Manufacturing Technology-I

IV semester B.Tech. Mechanical: A Section

Winter 2008-09 / Lecture - 4

VIT UNIVERSITY
(Estd. u/s 3 of UGC Act 1956)
School of Mechanical and Building Sciences

Dr. Jeevanantham. A.K. Ph.D.,
Assistant Professor
School of Mechanical and Building Sciences
VIT University, Vellore, India

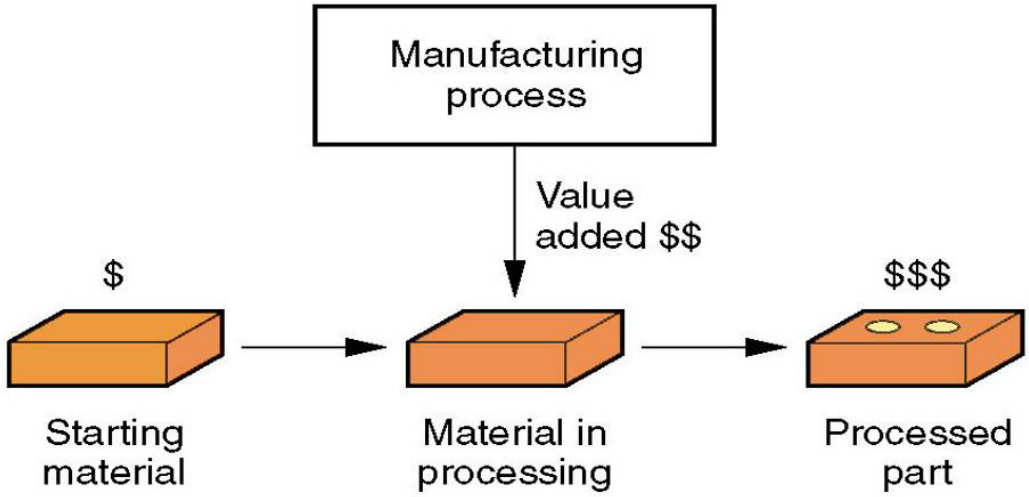
15th December 2008 – 8.00 to 8.50 am

Overview

- Classification of Manufacturing Processes
- Fundamentals of Casting
  - Solidification of molten metal
  - Fluidity of molten metal

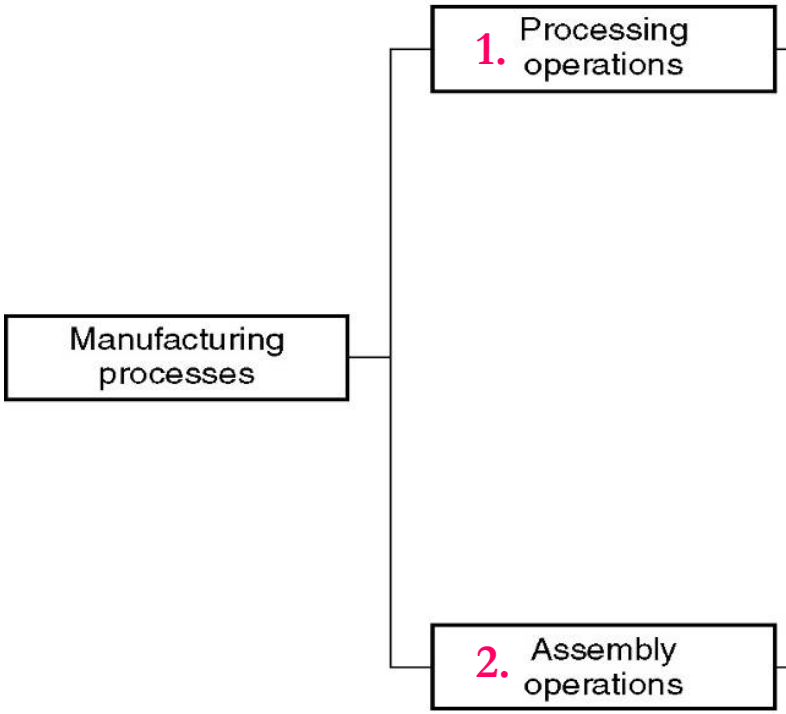
Manufacturing Process

- Transformation of materials into items of greater value by means of one or more processing and/or assembly operations
- Manufacturing *adds value* to the material by changing its shape or properties, or by combining it with other materials



Classification

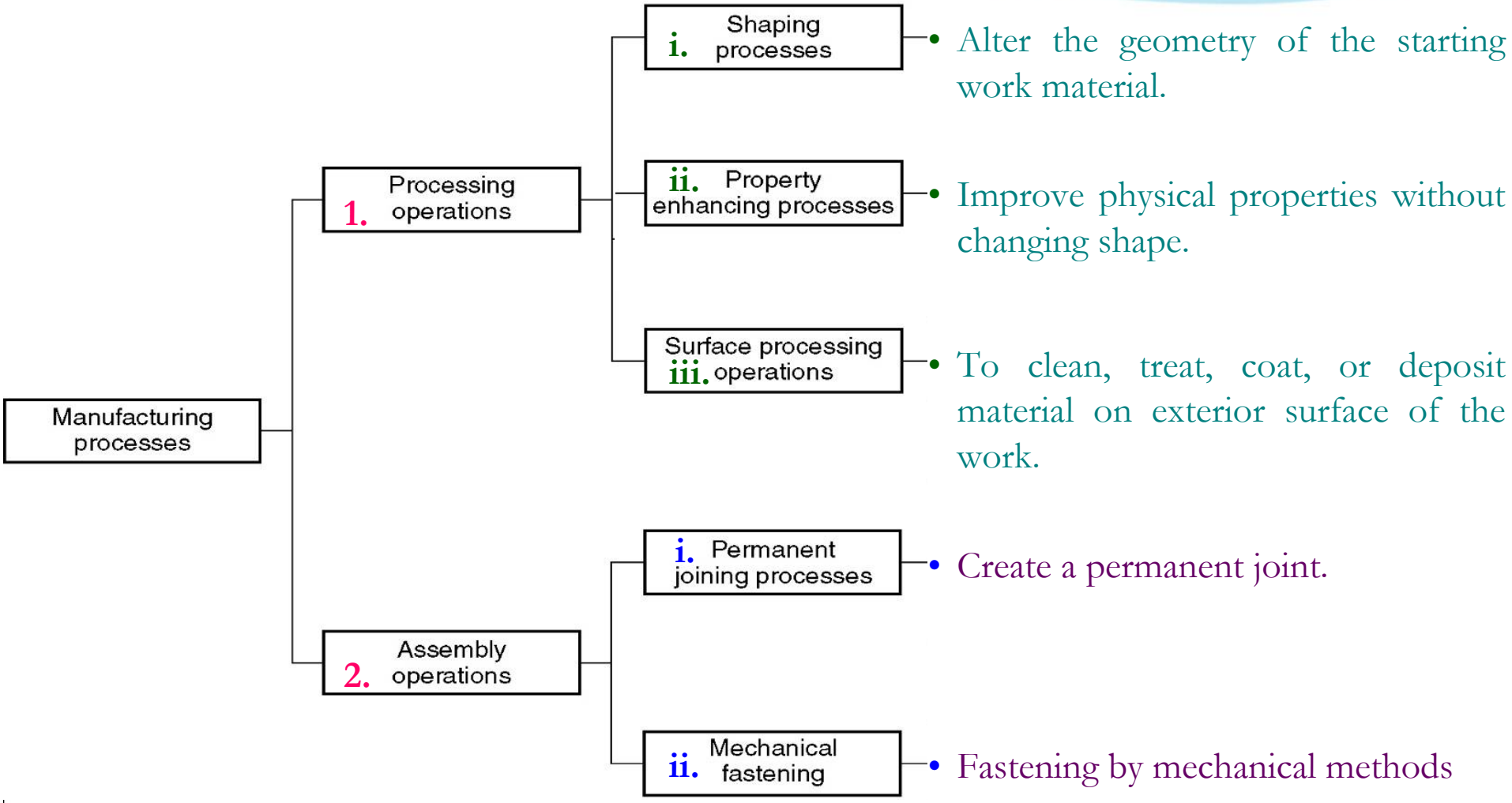
➢Two basic types:



