THE SKELETAL SYSTEM

Chapter 3

The skeletal system consists mainly of two important types of connective tissues - cartilage and bone. *(See Fig. 6)* In an embryo, the skeleton is mainly cartilage in nature, and by adulthood, most of this cartilage has been replaced by hardened bone. Cartilage continues to exist, however, in certain areas of the body such as the nose, outer ear, voicebox, and at points where bones attach to one another. Like other connective tissues, bone contains functional cells, called osteocytes, and a great deal of intercellular material. However, unlike other connective tissues, in bone most of this intercellular material becomes hardened by the deposition of mineral salts, especially calcium. This is a gradual process which occurs over a period of years, until a person's bones become fully developed into their normal adult form. This process of bone formation is called ossification. Even after bone has reached its normal state of "hardness", activity does not cease within bone tissue. Bones are dynamic organs, and have the ability to continually maintain and repair themselves throughout life.

Structure of Bone

The outer layer, or shell, of a bone is usually quite dense in nature, and is referred to as **compact bone.** *(See Fig. 20)* Although it is called compact bone, it nevertheless contains an intricate, structural arrangement of circular rings of tissue containing bone cells, hardened intercellular substances, and numerous minute canals for blood vessels. These complex structural units are referred to as **Haversian systems.**

The interior part of most bones consists of a more "spongy", or porous type of bone, which is referred to as **cancellous bone.** It contains many spaces that are occupied by red bone marrow, which is responsible for the manufacture of blood cells in the body. In addition, bones are covered with a tough, outer membrane called the **periosteum.** A long bone is made up of the diaphysis, or shaft, the epiphyses, or ends of the bone, the articular cartilage, which covers and cushions the ends of bones where they form a joint, and the medullary canal or cavity, containing yellow bone marrow.

Functions of Bone

The basic functions of bone can generally be summarized into five main areas, as follows:

1. Support - bone provides support and rigidity to the soft tissues of the body so that our normal, erect posture can be maintained.
2. Protection - bones help to protect the more delicate, vital organs which they surround, such as the protection provided to the brain by the bones of the cranium.
3. Movement - bones serve as levers, or points of attachment for the body's muscles, which pull on the bones and result in movement.

4. Storage - bones serve as warehouses, or storage areas, for important minerals in the body, such as calcium. When blood calcium levels rise above normal, the calcium moves into the bones and is stored. When calcium levels in the blood fall, some stored calcium leaves the bones and enters the bloodstream to be used throughout the body.

5. Hemopoiesis - this term is a combination to the Greek words "hemo", meaning blood, and "poiesis", meaning to make or manufacture. Blood cell production occurs primarily in the red bone marrow of the body.

TABLE B

Outline of the Skeleton

	Number of Bones
I. Axial Skeleton	
A. Skull	28
1. cranium	8
2. face	14
3. ear bones	6
B. Hyoid Bone	1
C. Vertebrae	26
D. Ribs	24
E. Sternum	1
Total Axial	**80**
II. Appendicular Skeleton	
A. Upper Extremity/Pectoral Girdle	
1. scapula	2
2. clavicle	2
3. humerus	2
4. radius	2
5. ulna	2
6. carpals	16
7. metacarpals	10
8. phalanges	28
Total Upper Extremity	**64**
B. Lower Extremity/Pelvic Girdle	
1. os coxa	2
2. femur	2
3. patella	2
4. tibia	2
5. fibula	2
6. tarsals	14
7. metatarsals	10
8. phalanges	28
Total Lower Extremity	**62**
Total Appendicular	**126**
Total Axial	**80**
Total in the Body	**206**

TABLE C

Bony Landmarks

Antrum or Sinus - An air cavity within a bone

Canal or Meatus - a tunnel-like passageway or opening in a bone

Condyle - a smooth, curved articular surface on a bone

Crest - a prominent ridge on a bone

Epicondyle - a prominence just above a condyle

Fissure - a narrow slit or groove in a bone

Fontanel - a temporarily unossified area between the cranial bones of an infant

Foramen - a hole in a bone

Fossa - a depression in a bone

Head - a ball-like articular projection on a bone

Process - any prominent projection or outgrowth of bone

Septum - a wall or partition which divides a body cavity

Tubercle or Tuberosity - a bump or elevation on a bone

Divisions of the Skeleton

The human skeleton consists of 206 classified bones, and they are generally grouped into two main subdivisions, called the axial and appendicular skeletons. Classified bones are those which are always present in the normal human body. The axial skeleton includes all of the bones of the skull, the hyoid bone, the thorax, and the spine. The appendicular skeleton includes the bones of the upper extremities and pectoral girdle (arms, wrists, hands, fingers, collar bones, and shoulder blades), plus the bones of the lower extremities and pelvic girdle (legs, ankles, feet, toes, and hip bones). *(See Figs. 6 & 7)*

