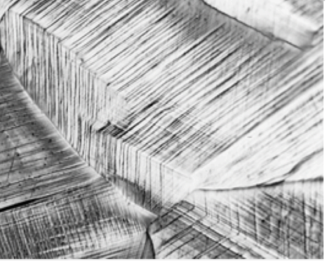
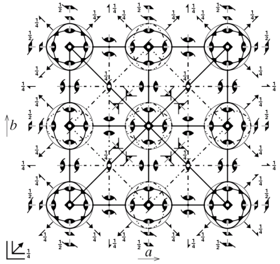
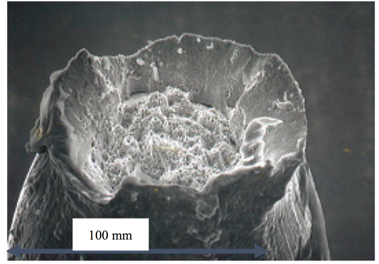
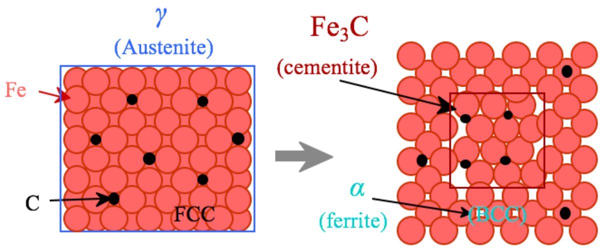








MEAM/MSE 507
Fundamentals of Materials

Instructor: Prof. Jordan R. Raney

TA: Min Wang

Grader: TBD

Week 1, Lecture 1: Course overview and logistics

Synchronous, Tuesday September 1

Welcome!

- **New to Penn?**
  - Reach out with any questions
- **Facing difficulties due to the challenges of 2020?**
  - Numerous resources available
- **Our course… online**
  - We will cover everything that we have in previous years…
  - But seeking to **maximize flexibility**.

Who we are

Instructor:

Prof. Jordan R. Raney

- Joined Penn/MEAM in 2016
- B.S. Physics, B.S. Computer Science (Minnesota)
- M.S. Materials Science (Caltech)
- Ph.D. Materials Science (Caltech)
- Post-doc Engineering & Applied Science (Harvard)

Pre-quarantine

Quarantine

Teaching Assistant:

Min Wang

- Ph.D. student in MEAM
- Undergraduate degree in materials

Grader: TBD

Goals and Scope

MEAM/MSE 507: Fundamentals of Materials

"Fundamentals" => Science.

- This is **not** a hands-on/applied "materials selection" course (MEAM 508 might be a better choice for you if you are looking for a course more related to "manufacturing and materials selection")
- **The goal** is to teach you the language and underlying foundation of materials science and engineering (a lot of which comes from physics and chemistry)

Who is this course designed for?

- **Graduate students** who want a **broad introduction to materials science** and the **underlying fundamental science**

Similar to "intro materials" courses for undergraduates, we will seek to cover a huge breadth of material. However, we will also go into more depth wherever it is valuable to do so, subject to time constraints.

Goals and Scope

Course description from the catalog:

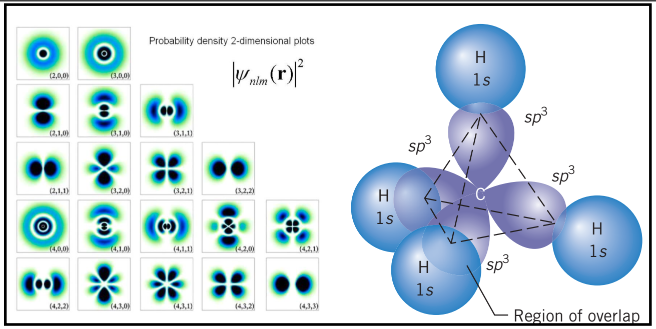
This course will provide a graduate level introduction to the science and engineering of materials. ***It is designed specifically to meet the needs of students who will be doing research that involves materials but who do not have an extensive background in the field****. The focus is on fundamental aspects of materials science and will emphasize phenomena and how to describe them.*

Note: If you are already an expert in materials science, or have a very strong undergraduate materials science background, you should take more specialized courses instead. E.g.,:

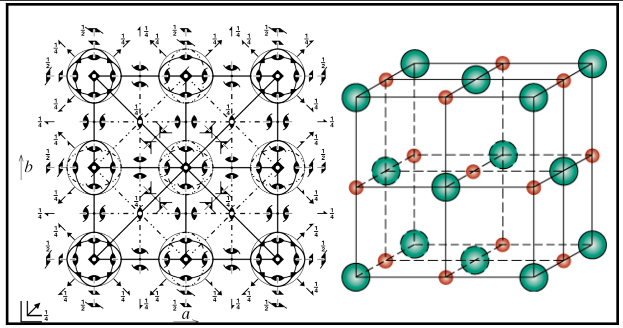
- **MSE 520:** Structure of Materials
- **MSE 530:** Thermodynamics and Phase Equilibria
- **MSE 536:** Electronic Properties of Materials
- **MSE 540:** Phase Transformations
- **MSE 570:** Physics of Materials
- **MSE 580:** Polymers
- **MSE 610:** Electron Microscopy

