3.3.3 Let's Summarize

- Let's summarize by going from the simple to the difficult.

- A perfectly *brittle* material like glass, with no internal nanocracks or other flaws, will fracture suddenly as soon as an ultimate *critical fracture stress* is reached.
If the brittle material does contain nanocracks or other flaws it will fracture suddenly at some lower stress.
    - For stresses below the fracture stress it will deform purely *elastically* and its *stiffness* is given by its *Young's modulus*.
    - If the stress is released, it assumes *exactly* its old shape again.
    - The energy needed to fracture the material is small.
  - You cannot bang brittle materials into shape. They have the shape they have or they are broken.

- A *ductile* material like any metal with a "perfect" internal structure in the sense that there are no nanocracks, will deform purely elastically exactly like a brittle material for stresses lower than the *yield stress*.
    - It's *stiffness* in the elastic region is given by its *Young's modulus*.
    - If the stress exceeds a critical value named "(critical) *yield stress*", it starts to deform *plastically*.
    - If the stress is released, *before* the critical yield stress is reached, it assumes *exactly* its old shape again.
    - If the stress is released *after* the critical yield stress has been reached and plastic deformation took place, its shape has *permanently changed*.
    - Eventually, for large stresses or strains, fracture occurs.
  - You can bang ductile materials into shape. Smiths shape a blade by inducing plastic deformation of the iron or steel.

- What exactly happens in the plastic part of the stress-strain curve for one and the same ductile material depends on many things.
  - There are "*hardening mechanisms*", increasing the yield stress while simultaneously decreasing *ductility*.
  - Plastic deformation itself is a hardening mechanism; called "*work hardening*". That means that the plastic properties of a given material that you measure in tensile test depend on its history that may be unknown to you. That makes plastic deformation a rather complex property.
  - The parameters of plastic deformation like the yield stress also depend on the *temperature*, very much so in many cases. Some materials like silicon that are perfectly brittle at room temperature become plastic at elevated temperature. Iron and steel are much easier to deform and shape at high temperatures as every smith will testify. At temperatures low enough they will turn brittle.

- *Fracture* thus occurs in two basic modes:
    - **Brittle fracture**, needing not much energy and therefore easy to induce.
    - **Ductile fracture**, the eventual failing after plastic deformation, taking lots of energy and therefore not so easy to do.
  - For any fracture we also have to look at how fast things happen and if the material contains nanocracks or other internal flaws that make it more prone to fracture.

- Taken all together we can draw two simple conclusions:

1. The precise internal structure of the material matters quite a bit. 2. The role of temperature is also something that needs to be looked at.

- Now we have our topics for several chapters to come!