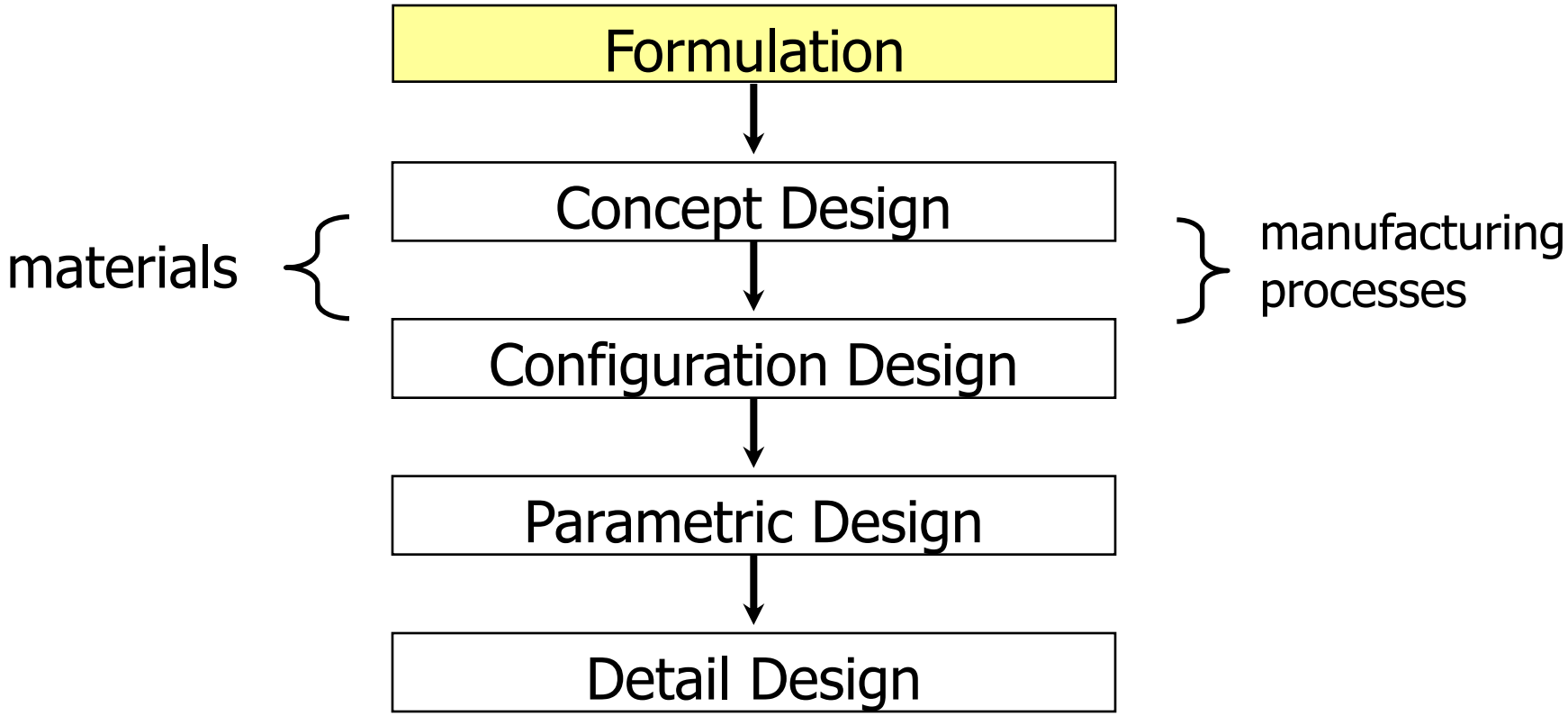
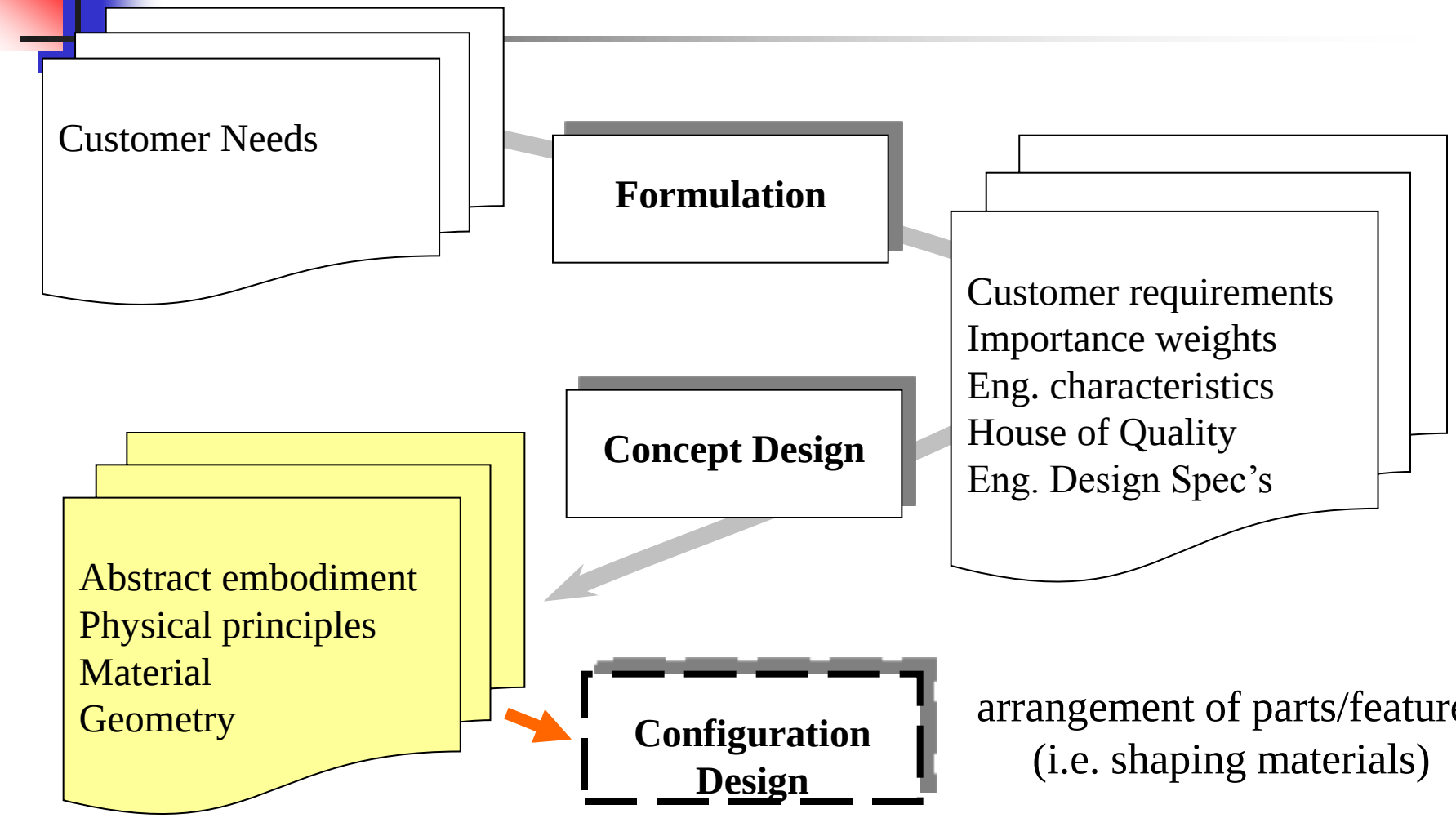
Material Properties

