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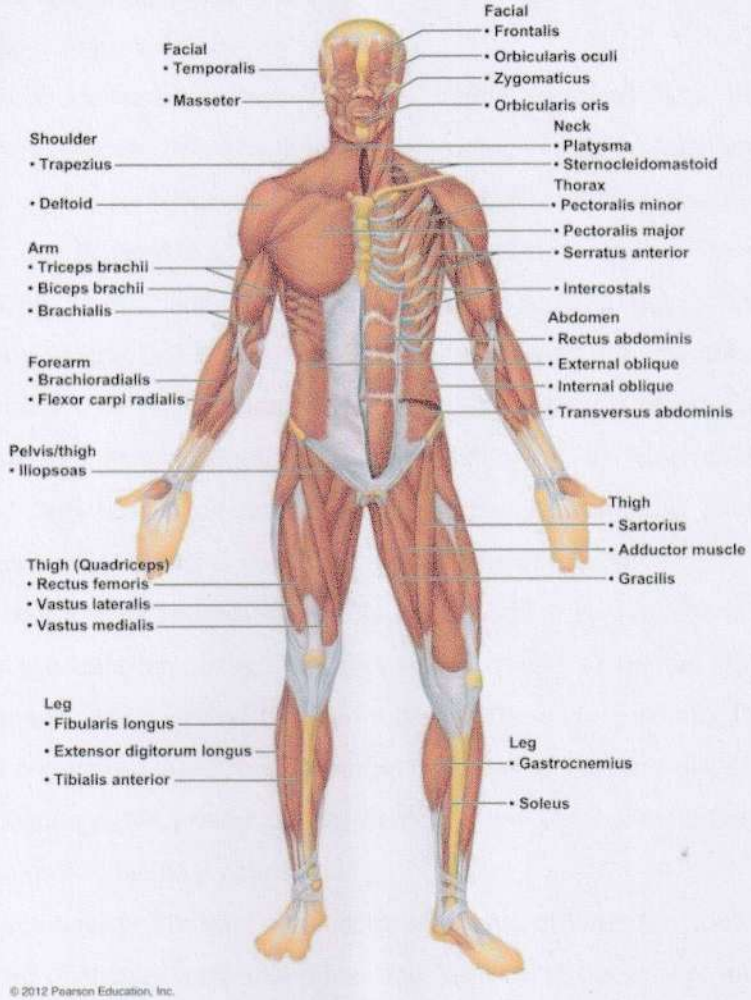
# Muscular system

The movement is one of the important characteristics of all the living animals. The muscle cells are specialized for contractile ability and to bring about movement as a result of their contraction. There is a wide variety of muscle types since they are required to perform different kinds of functions like movement of animal, maintenance of body posture and orientation, movement of gastrointestinal tract, circulatory movement, etc. They are also called as skeletal muscle because most of them move the skeleton. In vertebrates body, muscle have two kinds of arrangements,



those muscle which move the appendages find their origin and interactions on the endoskeleton structures and these are called the phasic muscles. This muscle function on lever system and always exist in antagonistic pairs. Beside muscles occurring in soft organs like heart urinary bladder digestive tract and body wall are called the tonic muscles and these muscles lack origin or insertion unlike the phasic muscles. The phasic muscles are mostly voluntary, while tonic muscles are purely involuntary in nature.

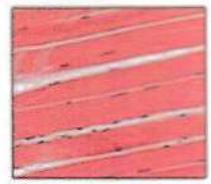
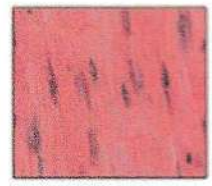
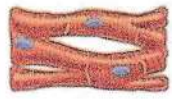
## Structure of muscles

In vertebrates three distinct types of muscles are found and these constitute 60-75% of total body weight.

- **Striated or skeletal muscles**
- **Non-striated or smooth muscles**
- **Cardiac or heart muscles**

1. **Striated or skeletal muscles:-** These are highly organised tissue that convert chemical energy to physical work. The fibres of the striated muscle typically extended from tendon or other connective tissue attached to one bone to a tendon attachment to another bone and muscle fibre lie parallel to each other thus, function in parallel. The striated muscle fibre ranges from 5 to 100 μm in diameter and up to several centimetres or more in length. They arise from single cell the myoblast which in turn fuse to myotubes. These myotubes differentiate into multinucleate membrane-bound muscle fibre. Each muscle fibre is composed of numerous parallel subunits termed myofibrils, which consist of longitudinally repeated units termed sarcomeres which are bounded on either side by the Z line. The sarcomeres of myofibril is functional unit of striated muscle.
2. **Non-striated or smooth muscles:-** The non striated or involuntary muscles and are devoid of dark and light bands these muscles are composed of spindle shaped cells with long tapering ends and a centrally placed nucleus. These are generally found in the walls of internal organs like digestive tract respiratory passages urinary bladder etc. They are slow in contraction and not under the voluntary control. These muscle fibres do contain acting and myosin contractile proteins.
3. **Cardiac muscle:-** The cardiac muscles are branched and only found in heart. They are composed of striated nucleated fibres thus identical to the striated muscles in many ways

the muscle fibre are arranged in a syncytial manner but do not appear to be fused with each other. The muscles are specialised in the sense that the stimulation at the one point cause all the muscle fibre to respond initiating the rhythmic beats of heart. These muscles are involuntary in nature.

