Chapter 15-2:
Processing of Polymers

ISSUES TO ADDRESS...

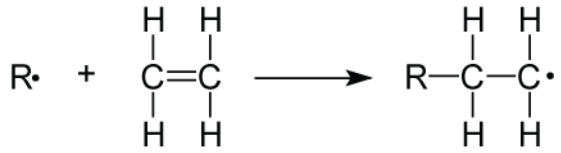
- Other issues in polymers
- What are the primary polymer processing methods?

Polymer Synthesis Reactions

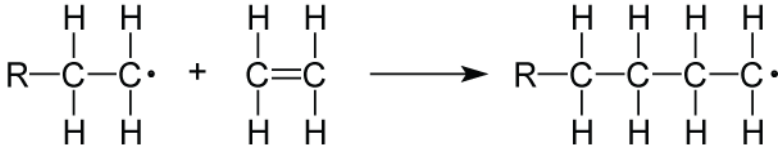
- There are two types of polymerization reactions
  - Addition (or chain) polymerization
  - Condensation (step) polymerization

Addition (Chain) Polymerization

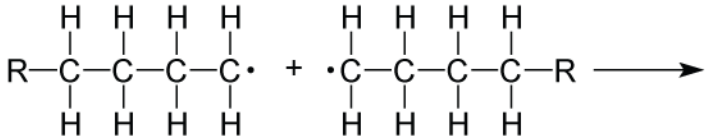
– **Initiation**

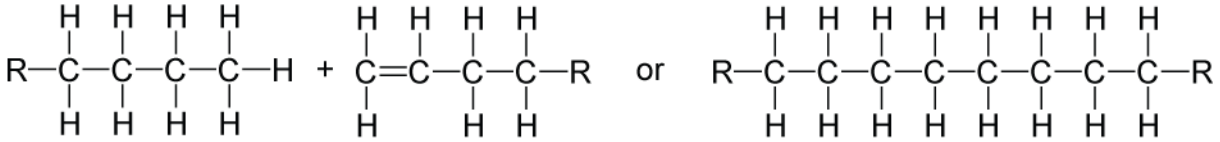


– **Propagation**



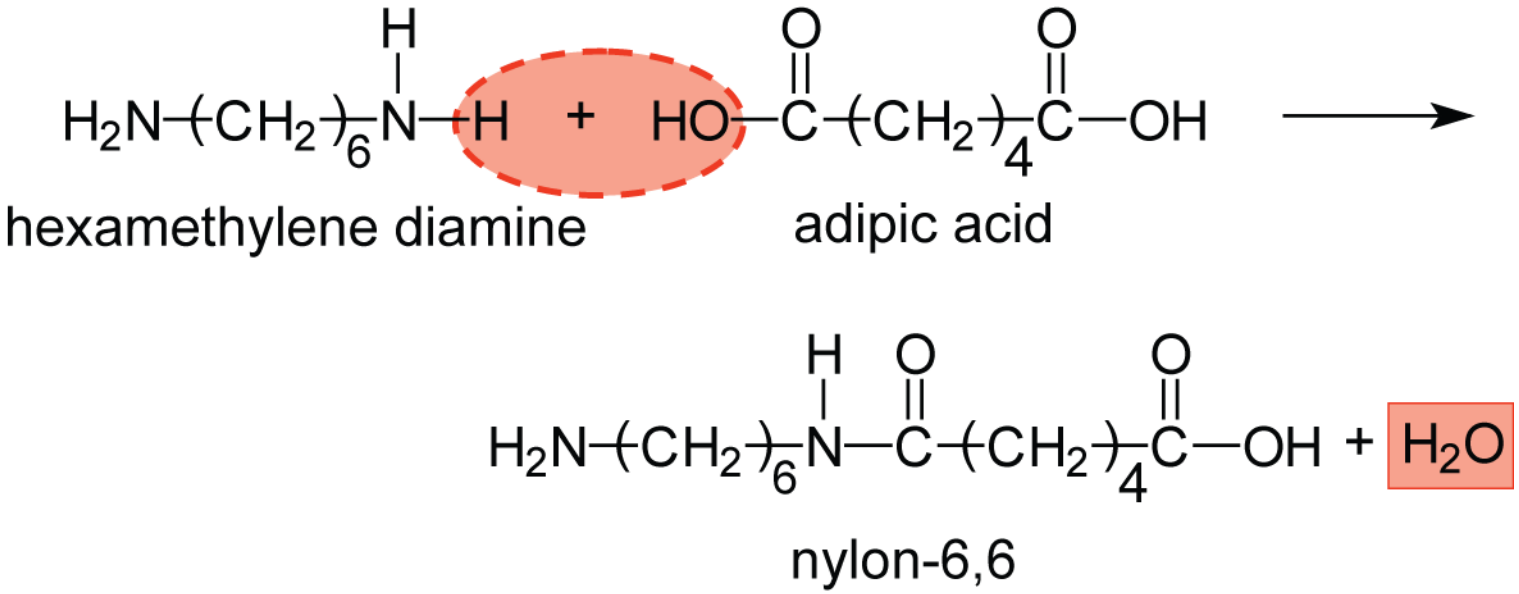
– **Termination**





Disproportionation Combination

Condensation (Step) Polymerization



Polymer Additives

Improve mechanical properties, processability, durability, etc.

- Fillers
  - Added to improve tensile strength & abrasion resistance, toughness & decrease cost
  - ex: carbon black, silica gel, glass, limestone, talc, etc.

- Plasticizers
  - Added to reduce the glass transition temperature T_g
  - Presence of plasticizer transforms brittle polymer to a plastic (ductile) one
  - Example: add plasticizer to PVC (Tg=87 ^{o}C) to make flexible tubings

Polymer Additives (cont.)

- Stabilizers

  Examples: Antioxidants or UV protectants

- Colorants
  - Dyes (small molecule that dissolves) and pigments (solid inorganic particles with colors)

- Flame Retardants
  - Substances containing chlorine, fluorine, and boron

Processing of Plastics

- Thermoplastic
  - can be reversibly cooled & reheated, i.e. recycled
  - heat until soft, shape as desired, then cool
  - ex: polyethylene, polypropylene, polystyrene.
- Thermoset
  - when heated they would form 3D molecular networks (chemical reaction)
  - degrades (doesn't melt) when heated to high temp
  - a **pre**polymer molded into desired shape, then the chemical reaction occurs (up heating or addition of cross-linking agents) to form network
  - ex: epoxy, phenolic resin

Processing Plastics – Compression Molding

Thermoplastics and thermosets

- polymer and additives placed in mold cavity
- mold heated and pressure applied
- fluid polymer assumes shape of mold

