Accelerator Physics

Application-driven Field

- Particle physics
- X-ray production
- Medical applications

Linear & Circular Geometries

Linear accelerator (above) and cyclotron (right)

Exotic Beam Generation:

Superradiance from bunched beam (left)

Timeline

Fundamental theme: new acceleration schemes push the field forward
Particle Physics: At the 'Naturalness' Crossroads

A Third Direction?

Higgs Meta-stability?

Welcome to Physics 18N!
Biophysics

Can we answer the questions from biology with the methods from physics?

**Technological Developments**
- imaging
- electronics
- spectroscopy

**Quantitative Methods**
- dynamical systems
- statistical mechanics
- signal processing

**Timeline**
- 1771: Galvani discovers "bioelectricity" by stimulating a frog leg
- 1905: Einstein publishes Brownian motion
- 1944: Schrödinger’s "What is Life?" lectures
- 1950s: X-ray crystallography is used to determine the structure of proteins and DNA
- 1990: Denk invents two-photon microscopy
- 1997: Steve Chu wins the Nobel Prize for optical trapping, later applied by Steve Block to study molecular motors
Ultracold atoms

Timeline
1924-25: Theory for Bose-Einstein condensation
1960: Invention of laser
1987: Laser cooling and trapping of neutral atoms
1995: First Bose-Einstein condensation in atomic gas

Quantum Simulator:
- Emulate quantum physics in real solids
- Hamiltonian engineering:
- Artificial potentials
- Interaction control

Precision measurements:
- Atomic clocks: $10^{-16}$ stability (1s in 300 million years)
- Test of fundamental physics: equivalence principle, etc.
Condensed Matter

Key Questions:
- What are the possible phases of matter?
- How do transitions between such phases occur?

Some, but not all, superconductors will levitate when placed above a magnet.

The quantum Hall effect is a quantization that appears in macroscopic samples and has been measured to a part in $10^9$.

1928: Bloch's theorem proven
1950: Landau and Ginzgberg develop general theory of phase transitions
1966: Kadanoff proposes block-spin renormalization group
1980: von Klitzing discovers quantum Hall effect
1986: Bednorz and Muller discover high-temperature superconductivity
2005: Fu and Kane propose topological insulators
Cosmology

What is the structure of the universe?

- 1929: Hubble discovers redshift increases with distance
- 1965: Penzias and Wilson discover CMB
- 1981: Guth proposes theory of cosmic inflation
- 1992: COBE detects CMB anisotropy
- 1998: High-Z Supernova Search Team discover accelerated expansion
- 2003: WMAP establishes Lambda-CDM standard model
- 2013: Planck supports Lambda-CDM, inflation