MSS

physiology

LEC no. 3

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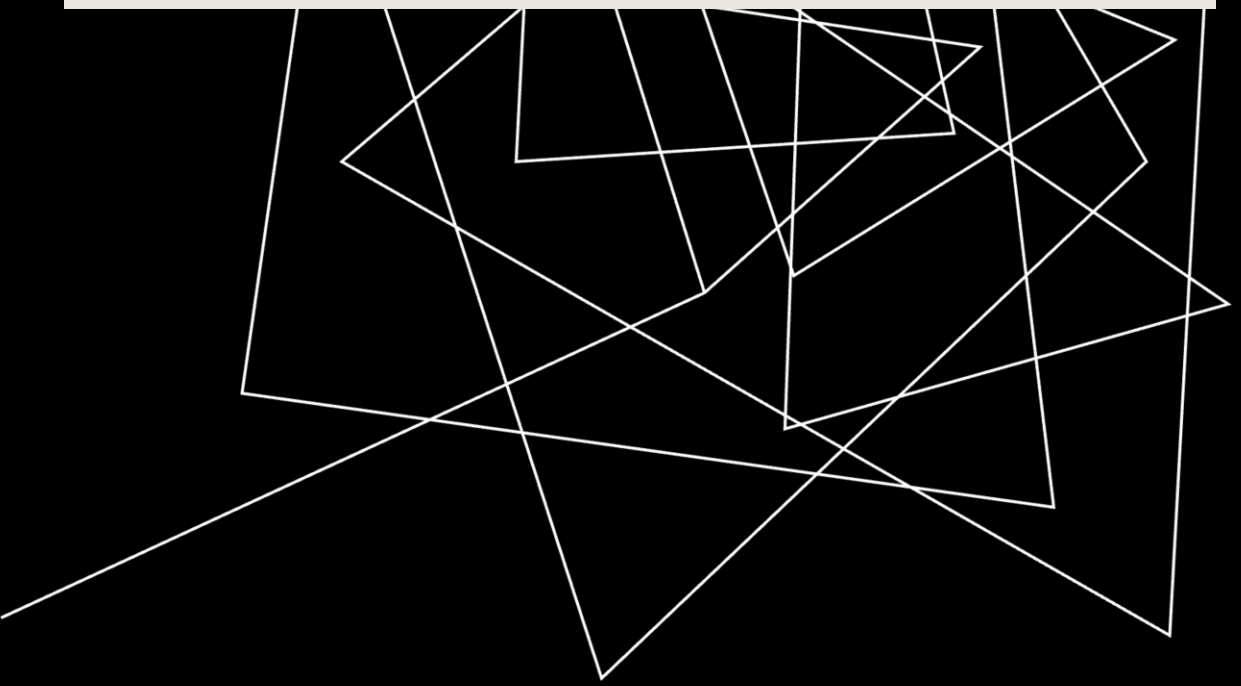
QUICK RECAP

last lecture we talked about:

muscle contraction cycle (mechanism at the molecular level / how does the skeletal muscle contract)

- contraction cycle
- thiory behind how these filament move(sliding filament mechanism)



المحاضرة لطيفة ان شاء الله🤞
بسم الله نبدأ....
😎 you can do it

Pay attention to the notes in yellow boxes and with **black font**, they are from the doctor's powerpoint notes, hence they are very important.

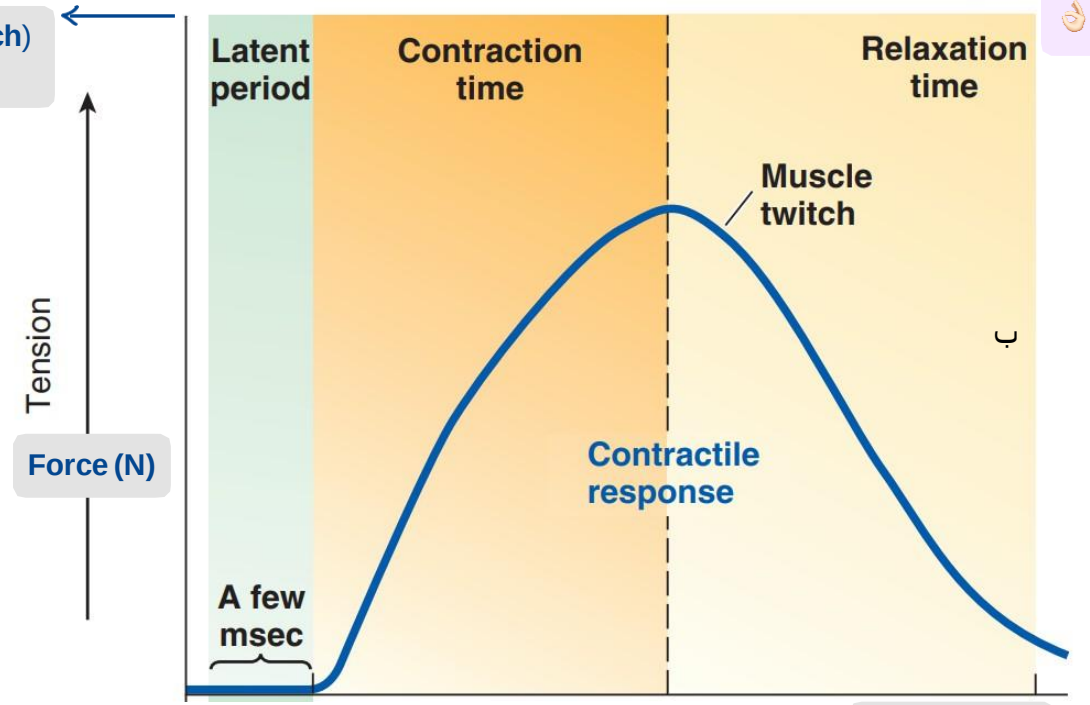
SKELETAL MUSCLE

Simple Muscle twitch

In this lecture we will talk about the whole muscle.

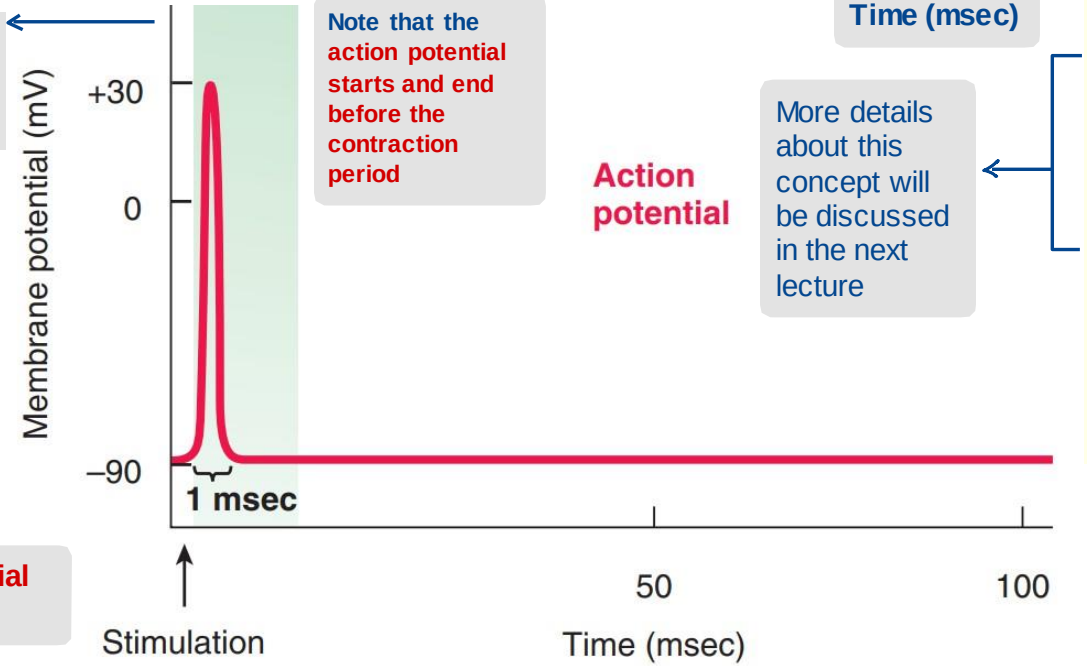
👌 الكلام طويل لكن اغلبه تفاصيل سابقة , الموضوع بسيط ان شاء الله

This graph shows (A Simple muscle twitch) and its a mechanical activity



This graph shows (the muscle action potential) , and it is an electrical activity.

Note that the action potential starts and end before the contraction period



More details about this concept will be discussed in the next lecture

In this picture we can notice that:
-The resting membrane potential of the skeletal muscle usually it is (-90).
-And then we have these action potential propagate through sarcolemma and then passing through T tubules until it reach terminal cisterna.

**All the muscle's action potential only take about (1 msec)

Note: 🌸
The onset of the resulting contractile response lags behind the action potential because the entire excitation-contraction coupling must occur before cross-bridge activity begins.
In fact, **the action potential is over before the contractile** apparatus even becomes operational.
This time delay of a few milliseconds between stimulation and onset of contraction is called the latent period
** the entire contractile response to a single action potential may last from 30 msec in fast contracting fibers(fast simple twitch)to 100 msec or more in slow contracting fibers (slow simple twitch).
This is much longer than the duration of the action potential that initiates contraction (30 to 100 msec as compared to 1 to 2 msec).

Even the fastest simple twitch still too slower than the muscle action potential.

In simple muscle Twitch usually we have what is called latent Period then the contraction time (phase) and then it is the relaxation time (phase).

Classification:

⭐**Latent period : it is the time that is happening from when the action potential reach and it release the calcium into Sarcoplasm and then starting the contraction cycle**

****Extra details from the previous lecture:** 📋

We have a stimulus … will cause > release of the acetylcholine into the Neuromuscular junction
… then the acetylcholine will bind to the> acetylcholine receptor that found in the motor end plate
… opening of these channels will allow >Na+ influx
… making muscle membrane potential more positive (Depolarization)
… this depolarization wave can separate until it reach > voltage gated Na+ channel
…Opening of voltage gated Na+ channel well cause> action potential
…This action potential will propagate through Sarcolemma also through T tubules until reaching terminal cisterna > they will find voltage gated calcium channel (dihydropyridine)
…the confirmational change of the dihydropyridine will cause > its moving away from Ca+2_release channel (foot protein/ ryanodine receptor)
… then the calcium ions will move from terminal cisterna to sarcoplasm > until it bind to troponin
… so will do a confirmational changes pulling the tropomyosin > exposing the myosin binding sites
… then we will start >(cross bridging) ⚡

All of this occurs during the latent period. Please note that the action potential starts and ends before muscle contraction begins.

