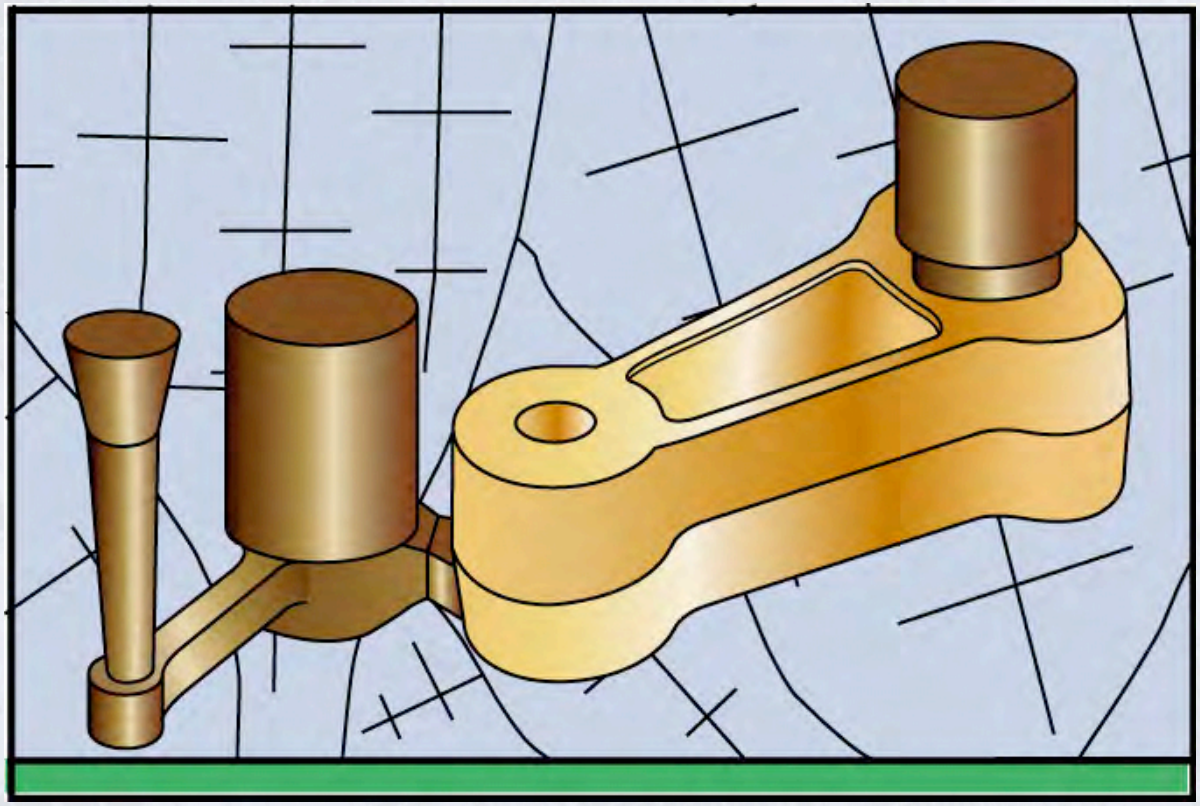
Chapter 10

Fundamentals of Metal Casting



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Solidification of Pure Metals

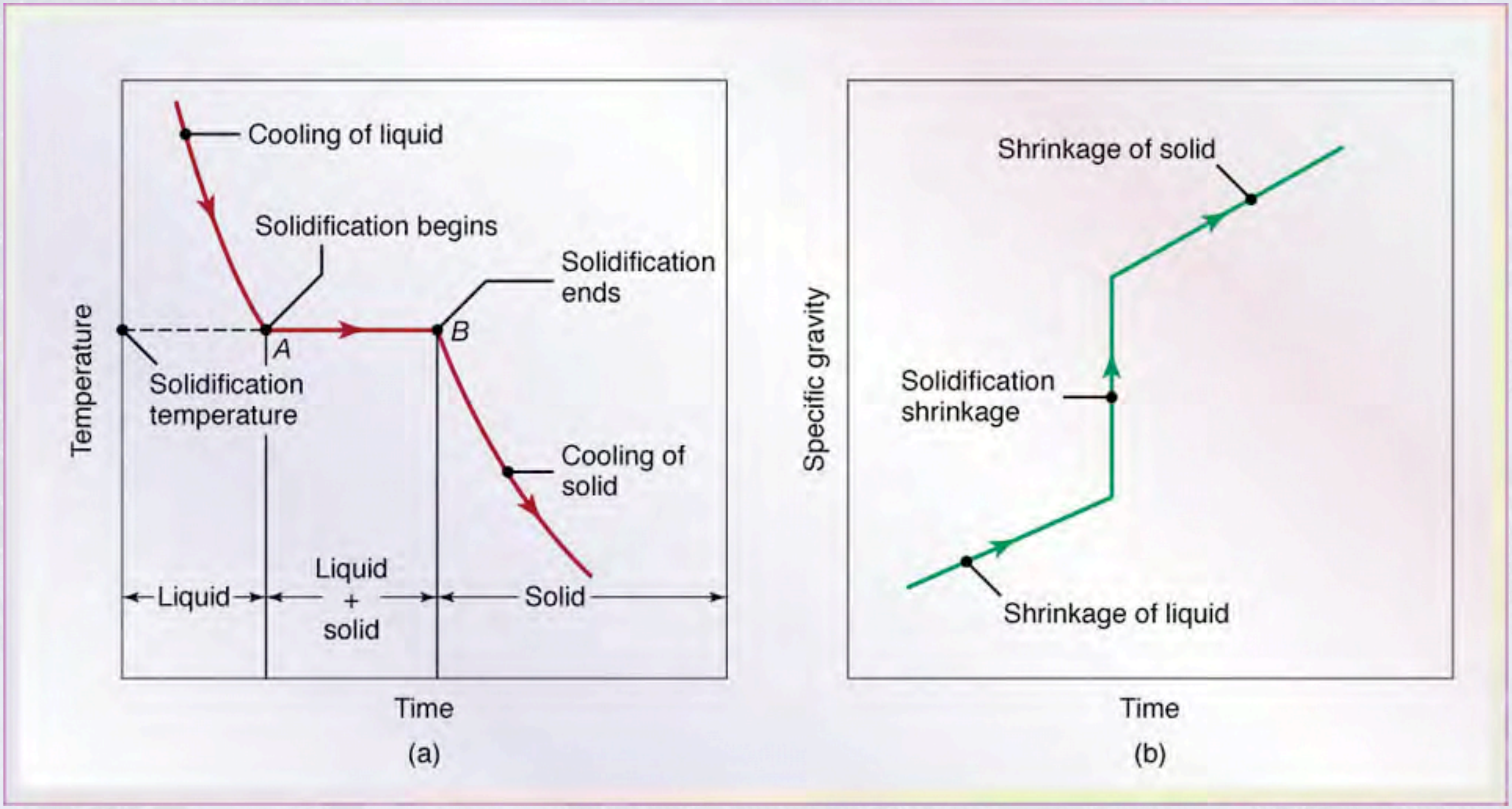

Figure 10.1 (a) Temperature as a function of time for the solidification of pure metals. Note that the freezing takes place at a constant temperature. (b) Density as a function of time

