

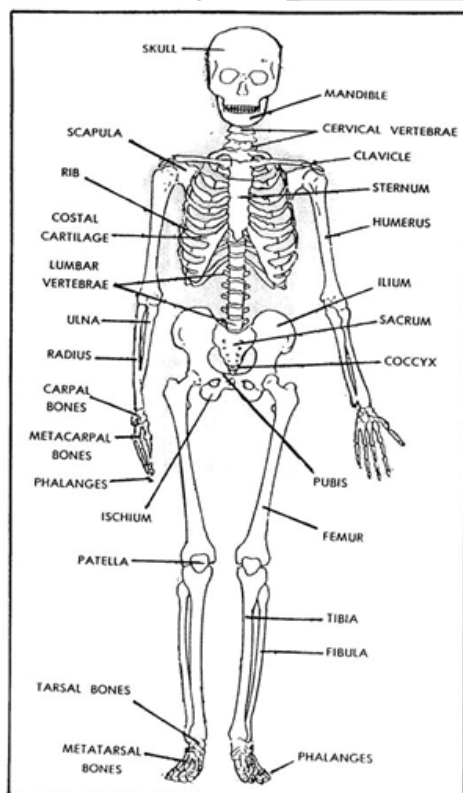
Biology

SKELETAL SYSTEM

Chapter

The skeletal system includes all of the bones and joints in the body. Each bone is a complex living organ that is made up of many cells, protein fibers, and minerals. The skeleton acts as a scaffold by providing support and protection for the soft tissues that make up the rest of the body. The skeletal system also provides attachment points for muscles to allow movements at the joints. New blood cells are produced by the red bone marrow inside of our bones. Bones act as the body's warehouse for calcium, iron, and energy in the form of fat. Finally, the skeleton grows throughout childhood and provides a framework for the rest of the body to grow along with it.

ANATOMY



The skeletal system in an adult body is made up of 206 individual bones. These bones are arranged into two major divisions: the axial skeleton and the appendicular skeleton. The axial skeleton runs along the body's midline axis and is made up of 80 bones in the following regions:

- ☐ Skull
- ☐ Hyoid
- ☐ Auditory ossicles
- ☐ Ribs
- ☐ Sternum
- ☐ Vertebral column
- ☐ The appendicular skeleton is made up of 126 bones in the following regions:
 - ☐ Upper limbs
 - ☐ Lower limbs
 - ☐ Pelvic girdle
 - ☐ Pectoral (shoulder) girdle

Skull

The skull is composed of 22 bones that are fused together except for the mandible. These 21 fused bones are separate in children to allow the skull and brain to grow, but fuse to give added strength and protection as an adult. The mandible remains as a movable jaw bone and forms the only movable joint in the skull with the temporal bone. The bones of the superior portion of the skull are known as the cranium and protect the brain from damage. The bones of the inferior and anterior portion of the skull are known as facial bones and support the eyes, nose, and mouth.

Hyoid and Auditory Ossicles

The hyoid is a small, U-shaped bone found



just inferior to the mandible. The hyoid is the only bone in the body that does not form a joint with any other bone—it is a floating bone. The hyoid's function is to help hold the trachea open and to form a bony connection for the tongue muscles. The malleus, incus, and stapes—known collectively as the auditory ossicles—are the smallest bones in the body. Found in a small cavity inside of the temporal bone, they serve to transmit and amplify sound from the eardrum to the inner ear.

Vertebrae

Twenty-six vertebrae form the vertebral column of the human body. They are named by region:

Cervical (neck) - 7 vertebrae

Thoracic (chest) - 12 vertebrae

Lumbar (lower back) - 5 vertebrae

Sacrum - 1 vertebra

Coccyx (tailbone) - 1 vertebra

With the exception of the singular sacrum and coccyx, each vertebra is named for the first letter of its region and its position along the superior-inferior axis. For example, the most superior thoracic vertebra is called T1 and the most inferior is called T12.

