ESO 205A (T)

Nature and Properties of Materials

Interaction session: 11-12 Monday
Tutorial: 11-12 Thursday

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Paradigm of the course

What is it for me in the course ?

- The Instructor gets to teach a large class and get a feeling of bossing around
- MSE and CHE UG: No choice bad luck
- Other UG: A chill course to finish my ESO credit requirement

Materials research cuts through disciplines and is inherently multi-disciplinary in nature

- During the pandemic, lot of work on material for N-95 masks
- Cheap PPE (PIPES of IIT Kanpur)
- PIPES comes from our undergrad from CSE who is now a faculty in BSBE
- To solve real life problems and have scientific and/or societal impact one needs breadth of knowledge and depth (expertise) in one field
- This course will offer you the breadth, get your own depth

How to enjoy the course ?

- Attitude matters
- Kaleidoscopic view of materials science
- Similar to menu tasting in a Big Fat Indian Wedding you have gatecrashed before you gorge on the items of choice
- Lacks rigour compared to say Thermodynamics
- Surely a course made for Discussion groups
- Be curious and imaginative

Grading

- Mid-sem 20 %
- End-sem 25%
- Quizzes 20%
- Assignments 15%
- Projects 10%
- Attendance and class participation in forums, discussion meets 10%

Course content

Topic	Suggested number of lectures
Introduction: Structure-property correlation in wide range of materials and its importance with examples (1L)	1
Structure (11L)	
• Structure at varying length scales : sub-atomic, atomic structure, microstructure, macrostructure	1
• 2D periodic patterns, symmetries and point groups	2
• Extend to 3D patterns, space groups, Bravais Lattices	1
• Rational crystallographic planes and directions	1
• Bonding, packing, coordination number	1
• Covalently bonded solids (e.g., diamond cubic, Si)	1
• Pauling's rules and ionic crystals	2
• Glasses and polymers	2
Role of Crystal Defects (5L)	
• Point defects: thermodynamics, Schottky and Frenkel defects, Kroger-Vink notation,	2
• Line defects (Edge and screw), Burgers Vector (can be taught just before the properties)	1
• Surface defects – Surfaces, interfaces, significance of scale	1
• Defect interactions – influence on properties	1

Basic Structure Characterization (3L)	
• X-Ray diffraction – Braggs Law, Structure Factor concept	1
• Microscopy Techniques	1
• Examples of structure characterization	1
Evolution of Microstructure (8L)	
• Phase Equilibria, phase diagrams	2
• Diffusion in the solid state	2
• Phase Transformation – mechanisms and kinetics	2
• Applications to microstructure design	2

Correlation of structure and Material Properties with selected case studies (12L)	
Mechanical Properties (6L)	
• Tensile properties: engineering and true stress-strain curves, elastic modulus, yield and tensile strengths, ductility and toughness, properties for different engineering materials	1
• Elastic modulus, bonding, atomic structure - Madlung constant	1

• Plastic deformation, slip, dislocation motion, critical resolved shear stress	1
• How to modify properties of materials – correlation to structure – strengthening mechanisms	2
• Introduction to fatigue and creep properties of materials with suitable examples	1
Electrical (conductors, semiconductors and insulators) and Magnetic Properties (6L)	
• Distinction between conductors, semiconductors and insulators	1
• Brief summary of Free electron theory and Band Theory	
• Relation of electrical properties with structure and microstructure with suitable examples	1-1/2
• Dielectric Materials with a brief introduction to ferroelectrics	1 1
• Magnetic materials and structure relations *e.g.* texture	1 1-1/2
Total number of lectures	**40**

Suggested Texts and Resources

- W.D. Callister, Materials Science and Engineering: A Introduction, Wiley
- V. Raghavan, Materials Science and Engineering, Prentice Hall, India
- J. Wulff et al, The structure and Property of Materials, Wiley
  - Vol. 1: Structure
  - Vol. 2: Thermodynamics of Structure
  - Vol. 3: Mechanical Behavior
  - Vol. 4: Electronic Properties
- M.F. Ashby and D.R.H. Jones, Engineering Materials, Pergamon
  An introduction to their properties and applications
  An introduction to microstructure

NPTEL course of Prof. Rajesh Prasad and Prof. Ashish Garg
E-Textbook by Prof. Anandh Subramanian