We will cover some aspects of all of these courses …

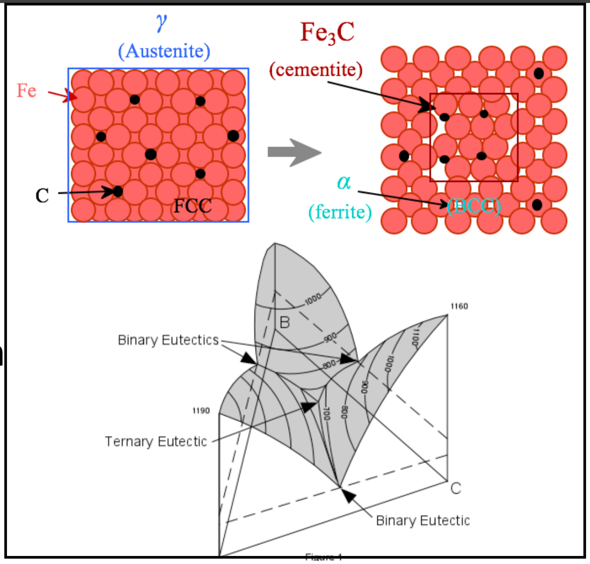
Major topics of the course



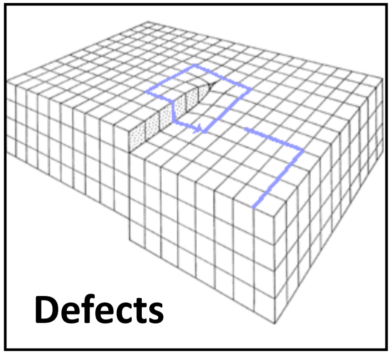
Quantum Mechanics and Bonding



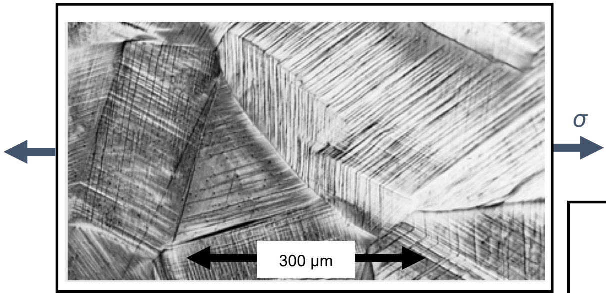
Symmetry, Crystallography, Diffraction



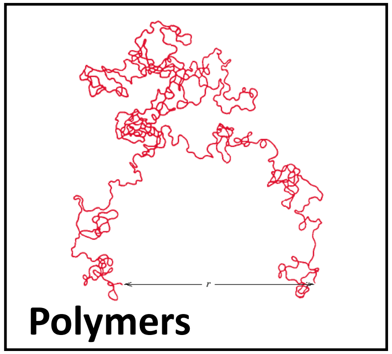
Phase Equilibrium



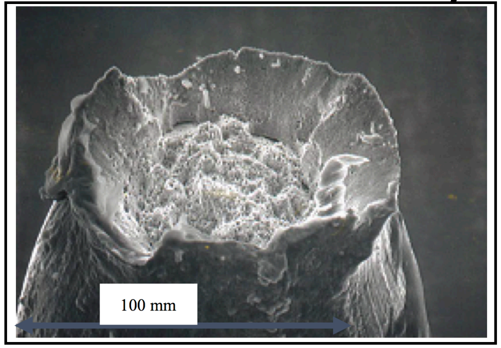
Defects



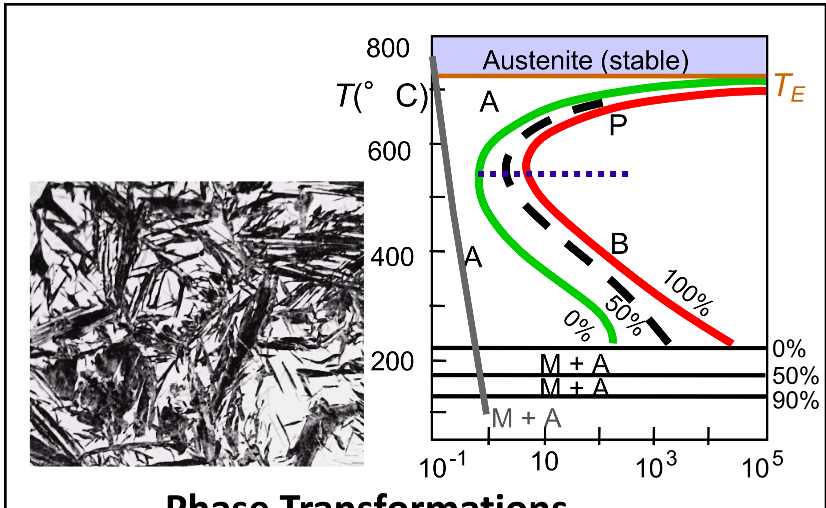
Diffusion and Plasticity



Polymers



Failure



Phase Transformations

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Approximate Schedule

Date	Topic
Week 1 (Aug. 31 – Sept. 4)	Foundational physics for materials science
Week 2 (Sept. 7 – Sept. 11)	Physics of electrons and bonding
Week 3 (Sept. 14 – 18)	Bonding and crystals
Week 4 (Sept. 21 – 25)	Crystal structure
Week 5 (Sept. 28 – Oct. 2)	Diffraction
Week 6 (Oct. 5 – 9)	Thermodynamics and phase diagrams
Week 7 (Oct. 12 – 16)	Defects
Week 8 (Oct. 19 – 23)	Diffusion
Week 9 (Oct. 26 – 30)	Plasticity
Week 10 (Nov. 2 – 6)	Failure
Week 11 (Nov. 9 – 13)	Phase transformations
Week 12 (Nov. 16 – 20)	Polymers
Week 13 (Nov. 23 – 27)	Polymers (also Thanksgiving break)
Week 14 (Nov. 30 – Dec. 4)	Polymers and composites
Week 15 (Dec. 7 – 8)	Polymers and composites (partial week – Thurs. Dec. 10 is a Monday schedule)

Course logistics

Canvas: The course is managed via Canvas. **Each week has its own Module**, which lists what students need to do. Assignments are uploaded via Canvas; lecture recordings are posted on Canvas.

Module 1: Overview

Module Description

We will use Modules in this course to organize course content, assignments, etc., by Week. I.e., Module 1 will list everything required for Week 1.

In Week 1 we will discuss the underlying physics that are essential to understanding bonding and molecular structure. Week 1 is slightly different than usual: Because we are just starting the course and have a good deal of logistics to discuss, the lectures will be held live via Zoom (and recorded for those who cannot attend synchronously). In future weeks the lectures will be pre-recorded, allowing us to use the synchronous class times for more interactive discussions of course concepts and problem solving.

For this week and all future weeks, synchronous sessions (Tuesdays and Thursdays at 4:30 pm Eastern) will be held at the following Zoom link:

https://upenn.zoom.us/j/98437446630?pwd=MWxQRzhwUmJ6NmhOdTk1aEZ3MzRndz09

Meeting ID: 984 3744 6630

Passcode: 299117

Objectives

Upon completion of this module, students should be able to:

- Understand the requirements and logistics of the course.
- Understand the historical experimental observations which led to the quantum mechanical view of atoms and molecules.