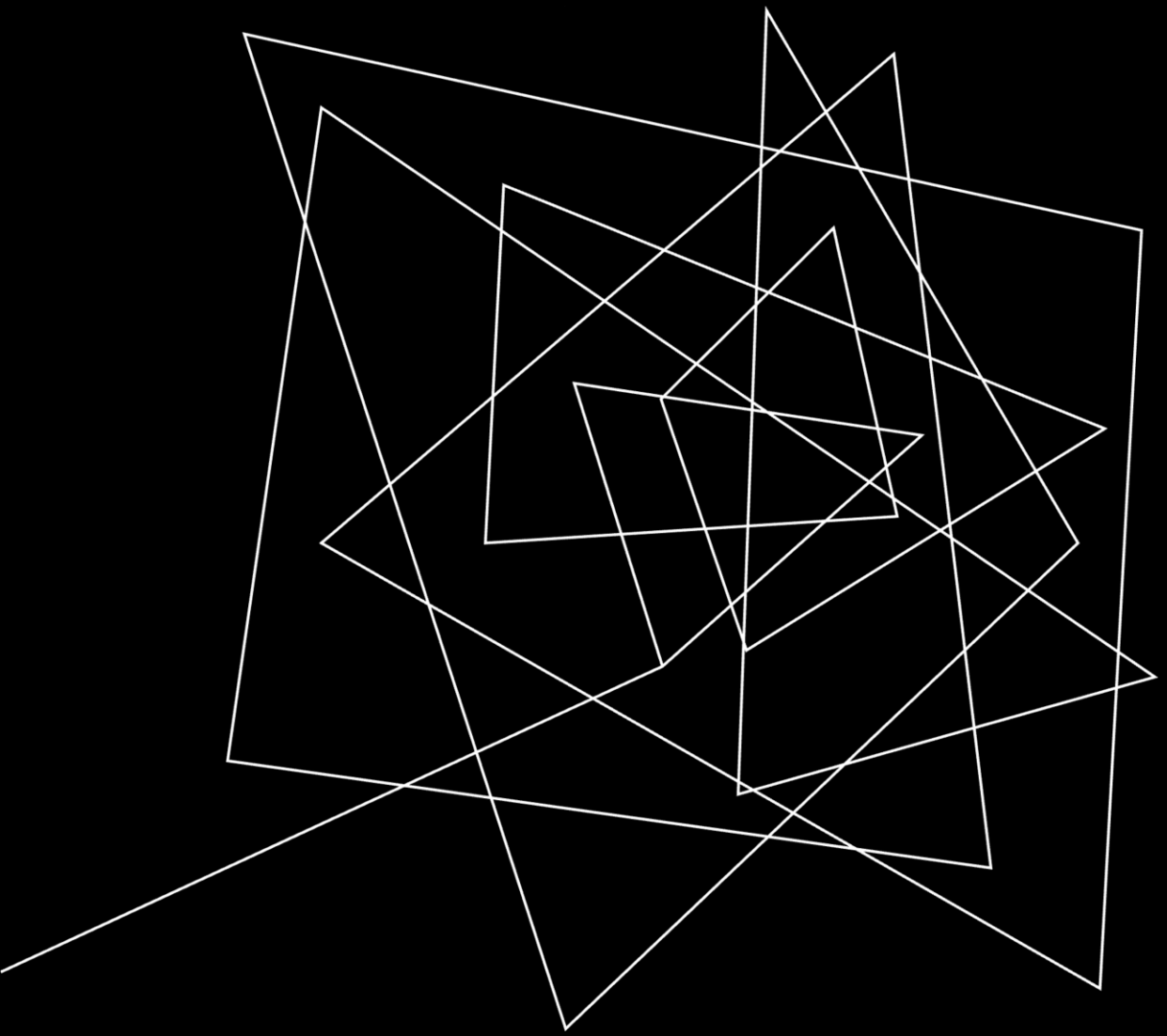
⭐**Contraction period:**

The contraction increases as long as - the Ca+2 level is increasing

⭐**Relaxation period:**

Pumping back the Ca+2 to the sarcoplasmic reticulum through Ca+2 _pumb > the Ca+2 level will decrease
Decreasing the ca+2 level > will reverse the whole contraction mechanism
Tropomyosin will again cover the myosin binding site……(the relaxation time)

Easy isn't it !! 👏🏻



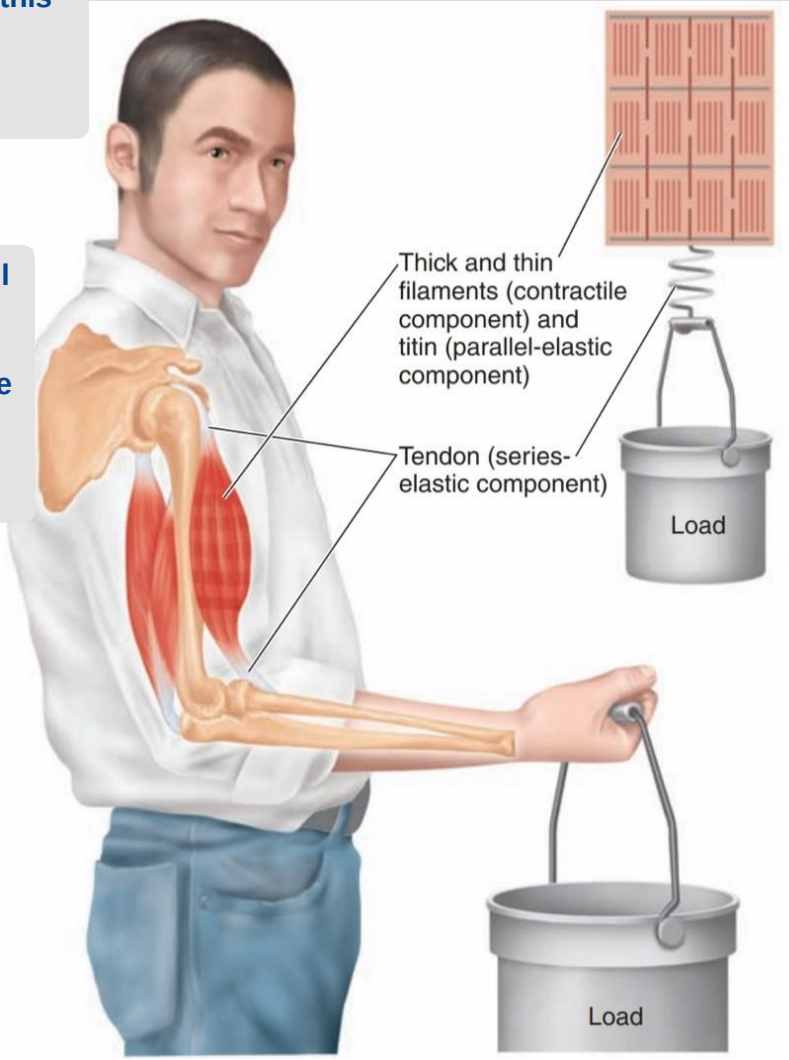
SKELETAL MUSCLE MECHANICS

Note: 🌸
Tension is produced **internally within the sarcomeres**, considered the contractile component of the muscle, as a result of cross-bridge activity and the resulting sliding of filaments.

Once we have an interaction Between actin and Myosin filaments within the sarcomere…> this will create a tension
… this tension that develop in the muscle > usually it will affect the insertion site

Muscle tension is transmitted to bone as the contractile component tightens the series-elastic component.

The event that occurs in the sliding filament mechanism…will result in> *developing of a muscle tension.*
When we are talking about the whole muscle contraction, it won't be only about the sarcomere shortening, this should be also transmitted to the: surrounding connective tissue& the tendon (thats happen if I can move the load, then this should be a higher power to be able to lift the load)



The series-elastic component behaves like a stif f spring (the tendon) placed between the internal tension generating elements (the muscle) and the bone that is to be moved against an external load (insertion point), or opposing force.

Note that because **muscle contraction can only pull and not push bone**, two different antagonistic muscles or muscle groups are situated to pull on opposite sides of the joint.
For example, the biceps can pull the joint in one direction (flexion) and the triceps can pull the joint in the other direction (extension).

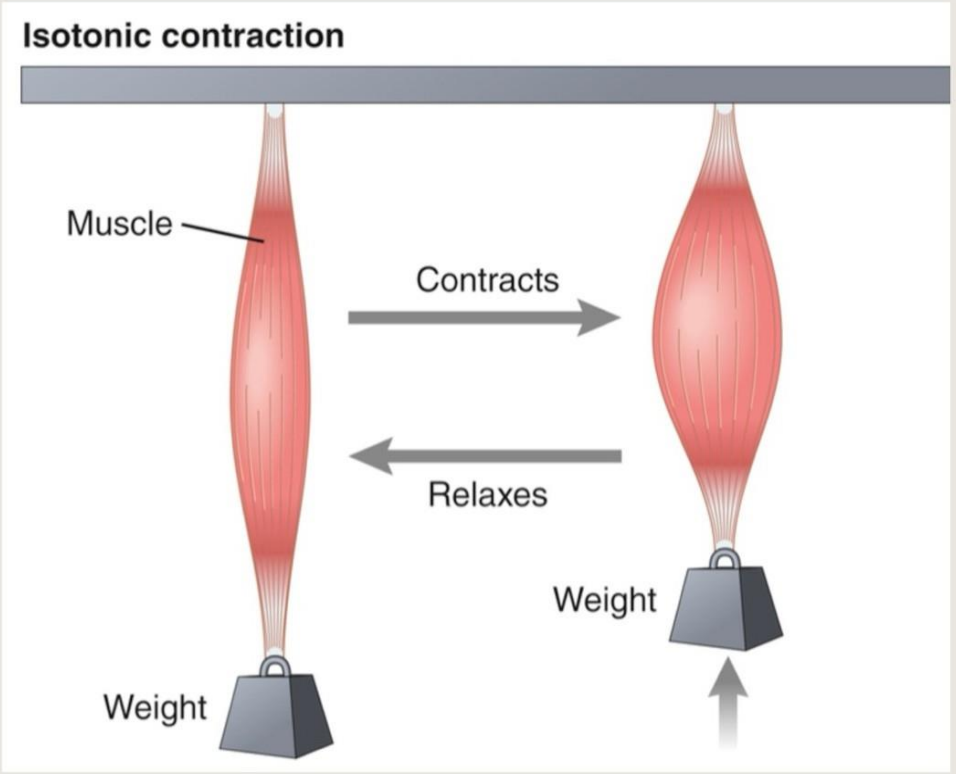
-Muscles contraction happens only when the insertion site got pulled toward the origin (can't contract by pushing),so we will be able to lift a load or something

