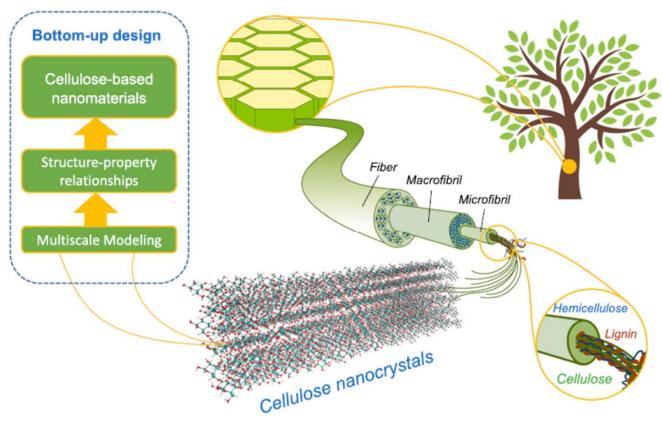
Wood

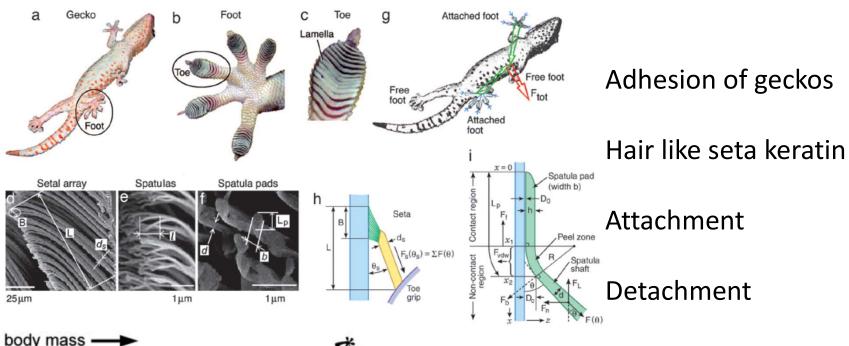


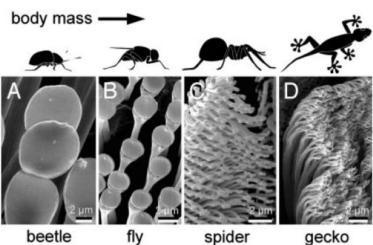
Nature is the best engineer

Martinez, PNAS 115 (2018) 7174

> Trees are examples of a structure at different length scales

Gecko or wall lizard



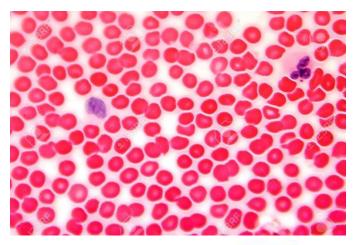


Can we learn from nature and prepare a suit for spiderman?

Biomimetics

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

Human blood







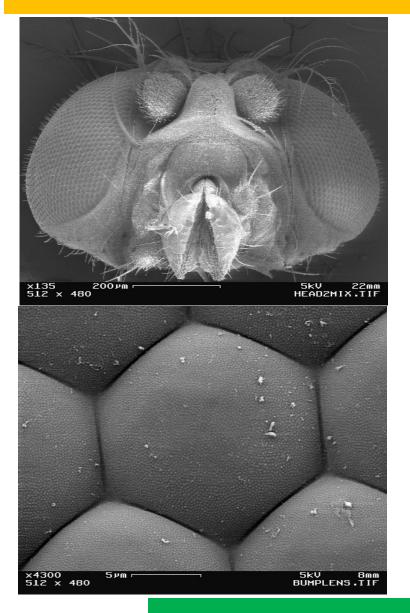


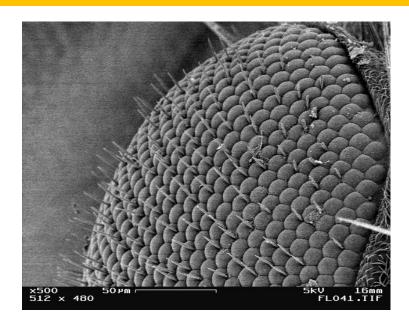
https://www.youtube.com/watch?v=h8cF5QPPm WU