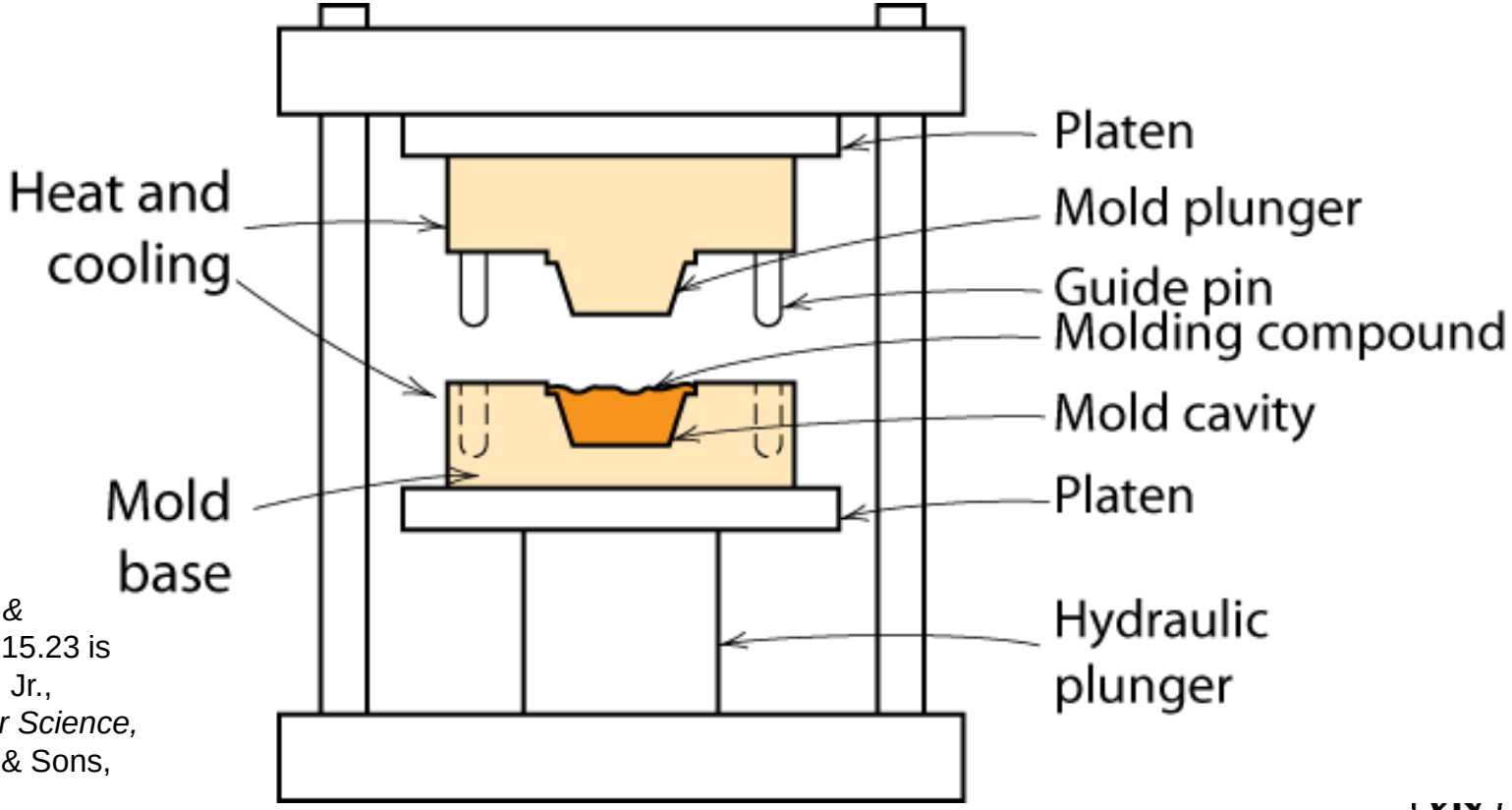


Fig. 15.23, *Callister & Rethwisch 8e*. (Fig. 15.23 is from F.W. Billmeyer, Jr., *Textbook of Polymer Science,* 3rd ed., John Wiley & Sons, 1984.)

Processing Plastics – Injection Molding

Thermoplastics and some thermosets

- when ram retracts, plastic pellets drop from hopper into barrel
- ram forces plastic into the heating chamber (around the spreader) where the plastic melts as it moves forward
- molten plastic is forced under pressure (injected) into the mold cavity where it assumes the shape of the mold

