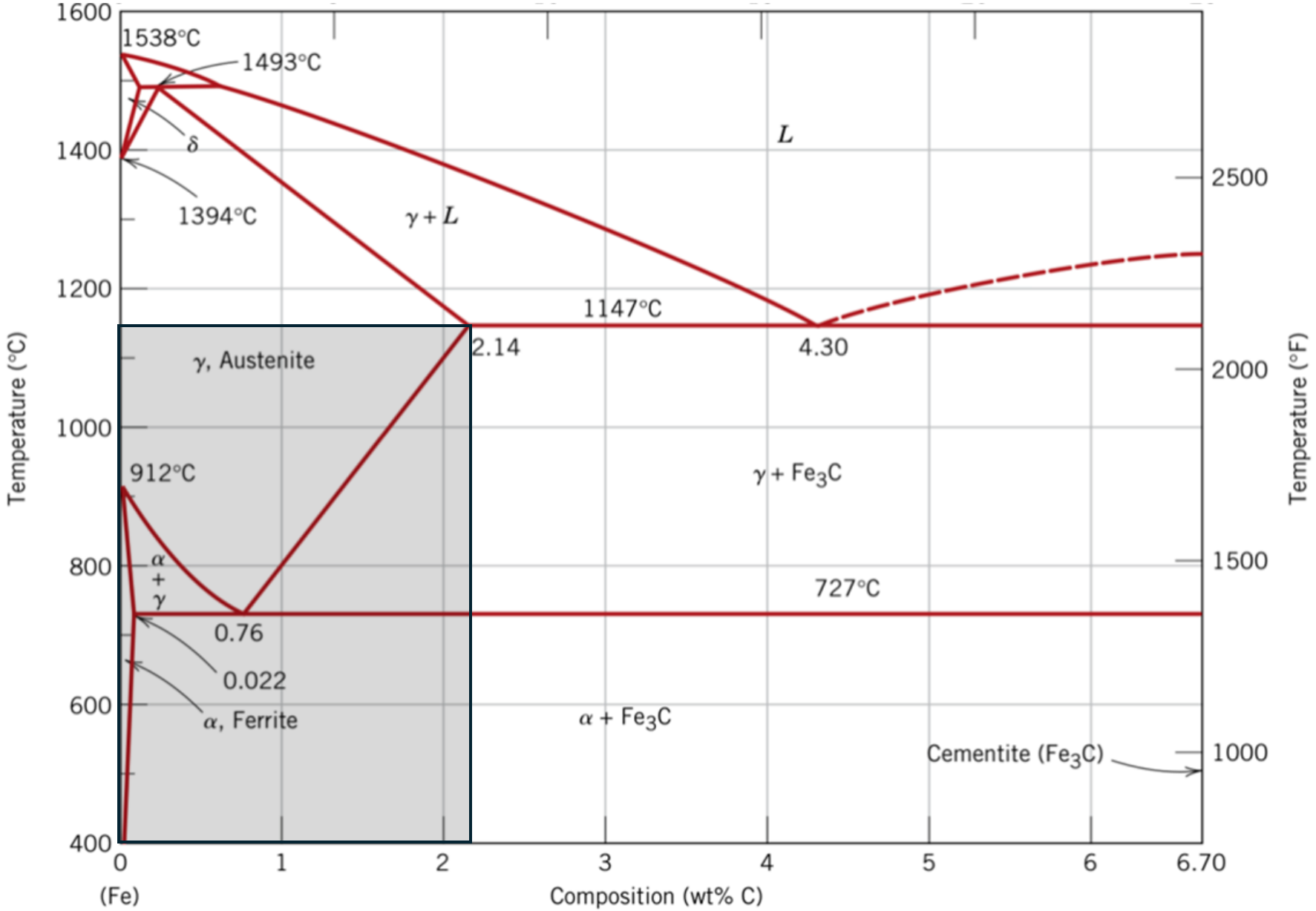
ME 330: Engineering Materials

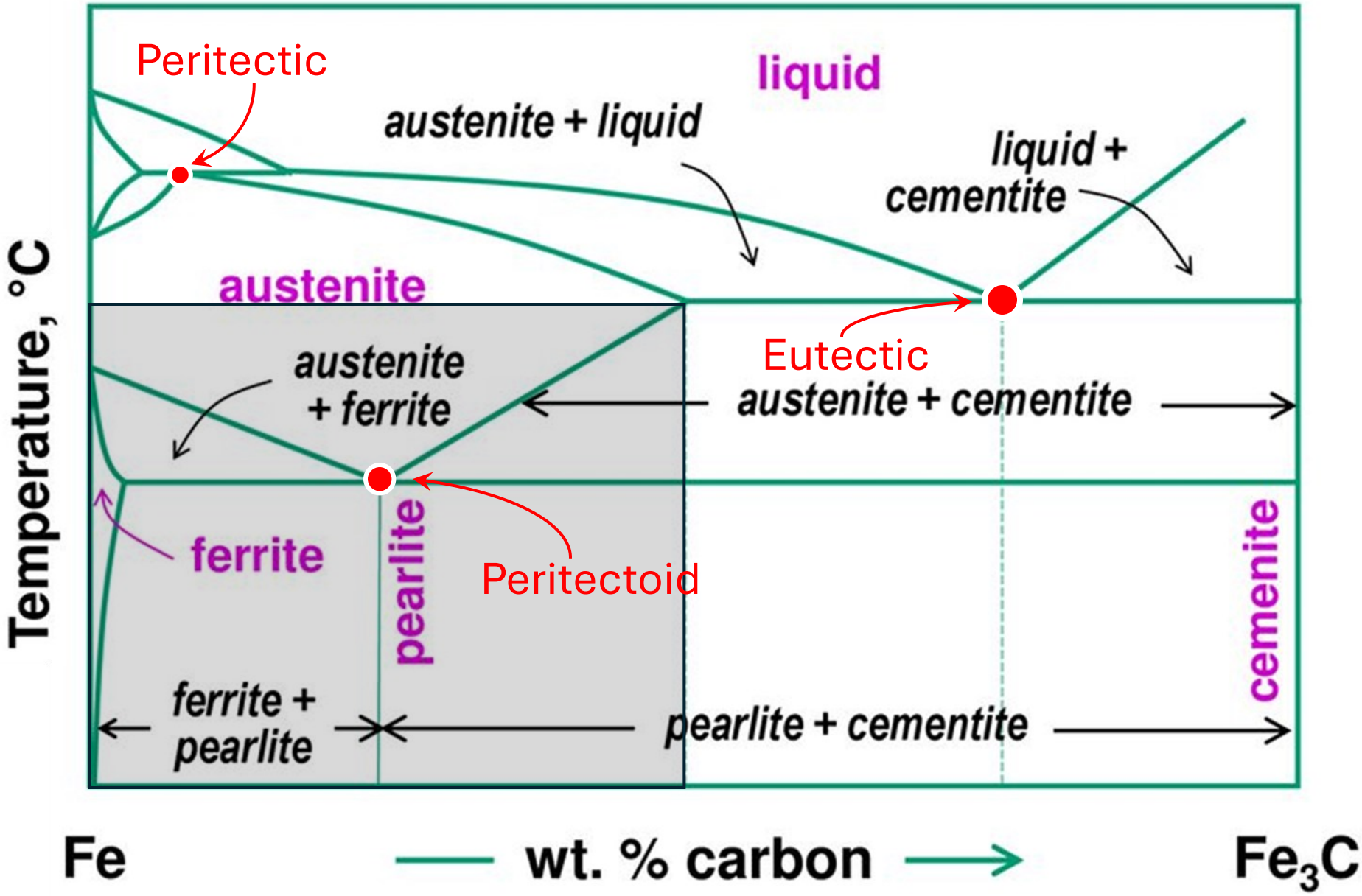
