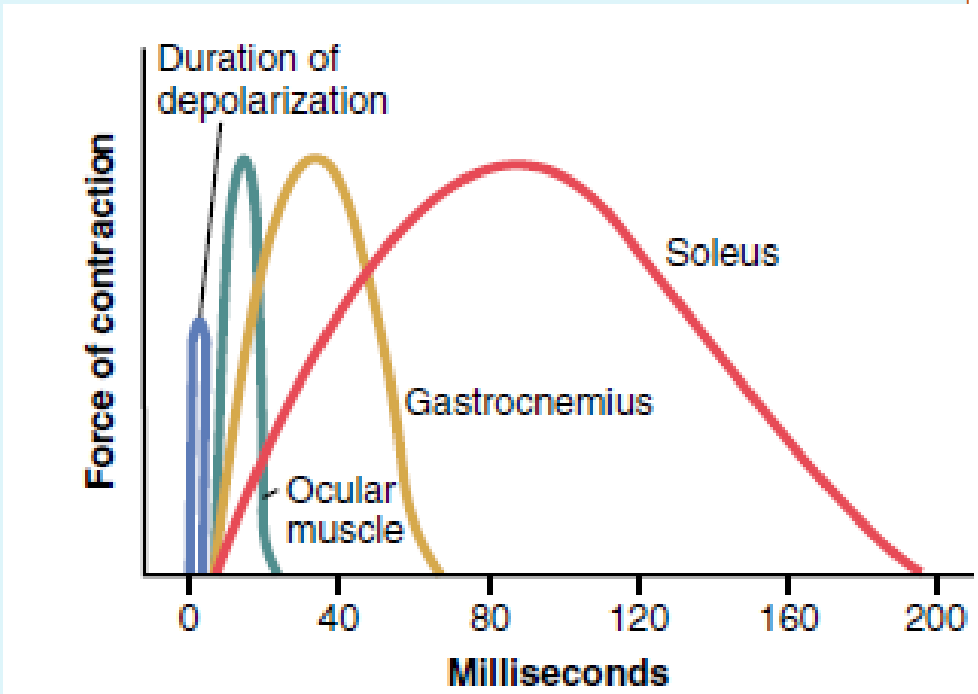
Properties of Skeletal muscles

Motor unit

- A motor neuron together with all the muscle fibres supplied by it is called a motor unit.
- Muscle fibers of motor unit are scattered throughout the muscle belly so even when only the muscle fibres of one motor unit contract, the whole muscle contracts.
- The larger the number of motor units activated, stronger the contraction.
- Since the unit of activation is a nerve fibre, the unit of contraction will be motor unit.

- The precision with which the contraction of a muscle may be graded depends on the size of the motor unit.
- Fewer than 2 or 3 muscle fibers per unit in laryngeal muscles-small & for fine control, twitch duration is less.
- Soleus muscle may have several hundred muscle fibers in a motor unit- large & for gross movement, twitch duration is more.



Properties of skeletal muscle

1. Excitability
2. Stretchability
3. Contractility
4. Load velocity relationship
5. Length tension relationship
6. Summation of contraction
7. Staircase Phenomenon or treppe
8. Tetanization &,
9. Post-tetanic potentiation

Properties of skeletal muscle

1. **Excitability**: it is ability of muscle fiber to respond to different types of stimulus (that change in environment) around and it is a physicochemical change.

2. **Stretchibility**: muscle fiber gets stretched before contraction.

3. **Contractility:**

3. Contractility

- It is the response of the muscle to a stimulus.
- Contraction is defined as the internal events of muscle with change in either tension or length of the muscle fibers.
- Types of contraction: It is based on change in tension or length of muscle fibers, there are two types;
  - Isotonic contraction
  - Isometric contraction

