Chapter 11: Metal Alloys Applications and Processing

- How are metal alloys classified and how are they used?
- How do properties vary throughout a piece of material that has been quenched, for example?
- How can properties be modified by heat treatment?

How to distribute your efforts on chapter 11

Read Only: 11-1 to 11-6 make sure you think about all the phase transformation we have been looking at while you read about the different kinds of steels and irons.

Study: 11-7 to 11-9 and think about lab V while you do so.

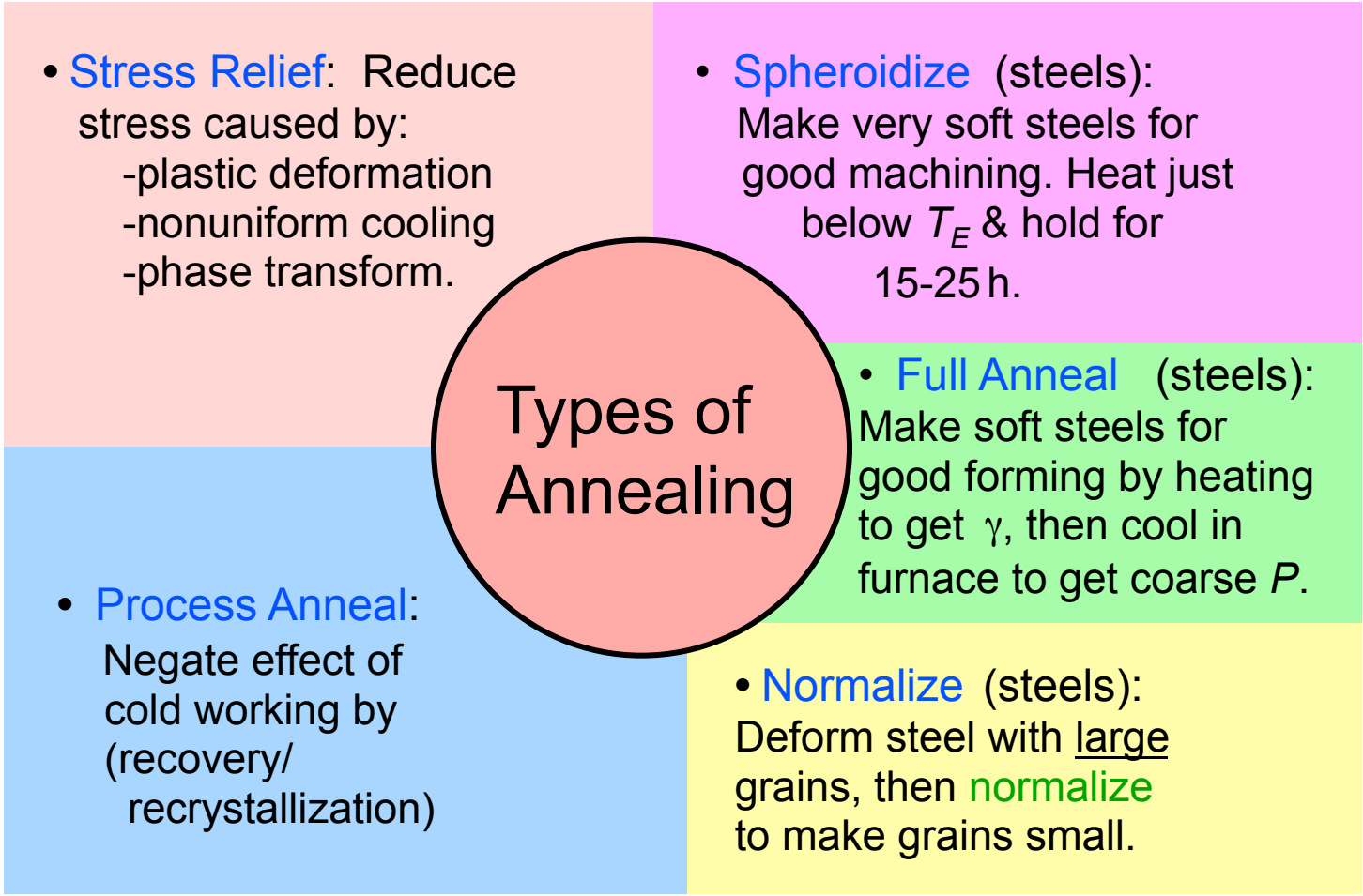
Basic concepts

- **Annealing: a heat treatment**
  - **heat up**
  - **hold for for an extended time period**
  - **cool**