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

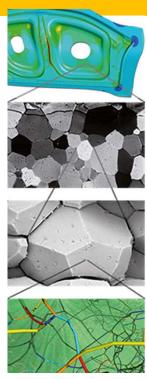
- Structure at different length scales
 - Macrostructure
 - Microstructure
 - Substructure
 - Crystal structure
 - Electronic structure
 - Nuclear structure

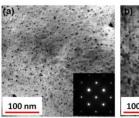
- > Length and time scales are linked
- Shrinking length scales smaller time scales (higher frequencies)

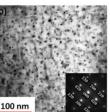
- > Car door is made of steel which is an alloy of iron and carbon s
 - Forming of sheet metal steel which is an alloy of iron and carbon (meter)
 - Grain size (tens to hundreds of micron)
 - Crystallite size (few to hundreds of nanometer)
 - Crystal structure (Angstrom)

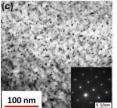
Car door

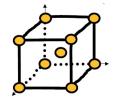
- Different length and time scale processes in materials decide properties
- Important to establish structureprocessing-property-performance paradigm
- Multi-length scale characterization and multi-time scale testing











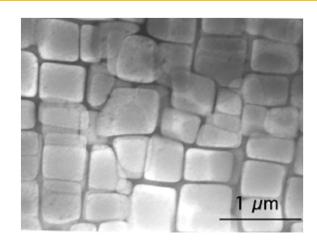
Meter to Angstrom

D. Raabe, User manual Dusseldorf Advanced Materials Simulation Kit

S. Mishra, K. Kulkarni, N. P. Gurao, JMAD, 87 (2015) 507.

Turbine and superalloy





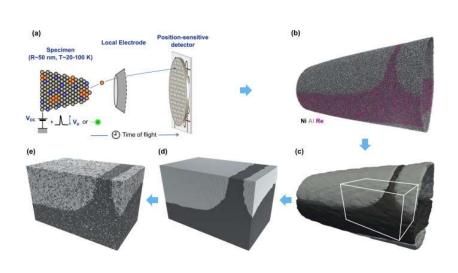
η 2 am:

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

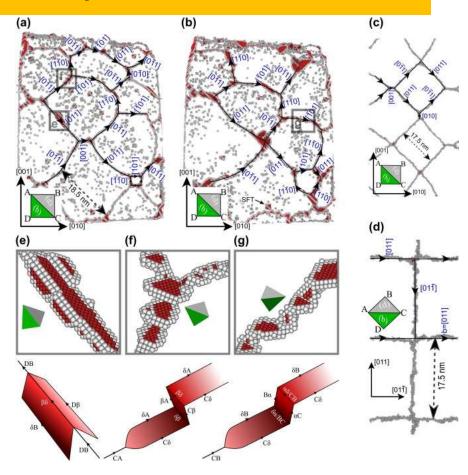
http://www.turbocare.com/gas_turbine_blades_buckets.html

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

Superalloys for the 21st century



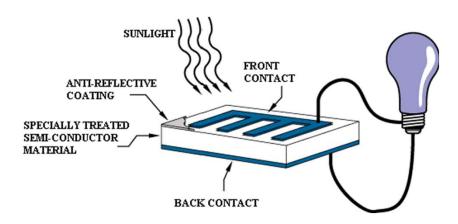
- Ni with addition of aluminium
- 10-12 minor elements
- Cooking an exotic dish
- Computational approach must
- Serendipity to Machine Learning and Artificial Intelligence