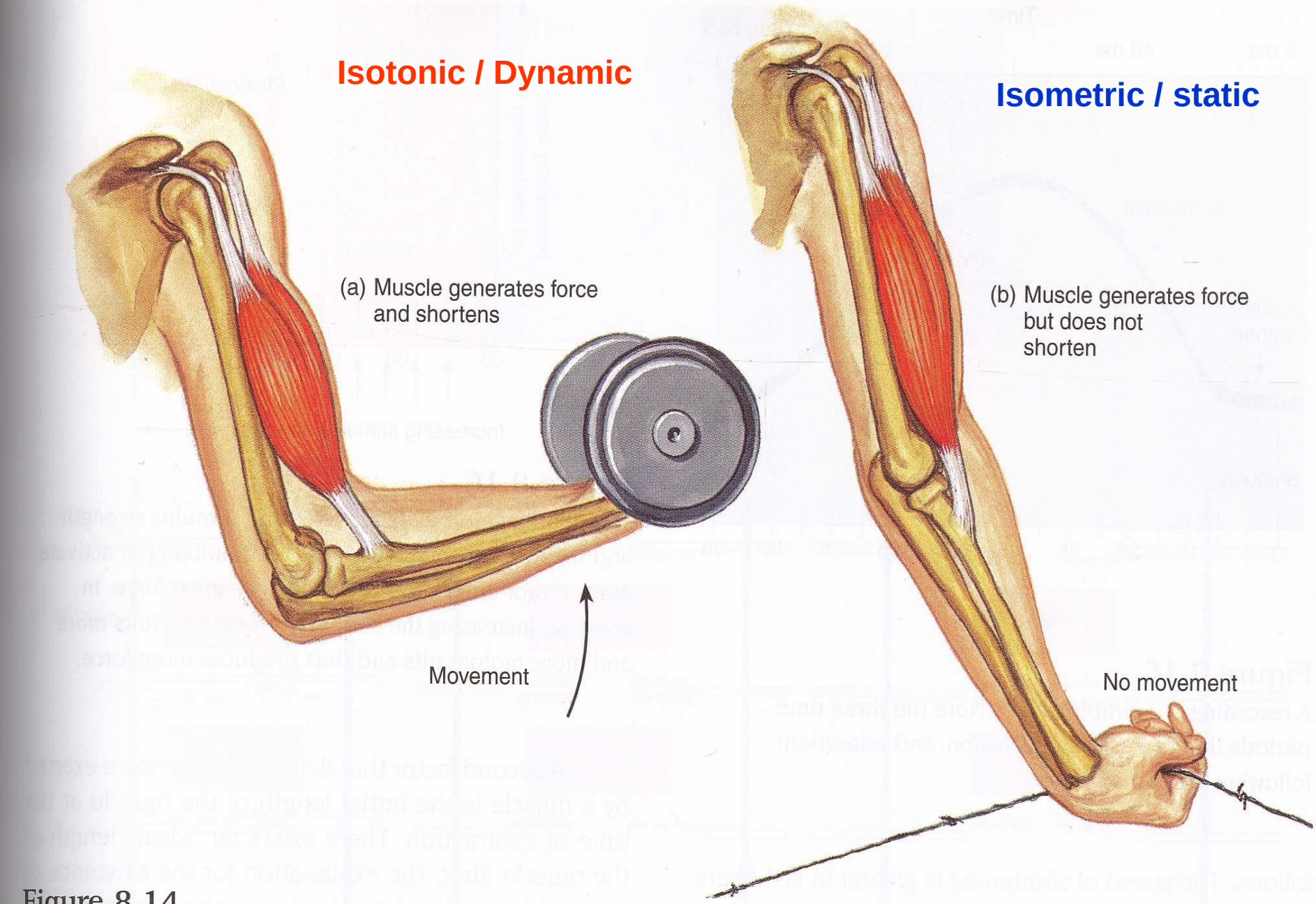


Figure 8.14

(*a*) Isotonic actions occur when a muscle contracts and shortens. (*b*) Isometric actions occur when a muscle exerts force but does not shorten.

Isometric contraction

- Isometric (isos= equal; metron= measure) contraction means contraction in which there is no change in length of the muscle but there is increase in tension.
- Here contraction means mechanical activation of the muscle. It may give rise to a reduction in length or increase in tension, or both.
- In isometric contraction reduction in length is prevented so only increase in tension occur.
- In this all sarcomeres don't shorten simultaneously. The sarcomeres which shorten do so by stretching those which do not.
- Ex. contraction of muscle of upper limb while trying to push wall

Isotonic contraction

- Isotonic contraction (isos=equal; tonos= tension) means contraction in which there is change of length at constant tension. The tension is equal to the weight lifted during contraction of the muscle.
- Shortening of individual sarcomeres causes shortening of the whole muscle. Since volume of the muscle remains constant, decrease in length is accompanied by an increase in thickness.
- It may be preloaded or after loaded. Preloaded is better at performance.
- Ex.when a heavy suitcase is to be placed on a table, we tend to let it hang from hand first before we lift it and put it on the table.