- **Function of annealing:**
  - **relieve stress**
  - **increase softness, ductility and toughness**
  - **produce specific microstructure**

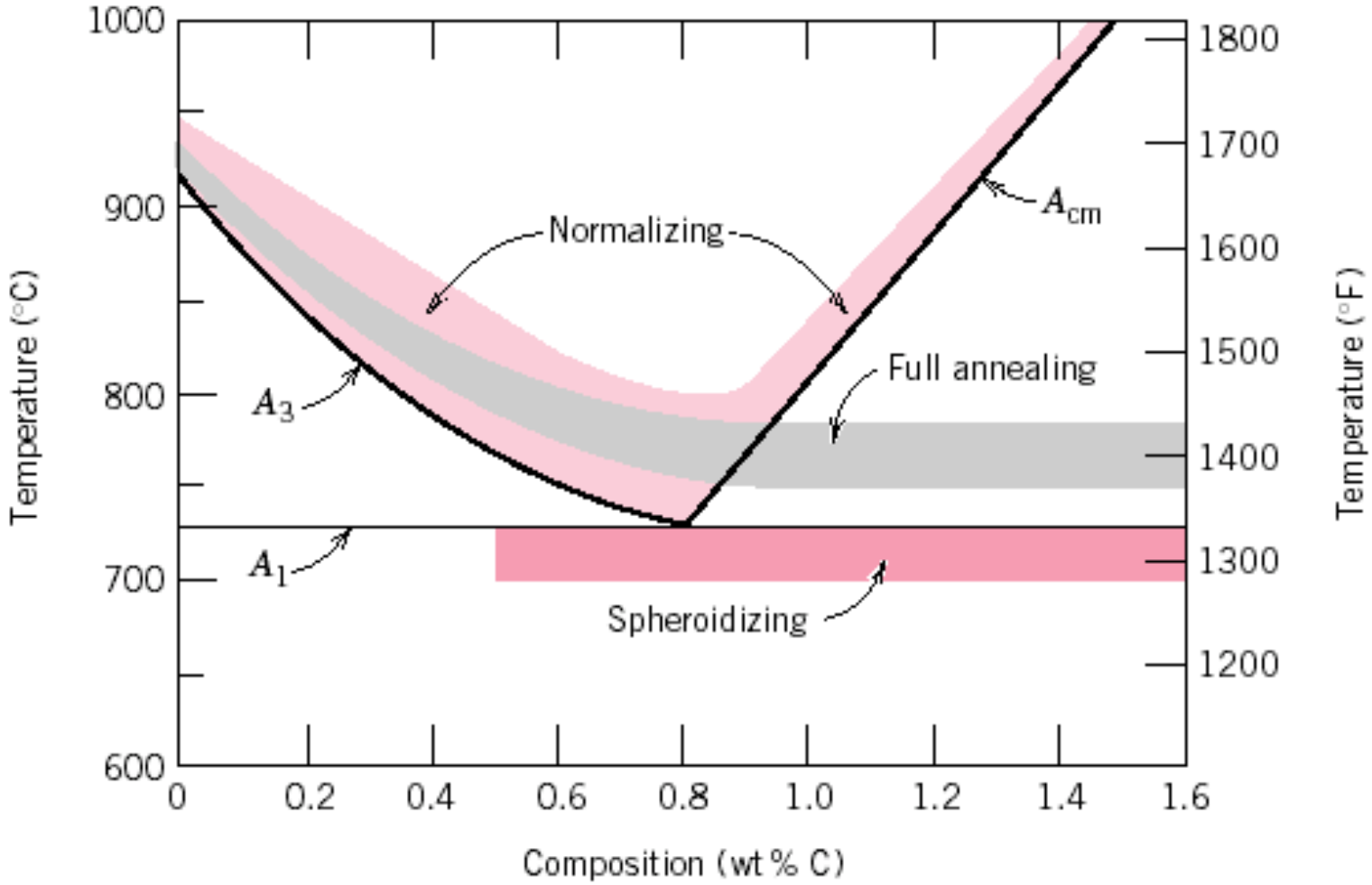
Thermal Processing of Metals

Annealing: Heat to T_{anneal}, then cool slowly.