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Cast Structures of Solidified Metals

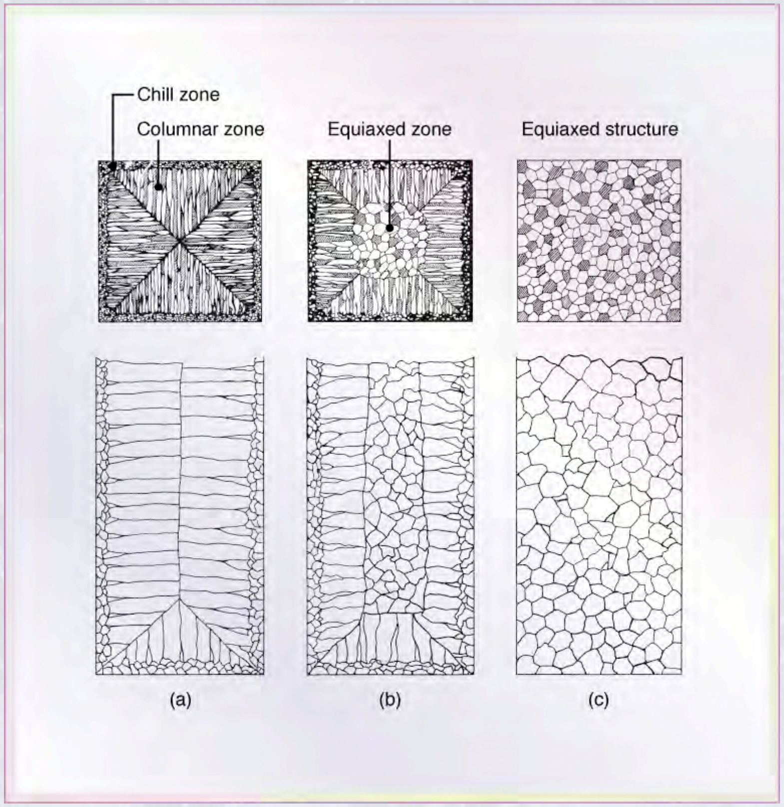

Figure 10.2 Schematic illustration of three cast structures of metals solidified in a square mold: (a) pure metals; (b) solid-solution alloys; and (c) structure obtained by using nucleating agents. *Source*: After G. W. Form, J. F. Wallace, J. L. Walker, and A. Cibula

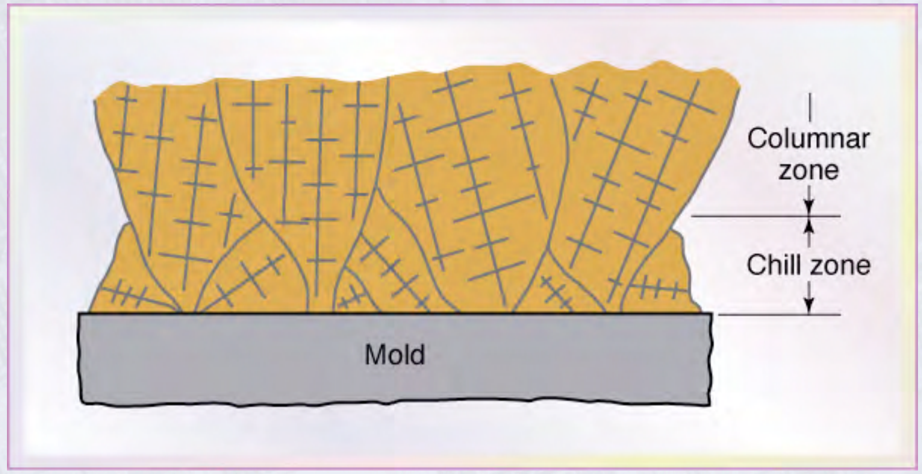

Figure 10.3 Development of a preferred texture at a cool mold wall. Note that only favorably oriented grains grow away from the surface of the mold

