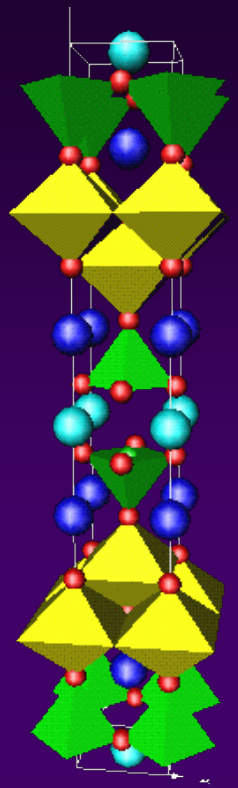
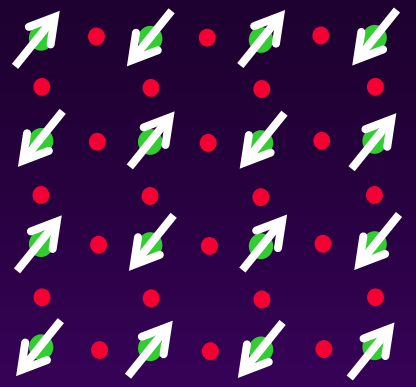
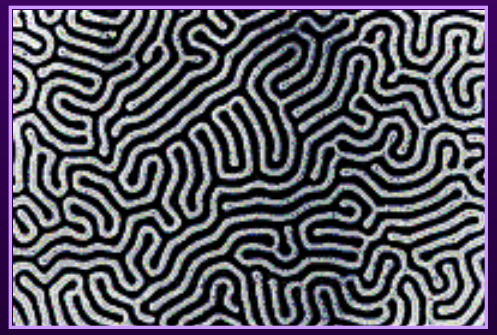




The Secret Life of Electrons in High Temperature Superconductors



Erica W. Carlson, PhD

PURDUE
UNIVERSITY

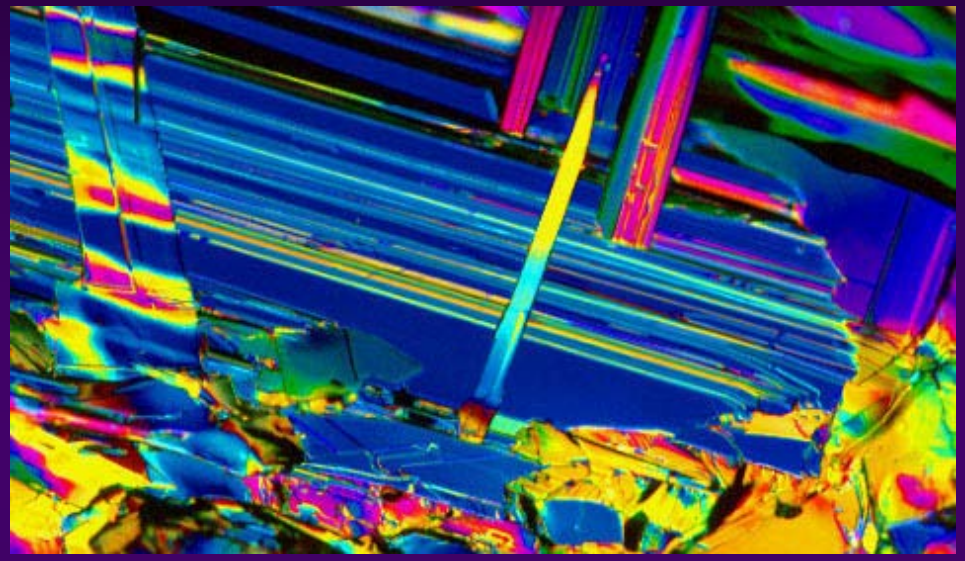
Metals

- Shiny
- Smooth
- Malleable
- Carry current (conduct electricity)

Metals and Current

- V = IR
- Resistance
- Wires radiate power away as heat
- You pay for more electricity than you receive!
- Electrons “scatter” off lattice, and lose energy

