

# The neuromuscular system & exercise

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# Objectives

- Identify the major components of CNS
- Outline motor neuron and its types
- Discuss Proprioceptors specific to muscles
- Differentiate among different types of Ms.
- Contrast slow and fast twitch Ms. Fibers
- Outline Ms. Fiber type distribution pattern among diverse groups of athletes.
- Explain how exercise training modifies Ms. Fibers and fiber types.

# Nervous System

## Central Nervous System (CNS)

- Brain (including retinas)
- Spinal cord
- Integrative/control centers

## Peripheral Nervous System (PNS)

- Cranial nerves III–XII
- Spinal nerves

## Afferent Division (sensory)

- Somatic and visceral neurons
- Conducts impulses from receptors to CNS

## Efferent Division (motor)

- Motor neurons
- Conducts impulses from the CNS to effectors

## Autonomic Nervous System

- Involuntary
- Conducts impulses from the CNS to cardiac muscle, smooth muscles, and glands

## Somatic Nervous System

- Voluntary
- Conducts impulses from the CNS to skeletal muscles

Sympathetic

Parasympathetic

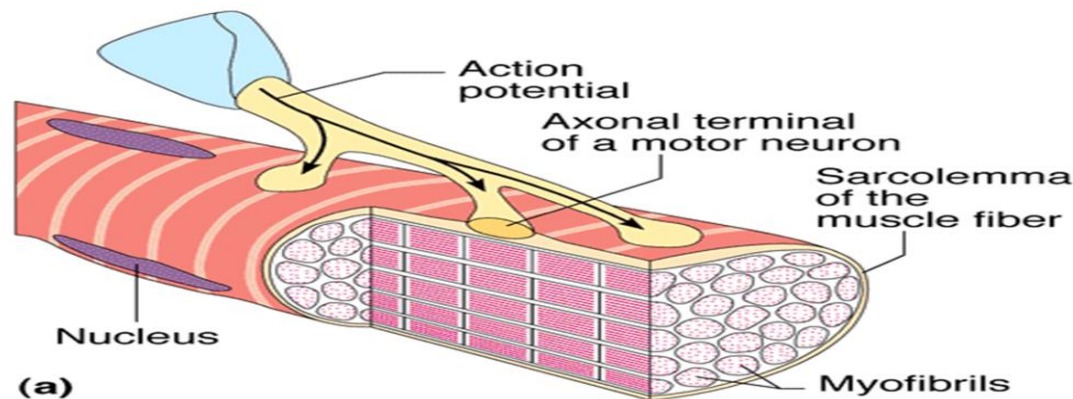
### Comparison of effects of sympathetic and parasympathetic activation on end organs

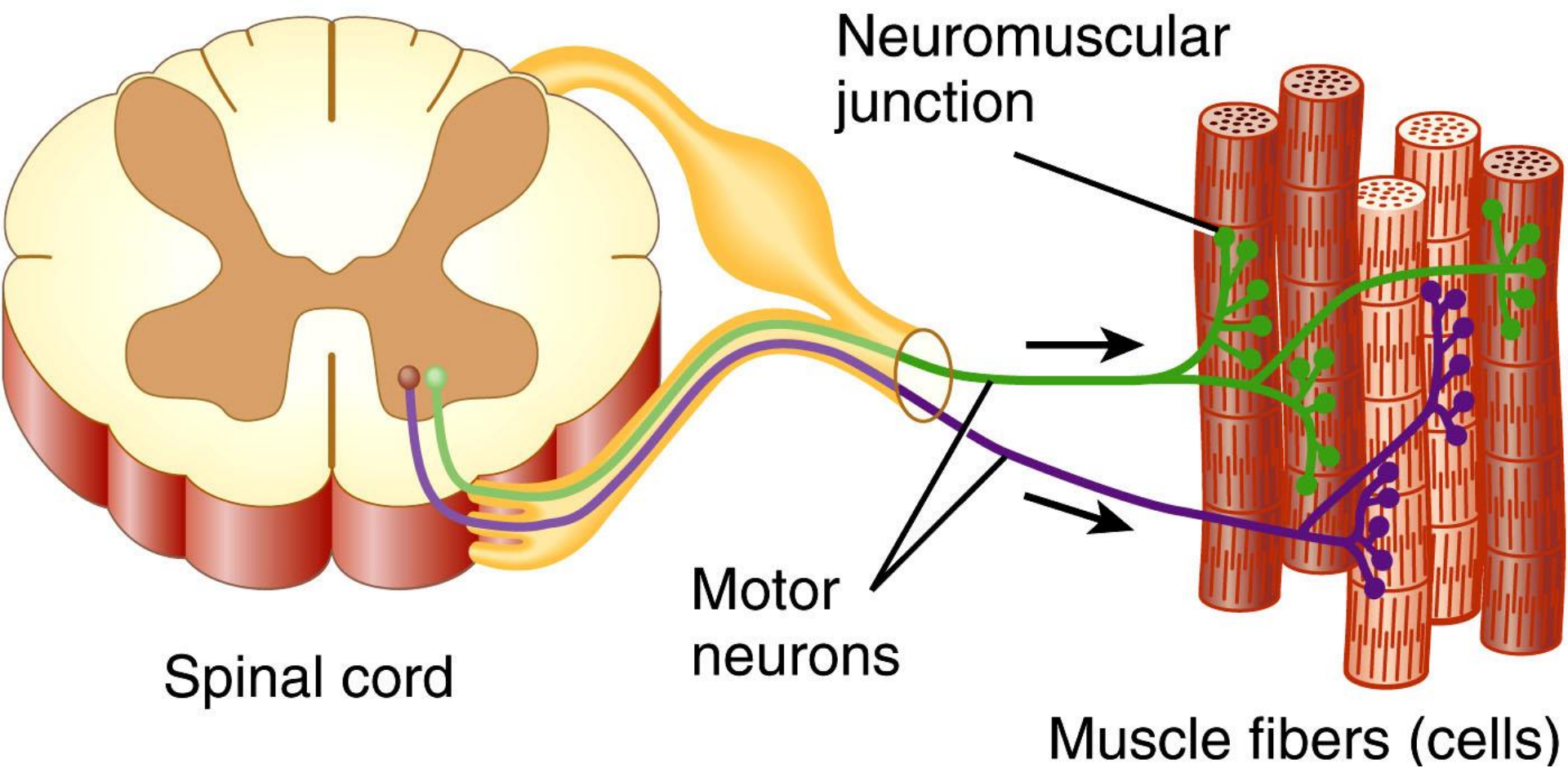
End organ	Sympathetic effects	Parasympathetic effects
Skeletal muscle	Increase blood flow	Decrease blood flow
Ventilation	Increase	Decrease
Sweat glands	Increase perspiration	No effect
Heart	Increase force and contraction rate	Decrease force and contraction rate
GI tract motility	Decrease	Increase
Eyes	Dilate pupils	Constrict pupils
Secretion of digestive juices	Decrease	Increase
Blood pressure	Increase mean pressure	Decrease mean pressure
Airways	Increase diameter	Decrease diameter