Ribs and Sternum

The sternum, or breastbone, is a thin, knife-shaped bone located along the midline of the anterior side of the thoracic region of the skeleton. The sternum connects to the ribs by thin bands of cartilage called the costal cartilage. There are 12 pairs of ribs that together with the sternum form the ribcage of the thoracic region. The first seven ribs are known as "true ribs" because they connect the thoracic vertebrae directly to the sternum through their own band of costal cartilage. Ribs 8, 9, and 10 all connect to the sternum through cartilage that is connected to the

cartilage of the seventh rib, so we consider these to be "false ribs." Ribs 11 and 12 are also false ribs, but are also considered to be "floating ribs" because they do not have any cartilage attachment to the sternum at all.

Pectoral Girdle and Upper Limb

The pectoral girdle connects the upper limb (arm) bones to the axial skeleton and consists of the left and right clavicles and left and right scapulae.

The humerus is the bone of the upper arm. It forms the ball and socket joint of the shoulder with the scapula and forms the elbow joint with the lower arm bones. The radius and ulna are the two bones of the forearm. The ulna is on the medial side of the forearm and forms a hinge joint with the humerus at the elbow. The radius allows the forearm and hand to turn over at the wrist joint.

The lower arm bones form the wrist joint with the carpals, a group of eight small bones that give added flexibility to the wrist. The carpals are connected to the five metacarpals that form the bones of the hand and connect to each of the fingers. Each finger has three bones known as phalanges, except for the thumb, which only has two phalanges.

Pelvic Girdle and Lower Limb

Formed by the left and right hip bones, the pelvic girdle connects the lower limb (leg) bones to the axial skeleton.

The femur is the largest bone in the body and the only bone of the thigh (femoral) region. The femur forms the ball and socket hip joint with the hip bone and forms the knee joint with the tibia and patella. Commonly called the kneecap, the patella is special because it is one of the few bones that are not present at birth. The patella forms in early childhood to support the knee for walking and crawling.

The tibia and fibula are the bones of the lower



leg. The tibia is much larger than the fibula and bears almost all of the body's weight. The fibula is mainly a muscle attachment point and is used to help maintain balance. The tibia and fibula form the ankle joint with the talus, one of the seven tarsal bones in the foot.

The tarsals are a group of seven small bones that form the posterior end of the foot and heel. The tarsals form joints with the five long metatarsals of the foot. Then each of the metatarsals forms a joint with one of the set of phalanges in the toes. Each toe has three phalanges, except for the big toe, which only has two phalanges.

Microscopic Structure of Bones

The skeleton makes up about 30-40% of an adult's body mass. The skeleton's mass is made up of nonliving bone matrix and many tiny bone cells. Roughly half of the bone matrix's mass is water, while the other half is collagen protein and solid crystals of calcium carbonate and calcium phosphate.

Living bone cells are found on the edges of bones and in small cavities inside of the bone matrix. Although these cells make up very little of the total bone mass, they have several very important roles in the functions of the skeletal system. The bone cells allow bones to:

- ❑ Grow and develop
- ❑ Be repaired following an injury or daily wear
- ❑ Be broken down to release their stored minerals

Types of Bones

All of the bones of the body can be broken down into five types:

Long

Long bones are longer than they are wide and are the major bones of the limbs. Long bones grow more than the other classes of bone

throughout childhood and so are responsible for the bulk of our height as adults. A hollow medullary cavity is found in the center of long bones and serves as a storage area for bone marrow. Examples of long bones include the femur, tibia, fibula, metatarsals, and phalanges.

Short

Short bones are about as long as they are wide and are often cubed or round in shape. The carpal bones of the wrist and the tarsal bones of the foot are examples of short bones.

Flat

Flat bones vary greatly in size and shape, but have the common feature of being very thin in one direction. Because they are thin, flat bones do not have a medullary cavity like the long bones. The frontal, parietal, and occipital bones of the cranium—along with the ribs and hip bones—are all examples of flat bones.

Irregular

Irregular bones have a shape that does not fit the pattern of the long, short, or flat bones. The vertebrae, sacrum, and coccyx of the spine—as well as the sphenoid, ethmoid, and zygomatic bones of the skull—are all irregular bones.

Sesamoid

The sesamoid bones are formed after birth inside of tendons that run across joints. Sesamoid bones grow to protect the tendon from stresses and strains at the joint and can help to give a mechanical advantage to muscles pulling on the tendon. The patella and the pisiform bone of the carpals are the only sesamoid bones that are counted as part of the 206 bones of the body. Other sesamoid bones can form in the joints of the hands and feet, but are not present in all people.



