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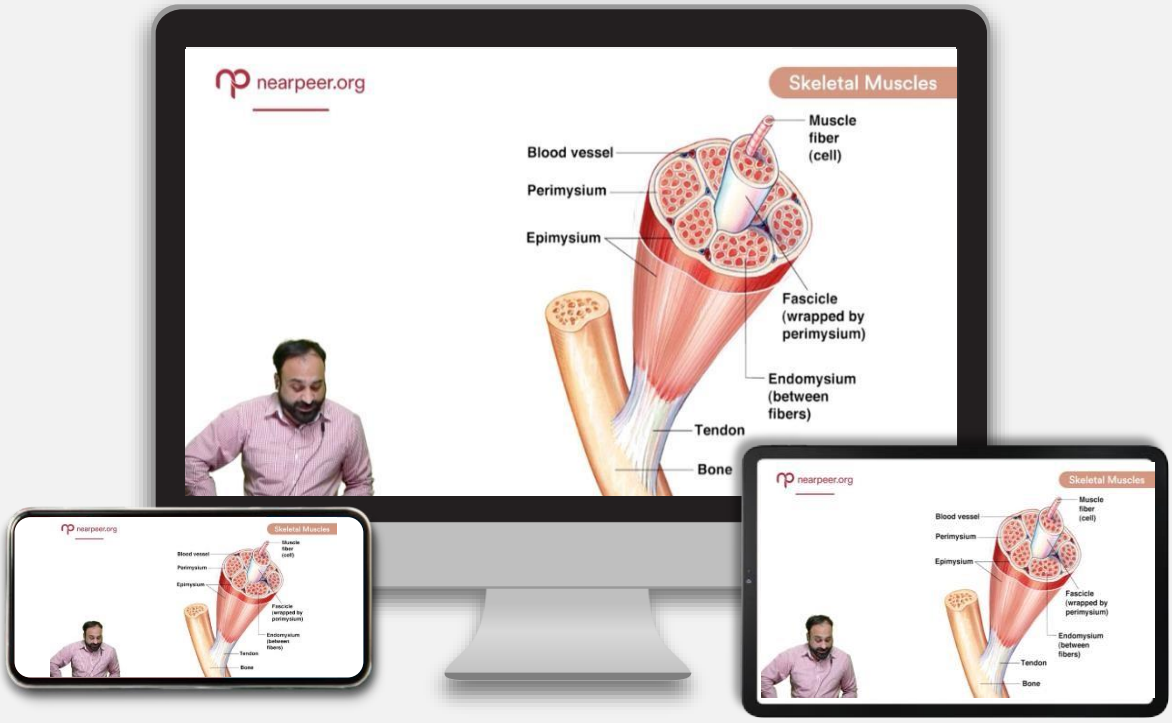


Support and Movement

Learning Objectives:

Cartilage

Types of muscles

Skeletal muscles

Cardiac muscles

Smooth muscles

- Structure of skeletal muscles
- Mechanism of skeletal muscle contractio
- Types of joints
- Gout and arthritis

Support and Movement

Some Major Functions of The Skeletal System:

(i) Support and Shape:

Bones support soft tissues and serve as attachment sites for most muscles and provide shape to the body.

(ii) Protection:

Bones protect critical internal organs, such as brain, spinal cord, heart, lungs and reproductive organs.

(iii) Movement:

Skeletal muscles attached to the bones help move the body.

(iv) Mineral Homeostasis:

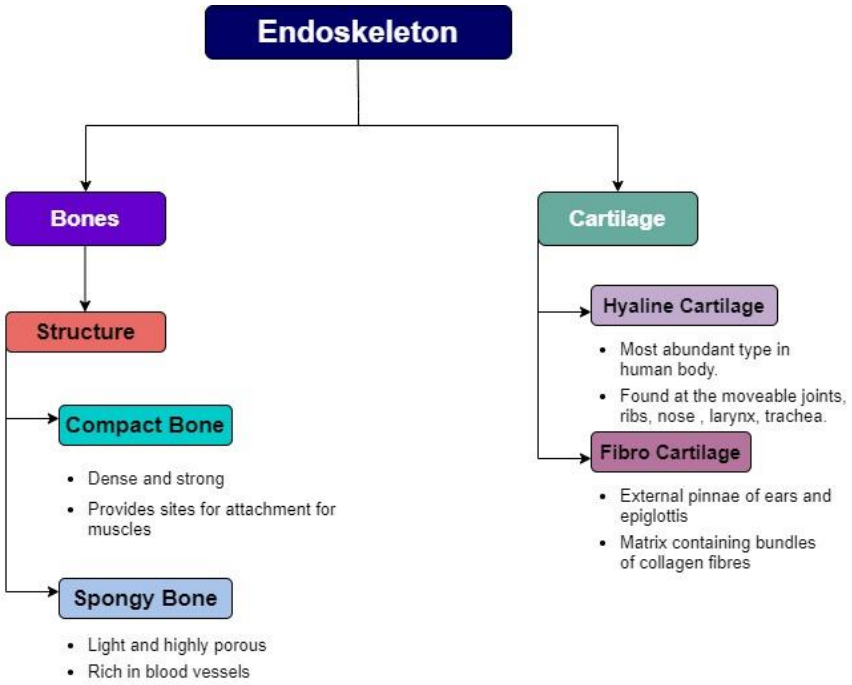
Bones serve as storehouse for calcium, phosphorus, sodium and potassium. Through negative feedback mechanisms, bones can release or take up minerals to maintain homeostasis.

(v) Blood Cell Production:

Red and white blood cells are produced in bone marrow. a connective tissue found within certain bones.

Bones and Cartilages

The endoskeleton is primarily made up of two types of tissues which are bones and cartilage. Both bones and cartilage are types of rigid connective tissue and consists of cells embedded in the matrix of protein called collagen.



1. Bone:

Bone is the most rigid form of connective tissue in which the collagen fibers are hardened by deposit of calcium phosphate.

Structure of a Bone:

Bones of arms and legs consist of two parts:

(i) Compact Bones:

It is an outer shell which is dense and strong and provides an attachment site for muscle

(ii) Spongy Bones:

Spongy bone is in the interior. It is light rich in blood vessels and highly porous. The cavities of spongy bone contain bone marrow where the blood cells are formed

Cells Associated with Bone:

There are three types of cells associated with the bone:

(i) Osteoblasts: These are bone- forming cells.

(ii) Osteocytes: These are mature bone cell.

(iii) Osteoclasts: These are bone dissolving cells.

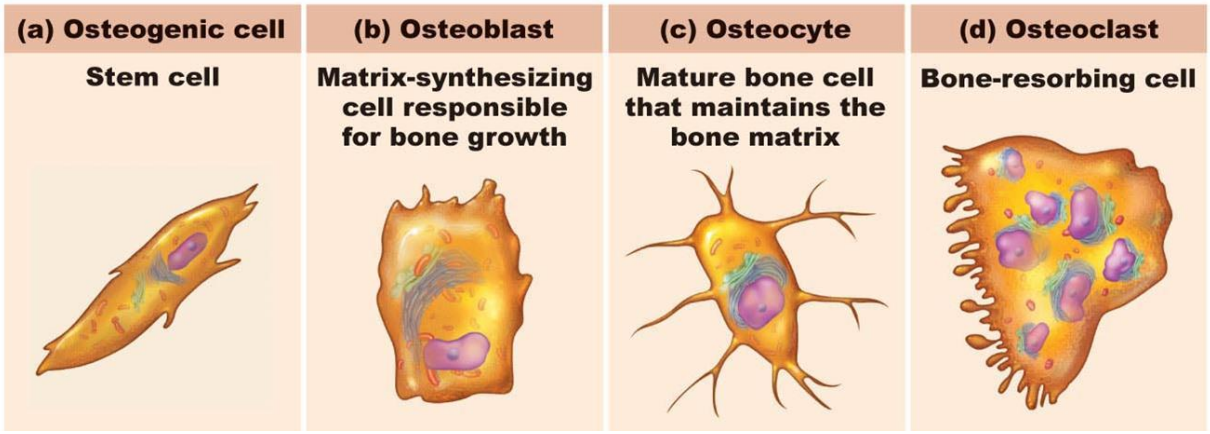


Fig. Cells of bone

Development of a Bone from Cartilage:

When a bone is replacing cartilage, the osteoclasts invade and dissolve the cartilage. Then osteoblasts replace it with bone. As bones grow, the matrix of the bone is hardened and the osteoblasts are gradually entrapped within it.

