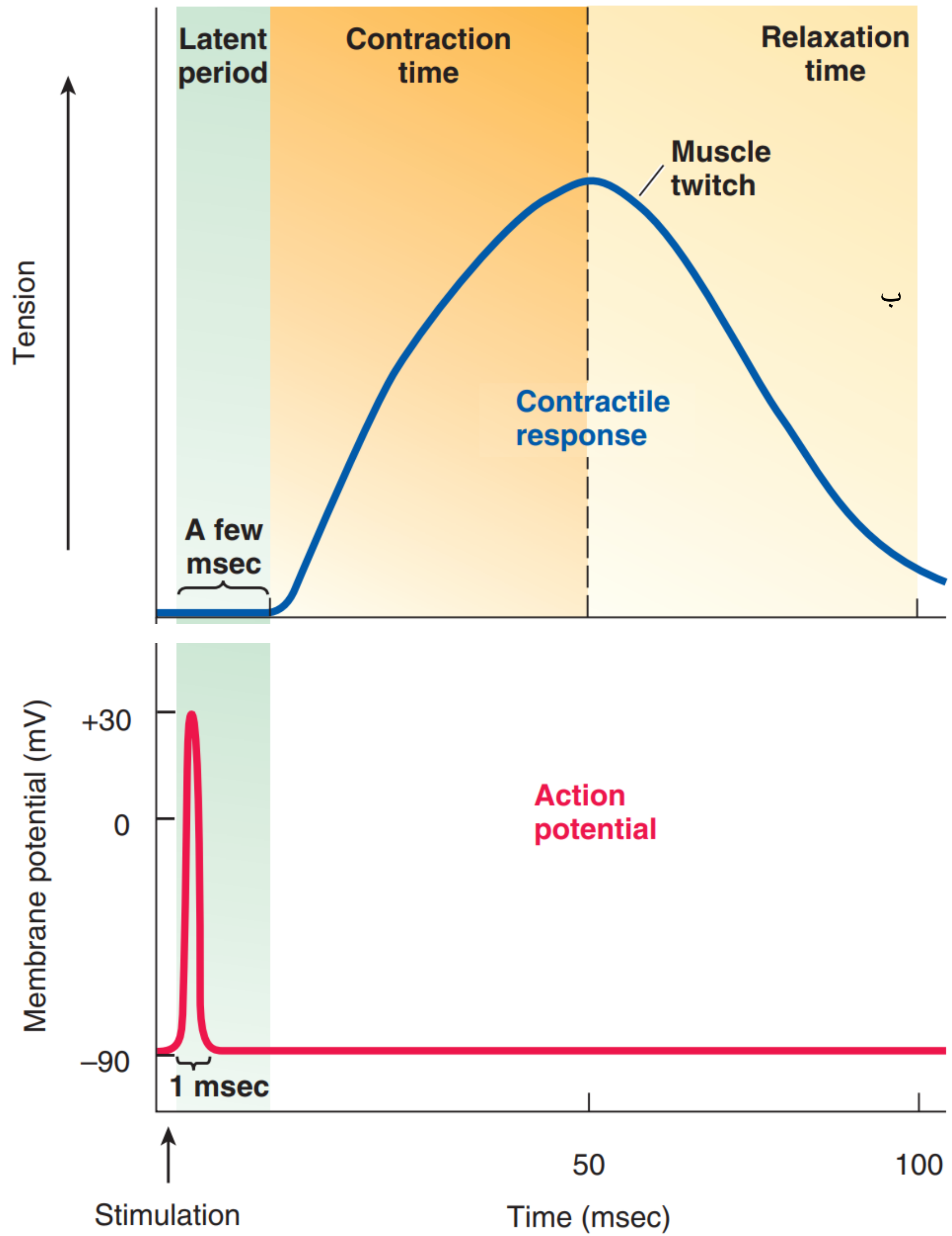
SKELETAL MUSCLE

Simple Muscle twitch



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 to 100 msec or more in slow contracting fibers.
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).

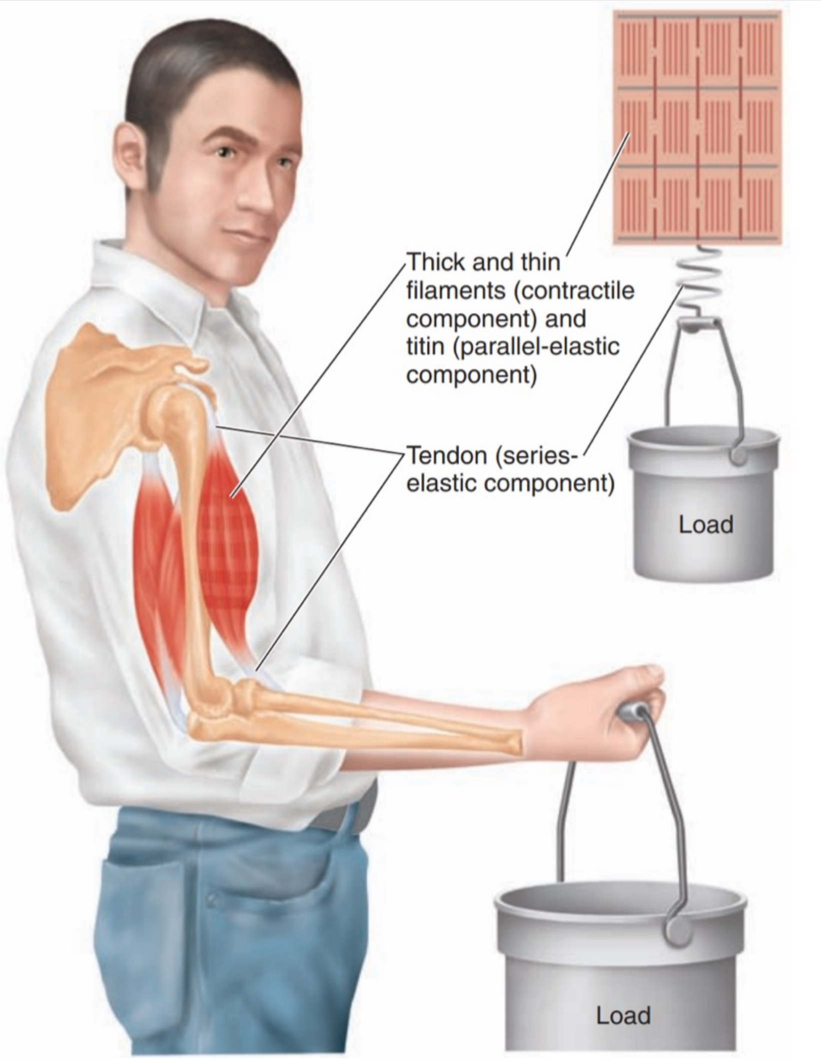
SKELETAL MUSCLE MECHANICS

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.