# Motor neurons

- stimulate muscle fibers to contract
- Motor neurons have a threadlike axon that extends from the brain or spinal cord to a group of muscle fibers to innervate them.
- The axon transmit the impulse in one direction only
- Form a neuromuscular junction (= myoneural junction)





## Control of Muscle Tension

# Motor neurons

- There are 3 motor neuron types

## Characteristics

- Axon
- Force production
- Contraction speed
- Fatigue resistance
- Motor unit MS. Fiber .

## Fast fatigability units

- Large axon
- High
- Fast
- Low
- Fast glycolytic

## fast fatigue resistance units

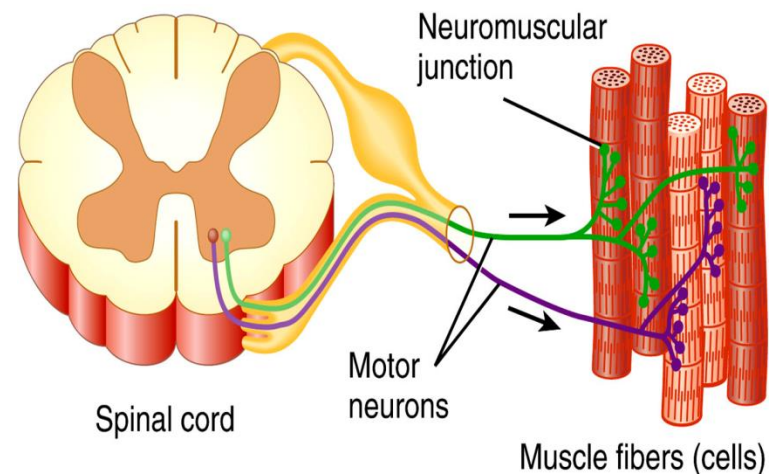
- Moderate axon
- Moderate
- Fast
- moderate
- Fast oxidative glycolytic

## slow units

- Small axons
- Low force
- Slow
- High
- Slow oxidative.

# Motor neurons

- Light ex. Predominantly recruited slow twitch units followed by activations of fast twitch motor units when **force output requirements** increase.





# Proprioception

- Proprioceptors - internal receptors located in skin, joints, muscles, & tendons which provide feedback relative to:
- tension, length, & contraction state of muscle.
- position of body & limbs.
- movements of joints.

