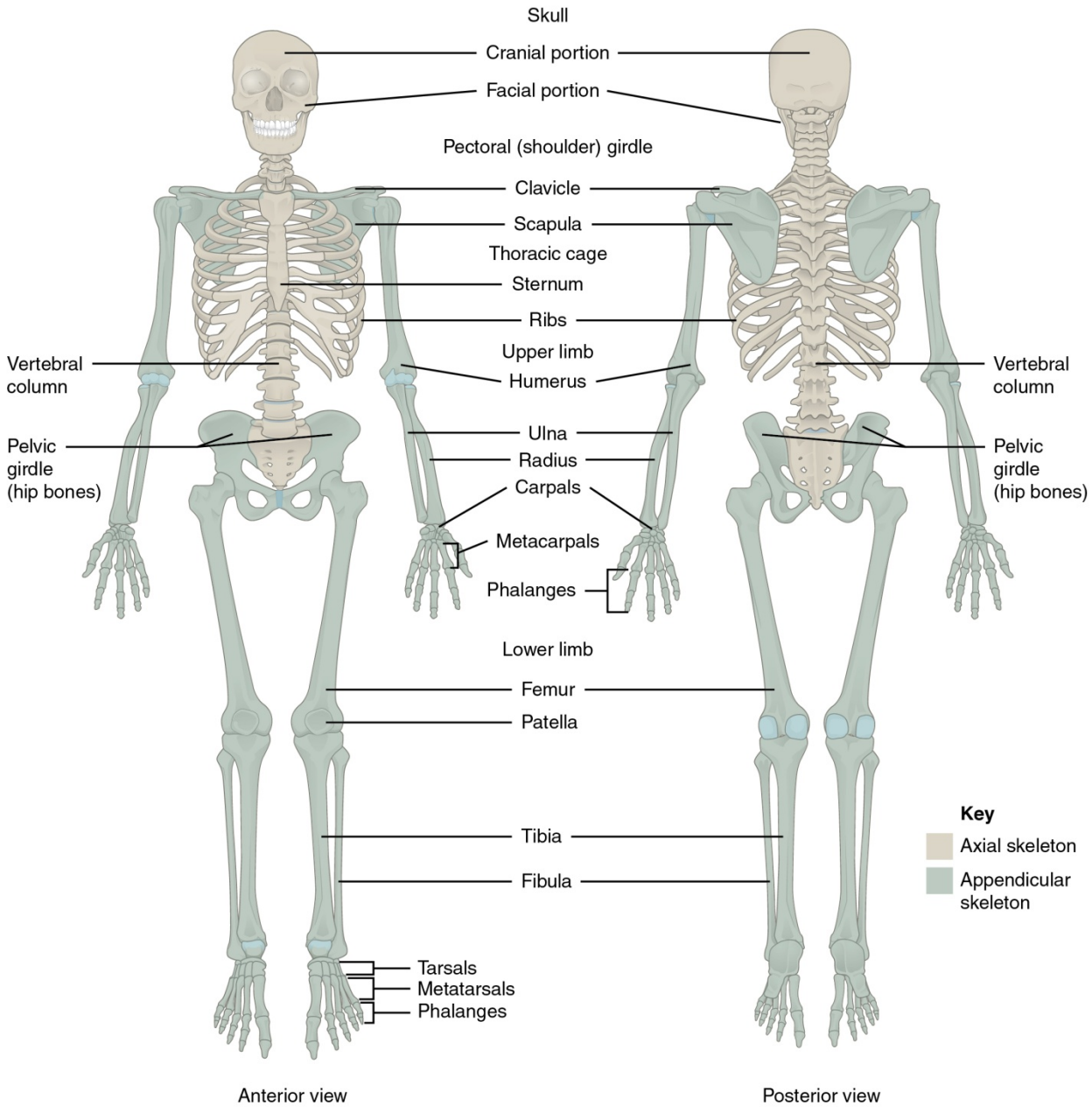
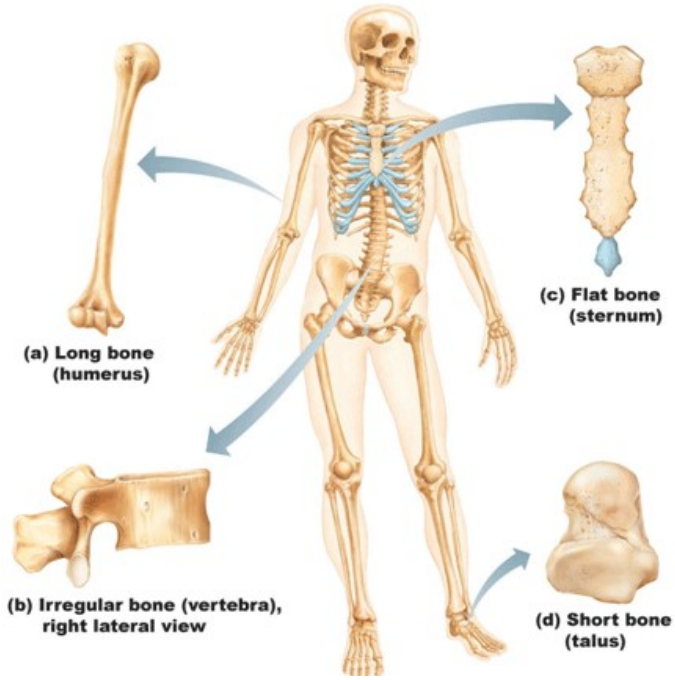
ANATOMY OF THE SKELETAL SYSTEM

The skeleton is subdivided into two divisions: the axial skeleton, the bones that form the longitudinal axis of the body, and the appendicular skeleton, the bones of the limbs and girdles.