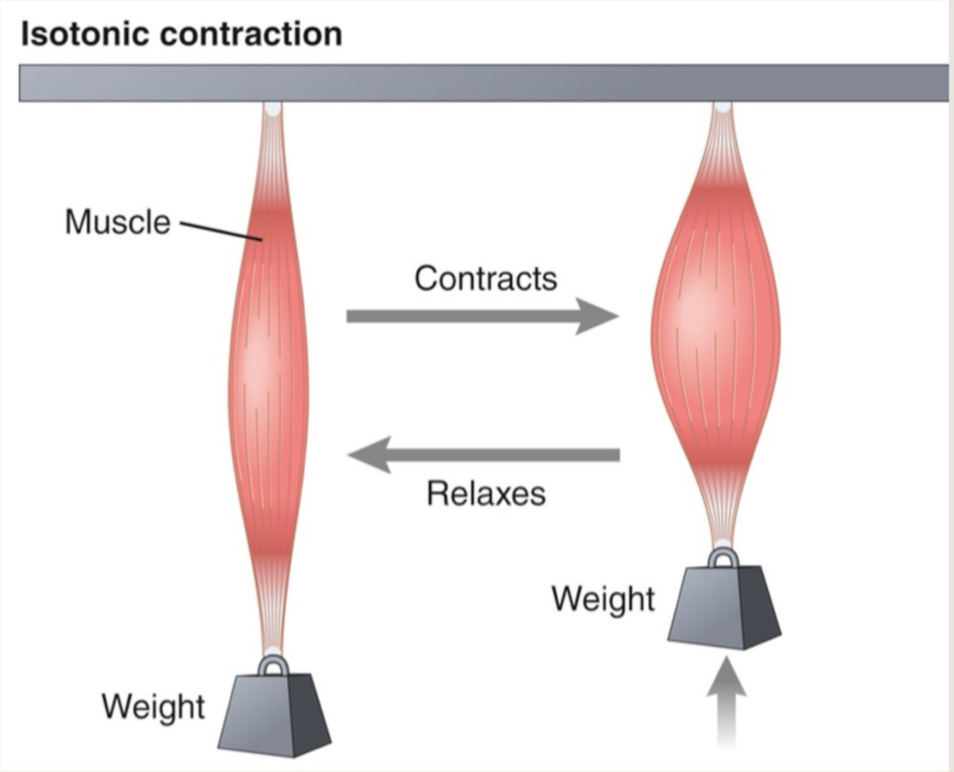
Muscle tension is transmitted to bone as the contractile component tightens the series-elastic component.

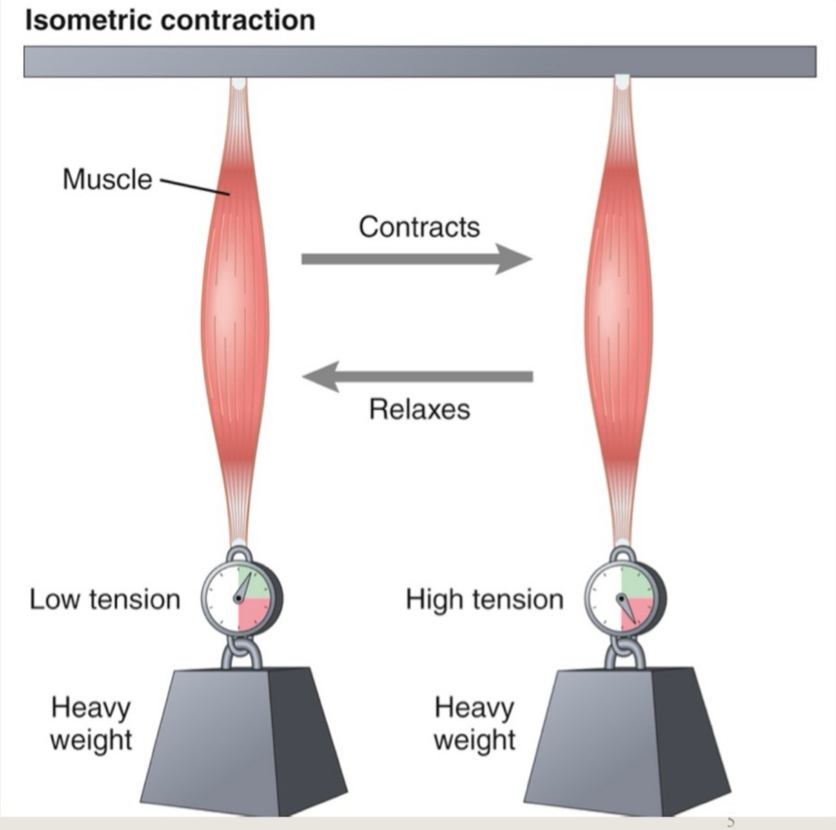
The series-elastic component behaves like a stiff spring placed between the internal tension generating elements and the bone that is to be moved against an external load, or opposing force

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).



