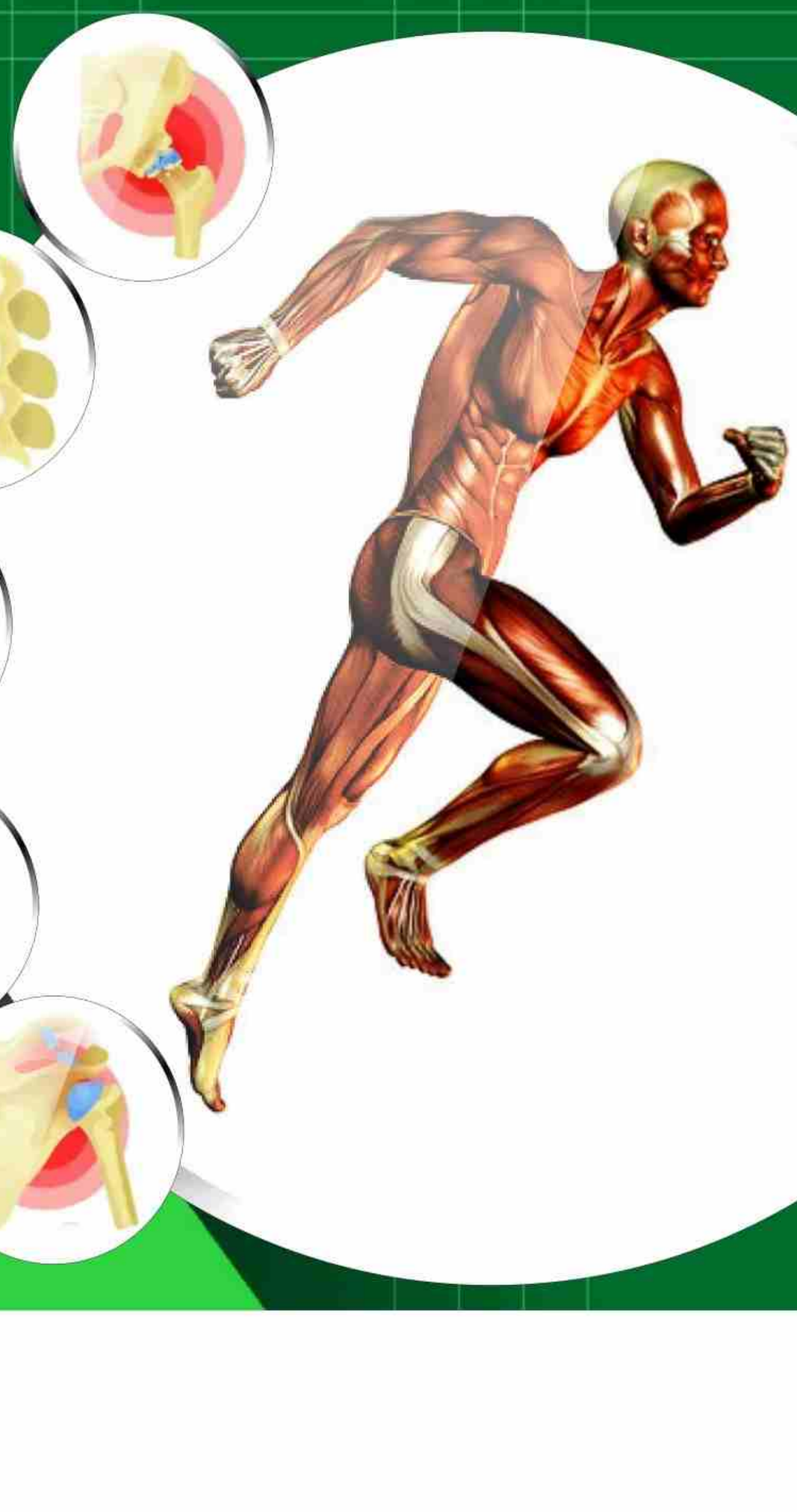
SUPPORT AND MOVEMENT

Chapter 16

Major Concept

In this Unit you will learn:

- Human skeleton
- Disorders of skeleton
- Muscles



Animals live in different habitats on earth. They need to develop appropriate physical adaptations to obtain resources in variable environmental conditions for existence. These adaptations help them to acquire food, shelter, and protection in their competitive surroundings. The adapted physical changes develop strong muscular and skeletal support system of the body that helps in movement and locomotion. Biologically, there is a difference between movement and locomotion. Movement is the changing position of an animal while locomotion is the type of movement of an organism in search of food and other needs over a long or short distance.

16.1. HUMAN SKELETON

The human skeleton acts as a framework of the body. Since it lies inside the body therefore called **endoskeleton**. Human endoskeleton comprises of **bones** and **cartilage** which provides shape of the body, makes blood cells through their red bone marrow, protection of internal organs and stores minerals. The branch of science deals with the study of human bones is called **osteology**. Bones and muscles are attached to form a well-coordinated musculoskeletal system. Humans have around 300 bones at birth but due to fusion of some bones it becomes 206 in adults.

16.1.1. Structure of bone

Bones are the toughest living structure, composed of different cells. Bones of the skeletal system differ in size and shape, but they are similar in their structure, development, and function. The major proportion of the bone is formed by collagen fibers and different types of cells while other components include minerals and 10 to 20% water. Collagen is the fibrous protein strengthening bone with calcium upon **calcification** or **ossification**.

A long bone has three distinct regions. The terminal regions are called **epiphysis**, middle region is called **diaphysis** and in between middle and terminal region is the **metaphysis** at both ends. The **epiphysis** is **a cancellous** or **spongy** part of the bone. It has small weight bearing cross linked regions called **trabeculae**. Epiphysis is filled with red bone marrow, which produces 20% blood cells that forms about 20% of the total mass of the skeleton.

The external part of the diaphysis is called **cortical bone**. Cortical bone forms almost 80 percent of the skeletal structure and consists of many small cylinders known as **osteons.** Each osteon is made of many lamellae, which are the concentric layers made of an organic part collagen and an inorganic part called hydroxyapatite, which is mostly calcium phosphate. In the center of every **osteon** is a haversian canal, which contains the blood supply and innervations of the bone cells. In the center of the bone is the **medullary canal,** a hollow space lined by a honeycomb like structure called the spongy or **cancellous bone**. The medullary canals contain the bone marrow which is the site of blood cell production.

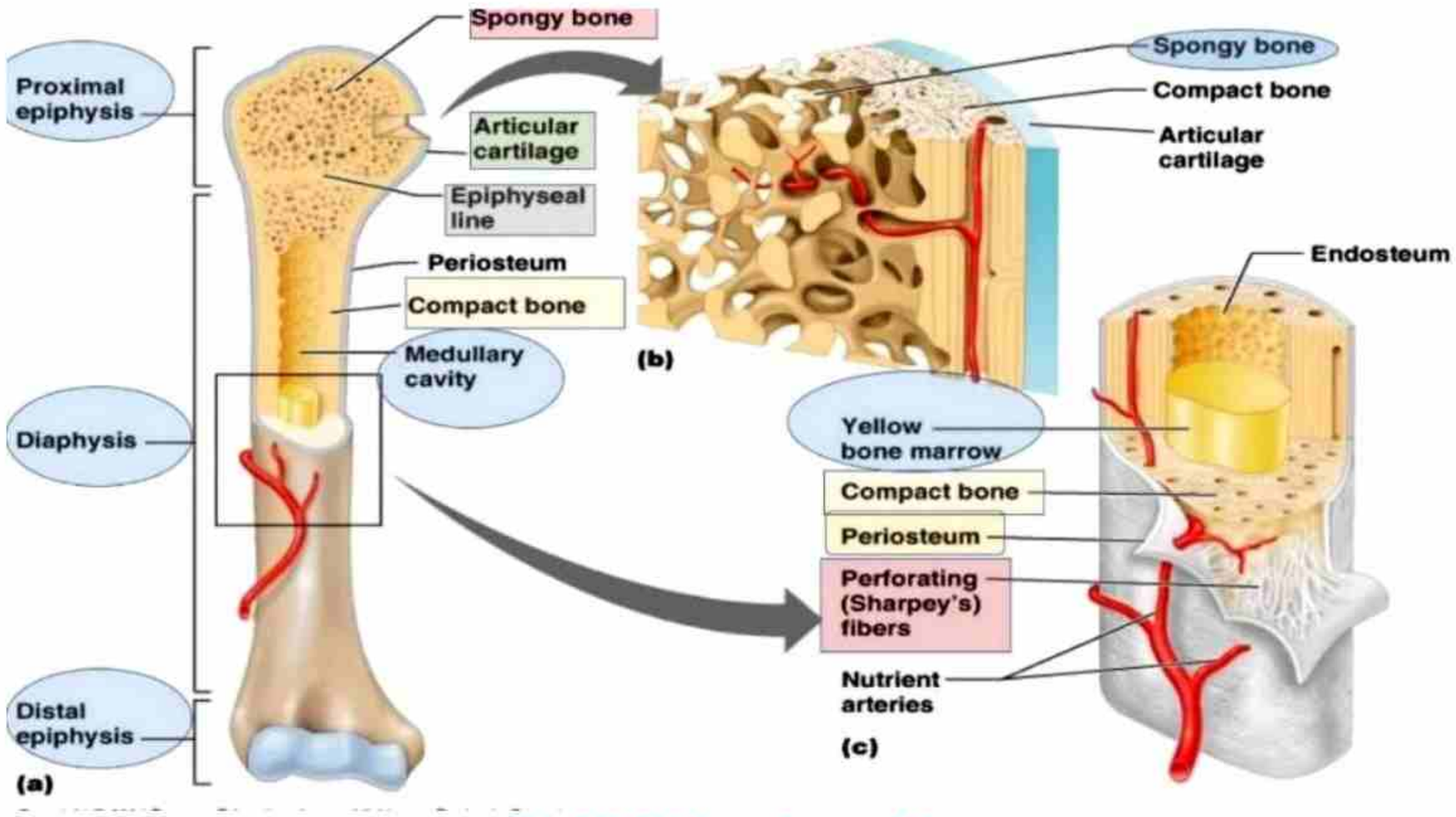


Fig 16.1 Structure of bone

The overall outer covering of the bone is called **periosteum** and the inner layer is called endosteum. Periosteum allows for attachment of muscle connective tissue (tendons) to the bone and provides pathways for blood and lymphatic vessels. **Endosteum** is a soft, thin layer that lines the inner cavity of long bones. It has progenitor stem cells. These **osteogenic progenitor cells** develop into **osteoblast** which secretes the bone matrix, and **chondroblast** which secrete cartilage. It plays a key role in the healing of fractures by creating new cells necessary for the bone to fuse.

There are three types of cells present in bone namely osteoblasts, osteocytes, and osteoclasts. **Osteoblasts** are the progenitor that secrete matrix around themselves to form spongy bone which later become compact bone. When osteoblast is isolated by surrounded matrix in the spaces called **lacunae**, they become **osteocytes**. Osteocytes are the mature cells that form the bones. The osteocytes direct osteoblasts to the site of the damage, hastening (fast) healing. **Osteoclasts** perform the job of breaking down the composite material in bones. Osteocytes also phagocytize the bony matrix. Once the matrix is removed osteoblast reforms a new bone material. It helps in demineralization and repair of bone.

16.1.2. Structure of cartilage

Cartilage is a soft flexible form of connective tissue surrounded by a layer called **perichondrium.** It is present in human skeleton and regarded as a precursor to bone in developing embryo. Cartilage is present in joints to provide cushion, reduce friction between bones, give them protection from compressive forces and weight bearing stresses during movement. Cartilage gets nutrition from their surrounding tissues by diffusion. Since they lack blood vessels therefore, they grow and repair slower than other tissues. Formation of cartilage is initiated by chondroblast cells located in outer covering of developing bone and divide to form **chondrocyte cells**. They are concentrated in lacunae in the cartilage and produce firm matrix that contain collagen protein, proteoglycan (formed by chondroitin sulphate and protein) and some other non-collagenous proteins to develop cartilage. There are three types of cartilage associated with skeleton which are different in their structure and function. **Hyaline cartilage** is present in between ribs and sternum, nose and at the bone surface in many joints. It has a smooth surface that allows tissues to slide easily. **Fibrocartilage** is the hardest among other cartilages. It is present as intervertebral disc, in knee joint and in pectoral girdle. **Elastic cartilage** is the most flexible and strong cartilage. It is located in the pinna of the ear, external and internal auditory tubes, epiglottis, and larynx.