Alloy Solidification

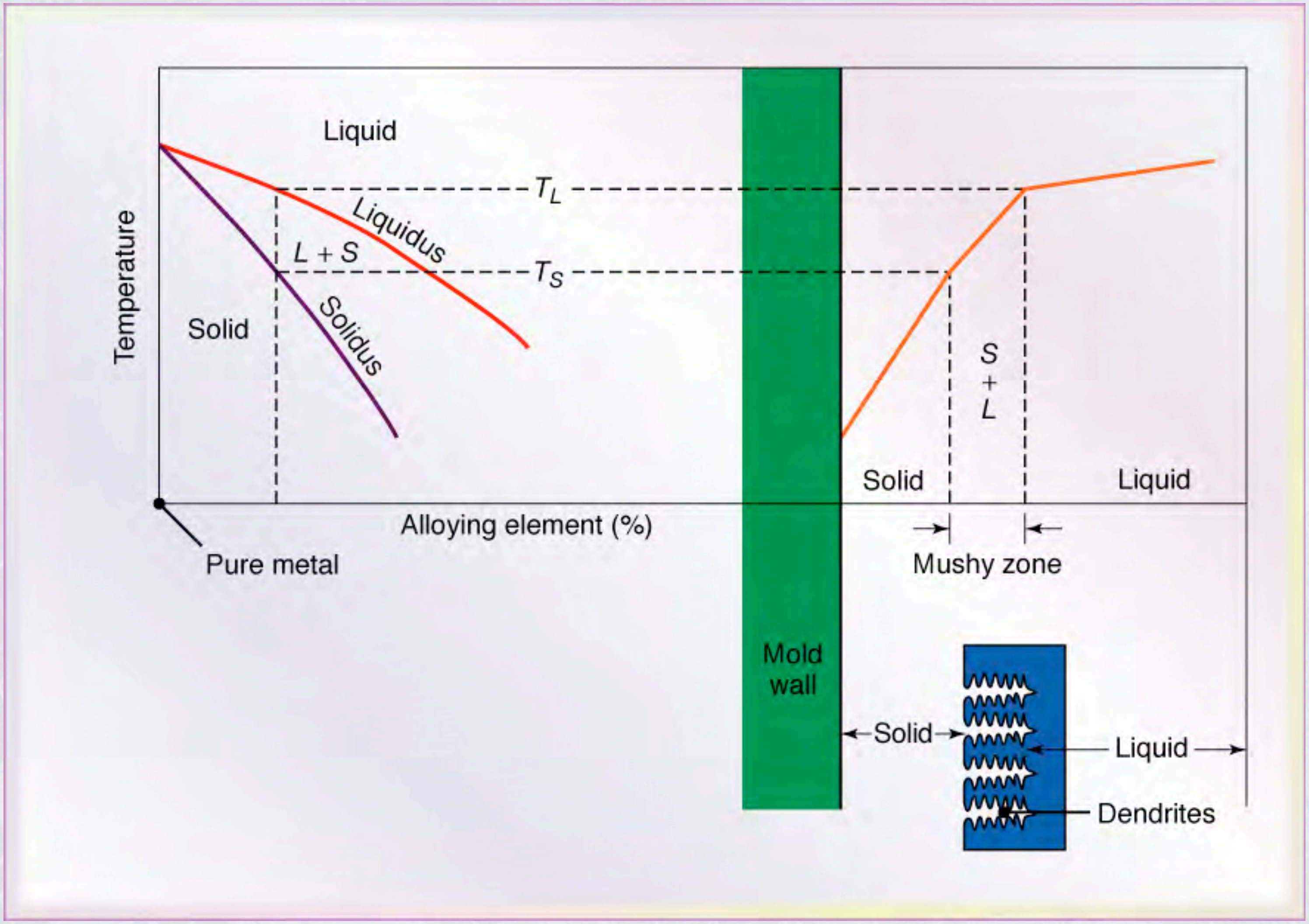

Figure 10.4 Schematic illustration of alloy solidification and temperature distribution in the solidifying metal. Note the formation of dendrites in the mushy zone.

Solidification of Iron and Carbon Steels

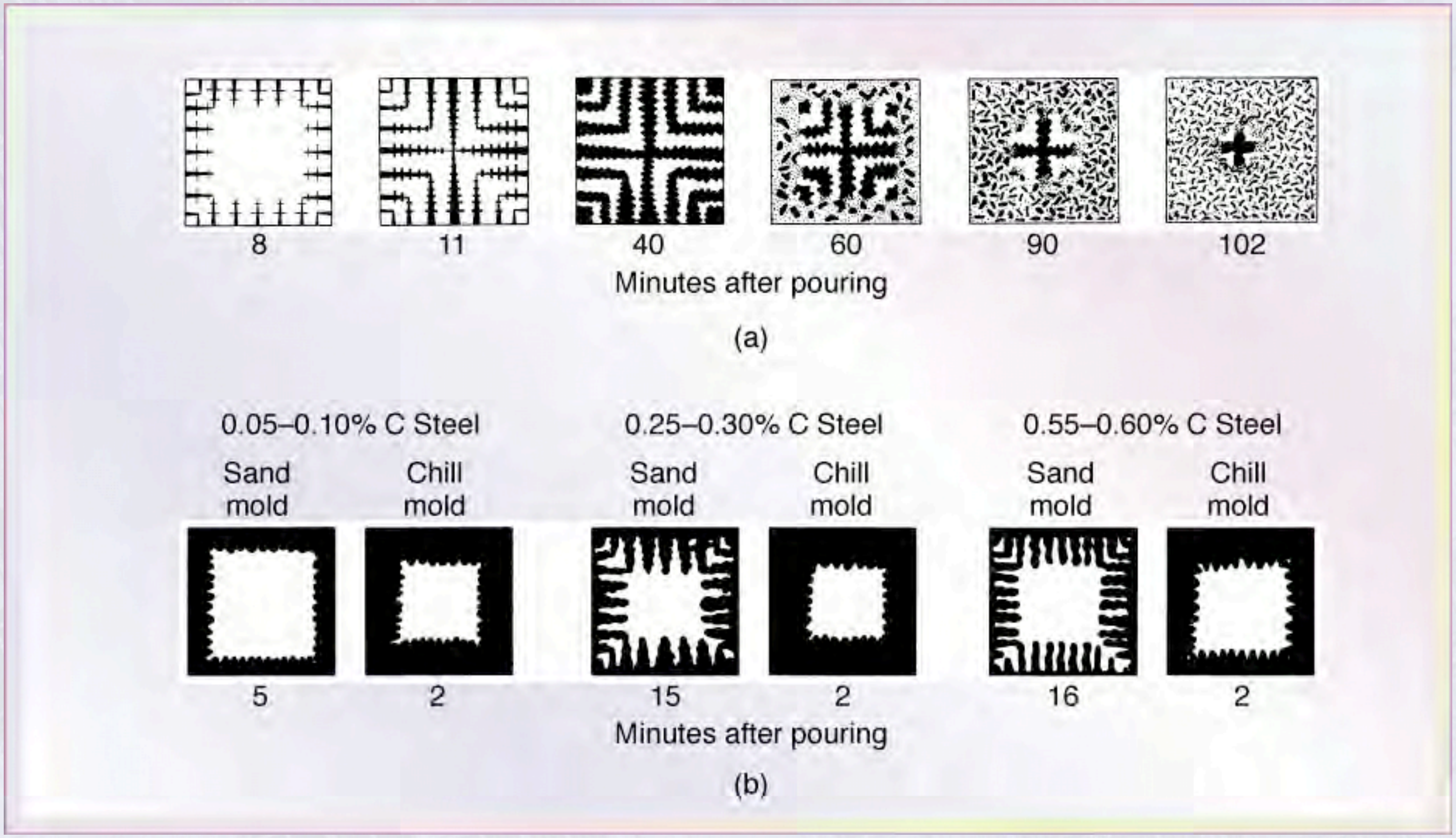

Figure 10.5 (a) Solidification patterns for gray cast iron in a 180-mm (7-in.) square casting. Note that after 11 minutes of cooling, dendrites reach each other, but the casting is still mushy throughout. It takes about two hours for this casting to solidify completely. (b) Solidification of carbon steels in sand and chill (metal) molds. Note the difference in solidification patterns as the carbon content increases. *Source:* After H. F. Bishop and W. S. Pellini