- Product function interdependence
- Mechanical properties
- Families of materials
- Materials first screening
- Ashby materials index rating method

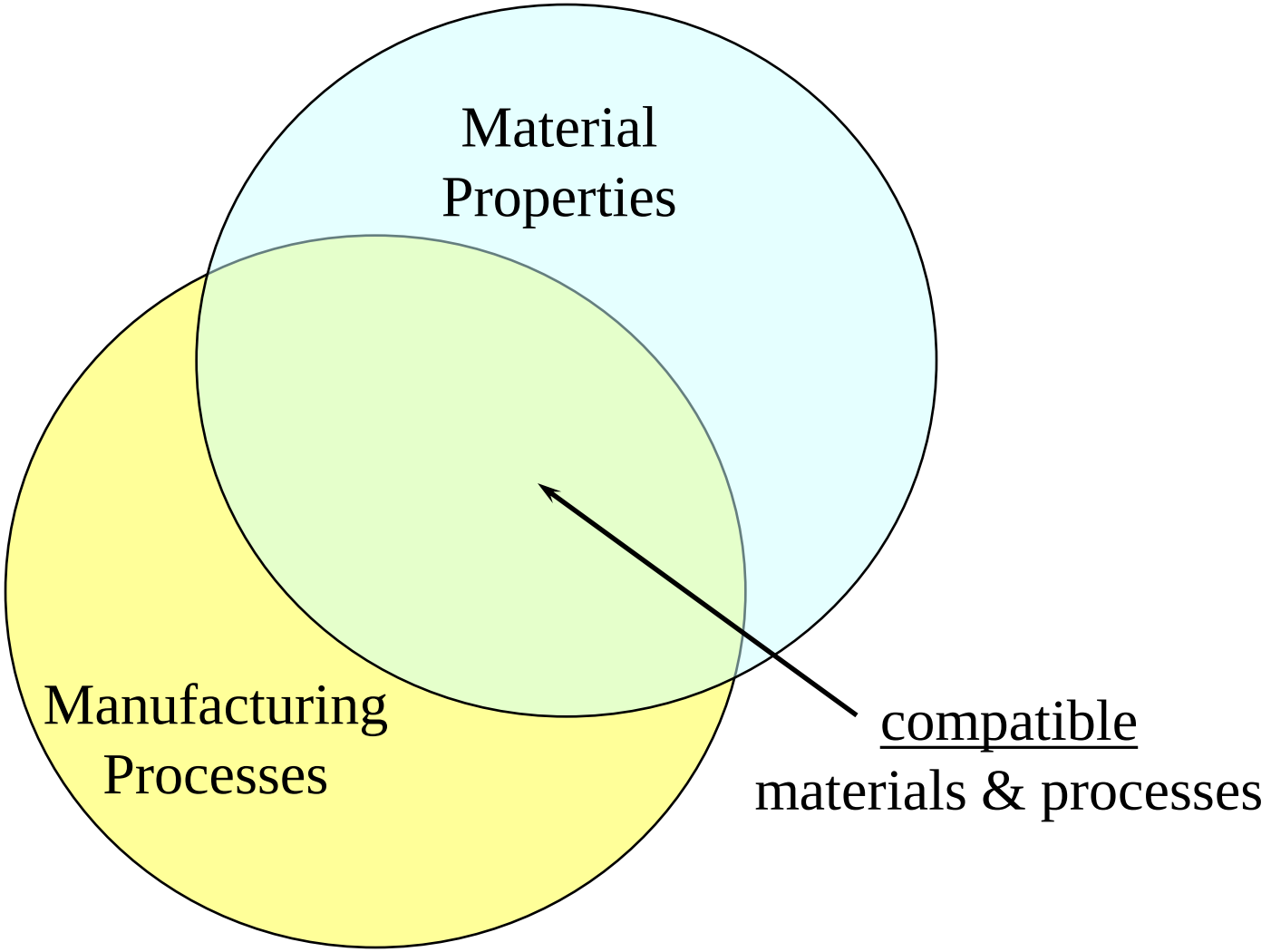
When do we select alternative materials?



