UNIT IV Chapter 9

Locomotion and Movement

Chapter Outline

Leaping movement is effected by the coordination of skeletal and neuromuscular systems.

Learning Objectives:

- *Relates the structure of skeletal muscle with its function.*
- *Learns to identify bones of the skeletal system.*
- *Gains knowledge about the disorders related to muscular and skeletal systems.*
- *Understands the benefits of regular exercise.*
- *Learn different types of bone fracture and the mechanism of healing.*

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Have you ever wondered how a dancer performs intricate dance steps or how a swimmer skillfully does a butterfly stroke? The muscles of our body work simultaneously with one another and with the skeletal system to perform the various movements. Our muscles have two functions: to generate motion and force. All these activities are controlled and coordinated by the skeletal, muscular and nervous system. The human body is capable of a wide range of movements from the gentle blinking of eye to running a 20 km marathon. Movement of organism from one place to another in search of food, shelter, mate and to escape from predators is called locomotion. Locomotion has evolutionary significance.

9.1 Types of movement

The different types of movements that occur in the cells of our body are amoeboid, ciliary, flagellar and muscular movement.

Amoeboid movement - Cells such as macrophages exhibit amoeboid movement for engulfing pathogens by pseudopodia formed by the streaming movement of the cytoplasm.

Ciliary movement - This type of movement occurs in the respiratory passages and genital tracts which are lined by ciliated epithelial cells.

Flagellar movement - This type of movement occurs in the cells which are having flagella or whip-like motile organelle. The sperm cells show flagellar movement.

Muscular movement -The movement of hands, legs, jaws, tongue are caused by the contraction and relaxation of the muscle which is termed as the muscular movement.

9.2 Types of muscles

Muscles are specialized tissues which are derived from the embryonic **mesoderm**. They are made of cells called **myocytes** and constitute 40 – 50 percent of body weight in an adult. These cells are bound together by a connective tissue to form a muscular tissue. The muscles are classified into three types, namely **skeletal, visceral** and **cardiac muscles.**

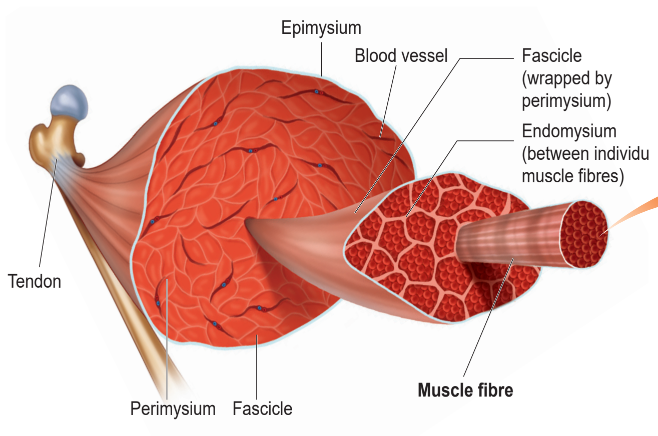
9.3 Skeletal muscle (Voluntary muscle)

Skeletal muscle is attached to the bone by a bundle of collagen fibres known as **tendon**. Each muscle is made up of bundles of **muscle fibres** called **fascicle**. Each muscle fibre contains hundreds to thousands of rod-like structures called **myofibrils** that run parallel to its length. The connective tissue covering the whole muscle is the **epimysium**, the covering around each fascicle is the **perimysium** and the muscle fibre is surrounded by the **endomysium**. They control the voluntary actions such as walking, running, swimming, writing hence termed as voluntary muscles.

9.3.1 Structure of a skeletal muscle fibre

Each muscle fibre is thin and elongated. Most of them taper at one or both ends. Muscle fibre has multiple oval nuclei just beneath its **plasma membrane** or **sarcolemma**. The cytoplasm of the muscle fibre is called the **sarcoplasm**. It contains glycosomes, myoglobin and sarcoplasmic reticulum. **Myoglobin** is a red- coloured respiratory pigment of the muscle fibre. It is similar to haemoglobin and contains iron group that has affinity towards oxygen and serves as the reservoir of oxygen. **Glycosomes** are the granules of stored glycogen that provide glucose during the period of muscle fibre activity. Actin and myosin are muscle proteins present in the muscle fibre.

Along the length of each myofibril there are a repeated series of dark and light bands (Figure 9.1). The dark **A-bands** (Anisotropic bands) and the light **I-bands** (Isotropic bands) are perfectly aligned with one another. This type of arrangement gives the cell a striated appearance. Each dark band has a lighter region in its middle



called the **H-Zone** (H-Helles: means clear). Each H-zone is bisected vertically by a dark line called the M-line (M-for middle). The light I-bands also have a darker mid line area called the **Z–disc** (from the German "Zwischenscheibe" the disc inbetween the I-bands).

The myofibrils contain the contractile element, the **sarcomere** which is the functional unit of the skeletal muscle. A Sarcomere is the region of a myofibril between two successive Z-discs. It contains an A-band with a half I-band at each end. Inside the sarcomere two types of filaments are present namely the **thick** and **thin filaments**.

The thick filaments extend the entire length of the A-band, the thin filaments extend across the I-band and partly into the A-band. The invagination of the sarcolemma forms transverse tubules **(T–tubules)** and they penetrate into the junction between the A and I-bands.

Muscle Terminology

General Term	Muscle Equivalent
Cell	Muscle fibre/ Myofibril
Plasma membrane	Sarcolemma
Cytoplasm	Sarcoplasm
Endoplasmic reticulum	Sarcoplasmic reticulum

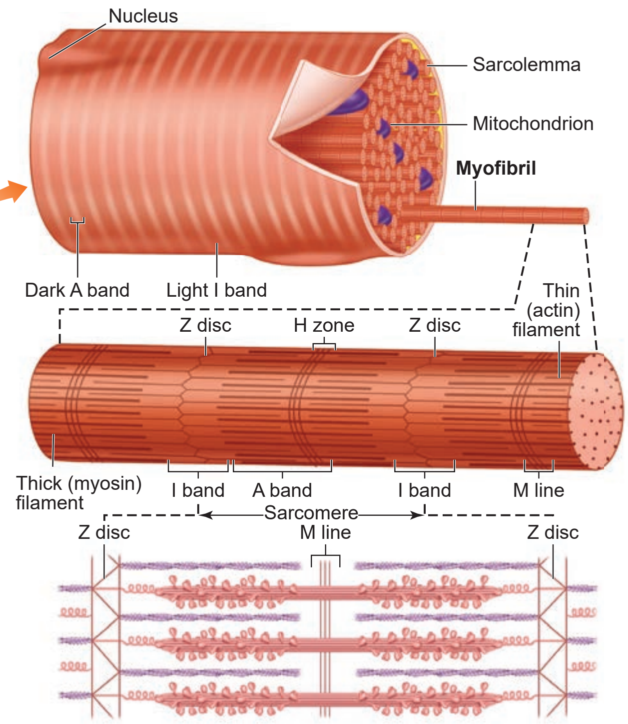


Figure 9.1 Organizational level of a skeletal muscle

9.4 Structure of contractile proteins

Contraction of the muscle depends on the presence of contractile proteins (Figure 9.2) such as **actin** and **myosin** in the myofilaments. The thick filaments are composed of the protein myosin which are bundled together whose heads produce at opposite ends of the filament. Each myosin molecule is made up of a monomer called meromyosin. The meromyosin has two regions, a globular head with a short arm and a tail. The short arm constitutes the heavy meromyosin (HMM). The tail portion forms the light meromyosin (LMM). The head bears an actin-binding site and an ATP- binding site. It also contains ATPase enzyme that split ATP to generate energy for the contraction of muscle. The thin filaments are composed of two interwined actin molecules. Actin has polypeptide subunits called globular actin or G–actin and filamentous form or F-actin. Each thin filament is made of two F-actins helically wound to each other. Each F-actin is a polymer of monomeric G-actins. It also contains a binding site for myosin. The thin filaments also contain several regulatory proteins like **tropomyosin** and **troponin** which help in regulating the contraction of muscles along with **actin** and **myosin**.