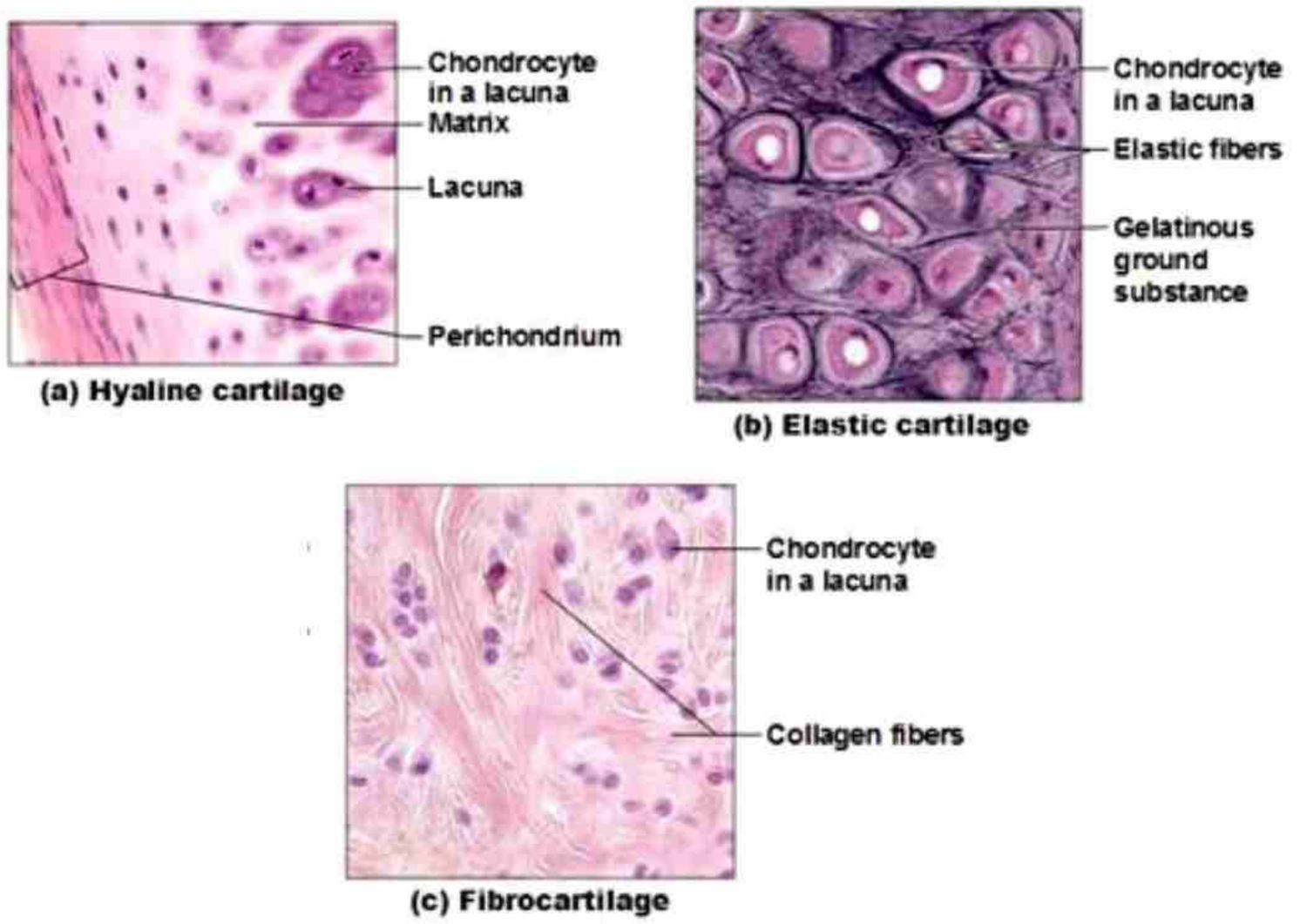


Fig. 16.2 Types of catilage in skeleton

Table 16.1 DIFFERENCE BETWEEN BONE AND CARTILAGE

CHRACTERISTICS	BONE	CARTILAGE
Strength	Hard	Soft
Formation	Formed by osteocytes	Formed by chondrocytes
Calcification	Bones are calcified i.e.; calcium and minerals are deposited	Not calcified
Covering	Covered by periosteum	Covered by perichondrium
Protection	Provide protection and support to the body	Protect joints
Water	10-20% water present in bones	80% water present in cartilage
Blood cells	Forms blood cells	Does not form blood cells

16.1.3. Division Human skeleton

Human skeleton is subdivided into two major divisions called the axial skeleton and the appendicular skeleton.

The Axial skeleton

The axial skeleton is on the central axis of the body and comprises the skull, vertebral column and thoracic cage including ribs and sternum. It has eighty (80) bones, including twenty-eight bones in the skull, one hyoid bone, twenty-six bones in the vertebral column, twenty-four ribs and one sternum.

The **skull bones** are further divided into cranial bones, facial bones, and auditory ossicles. The **cranial** bones protect brain and provide attachment for the essential receptor organs. Cranial bones are eight which include two **parietal**, two **temporal**, one **frontal**, one **occipital**, one **ethmoid** and one **sphenoid** bone. The **facial** bones protect soft tissues of the face, help in breathing, eating, facial expressions, speech, and structure.

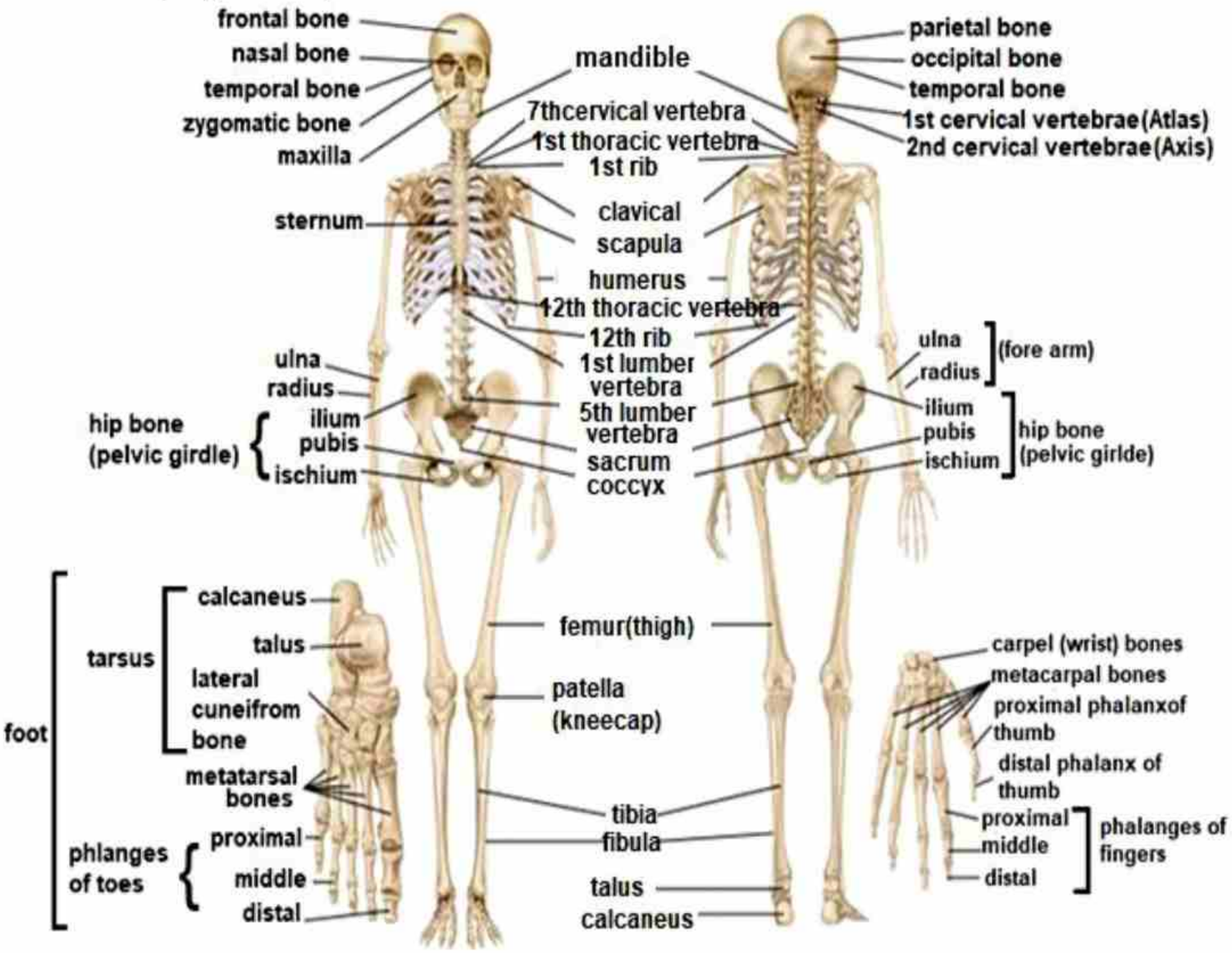


Fig. 16.3 Human skeleton

The **auditory ossicles** help in transmission of sound waves from external environment to the inner ear. They are six including two **malleus**, two **stapes** and two **incus**. A bone lies in between skull and postcranial skeleton called the **hyoid bone.** It is "U" shaped and provides attachment for the tongue and muscles of the oral cavity.

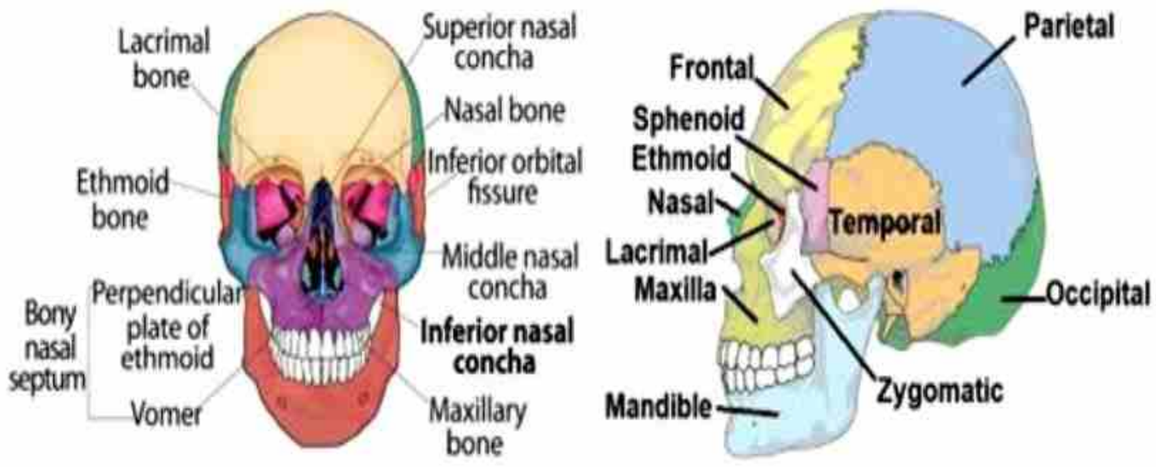


Fig. 16.4 Bones of human skull

The **vertebral column** protects spinal cord and serves as the site for blood cells production. Vertebral column consists of seven **cervical**, twelve **thoracic**, five **lumber**, one **sacrum** and one **coccyx** vertebrae. These vertebrae are fixed in different regions of the body, cervical in neck, thoracic in chest and anteriorly attached with the ribs, lumber in abdominal region behind the chest, sacral (formed by the fusion of five vertebrae) and at the last coccyx (formed by the fusion of four vertebrae).

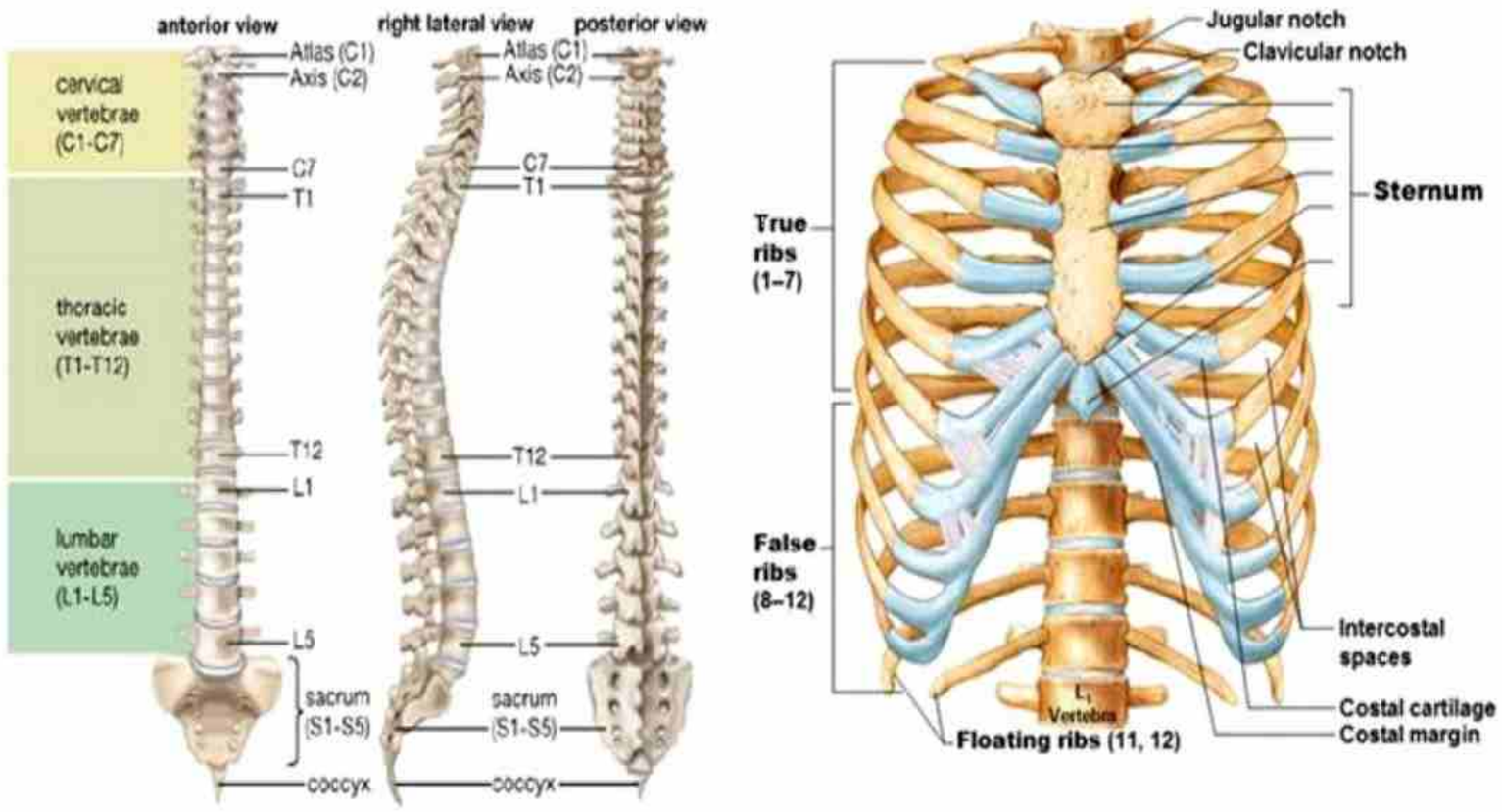


Fig. 16.5 Human Ribs and Vertebral column

The **rib cage** is formed by ribs and sternum. Each rib is flat and curved, supports the thorax wall and provides space for thoracic visceral organs. Ribs are twelve pairs, out of them first seven pairs are directly attached with sternum by cartilage and are called true ribs. The remaining five pairs are called false ribs due to their attachment to the sternum. Among the five pairs there are the last two pairs are called floating ribs because these are not associated by means of common costal cartilage sternum and even other pairs of ribs.