TYPES OF CONTRACTION

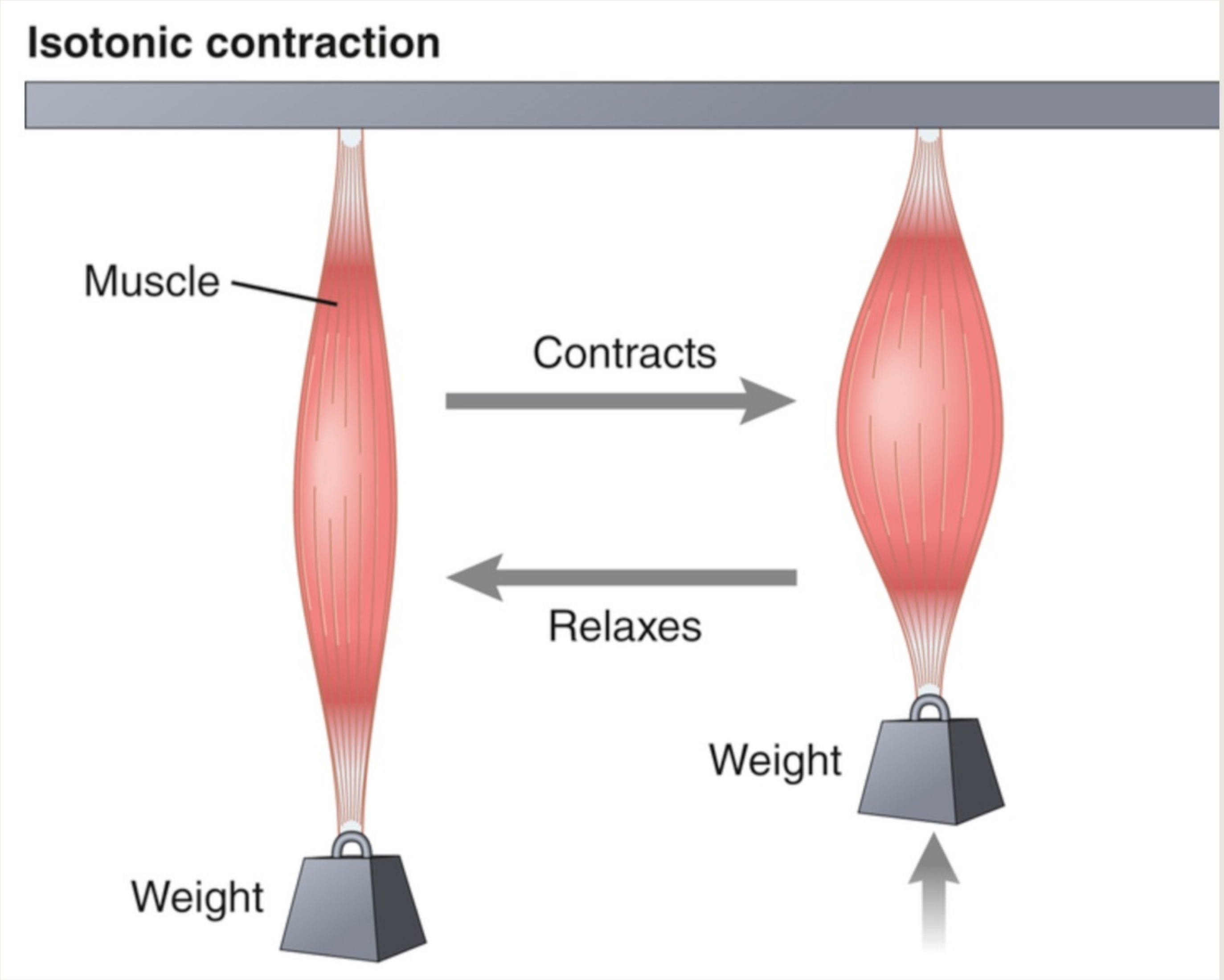




Note:🌸
Not all muscle contractions shorten muscles and move bones.

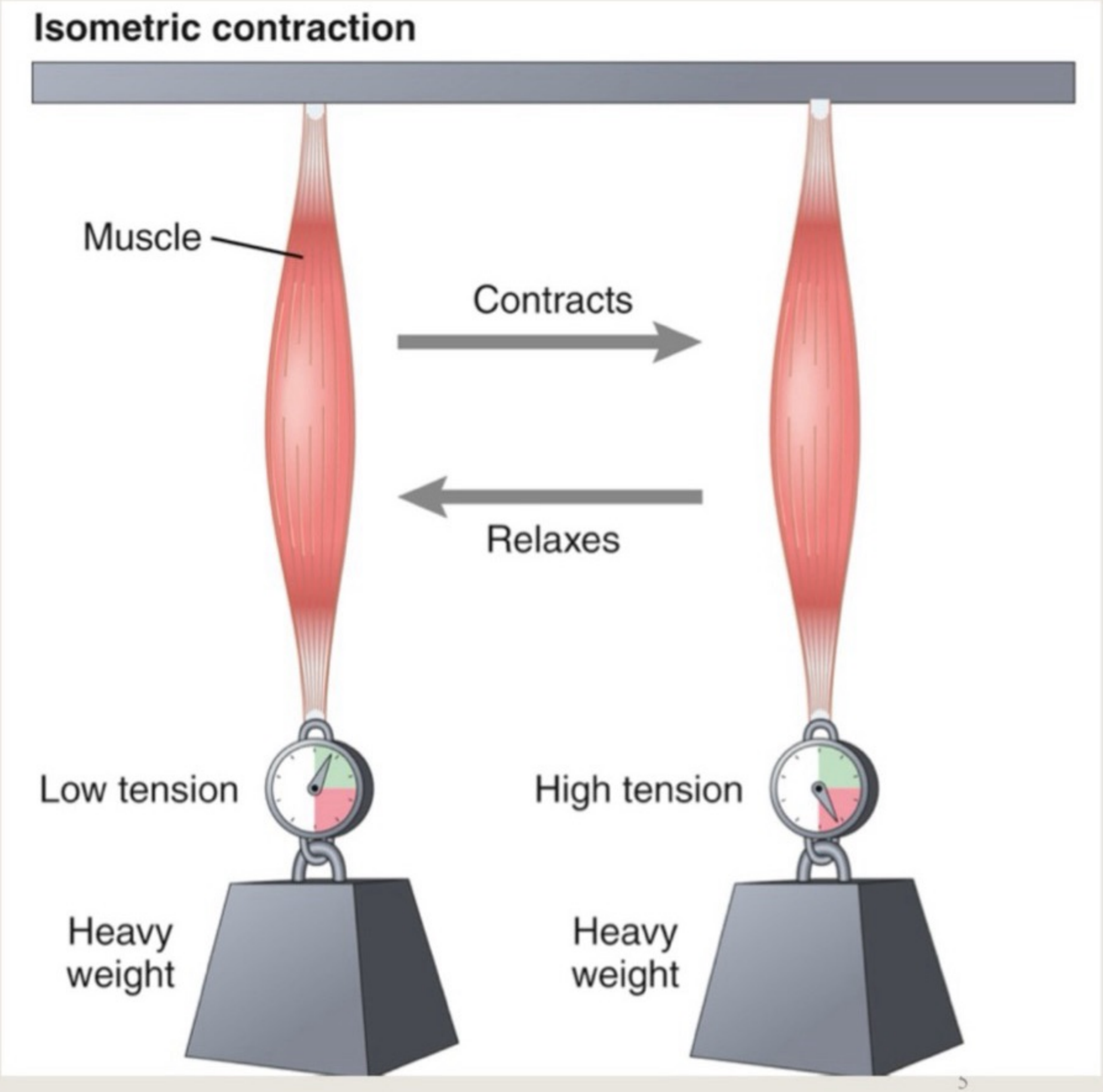
** For a muscle to shorten during contraction, **the tension developed in the muscle must exceed the forces that oppose movement of the bone to which the muscle's insertion is attached.**