CLASSIFICATION OF BONES



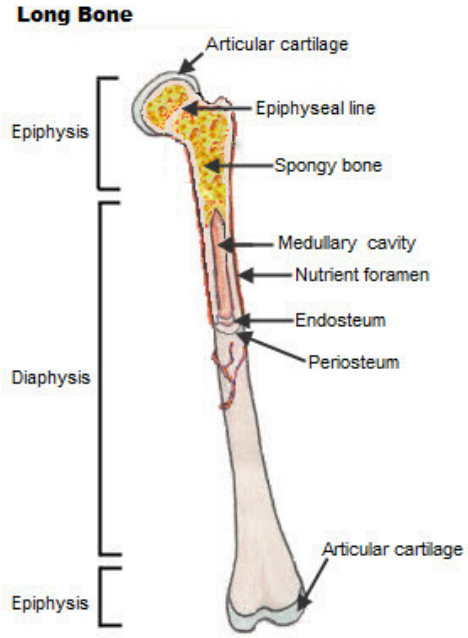
The adult skeleton is composed of 206 bones and there are two basic types of osseous, or bone, tissue: compact bone and spongy bone, and are classified into four groups according to shape: long, short, flat, and irregular.

- **Compact bone.** Compact bone is dense and looks smooth and homogeneous.
- **Spongy bone.** Spongy bone is composed of long, needle-like pieces of bone and lots of open space.
- **Long bones.** Long bones are typically longer than they are wide; as a rule, they have a shaft with heads at both ends, and are mostly compact bone.
- **Short bones.** Short bones are generally cube-shaped and mostly contains spongy bone; **sesamoid bones**, which form within tendons, are a special type of short bone.
- **Flat bones.** Flat bones are thin, flattened, and usually curved; they have two thin layers of compact bone sandwiching a layer of spongy bone between them.
- **Irregular bones.** Bones that do not fit one of the preceding categories are called irregular bones.

GROSS ANATOMY

The gross structure of a long bone consists of the following:

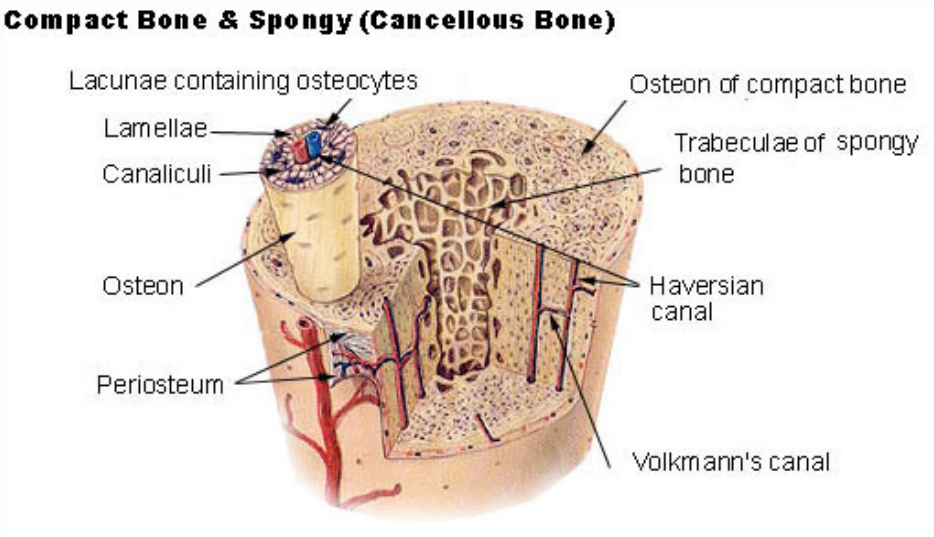
- **Diaphysis.** The diaphysis, or shaft, makes up most of the bone's length and is composed of compact bone; it is covered and protected by a fibrous connective tissue membrane, the **periosteum**.
- **Epiphyses.** The epiphyses are the ends of the long bone; each epiphysis consists of a thin layer of compact bone enclosing an area filled with spongy bone.
- **Articular cartilage.** Articular cartilage, instead of a periosteum, covers its external surface; because the articular cartilage is glassy hyaline cartilage, it provides a smooth, slippery surface that decreases friction at joint surfaces.
- **Epiphyseal plate.** The epiphyseal plates can cause the lengthwise growth of a long bone; by the end of puberty, when hormones inhibit long bone growth, epiphyseal plates have been completely replaced by bones, leaving only the epiphyseal lines to mark their previous location.
- **Yellow marrow.** In adults, the cavity of the shaft is primarily a storage area for adipose (fat) tissue called the yellow marrow, or **medullary**, cavity.
- **Red marrow.** However, in infants, this area forms blood cells and red marrow is found there; in adult bones,
- **Bone markings.** Even when looking casually at bones, one can see that their surfaces are not smooth but scarred with bumps, holes, and ridges; these bone markings reveal where muscles, tendons, and ligaments were attached and where blood vessels and nerves passed.