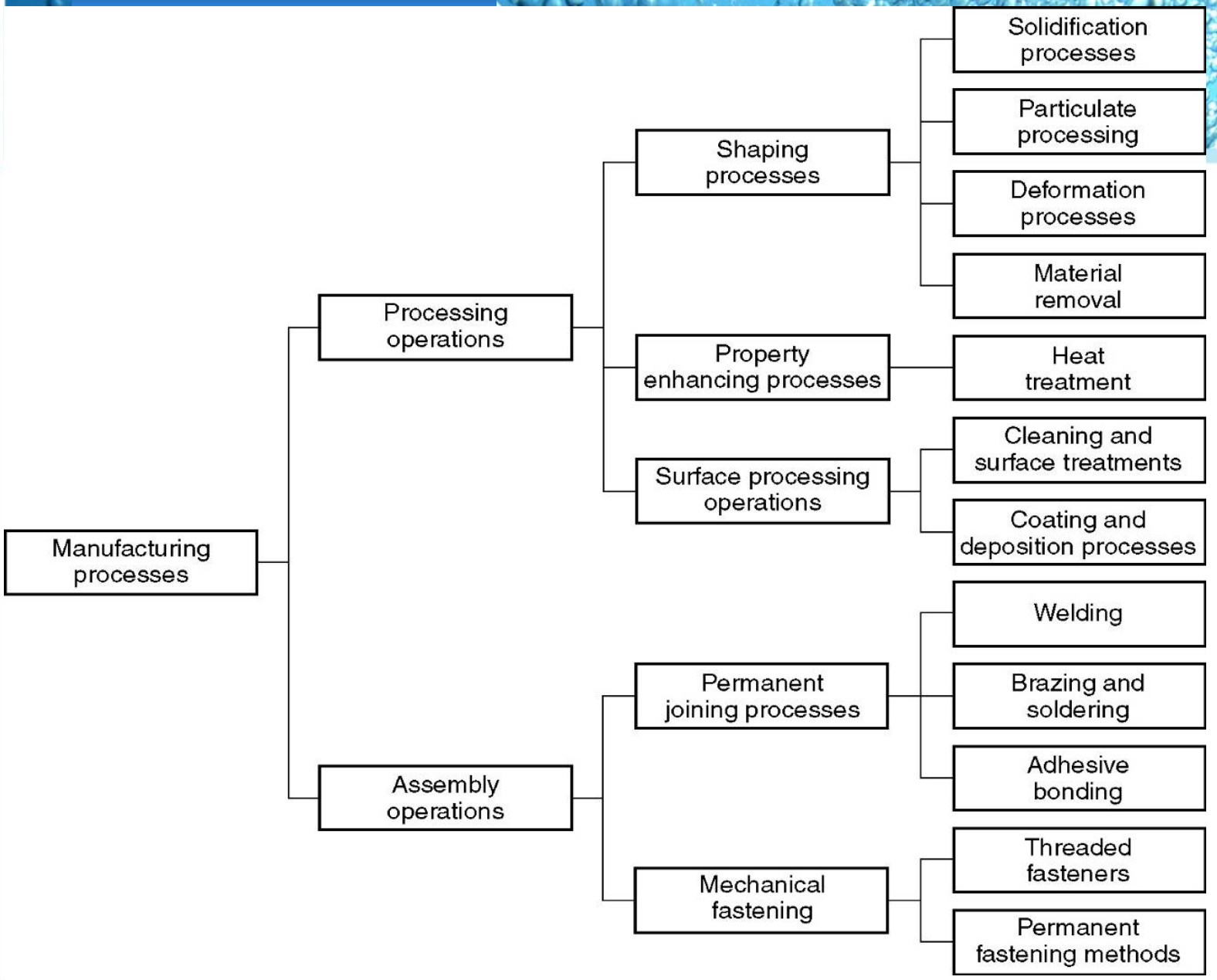
- Transform a work material from one state of completion to a more advanced state
  - Operations that change the geometry, properties, or appearance of the starting material

- Join two or more components to create a new entity.

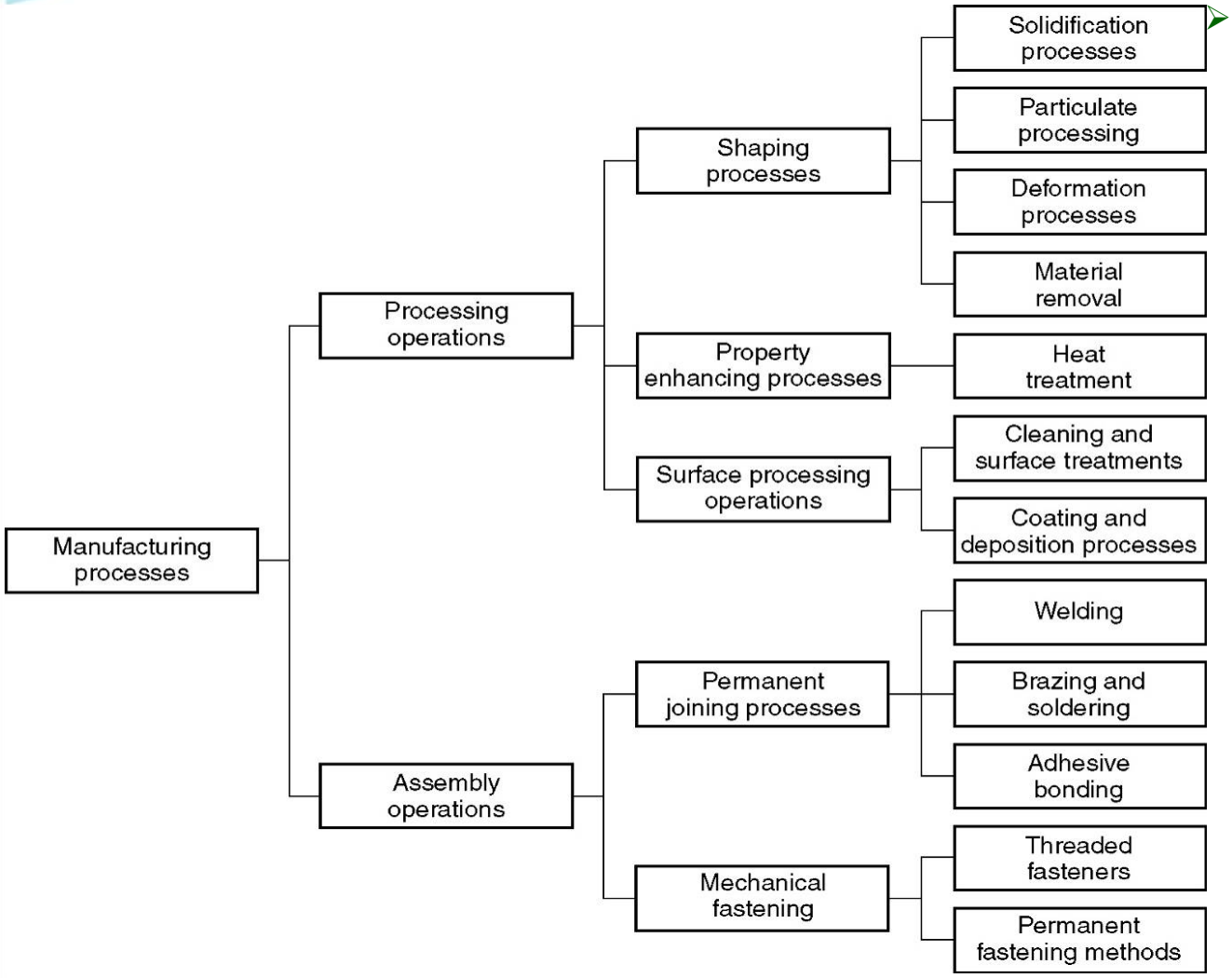
Classification



Classification



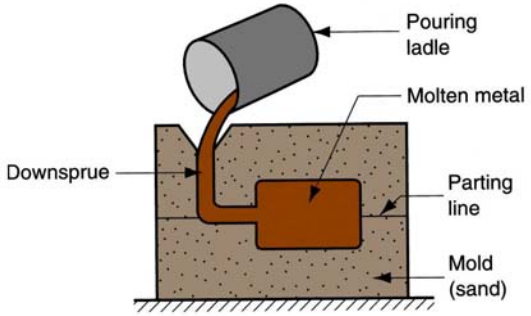
Classification



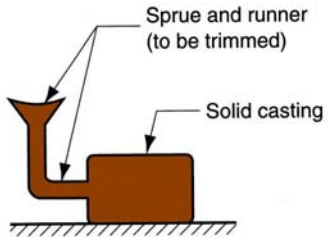
- Starting material is a heated liquid or semifluid – **CASTING,**