Besides the 206 classified bones of the body, there are two other recognized types of bones, which are very irregular, and may or may not be present in a given individual. The first of these "unclassified" bones are called **sutural bones,** which are small, chip-like pieces of bones sometimes found embedded between the cranial bones. The points at which the cranial bones meet are referred to as sutures. The other type of unclassified bones are called **sesamoid bones.** The word sesamoid literally means "resembling a sesame seed". By definition, these small, variable bones are occasionally found embedded in tendons, most often at points where pressure exists, such as where a tendon moves over a bony prominence. The kneecaps are exceptions in that they develop in, and are surrounded by tendon, but are present in all

bodies; thus they are classified sesamoid bones.

Axial Skeleton

The **skull**, which contains 28 bones, may be subdivided into three categories: the cranium, the face, and the ear bones. *(See Figs. 8, 9, 10, 11)*

The **cranium** consists of eight bones which form the cranial cavity and which house the brain.

1. The **frontal** bone forms the forehead area, the front, top of the cranium, and the upper part of the eyesockets. Important landmarks of the frontal bone include the **supraorbital margins,** or the upper rim of the eyesockets, the **superciliary arches,** which are elevations at and above the medial ends of the eyebrows, the **glabella,** which is a prominence just above the nasal bones, between the medial ends of the eyebrows, and the **frontal eminences,** which are described as gently rounded prominences at the upper border of the forehead. Also contained within the frontal bone are the **frontal sinuses,** which are cavities that communicate with the nasal passages. *(See Fig. 9)*

2. The **parietal bones** form the majority of the upper sides and top of the cranium. *(See Fig. 9)*

3. The **temporal bones** form the lower sides of the cranium, basically surrounding the ears. The upper flat portion, adjacent to the parietal bones, is called the **squama.** The inferior, or petrous portion, includes the hearing canal, and houses the tiny ear bones. The **zygomatic process** is a projection on the temporal bone which extends forward, anterior to the hearing canal, to unite with the cheek bone. The **mastoid process** is a prominent projection on the inferior part of the temporal bone, just behind the lobe of the ear. The **external auditory meatus**, or hearing canal, is a tunnel in the temporal bone which extends medially from the external ear to the middle ear. The **mandibular fossa** is a depression on the temporal bone, just anterior to the external auditory meatus, which articulates with the condyles of the lower jaw. The **carotid canal** is a passageway in the temporal bone through which the internal carotid artery passes in taking blood to the brain. *(See Fig. 9)*

4. The **occipital bone** makes up the lower back part of the cranium. The large opening in the inferior portion of the occipital bone, through which the spinal cord passes to connect to the brain, is called the **foramen magnum.** The **occipital condyles,** located on either side of the foramen magnum, articulate with the top bone of the spinal column. Also, the prominent tubercle on the posterior surface of the occipital bone is called the **external occipital protuberance.** *(See Fig. 11)*

5. The **sphenoid bone** is sometimes described as the "bat-shaped" bone, and helps make up the floor of the cranial cavity, the back of the eye-

sockets, and part of the temple area. One of its prominent landmarks is the **sella turcica,** which is a depression in the center of the superior portion of the sphenoid, and which holds the pituitary gland. In addition, the sphenoid bone also contains **paranasal sinuses.** *(See Fig. 10)*

6. The **ethmoid bone** is a very irregular shaped bone, which helps make up the floor of the cranial cavity, part of the eyesocket, and the upper part of the nasal cavity. It has a number of important landmarks, including the **cribriform plate,** which is the flat, superior surface of the ethmoid, which is involved in making up the floor of the cranial cavity. It contains many small holes for the passage of nerves into the nasal cavity. Also, the ethmoid contains a noticeable vertical projection on its superior portion called the **crista galli.** The crista galli is so named because it is thought to look like a rooster's comb. The **vertical or perpendicular plate** of the ethmoid is a thin, flat plate of bone which extends down into the nasal cavity on the midline, and helps make up the nasal septum. The ethmoid bone also contains **paranasal sinuses.** *(See Fig. 9)*

The **face** is the second main subdivision of the skull, and consists of a total of 14 bones.