Basic Types of Cast Structures

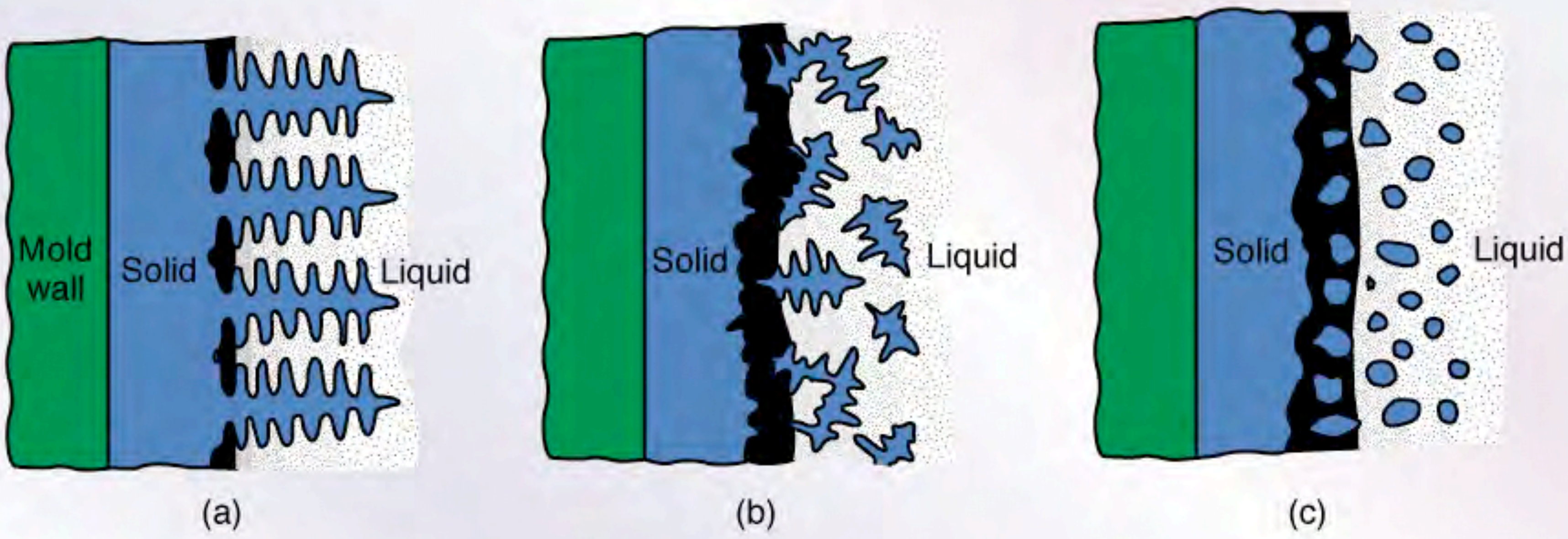

Figure 10.6 Schematic illustration of three basic types of cast structures: (a) columnar dendritic; (b) equizxed dendritic; and (c) equiaxed nondendritic. *Source:* Courtesy of D. Apelian

Cast Structures

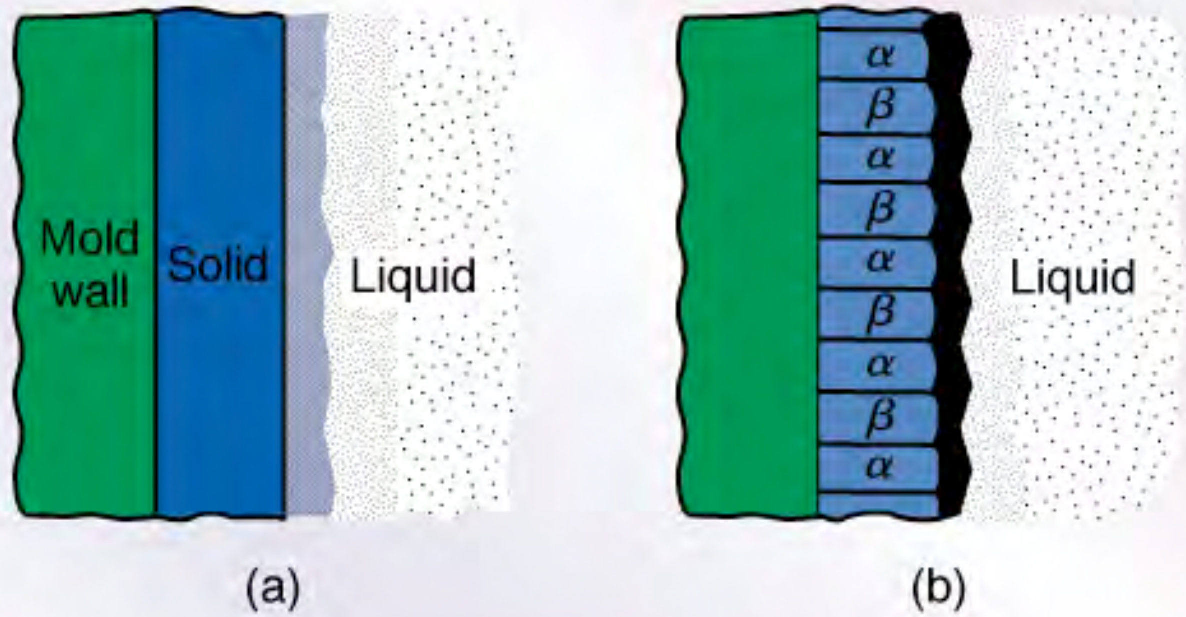

Figure 10.7 Schematic illustration of cast structures in (a) plane front, single phase, and (b) plane front, two phase. *Source*: Courtesy of D. Apelian

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Fluid Flow and Solidification Time

Bernoulli's theorem $$h + \frac{p}{\rho g} + \frac{v^2}{2g} = \text{constant}$$

Mass continuity $$Q = A_1 v_1 = A_2 v_2$$

Sprue design $$\frac{A_1}{A_2} = \sqrt{\frac{h_2}{h_1}}$$

Reynolds number $$\text{Re} = \frac{vD\rho}{\eta}$$

Chvorinov's Rule $$\text{Solidification time} = C\left(\frac{\text{Volume}}{\text{Surface Area}}\right)^n$$

Casting Design and Fluidity Test

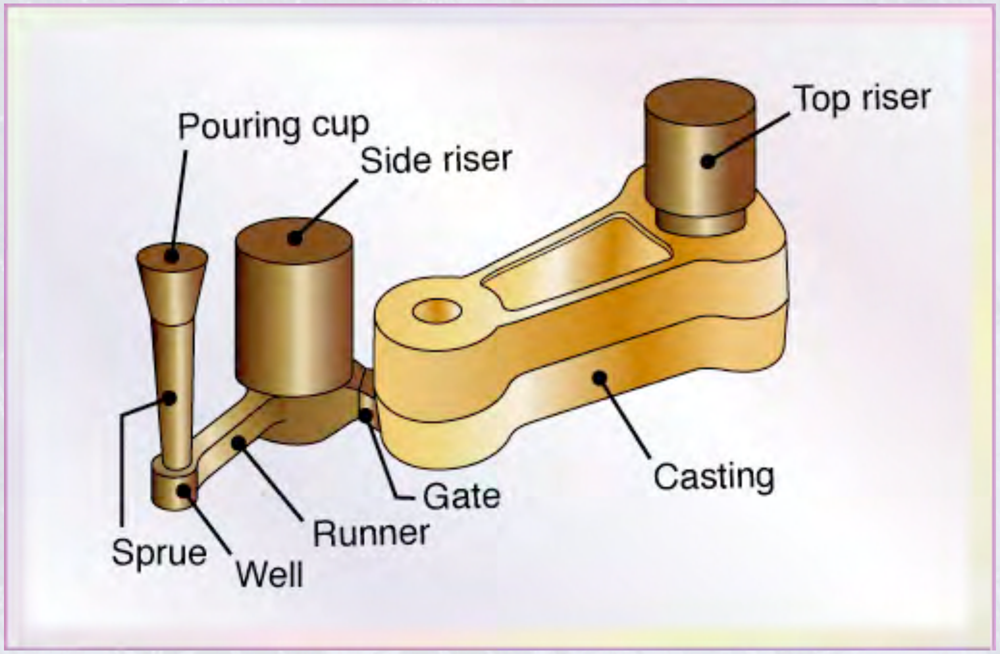

Figure 10.8 Schematic illustration of a typical riser-gated casting. Risers serve as reservoirs, supplying molten metal to the casting as it shrinks during solidification.

