(Objective Checklist, continued)

- Discuss the importance of the intervertebral discs and spinal curvatures.
- Explain how the abnormal spinal curvatures (scoliosis, lordosis, and kyphosis) differ from one another.

APPENDICULAR SKELETON (pp. 153–160)

- Identify on a skeleton or diagram the bones of the shoulder and pelvic girdles and their attached limbs.
- Describe important differences between a male and female pelvis.

JOINTS (pp. 163–168)

- Name the three major categories of joints, and compare the amount of movement allowed by each.

DEVELOPMENTAL ASPECTS OF THE SKELETON (pp. 168–170)

- Identify some of the causes of bone and joint problems throughout life.

Although the word *skeleton* comes from the Greek word meaning "dried-up body," our internal framework is so beautifully designed and engineered that it puts any modern skyscraper to shame. Strong, yet light, it is perfectly adapted for its functions of body protection and motion. Shaped by an event that happened more than one million years ago—when a being first stood erect on hind legs—our skeleton is a tower of bones arranged so that we can stand upright and balance ourselves. No other animal has such relatively long legs (compared to the arms or forelimbs) or such a strange foot, and few have such remarkable grasping hands. Even though the infant's backbone is like an arch, it soon changes to the swayback, or S-shaped, structure that is required for the upright posture.

The skeleton is subdivided into two divisions: the **axial skeleton,** the bones that form the longitudinal axis of the body, and the **appendicular skeleton,** the bones of the limbs and girdles. In addition to bones, the **skeletal system** includes *joints, cartilages,* and *ligaments* (fibrous cords that bind the bones together at joints). The joints give the body flexibility and allow movement to occur.

Bones: An Overview

At one time or another, all of us have heard the expressions "bone tired," "dry as a bone," or "bag of bones"—pretty unflattering and inaccurate images of some of our most phenomenal organs. Our brains, not our bones, convey feelings of fatigue, and bones are far from dry. As for "bag of bones," they are indeed more obvious in some of us, but without them to form our internal skeleton, we would creep along the ground like slugs. Let's examine how our bones contribute to overall body homeostasis.

Functions of the Bones

Besides contributing to body shape and form, our bones perform several important body functions:

1. **Support.** Bones, the "steel girders" and "reinforced concrete" of the body, form the internal framework that supports and anchors all soft organs. The bones of the legs act as pillars to support the body trunk when we stand, and the rib cage supports the thoracic wall.
2. **Protection.** Bones protect soft body organs. For example, the fused bones of the skull