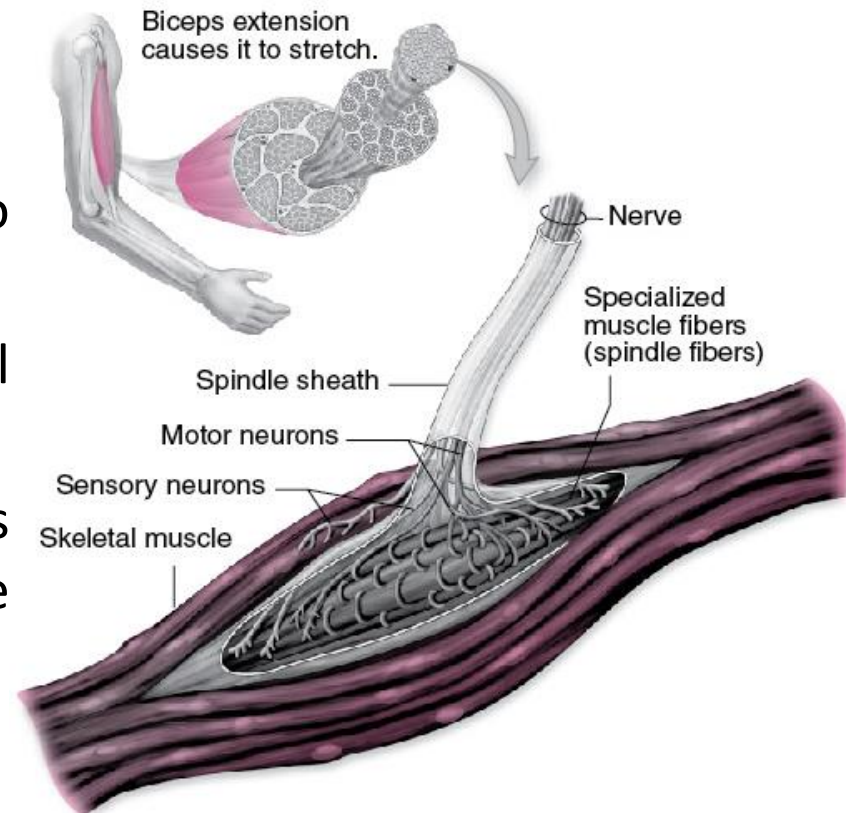
# Proprioception

- Proprioceptors specific to muscles
  - Muscles spindles
    - concentrated primarily in muscle belly between the fibers & run parallel with muscle fibers
    - Provide mechanosensory information about change in muscle fiber length & stretch .
    - It responses to Ms. Stretch through reflex action by initiated a strong MS. Action .
  - Golgi tendon organs (GTO)
    - found serially in the tendon close to muscle tendon junction
    - sensitive to both muscle tension & active contraction
    - Much less sensitive to stretch than muscle spindles
    - require a greater stretch to be activated

# Muscle spindle

## The main components of stretch reflex(Monosynaptic):-

1. Muscle spindle that respond to rapid muscle stretch .
2. Afferent Impulse is sent to the spinal cord .
3. Spinal cord activates motor neurons of agonist muscle (contacts) while inhibiting the antagonist muscle.