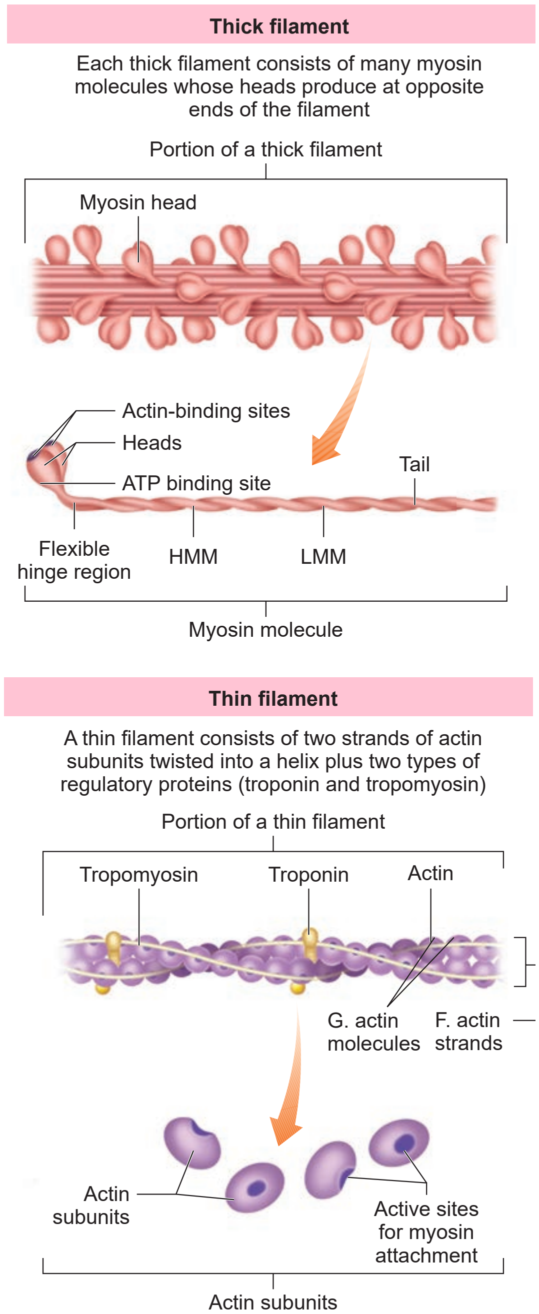


Figure 9. 2 Composition of thick and thin filaments

9.5 Mechanism of muscle contraction

Sliding filament theory: In 1954, Andrew F. Huxley and Rolf Niedergerke proposed the sliding-filament theory to explain muscle contraction. According to this theory, overlapping actin and myosin filaments of fixed length slide past one another in an energy requiring process, resulting in muscle contraction. The contraction of muscle fibre is a remarkable process that helps in creating a force to move or to resist a load. The force which is created by the contracting muscle is called muscle tension. The load is a weight or force that opposes contraction of a muscle. Contraction is the creation of tension in the muscle which is an active process and relaxation is the release of tension created by contraction. Muscle contraction is initiated by a nerve impulse sent by the central nervous system (CNS) through a motor neuron. The junction between the motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor end plate. When nerve impulse reaches a neuromuscular junction, acetylcholine is released. It initiates the opening of multiple gated channels in sarcolemma. The action potential travels along the T-tubules and triggers the release of calcium ions from the sarcoplasmic reticulum. The released calcium ions bind to troponin on thin filaments. The tropomyosin uncovers the myosin-binding sites on thin filaments. Now the active sites are exposed to the heads of myosin to form a cross-bridge (Figure 9.3). During cross-bridge formation actin and myosin form a protein complex called actomyosin. Utilizing the energy released from hydrolysis of ATP, the myosin head rotates until it forms a 90^{o} angle with the long axis of the filament. In this position myosin binds to an actin and activates a contraction – relaxation cycle which is followed by a power stroke.

The power stroke (cross-bridge tilting) begins after the myosin head and hinge region tilt from a 90° angle to a 45° angle. The cross-bridge transforms into strong, high-force bond which allows the myosin head to swivel. When the myosin head swivels it pulls the attached actin filament towards the centre of the A-band. The myosin returns back to its relaxed state and releases ADP and phosphate ion. A new ATP molecule then binds to the head of the myosin and the cross-bridge is broken. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. This movement is similar to the motion of an oar on a boat. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. The power stroke repeats many times until a muscle fibre contracts. The myosin heads bind, push and release actin molecules over and over as the thin filaments move toward the centre of the sarcomere. The repeated formation of cross-bridge cycles cause the sliding of the filaments only but there is no change in the lengths of either the thick or thin filaments. The Z- discs attached to the actin filaments are also pulled inwards from both the sides, causing the shortening of the sarcomere (i.e. contraction). This process continues as long as the muscle receives the stimuli and with a steady flow of calcium ions. When motor impulse stops, the calcium ions are pumped back into the sarcoplasmic reticulum which result in the masking of the active sites of the actin filaments. The myosin head fails to bind with the active sites of actin and these changes cause the return of Z-discs back to their original position, i.e. relaxation. (Figure 9.3)