Based on discussion in Section 11.7, *Callister 7e*.

Heat Treatment

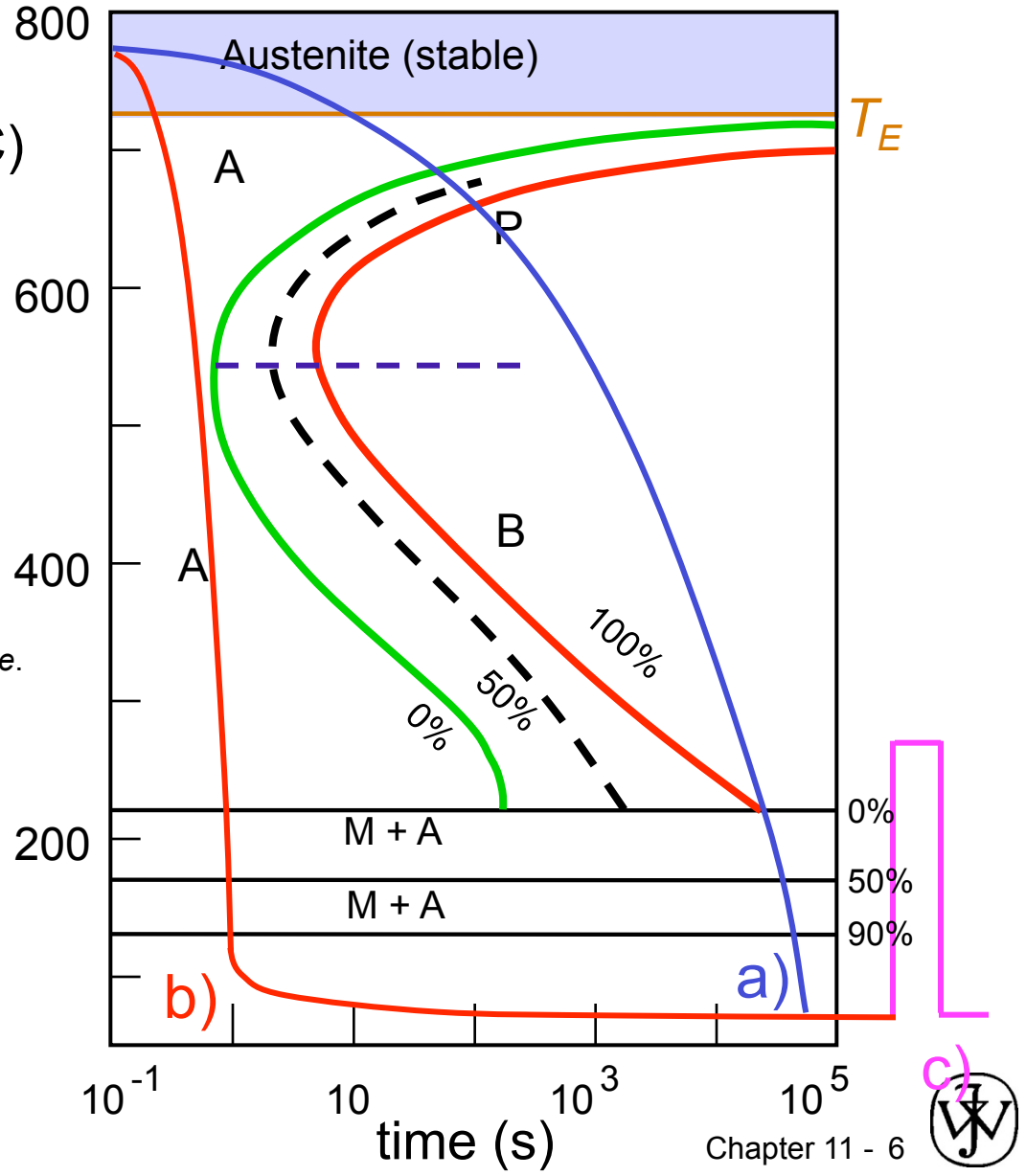


Heat Treatments

a) Annealing

b) Quenching

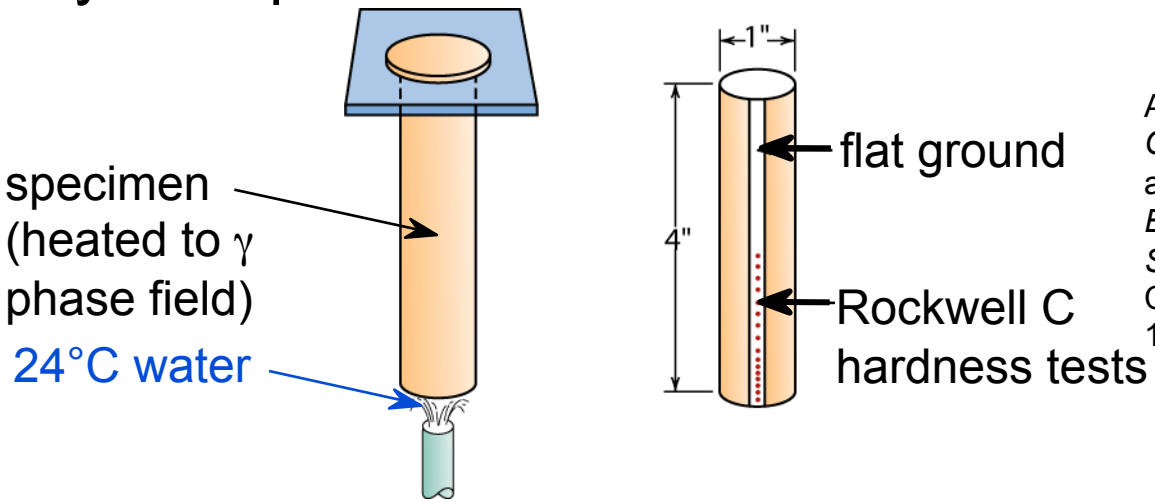
c) Tempered Martensite



Adapted from Fig. 10.22, *Callister 7e*.

Hardenability--Steels