Microscopic Anatomy

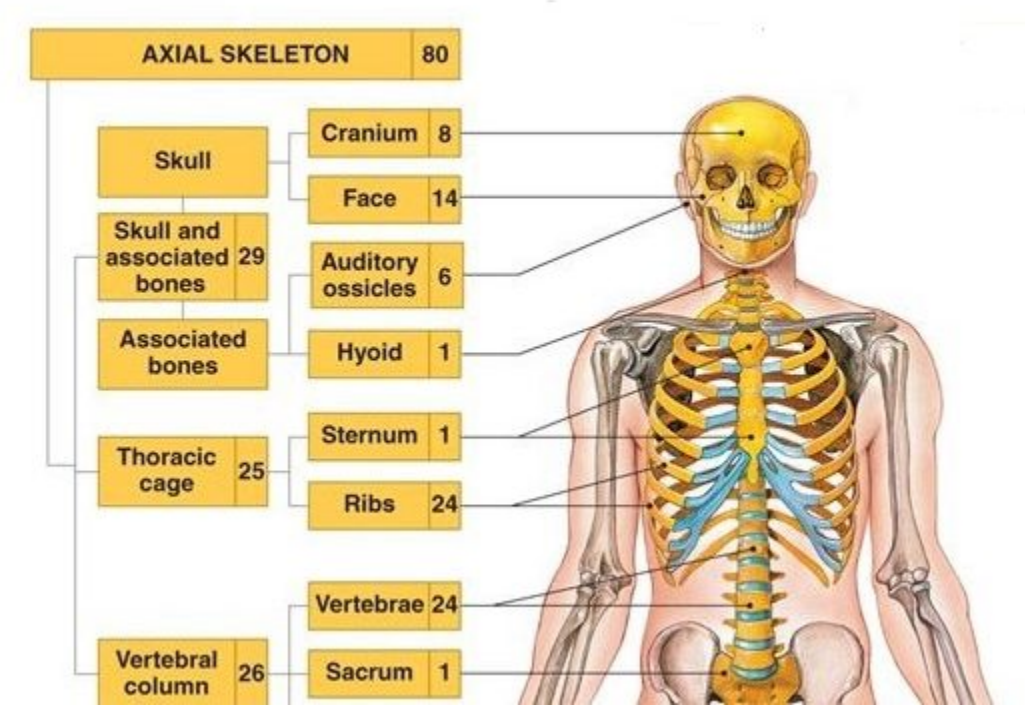
To the naked eye, spongy bone has a spiky, open appearance, whereas compact bone appears to be very dense.

- **Osteocytes.** The mature bone cells, osteocytes, are found within the matrix in tiny cavities called **lacunae**.
- **Lamellae.** The lacunae are arranged in concentric circles called lamellae around central (**Haversian**) canals.
- **Osteon.** Each complex consisting of central canals and matrix rings is called an osteon, or **Haversian system**.
- **Canaliculi.** Tiny canals, canaliculi, radiate outward from the central canals to all lacunae; the canaliculi form a transportation system that connects all the bone cells to the nutrient supply through the hard bone matrix.
- **Perforating canals.** The communication pathway from the outside of the bone to its interior (and the central canals) is completed by perforating (**Volkmann's**) canals, which run into the compact bone at right angles to the shaft.



Axial Skeleton

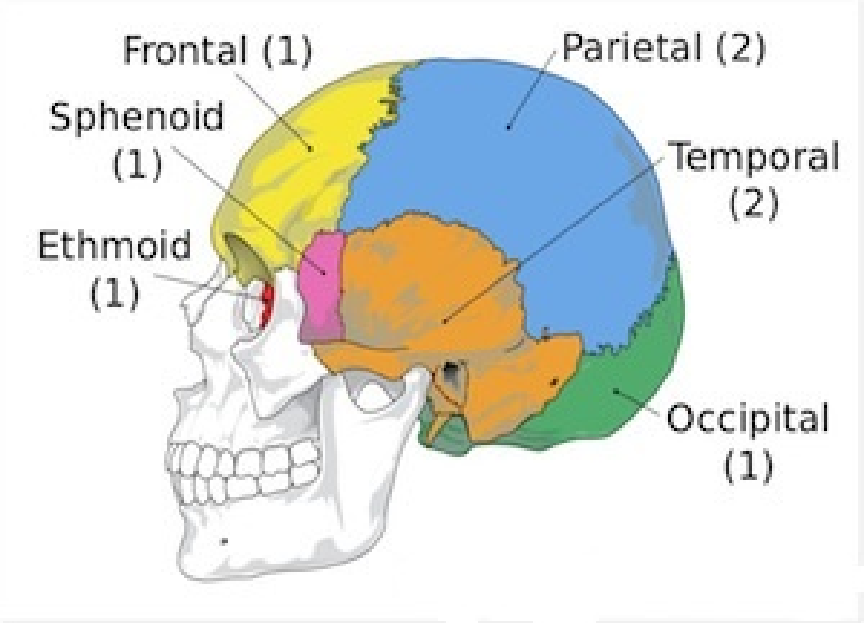
1. Skull
2. Vertibral Collumn
3. Thoracic Cage



The skull (29 bones):

- It protects the brain forming a hard box of bones outside the brain.
- The skull consists of 29 bones (including the ear ossicles, mandible and hyoid).
- The skull can be divided into:
    - The **cranial bones (cranium)**
    - The **facial bones**
- The cranium consists of the following **8 bones**:
    - **Frontal (1):** Anterior and superior part of cranium, forehead and brow areas, which protects front part of the brain.
    - **Parietal (2):** Superior sides and roof cranium, between frontal and occipital bones, that protects the top and sides of the brain.
    - **Temporal (2):** sides and base of cranium at temples that protect the ear ossicles.
    - **Occipital (1):** Posterior part of the cranium including the base that protects the posterior part of the brain.

- **Ethmoid (1):** Base of cranium, anterior to the body of sphenoid and forms the roof of nasal cavity and septum.
- **Sphenoid (1):** Base of cranium, anterior to occipital and temporal bones which houses the pituitary gland.