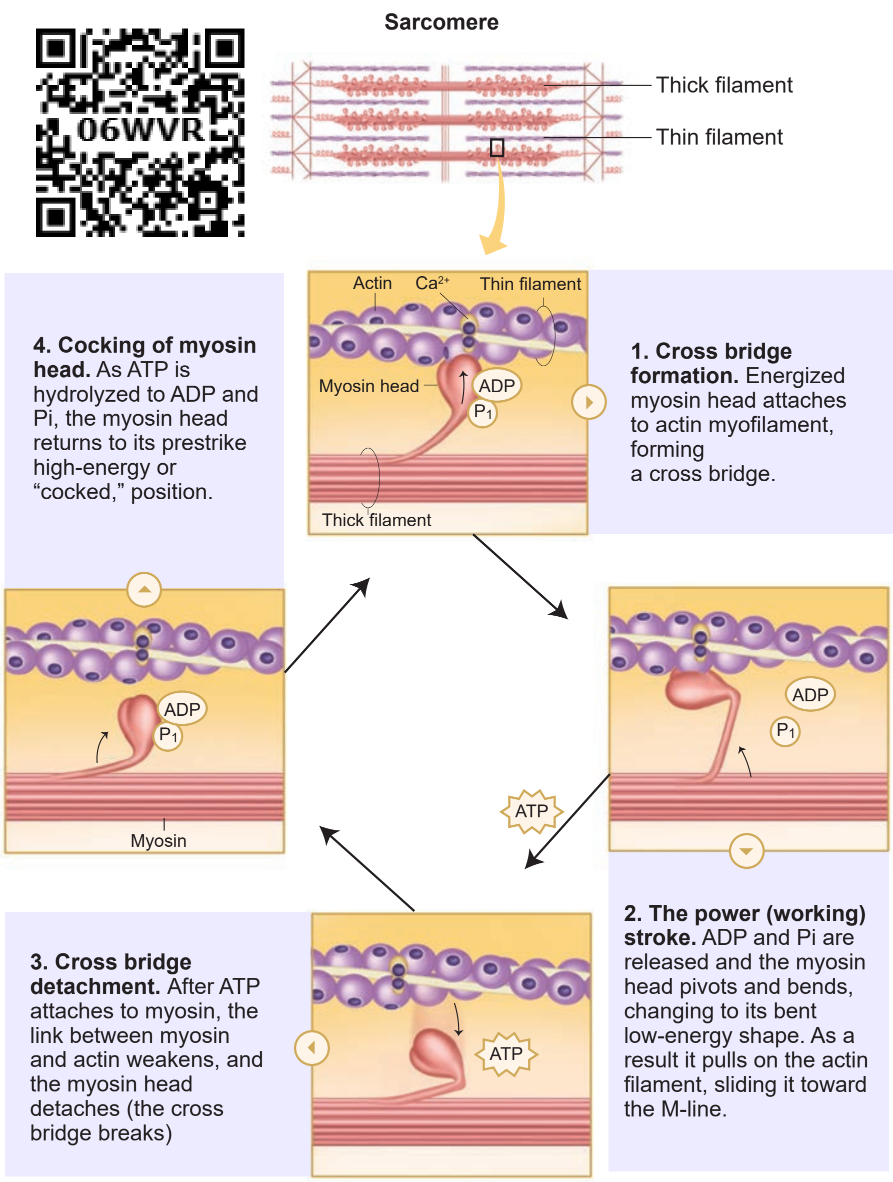


Figure 9.3 Cross-bridge cycle of muscle contraction

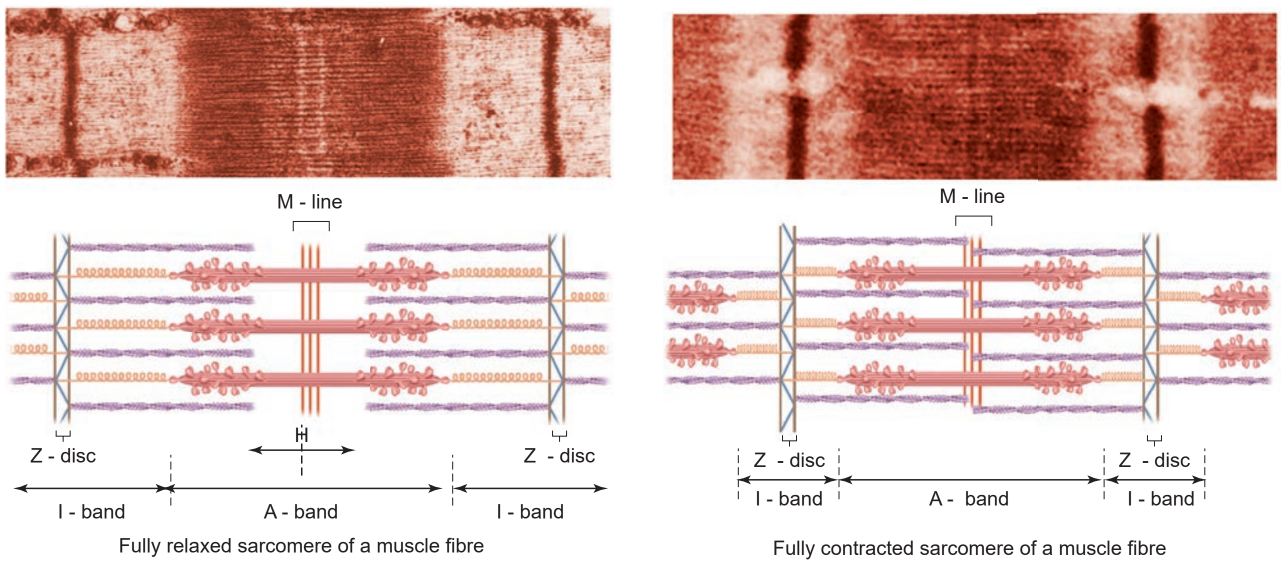


Figure 9.4 Sliding filament model of muscle contraction

Schematic Presentation of Muscle Contraction

- Muscle contraction is initiated by the signal from CNS
- ↓ Release of acetylcholine at the neuromuscular junction
- ↓ Causes action potential in muscle fibre
- ↓ Triggers the release of calcium ions from sarcoplasmic reticulum
- ↓ Calcium ions combine with troponin and tropomyosin uncovers the binding sites on actin and initiates contraction
- ↓ Myosin binding sites on actin exposed. Myosin head binds to actin
- ↓ Myosin head executes power stroke
- ↓ Actin filament slides towards the centre of sarcomere (contraction)
- ↓ Signal from CNS stops; calcium ions are pumped back into the sarcoplasmic reticulum
- ↓ Tropomyosin masks the binding sites. Filaments pulled back to the original position (relaxation)

9.6. Types of skeletal muscle contraction

There are two primary types of muscle contractions. They are **isotonic contraction** and **isometric contraction**. The types of contractions depend on the changes in the length and tension of the muscle fibres at the time of its contraction.

Isotonic contraction (iso- same, ton- weight/resistance)

In isotonic contraction the length of the muscle changes but the tension remains constant. Here, the force produced is unchanged. Example: lifting dumb bells and weightlifting.

Isometric contraction (iso- same, metric-distance)

In isometric contraction the length of the muscle does not change but the tension of the muscle changes. Here, the force produced is changed. Example: pushing against a wall, holding a heavy bag.

Types of skeletal muscle fibres

The muscle fibres can be classified on the basis of their rate of shortening, either fast or slow and the way in which they produce the ATP needed for contraction, either oxidative or glycolytic. Fibres containing myosin with high ATPase activity are classified as fast fibres and with lower ATPase activity are classified as slow fibres. Fibres that contain numerous mitochondria and have a high capacity for oxidative phosphorylation are classified as **oxidative fibres**. Such fibres depend on blood flow to deliver oxygen and nutrients to the muscles. The oxidative fibres are termed as **red muscle fibres**. Fibres that contain few mitochondria but possess a high concentration of glycolytic enzymes and large stores of glycogen are called **glycolytic fibres**. The lack of myoglobin gives pale colour to the fibres, so they are termed as **white muscle fibres**.

Skeletal muscle fibres are further classified into three types based on the above classification. They are slow – oxidative fibres, fast – oxidative fibres and fast – glycolytic fibres.

1. **Slow – oxidative fibres** have low rates of myosin ATP hydrolysis but have the ability to make large amounts of ATP. These fibres are used for prolonged, regular activity such as long distance swimming. Long – distance runners have a high proportion of these fibres in their leg muscles.
2. **Fast – oxidative fibres** have high myosin ATPase activity and can make large amounts of ATP. They are particularly suited for rapid actions.
3. **Fast – glycolytic fibres** have myosin ATPase activity but cannot make as much ATP as oxidative fibres, because their source of ATP is glycolysis. These fibres are best suited for rapid, intense actions, such as short sprint at maximum speed.

Which myofilament has the binding sites for calcium? Name the specific molecule that binds with calcium.

DO YOU KNOW?

Skeletal Muscle Glycogen Analysis (SMGA) –Used to measure an Athlete's sporting performance by taking muscle biopsies. It is a standard method to measure muscle glycogen. Muscle glycogen provides the main source of energy during anaerobic exercise. Furthermore, total glycogen stores within the body also contribute significantly to energy metabolism in endurance-type events lasting longer in duration. A single glycogen molecule may contain 5000 glucose units compared to that of 5000 individual glucose molecules.

9.7 Properties of Skeletal Muscles

The four major properties of skeletal muscles are

Excitability/Irritability—The ability to respond or contract in response to chemical and electrical signals.

Contractility—The ability to shorten which causes movement of the structures to which the muscles are attached.

Conductivity —Stimulus acting on one region of muscle fibre spreads to all parts of the muscle is known as conductivity.

Elasticity/Distensibility—The ability to return to the original resting length after a muscle has been stretched.

9.8 Skeletal system and its function

The skeletal system is constituted by a framework of bones and cartilages. It is derived from the embryonic **mesoderm**. Muscles are attached to the bones by means of tendons and provide the necessary force required for the bones of the skeleton to operate as levers. There are three types of skeletal systems. They are,

Hydrostatic skeleton, which is found in soft-bodied invertebrates. It is a fluid filled-cavity encircled by muscles (e.g. Earth worm).

Exoskeleton, which is found in invertebrates. It is a rigid hard case present outside the body of animals (e.g. Cockroach).

Endoskeleton, which is found inside the body of vertebrates. It is composed of bones and cartilages, surrounded by muscles. (eg. Human being).

In human beings, the skeletal system is made up of 206 bones and cartilages. It is grouped into two principal divisions – the **axial skeleton** and the **appendicular skeleton**. The axial skeleton consists of 80 bones and the appendicular skeleton consists of 126 bones (Figure 9.6 and Table.1).

Functions of skeletal system

- **Support** –It forms a rigid framework and supports the weight of the body against gravity.
- **Shape** - It provides and maintains the shape of the body.

All muscles produce movement, but only skeletal muscle is responsible for locomotion. What is meant by this statement?