Appendicular skeleton

The appendicular skeleton consists of 126 bones. This division of skeleton is further divided into pelvic and pectoral girdle with associated bones.

Pectoral girdle and Fore limb bones

The **pectoral girdle** provides structural support to the upper region of the body. The total number of bones associated with pectoral girdle are **sixty-four** (both sides) which include two clavicle and two **scapula** (both side) in pectoral gridle while the anterior limb (arm) bones associated with girdle are two **humerus**, two **radius**, two **ulna**, sixteen **carpals**, ten **metacarpals** and twenty-eight **phalanges** in both limbs.

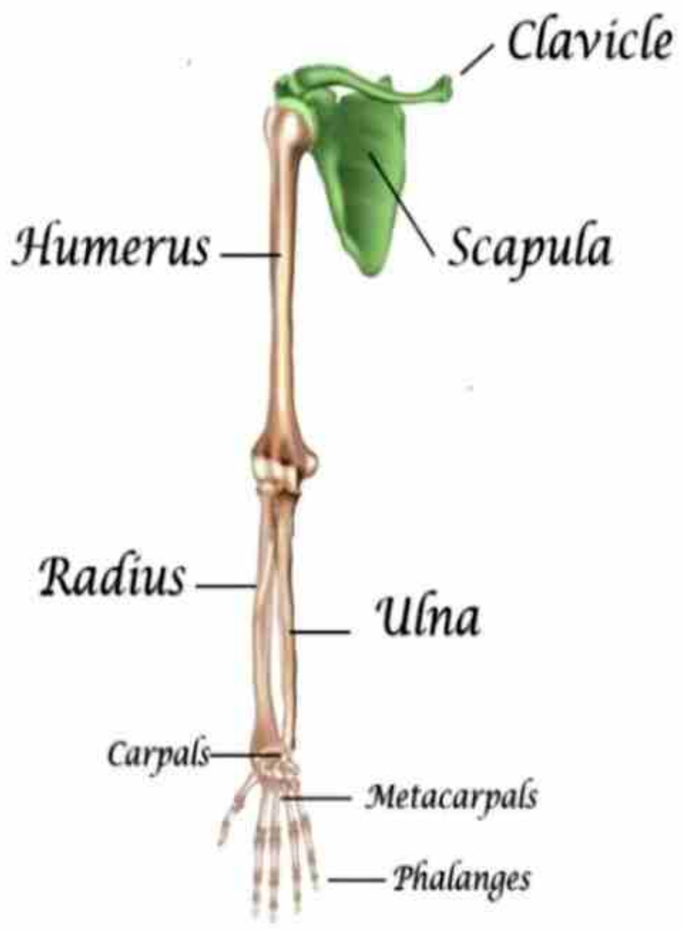


Fig. 16.6 Bones of Forelimb

Pelvic girdle and Hind limb bones

The pelvic girdle supports the body weight, helps in movement, and protects pelvic viscera including parts of urinary system and reproductive organs. The total number of bones in pelvic girdle and associated lower limb bones are **sixty-two**. The pelvic girdle is formed by two ilium, two pubis and two ischium bones. All these bones are fused to form **innominate**, hip, or curved **coxal** bones in two halves.

The two coxal bones form bowel shape pelvises that keep the female reproductive organs. The ring-like shape of the girdle is due to the joining of coxal bone with the sacrum of vertebral column at anterior side and below by a joint in between pubic part called **pubic symphysis**. The posterior limbs include two **femur**, two **tibia**, two **fibula**, two **patella**, fourteen **tarsals**, ten **metatarsals** and twenty- eight **phalanges**.

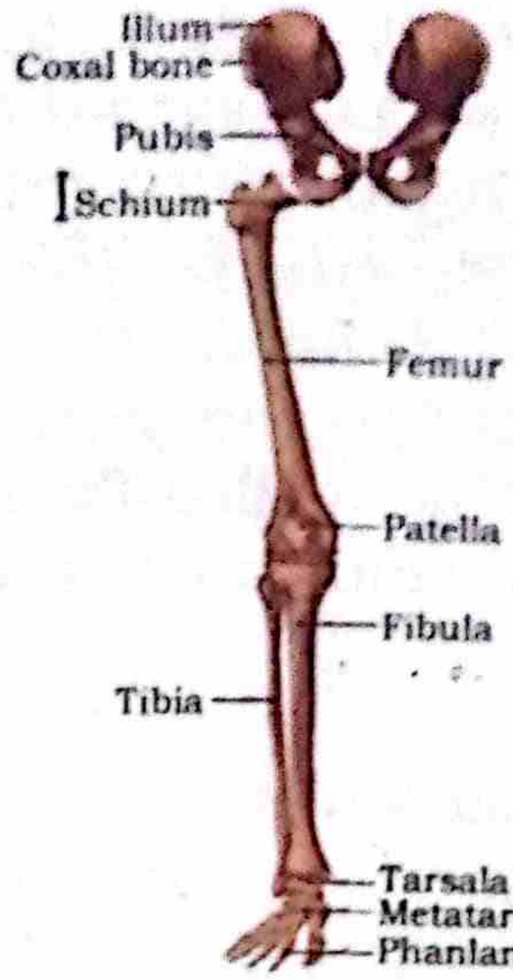


Fig. 16.7 Bones of Hindlimb

16.1.4. Types of joints

A joint is the articulating functional junction of two or more bones. There are approximately 360 joints in our body. Joints are classified by the type of tissues that bind the bone at each junction. The major groups of joints are **fibrous joints**, **cartilaginous joint** and **synovial joints**.

Fibrous joints

These joints hold the bone by dense connective tissue containing collagenous fibers.

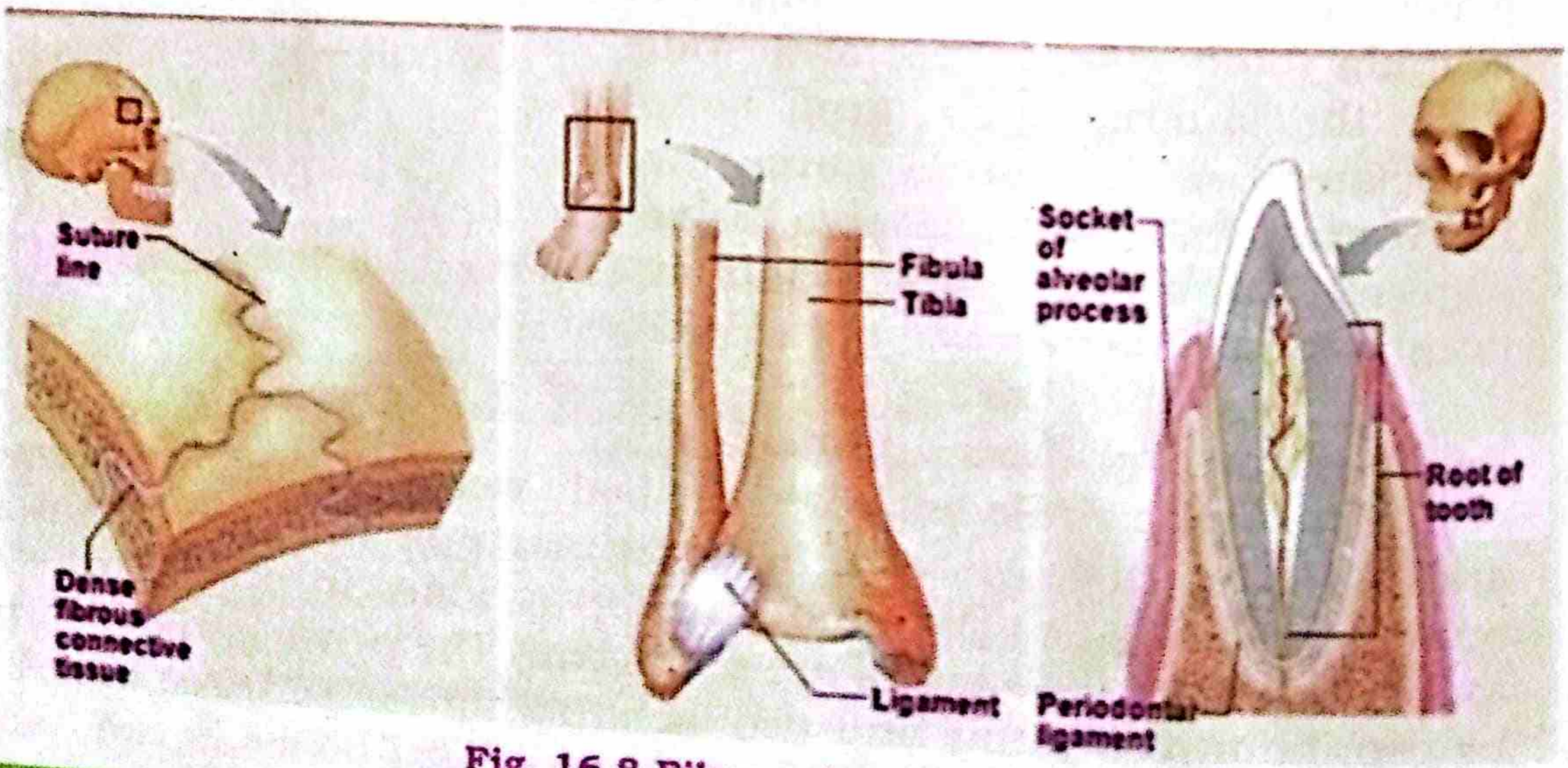


Fig. 16.8 Fibrous joint

Cartilaginous joints

Joints which join two bones articulated by hyaline or fibrocartilage.