- Conceptually understand how the quantum mechanical view of atoms differs from classical expectations.

Assignments & Assessments

- There are no assignments or assessments for Module 1. Students should attend the lectures on Tuesday 9/1 and Thursday 9/3, or watch the recordings afterward. This page will be updated with the lecture files as soon as they are available.

Readings

Required Readings

- Syllabus

Recommended Readings

- Callister *Materials Science and Engineering 9th edition*: Chapter 1 (intro to materials science)
- Callister *Materials Science and Engineering 9th edition*: Sections 2.1-2.3 (intro to atomic structure)

◂ Previous | Next ▸

Course logistics

In a typical week:

- Students will be provided with pre-recorded / asynchronous lectures. **They should watch these by Wednesday** and take a brief concept quiz.
- **Tuesday synchronous sessions** will be used to work through example problems. **Thursday sessions** will be used to discuss key concepts from the week's lectures.

Piazza forum: There will be a Piazza forum for the course in which students can ask questions about the material being covered. One goal of this forum is to foster student-student interaction. To that end, if a student is the first to answer another student's technical question on Piazza that is endorsed by an instructor he/she will receive extra credit.

Office hours: There will be more office hours than usual. We will make a post on Piazza regarding scheduling after class.

Grading Criteria

Homework – 20% (traditional problem solving)

Unit quizzes – 20%

Lit review project 1 – 15% (bonding, crystallography, or diffraction)

Lit review project 2 – 15% (phase diagrams, defects, diffusion, or plasticity)

Lit review project 3 – 15% (failure, phase transformations, or polymers)

Participation – 15% (on-time completion of concept quizzes, etc.)

Traditional exams – None

Textbook

There is no required textbook for this course. There is no appropriate textbook at the graduate level for a one semester materials course.

If this is your first materials course, you might find this undergraduate book helpful at a qualitative level: *Materials Science and Engineering: An Introduction*, 9th Edition, by William D. Callister, Jr. and David G. Rethwisch, John Wiley & Sons, Inc., ISBN 978-1-118-47770-0

I will also provide readings from specialized texts when appropriate.

Course flexibility

- Your feedback during the course will be extremely valuable. We are trying new things (e.g., asynchronous lectures). If you see ways to improve, let me know. We may be able to change how we do things to address your concerns.

- We know many of you are affected by 2020's challenges. Let us know if we can help. We will have more office hours than usual to make sure we're available for you.