- Ability to form martensite
- Jominy end quench test to measure hardenability.



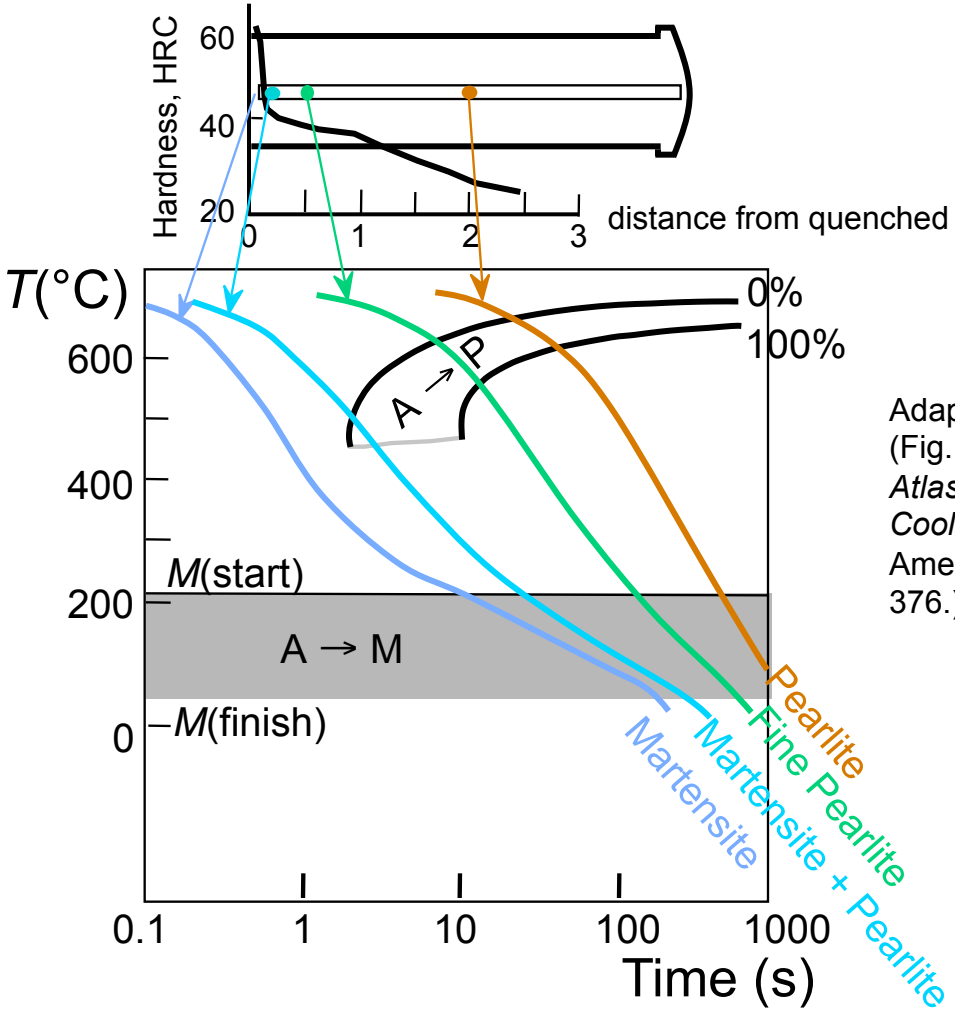
Adapted from Fig. 11.11, *Callister 7e*. (Fig. 11.11 adapted from A.G. Guy, *Essentials of Materials Science*, McGraw-Hill Book Company, New York, 1978.)