| | Main features | Location | Type of cells | Histology |
|---|---|---|---|---|
| Skeletal muscle | - Fibers : striated, tubular and multi nucleated<br>- Voluntary<br>- Usually attached to skeleton |  |  |  |
| Smooth muscle | - Fibers : non-striated, spindle-shaped, and uninucleated.<br>- Involuntary<br>- Usually covering wall of internal organs. |  |  |  |
| Cardiac muscle | - Fibers : striated, branched and uninucleated.<br>- Involuntary<br>- Only covering walls of the heart. |  |  |  |

## Chemical composition of muscles:-

1) **Water**:- Muscle contains about 72 80% of water. Water provides good medium for organic and inorganic compounds. water reduces friction and dehydration of muscle.
2) **Proteins**:- the contractile property of muscle is due to presence of protein.
    i. **Mayosin**:- myosin is like a golf club with a short compact head molecule and a long shaft.

ii. **Actin**:- it is a globulin and being structurally attach to the Z line or membrane and is difficult to extract from the muscle. the actin filament resembles 2 strings on beads twisted into a double helix each bead is a molecule of G-actin (global actin).

iii. **Tropomyosin**:- This protein contributes about 3 to 8% of total protein content of muscle fibre. It lacks ATPase activity and there are two forms of tropomyosin the tropomyosin A and tropomyosin B.

iv. **Troponin**:- Attached to each tropomyosin is a complex of globular protein molecules collectively called troponin.

v. **Actinin**:- It is present in Z line. It can strongly react with actin and can form cross linking with F actin filaments.

3) **Organic compounds:-** Muscle is a store house of glycogen and oxidation of the glycogen provides energy in the form of ATP.

4) **Inorganic compounds:-** The potassium and sodium ions are chiefly present in muscles. These ions are important in bringing about the action potential, since the action potential causes depolarization of the plasma membrane or sarcolemma and consequently contraction process is initiated. Besides magnesium, phosphorus and calcium ions are also present and play their role.

## Structure of muscles:-

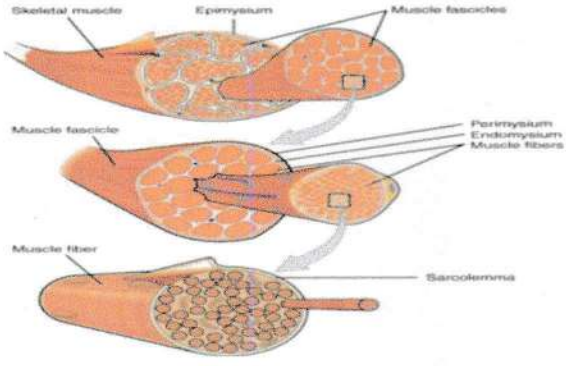



Figure 1. The Three Connective Tissue Layers. Bundles of muscle fibers, called fascicles, are covered by the perimysium. Muscle fibers are covered by the endomysium.

Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fiber bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. fasica, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a fasciculus and is surrounded by a layer of connective tissue called the permysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium.

Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction. The coverings also provide pathways for the passage of blood vessels and nerves.

Commonly, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle, the belly or gaster, to form a thick ropelike tendon or a broad, flat sheet-like aponeurosis. The tendon and aponeurosis form indirect attachments from muscles to the periosteum of bones or to the connective tissue of other muscles. A muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction.

## Skeletal muscle fibers: -

Skeletal muscle cells are long and cylindrical, they are commonly called as muscle fibers. Skeletal muscle fibers can be quite large for human cells. During early development, embryonic myoblasts, each with its own nucleus, fuse with up to hundreds of other myoblasts to form the multinucleated skeletal muscle fibers. Multiple nuclei mean multiple copies of genes, permitting the production of the large amounts of proteins and enzymes needed for muscle contraction.

The plasma membrane of muscle fibers is called the **sarcolemma**, the cytoplasm is referred to as **sarcoplasm**, and the specialized smooth endoplasmic reticulum, which stores, releases, and retrieves calcium ions ($Ca^{++}$) is called the **sarcoplasmic reticulum (SR)**. The functional unit of a skeletal muscle fiber is the sarcomere, a highly organized arrangement of the contractile myofilament's actin (thin filament) and myosin (thick filament), along with other support proteins.