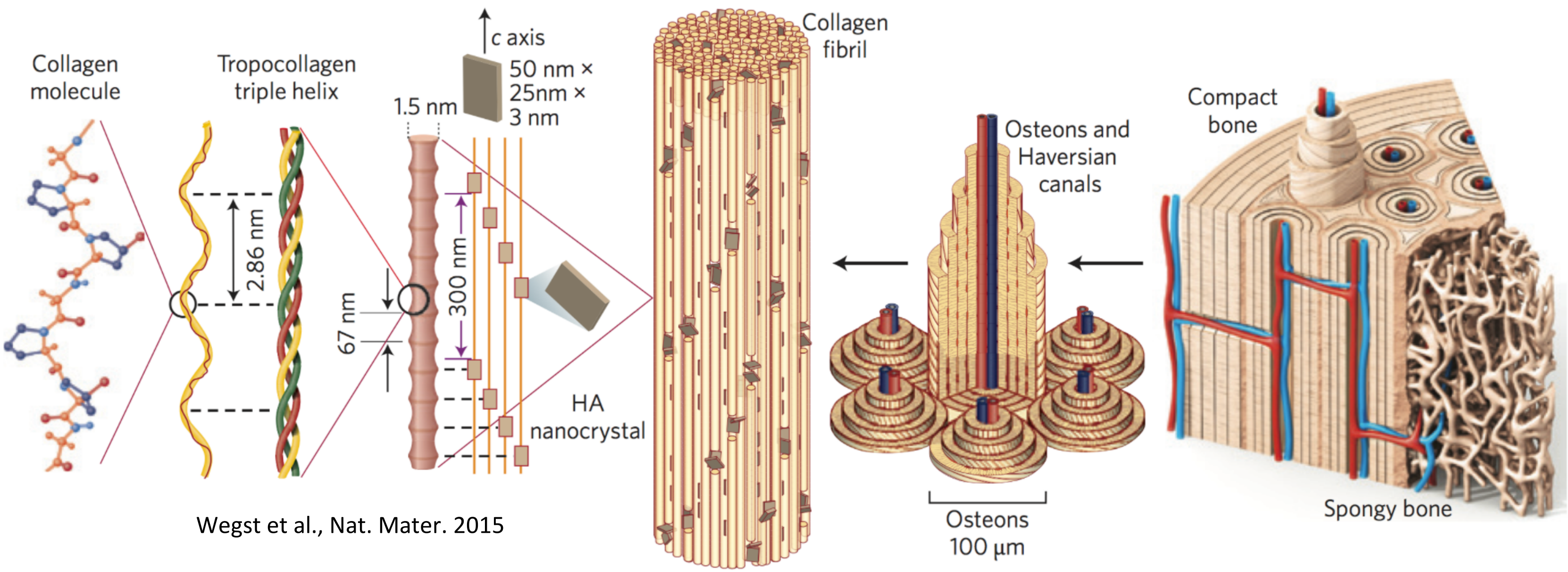
- Based on new university guidelines, P/F grading is an option for everyone for Fall 2020.

What qualifies as a “material”?