2. Cartilage:

Development of Cartilage:

Cartilage is formed of living cells called chondrocytes which secrete flexible elastic. Non-living matrix called collagen that surrounds the chondrocytes. No blood vessels penetrate into the cartilage. Cartilage is much softer than a bone. It is a form of connective tissue.

Location:

Cartilage covers the ends of the bone at the joint. It also supports the flexible portion of nose and external ears.

Types of Cartilage:

There are two main types of cartilage.

(i) Hyaline Cartilage: It is the most abundant type in human body and is found at the moveable joints.

(ii) Fibro Cartilage: It has matrix containing bundles of collagens fibers. It forms external pinnae of ears and in the epiglottis.

Joints

Joints occur where bones meet.

Function: Joints not only hold our skeleton together but also give it the mobility.

1. Classification of Joints on the Basis of Movement:

There are 3 types of joints on the basis of the amount of movement allowed by them:

(i) Immovable Joints:

Such joints are present in the skull. These joints allow no movement.

(ii) Slightly Movable Joints:

Hyaline cartilage forms joint between growing bone & allow little movement.

(iii) Freely Movable Joints:

The freely movable joints are of two types viz. hinge joint and ball and socket joint.

2. Classification of Joints on the Basis of Structure:

(i) Fibrous Joints (Immovable Joints):

These joints are held together by short fibers embedded in connective tissue. Example: Joints in the skull, and the joint which fix teeth into the jaws.

(ii) Cartilaginous Joints (Slightly Movable Joints):

These joints allow little or no movement. These are of two types:

(i) Hyaline cartilage formed joint between growing bones

(ii) Fibrous cartilage joints are found between vertebrae at the point where coxal bones meet in front of the pelvis.

(iii) Synovial Joints (Freely' Movable Joints): These joints contain a cavity filled with fluid. This fluid reduces the friction between the moving joints.

The joint is surrounded by a layer of connective tissue called fibrous capsule and their inner layer the synovial membrane. Some parts of capsule are modified to form distinct ligament holding the hones together. Based on structure and movements allowed the synovial joints can be classified further into following major types.

1. Hinge Joint:

It is the joint that allows the movements in two directions.

Examples: These are at elbow, knee and fingers.

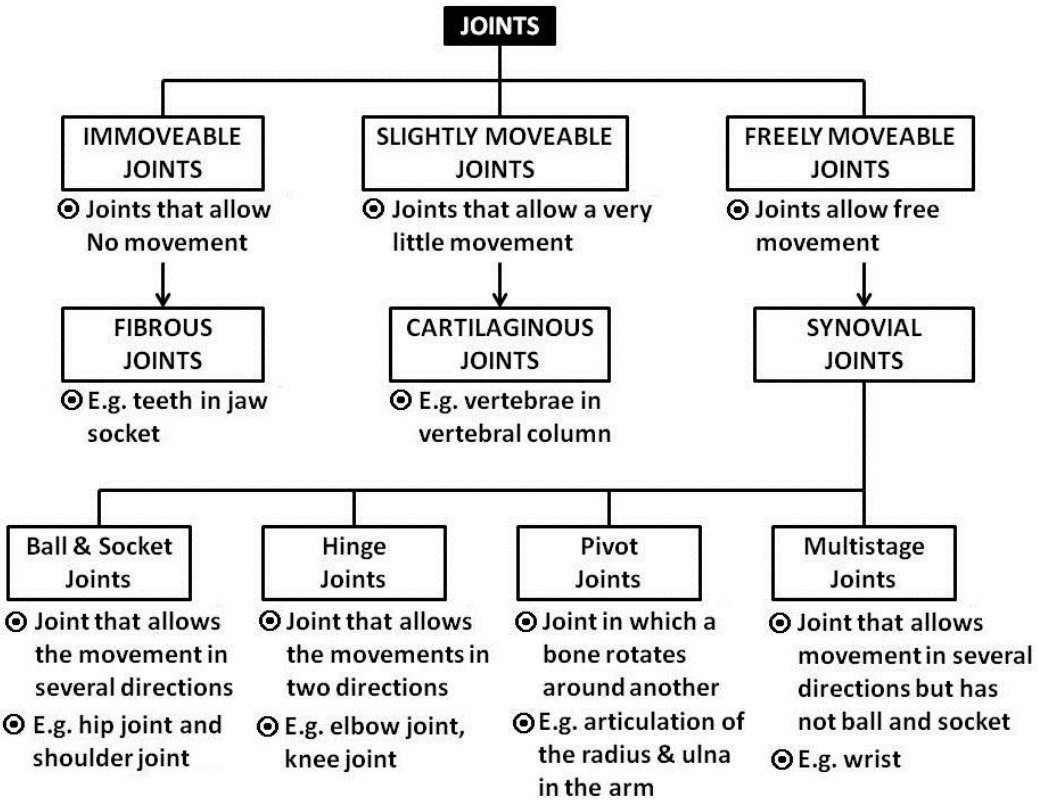
Arrangements of Muscles: At these joints, pair of muscles arc arranged in the same plane as that of joints, One end of each muscle (the origin) is fixed to the immovable bone on one side of joint and the other end of muscles (the insertion) is attached to the far (distal) side of the joint.