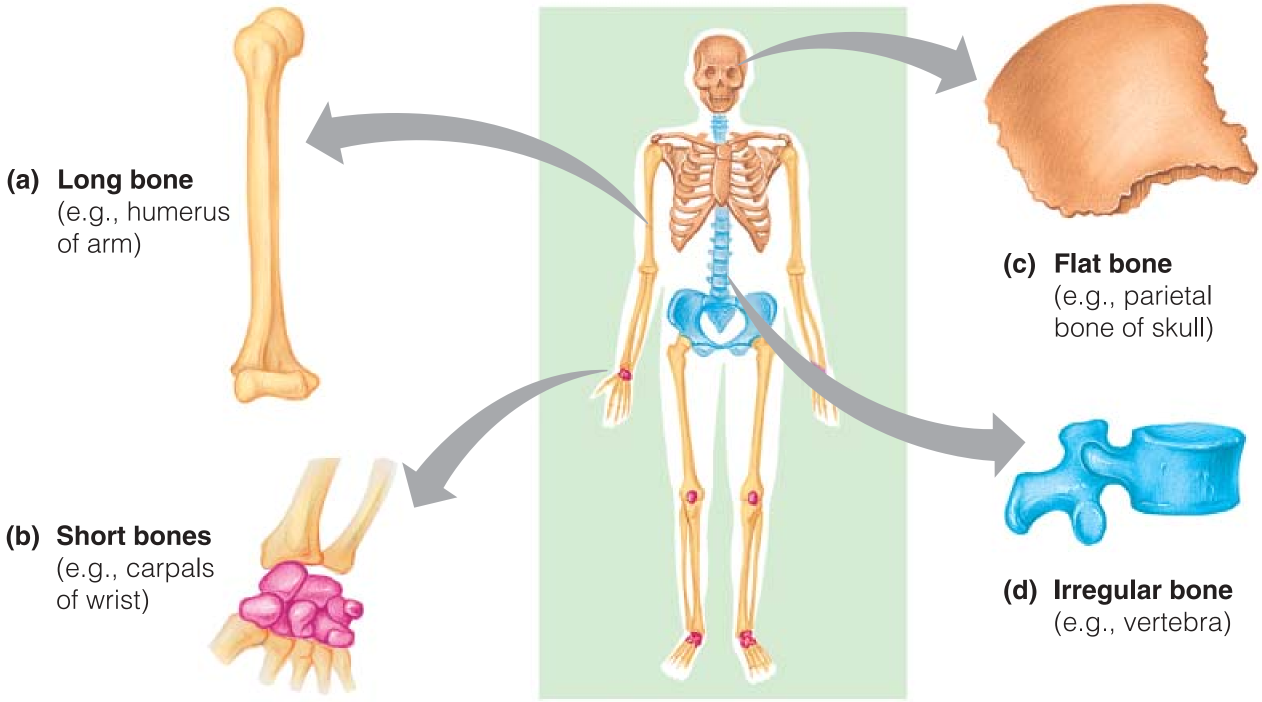

FIGURE 5.1 **Classification of bones on the basis of shape.**

provide a snug enclosure for the brain, allowing one to head a soccer ball without worrying about injuring the brain. The vertebrae surround the spinal cord, and the rib cage helps protect the vital organs of the thorax.

3. **Movement.** Skeletal muscles, attached to bones by tendons, use the bones as levers to move the body and its parts. As a result, we can walk, swim, throw a ball, and breathe. Before continuing, take a moment to imagine that your bones have turned to putty. What if you were running when this change took place? Now imagine your bones forming a rigid metal framework inside your body, somewhat like a system of plumbing pipes. What problems could you envision with this arrangement? These images should help you understand how well our skeletal system provides support and protection while allowing movement.
4. **Storage.** Fat is stored in the internal cavities of bones. Bone itself serves as a storehouse for minerals, the most important being calcium and phosphorus, although others are also stored. A small amount of calcium in its ion form (Ca^{2+}) must be present in the blood at all times for the nervous system to transmit messages, for muscles to contract, and for blood to clot. Because most of the body's calcium is deposited in the bones as calcium salts, the bones are a convenient place to get more calcium ions for the blood as they are used up. Problems occur not only when there is too little calcium in the blood, but also when there is too much. Hormones control the movement of calcium to and from the bones and blood according to the needs of the body. Indeed, "deposits" and "withdrawals" of calcium (and other minerals) to and from bones go on almost all the time.
5. **Blood cell formation.** Blood cell formation, or hematopoiesis (hem″ah-to-poi-e′sis), occurs within the marrow cavities of certain bones.

Classification of Bones

The adult skeleton is composed of 206 bones. There are two basic types of osseous, or bone, tissue: **Compact bone** is dense and looks smooth and homogeneous. **Spongy bone** is composed of small needlelike pieces of bone and lots of open space.

Bones come in many sizes and shapes (Figure 5.1). For example, the tiny pisiform bone of the wrist is the size and shape of a pea, whereas the femur, or thigh bone, is nearly 2 feet long and has a large, ball-shaped head. The unique shape of each bone fulfills a particular need. Bones are classified according to shape into four groups: long, short, flat, and irregular (Figure 5.1).

As their name suggests, **long bones** are typically longer than they are wide. As a rule they have a shaft with heads at both ends. Long bones are mostly compact bone. All the bones of the limbs, except the wrist and ankle bones, are long bones.

Short bones are generally cube-shaped and contain mostly spongy bone. The bones of the wrist and ankle are short bones. *Sesamoid* (ses′ah-moyd) *bones,* which form within tendons, are a special type of short bone. The best-known example is the patella, or kneecap.

Flat bones are thin, flattened, and usually curved. They have two thin layers of compact bone sandwiching a layer of spongy bone between them. Most bones of the skull, the ribs, and the sternum (breastbone) are flat bones.

