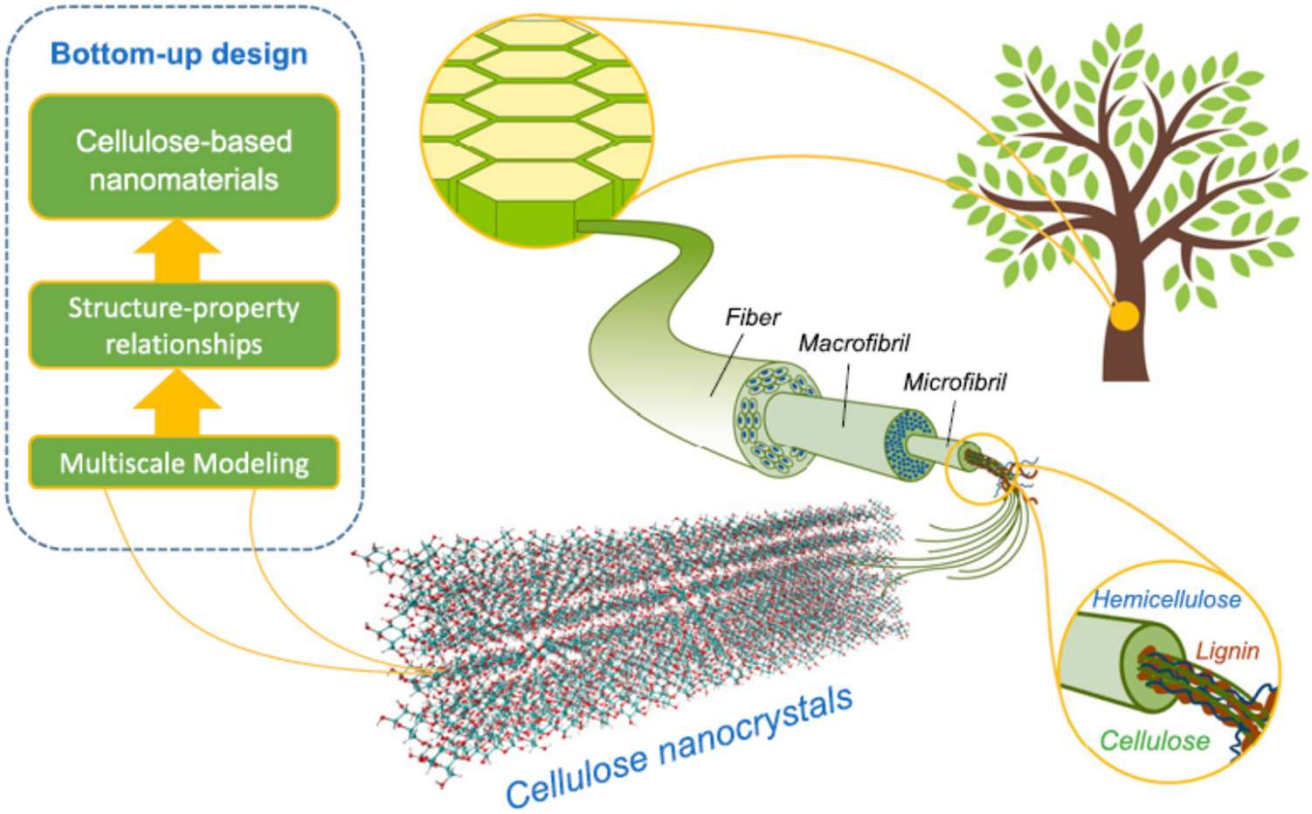
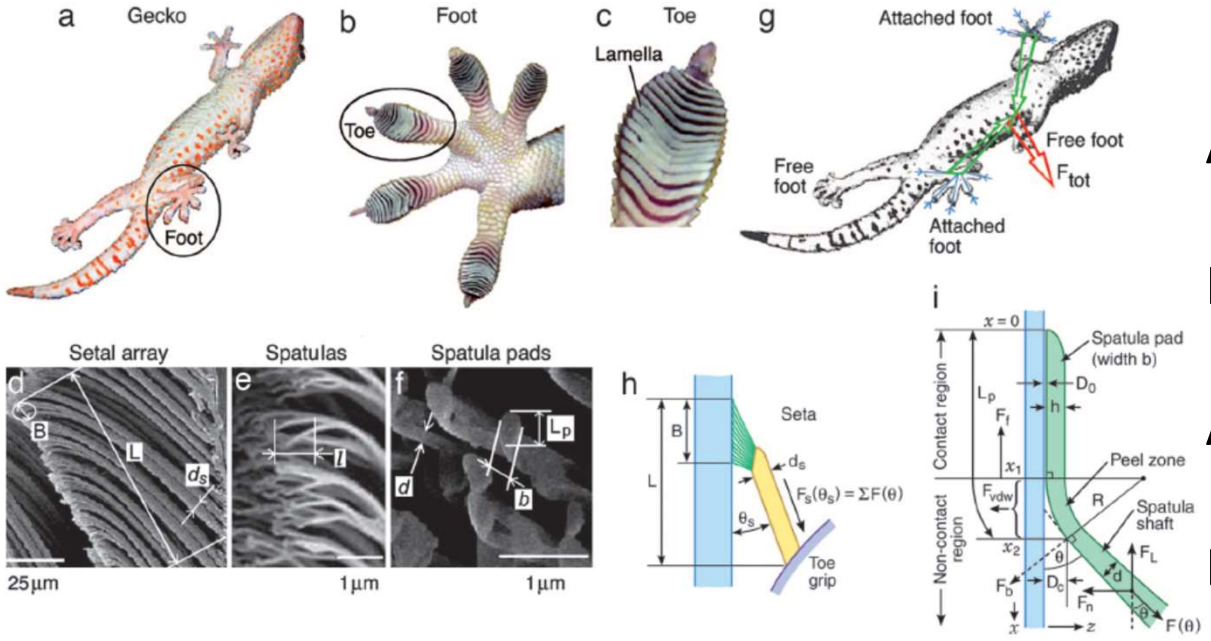
Wood