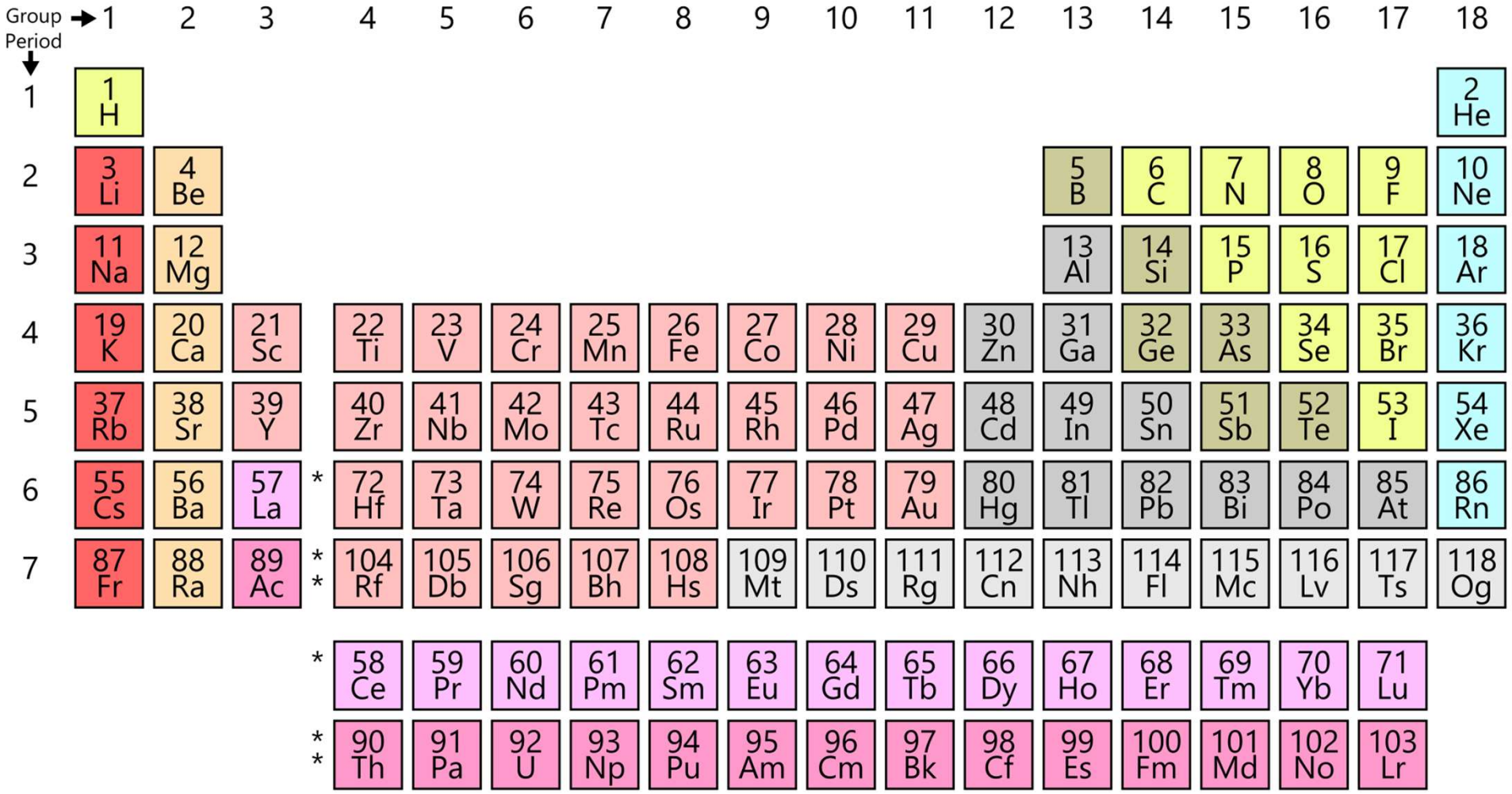
- I will share reading material for different topics

