Ashur University
College of Medicine

Grade 2
Neuroscience

Skeletal muscle contraction

Ass. Professor Internal Medicine

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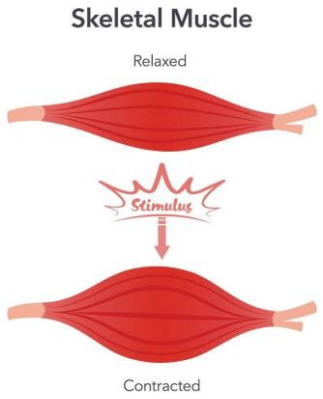


Objectives:

1-Define simple muscle twitch?

2-Describe the sequential events in muscle contraction according to the sliding filament theory.

3-Compare the two types of muscle contraction.

4-Recognize the meaning of summation of contraction and its types.

5-Detrmine the effect of changing length on skeletal muscle tension.

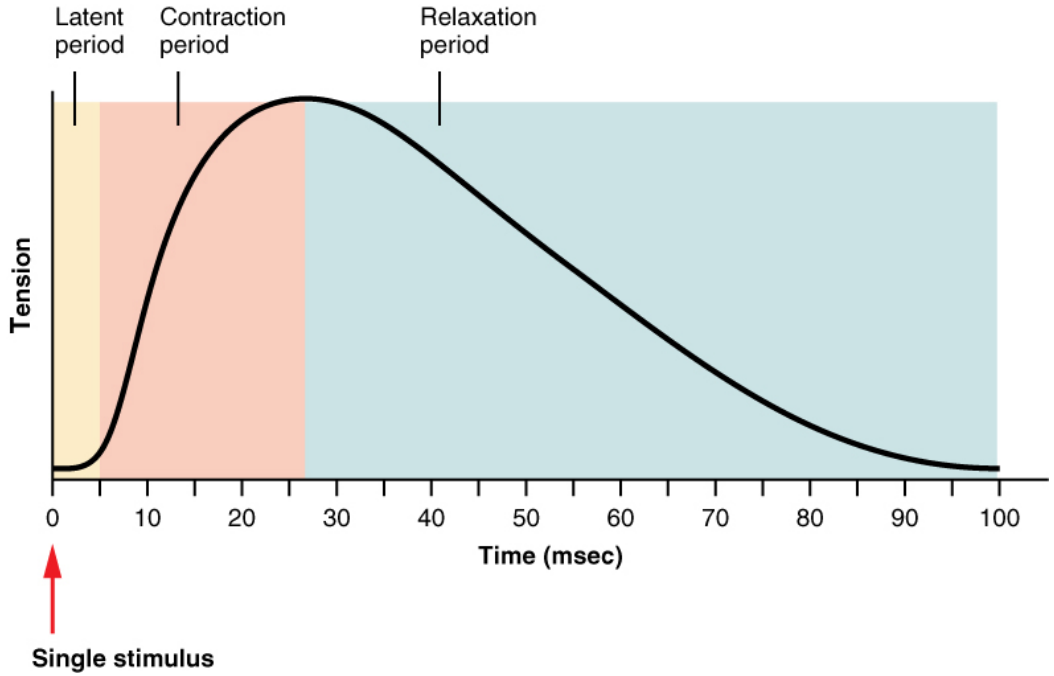
6-Differntiate between the 2 types of muscle fibers and motor units.

7-Outline the abnormalities in muscle fiber contractions.

Simple muscle twitch:

- Is a single contraction followed by single relaxation in response to action potential .**It is measured usually by a device called Myogram**.
- A single muscle twitch has a **latent period**, a **contraction phase** when tension increases, and a **relaxation phase** when tension decreases.



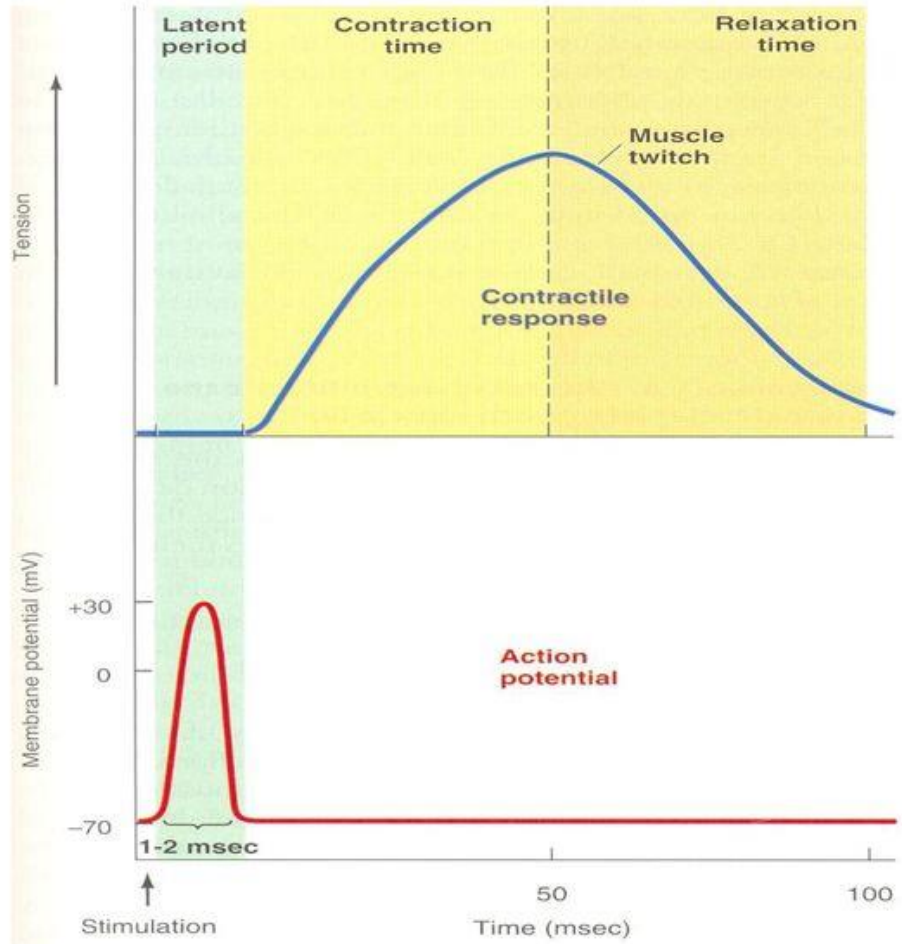


Characteristics of Whole Muscle Contraction

Simple Muscle Twitch;

Comprised of 3 phases:

1. **Latent Period.**
2. **Contraction Phase**
3. **Relaxation phase**



Excitation contraction coupling (ECC)

- Refers to the series of events that link the action potential (excitation) of the muscle cell membrane (the sarcolemma) to muscular contraction.

1- Sliding filament theory:

The sliding filament theory explains how myosin and actin interact to cause a muscle contraction.It is the process of muscle contraction involving the sliding of actin & myosin myofilaments past each other to shorten the length of each sacromere.**There are 5 stages**:

1-resting

2- excitement-contraction

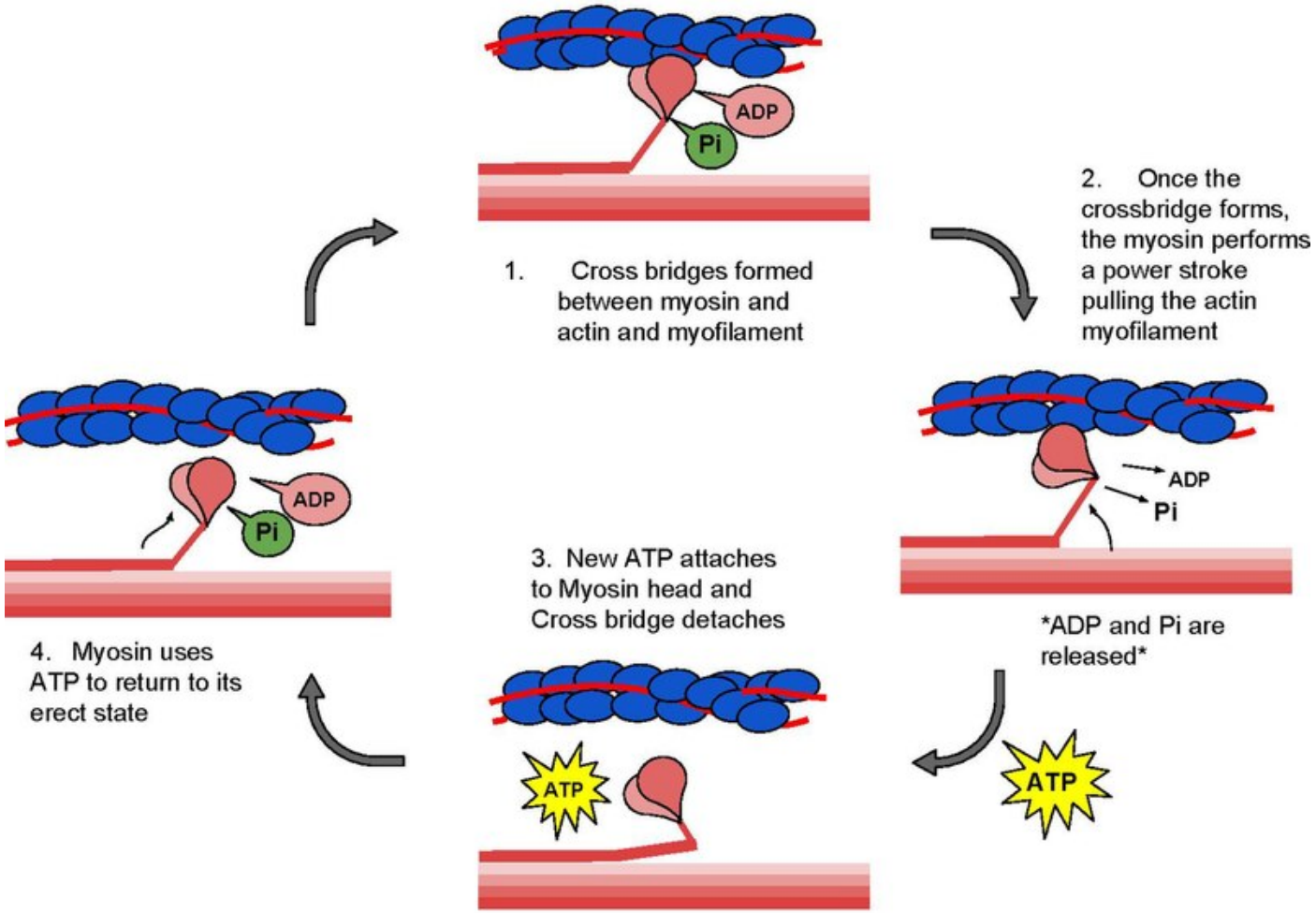
3- contraction

4- recharge

5- relaxation.

Sliding filament theory

explains muscle contraction. This process involves the sliding of thick and thin filaments within sarcomeres, resulting in contraction. This motion is facilitated by the interaction between the proteins myosin and actin, powered by ATP.



Step 1: Calcium ions.

Calcium ions are released by the sarcoplasmic reticulum in the actin filament.

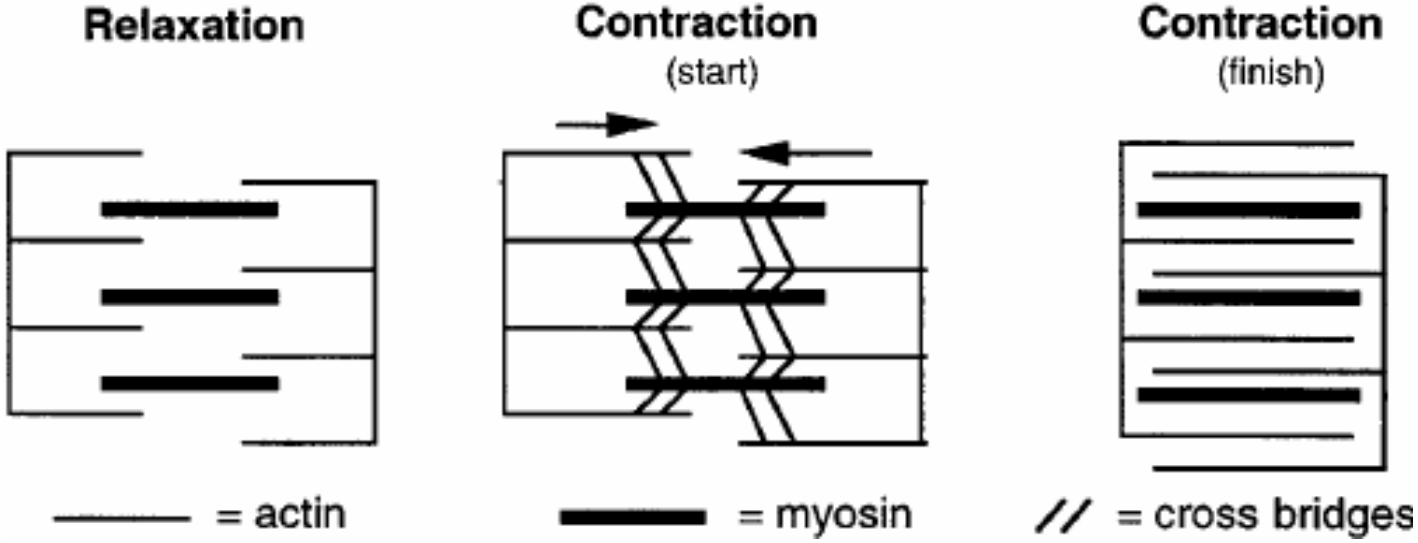
Step 2: cross bridge forms.

Step 3: Myosin head slides.

Step 4: skeletal muscle contraction has occurred.

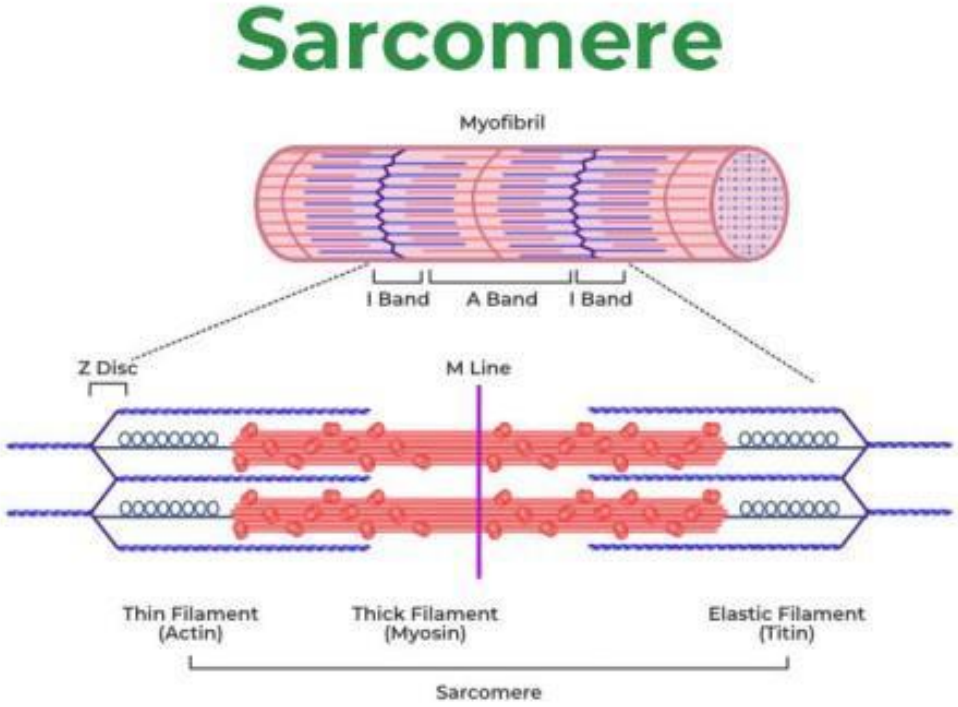
Step 5: Cross bridge breaks.