TYPES OF CONTRACTION



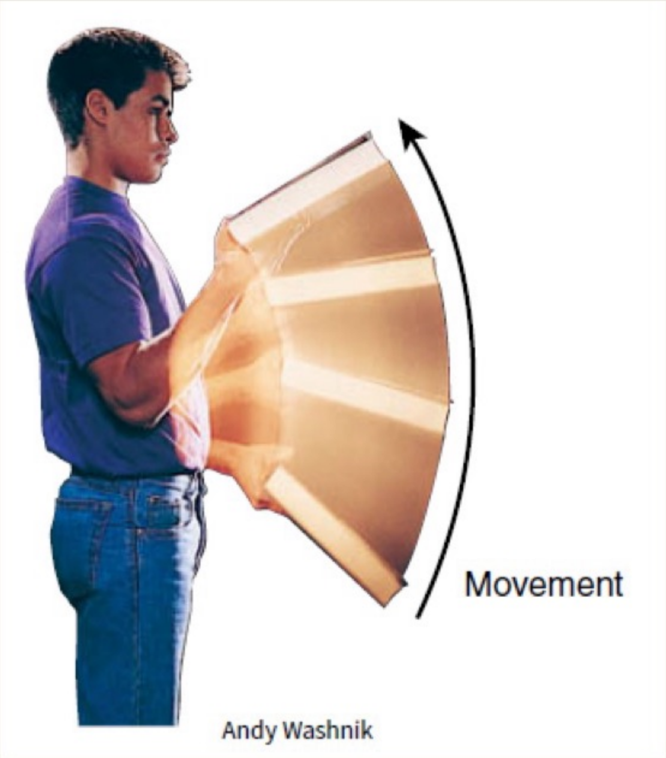
Note:🌸
Isotonic contraction occurs when the force of the muscle contraction is greater than the load, and the tension on the muscle remains constant during the contraction. When the muscle contracts, it shortens and moves the load.

TYPES OF CONTRACTION

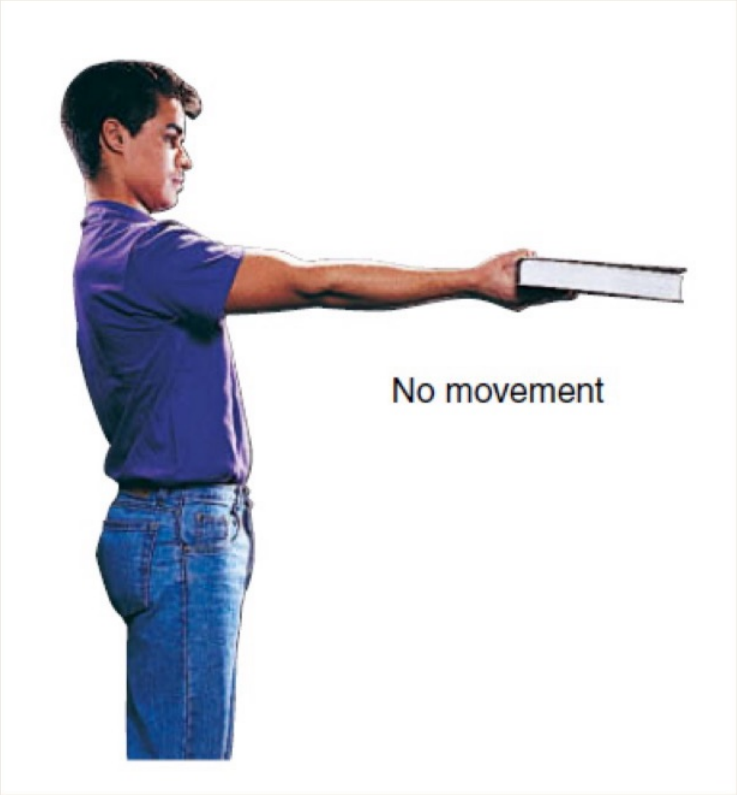


Note:🌸
Isometric contraction occurs when the load is greater than the force of the muscle contraction; the muscle creates tension when it contracts, but the overall length of the muscle does not change.

TYPES OF CONTRACTION



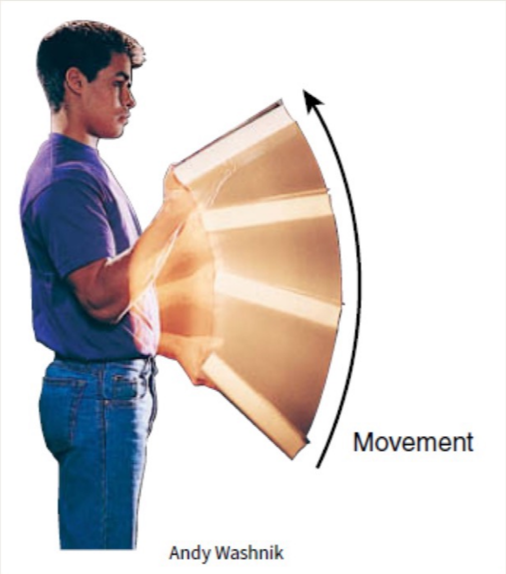
Isotonic contraction



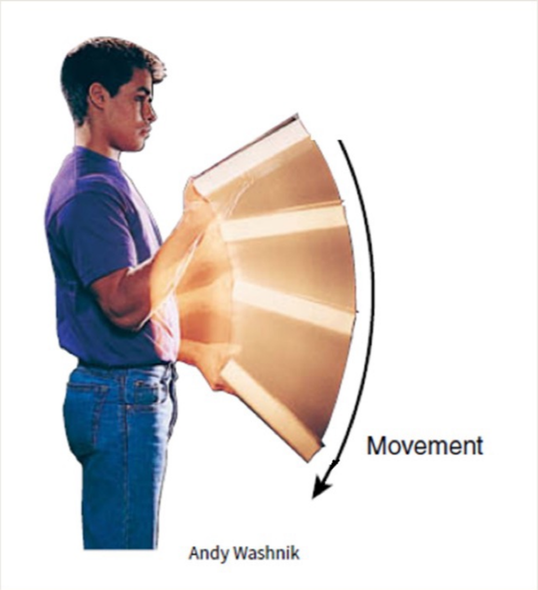
Isometric contraction

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).

