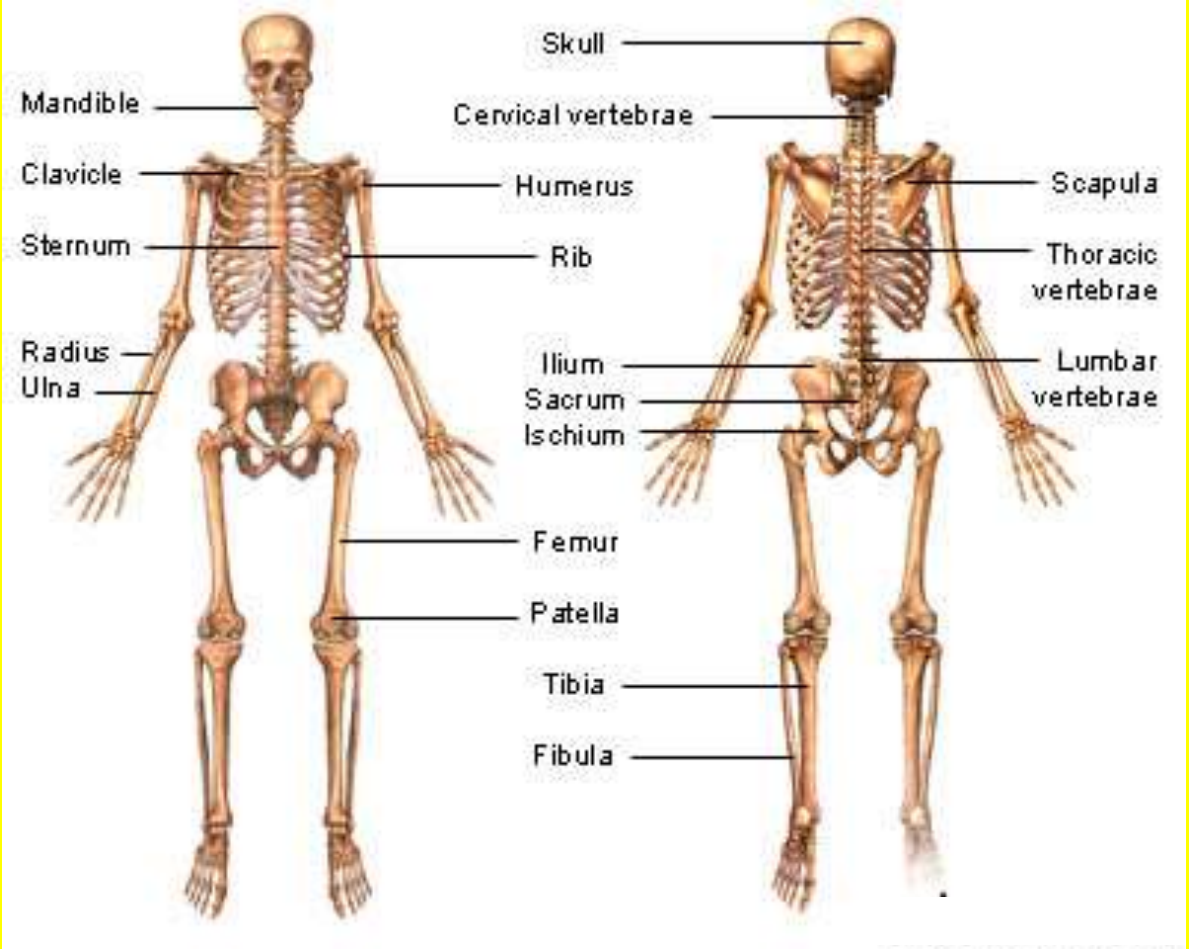

Anatomy &
Physiology
SKELETAL SYSTEM

What is the skeletal system?

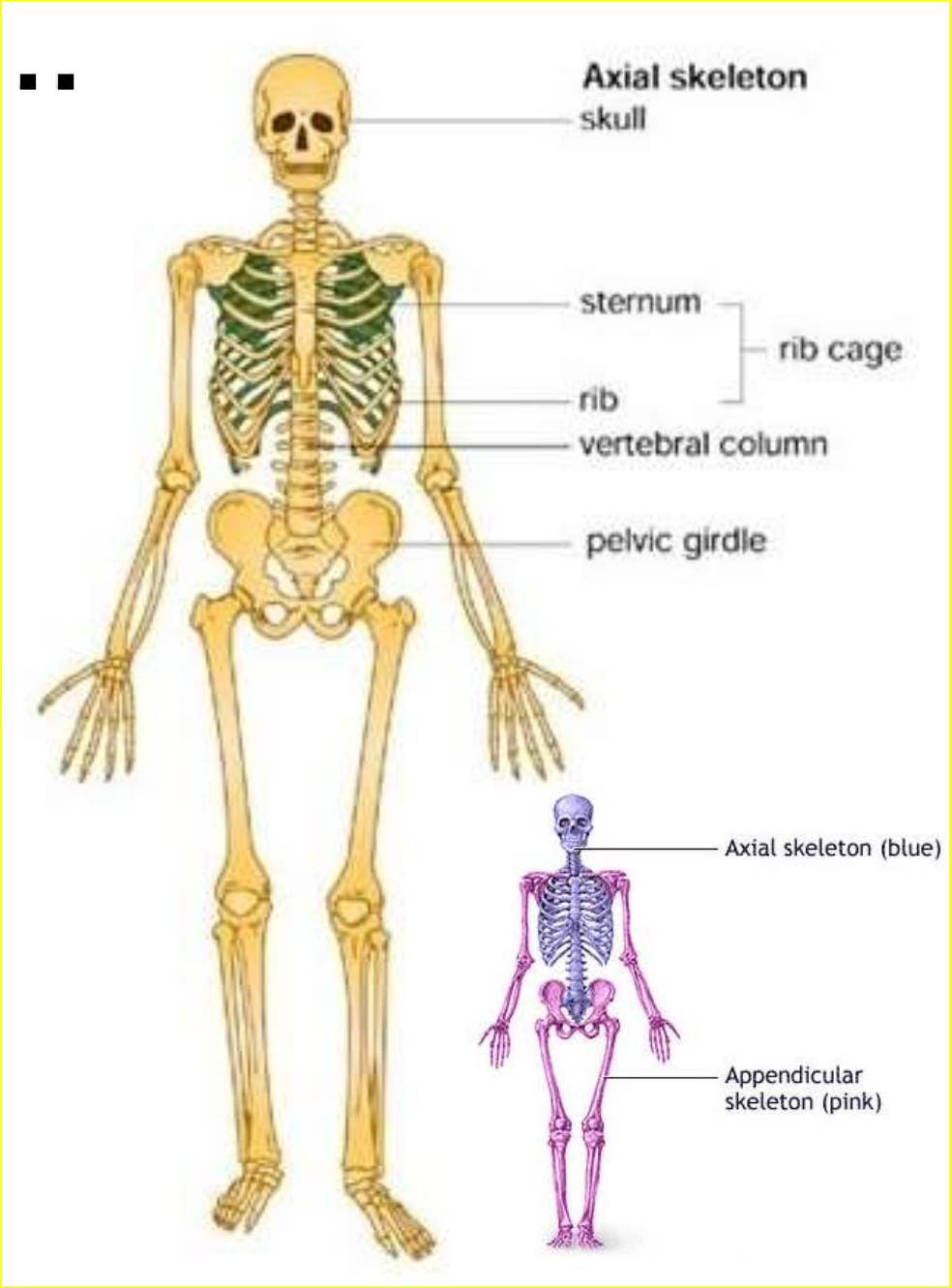


The adult skeletal system is composed of 206 bones that, along with cartilage, tendons, and ligaments, make up the framework or skeleton of the body.

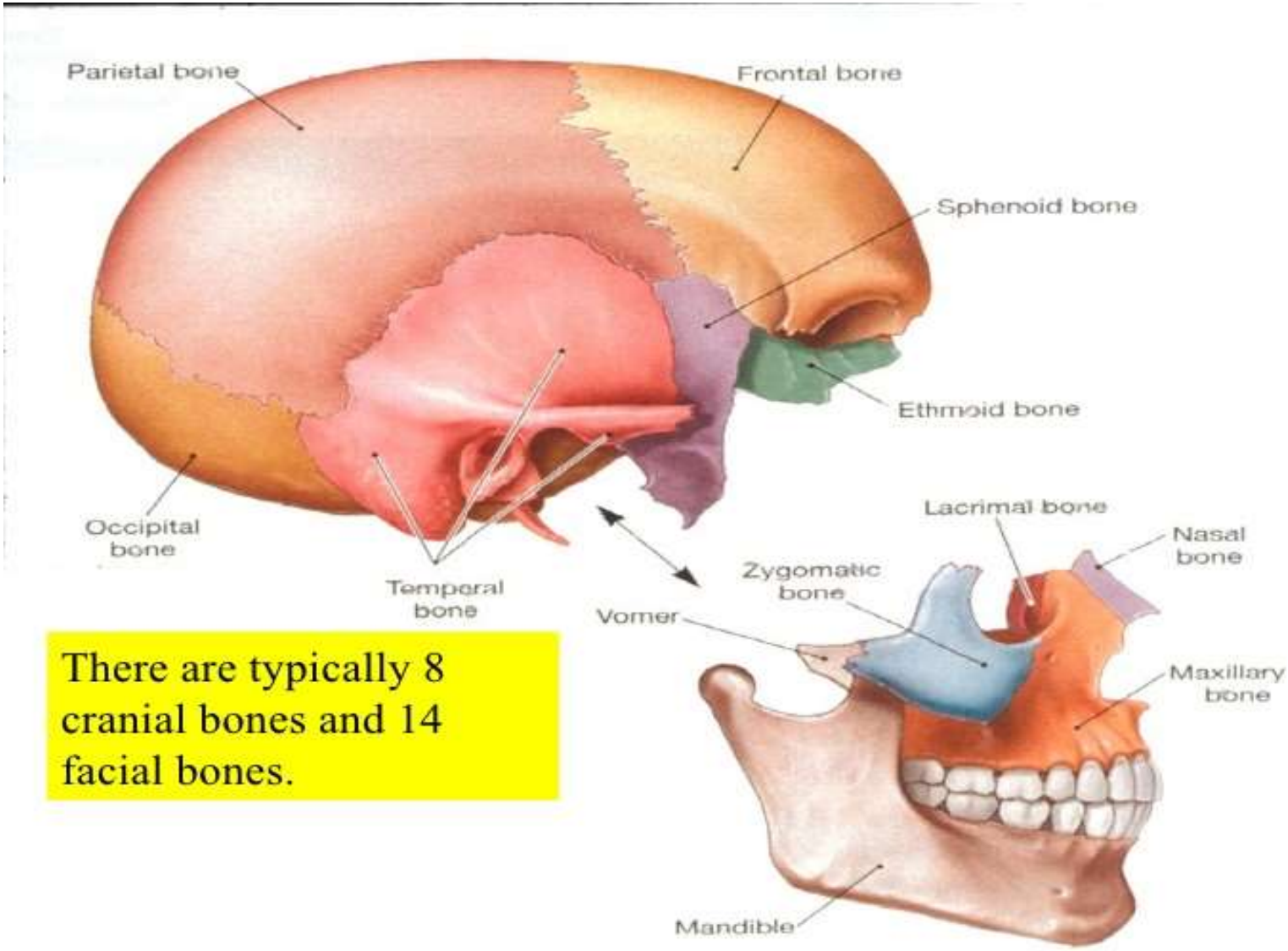
Axial skeleton…

The skeleton can be divided into two main parts. The axial skeleton consists of 80 bones. The primary bones of the axial skeleton are the skull, spine, ribs and sternum (thorax).

The adult skull consist of 22 bones, which is further classified into cranial(8 bones) and facial (14).



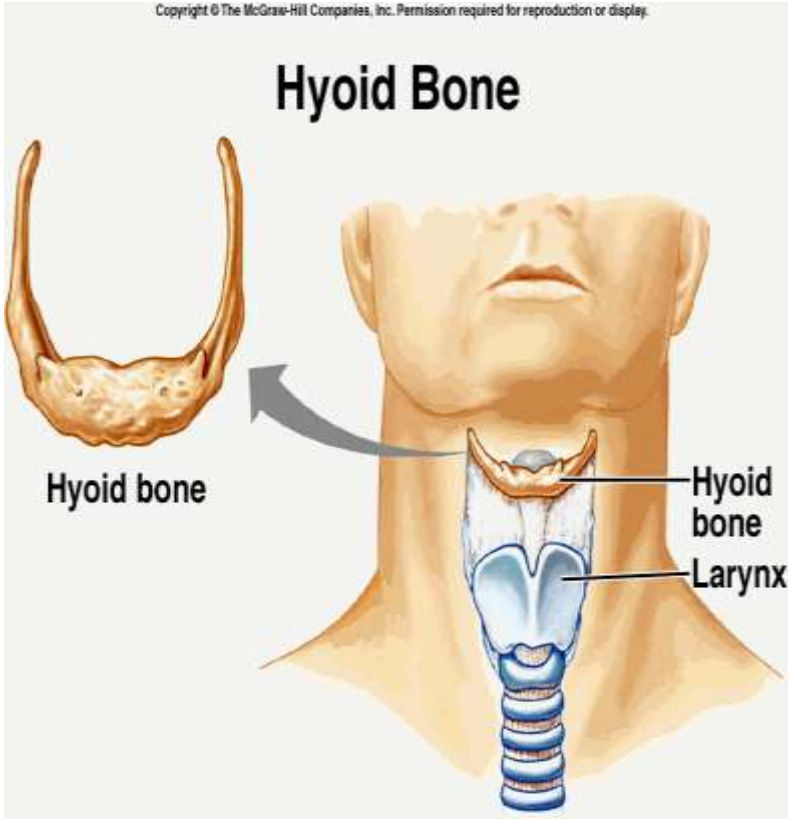
SKULL AND FACIAL BONES



There are typically 8 cranial bones and 14 facial bones.

