Manufacturing Processes

- Product example
- Manufacturing process definition
- Deformation processes
- Casting processes
- Sheet metalworking
- Hammer Forging Video
- Polymer processing

How would we manufacture a mountain bike ?

(Courtesy of Trek Bicycle, 2002)

Manufacturing process decisions

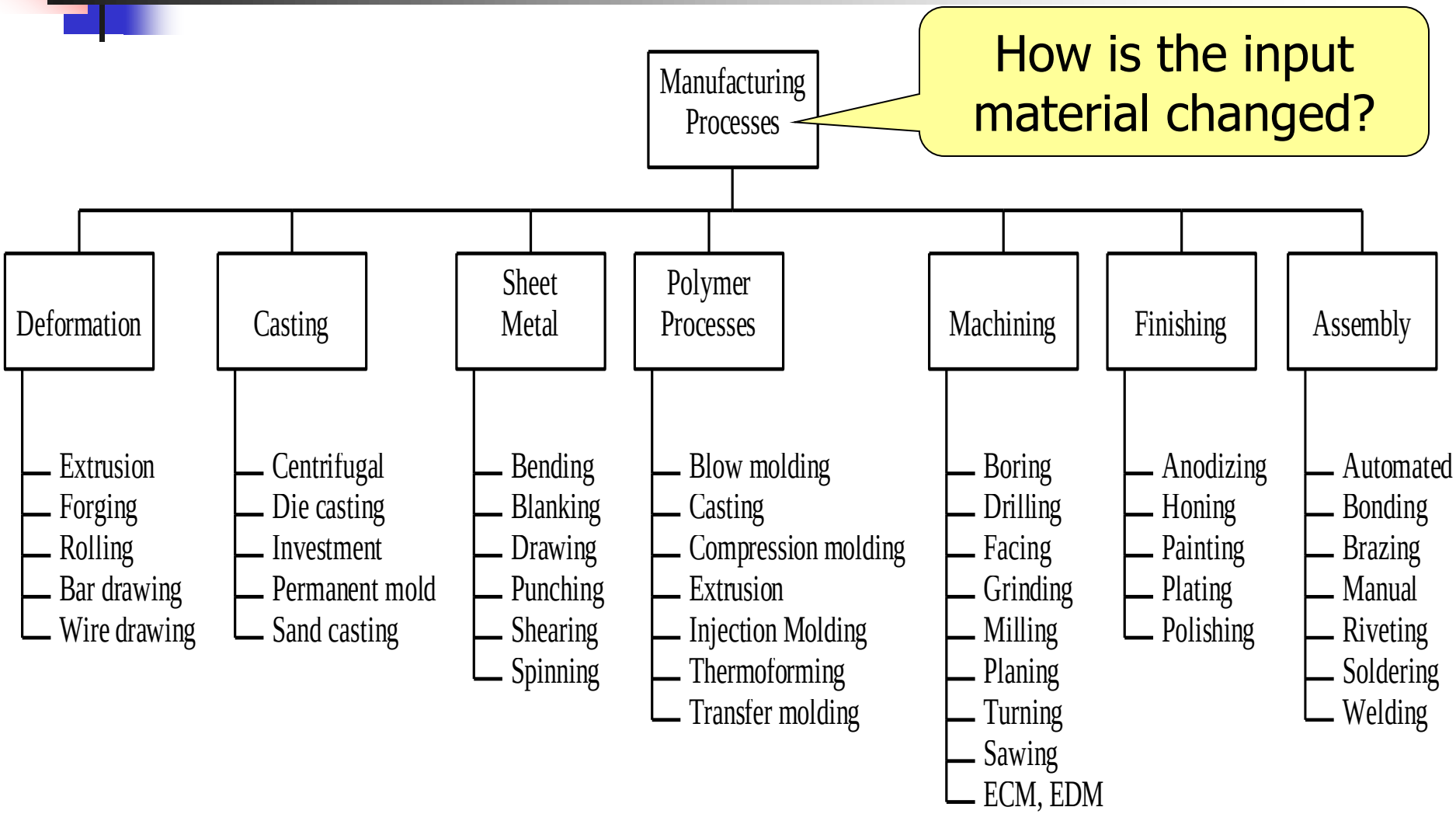
- Specific manufacturing processes?
- How do the selected materials influence the choice of manufacturing processes?
- Does product function or performance issues influence our choice of mfg. processes?
- What criteria should we use to select processes?
- Which criteria are more important?
- Who will make the final decisions?

Parts undergo sequence of processes

Changes?

- *Primary* - alter the ("raw") material's basic shape or form.
  - Sand casting
  - Rolling
  - Forging
  - Sheet metalworking
- *Secondary* - add or remove geometric features from the basic forms
  - Machining of a brake drum casting (flat surfaces)
  - Drilling/punching of refrigerator housings (sheet metal)
  - Trimming of injection molded part flash
- *Tertiary* - surface treatments
  - Polishing
  - Painting
  - Heat-treating
  - Joining

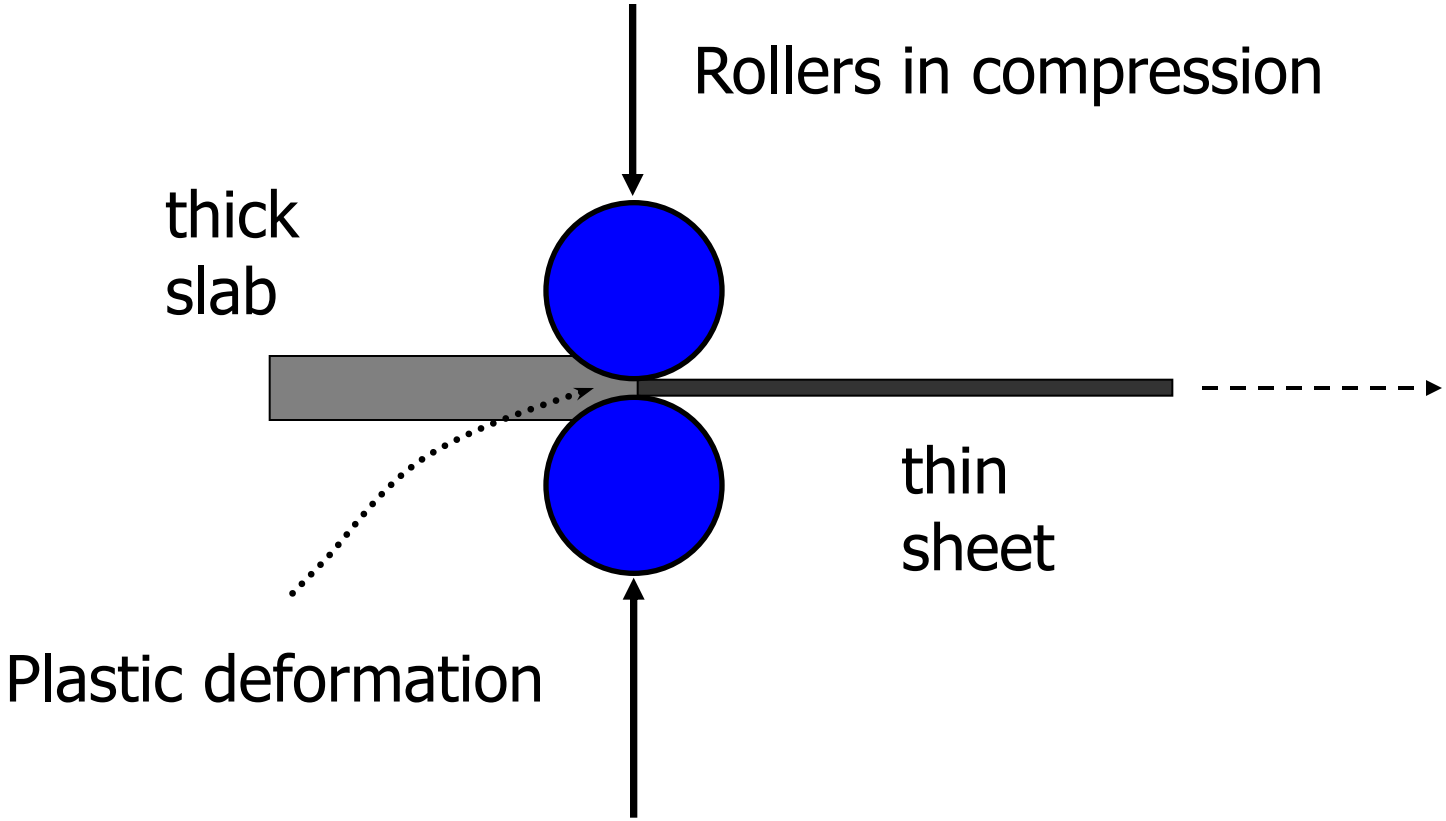
Types of manufacturing processes



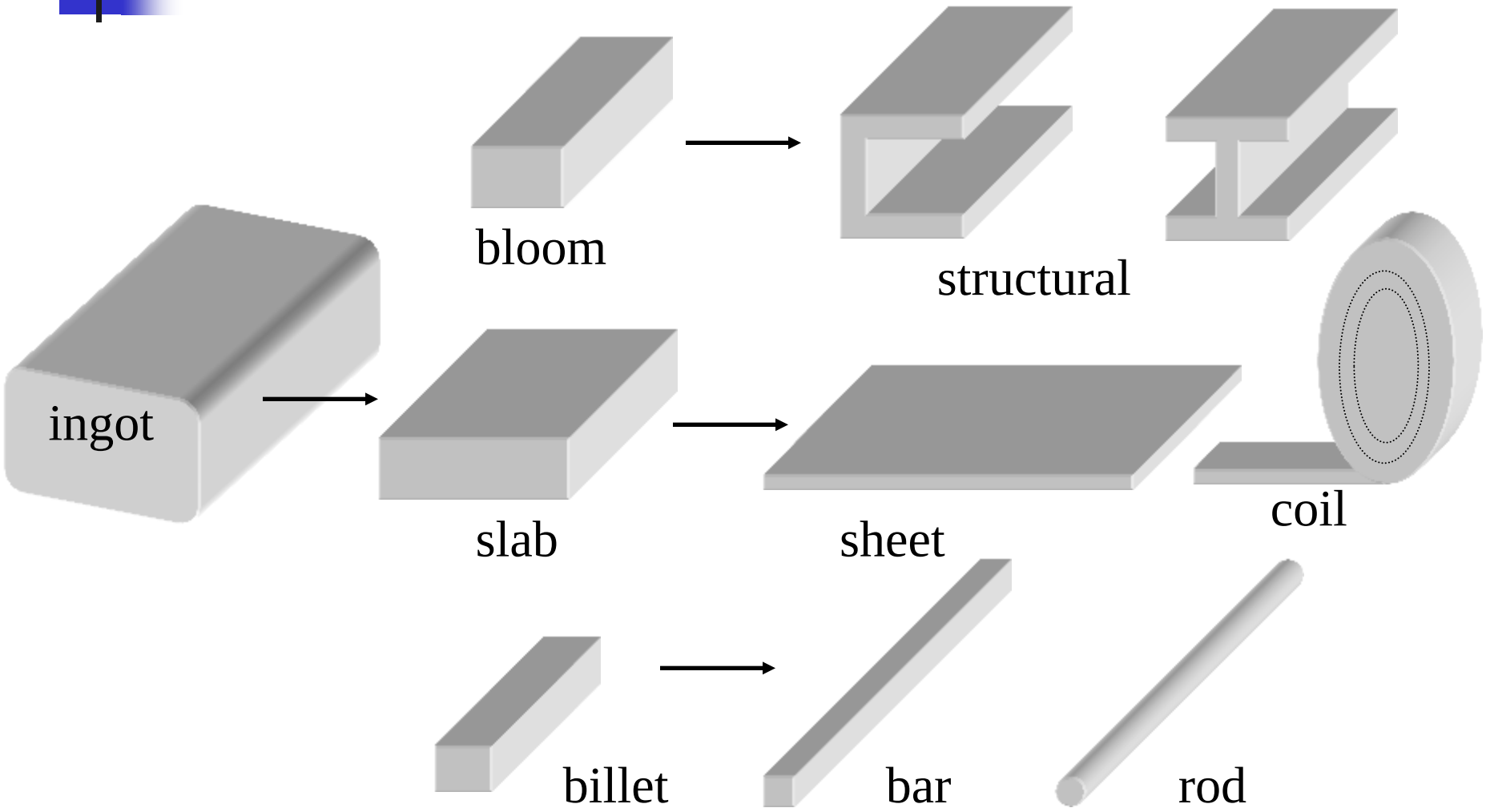
Deformation processes

- Rolling
- Extrusion
- Drawing
- Forging

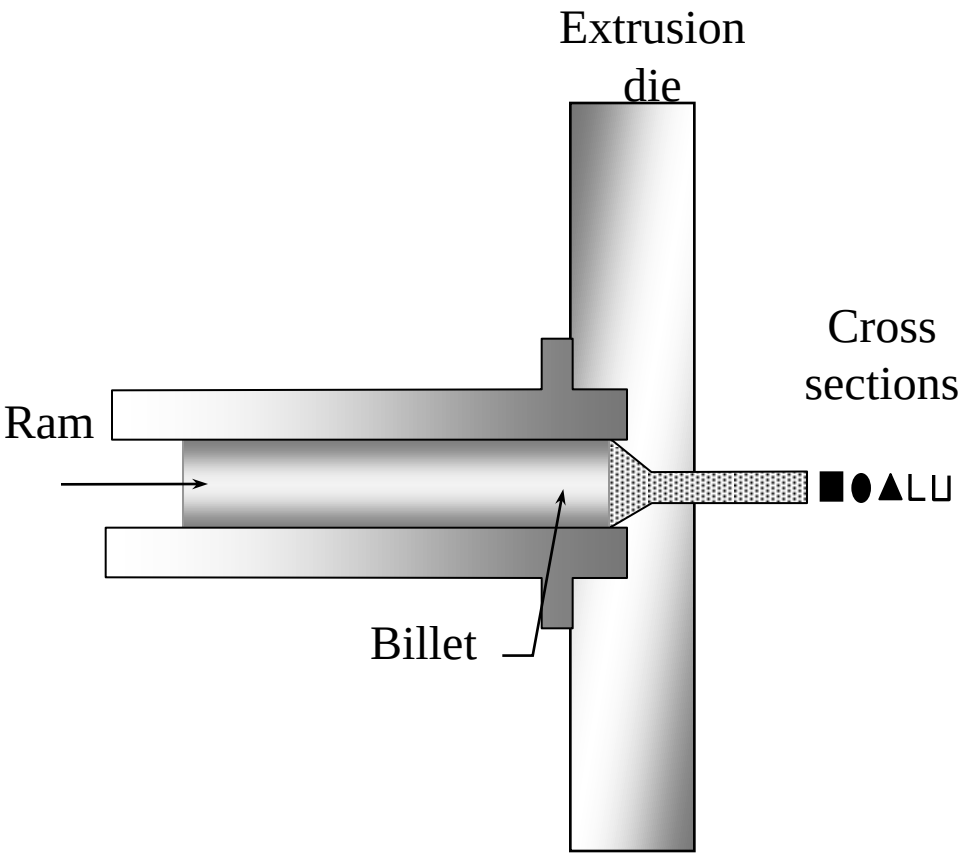
Rolling (of ductile materials)