Lab - 5

Heat Treatment of Steel

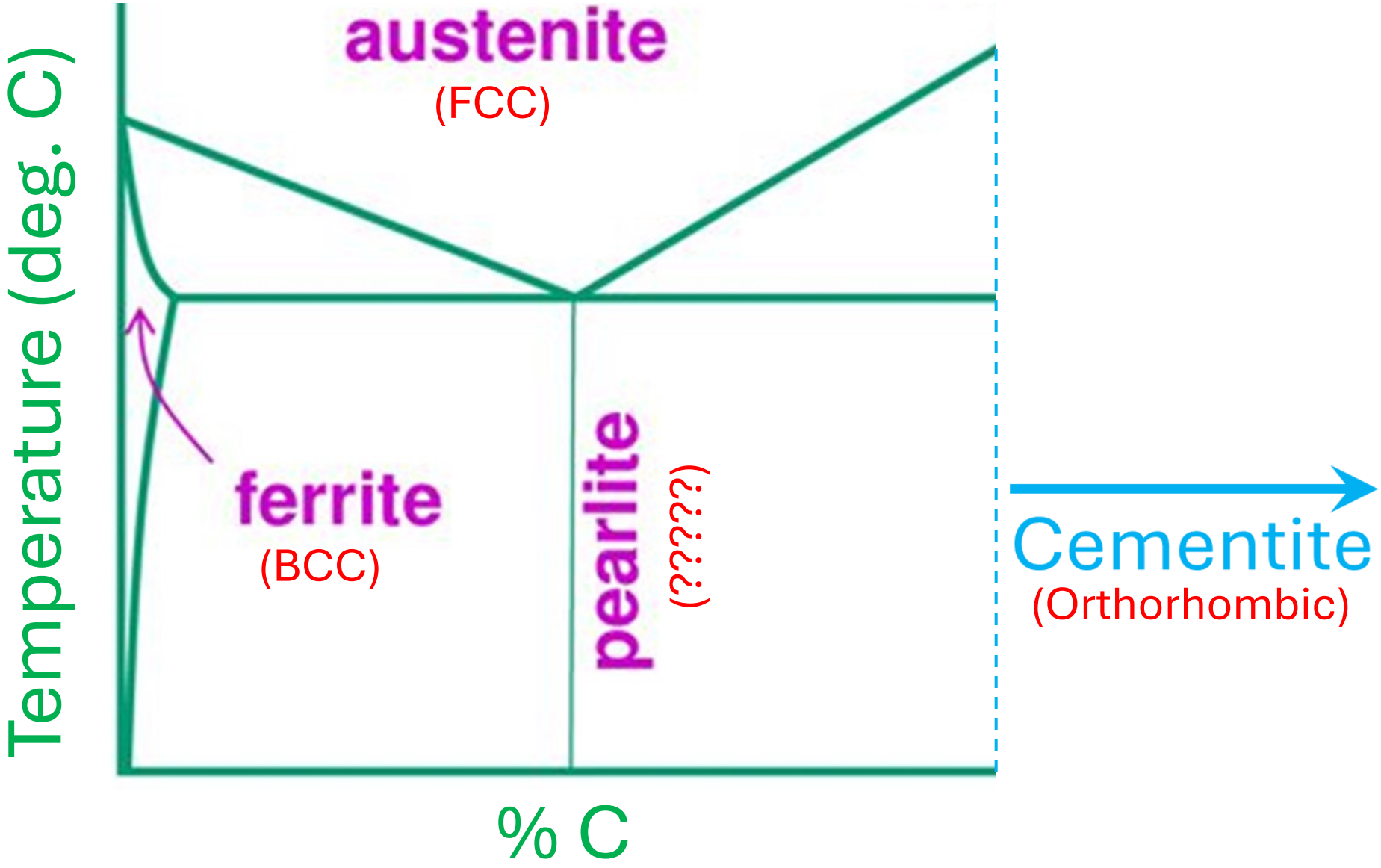
Equilibrium $Fe - Fe_3C$ Phase Diagram