Auditory and Hyoid bones

- The auditory ossicles are six small bones found within the inner ear canal in the skull. There are three auditory ossicles on each side of the head, known as the: Malleus, incus and stapes
- They work together to transmit sound waves from the surrounding environment to the structures of the inner ear.
- The hyoid is a U-shaped bone found at the base of the jaw. It serves as a point of attachment for muscles and ligaments in the neck.
- It is the only bone that does not articulate with another bone.
- It acts as a moveable base for the tongue and for the muscles that raise and lower the larynx for speech and swallowing



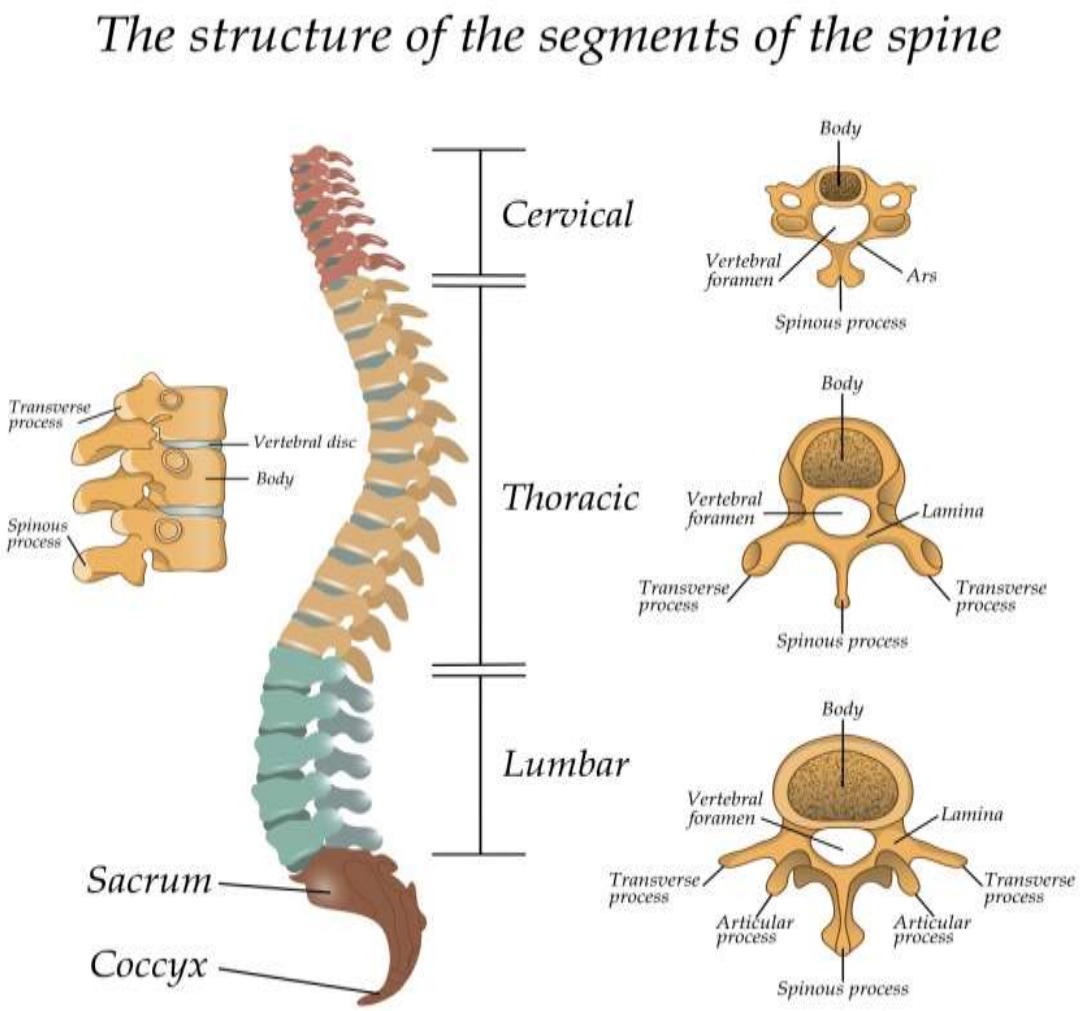
Vertebral column

The vertebral column is made up 26 bones. The first 24 are all vertebrae, followed by the sacrum and coccyx (tailbone).

The 24 vertebrae can be further divided into the:

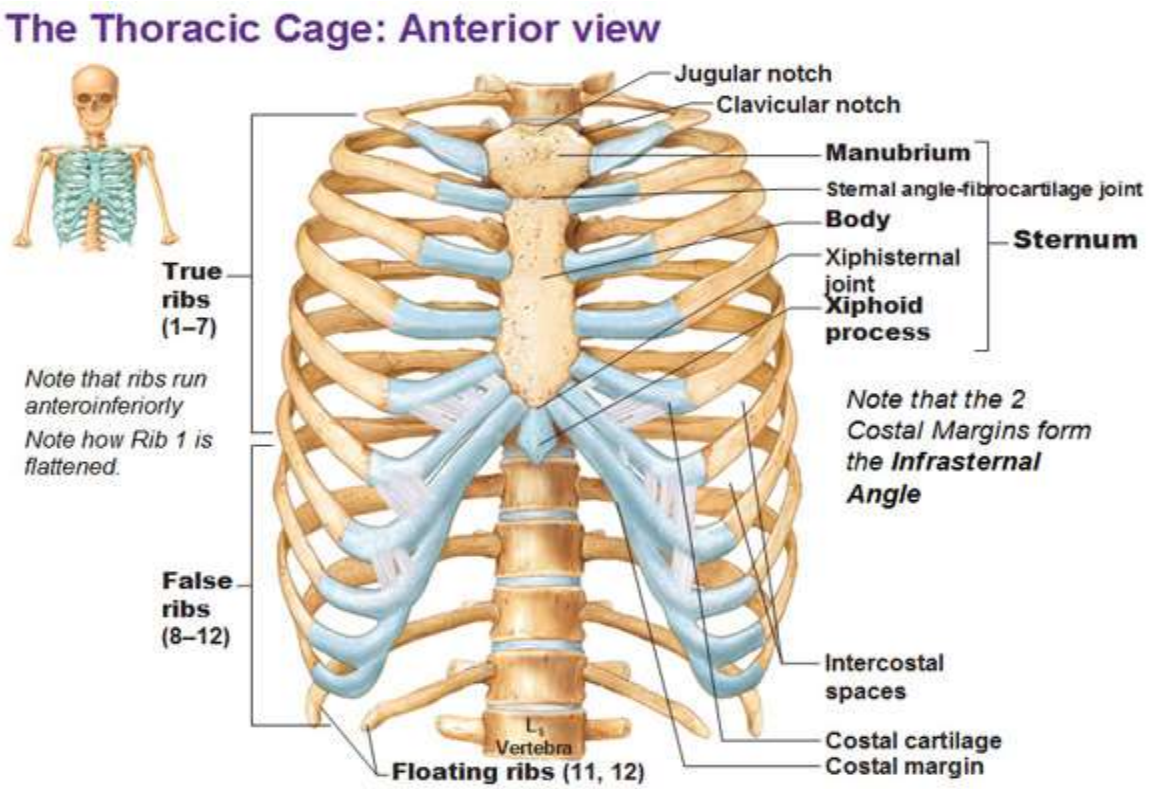
- **Cervical vertebrae.** These seven bones are found in the head and neck (C1-C7).
- **Thoracic vertebrae.** These 12 bones are found in the upper back(T1-T12).
- **Lumbar vertebrae.** These five bones are found in the lower back(L1-L5).

The curved structure gives the spinal column great strength and shock-absorbing qualities.



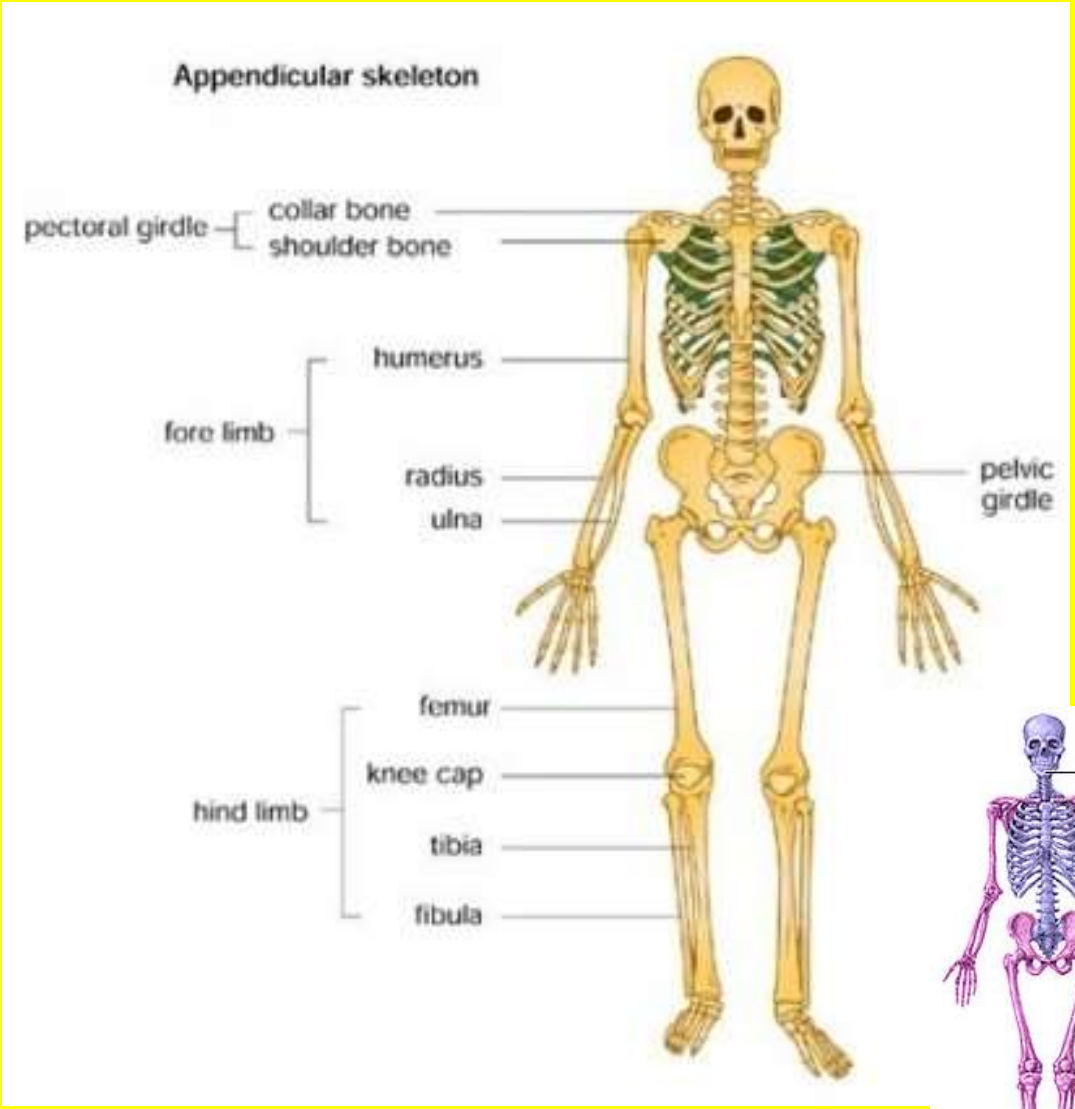
The sacrum and coccyx(Tailbone) are both made up of several fused vertebrae. They help support the weight of the body while sitting. They also serve as attachment points for various ligaments.

Thoracic cage

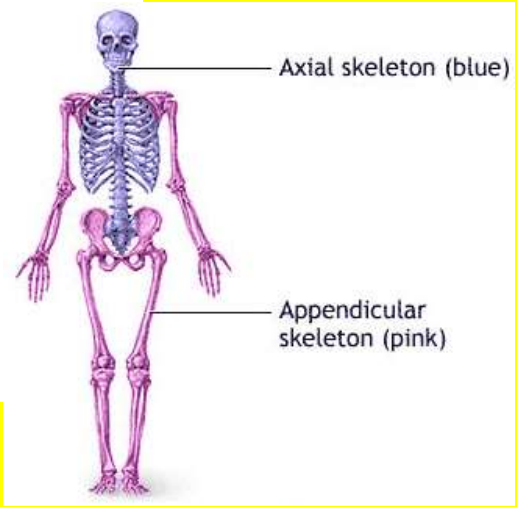


- The thoracic cage is made up of the sternum (breastbone) and 12 pairs of ribs. These bones form a protective cage around the organs of the upper torso, including the heart and lungs.
- Some of the ribs attach directly to the sternum, while others are linked to the sternum via cartilage. Some have no attachment point and are referred to as “floating ribs.”

Appendicular skeleton…

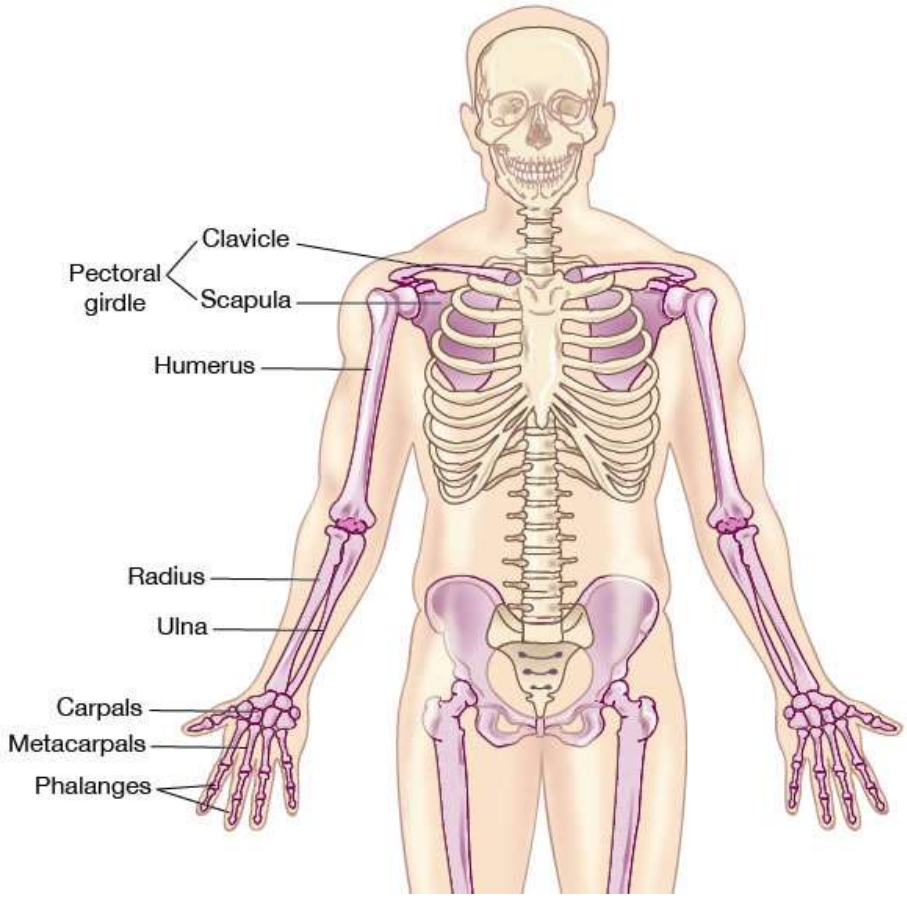


The appendicular skeleton consists of 126 bones. The primary bones of this skeleton are the shoulder or pectoral girdle, arms, hands, pelvic girdle, legs, and feet.



pectoral girdle and upper limb

- The pectoral girdle is where the arms attach to the axial skeleton. It's made up of the clavicle (collarbone) and scapula (shoulder blade).
- Each arm contains 30 bones, known as the:
- **Humerus.** The humerus is the long bone of the upper arm.
- **Radius.** The radius is one of two long bones of the forearm, found on the thumb side.
- **Ulna.** The ulna is the second long bone of the forearm, found on the pinky finger side.
- **Carpals.** The carpals are a group of eight bones found in the wrist area.