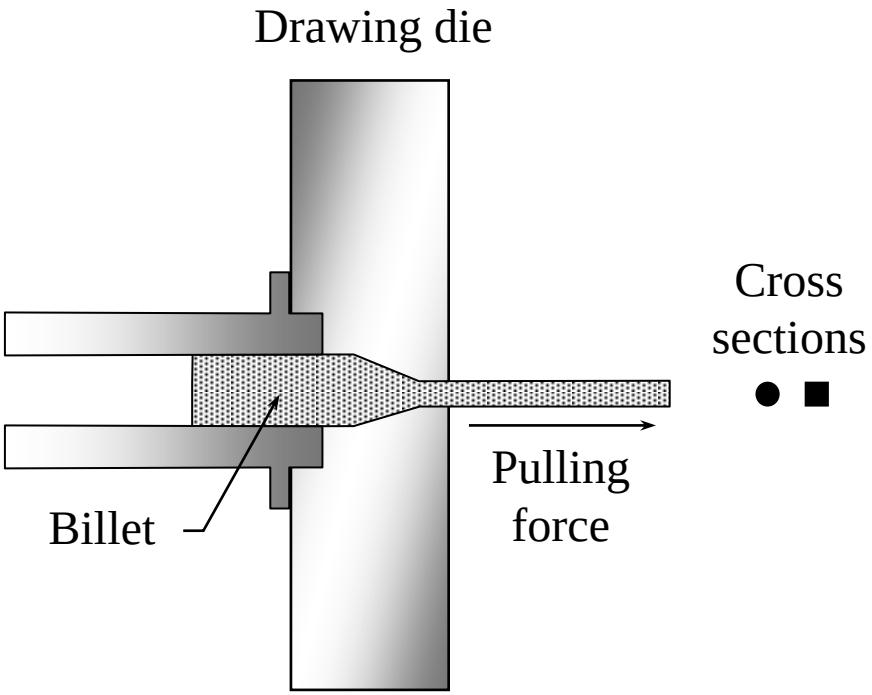
Rolling



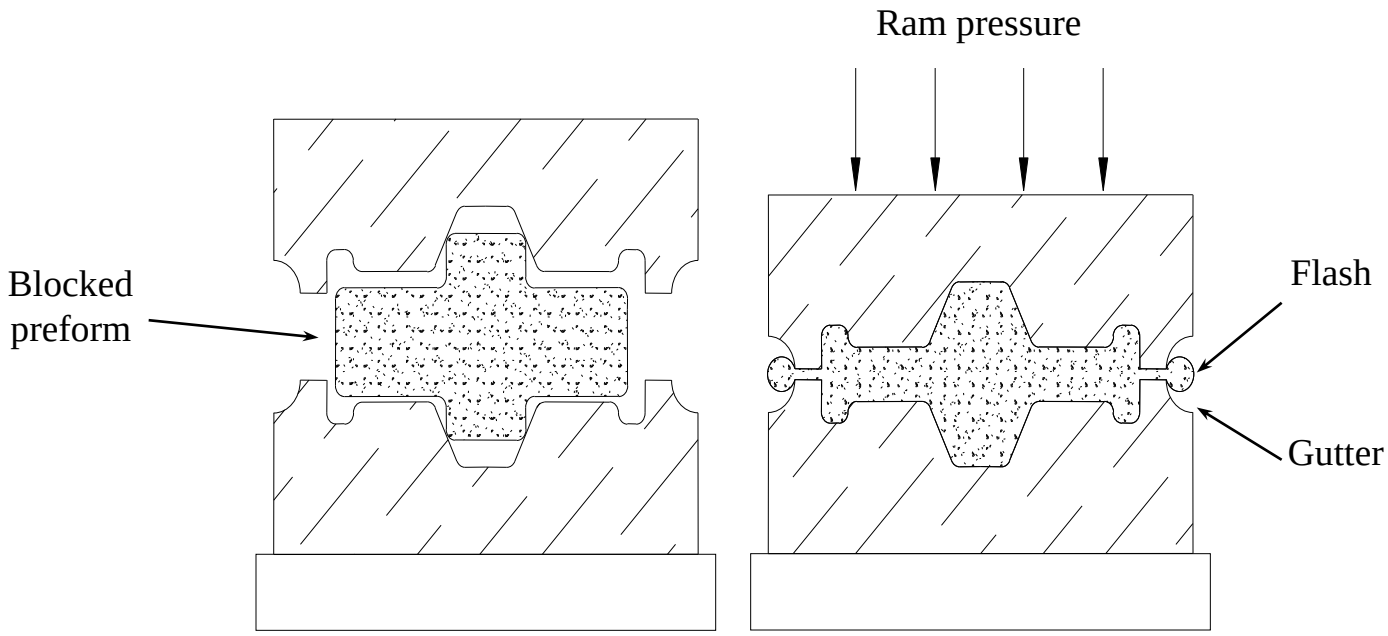
Extrusion



Drawing



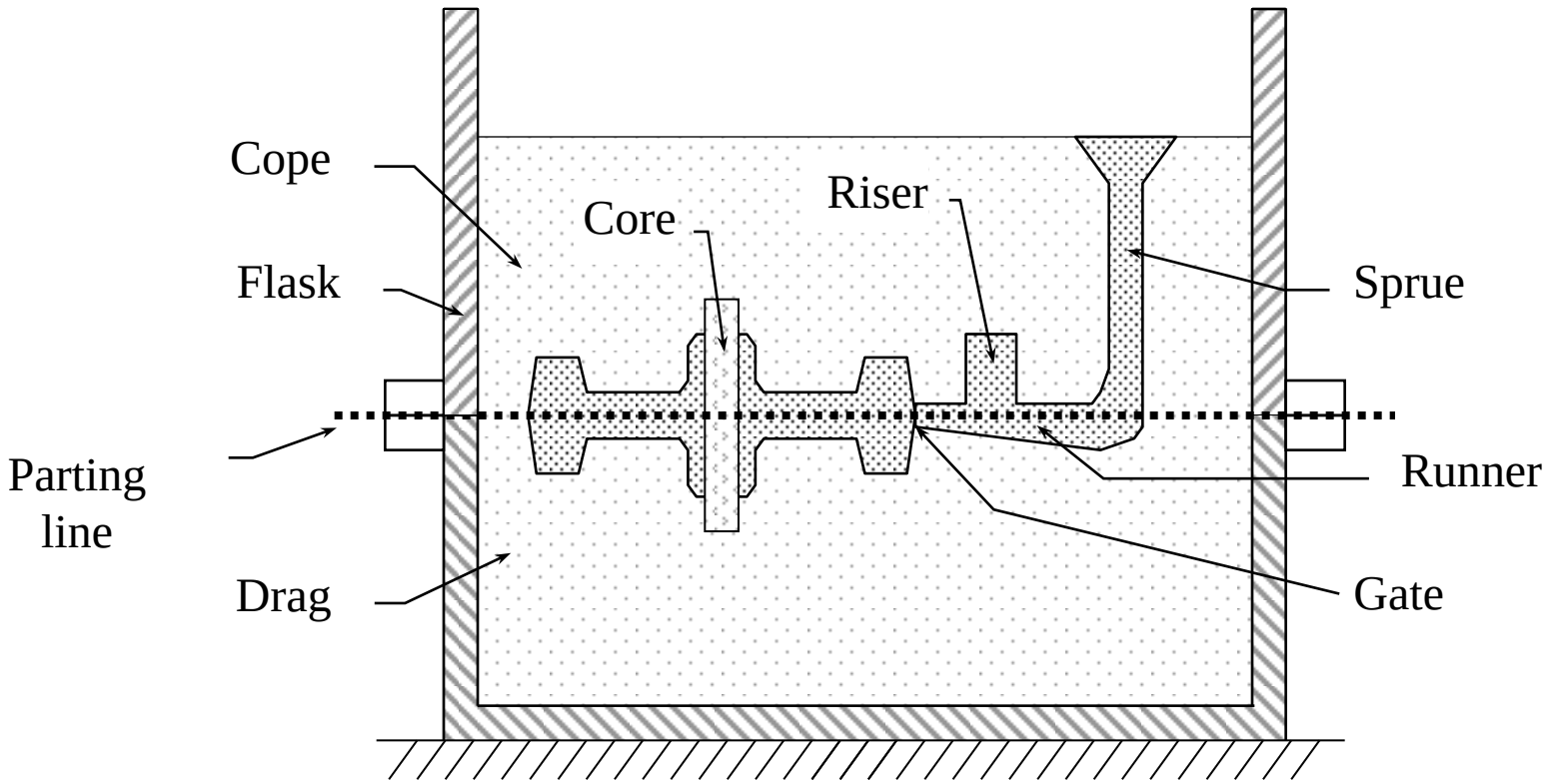
Forging (closed-die)



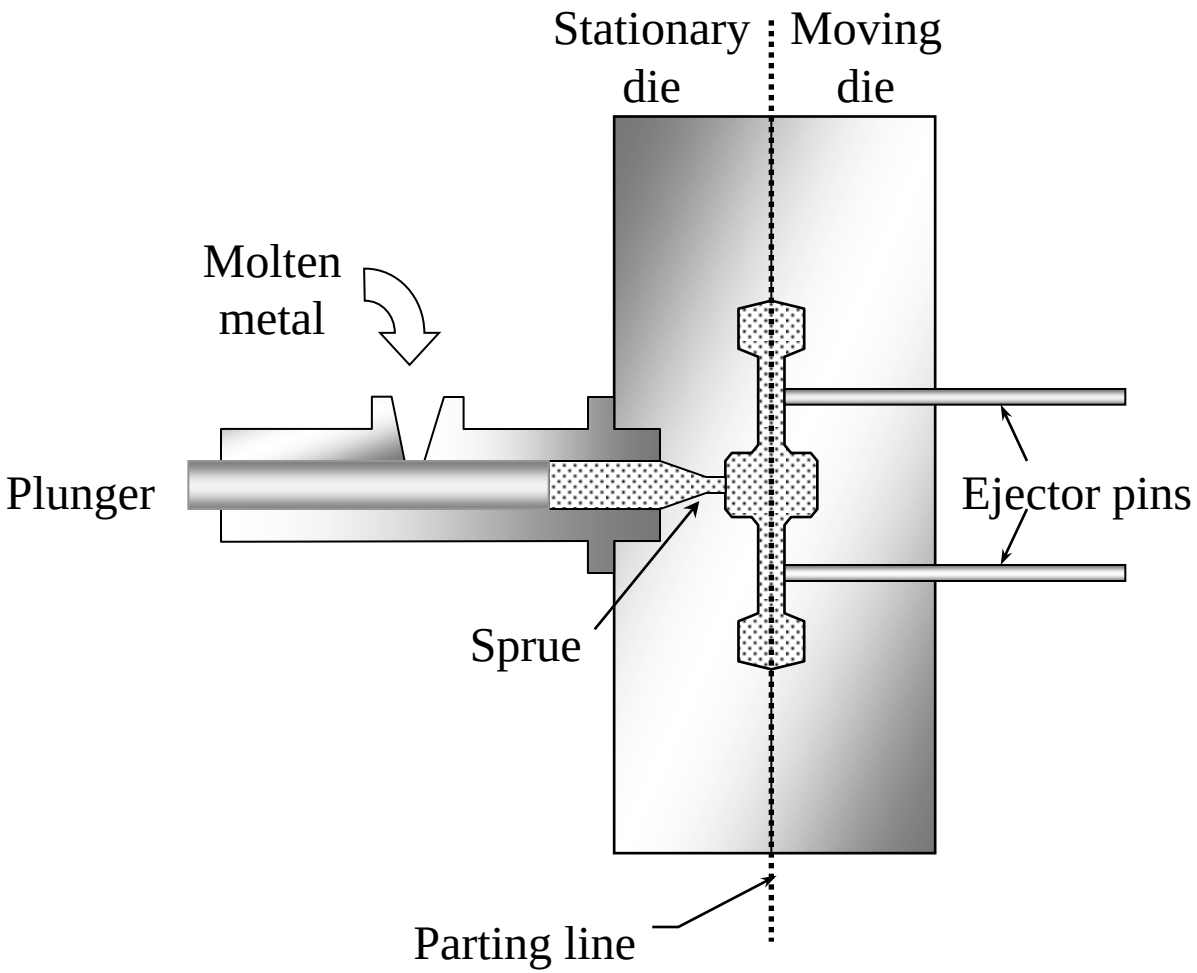
Casting Processes

- Sand casting
- Die casting
- Investment casting

Sand casting (closed-mold)