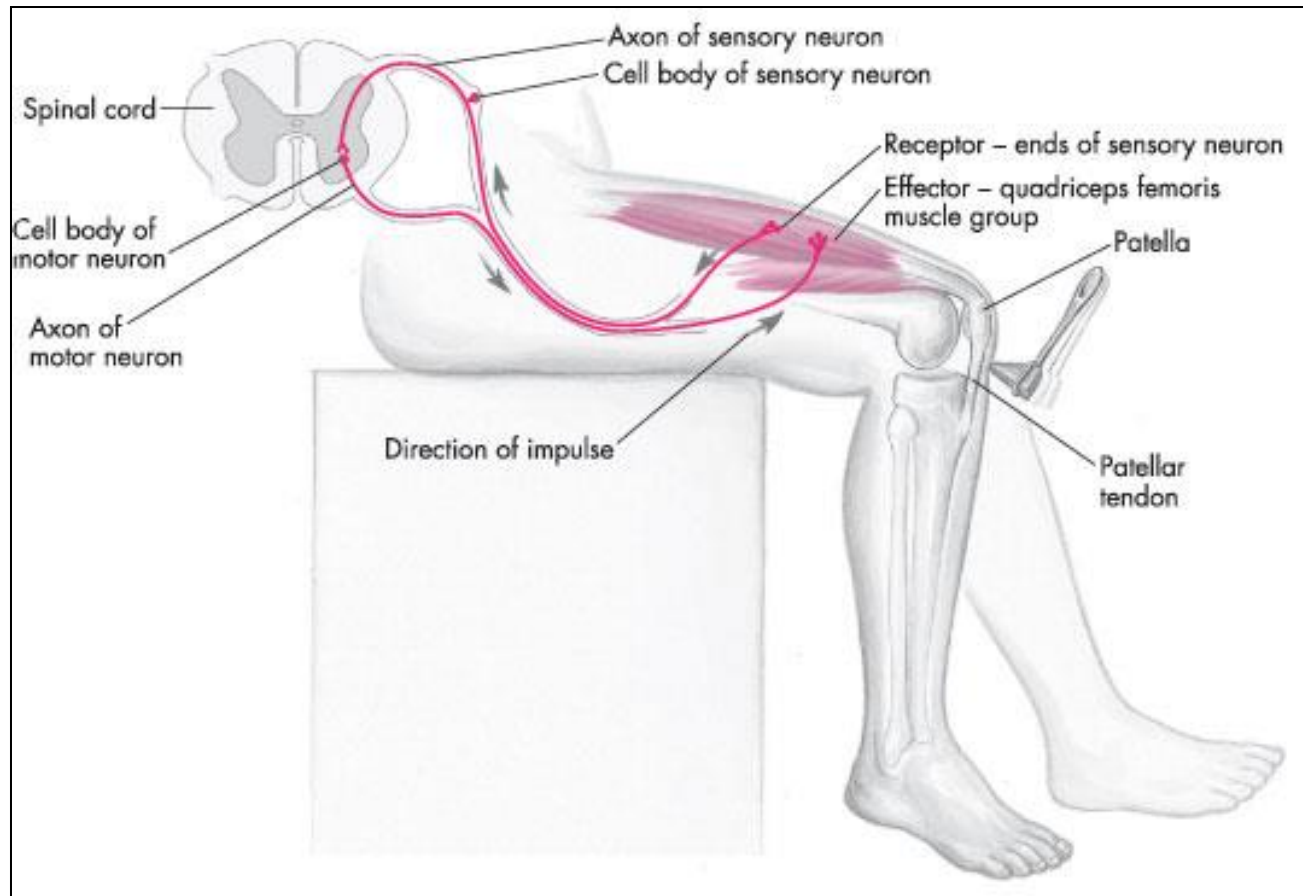


### Major function of a muscle spindle:

This provides an important regulatory control function for total body movement & posture . Postural MS. Required continual subconscious activity to adjust to pull in gravity in upright posture .

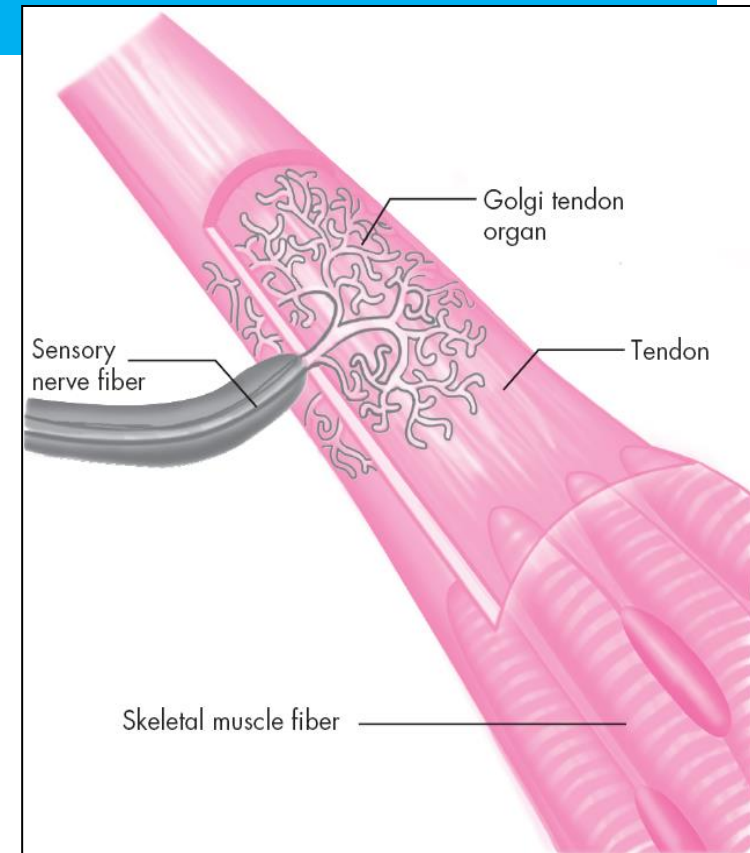
# Monosynaptic Reflex

- Ex. Knee jerk or patella tendon reflex



# Golgi Tendon Organ

- Golgi tendon organ
- Tension in tendons & GTO increases as muscle contract, which activates GTO
  1. GTO stretch threshold is reached
  2. Impulse is sent to CNS
  3. CNS causes muscle to relax
  4. facilitates activation of antagonists as a protective mechanism



## Major function:

GTO protects muscle or its connective tissues from injury by sudden excessive contraction or stretch by causing its muscle to relax. So it inhibits undue strain .



# MUSCULAR SYSTEM

## **Muscle Function:**

- **Producing movement**
- **Stabilizing joints**
- **Maintaining posture**
- **Moving substances within the body**
- **Producing heat— muscle contraction generates 85% of the body's heat**

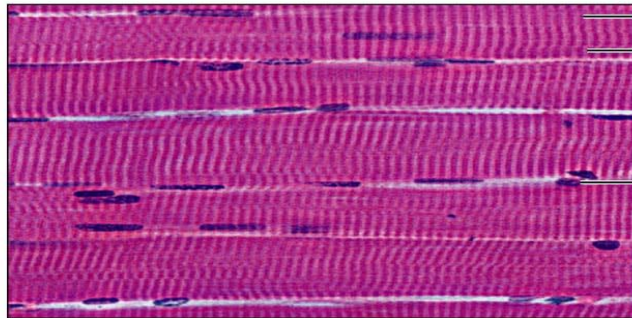
# Characteristics of Muscle Tissue

- **Excitability**- receive and respond to stimuli
- **Contractility**- ability to shorten and thicken
- **Extensibility**- ability to stretch
- **Elasticity**- ability to return to its original shape after contraction or extension