•**Metacarpals.** The metacarpals are five bones found in the middle area of the hand.

•**Phalanges.** The phalanges are 14 bones that make up the fingers.

pelvic girdle and lower limb

The pelvic girdle, commonly known as the hips, is where the legs attach to the axial skeleton. It's made up of two hipbones — one for each leg.

Each hip bone consists of three parts, known as the:

•**Ilium.** The ilium is the top portion of each hip bone.

•**Ischium.** The ischium is a curved bone that makes up the base of each hip bone.

•**Pubis.** The pubis is located in the front part of the hip bone

Each leg is composed of 30 bones, known as the:

•**Femur.** The femur is the large bone of the upper leg.

•**Tibia.** The tibia is the main bone of the lower leg. It forms the shin.

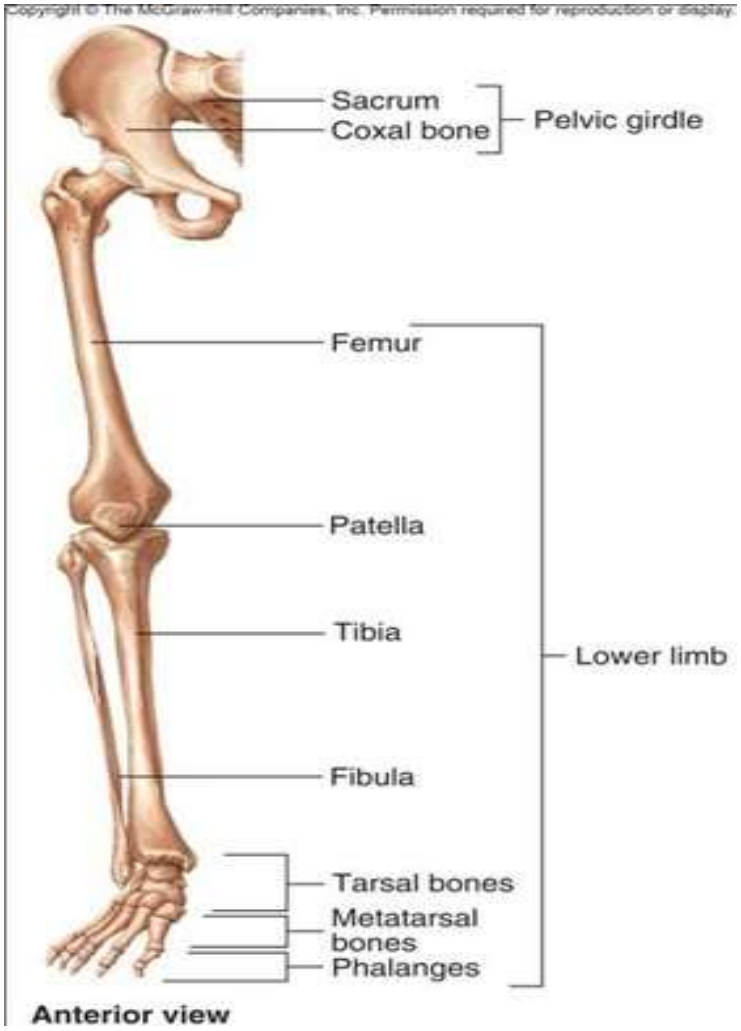
•**Fibula.** The fibula is the second bone in the lower leg, found in the outer leg.

•**Patella.** The patella is also called the kneecap.

•**Tarsals.** The tarsals are the seven bones that make up the ankle.

•**Metatarsal.** The metatarsals are the five bones that make up the middle area of the foot.

•**Phalanges.** The phalanges are 14 bones that comprise the toes.



What is the function of the skeletal system?

- The skeletal system's main function is to provide support for the body. For example, the spinal column provides support for the head and torso. The legs, on the other hand, support and bear the weight of the upper body while a person stands.

But the skeletal system has several additional functions, including:

- **Protecting internal organs from injury.** For example, the skull protects the brain, while the thoracic cage protects the heart and lungs.
- **Allowing for movement.** Muscles attach to bones through tendons. This connection allows the body to move in many different ways.
- **Producing blood cells.** The soft bone marrow inside of many bones produces red blood cells, white blood cells, and platelets.
- **Storing minerals and nutrients.** Bones can store and release minerals, including calcium and phosphorus, which are important for many bodily functions. Additionally, adipose (fat) tissue that can be used as energy can be found in part of the bone marrow.

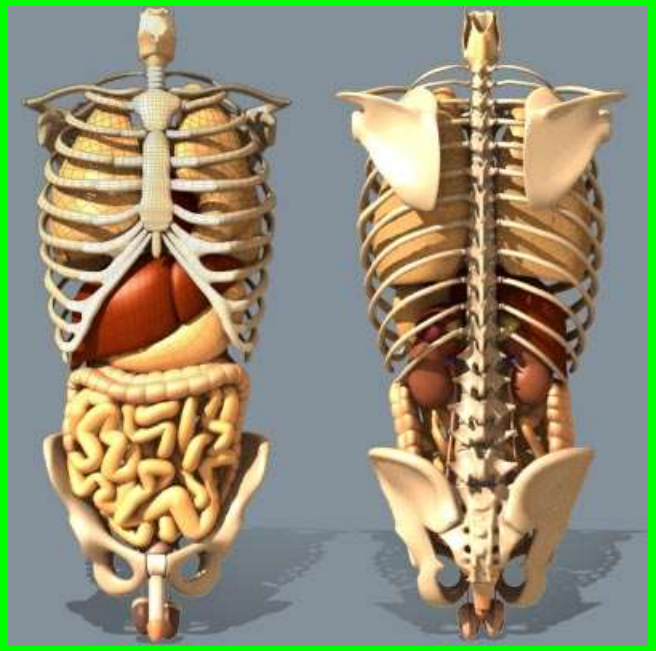
Bone Cells and Matrix

- **Histology** is the study of the microanatomy of cells, tissues, and organs as seen through a microscope.
- Bone is a strong, flexible and semi-rigid supporting tissue. It can withstand compression forces, and yet it can bend. Like cartilage, and other types of connective tissue, bone is made up of **Cells** and **Extracellular matrix**:
- The fundamental components of bone, like all connective tissues, are cells and matrix. There are three key cells of bone tissue. They each have unique functions and are derived from two different cell lines.
- Osteoblasts synthesize the bone matrix and are responsible for its mineralization. They are derived from osteoprogenitor cells, a mesenchymal stem cell line.
- Osteocytes are inactive osteoblasts that have become trapped within the bone they have formed.
- Osteoclasts break down bone matrix through phagocytosis. Their activity occurs along their ruffled border, and the space between the osteoclast and the bone is known as Howship's lacuna.

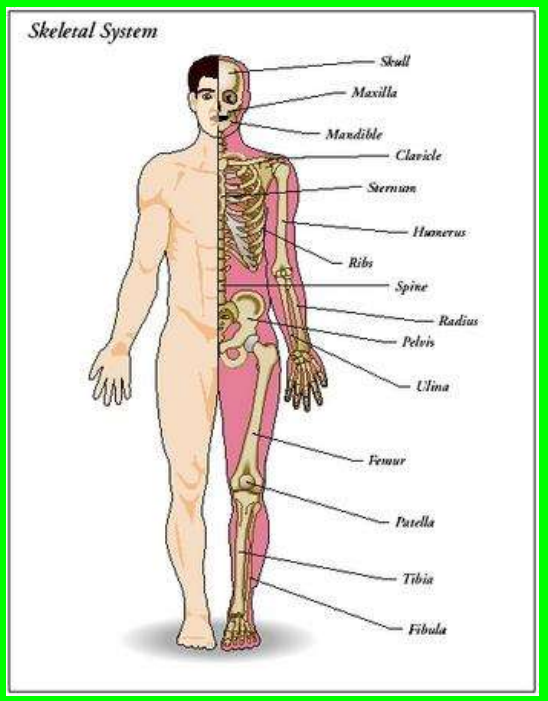
Bone Matrix

- **Extracellular matrix**, which is made up of an organic matrix (30%) containing proteoglycans (but less than cartilage), glycosaminoglycans, glycoproteins, osteonectin (anchors bone mineral to collagen) and osteocalcin (calcium binding protein). There are collagen fibres (mostly type I (90%), with some type V). Only 25% of bone is water. Almost 70% of bone is made up of bone mineral called hydroxyapatite.
- **Before the extracellular matrix is calcified, the tissue is called osteoid (bone-like) tissue. When the concentrations of calcium and phosphate ions rise high enough, they are deposited into the extracellular matrix, and the bone calcifies.**

Functions of bones…

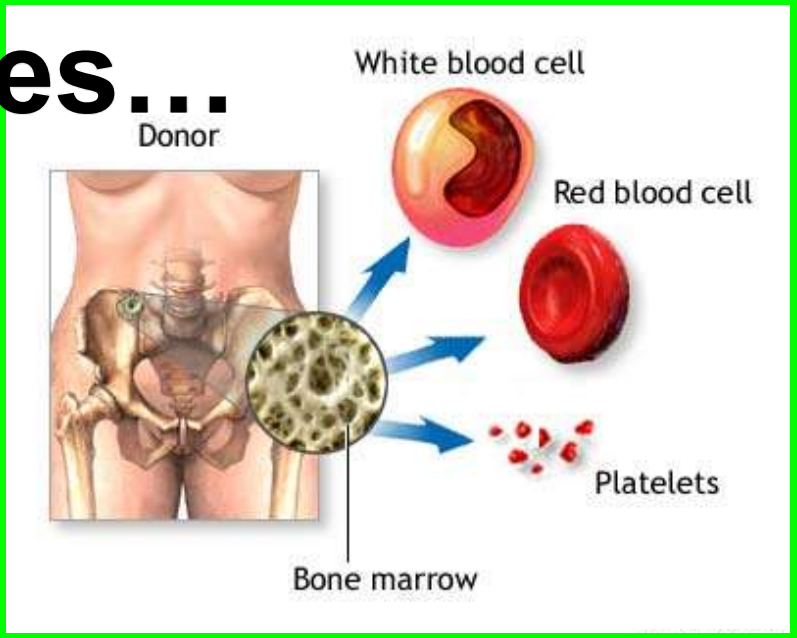


Bones are composed of about 50% water and 50% a solid, calcified, rigid substance known as osseous (AH see us) tissue.



1. **Bones provide shape, support, and the framework of the body.**
2. **Bones protect internal organs.**
3. **Bones serve as a storage place for minerals such as salts, calcium, and phosphorus.**

Functions of bones…

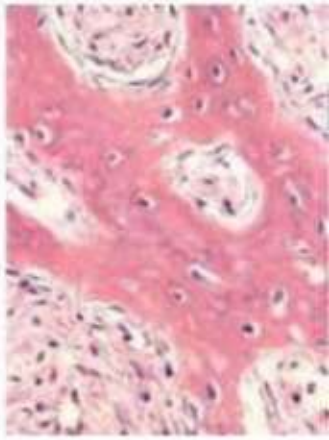


4. **Bones play an important role in hematopoiesis (hee MAT ah poh EE siss)… the formation of blood cells that takes place in bone marrow.**
5. **Bones provide a place to attach muscles.**
6. **Bones make movement possible through articulation (manner in which the parts come together at a joint) .**

Types of Bones

- The first bone formed at any site is **woven** (or primary) bone, but this is soon replaced by **lamellar** bone.
  In **woven bone** the collagen fibers are random.
  In **lamellar bone**, the collagen fibers have become re-modelled to become more parallel - in layers.
- There are two types of **mature bone**:
- **1. Compact -** which is found in the shafts of long bones (in the diaphyses). This makes up 80% of all bone.
- **2. Spongy (cancellous) bone** - which is found at the **ends of long bones** (in the epiphysis). This makes up 20% of all bone. This type of bone contains red bone marrow and a network of bony trabeculae.

Woven vs. Lamellar Bone



- **Woven bone – weak**
  - Haphazard organization of fibers
  - Osteoblasts produce osteoid rapidly
  - In all fetal bones – replaced later by lamellar bone
  - Also present after fractures – initially woven bone as healing occurs.
- **Lamellar bone - strong**
  - Secondary bone created by remodeling of woven bone.
  - Highly organized alignment of collagen in sheets
  - Fibers run in opposite directions in cross-section
    - tensile strength
  - Less osteocytes

Bone structure…

The features in this long bone illustrate those found in all bones.

<u>Epiphysis</u> (ĭ PIF ah siss) - growing end

<u>Diaphysis</u> (dye AF ah siss) – shaft, has walls o cortical bone and an underlying network of trabecular bone.