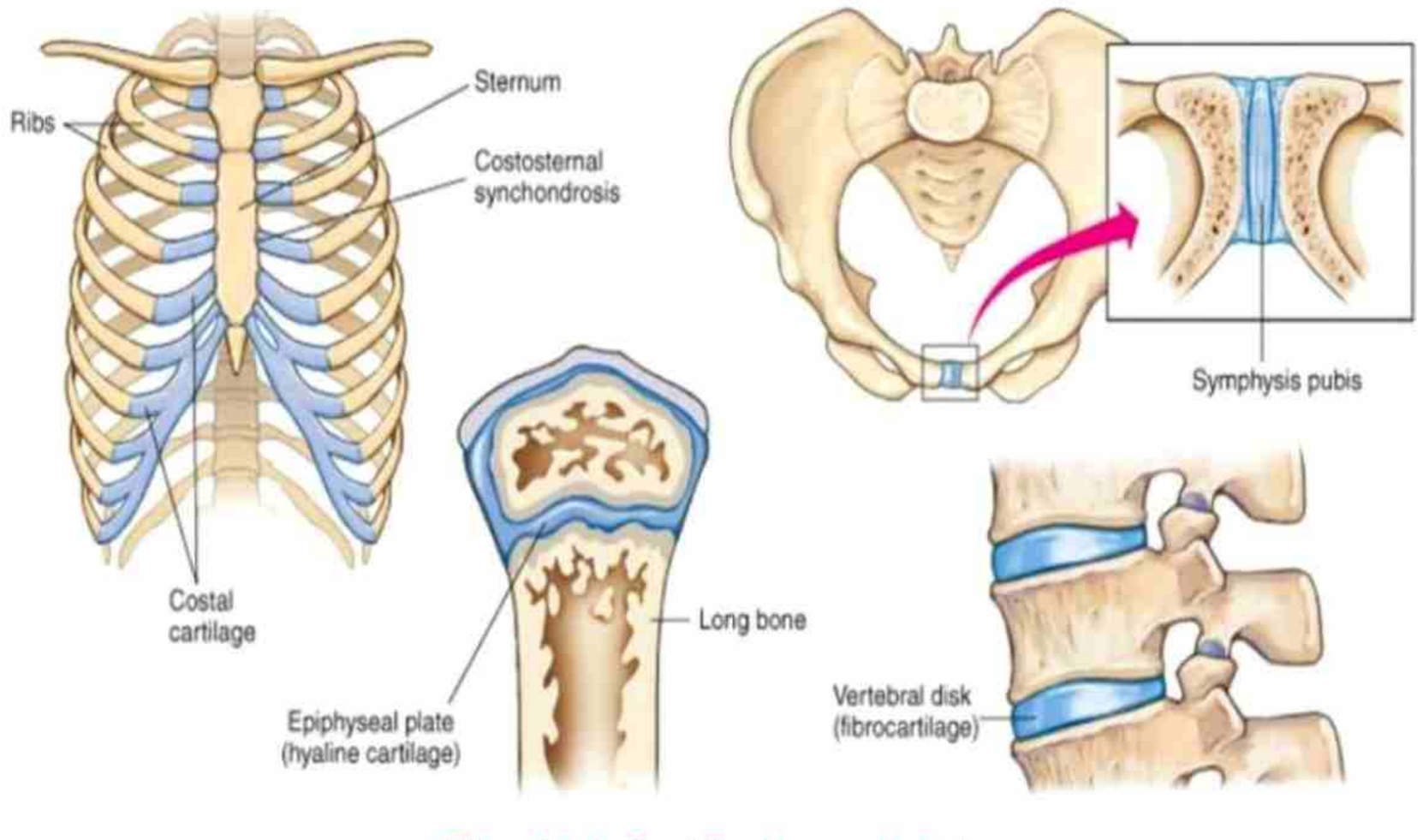


Fig. 16.9 Cartilaginous joints

Synovial joints

Most of the joints in skeletal system are synovial due to their free movability. These are more complex then other joints in structure. Synovial joints generally consists of a joint capsule and synovial membrane that secretes synovial fluid. The joint capsule holds together the bones and encloses the outer part of a joint. The inner membrane of capsule is few cells thick covers the surface within the joint capsule called the **synovial membrane**. Synovial memebrane surrounds a closed sac called **synovial cavity** and secrete **synovial fluid** to fill this cavity. Synovial fluid lubricate and nourish the articulating cartilage surface wihthin the joint.. There are different types of synovial joints present in our body. **Hinge joint** present in between the humerus and the ulna bones allowing flexion and extension in just one plane. **Pivot joint** present in proximal and distal radio-ulnar joint allows twisting movement. **Ball and socket joint** of shoulder and hips moves the organ in all direction,

condyloid joint is the modified but structurally different ball and socket joint that also allow the movement in all direction for example wrist joint (radio-carpal joint). **Gliding joint** is also called the plane join. It only permits limited movement like bending and slipping one bone over to another, for example, wrist and vertebral column.

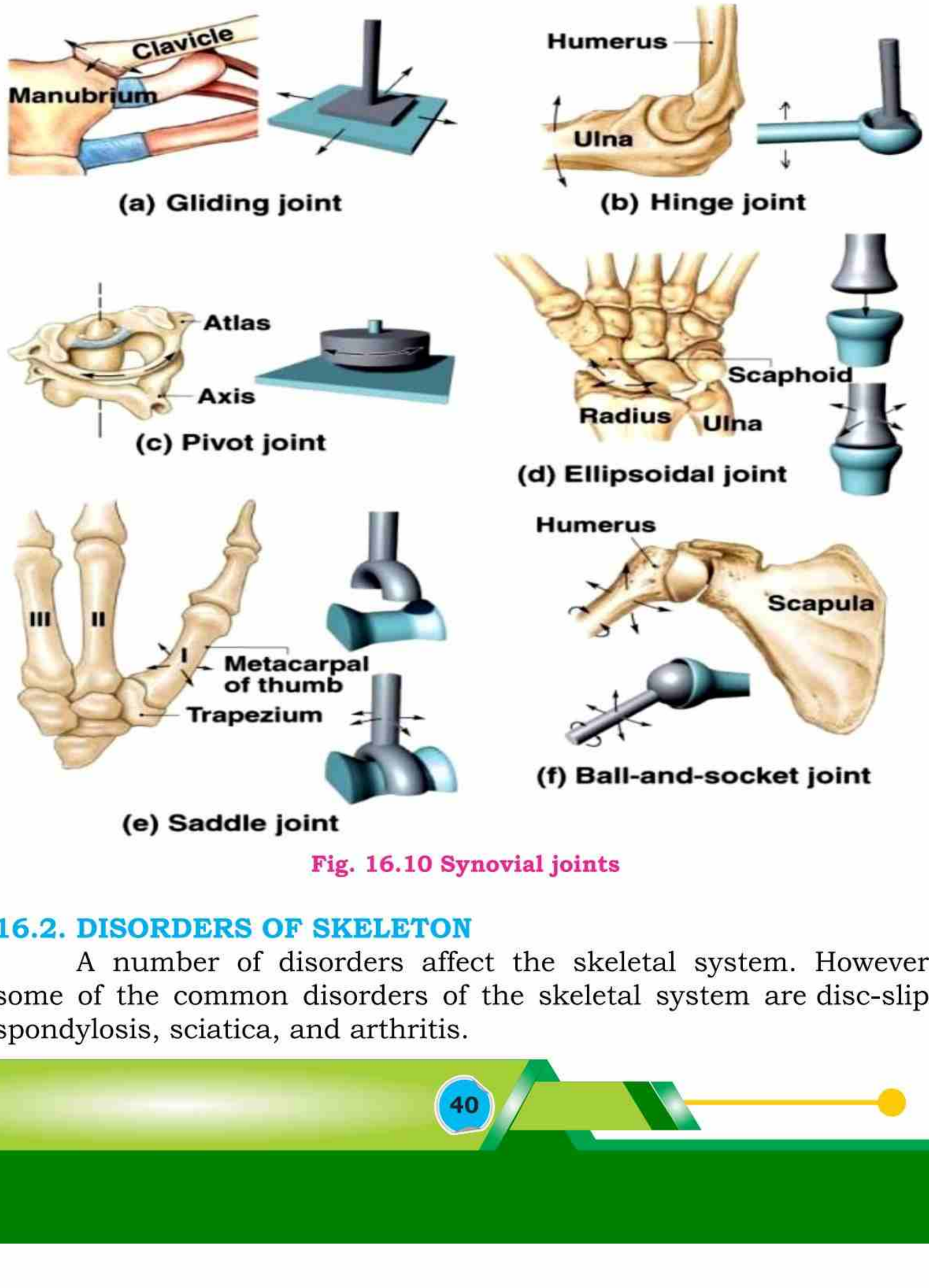


Fig. 16.10 Synovial joints

16.2. DISORDERS OF SKELETON

A number of disorders affect the skeletal system. However, some of the common disorders of the skeletal system are disc-slip, spondylosis, sciatica, and arthritis.

16.2.1. Common Disorders of Skeleton

Spondylosis

Spondylosis is related to abnormal or degenerative changes in vertebrae. These changes may develop abnormal outgrowth (spur), narrowing the gap between adjacent vertebrae and degeneration of intervertebral discs due to aging. It can occur in the cervical spine (neck), thoracic spine (upper and mid back), or lumbar spine (low back). Lumbar spondylosis and cervical spondylosis are the most common.

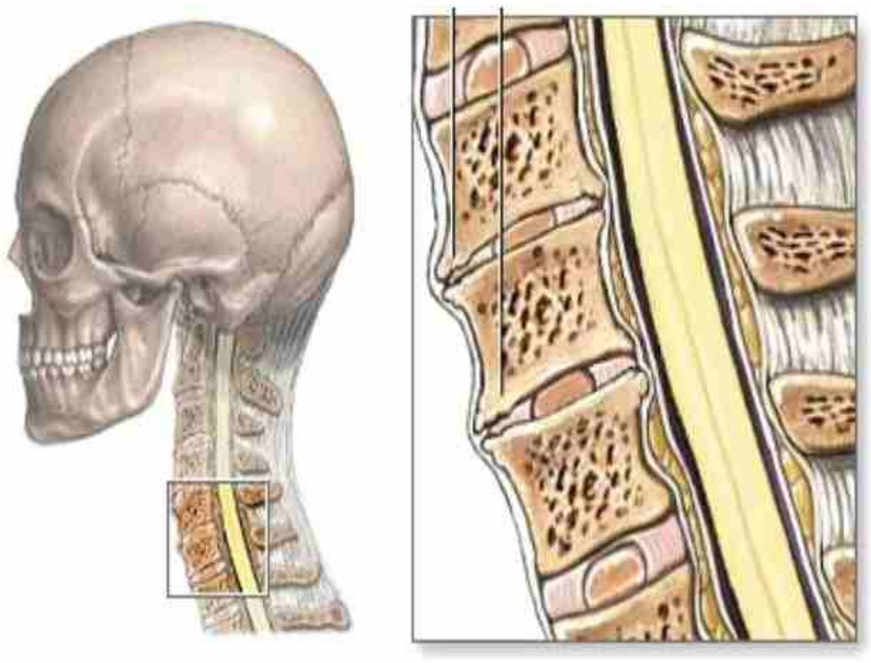


Fig. 16.11 Spondylosis

Degeneration of vertebrae results in the compression of nerves which can cause symptoms such as pain, numbness, and tingling.

Sciatica

Sciatica is the compression or injury in sciatic nerve located in posterior limbs. The sciatic nerve is the longest and thickest nerve in the body. It is made up of five nerve roots which come together to form a right and left sciatic nerve on each side of the body. Sciatic nerve runs through hips and goes down the leg, ending just below the knee then branches into other nerves, which continue down the leg and into the foot and toes. The main symptoms of sciatica pain originate in the lower back and radiate down the leg. Sciatica can come on suddenly or gradually. It depends on the cause.

Fig. 16.12 Sciatica

Disc Slip

The vertebrae are cushioned by cartilaginous discs. These discs act as shock absorbers and protect vertebrae from daily activities like walking, lifting, running etc. Each disc has two regions; the tough outer ring and inner soft and gelatinous region. Any injury or weakness can cause the inner portion to protrude by breaking the outer ring. This is known as a slipped, herniated, or prolapsed disc. This results in severe pain and extreme discomfort. If the slipped disc compresses one of the spinal nerves, the victim may also experience numbness and pain along the affected nerve. Pain that extends to the arms or legs and never settled in any posture of the body.

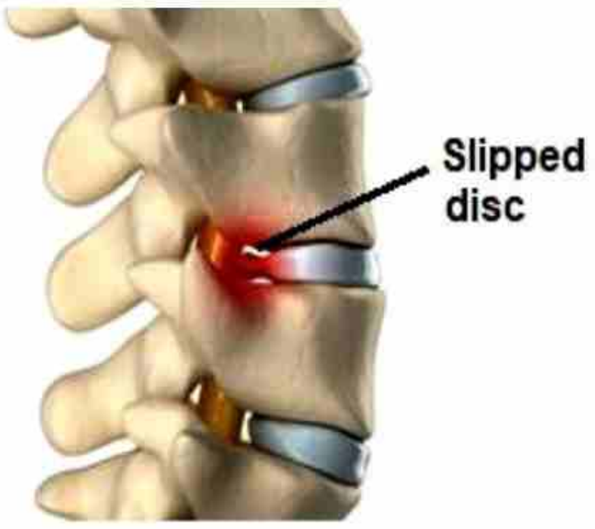


Fig. 16.13 Disc Slip

Arthritis

Arthritis is a disease that affects joints. It usually involves inflammation or degeneration of joints. It causes pain and inflammation, making it difficult to move or stay active. There are many types of arthritis. Each form causes different symptoms and may need different treatments. While arthritis usually affects older adults. **Osteoarthritis** develops when joint cartilage breaks down from repeated stress. It is the most common form of arthritis. **Ankylosing spondylitis,** or arthritis of the spine (usually your lower back). **Gout,** a disease that causes hard crystals of uric acid to form in the joints. **Rheumatoid arthritis** a disease that causes the immune system to attack synovial membranes in your joints.