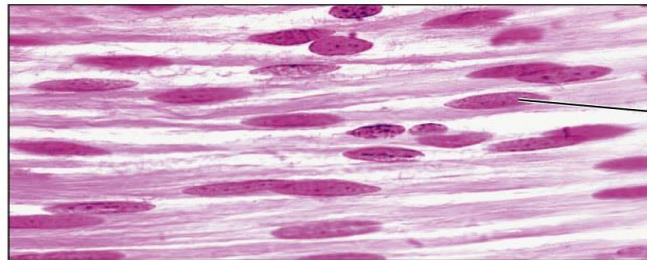
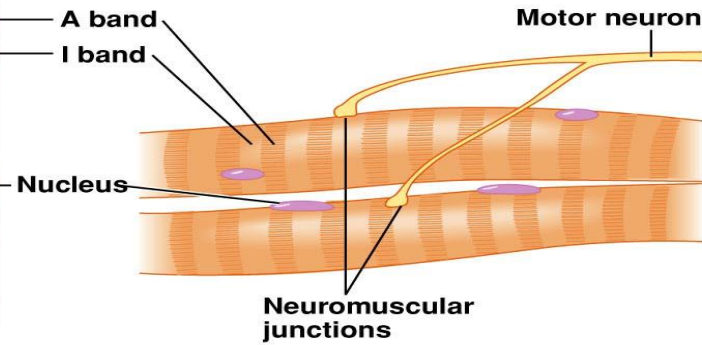
# Types of Muscle

	Skeletal Muscle	Smooth Muscle	Cardiac Muscle
Location	Attached to bone	On hollow organs, glands and blood vessels	Heart
Function	Move the whole body	Compression of tubes & ducts	Heart contraction to propel blood
Nucleus	Multiple, peripheral	Single, central	Central & single
Control	voluntary	involuntary	involuntary
Striations	yes	no	yes
Cell Shape	Cylindrical	Spindle-shaped	Branched

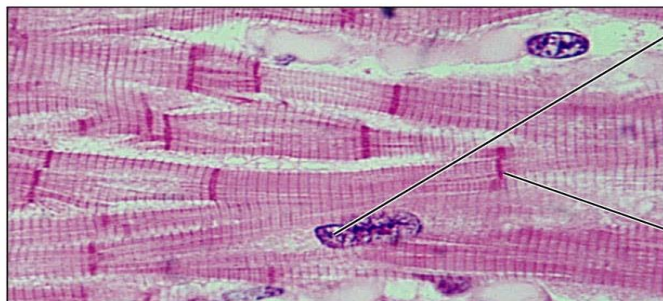
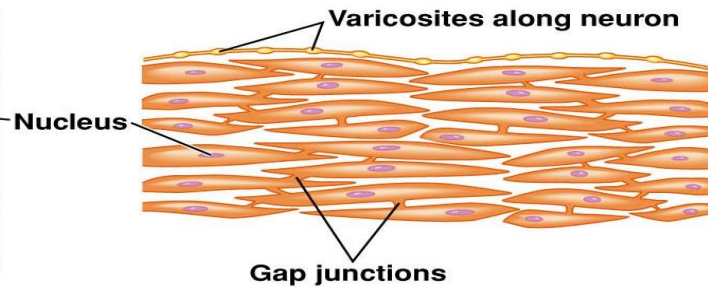
# Muscle Tissue Types



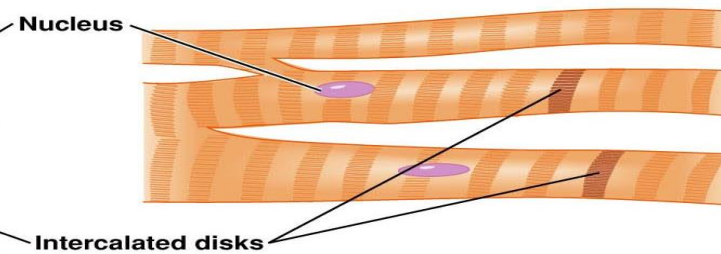
**(a)** Skeletal muscle



**(b)** Smooth muscle



**(c)** Cardiac muscle



# Skeletal muscle anatomy

- **Epimysium**

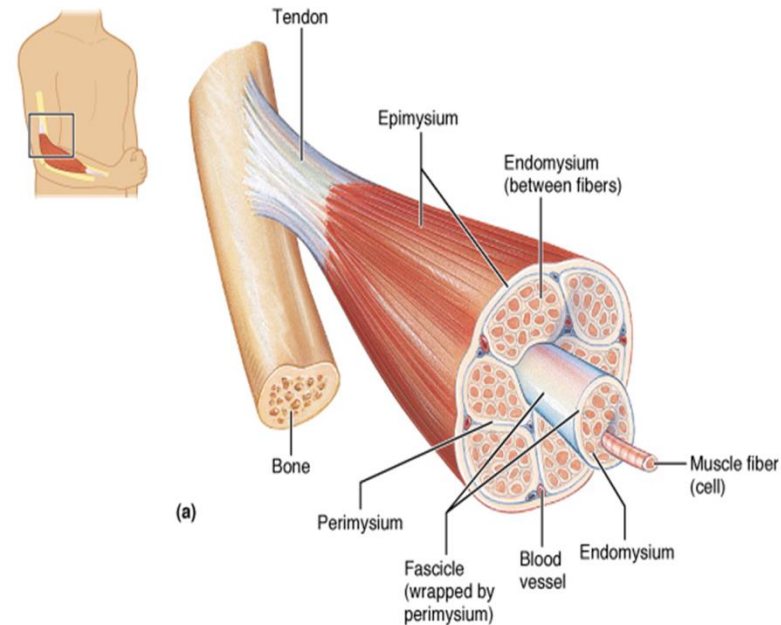
sheath enveloping entire Ms.