2. Ball and Socket Joint:

It is the joint that allows the movement in several directions.

Examples: Hip joint and shoulder joint.

Arrangements of Muscles: Such joints have at least two pairs of muscles present perpendicular to each other. They provide maximum flexibility.



Deformities of Skeleton

Some major causes of deformation are as follows:

(i) Genetic Deformities:

(a) Cleft Palate: It is a condition in which palatine processes of maxilla and palatine fail to fuse. The persistent (constant) opening between the oral and nasal cavity interferes with sucking.

It can lead to inhalation of food into the lungs causing aspiration pneumonia:

(b) Microcephaly: This is the condition in which the individuals have small sized skull. This is caused by some genetic defect.

(c) Arthritis: It covers over 100 different types of inflammatory or degenerative diseases that damage the joints. Osteoarthritis (O, A) is the most common chronic arthritis. It is a degenerative joint disease also caused by genetic defect.

(ii) Hormonal Deformities:

There are some hormonal deformities:

Osteoporosis: It is a group of diseases in which bone releases some depositions. As a result, the bone mass is reduced but the chemical composition of the matrix remains normal, factors Causing Osteoporosis: Osteoporosis mostly occurs in aged women having decreased estrogen level.

Other factors include insufficient exercise, smoking and diet poor in calcium and protein etc. Protection: Estrogen replacement therapy (ERT).

(iii) Nutritional Deformities:

Following are two major Nutritional deformities:

(a) Osteomalacia (Soft Bones): It includes a number of disorders in which the bones receive insufficient minerals.

Causes: In this disease, calcium salts are not deposited and hence bones soften and weaken.

Symptoms/Effects: The main symptom is the pain when weight is put on affected bones. Weight bearing bones of legs and pelvis bend and deform.

(b) Rickets:

It is another disease in children with bowed (curved) legs and deformed pelvis.

Causes: It is caused by deficiency of calcium in diet or vitamin 'D' deficiency.

Treatment: Vitamin 'D' fortified milk and exposing skin to sunlight to cure disorder.

(iv) Deformities Due to Physical Trauma:

Following are three major deformities due to physical trauma:

(a) Disc-Slip:

Disc: Each intervertebral disc is a cushion - like pad composed of two parts.

(i) Nucleus Pulposus: It is an inner semi fluid material which acts as rubber ball to give a disc its elasticity and compressibility.

(ii) Annulus Fibrosus: It is a strong outer ring of fibrocartilage. The annulus fibrosus holds together successive vertebrae.

Functions of the Disc:

The discs act as shock absorber during walking, jumping running and to lesser extent to bend laterally.

Herniation:

Severe or sudden physical trauma (shock) to spines may result in herniation of one or more discs (commonly known as slipped disc).

There is rupture of annulus fibrosus followed by protrusion of the spongy nucleus pulposus. If the protrusion (projection) presses on spinal cord or on spinal nerves (arising from cord) then severe pain is generated or even there is destruction of the nervous structure.

Treatment:

Bed rest traction and painkiller. If this fails disc may be removed surgically.

(b) Spondylosis:

It is the disease, which causes immobility and fusion of vertebral joint.