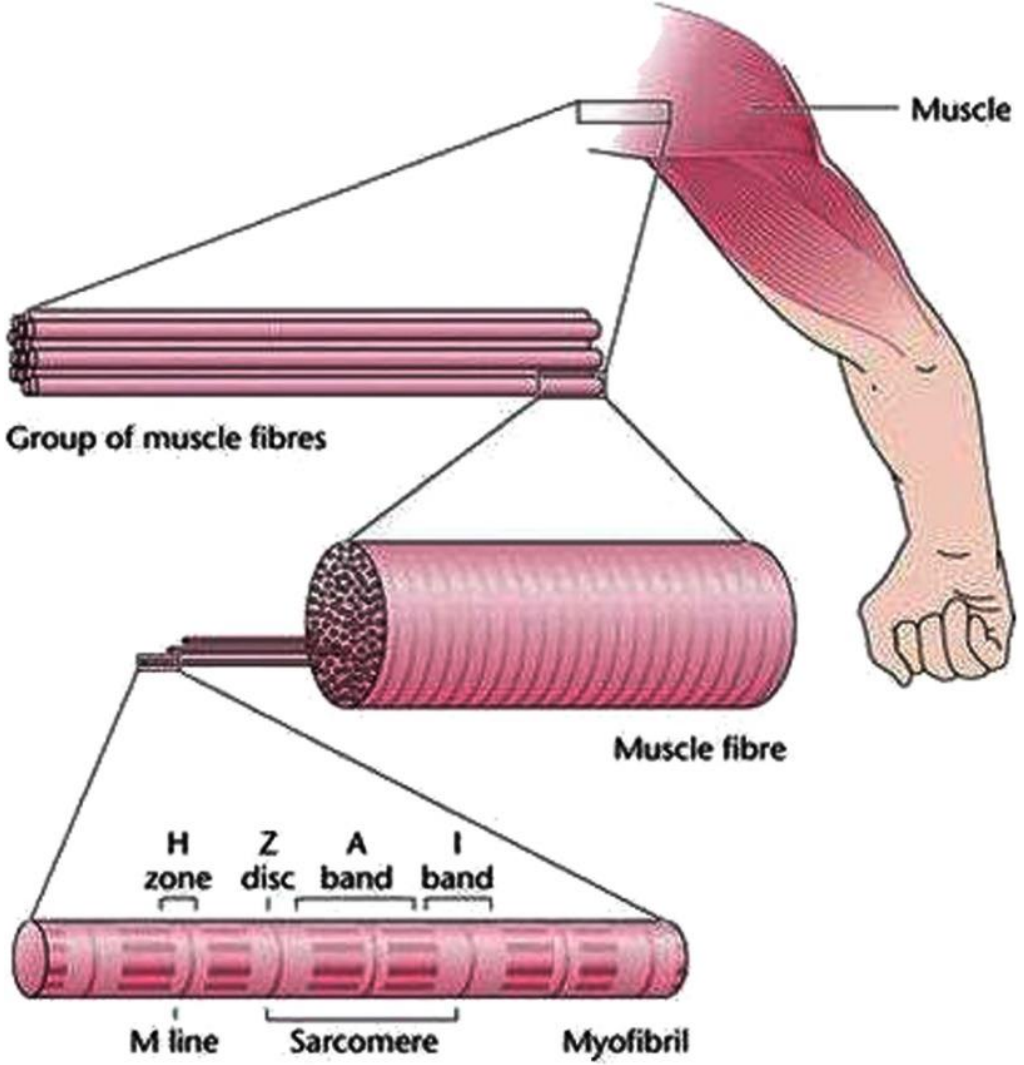
Step 6: troponin.



- The formation of cross bridges between actin and myosin heads → sliding of thin on thick filaments producing shortening (the sarcomere will be shortened)

- Muscle fiber



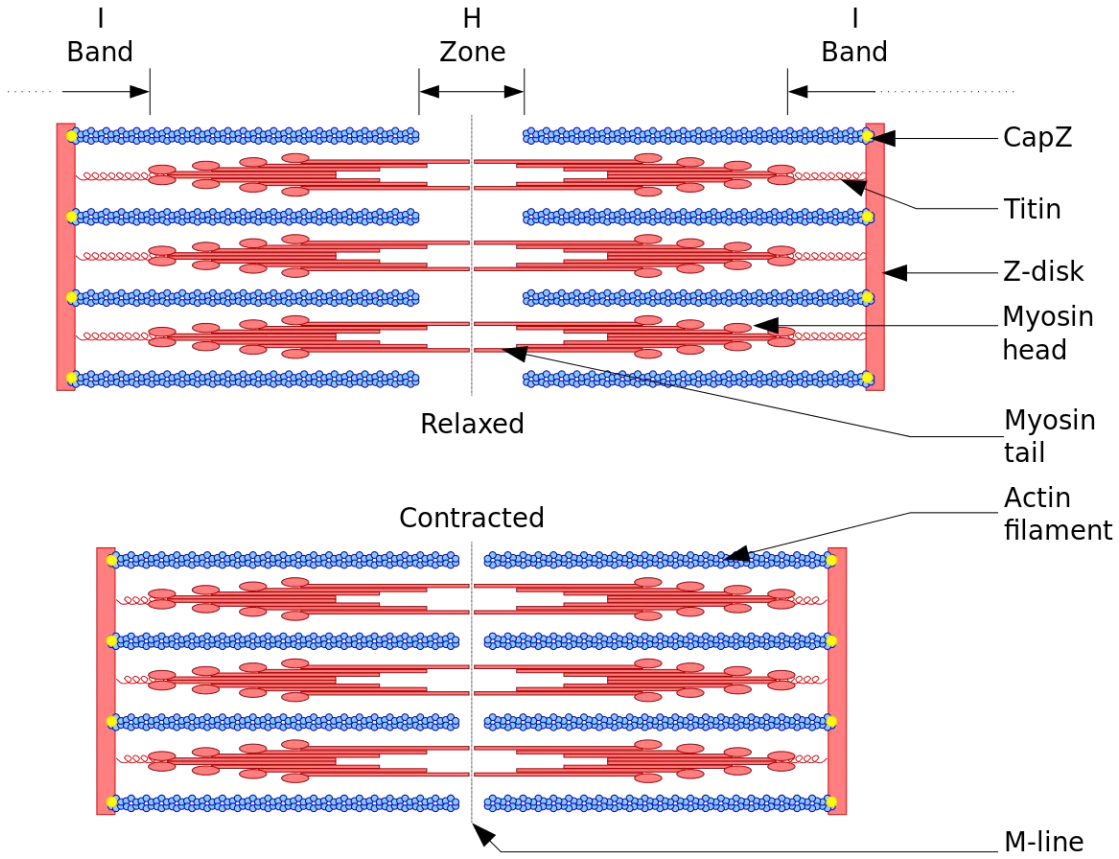


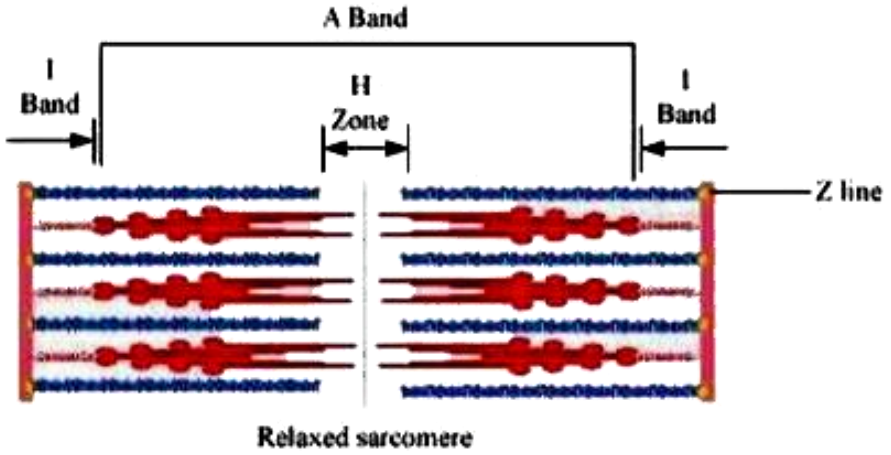
- So during muscle contraction

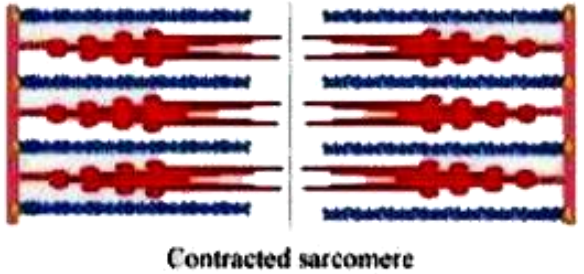
1- **The Z lines** move closer to each other.