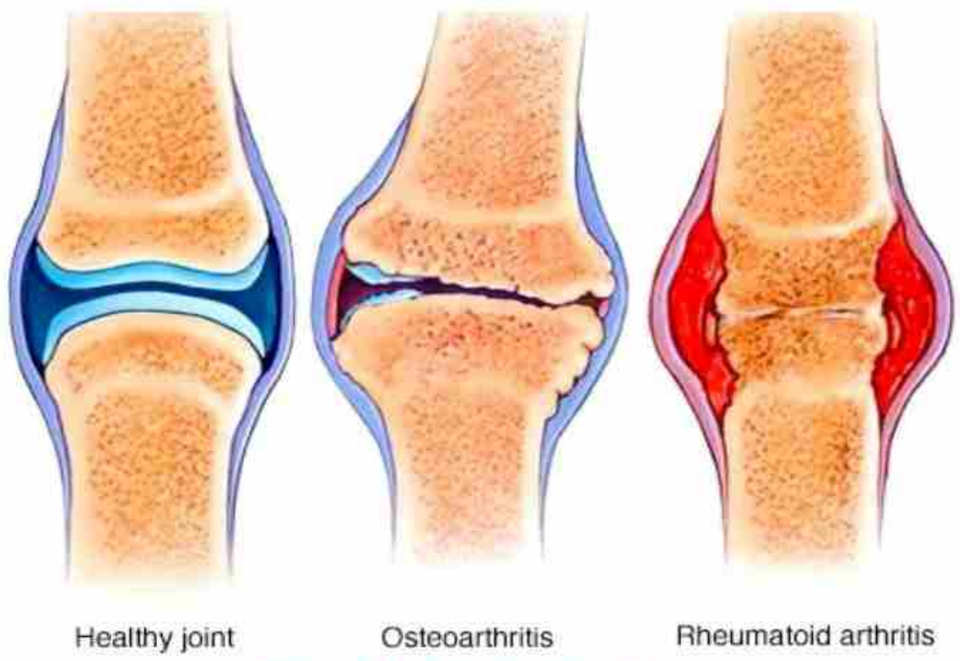


Fig. 16.14 Arthritis

16.2.2. Types of bone fractures

Fracture is the breaking of bone due to any injury. The types of fractures are simple fractures, compound fractures and complicated fractures. A **simple fracture** is also called closed fracture in which bone is cracked but does not break the skin and not exposed. A **compound fracture** is characterized by the complete breaking of bone and the piece of bone is visibly piercing outside the skin. When the fracture damages the surrounding structures including organs, veins, arteries, or nerves, it is called a **complicated fracture**.

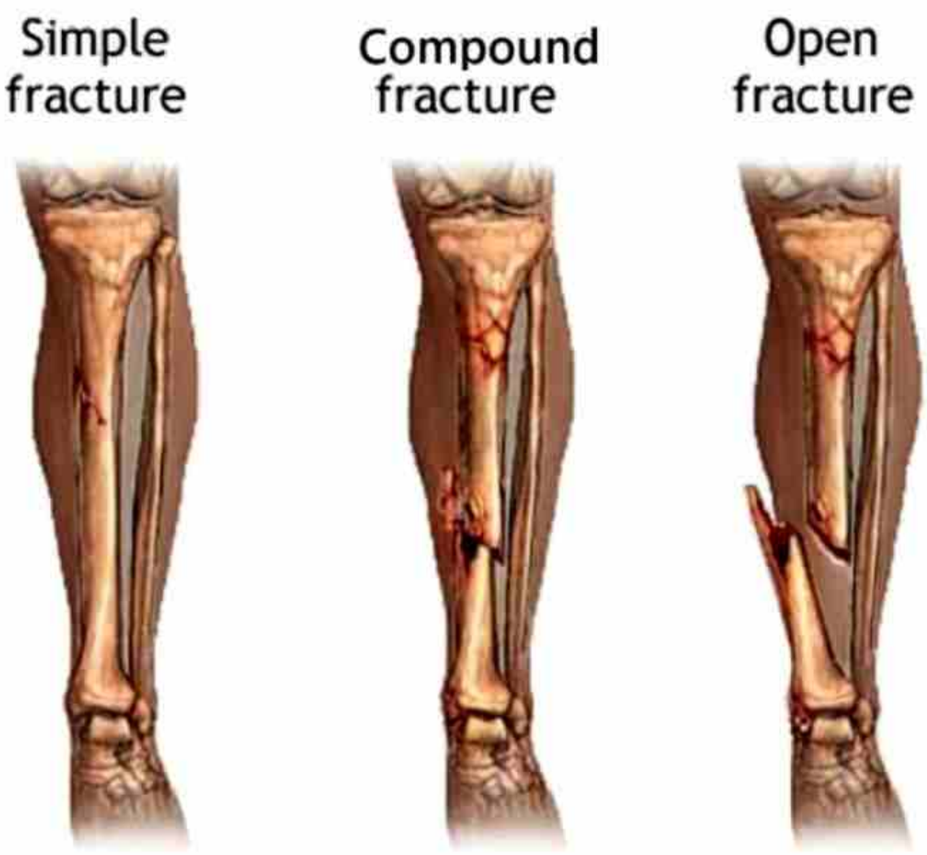


Fig. 16.15 Types of Bone Fractures

Fracture is accompanied by intense pain at the place of initial injury, tenderness at the site, a sensation of grating or grinding with movement, and inability to use the limb or body part supported by the bone. Physical signs include deformity of the part, swelling in the region of the fracture, discoloration of the overlying skin, and abnormal mobility of the bone.

The repair process of simple fractures.

The fractured or broken bone undergoes repair through four stages:

a) Hematoma stage

When fracture occurs the blood vessels within the bone and its surrounding periosteum break. Blood escapes and massively accumulates into the surroundings which form a clot called **hematoma**. The immune system activates and induces swelling at the site of injury. Receptors develop pain sensation and due to

suspended blood supply, the bone cells are deprived of nutrients and begin to die. The hematoma internally sealed the fracture site, preventing further blood loss and provides a framework for healing process.

b) Fibrocartilaginous callus formation

Within weeks new blood vessels and numerous osteoblasts develop from the periosteum and enter the hematoma. Osteoblast quickly divides and gives rise to the spongy bone in the region close to the new blood vessels. The next phase of healing begins by the formation of new tissues called granulation tissues. These tissues contain new blood vessels and a complex of fibroblasts, vascular endothelial cells, and macrophages within a matrix of collagen and fibrin. All of them are added up and develop a mesh work called **fibrocartilage callus** at the ends of the broken bone. The dead cells are phagocytosed by macrophages. The osteoblast develops the spongy bone and fibroblast cells produce collagen fibers to reform the fractured bone.

c) Bony callus formation stage

When the soft callus is formed, later it is calcified and turned into hard bony callus. As the bony callus formation progresses it is replaced with bone. The hard callus formation is initiated around three weeks after the fracture and continues for about three months. When cartilage becomes ossified, it contains osteoblasts, osteoclasts, and bone matrix.

d) Remodeling stage

Bone remodeling is the stage when old bone tissues are removed and replaced with new ones that join both fractured sides. Remodeling starts when the osteoblast cells detect the fracture and induces monocytes to fuse together to form a multinucleated osteoclast cell. The osteoclast matures and activates to start resorbing bones as the bone resorption proceeds, osteoblasts start producing collagen to fill in the lacunae created by the osteoclasts and calcium phosphate begin to deposit, forming hydroxyapatite. The osteoblast keeps producing new bony material and turns into osteocytes. Finally, the bony callus is then remodeled by osteoclasts

and osteoblasts and compact bone is added just like the original, unbroken bone and fracture is healed. This remodeling can take many months; the bone may remain uneven for years.

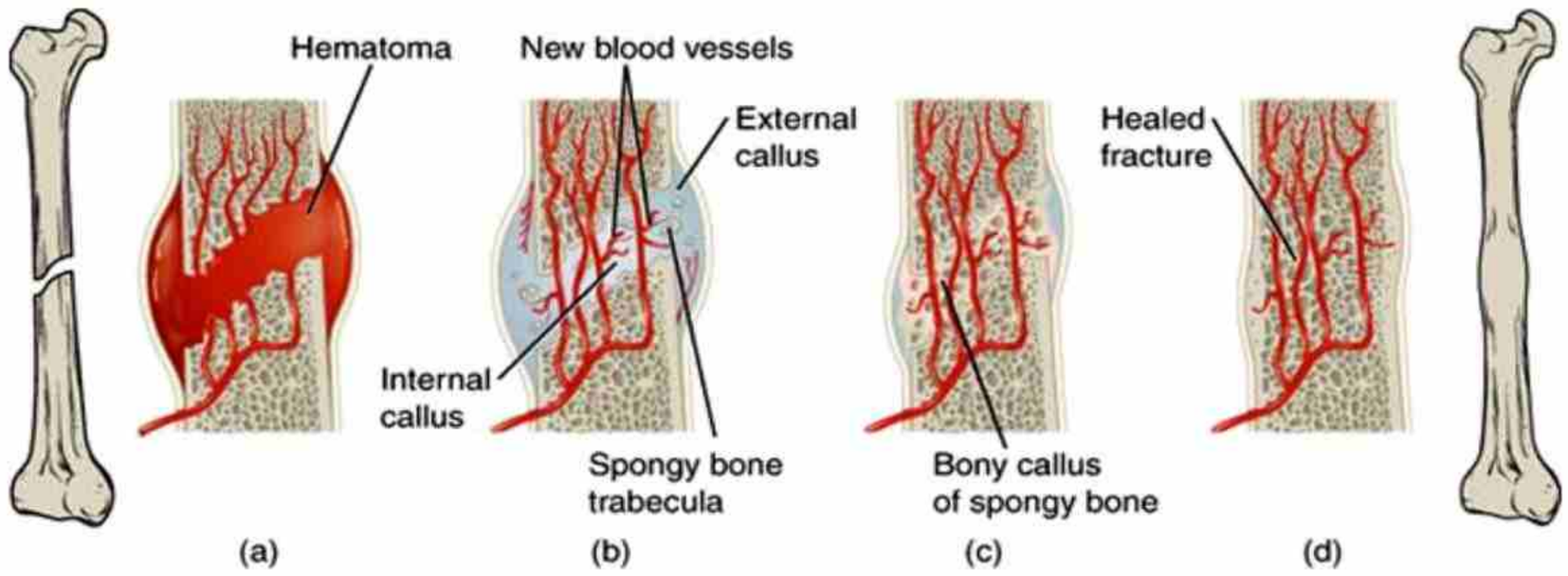


Fig. 16.16 Stages of fracture repair

16.2.3. The injuries in joints

Joints are injured when the ligaments are twisted or torn due to overuse of muscles, repeated heavy physical activities or any injury. The common types of joint injuries are as follows:

Dislocations

Dislocation is the complete change of position or separation of the bones in a joint due to any injury, arthritis or weakening of muscles and tendons. It may damage the nerves and surrounding tissues. The common symptoms of dislocation are severe pain, swelling, instability of joint, inability to move a joint, bruising.

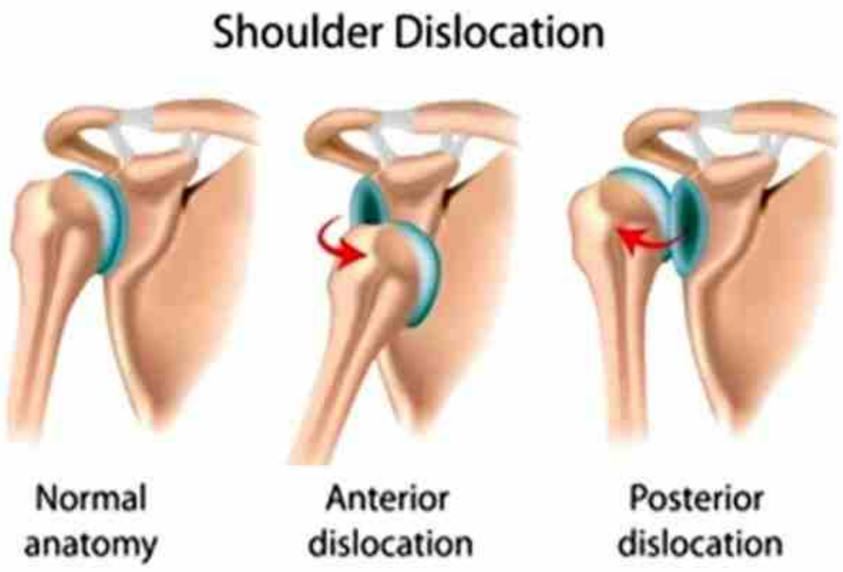


Fig. 16.17 Dislocation

Dislocation can be managed by surgery, physical bone manipulation by the doctor, rest, physical therapies.

Sprain

Sprain is related to the mild to severe grade of stretching or tearing of a ligament that holds a joint's bones together. Sprains can be the result of a sudden twist of the limb associated with the joint. Sprains usually occur in the ankles, knees, and wrists. The common symptoms of sprains are pain, swelling, inflammation and bruising. A person suffering with sprain must take rest, foment with ice packs, use bandages over the injury and sometimes surgery is needed.

Fig. 16.18 Sprain

The first-aid treatment for joint injuries and fractures.

First aid refers to medical attention usually administered immediately after the injury occurs and where it occurred. Keep the patient in resting condition. Apply an icepack (cold compress) wrapped in a wet cloth to the injury for some time. Apply a compression elastic bandage firmly to the injury that extends well beyond the injury. Elevate the injured part. Use broad bandages (where possible) to prevent movement at joints above and below the fracture. Support the limb, carefully passing bandages under the natural hollows of the body. Place a padded splint along the injured limb. Place padding between the splint and the natural contours of the body and secure firmly.

16.3.1 Muscles

A muscle is the group or bundle of tissue in the body which can contract and relax to produce movement in various parts of the body and locomotion. Muscles also facilitate the movement of the body fluid, particularly lymph. There are three types of muscles involved in this process. The smooth muscles, cardiac muscles, and skeletal muscles.