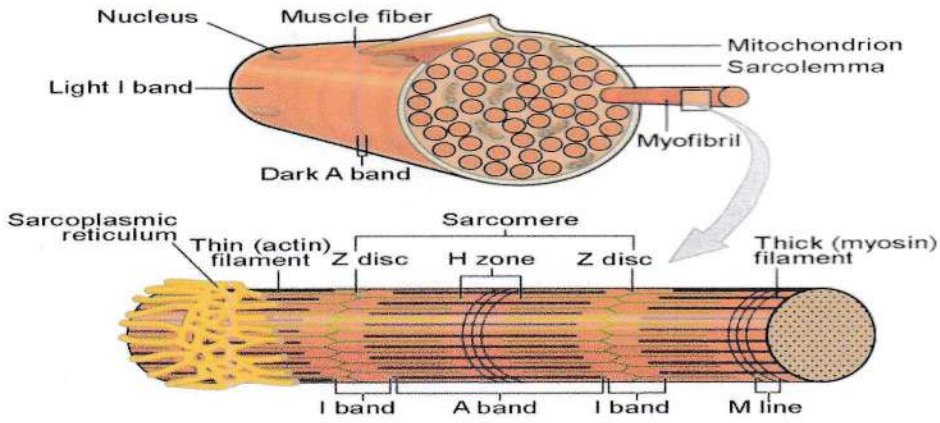
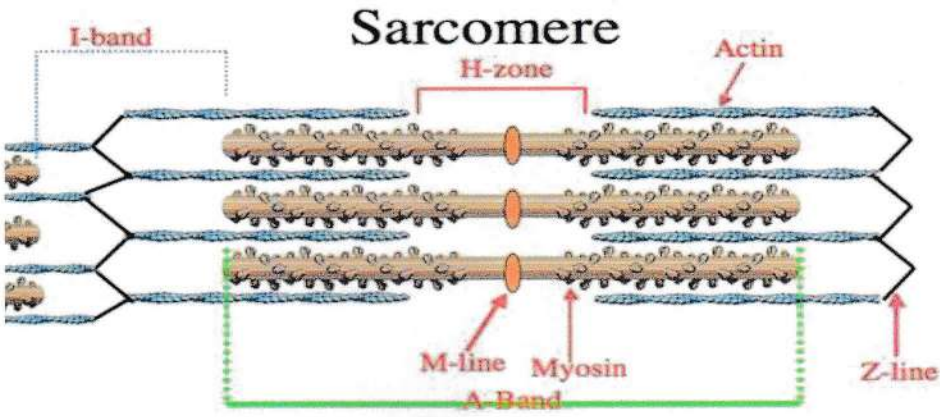



**Figure 2. Muscle Fiber.** A skeletal muscle fiber is surrounded by a plasma membrane called the sarcolemma, which contains sarcoplasm, the cytoplasm of muscle cells. A muscle fiber is composed of many fibrils, which give the cell its striated appearance.

## The Sarcomere: -




Sarcomeres are the small contractile repeated units of the myofibril. Sarcomere is a region of myofibril between two successive Z-lines. It contains H-zone, M-line. It also contains series of dark bands(A-band) and light bands(I-band). Thick filament extends across entire length of A band. Thin filament extends across the I-band and partly into A-band. These are the filaments which have basic role in contraction and these are present in a sarcomere.

## The Neuromuscular Junction: -

The neuromuscular junction (NMJ) is a synaptic connection between the terminal end of a motor nerve and a muscle (skeletal/ smooth/ cardiac). It is the site for the transmission of action potential from nerve to the muscle. It is also a site for many diseases and a site of action for many pharmacological drugs.

## Excitation-Contraction Coupling: -

Cardiac excitation-contraction coupling (Cardiac EC coupling) describes the series of events, from the production of an electrical impulse to the contraction of muscles in the heart. This process is of vital importance as it allows for the heart to beat in a controlled manner, without the need for conscious input. EC coupling results in the sequential contraction of the heart muscle that allows blood to be pumped, first to the lungs (pulmonary circulation) and then around the rest of the body (systemic circulation) at a rate between 60 and 100 beats every minute, when the body is at rest. This rate can be altered, however, by nerves that work to either increase heart rate (sympathetic nerves) or decrease it (parasympathetic nerves), as the body's oxygen demands change. Ultimately, muscle contraction revolves around a charge atom (ion), calcium which is responsible for converting the electrical energy of the action potential into mechanical energy (contraction) of the muscle. This is achieved in a region of the muscle cell, called the transverse tubule during a process known as calcium induced calcium release.

## Sliding Filament Model of Contraction: -

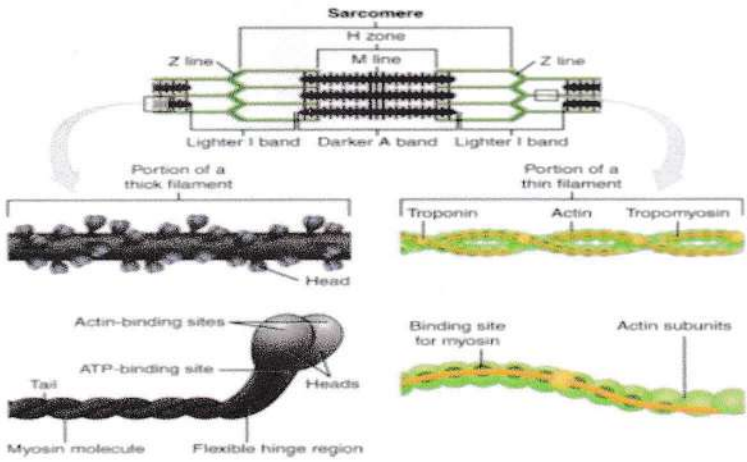
Muscles are fibres which cause movement in our body. They also enable the functioning of our internal organs. Specialists claim that a human body has around 650 muscles, skeletal muscles to be precise.