- **Protection** – It protects the delicate internal organs of the body.
- **Acts as reservoir** – It stores minerals such as calcium and phosphate. Fat (Triglyceride) is stored in yellow bone marrow and represents a source of stored energy for the body.
- **Locomotion** – It acts as lever along with the muscles attached to it.
- **Strength** – It can withstand heavy weight and absorbs mechanical shock.
- **As a haemopoietic tissue** – Red and White blood cells are produced in the bone marrow of the ribs, spongy bones of vertebrae and extremities of long bones.

9.9 The Axial skeleton

Axial skeleton forms the main axis of the body. It consists of the skull, hyoid bone, vertebral column and thoracic cage.

a) The Skull

The skull is composed of two sets of bones – cranial and facial bones. It consists of 22 bones of which 8 are cranial bones and 14 are facial bones (Figure 9.5). The cranial bones form the hard protective outer covering of the brain and called the brain box. The capacity of the cranium is 1500 cm^3. These bones are joined by sutures which are immovable. They are a **paired parietal, paired temporal** and **individual bones** such as the **frontal, sphenoid, occipital and ethmoid**.

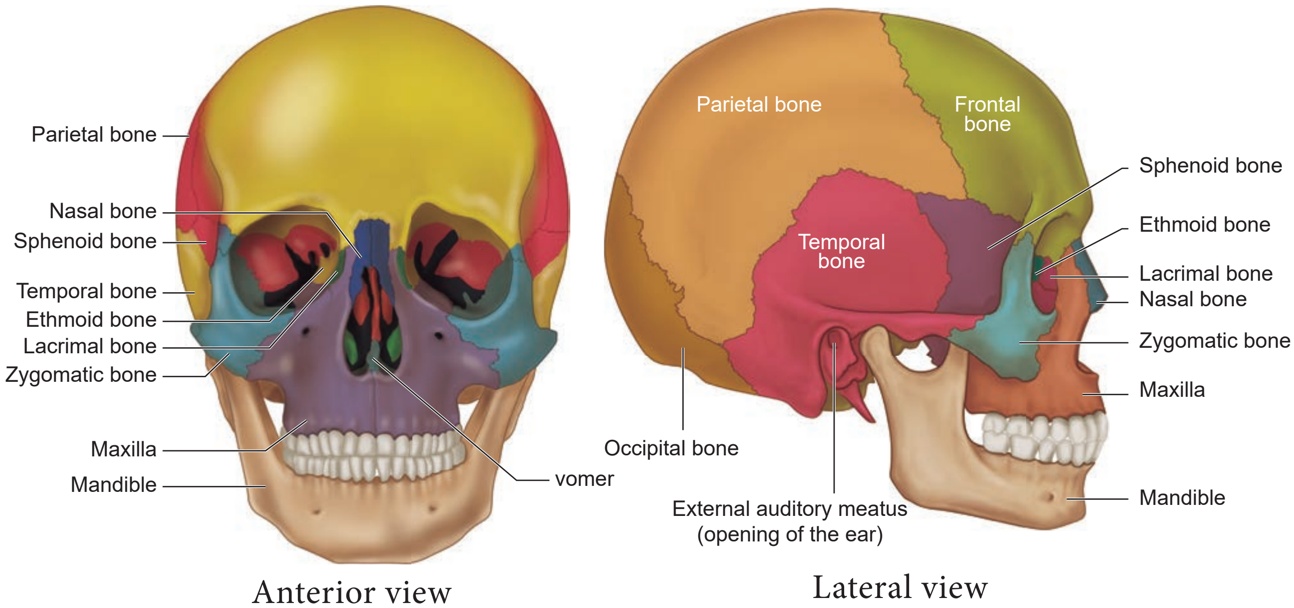


Figure 9. 5 Structure of the skull

The large hole in the temporal bone is the **external auditory meatus**. In the facial bones **maxilla, zygomatic, palatine, lacrimal, nasal** are paired bones whereas **mandible** or **lower jaw** and **vomer** are **unpaired bones**. They form the front part of the skull. A single U-shaped **hyoid bone** is present at the base of the buccal cavity. It is the only one bone without any joint. Each middle ear contains three tiny bones- **malleus**, **incus** and **stapes** collectively are called **ear ossicles**. The upper jaw is formed of the **maxilla** and the lower jaw is formed of the **mandible**. The upper jaw is fused with the cranium and is immovable. The lower jaw is connected to the cranium by muscles and is movable. The most prominent openings in the skull are **the orbits** and **the nasal cavity**. **Foramen magnum** is a large opening found at the posterior base of the skull**.** Through this opening the medulla oblongata of the brain descends down as the spinal cord.

b) The Vertebral Column

Vertebral column is also called the back bone. It consists of 33 serially arranged vertebrae which are interc onnected by cartilage known as intervertebral disc (Figure 9.6). The vertebral column extends from the base of the skull to the pelvis and forms the main frame work of the trunk. The vertebral column has five major regions. They are, **the Cervical**, **Thoracic**, **Lumbar**, **Sacrum** (5 sacral vertebrae found in the infant which are fused to form one bone in the adult) and

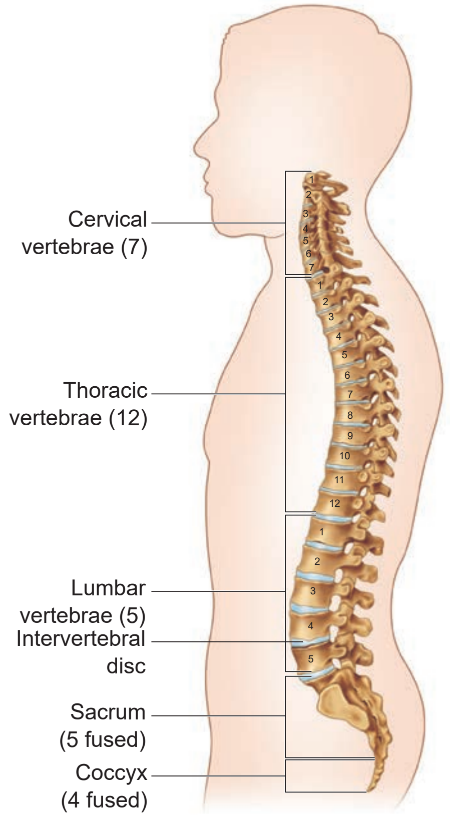


Figure 9. 6 Vertebral Column

Coccyx (4 coccygeal vertebrae found in the infant which are fused to form one bone in the adult).

Each vertebra has a central hollow portion, the neural canal, through which the spinal cord passes. The first vertebra is called as the **atlas** and the second vertebra is called as the **axis**. Atlas is articulated with the occipital condyles.

The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back.

(c) The Sternum (Chest bone)

Sternum is a flat bone on the mid ventral line of the thorax. It provides space for the attachment of the thoracic ribs and abdominal muscles.

(d) The Rib cage

There are 12 pairs of ribs (Figure 9.7). Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal end, hence called bicephalic. The first seven pairs of ribs are called '**true ribs**' or **vertebro–sternal ribs**. Dorsally they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilages. The 8th, 9th and 10th pairs of ribs do not articulate directly with the sternum but joined with the cartilaginous (hyaline cartilage) part of the seventh rib. These are called **'false ribs'** or **vertebro-chondral ribs**. The last 11th and 12th pairs of ribs are not connected ventrally. Therefore, they are called as **'floating ribs'** or **vertebral ribs**. Thoracic vertebrae, ribs and sternum together form the ribcage.

Rib cage protects the lungs, heart, liver and also plays a role in breathing.

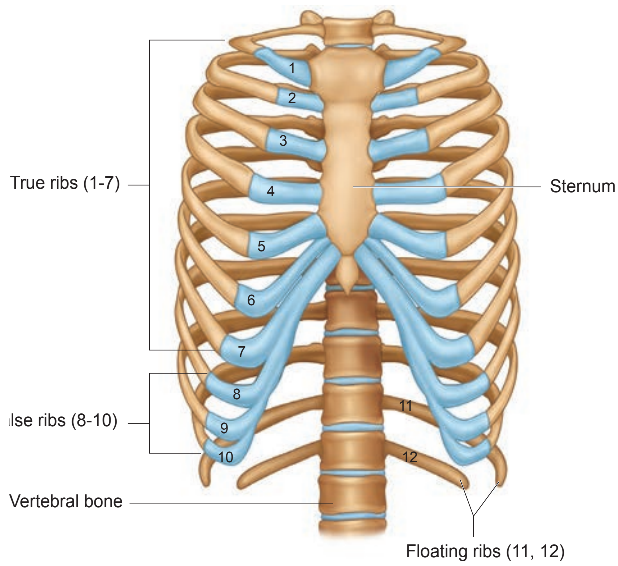


Figure 9.7 Rib cage

9.10 The Appendicular skeleton

The bones of the upper and lower limbs along with their girdles constitute the appendicular skeleton. The appendicular skeleton is composed of 126 bones.