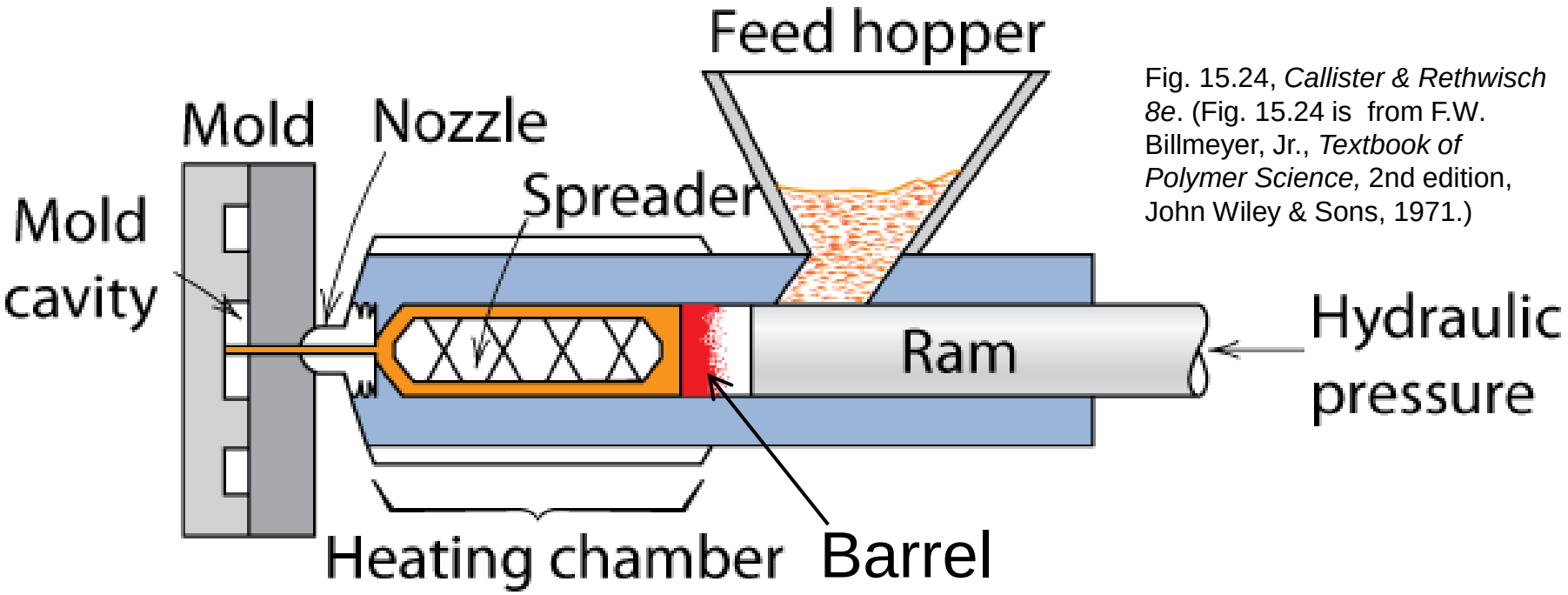


Fig. 15.24, *Callister & Rethwisch 8e*. (Fig. 15.24 is from F.W. Billmeyer, Jr., *Textbook of Polymer Science,* 2nd edition, John Wiley & Sons, 1971.)

Processing Plastics – Extrusion

thermoplastics

- plastic pellets drop from hopper onto the turning screw
- plastic pellets melt as the turning screw pushes them forward by the heaters
- molten polymer is forced under pressure through the shaping die to form the final product (extrudate)