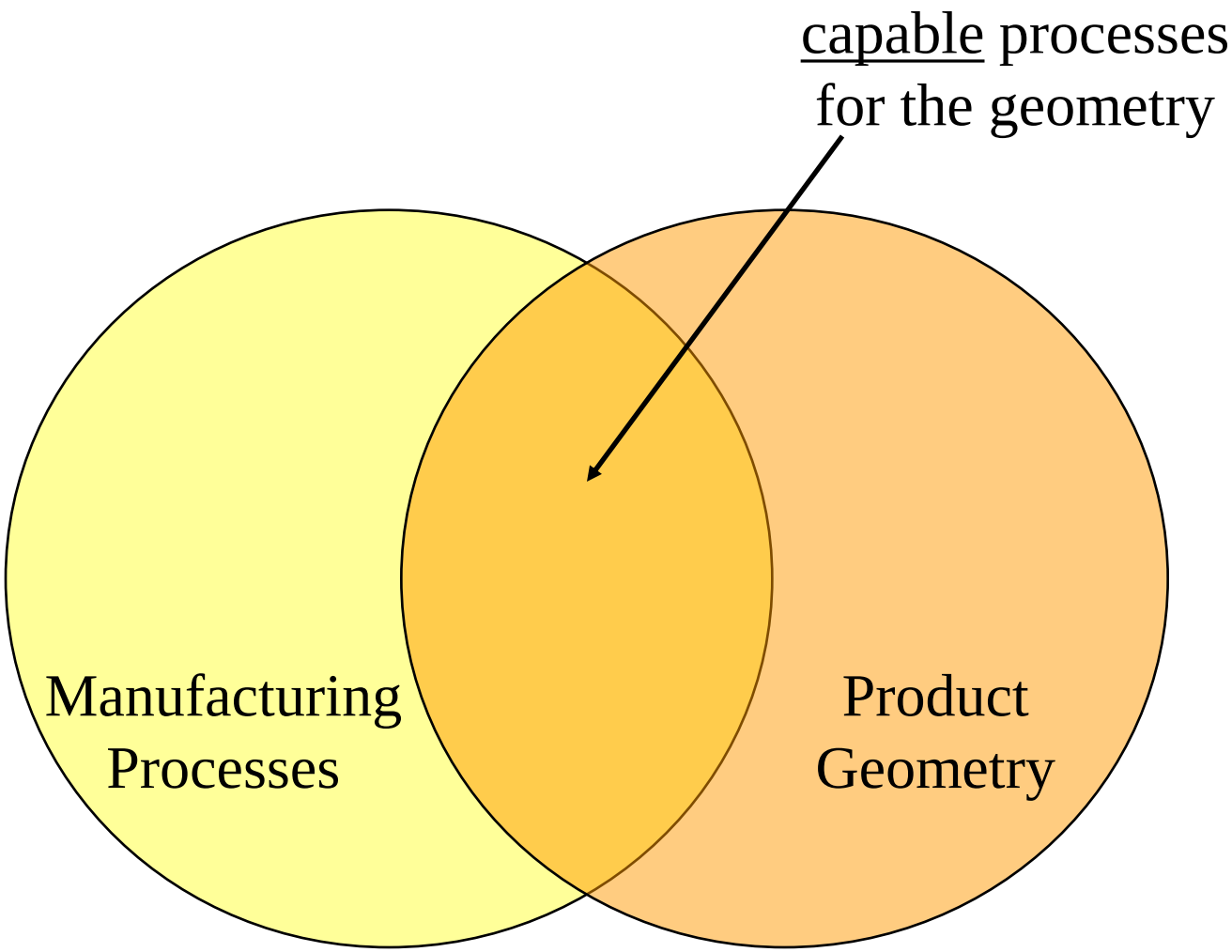
Our decisions so far have included ...