  PLASTIC MOULDING

Usually involves melting, solidification & cooling processes to get final product

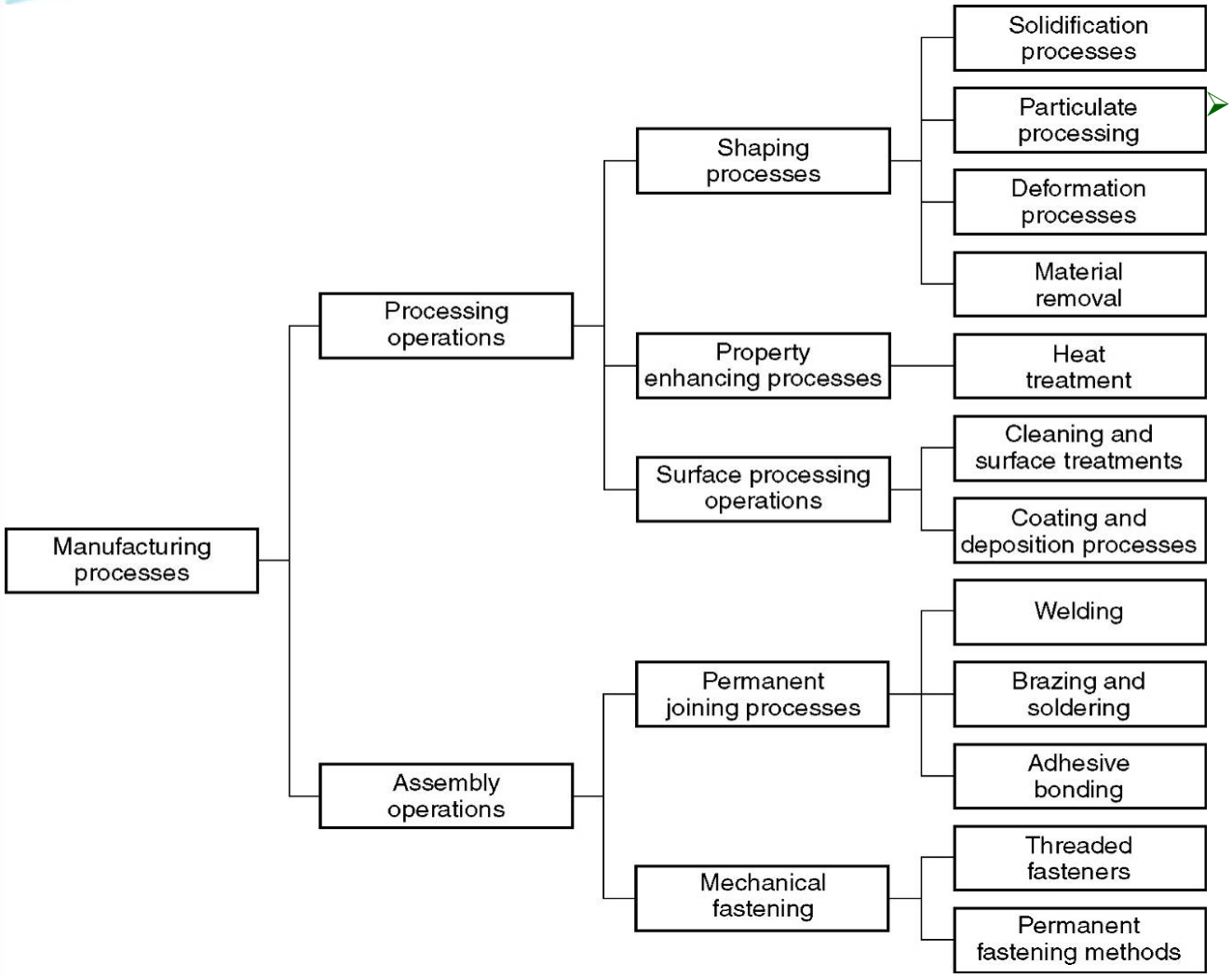


(1)



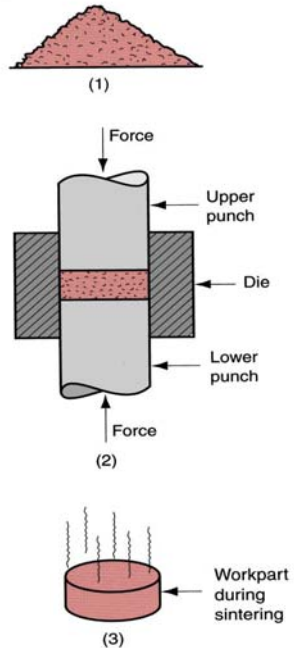
(2)

Classification

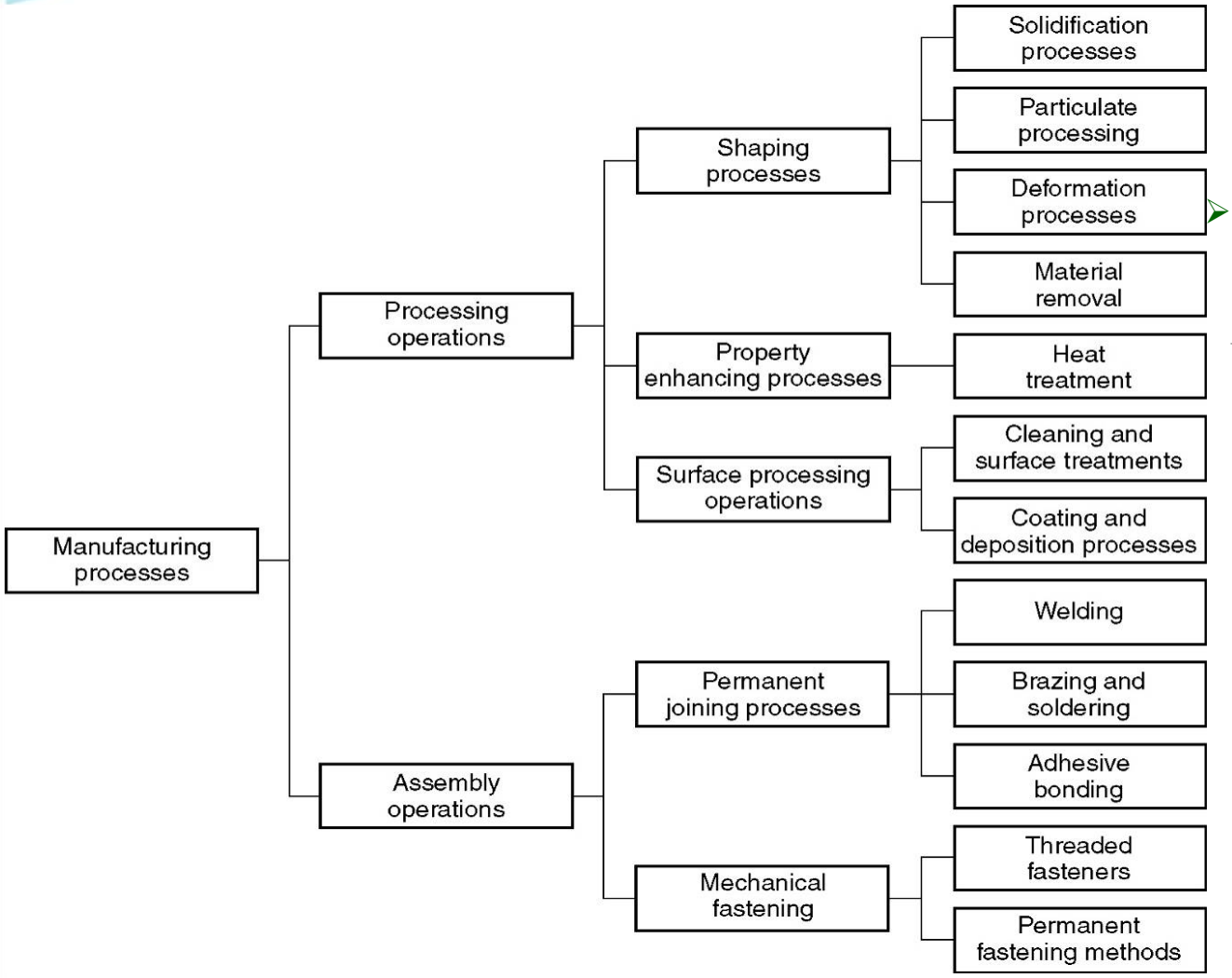


- Starting material consists of powders – **POWDER METALLURGY.**

Usually involves pressing and sintering, in which powders are first compressed and then heated to bond the individual particles