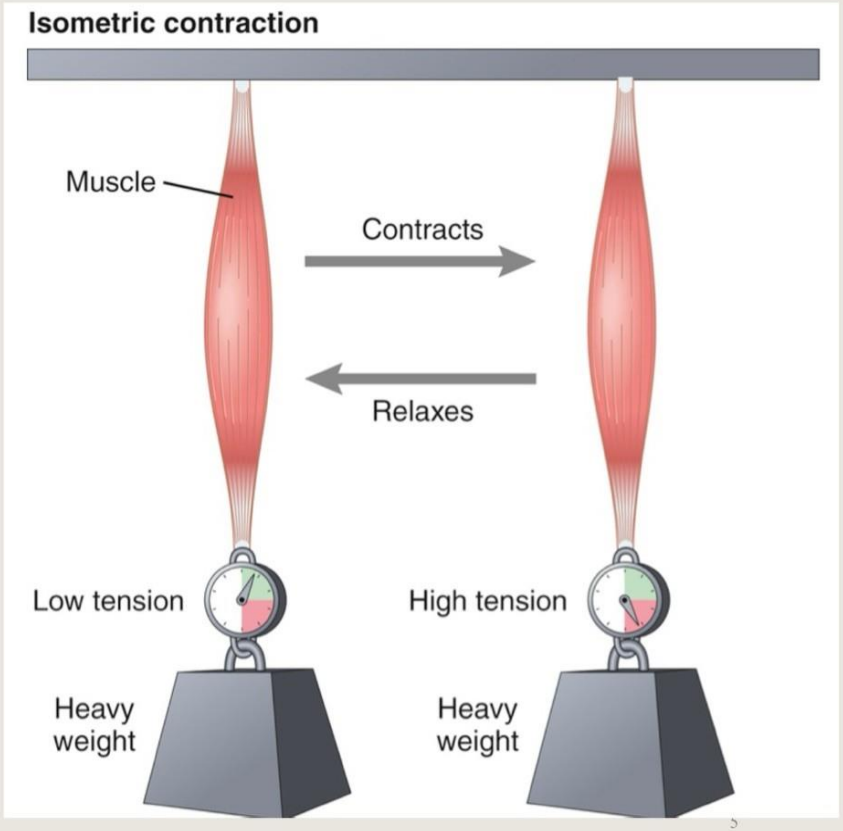
We can classify the contraction into 2 different kinds
➡️ The first way is (Isotonic vs Isometric)
** when there is no movement**

TYPES OF CONTRACTION

We have 2 varieties that could change:
-The tone
&
-The distance
(If one changes the other one will stay constant)

Isotonic refers to = same weight





Note: 🌸
Not all muscle contractions shorten muscles and move bones.

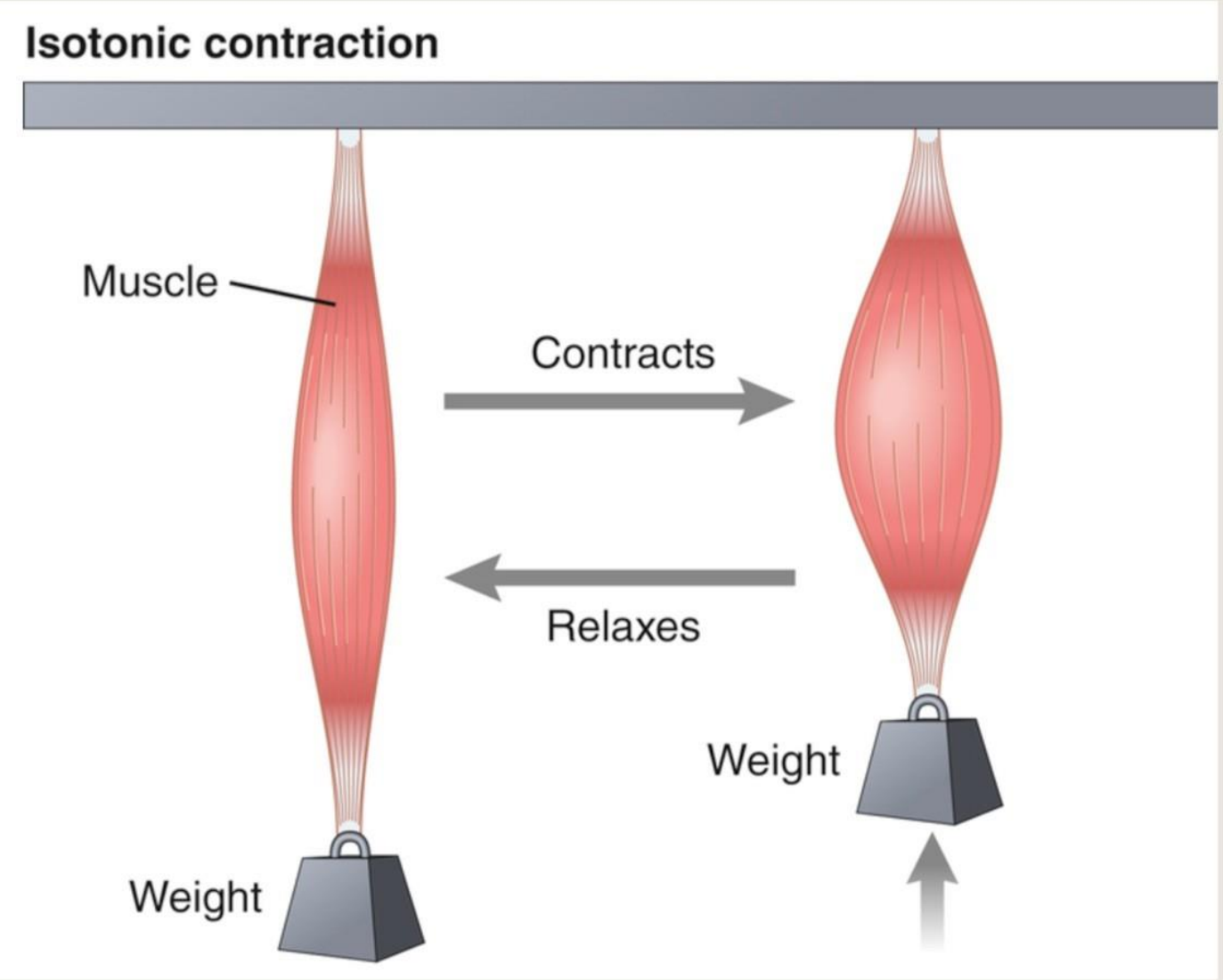
** For a muscle to shorten during contraction, **the tension developed in the muscle must exceed the forces that oppose movement of the bone to which the muscle's insertion is attached**.

💡 The variable that would change is :
Metric (distance)

We call it Isotonic contraction ; As you're able to move the load.

TYPES OF CONTRACTION

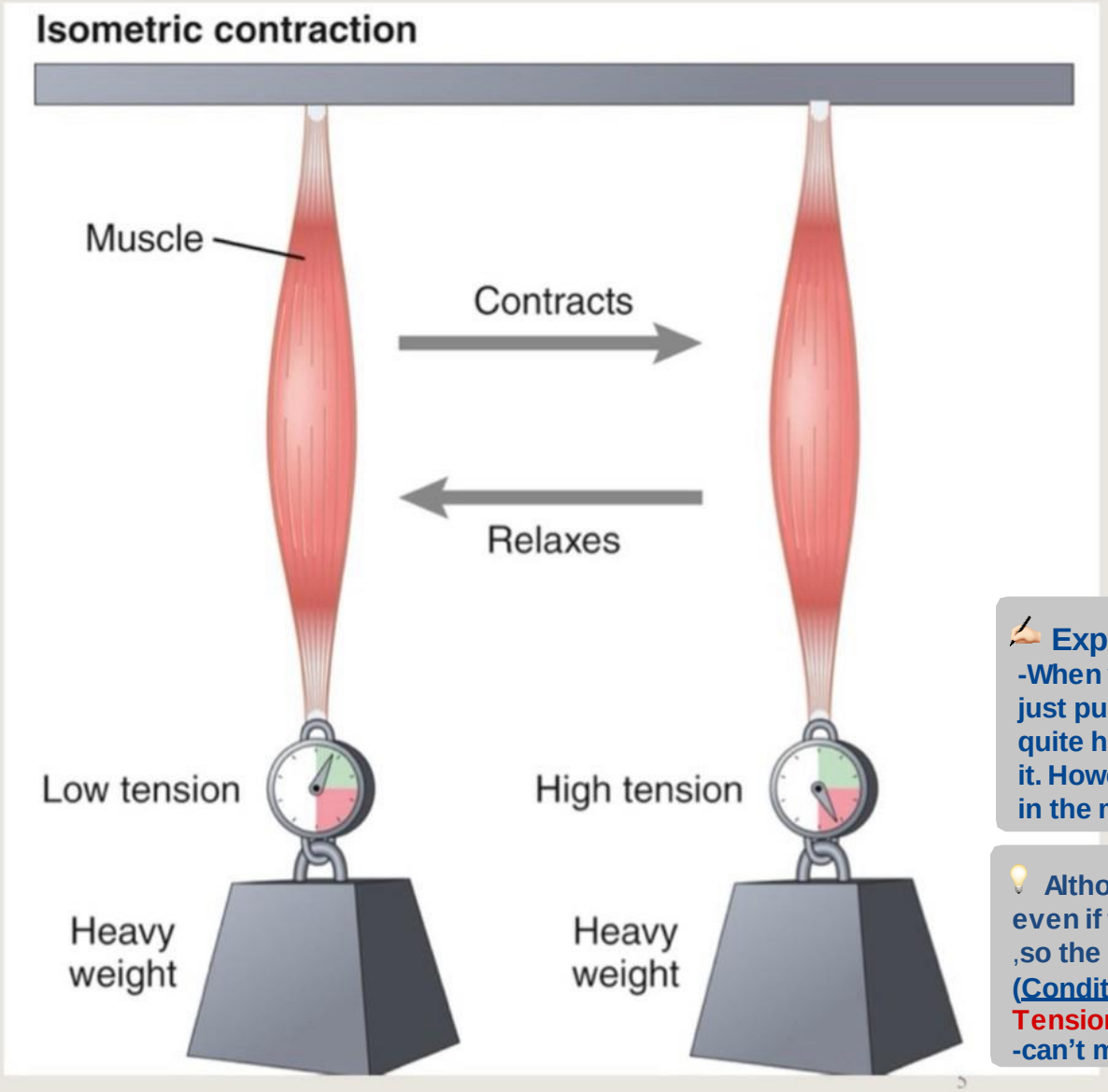
When you have a weight or a load that you can actually move it from place to another



Note:🌸
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.