TYPES OF CONTRACTION



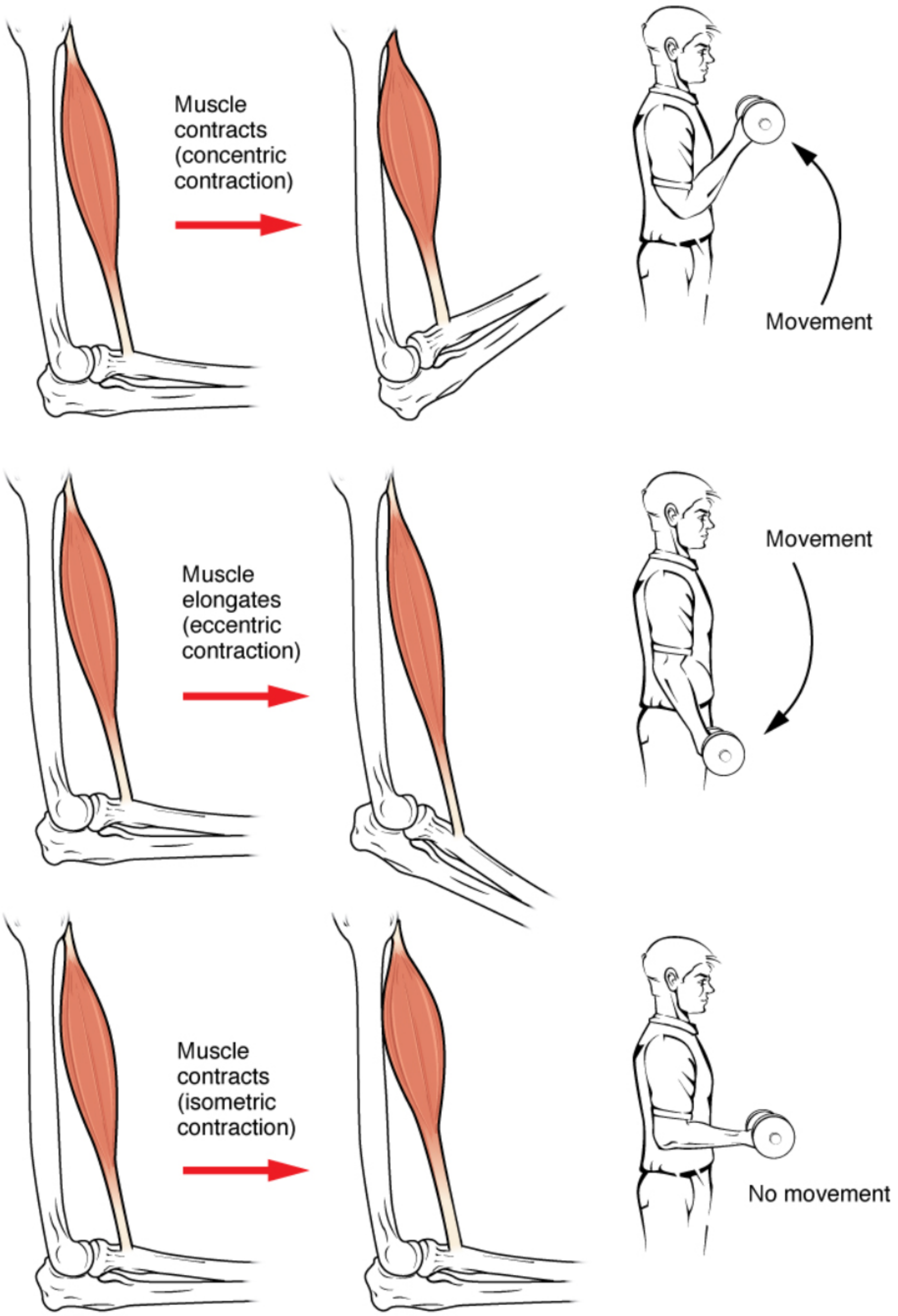
Concentric contraction

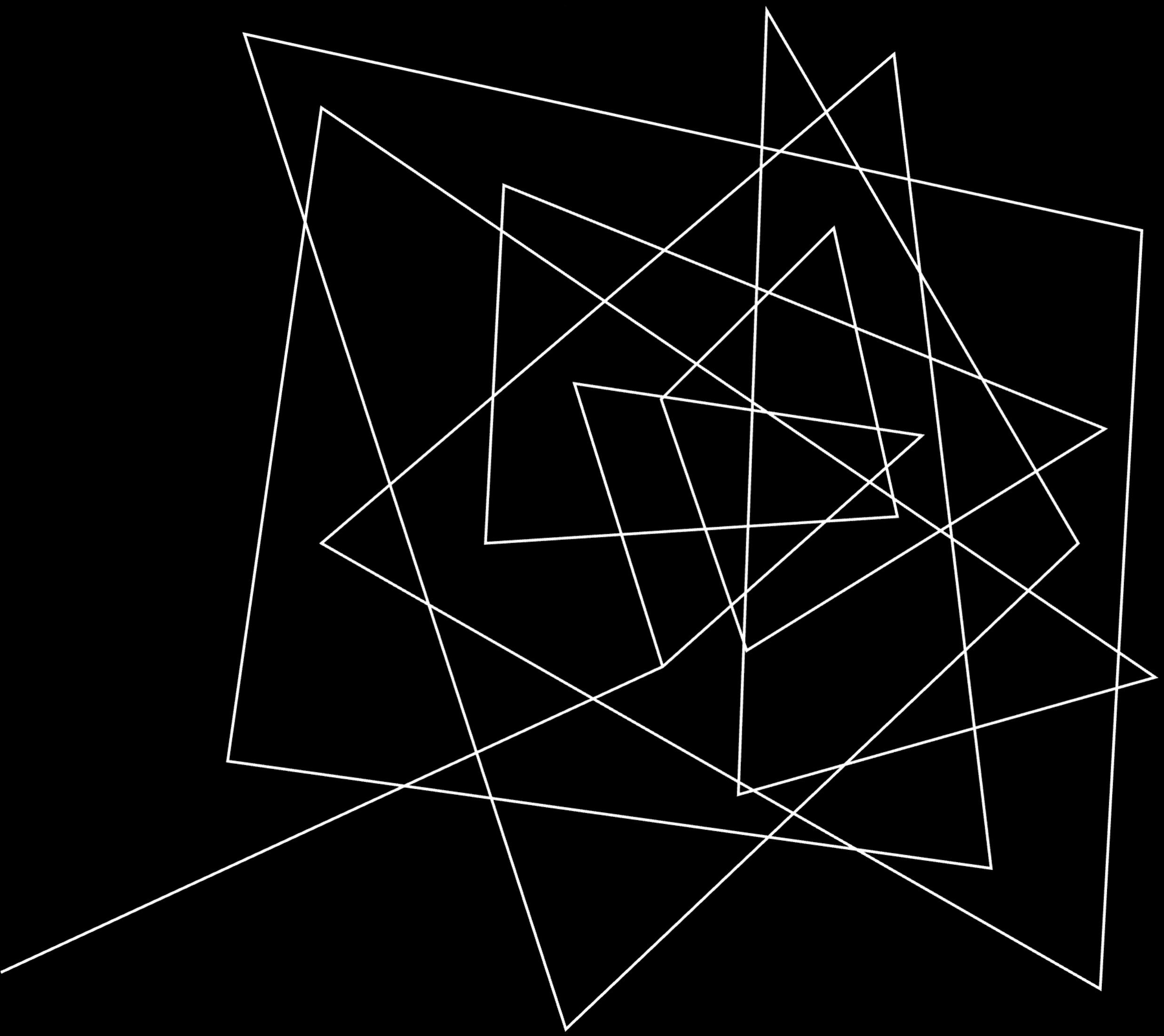


Eccentric Contractions

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.

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

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:🌸
