**Liquidus:**
Anything above is liquid

**Solidus:**
Anything below is solid

**Eutectic reaction:**
$L \rightarrow \alpha + \beta$

At one temperature = invariant
Figure 4.30 (a) Eutectic equilibrium diagram with all the phase fields marked. (b) Schematic drawing of the development of different morphologies in all alloys across the equilibrium diagram.

Microstructures:

- **X1**: Solid β forms first and continues until all solid β forms.
- **X2**: Solid β forms first at T_E, eutectic forms → α + β
- **X3**: Solid α forms first at T_E, eutectic forms → α + β
- **X4**: Cools down until the eutectic temperature T_E → eutectic α + β forms.

Fig. 35. Sketch showing microstructures in simple eutectic system. Note: the photographs in Fig. 42 and 43, although of alloys involving solid solutions, are typical of eutectic systems and should be compared with this sketch.
Shows direction of growth of eutectic (nucleate on $\alpha$)

1) Primary $\alpha$ dendrite

2) Eutectic colony

Boundary between colony
(a) Cu-Ag (x 250)
(b) Al-Si (x 150)
(c) Zn-MgZn₂ (x 500)
(d) Cd-Bi (x 500)
(e) Co-TaC (x 700)
(f) Fe-Fe₃B (x 300)
Figure 4.35 Microstructures of silver–aluminium alloys of three different compositions.
(a) Hypo-eutectic; non-faceted dendrites of the Ag₃Al compound in a eutectic matrix (x 350).
(b) Eutectic alloy; lamellar microstructure (x 150).
(c) Hyper-eutectic; non-faceted Al-rich dendrites in eutectic matrix. (x 350)

Figure 4.69 Transverse microstructure of Al–Si, grown at a very slow growth rate and in a steep temperature gradient (x 50)
(Courtesy of M. G. Day

Figure 4.36 Typical metal–metal eutectic microstructures, transverse sections: (a) lamellar;
(b) ribbon-like; (c) fibrous

Figure 4.70 Fibrous silicon morphology in a rapidly frozen Al–Si eutectic alloy (x 15,000)
(Courtesy of M. G. Day

Idealised shape of eutectic solid–liquid interface showing the cross-diffusion of solute ahead of the interface.
First phase of the eutectic to grow often grows on the pro-eutectic phase

Different views of the same eutectic
Eutectic colonies
Peritectic Microstructures

\[ L + \alpha \rightarrow \beta \]

Figure 4.85 Schematic drawing of peritectic reaction as it actually occurs

Figure 4.86 Thermal analysis of peritectic reaction

MIGHT BE SOME \( \alpha \) LEFT (NON-EQUILIBRIUM)
Tp is the peritectic temperature.

(a) Structure on reaching Tp
(b) Structure after peritectic reaction

(c) Structure at T_s: completely solid as grains of β of composition S
Peritectic reaction: $L + \varepsilon \rightarrow \eta$

Figure 4.87: (a) Part of the copper–tin equilibrium diagram. (b) Microstructure of Sn–35 at % Cu alloy, showing primary crystals of $\varepsilon$ (grey phase) coated with $\eta$ (white phase) in matrix of eutectic (mottled regions)
Peritectic reaction: $L + \varepsilon \rightarrow \eta$

Figure 4.88 (a) Part of the silver–zinc equilibrium diagram. (b) The microstructure of the zinc–3.5 at % Ag alloy: primary dendrites of ε-phase in a zinc-rich matrix.
3) sparse (i.e. not very much of the other phase) 

$\beta + \gamma$

1) Primary $\alpha$

2) $\beta$ formed from peritectic reaction 

$L + \alpha \rightarrow \beta$
Examples of peritectic reactions
Cascades of peritectic reactions

Might expect single phase....
but if as-cast, or not
annealed for long enough,
might be surprised!
Peritectic Reaction: \( L + \alpha \rightarrow \beta \)

A solid \( \alpha \) forms and then reacts at a lower temperature with liquid \( L \) to varying extent, depending on the composition to form \( \beta \).

Any alloy within QR composition undergoes the peritectic reaction.
\( \alpha \) forms first in all.
Between QR and P at \( T_p \), some of the \( \alpha \) reacts with liquid to form \( \beta \).
At P (peritectic point) all \( \alpha \) react \( \rightarrow \beta \) formed.
Between P and R: All \( \alpha \) react, some liquid left; later all solidifies \( \rightarrow \beta \).
A phase diagram showing various phase transitions and compositions as a function of temperature. The diagram includes regions labeled with different phase compositions such as \( \alpha + \gamma \), \( \eta + \gamma \), \( \alpha + \eta \), \( \eta + \gamma_1 \), and \( \eta + \delta' \). It also highlights critical points and monotectic reactions. The composition axis is labeled from A to B.
## Invariant reactions

<table>
<thead>
<tr>
<th>Type</th>
<th>Reaction</th>
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<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eutectic (involves liquid and solid)</td>
<td><img src="image1" alt="Diagram" /></td>
<td>Monotectic</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Eutectoid (involves solid only)</td>
<td><img src="image3" alt="Diagram" /></td>
<td>Monotectoid</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Peritectic (involves liquid and solid)</td>
<td><img src="image5" alt="Diagram" /></td>
<td>Syntectic</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>Peritectoid (involves solid only)</td>
<td><img src="image7" alt="Diagram" /></td>
<td>Peritectoid</td>
<td><img src="image8" alt="Diagram" /></td>
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