💡Sarcomeres will shorten and overlap, and because we can move the load ->we will have a visible shortening of the the whole muscle

TYPES OF CONTRACTION

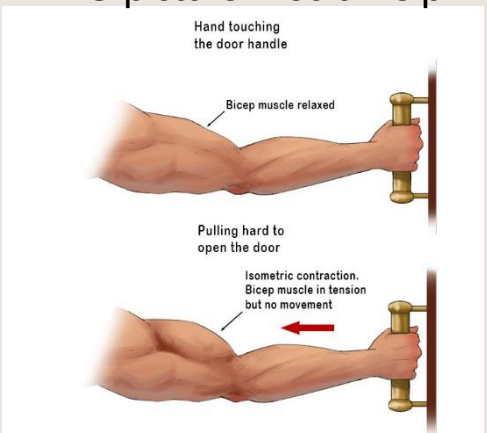


Note:🌸
Isometric contraction occurs when the load is greater than the force of the muscle contraction; the muscle creates tension when it contracts **(its maximally contracted)**, but the overall length of the muscle does not change.**(as we couldn't pull the insertion towards the origin)**

💪 **Explanation:**
-When you have a very heavy weight (ex: if you're just pushing the wall or trying to lift something quite heavy from the ground) that you can't move it. However you can see an increase in the tension in the muscle

💡 **Although the sarcomere shortening will occur and even if the filaments slide, you can't pull the tendon ,so the muscle as a whole does not shorten.**
(Condition) To be able to pull the tendon:
Tension > load weight
-can't move the object-> can't pull the tendon

This picture would help

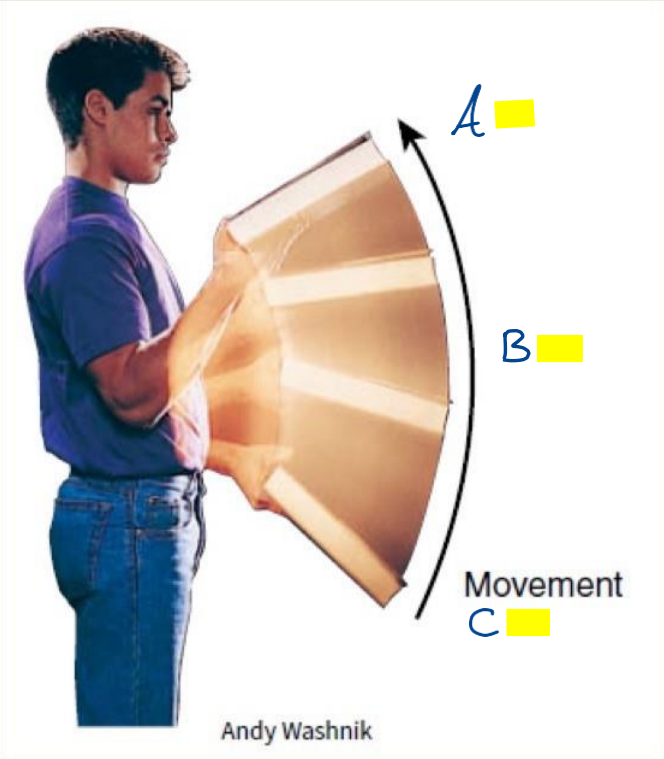


⬆️weight->⬆️the tension to move it

Stop at: Maximally contracted muscle: all the muscle fibers are contracted in their maximum length

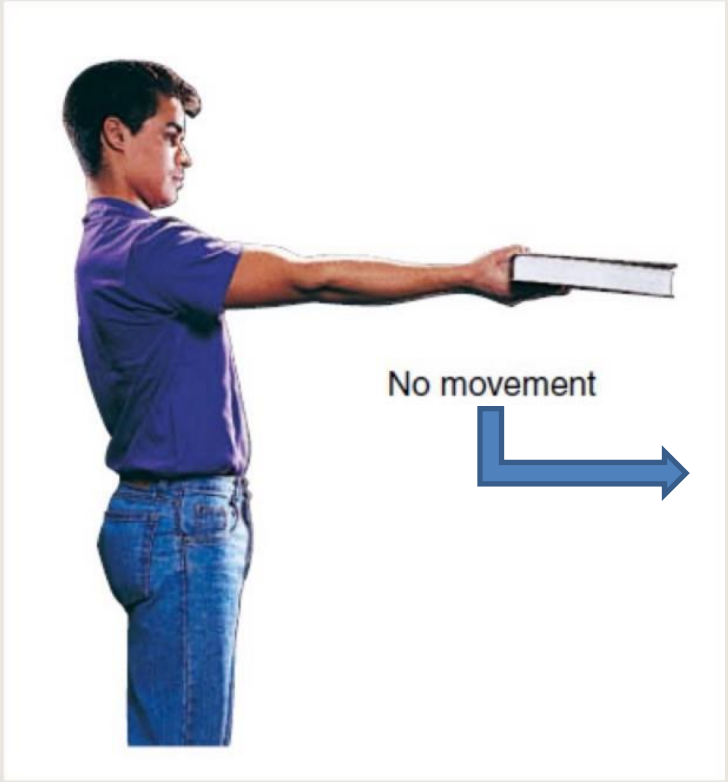
TYPES OF CONTRACTION

***The same book and we were able to move it**



Isotonic contraction

We consider it this way according to (Guyton) book,although it's definitely not accurate as tension in A ≠tension in B≠ tension in C ,we still call it isotonic contraction for simplification porpoises



Isometric contraction

The contraction would be isometric in 2 cases:

-the load is too heavy than the tension that developed in the muscle (can't move it)

-Intentionally holding an object with no movement(🧠يقولك).

Note:🌸

Submaximal isometric contractions are important for maintaining posture (such as keeping the legs stiff while standing) and for supporting objects in a fixed position (such as holding a beverage between sips).

Sub-maximal contraction is

Important in the postures of the spine to hold up the neck (it's called tone)

💡We don't have a complete overlap between Actin and myosin filaments, even if we have a complete interaction between them in certain fibers (The muscle is composed of thousands of fibers, so some of these fibers will be contracted, and the other will be like resting in the same muscle) .

***For example:**

when you hold an object not all the biceps Fiber will work, but if you increase the weight of the object you might reach your biceps maximum contraction level in it's all fibers and sarcomeres … according to your tolerance> you will finally get tired and your muscle well reach fatigue level .(more details about this in next lecture)

We can classify the isotonic contraction into 2 different kinds:

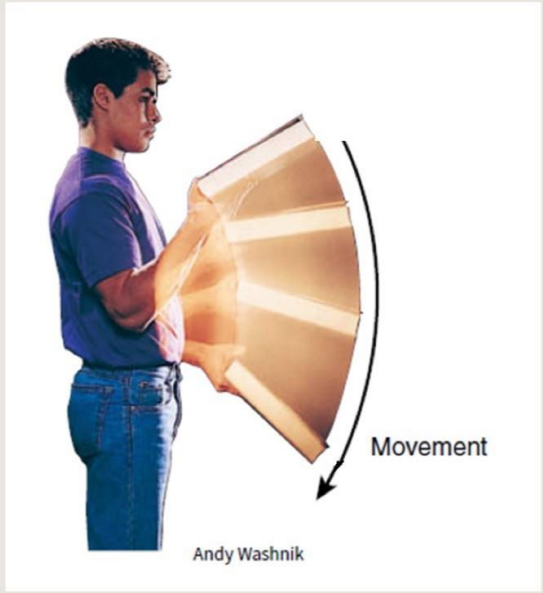
➡️ concentric & eccentric

** depending on the direction of movement**

TYPES OF CONTRACTION

Concentric contraction

⭐In this way, we will have:
- shortening of biceps



Eccentric Contractions

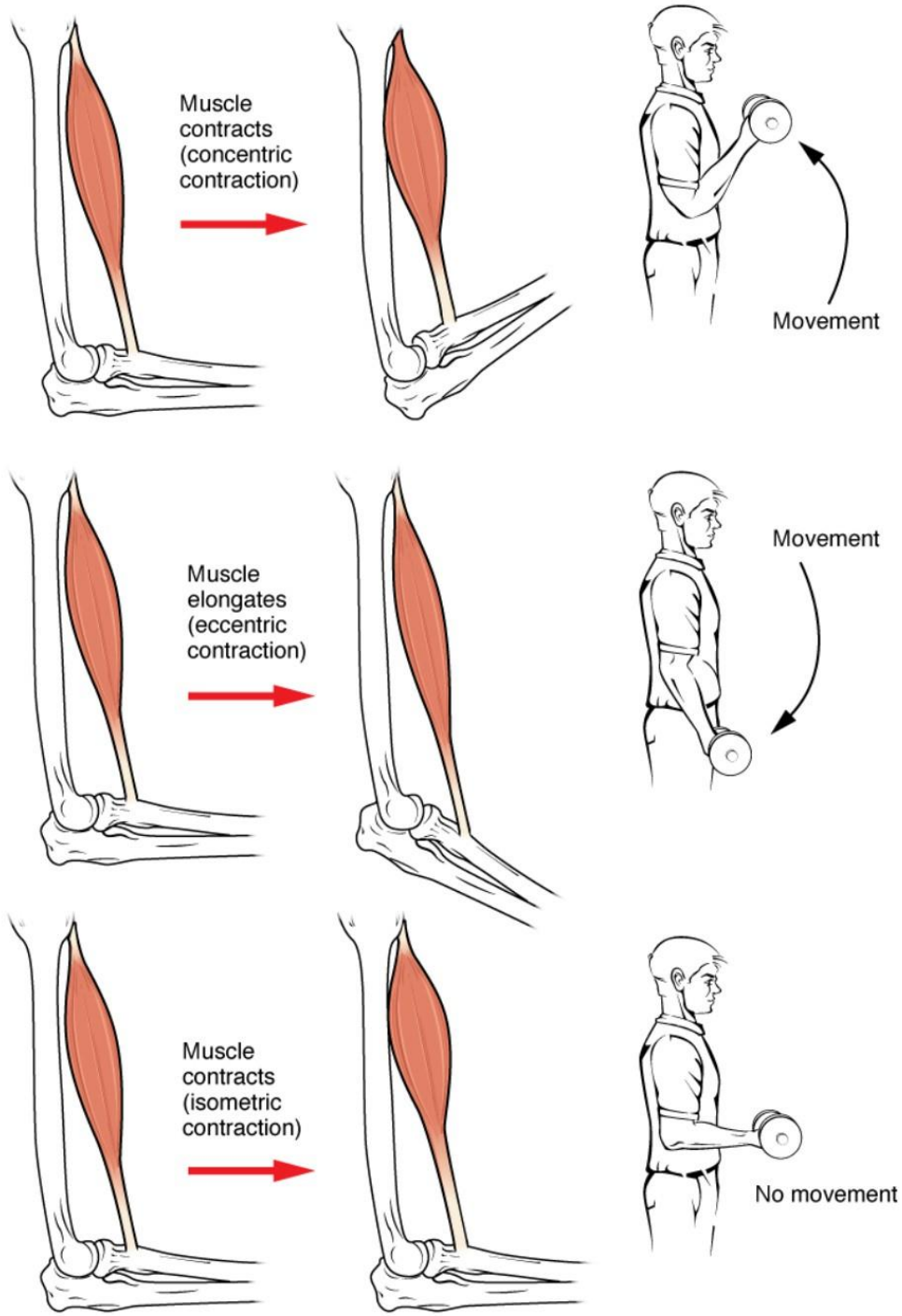
⭐In this way we will have:
- lengthen of biceps
-shortening of triceps