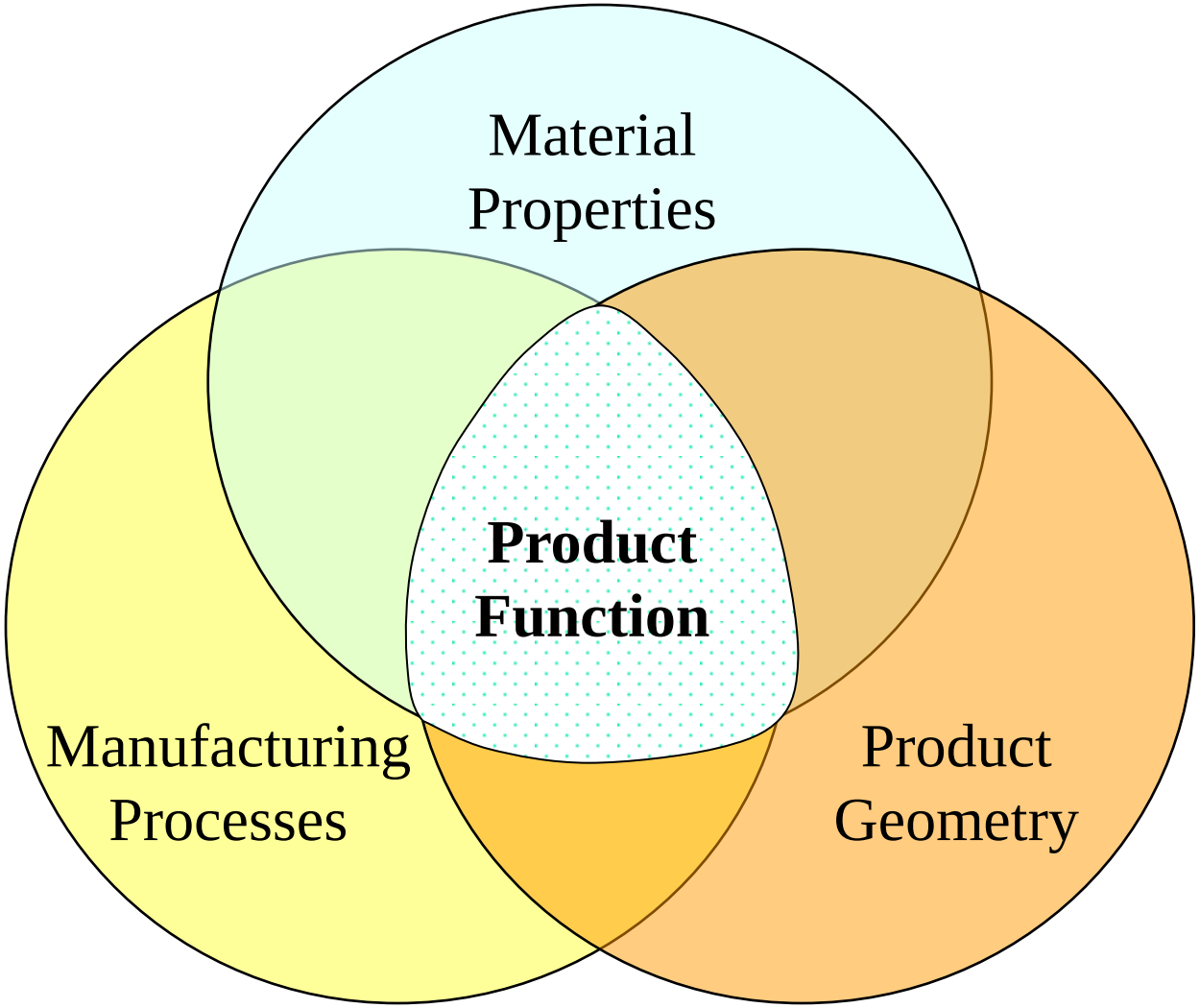
Interdependence



Interdependence



Product function is interdependent



Material properties

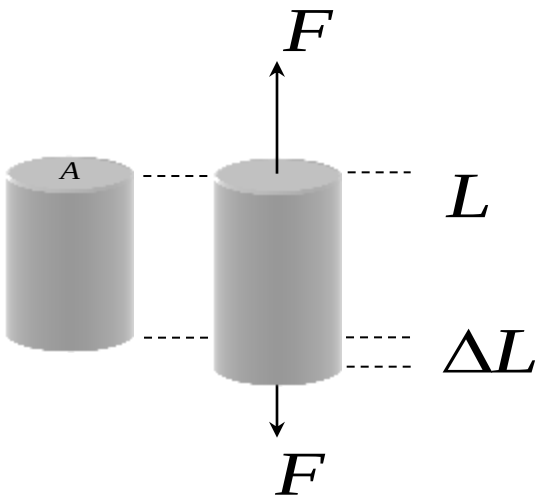
- Mechanical properties

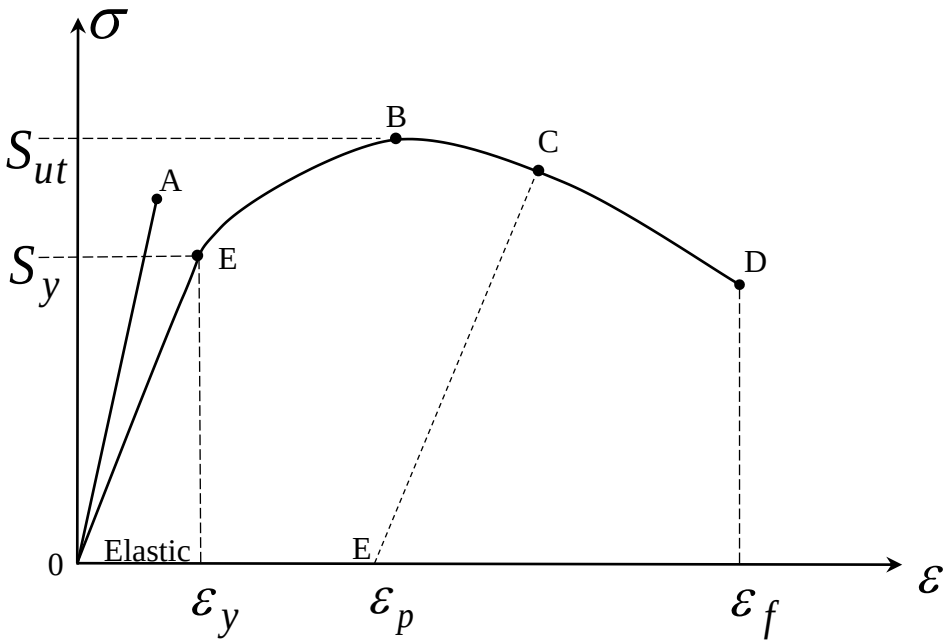
  quantities that characterize the behavior of a material in response to external, or applied forces

- Physical properties

  quantities that characterize the behavior of a material in response to physical phenomena other than mechanical forces …(e.g. such as heat, electricity, radiation)

Mechanical Properties – strength

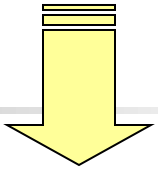




$$\text{stress} = \sigma = F / A$$

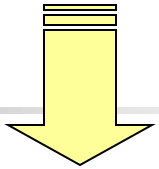
$$\text{strain} = \varepsilon = \Delta L / L$$