Smooth muscles

Smooth muscles do not show striations hence called smooth muscles. These are present in hollow visceral organs like urinary bladder, respiratory tract, blood vessels, reproductive system etc. Smooth muscles cells are spindle shaped having single nucleus.

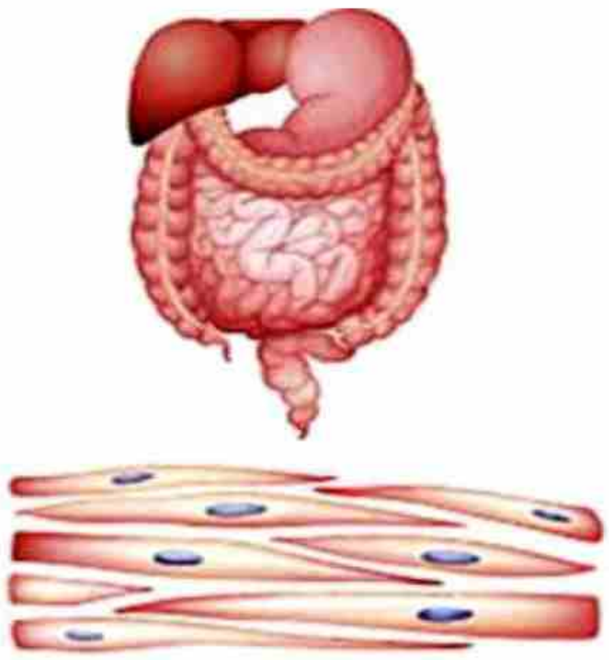


Fig. 16.19 Smooth Muscles

Cardiac muscles

Cardiac muscles are located only in the heart. These muscles are striated in structure but involuntary in function. Cardiac muscles are branched, bifurcated and their unit cells contain single or double cell nuclei. Cardiac muscle cells are strongly interconnected by a specialized structure called **an intercalated disc**. The cardiac muscles are arranged in a branching network where cells are joined together and make a **syncytium**.

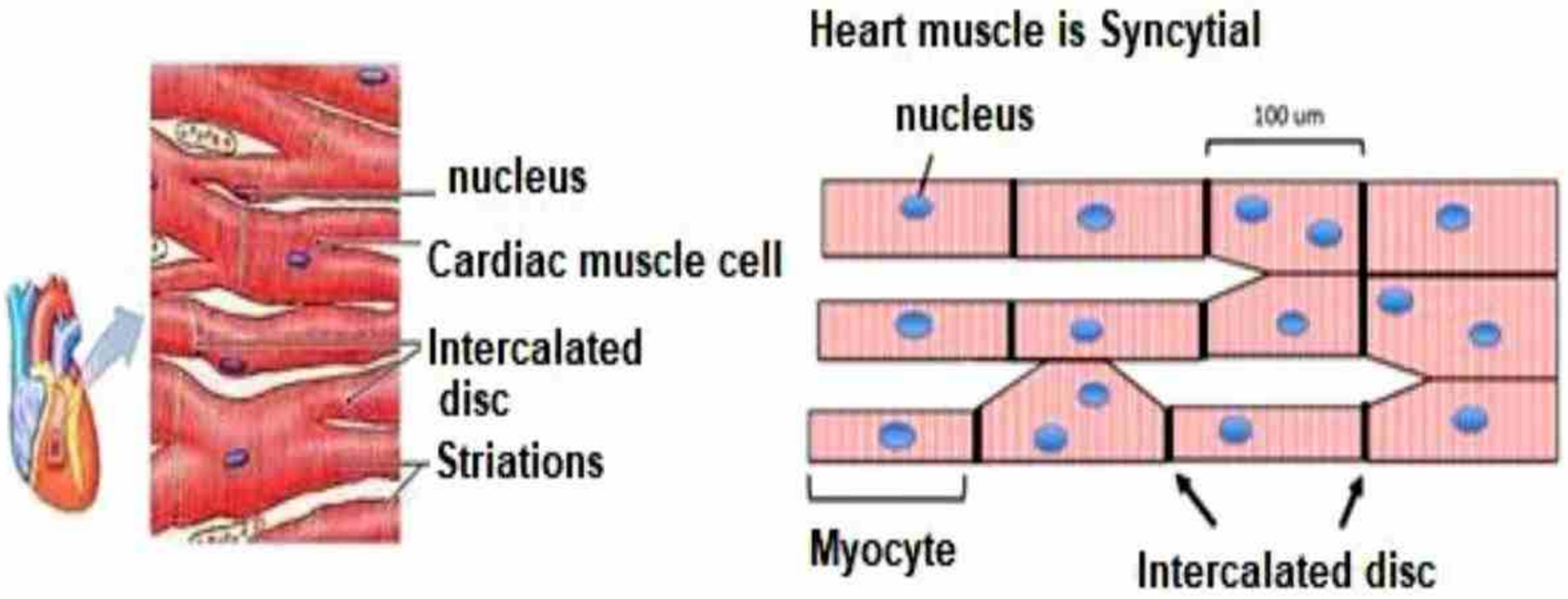


Fig. 16.20 Cardiac Muscles

The cardiac syncytium is a network of **cardiomyocytes** connected by intercalated discs that enable the rapid transmission of electrical impulses through the network. The cardiac muscles are the strongest among all. They work continuously throughout life and amazingly do not get fatigued. This is because they have numerous mitochondria and continuous supply of oxygenated blood.

Skeletal muscles

The muscles attached to skeleton are called skeletal muscles. The cells are striated, cylindrical and multinucleated. These are located in those organs which can perform voluntary movement like arms, legs, neck etc. They are arranged in bundles and the pattern of striations on muscle surface.

Fig. 16.21 Skeletal Muscles

16.3.2 Comparison of types of Muscles

Smooth muscles	Cardiac muscles	Skeletal muscles
They do not show striations	They show striations	They show striations
These muscles are spindle shaped	These muscles are cylindrically branched	These are cylindrical and unbranched
Present in hollow, visceral organs	Present in heart	Attached with skeleton
They are involuntary in action	They are involuntary in action	They are voluntary in action
They do not make cross bridges during movement	Cross bridges are formed	Cross bridges are formed
Instead of troponin, they contain calmodulin in actin filaments	They have troponin in actin filament	They have troponin in actin filament.

The structure of Skeletal muscle

A muscle is composed of thousands of **muscle fibers** grouped in bundles. The overall muscle organ is surrounded by a membrane called **epimysium.** Muscle fiber is gathered inside the epimysium in many groups. Each group of fibers is called a **fascicle** surrounded by a membrane called **perimysium**. Inside each fascicle a muscle fiber

is enveloped in a thin connective tissue layer of collagen called the **endomysium**.

Skeletal muscles have numerous supplies of blood vessels and nerves. The nerves are connected with muscle by neurons which initiate the mechanism of movement in muscle when order is given by nervous system.

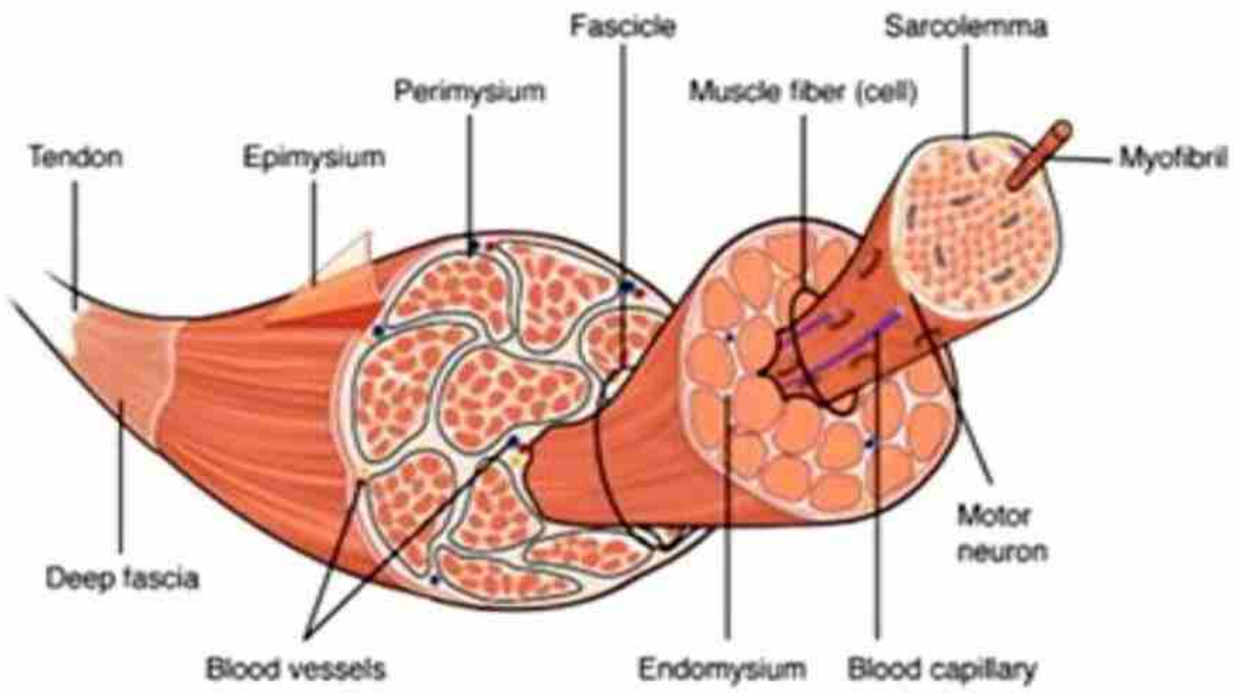


Fig. 16.22 Structure of Skeletal Muscle

The Ultra Structure of Skeletal Muscle Fiber

Muscle fiber is considered a cell of skeletal muscle with many **myofibrils**. Each muscle fiber has a covering just like a cell membrane called **sarcolemma**. The cytoplasm or **sarcoplasm** contains numerous nuclei and mitochondria. Each myofibril is connected with the axon of motor neuron at a place called **neuromuscular junction**. The specific neuromuscular junctions where mitochondria are abundant.

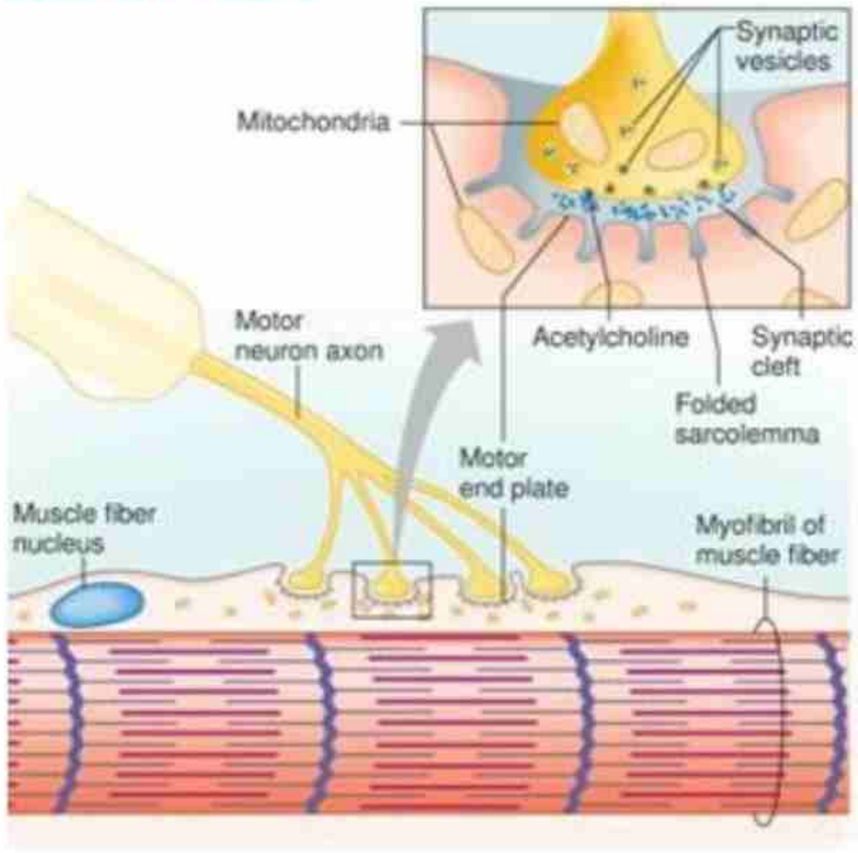


Fig. 16.23 Neuromuscular Junction

The sarcolemma is extensively folded s **motor end plate**. The sarcolemma permits calcium ions to enter or leave the myofibril from their specific proteinic gateways. Within the sarcoplasm, a membranous network is present that runs parallel to the myofibril called **sarcoplasmic reticulum**. It is the storage house for calcium ions used in muscle contraction. It extends inward to form a membranous channel called **T-tubules** that runs perpendicular and connected with sarcoplasmic reticulum.