- **Perimysium**

Binds Ms. Fibers together

- **Endomysium**

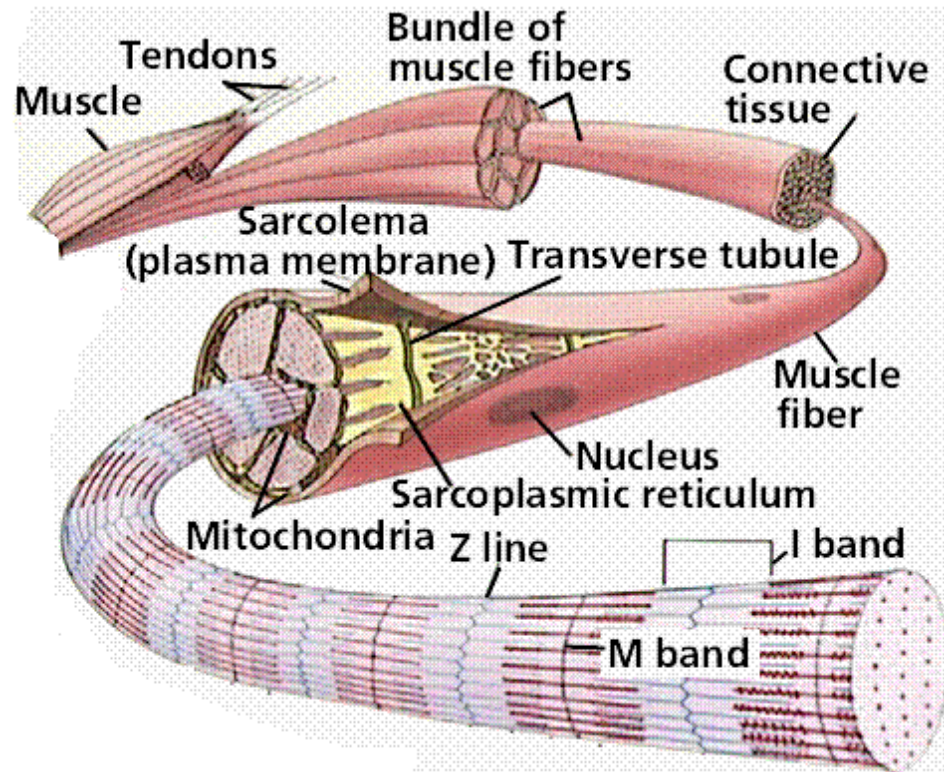
Sheath of C.T. surrounding MS. Fibers



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# Skeletal Muscle Anatomy



- **Each muscle-** has thousands of muscle fibers in a bundle running from origin to insertion bound together by connective tissue through which run blood vessels and nerves.
- **Each muscle fiber -** contains many nuclei, **sarcoplasmic reticulum**, many thick and thin **myofibrils** running lengthwise the entire length of the fiber, and many **mitochondria** for energy

# Sarcomere

**sarcomere** -The basic functional unit of the muscle fiber consists of thick and thin filaments between two Z disks.

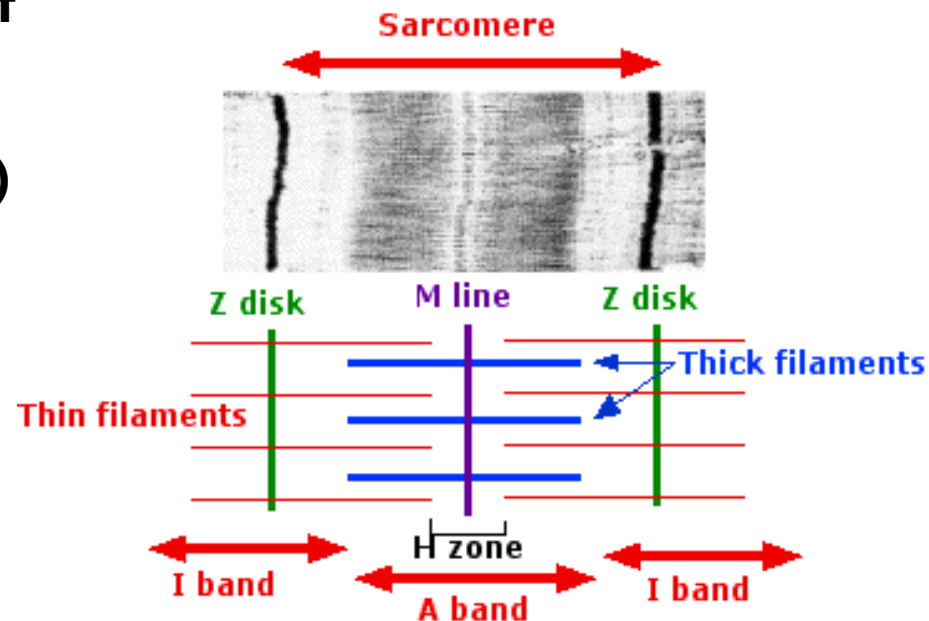
**thick filaments** - with **myosin** (protein) molecules