(c) Sciatica:

It is the acute pain radiating over the course of sciatic nerve.

Causes:

It is due to:

- Injury of proximal sciatic nerve which might follow a fall.
- A herniated disc or

- Improper administration of an injection into the buttock.

Symptoms/Effects:

The effect on lower limb depends upon the course of the sciatic nerve injured. When sciatic nerve is completely transected, the legs become nearly useless. They cannot be flexed and all foot-ankle movement is lost.

Recovery:

Slow and incomplete.

(v) Arthritis:

Arthritis is inflammatory or degenerative disease that damage joints. Symptoms: Main symptoms are pain, stiffness and swelling of the joint.

(a) **Acute Arthritis:**

It is due to bacterial invasion and arc treated with antibiotics.

Symptoms:

The membrane, lining the joint thickens, fluid production is decreased. As a result, friction is increased.

Treatment:

It is treated with antibiotics.

(b) **Chronic Arthritis:**

These are osteoarthritis, rheumatoid arthritis, and gouty arthritis.

(vi) Gout:

Gout is a very painful form of arthritis caused by uric acid crystals that form in and around the joints. It's the most common type of inflammatory arthritis.

Muscles

The bundles of cells or fibers that can be contracted and expanded to produce physical movements.

These cells contain numerous filaments of special protein called actin and myosin. Many multi-cellular animals have evolved these specialized cells for movement.

Kinds of Muscles:

The vertebrates have three kinds of muscles which are smooth muscles. skeletal muscles and cardiac muscles.

1. Smooth Muscles:

(i) **Muscle Shape:** The muscle is unstriped i.e. it has no striations.

(ii) **Cell Shape:** The cells an; long and spindle shaped with each containing a single nucleus,

(iii) **Control:** It is not under the voluntary control.

(iv) **Speed of Contraction:** Slow

(v) **Cause of Contraction:** Spontaneous, stretch, nervous system and hormones.

Examples: These muscles are found in the blood vessels, digestive tract and man) other organs.

(vi) **Earliest Form:** Smooth muscles were the earliest form of muscle to evolve and it is found throughout animal kingdom.

(vii) **Summary:** Smooth muscle tissue is visceral, non-striated and involuntary

(i) **Muscle Shape:** Irregular stripes

(ii) **Cell Shape:** Heart muscle is composed of chains of single cell, each with its own nucleus. The cells are branched, interconnected and organized into fibers.

(iii) **Control:** It is not under the voluntary control.

(iv) **Speed of Contraction:** Immediate

(v) **Cause of Contraction:** Spontaneous

Examples: These are muscles of the heart. They constitute most of the mass of the heart walls.

3. Skeletal Muscles:

(i) **Definition:** The muscles that are attached with the skeleton and associated with the movement of bones arc called skeletal muscles.

(ii) **Muscle Shape:** Skeletal muscles arc also called striped or striated muscle because they show alternate light and dark bands.

(iii) **Cell Shape:** Spindle or cylindrical.

(iv) **Tendons:** Generally, each end of entire muscle is attached to bone b: a bundle of collagen, non-elastic fibers known as tendons.

(v) **Control:** The skeletal muscles arc consciously controlled and therefore are called voluntary, muscles.

(vi) **Speed of Contraction:** Slow to rapid

(vii) **Cause of Contraction:** Nervous system

Examples: Triceps and biceps.

CARDIAC MUSCLES	SMOOTH MUSCLES	SKELETAL MUSCLES
Muscles which make the structure of heart	Muscles which make the structure of hollow, tubular organs	Muscles which are attached to skeleton
Involuntary	Involuntary	Voluntary
Branched	Unbranched	Unbranched
Barrel-shaped cells	Spindle shaped cells	Barrel-shaped cells
Uninucleated	Uninucleated	Multinucleated
Have irregular striation	No striations	Have regular striation
Speed of contraction is intermediate	Speed of contraction is slow	Speed of contraction is Slow to rapid
Pumps blood	Control movement of substance through hollow organs	Moves the skeleton

Structure of A Skeletal Muscle Fiber

Muscle:

Each muscle consists of muscle bundles which arc further composed of muscle fiber or cells.