The **<u>metaphysis</u>** is the area in which the shaft of the bone joins the epiphyseal growth plate

<u>Periosteum</u> (peri OSS tee um) - outside covering

<u>Medullary</u> (MED ul air ee)- inner space containing bone marrow

<u>Endosteum</u> (en DOS tee um)- lining of medullary cavity

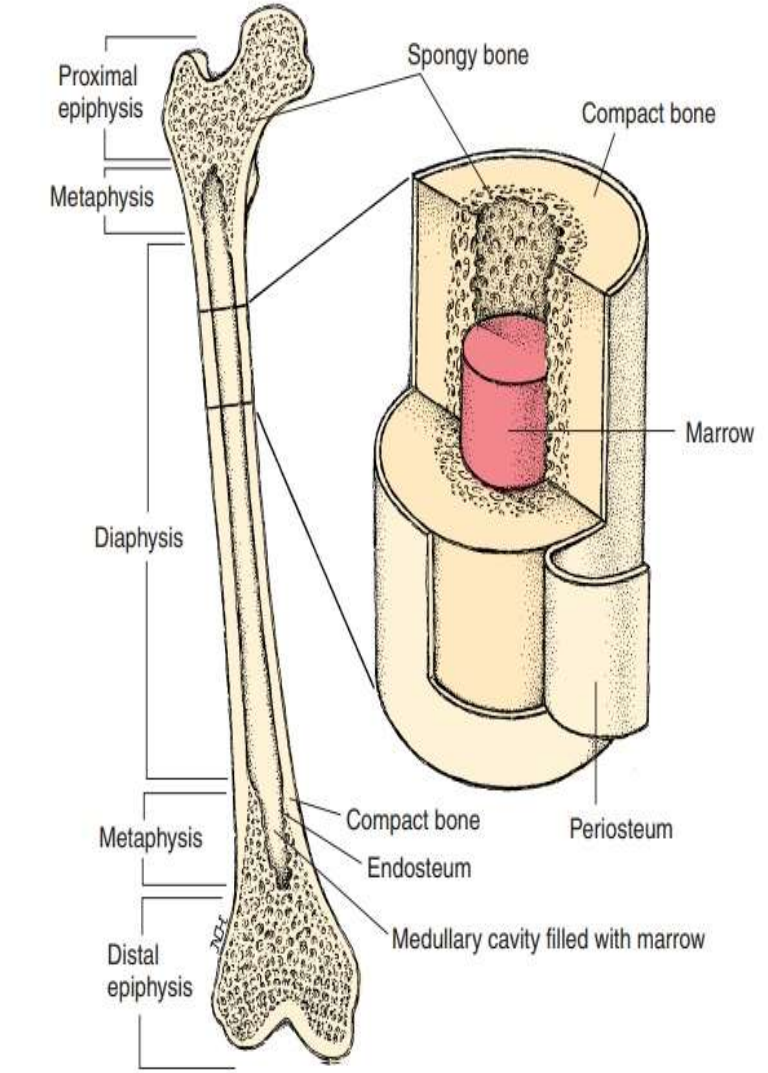
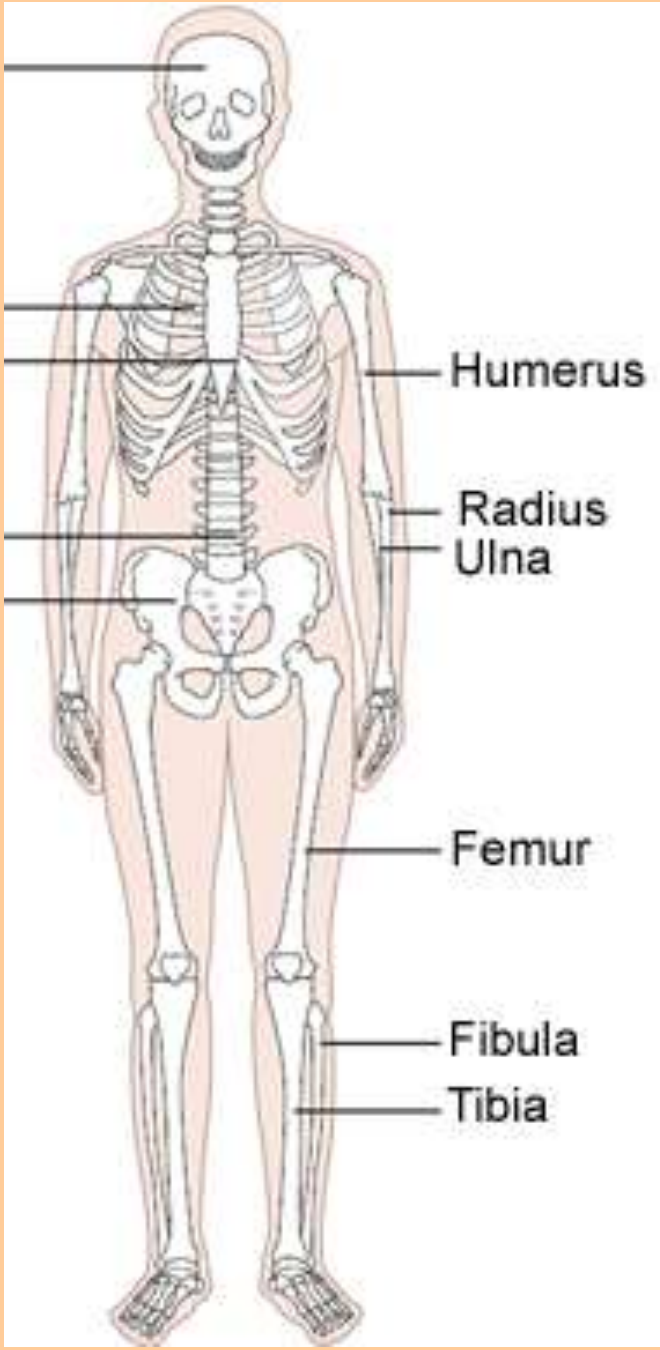


FIGURE . Parts of a Long Bone

Classifications of bones by shape…

Bones can be classified by shape. 4 of those classifications are:

LONG bones include the femur (thigh), tibia (larger shin), fibula (smaller shin bone), humerus (upper arm), radius (larger forearm), and ulna (smaller forearm).



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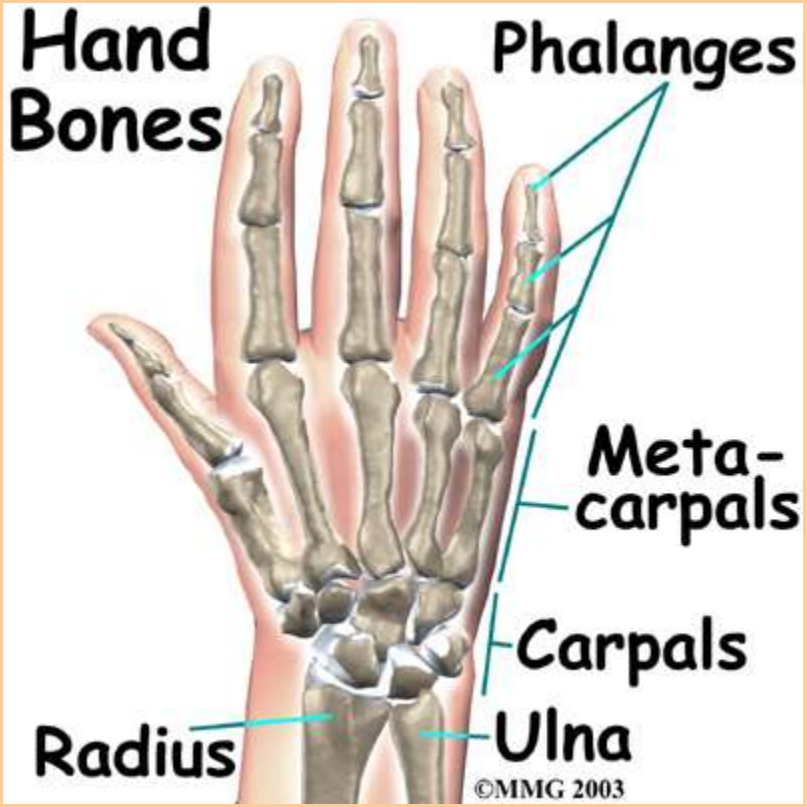

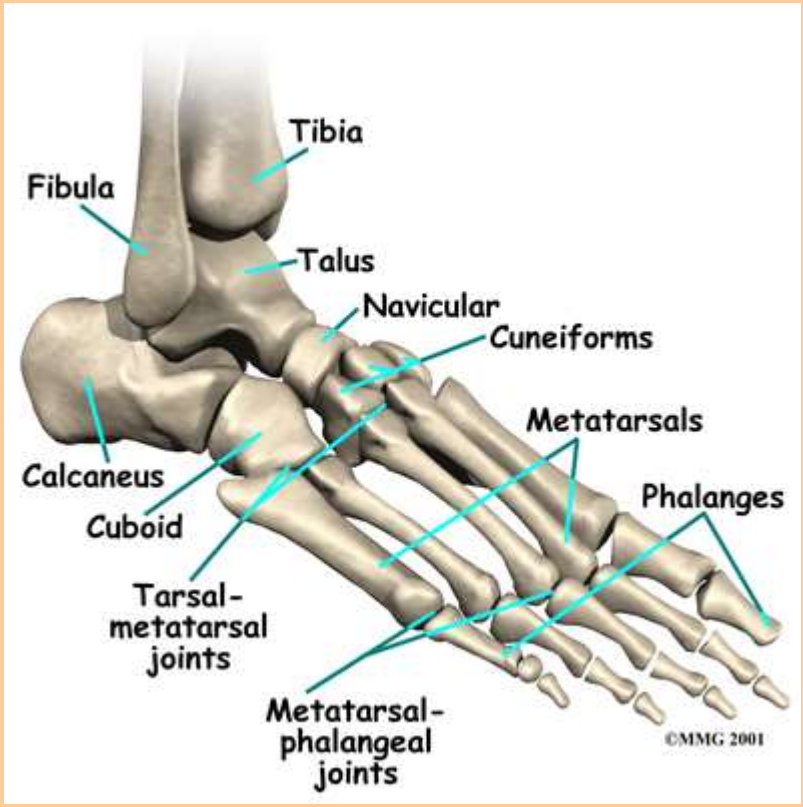

SHORT bones include the carpals of the wrist and tarsals of the ankle.

Classifications of bones by shape…

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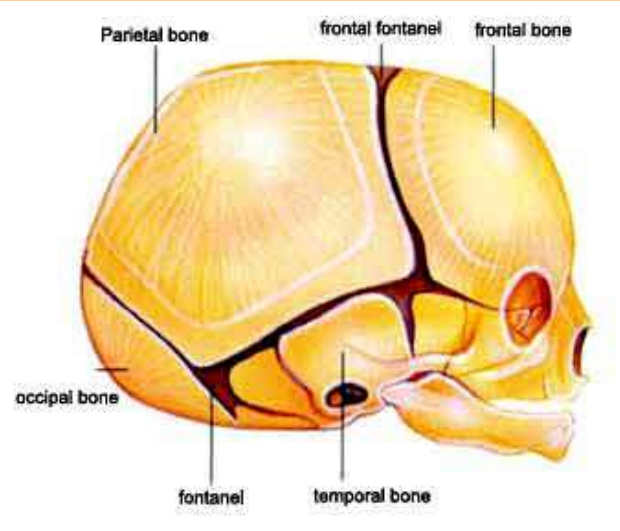

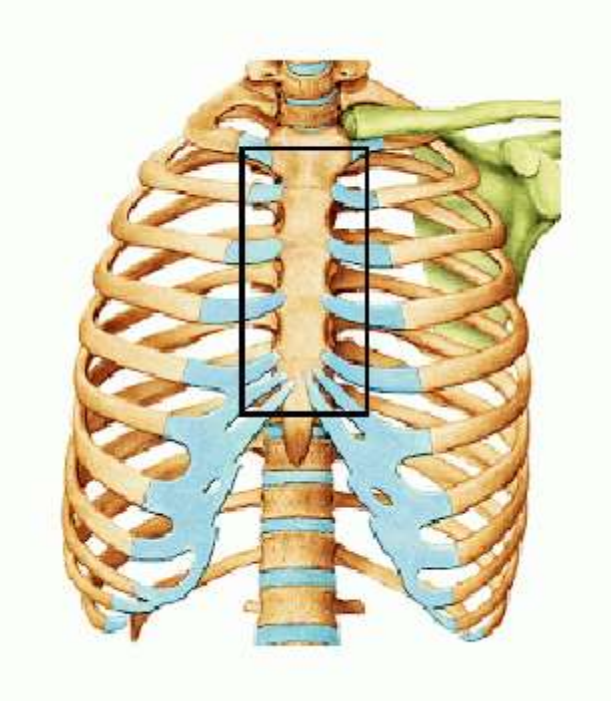

FLAT bones include the skull, sternum (breastbone), and scapula (shoulder bone).

Classifications of bones by shape…

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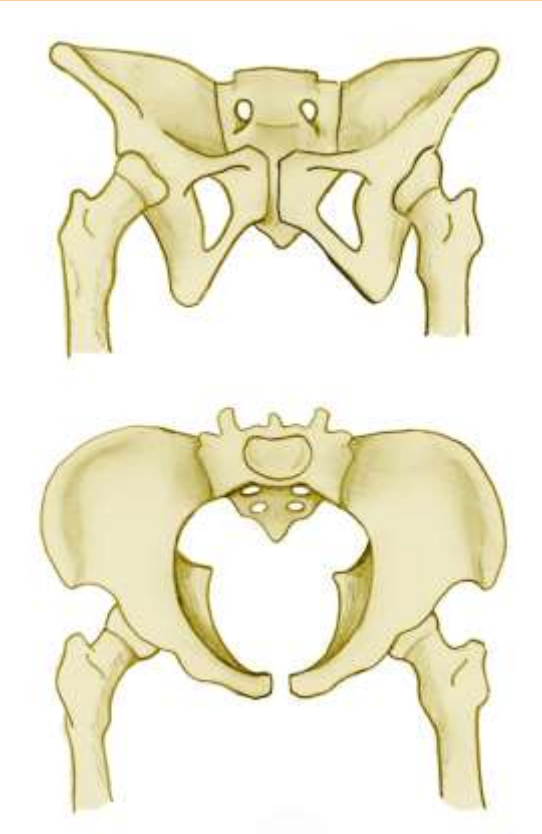
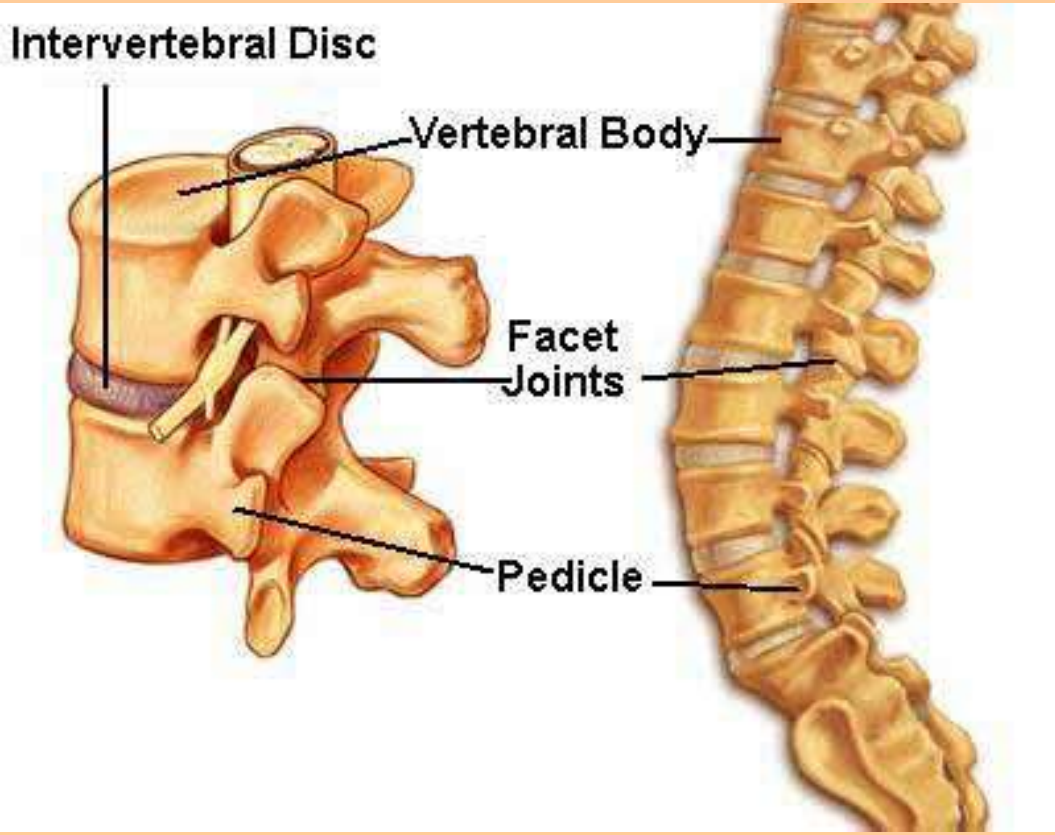
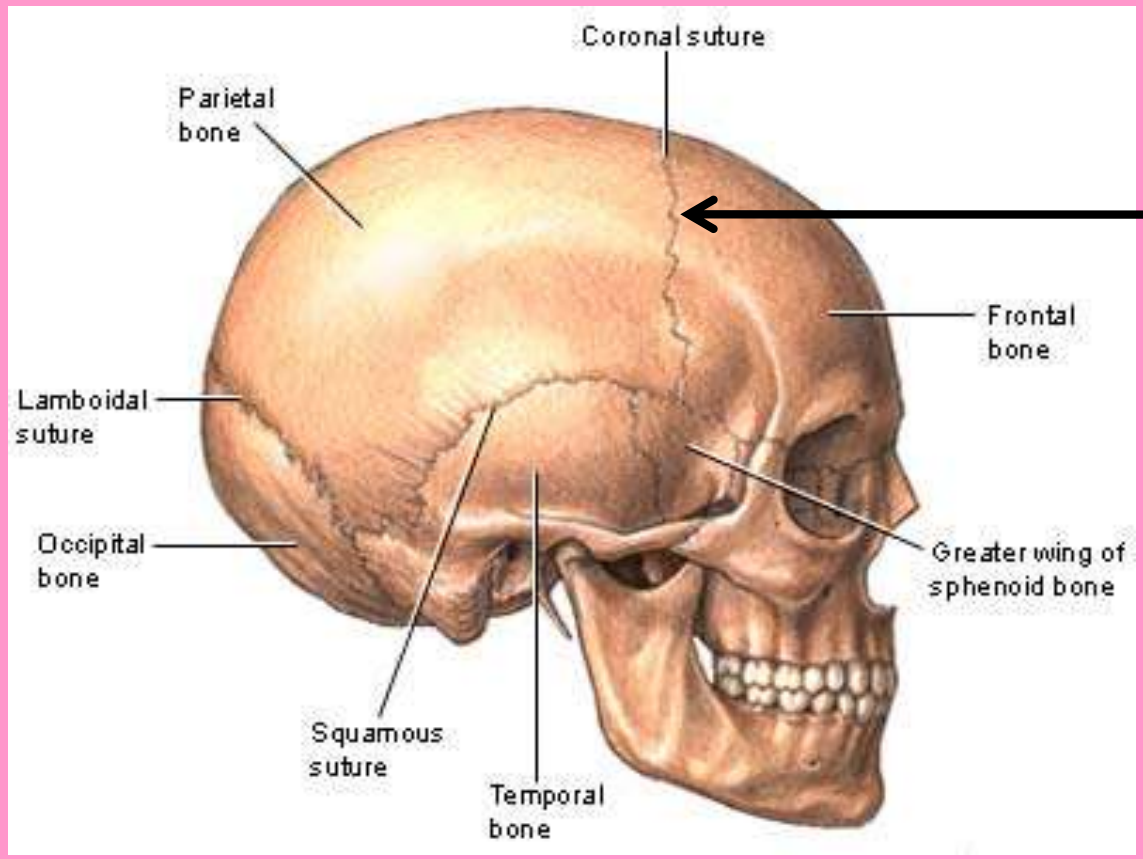