2- **The I band becomes shorter**

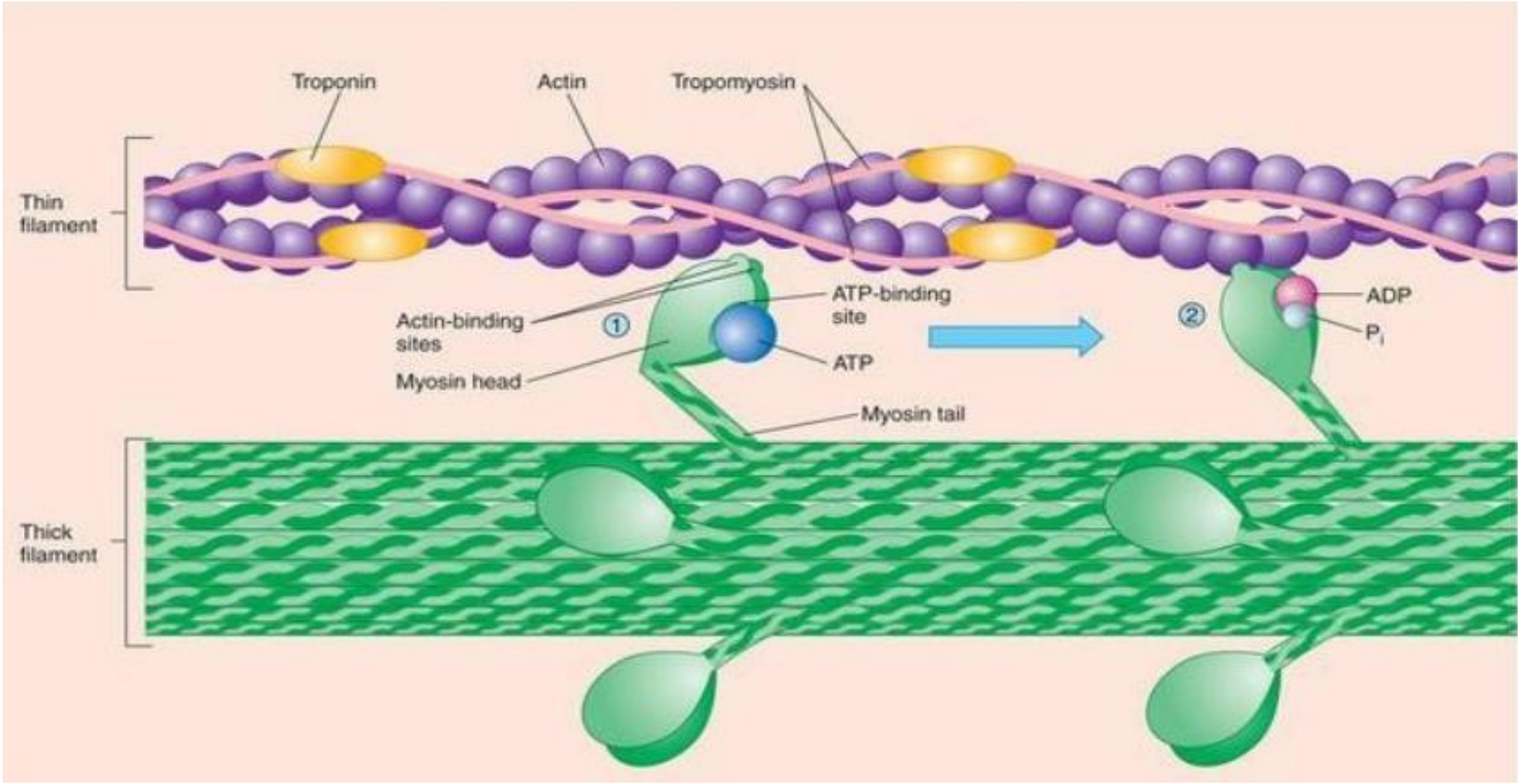
3- **The A band stays at the same length**.





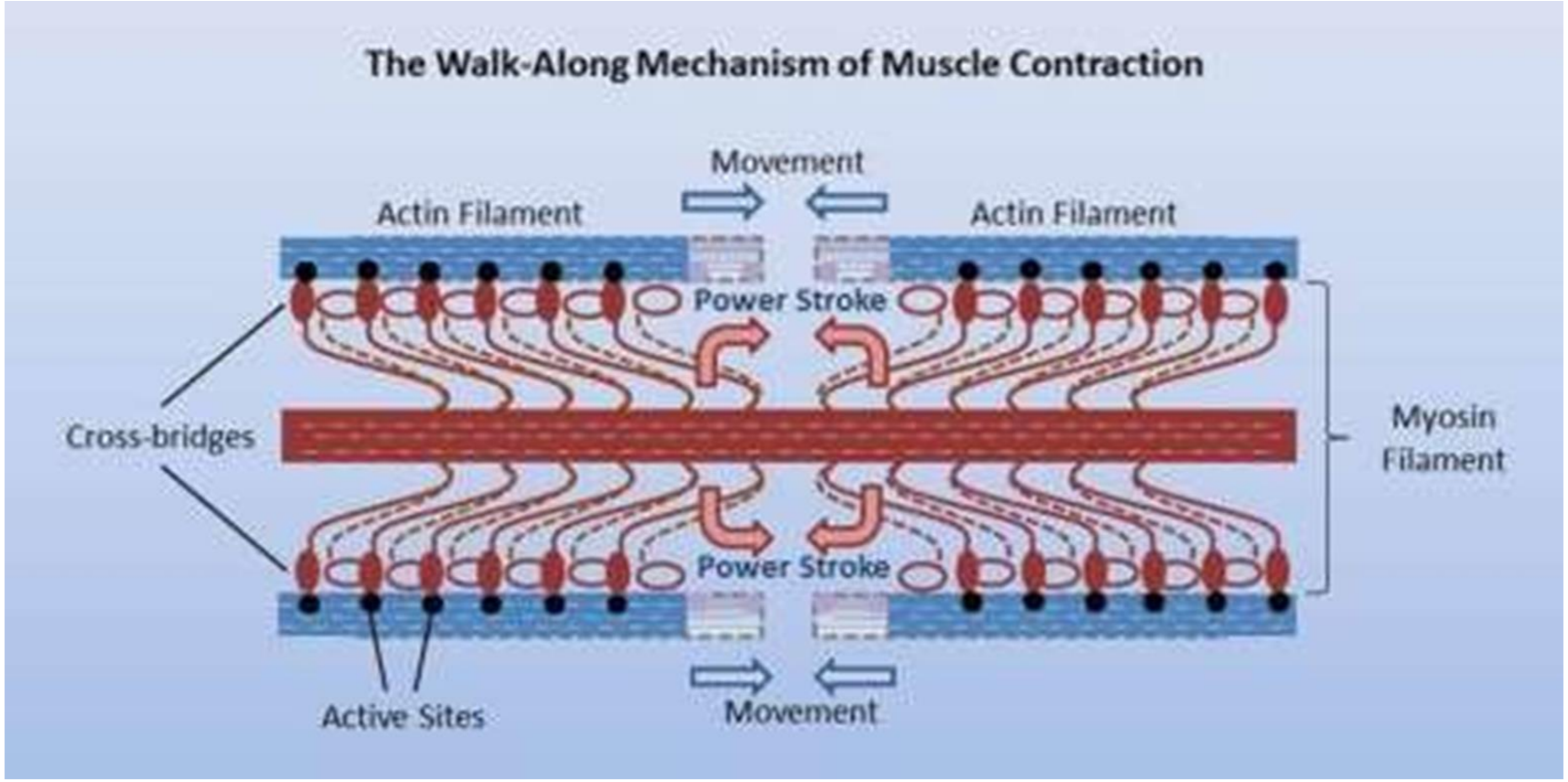


Skeletal Muscle



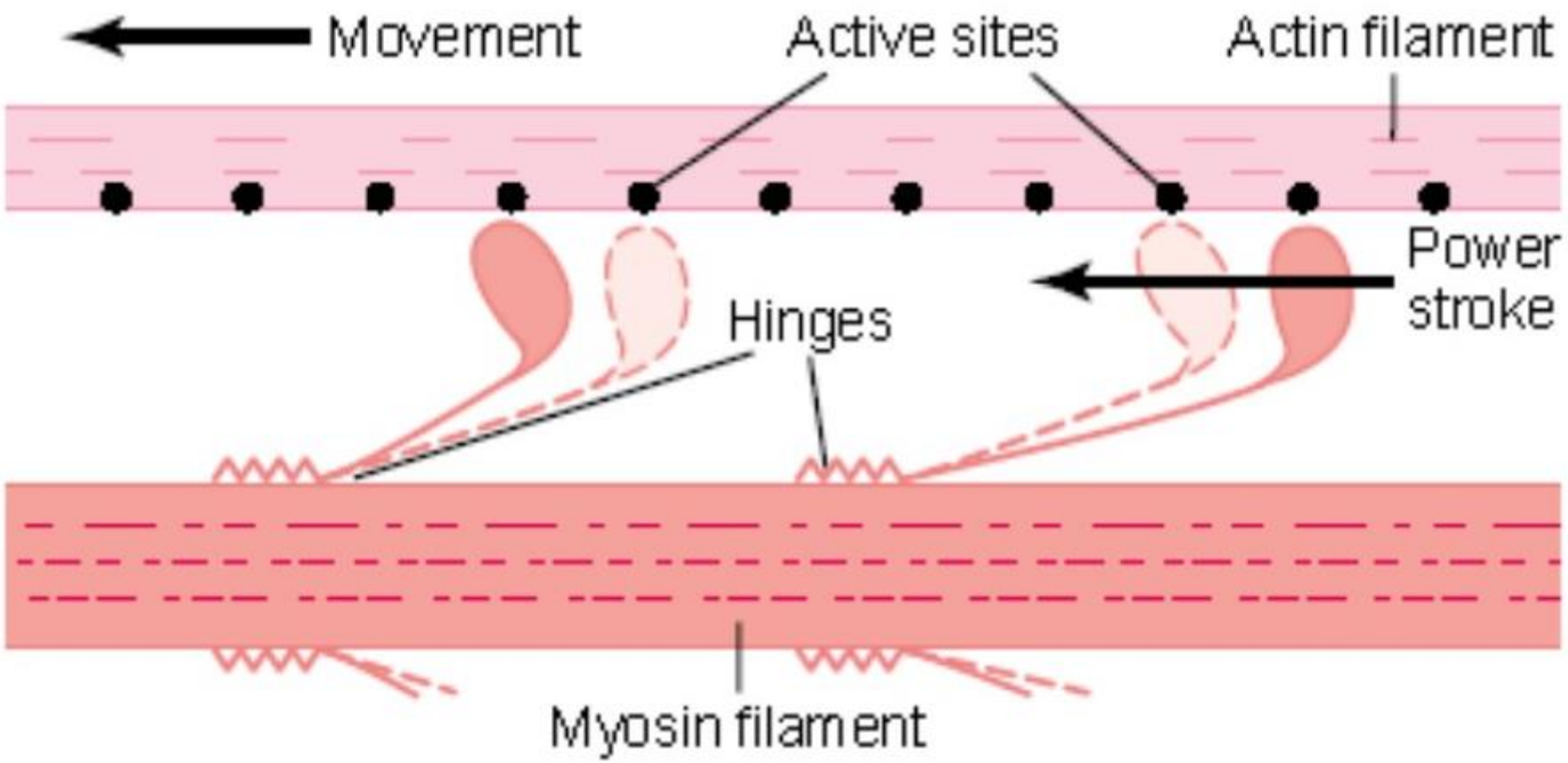
2- The walk- along or Rachet theory of contraction:

This theory suggests that the sliding during muscle contraction is produced by attaching, breaking and reforming of the cross linkages between actin and myosin heads, the intensity of the interaction depends on the number of cross linkages.