Parts of Bones

The long bones of the body contain many distinct regions due to the way in which they develop. At birth, each long bone is made of three individual bones separated by hyaline cartilage. Each end bone is called an epiphysis (epi = on; physis = to grow) while the middle bone is called a diaphysis (dia = passing through). The epiphyses and diaphysis grow towards one another and eventually fuse into one bone. The region of growth and eventual fusion in between the epiphysis and diaphysis is called the metaphysis (meta = after). Once the long bone parts have fused together, the only hyaline cartilage left in the bone is found as articular cartilage on the ends of the bone that form joints with other bones. The articular cartilage acts as a shock absorber and gliding surface between the bones to facilitate movement at the joint.

Compact bone is made of a matrix of hard mineral salts reinforced with tough collagen fibers. Many tiny cells called osteocytes live in small spaces in the matrix and help to maintain the strength and integrity of the compact bone. Deep to the compact bone layer is a region of spongy bone where the bone tissue grows in thin columns called trabeculae with spaces for red bone marrow in between. The trabeculae grow in a specific pattern to resist outside stresses with the least amount of mass possible, keeping bones light but strong. Long bones have a spongy bone on their ends but have a hollow medullary cavity in the middle of the diaphysis. The medullary cavity contains red bone marrow during childhood, eventually turning into yellow bone marrow after puberty.

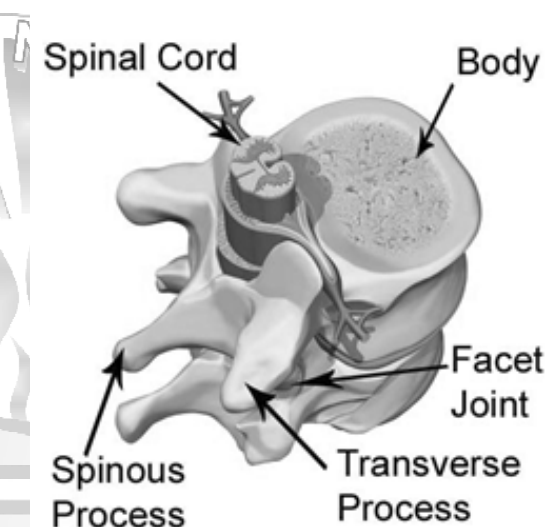
Articulations

An articulation, or joint, is a point of contact between bones, between a bone and cartilage, or between a bone and a tooth.

Types of Joints

A joint is the point where two or more bones meet. There are three main types of joints; Fibrous (immovable), Cartilaginous (partially moveable) and the Synovial (freely moveable) joint.

Fibrous (synarthrodial): This type of joint is held together by only a ligament. Examples are where the teeth are held to their bony sockets and at both the radioulnar and tibiofibular joints.



Cartilaginous (synchondroses and sympheses): These joints occur where the connection between the articulating bones is made up of cartilage for example between vertebrae in the spine.

Diagram: A cartilaginous joint between two vertebrae

Synchondroses are temporary joints which are only present in children, up until the end of puberty. For example the epiphyseal plates in long bones. Symphysis joints are permanent cartilaginous joints, for example the pubic symphysis.


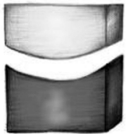






Synovial Joints


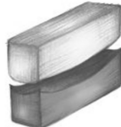

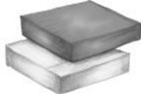
Synovial (diarthrosis): Synovial joints are by far the most common classification of joint



within the human body. They are highly moveable and all have a synovial capsule (collagenous structure) surrounding the entire joint, a synovial membrane (the inner layer of the capsule) which secretes synovial fluid (a lubricating liquid) and cartilage known as hyaline cartilage which pads the ends of the articulating bones. There are 6 types of synovial joints which are classified by the shape of the joint and the movement available.