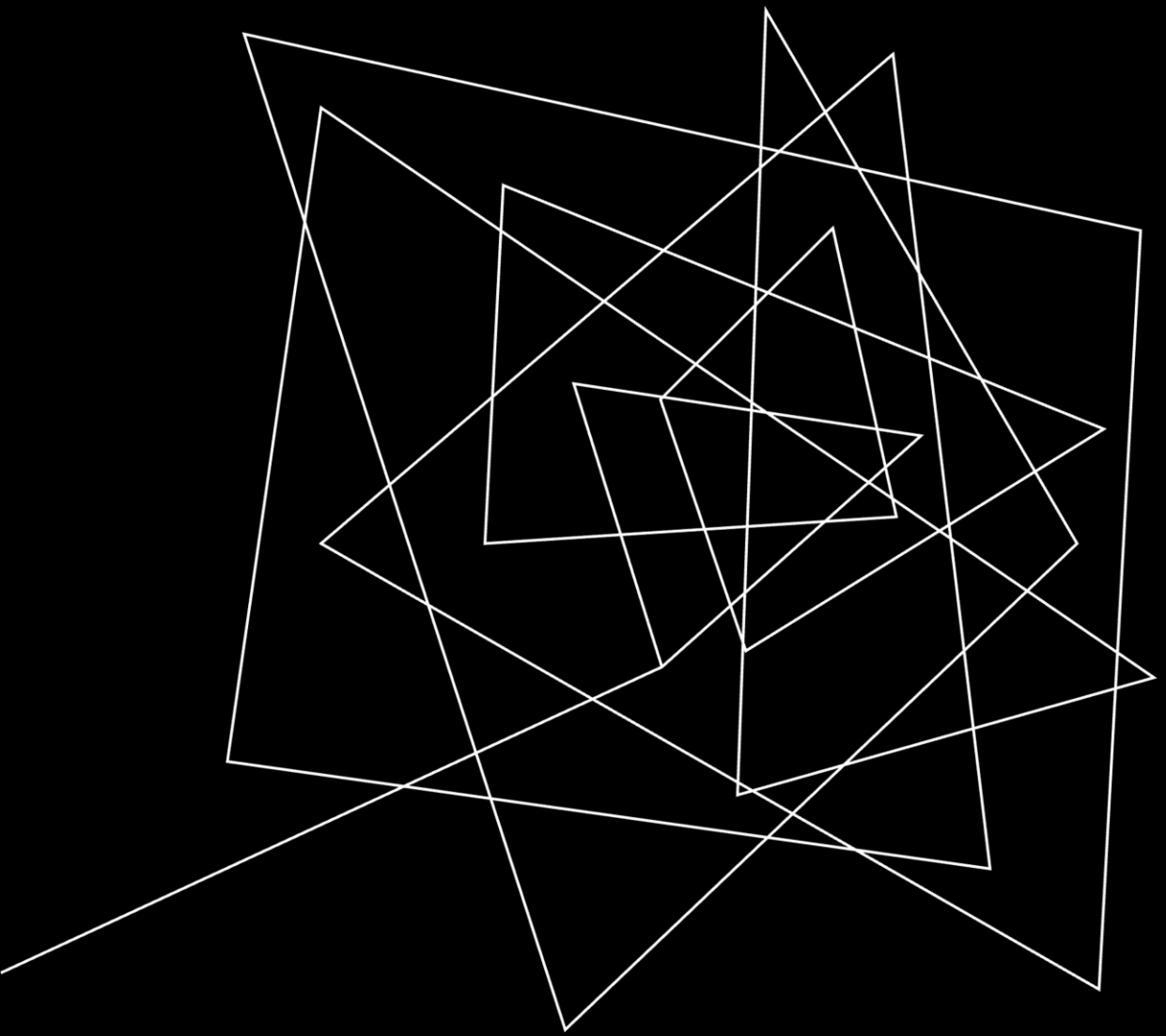
Note:🌸

There are also two other descriptors of muscle contraction —concentric and eccentric.

In concentric contractions the muscle shortens, whereas with eccentric contractions the muscle lengthens.(but we still could feel some tension -to overcome this movement-until it reach it's relaxed position)

An example of an eccentric contraction is lowering a book to place it on a desk. During this action, the muscle fibers in the biceps are lengthening but are still actively contracting in opposition to being passively stretched by the load. The contraction itself does not lengthen the muscle; **the contraction is resisting the stretch of the muscle imposed externally by the weight of the book.**


Muscle contracts (concentric contraction)
Movement
Muscle elongates (eccentric contraction)
Movement
Muscle contracts (isometric contraction)
No movement



CONTRACTIONS OF A WHOLE MUSCLE CAN BE OF VARYING STRENGTH

Contractions of a whole muscle can be of varying strength

How can I increase muscle contraction(strength)?

A. The number of muscle fibers contracting within a muscle

- Extent of motor unit recruitment

كم عدد الخلايا

B.The tension developed by each contracting fiber.

- 1. Frequency of stimulation
- 2. Length of the fiber at the onset of contraction
- 3. Extent of fatigue
- 4. Thickness of the fiber

مقدار ال tension في كل خلية

Note:🌸
The two main factors subject to control to accomplish gradation of contraction are **the number of motor units stimulated and the frequency of their stimulation**.
The areas of the **brain** that direct motor activity combine tetanic contractions and precisely timed shifts of asynchronous motor unit recruitment to execute smooth rather than jerky contractions

The frequency of stimulation and the muscle length at onset of contraction-can vary from contraction to contraction. Other determinants of muscle fiber tension —how resistant the muscle fiber is to fatigue and how thick the fiber is— do not vary from contraction to contraction but depend on the fiber type and can be modified over time

The green neuron makes different neuromuscular junction with 3 muscle fibers. Purple one with 2 muscle fibers and These are all from the same muscle

Motor Unit

A motor unit consists of a somatic motor neuron plus all of the skeletal muscle fibers it stimulates.

Stimulation of the green nerve will produce action in the fibers that innervated by it.

Skeletal muscles are composed of different motor units, and this will allow the separate stimulation of each motor.

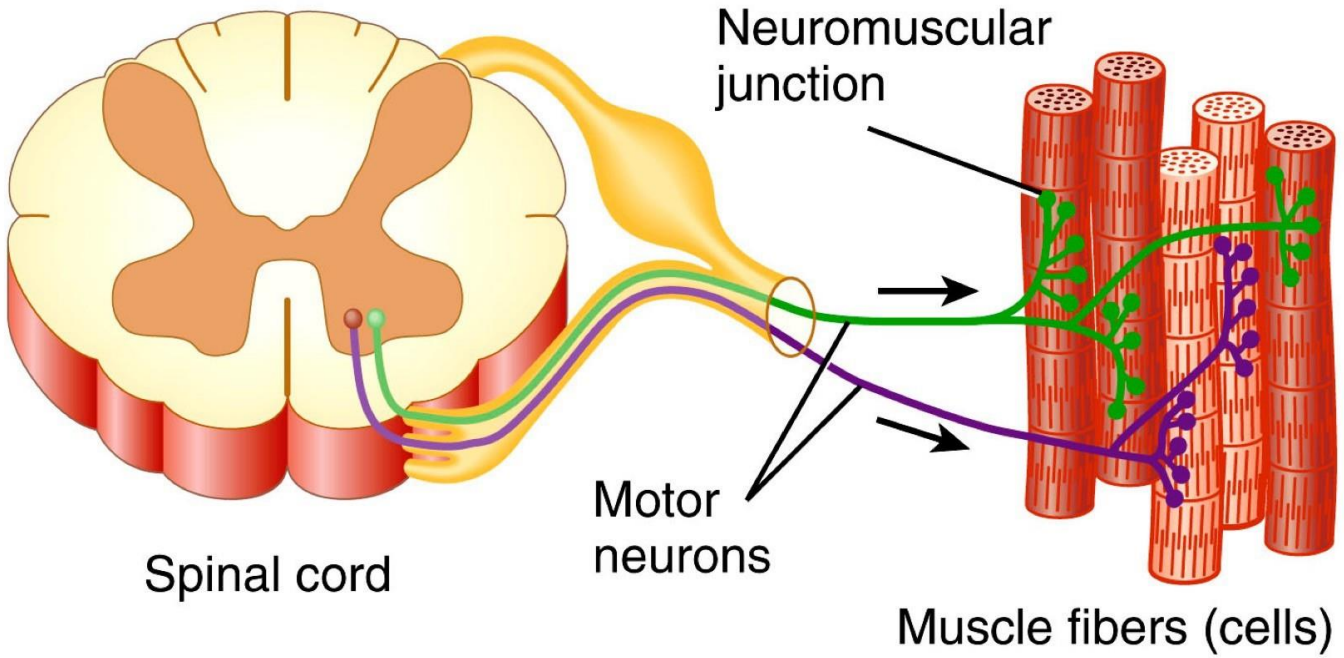


Figure 10.13 Tortora - PAP 12/e

Note:

When a motor neuron enters a muscle, it branches, with each axon terminal supplying a single muscle fiber.

