Summary

- Lessons
- Questions

- Minimal model → 2D Dirac Hamiltonian
  → interaction connections to HEP
  - Energetic reason: linear dispersion over ~3 eV (high energy QC)
    ARPES (Lanzara)
  - Symmetry: Inversion, Time reversal (Haldane)

- Low energy physics close to the Dirac point!
  - Disorder
  - Electron-electron
  - Electron-phonon
  - Electron-plasmon (doped)
  - Multilayers
  - Mesoscopics

Disorder

- Conventional (semi-conductors) (Das Sarma, Von Oppen, Nomura, MacDonald, Pereira)
  - Long range (Coulomb), short range
- Exotic (connections to soft condensed matter)
  - gauge disorder (Shankar)
  - ripples (Geim)
  - topological defects (Dresselhaus, Vozmediano)
    - pentagons, heptagons, Stone-Wales
- Weak (anti-) localization (Guinea, Efetov, Falko, Geim, de Heer, Sheng)
- Strong-localization
  - Zitterbewegung → Multi-particle production (inflation?) (Sheng)
  - FQHE ? (Goerbig)
  - Applications

Interactions

- Perturbative RG
  - Short range → Irrelevant
  - Long range → Marginally Irrelevant
    - → $v_F = v_F^0 + e^2 \ln\left(\frac{\Lambda}{k}\right)$
      (Guinea, Vozmediano, MacDonald, Vafek, Herbut, Wunsch, Shankar)
- Intermediate to Strong interactions → New phases
  CDW, Ferro, Antiferro
- High magnetic fields (Quenching of Kinetic energy)
  → Landau level splitting (Kim)
  QH Ferromagnet (Nomura, MacDonald, Sheng)

Electron-Boson interactions

Boson = phonon, plasmon

- Strong-coupling (RPA/MAK) (Dresselhaus, Kim, Hwang)
- Density dependent (")
- Effect on dispersion "Kink" (ARPES) (Lanzara)

- Where is superconductivity? K.E.
  - Proximity Effect (Lau, Andrei)
    - Cooper pairs
  - Supercurrent flow (?) only Delft (?)
- Can superconductivity be helped? (Uchoa)

Multilayers

- Sanee issues + inter-plane hopping (Bras, Basov, Wilson, Stauber)
  - stacking order
  - Moire patterns (Santos)
  - turbostratic graphene (Dresselhaus)

- Graphene x Epitaxial Graphene (Geim, Kim) / (de Heer)

No prejudice !

Graphite (3D) (Tsai, Basov, Andrei)

↑

Graphene (2D)

Edges (Brey, Fertig)

↑

Ribbons (1D)

Nanotubes + B.C.

Mesoscopics

New quantum numbers (higher symmetries)
- Valley
- Chirality

→ "valleytronics" (Beenakker)

→ "neutrino" billiards (Lau)

→ negative refraction index (Falko)