• **Osteocytes**: These cells form a large component of mature bone. Osteocytes have long, branching arms that connect them to neighboring osteocytes. This allows them to exchange minerals and communicate with neighboring cells.

• **Osteoclasts**: These large macrophage-type cells secrete acidic enzymes to break down bone matrix and reabsorb existing bone, thus enabling remodeling of bone.

Inorganic bone components consist of hydroxyapatites (mineral salts), primarily calcium phosphate. These calcium salts are present in the form of tiny crystals, which contribute to bone hardness or rigidity.5

Bones have a solid outer shell (cortical, or compact, bone) and a honeycomb inside (known as cancellous, spongy, or trabecular bone). The human skeleton is composed of approximately 80% compact bone and 20% cancellous bone. Cortical bone has an outer periosteal surface and inner endosteal surface. Periosteal surface activity is important for appositional growth and fracture repair. All bone is made up of structural units known as osteons. In cortical bone, an osteon consists of concentric layers (lamellae) of osteocytes and matrix around small blood vessels (haversian canal; figure 1.1). The osteocytes within osteons are interconnected by small channels known as canaliculi. Cortical structure
Musculoskeletal system and microstructure contribute to the mechanical competence of the entire bone. The crystalline component of the structure provides compressive strength and brittleness, while collagen fibrils provide tensile strength and toughness. Cortical bone develops microcracks when stressed in order to dissipate energy during catastrophic loading events. Age-related accumulation of microdamage weakens cortical bone tissue and possibly contributes to increased susceptibility to fracture. Bone formation typically exceeds bone resorption on the periosteal surface, so bones normally increase in diameter with aging.

Cancellous bone (figure 1.2) is made up of a honeycomb network of thin plates (trabeculae) and rods interspersed in the bone marrow compartment. It is found in the ends of long bones near joints, in vertebral bodies, and in flat bones such as the ilium of the pelvis. Cancellous bone is also composed of osteons, called packets. Cancellous bone has a higher level of remodeling than cortical bone; however, both engage in the remodeling process.

Mature cortical bone and cancellous bone normally exhibit a lamellar pattern, in which collagen fibrils are laid down in alternating orientations. The mechanism by which osteoblasts lay down collagen fibrils in a lamellar pattern is unknown. Similar to plywood, lamellar bone has great strength resultant from the alternating orientations of collagen fibrils. This lamellar pattern is absent in woven (immature) bone. In immature bone, the collagen fibrils are laid down in a disorganized manner that makes the bone weaker than lamellar (mature) bone. Woven bone is normally produced during initial formation of primary bone. It may also be seen in association with conditions that result in high bone turnover, such as osteitis fibrosa cystica, Paget’s disease, or hyperparathyroidism.

Bone health depends on both nonmechanical and mechanical influences. Nonmechanical factors are broad and encompass individual genetic determinants such as gender, cellular metabolism, and hormone and cytokine production, as well as nutritional components such as calcium and vitamin D. Mechanical factors include loads or stress that influence osteoblast and osteoclast cell activity. Excessive mechanical stress or a prolonged lack of loading can significantly change bone structure. This can result in a variety of musculoskeletal concerns. For example, excessive loading of the lumbar facet joints due to inappropriate postures (exaggerated lordosis) or movements over time can cause hypertrophy of the bony articular processes of the vertebrae. This hypertrophy can create stenosis of the intervertebral foramina and subsequent nerve root impingement. Conversely, lack of loading causes weakening of the bones and increased susceptibility to fracture. The occurrence of these types of fractures in the long bones of the lower limbs of people who depend on wheelchairs for mobility have been well documented. Bones adapt to the physical stresses placed on them through the coordinated action of osteoclasts and osteoblasts. The principle of bone adaptation to stress is known as Wolff’s Law. It states that a bone’s internal and external architecture change in response to the stresses (or lack thereof) placed on it.

Biomechanical Properties

In order for bones to function normally, they must exhibit a number of mechanical properties. Similar qualities can be found in other infrastructure materials such as wood and steel. Bones have to be able to absorb stress, strain, and shear resultant from the functional demands placed on them. These mechanical properties include anisotropy, viscoelasticity, and loading modes as well as responses due to compression (load-bearing stress) and tension (muscle strain) forces.

Anisotropy is the ability to respond differently to forces applied in different directions. The