Introduction

- Everything is made of something
- Natural and man made things
- Engineers deal with matter and theoretical physicist with dark matter
- Matter is a material
- Different classes of materials
- Materials drive civilization

https://www.tvguide.com/tvshows/the-big-bang-theory/288041/

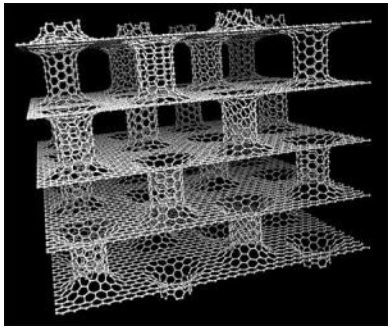
The Periodic Table

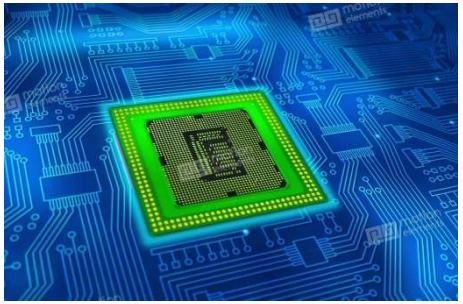


https://en.wikipedia.org/wiki/Periodic_table#/media/File:Simple_Periodic_Table_Chart-en.svg

- Your first communication device versus the one you are using for this class

- Stone age – Bronze age – Iron age – Silicon age – Carbon age





https://www.youtube.com/watch?v=UL7beNWNLEQ
https://www.amazon.in/
https://www.ancient-origins.net/
https://predictabledesigns.com/

- Different classes of materials
- Metals and alloys, Polymers, Elastomers, Ceramics, Glasses, Composites
- Metallic materials, Polymers, Ceramics and Composites
- Distinct properties and characteristic lead to different functionality
- Look at the kitchen: Tea is boiled in a steel pot, filtered through a plastic mesh and served in a porcelain cup.
- Clothing material: cotton, wool, polyster