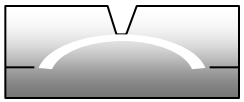


Die casting

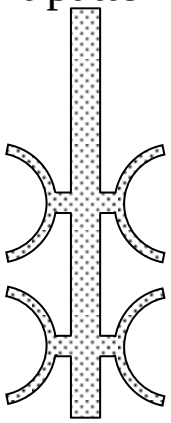

Stationary die
Moving die
Molten metal
Plunger
Ejector pins
Sprue
Parting line

Investment casting

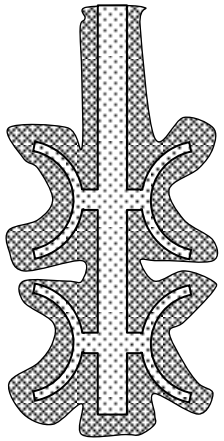
Wax pattern is cast



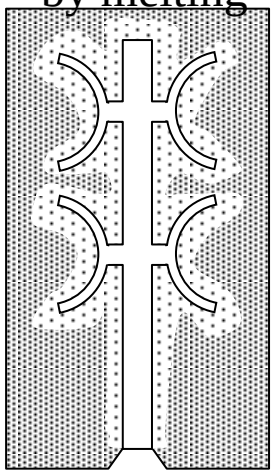
4-part pattern tree



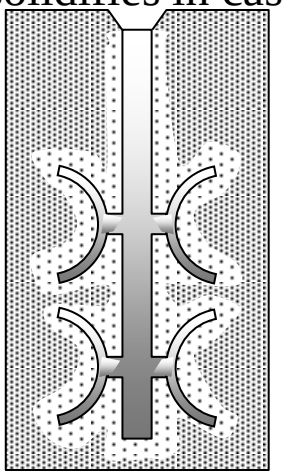
Ceramic mold (hardened slurry)