1. Is pure Aluminum a material? Easy

2. Polymers … ?

3. Is bone a material?

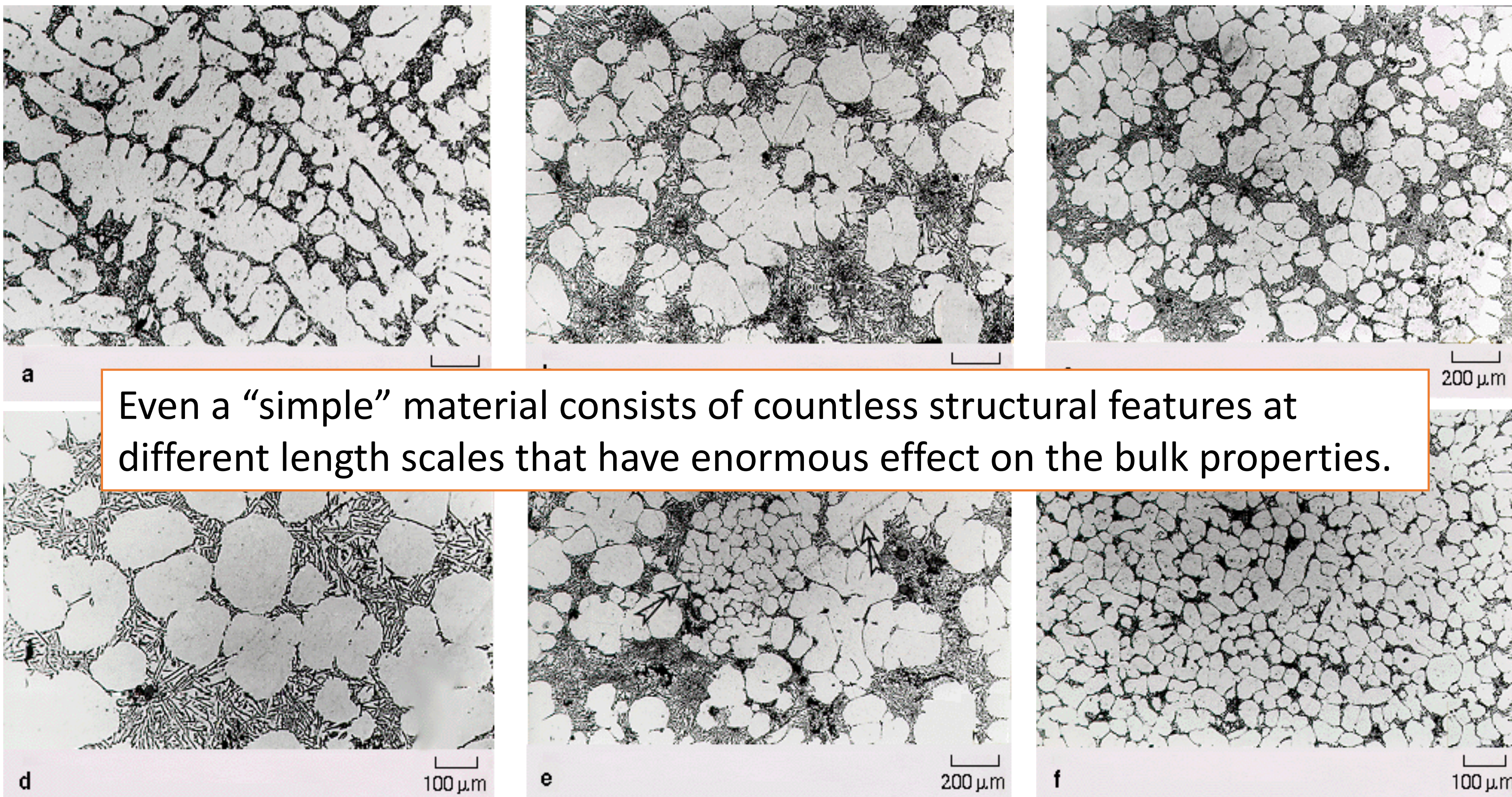


Wegst et al., Nat. Mater. 2015

What qualifies as a “material”?

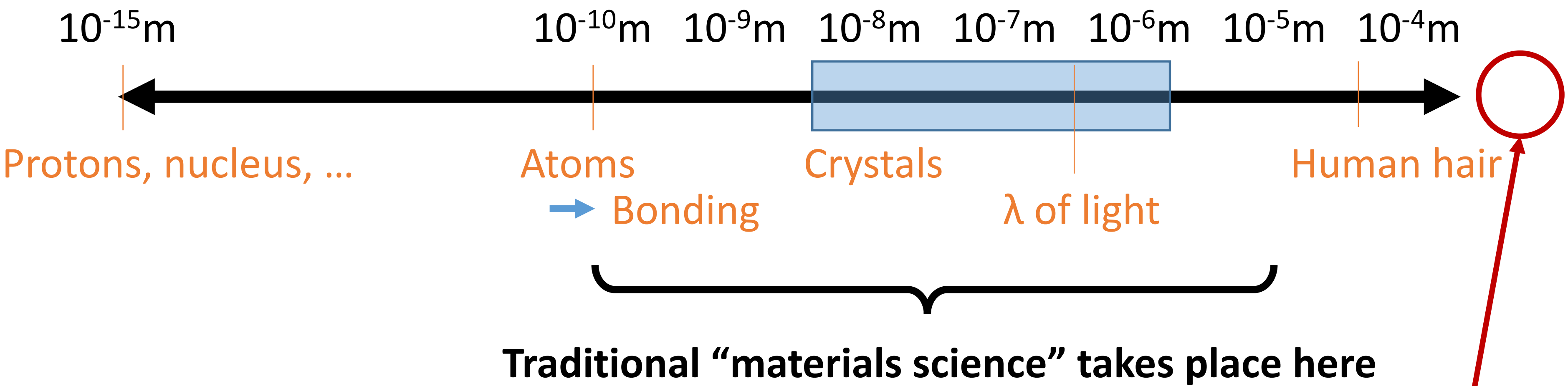
1. Is pure Aluminum a material? Yes, but…

C. Vivès, JOM 1998; 50(2)



Even a “simple” material consists of countless structural features at different length scales that have enormous effect on the bulk properties.

“Material” and “Structure”



The properties of bulk “materials” that we observe at macroscopic length scales are determined by structural features at many lower length scales:

- Type of bonding
- Order vs disorder at nanometer/micrometer length scales (e.g., mean size of crystalline regions)
- Defects
- Etc.

Because we can **control** some of these **“structural” features via processing parameters**, we can **tune the properties** of many materials at macroscopic scales.