Superconductors



http://micro.magnet.fsu.edu

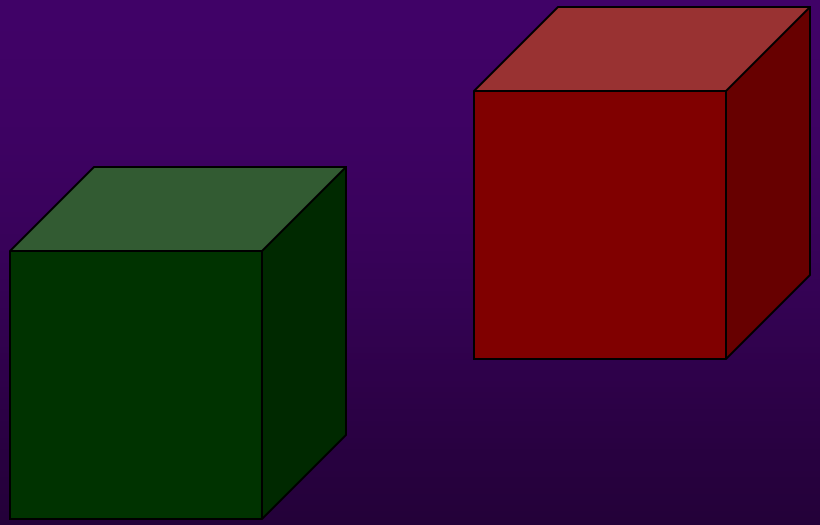
- Carry current perfectly
- Do not lose energy
- Current in a loop will run *forever*
- Expel magnetic fields (Meissner effect)


浮いた 土佐ノ海
TOSANOUMI
(Sumo Wrestler)
Height of Tosanoumi 186cm
Weight of Tosanoumi 142kg
Weight of disk 60kg
Total weight 202kg
As of February '95
協力：財団法人 日本相撲協会

How does it happen?

Matter

Can two pieces of matter occupy the same space at the same time?



Two kinds of particles

Fermions

(spin 1/2, 3/2, 5/2, etc.)

- Cannot occupy the same space at the same time
- Pauli exclusion principle

Antisocial

Bosons

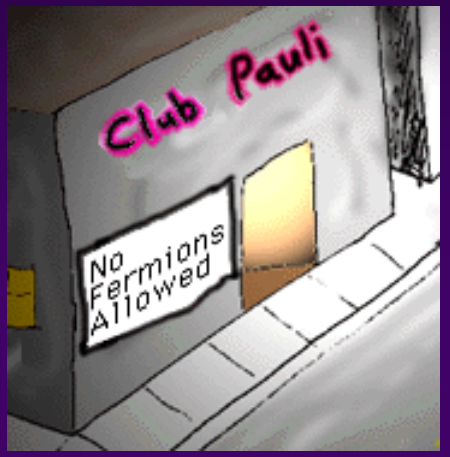
(spin 0, 1, 2, etc.)