1. The **nasal bones** are two small bones making up the area we commonly think of as the bridge of the nose *(See Fig. 8)*
2. The two **lacrimal bones** are located in the anterior, medial portion of the eyesockets. The word lacrimal comes from the Latin word for "tears". *(See Fig. 8)*
3. The **vomer bone** is located on the midline in the base of the nasal cavity. Along with the perpendicular plate of the ethmoid bone, it helps form the nasal septum, which is the wall that divides the nasal cavity into right and left parts. *(See Fig. 8)*
4. The **zygomatic or malar bones** are commonly called the cheek bones. They also help form the eyesocket. *(See Fig. 8)*
5. The **palatine bones** are two small bones which help form the posterior part of the roof of the mouth. It is from these bones which we get the commonly used word "palate", which refers to the roof of the mouth. *(See Fig. 11)*
6. The **maxillary bones** are the upper jaw bones. Although there are technically two maxillary bones, they are often referred to as the **maxilla.** They also help form the eyesocket and the walls of the nasal cavity. The part of the maxilla into which the roots of the teeth are embedded is called the **alveolar process.** The horizontal portion of the maxilla, which forms the anterior portion of the roof of the mouth, is referred to as the palatine process. The maxillary bones actually make up a greater portion of the palate, or bony roof of the mouth, than do the **palatine bones.** Also contained within the maxillary

bones are the two large cavities referred to as the maxillary sinuses. *(See Fig. 9)*

7. The **mandible** is the lower jaw bone. Its main horizontal and anterior portion is referred to as the **body,** while the vertical, posterior portion is called the **ramus.** The inferior, anterior part of the mandible, which we might call the "tip of the chin", is known as the **mental eminence.** Like the maxilla, that portion of the mandible into which the teeth are embedded, the superior part of the body, is referred to as the **alveolar process.** The point at which the inferior line of the body of the mandible turns upward is referred to as the angle of the mandible. The **angle** can be easily felt just inferior to the earlobe. The **mandibular condyle** fits into a depression on the temporal bone, called the **mandibular fossa,** to make up the lower jaw joint. *(See Fig. 8)*

8. Each of the two **inferior nasal concha** can be described as a bony ridge, or "ledge", located on the lateral wall of the nasal cavity. Just above the inferior nasal concha on each side of the nasal cavity are the similar middle and superior conchae. However, these are not separate facial bones, as are the inferior conchae, but are considered part of the ethmoid bone. *(See Fig. 8)*

Besides the cranial and facial bones, the skull contains within it three pairs of tiny ear bones referred to as the **auditory ossicles**. Actually, these little bones are located within the middle ear, which is a small cavity within the temporal bone. These bones are all named for their shapes, and are called the **malleus** (hammer), the **incus** (anvil), and the **stapes** (stirrup). They are important to the hearing process, as they are involved in transmitting vibrations which result when sound waves travel down the hearing canal and strike the ear drum. These vibrations result in impulses which are eventually interpreted as sound by the nerves and specialized structures located in the inner ear.

The **hyoid bone** is a horseshoe shaped bone located in the cervical region, just above the voicebox. It is somewhat unique in that it does not directly articulate with any other bone. It serves as a point of attachment for a number of muscles involved with movements in the tongue, mouth and throat areas. *(See Fig. 12)*

The bones of the spinal column, known as the **vertebrae,** are arranged in a way which allows for both strength and support, plus flexibility and movement. *(See Fig. 13)* Although there are some differences in size, shape, and detail, most of the vertebrae are similar in structure. *(See Fig. 14)* There are 26 of them stacked one on top of another to form the main support structure of the body - the spine. A side view of the spine indicates that it is not a perfectly straight column like you might see supporting the front of a colonial style home, but one with significant curvatures. The spinal column serves not only to support the body, but as a protective passageway for the spinal cord, an essential component of the central nervous system. The 26 vertebrae are

usually divided into several main groupings, with the upper seven in the neck area being referred to as **cervical vertebrae**. The most superior of these, or C-1, is also known as the **atlas.** This is the vertebrae which articulates with the occipital bone, and upon which the skull rests. Below the atlas is C-2, or the **axis,** which forms a special articulation with the atlas that allows a pivoting action, enabling the head to be turned from side to side.

The twelve vertebrae inferior to those in the cervical region are designated **thoracic vertebrae**. They could be described as being in the upper back area. They do not have individual names, but are simply designated T -1 through T-12. They do, however, have an important distinction, in that each of them articulates with one of the pairs of ribs. Thus, it makes sense that there would be twelve pairs of ribs to match up with the twelve thoracic vertebrae.