The Central Paradigm

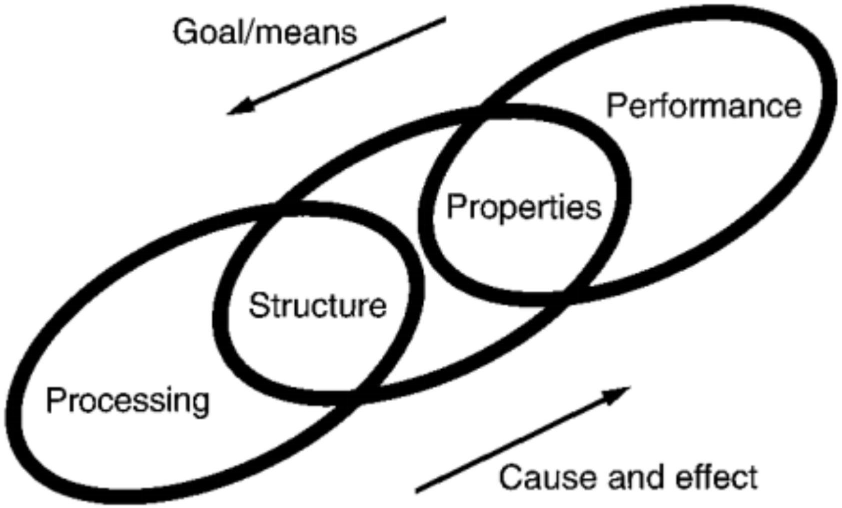
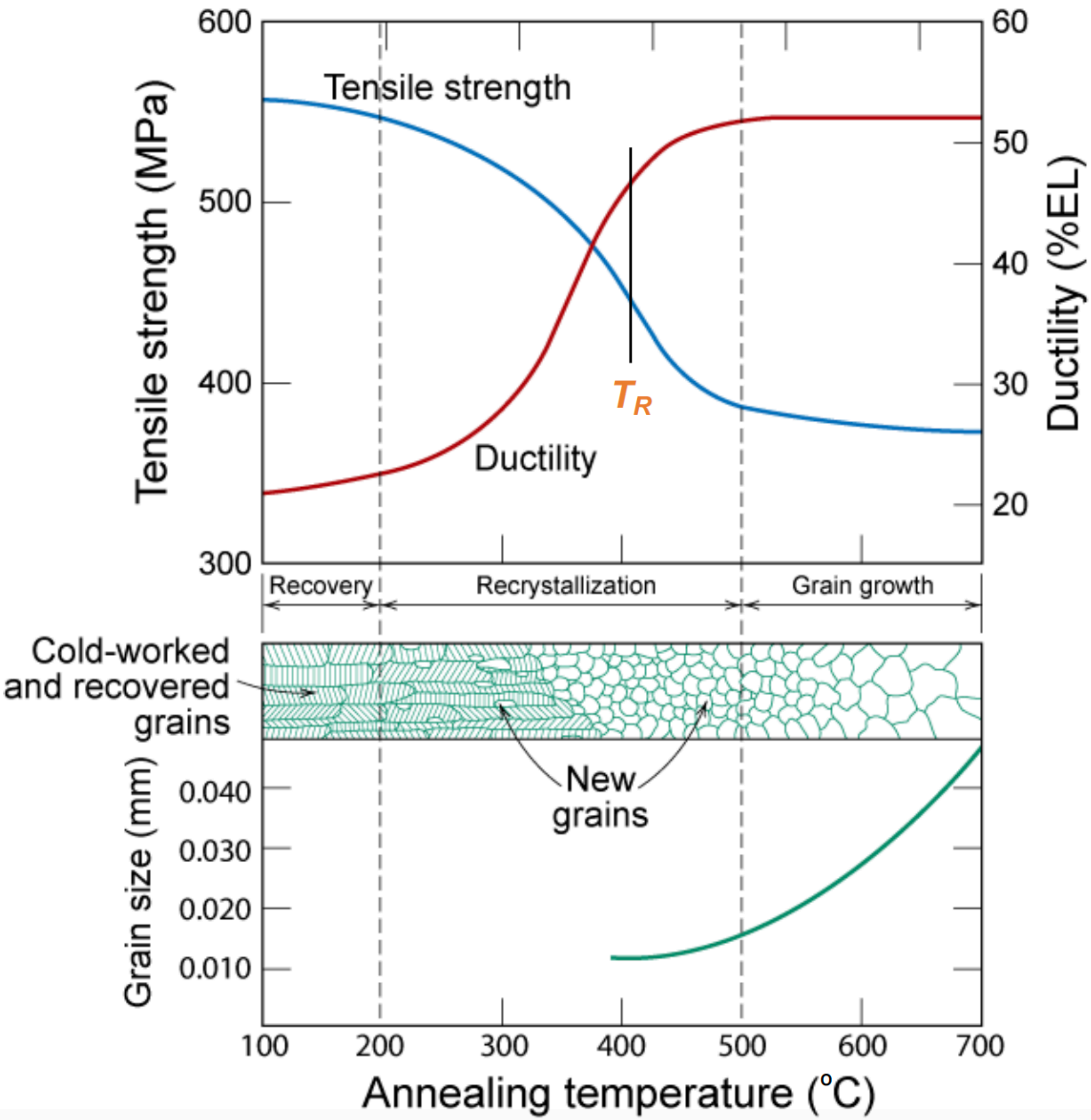


Fig. 1. Three-link chain model of the central paradigm of materials science and engineering.

G.B. Olson, *Science* 1997.