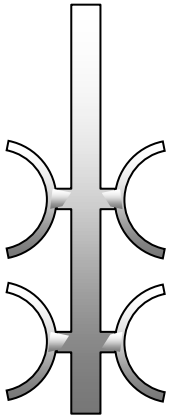
Wax removed by melting



Molten metal solidifies in cast



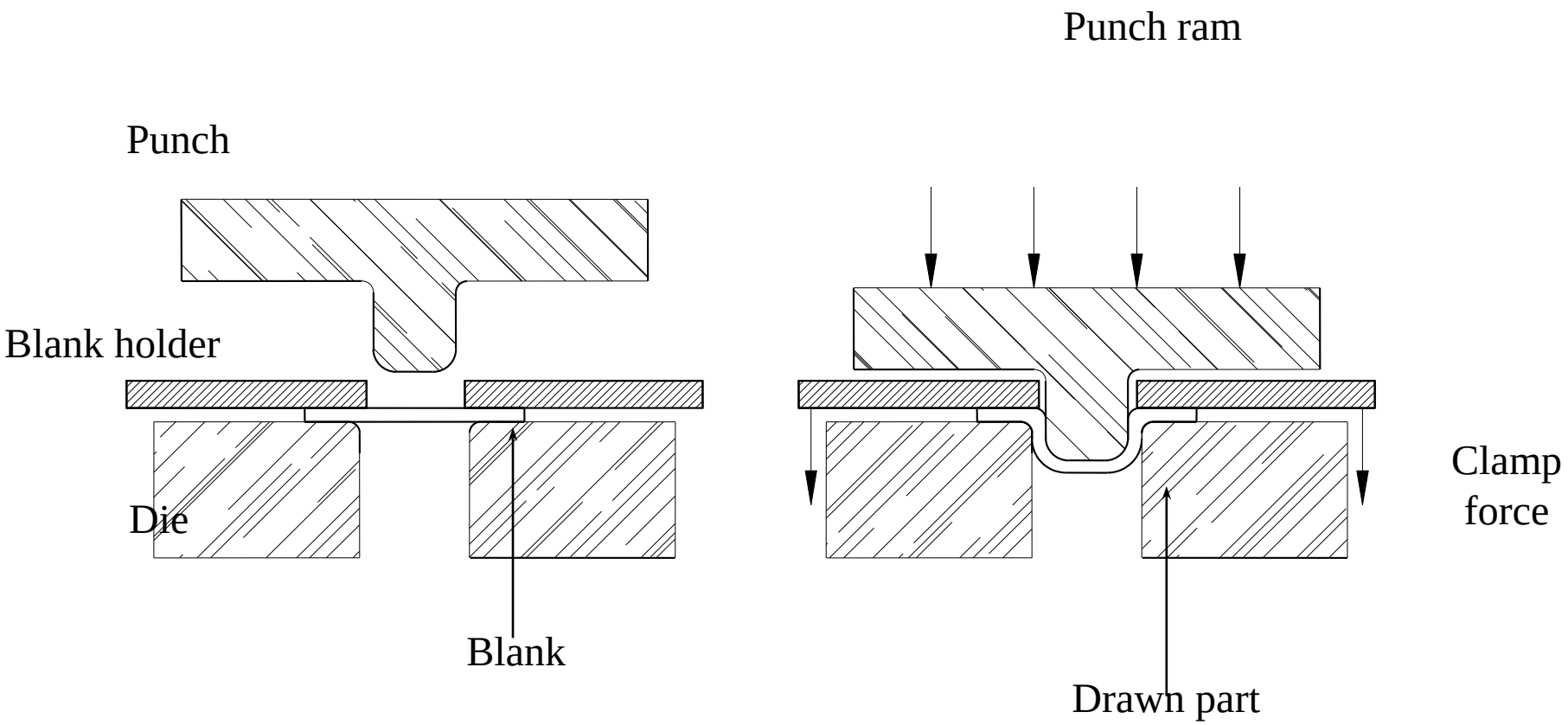
Ceramic mold is removed

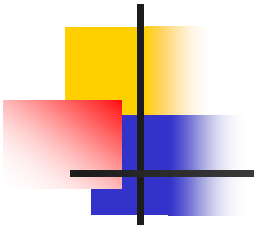


Sheet Metalworking

- Bending
- Blanking
- Drawing
- Punching
- Shearing
- Spinning

Sheet metal drawing

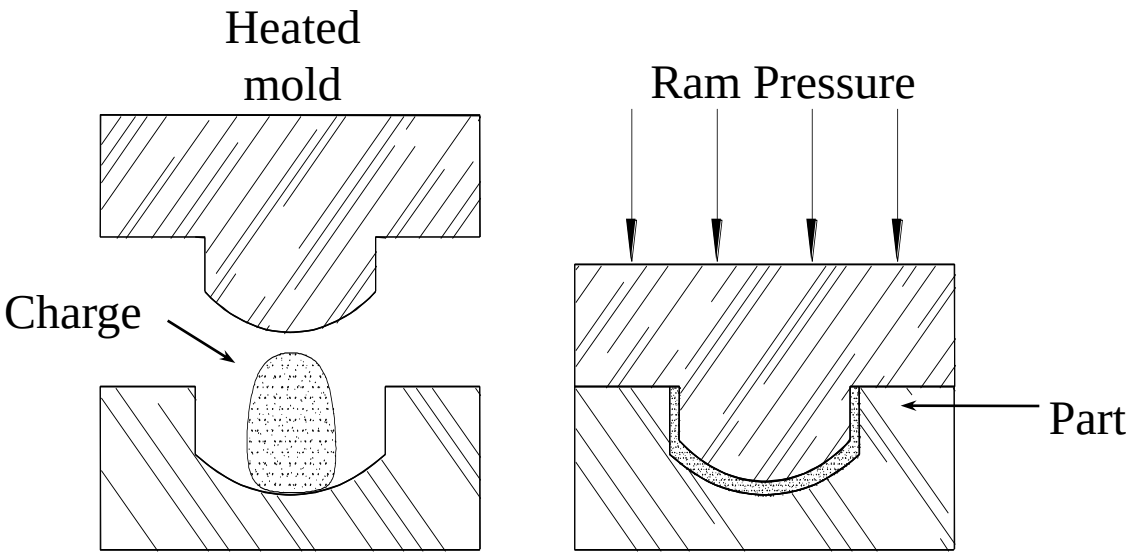




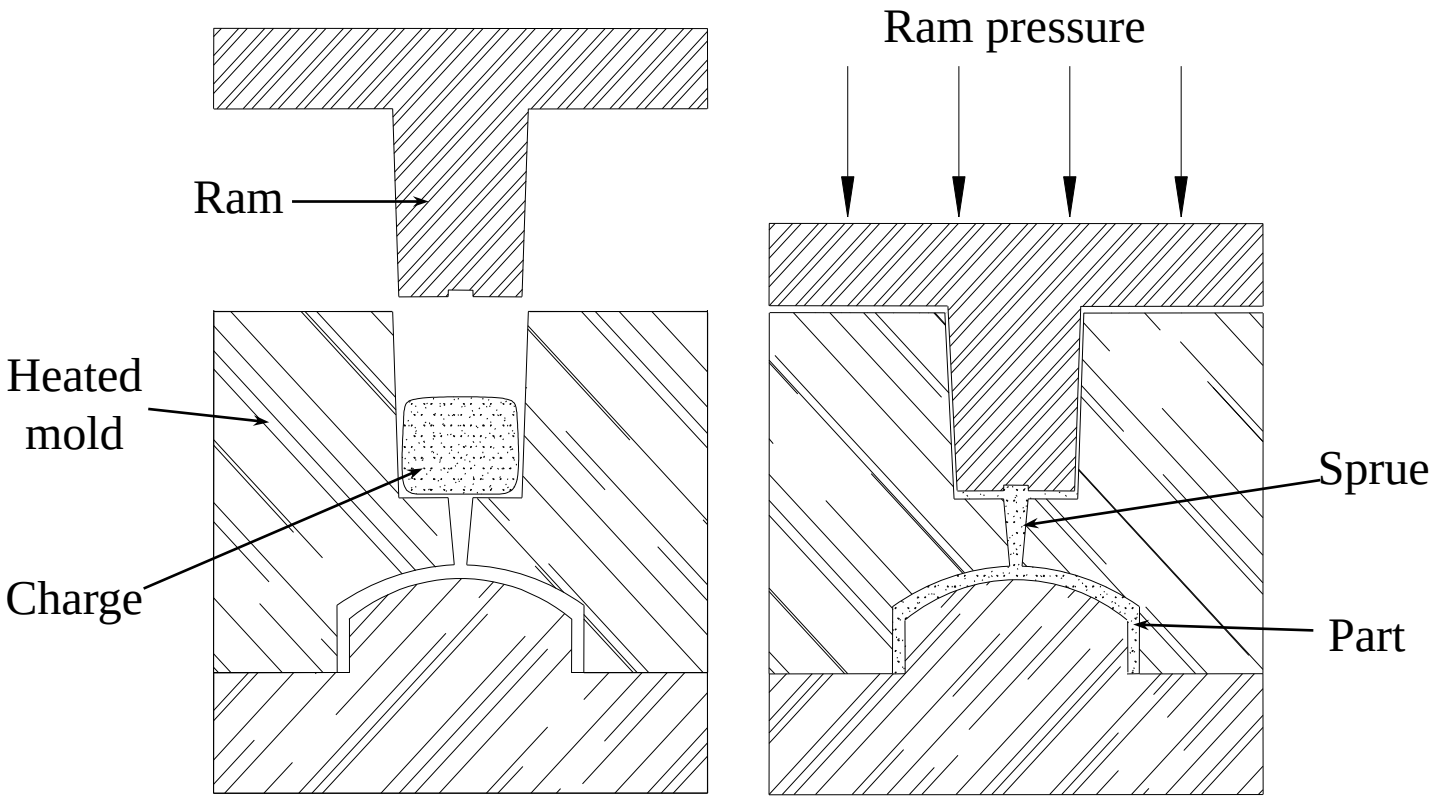
Polymer Processes

- Compression molding
- Transfer Molding
- Blow molding
- Injection molding

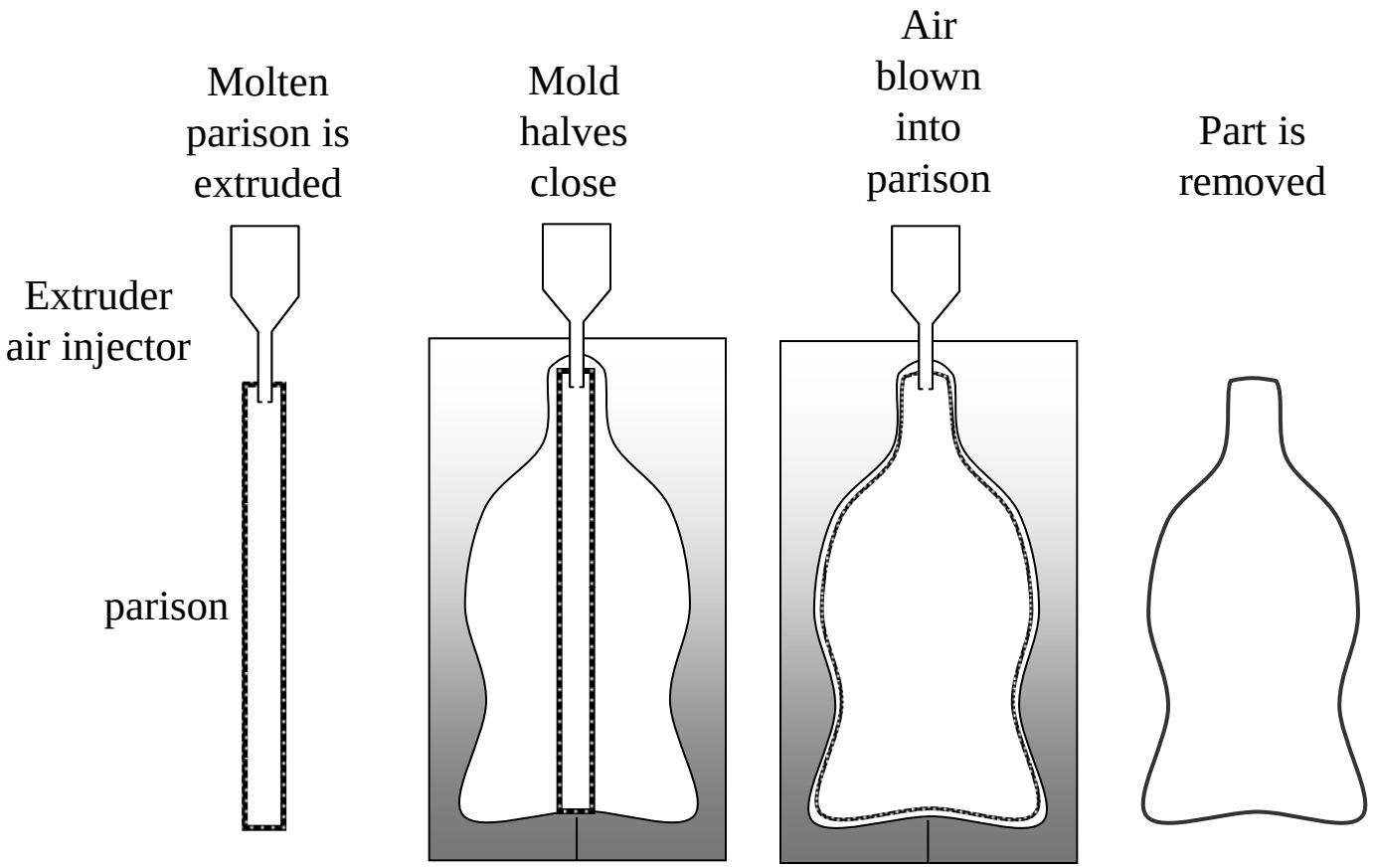
Compression molding



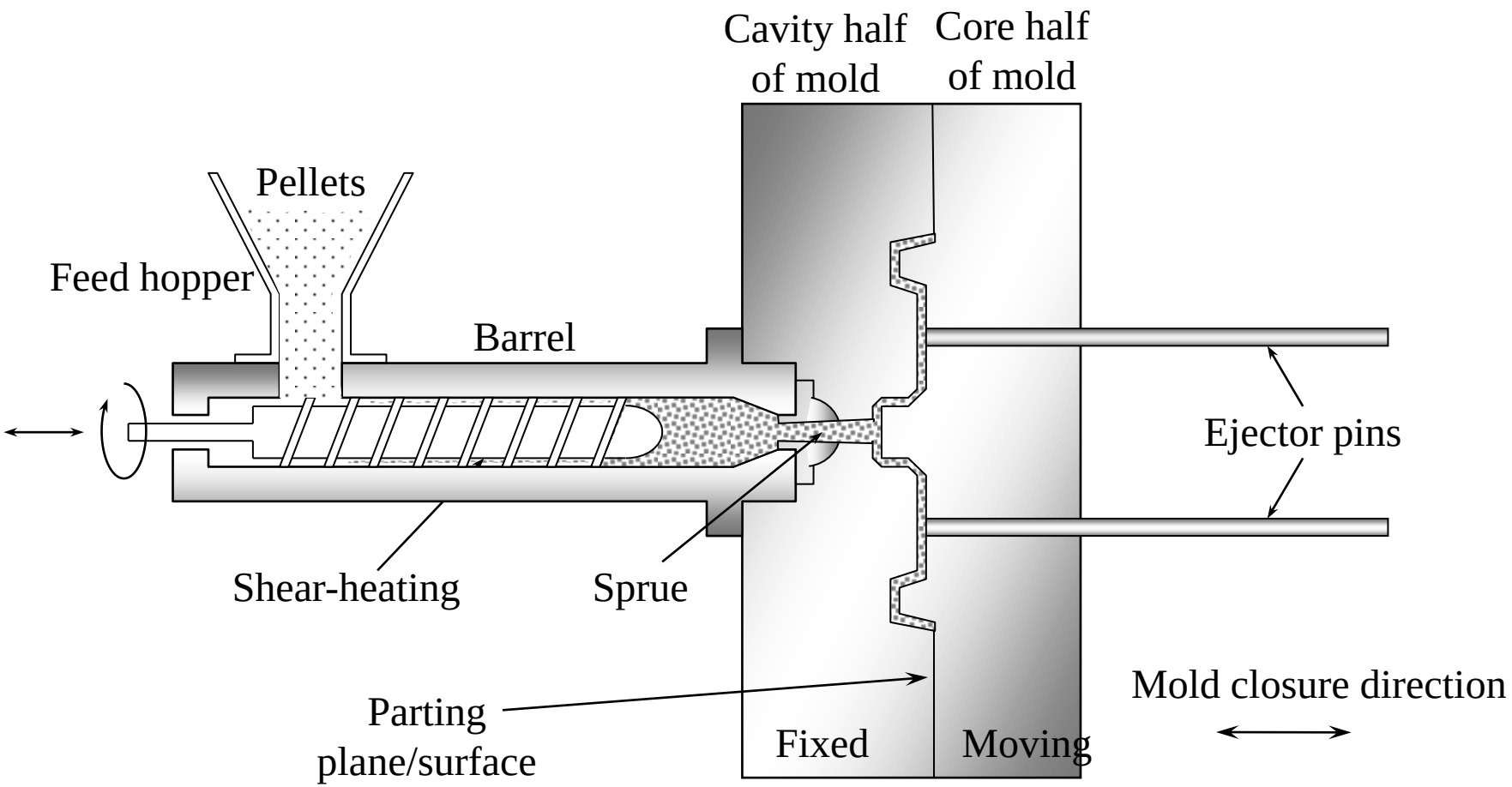
Transfer molding



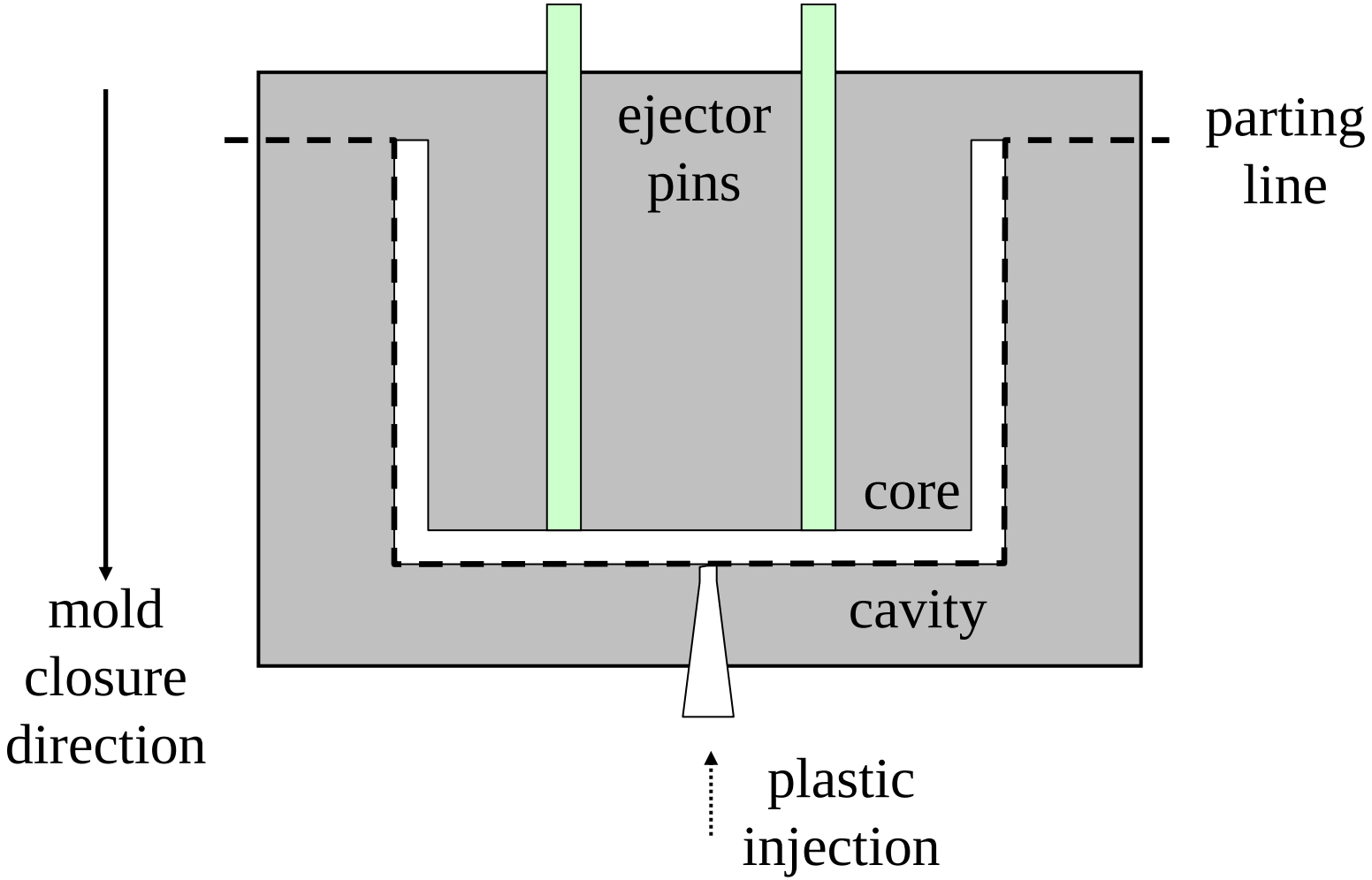
Blow molding



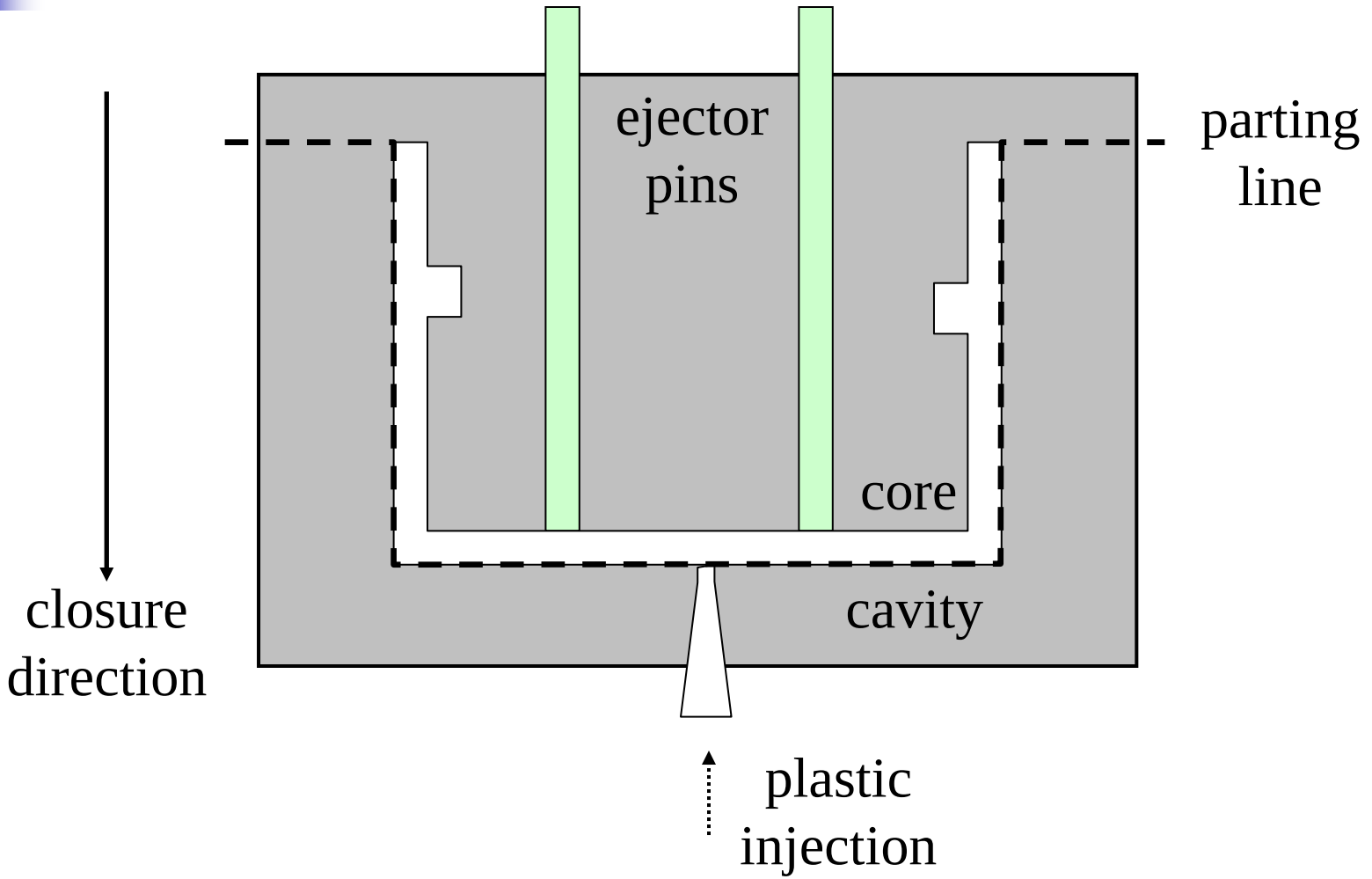
Injection molding



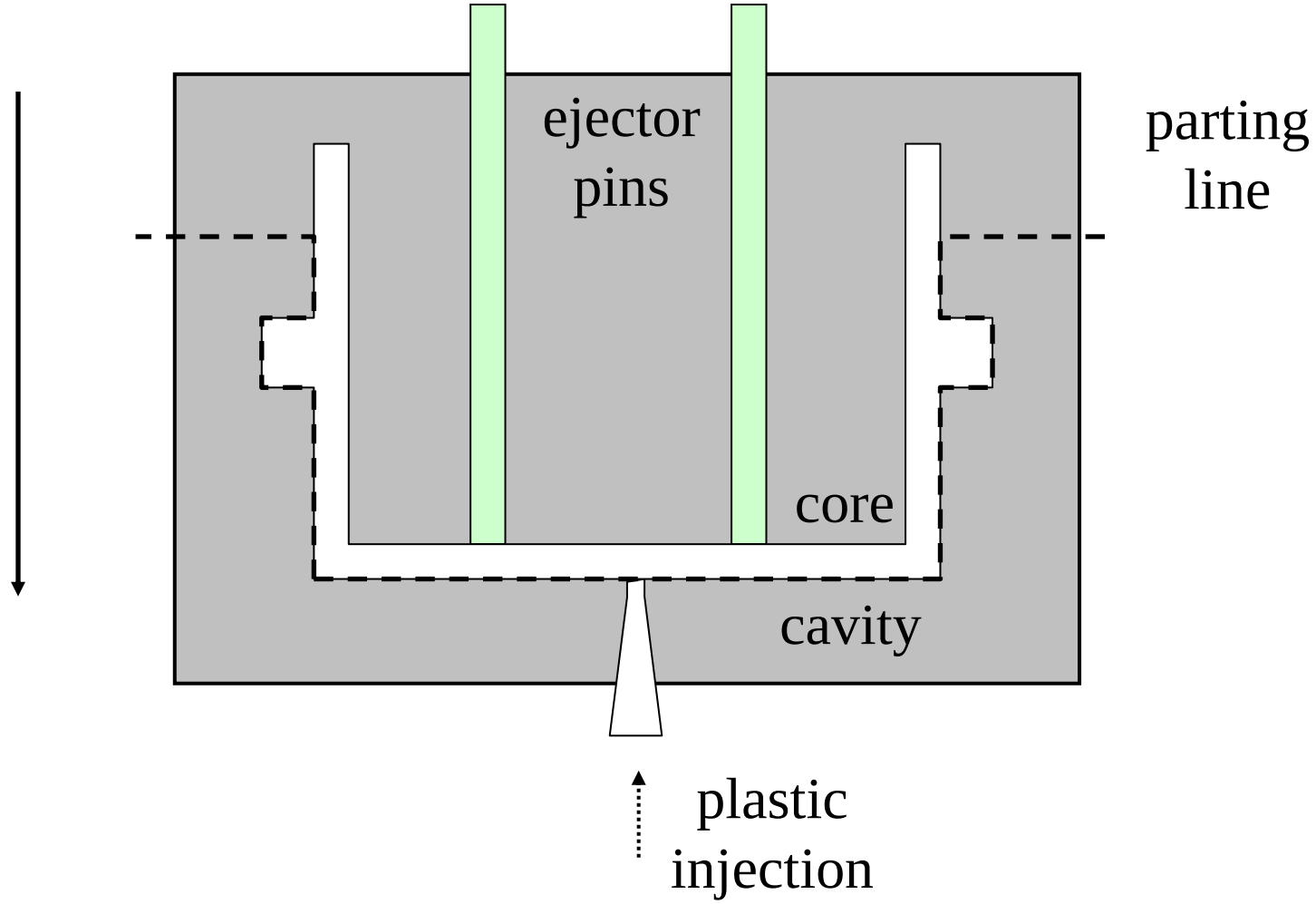
Example of a box …with no undercuts



Internal undercuts



External undercuts



Solidification processes summary

molten material → freezing → solid Part

Recall

Casting Processes
- Sand Casting
- Die Casting
- Investment Casting
- Centrifugal

Polymer Processes
- Injection Molding
- Blow Molding
- ThermoForming
- Compression Molding

considerations