Phase of $Fe - Fe_3C$ System



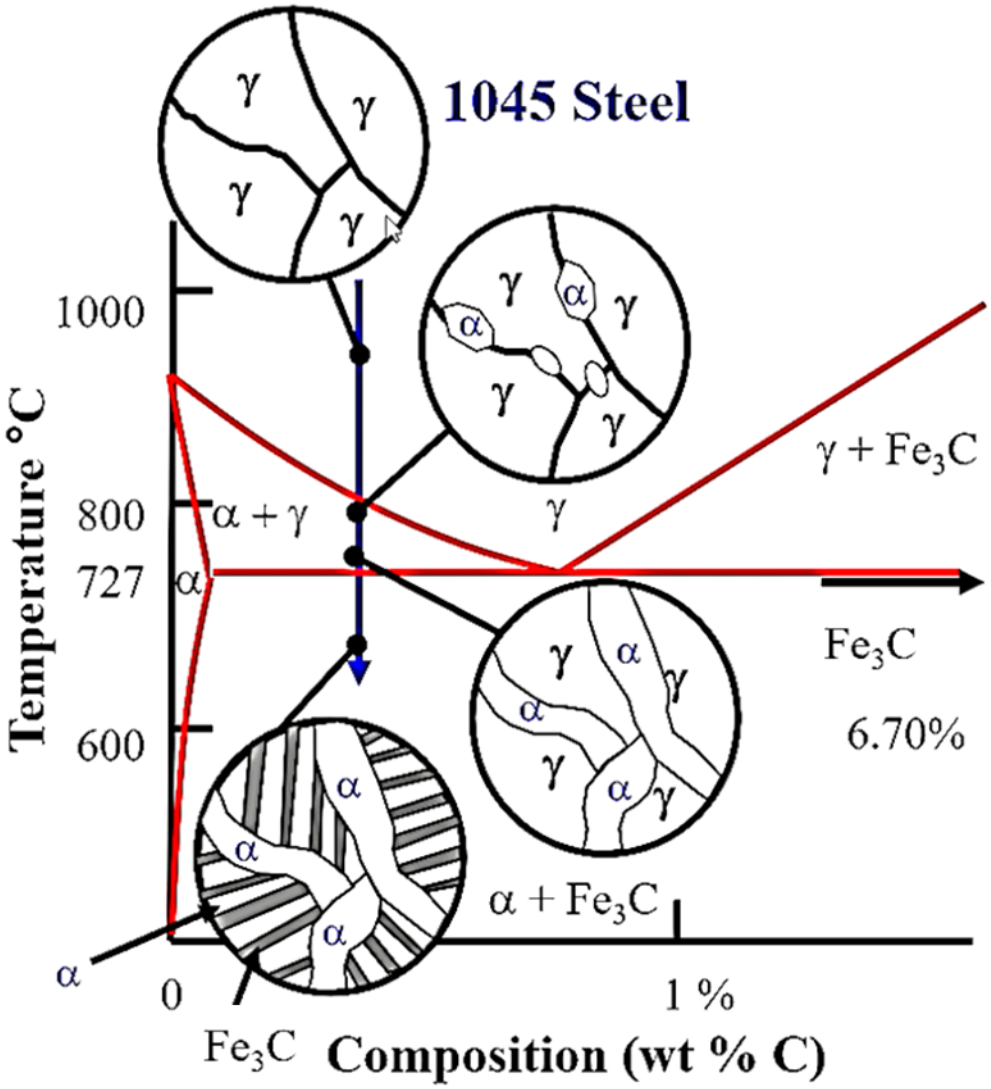
Crystal structure of different phases (Steel)