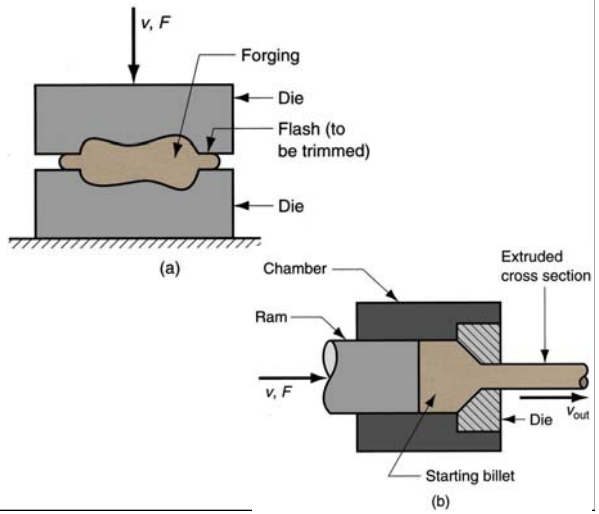
Classification



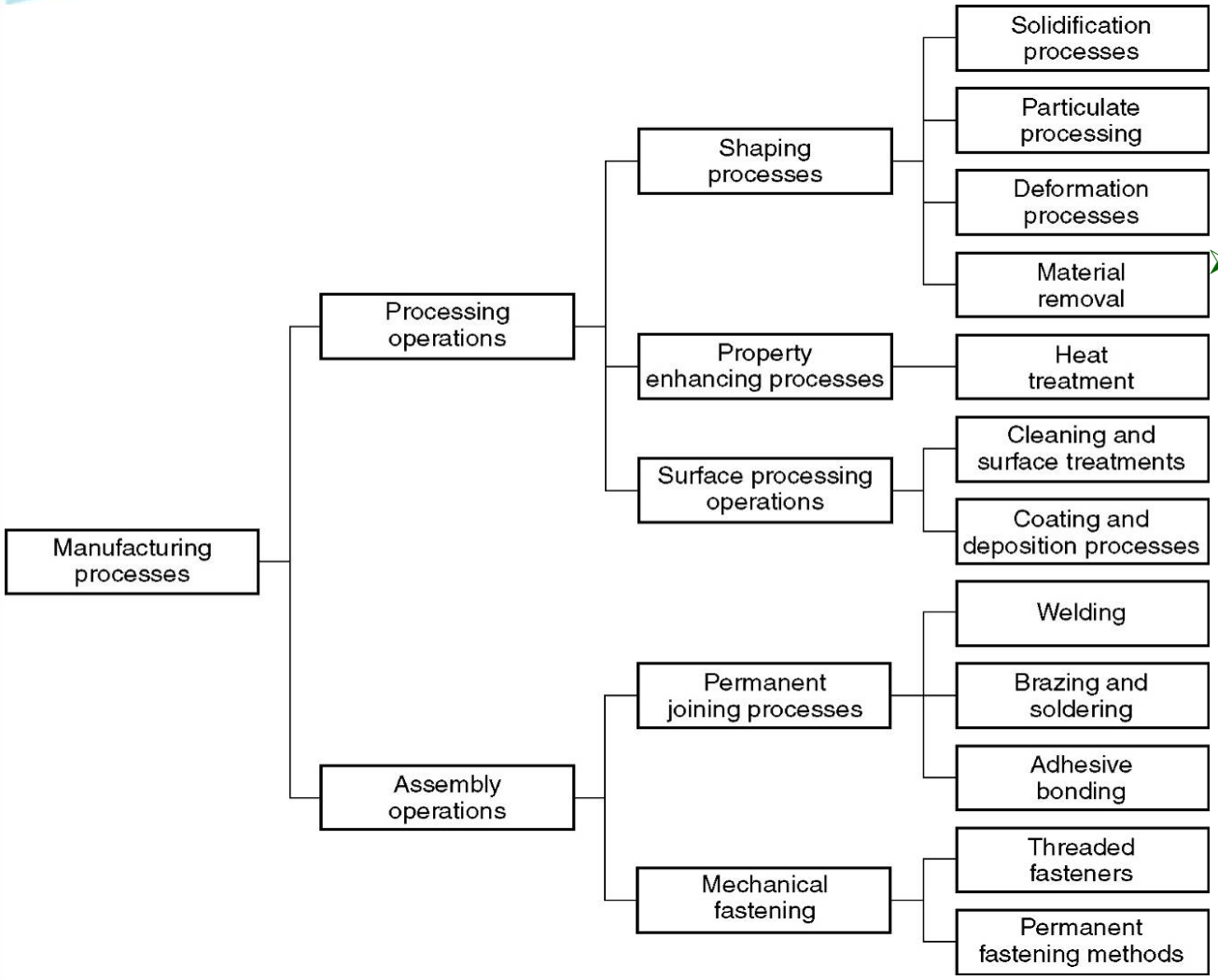
- starting material is a ductile solid (commonly metal) – **FORMING.**

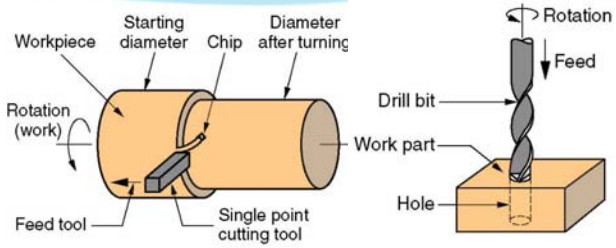
Usually the material is shaped by application of forces that exceed the yield strength of the material