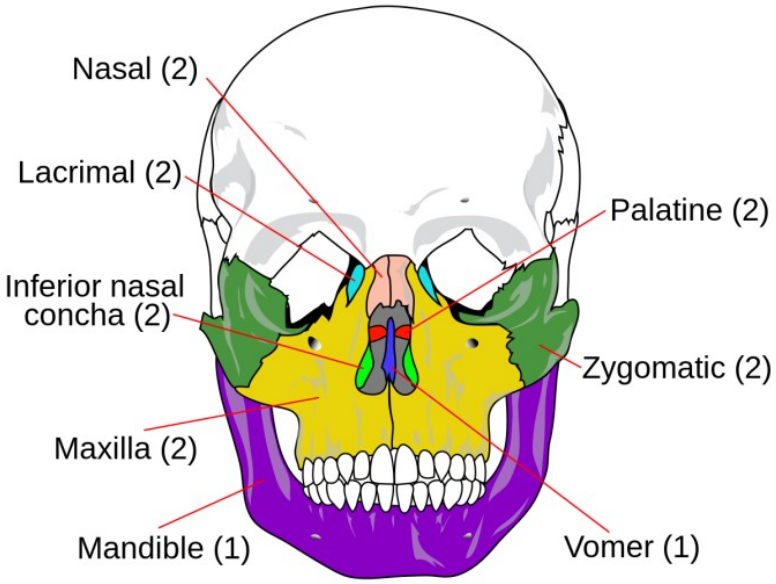


The facial bones consist of the following **14 bones** present in the face:

- **Lacrimal (2):** Small, thin and rectangular, form the medial wall of eye orbits.
- **Nasal (2):** Small, oblong and form the upper bridge of nose, attached to a nasal cartilage.
- **Inferior nasal conchae (2):** Thin, shaped like curved leaves, form the lateral walls of nasal cavities.
- **Zygomatic (2):** Cheek bones below and lateral to orbits.
- **Vomer (1):** Thin, forms the posterior and inferior part of nasal septum.
- **Maxillae (2):** Upper jaw and anterior part of the hard palate.
- **Palatine (2):** L-shaped, posterior part of hard palate and the floor of nasal cavity and orbit.
- **Mandible (1):** Largest and strongest facial bone, lower jaw, extending from chin to mandibular fossa of temporal bone.

Other skull bones:

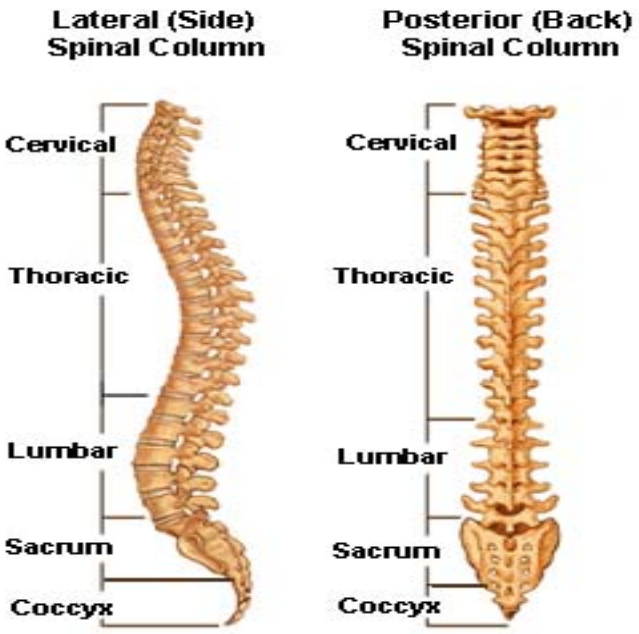
- **Hyoid (1):** U-shaped, below the root of tongue and above the larynx, site of attachment for some muscles that help in speaking and swallowing.
- **Ossicles of ear (6): Incus (2), Malleus (2) and Stapes (2)** Lying inside the cavity of temporal bone that convey sound vibrations from eardrum to the inner ear.



14 Facial Bones

The vertebral column (26 bones):

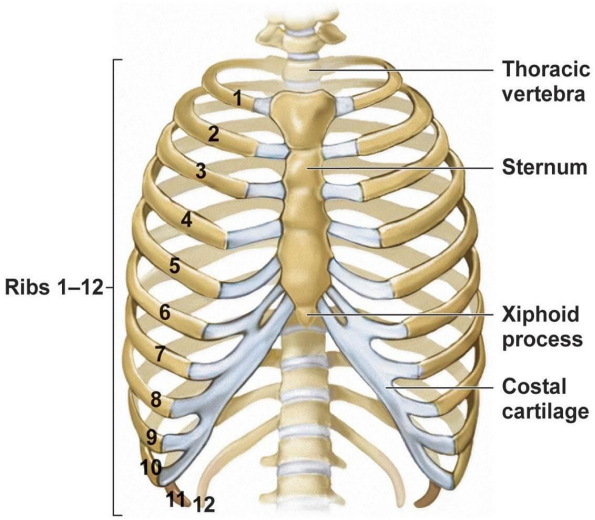
- It is commonly called the **spine** or the spinal column which is a roughly S-shaped column of bones.
- It extends from the base of the skull through the entire length of the trunk.
- This column consists of 26 separate bones called **vertebrae**.
- The vertebral column is stabilized by ligaments, muscles and intervertebral disks to permit twisting and bending movements.
- The vertebrae in the vertebral column are arranged as follows:
    - **Cervical vertebrae (7):** First (Atlas), second (Axis) and seventh vertebrae are modified; third through sixth are typical, support head and allow movement of neck.
    - **Thoracic vertebrae (12):** Bodies and transverse processes have facets that articulate with the ribs; allow some movement of spine in the thoracic region.
    - **Lumbar vertebrae (5):** Largest, strongest vertebrae, allow forward and backward bending of spine
    - **Sacral vertebrae (1):** Wedge-shaped, made up of 5 fused bones, support the vertebral column and give strength and stability to the pelvis.
    - **Coccygeal vertebrae (1):** Triangular tail bone (4 bones fused to form 1), united with the sacrum by intervertebral disk.