IRREGULAR bones include the vertebrae (spine), and pelvic.

Joints…

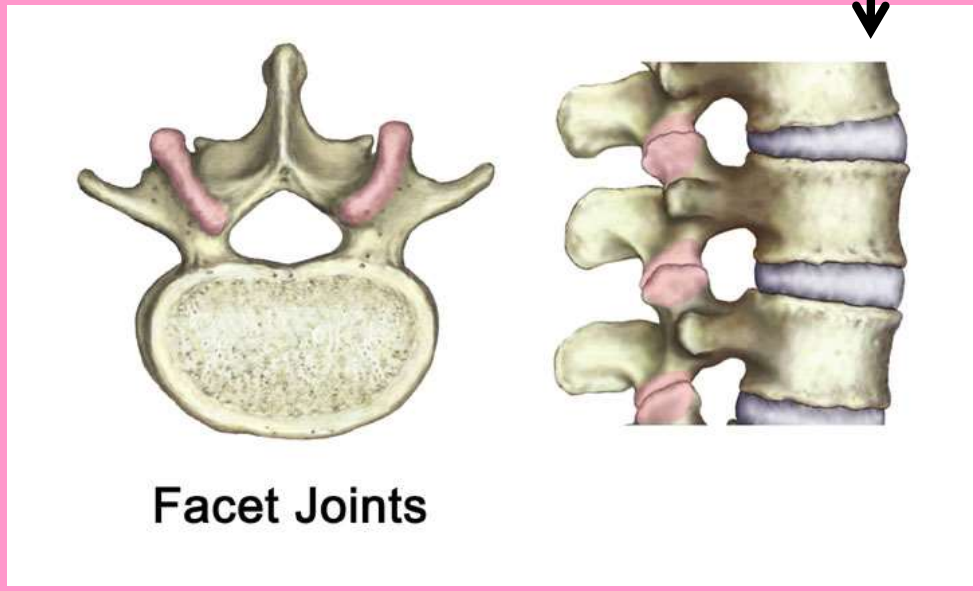
A joint is a place where two or more bones connect. The manner in which they connect determines the type of movement allowed at that joint.

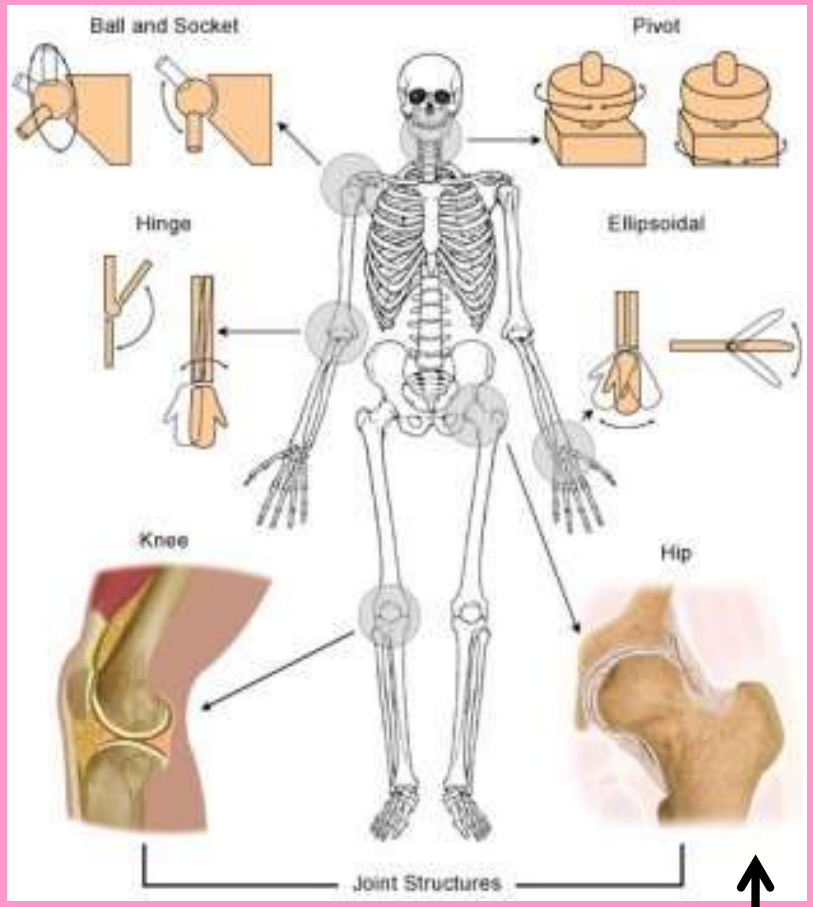


A synarthrosis (sĭn ahrTHROW siss) is a joint that allows no movement. An example would be a cranial suture.

Joints…

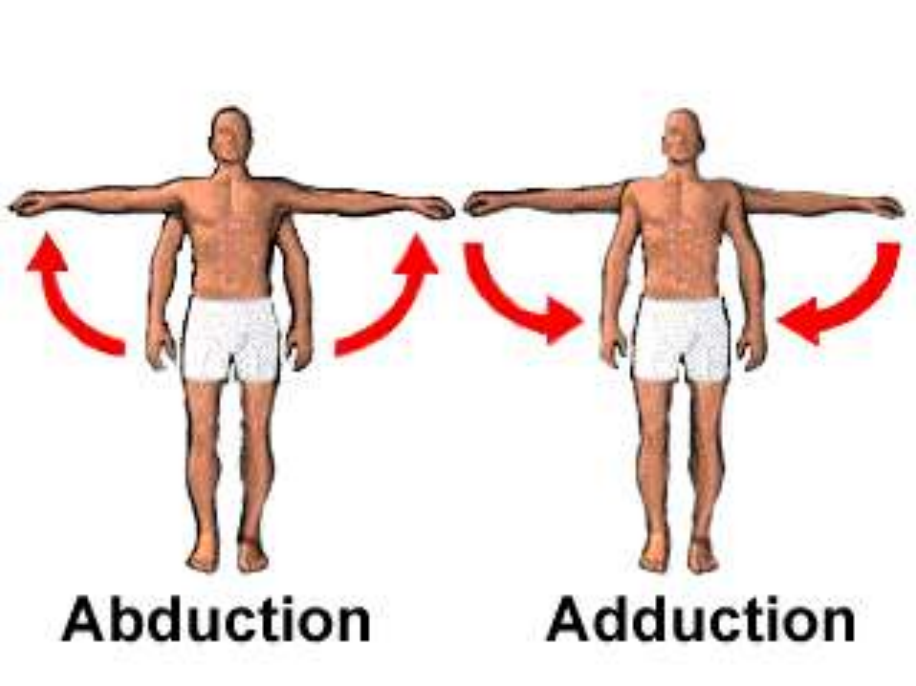
A amphiarthrosis (am fee ahr THROW siss) is a joint that allows slight movement. An example would be a vertebra.

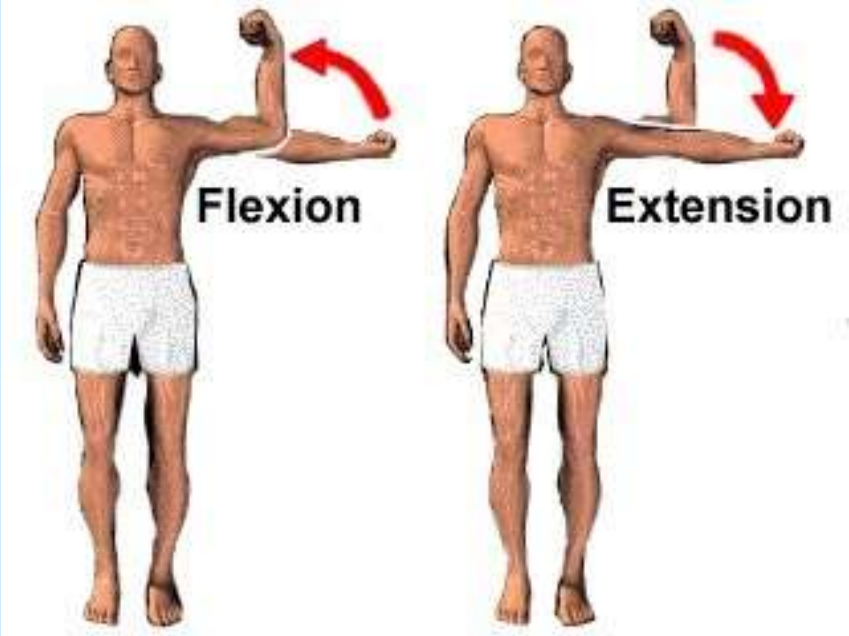




A diarthrosis (dye ahr THROW siss) is a joint that allows free movement in a variety of directions, such as knee, hip, elbow, wrist, and foot.

Types of body movements at diarthrotic joints…





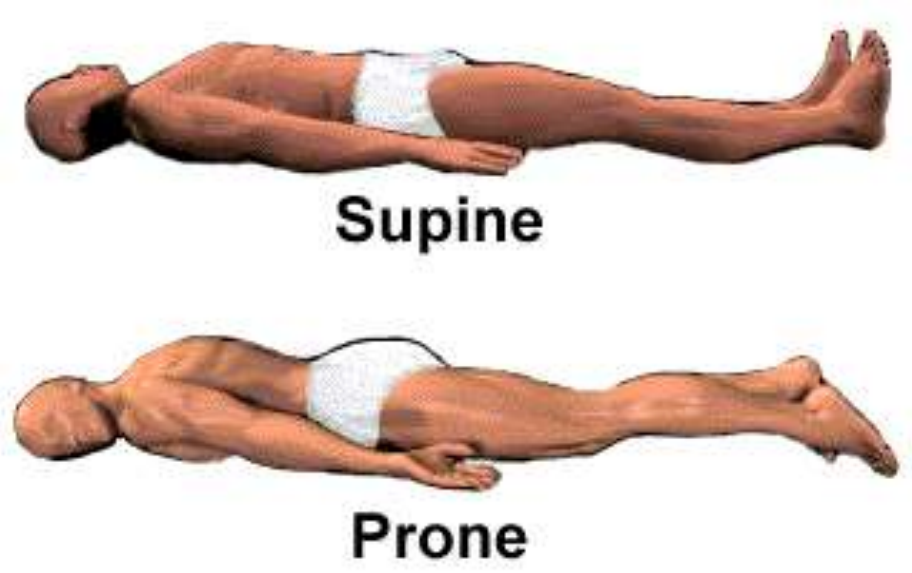
<u>Abduction:</u> moving a body part away from the middle.

