1.3 The Crystal Structure of Metals

When metals solidify from a molten state (Chapter 10), the atoms arrange themselves into various orderly configurations, called **crystals**; this atomic arrangement is called **crystal structure** or **crystalline structure**. The smallest group of atoms showing the characteristic **lattice structure** of a particular metal is known as a **unit cell.**

The following are the three basic atomic arrangements in metals:

1. **Body-centered cubic (bcc)**; alpha iron, chromium, molybdenum, tantalum, tungsten, and vanadium.
2. **Face-centered cubic (fcc)**; gamma iron, aluminum, copper, nickel, lead, silver, gold, and platinum.
3. **Hexagonal close-packed (hcp)**; beryllium, cadmium, cobalt, magnesium, alpha titanium, zinc, and zirconium.

These structures are represented by the illustrations given in Figs. 1.3–1.5, in which each sphere represents an atom. The distance between the atoms in these

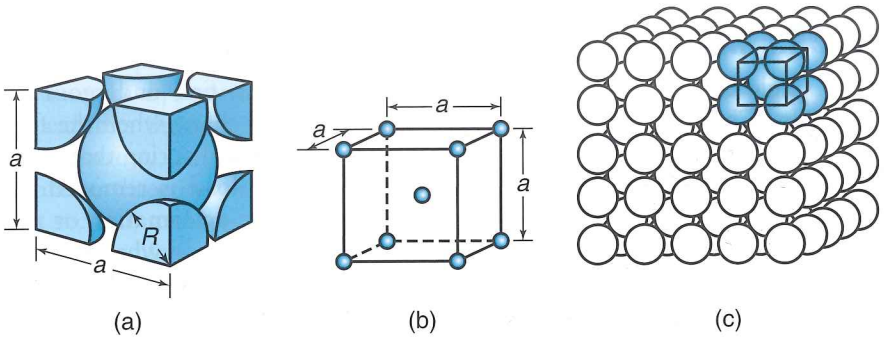

FIGURE 1.3 The body-centered cubic (bcc) crystal structure: (a) hard-ball model, (b) unit cell, and (c) single crystal with many unit cells.

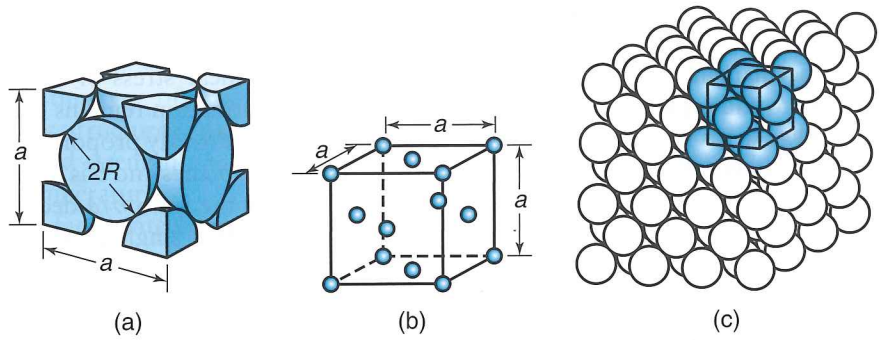

FIGURE 1.4 The face-centered cubic (fcc) crystal structure: (a) hard-ball model, (b) unit cell, and (c) single crystal with many unit cells.

crystal structures is on the order of 0.1 nm. The models shown are known as **hard-ball** or **hard-sphere** models, and can be likened to tennis balls arranged in various configurations in a box.

In the three structures illustrated, the hcp crystals have the most densely packed configurations, followed by fcc and then bcc. In the hcp structure, the top and bottom planes are called **basal planes**. All three arrangements can be modified by adding atoms of some other metal or metals, known as **alloying**, often to improve various properties of the metal.

The appearance of more than one type of crystal structure in metals is known as **allotropism** or **polymorphism** (meaning "many shapes"). Because the properties and behavior of a particular metal depend greatly on its crystal structure, allotropism is an important factor in the heat treatment of metals, as well as in metalworking and welding operations, described in Parts III and VI, respectively. Single crystals of metals are now produced as ingots in sizes on the order of 1 m long and up to 300 mm in diameter, with applications such as turbine blades and semiconductors (see Sections 11.5 and 28.3). Most metals used in manufacturing are, however, polycrystalline, as described in Section 1.5.

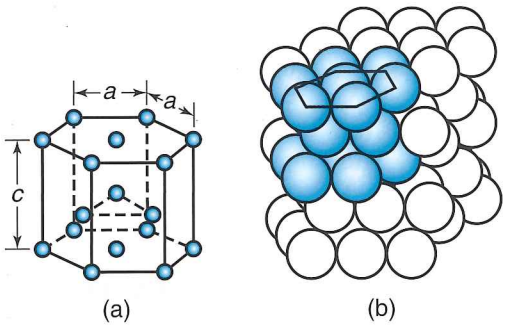

FIGURE 1.5 The hexagonal close-packed (hcp) crystal structure: (a) unit cell and (b) single crystal with many unit cells.