Examples: Forging, Extrusion…



Classification

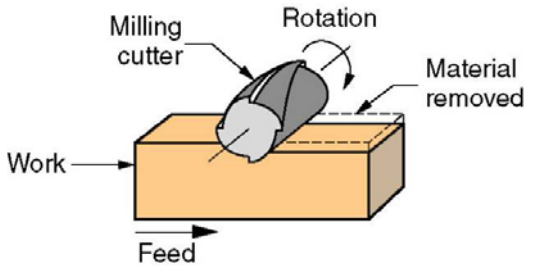




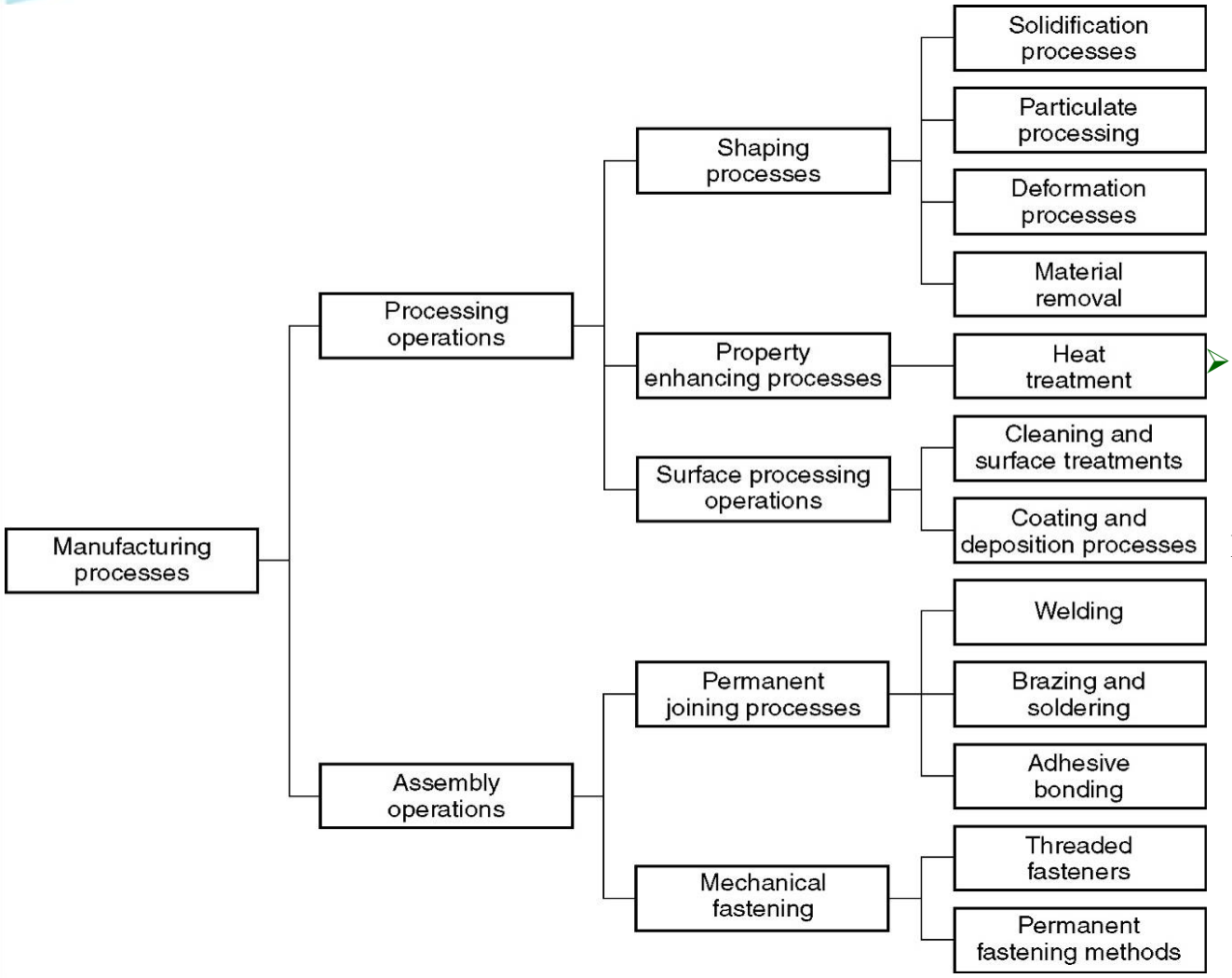
- Starting material is a ductile or brittle solid – **METAL CUTTING.**

Excess material removed from the starting piece so what remains is the desired geometry

Examples: machining such as turning, drilling, and milling; also grinding and nontraditional processes



Classification

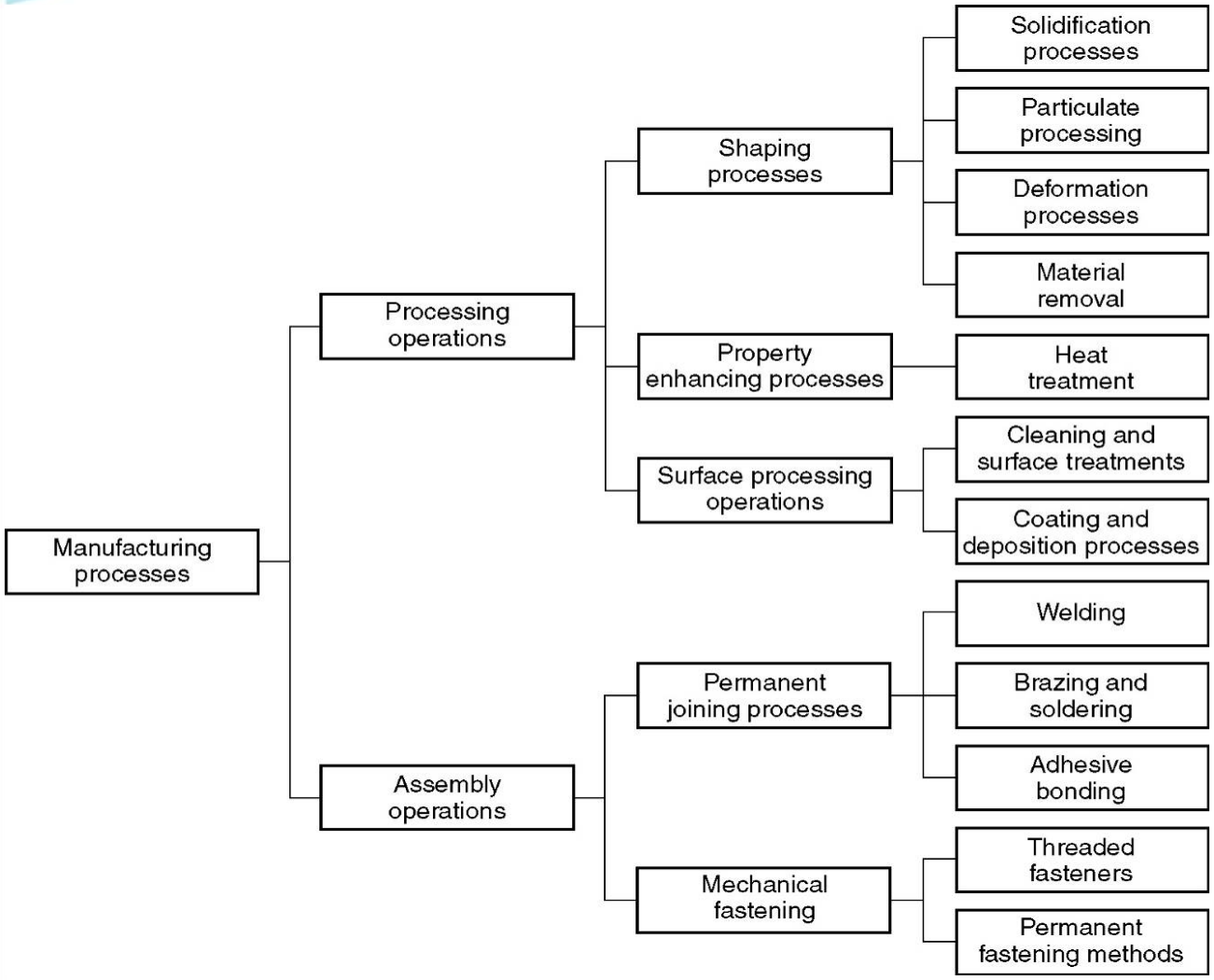


- Performed to improve mechanical or physical properties of work material – **HEAT TREATMENT.**

Example:

- Heat treatment of metals and glasses
- Sintering of powdered metals and ceramics