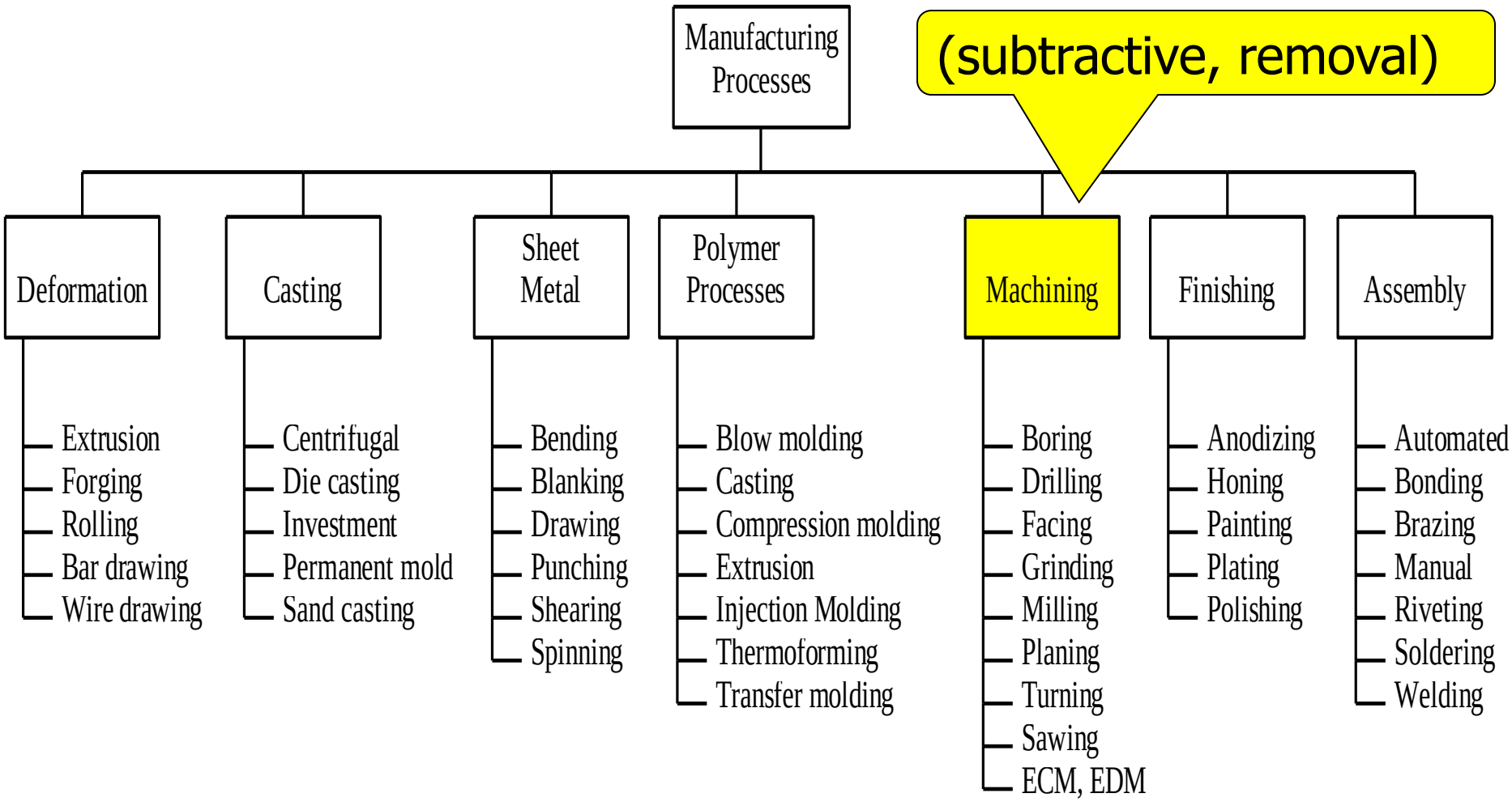
- Flow (voids, flash)
- Cooling time (cycle time)
- Temperature
- Mold complexity
- Warpage
- Post processing
- Costs (materials, tooling, processing)

Add to your notes

Manufacturing Processes - Part B

- Machining
- Finishing
- Assembly
- Some other processes

Machining processes



Machining – removal of material…

Sawing –using a toothed blade.
Milling – from a flat surface by a rotating cutter tool.
Planing – using a translating cutter as workpiece feeds.
Shaping - from a translating workpiece using a stationary cutter.
Boring - increasing diameter of existing hole by rotating the workpiece.
Drilling- using a rotating bit forming a cylindrical hole.
Reaming – to refine the diameter of an existing hole.
Turning - from a rotating workpiece.
Facing - from turning workpiece using a radially fed tool.
Grinding - from a surface using an abrasive spinning wheel.
Electric discharge machining - by means of a spark.

Machining process considerations

solid material → machining → material removed

Recall

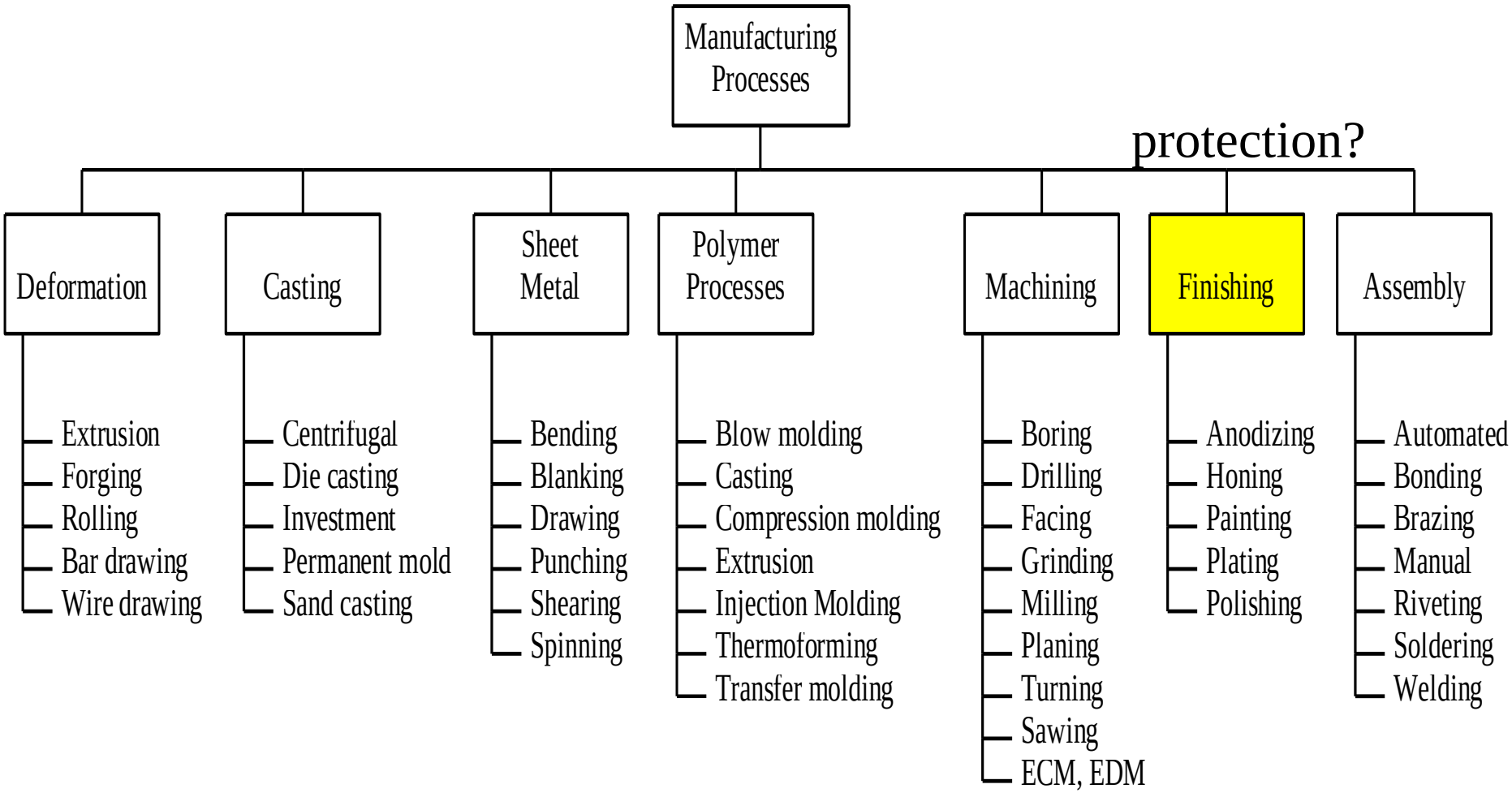
sawing, turning, boring, milling,
drilling, grinding, ECM