E.g., in metallurgy, quenching **temperature** (processing) changes **average crystal size** (structure) which can alter **ductility** (property/performance)

Process-structure-properties



T_R is the recrystallization temperature

This is an example of how mechanical properties drastically depend on the processing conditions *without changing the composition at all.*

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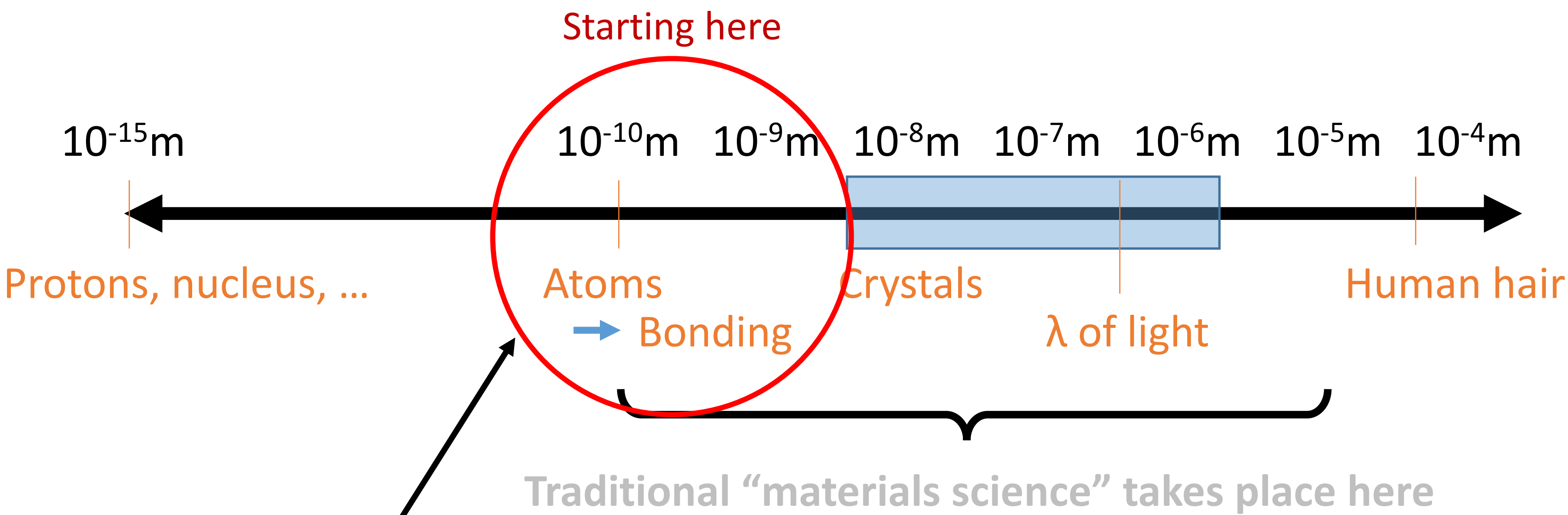
Atomic structure



How do we know anything about the structure of atoms? **Experimental observation.**

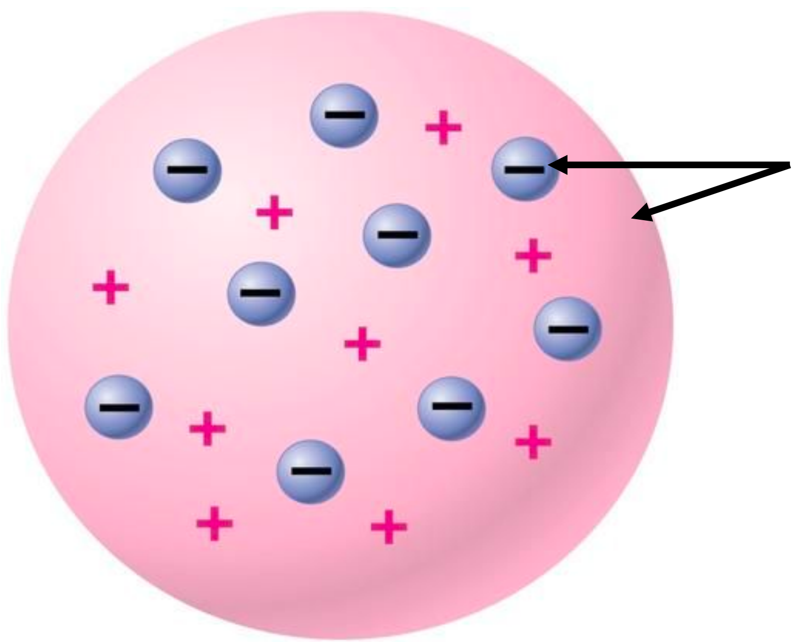
Atomic structure: Plum Pudding Model

<u>Experiments:</u>

1. Electrically neutral
2. Discovery of subatomic particles
   - JJ Thompson discovers electron, 1897

Implication: There must be something with positive charge to cancel out the electrons