- Hardness versus distance from the quenched end.

Adapted from Fig. 11.12, *Callister 7e*.

Why Hardness Changes W/Position

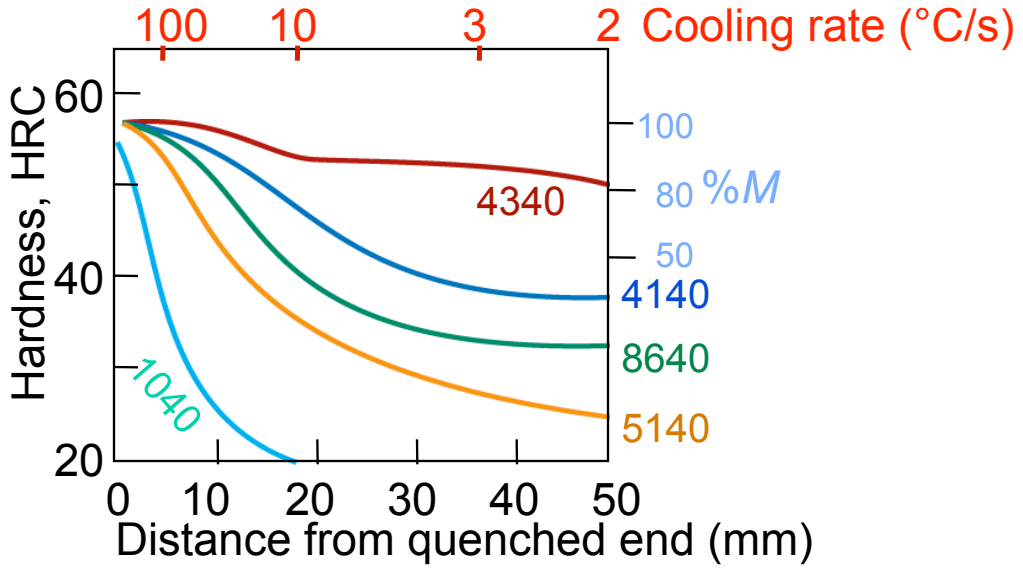
- The cooling rate varies with position.



Adapted from Fig. 11.13, *Callister 7e*. (Fig. 11.13 adapted from H. Boyer (Ed.) *Atlas of Isothermal Transformation and Cooling Transformation Diagrams*, American Society for Metals, 1977, p. 376.)