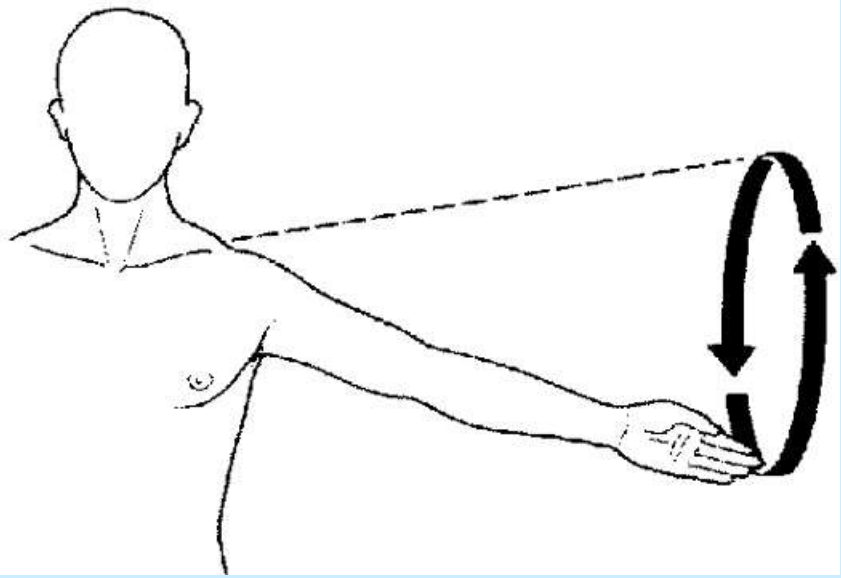
<u>Adduction:</u> moving a body part toward the middle.

<u>Flexion</u>: bending a limb

<u>Extension</u>: straightening a flexed limb

Types of body movements at diarthrotic joints…





<u>Supination:</u> lying supine or face upward; or turning the palm or foot upward.

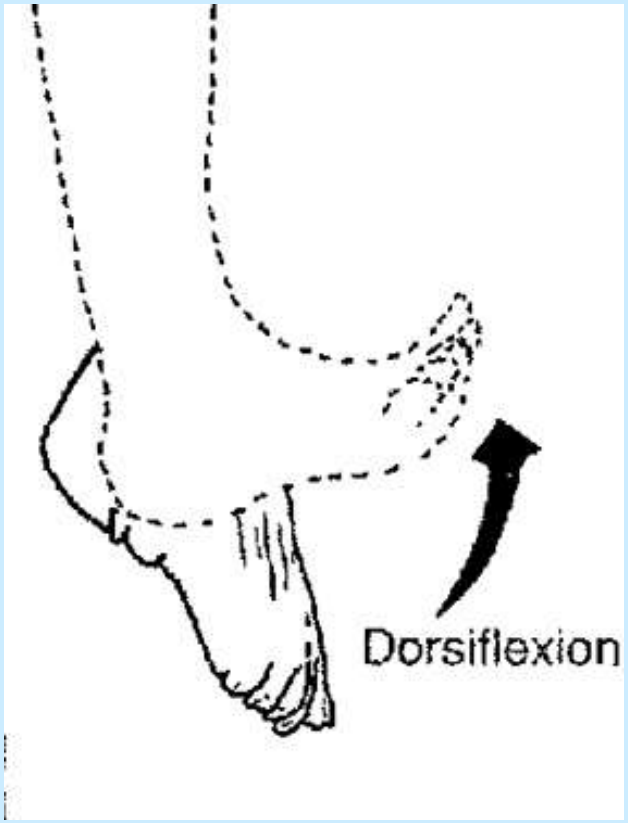
<u>Pronation:</u> lying prone or face downward; or turning the palm downward.

<u>Circumduction:</u> moving a body part in a circular motion

Types of body movements at diarthrotic joints…

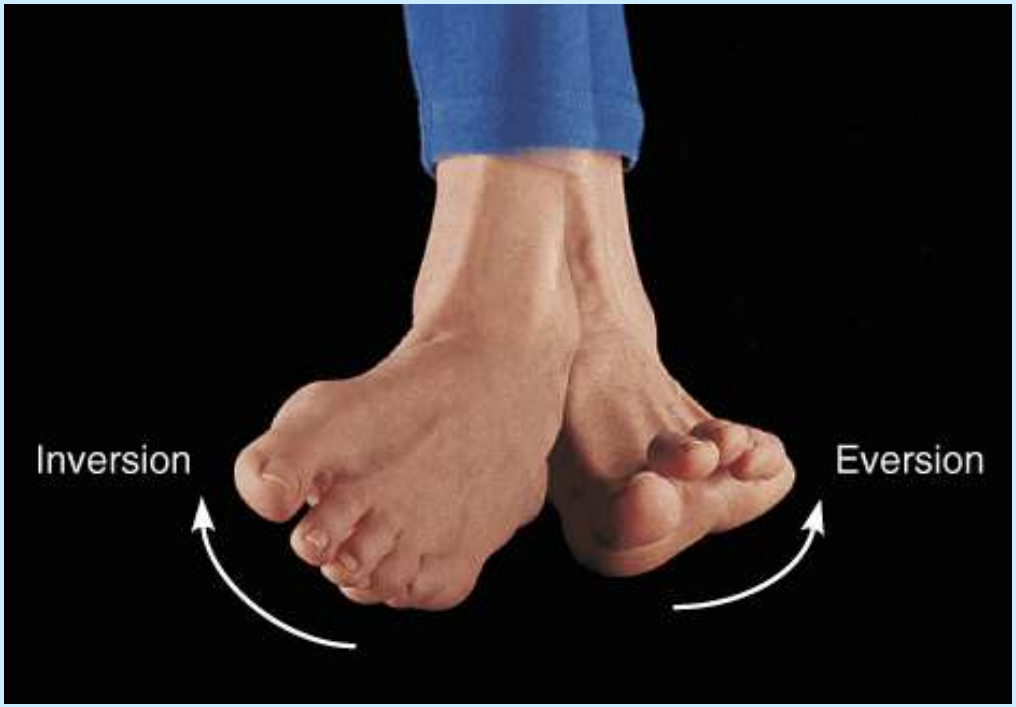
<u>Protraction:</u> moving a body forward.

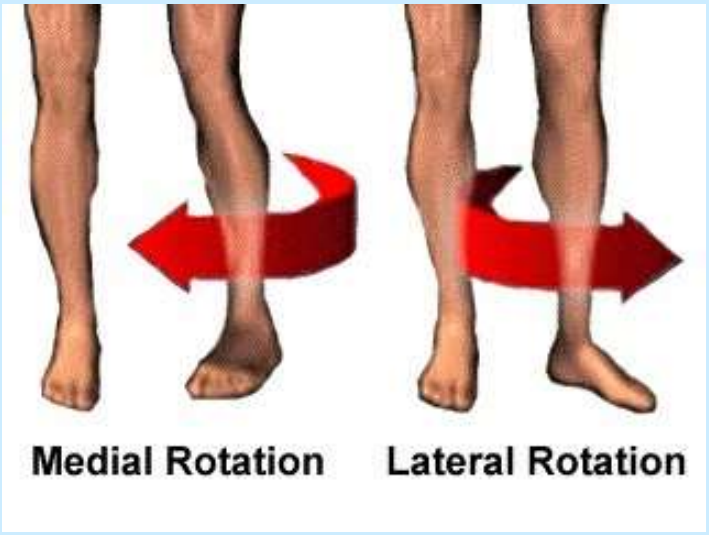
<u>Retraction:</u> moving a body part backward.



<u>Dorsiflexion:</u> bending a body part backwards.

Types of body movements at diarthrotic joints…

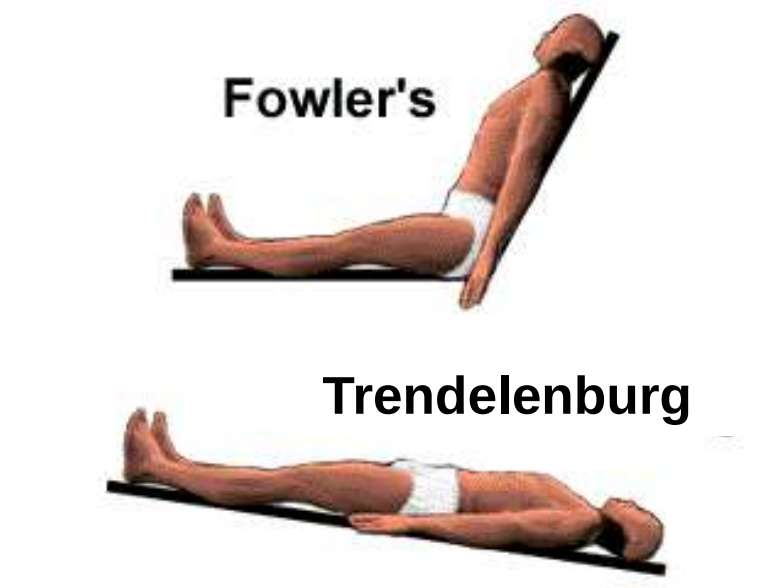


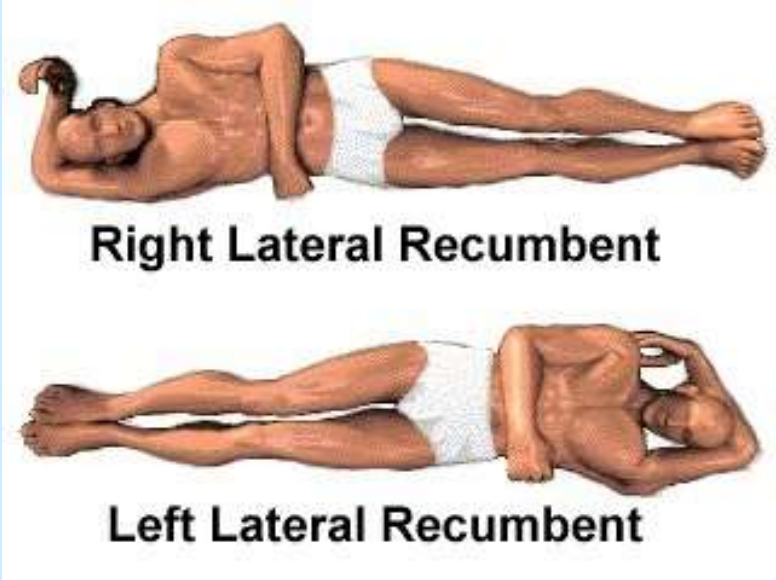


Inversion: turning inward.
Eversion: turning outward.

Rotation: moving a body part around a central axis

Types of body movements at diarthrotic joints…



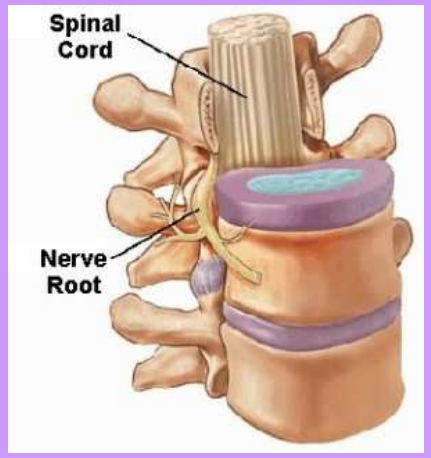


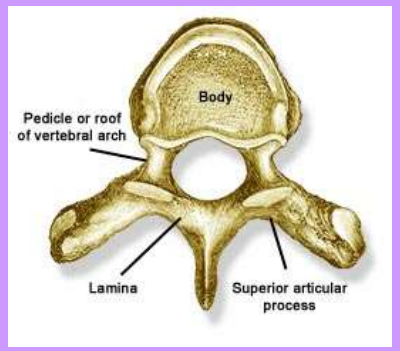
<u>Fowler's position:</u> **sitting straight up or reclining slightly; legs straight or bent.**

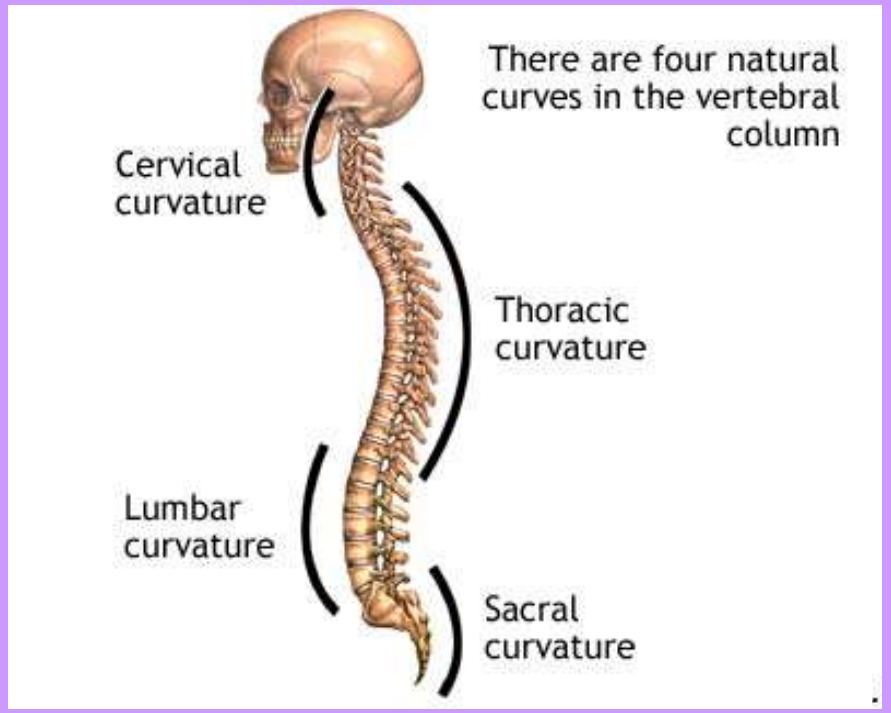
<u>Trendelenburg position:</u> **(TREN duh len burg) lying supine with head lower than feet.**