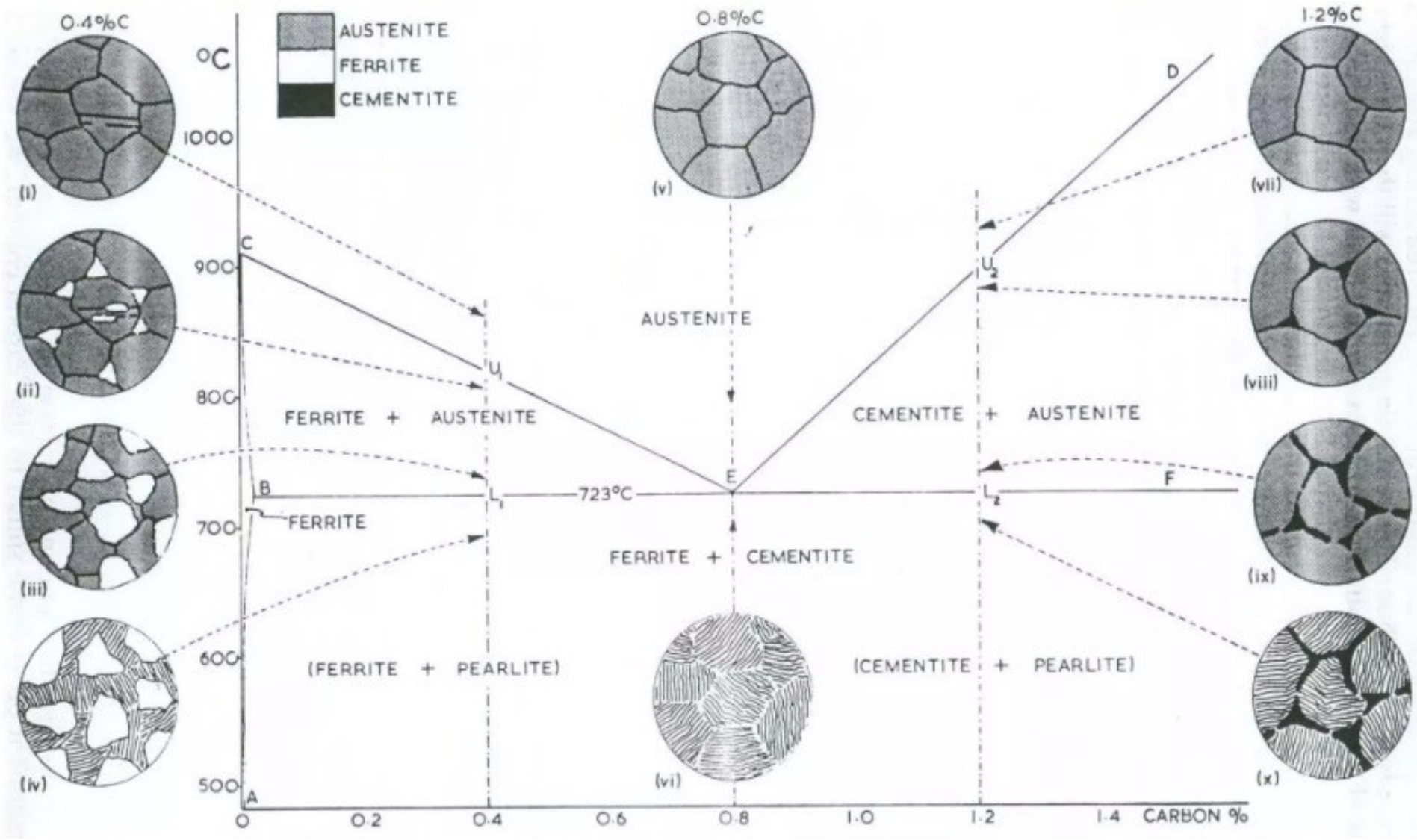
Equilibrium Transformation

- Starts from pure Austenite (FCC-γ)
- α (Pro-Eutectoid Ferrite) starts to nucleate @ grain boundaries
- Upon crossing Eutectoid isotherm remaining γ turns into Pearlite.

