

The human **skeleton** contains 206 named bones which perform a multitude of functions. Bones actively support the weight of the body. They protect essential organs like the brain and the lungs. They are the levers that are pulled upon by skeletal muscles to create movement. They store minerals such as **calcium** (Ca^{2+}) and **phosphate** (PO_4^{2-}). They are the site of blood cell formation (**hematopoiesis**). They provide storage for **triglycerides**.

Bones have an exterior composed of **compact bone** and an interior that contains **spongy bone** (**cancellous bone**). Compact bone appears solid to the naked eye. Spongy bone contains a multitude of spaces found in between needle-like struts of bone called **trabeculae**.

There are 4 basic types of bone: **long bones**, **short bones**, **flat bones**, and **irregular bones**. Long bones are longer than they are wide. All bones of the appendages (except for the **patellae**, **carpals**, and **tarsals** are long bones. Short bones are roughly cube-shaped. Carpals and tarsals are short bones. Flat bones are thin, flattened, and usually a bit curved. The **sternum**, **scapulae**, **ribs**, and most **skull** bones are flat bones. Irregular bones have weird shapes that don't fit the other designations. The **vertebrae** and **hip bones** are irregular.

A long bone consists of a shaft (**diaphysis**), a pair of expanded ends (**epiphyses**), and a pair of membranes. The diaphysis forms the long axis of the bone and consists of a collar of compact bone surrounding a central **medullary cavity**. In adults, the medullary cavity typically contains **yellow bone marrow** which is rich in triglycerides.

Epiphyses are the expanded, rounded ends of the long bone that **articulate** (form a joint) with other bones. Epiphyses have an exterior of compact bone and an interior of spongy bone. The joint surfaces of the epiphyses are covered by a layer of hyaline cartilage (**articular cartilage**). In children, the epiphysis contains a disc of hyaline cartilage (the **epiphyseal plate**) which allows for growth along the long axis. In adult long bones, only a remnant (the **epiphyseal line**) of the epiphyseal plate remains. Long bones in the appendages have epiphyses designated as proximal or distal.

The exterior of the bone (except joint surfaces) is covered by a double-layered membrane known as the **periosteum**. The outer portion of the periosteum is composed of dense irregular connective tissue and is the **fibrous layer**. The inner portion of the periosteum is made of bone forming cells (**osteoblasts**) and is the **osteogenic layer**. The periosteum is the anchor point for the attachment of ligaments and tendons to bone. The periosteum is tightly attached to the compact bone it surrounds by clusters of collagen fibers known as **perforating fibers**. The periosteum is quite vascular and contains much nervous tissue. The blood and nerve supply to the bone extends from the periosteum and enters the bone tissue by way of holes known as **nutrient foramina**.

The medullary cavity, surfaces of the trabeculae and interiors of the channels within compact bone are all lined by a membrane known as the **endosteum**. The endosteum contains bone-forming cells (osteoblasts) and bone-destroying cells (**osteoclasts**).

Flat bones consist of a pair of plates of compact bone separated by an interior of spongy bone (the **diploë**). Red bone marrow is found in the spaces of the spongy bone contains hematopoietic (blood forming) tissue.

Compact bone consists of cylinders known as **osteons**. An osteon is a weight-bearing tube oriented along the long axis of the bone. It has a series of concentric layers of bone tissue (**lamellae**) surrounding a lumen (**central canal**). Lamellae are composed of bone matrix containing **lacunae** that house mature bone cells (**osteocytes**). The central canal contains the blood vessels and nerves serving the cells of the osteon. Central canals are linked to one another and to nutrient foramina by **perforating canals** which run perpendicular to the long axis of the bone. The osteocytes are spider-like cells in that they have long extensions that spread through the matrix via small channels called **canaliculi**. The extensions of one osteocyte are often linked to the extensions of other osteocytes by gap junctions. This allows nutrients and signals to pass from cell to cell within the bone. (Spongy bone does not contain osteons.)

Bone matrix surrounds osteocytes in both compact and spongy bone. Bone matrix is strong, flexible and dynamic. $\frac{1}{3}$ of the matrix is composed of **osteoid** which consists of ground substance and collagen fibers produced by osteoblasts. Collagen provides the bone with flexibility as well as incredible tensile strength. $\frac{2}{3}$ of bone matrix is composed of minerals – primarily **calcium phosphate** (CaPO_4). The mineral component gives bone its hardness and its ability to resist compression.

Long bone growth in length occurs at epiphyseal plates. W/i the plate, chondrocytes divide producing new cells. These new cells push older chondrocytes towards the diaphysis causing the bone to lengthen. The older chondrocytes near the diaphysis then grow causing their lacunae to enlarge. Then the surrounding matrix calcifies which diminishes the ability of nutrients to diffuse to the chondrocytes. These chondrocytes then die. This leaves an area next to the diaphysis consisting of spaces separated by calcified cartilage. Osteoblasts and osteoclasts move in and transform the calcified spicules into new spongy bone. As this occurs the epiphyseal plate does not change in size since its rate of growth at its epiphyseal end is equal to its rate of transformation into bone at its diaphyseal end. During childhood, epiphyseal plate activity is stimulated by **growth hormone** released by the **pituitary gland**. At puberty, blood levels of sex hormones (**testosterone** or **estrogens**) increase. This causes two things to occur. It causes an increase in the conversion of the cartilage to bone (resulting in increased bone length), but it also decreases the rate of production of new cartilage in the plate (ultimately ending the ability of the long bone to grow).

Growth in width is a product of the activity of the osteoblasts in the osteogenic layer of the periosteum. The deposition of bone on the outer surface is balanced by the destruction of bone adjacent to the marrow cavity by osteoclasts within the endosteum.

Bone is a dynamic tissue. It is constantly being remodeled and reshaped in response to the stresses and demands put upon it. Bone remodeling consists of both **bone deposition** (production of new bone matrix by osteoblasts) and **bone resorption** (destruction of bone matrix by osteoclasts). Where these events occur is often determined by the external stress (or lack thereof) placed on the bone.

Additionally, bone deposition and resorption are controlled by blood levels of calcium. Calcium is essential to physiological functions, including muscle contraction, nerve signaling, and blood clotting. A decrease in blood calcium levels prompts the **parathyroid glands** (found on the posterior of the trachea) to secrete **parathyroid hormone (PTH)**. PTH will increase blood calcium by acting on both skeletal and non-skeletal tissues. It stimulates the activity of osteoclasts. The resulting breakdown of inorganic bone matrix releases calcium into the blood. PTH also increases absorption of dietary calcium in the intestines and decreases calcium output in the urine.

In order for the proper maintenance of bone tissue, blood levels of calcium and phosphorus must be sufficient. Absorption of dietary calcium is depended on vitamin D which is produced within the blood vessels of the dermis upon exposure to ultraviolet radiation. Vitamin C promotes new bone production by increasing osteoblast activity and decreasing osteoclast activity.