Muscles are specialized tissues having the property of elasticity, where each muscle has innumerable muscle fibres. Muscle fibres successively have thin and tiny strands called myofibrils. For movement, muscles need to contract. It contracts when tension-generating sites within the muscle fibres are activated. This mechanism is explained by the sliding filament theory.

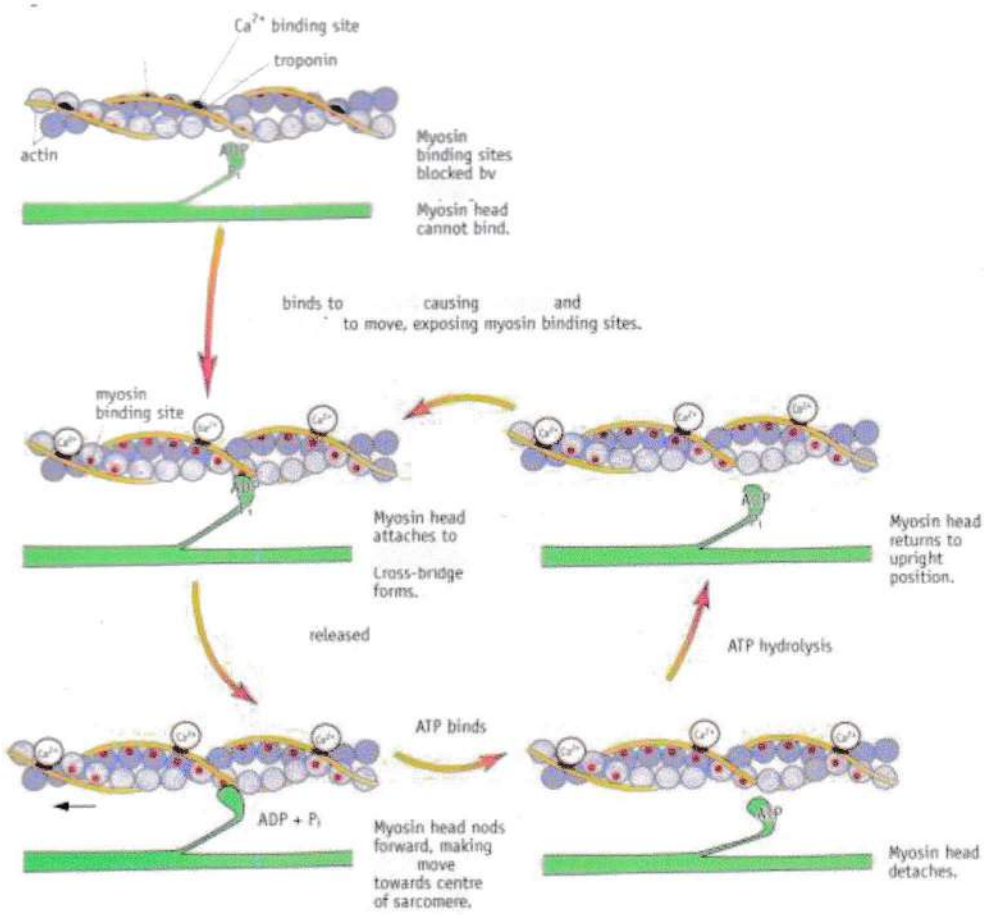
The sliding filament theory is a suggested mechanism of contraction of striated muscles, actin and myosin filaments to be precise, which overlap each other resulting in the shortening of the muscle fibre length. Actin (thin) filaments combined with myosin (thick filaments) conduct cellular movements.

Myosin is a protein that converts ATP (chemical energy) into mechanical energy, thus creating thrust and movement. This movement generates muscular contraction and movement of non-muscle cells, such as mitosis and meiosis (cell division).

Also, actin polymerization and actin-myosin interaction are responsible for movements of a cell across a surface. Actin filaments have myosin-binding sites which are revealed when troponin molecules bind to calcium ions in filaments, facilitating bridge formation between actin and myosin. This process is fuelled by ATP, which acts as an energy source. ATP is hydrolysed in the




heads of molecules of myosin causing a change in the shape of the head and binding to actin filaments




## ATP and muscle contraction: -

ATP prepares myosin for binding with actin by moving it to a higher- energy state and a "cocked" position. Once the myosin forms a cross-bridge with actin, the Pi disassociates and the myosin undergoes the power stroke, reaching a lower energy state when the sarcomere shortens ATP must bind to myosin to break the cross-bridge and enable the myosin to rebind to actin at the next muscle contraction.

## Mechanical properties of Muscle: -

The muscles provide a system wherein the chemical energy is con verted into the mechanical energy. The different mechanical properties of the muscles include:

**(a) Muscle twitch**

The twitch includes (1) latent phase or period, the response of a muscle to a single stimulus is known as (i) contraction phase, (ii) relaxation phase.

The latent period is a brief period which occurs between the time of stimulation and the actual starting of the contraction. The latent period varies with the species, type of muscle, temperature and the internal conditions of the muscle. In frog muscle, it lasts for about 10 milliseconds. The contraction phase is the time interval in which the muscle reaches the peak of its contraction and performs work. It lasts about 40 milliseconds. The relaxtion phase occurs following withdrawal of the stimulus and the muscle relaxes to its original length. It lasts for about 50 milliseconds.