Martinez, PNAS 115 (2018) 7174

- Nature is the best engineer
- Trees are examples of a structure at different length scales

Gecko or wall lizard

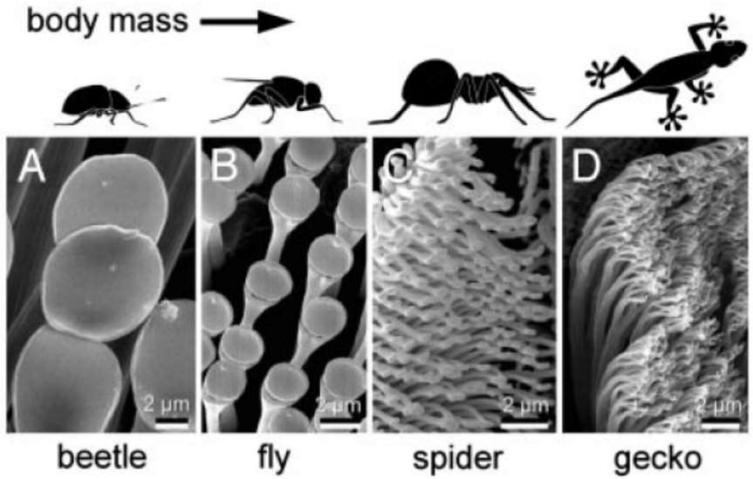


Adhesion of geckos

Hair like seta keratin

Attachment

Detachment

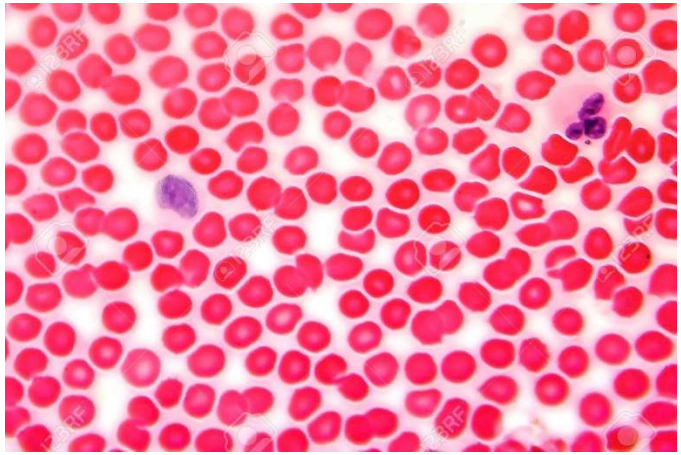