<u>Lateral recumbent:</u> **lying on your left or right side**

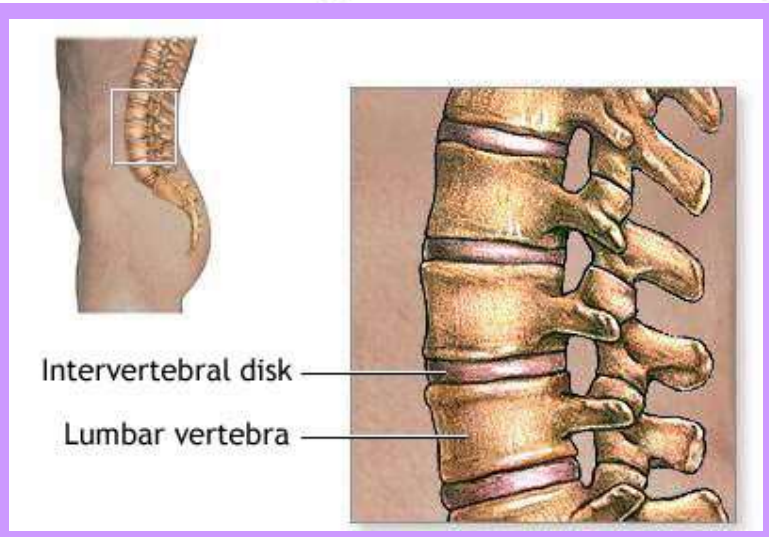
The vertebral column…



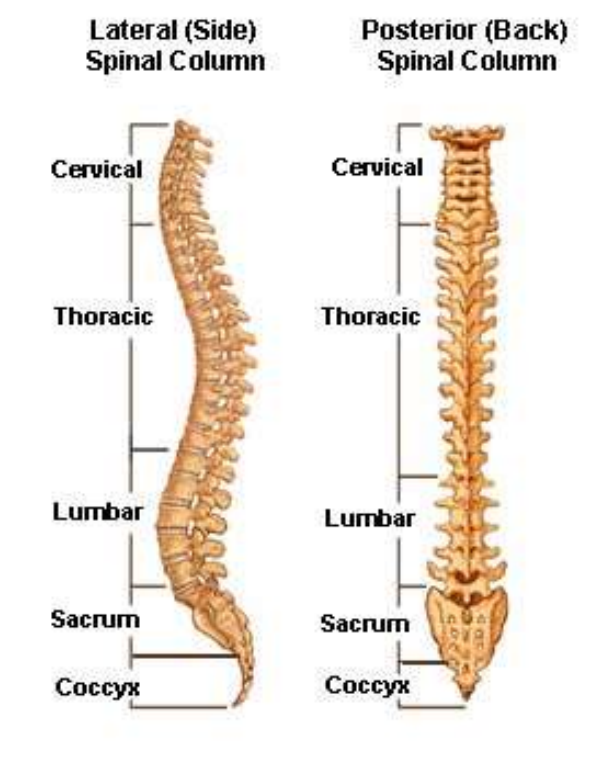


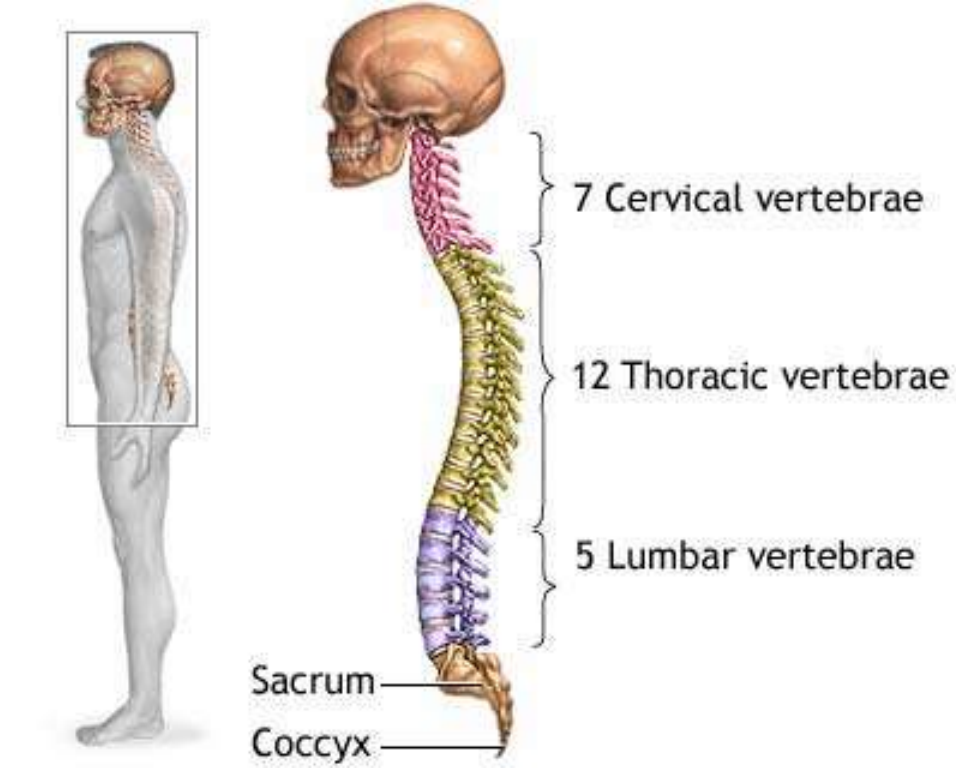


The vertebral column is composed of separate bones called vertebrae, connected to form four spinal curves. A curve has more strength than a straight line, so can support the weight of the body and provide balance needed to walk.



The vertebral column…





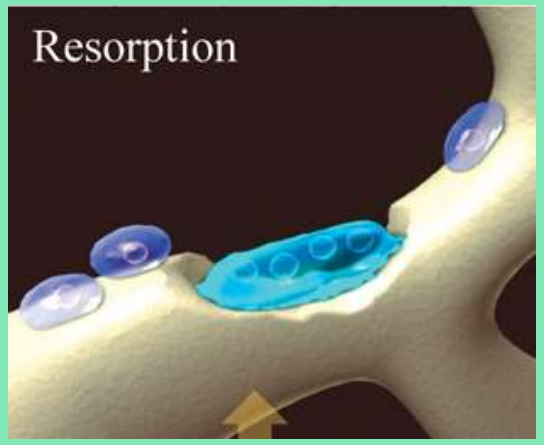
The cervical curve contains the first 7 vertebrae; the thoracic curve contains the next 12; the lumbar curve contains 5. The sacral curve does not contain vertebrae. It contains the sacrum and coccyx (KOCK siks) or tailbone.

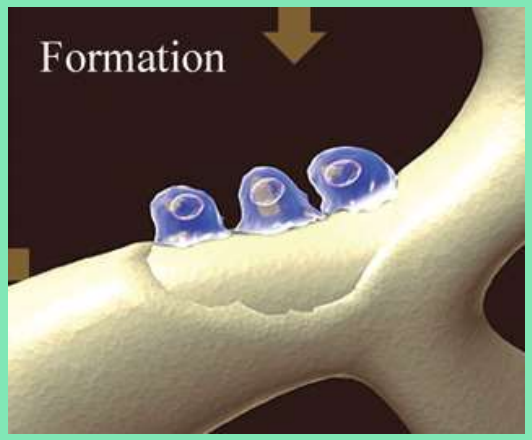
The male and female pelvis…

The pelvis is the lower portion of the trunk of the body. The hip bones, sacrum, and coccyx form the pelvic basin. Hip bones include the ilium (Ĭl ee um), pubis (PYU bus), and ischium (ISS kee um).

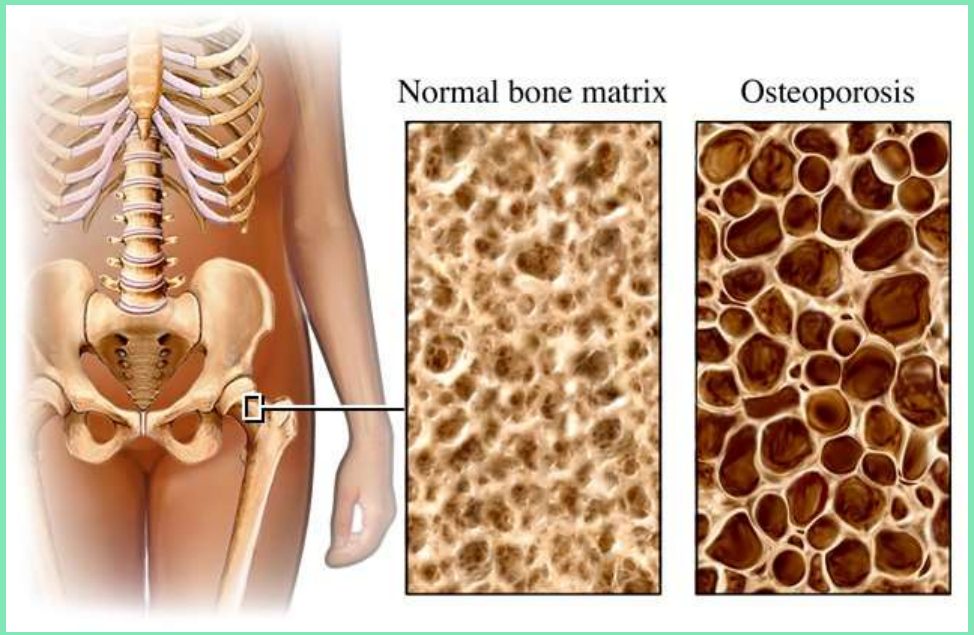
The male pelvis is shaped like a funnel and is heavier and stronger than the female. The female pelvis is oval to round, and wider than the male.

Bone growth and resorption…





Bone is continually remodeled. It is broken down by <u>osteoclasts</u> in a process called <u>resorption</u>, and formed again by <u>osteoblasts</u>. Bone formation and healing slow down as part of the aging process.



<u>Osteoporosis</u> is an age-related loss of bone mass or density.

Bone Development

- Bone development begins with the replacement of collagenous mesenchymal tissue by bone. This results in the formation of woven bone, a primitive form of bone with randomly organized collagen fibers that is further remodeled into mature lamellar bone, which possesses regular parallel rings of collagen. Lamellar bone is then constantly remodeled by osteoclasts and osteoblasts. There are two different methods by which bone is produced from mesenchymal tissue:
- Endochondral ossification is the process by which cartilage is progressively replaced by bone at the epiphyseal growth plates. This occurs in long bones, the vertebrae, and the pelvis.
- Intramembranous ossification is the process by which mesenchymal tissue is directly replaced by bone without an intermediate cartilage step. It occurs most notably in the bones of the skull.

Intramembranous Ossification

- Four steps

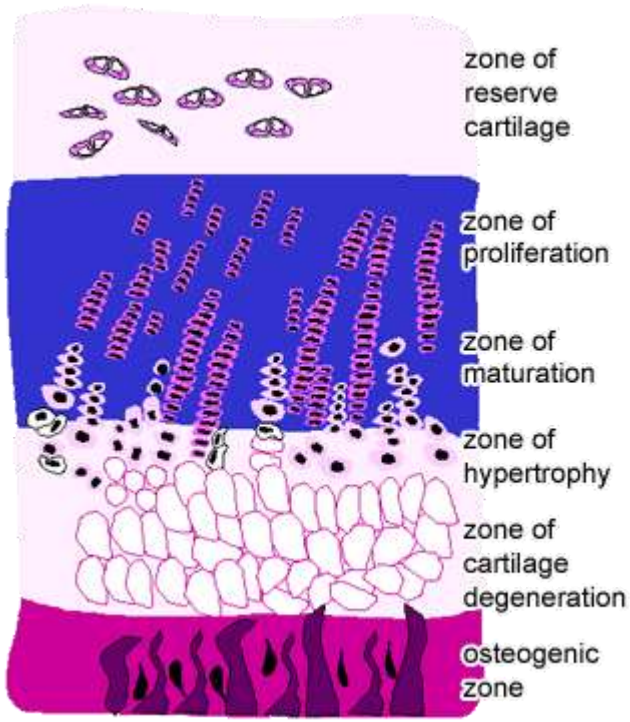
1. Development of ossification center
   - Mesenchyme cells → osteogenic→ osteoblasts
   - Osteoblasts secrete organic matrix
2. Calcification: cells become osteocytes
   - In lacunae they extend cytoplasmic processes to each other
   - Deposit calcium & other mineral salts
3. Formation of trabeculae (spongy bone)
   - Blood vessels grow in and red marrow is formed
4. Periosteum covering the bone forms from mesenchyme

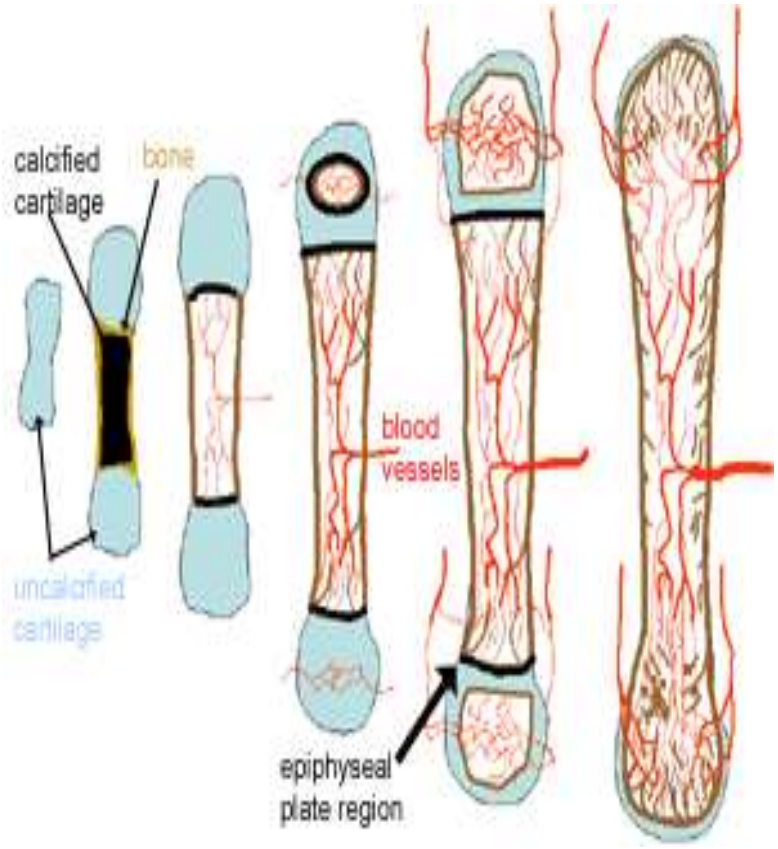
endochondral ossification

- In **endochondral ossification**:

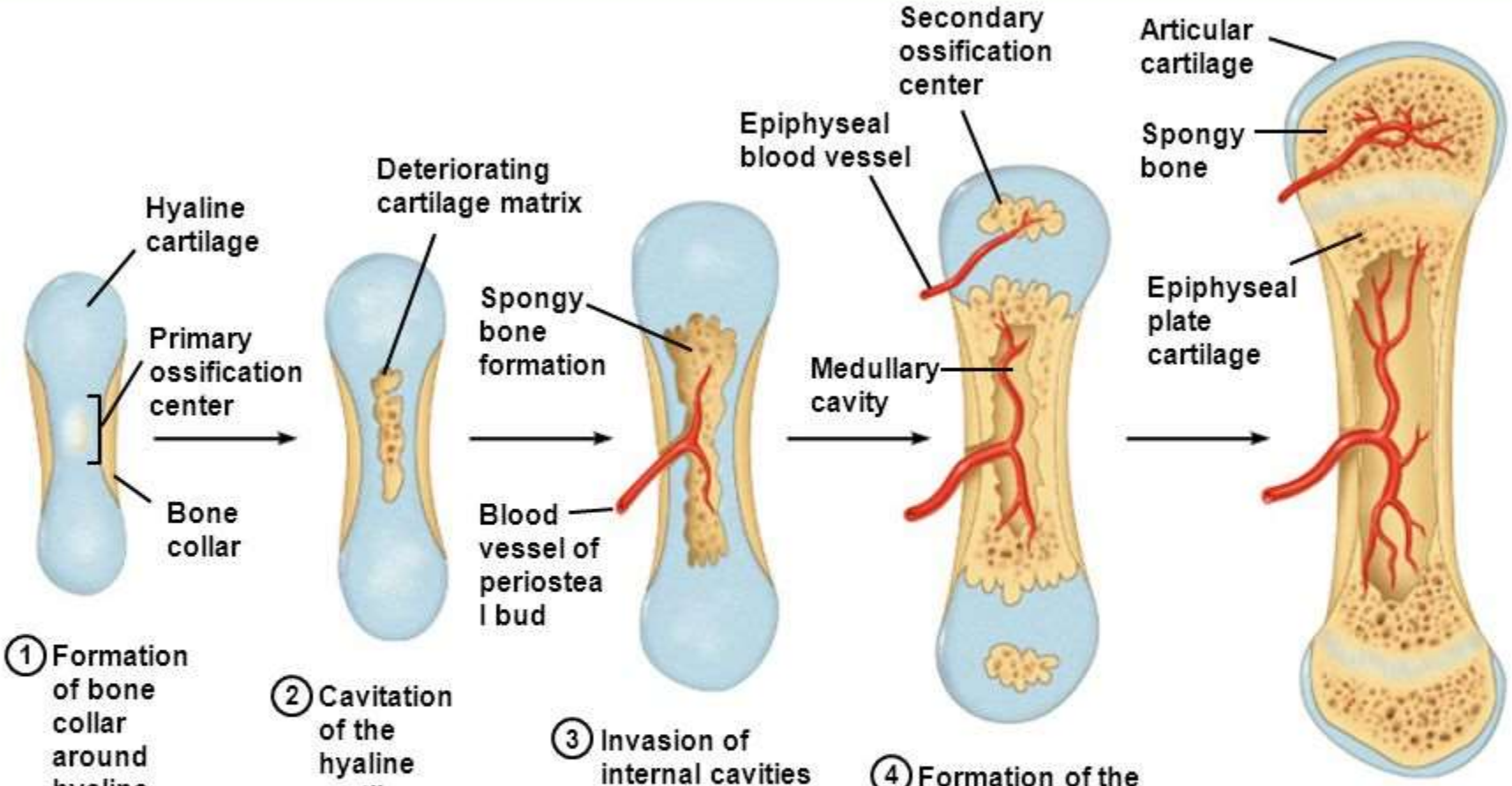
1. The bone is formed onto a temporary cartilage model.
2. The cartilage model grows (zone of proliferation), then chondrocytes mature (zone of maturation) and hypertropy (zone of hypertrophy), and growing cartilage model starts to calcify.
3. As this happens, the chondrocytes are far from blood vessels, and are less able to gain nutrients etc, and the chondrocytes start to die (zone of cartilage degeneration). The fragmented calcified matrix left behind acts as structural framework for bony material.
4. Osteoprogenitor cells and blood vessels from periosteum invade this area, proliferate and differentiate into osteoblasts, which start to lay down bone matrix (osteogenic zone).

endochondral ossification





Stages of Endochondral Ossification



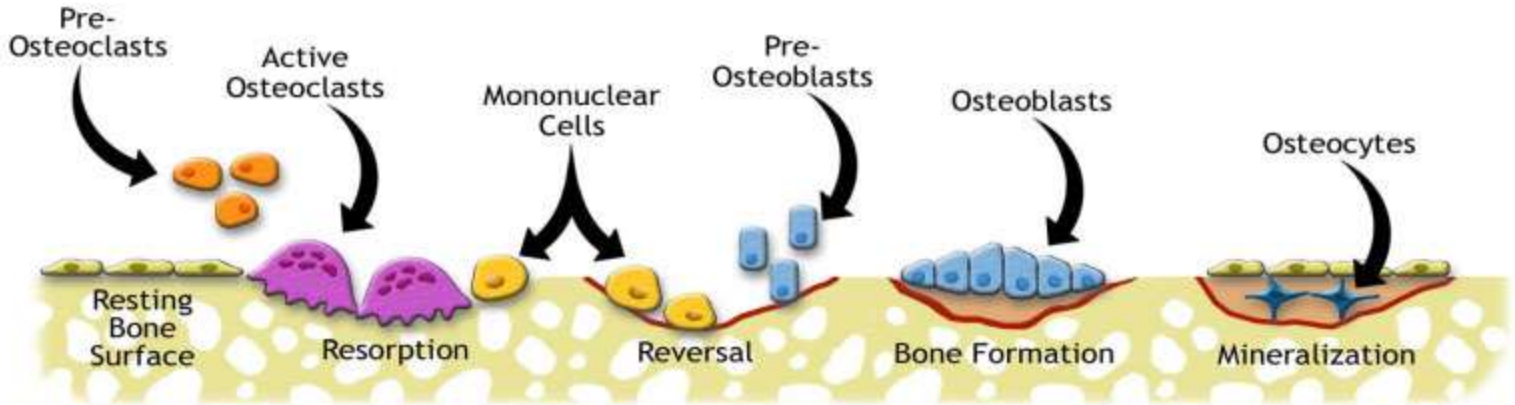
1. Formation of bone collar around hyaline cartilage model.
2. Cavitation of the hyaline cartilage within the cartilage model.
3. Invasion of internal cavities by the periosteal bud and spongy bone formation.
4. Formation of the medullary cavity as ossification continues; appearance of secondary ossification centers in the epiphyses in preparation for stage 5.
5. Ossification of the epiphyses; when completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages

Figure 6.8

Bone Remodeling

- In adults, after growth has ceased, bone is formed by the osteoblasts only where it was previously resorbed by the osteoclasts. This follows a specific sequence of events, and takes about three months in total to complete:
- Activation - In the process of activation, osteoblasts induce osteoclasts to break down bone matrix. This occurs via the Receptor Activator for NFkB-Ligand (RANK-L) signaling pathway, in which RANK-L on the surface of osteoblasts binds to RANK on osteoclasts to turn them on. This process lasts for approximately 3 days.
- Resorption - In resorption, the ruffled border of the osteoclast forms a sealing zone which isolates the area of bone erosion. Organic acids and lysosomal enzymes dissolve the mineral component and break down the organic matrix, respectively. This process occurs at approximately 14 days.
- Reversal - Over time, osteoblasts begin to replace osteoclasts at the site of bone turnover.
- Formation - Osteoblasts begin to lay down new lamellar bone on top of old bone. In doing so, cement lines are created to mark the borders between old and new bone matrix. This can take up to 70 days to complete

Bone Remodeling Cycle



Factors Affecting Bone Development, Growth, and Repair

- **Deficiency of Vitamin A – retards bone development**
- **Deficiency of Vitamin C – results in fragile bones**
- **Deficiency of Vitamin D – rickets, osteomalacia**
- **Insufficient Growth Hormone – dwarfism**
- **Excessive Growth Hormone – gigantism, acromegaly**
- **Insufficient Thyroid Hormone – delays bone growth**
- **Sex Hormones – promote bone formation; stimulate ossification of epiphyseal plates**
- **Physical Stress – stimulates bone growth**

Effects of Aging on Skeletal System

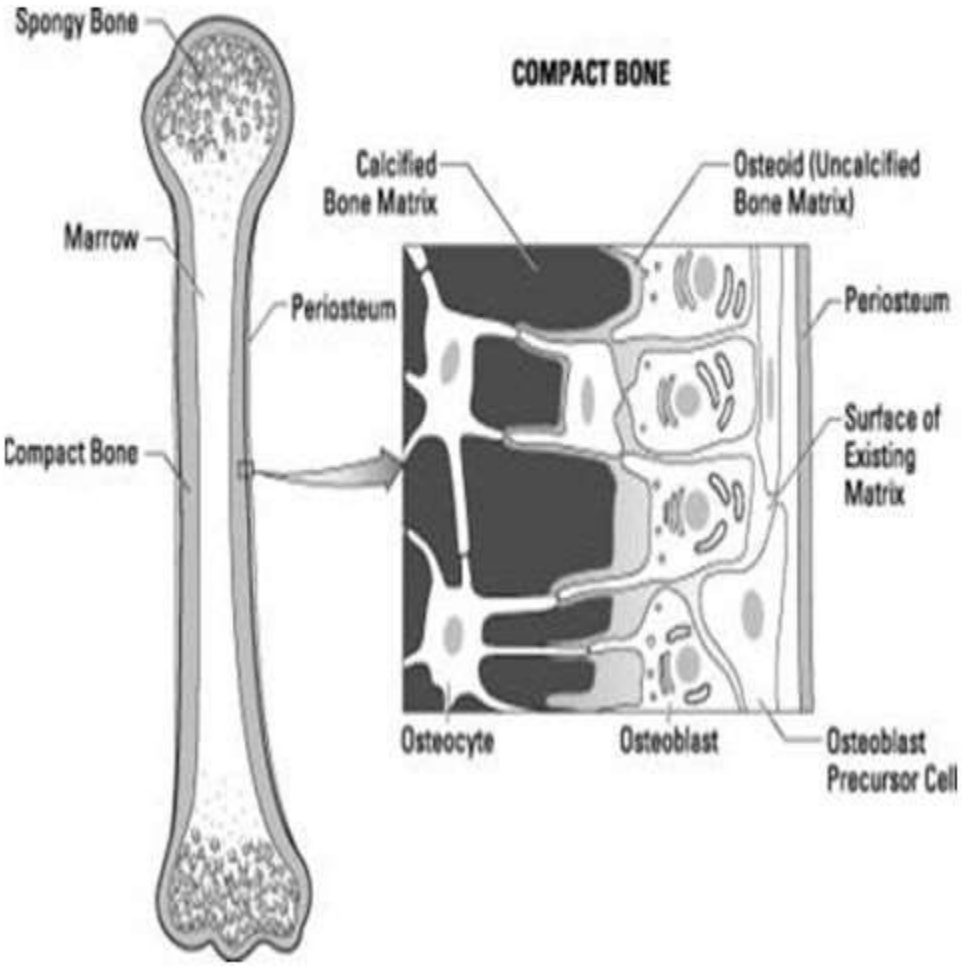
- Bone matrix decreases. More brittle due to lack of collagen; but also less hydroxyapetite.
- Bone mass decreases.
  - Highest around 30.
  - Men denser due to testosterone and greater weight.
  - African Americans and Hispanics have higher bone masses than Caucasians and Asians.
  - Rate of bone loss increases 10 fold after menopause.
  - Cancellous bone lost first, then compact.
- Increased bone fractures
- Bone loss causes deformity, loss of height, pain, stiffness
  - Stooped posture
  - Loss of teeth

Effects of aging on the skeletal system

- Bone mass starts to reduce between the age of 30 and 40 years.

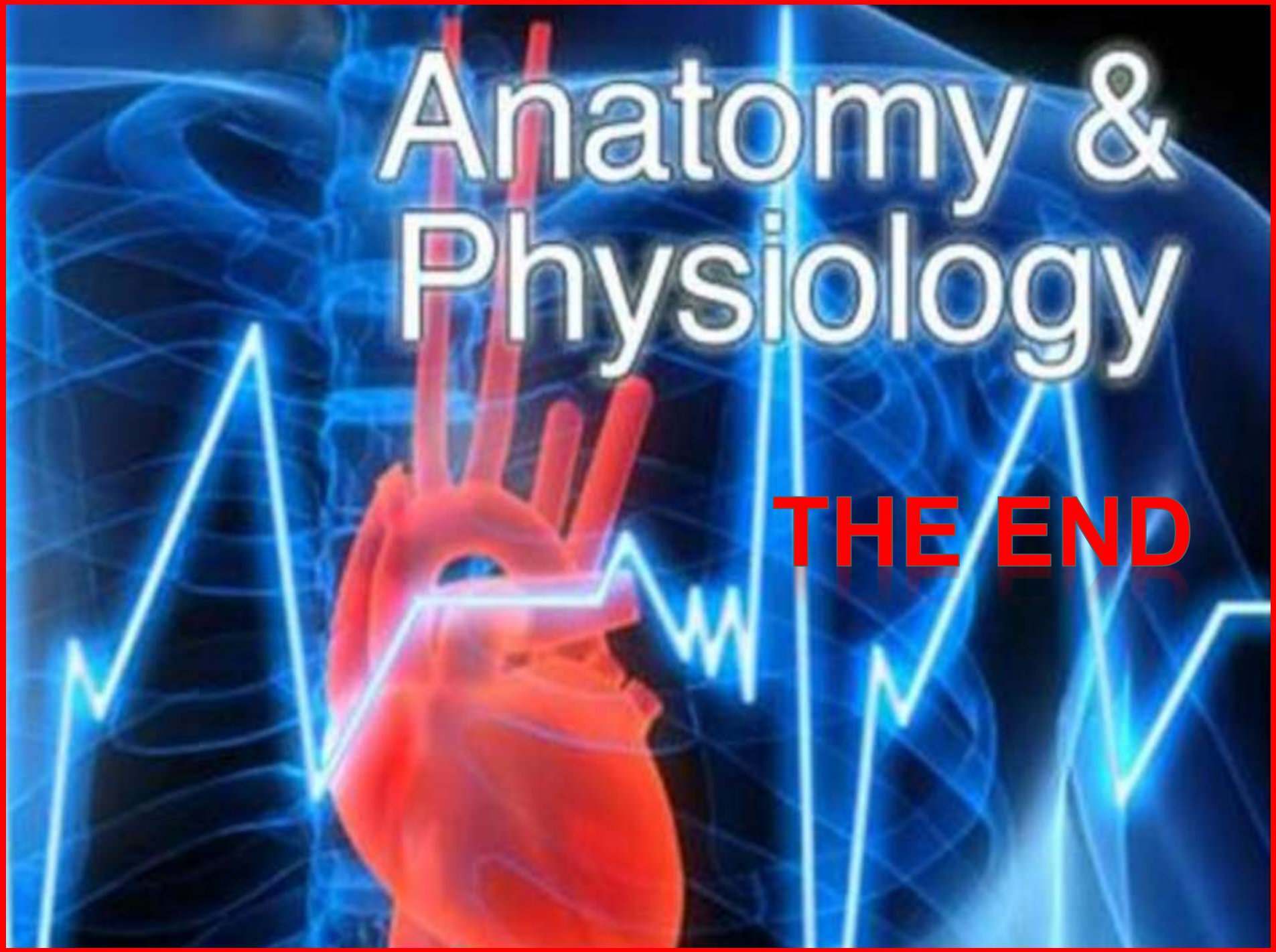
- Osteoblast (cells that make bone) activity declines but osteoclast (bone cell that resorbs bone tissue) activity continues at normal levels

- Bones break more easily and do not repair well



EFFECTS OF AGING

- With aging, the bones gradually lose calcium. As a result, they become more fragile and are more likely to break, even with minor falls. Healing of fractures is also slower in the old than in the young.
- The incidence of osteoporosis, a disease characterized by a loss of calcium and minerals from bone, also increases with age. It occurs more frequently in women after menopause than in men and is especially evident in the spinal column. Back pain is a primary symptom of the disease.
- The mobility of joints diminishes with age and the incidence of arthritis increases.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