**(b) All or None response**

The response of a muscle fibre is independent of the type or strength of the stimulus. Hence, when the muscle fibre contracts it contracts to its maximum provided the conditions remain constant A minimum strength of the stimulus is needed to bring about contr action. In case strength of the stimulus is below the threshold level required for the contraction, the muscle fibre will not contract at all and when the strength of the stimulus is at the threshold level or more the muscle fibre contracts to the maximum.

**(c) isotonic and isometric contractions**

In isotonic contraction the muscle shortens in length and pulls on another structure, such as bone, bringing about movement. During such a contraction the tension in the muscle fibre does not change during contraction phase. In isometric contraction, the length of the muscle remains the same, but tension in the muscle increases greatly. It does not result in the body movement. It can be demons treated by carrying load in an extended arm.

**(d) Heat Production**

The muscles produce heat as a result of oxidation process, both during rest and at work. However, heat production is more when the muscle is undergoing contraction. The heat energy is needed to maintain the structure and electro-chemical gradients in the muscle.

## Muscles Disorders

## Fibromyalgia:

Fibromyalgia is the second most common condition affecting our bones and muscles. Yet it's often misdiagnosed and misunderstood. Its classic symptoms are widespread muscle and joint pain and fatigue. Women are twice as likely as men to have fibromyalgia. Symptoms often appear during middle age.

**Causes:**

- Stressors such as: being born premature, traumatic life events such as abuse, accidents.
- Medical conditions such as viral infections or other illnesses.
- Anxiety, depression, other mood disorders, PTSD.
- Poor sleep.
- Lack of exercise.

**Symptoms :** Widespread muscle pain and joint pain along with fatigue and poor sleep are the defining symptoms of fibromyalgia.

- Anxiety or depression.
- Digestive problems, including diarrhea or constipation.
- Face or jaw pain (temporomandibular disorders).
- Headaches or migraines.
- Memory problems.
- Tingling or numbness in hands or feet.

**Multiple sclerosis :** Multiple sclerosis is a chronic disease that affects the central nervous system, which is the brain, spinal cord, and optic nerves. Scientist believe it is an autoimmune disorder that affects the central nervous system (CNS). When a person has an autoimmune disease , the immune system attacks healthy tissues.

**Symptoms :**

- **Muscle weakness**: People may develop weak muscles due to lack of use or stimulation due to nerve damage.
- **Numbness and tingling**: A pins and needles-type sensation is one of the earliest symptoms of MS and can affect the face, body, arms, and legs.
- **Lhermitte's sign**: A person may experience a like an electric shock when they move their neck, known as Lhermitte's sign.
- **Spasticity and muscle spasms:** This is an early sign of MS. Damage to nerve fibers in the spinal cord and brain can cause painful muscle spasms, including in the legs.

- **Pain:** Pain is a common symptom in MS. Neuropathic pain is directly due to MS, while muscle spasticity or stiffness may cause localized pain.

**Muscles cramps :** Muscle cramps are sudden, involuntary contractions that occur in various muscles. These contractions are often painful and can affect different muscle groups.Commonly affected muscles include those in the back of your lower,the back of your thigh, and the front of your thigh.

A sudden, sharp pain, lasting from a few seconds to 15 minutes, is the most common symptom of a muscle cramp. In some cases, a bulging lump of muscle tissue beneath the skin can accompany a cramp as well.

**Causes:**

- Muscle cramps have several causes. Some cramps result from overuse of your muscles. This typically occurs while you're exercising.

- Muscle injuries and dehydration can also trigger cramps. Dehydration is the excessive loss of fluids in the body.

- In some cases, a medical condition can cause muscle cramps. These conditions include:

- spinal nerve compression, which can cause muscle cramps in your legs when walking or standing

- alcoholism ,pregnancy ,kidney failure ,hypothyroidism, or low thyroid gland function.

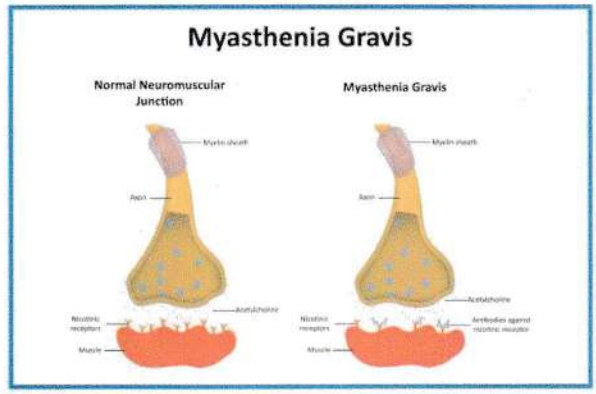
**Muscular Dystrophy :** Muscular dystrophy refers to a group of more than 30 inherited (genetic) diseases that cause muscle weakness. These conditions are a type of myopathy, a disease of the skeletal muscles. Over time, muscles shrink and become weaker, affecting your ability to walk and perform daily activities like brushing your teeth. The disease also can affect your heart and lungs. Some forms of muscular dystrophy are apparent at birth or develop during childhood. Some forms develop later during adulthood. Currently, there isn't a cure.