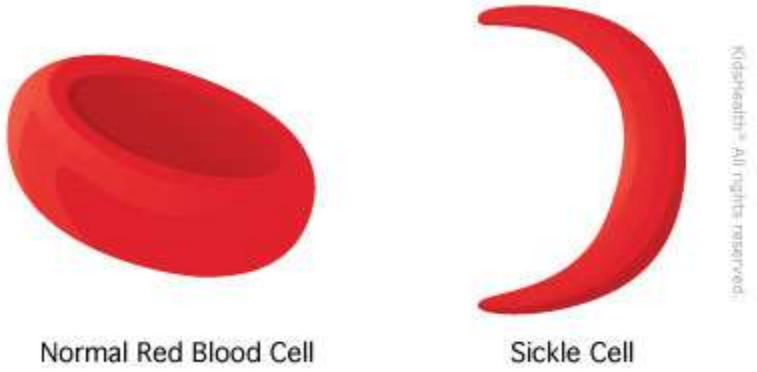
Can we learn from nature and prepare a suit for spiderman ?

Biomimetics

Gao and Yao, PNAS 101 (2004) 7851
Tian, et al. PNAS103 (2006) 19320

Human blood



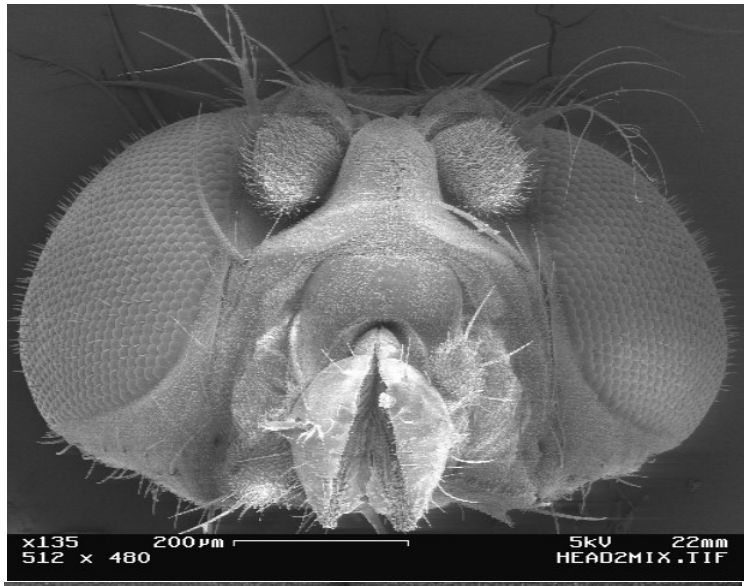


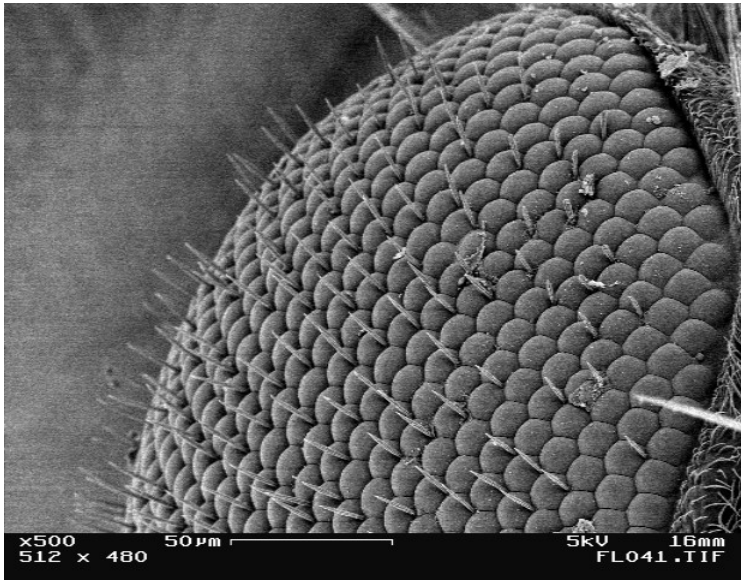
https://www.youtube.com/watch?v=h8cF5QPPmWU