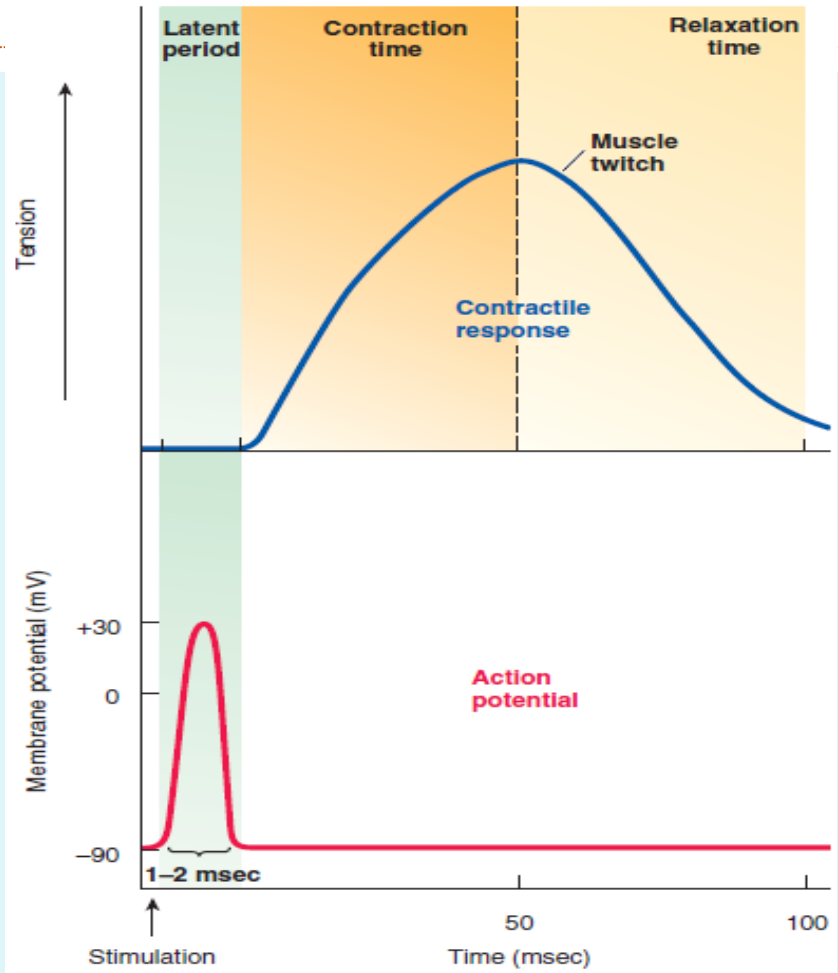
Differences between Isometric & isotonic contraction

Isometric contraction	Isotonic contraction
1. No change in length but increase in tension	1. No change in tension during contraction but shortening of length.
2. No sliding of filaments	2. Sliding of filaments
3. No external work done	3. External work done
4. Increases when load increases	4. Decreases when load increases
5. Heat released is less	5. Heat released is more
6. **E.g: attempting to lift an immoveable object, holding a weight at arm's length, pushing a wall etc.**	6. **E.g: Simple flexion of arm. lifting moveable object, walking etc.**