Fundamental properties



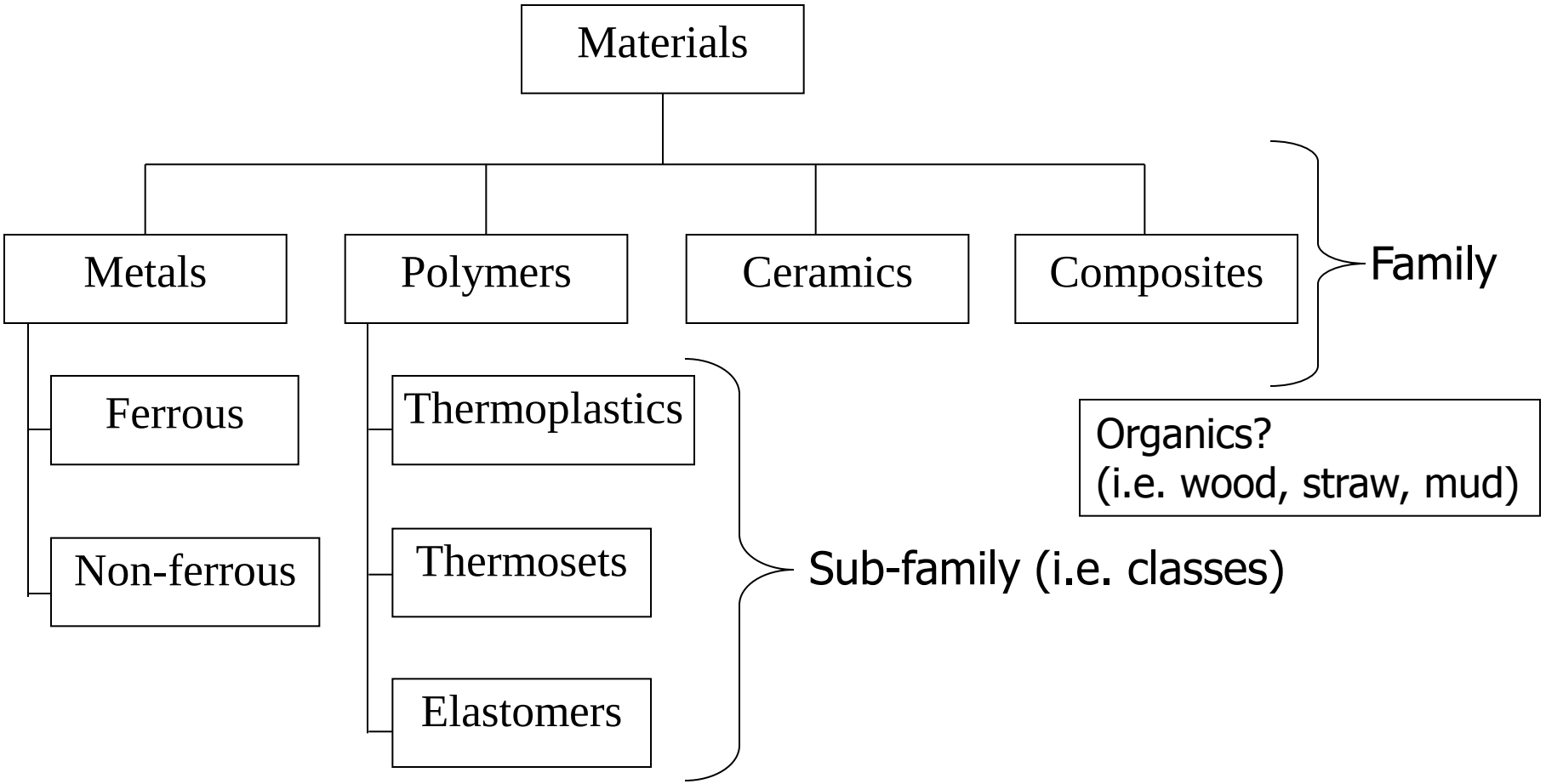
Characteristic	Behavior	Property	Units
Strength	strong, weak	ultimate strength	MPa (ksi)
Elastic strength	elastic then plastic	yield strength	MPa (ksi)
Stiffness	flexible, rigid	modulus of elasticity	MPa (Mpsi)
Ductility	draws, forms easily	% elongation, % area reduction	dimensionless
Hardness	resists surface indentation	Brinell No.	MPa (ksi)
Corrosion resistance	resists chemicals, oxidation	galvanic series	activity number