The vertebral column of infants consists of 33 bones, in which sacral region has 5 bones and coccygeal region has 4 bones which are not yet fused.

The sternum and the rib cage (25 bones):

- The cage-like thoracic skeleton protects the heart, the lungs and some abdominal organs.
- The rib cage anteriorly consists of 12 pairs of ribs, 12 costal cartilages and the sternum.
- The **sternum** or the **breast bone (1):** The midline bony structure of the anterior chest wall.
- It resembles a dagger in the adult that consists of a **manubrium**, a **body** and **xiphoid process**.
- Ribs are long, curved bones, varying in length and width. With costal cartilages,they provide flexible mechanism for breathing and support bones of upper extremities.
- 12 pairs of ribs altogether can be divided into 3 types:
    - **True ribs (1^{st}-7^{th} pairs):** They arise from the thoracic vertebrae at the back and attach directly to the sternum in the front.
    - **False ribs (8^{th} -10^{th} pairs):** They arise from the thoracic vertebrae at the back but don't attach to the sternum directly, instead attach to the cartilage of the 7^{th} true rib.
    - **Floating ribs (11^{th} and 12^{th} pairs):** They are attached only to the vertebral column at the back and nothing in the front.



Appendicular Skeleton

- Appendicular skeleton is composed of bones which lie on the lateral sides of the mid axial line of our body and consists of the hanging bones.
- It can be divided into two groups;

1. **The upper extremities** (Pectoral girdle and the bones of upper limbs)
2. **The lower extremities** (Pelvic girdle and the bones of lower limbs)

***Girdle** is the bony or cartilaginous arch that supports the limbs of the vertebrates.

The upper extremities (64 bones):

- The upper extremity is connected to and supported by the axial skeleton by only one joint (pectoral girdle or the shoulder joint) and many muscles.
- The joint is the **sternoclavicular joint** between the manubrium of the sternum and the clavicle.
- The upper extremities consist of 64 bones which include;

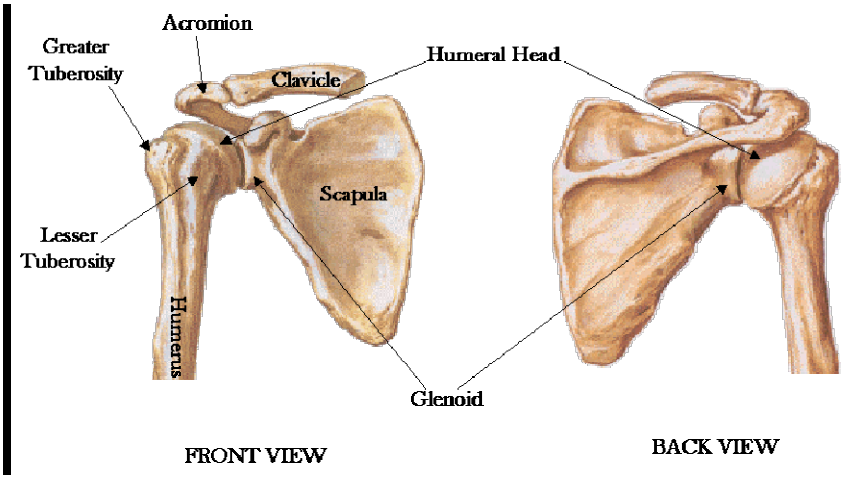
1. **Clavicle (2):**

- It is a collar bone, double curved long bone with rounded medial end and flattened lateral end.
- It holds the shoulder joint and arm away from thorax so upper limb can swing freely.

2. **Scapula (2):**

- It is a shoulder blade which is flat and triangular with horizontal spine separating fossae.
- It is the site of attachment of muscles of arm and chest.

- The **glenoid fossa** receives the head of humerus.



3. **Humerus (2):**

- It is the longest and the largest bone of the upper limb.
- It forms **ball and socket joint** with the glenoid fossa of scapula.
- Muscles of the shoulder and arm attach to the humerus permitting arm to flex and extend at elbow.

4. **Radius** and **ulna (4):**
   - Radius is the shorter of two bones present in forearm.
   - It allows forearm to rotate in radial motion.
   - Ulna is the larger of the two bones in forearm.
   - Larger proximal end consists of **olecranon process** (prominence of elbow).
   - It forms hinge joint at the elbow.

4. **Carpals (16):**
   - They are small and short bones of the wrist.
   - 8 carpals are arranged in 2 transverse rows of 4.
   - They help in slight gliding movement because of attached ligaments.

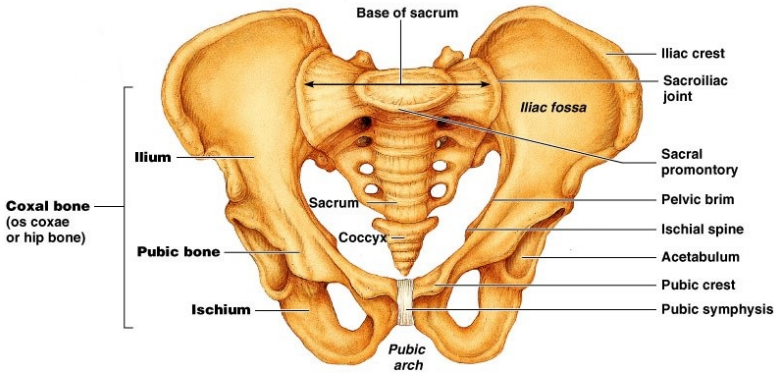
6. **Metacarpals (10):**
   - They are five miniature long bones in each hand in fan like arrangement.
   - They articulate with the fingers at metacarpo-phallangeal joint (the knuckles).
   - They aid in opposition movement of thumb and enable cupping of hand.