considerations

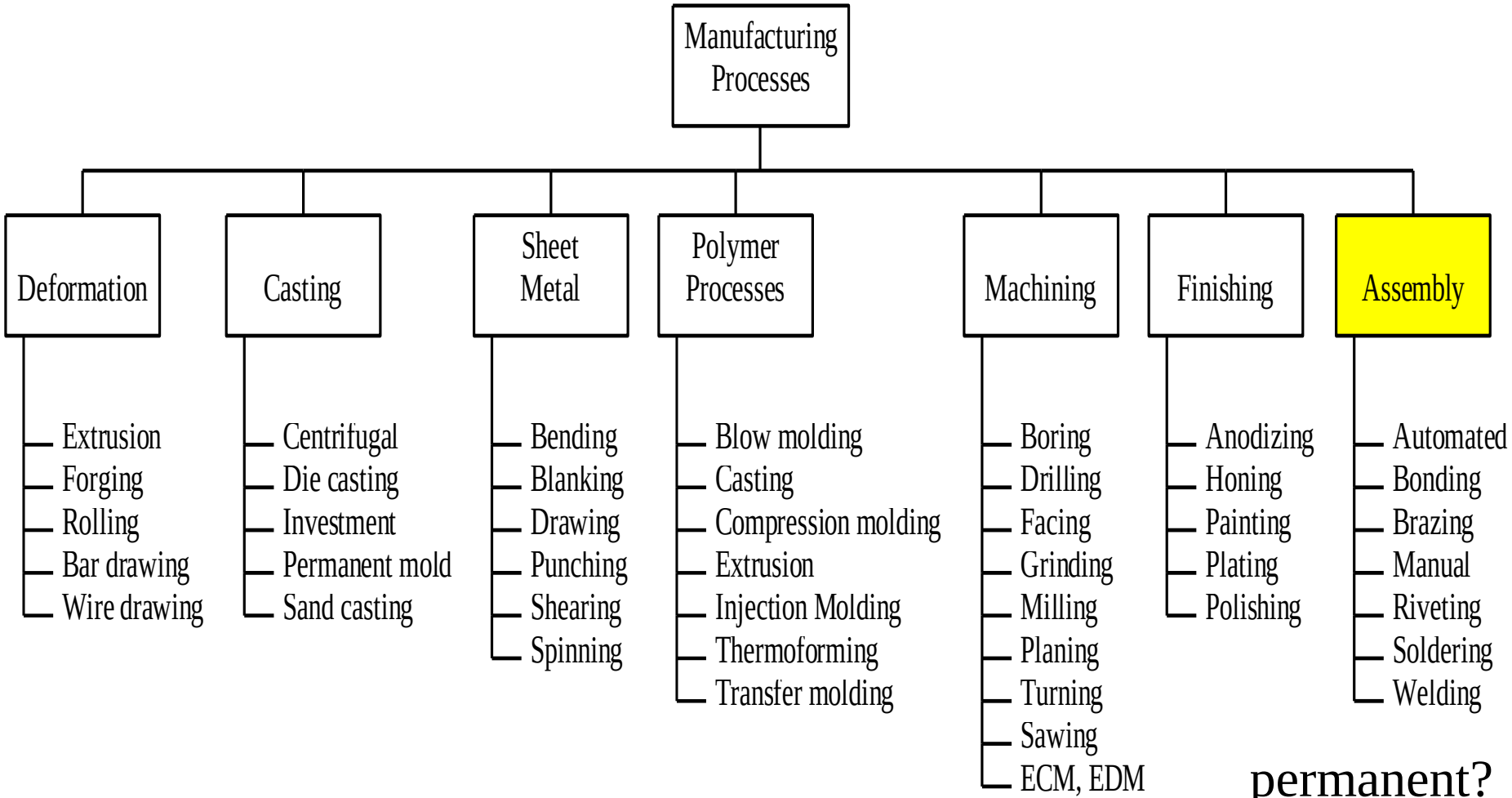
hardness, strength of material
shear forces = strong jigs & fixtures
tool/bit wear, replacement
size of workpiece, fit machine?
volume removed
rate of removal, hp needed
tolerances
operator skill, CNC
costs (materials, tooling, processing)

Add to your notes

Finishing processes



Assembly processes – fastening / joining of 2 or more components



permanent?

Rotomolding-rotational molding

Steps in Rotational Molding Process:

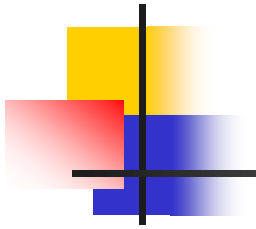
1.A pre-measured amount of plastic resin is placed into a mold.

2.The mold is then moved into an oven where it is rotated on both axis. As the resin melts, it coats the inside surface of the mold cavity, allowing for excellent uniform wall thickness.

3.Once the resin is completely fused, the mold is removed from the oven and cooled by air or water.

4.Then the part is removed from the mold

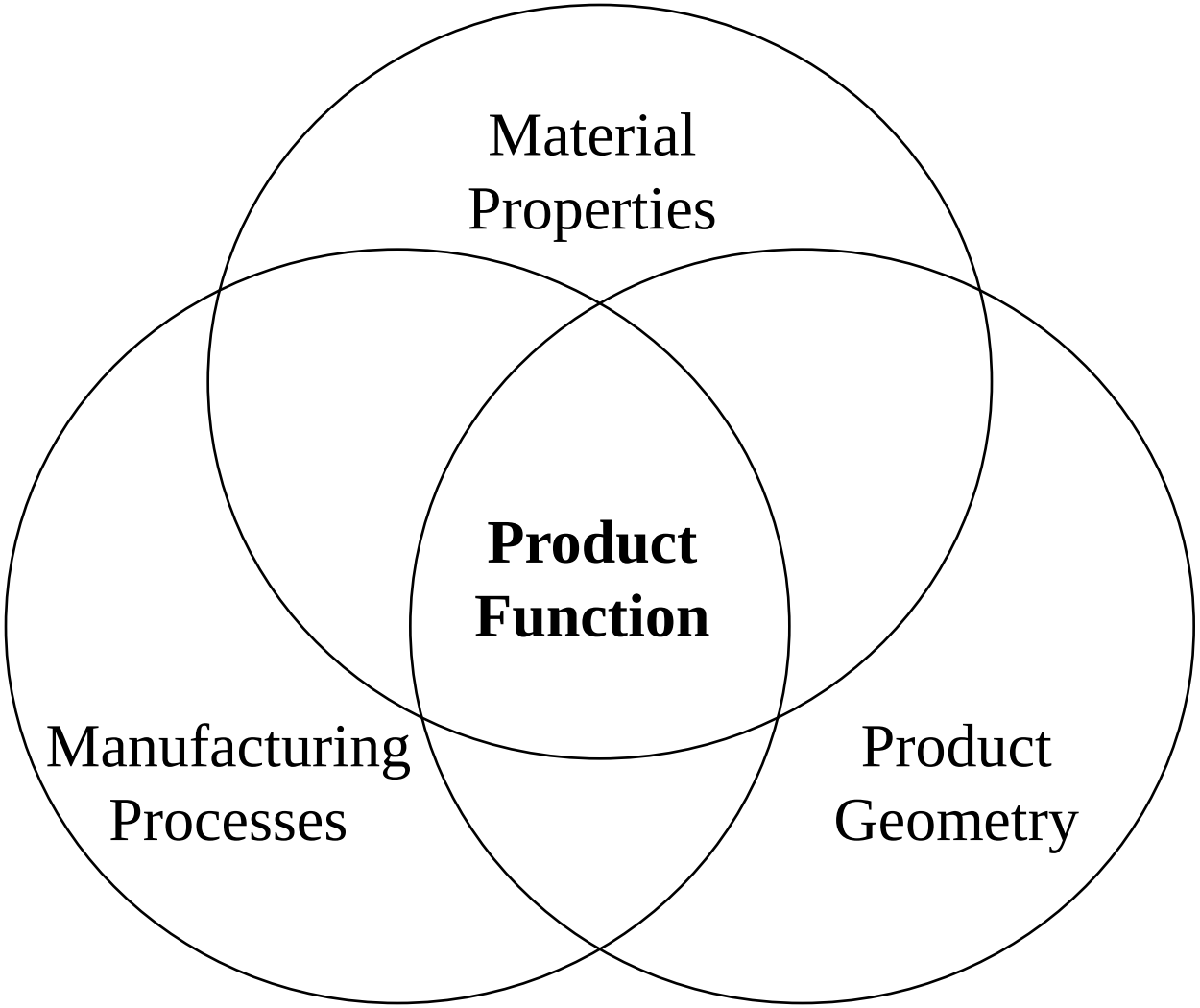
gas tank



Manufacturing Processes – Part C

- Material compatibilities
- Process (shape) capabilities
- Manufacturing costs

Product Function is Interdependent



Process / Material Screening

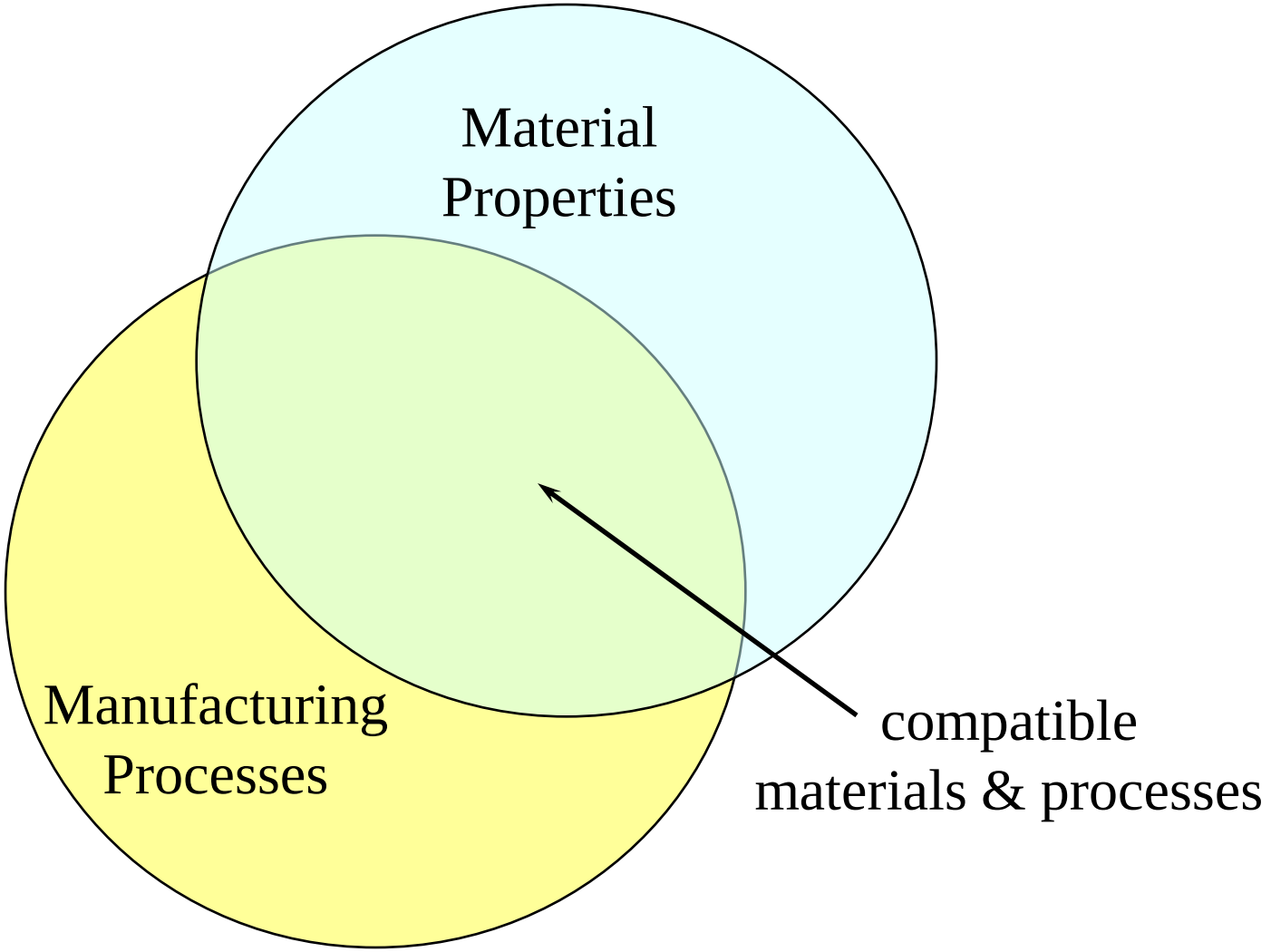
Process-First Approach

Part Information
1. Production Volume
2. Part Size (overall)
3. Shape Capability (features)
   - boss/depression 1D
   - boss/depression >1D
   - holes
   - undercuts (int./ext.)
   - uniform walls
   - cross sections –
     (uniform /regular)
   - rotational symmetry
   - captured cavities

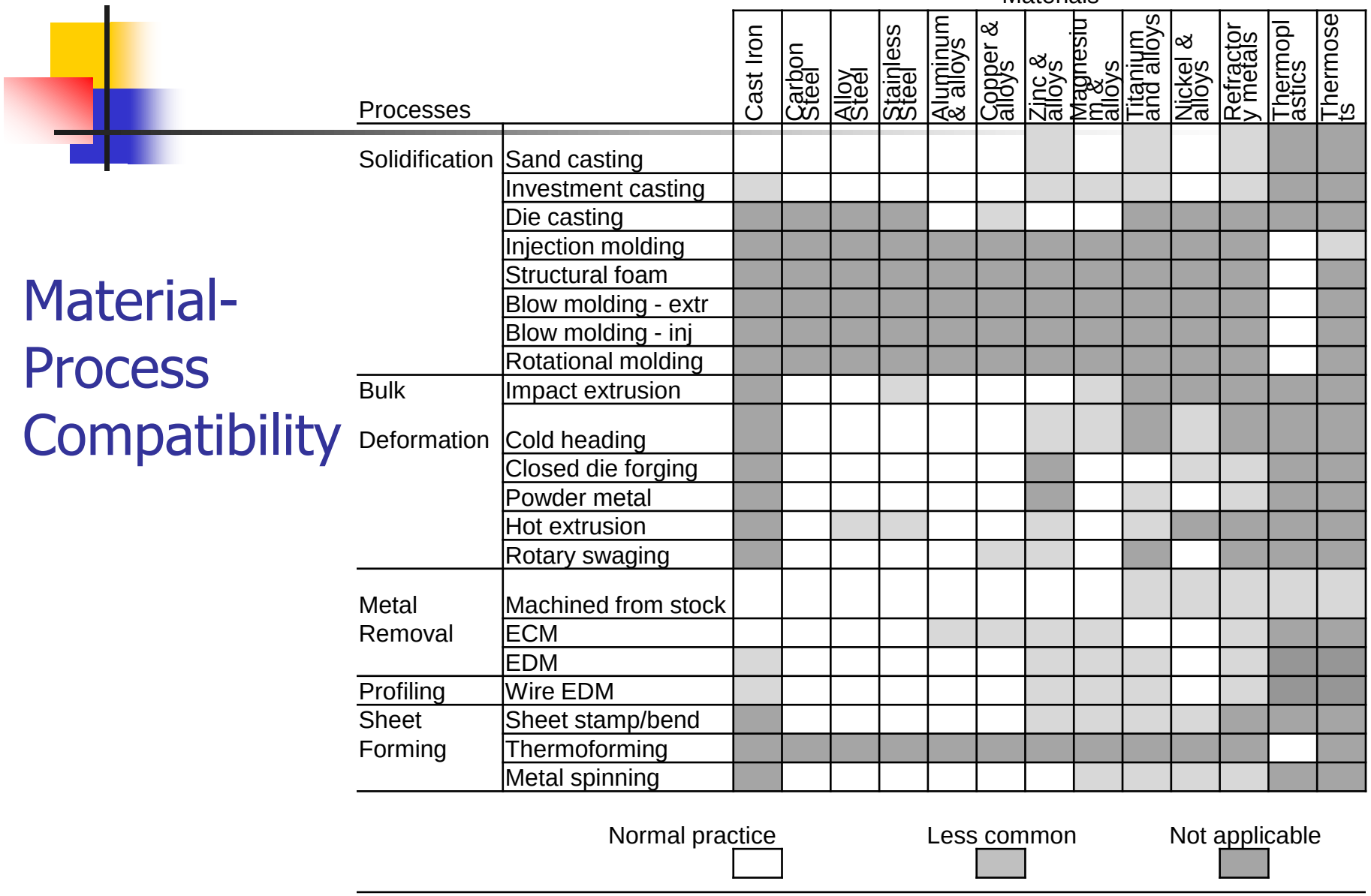
Material First Approach

Application Information
1. Applied Loads
   - magnitude
   - cyclic nature (fatigue)
   - rate (slow, impact)
   - duration (creep)
2. Ambient Conditions
   - temperature
   - moisture
   - sunlight (ultra-violet)
   - chemical liquids/vapors
3. Safety/Legal (FDA, UL)
4. Cost