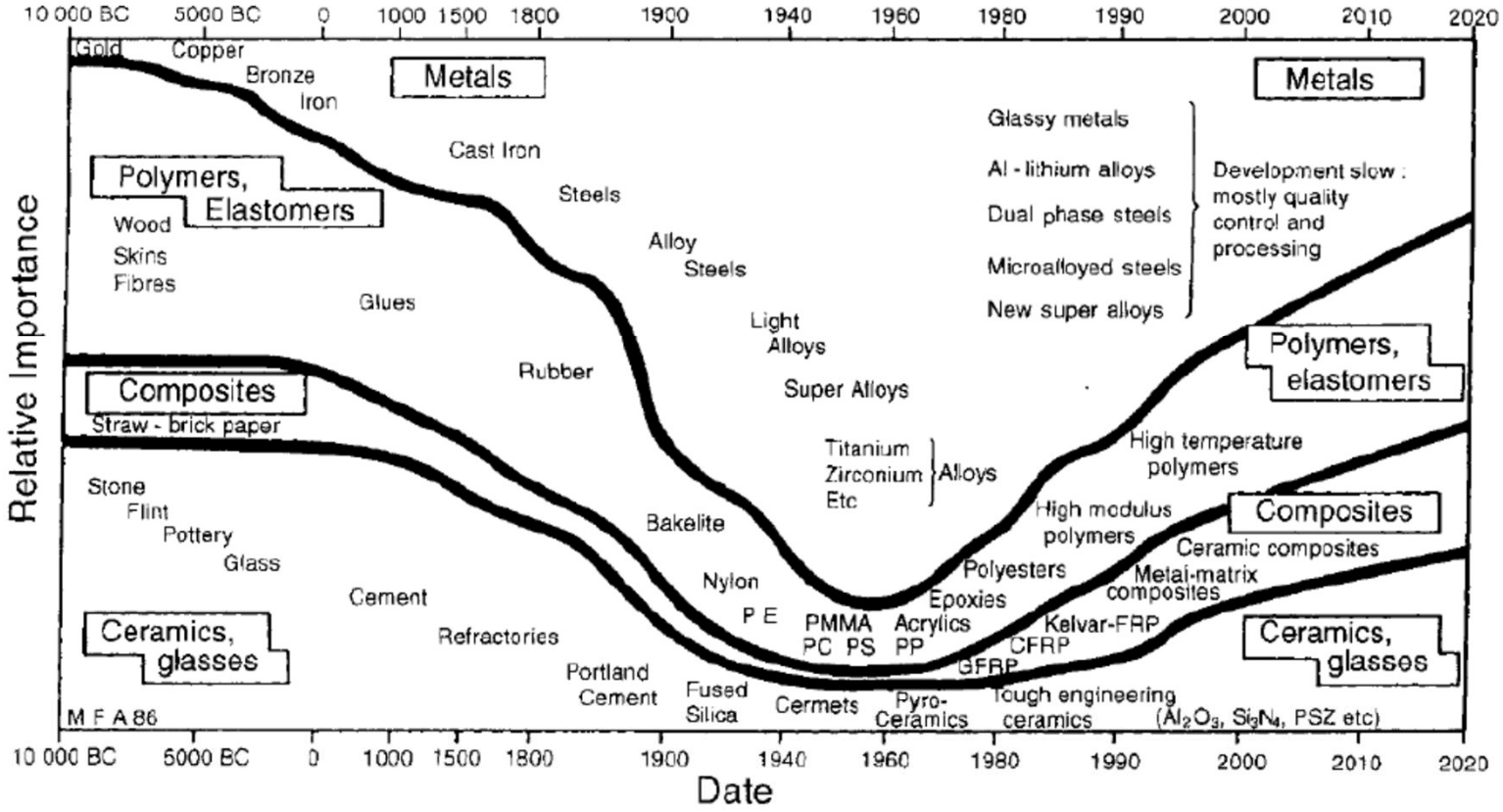
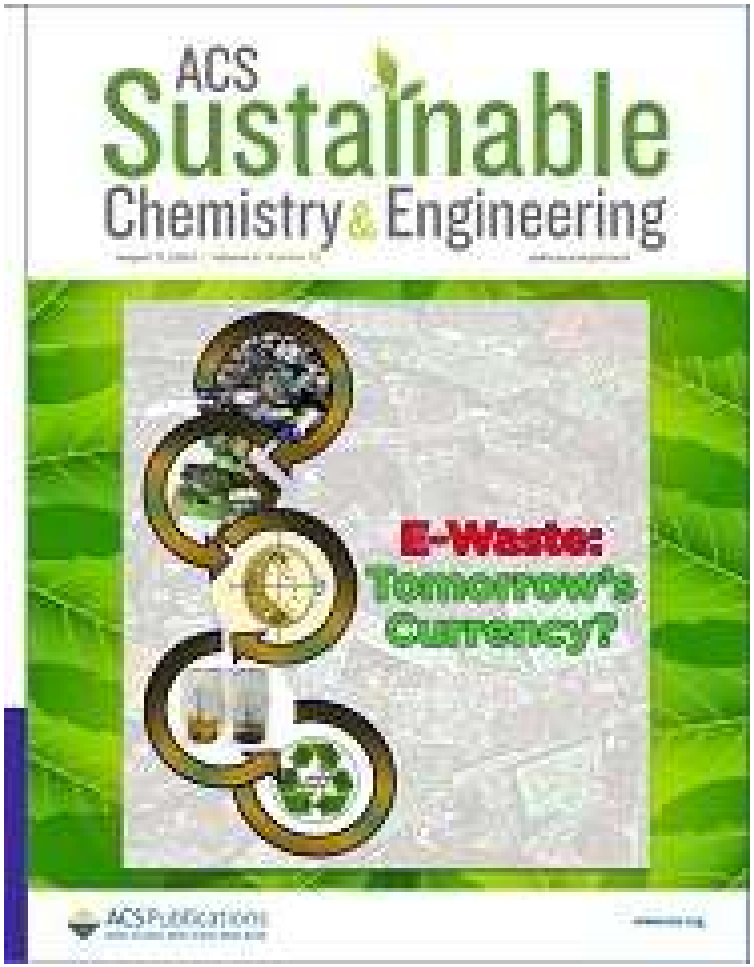


Figure 2: The evolution of engineering materials with time. 'Relative Importance' in the stone and bronze ages is based on assessments of archaeologists: that in 1960 is based on allocated teaching hours in UK and US universities; that in 2020 on predictions of material usage in automobiles by manufacturers. The time scale is non-linear. The rate of change is far faster today than at any previous time in history. Source: Ashby [18].

Marques Journal of Performability Engg. 10 (2014) 589

- Selection of materials
- Availability
- Sustainability
- Environmental concerns

- Design for future generation
- Are we leaving a better Earth for the next generation ?
- Mining, manufacturing, chemical industries, energy….