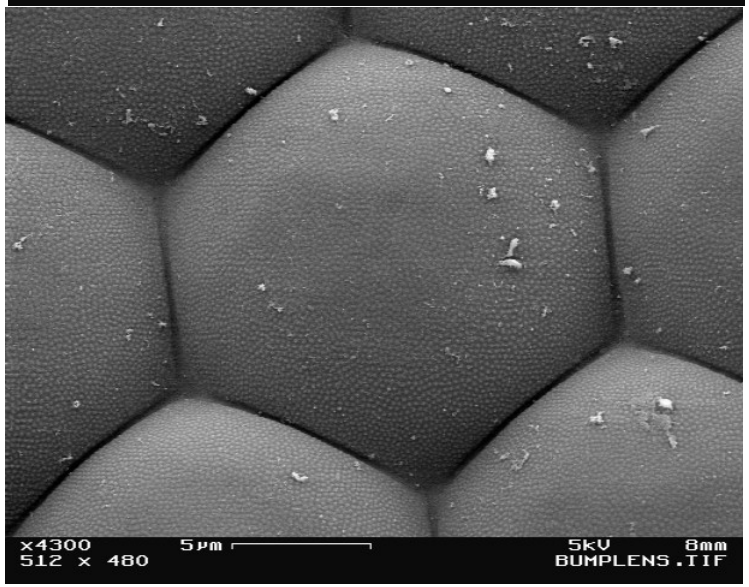
https://www.123rf.com/photo_89929670_human-blood-smear-under-microscope-light-photomicrograph.html

https://kidshealth.org/en/teens/sickle-cell-anemia.html

Eye of a fly







http://www2.optics.rochester.edu/workgroups/cml/opt307/spr04/kevin/index.html

Structure of engineering materials

- Structure at different length scales
  - Macrostructure
  - Microstructure
  - Substructure
  - Crystal structure
  - Electronic structure
  - Nuclear structure

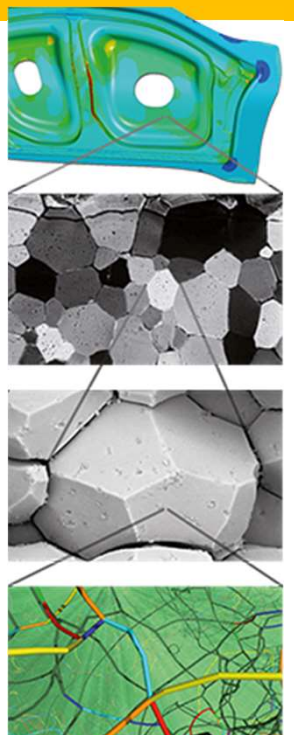
- Length and time scales are linked

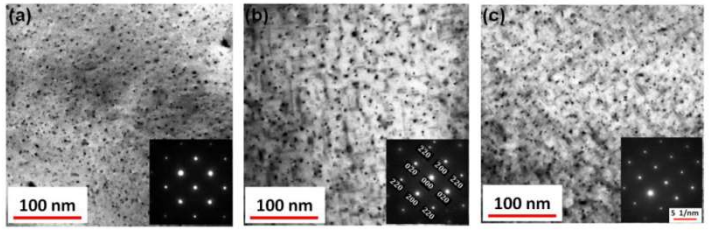
- Shrinking length scales smaller time scales (higher frequencies)

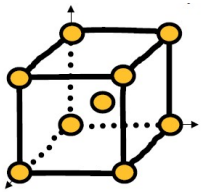
- Car door is made of steel which is an alloy of iron and carbon s
  - Forming of sheet metal steel which is an alloy of iron and carbon (meter)
  - Grain size (tens to hundreds of micron)
  - Crystallite size (few to hundreds of nanometer)
  - Crystal structure (Angstrom)

Car door

- Different length and time scale processes in materials decide properties
- Important to establish structure-processing-property-performance paradigm
- Multi-length scale characterization and multi-time scale testing