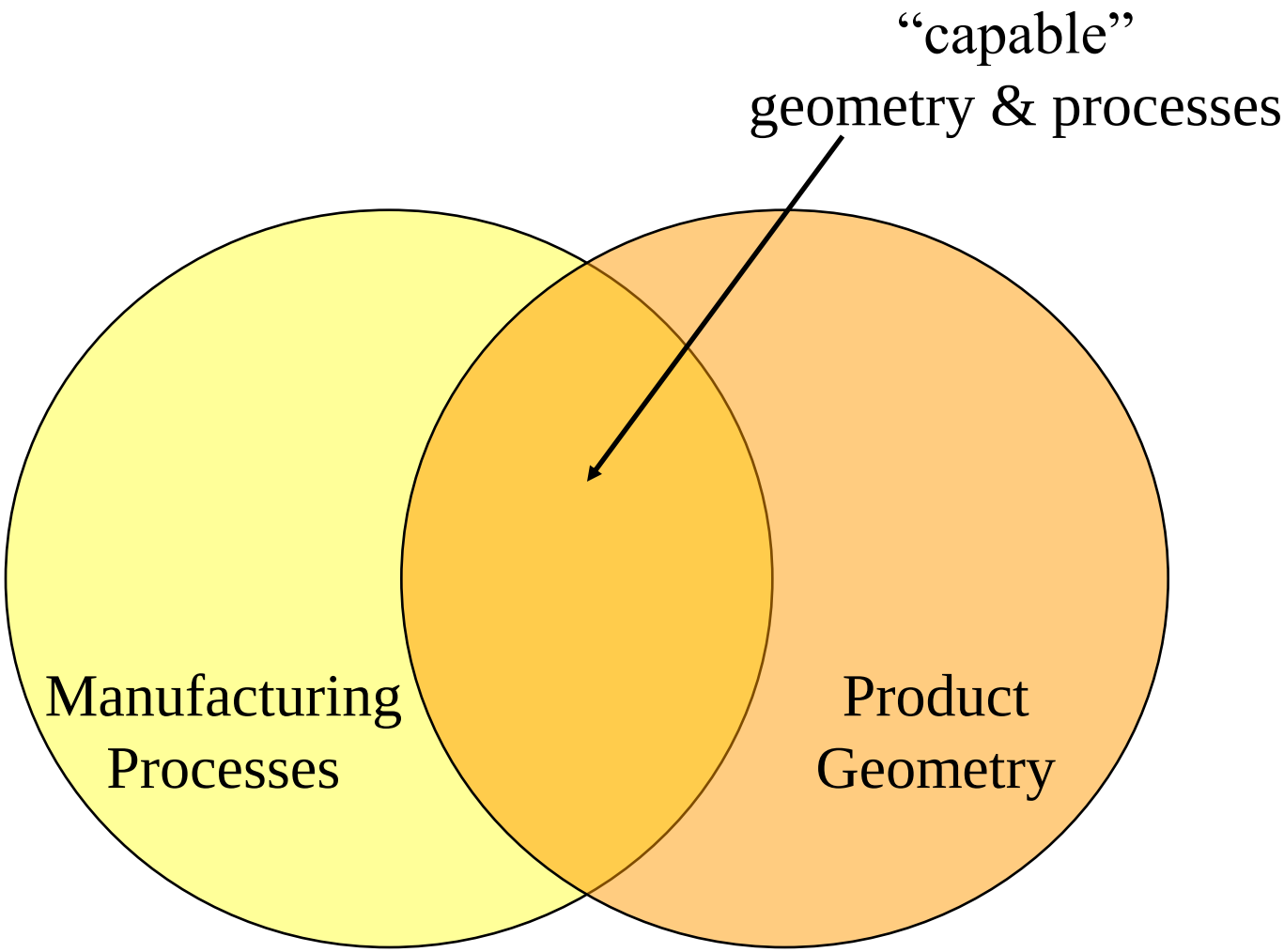
Are materials compatible with mfg. process?



Material-Process Compatibility



Is process capable of producing part geometry?



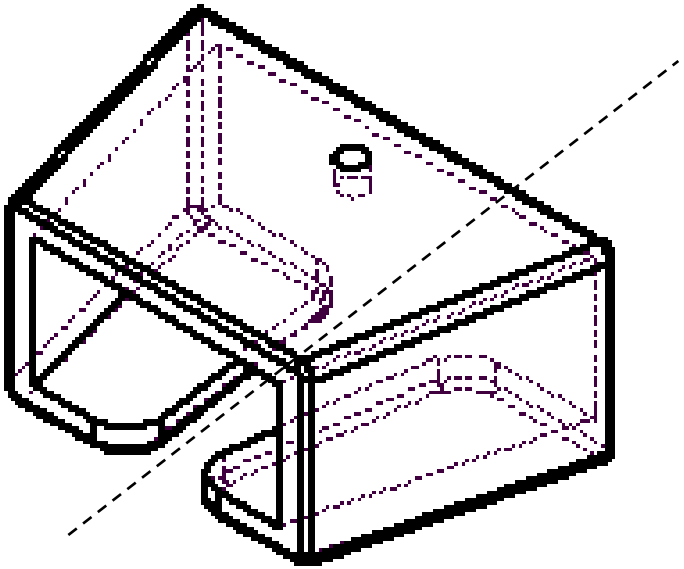
Process-first selection approach

Part Information

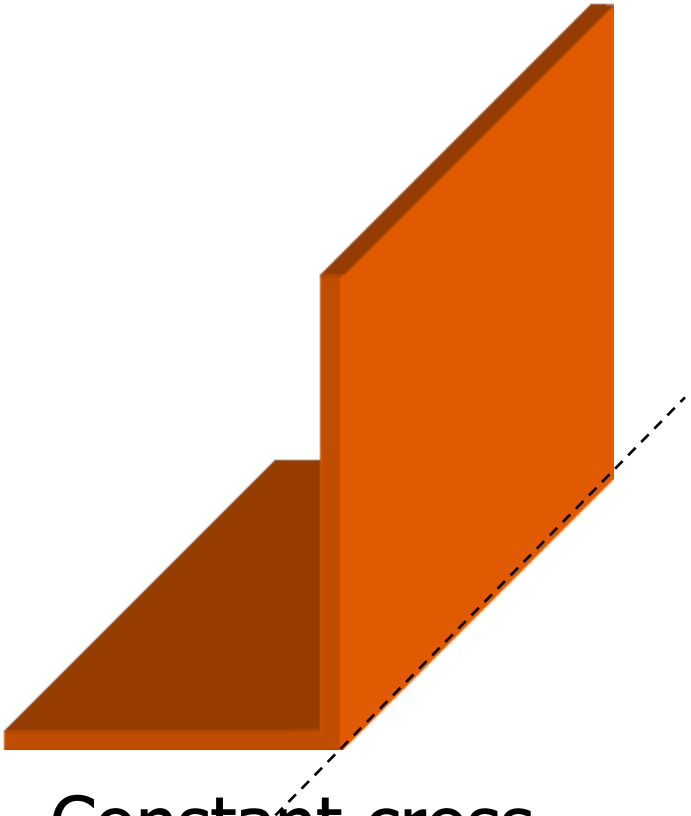
1. Production Volume (run qty)
2. Part Size (overall)
3. Shape Capability (features)

boss/depression 1D	uniform cross sections
boss/depression >1D	regular cross sections
holes	rotational symmetry
undercuts (int./ext.)	captured cavities
uniform walls	

Uniform wall (thickness) but…

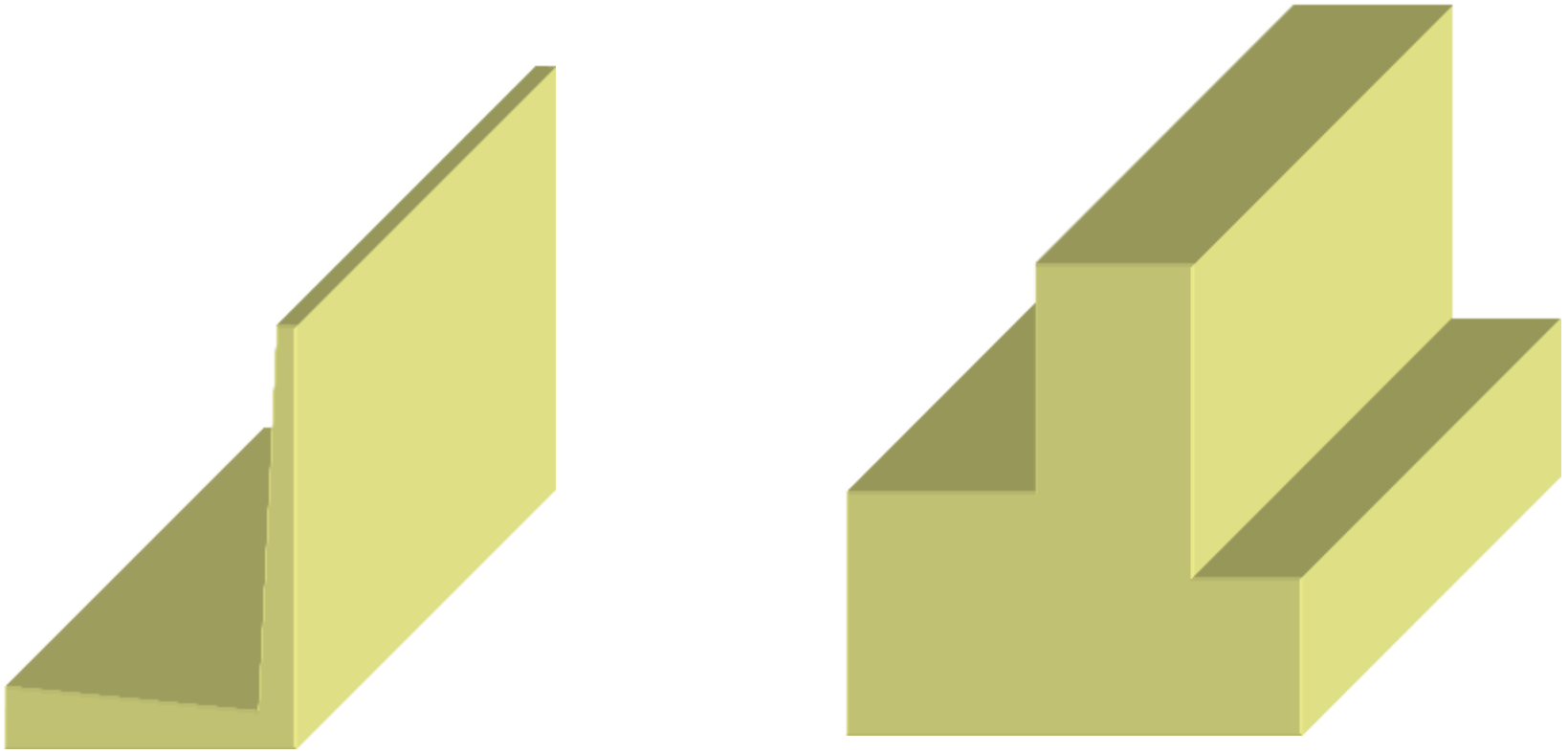


Varying cross section



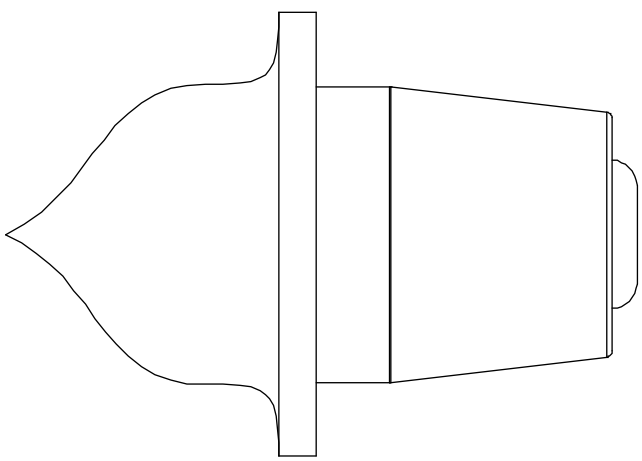
Constant cross section

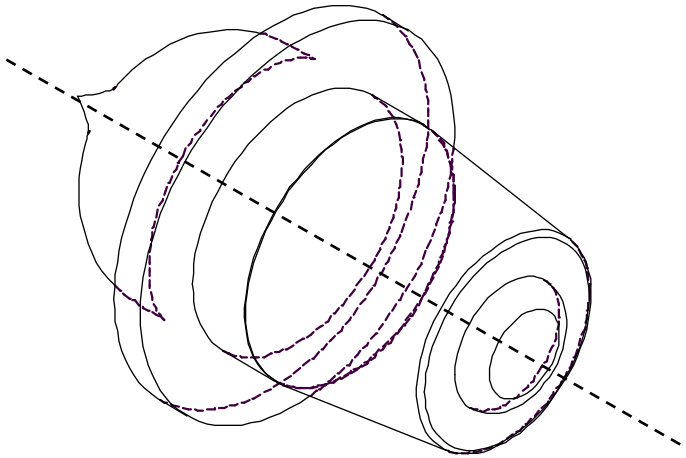
Uniform cross section (constant cross section)