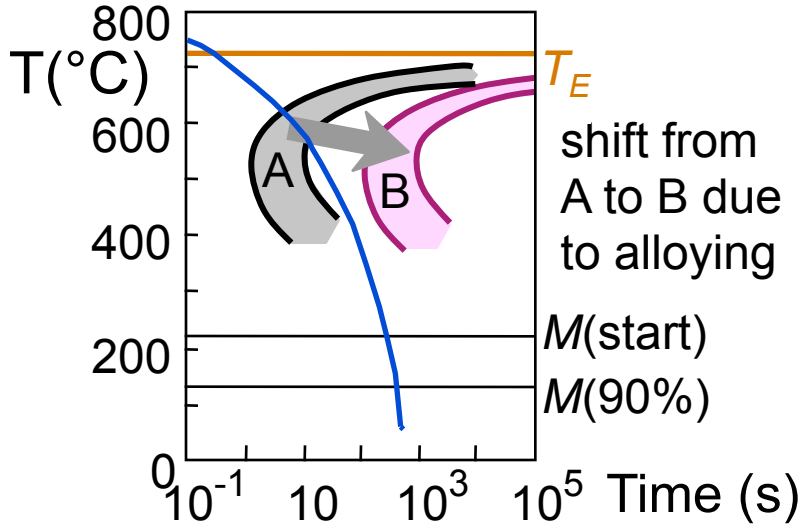
Hardenability vs Alloy Composition

- Jominy end quench results, C = 0.4 wt% C



Adapted from Fig. 11.14, *Callister 7e*.
(Fig. 11.14 adapted from figure furnished courtesy Republic Steel Corporation.)

- "Alloy Steels" (4140, 4340, 5140, 8640)
  - --contain Ni, Cr, Mo (0.2 to 2wt%)
  - --these elements shift the "nose".
  - --martensite is easier to form.



Quenching Medium & Geometry

- Effect of quenching medium:

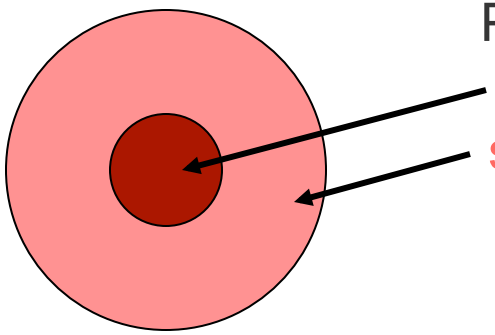
Medium	Severity of Quench	Hardness
air	low	low
oil	moderate	moderate
water	high	high

- Effect of geometry:

  When surface-to-volume ratio increases:

