Particle Physics \( \rightarrow \text{pog.161-80} \)

**Summary of Matter**
- Elementary particles: Smallest possible pieces

**Composite Particles**
- \( p, n, \) nuclei, \( \pi, K, \eta, \phi, \) \( \omega, \) \( \Lambda, \Lambda' \)
- \( \Delta^+, \Sigma^+, \Sigma^0, \Sigma^- \) \( \text{baryons} \)
- \( s = 0, \frac{1}{2} \)

**Elementary Particles**
- No internal structure

**Quarks**
- \( u, d, s, c, b, \) \( \tau \)
- \( s = \frac{1}{2} \)
- \( \bar{u}, \bar{d}, \bar{s}, \bar{c}, \bar{b}, \bar{\tau} \)
- Leptons + quarks obey Pauli E.P.

**Leptons**
- \( e^+, e^-, \mu^+, \mu^- \)
- \( \nu_e, \nu_{\mu}, \nu_\tau \text{ in sum} \)
- \( p = u u d \)
- \( n = u d d \)

**Weak I/A**
- Weak charge can distinguish \( s, s' \)
- Left-handed particle + right-handed particle
- Left-handed particle: direction of spin opposite motion
- Right-handed particle: direction of spin same as motion
- Weak I/A not mirror-symmetric
- Single quarks do not exist because color charge is
  so strong
- Can't see color charge
different colors are always attracted to each other

3rd kind of charge: color charge
- Red, green, blue
  - P = + +
- Every quark comes in 3 colors
- Leptons don't have color

- What kind of quark, anti?, L/R-handed, color
  If quark is L, anti-quark is R
- Each color has anti-color, quarks carry anti-color

Bosons (S=1)
- EM: 8 photon
- Weak:
  - d = u + e⁻ + Z
  - W⁺, W⁻, Z°
  - Have mass (heavy)


electron

- Gluons carry 2 charges: color + color
- 8 Gluons

Mesons: 1 quark + 1 anti-quark
- \( \pi^+ \) u\( \bar{d} \)
- \( \pi^0 \) u\( \bar{u} \)

Baryons: 3 quarks

- Standard model: describes everything in observable universe
- Can make predictions, e.g., magnetic dipole moments

Lagrangian = Recycle

Higgs Boson: very heavy particle (2nd heaviest)
- Everything gets mass because of interaction with Higgs field
- More IA = more mass
- Quantum Chromo Dynamics