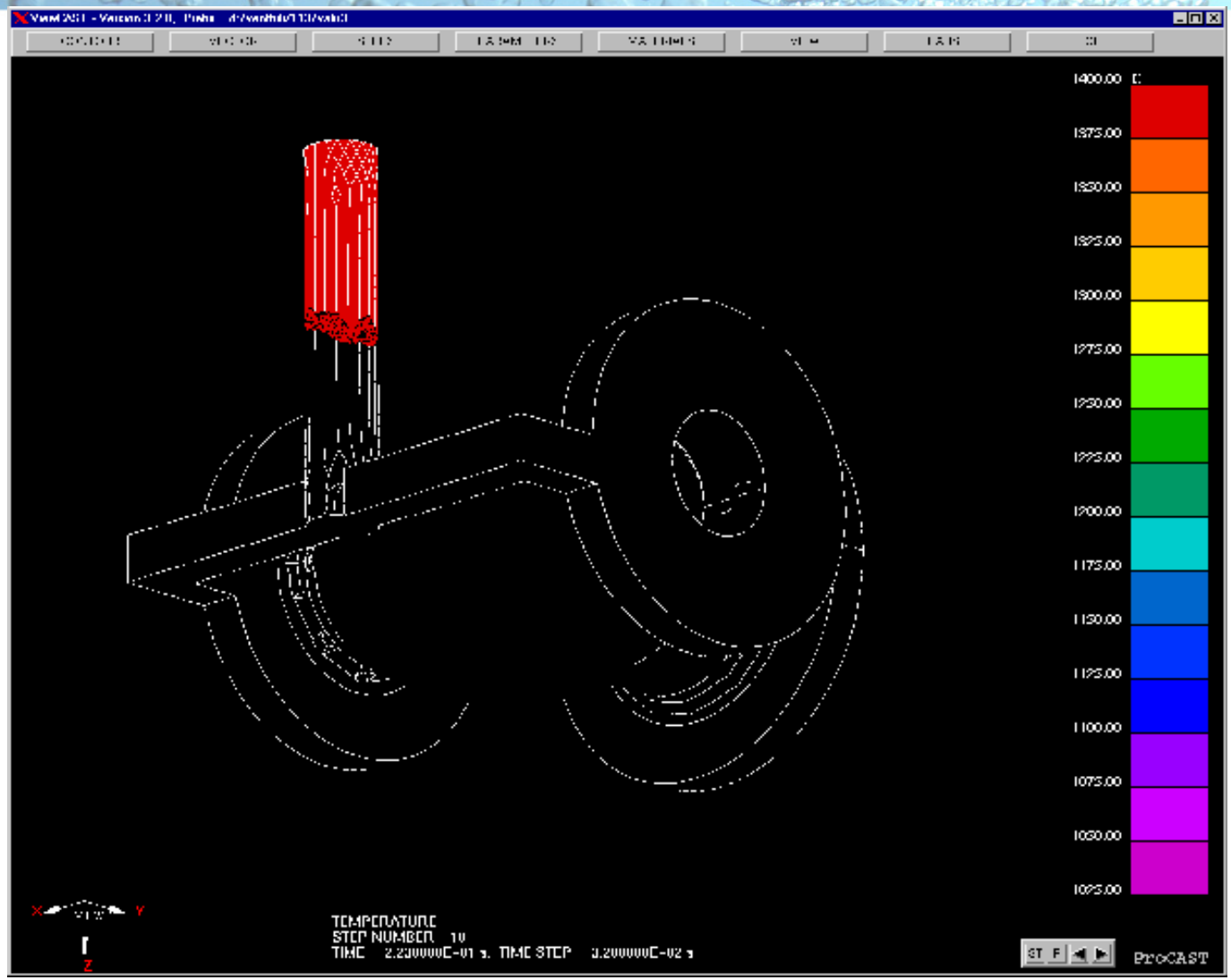
Classification



Basic Mfg Processes :

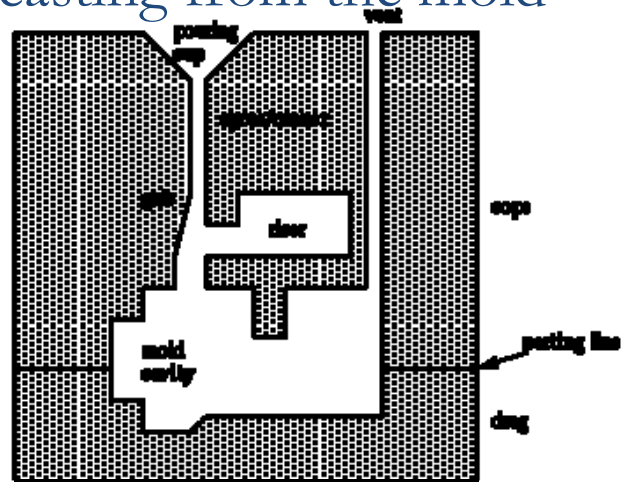
1. **Casting**
2. **Forming**
3. **Machining**
4. **Joining and Assembly**
5. **Finishing**
6. **Heat Treatment**
7. **Other**
   - Inspection / Quality Control
   - Packaging
   - Transportation
   - Waste / Scrap disposal

Casting


1400.00
1375.00
1350.00
1325.00
1300.00
1275.00
1250.00
1225.00
1200.00
1175.00
1150.00
1125.00
1100.00
1075.00
1050.00
1025.00
TEMPERATURE
STEP NUMBER 10
ProCAST

Casting

- Basic steps:
  - a. Preparing pattern (shape similar to the product to be manufactured) and mould
  - b. Preparing molten metal
  - c. Pouring molten metal into the mold cavity
  - d. Allowing it to solidify
  - e. Removing the casting from the mold
  - f. Finishing



Casting

- (a) Casting can produce very complex geometry parts with internal cavities and hollow sections.

- (b) It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms)

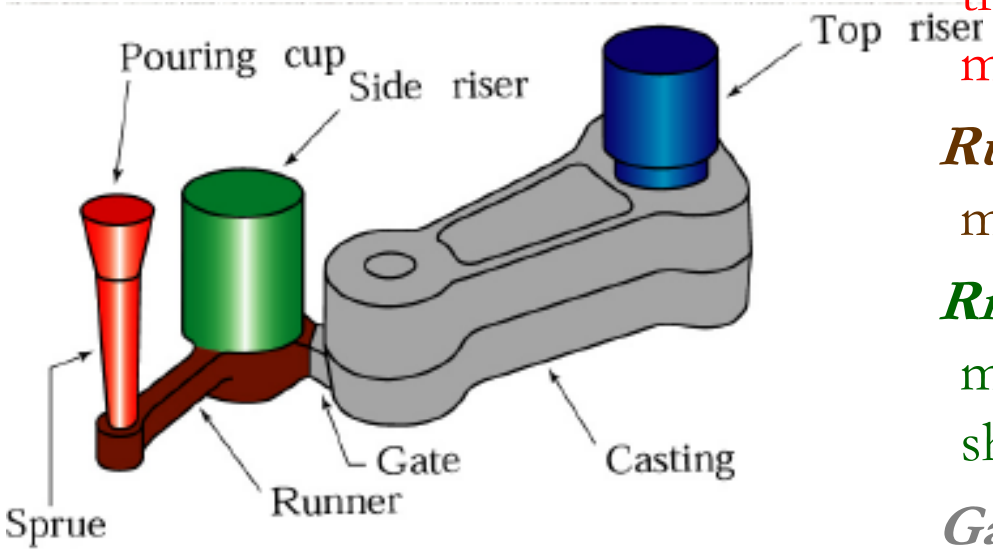
- (c) It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used

- (d) Cast metal is isotropic – it has the same physical/mechanical properties along any direction.

Fluid Flow

Basic casting system:

- Fluid is pored though a pouring basin/cup
- Flows though the gating system into the mold cavity



Sprue: a vertical channel though which the molten metal flows downward in the mold

Runners: channels that carry the molten metal from the sprue to the mold cavity

Risers: serve as reservoirs to supply the molten metal necessary to prevent shrinkage.

Gate: portion of the runner though which the molten metal enters the mold cavity

Solidification

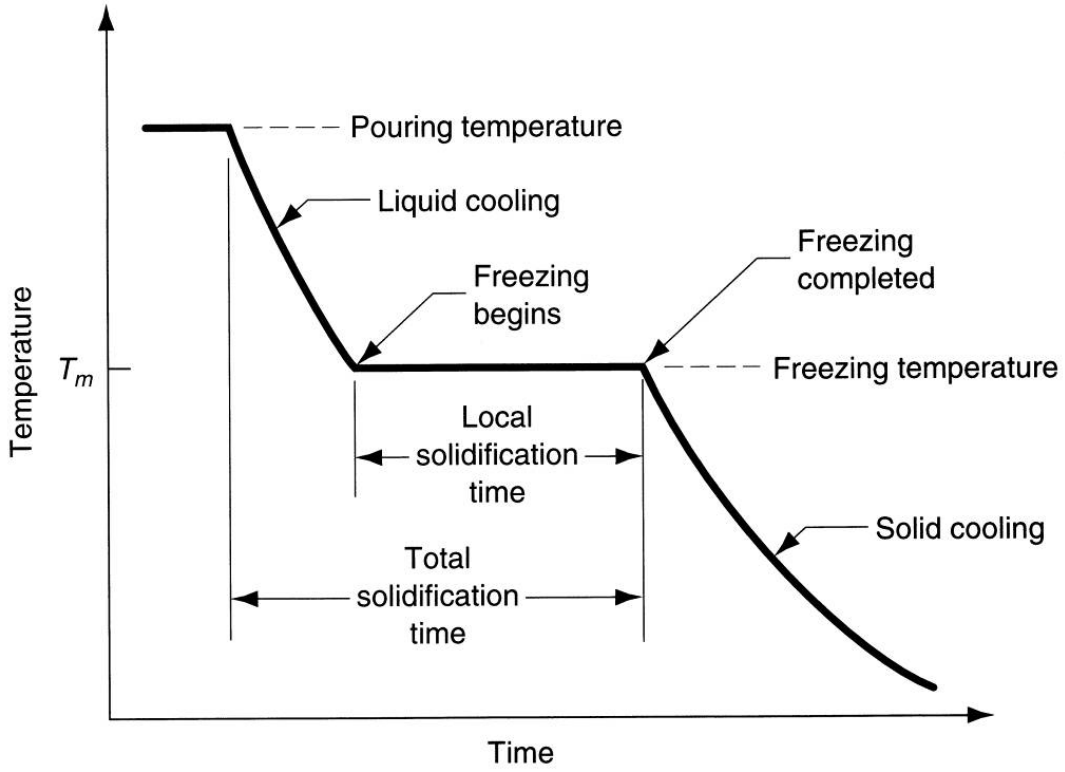
- Affected by
  - Thermal and metallurgical properties of metal
  - Thermal properties of mold – it affects rate of cooling
  - Shape of mold
  - Geometric relationship between volume and surface area of casting