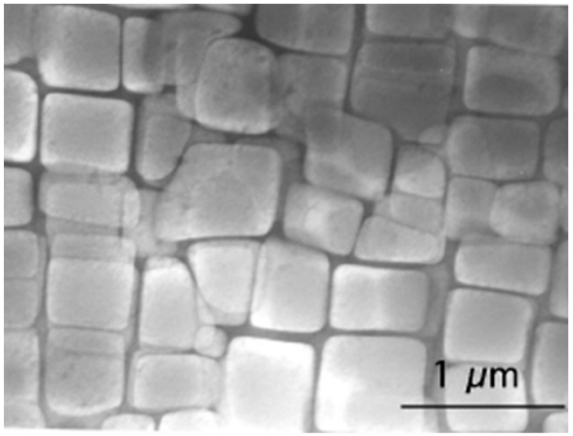


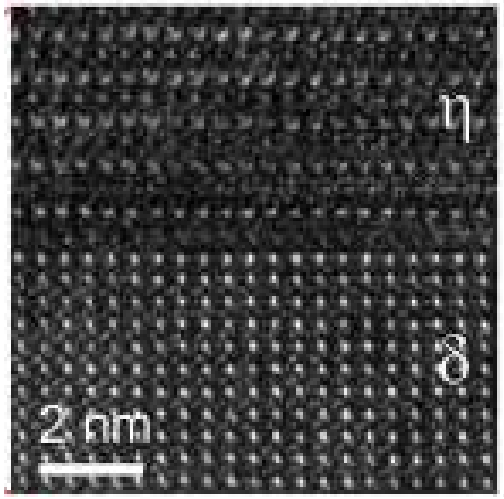


Meter to Angstrom

D. Raabe, User manual Dusseldorf Advanced Materials Simulation Kit
S. Mishra, K. Kulkarni, **N. P. Gurao**, **JMAD,** 87 (2015) 507.

Turbine and superalloy



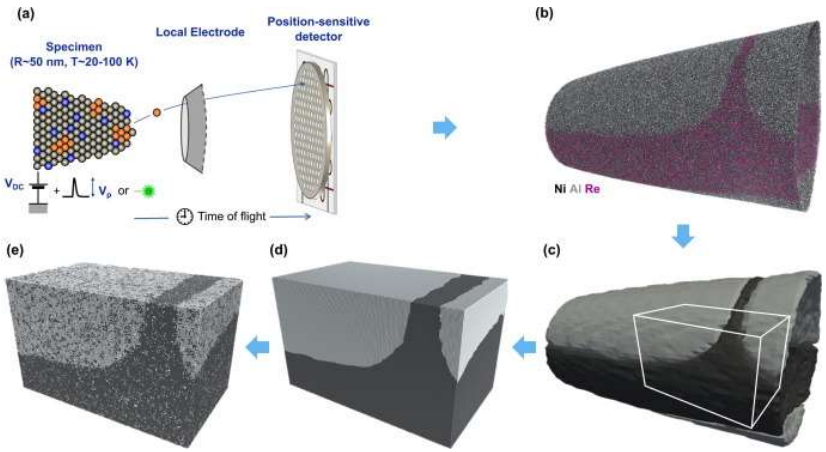


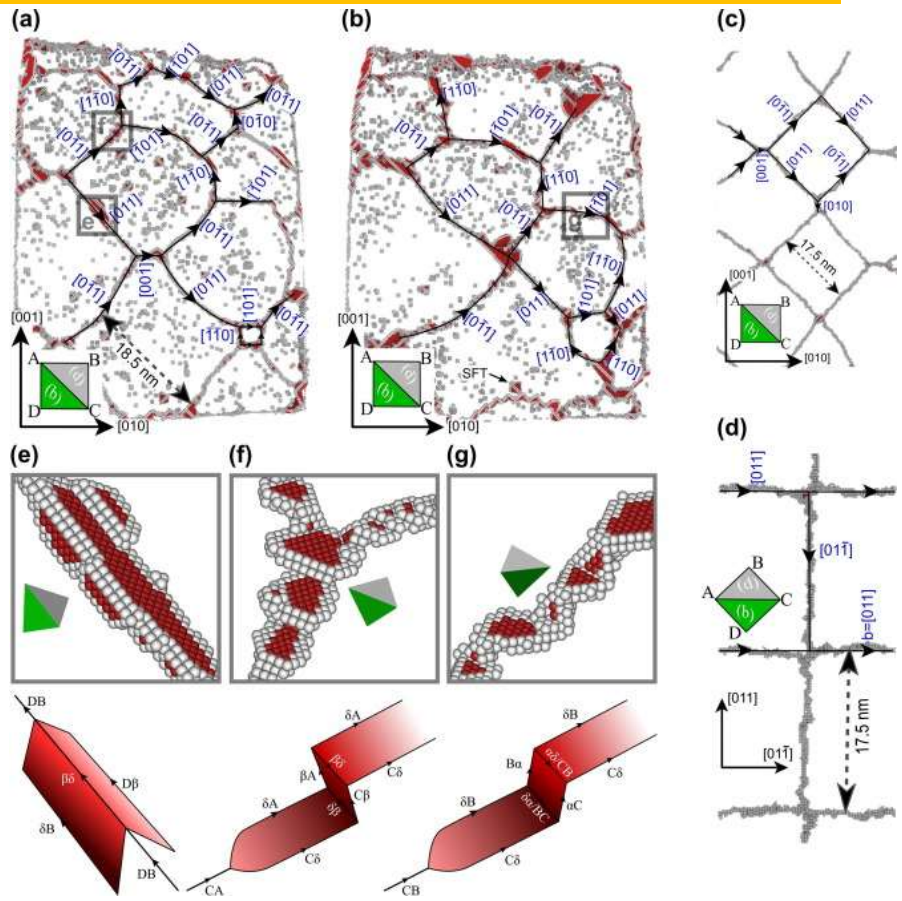
http://www.turbocare.com/gas_turbine_blades_buckets.html