(a) The Pectoral girdle

The upper limbs are attached to the pectoral girdles. These are very light and allow the upper limbs a degree of mobility not seen anywhere else in the body. The girdle is formed of two halves**.** Each half of the pectoral girdle (Figure 9.8) consists of **a clavicle** or **collar bone** and a **scapula**. The scapula is a large, thin, triangular bone situated in the dorsal surface of the ribcage between the second and seventh ribs. It has a slightly elevated ridge called the spine which projects as a flat, expanded process called the **acromion**. The clavicle articulates with this process. Below the acromion is a depression called the **glenoid cavity** which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures which lies horizontally and connects axial skeleton with appendicular skeleton.

The Upper limb

The upper limb consists of 30 separate bones and is specialized for mobility. The skeleton of the arm, the region between the shoulder and elbow is the **humerus**. The head of humerus articulates with the **glenoid cavity** of the scapula and forms the shoulder joint. The distal end of humerus articulates with the two forearm bones the **radius** and **ulna**. The forearm is the region between the elbow and the wrist. **Olecranon process** is situated at the upper end of the ulna which forms the pointed portion of the elbow.The hand consists of **carpals, metacarpals** and **phalanges.**

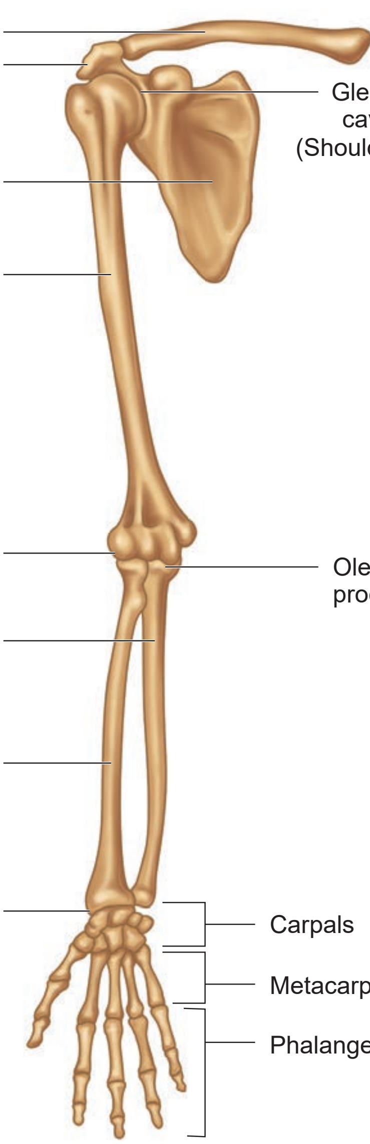


Figure 9. 8 Pectoral girdle with upper limb

Carpals,the wrist bones, 8 in number are arranged in two rows of four each. The anterior surface of the wrist has tunnel-like appearance, due to the arrangement of carpals with the ligaments. This tunnel is termed as **carpal tunnel**.

CTS-(Carpal Tunnel Syndrome) – The narrow passage (tunnel) bounded by bones and ligaments in the wrist gets narrowed and pinches the median nerve. This syndrome is mostly seen among the clerks, software professionals and pregnant women and people who constantly play or text in mobile phones.

Metacarpals,the palm bones are 5 in number and **phalanges** the digits bones are 14 in number.

(b) Pelvic Girdle

The pelvic girdle is a heavy structure specialized for weight bearing. It is composed of two hip bones called coxal bones that secure the lower limbs to the axial skeleton (Figure 9.9). Together, with the sacrum and coccyx, the hip bones form the basin-like bony pelvis.

Each coxal bone consists of three fused bones, **ilium, ischium** and **pubis**. At the point of fusion of ilium, ischium, and pubis a deep hemispherical socket called the acetabulum is present on the lateral surface of the pelvis. It receives the head of the femur or thigh bone at the hip joint and helps in the articulation of the femur. Ventrally the two halves of the pelvic girdle meet and form the **pubic symphysis** containing fibrous cartilage.

The **ilium** is the superior flaring portion of the hip bone. Each ilium forms a secure joint with the sacrum posteriorly.

The **ischium** is a curved bar of bone. The V-shaped **pubic bones** articulate anteriorly at the **pubic symphysis**. The pelvis of male is deep and narrow with larger heavier bones and the female is shallow, wide and flexible in nature, and this helps during pregnancy which is influenced by female hormones.

The pelvic girdle is a heavy, strong girdle. How does its structure reflect its function?

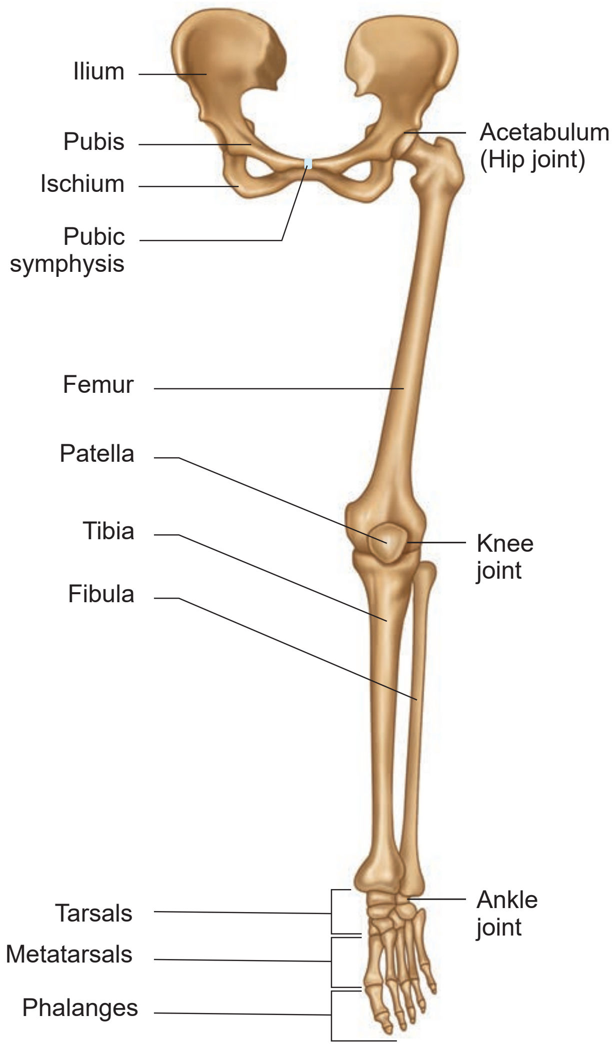


Figure 9.9 Pelvic girdle with lower limb

The Lower limb

The lower limb consists of 30 bones which carries the entire weight of the erect body and is subjected to exceptional forces when we jump or run. The bones of the lower limbs are thicker and stronger than the upper limbs. The three segments of each lower limb are **the thigh**, **the leg** or **the shank** and **the foot**. **The femur** is the single bone of the thigh. It is the largest, longest and strongest bone in the body. The head of femur articulates with **the acetabulum** of the pelvis to form the hip joint. Two parallel bones, **the tibia** and **fibula**, form the skeleton of the shank. A thick, triangular **patella** forms the knee cap, which protects the knee joint anteriorly and improves the leverage of thigh muscles acting across the knee. The foot includes the bones of ankle, **the tarsus**, **the metatarsus** and **the phalanges or toe bones**. The foot supports our body weight and acts as a lever to propel the body forward, while walking and running. **The tarsus** is made up of seven bones called tarsals. **The metatarsus** consists of five bones called metatarsals. The arrangement of the metatarsals is parallel to each other. There are 14 **phalanges** in the toes which are smaller than those of the fingers.