Pearlite= { Eutectoid Ferrite + Cementite }

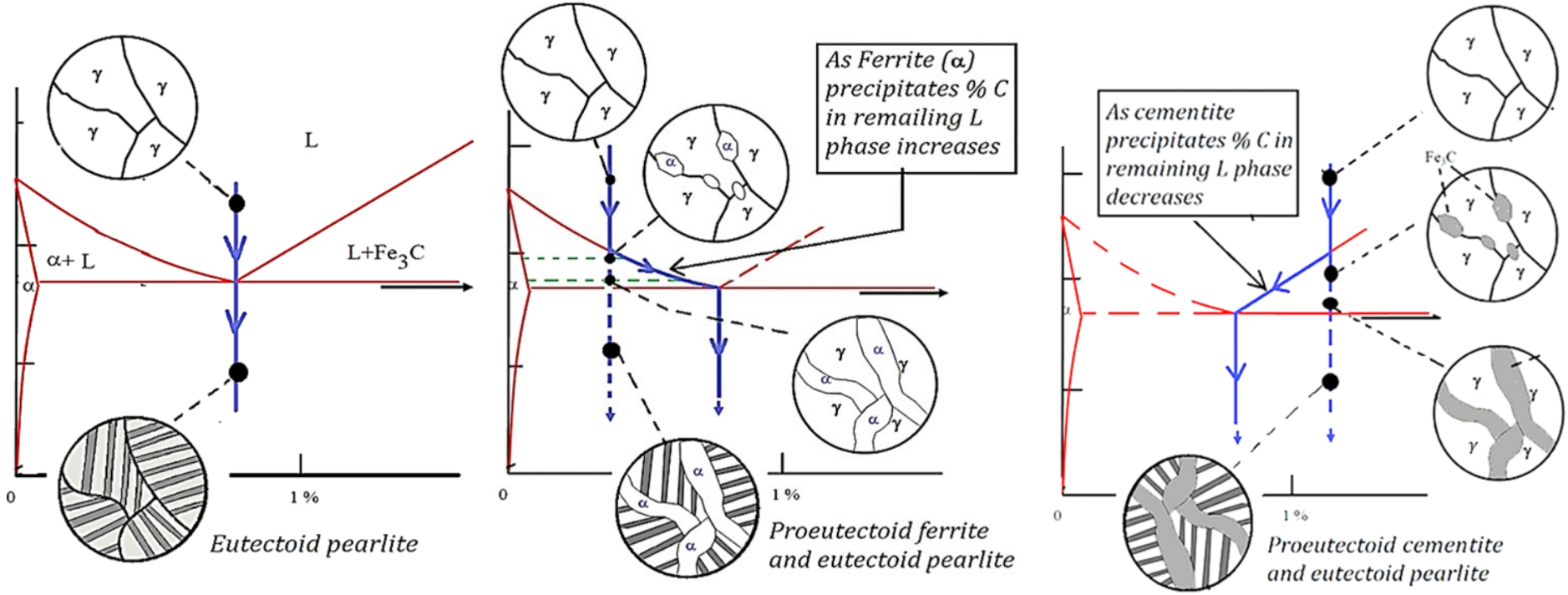


Evolution of Microstructure



% C

Equilibrium Phase Transformation



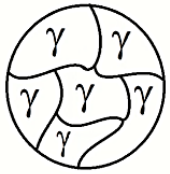
Pearlite= { Eutectoid Ferrite + Cementite }

Heat treatments

- Annealing - Starts from Austenite, Coarse pearlite — Slow cooling
- Normalizing - Starts from Austenite, Fine pearlite — Air cooling
- Quenching - Starts from Austenite, Martensite — Fast cooling
- Tempering - Starts below $T_{Eutectoid}$, (Hold long time @ high temperature) Tempered Martensite — Air cooling

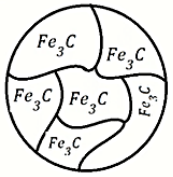
Non-Equilibrium Phases

- **Austenite**
  - FCC Structure.
  - Above 725 ^{0}C.
  - Transforms to other phases.

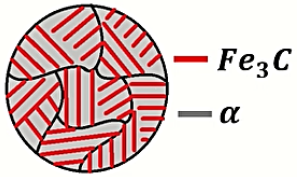


- **Ferrite**
  - Iron + C in solid solution.
  - Max. C is 0.022%.
  - Ductile.

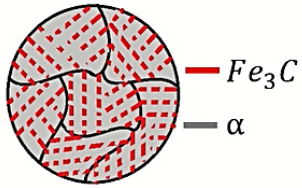
- **Cementite**
  - Compound, Fe_3C.