- Single crystal turbine blades of nickel based superalloy
- Gamma-Gamma prime microstructure
- Higher temperature, higher efficiency
- Operate above melting point

https://www.sciencedirect.com/science/article/pii/S0925838819334036

Superalloys for the 21st century



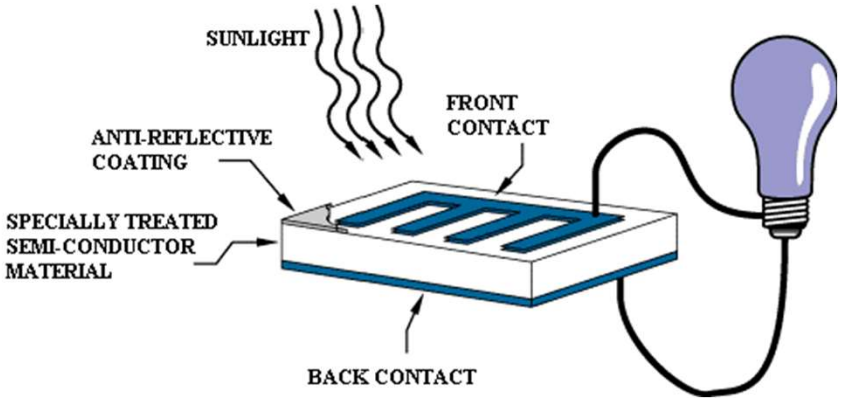


- Ni with addition of aluminium
- 10-12 minor elements
- Cooking an exotic dish
- Computational approach must
- Serendipity to Machine Learning and Artificial Intelligence

https://www.sciencedirect.com/science/article/pii/S1359645415002268

Photovoltaics

- Solar energy harvesting has picked up in India
- Silicon: single or polycrystal
- SX Si rejected by electronic industry used by solar
- Band gap important
  - Macrostructure
  - Microstructure
  - Substructure
  - Crystal structure
  - Electronic structure



http://butane.chem.uiuc.edu/pshapley/genchem2/c5/1.html

Functional materials

- Different materials are used to make a device
- Functional materials can bridge the gap
- Shape memory alloys
- Gas sensors
- Semiconductors
- Magnetic memories
- Smart phone screen

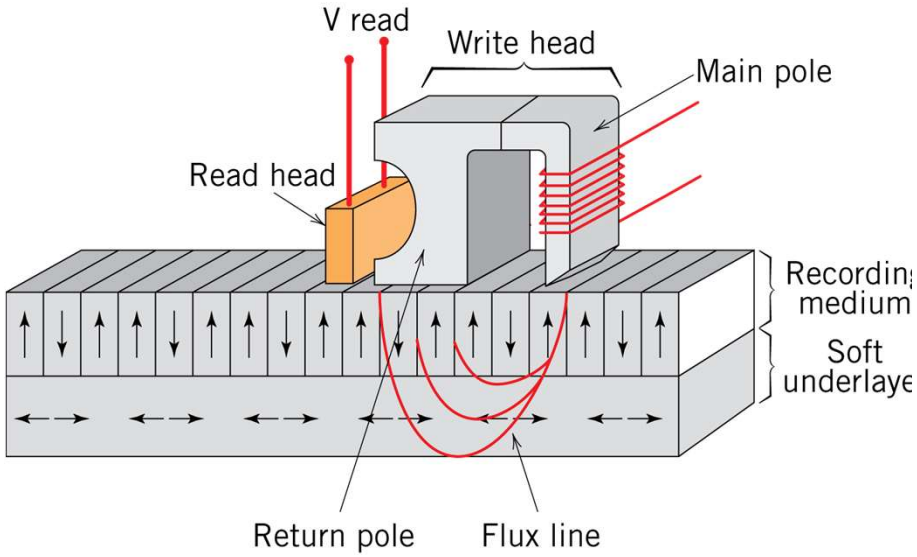
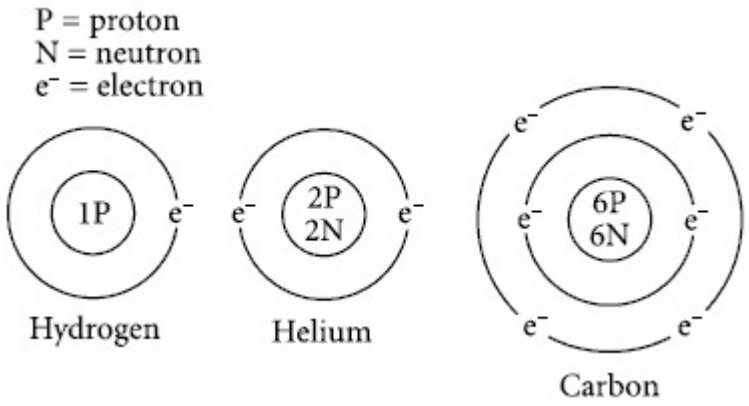