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

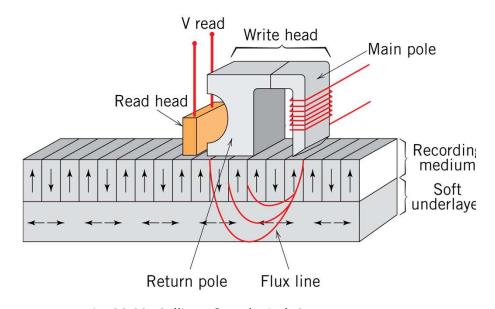
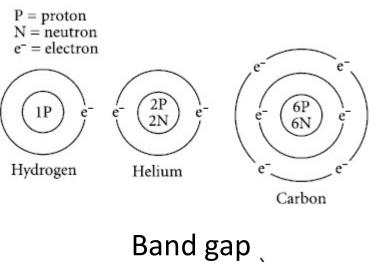
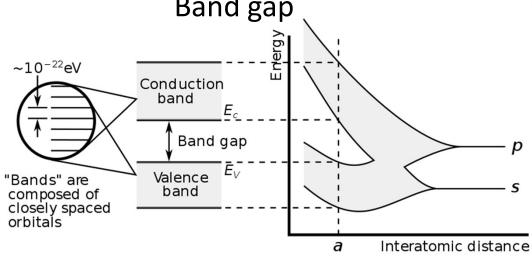


Fig. 20.23, Callister & Rethwisch 8e.

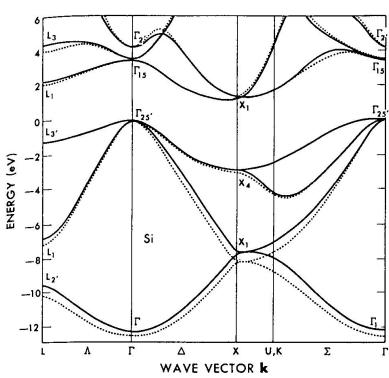
Electronic structure

Individual atoms





Solids



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.....

Subatomic Particle Plush Toys FROM THE STANDARD MODEL OF PHYSICS & beyond UP QUARK CHARM TOP QUARK QUARK A teeny little point This heavyweight inside the proton champion doesn't A second and neutron, it is generation five long enough to friends forever with goark, he is make friends with PHOTON the down quark. The massless wavicle we know and love. 000 QUARK QUARK QUARK A tiny little point What's so strange This third inside the proton about this second generation qua generation quark? and neutron, it is is guttin' on the friends forever with the up quark, GLUON NEUTRINO NEUTRINO NEUTRINO W BOSON This minuscule Like the other 2 He's a tau now, bandit is so light, neutrinos, he's got but what type of Z BOSON he is gractically an identity prisis neutrino will be massless. from oscillation be next? MUON ELECTRON TAU A Theavy A "heavy muon electron" who who could stand this negatively As the carrier particles of lives fast and charged, busy 671 to fase a little the weak nuclear force, guy likes to bond. weight. they're downright obese. HIGGS SPECIAL!
To celebrate the Utarian of the LINC. HIGGS BOSON there will be a SPECIAL PRICE on He's the one everyone GRAVITON HIGGS BOSONS OF SEPTEMBER 10 yet theoretically PROTON he's playing hard to get. exerculanche's We would not be You'd be smilling too if got big legs for here without her everyone was looking to positivity. EOR DARK MATTER NEUTRON TACHYON The mysterious He insists on Can this devious and missing mass. clever particle really Difficult to see travel faster because he's than light?

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

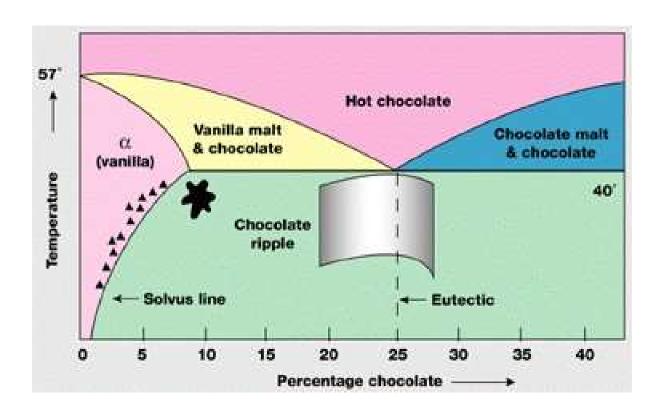
Thank you

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