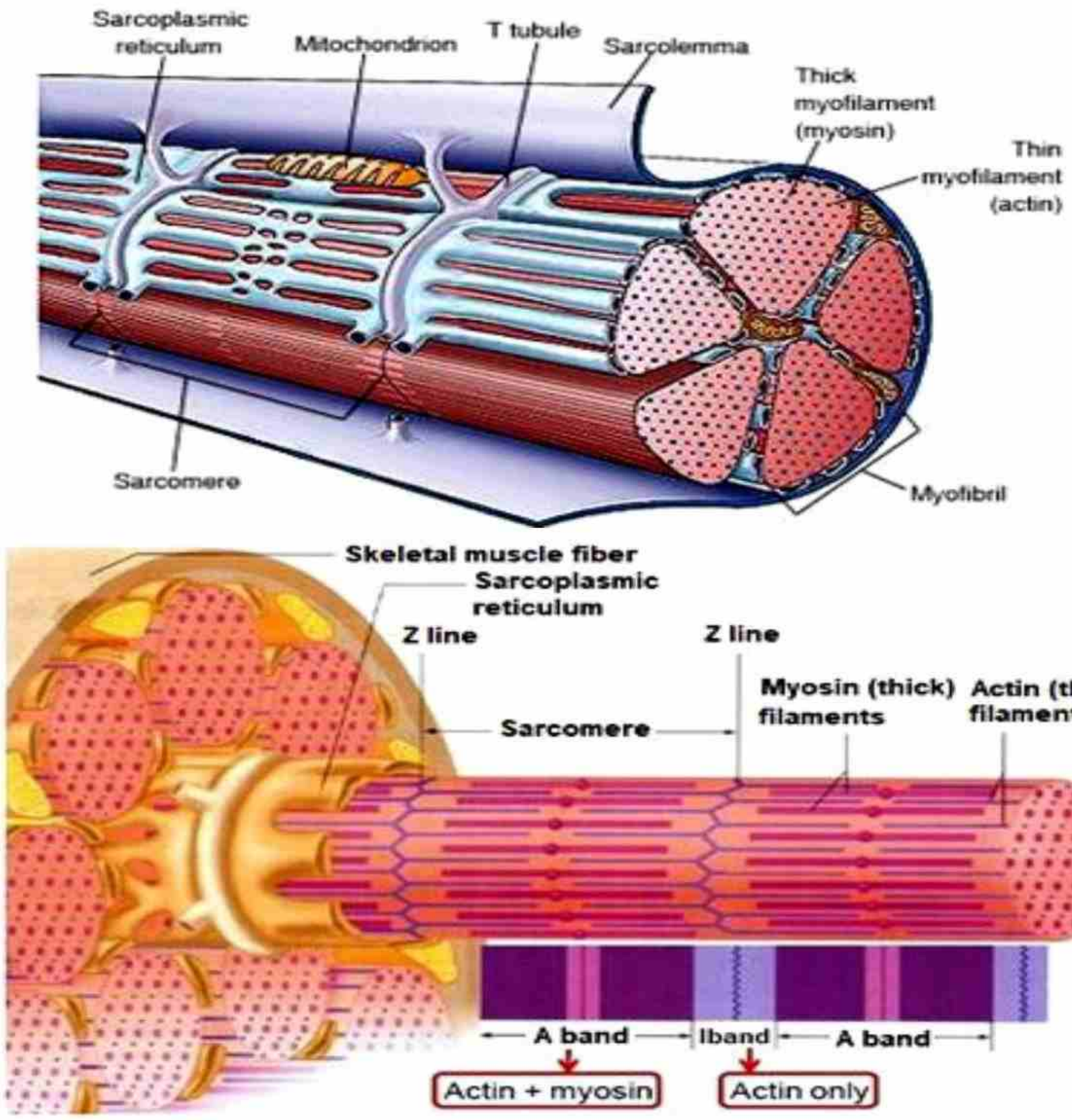


Fig. 16.24 Ultra Structure of Skeletal Muscle

Myofibril contains two kinds of protein filaments called **actin** and **myosin**. Each myosin filament is thick, 16nm in diameter and composed of myosin monomers. It has two twisted strands with projected heads outward which form a cross link with actin filament. Each actin filament is thin, 7-8 nm in diameter, double stranded, twisted and contains actin monomers associated with two other proteins called **troponin** and **tropomyosin**. Each actin monomer has a binding site for myosin cross bridges for attachment. Troponin is a complex of three different subunits called troponin C, I and T. Each subunit is assigned for specific function such as the troponin C (Tn-C) bind Ca^{2+}, the troponin I (Tn-I) inhibit actomyosin interaction and troponin T (Tn-T) is used for binding tropomyosin.

The organization of actin and myosin filaments develops alternating **light** and **dark** regions seem like striations or bands. The light region contains only actin filament called **'I' band (isotropic band).** Actin filaments of I band connected by **Z line or disc** (zwischen means middle).

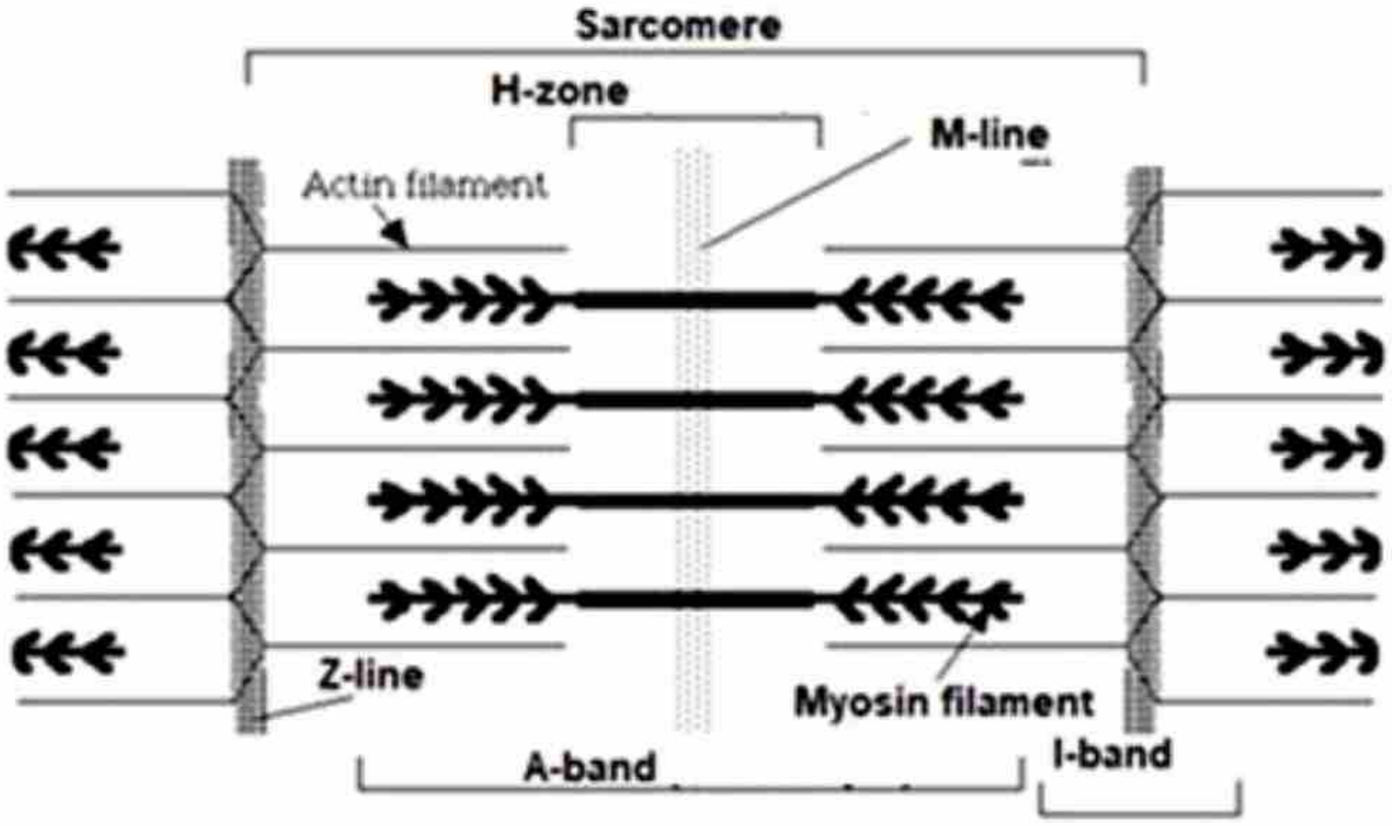


Fig. 16.25 Sarcomere of skeletal muscle

The dark region contains thick myosin filaments overlapping thin actin filaments called **"A" band (Anisotropic band)**. The myosin filaments are connected by **"M" line or disc** (Myomesin: protein). The A band has a slightly lighter middle region called **"H" zone** (Helle:

light) containing only myosin filament. The region between two 'Z' lines is called **sarcomere**.

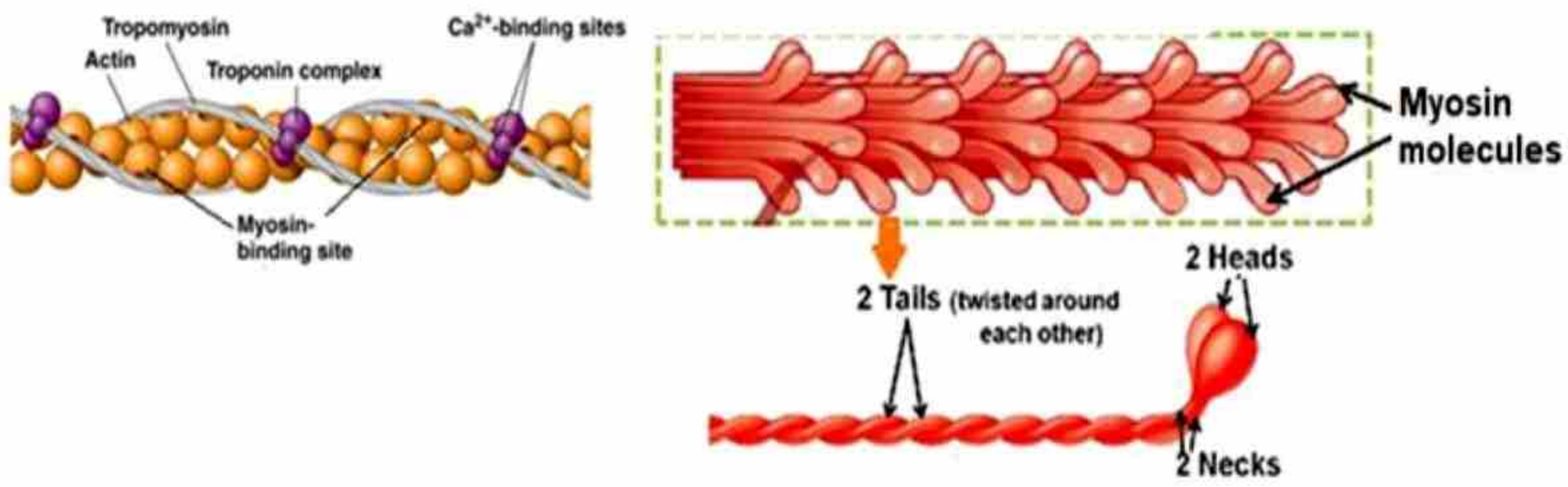


Fig. 16.26 Actin and Myosin filament

16.3.4 The sliding filament model of muscle contraction

The sliding filament model of muscle contraction, put forward by **Hugh Huxley and Jean Hanson** in 1954. According to this theory when sarcomere shortens, the thick and thin filaments do not themselves change their length. They just slide past one another, with the thin filaments moving toward the center of the sarcomere from both ends. As this occurs, the H zone and I bands get narrower, the regions of overlap widen, and the Z lines move closer together, shortening the sarcomere.

The sub-stages of sliding filament model are as follows:

The Cross Bridge Cycle

This cycle begins when muscle fibers are stimulated by receiving the nerve impulse at the motor end plate. Motor neurons release a neurotransmitter acetylcholine that opens the proteinic gateway in T-tubules and then in sarcoplasmic reticulum to release the stored calcium ions that initiate muscle contraction. The calcium ions are released and bind with the troponin of thin filament. This binding depolarizes tropomyosin along the actin filament, which in turn twists and exposes the myosin binding sites located on actin monomers. In the next step the myosin head rises by getting energy from ATP when bind ATP is hydrolyzed into ADP and phosphate by an enzyme ATPase. This causes the myosin head to extend and attach to the binding site of an actin and both actin and myosin

filaments are cross linked to form a cross bridge. This action called power stroke is triggered allowing myosin to pull the actin filament toward the M line, thereby shortening the sarcomere. ADP and phosphate are released during the power stroke. The myosin remains attached to the actin until a new molecule of ATP binds, freeing the myosin. Having been unbound from actin, the myosin heads resume their starting positions and are ready to begin a new sequence of actin binding. Thus, the presence of further calcium ions will trigger a new contraction cycle.

Relaxation

When nerve impulse ceases, two events relax the muscle fiber. During the first event the acetylcholine that remains in the synapse is rapidly decomposed by an enzyme called acetylcholine-esterase.