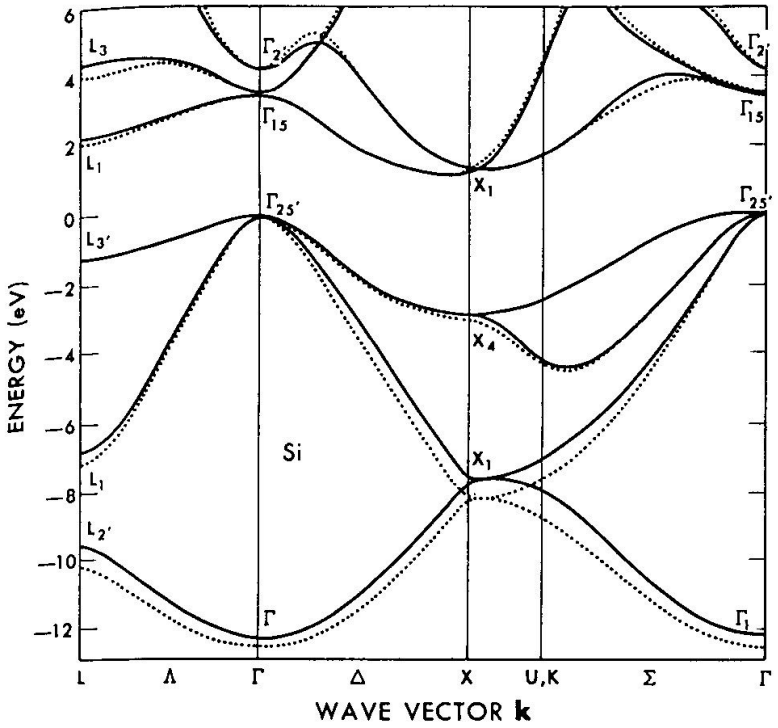
Fig. 20.23, *Callister & Rethwisch 8e.*

Electronic structure

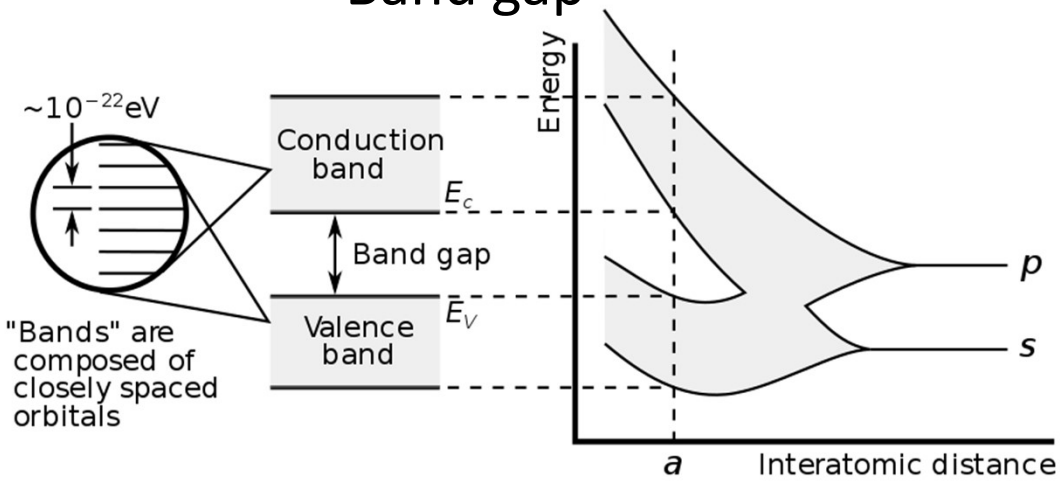
Individual atoms



Solids



Band gap



https://en.wikipedia.org/wiki/Band_gap

Nuclear structure

- Particle physics
- We are in Sheldon territory
- Neutron
- Neutron star
- I am as good as Penny !
- But you may try…..

http://entangled.wordpress.com/2008/09/02/subatomic-particle-plush-toys/

Where do we go from here ?

- Achievements of past are problems of today/tomorrow