Types of Synovial Joint

Joint Type	Movement at joint	Examples	Structure
Hinge	Flexion/Extension		
Pivot	Rotation of one bone around another	 Top of the neck (atlas and axis bones)	 Pivot Joint
Ball and Socket	Flexion/Extension/Adduction/Abduction/Internal & External Rotation	 Shoulder/Hip	 Ball and socket joint
Saddle	Flexion/Extension/Adduction/Abduction/Circumduction	 CMC joint of the thumb	 Saddle joint

Condyloid	Flexion/Extension/Adduction/Abduction/Circumduction	 Wrist/MCP & MTP joints	 Condyloid joint
Gliding	Gliding movements	 Intercarpal joints	 Gliding joint

PHYSIOLOGY

Support and Protection

The skeletal system's primary function is to form a solid framework that supports and protects the body's organs and anchors the skeletal muscles. The bones of the axial skeleton act as a hard shell to protect the internal organs—such as the brain and the heart—from damage caused by external forces. The bones of the appendicular skeleton provide support and flexibility at the joints and anchor the muscles that move the limbs.

Movement

The bones of the skeletal system act as attachment points for the skeletal muscles of the body. Almost every skeletal muscle works by pulling two or more bones either closer together or further apart. Joints act as pivot points for the movement of the bones. The regions of each bone where muscles attach to the bone grow larger and stronger to support the additional force of the muscle. In addition, the overall mass and thickness of a bone increase when it is under a lot of stress from lifting weights or supporting body weight.

Hematopoiesis

Red bone marrow produces red and white blood cells in a process known as



hematopoiesis. Red bone marrow is found in the hollow space inside of bones known as the medullary cavity. Children tend to have more red bone marrow compared to their body size than adults do, due to their body's constant growth and development. The amount of red bone marrow drops off at the end of puberty, replaced by yellow bone marrow.

Storage

The skeletal system stores many different types of essential substances to facilitate growth and repair of the body. The skeletal system's cell matrix acts as our calcium bank by storing and releasing calcium ions into the blood as needed. Proper levels of calcium ions in the blood are essential to the proper function of the nervous and muscular systems. Bone cells also release osteocalcin, a hormone that helps regulate blood sugar and fat deposition. The yellow bone marrow inside of our hollow long bones is used to store energy in the form of lipids. Finally, red bone marrow stores some iron in the form of the molecule ferritin and uses this iron to form hemoglobin in red blood cells.

Growth and Development

The skeleton begins to form early in fetal development as a flexible skeleton made of hyaline cartilage and dense irregular fibrous connective tissue. These tissues act as a soft, growing framework and placeholder for the bony skeleton that will replace them. As development progresses, blood vessels begin to grow into the soft fetal skeleton, bringing stem cells and nutrients for bone growth. Osseous tissue slowly replaces the cartilage and fibrous tissue in a process called calcification. The calcified areas spread out from their blood vessels replacing the old tissues until they reach the border of another bony area. At birth, the skeleton of a newborn

has more than 300 bones; as a person ages, these bones grow together and fuse into larger bones, leaving adults with only 206 bones.

Flat bones follow the process of intramembranous ossification where the young bones grow from a primary ossification center in fibrous membranes and leave a small region of fibrous tissue in between each other. In the skull these soft spots are known as fontanels, and give the skull flexibility and room for the bones to grow. Bone slowly replaces the fontanels until the individual bones of the skull fuse together to form a rigid adult skull.

Long bones follow the process of endochondral ossification where the diaphysis grows inside of cartilage from a primary ossification center until it forms most of the bone. The epiphyses then grow from secondary ossification centers on the ends of the bone. A small band of hyaline cartilage remains in between the bones as a growth plate. As we grow through childhood, the growth plates grow under the influence of growth and sex hormones, slowly separating the bones. At the same time the bones grow larger by growing back into the growth plates. This process continues until the end of puberty, when the growth plate stops growing and the bones fuse permanently into a single bone. The vast difference in height and limb length between birth and adulthood are mainly the result of endochondral ossification in the long bones.

Clinical disorders

Bones, tendons, ligaments and cartilage make up the skeletal system. The primary function of the skeletal system is providing support for the body to maintain posture and movement. The skeletal system protects the internal organs such as the brain and heart. Diseases affecting the skeletal system break down the bones or connecting tissues that allow the system to protect the body and function properly.



Fractures

AA broken bone or bone fracture occurs when a force exerted against a bone is stronger than the bone can bear. This disturbs the structure and strength of the bone, and leads to pain, loss of function and sometimes bleeding and injury around the site. Common bone fractures include the wrist, ankle and hip. Hip fractures occur most often in older people. Broken bones take around four to eight weeks to heal, depending on the age and health of the person and the type of break.