**thin filaments** - with **actin** (protein) molecules plus smaller amounts of **troponin** and **tropomyosin**.

**striations** -of dark **A bands** and light **I bands**.

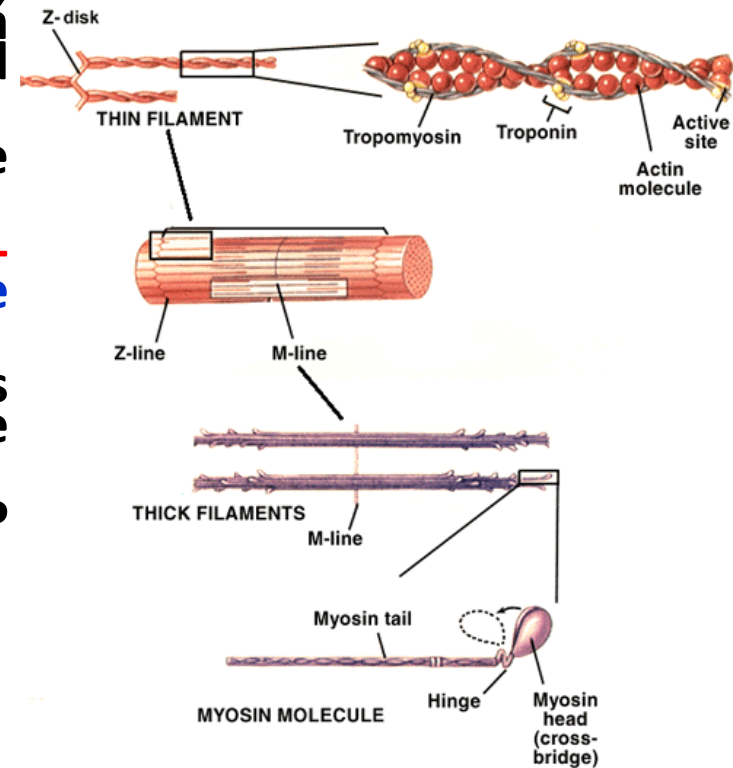
**A bands**- are bisected by the H zone with the M line.

**I bands**- are bisected by the Z disk or line.



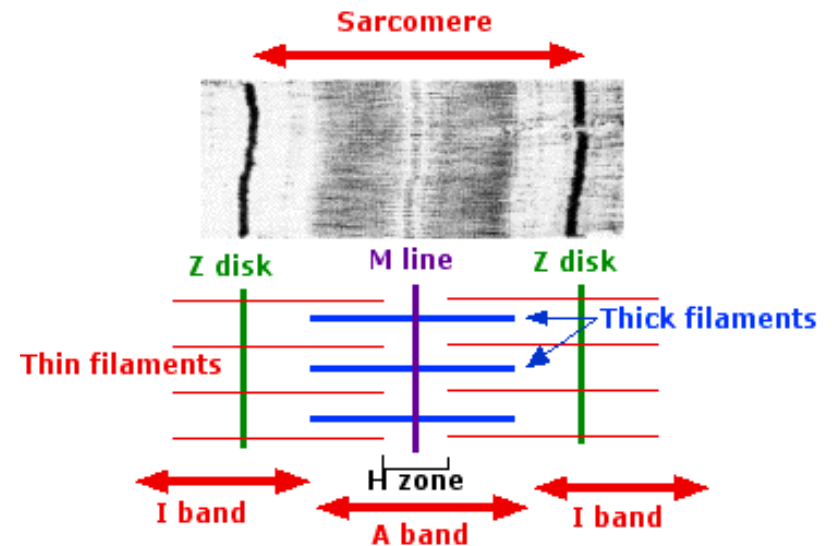
# Sliding-Filament Model

- **Thick filaments**, - myosin molecules contain, the **myosin head**, which has binding sites on the actin molecules of the thin filaments and ATP.
- **Activating the muscle fiber** causes the sarcolemma release of **Ca<sup>2+</sup> ions**
- causing a change in the **troponin-tropomyosin complex**, which exposes the binding sites on actin
- the myosin heads bind to actin molecules as the thin actin filaments slides along the myosin.
- **Linkages** break and reform (using ATP energy) further along the thick filaments.
- <https://www.youtube.com/watch?v=0kFmb rRJq4w>



# Muscle Contraction

- As the **muscle contracts** - the width of the I bands and H zones decrease causing the Z disks to come closer together, but there is no change in the width of the A band because the thick filaments do not move.
- As the **muscle relaxes or stretches** - the width of the I bands separate as the thin filaments move apart but the thick filaments still do not move.