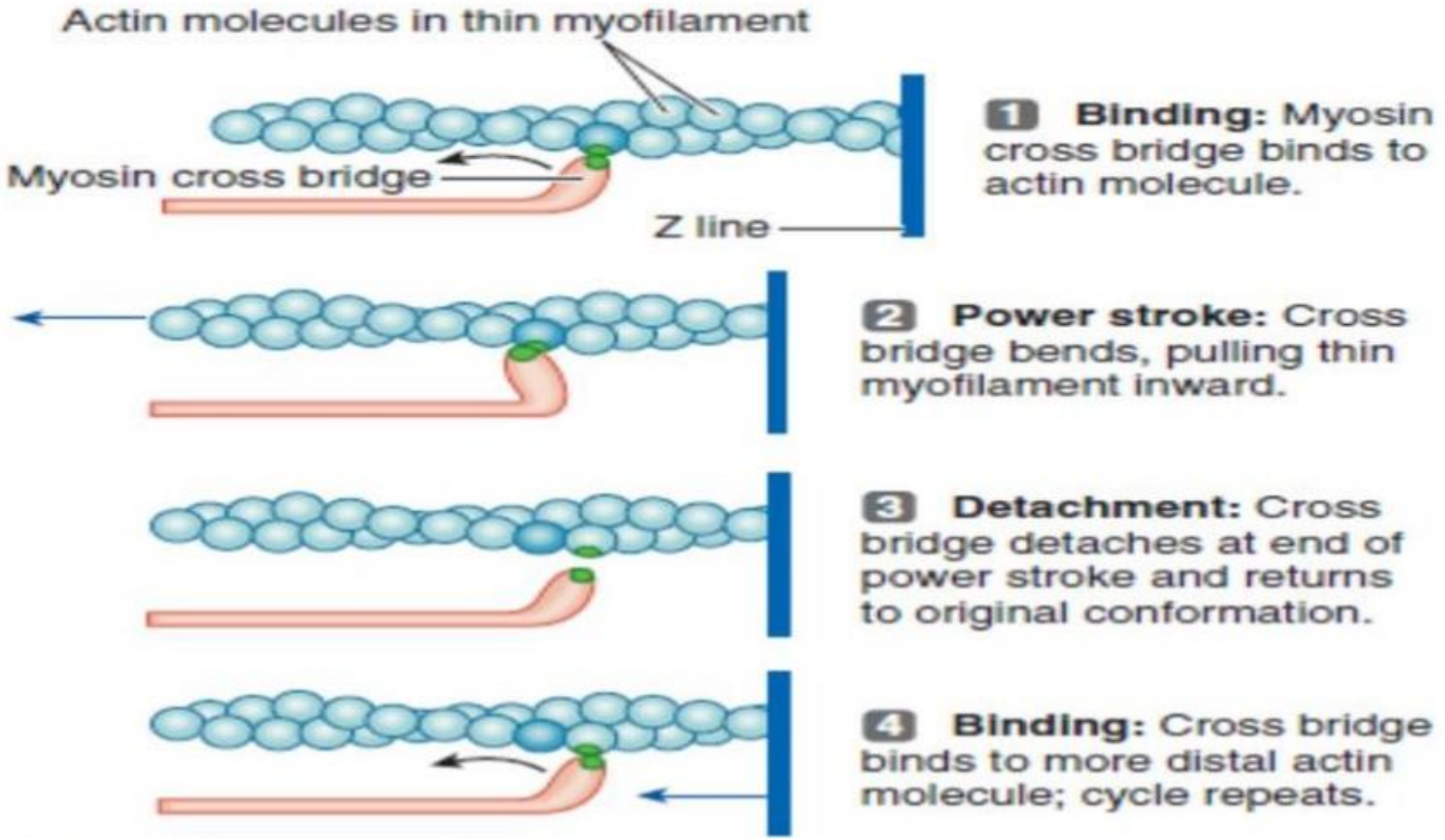


- After uncovering of the active sites of the actin.
- Myosin head link to actin at 90 degrees angle, the head tilts towards the arm to pull the actin filament along with it.
- Producing movement by pulling.
- Disconnect (breaks away from the active site, then the head returns to its extended direction.
- The head combines with a new active site and the process is repeated. The pulling of the heads of myosin to actin is called the **power stroke**.

Power Stroke

- 

Power Stroke



Cross - Bridge Cycling

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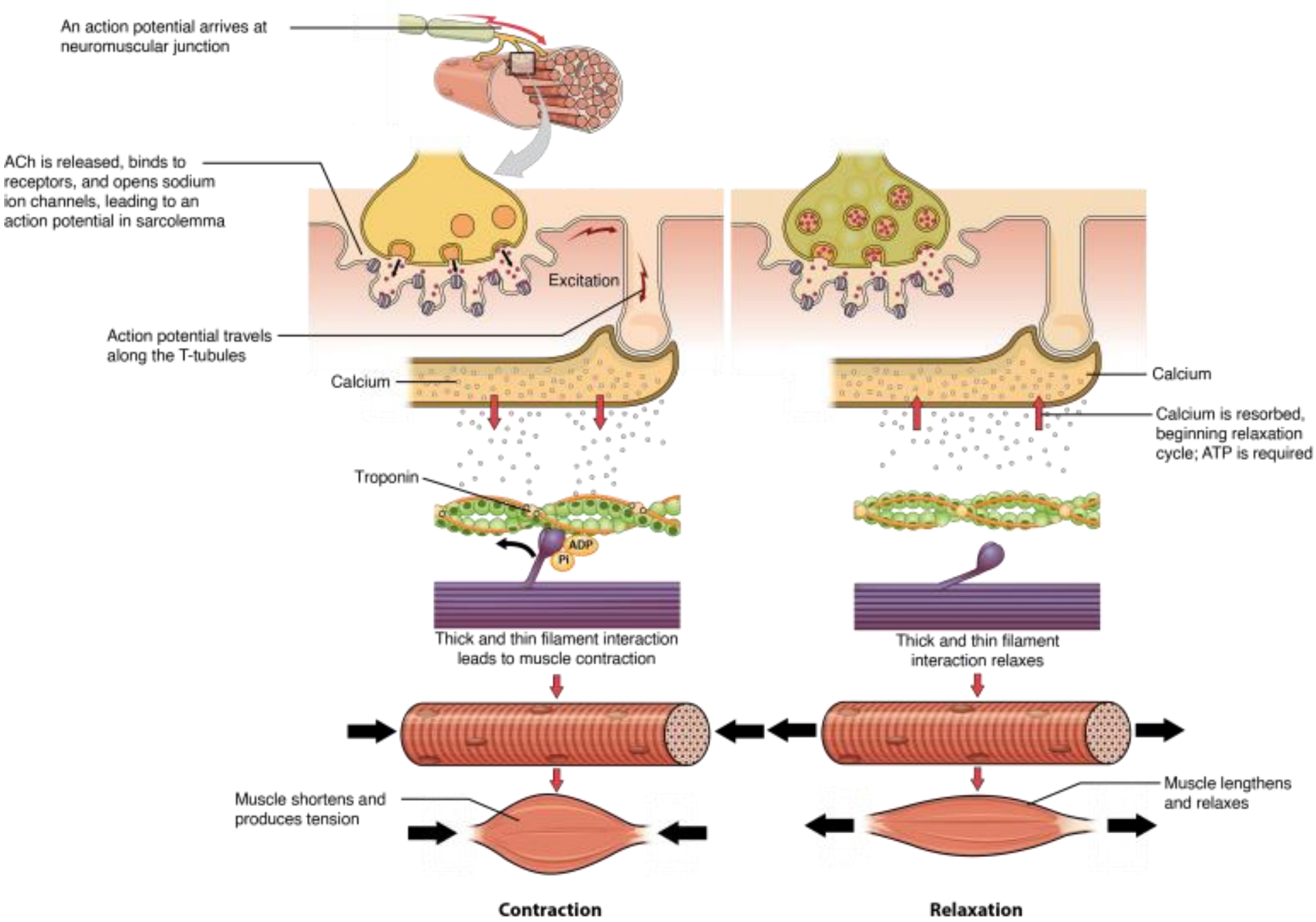


Steps in relaxation:

1- After a fraction of a second, the **calcium ions are pumped actively back into the sarcoplasmic reticulum by a Calcium membrane pump**, they are going to diffuse into the terminal cisterns to be released by the next action potential.