Structure of a typical long bone

A typical long bone has a **diaphysis**, **epiphyses** (singular-epiphysis) and **membranes** (Figure 9.10). A tubular diaphysis or shaft, forms the long axis of the bone. It is constructed of a thick collar of compact bone that surrounds a central **medullary cavity** or **marrow cavity**. The epiphyses are the bone ends. Compact bone forms the exterior of epiphyses and their interior contains spongy bone with red marrow. The region where the diaphysis and epiphyses meet is called the **metaphysis**. The external surface of the entire bone except

Table: 9.1 Bones of the skeletal system

Skeleton	Name of Bone		Number of bones	Total number of bones
Axial skeleton (80 bones)	Skull	Cranium Facial bone Bones of middle ear Hyoid bone	8 14 6 (2 × 3) 1	29
	Vertebral column	Cervical Thoracic Lumbar Sacral Coccyx	7 12 5 5 bones fused to 1 bone 4 bones fused to 1 bone	26 (in adults)
	Sternum		1	1
	Ribs		12 × 2 = 24	24
Appendicular skeleton (126bones)	Fore limb	Humerus Radius Ulna Carpals Metacarpals Phalanges	1 1 1 8 5 14	(2 × 30) 60
	Hind limb	Femur Tibia Fibula Tarsal Metatarsals Phalanges Patella (Knee bone)	1 1 1 7 5 14 1	(2 × 30) 60
	Pectoral girdle	Scapula Clavicle	1 1	(2 × 2) 4
	Pelvic girdle	Innominate (Ilium, ischium and pubis fused into one bone)	1	(1 × 2) 2
			Total number of bones in adults	206

the joint surface is covered by a double-layered membrane called the **periosteum**. The outer fibrous layer is dense irregular connective tissue. The inner osteogenic layer consists of **osteoblasts** (bone- forming cells) which secrete bone matrix elements and **osteoclasts** (bone-destroying cells). In addition, there are primitive stem cells, osteogenic cells, that give rise to the osteoblasts. The periosteum is richly supplied with nerve fibres, lymphatic vessels and blood vessels. Internal bone surfaces are covered with a delicate connective tissue membrane called the **endosteum**. The endosteum covers the trabeculae of spongy bone and lines the canals that pass through the compact bone. It also contains both osteoblasts and osteoclasts. Between the epiphysis and diaphysis **epiphyseal plate** or **growth plate** is present.

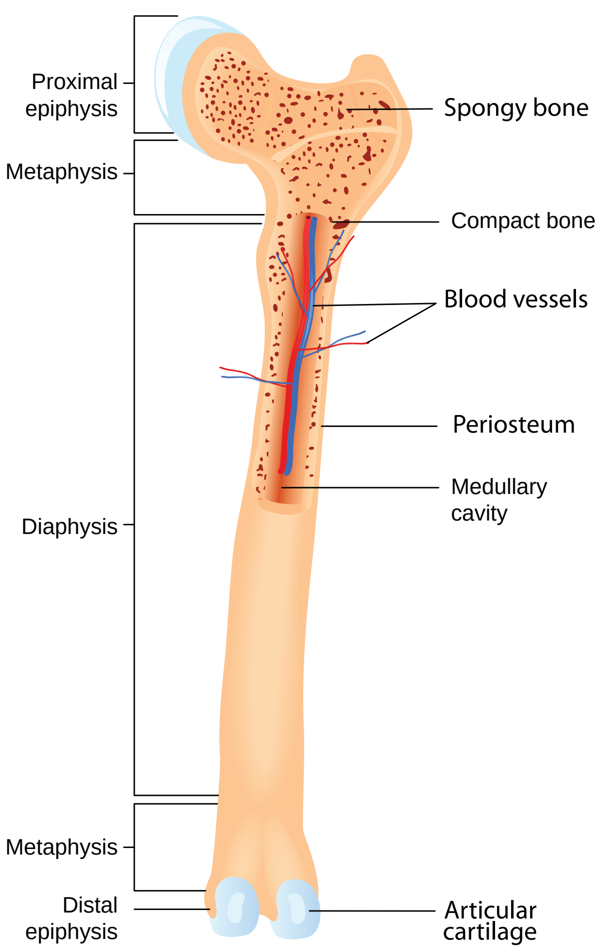


Figure 9.10 Structure of a long bone

9.11 Types of joints

Joints are essential for all types of movements performed by the bony parts of the body. The joints are points of contact (Figure 9.11) between bones.

Sometimes they are playing a protective role in the process. Force generated by the muscles are used to carry out the movement through joints which helps human functional activity of daily living and ambulation. The joint acts as a fulcrum of a lever.

(i) **Fibrous joints or Synarthroses:** They are immovable fixed joints in which no movement between the bones is possible. Sutures of the flat skull bones are fibrous joints.

(ii) **Cartilaginous joints or Amphiarthroses:** They are slightly movable joints in which the joint surfaces are separated by a cartilage and slight movement is only possible. E.g., Joints of adjacent vertebrae of the vertebral column.

(iii) Synovial joints or Diarthroses joints: They are freely movable joints, the articulating bones are seperated by a cavity which is filled with synovial fluid.

Pivot joint	between atlas and axis
Plane/gliding joint	between the carpals
Saddle joint	between the carpal and metacarpal
Ball and socket joint	between humerus and pectoral girdle
Hinge joint	knee joint
Condyloid or Angular or Ellipsoid	between radius and carpal

An exhausted student was attending a lecture. After 30 minutes or so, he lost interest and he let go with a tremendous yawn. To his great distress he couldn't close his mouth –his lower jaw was locked open. What do you think would have caused it?

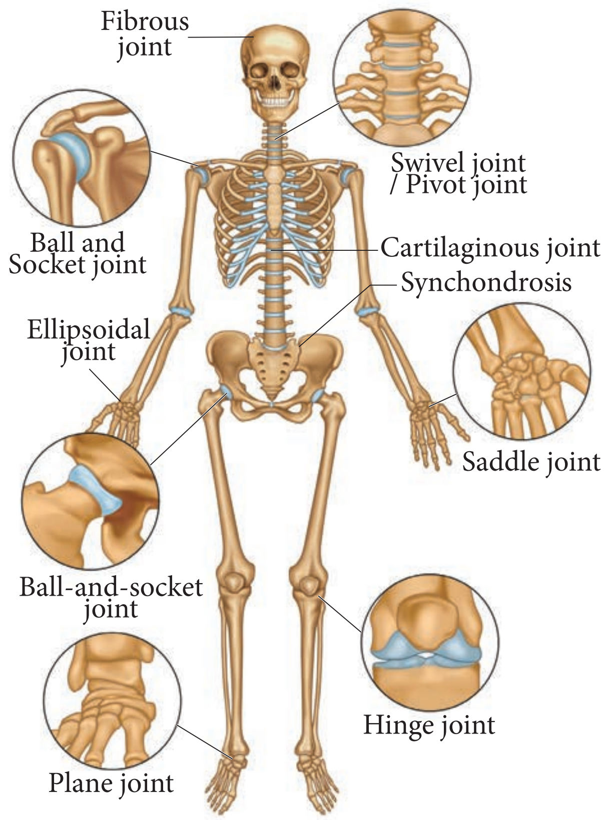


Figure 9. 11 Types of joints

9.12 Disorders of muscular and skeletal system

(a) Disorders of muscular system

Myasthenia gravis:

An autoimmune disorder affecting the action of acetylcholine at neuro-muscular junction leading to fatigue, weakening and paralysis of skeletal muscles. Acetylcholine receptors on the sarcolemma are blocked by antibodies leading to weakness of muscles. When the disease progresses, it can make chewing, swallowing, talking and even breathing difficult.

Tetany:

Rapid muscle spasms occur in the muscles due to deficiency of parathyroid hormone resulting in reduced calcium levels in the body.

Muscle fatigue:

Muscle fatigue is the inability of a muscle to contract after repeated muscle contractions. This is due to lack of ATP and accumulation of lactic acid by anaerobic breakdown of glucose

Atrophy:

A decline or cessation of muscular activity results in the condition called atrophy which results in the reduction in the size of the muscle and makes the muscle to become weak, which occurs with lack of usage as in chronic bedridden patients.