Solidification of Metals

- Solidification differs depending on whether the metal is
  - A pure element or
  - An alloy

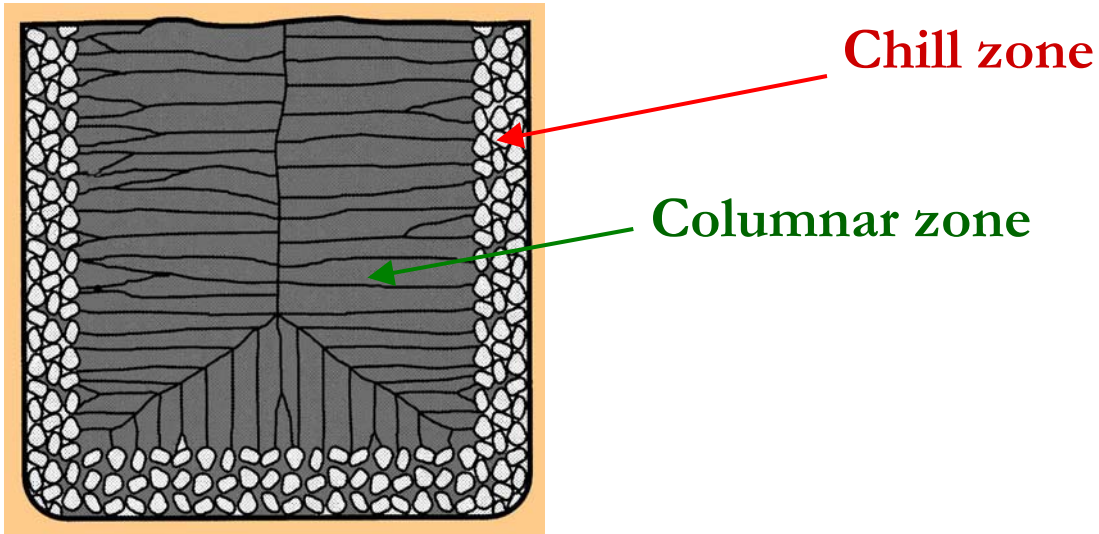
Solidification of Pure Metals

- A pure metal solidifies at a constant temperature equal to its freezing point (same as melting point)
- Cooling curve for a pure metal during casting :



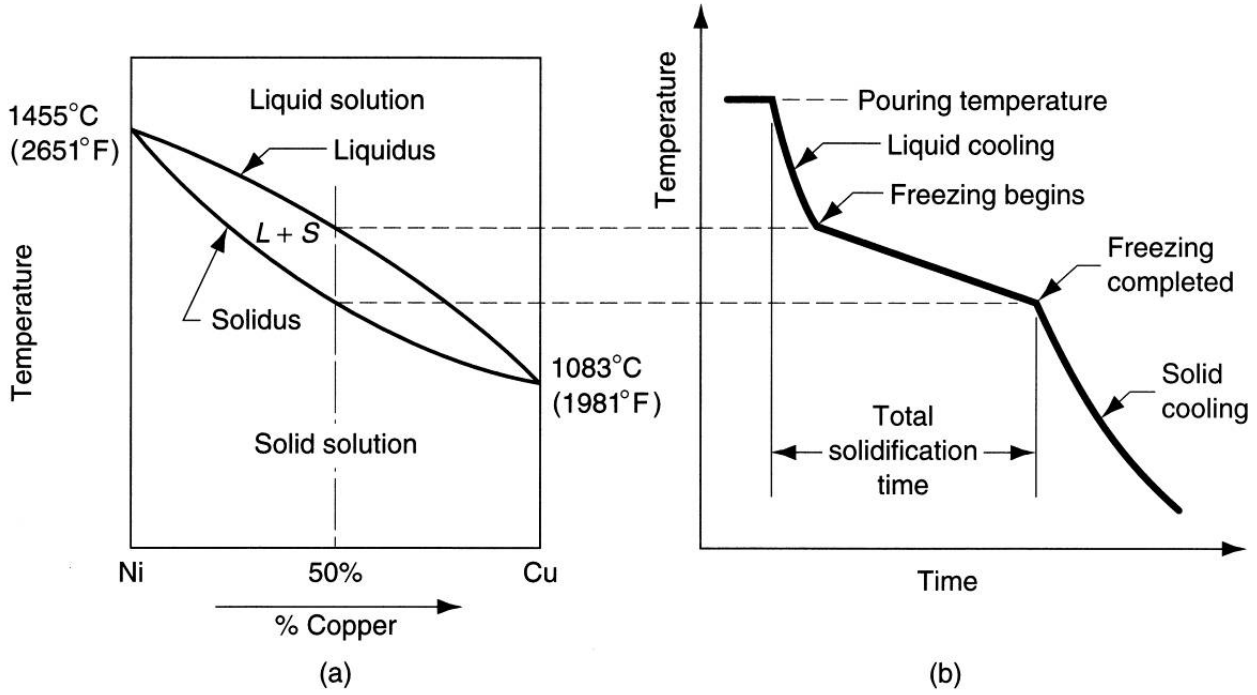
Solidification of Pure Metals

- Due to chilling action of mold wall, a thin skin of solid metal is formed at the interface immediately after pouring
- Characteristic grain structure in a casting of a pure metal, showing **randomly oriented grains of small size** (due to rapid cooling at wall) near the mold wall, and **large columnar grains** (grows opposite direction to the heat transfer) oriented toward the center of the casting



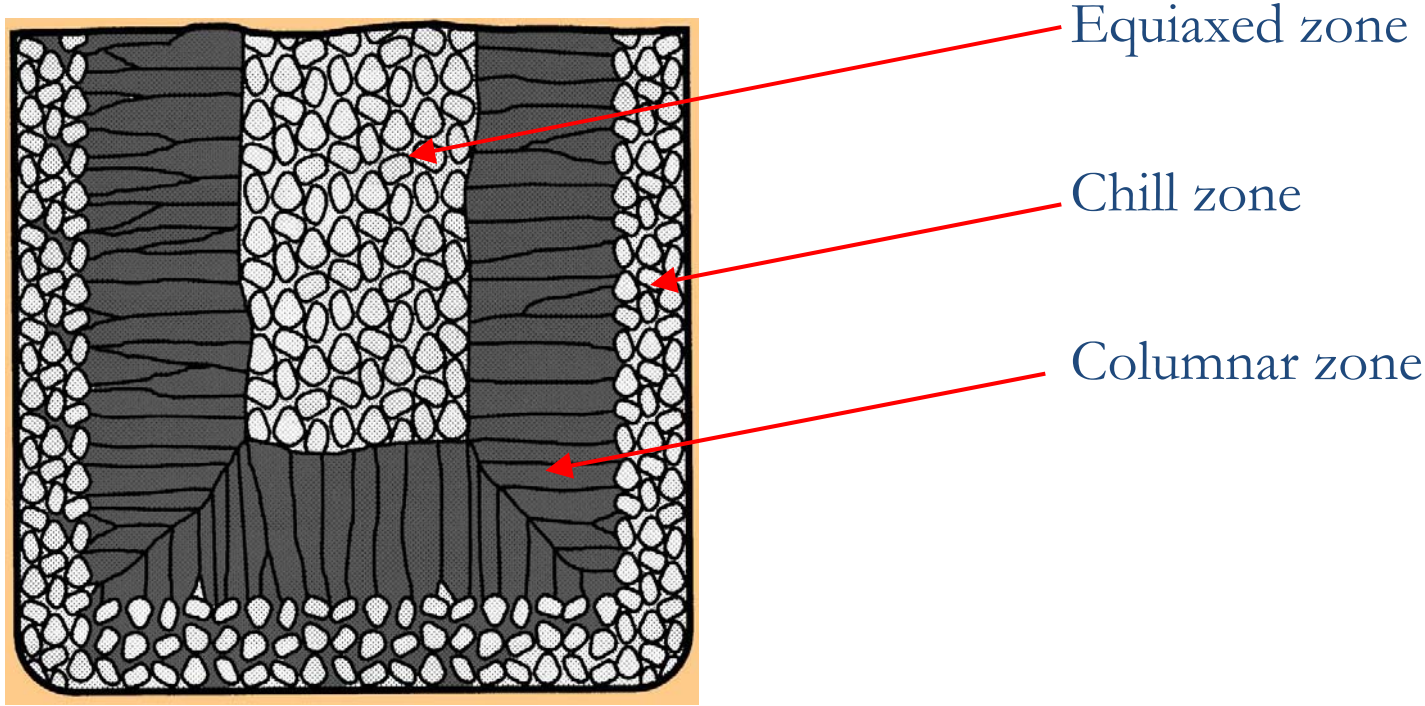
Solidification of Alloy Metals

- Most alloys freeze over a temperature range rather than at a single temperature.
- Solidification in alloys begins when the temperature drops below the liquidus T_L and is complete when it reaches the solidus, T_S
- (a) Phase diagram for a copper-nickel system (b) associated cooling curve for a 50%Ni-50%Cu composition during casting.