Inferior to the thoracic vertebrae are the five in the lower back area referred to as the **lumbar vertebrae**. They are designated L-1 through L-5.

Immediately inferior to L-5 is the **sacrum,** which is actually a bone resulting from the fusion of five separate vertebrae in a developing child. In addition to the adjacent vertebrae, the sacrum articulates with the two hip bones to help form the pelvis.

The most inferior vertebra, sometimes referred to as the "tail bone", is the **coccyx.** Like the sacrum, the coccyx is a bone which was formed by the fusion of several separate bones in the developmental process.

Besides the skull, hyoid bone, and the spine, the axial skeleton includes the **thorax,** or chest area. The thorax consists of the thoracic vertebrae, the ribs, and the **sternum,** or breastbone. *(See Fig. 15)* The sternum is considered to be a single bone, but was originally three segments during development. The superior segment is called the **manubrium,** the middle segment the **body** or **gladiolus,** and the inferior segment the **xiphoid process**.

There is a total of twelve pairs of ribs, seven of which are attached by their costal cartilages directly to the sternum. These upper seven pairs of ribs are often referred to as **true ribs** as a result of their articulation with the sternum. The bottom five pairs of ribs do not attach directly to the sternum, and are referred to as **false ribs**. Of these, ribs numbered 8, 9, and 10 have cartilages which attach them to the rib above. However, ribs numbered 11 and 12 have no anterior cartilages, and are called **floating ribs.** Posteriorly, each pair of ribs articulates with one of the thoracic vertebrae. *(See Fig. 15)*

Appendicular Skeleton

There are 126 bones in the appendicular skeleton, which consists of the upper and lower extremities, plus the pectoral and pelvic girdles. The pectoral girdle includes the **scapulae,** or shoulder blades, and the **clavicles,** or collar bones. The medial end of the clavicle articulates with the manubrium of the sternum, while the lateral end joins with the superior part of the scapula to help form the shoulder area. The scapula contains several special landmarks, including the **acromion**, which is its superior, lateral projection that articulates

with the clavicle, and the **coracoid process**, which serves as an anchoring point for several muscles. The name of the coracoid process is derived from the Latin words meaning "resembling a crow's beak". *(See Figs. 6 & 7)*

The ball-like superior end of the **humerus,** which is known as the **head,** also articulates with the scapula to form the shoulder joint. *(See Fig. 6 & 7)* The word "humerus", which is the scientific name for the upper arm bone, actually means "shoulder" in Latin. The **glenoid cavity** is a depression on the scapula into which the head of the humerus fits in order to form the shoulder joint. The inferior end of the humerus contains smooth, curved articular surfaces called the **humeral condyles**. These condyles articulate with the **radius** and **ulna** to form the elbow joint. As a matter of fact, the word "ulna" comes from the Latin word meaning "elbow". The ulna is the medial of the two forearm bones, and its superior end, which we commonly think of as our elbow, is called the **olecranon process.** The radius is the lateral bone of the forearm, and both it and the ulna articulate with the wrist bones, or **carpals.** There is a total of eight carpal bones in each wrist. *(See Fig. 19)*

The prefix "meta-" comes from the Latin for "beyond", and so the bones of the hand, which are just beyond the wrist bones, are appropriately called **metacarpals.** There are five metacarpals in each hand.

Finally, making up the fingers, are a series of bones called **phalanges,** which comes from the Greek word for "row". Each finger contains a row of three bones, with only two in the thumb. This makes for a total of 14 phalanges in each upper extremity. They are not individually named, but are simply referred to as the proximal, middle, and distal phalange of each finger. Thus, the bones of the ring finger on the left hand, for example, would be called the third proximal, the third middle, and the third distal phalanges of the left hand.

The hip bones, or **os coxa**, make up the so called pelvic girdle. *(See Fig. 16, 17, 18)* Like the sternum, each os coxa originally developed as three separate pieces, which fuse together to become a single bone. The broad, superior portion of the os coxa is called the **ilium,** from the Latin word for "flank". Its upper rim is called the **iliac crest.** The inferior portion, which is the part we would sit on, is called the **ischium,** from the Greek word for "hip". The inferior, anterior segment, just above the genital region, is called the **pubis,** or **pubic bone**. Another important landmark of the os coxa is the **acetabulum,** which is the cup-like area into which the head of the upper leg bone fits to make up the hip joint. Along with the sacrum and coccyx, the two os coxa help make up the **pelvis.** The upper part of the pelvis, basically above the hip joint, is sometimes called the false pelvis, and the inferior portion is called the true pelvis.