Muscle pull:

Muscle pull is actually a muscle tear. A traumatic pulling of the fibres produces a tear known as sprain. This can occur due to sudden stretching of muscle beyond the point of elasticity. Back pain is a common problem caused by muscle pull due to improper posture with static sitting for long hours.

Muscular dystrophy:

The group of diseases collectively called the muscular dystrophy are associated with the progressive degeneration and weakening of skeletal muscle fibres, leading to death from lung or heart failure. The most common form of muscular dystrophy is called **Duchene Muscular Dystrophy (DMD)**.

b) Disorders of skeletal system

Arthritis and osteoporosis are the major disorders of skeletal system.

1. Arthritis:

Arthritis is an inflammatory (or) degenerative disease that damages the joints. There are several types of arthritis.

(i) **Osteoarthritis:** The bone ends of the knees and other freely movable joints wear away as a person ages. The joints of knees, hip, fingers and vertebral column are affected.

(ii) **Rheumatoid arthritis:** The synovial membranes become inflamed and there is an accumulation of fluid in the joints. The joints swell and become extremely painful. It can begin at any age but symptoms usually emerge before the age of fifty.

(iii) **Gouty arthritis or Gout:** Inflammation of joints due to accumulation of uric acid crystals or inability to excrete it. It gets deposited in synovial joints.

2. Osteoporosis:

It occurs due to deficiency of vitamin D and hormonal imbalance. The bone becomes soft and fragile. It causes rickets in children and osteomalacia in adult females. It can be minimized with adequate calcium intake, vitamin D intake and regular physical activities.

9.13 Benefits of regular Exercise

Exercise and physical activity fall into four basic categories. Endurance, Strength, Balance and Flexibility.

Endurance or aerobic activities increase the breathing and heart rate. They keep the circulatory system healthy and improve overall fitness.

Strength exercises make the muscles stronger. They help to stay independent and carry out everyday activities such as climbing stairs and carrying bags.

Balance exercises help to prevent falls which is a common problem in older adults. Many strengthening exercises also improves balance.

Flexibility exercises help to stretch body muscles for more freedom of joint movements. Regular exercises can produce the following beneficial physiological changes:

- The muscles used in exercise grow larger and stronger.
- The resting heart rate goes down.
- More enzymes are synthesized in the muscle fibre.
- Ligaments and tendons become stronger.
- Joints become more flexible.
- Protection from heart attack.
- Influences hormonal activity.
- Improves cognitive functions.
- Prevents Obesity.
- Promotes confidence, esteem.
- Aesthetically better with good physique.
- Over all well-being with good quality of life.
- Prevents depression, stress and anxiety.

During muscular exercise, there is an increase in metabolism. The O_2 need of the muscles is increased. This requirement is met with more oxygen rich RBCs available to the active sites. There is an increase in heart rate and cardiac output. Along with balanced diet, physical activity plays a significant role in strengthening the muscles and bones.

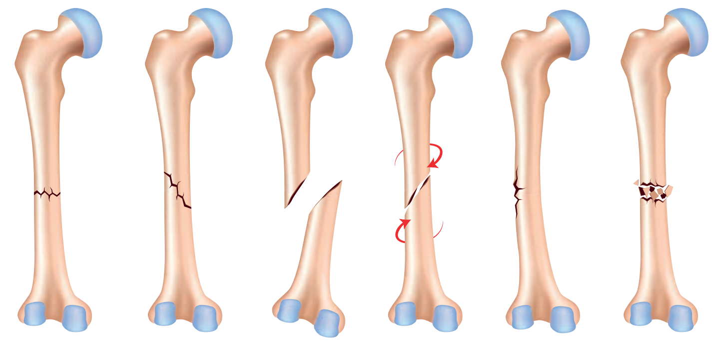


Figure 9.12 Types of bone fracture

9.14 Bone Fracture

Even though the bones are strong, they are also susceptible to fractures or breaks. Fractures may be classified based on the

(i) Positioning of the bone ends

(ii) completeness of the break

(iii) orientation of the break relative to the long axis of the bone and

(iv) penetration through the skin. In addition to the above classifications, all fractures can be described in terms of the location of the fracture, the external appearance of the fracture or the nature of the break (Figure 9.12).

The following are the common types of fractures,

1. **Tranverse** - A fracture that is at right angle to the bone's long axis.
2. **Oblique non-displaced**-A fracture that is diagonal to the bone's long axis and the fractured bone is not displaced from its position.
3. **Oblique displaced** - A fracture that is diagonal to the bone's long axis and the fractured bone is displaced from its position.
4. **Spiral** - Ragged break occurs when excessive twisting forces are applied to a bone (common sports fracture).
5. **Greenstick** - Bone breaks incompletely, just like a green twig breaks. It is common in children, because of the flexibility of the bones.
6. **Comminuted** – Bone fragmented into three or more pieces. Particularly common in the aged, whose bones are brittle (hard but easily broken).

9.14.1 Mechanism and healing of a bone fracture

Bone is a cellular, living tissue capable of growth, self-repair and remodeling in response to physical stresses. In the adult skeleton, bone deposit and bone resorption occur. These two processes together constitute in remodeling of bone. There are four major stages in repairing a simple fracture (Figure 9.13).

1. **Formation of haematoma**

   When a bone breaks the blood vessels in the bone and surrounding tissues are torn and results in haemorrhage. Due to this a haematoma, a mass of clotted blood forms at the fracture site. The tissues at the site becomes swollen, painful and inflammed. The death of bone cells, occur due to lack of nutrition.

2. **Formation of fibrocartilaginous callus**

   Within a few days several events lead to the formation of soft granulation tissue called callus. Capillaries grow into the haematoma and phagocytic cells invade the area and begin to clean up the debris. Meanwhile the fibroblasts and osteoblasts invade from the nearby periosteum and endosteum and begin reconstructing of the bone. The fibroblasts produce fibres. The chondroblasts secrete the cartilage matrix. Within this repair tissue, osteoblasts begin forming spongy bone. The cartilage matrix later calcifies and forms the fibrocartilaginous callus.

3. Formation of Bony callus

New bone trabeculae begin to appear in the fibro cartilaginous callus. Gradually that is converted into a bony (hard) callus of spongy bone. Bony callus formation continues until a firm union is formed about two months later to an year for complete woven bone formation.

4. Remodeling of Bone

Bony callus formation will be continued for several months. After that the bony callus is remodelled. The excess material on the diaphysis exterior and within the medullary cavity is removed and the compact bone is laid down to reconstruct the shaft walls. The final structure of the remodelled area resembles like the unbroken bony region.

9.15 Dislocation of joints and treatment

Dislocation of joint is the total displacement of the articular end of the bone from the joint cavity. The normal alignment of the bones becomes altered. Joints of the jaw, shoulders, fingers and thumbs are most commonly dislocated.

Dislocations of joints are classified as (i) Congenital deformities (ii) Traumatic (iii) Pathological and (iv)Paralytic.

(i) **Congenital deformities** are due to genetic factors or factors operating on the developing foetus.

(ii) **Traumatic dislocation** is due to serious violence. It occurs in the shoulder, elbow and hip.

(iii) **Pathological dislocation** is caused by some diseases like tuberculosis. It may cause dislocation of the hip.

(iv) **Paralytic dislocation** caused by paralysis of one group of muscles of an extremity.

Treatment

If the joint doesn't return to normal condition naturally the following treatments should be given.