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

Motor Unit

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

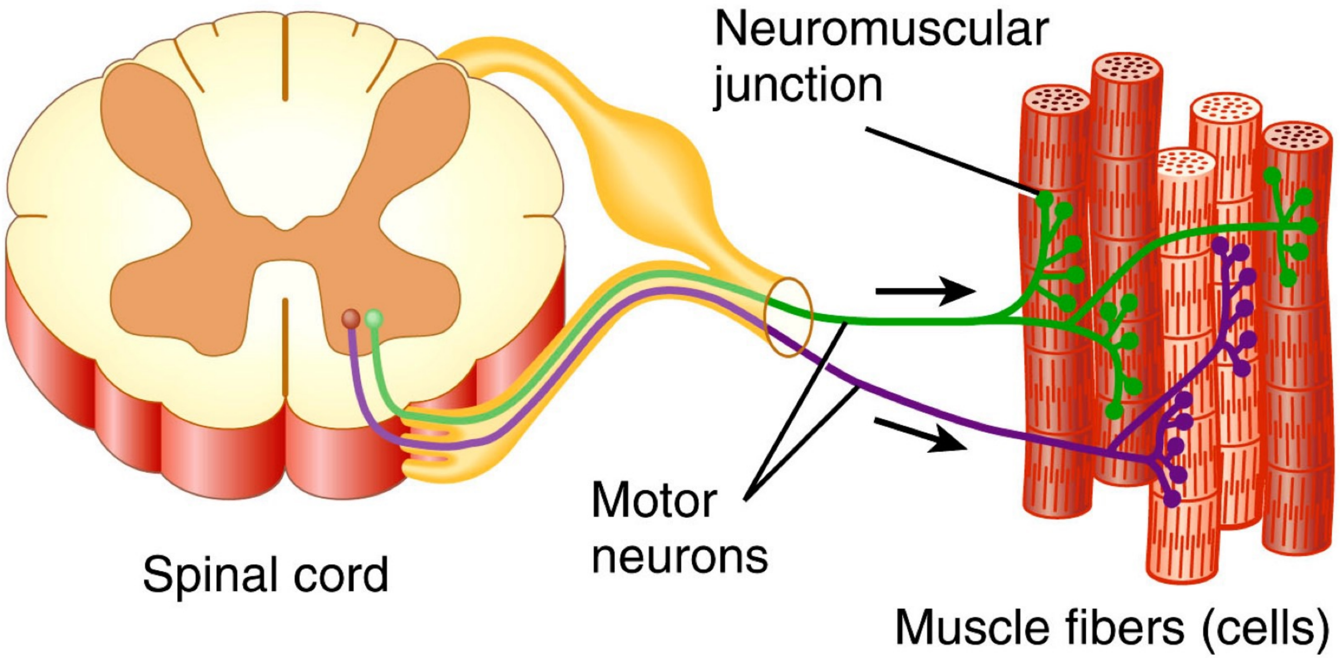


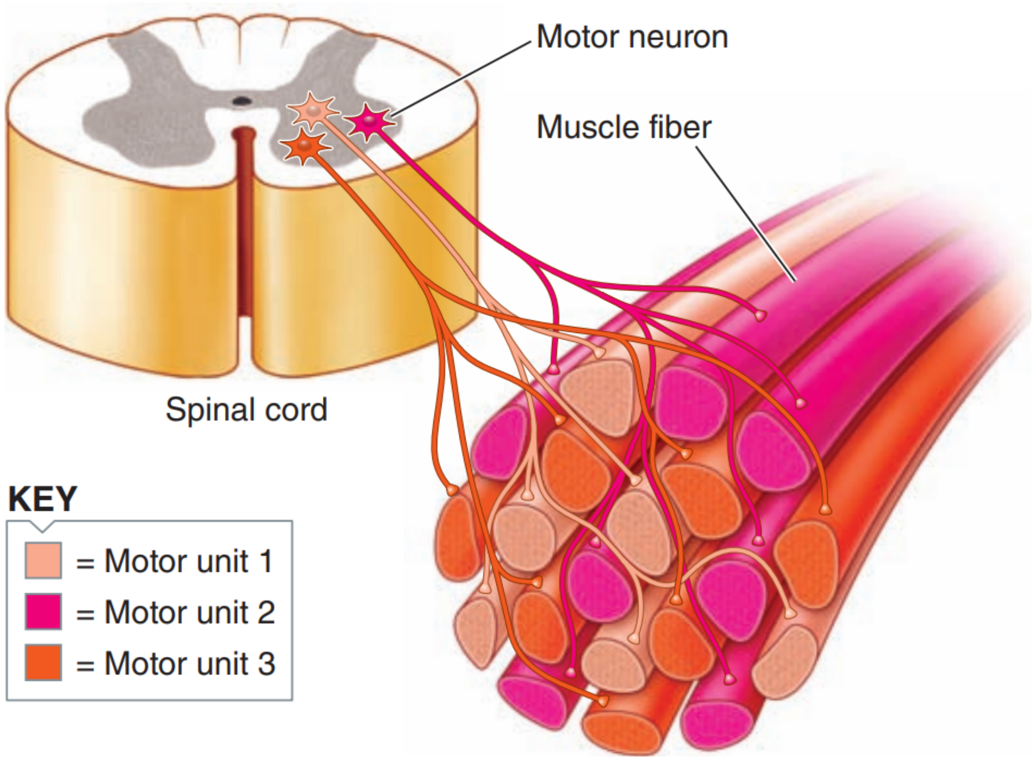
Figure 10.13 Tortora - PAP 12/e

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.**



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**.