Muscle Fiber:

Skeletal muscle fibers arc huge cells. Each muscle fiber is long cylindrical cell; each cell has many oval nuclei arranged just beneath its sarcolemma. Their diameter is 10 – 100 µm.

Sarcoplasm of muscle fiber is similar to the cytoplasm of other cell but it contains usually large amount of stored glycogen and a unique oxygen bonding protein called myoglobin. Myoglobin is a red pigment that stores oxygen.

Structure of a Muscle Fibre in High Magnification:

Myofibrils: Each muscle fibre contains a large number of myofibrils. Each myofibril is 1 – 2 µm in diameter.

These myofibrils run in parallel way and extend the entire length of the cell. Bundles of these fibrils arc enclosed by the muscle cell membrane or sarcolemma. The myofibril contains myofilaments.

Ultra Structure of Myofilament:

Myofilament is made up of thick and thin filament.

(i) Thick Filament:

The thick filaments, which are about 16 nm in diameter, are composed (If myosin. structure of a thick (myosin) filament.

Each Myosia molecule has tail ending in two globular heads. The heads are sometimes called cross bridges because they link the thick and thin myofilaments together during contraction.

Myosin tail consists of two long polypepti chain coiled together.

(ii) Thin Filament:

Thin filaments are 7 - 8 nm thick and composed of chiefly actin molecule.

Structure of Thin (Actin) Filament:

The actin molecules are arranged in two chains which twist around each other like twisted double strand of pearls.

There are two strands of another protein called tropomyosin which twist around the actinchains.

Another major protein in thin filament is troponin.

It is three polypeptide complex, one binds to actin another binds to tropomyosin while third binds calcium ions.

Sarcomere:

A sarcomere is the legion of a myofibril b tween two successive Z-lines and is the smallest contractile unit of muscle fibre. A myofibril has many sarcomeres.

In each sarcomere a series of dark and light bands are evident along the length of each myofibril.

Dark Bands:

The dark bands are called A hand because they are anisotropic that is they can polarize visible light.

Each A band has it lighter stripe in its midsection called H-zone (H stands for “hele” means bright).

The H-zone is bisected by dark line called M-line.

Light Bands:

The light bands called I-band are isotropic or non-polarizing. The I-band, have mid line called |Z-line, (Z for zwish means between).

Filaments of A and I-band:

The filament extending the entire central thick length of the A-band are myosin filaments.

The filaments extending across the I-band and partly into the A-band arc thin actin filaments.

Each myosin filament is surrounded by six actin filaments on each end.

Muscle Cell Appearance:

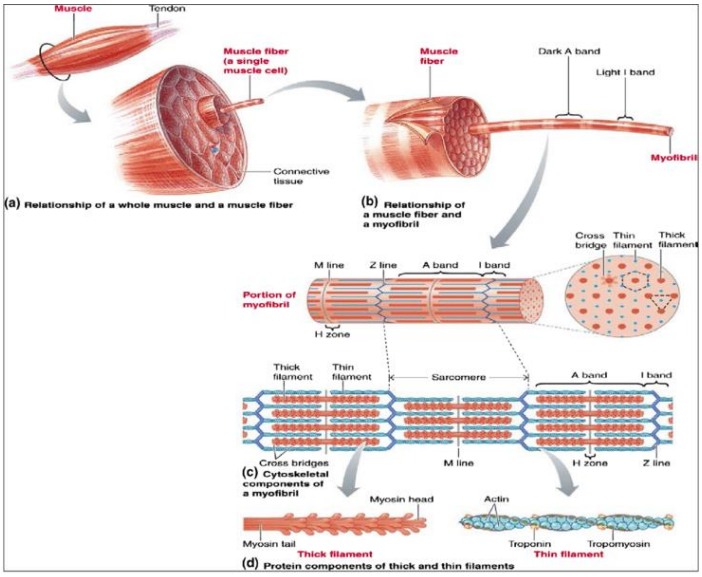
The striped appearance of the skeletal muscle cell is due to it, light and dark bands. **T-**

Tubule, T-system and Triad:

The sarcolemma of muscle fibre cell penetrates deep into the cell to form hollow elongated tube, the transverse tubule, T-tubule. The lumen or I-tubule is continuous with the extracellular fluid.

The thousands of T-tubules of each muscle cell are collectively called T-system. It extends and encircles the myofibril at the level of Z-line or A and I-junction.