2- The **release of calcium ions from Troponin C**,

3- Then **cessation of binding between actin and myosin** (i.e. tropomyosin returns to its site.

4- **Contraction stops**.

Relaxation of a Muscle Fiber:

Ca^{++} ions are pumped back into the **Sarcoplasmic Reticulum (SR)** , which causes the **tropomyosin to reshield the binding sites on the actin** strands. A muscle may also stop contracting when **it runs out of ATP** and becomes fatigued.

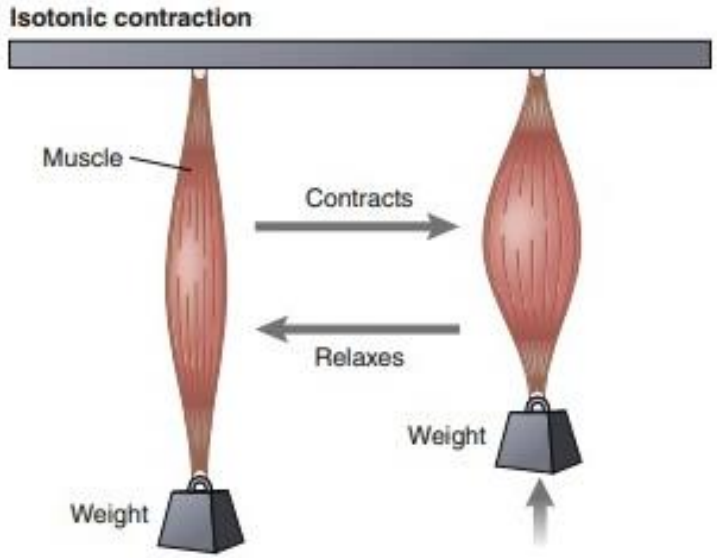
What can Stop a Muscle Contraction?

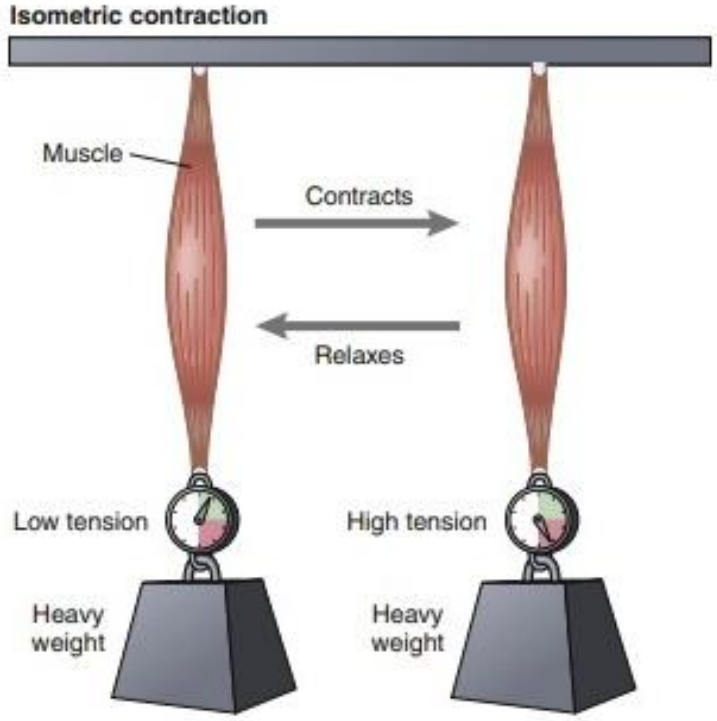
- **Energy system fatigue**: There is **no more ATP left** in the muscle cell so it can not contract.
- **Nervous system fatigue** : The nervous system is **not able to create action potential** sufficiently and cause calcium release.
- **Voluntary nervous system control**: The nerve that sends signals to the muscle to contract stops sending that signal. Hence, no more calcium ions will enter the muscle cell and the contraction stops
- **Sensory nervous system information** : A **sensory neuron provides feedback to the brain** indicating that a muscle is injured while the human body is trying to lift a heavyweight. As a result, the impulse to that muscle telling it to contract is stopped.

Types of contraction

1- Isotonic contraction occurs when the force of the muscle contraction is greater than the load, and the tension on the muscle remains constant during the contraction. **When the muscle contracts, it shortens and moves the load**. e.g lifting a box.

2- Isometric contraction occurs when the load is greater than the force of the muscle contraction; the muscle creates tension when it contracts, but the **overall length of the muscle does not change**. e.g. trying to lift a heavy object





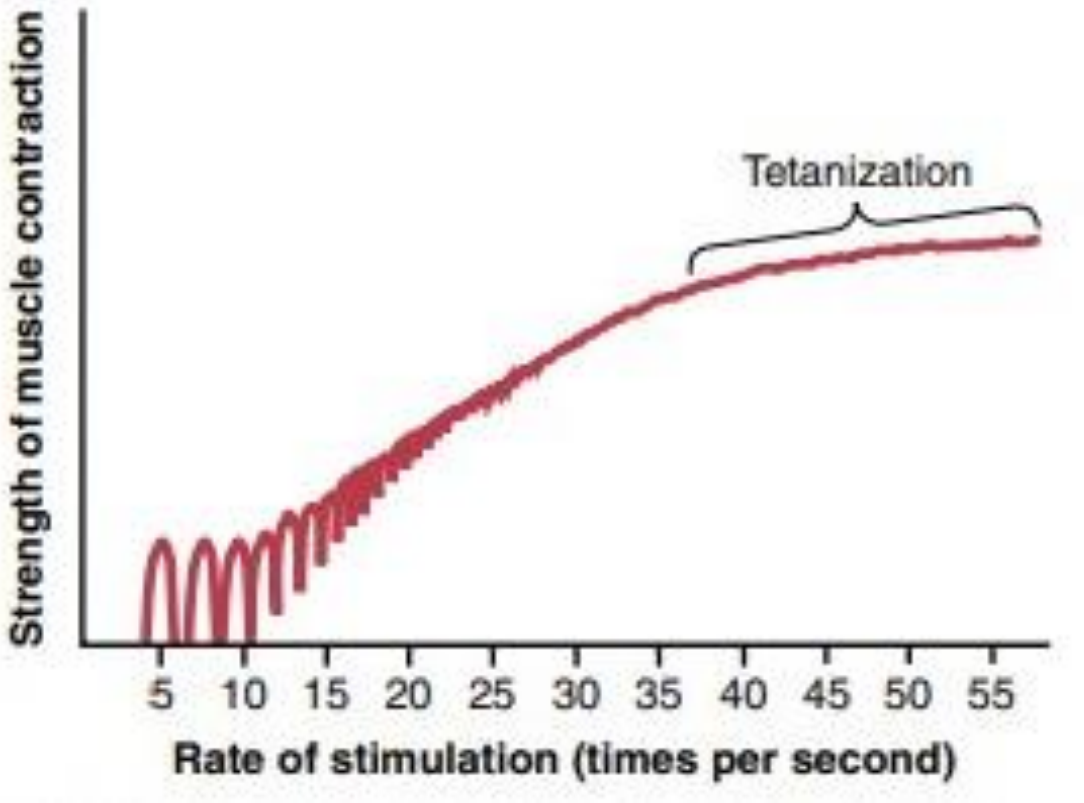
- **The summation of contraction**:

- It means **the adding together of individual twitch contractions** to increase the intensity of overall contraction. Because the contractile mechanism has no refractory period. **Repeated stimulation**, before relaxation can produce additional activation of the contractile elements . The response will be added to that already present, this is called **"summation of contraction**".

  It depends on the frequency of stimulation. It occurs in 2 ways:

  1 – By increasing the **number of motor units** contracting simultaneously, which is called **Multiple fiber summation**

  2 - By increasing the **frequency of contraction**, which is called **frequency summation** and can lead to **tetanization.** Tetany occurs because enough calcium ions are maintained in the muscle sarcoplasm.