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.

** **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.
- 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.

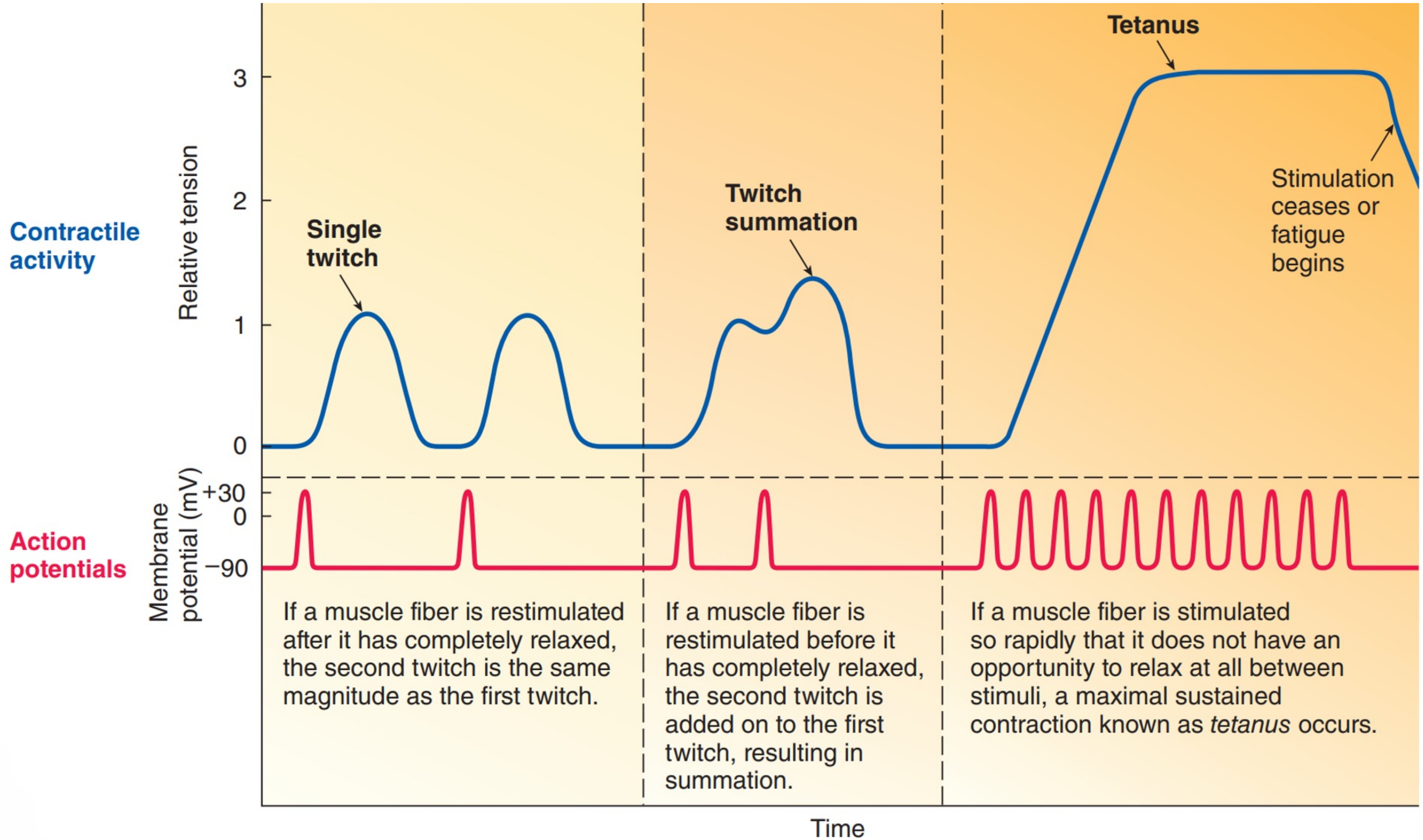
Contractions of a whole muscle can be of varying strength

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



(a) No summation **(b)** Twitch summation **(c)** Tetanus

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.