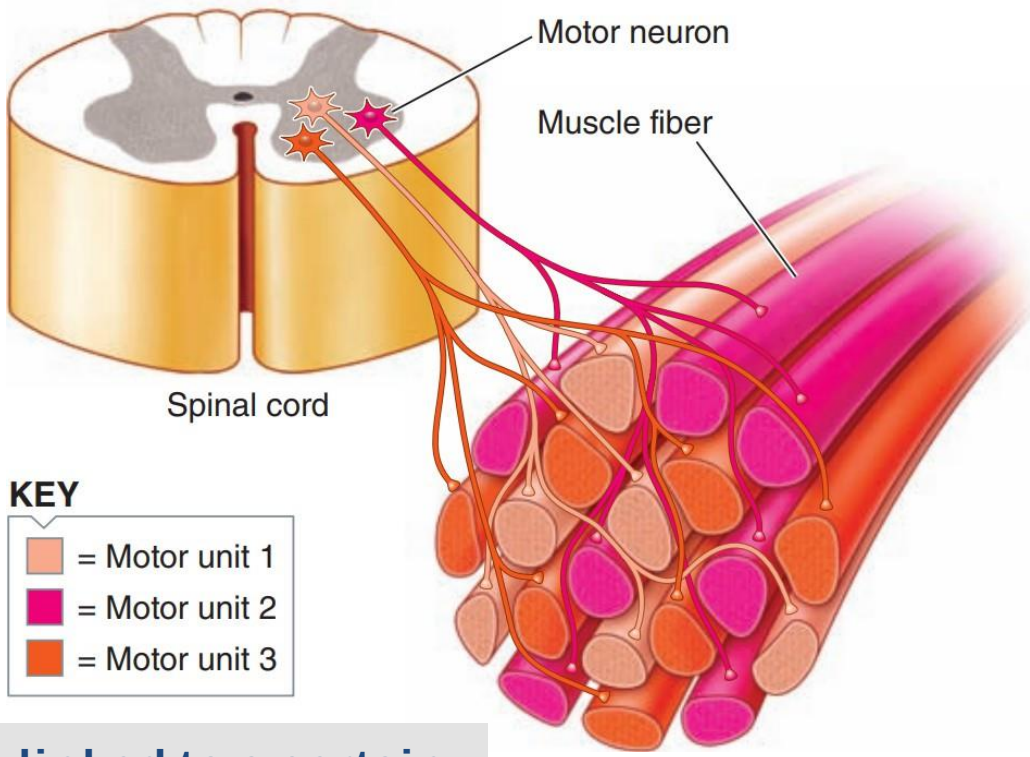
**Typically, the muscle fibers of a motor unit are dispersed throughout a muscle rather than clustered together.

* simultaneous contraction results in an evenly distributed, although weak, contraction of the whole muscle.

Motor Unit

- **The greater the number of fibers contracting, the greater the total muscle tension.**

- **For a weak contraction of the whole muscle, only one or a few of its motor units are activated. For stronger and stronger contractions, more and more motor units are recruited, or stimulated to contract simultaneously, a phenomenon known as motor unit recruitment.**



↑Muscle recruitment →↑number of the muscle fibers that are contract →↑total muscle tension

Each motor neuron is linked to a certain number of muscle fibers, depending on when you need a precise movement. Do you think the number of muscle fibers for each neuron will be less or more in precise movement? Of course less

Motor Unit

Note:

For muscles that produce **precise, delicate** movements, such as external eye muscles and hand muscles, a single motor unit may contain as **few as a dozen muscle fibers**. **muscle recruitment in these muscles will cause small increase in tension.** Because so few muscle fibers are involved with each motor unit, **recruitment** of each additional motor unit **adds only a small increment** to the whole muscle's strength of **contraction**. These small motor units allow fine control over muscle tension.

In contrast, in muscles designed for powerful, coarsely controlled movement, such as those of the legs, a single motor unit may contain 1500 to 2000 muscle fibers. Recruitment of motor units in these muscles results in large incremental increases in whole-muscle tension. More powerful contractions occur at the expense of less precisely controlled gradations. **muscle recruitment in these muscles will cause high increase in tension.**

** **Thus, the number of muscle fibers participating in the whole muscle's total contractile effort depends on the number of motor units recruited and the number of muscle fibers per motor unit in that muscle.**

MUSCLE TONE

- A small amount of tension in the muscle due to weak contractions of motor units.
- **Submaximal contraction.(shifts between motor units)**
- Small groups of motor units are alternatively active and inactive in a constantly shifting pattern to sustain muscle tone.
- Muscle tone keeps skeletal muscles firm.
- Keep the head from slumping forward on the chest.
- Delay or prevent fatigue in submaximal contractions (Asynchronous recruitment)

MUSCLE TONE

Note: 🌼
Even when muscles are at rest, a certain amount of tautness usually remains, called muscle **tone**. Because normal skeletal muscle fibers do not contract without an action potential to stimulate the fibers, skeletal muscle tone results entirely from a low rate of nerve impulses coming from the spinal cord.
These nerve impulses, in turn, are controlled partly by signals transmitted from the brain to the appropriate spinal cord anterior motoneurons and partly by signals that originate in muscle spindles located in the muscle.

To delay or prevent fatigue (inability to maintain muscle tension at a given level) during a sustained contraction involving only a portion of a muscle's motor units, as is necessary in muscles supporting the weight of the body against the force of gravity, **asynchronous recruitment** of motor units takes place. The body alternates motor unit activity, like shifts at a factory, to give motor units that have been active an opportunity to rest while others take over. Changing of the shifts is carefully coordinated, so the sustained contraction is smooth rather than jerky.
Asynchronous recruitment is possible only for submaximal contractions, during which only some of the motor units must maintain the desired level of tension. During maximal contractions, when all muscle fibers must participate, it is impossible to alternate motor unit activity to prevent fatigue. This is one reason you cannot support a heavy object as long as you can support a light one.

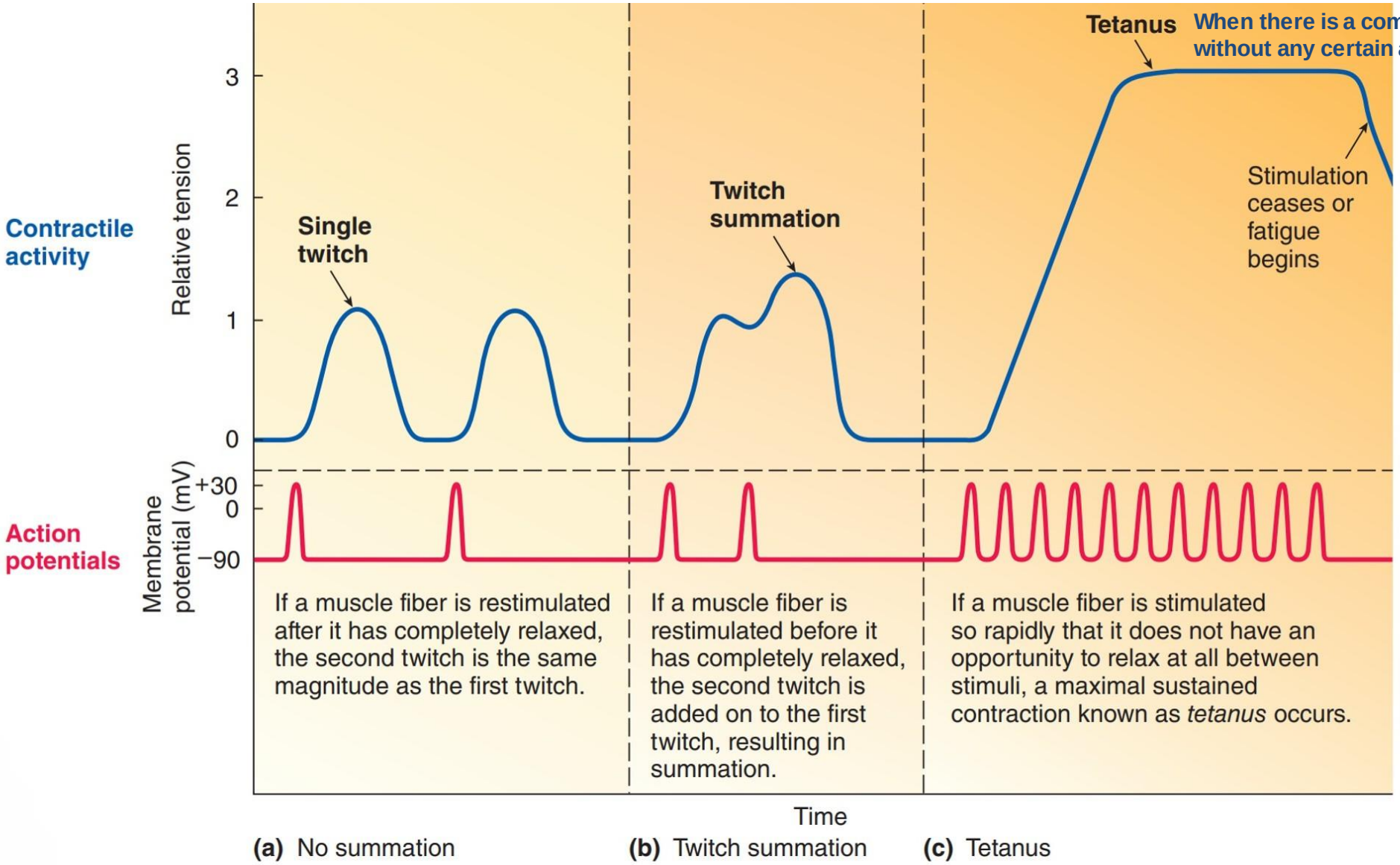
Contractions of a whole muscle can be of varying strength

A. The number of muscle fibers contracting within a muscle

- Extent of motor unit recruitment

B.The tension developed by each contracting fiber.