- Can occupy the same space at the same time

All Follow the Crowd

Electrons are Fermions

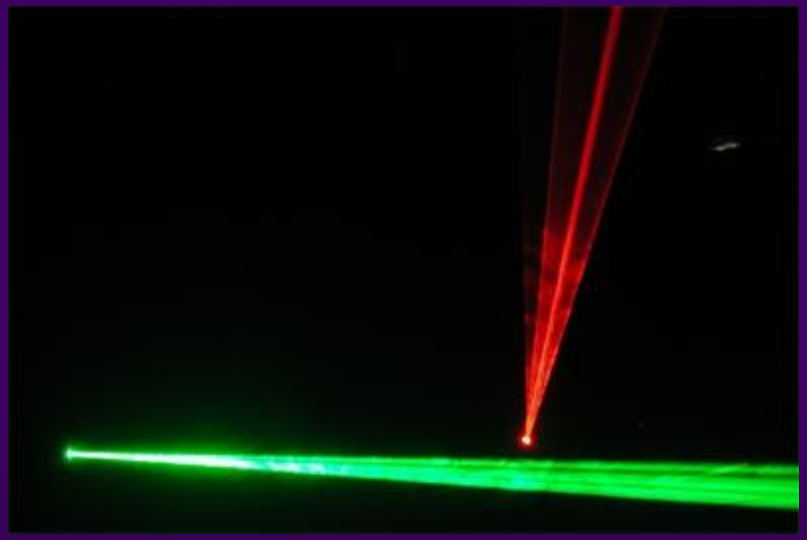
Pauli exclusion principle



Why most matter cannot occupy the same space at the same time

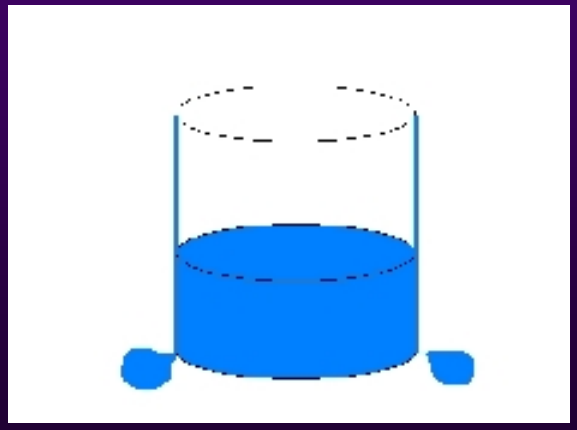
Bosons

Can occupy the same space at the same time



Photons are bosons
→ lasers

Helium is a boson
→ superfluidity



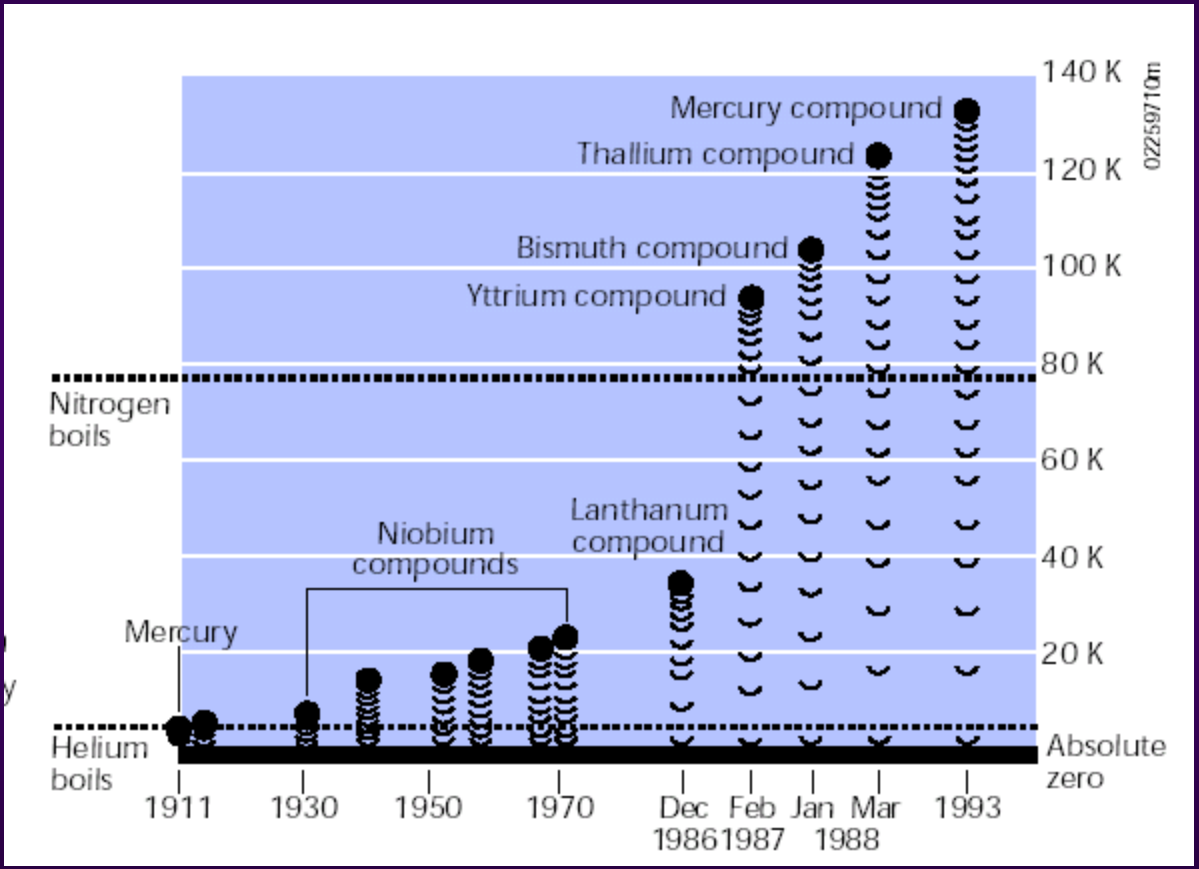
Bose condensation

- At low temperature, bosons flock to the lowest level
- Very stable state!
- Dissipationless flow
- Superfluidity (Helium)
- Superconductivity (metals at low temperature)

