and – 3/2 rather than the mislabeled middle deciplet plot of + 1 and -1 – did you catch that?}. There is more information shown in: www.sackett.net/DP_.pdf2 (pages 211-218, "Lie Group Representations"). The decuplet **10** can be understood simply without much math because key quark spins are aligned {e.g.,| ↑ ↑ ↑ 〉 }. It predicts the "Omega-minus" particle Ω^- = {sss} with three strange quarks and helped solidify Gell-Mann's quark model.

To stack 3 of the same fermion things together implies that each s must have some new additional quantum number {like red, green and blue color with the combination making "white"}.

Baryon flavor group $SU(3)_F$ was no longer considered to be fundamental after finding the additional c b and t quarks and is mainly now used for gluon/quark colors, $SU(3)_c$.

On page 272, an alternate attempt at SU(3) by Sakata used p,n and Λ particle as bases – the lambda is sud, so Gell-Mann's strangeness might have been minus lambda-ness. The omega-minus is sss.

Page 278 The bubble chamber photo is actually much more complex with many more tracks: A beam of Kaons K^- hits Hydrogen protons p and one goes to:

$$K^- + p \rightarrow K^o + K^+ \Omega^- \rightarrow \pi^- + \Xi^o \rightarrow \gamma + \gamma + \Lambda^o \rightarrow p + \pi^- .$$

Or s-ubar + uud → d-sbar+ u-sbar+ sss, then sss→ uss+ d-ubar {'bar' meaning anti-particle}. A missing s is due to a weak decay like s→ u + W^- boson→ d-ubar. And finally, Λ = dus → uud + d ubar via a K^-.

Technically, this process isn't a "V" but a final unbalanced high-energy proton and pion which are both charged and visible on bubble tracks.

288 The <u>Lederman, Schwartz, Steinberger experiment:</u> AGS protons hit Beryllium→ pions → muons and muon neutrinos. ν_μ + matter → μ in a spark chamber (and not e's !) ⟹ muon-ness. Muon-ness is different from electron-ness, so we have 4 leptons (e, ν_e, μ, ν_μ). So, match this with 4 quarks, (u,d,s,c). The concept of charm explaining the absence of weak neutral currents is very difficult to grasp, p 292- very complex Feynman diagram.

For what happened **<u>after</u>** <u>our 1984 book</u> see, **"The Last Decade in Experimental Particle Physics,"** (e.g., Page 99-116: Neutrino oscillations 2001+, quark-gluon plasma 2011, bottom CP violation 2006, and finally the Higgs in 2012).

http://www.sackett.net/DP_Stroll.pdf. And pages 117- 122 is on " Rotations of Base States." For example, the weak bosons <u>do not see</u> quarks the way the strong force does! In place of seeing a d quark, a "W" sees two superimposed quarks as d' = $\cos\theta_c$ d + $\sin\theta_c$ s. (θ_c is called the Cabibbo angle). Cabibbo should have received a Nobel prize for this!

<u>Gerard 't Hooft</u> wrote up a summary of his contributions and perspective as referenced below. It is a hard paper but shows the level of difficulty in solving renormalization and also the strange difficulty of later problems. All of this is a realm of extreme genius. Gerard 't Hooft, "Renormalization of Gauge Theories, 1998."
https://cds.cern.ch/record/375133/files/9812203.pdf

Renormalization, writes David Tong, a theorist at the University of Cambridge, is "arguably the single most important advance in theoretical physics in the past 50 years."

<u>Relevant Nobel Prizes after 1950:</u>

1955 Willis Lamb
1957 Lee and Yang
1960 Don Glaser, Bubble Chamber
1965 Feynman, Schwinger, Tomonaga

1969 Gell-Mann
1976 Richter and Ting (Charm)
1977 Phillip Anderson
1979 Weinberg, Salam, Glashow, Electroweak theory
1980 Cronin and Fitch (K meson Charge-Parity violation).
1984 Rubbia, van der Meer, W an Z at CERN
1988 Steinberger, Lederman, Schwartz mu-neutrino
1990 Friedman, Kendall, Taylor partons
1995 Perl tau lepton
1999 Veltman t'Hooft Yang-Mills electroweak theory
2002 Koshiba and Ray Davis, neutrinos
2004 Gross, Politzer, Wilczek asymptotic freedom
2008 Nambu, Kobayashi, Maskawa {"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"}
2013 Englert and Higgs {Higgs mechanism}