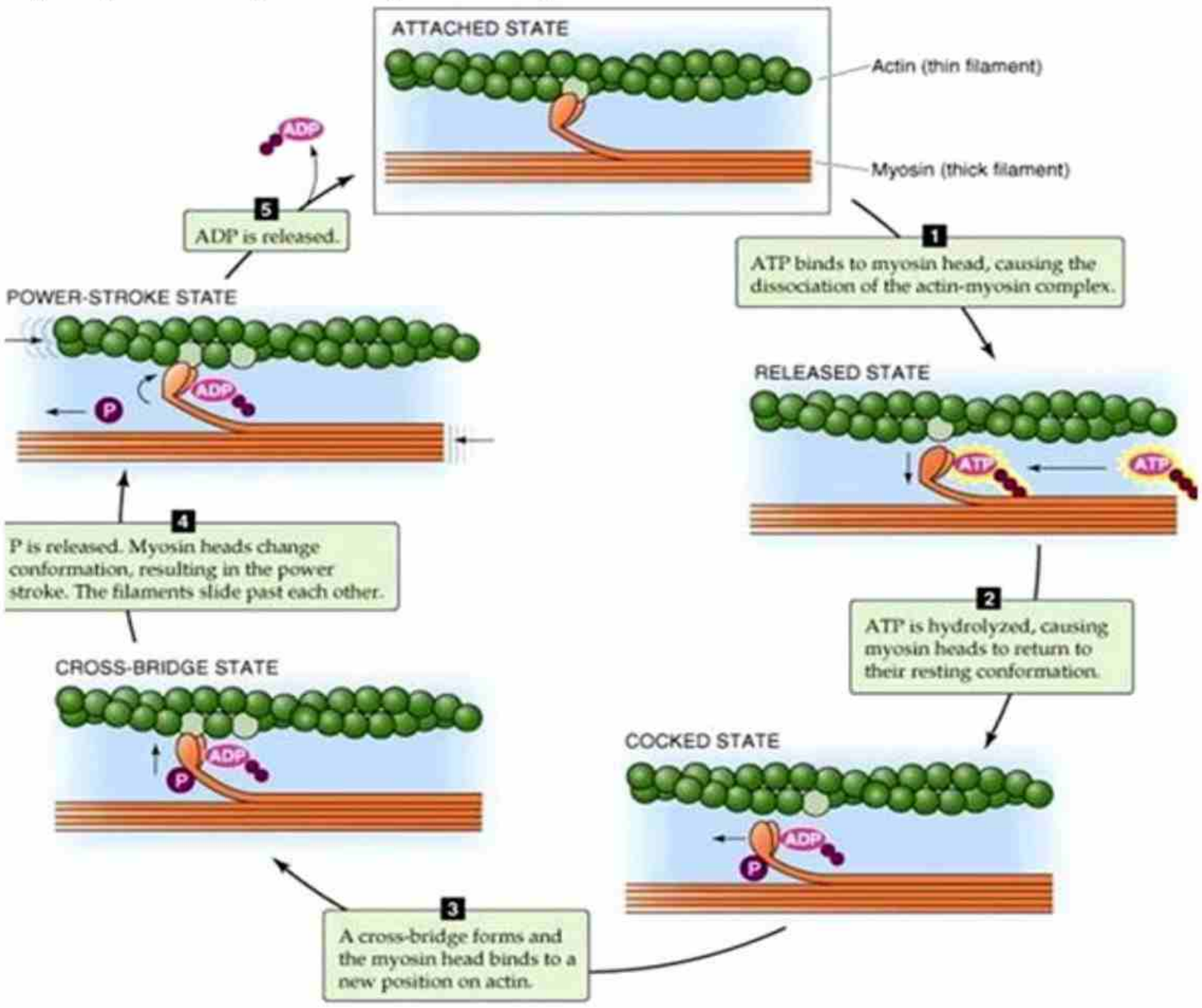


Fig. 16.27 Cross bridge cycle of skeletal muscle

This enzyme is present in synapse and on the membranes of the motor end plate. The action of acetylcholine-esterase prevents a single nerve impulse from continuously stimulating muscle fiber. During the second event when acetylcholine is broken down, the stimulus to the sarcolemma and the membranes within the muscle fiber ceases. The calcium pump (which requires ATP) quickly moves calcium ions back into the sarcoplasmic reticulum, decreasing the calcium ion concentration of the cytosol. Consequently, the muscle fiber relaxes.

16.3.5. The action of antagonistic muscles in the movement of knee joint

The ability of a muscle to oppose the action or effect of another muscle is called antagonistism. An antagonist muscle is relaxed while the other side opposite to antagonist muscle contracted called agonistic muscles. Knee joint is the largest and most complex of the synovial joints. It is formed by the articulation of distal end of femur and proximal end of tibial bone while anterior to the junction of these bones, patella bone is articulated. The antagonistic muscles of the knee joint are the group of hamstring muscles as **flexor muscles** and the group of quadriceps muscles as **extensor muscles**.

The **hamstring muscles** are made up of three individual muscles located in the back of the thigh, originating from hip, and inserting to the knee. Hamstring tendons attach to bones in pelvis, knee, and lower leg. Hamstring muscles serve a variety of functions, including bending the knee joint, extending, or rotating the hip joint.

Extra Reading Material

A hamstring muscle strain is the result of overstretched muscle fibers. Hamstring strains can range from mild to severe.

The **quadriceps** is made up of four different muscles. It is in the anterior region of the thigh. The quadriceps is a hip flexor and knee extensor. They form the main bulk of the thigh, and collectively are one of the most powerful muscles in the body. The quadriceps all work to extend (straighten) the knee. The quadriceps are primarily active in kicking, jumping, cycling, and running.

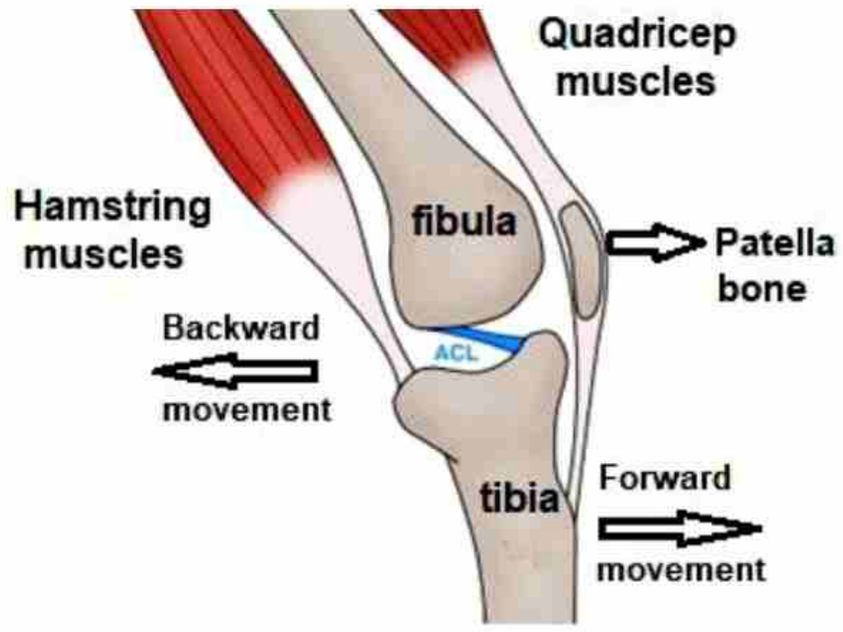


Fig. 16.28 Knee Joint Muscles

16.3.6 Muscle fatigue

A muscle exercised persistently for a longer period may lose its ability to contract, a condition called fatigue. It is most likely to arise from accumulation of lactic acid in the muscles due to anaerobic ATP production. The lowered pH from the lactic acid prevents muscle fibers from responding to stimulation. When lactic acid is produced, it diffuses out from the muscle fiber and is carried in the blood stream to the liver. Liver cells can react to lactic acid to form glucose. This requires ATP and ATP production is conditioned with the availability of oxygen. Therefore, when a person rests and acquires enough oxygen, lactic acid quickly breaks down and the muscle returns to normal.

Cramps

A muscle cramp is a painful stiffness in a muscle due to a sudden, involuntary contraction. A person feels sudden tightening as if they have flexed their muscle while it is actually relaxed. Muscle cramps have several causes like overuse of muscles while exercising, muscle injuries, dehydration, low levels of minerals like calcium, potassium, sodium, magnesium, low blood supply to the legs during physical activities. Usually, cramps can be relief by stretching or gently massaging the muscle, applying heat and use of ice when the muscle is sore, getting more fluids if dehydrated.

16.3.7 Differentiate between Tetany and Tetanus

TETANY	TETANUS
Tetany or tetanic seizure is a medical sign consisting of the involuntary contraction of muscles	Tetanus is an infectious disease affecting the central nervous system
caused by disorders that increase the action potential frequency of muscle cells or the nerves that innervate them	caused by a bacterium called *Clostridium tetani.*
Tetany can be the result of an electrolyte imbalance. Most often low calcium level, hypocalcemia, or magnesium, potassium deficiency, increased acidic (acidosis) or alkali (alkalosis) in the body.	Tetanus can be because of intravenous drugs inducted through contaminated needles by the abusers.
No toxins involve	Bacterium release neurotoxin called tetanospasmin, which acts on the synapses and causes muscular spasms and neuromuscular junction blockade
Severe vitamin D deficiency may be associated with hypocalcemia, which may cause tetany or seizures.	These functional impairments are manifested as flexor muscle spasms. The impact of the toxin on the sympathetic nervous system causes autonomic dysfunction.
a person may only die If tetany occurs in respiratory tract.	A person may die when the infection becomes severe.

SUMMARY

- Human skeleton acts as a framework of the body and the study of human bones is called osteology.
- Bone has distinct regions called epiphysis, diaphysis and metaphysis and covered by different layers
- Bones and cartilage are composed of numerous cells.
- Different types of cartilages are located in skeleton and plays vital role in protecting joints
- Human skeleton is formed by numerous bones and has two major divisions called axial and appendicular skeleton which include separate bones.
- Bones are joined to form different joints. The major groups of joints are called fibrous, synovial, and cartilaginous joints.
- The common disorders of the skeletal system are disc slip, spondylosis, sciatica, and arthritis.
- Repair of several types of bone fracture takes place in different steps in sequence i.e., hematoma formation, internal and external callus formation, replacement of cartilage by trabecular bone and remodeling.
- First-aid treatment is also used for the injuries in joints like dislocation and sprain.
- There are three types of muscles in the body that perform movement.
- Skeletal muscles are present in organs that work voluntarily, non-skeletal muscles in involuntary organs and cardiac muscles in heart.
- Skeletal muscle fiber contains numerous myofibril which contain two kinds of protein filaments namely actin and myosin.
- These filaments are cross linked and perform muscles contraction. Due to abnormal muscle contraction tetany and cramps takes place.

EXERCISE

1. Encircle the correct choice.

i) The type of bone cell that tears down bone during the building and remodeling process are
(a) Osteocytes (b) Osteoblasts
(c) Osteoclasts (d) Bone lining cells

ii) During bone formation, as the periosteum calcifies, it gives rise to a thin plate of compact bone called
(a) Periosteal bud (b) Periosteal bone collar
(c) Primary ossification center (d) Epiphyseal plate

iii) The ring like shape of the girdle is due to the joining of coxal bone with the sacrum of vertebral column at anterior side and below by a joint in between pubic part called
(a) Pubic symphysis (b) Iliac junction
(c) Pelvic symphysis (d) Syndesmosis

iv) Cartilage is a soft flexible form of connective tissue surrounded by a layer called
(a) Myocardium (b) periosteum
(c) Osteoderm (d) Perichondrium.

v) An antagonist muscle is relaxed while the other side opposite to antagonist muscle
(a) Contracted (b) Relaxed
(c) No change (d) Extremely relaxed

vi) The stage when old bone tissues are removed and gets replaced with new ones that joins both fractured sides called
(a) Bone remodeling stage (b) Bone callus formation
(c) Cartilaginous callus formation (d) Hematoma formation

vii) Which is related to the mild to severe grade of stretching or tearing of a ligament that holds the bones of a joint together?
(a) Spasm (b) Tetany
(c) Sprains (d) Cramps

viii) Muscle fiber are gathered in many groups each group of fibers is called a fascicle which is surrounded by a membrane called
(a) Sarcolemma (b) Perimysium
(c) Endomysium (d) Epimysium

ix) The heart muscles arranged in a branching network where cells are joined together and making a
(a) Syncytium (b)Sarcoplasmic reticulum
(c) Endoplasmic reticulum (d) T-tubules

x) These joints hold the bone by dense connective tissue contain collagenous fibers
(a) Fibrous joints (b) Syndesmosis
(c) Gomphosis (d) Synovial joints

2. Write short answers of the following questions:

1. How is the cartilage useful for our skeletal system?
2. Give a comparison of major types of joints
3. How is the healing of fractured bone initiated pain developing?
4. How to conduct a first aid treatment for joint injuries and fractures?
5. Give a comparison of types of muscles.
6. Why is calcium essential for cross bridge formation?
7. How the nervous coordination regulates muscle contraction mechanism?
8. How is tetany different from tetanus?
9. Explain the different types of cartilage.

3. Write detail answers of the following questions:

1. Explain the structure of skeletal muscles and ultra structure of skeletal muscle fiber with labelled diagram.
2. Explain the repair process of simple fractures
3. Explain the cross-bridge cycle of muscle contraction with labelled diagram