Superconductivity

- Pair electrons → form *bosons*
- Bosons condense into the lowest orbital
- Quantum mechanics! Very stable state
- Dissipationless current flow

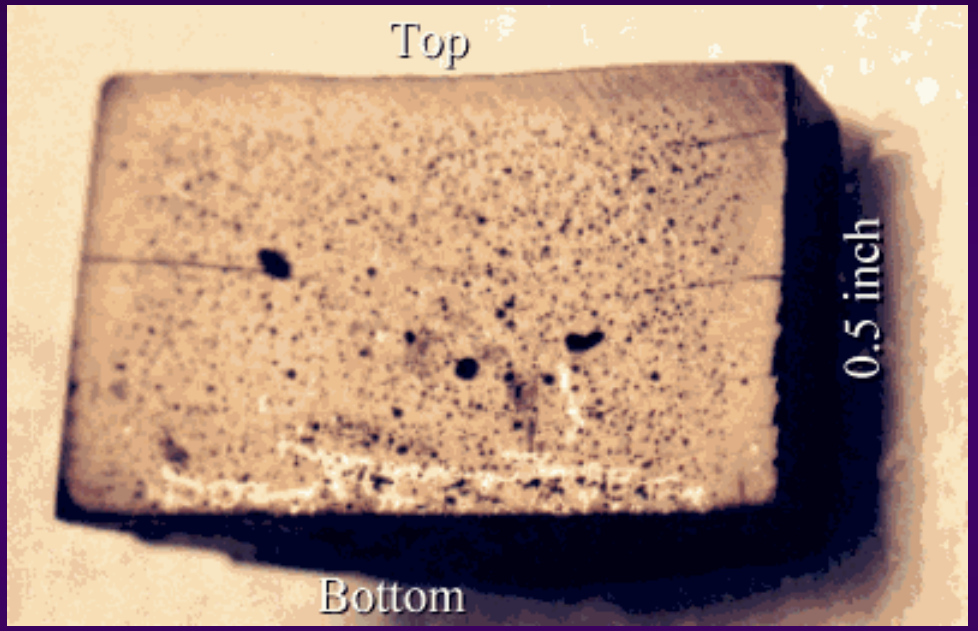
And then there was 1986



http://www.eere.energy.gov/superconductivity/pdfs/frontiers.pdf

Mysteries of High Temperature Superconductors

- Brittle
- Ceramic
- Not Shiny
- Not metallic
- Magnetic inside!
- Make your own

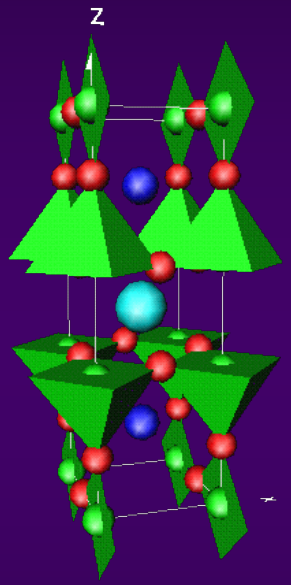


http://www.superconductivecomp.com/

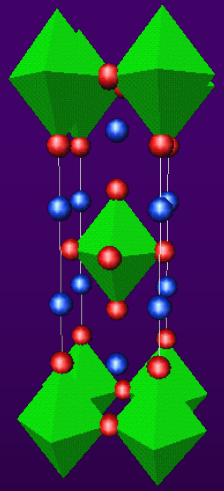
http://www.ornl.gov/reports/m/ornlm3063r1/pt7.html

We don’t know how they work!