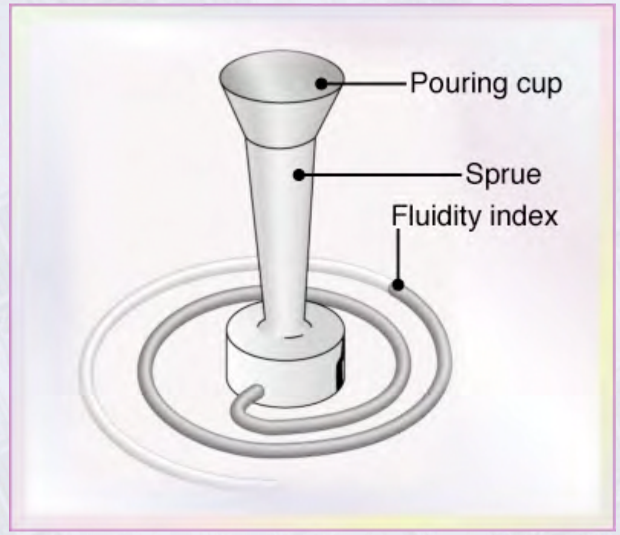

Figure 10.9 A test method for fluidity using a spiral mold. The *fluidity index* is the length of the solidified metal in the spiral passage. The greater the length of the solidified metal, the greater is its fluidity.

Temperature Distribution during Metal Solidification

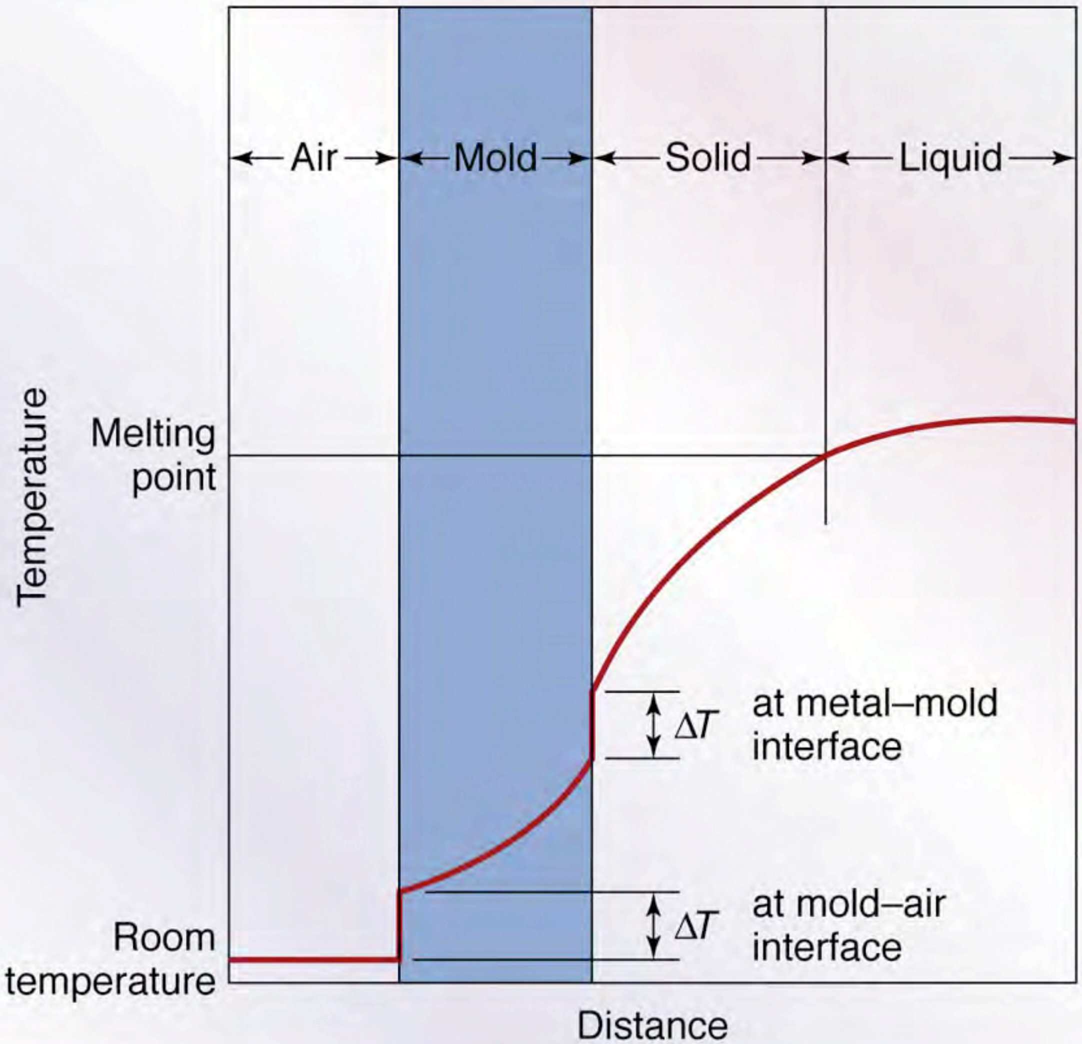

Figure 10.10 Temperature distribution at the interface of the mold wall and the liquid metal during the solidification of metals in casting