**Causes:** Genetic mutations, or changes, cause most forms of muscular dystrophy. One or both parents may pass a faulty gene to their child even if the parent doesn't have the condition. Rarely, a person develops muscular dystrophy spontaneously, meaning there's no known cause.

**Symptoms:**

- Enlarged calf muscles.
- Difficulty walking or running.
- Unusual walking gait (like waddling).
- Trouble swallowing.
- Heart problems, such as arrhythmia and heart failure (cardiomyopathy).
- Learning disabilities.
- Stiff or loose joints.
- Muscle pain.
- Curved spine (scoliosis).
- Breathing problems.

**Myasthenia Gravis :** Myasthenia Gravis (MG) is an autoimmune condition that causes signal transmission issues at the neuromuscular junction. As a result, the muscles get fatigue fast and improve after taking rest.
It mostly affects the muscles that regulate eye movements, facial expressions, chewing, and swallowing in the early stages. As the condition worsens, the neck and limb muscles may be affected, making it difficult to hold the head up, walk upstairs, and raise the arms. Breathlessness may occur if left untreated.

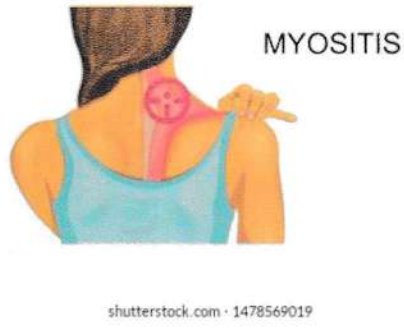



**Causes:** Myasthenia gravis is not hereditary or contagious. It usually appears later in life when antibodies in the body assault normal muscle receptors. This inhibits a hormone that is required to induce muscular contraction. When a mother with myasthenia gravis transfers the antibodies to the baby, a short form of myasthenia gravis might emerge. It usually resolves itself in 2 to 3 months.

**Symptoms:**

- droopy eyelids
- slurred speech
- weak arms, legs or neck
- shortness of breath and occasionally serious breathing difficulties
- difficulty making facial expressions
- problems chewing and difficulty swallow.

**Myositis :** Myositis is the name for a group of rare conditions that can cause muscles to become weak, tired and painful. The word myositis simply means inflammation in muscles. If something is inflamed, it may be swollen. Myositis can affect people of any age, including children.




The main muscles to be affected are around the shoulders, hips and thighs.
Having myositis can also lead to other parts of the body being affected, such as the skin, lungs or heart.
Sometimes myositis can affect the muscles that carry out tasks such as breathing and swallowing.
There are several types of myositis. The two most common types are polymyositis and dermatomyositis.

'Poly 'means many. Polymyositis means that many muscles are affected by inflammation. This type doesn't often affect other parts of the body much.

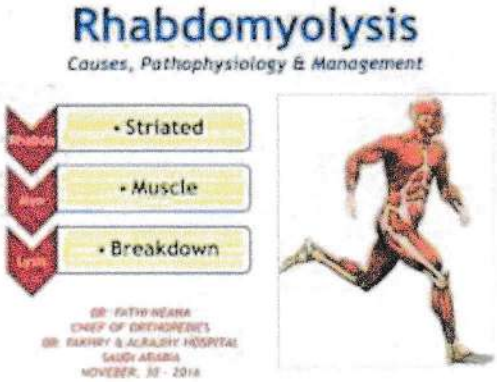
Dermatomyositis causes similar symptoms in muscles, but there is also a skin rash. 'Derma 'means skin.

Polymyositis, dermatomyositis, as well as other types of myositis, are autoimmune conditions.

**Symptoms:**

- weak and tired muscles that can make everyday tasks such as climbing stairs, brushing hair, and getting in and out of cars difficult .
- pain in muscles
- muscles feeling tender to touch
- muscles can sometimes swell
- generally feeling unwell
- weight loss
- night sweats.

**Rhabdomyolysis:** Rhabdomyolysis is a serious syndrome due to a direct or indirect muscle injury. It results from the death of muscle fibers and release of their contents into the bloodstream. This can lead to serious complications such as renal (kidney) failure. This means the kidneys cannot remove waste and concentrated urine. In rare cases, rhabdomyolysis can even cause death.





**Causes:**

- A crush injury such as from an auto accident, fall, or building collapse
- Long-lasting muscle compression such as that caused by prolonged immobilization after a fall or lying unconscious on a hard surface during illness or while under the influence of alcohol or medication
- Electrical shock injury, lightning strike, or third-degree burn
- Venom from a snake or insect bite

**Symptoms:** Signs and symptoms of rhabdomyolysis may be hard to pinpoint. This is largely true because the course of rhabdomyolysis varies, depending on its cause. And, symptoms may occur in one area of the body or affect the whole body.

- Abdominal pain
- Nausea or vomiting
- Fever, rapid heart rate
- Confusion, dehydration, fever, or lack of consciousness.