Fundamental properties

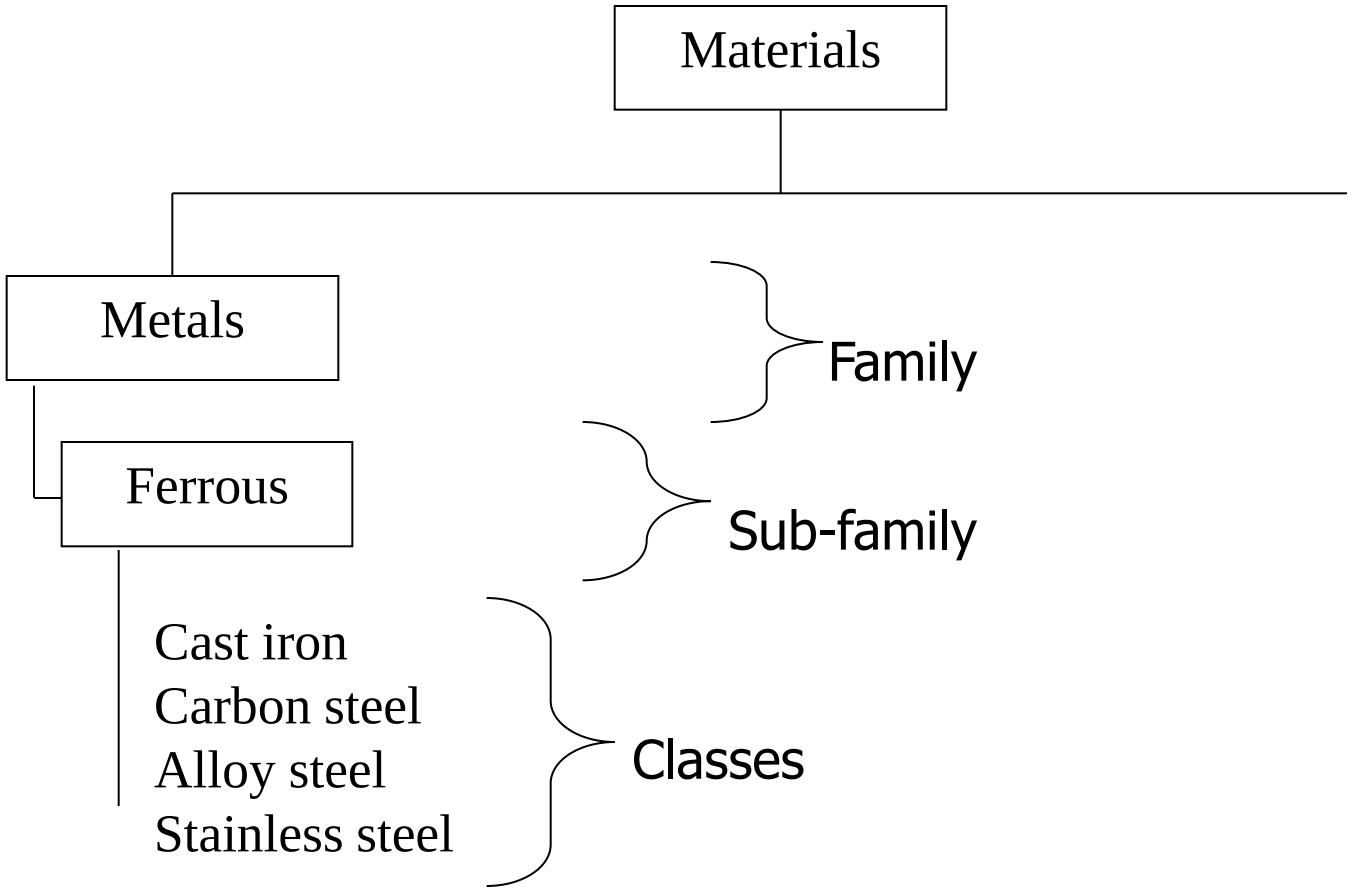


Characteristic	Behavior	Property	Units
Fatigue resistance	endures many load cycles	endurance limit	MPa (Mpsi)
Conductivity (heat, electric)	conducts, insulates	thermal conductivity electrical conductivity	(Btu/hr) / (F-ft), Mhos
Creep resistance	time dependent stretching	creep strength	MPa (ksi)
Impact resistance	shock, impact loads	Charpy energy	N-m, (ft-lbs)
Density (mass) Density (weight)	heavy, light	mass density weight density	kg/m^3, $(slugs/ft^3)$ N/m^3, (lbs/ft^3)
Temperature tolerance	softens, or melts easily	melting point	degrees C, F