  - Hard and Brittle.
  - Contains 6.7% C.



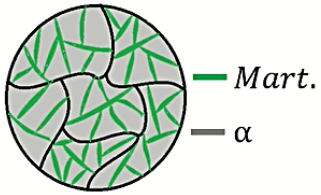
- **Pearlite**
  - Formed by diffusion.
  - Ferrite and cementite.
  - Lamellar structure.
  - Stronger than ferrite.



- **Bainite**
  - Not as much diffusion.
  - Ferrite and cementite.
  - Not lamellar structure.
  - Harder that pearlite.

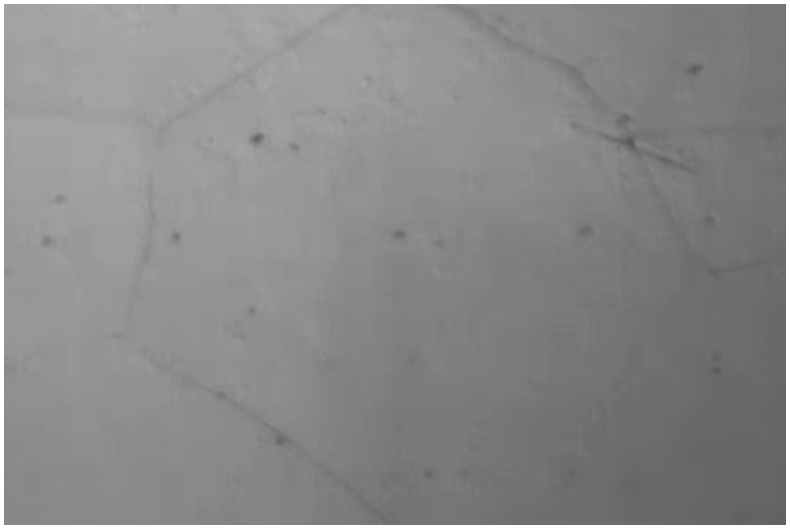


- **Martensite**
  - Diffusion less.
  - Speed of sound.
  - BCT Structure (body-centered tetragon).
  - Strong and brittle.



Martensitic transformation

- Diffusion less process
- C-atoms are trapped in the interstitials
- Austenite (FCC) polymorphically transforms to Martensite (BCT)



- Martensite is a non-equilibrium phase.
- Martensite rapidly transform into other structures upon heating.
- Martensite is locally formed and is supersaturated with Carbon.

Iron Forging @ High Temperature

https://www.youtube.com/watch?v=q_ZhgOlxX_A&t=15s