- 1. Frequency of stimulation
- 2. Length of the fiber at the onset of contraction
- 3. Extent of fatigue
- 4. Thickness of the fiber



Note: 🌸

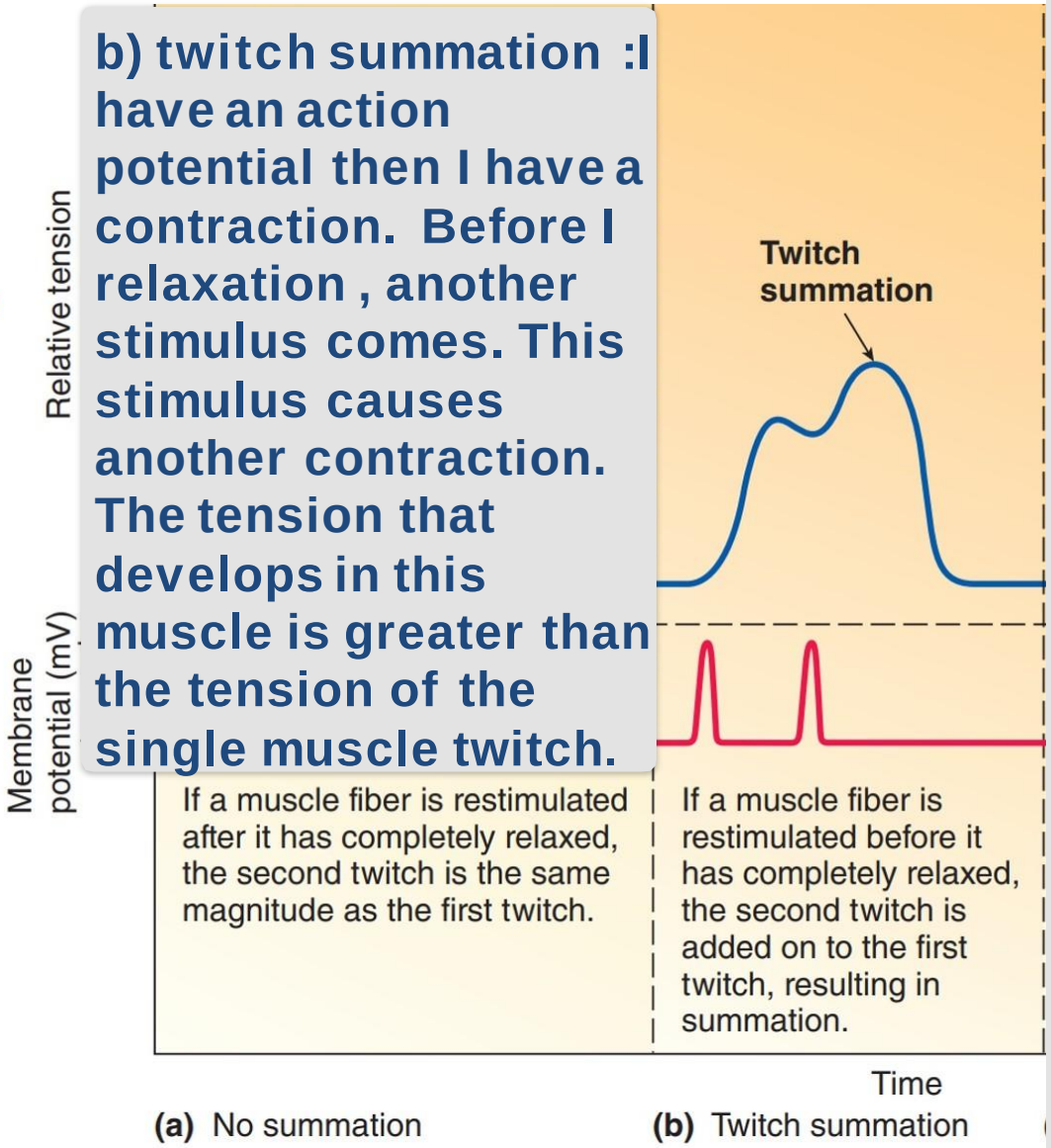
(b) The two twitches from the two action potentials add together, or sum, to produce greater tension in the fiber than that produced by a single action potential, a process known as twitch summation

(c) A tetanic contraction is usually three to four times stronger than a single twitch.

** The most important factor in the development of twitch summation is sustained elevation in cytosolic Ca2 as the frequency of action potentials increases.

I could do this (summation) because of that action potential starts and ends in latent period (I am not in refractory period)

b) twitch summation :I have an action potential then I have a contraction. Before I relaxation , another stimulus comes. This stimulus causes another contraction. The tension that develops in this muscle is greater than the tension of the single muscle twitch.



b)twitch summation : The tension depends on the amount of sliding between actin and myosin. There is an action potential, which means there is calcium Before the calcium returns to its stores, another action potential arrives, which drives more calcium, means there are more myosin binding sites, means more cross bridging then sliding toward the midline and more shortening of sarcomere

Note: 🌸

(b) The two twitches from the two action potentials add together, or sum, to produce greater tension in the fiber than that produced by a single action potential, a process known as twitch summation

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** The most important factor in the development of twitch summation is sustained elevation in cytosolic Ca2 as the frequency of action potentials increases.

Contractions of a whole muscle can be of varying strength

A. The number of muscle fibers contracting within a muscle

- Extent of motor unit recruitment

Extent of motor unit recruitment and frequency of stimulation This is the job of the central nervous system (CNS).

B.The tension developed by each contracting fiber.

- 1. Frequency of stimulation
- 2. Length of the fiber at the onset of contraction
- 3. Extent of fatigue
- 4. Thickness of the fiber

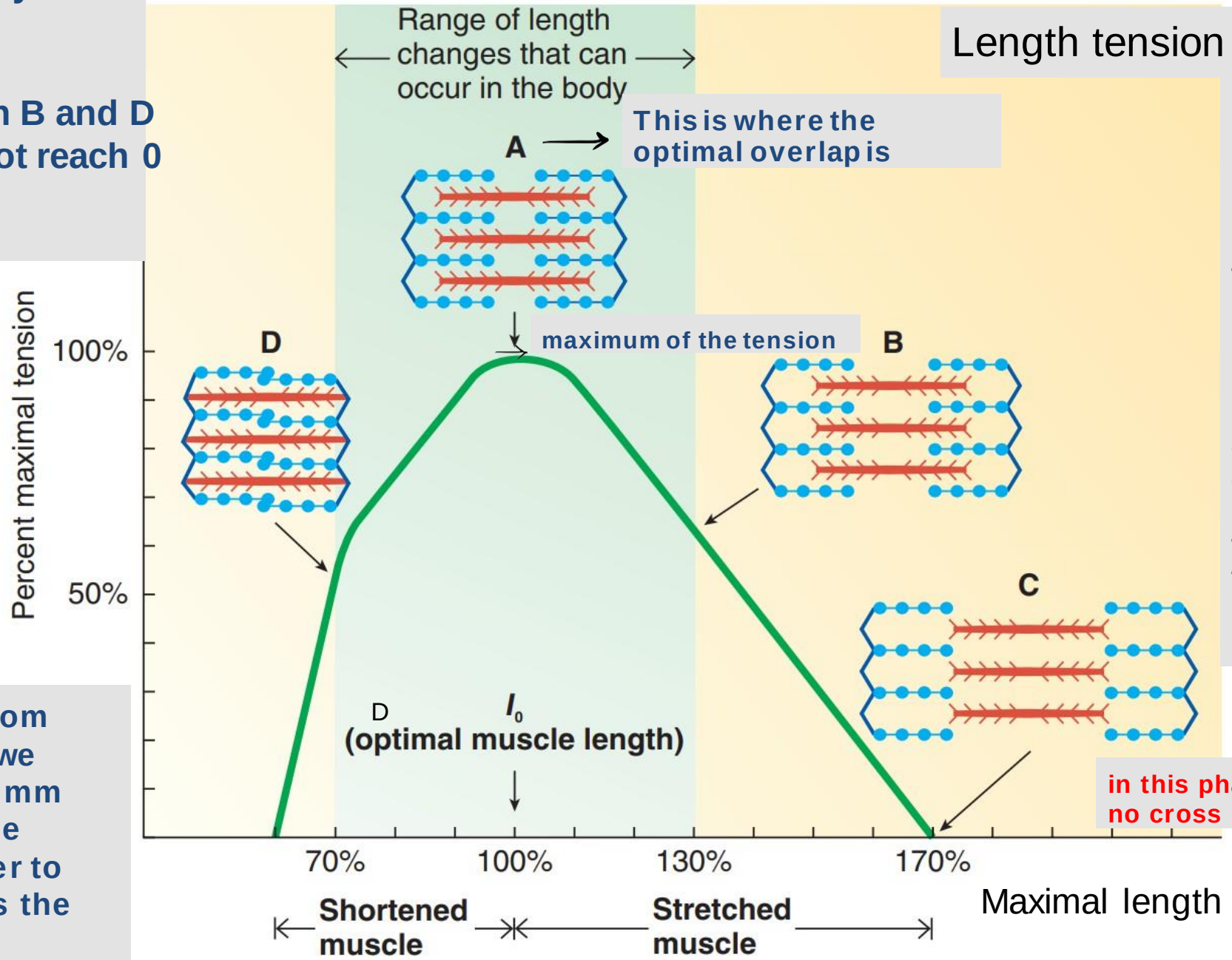
The length of the muscle fiber is fixed. There is an origin and an insertion. However, the length of these fibers can be changed by increasing or decreasing by 30%. So it can vary between contraction and contraction from one movement to another.

The third and fourth points this is inherit that is meaning the muscle itself is how God created it. It is known how much tension it will give ,it can't vary from contraction to another.

Length tension relationship

This is hypothetically on sarcomere level:

Human lies between B and D naturally and can not reach 0 tension in normal conditions.