## Invertebrates muscular system

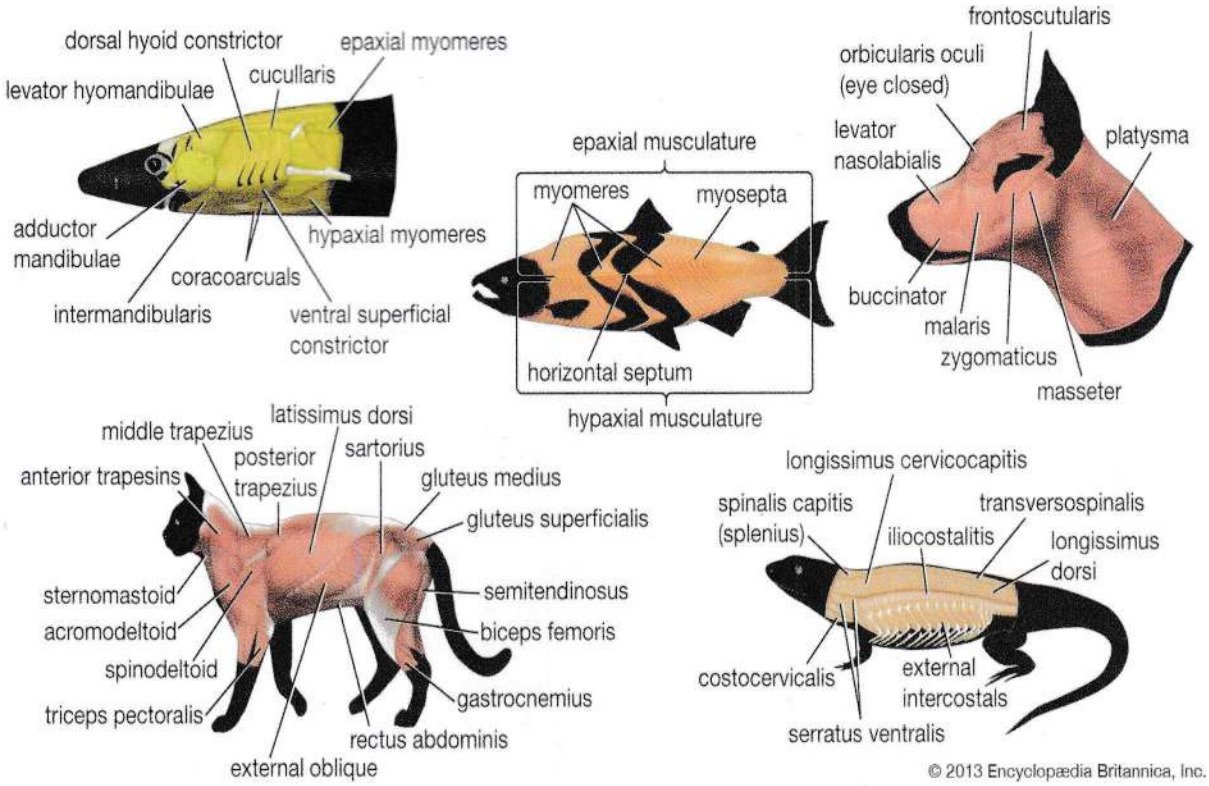
1) The muscular system of inveterate can be divided into three major classes on basis of their striations patterns: transversely striated, obliquely striated, smooth muscle. Of all vertebrate muscles the transversely striated muscle with continuous Z lines is the most similar to the vertebrate skeletal muscle and present in arthropods, whose musculature only consistent of this cell type. These muscle are Multinucleate cells that contain myofibrils showing well defined sarcomeres.
2) Transversely striated muscles with discontinuous Z line consisting of multiple small electron dense patches are found in translucent portions of adductor muscles of some bivalves and in heart muscle of the gastropods. This muscle is formed by Mononucleated cells with centrally located nuclei and single myofibril.
3) The obliquely striated muscle appears in nematodes, annelids, molluscs, branchiopods consist of Mononucleated cells with both thick and thin myofilaments which form sarcomeres delimited by Z lines.
4) Smooth muscles have been reported in coelenterates, annelids, molluscs, branchiopods, echinoderms but is lacking in arthropods. These muscles cells have a centrally located nucleus and abundant thin and thick myofilaments without apparent sarcomeres.
5) In arthropods specifically in class insecta there are three types of skeletal muscles
    - Tubular muscles Eg. Flight muscles of odonata etc.
    - Microfibrillar muscles Eg. Leg muscle of Melolontha
    - Indirect flight muscles Eg. Thoracic muscles of Apis
6) Each muscle is made up of a number of fibers,which are long usually multinucleate cells running the length of the muscle myofibrils. The fibrils are long serial arrays of contractile units known a sarcomeres. Each sarcomere is composed of interdigitated molecular filaments, consisting mainly of two proteins: Myosin and Actin. The Synchronous muscle each contraction is driven by a single neural stimulus (elevator muscle and depressor muscle) and The Asynchronous skeletal muscles are specialized muscles in which neural stimulation is asynchronous with respect to contraction (vertical muscle and longitudinal muscle).