7. **Phalanges (28):**
   - They are miniature long bones; 2 in each thumb and 3 in each finger.
   - They articulate with each other at inter-phalangeal joint and allow fingers to participate in stable grips.

The lower extremities (62 bones):

- It can be divided into two parts; the pelvic girdle or the hip joint and the bones of lower limbs.
- The lower extremities consist of 62 bones which include:

1. **Pelvic girdle (2):**
   - The bone is called pelvis or hip bone or coxa.
   - It is an irregular bone formed by the fusion of **ilium, ishium** and **pubis** (which are separate in children).
   - The hip bone is fused with the sacrum and coccyx to form a **pelvis**.
   - The head of femur fits into the **acetabulum** in the pubis of hip bone to form a ball and socket joint.
   - Pelvis girdle is also the site of attachment of trunk and lower limb muscles.
   - It also transmits body weight to femur.

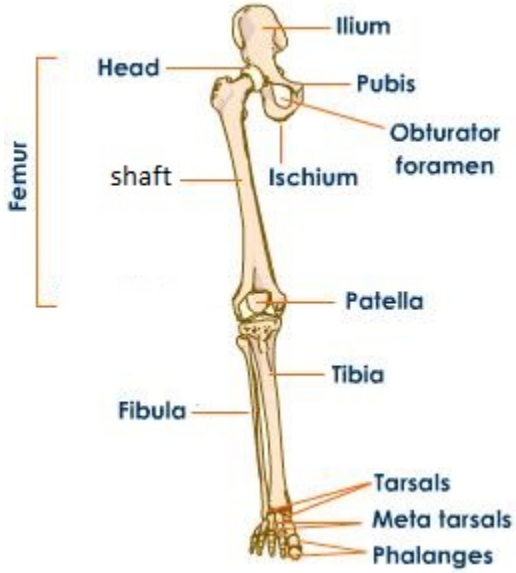


Pelvic girdle (hip bones)

2. **Femur (2):**
   - It is a typical long bone in the thigh (also called a thigh bone).
   - It is the longest, strongest and heaviest bone.
   - It forms a ball and socket joint with the pelvic bones.
   - Femur provides articular surfaces for knee and supports the body.
3. **Patella (2):**
   - It is roughly triangular or circular flat sesamoid bone (developed from the tendon **quadriceps femoris**).
   - It increases the leverage for quadriceps muscle by keeping tendon away from the axis of rotation.
   - It protects the knee joint.
4. **Tibia** and **fibula (4):**
   - Tibia is the larger long bone of the lower leg (calf region) which articulates with the femur, fibula and tarsals.
   - It supports the body weight transmitting it from femur to the tarsals.
   - Fibula is the smaller long bone of the lower leg.
   - It articulates proximally with tibia and distally with tarsals.
   - It bears little body weight but gives strength to the ankle joint.
5. **Tarsals (14):**
   - They are short bones in the ankle region (also called the heelbones).
   - They are 7 in each ankle and with the metatarsals form the arches of foot.
   - They also bear body weight, raise the body and transmit thrust during running and walking.
6. **Metatarsals (10):**
   - They are miniature long bones, 5 in each foot and form the sole.

- With tarsals, they form arches of feet and also improve stability while standing.
- Metatarsals also absorb shocks, bear weight and aid in locomotion.

7. **Phalanges (28):**
   - They are the miniature long bones in the toes.
   - They are arranged as in hand (2 in each big toe and 3 in each other toe).
   - They provide stability during locomotion.



Functions of the Skeletal System

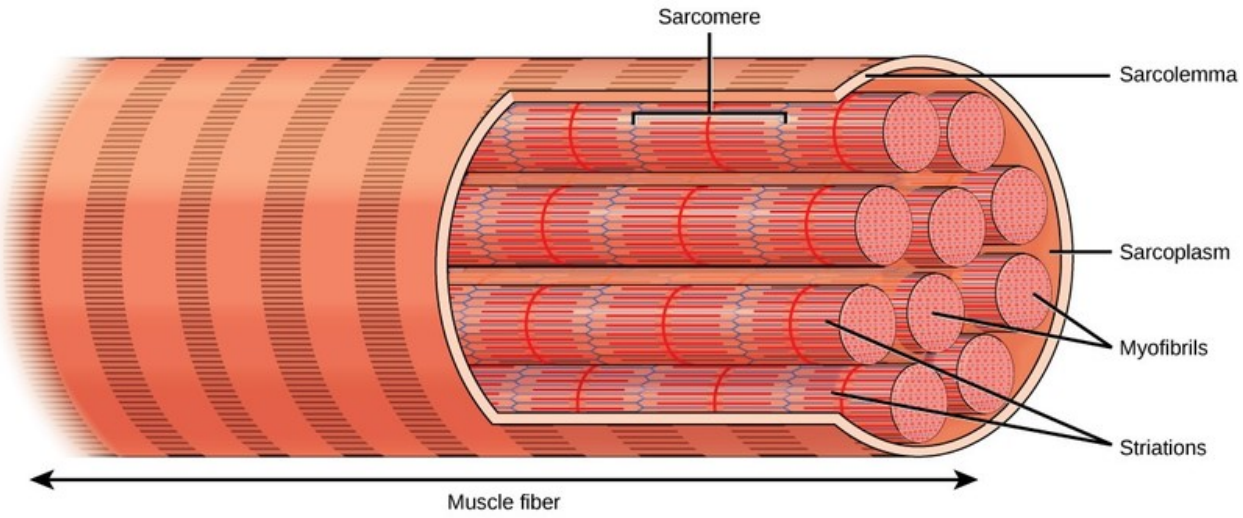
Besides contributing to body shape and form, our bones perform several important body functions.