The T-tubule and terminal portion of the adjacent envelope of sarcoplasmic reticulum, form triads at regular interval along the length of the fibril.



Mechanism of Muscle Contraction:

When muscle fibre contracts the thin and thick filaments undergo shining. The I-band reduces in length and I-line gets closer, to explain all these events in muscle contraction. H-Huxley, A. F. Huxley and their colleagues suggested a hypothesis in 1954. This is called "Sliding filament model" of muscle contraction.

Sliding Filament Model of Muscle Contraction:

According to this theory the thin filaments slide past the thick filaments so that actin and myosin filaments overlap to greater degree.

Thus the Z-line is brought close together. I-band shortens the H-zone disappears.

In this process of contraction, the cross bridges (If thick filament become attached to binding sites on the actin filament. The cross bridges then contract to pull the actin filament towards center of sarcomeres.

Control of Cross Bridges:

Muscle at Rest:

When the muscle is at rest the tropomyosin covers the sites on the actin chain where the head of myosin becomes attached.

Muscle Contraction:

When the muscle is required to contract then following steps occur:

(i) Calcium ions bind with the troponin molecule and cause them to move slightly.

(ii) The tropomyosin is displaced and the sites on the actin chain where the head of myosin becomes attach are exposed.

(iii) Once the myosin head has become attached to the actin filament. ATP is hydrolyzed and the bridge goes to its cycle.

ATP is needed to break the link between the myosin bridge and the actin. This ATP is provided by the large number of mitochondria present in each muscle cell.

Rigor Mortis

We know that ATP is needed to break the link between the myosin bridge and the actin. After death the amount of ATP in the body falls. Under these conditions the bridges cannot be broken and so they remain firmly bound.

As a result the body becomes stiff a condition known as rigor mortis.

Controlling the Actin-Myosin Interaction by Ca^{++} Ions:

1. **Initiation of Muscle Contraction**

Muscle contraction is initiated by nerve impulse arriving from the neuromuscular junction. All the fibres connected by a single motor neuron are a "Motor Unit" and contract simultaneously in response to the action potential tired by the motor neuron.

2. **T-tubule and Sarcoplasmic Reticulum:**

The nerve impulse is carried through the T-tubular to the adjacent sarcoplasmic reticulum (SR).

Sarcoplasmic Reticulum (S.R.) i, continued system of the sarcoplasm around each myofibril.

It is like endoplasmic reticulum but without ribosomes and shows a highly specialized repeating pattern.

3. **Role of Ca^{++} Ions:**

The calcium gate of SR open the calcium is released into the cytosol. Next step is the binding of calcium ions to troponin molecules of the thin filament.

The binding sites are exposed and cross bridges with myosin call form and contraction occurs.

All or None Response:

The contraction of each muscle is based on "all or none" principle i.e. all of its fibrils participate in contraction. The degree of contraction depends upon the number of fibers that participate in contraction (this is called varying degree response).

Energy for Muscle Contraction

Energy for muscle contraction comes from the ATP. There are different sources of ATP.

1. **Aerobic Respiration:**

Supply of ATP is maintained by the aerobic break down of glucose in muscle cell. This glucose comes from stored glycogen in the cell.

2. **Creatine Phosphate:**

When more energy is required due to high metabolism, it is provided by another energy storing substances called creatine phosphate.

3. **Anaerobic Respiration:**

Sometimes during oxygen deficiency or very high metabolism (prolong, or tough muscular activity), ATP difference is provided by anaerobic breakdown of glucose into lactic acid.

Problem of Anaerobic Respiration:

The major problem is lactic acid accumulation which causes muscle fatigue. At rest, 1/5 lactic acid is broken aerobically and its energy is used to change remaining 4/5 lactic acid into glucose.

Effect of Exercise on Muscle:

Changes occur in the muscle according to the amount of its work. When muscles are used actively then followings changes occur:

(i) They increase in size or strength

(ii) They become more efficient and fatigue resistant.

(iii) Capillaries surrounding the muscle fibres and the mitochondria within them increase in number.

(iv) Muscle fibre synthesizes more Myoglobin.

The result is more efficient muscle metabolism. Similarly, the muscles become resistance to fatigue.