Solidified Skin on a Steel Casting

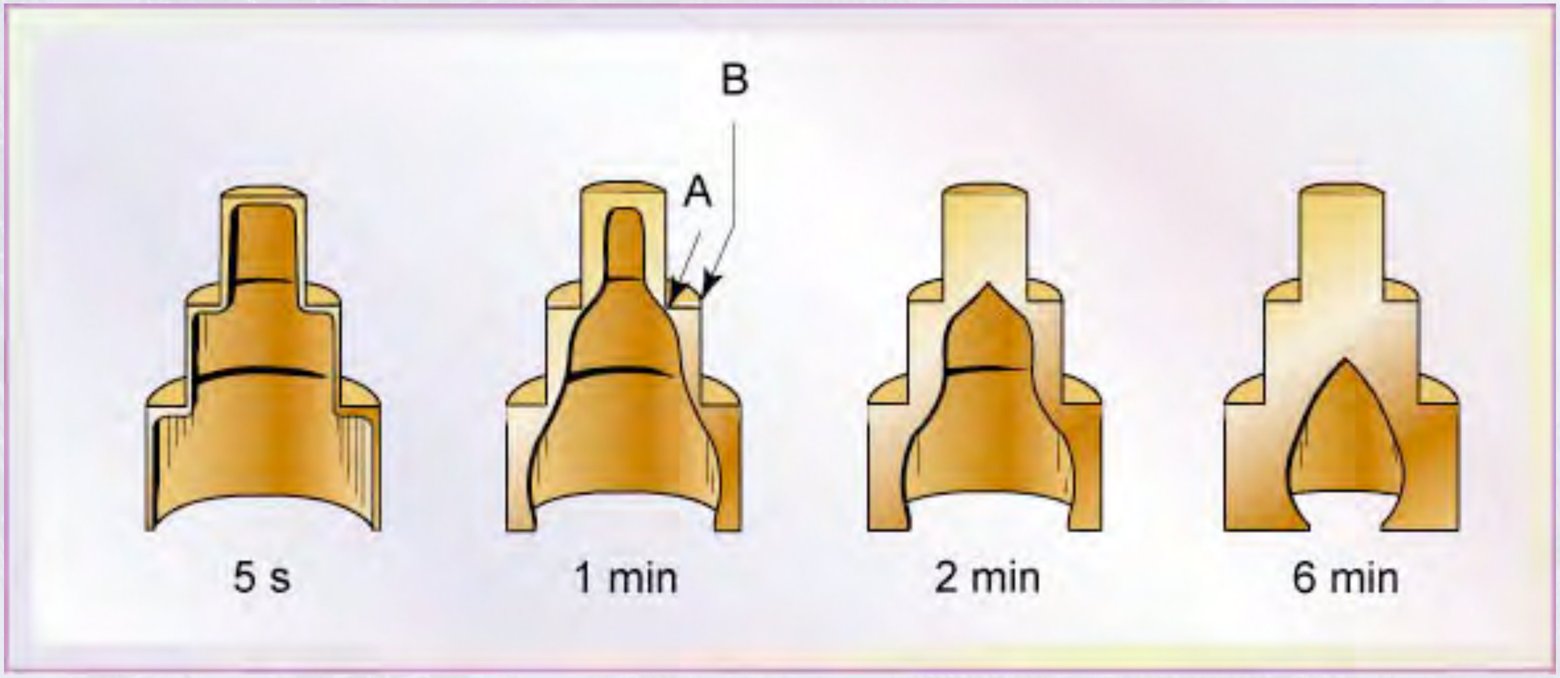

Figure 10.11 Solidified skin on a steel casting. The remaining molten metal is poured out at the times indicated in the figure. Hollow ornamental and decorative objects are made by a process called slush casting, which is based on this principle. *Source:* After H. F. Taylor, J. Wulff, and M. C. Flemings

Solidification Contraction or Expansion

TABLE 10.1

Volumetric Solidification Contraction or Expansion for Various Cast Metals

Contraction (%)		Expansion (%)	
Aluminum	7.1	Bismuth	3.3
Zinc	6.5	Silicon	2.9
Al-4.5% Cu	6.3	Gray iron	2.5
Gold	5.5		
White iron	4-5.5		
Copper	4.9		
Brass (70-30)	4.5		
Magnesium	4.2		
90% Cu-10% Al	4		
Carbon steels	2.5-4		
Al-12% Si	3.8		
Lead	3.2		

Hot Tears in Castings

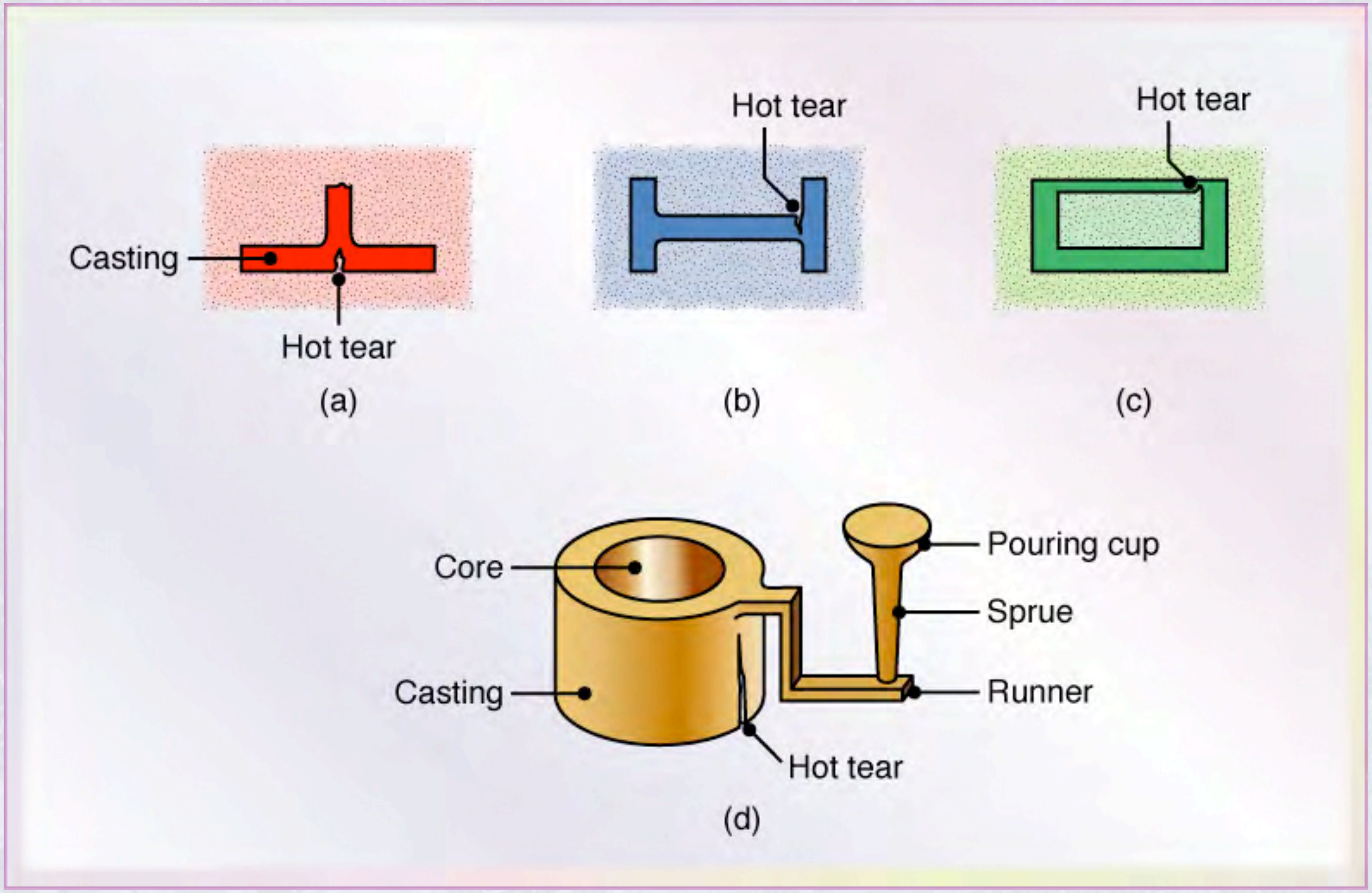

Figure 10.12 Examples of hot tears in castings. These defects occur because the casting cannot shrink freely during cooling, owing to constraints in various portions of the molds and cores. Exothermic (heat-producing) compounds may be used (as exothermic padding) to control cooling at critical sections to avoid hot tearing