1. **Support.** Bones, the "steel girders" and "reinforced concrete" of the body, form the internal framework that supports the body and cradle its soft organs; the bones of the legs act as pillars to support the body trunk when we stand, and the rib cage supports the thoracic wall.
2. **Protection.** Bones protect soft body organs; for example, the fused bones of the skull provide a snug enclosure for the brain, the vertebrae surround the spinal cord, and the rib cage helps protect the vital organs of the thorax.
3. **Movement.** Skeletal muscles, attached to bones by tendons, use the bones as levers to move the body and its parts.
4. **Storage.** Fat is stored in the internal cavities of bones; bone itself serves as a storehouse for minerals, the most important of which are calcium and phosphorus; because most of the body's calcium is deposited in the bones as calcium salts, the

bones are a convenient place to get more calcium ions for the blood as they are used up.

5. **Blood cell formation.** Blood cell formation, or hematopoiesis, occurs within the marrow cavities of certain bones.

MUSCLE CONTRACTION



Initiation of Muscle Contraction

Step 1) Neuromuscular Control

The axons of the nerve cells of the spinal cord branch and attach to each muscle fiber forming a **neuromuscular junction**.

i). An action potential passes down the nerve.

ii). The nerve releases Ca++ that results in the release of **Acetylcholine (ACh)**

Step 2). ACh binds with the sarcolemma.

Step 3). Muscle Fiber Action Potential

i). <u>ACh binds</u> with receptors and <u>opens Na+</u> channels

1. Na+ Channels open and Na+ in----------→ depolarization occurs in muscle fiber. Thus depolarization spreads.

ii). **The <u>K+ channels open</u> and the <u>region repolarizes</u>**

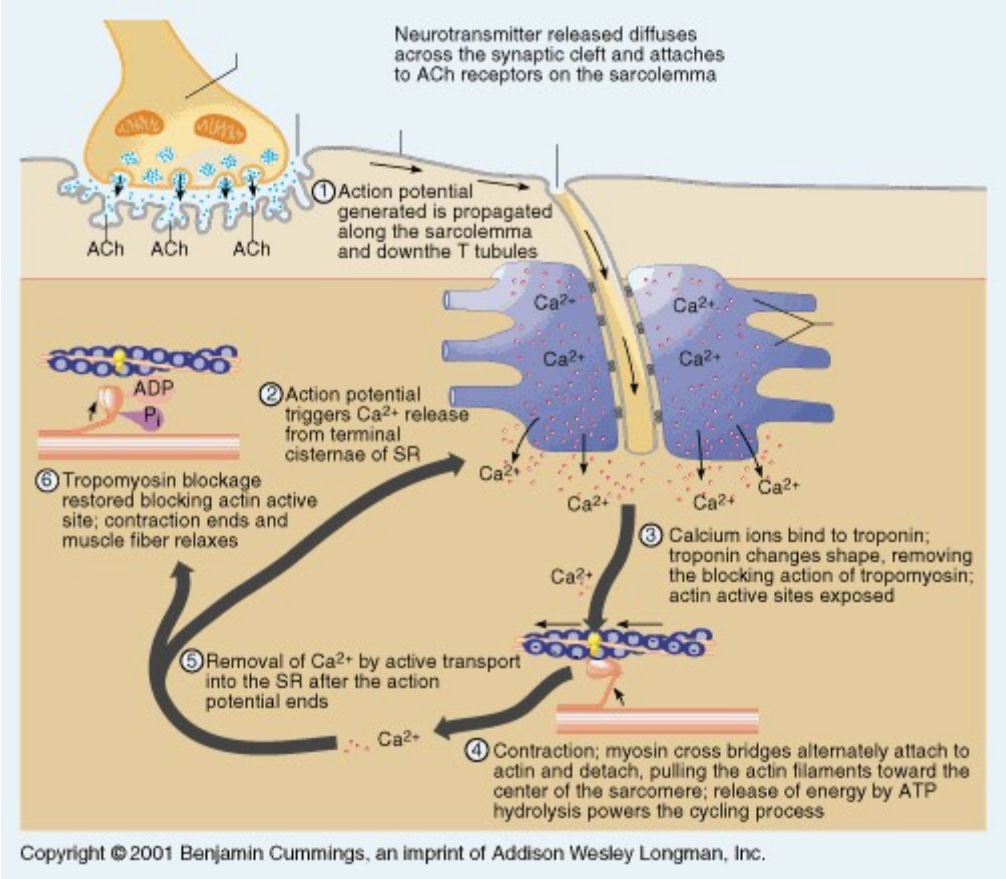
- Immediately after the action potential passes the membrane permeability changes again.
- Na+ channels close and K+ channels open.
- K+ rushes out of the cell.
- Cell reploraizes

Step 4). Ca++ is released from the sarcoplasmic reticulum.

i). Ca++ is stored in the **sarcoplasmic reticulum**.

ii). Depolarization releases the Ca++.

iii). The Ca++ clears the actin binding sites.