  --cooling rate increases

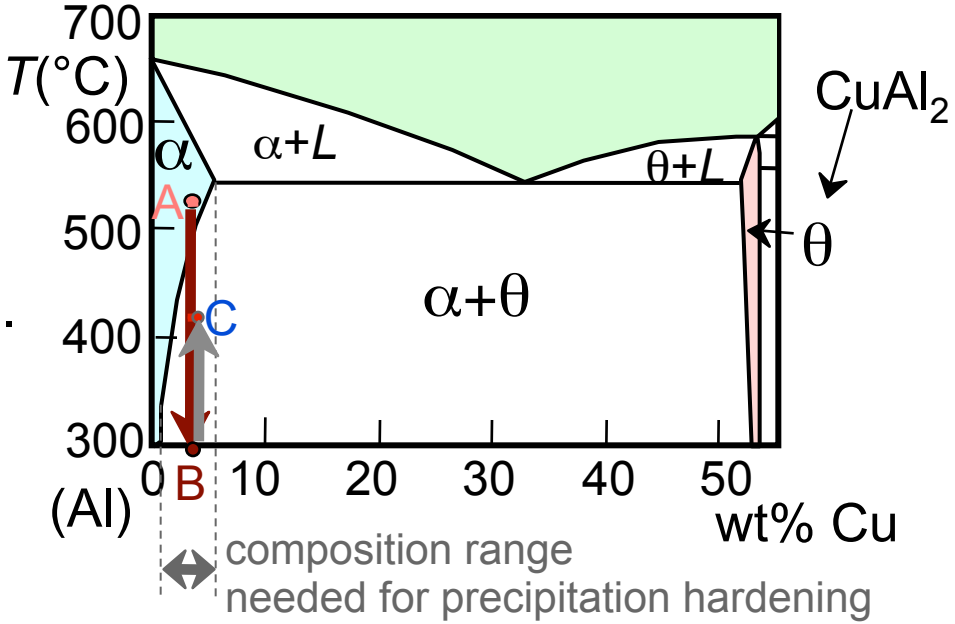
  --hardness increases



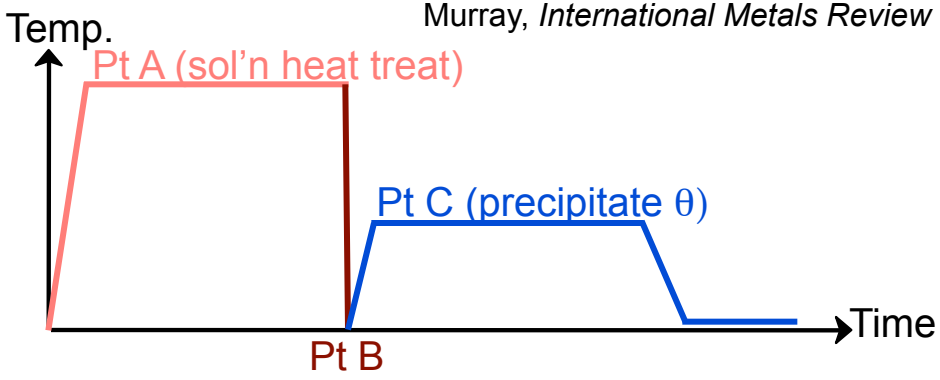
Position	Cooling rate	Hardness
center	low	low
surface	high	high

Precipitation Hardening

- Particles impede dislocations.
- Ex: Al-Cu system
- Procedure:
  - --Pt A: solution heat treat (get α solid solution)
  - --Pt B: quench to room temp.
  - --Pt C: reheat to nucleate small θ crystals within α crystals.
- Other precipitation systems:
  - Cu-Be
  - Cu-Sn
  - Mg-Al



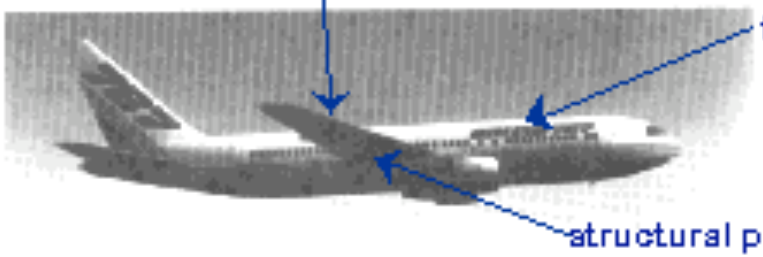
Adapted from Fig. 11.24, *Callister 7e*. (Fig. 11.24 adapted from J.L. Murray, *International Metals Review* **30**, p.5, 1985.)



Adapted from Fig. 11.22, *Callister 7e*.

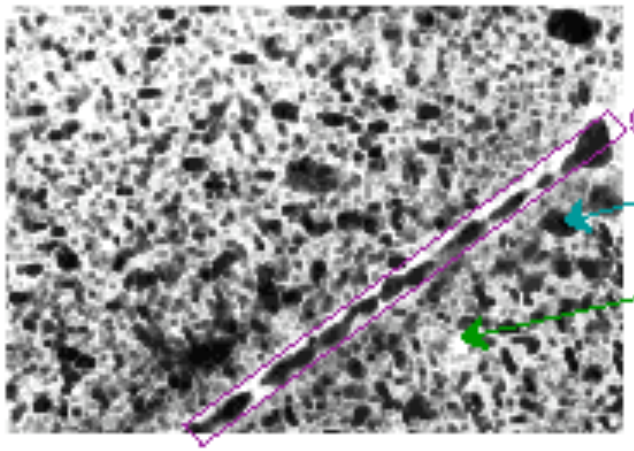
Example: 7150-T651 Al alloy

- **Boeing 757**



Callister,
Fig. 11.0(a)

- **Microstructure: $MgZn_2$ particles**



Callister,
Fig. 11.0(b)

Summary

- Steels: increase *TS*, Hardness (and cost) by adding
  --C (low alloy steels)
  --Cr, V, Ni, Mo, W (high alloy steels)
  --ductility usually decreases w/additions.
- Non-ferrous:
  --Cu, Al, Ti, Mg, Refractory, and noble metals.
- Hardenability
  --increases with alloy content.
- Precipitation hardening
  --effective means to increase strength in
  Al, Cu, and Mg alloys.