Bones that do not fit one of the preceding categories are called **irregular bones.** The vertebrae, which make up the spinal column, and the hip bones fall into this group.

Structure of a Long Bone

Gross Anatomy

The gross structure of a long bone is shown in Figure 5.2. The **diaphysis** (di-af′ĭ-sis), or shaft, makes up most of the bone's length and is composed of compact bone. The diaphysis is covered and protected by a fibrous connective tissue membrane, the **periosteum** (per-e-ŏs′te-um). Hundreds of connective tissue fibers, called **perforating,** or **Sharpey's, fibers,** secure the periosteum to the underlying bone. The **epiphyses** (ĕ-pif′ĭ-sēz) are the ends of the long bone. Each epiphysis consists of a thin layer of compact bone enclosing an area filled with spongy bone. **Articular cartilage,** instead of a periosteum, covers its external surface. Because the articular cartilage is glassy hyaline cartilage, it provides a smooth, slippery surface that decreases friction at joint surfaces.

In adult bones, there is a thin line of bony tissue spanning the epiphysis that looks a bit different from the rest of the bone in that area. This is the **epiphyseal line.** The epiphyseal line is a remnant of the **epiphyseal plate** (a flat plate of hyaline cartilage) seen in a young, growing bone. Epiphyseal plates cause the lengthwise growth of a long bone. By the end of puberty, when hormones inhibit long bone growth, epiphyseal plates have been completely replaced by bone, leaving only the epiphyseal lines to mark their previous location.

In adults the cavity of the shaft is primarily a storage area for adipose (fat) tissue. It is called the **yellow marrow,** or **medullary, cavity.** However, in infants this area forms blood cells, and **red marrow** is found there. In adult bones, red marrow is confined to the cavities of spongy bone of flat bones and the epiphyses of some long bones.

Even when looking casually at bones, one can see that their surfaces are not smooth but scarred with bumps, holes, and ridges. These **bone markings,** described and illustrated in Table 5.1, reveal where muscles, tendons, and ligaments were attached and where blood vessels and nerves passed. There are two categories of bone markings: (a) *projections,* or *processes,* which grow out from the bone surface, and (b) *depressions,* or *cavities,* which are indentations in the bone. These terms do not have to be learned now, but they can help you remember some of the specific markings on bones to which you will be introduced later in this chapter.

There is a little trick for remembering the bone markings listed in the table: All the terms beginning with **T** are projections. The terms beginning with **F** (except *facet*) are depressions.

Microscopic Anatomy

To the naked eye, spongy bone has a spiky, open appearance, whereas compact bone appears to be very dense. Looking at compact bone tissue through a microscope, however, one can see that it has a complex structure (Figure 5.3). It is riddled with passageways carrying nerves, blood vessels, and the like, which provide the living bone cells with nutrients and a route for waste disposal. The mature bone cells, **osteocytes** (os′te-o-sītz″), are found in tiny cavities within the matrix called **lacunae** (lah-ku′ne). The lacunae are arranged in concentric circles called **lamellae** (lah-mel′e) around **central (Haversian) canals.** Each complex consisting of central canal and matrix rings is called an **osteon,** or **Haversian system.** Central canals run lengthwise through the bony matrix, carrying blood vessels and nerves to all areas of the bone. Tiny canals, **canaliculi** (kan″ah-lik′u-li), radiate