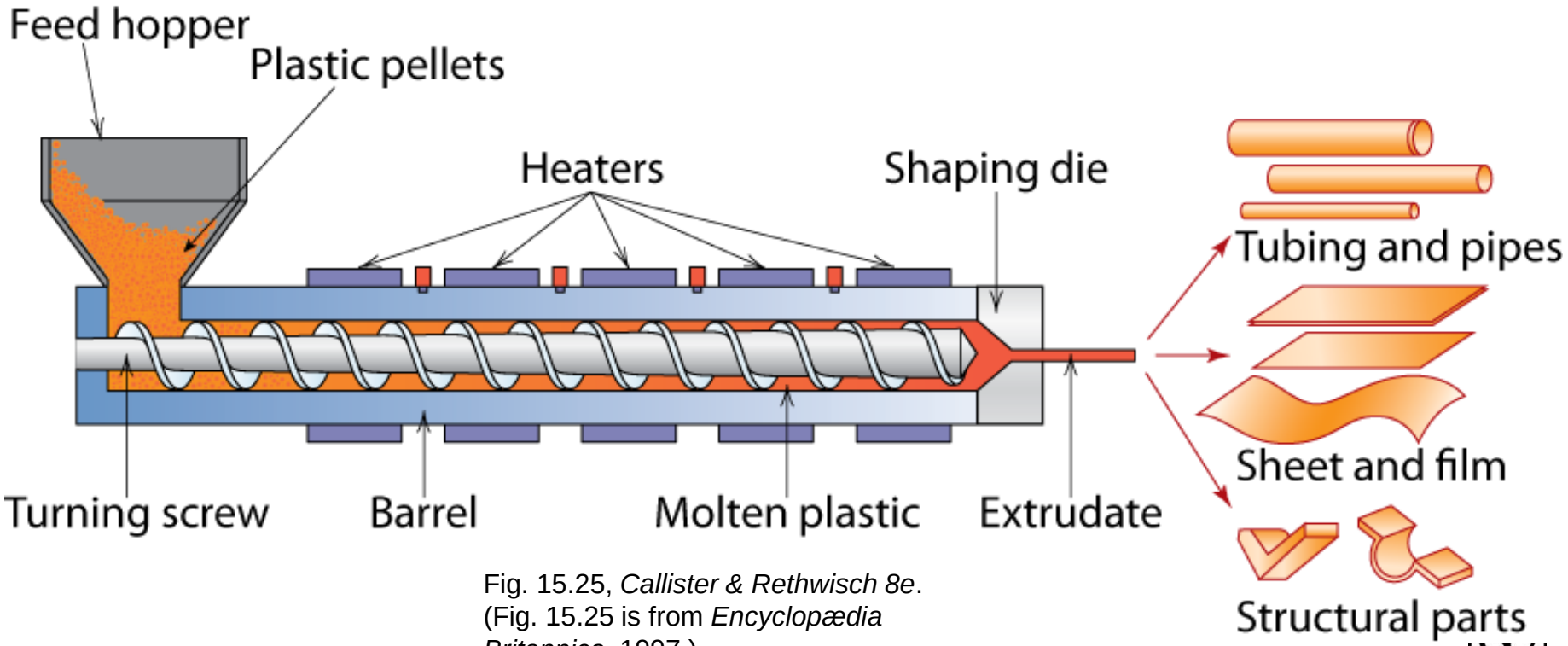


Fig. 15.25, *Callister & Rethwisch 8e*.
(Fig. 15.25 is from *Encyclopædia Britannica,* 1997.)