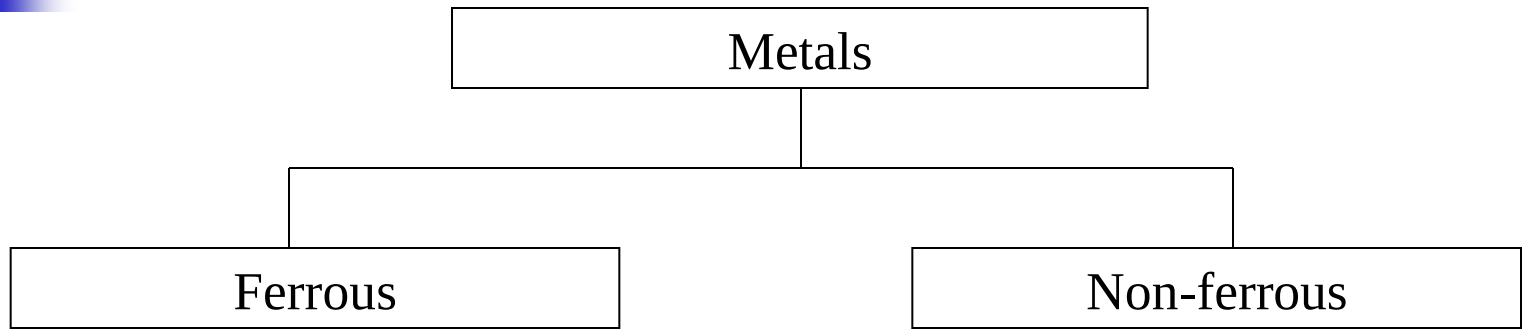
Material families / sub-families



Material sub-families / classes



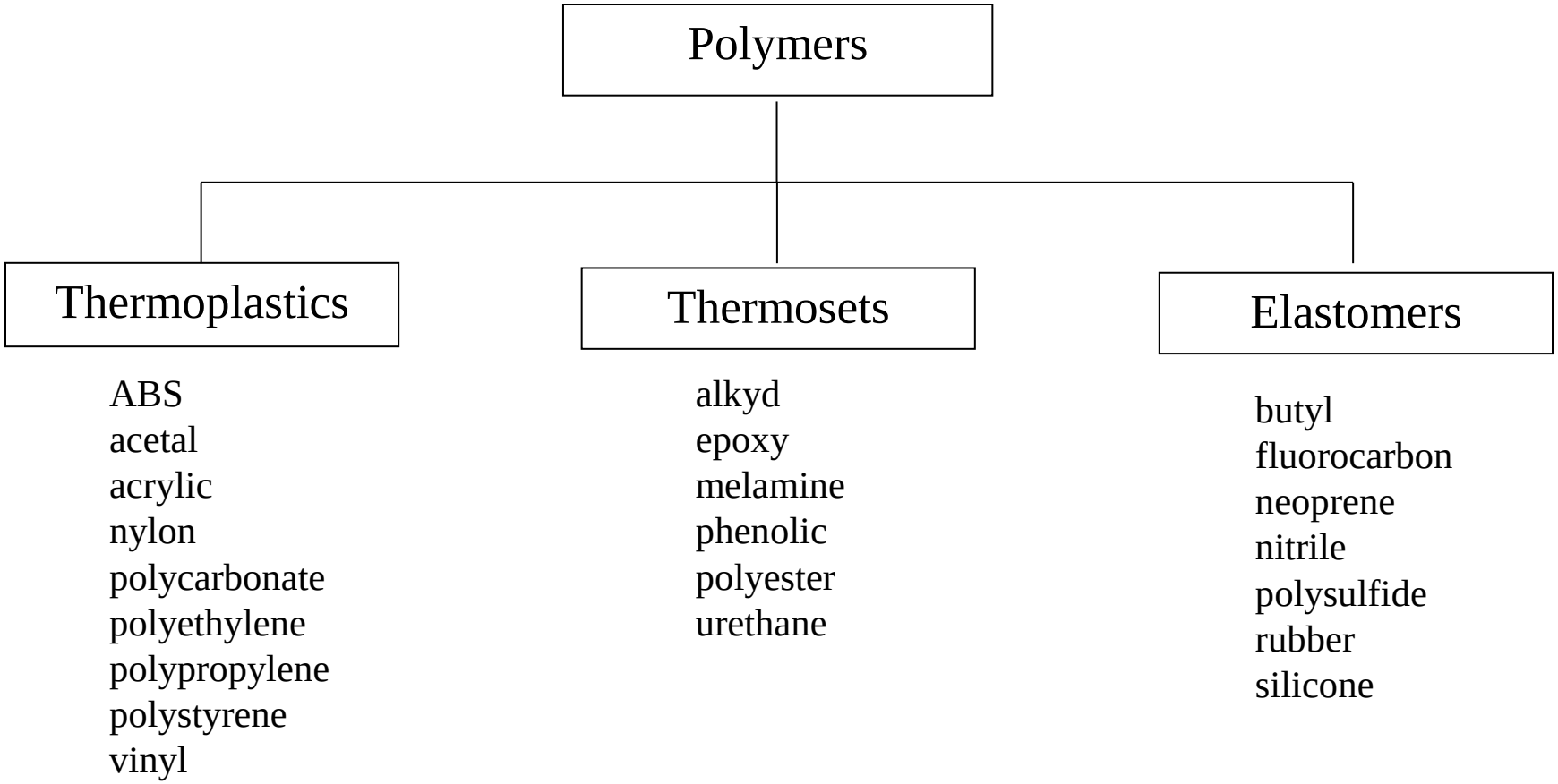
Metals



cast iron
carbon steel
alloy steel
stainless steel

aluminum
brass
bronze
copper
lead
magnesium
nickel
tin
titanium
tungsten
zinc

Polymers


Polymers
Thermoplastics
Thermosets
Elastomers
ABS
acetal
acrylic
nylon
polycarbonate
polyethylene
polypropylene
polystyrene
vinyl
alkyd
epoxy
melamine
phenolic
polyester
urethane
butyl
fluorocarbon
neoprene
nitrile
polysulfide
rubber
silicone

Ceramics

Ceramics

alumina
beryllia
diamond
magnesia
silicon carbide
silicon nitride
zirconia

Composites

Composites

carbon fiber (graphite)
ceramic matrix
glass fiber
Kevlar fiber
metal matrix

Property profiles by family

Characteristics	Metals	Ceramics	Polymers
strength	strong	strong –C weak – T	weak
elastic strength	very	some	some
stiffness	very	very	flexible
ductility	ductile	brittle	---
hardness	medium	hard	soft
corrosion resistance	poor	good	excellent
fatigue resistance	good	---	---
conductivity (heat/electric)	conductor	insulator	insulator
creep resistance	good	---	poor
impact resistance	good	poor	good
density	heavy	medium	light
temperature tolerance	good	super	poor

Material indices (Ashby approach)

$$performance \leq f_1(F)\, f_2(G)\, f_3(M)$$

- Given the same cost/volume… which is stronger?