Types of bone fracture

Different types of fracture include:

- ❑ Closed (simple) fracture – the broken bone has not pierced the skin
- ❑ Open (compound) fracture – the broken bone juts out through the skin, or a wound leads to the fracture site. Infection and external bleeding are more likely
- ❑ Greenstick fracture – a small, slender crack in the bone. This can occur in children, because their bones are more flexible than an adult's bones
- ❑ Hairline fracture – the most common form is a stress fracture, often occurring in the foot or lower leg as a result of repeated stress from activities such as jogging or running
- ❑ Complicated fracture – structures surrounding the fracture are injured. There may be damage to the veins, arteries or nerves, and there may also be injury to the lining of the bone (the periosteum)
- ❑ Comminuted fracture – the bone is shattered into small pieces. This type of complicated fracture tends to heal more slowly
- ❑ Avulsion fracture – muscles are anchored

to bone with tendons, a type of connective tissue. Powerful muscle contractions can wrench the tendon free and pull out pieces of bone. This type of fracture is more common in the knee and shoulder joints

- ❑ Compression fracture – occurs when two bones are forced against each other. The bones of the spine, called vertebrae, can have this type of fracture. Older people, particularly those with osteoporosis, are at higher risk.

Treatment

- ❑ Casting—After the broken bones have been manipulated back into their proper positions, a plaster or fiberglass cast is applied to keep the bones from moving while they heal.
- ❑ External fixation—Pins or wires are set into the bone through the skin above and below the fracture. These are connected to a ring or a bar outside the skin that holds the pins in place. After the bones have healed, the pins are removed.
- ❑ Internal fixation—In a surgical procedure, metal rods, wires, or screws are inserted in the bone fragments to keep them together.

Arthritis

It is a joint disorder causing inflammation and pain in the affected area. There are several forms of arthritis. The most common is osteoarthritis and rheumatoid arthritis. Osteoarthritis is a chronic degenerative joint disease. The breakdown of cartilage in this form of arthritis leads to the bones rubbing together, causing stiffness, pain and eventual loss of movement in the joint. Rheumatoid arthritis, also a chronic disease, is characterized by inflammation in the lining of the joints. Both forms of arthritis can progress



and become debilitating, causing loss of normal functioning in daily life. The cause of arthritis is difficult to determine. Risk factors may include genetics, age, weight and previous injury to the joints. Treatments for arthritis include medication, physical therapy and possible surgery options

Osteoporosis

Osteoporosis causes low bone mass and structural deterioration of bone tissue. This increases fragility of bones and may be prevented as well as treated upon onset. Osteoporosis statistics indicate women are currently at higher risk than men for development of this disease due to risk factors of small frame and less bone tissue volume. Simple prevention methods such as healthy nutrition habits, increased calcium in daily diet and exercise may decrease risk of developing this disease. Osteoporosis treatment includes nutrition planning, exercise and hormone therapy. Osteoporosis is one disease of the skeletal system. It is characterized by an abnormally high decrease in the amount of bone tissue in the skeleton (see picture below). This decrease in bone mass substantially reduces the amount of strength that bones have. These brittle bones are far more susceptible to fracture than strong bones. Osteoporosis is usually clinically "silent" until a fracture occurs. Decreased bone mass is one

of the leading causes of bone fracture in the country.

Leukaemia

Leukemia is a cancer influenced heavily by the skeletal system. Although it is a condition that primarily affects the blood, leukaemia is still associated with the skeleton because it begins in the marrow of the bone.

Blood cell development, or hematopoiesis, begins with immature stem cells in marrow which may produce any of the three types of blood cells (erythrocytes, leukocytes, and thrombocytes). Molecules called growth factors act upon them, and they divide rapidly, becoming blast cells. The blast cells eventually become one of the three blood cell types.

In a person with Lukaemia, there is a dramatic increase in the number of leukocytes produced. Cancerous leukocytes are not able to fight disease like normal leukocytes. The bone marrow becomes crowded with abnormal leukocytes, leading to a decrease in the production of red blood cells and platelets. A lack of these blood cells leads to weakness and profuse bleeding. Patients of leukemia are very susceptible to infections because of the decrease in normal leukocytes. Leukemia can also lead to *dysfunctions* of various organs due to accumulations of abnormal leukocytes in the blood.