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ACS Sustainable Chemistry & Engineering

pubs.acs.org/journal/ascecg

Research Article

Green Route for Beneficiation of Metallic Materials from Electronic Waste for Selective Reduction of CO_2

Nidhi Sharma, Anurag Bajpai, Pradeep Kumar Yadav, Subramanian Nellaiappan, Sudhanshu Sharma,* Chandra Sekhar Tiwary,* and Krishanu Biswas*

Cite This: https://dx.doi.org/10.1021/acssuschemeng.0c03605

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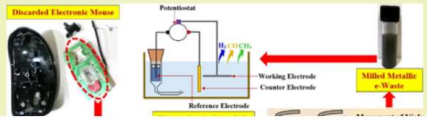
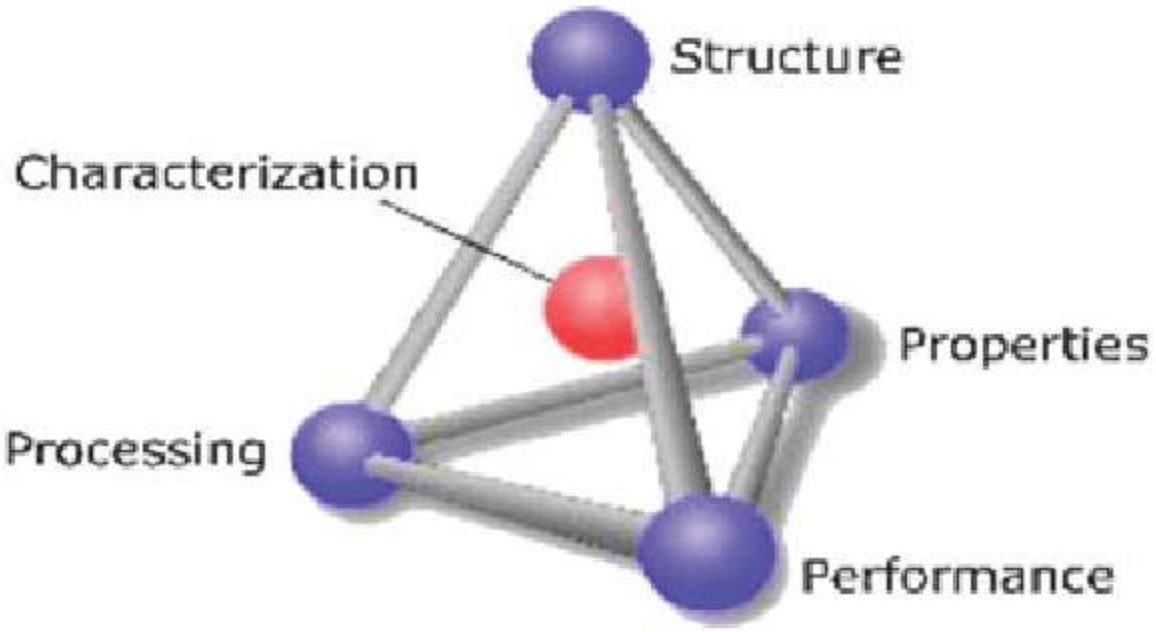
ABSTRACT: The effective disposal of ever-increasing electronic waste (e-waste) is one of the grand challenges for the scientific and technological community today. As e-waste has exponentially been increasing the burden on our environment with long-term effects on the ecosystem, the need for finding sustainable means to recover, reuse, and recycle the materials available in the e-waste is much



The Foundation



Cross et al. MRS Bulletin 2015

Structure

- Structure is arrangement of parts/objects to make something complex
- Structure decides properties like company decides character
- Iron is present in fences that rusts but utensils do not
- Horse shoe and landing gear of aircraft contains iron
- Blood contains iron
- Difference in chemistry and structure