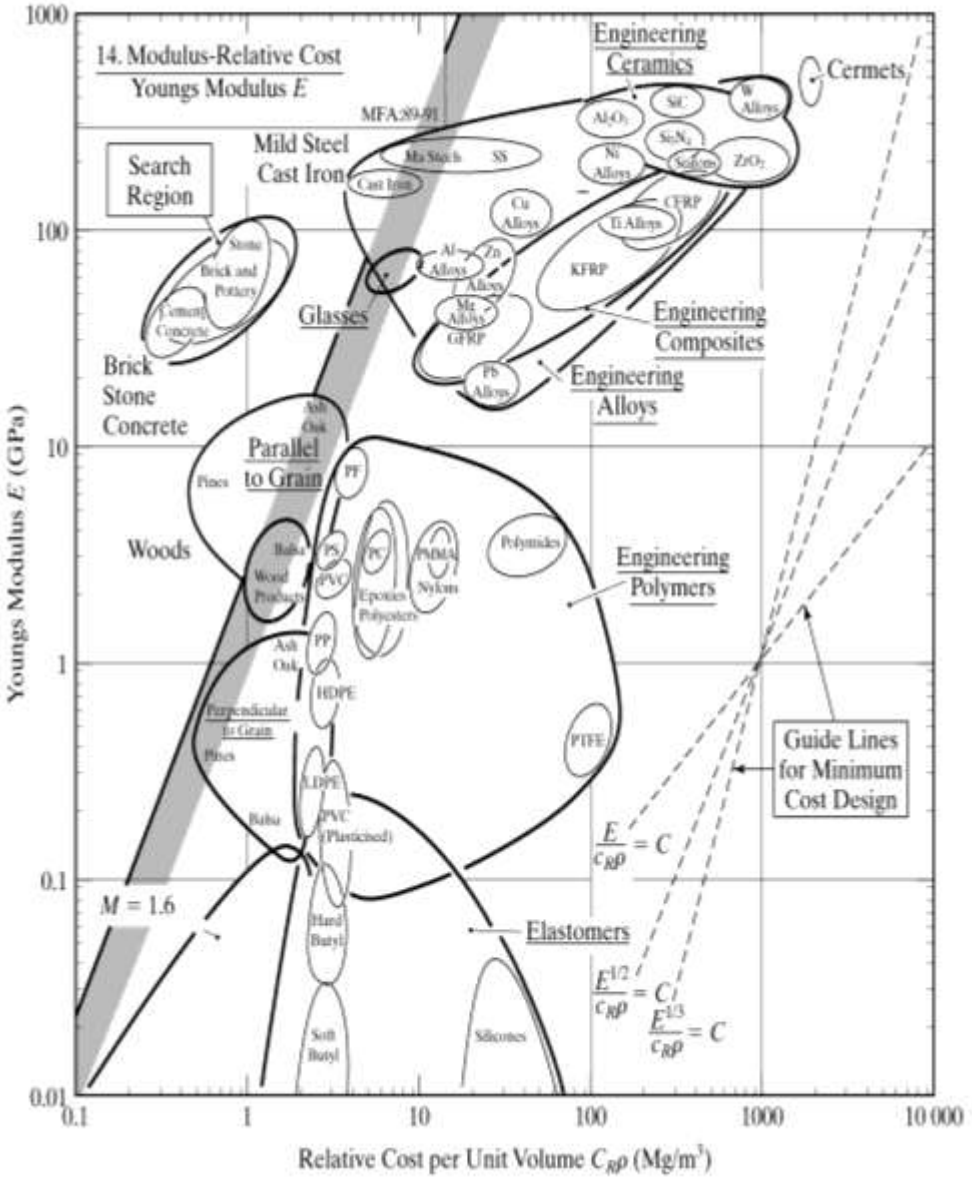
  index = Strength/cost

- Given the same cost/volume… which is stiffer?

  index = Young's modulus/cost

Ashby Charts

How can we use them?



How do we choose a material?

Product function depends upon…
material, manufacturing process, geometry

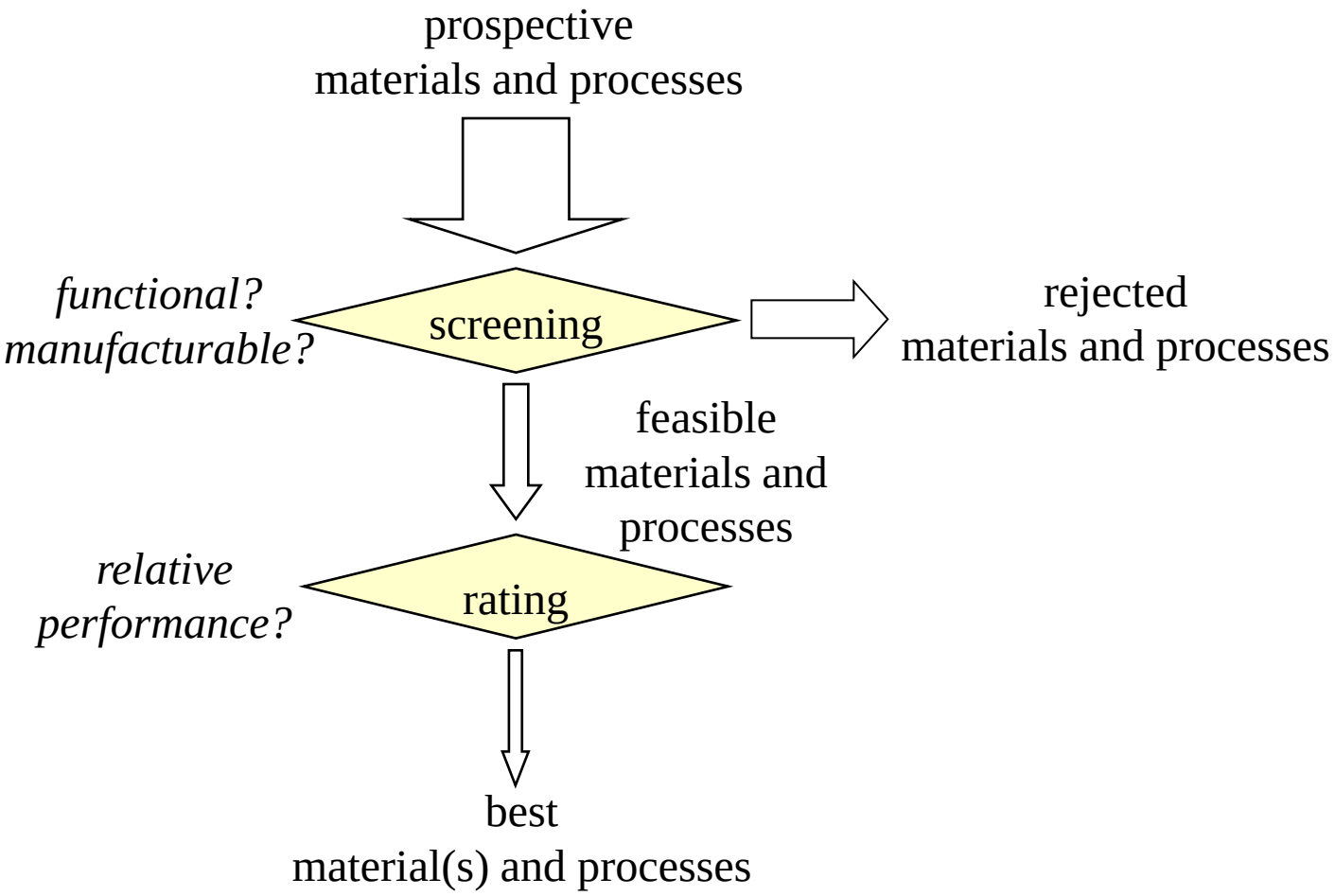
We have to consider all three

- Do we select a few feasible materials first…
  then select the specific mfg process?

or

- Do we select a few feasible mfg processes…
  then select the specific material?

Materials selection process



Materials first approach
---------Information from application

1. Applied loads
   - magnitude
   - cyclic nature (steady, fatigue)
   - rate (slow, impact)
   - duration (creep)
2. Ambient conditions
   - temperature
   - moisture
   - sunlight
   - chemical liquids/vapors
3. Safety
4. Cost

Process First Approach ----- Part Information

1. Production volume
2. Part size (overall)
3. Shape capability (features)
    - boss/depression 1D
    - boss/depression >1D
    - holes
    - undercuts (internal/external)
    - uniform walls
    - cross sections (uniform /regular)
    - rotational symmetry
    - captured cavities

Summary

- Product function interdependence
- Mechanical properties
- Physical properties
- Families, sub, classes of materials
- Performance indices
- Ashby charts
- Materials first approach
- Process first approach
- Selection---screening, then evaluation