<u>Atomic model based on above: "Plum Pudding Model"</u>



Discrete negative charges embedded in a "sea" of positive charge

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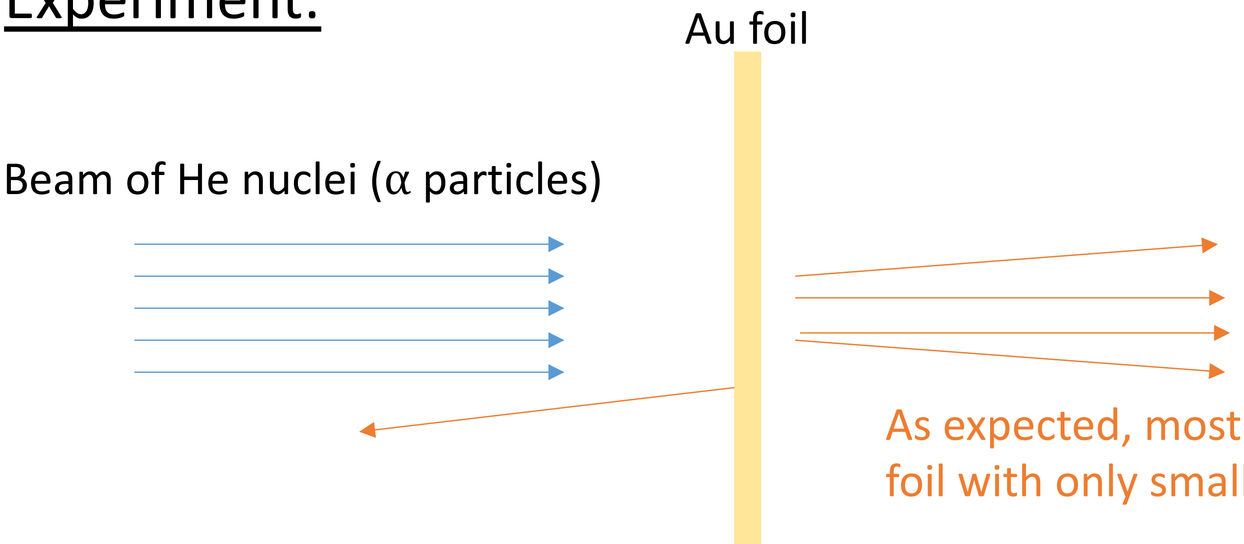
Atomic structure: Rutherford Experiment

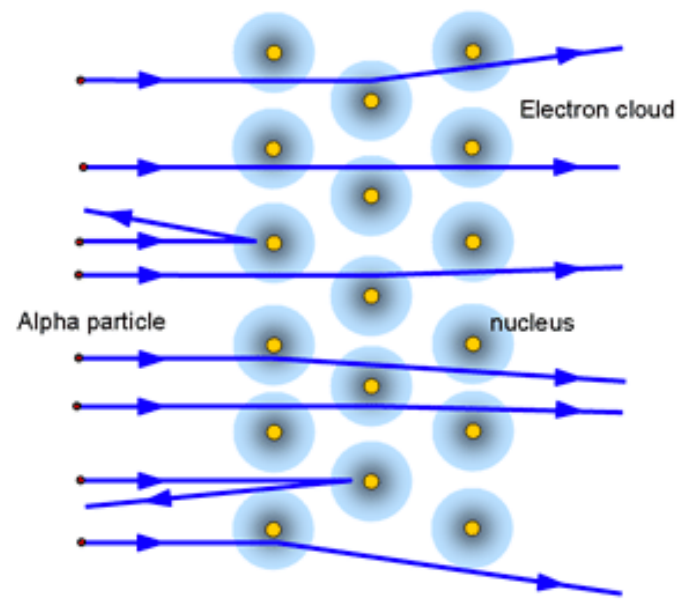
Experiment:



As expected, most particles pass through the foil with only small changes to trajectory

… But some particles rebound back, requiring a very large change to momentum.

This is only possible if the *mass* of the atom is actually concentrated (the *nucleus*):



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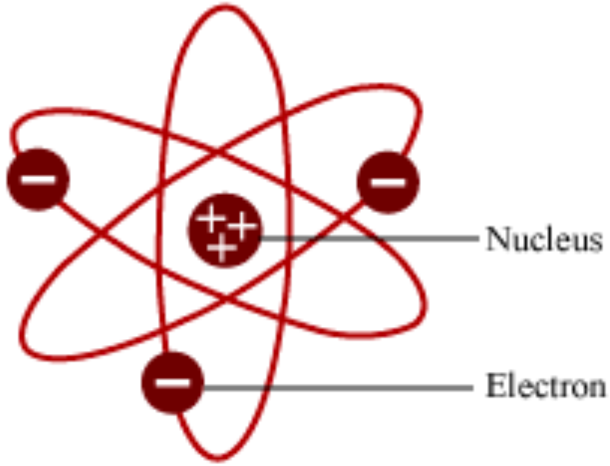
Atomic structure: Rutherford/planetary Model

Rutherford model:



- Electrons were known to be of very low mass, so the mass would have to be concentrated with the positive charge
- If the positive and negative charges are separated, the Coulomb force would pull them toward one another—**requires that the electrons are moving**

Huge problem: From classical physics, a charged particle accelerating in an electromagnetic field must emit radiation—and therefore lose energy. The electrons would therefore spiral in toward the nucleus.

Atoms would be unstable in this model.

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