Page 219 "The Bronx High School of Science" had 8 Nobel Prize Winners:
Leon N. Cooper {1947, Cooper pairs for BCS}, Sheldon Lee Glashow (1950), Steven Weinberg *and physicist Gerald Feinberg,* Roy J. Glauber {1941, Optical coherence}, Russell A. Hulse {1966 first binary pulsar}, H. David Politzer {1966, QCD β-function} , Melvin Schwartz {1949, neutrino beams}, and a chemist Robert J. Lefkowitz {1959 for his work with G protein-coupled receptors}. But then there was also: Lenny Susskind, and Neil deGrasse Tyson (1976).

This, my 6th reading of The Second Creation was just as interesting and thought provoking as the previous readings. It is a very rich and challenging book, and I'm sure I'll read it several more times for the knowledge and enjoyment of history.

"The Square Root of Reality:"

In Quantum Mechanics, real measurement probabilities obey Probability $=\psi^*\psi$, where ψ all by itself is complex, $\psi(x,t) \in$ C. Hamilton's quaternions, H, were the first example of "hyper-complex numbers" which, in this case, have three different square roots of -1 called i, j, k). Electron spin uses Pauli matrices σ^i such as $\sigma^1\sigma^1 = I$ (and the sigmas {in $\sqrt{I}$ } are in "complex quaternions," C×H. "Numbers" beyond this are represented by **matrices**. For the case of hypercomplex 4×4 "gamma matrices, γ^{μ}'s" the Dirac equation can be considered as "the 'square root' of the relativistic Klein-Gordon equation" which itself a wave equation for spin-zero particles with mass (page 84).

That is, {$\sqrt{\ }$ } : $[\partial^{\mu}\partial_{\mu} + (mc/\hbar)^2]\,\Psi = 0 \rightarrow i\hbar\gamma^{\mu}\partial_{\mu}\psi - mc\,\psi = 0$, where $\partial_{\mu} \equiv \partial / \partial x^{\mu}$ for index-mu values 0,1,2,3 – and $(\gamma^i)^2 = -I$ for i=1,2,3. For just the derivatives part, we could write: "d'Alembertian" $\Box\psi = (\gamma^{\mu}\partial_{\mu})(\gamma^{\nu}\partial_{\nu})\psi$.

The Alien New World of Gamma Matrices:
One can make a 4^2 bigger space by considering combinations of **products** of these gamma-matrices such as $\gamma^5 = i\,\gamma^0\gamma^1\gamma^2\gamma^3$ which is needed for describing intrinsically "right and left handed" particles used in the theory of weak interactions. Being subject to this bigger expanded {and to us} alien "gamma space, Γ^A's ", **allows**

<u>very strange new things to happen</u> that are beyond what we see in our Euclidean world – like **making antimatter** such as positrons, and doing time reversal, and breaking mirror symmetry (parity). Do electrons "live" in this expanded world, or is its math isomorphic to some similar reality?

There is an operator for antimatter called 'charge conjugation' that can look like the product C= i $\gamma^o \gamma^2$ operating on state Ψ(r,t). Time reversal can be T = i $\gamma^1 \gamma^3$; Parity is P = γ^o.

The combination PCT = $\gamma^o \gamma^5 = \gamma^o \gamma^o \gamma^1 \gamma^2 \gamma^3$ gives essentialy no action, 1x. Any QFT is invariant under the operation PCT.

If γ^μ refers to a vector, $\gamma^\mu \gamma^5$ is an "axial vector" (page 211, changes sign in a mirror similar to the cross product for ordinary vectors A×B).

"Fermi interactions" turned out to involve a <u>combination</u> of these such as **" V-A"** = vector minus axial vector or $\gamma^\mu (1-\gamma^5)$, pages 210-214, 1958.