- Manipulation or repositioning
- Immobilization
- Medication
- Rehabilitation

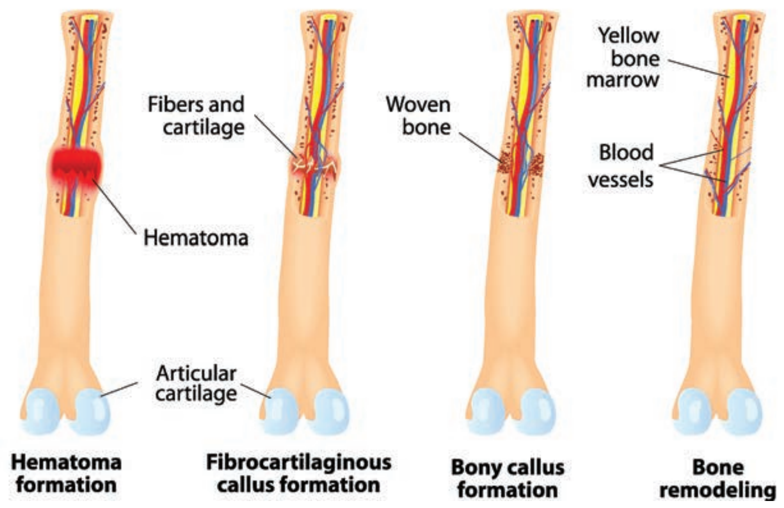


Figure 9.13 Mechanism and healing of bone fracture

9.16 Physiotherapy

Physiotherapy is the therapeutic exercise to make the limbs work near normally. It is a rehabilitation profession with a presence in all health care centres. Therapeutic exercises are carried out by physiotherapists. The common problem at the end of fracture treatment is the wasting of muscles and stiffness of joints. These problems can be restored by the physiotherapy with gradual exercises. It has proven to be effective in the post surgery treatment and management of arthritis, spondylosis, musculo skeletal disorders, stroke and spinal cord injury.

Summary

Movement is one of the significant features of living organisms. The different types of movements are amoeboid movement, ciliary movement, flagellar movement and muscular movement. Three types of muscles are present in human beings. They are the skeletal muscle, visceral muscle and cardiac muscle. The skeletal muscles are attached to the bones by tendons.

The most striking microscopic feature of skeletal muscle is a series of light and dark bands. The muscles exhibit the properties such as excitability, contractibility, conductibility and elasticity. There are two types of muscle contraction. They are isotonic and isometric contractions.

The skeletal system consists of a frame work of bones and cartilages. The skeletal system is grouped into two principal divisions: the axial skeleton and the appendicular skeleton. There are three types of joints present in the body: fibrous, cartilaginous and synovial joints.

The disorders related to muscular system are myasthenia gravis, muscular dystrophy, tetany, muscle fatigue, muscle pull, atrophy and rigor mortis. The disorders of the skeletal system are arthritis and osteoporosis. Regular body exercise keeps the body fit and healthy.

A typical long bone has a diaphysis (shaft), epiphyses (singular-epiphysis) and membranes. Even though the bones are strong, they are also susceptible to fractures or breaks.There are four major stages in repairing a simple fracture.

Physiotherapy is the therapeutic exercise to make the limbs work near normally.

Evaluation

1. Muscles are derived from
   a. ectoderm
   b. mesoderm
   c. endoderm
   d. neuro ectoderm

2. Muscles are formed by
   a. myocytes
   b. leucocytes
   c. osteocytes
   d. lymphocytes

3. The muscles attached to the bones are called
   a. skeletal muscle
   b. cardiac muscle
   c. involuntary muscle
   d. smooth muscles

4. Skeletal muscles are attached to the bones by
   a. tendon
   b. ligament
   c. pectin
   d. fibrin

5. The bundle of muscle fibres is called
   a. Myofibrils
   b. fascicle
   c. sarcomere
   d. sarcoplasm

6. The pigment present in the muscle fibre to store oxygen is
   a. myoglobin
   b. troponin
   c. myosin
   d. actin

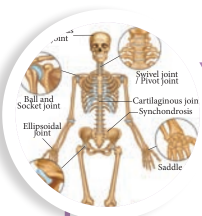
7. The functional unit of a muscle fibre is
   a. sarcomere
   b. sarcoplasm
   c. myosin
   d. actin

8. The protein present in the thick filament is
   a. myosin b. actin
   c. pectin d. leucin
9. The protein present in the thin filament is
   a. myosin b. actin
   c. pectin d. leucin
10. The region between two successive Z-discs is called a
   a. sarcomere b. microtubule
   c. myoglobin d. actin
11. Each skeletal muscle is covered by
   a. epimysium b. perimysium
   c. endomysium d. hypomysium
12. Knee joint is an example of
   a. saddle joint b. hinge joint
   c. pivot joint d. gliding joint
13. Name of the joint present between the atlas and axis is
   a. synovial joint b. pivot joint
   c. saddle joint d. hinge joint
14. ATPase enzyme needed for muscle contraction is located in
   a. actinin b. troponin
   c. myosin d. actin
15. Synovial fluid is found in
   a. Ventricles of the brain
   b. Spinal cord
   c. immovable joint
   d. freely movable joints.
16. Inflammation of joints due to accumulation of uric acid crystals is called as
   a. Gout
   b. myasthenia gravis
   c. osteoporosis
   d. osteomalacia
17. Acetabulum is located in
   a. collar bone
   b. hip bone
   c. shoulder bone
   d. thigh bone
18. Appendicular skeleton is
   a. girdles and their limbs
   b. vertebrae
   c. skull and vertebral column
   d. ribs and sternum
19. The type of movement exhibits by the macrophages are
   a. flagellar b. ciliary
   c. muscular d. amoeboid
20. The pointed portion of the elbow is
   a. acromion process
   b. glenoid cavity
   c. olecranon process
   d. symphysis
21. Name the different types of movement.
22. Name the filaments present in the sarcomere.
23. Name the contractile proteins present in the skeletal muscle.
24. When describing a skeletal muscle, what does “striated” mean?
25. How does an isotonic contraction take place?
26. How does an isometric contraction take place?
27. Name the bones of the skull.
28. Which is the only jointless bone in human body?
29. List the three main parts of the axial skeleton
30. How is tetany caused?
31. What are the functions of the skeletal system?

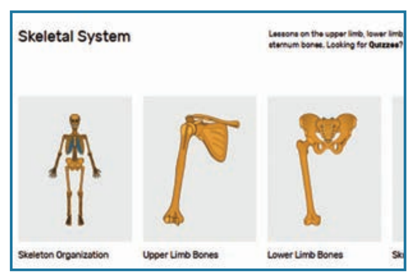
32. What are the different types of rib bones that form the rib cage?
33. What are the bones that make the pelvic girdle?
34. List the disorders of the muscular system.
35. Explain the sliding- filament theory of muscle contraction.
36. What are the benefits of regular exercise?
37. What are the different types of bone fracture?
38. Write about the mechanism and healing of bone fracture.
39. What is meant by physiotherapy?
40. Comment on the dislocation of joints.

ICT Corner

We like to move



Let's explore the skeletal system page to understand the **skeletal organization.**

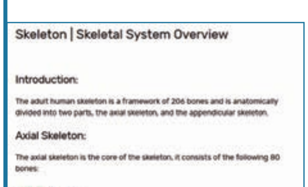


Step – 1 Use the URL to reach the 'Skeletal System' page. From grid select 'Skeleton Organization' and explore the skeleton's general anatomical arrangement and functions.

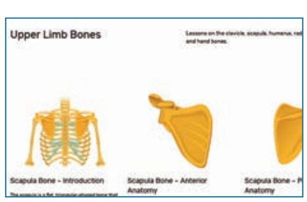
Step – 2 Then reach the 'Skeleton Organization page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Upper Limb Bones' from the grid and explore the anatomy and functions of the clavicle, scapula, humerus, radius, ulna, carpal, and hand bones.

Step – 3 Follow the above steps and explore the interactives of each part and its functions.

Step – 4 Use the reference given below the page to acquire additional details about 'Skeletal System'.



Step 1



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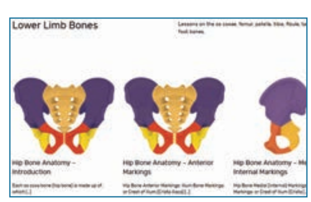
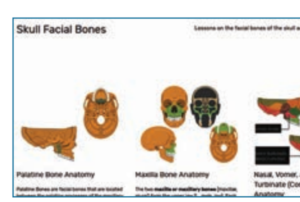


Step 3



Step 4

Skeletal System's URL:

https://www.getbodysmart.com/skeletal-system

* Pictures are indicative only