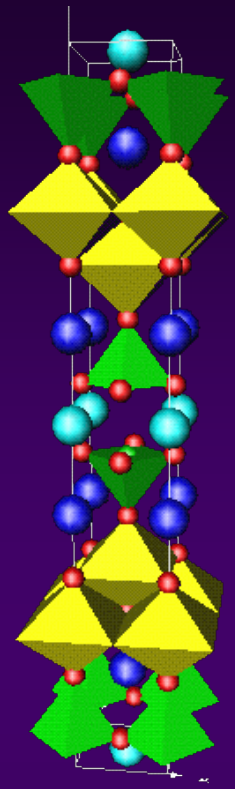
High Temperature Superconductors



$YBCO_7$

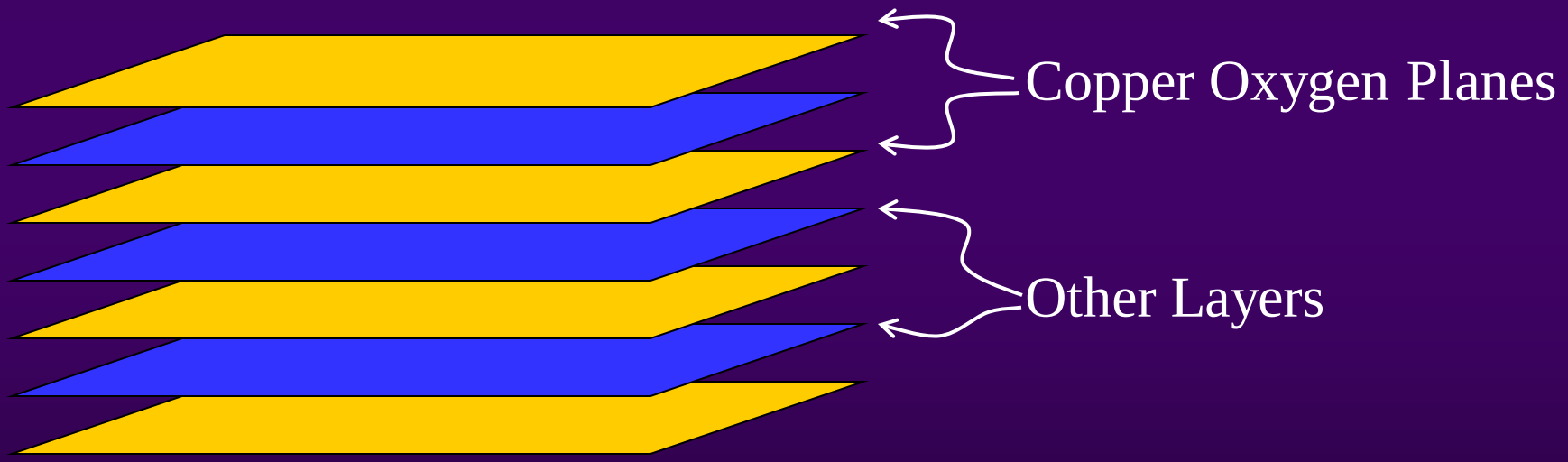


LSCO



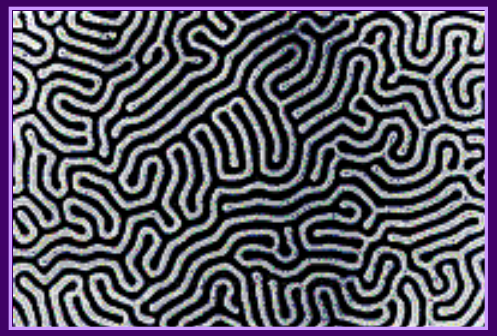
HgCuO

High Temperature Superconductors

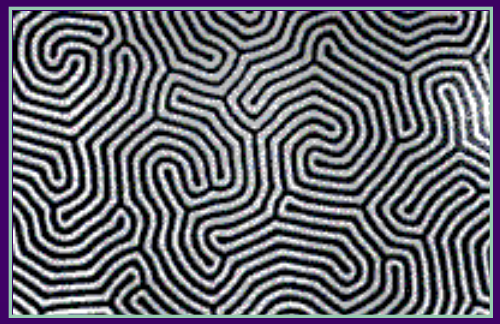


Layered structure → quasi-2D system

Competition often produces stripes



Ferrofluid
confined between
two glass plates
Period ~ 1cm



Ferromagnetic
garnet film
Faraday effect
Period ~ 10^{-5} m

Ferromagnetic
garnet film
Period ~ 10^{-5} m

Block copolymers
Period ~ $4X10^{-8}$ m

What's so special about 1D?

→ *solitons*

Disturbances in 3D:	dissipate as ~	$1/R^2$	Like the intensity of light
Disturbances in 2D:	dissipate as ~	$1/R$	Like a stone thrown in a pond
Disturbances in 1D:	"dissipate" as ~	1	Like a wave in a canal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