## Vertebrate muscular system

1) In fishes the there are two divisions of muscles epaxial (upper) and hypaxial (lower). Each myotome contribute one muscles segment called myomere. The myomere are more angled and are moulded into interlocking cones. Strap like hypobranchial muscle extend from pectoral girdle to the visceral arches. Serve to open the jaw and pull gills downward and backward evolved from hypaxial muscle retaining the longitudinal orientation of fibers. In dorsal mass abductor or levators helps to move fins upward and downward. In ventral mass the adductor or depressor muscle helps to move downward or backward.
2) In amphibians, Their lateral septum is more dorsal in position myotomes are primitive. Muscle fibers still course from one myocommata to the next. The entire epaxial mass formed dorsalis trunci myotomes which are vertically arranged. In adult urodeles ventral

trunk muscles begging from the outside there are superficial and deep external oblique. Transversus fibers almost in a vertical position. It lies next to peritoneum.

3) In reptiles, the epaxial muscle function to extend or straight the spine and provide some lateral flexion and lacks mayosepta. Hypasxial muscles function to bend spine and provide lateral bending. Integumentary muscle present in snake the costocutaneous Helps to move skin.
4) Im birds, the birds have approximately 175 different muscles. Skin muscles helps brids in its flight by adjusting feathers. Tail muscle ( pygostyle), the pectorals or the breast muscle and stringy muscles of the vertebral column. The supracoracoideus works using a pulley like system to lift the wing while pectorals provide powerful downstroke.
5) In mammals, epaxial muscle lack myosepta and hypaxial muscle loacted below transverse process. The intercostal muscles Present in anterior ribs



| APPENDICULAR MUSCLES | FISHES | AMPHIBIANS | REPTILES | BIRDS | MAMMALS |
|---|---|---|---|---|---|
| Adductor muscles | Dorsal; flex fins | Ventral; recovery | Ventral; recovery | Ventral; recovery | Ventral; recovery |
| Abductor muscles | Ventral; extend fins | Dorsal; propulsive | Dorsal; propulsive | Dorsal; propulsive | Dorsal; propulsive |
| Other characteristics | Intrinsic muscles are limited in number & undifferentiated | Much more complex than in fish | More numerous & diverse than in amphibians | Intrinsic musculature is reduced | Similar to reptiles but more diverse |
| FUNCTION | Balance and orientation | Support and locomotion | Support and locomotion | Support and locomotion | Support and locomotion |

| JAW MUSCLES | FISHES | AMPHIBIANS | REPTILES | BIRDS | MAMMALS |
|---|---|---|---|---|---|
| Branchiomeric | Constrictors and levator muscles | Associated with mandibular, hyoid and pharyngeal arches | Associated with mandibular, hyoid and pharyngeal arches | Associated with mandibular, hyoid and pharyngeal arches | Highly modified; mandibular, hyoid and pharyngeal arches |
| FUNCTION | Breathing and feeding | Contribute to larynx (vocalization) and throat | Contribute to larynx (vocalization) and throat | Contribute to larynx (vocalization) and throat | Control vocal functions within larynx |
| Hypobranchial | Attached posteriorly to pectoral skeleton | Associated with pharyngeal arches | Associated with pharyngeal arches | Associated with pharyngeal arches | Associated with pharyngeal arches |
| FUNCTION | Serve to open the jaws and pull the gills downward and backward | Movement of the larynx, hyoid apparatus and tongue | Movement of the larynx, hyoid apparatus and tongue | Movement of the larynx, hyoid apparatus and tongue | Movement of the larynx, hyoid apparatus and tongue |

| AXIAL MUSCLES | FISHES | AMPHIBIANS | REPTILES | BIRDS | MAMMALS |
|---|---|---|---|---|---|
| Epaxial *(Upper)* | Solid mass; above the lateral septum | Muscle masses subdivided and rearranged into longitudinal muscles | Muscle masses subdivided and rearranged into longitudinal muscles | | Muscle masses subdivided and rearranged into longitudinal muscles |
| Hypaxial *(Lower)* | Solid mass; below the lateral septum | 2 outer oblique layers; 1 inner transverse layer; rectus abdominis | 2 outer oblique layers and 1 inner transverse layer; rectus abdominis | 2 outer oblique layers and 1 inner transverse layer; rectus abdominis | Oblique layers are further subdivided, separated by intercostal muscles |
| Septum | Transverse/ Lateral septum | Dorsally position | Linea alba | | |
| Myotomes | Present | Present | Absent | | |
| Myosepta | Present | Present | Absent | | Absent |
| FUNCTION | To produce an undulating motion that propels the fish through the water | Maintenance of posture, head movement, and respiration | Maintenance of posture, head movement, and respiration | Maintenance of posture, head movement, and respiration | Maintenance of posture, head movement, and respiration |

## Functions of muscular system

- Body movement (locomotion)
- Maintenance of posture
- Respiration (diaphragm and intercostal contractions)
- Communication (verbal and facial)
- Constriction of organs and vessels (peristalsis of intestinal tract etc)
- Heart beat
- Production of body heat (thermogenesis)
- The Contractility and nearly all movement of body is result of muscle contraction.
- Joint stability
- Protection

## References


- Mam notes
- Comparative anatomy of vertebrates
- Fundamentals of animal physiology
- Wikipedia
- Google