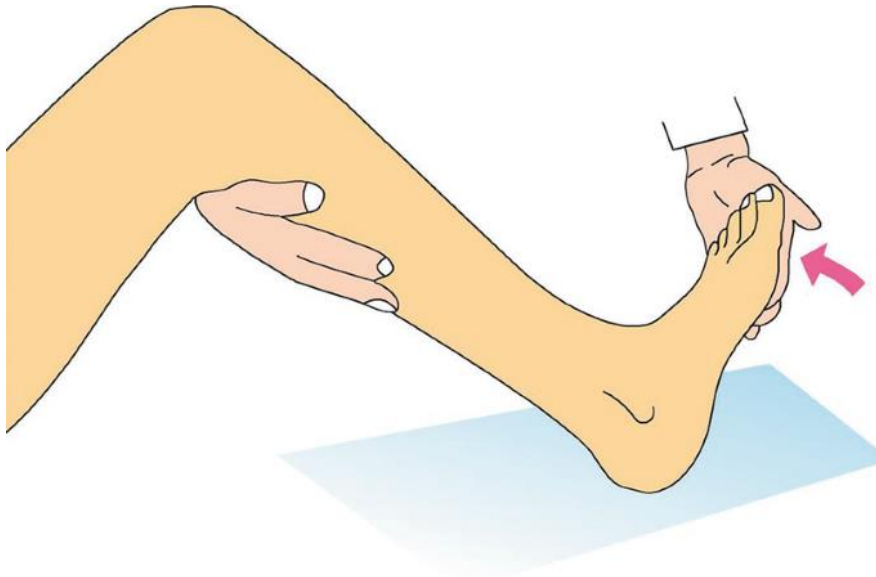


Frequency summation and tetanization

Tetanus



- If a lower frequency is used, there will be a period of incomplete relaxation between the summated stimuli; this condition is called **incomplete tetanization** or **clonus**.
- **Clonus is an abnormal reflex response that involves involuntary and rhythmic muscle contractions**. It happens in response to a brisk muscle stretch. **Damage to the nerves**, as in clonus, causes involuntary muscle contractions or spasms. It leads to muscle tightness and pain.

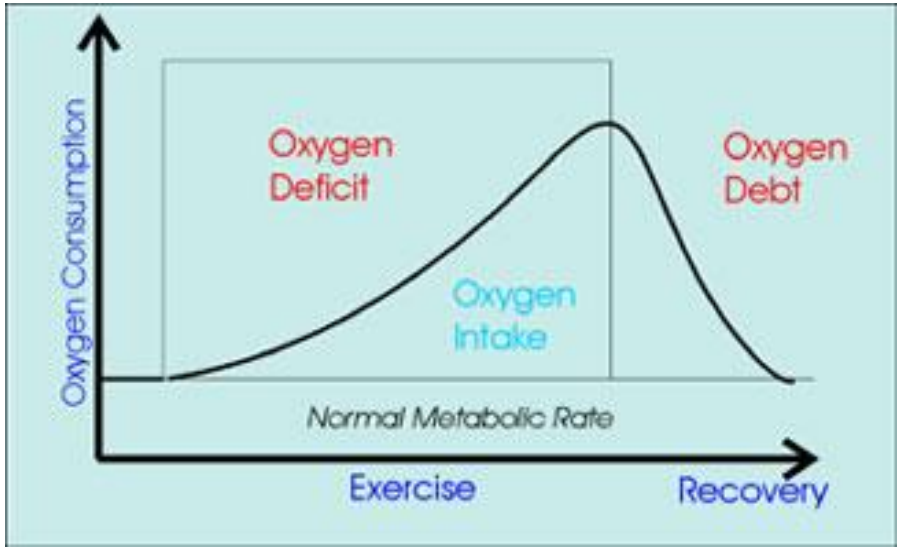




The oxygen debt mechanism

- During exercise the blood vessels dilates to provide enough O 2 for the muscle, the **energy is supplied by aerobic glycolysis**. If the exercise is severe or continues for longer periods, the **anaerobic glycolysis** contribute also to provide energy.

Because lactic acid will diffuse to the blood it will lower the PH ,accumulate in the muscle causing muscle exhaustion. **So after the exercise there will be a period of hyperventilation to produce the extra amount of O2 in order to remove the lactic acid** and to rebuild the storage of ATP.



The O2 debt when the demand for O2 is greater than the supply.

The amount of oxygen required to remove the lactic acid, and replace the body's reserves of oxygen, is called the oxygen debt.

Types of muscle fibers

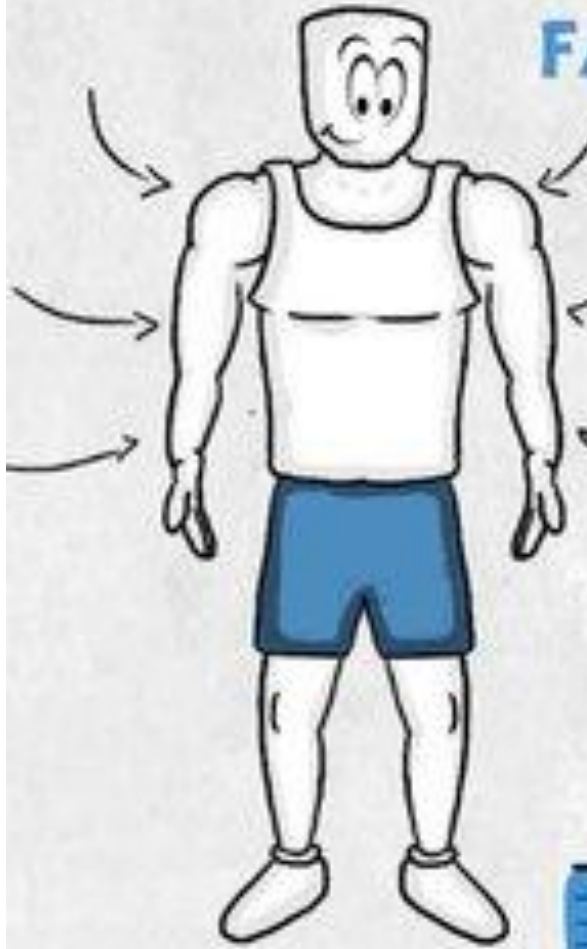
3 types according to the differences in enzyme activity, metabolism and contractile properties.

1- Type I fibers: these are darker than other muscles **called Red muscles** or the **slow fibers**, they respond slowly and have **longer duration of action (resist fatigue).** e.g. muscles in the back and in the lower limbs.

2- Type II b: **called the white muscles** or the **fast fibers**, they are innervated by large mylinated fibers, they have **short duration of action(fatigue quickly).** They are specialized for fine skilled movement e.g. muscles of the hand and the extra-ocular muscles.

3- Type II a: this is rare type in human, has properties **similar to type I**, and other properties to **type II**. (**Red and white**).

FAST TWITCH FIBERS



Type 2a or 2b

Anaerobic

Pale in Colour

Low blood supply

Fatigue rapidly

low number of capillaries

Low number of mitochondria

SPRINTER

↓

FAST TWITCH FIBERS



Fatigue rapidly



SLOW TWITCH FIBERS



Type 1

Aerobic

Red in Colour

High blood supply

Fatigue slowly

High number of capillaries

High number of mitochondria

MARATHONER

↓

SLOW TWITCH FIBERS



Fatigue slowly



PARALLEL COACHING

The motor units

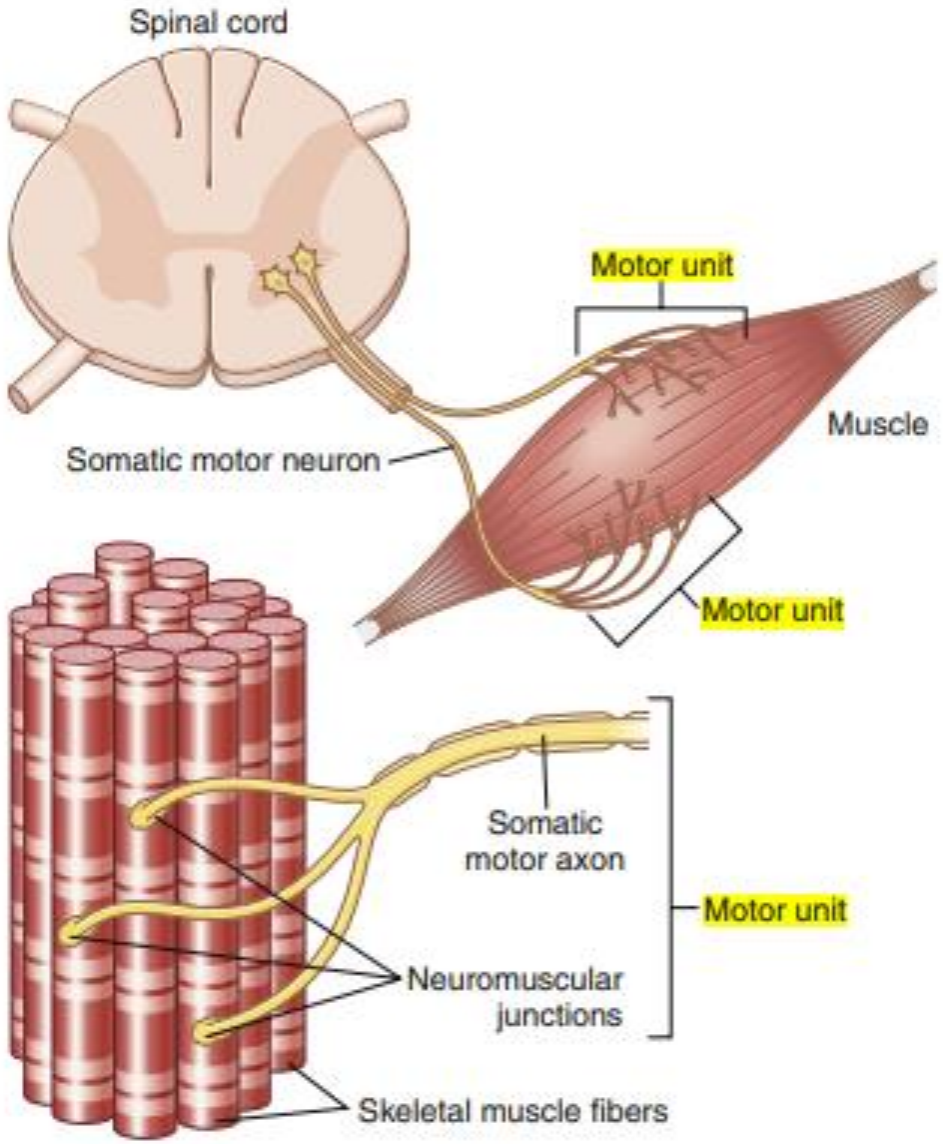
- All the muscle fibers innervated by a single nerve fiber are called a