# Types of Skeletal Muscle Fibers

- Muscle fibers are classified into two main types:-
  - 1) **Slow-twitch** (Slow oxidative fibers)
  - 2) **Fast-twitch**
    - a) Fast oxidative-glycolytic fibers(FOG)
    - b) Fast glycolytic fibers(FG)





# Types of Skeletal Muscle Fibers & suitable activity

- **Slow Oxidative Fibers (SO fibers)**
  - Smallest in diameter
  - Least powerful type of muscle fibers
  - Appear dark red (more myoglobin)
  - Generate ATP mainly by aerobic cellular respiration
  - Have a slow speed of contraction
  - Very resistant to fatigue
  - Capable of prolonged, sustained contractions for many hours
  - Adapted for maintaining posture and for aerobic, endurance-type activities such as running a marathon

# Types of Skeletal Muscle Fibers & suitable activity

- **Fast Glycolytic Fibers (FG fibers)**

- Largest in diameter
- Generate the most powerful contractions
- Have low myoglobin content
- Relatively few blood capillaries
- Few mitochondria
- Appear white in color
- Generate ATP mainly by glycolysis
- Fibers contract strongly and quickly
- Fatigue quickly

Adapted for intense anaerobic movements of short duration

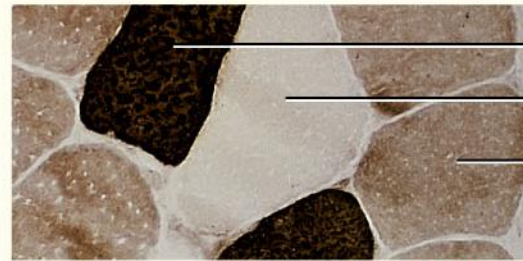
- **Weight lifting .**

# Types of Skeletal Muscle Fibers & suitable activity

- **Fast Oxidative–Glycolytic Fibers (FOG fibers)**
  - Intermediate in diameter between the other two types of fibers
  - Contain large amounts of myoglobin and many blood capillaries
  - Have a dark red appearance
  - Generate considerable ATP by aerobic cellular respiration
  - Generate some ATP by anaerobic glycolysis
  - Moderately high resistance to fatigue
  - Speed of contraction faster than SO

Contribute to activities such as walking and sprinting

# Types of Skeletal Muscle Fibers



LM 440x

Transverse section of three types of skeletal muscle fibers

Slow oxidative fiber

Fast glycolytic fiber

Fast oxidative-glycolytic fiber

## SLOW OXIDATIVE (SO) FIBERS

## FAST OXIDATIVE–GLYCOLYTIC (FOG) FIBERS

## FAST GLYCOLYTIC (FG) FIBERS

### STRUCTURAL CHARACTERISTIC

Fiber diameter	Smallest.	Intermediate.	Largest.
Myoglobin content	Large amount.	Large amount.	Small amount.
Mitochondria	Many.	Many.	Few.
Capillaries	Many.	Many.	Few.
Color	Red.	Red-pink.	White (pale).

### FUNCTIONAL CHARACTERISTIC

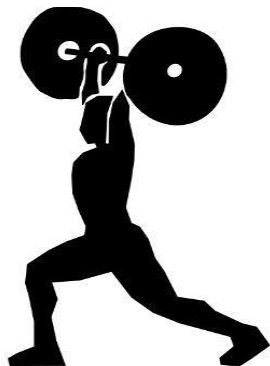
Capacity for generating ATP and method used	High capacity, by aerobic (oxygen-requiring) cellular respiration.	Intermediate capacity, by both aerobic (oxygen-requiring) cellular respiration and anaerobic (do not require oxygen) cellular respiration (glycolysis).	Low capacity, by anaerobic cellular respiration (glycolysis).
Rate of ATP hydrolysis by myosin ATPase	Slow.	Fast.	Fast.
Contraction velocity	Slow.	Fast.	Fast.
Fatigue resistance	High.	Intermediate.	Low.
Creatine kinase	Lowest amount.	Intermediate amount.	Highest amount.
Glycogen stores	Low.	Intermediate.	High.
Order of recruitment	First.	Second.	Third.
Location where fibers are abundant	Postural muscles such as those of the neck.	Lower limb muscles.	Upper limb muscles.
Primary functions of fibers	Maintaining posture and aerobic endurance activities.	Walking, sprinting.	Rapid, intense movements of short duration

# Distribution and Recruitment of Different Types of Fibers

- Most muscles are a mixture of all types of muscle fibers
- Proportions vary, depending on the action of the muscle, the person's training regimen, and genetic factors
  - Postural muscles of the neck, back, and legs have a high proportion of **SO** fibers
  - Muscles of the shoulders and arms have a high proportion of **FG** fibers
  - Leg muscles have large numbers of both **SO** and **FOG** fibers

# Exercise and Skeletal Muscle Tissue

- Ratios of fast glycolytic and slow oxidative fibers are genetically determined
  - Individuals with a higher proportion of FG fibers
    - Excel in intense activity (weight lifting, sprinting)
  - Individuals with higher percentages of SO fibers
    - Excel in endurance activities (long-distance running)





# Exercise and Skeletal Muscle Tissue

- Various types of exercises can induce changes in muscle fibers. As specific ex. Training improve the metabolic capacity of each fiber type.
    - Aerobic exercise possess the greatest % of slow twitch fibers. e.g. distance runners & cross-country skiers.
      - Endurance exercises do not increase muscle mass
    - Exercises that require short bursts of strength possess an increase in fast twitch muscle fibers.
- Muscle enlargement (hypertrophy) due to increased synthesis of thick and thin filaments (size and number of contractile proteins ).
- e.g. Sprint athletes .
- Equal fiber type distribution exists for throwers, jumpers.

# Thanks