This diagram called length tension relationship, that is mean there is an optimal length that the sarcomere prefer to work. Optimal length that is mean optimal overlap btw actin and myosin and this allow more efficient cross bridging and then pulling towards the M line and this is at the level of one sarcomere

They concluded from this drawing that we need from 2 to 2.2 mm of the length of the sarcomere in order to talk about it this is the optimal length

Maximal length → tension is 0

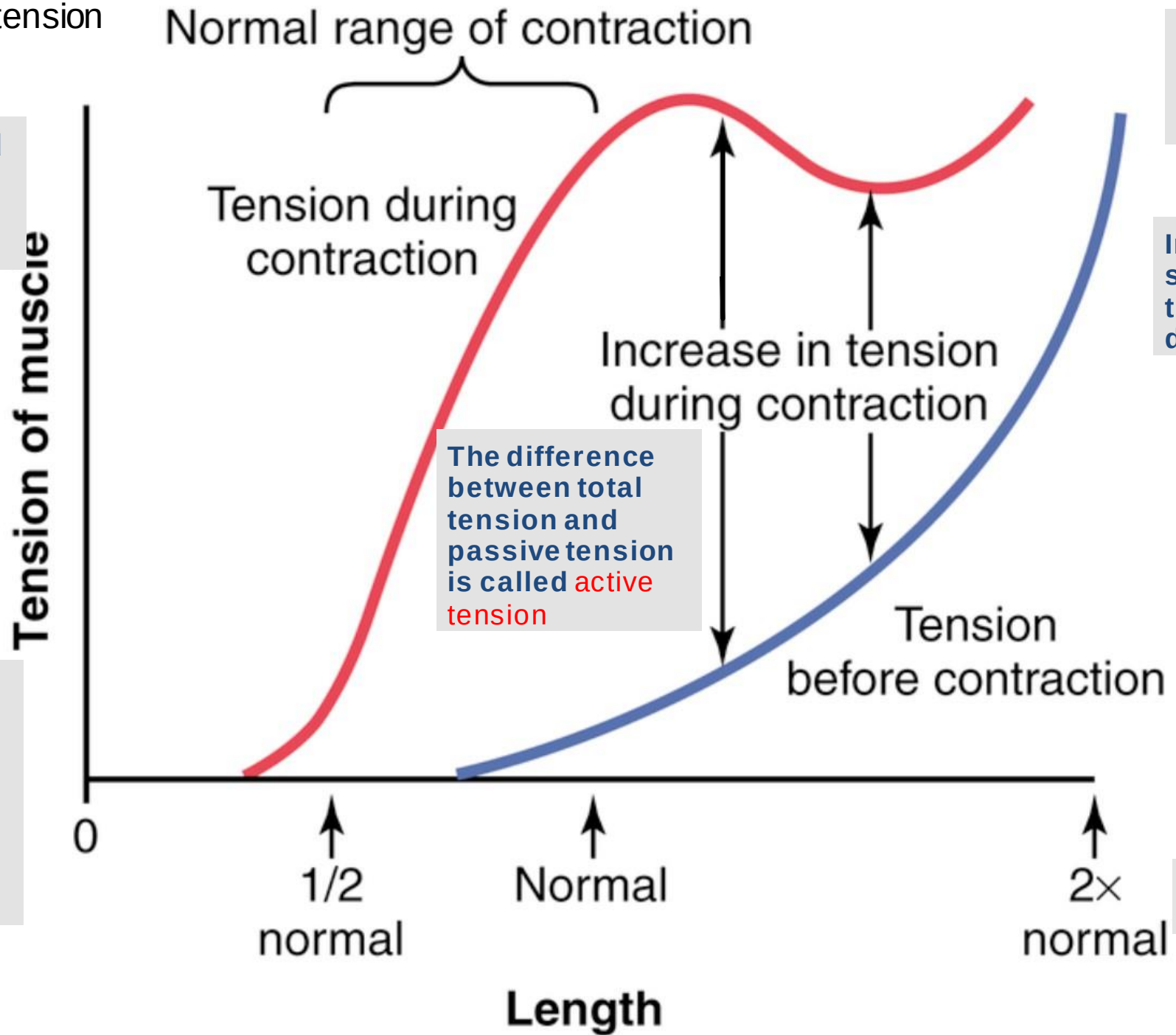
Muscle fiber length compared with optimal length

Note: 🌼
A relationship exists between the length of the muscle before the onset of contraction and the tetanic tension that each contracting fiber can subsequently develop at that length.
Every muscle has **an optimal length (lo) at which maximal force** can be achieved during a tetanic contraction beginning at that length-that is, more tension can be achieved during tetanus when beginning at lo than can be achieved when the contraction begins with the muscle longer or shorter than **(lo)**.This length-tension relationship can be explained by the sliding filament mechanism of muscle contraction.

Contractile Activity at **(lo)**, when maximum tension can be developed (point A), the thin filaments optimally overlap the regions of the thick filaments where the cross bridges are located. At this length, a maximal number of cross bridges and actin molecules are accessible to each other for cycles of binding and bending. The central region of thick filaments, where the thin filaments do not overlap at **(lo)**, lacks cross bridges; only myosin tails are found here.

The extremes in muscle length that prevent development of tension occur only under experimental conditions, when a muscle is removed and stimulated at various lengths.
Attachment of muscles to the skeleton imposes limits on muscle shortening and lengthening. Muscles are positioned so that their relaxed length (the length when the muscle is not actively contracting or passively positioned) is approximately at **(lo)**; **thus, they can achieve near maximal tetanic contraction** most of the time. Furthermore, because of skeletal constraints, muscles cannot be stretched or shortened more than 30% of their optimal length. Even at the outer limits **(130% and 70% of lo), the muscles still can generate half their maximum tension.**

Whole muscle length-tension relationship



The red curve is called total tension and the blue curve is called passive tension

in total tension curve, meaning the muscle had tension before contraction, and when you gave it electrical stimulation, it had additional tension.

When I do stimulation on optimal length, look at the tension increase (the difference between red and blue curve)
But when I am on maximal stretch less tension developed.

The difference between total tension and passive tension is called active tension

this diagram at the level of the whole muscle

In this diagram I keep stretching and see the tension that is developed.

In the blue curve, muscle length increases with increasing stretching

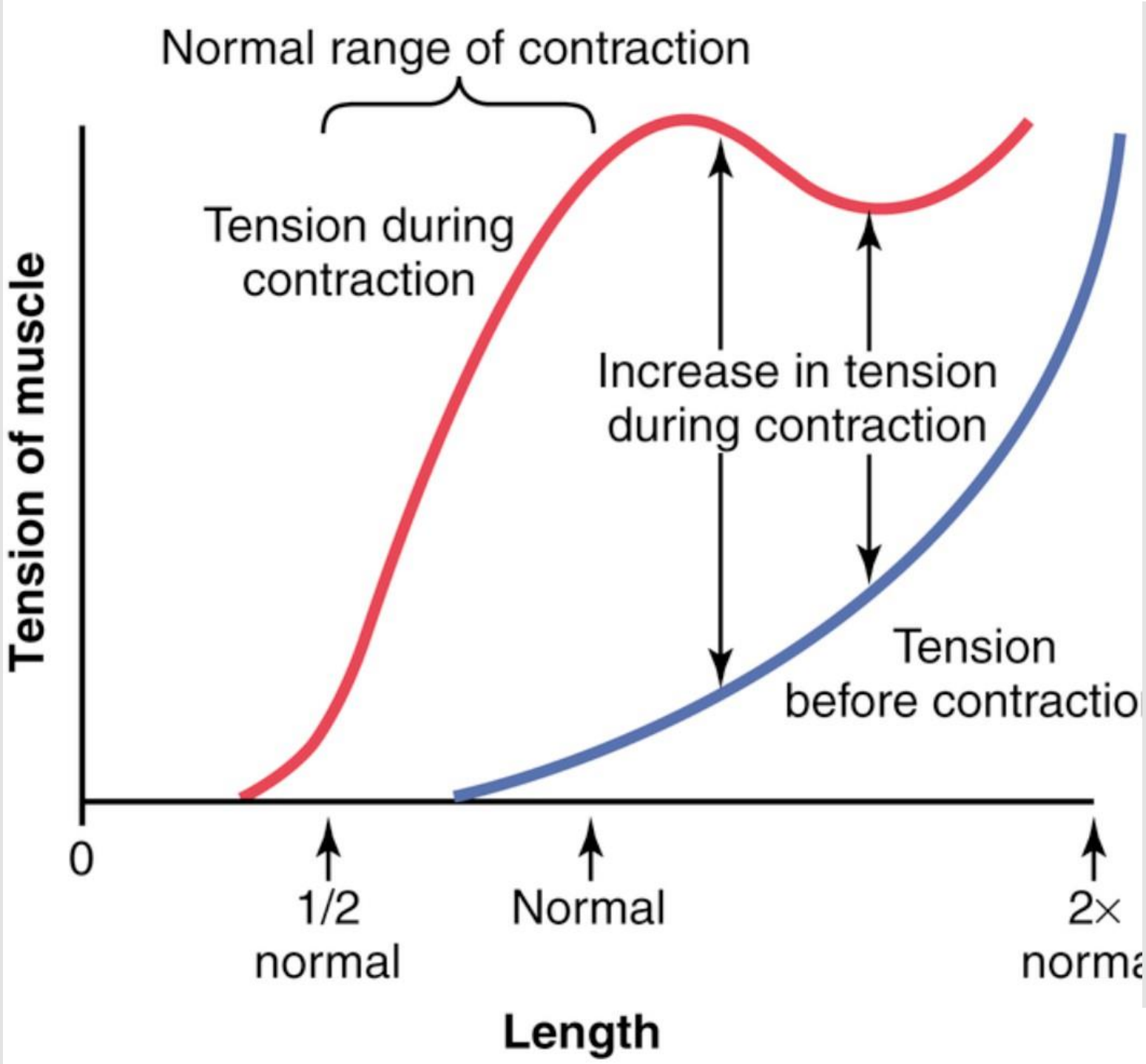
Focus on Active tension concept which is the difference between red and blue curves.

doctor said it is important!!

Read the curves. Important!!

recap
How do we want to increase the contraction of the muscle?
This depends on the movement I want to do and the weight I want to carry
If it is light, we use a small number of motor units
The more I recruit for the motor unit, the more fibers that go into the contraction, and then I can create more tension.

Every muscle fiber
How can we increase the tension inside the muscle fiber
I have to keep stimulating it and it produces a lot of acetyl cholin and increases calcium, then more cross bridging, then more increase in contraction.



If you do maximum shortening of the muscle, the tension value becomes zero
*in humans god created origin and insertion in optimal length +-30% and this will allow fluctuation in the tension between 50%-100%. We cannot stretch muscles beyond a certain point in humans (all observations are experimental).

In the laboratory, when they do these experiments on the muscle, what position is the muscle in?
isometric contraction
They fix it on one side, and on the other side, they change the level of stretching

Note:🌼
The top curve is similar to that in the previous slide, but the curve here **depicts tension of the intact whole muscle rather than of a single muscle fiber**.
The whole muscle has a large amount of **connective tissue in it**; in addition, the sarcomeres in different parts of the muscle do not always contract the same amount. Therefore, the curve has somewhat different dimensions from those shown for the individual muscle fiber, but it exhibits the same general form for the slope in the normal range of contraction.

when the muscle is at its normal resting length, which is at a sarcomere length of about 2 micrometers, it contracts on activation with the approximate maximum force of contraction. However, the increase in tension that occurs during contraction, called active tension, decreases as the muscle is stretched beyond its normal length-that is, to a sarcomere length greater than about 2.2 micrometers. This phenomenon is
demonstrated by the decreased length of the arrow in the figure at greater than normal muscle length.

Thank you for your hard work👍
🤍