motor unit.

There are **2 types** of motor units:

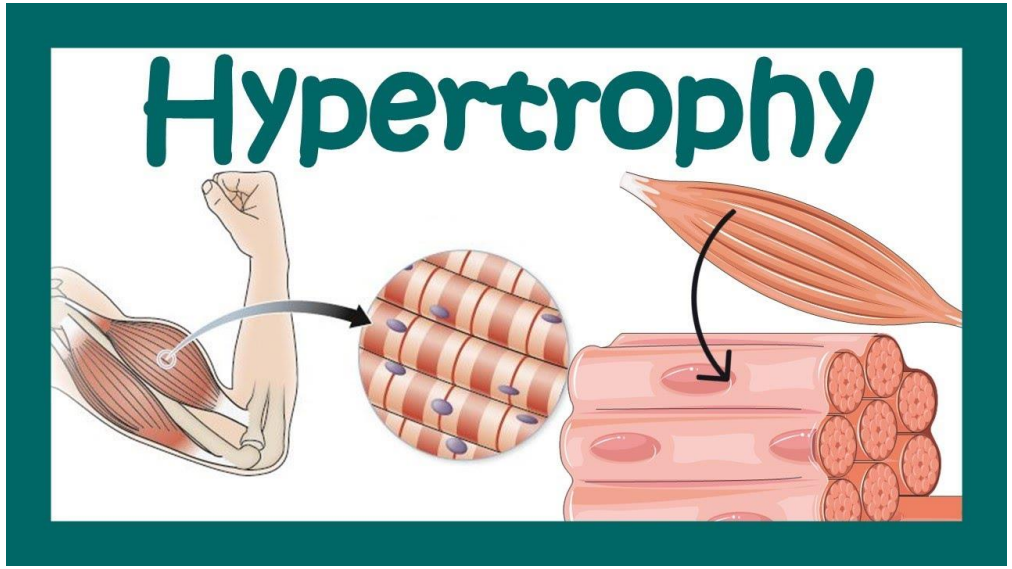
1- Small motor units: contain 3-6 muscle fibers, concerned with fine graded, precise movement, like movements of the hand.

2- Large motor units :contain usually 120-165 muscle fibers ,like muscles of the back. Do not need fine control.



Muscle Adaptation

- Muscle adaptations to exercise include morphofunctional modifications triggered by the repetition of muscular contraction bouts, leading to **increased mitochondrial biosynthesis** and **angiogenesis**, **fibers hypertrophy** and fundamental **changes in cell metabolism**, including increase lactate tolerance.





Abnormalities in muscle contraction

Denervation: Means the deprivation of muscles from the nerve supply ,the following will happen:

1- Immediate loss of muscular activity.

2- Abnormal excitability.

3- Atrophy of the muscle If after 2 months the nerve supply back, full return of function , but after 3 months the return back of muscle function is less.

Rigor: When the muscle fiber is completely depleted of ATP and phosphoryl creatinin, they develop a state of complete contraction causing increase rigidity after death because no ATP available for relaxation ,in this state **Rigor mortis**.

Muscle fatigue:

- **Depletion of glycogen stores in the muscle** (inability of the contractile and metabolic processes to continue supplying the same work) and decreased glucose in the blood.
- **Diminished transmission in the neuromuscular junction (NMJ)** .
- **Interruption of blood supply** or flow results in **nutrient and O2 deficiency**.
- **Depletion of phosphocreatine concentration**.
- **Accumulation of hydrogen (H+)** and changes in pH values.
- **Adenosine triphosphate (ATP) is the body's "molecular currency**," created during the Krebs cycle (also known as the citric acid cycle). ATP converts to adenosine diphosphate (ADP) and can only sustain a high-intensity movement for a few seconds. This timeframe can be extended using phosphocreatine. Phosphocreatine donates a phosphate group to convert ADP back to ATP, thereby extending the time the body can perform high-intensity exercise.

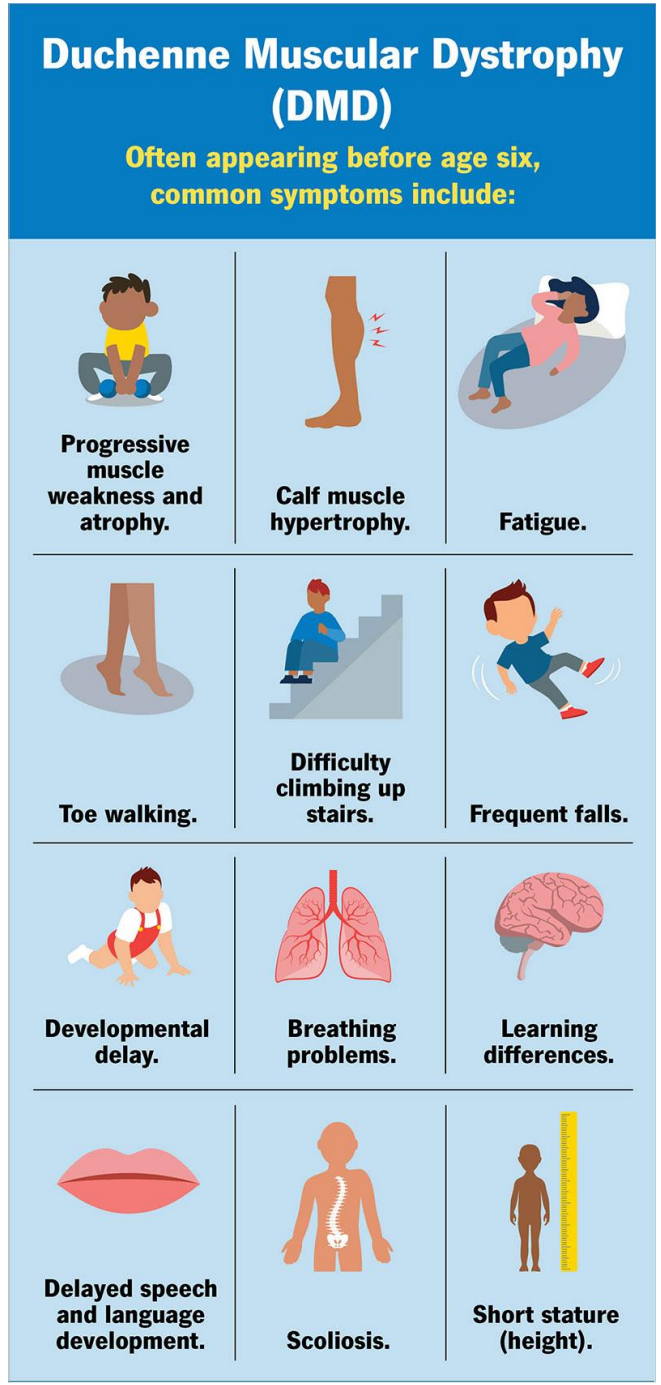
Muscular Dystrophy

- The muscular dystrophies include several inherited disorders that cause **progressive weakness** and **degeneration of muscle fibers**, which are replaced by fatty tissue and collagen. One of the most common forms of muscular dystrophy is **Duchenne muscular dystrophy (DMD).** This disease affects only males because it is transmitted as an **X-linked recessive trait**.









Thank You