The **femur** is the large bone of the upper leg, or the area we might commonly call the thigh. *(See Fig. 6 & 7)* On its superior end, the femoral head articulates with the os coxa in the acetabulum, and the inferior end of the femur consists of two condyles which articulate with a lower leg bone to make up the knee joint. In addition, the inferior, anterior end of the femur

articulates with the **patella,** or kneecap. The patella slides up and down in a grove on the femur, and serves as an important point of attachment for several muscles of the leg. It is often categorized as a sesamoid bone, due to the fact that it actually develops within the tendon of one of the femoral muscles. By definition, a sesamoid bone is one which is embedded in tendon.

As mentioned earlier, the inferior end of the femur articulates with the top of the **tibia,** or "shin bone". The tibia is considered the medial bone of the lower leg. Along the anterior margin of the tibia is a rather pronounced ridge, referred to as the **tibial crest**. On the distal end of the tibia is the projection referred to as the **medial malleolus**. Although it is not actually a bone of the ankle, the medial malleolus is what we may commonly refer to as our "inside ankle bone". The projection which we might commonly call our "outside ankle bone" is the **lateral malleolus**. It also is not an ankle bone, but the inferior end of the **fibula,** the lateral bone of the lower leg.

The bones which do make up the ankle area are referred to as **tarsals.** There are seven tarsals in each ankle, one of which is the **calcaneus,** or heel bone. The bones of the foot, or those just beyond the ankle, are referred to as **metatarsals.** There are five of these bones in each foot. And, finally, the bones of the toes are called **phalanges,** just as those in the fingers are. They are equal in number to the phalanges of the fingers, there being a total of 14 phalanges in each foot. Thus, as one can readily see, of the 206 classified bones in the human body, over one quarter, or 56 of them, are phalanges. *(See Fig. 21)*

Arthrology

The prefix "arthro-" refers to joints, or articulations, so the term **arthrology** refers to the study of articulations. An articulation is simply a point of union between two bones, or cartilage and bone, and all bones in the body, except the hyoid bone, articulate with other bones. The joints of the body are often categorized based on the relative amount of movement which exists at the joint. The first of these categories is called a **synarthrosis,** or an immovable articulation. At this type of joint, there is no movement intended by the body. A good example of synarthroses are the **cranial sutures**, which is the name given to the point at which the bones of the cranium come together. The edges of these bones have tightly interlocking teeth-like processes which hold them firmly together. The sternocostal articulations, or the point at which the ribs attach to the sternum, are another example of synarthroses.

Amphiarthroses, or slightly movable articulations, allow a small amount of movement at the joint. Unlike synarthroses, there is often a piece of specialized cartilage separating the two bones in an amphiarthrosis. For example, the **pubic symphysis**, or the point at which the two pubic bones join at the median plane, is classified as an amphiarthrosis. Also, the **sacro-iliac articulation**, where the sacrum meets up with the two os coxae, is another example of a slightly movable articulation. A final example of amphiarthroses are the intervertebral articulations, between the bodies of the vertebrae. Some movement is necessary at these points in order for the body to be able to twist and

bend in its normal fashion. Most of the vertebrae are separated by disc-shaped pads of cartilage, which provide needed cushioning between the bones.

The third major category of articulations are the **diarthroses,** or freely movable articulations. These types of joints allow significant movement - sometimes only in one direction, and sometimes in several directions. As opposed to other joints, diarthroses are characterized by the fact that they posses a sleeve, or capsule, which surrounds the joint. Within this capsule is the joint cavity, which is lined with a smooth, connective tissue membrane called synovial membrane. This membrane secretes a lubricating fluid to reduce friction in the joint. Also present in these types of joints are layers of articular cartilage which cover the ends of the bones forming the joints. Diarthroses are the most numerous of the articulations in the body. Examples of freely movable articulations are those in the hip, knee, elbow, and shoulder areas.

Ligaments are tough bands of fibrous connective tissue which help to stabilize a diarthritic joint. They actually help hold the two bones together in their proper position, and restrict movement from occurring in the wrong direction. However, sudden and excessive force applied to a joint can cause a tearing of these ligaments. Torn knee ligaments are a common athletic type of injury, especially when strong force is applied to the knee area from the side, or when the knee twists abnormally while bearing weight.

Closely associated with most freely movable joints, but also found in other areas of the body, are small, fluid-filled sacs called **bursae.** Bursae provide additional cushioning and friction reducing properties to areas of the body where a lot of movement occurs. They are usually found in such areas as where tendons rub over bones, between ligaments and bones, or between muscles and bones.