Contractions of a whole muscle can be of varying strength

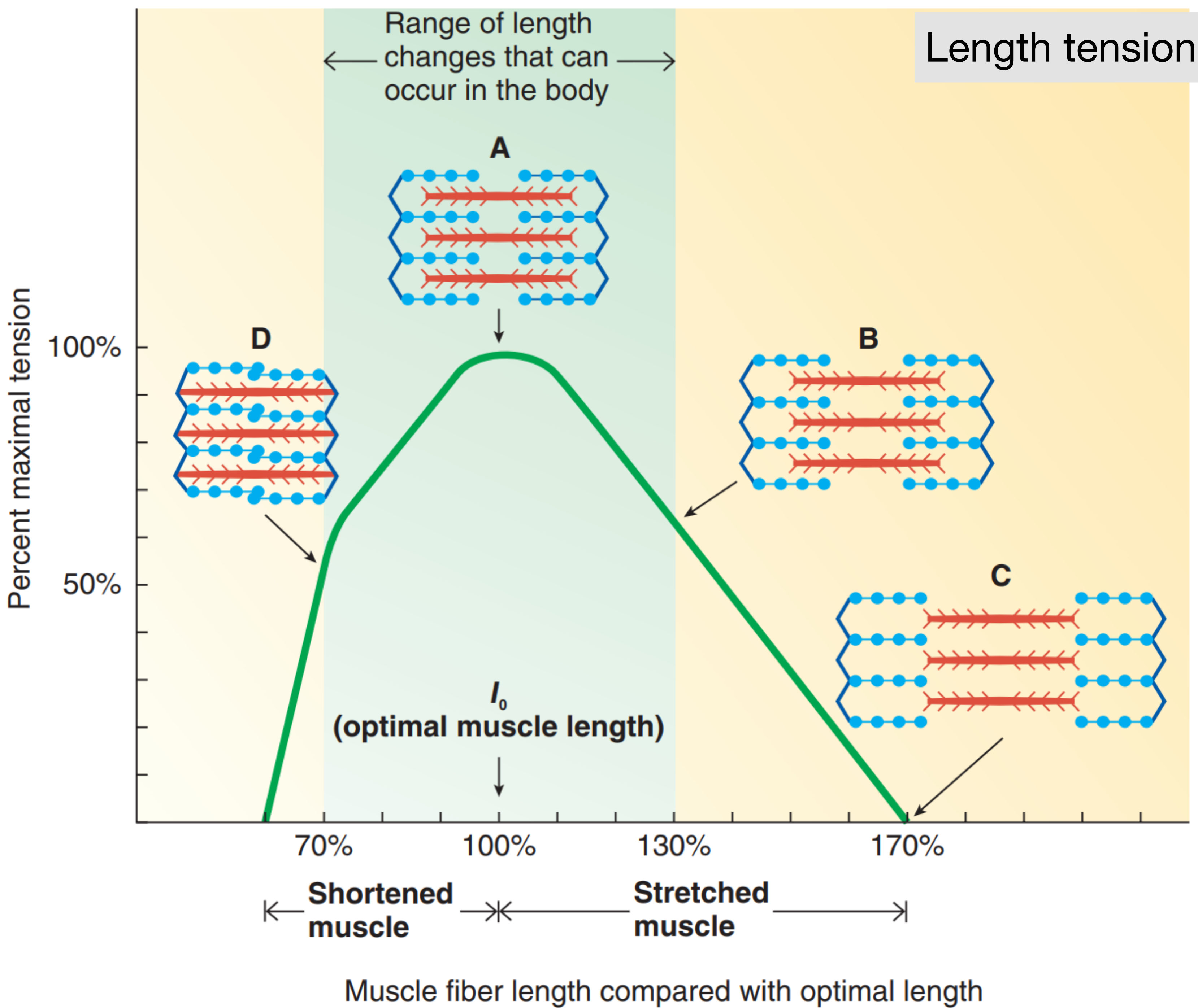
A. The number of muscle fibers contracting within a muscle

- 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

Length tension relationship



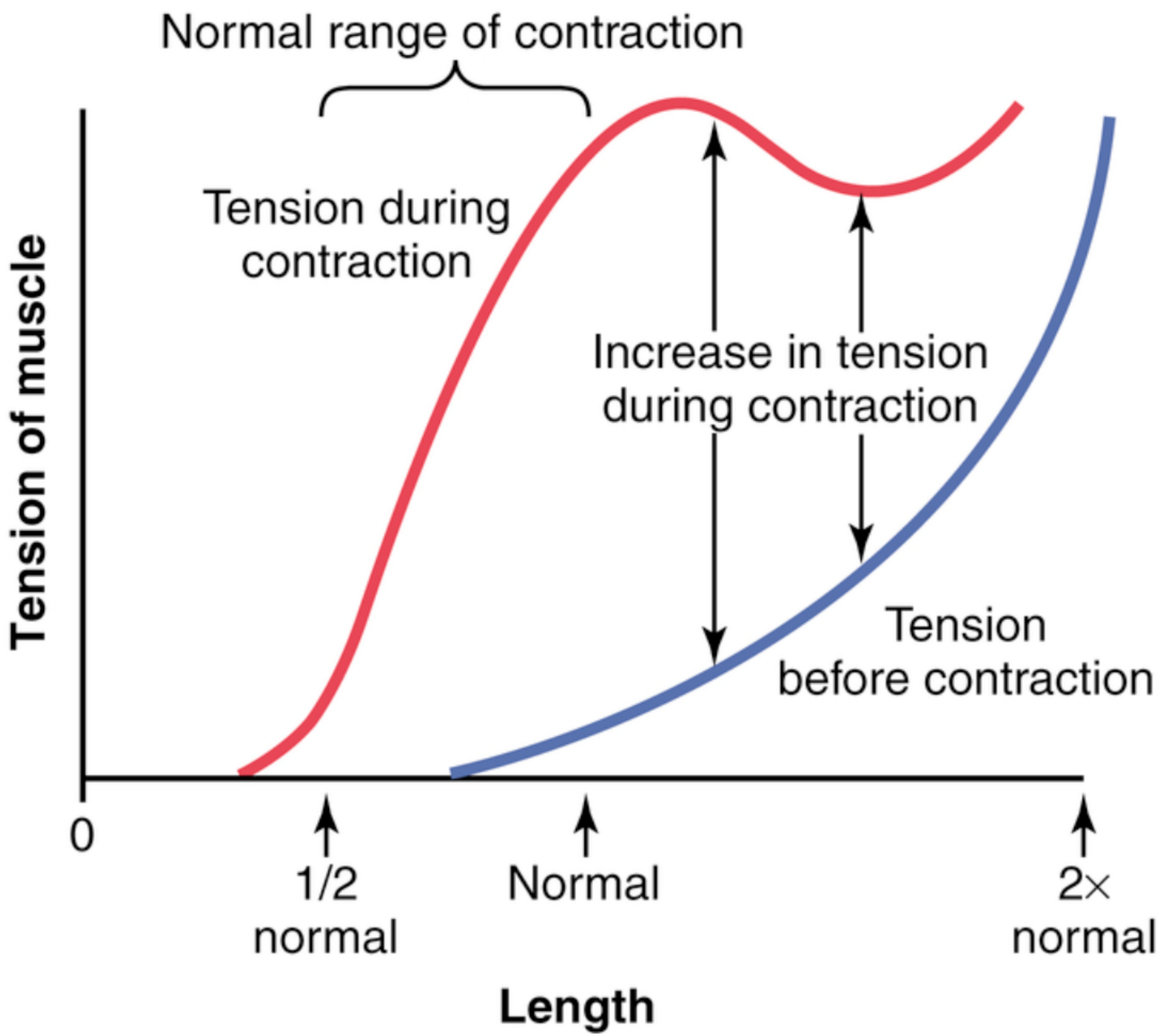
Note:🌼

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 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.**


Normal range of contraction
Tension during contraction
Increase in tension during contraction
Tension before contraction
Tension of muscle
0
1/2 normal
Normal
2× normal
Length

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🫡
🤍