Processing Plastics – Blown-Film Extrusion

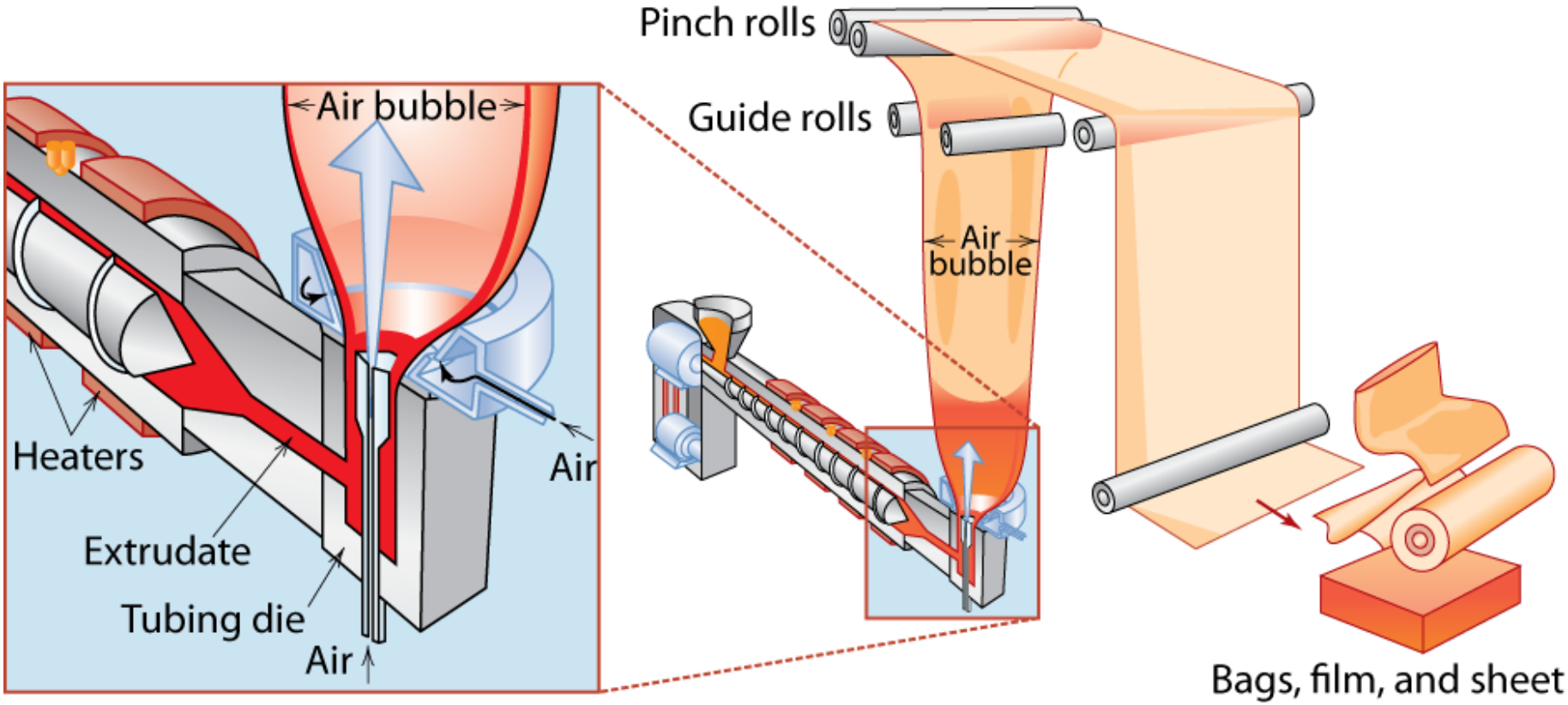


Fig. 15.26, *Callister & Rethwisch 8e*.
(Fig. 15.26 is from *Encyclopædia Britannica,* 1997.)

Polymer by Physical Forms (1)

Bulk

Fibers - length/diameter >100

- Primary use is in textiles.
- Fiber characteristics:
  - high tensile strengths
  - high degrees of crystallinity
  - structures containing polar groups
- Formed by spinning
  - extrude polymer through a spinneret (a die containing many small orifices)
  - the spun fibers are drawn under tension
  - leads to highly aligned chains - fibrillar structure

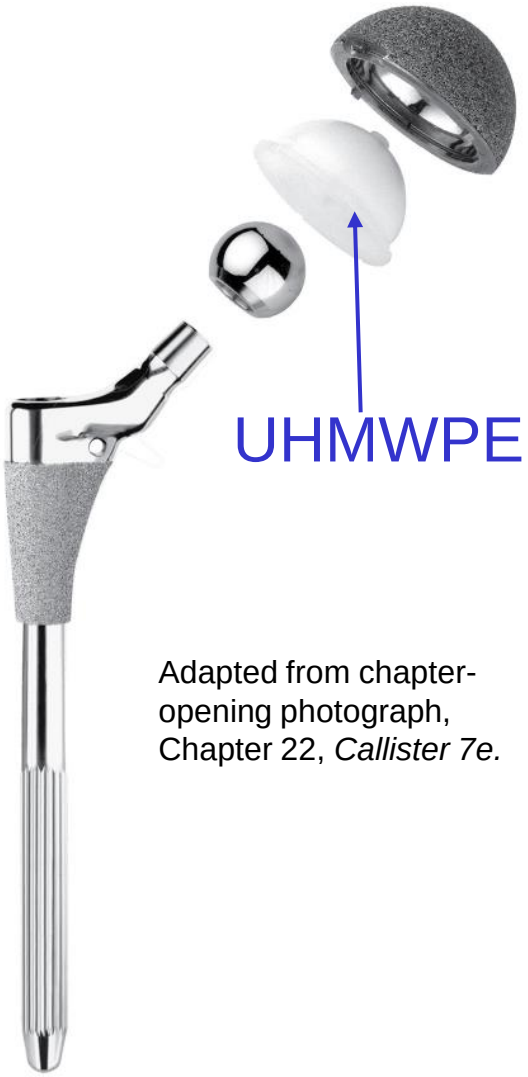
Polymer by Physical Forms (2)

- Films – produced by blown film extrusion
- Coatings – thin polymer films applied to surfaces – i.e., paints, varnishes
  - protects from corrosion/degradation
  - decorative – improves appearance
  - can provide electrical insulation
- Foams – gas bubbles incorporated into plastic
- Adhesives – bonds two solid materials (adherands)
  - bonding types:
    1. Secondary – van der Waals forces
    2. Mechanical – penetration into pores/crevices

Other Advanced Polymers

Ultrahigh Molecular Weight Polyethylene (UHMWPE)

- Molecular weight ca. 4×10^6 g/mol
- Outstanding properties
  - high impact strength
  - resistance to wear/abrasion
  - low coefficient of friction
  - self-lubricating surface
- Important applications
  - bullet-proof vests
  - golf ball covers
  - hip implants (acetabular cup)



Adapted from chapter-opening photograph, Chapter 22, *Callister 7e.*

Summary

- Polymer Processing
  -- compression and injection molding, extrusion, blown film extrusion
- Polymer melting and glass transition temperatures
- Polymer applications
  -- elastomers
  -- fibers
  -- coatings
  -- adhesives
  -- films
  -- foams
  -- advanced polymeric materials