Examples: Aerobic exercise such as swimming, joggings and fast walking.

When Muscles are not used:

Complete immobilization of muscle leads to muscle weakness and severe atrophy (deterioration).

Muscle Fatigue

Muscle fatigue is a state of physiological inability to contract.

Causes:

(a) Deficiency of ATP:

Muscle fatigue results from relative deficit of ATP. When no ATP is available, contractures (or states of continuous contractions) result because the cross bridges arc unable to detach.

(b) Accumulation of Lactic Acid and Ionic Imbalances:

Excess accumulation of lactic acid and ionic imbalances arc also the causes of muscle fatigue. Lactic acid is formed as a result of anaerobic breakdown of glucose.

Lactic acid drops muscle pH. As a result, pain starts in the muscle, which causes extreme fatigue (tiredness).

Tetany:

Cause:

Tetany is the disease caused by low calcium in the blood.

Symptoms:

(i) It increases the excitability of neurons and results in loss of sensations.

(ii) Muscle twitches (jerks) and convulsions occur.

(iii) If untreated the disease progresses to spasm of larynx, respiratory paralysis and ultimately death occurs.

Cramp:

It is also known as tetanic contraction of the entire muscle.

Causes:

It is due to low blood sugar level, electrolyte depletion, dehydration and irritability of spinal cord and neurons.

Symptoms:

It lasts for just few seconds or several hours, causing the muscles to become taut (stiff) and painful. It is most common in thigh and hip muscles it usually occurs at night or after exercise.

Tetanus:

Causal Organism:

It is an acute infectious disease caused by anaerobic bacterium Clostridium tetanic.

Symptoms:

Persistent painful spasms of some skeletal muscles. It begins gradually with stiffness of jaws and neck muscles. Then it progresses to fixed rigidity of jaws (lock jaw) and spasms of trunk and limb muscles. It is usually fatal due to respiratory failure.

Mortality Rate:

The tetanus is the major killer in developing countries where the mortality rate is 40 percent. It is very rare in developed countries.

Arrangement of Skeletal Muscle for Movement of Skeleton:

The skeletal muscle moves with the help of skeleton.

Parts of a Skeletal Muscle:

Skeletal muscle has three parts:

(i) **Origin:** It is the end of muscle which remains fixed when contracts muscle.

(ii) **Insertion:** It is the end of muscle that moves the bone.

(iii) **Belly:** It is thick part between origin and insertion, which contract.

Bone to bone and muscle to bone attachment by connective tissue, a connective tissue binds other tissue and helps to maintain body form by holding the various organs together. Connective tissue fibrils have two specialized kinds.

(i) **Ligaments:** These connective tissue fibrils attach bone to bone and are slightly elastic.

(ii) **Tendons:** These connective tissue fibrils attach muscles to bones and are non-elastic.

Movement of Bones

The majority of muscle tissue in our body is skeletal muscle.

Movement of Skeletal Muscles:

The skeletal muscles produce movements by pulling on tendons through cords of connective tissues that attach muscle to the bones. The tendons then pull on bones.

Attachment of a Skeletal Muscle:

Most muscles pass across a joint and are attached to the bones that form joints. When such muscle contracts it draws one bone towards or away from "the bone with which it articulates.

Movement of Antagonistic Muscles:

There are 650 muscles in human body, most of which occurs in pairs. At joint these muscles work against each other by contraction. This relationship is called antagonistic.

Movement of Elbow Joint:

The best example is the movement of elbow joint by biceps and triceps the biceps bend the arm at the elbow joint and triceps straightens it.

(i) **Bending of Arm:**

It is by three muscles:

(a) The biceps brachii muscle arises from the two heads of scapula and is inserted into the medial surface of the radius bone.

The other two muscles (brachialis and brachioradilus) lie below the biceps brachii.

(b) The brachialis arises from the anterior surface of the lower $3/5^{th}$ of the humerus and inserted in to the ulna.

(c) The brachioradilus arises from the lateral side of the lower end of the humerus and inserted in the radius.

When these muscles contract they lift radius and ulna and bend the arm at the elbow.

(ii) **Straightening of Arm:**

When triceps contracts it straightens arm at elbow.

In the antagonistic pairs one muscle reverses the effect of the other but do not contract simultaneously.