Solidification of Alloy Metals

- Characteristic grain structure in an alloy casting, showing segregation of alloying components in center of casting
- Within the T_L and T_S Temperature range, the alloy is like a slushy with **columnar dendrites**



Effects of Cooling Rate

- Slow cool rates results in course grain structures (10^2 K/s)
- Faster cooling rates produce finer grain structures (10^4 K/s)
- For even faster cooling rates, the structures are amorphous (10^6 – 10^8 K/s)

- Grain size influences strength of a material
  - Smaller grains have higher ductility and strength
    - Smaller grains help prevent *hot tearing* and/or cracks in the casting

Solidification Time

- Solidification takes time
- Total solidification time T_{TS} = Time required for casting to solidify after pouring
- T_{TS} depends on size and shape of casting by relationship known as ***Chvorinov's Rule***

$$TST = C_m \left(\frac{V}{A} \right)^n$$

where TST = total solidification time;

V = volume of the casting;

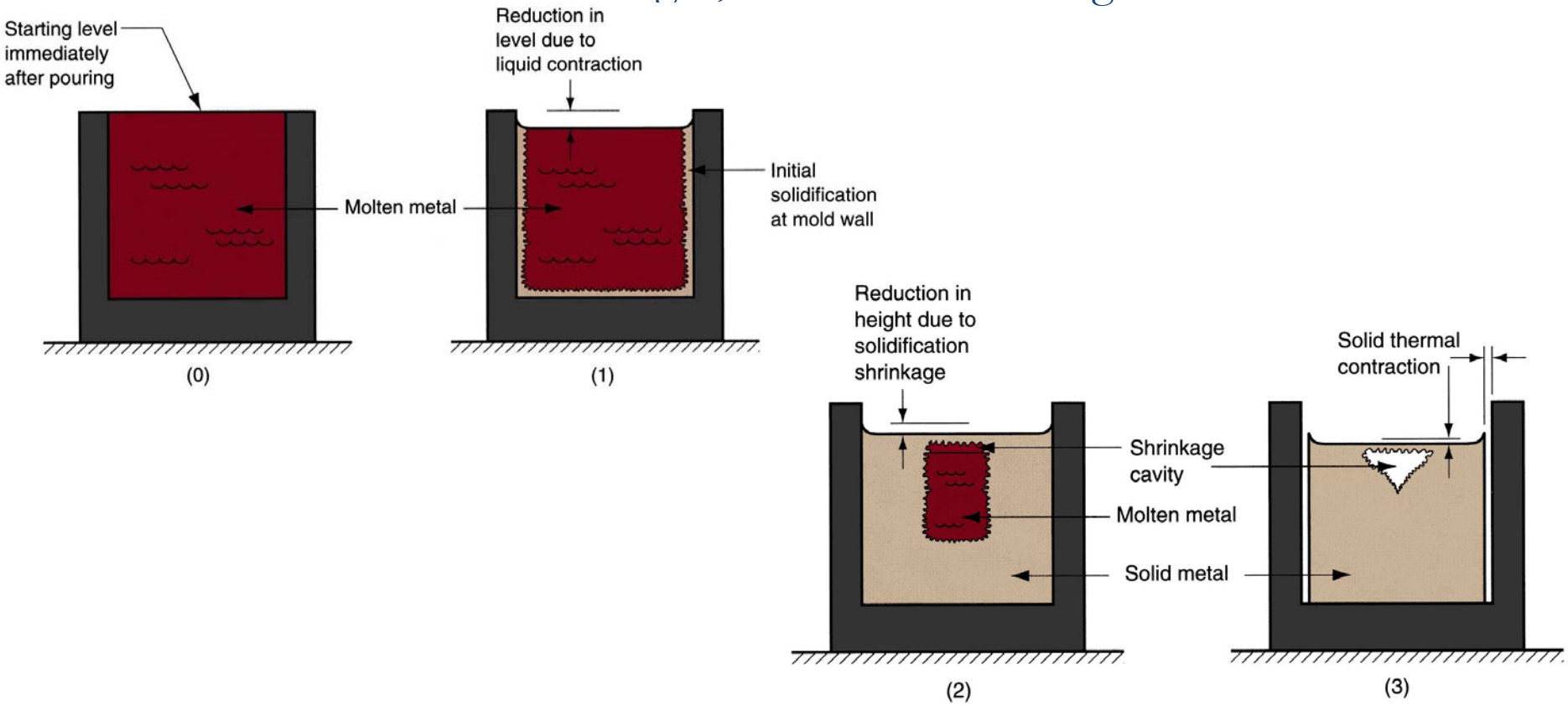
A = surface area of casting;

n = exponent with typical value = 2;

C_m = *mold constant.*

Shrinkage

- Because of thermal expansion characteristics, metals shrink (contract) during solidification and cooling.
- It causes: Dimensional changes, sometimes cracking



Fluid Flow

- Successful Casting System: proper design and control of solidification to ensure adequate fluid flow
- Properly designed gating system avoids Premature cooling, Turbulence, Gas entrapment
- Two basic principles of fluid flow
  - **Bernoulli's Theorem**
  - **The law of mass continuity**
- *Flow Characteristics*: Turbulence is an important consideration in gating systems.

  Reynolds Number is used to quantify this aspect
  - $0 < Re < 2000$ => laminar flow
  - $2000 < Re < 20\,000$ => mixture of laminar and turbulent flow
  - $Re > 20\,000$ => severe turbulence

  Techniques for minimizing turbulence
  - Avoid sudden changes in flow direction
  - Dross or slag can be eliminated by vacuum casting
  - Use of filters eliminates turbulent flow in the runner system

Fluid Flow

- **Bernoulli's Theorem**
  - Principle of conservation of energy and relates pressure, velocity, the elevation of fluid at any location

$$h \quad \frac{p}{\rho g} + \frac{v^2}{2g} = \text{Constant}$$

  - h is the elevation of fluid at any location
  - p - pressure at that elevation
  - v - velocity of liquid at that elevation
  - g - gravitational constant

$$h_1 \quad \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 \quad \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + f$$

  - f – frictional loss in the liquid as it travels
  - Subscripts 1 and 2 represent two different elevations

Fluid Flow

- **The law of mass continuity**
  - States that for incompressible liquids and in a system with impermeable walls, the rate of flow is constant.

$$Q = A_1 v_1 = A_2 v_2$$

  - Q is the rate of flow (m^3/s)
  - A is the cross-sectional area of liquid system
  - v is the average velocity of the liquid in that cross-section location
  - Subscripts 1 and 2 refer to different location in the system

Fluidity of Molten Metal

- **Fluidity** of Molten Metal : The capability of molten metal to fill mold cavities is called *fluidity*.

The following influence fluidity

- **Characteristics of molten metal**
  - Viscosity ↑ ↓
  - Surface tension ↑ ↓
  - Inclusions
  - Solidification pattern of the alloy
- **Casting parameters**
  - Mold design
  - Mold material and its surface characteristics (Thermal conductivity ↓, rough surface ↑)
  - Degree of superheat ↑ ↑
  - Rate of pouring ↓ ↓
  - Heat transfer

Note: Castability – describes the case with which a metal can be cast to obtain a part with good quality.

Test for Fluidity

- A test method for fluidity using **a spiral mold**. The fluidity index is the length of the solidified metal in the spiral passage. The greater the length of the solidified metal, the greater is its fluidity