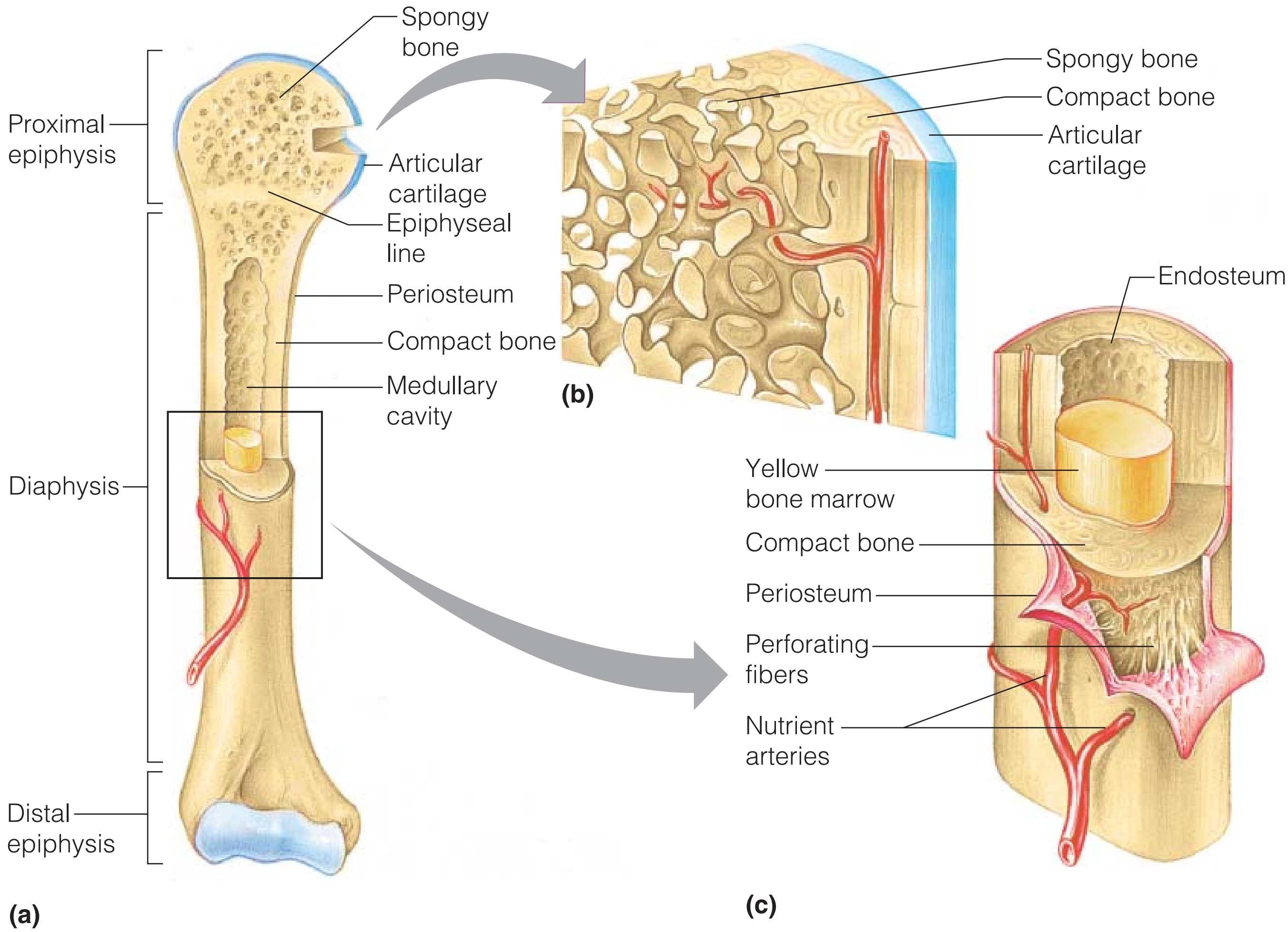

FIGURE 5.2 **The structure of a long bone (humerus).** **(a)** Anterior view with longitudinal section cut away at the proximal end. **(b)** Pie-shaped, three-dimensional view of spongy bone and compact bone of the epiphysis. **(c)** Cross section of the shaft (diaphysis). Note that the external surface of the diaphysis is covered by a periosteum, but the articular surface of the epiphysis (see b) is covered with hyaline cartilage.

outward from the central canals to all lacunae. The canaliculi form a transportation system that connects all the bone cells to the nutrient supply through the hard bone matrix. Because of this elaborate network of canals, bone cells are well nourished in spite of the hardness of the matrix, and bone injuries heal quickly and well. The communication pathway from the outside of the bone to its interior (and the central canals) is completed by **perforating (Volkmann's) canals,** which run into the compact bone at right angles to the shaft.

Bone is one of the hardest materials in the body, and although relatively light in weight, it has a remarkable ability to resist tension and other forces acting on it. Nature has given us an extremely strong and exceptionally simple (almost crude) supporting system without giving up mobility. The calcium salts deposited in the matrix give bone its hardness, whereas the organic parts (especially the collagen fibers) provide for bone's flexibility and great tensile strength.