Common Casting Defects

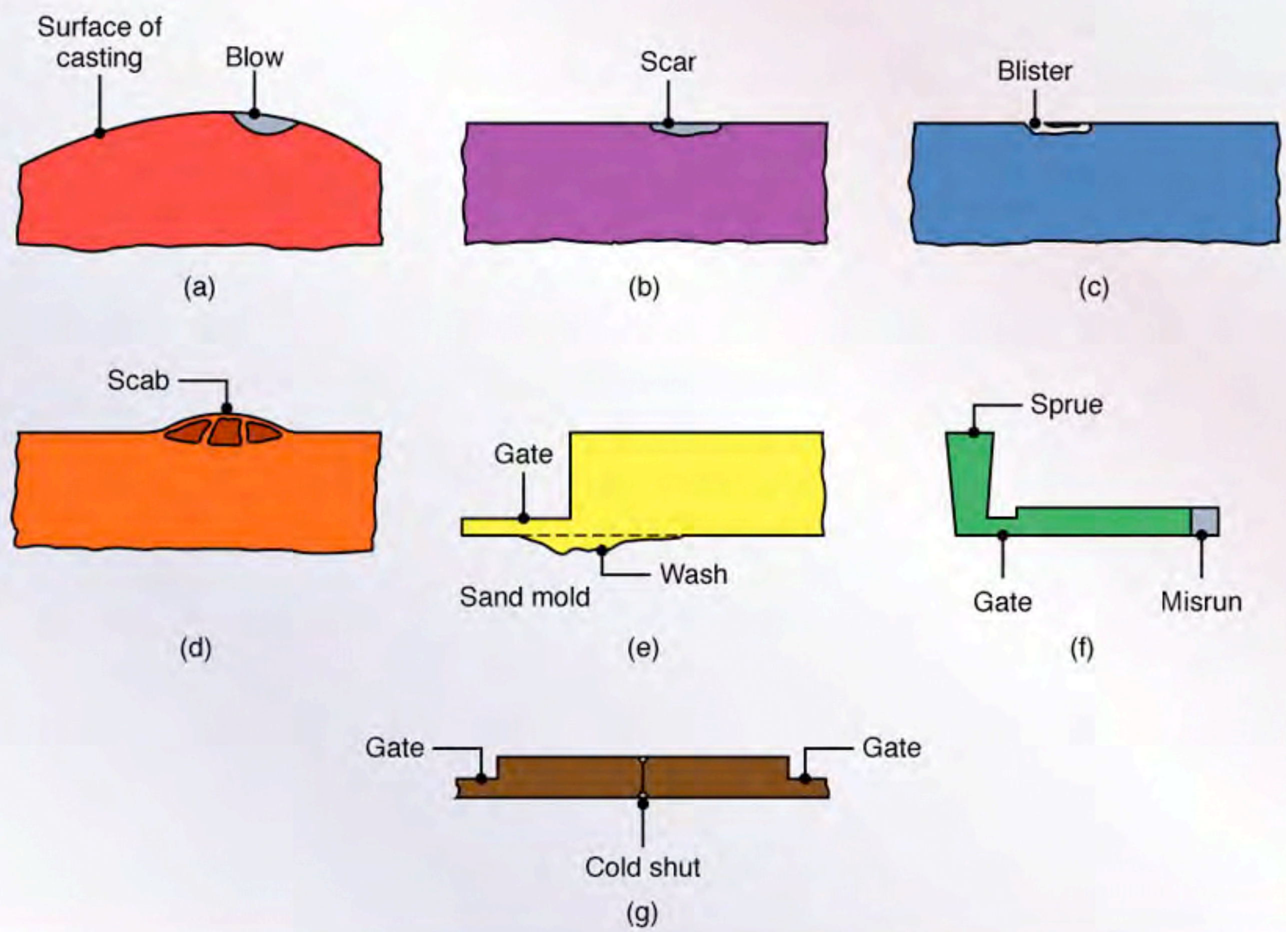

Figure 10.13 Examples of common defects in castings. These defects can be minimized or eliminated by proper design and preparation of molds and control of pouring procedures. *Source*: After J. Datsko.

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Types of Internal and External Chills used in Casting