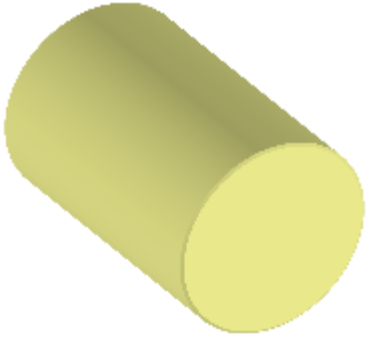


Non-uniform wall thicknesses

Axis of rotation (symmetry)

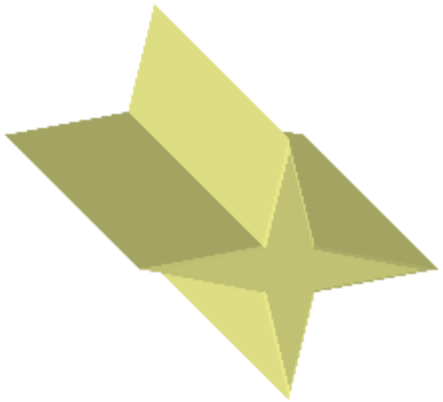






Regular cross section (regular pattern)

Regular
(i.e.pattern)



Regular
(i.e.pattern)

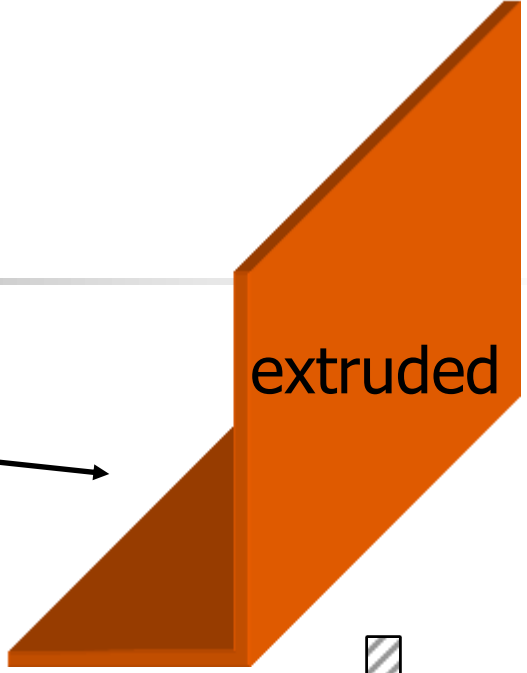
not-regular

Captured cavities

Enclosed (hollow)

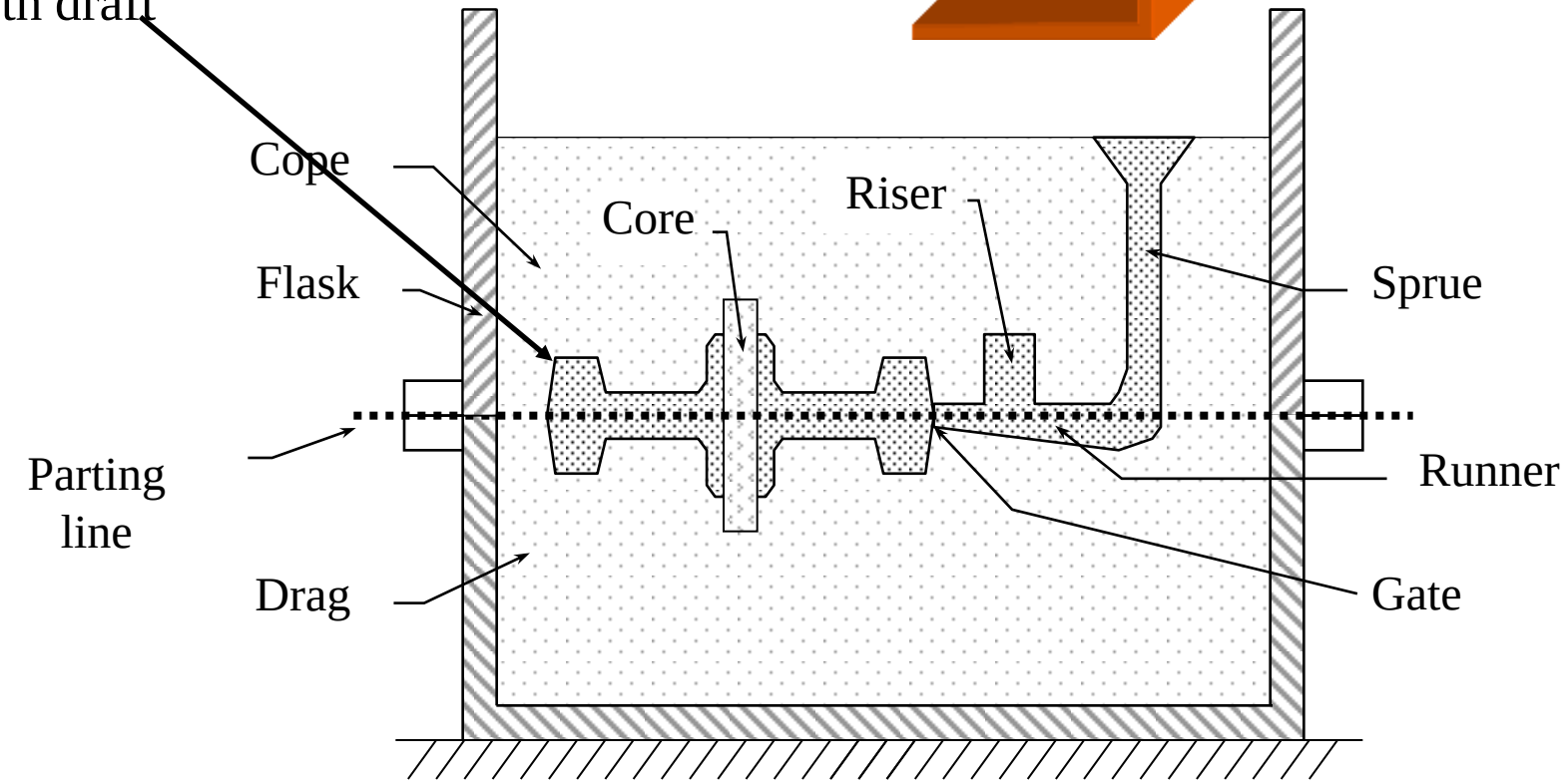
And, rotationally molded parts

Draft free surfaces



No draft

With draft



Manufacturing costs of a part

Total Manufacturing Cost = Material + Tooling + Processing

	raw mat'ls	molds	labor
		fixtures	electricity
		jigs	supplies
		tool bits	O/H
			(deprec.)

TMC = M + T + P (6.1)

Material costs per part

Let M = total materials costs (raw, bulk)
q = production quantity

Then material costs per part, c_M is
$c_M = M/q$ = (cost/weight x weight) / number of parts

Let's reorganize the variables in the equation above
c_M = [cost/weight] [weight/number of parts]
= (cost/weight) (weight/part), and therefore
c_M = cost/part

Material cost per part (continued)

Let

c_w = material cost per unit weight, and

w_p = weight of finished part

w_w = weight of wasted material, scrap

α = ratio of wasted material weight / finished weight

= w_w / w_p

Then the material cost per part, c_M is

$$c_M = c_w (w_p + w_w) = c_w (w_p + \alpha w_p) \quad (6.2)$$

$$c_M = c_w w_p (1 + \alpha) \quad (6.3)$$

e.g. sand casting

c_M = ($1/lb)(1lb/part)(1+.05) = $1.05/part

Tooling cost per part

Let

T= total cost of molds, fixtures per production run

q = number of parts per run

Then

$$c_T = T/q \qquad (6.4)$$

e.g. sand casting

c_T = ($10,000/run) / (5000 parts/run) = $2.00/part

Processing cost per part

Let

c_t = cost per hour, (machine rate + labor)

t = cycle time (hours per part)

then $c_P = c_t\, t$ (6.5)

e.g. sand casting

c_P = ($30/hr) (0.3 hrs/part) = $9/part

Total cost per part

Cost per part,

$$c = c_M + c_T + c_P$$

$$c = c_w w_p (1+ \alpha) + T/q + c_t t \qquad (6.6)$$

e.g. sand casting

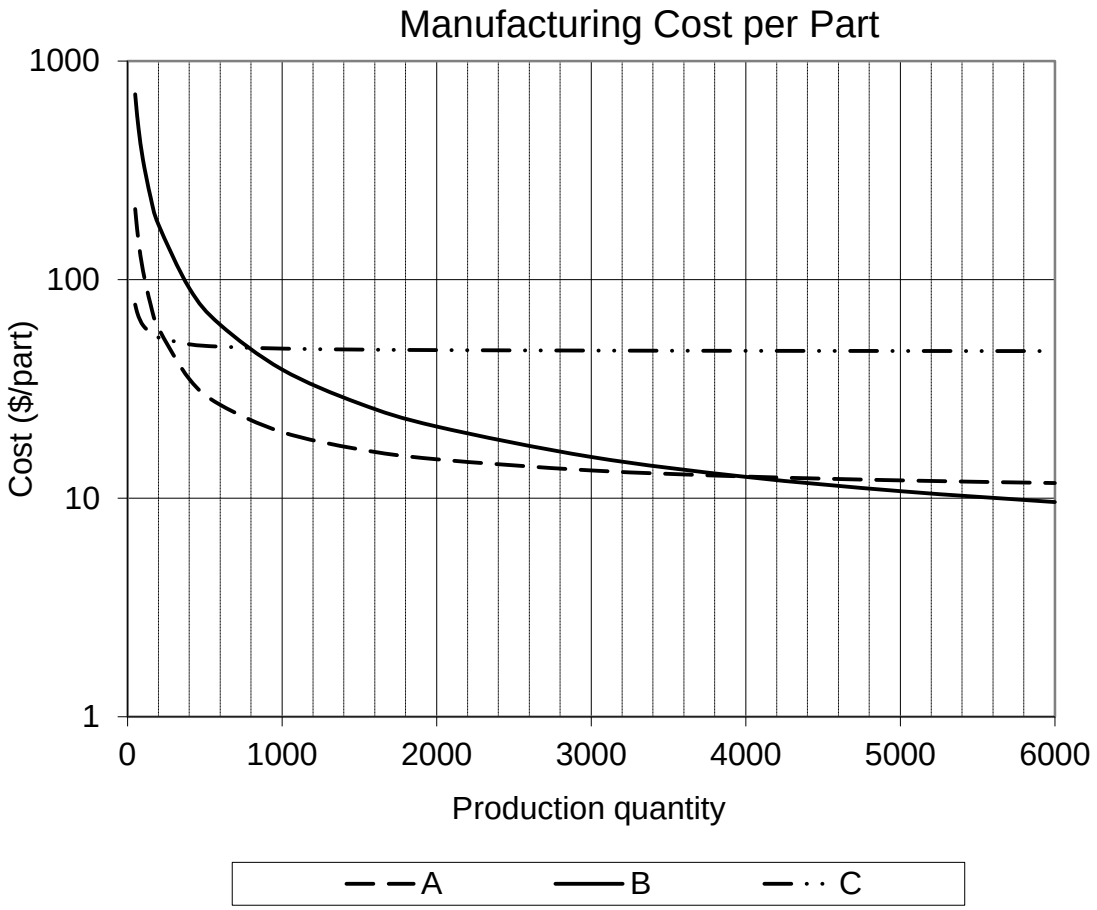
$$c = \$1.05 + \$2.00 + \$9.00$$

$$c = \$12.05 \text{ / part}$$

Example costs for 5000 part run

	Alternative		
	A	**B**	**C**
Mfg. Process	Sand casting	Injection molding	Machining
Material	Aluminum alloy	ABS	Bronze alloy
Part weight (lb)	1	3	2
alpha	0.05	0.01	0.2
Material cost ($/lb), c_w	1	0.25	0.75
Tooling cost ($), T	10000	35000	1500
Production quantity, q	5000	5000	5000
Cycle time (hrs/part), t	0.3	0.03	0.6
Machine rate ($/hr)	30	100	75
Part cost ($/part)	12.05	10.76	47.1

Run quantity is important!



A-Sand casting B-Inj.Molding C-Machining

How can we lower the cost of parts?

$$c = \underset{\downarrow\downarrow \quad \downarrow}{c_w w_p (1+\alpha)} + \underset{\downarrow\uparrow}{T/q} + \underset{\downarrow\downarrow}{c_t t} \qquad (6.6)$$

1) purchase less expensive materials,
2) keep our finished part weight low
3) produce little manufactured waste
4) design simple parts that result in less expensive tooling
5) make many parts production run (i.e. batch)
6) choose a manufacturing process that has a low cycle time & cost per hour

Goal: minimize the sum of the terms!
(not any one term in particular)

Summary

- Parts are made w/ primary, secondary, and tertiary manufacturing processes.
- Fundamental processes include: bulk deformation, casting, sheet metal working, polymer processes, machining, finishing, and assembly.
- Manufacturing costs include material, tooling, and processing costs.
- Some processes are more compatible with certain materials.
- Some processes are more capable at generating certain geometric features.
- Process selection considerations include: part size, geometric complexity, and production quantities.