- We have a tendency to take more than what we need and we waste
- Human intellect vs. human greed
- Challenges
  - Health care ignore Ebola suffer from Covid
  - Pollution and Global warming
  - Clean energy and food for all
  - Secure Cyberspace
  - Mental health
  - No wars

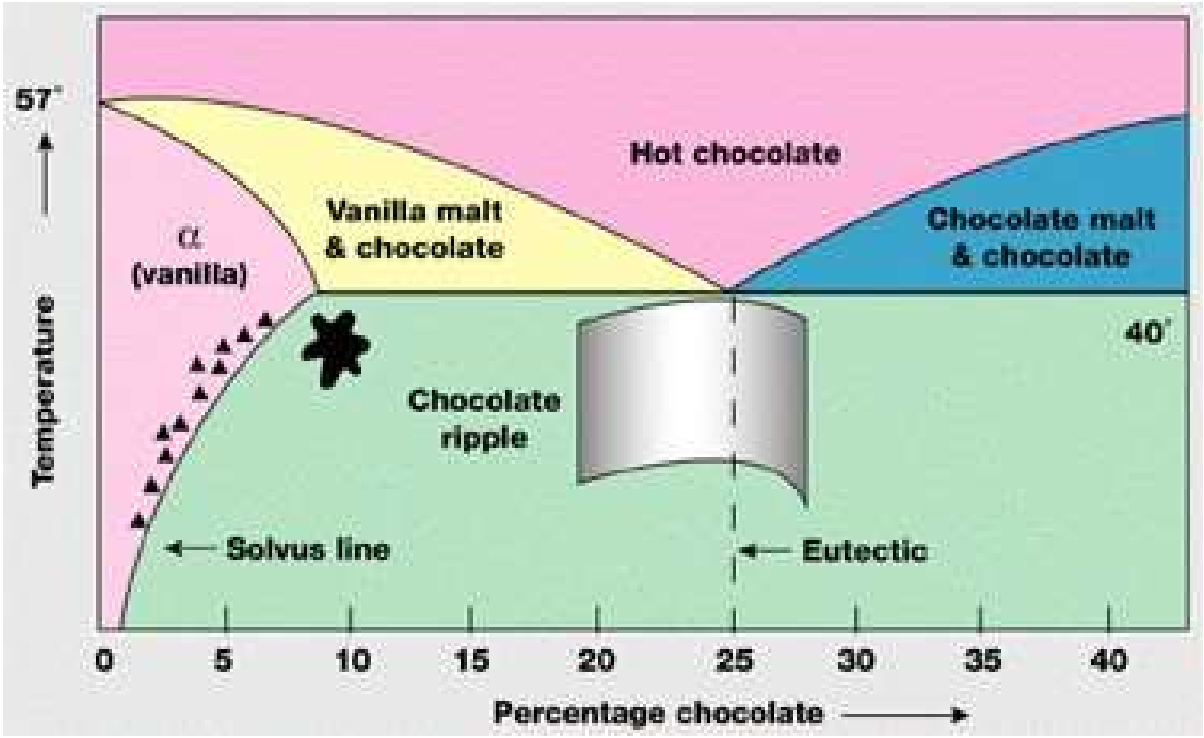
Thank you

Nuclei 99.9%
weight

Electron cloud
10^14:1

Neutron star

Bar structure



http://foodfordesign.blogspot.com/2006/09/phase-diagram-of-chocolate-and-vanilla.html