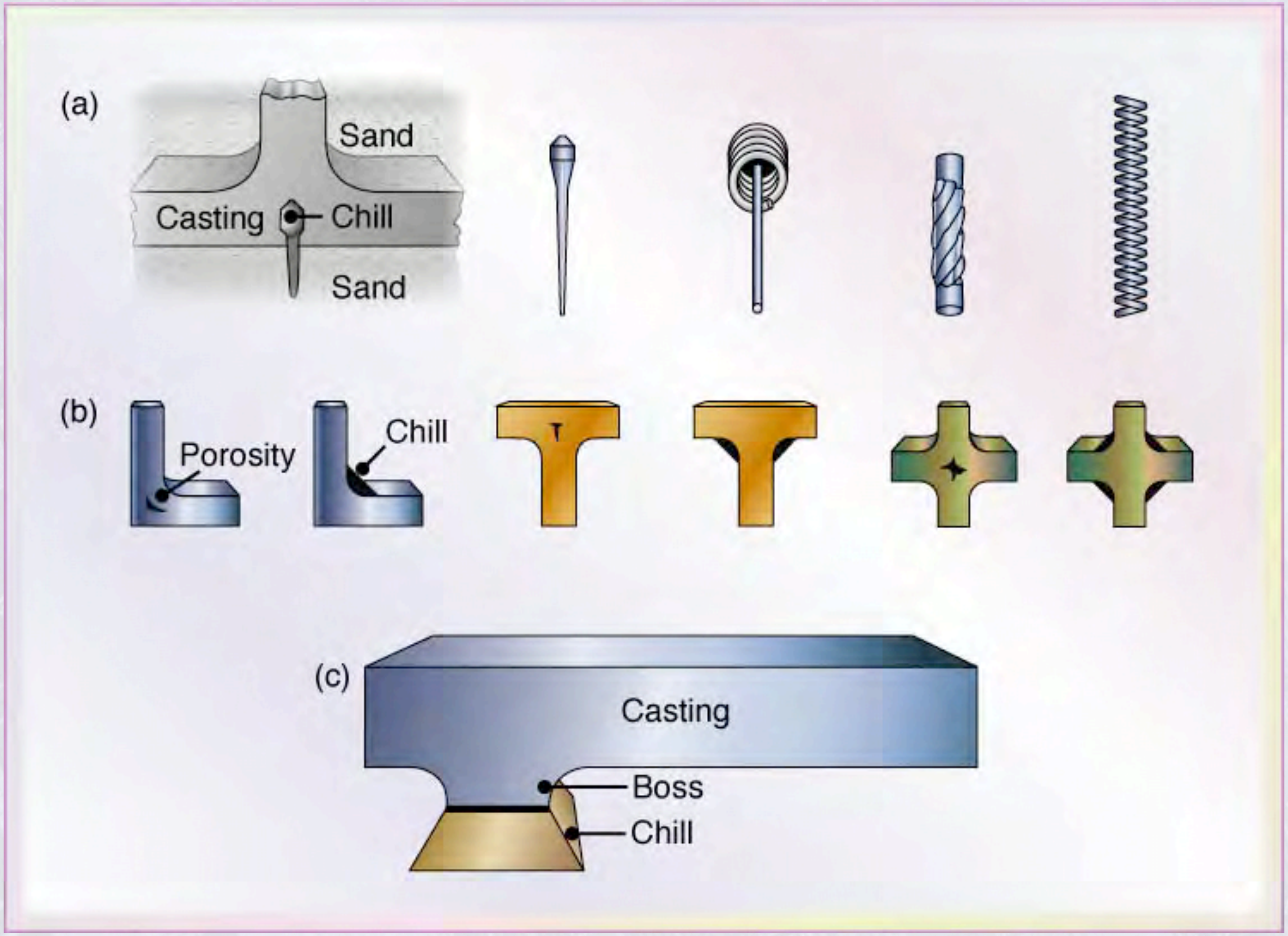

Figure 10.14 Various types of (a) internal and (b) external chills (dark areas at corners) used in castings to eliminate porosity caused by shrinkage. Chills are placed in regions where there is a larger volume of metal, as shown in (c).

Solubility of Hydrogen in Aluminum

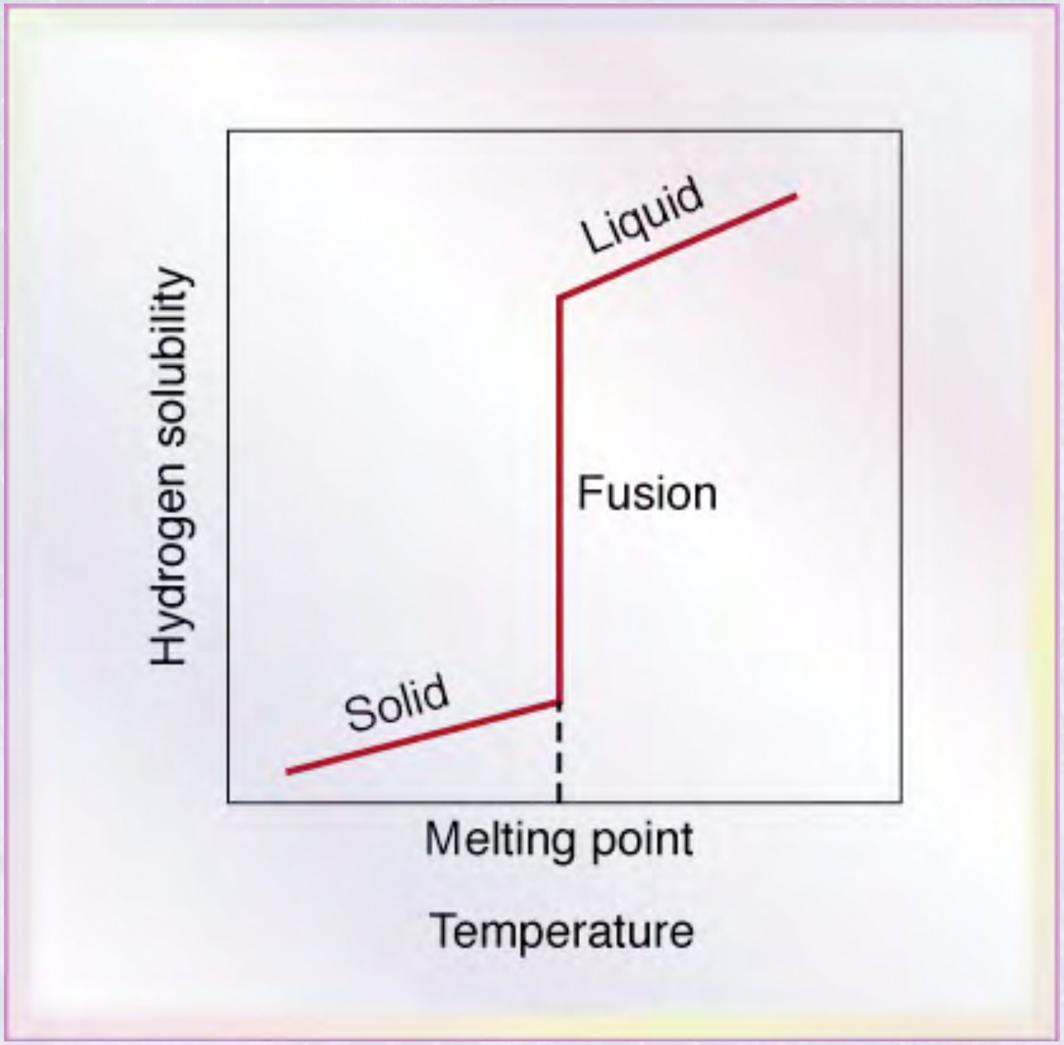

Figure 10.15 Solubility of hydrogen in aluminum. Note the sharp decrease in solubility as the molten metal begins to solidify.

Casting of an Aluminum Piston

Figure 10.16 Aluminum piston for an internal combustion engine: (a) as-cast and (b) after machining.

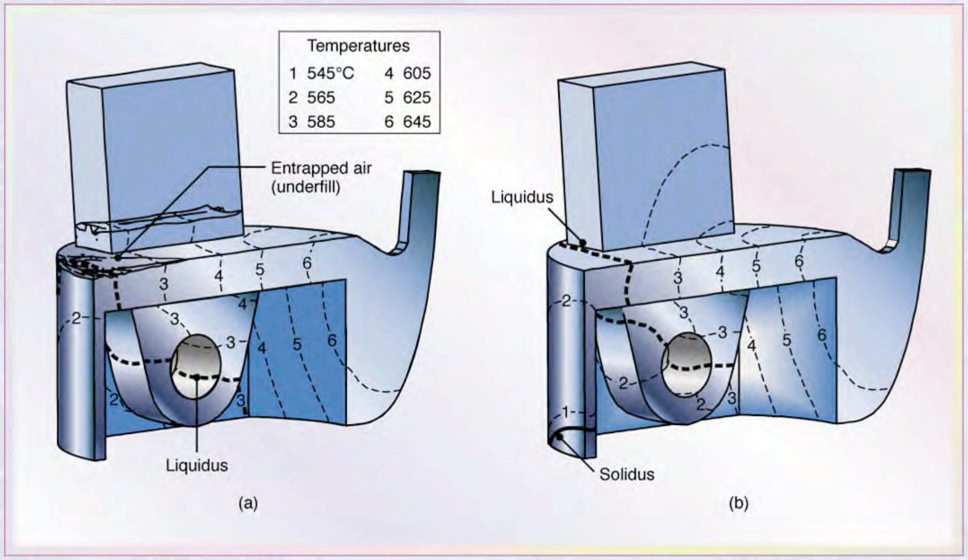

Figure 10.17 Simulation of mold filling and solidification. (a) 3.7 seconds after start of pour. Note that the mushy zone has been established before the mold is filled completely. (b) Using a vent in the mold for removal of entrapped air, 5 seconds after pour.

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