Cross et al. MRS Bulletin 2015

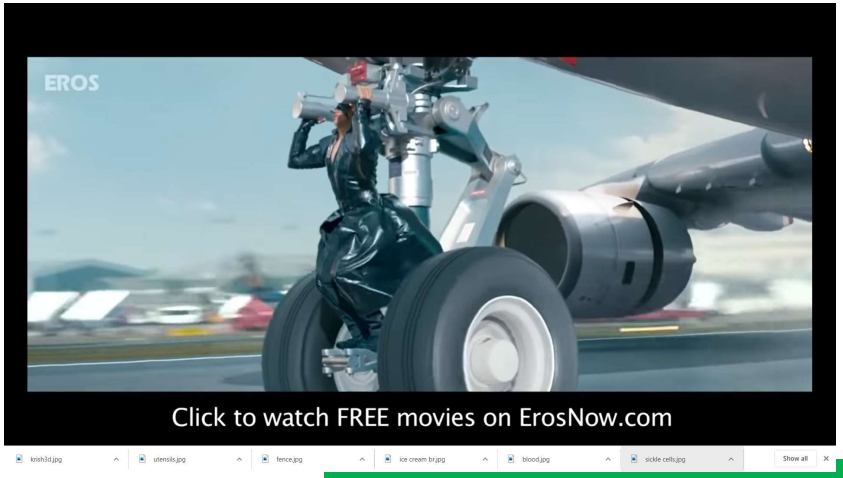
Iron

Iron fence

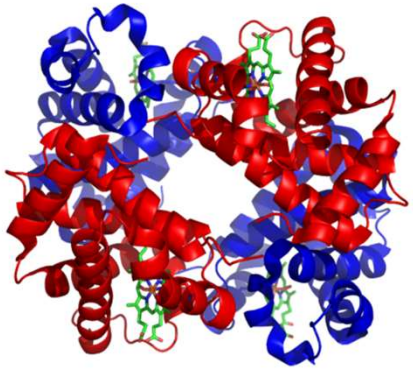
Stainless steel utensils

Horse shoe of construction steel (saria)

Landing gear of steel that contains iron



You become anemic if less iron in blood



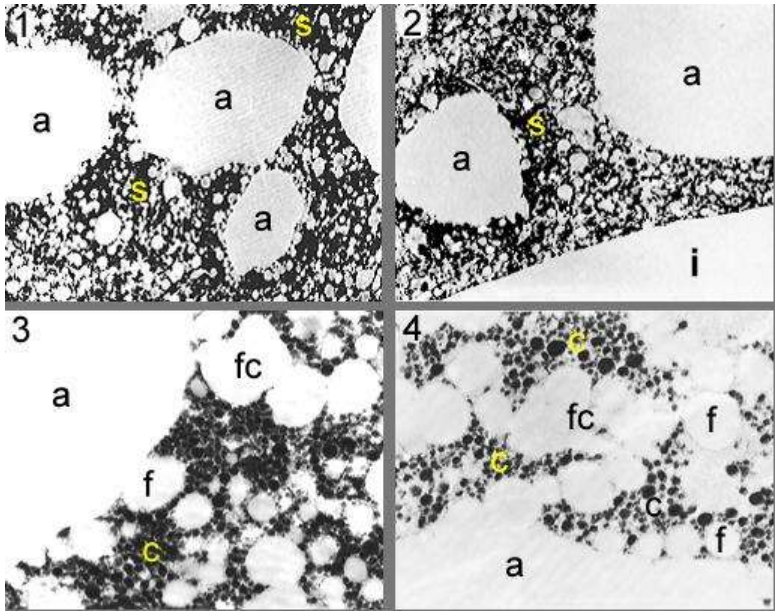
Hemoglobin

Will of steel ?

Ice cream

- Ice cream is mostly air with some milk fat, syrup and flavour
- Small size of ice crystals and better emulsion of fat and syrup with air
- Ever wondered why home made ice cream not as good as the commercial one
- Liquid nitrogen ice cream tastes better

https://www.compoundchem.com/2015/07/14/ice-cream/



Figures 1 and 2 are cross sections of ice cream at low magnification as viewed by TEM after freeze substitution, showing the unfrozen serum phase (s), air bubbles (a), and an ice crystal (i). In the unfrozen serum, dispersed fat globules and casein micelles are just discernible. At higher magnification (**Figures 3 and 4**), fat globule (f) adsorption to the air serum interface (a) and fat clustering (fc) from partial coalescence in the serum phase can be seen. Highly freeze-concentrated casein micelles (c) can also be seen in the serum phase.

https://www.uoguelph.ca/foodscience/book/export/html/2216