Step 5). Sliding Filament Theory of Contraction

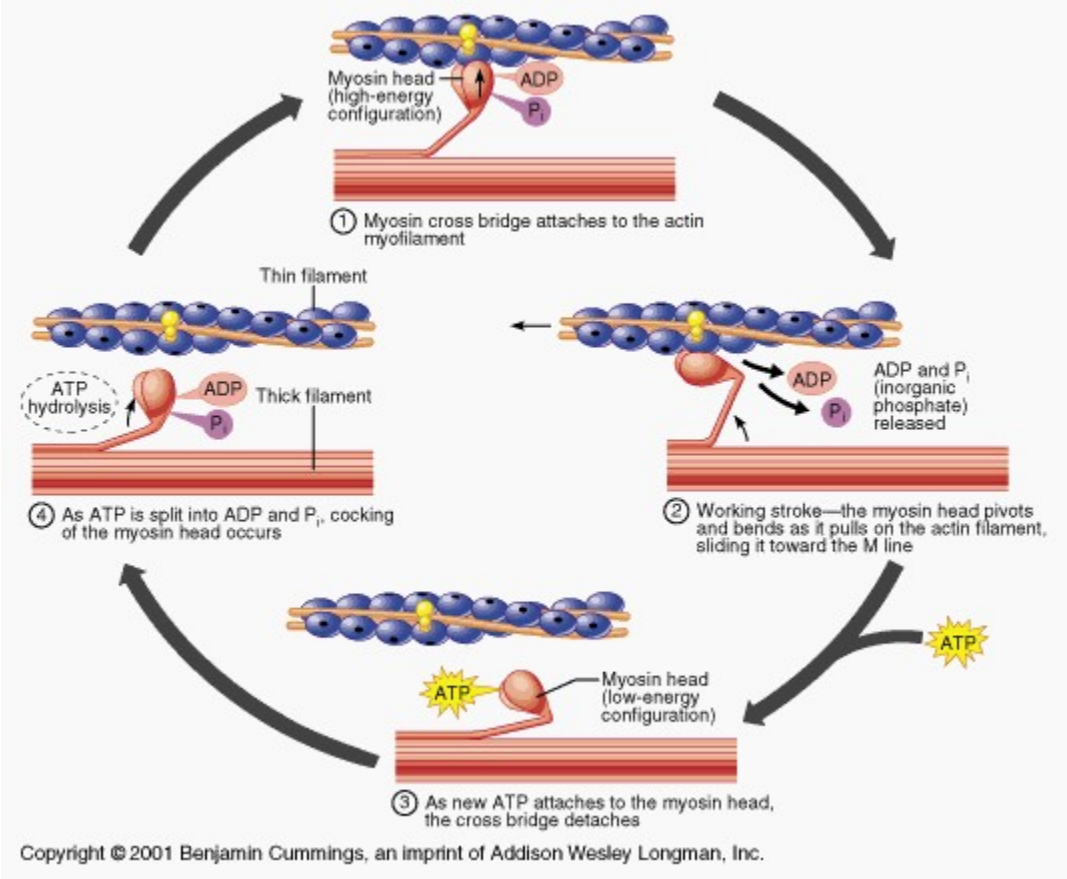
During muscle contraction the thin actin filaments slide over the thick myosin filament.

When Calcium is present the blocked active site of the actin clears.

Step A: Myosin head attaches to actin. (High energy ADP + P configuration)

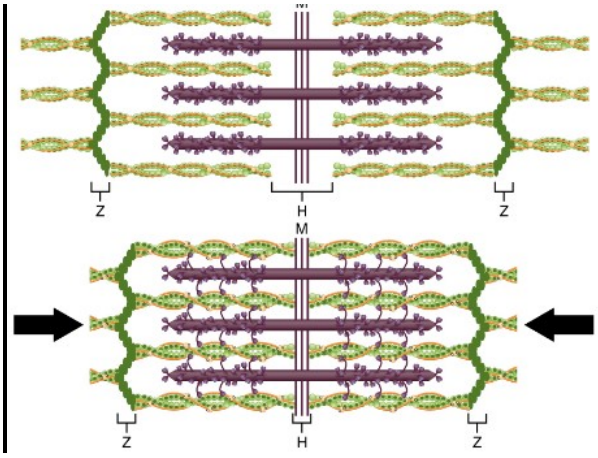
Step B: Power stroke: myosin head pivots pulling the actin filament toward the center.

Step C: The cross bridge detaches when a new ATP binds with the myosin.



The end result is a shortening of the sarcomere.

- The distance between the **Z discs** shortens
- The **H zone** disappears
- The **dark A band** increases because the actin & the myosin overlap more
- The **light I band** shortens.



Step 6). Ca++ is removed from the cytoplasm

Step 7). Tropomysin blocks the actin site.

The structure of Neuromuscular junction can be broadly divided into three parts:

1. Presynaptic

2. Synaptic cleft

3. Postsynaptic portions.

1. Presynaptic Portion:

i. Motor neurons that have their cell bodies in the anterior horn of spinal cord or brainstem innervate the skeletal muscle. Motor neuron axons are myelinated and are the largest diameter axons in the body.

ii. As the motor neuron axon approaches the skeletal muscle fiber it loses its myelin sheath and divides into number of fine branches (terminal axons) which end in small swellings (knobs) called terminal buttons, at the center of muscle fiber in the groove (synaptic trough) but outside the muscle fiber membrane.

iii. Each muscle fiber is supplied by one motor neuron terminal. The motor neuron plus the muscle fiber it innervates is called as motor unit.

iv. Terminal buttons (synaptic knobs) contains plenty of mitochondria and neurotransmitter vesicles. The acetylcholine (ACh) is synthesized in mitochondria and stored in vesicles.

v. The vesicles are clustered around a specific point called active zone, where voltage-gated Ca^{++} channels are present and mediate ACh release.

2. Synaptic Cleft:

i. This is gap between the terminal button and muscle fiber (50-100 nm wide).

ii. The basement membrane of muscle fiber in the cleft contains the enzyme acetyl Cholinesterase, which hydrolyzes ACh into acetate and choline.

3. Postsynaptic Portion (End Plate Membrane):

i. The muscle fiber plasma membrane that lies directly under terminal axon portion is known as the end plate membrane (motor end plate).

ii. The endplate membrane is thrown into several folds called junctional folds, which contains nicotinic type of ACh receptors at their crests.