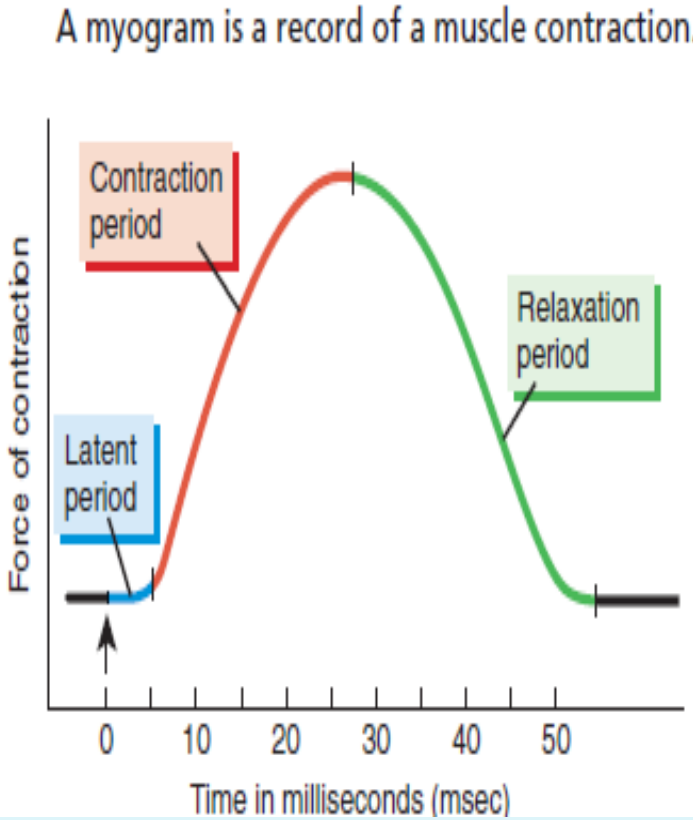
Twitch contraction

- The contractile response of a skeletal muscle to a single brief stimulus is called a simple muscle twitch.or, **A single action potential in a muscle fiber produces a brief, weak contraction called a twitch (too short & too weak).**

- Duration varies from 20 ms to 200 ms depending whether it is a fast or a slow muscle.



● **FIGURE 8-13 Relationship of an action potential to the resultant muscle twitch.** The duration of the action potential is



Twitch contraction

Latent Period includes time taken for following:

i) impulse to travel to end of the nerve

ii) NMT

iii) ECC

iv) shortening of contractile elements

v) stretching of series elastic elements

- Shortening of the sarcomeres stretches the series-elastic component(SEC).
- SEC have a certain degree of passive elasticity & behave like a stretchy spring placed between contractile component and the bone.
- Muscle tension is transmitted to the bone by tightening of the SEC. This force applied to the bone moves the bone against a load so contraction occur.

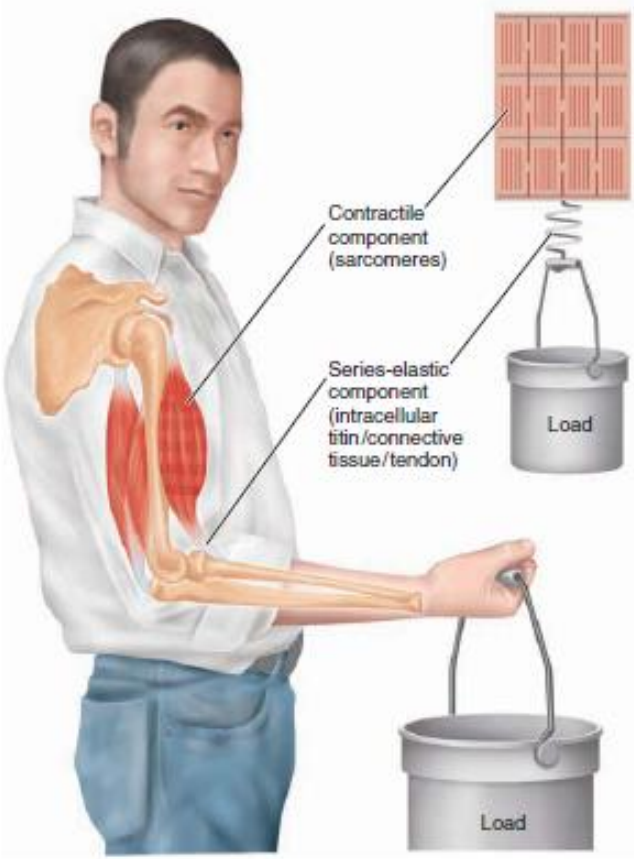


FIGURE 8-14 Relationship between the contractile component and the series-elastic component in transmitting muscle tension to bone. Muscle tension is transmitted to the bone by means of the stretching and tightening of the muscle's elastic connective tissue and tendon as a result of sarcomere shortening brought about by cross-bridge cycling.

4.Load velocity relationship

- *Effect of load on velocity of shortening of muscle*

•Inverse relationship seen i.e. Velocity of fiber shortening is inversely proportional to the degree of load.

<u>With increasing load</u>

i) Latent period increases

ii) Distance shortened decreases &

iii) Decrease in total duration of twitch

- When the load becomes so heavy that the muscle cannot lift it (Po), velocity of contraction becomes zero.
- Since with Po there is no shortening, the contraction is isometric.
- Thus twitch tension during isometric contraction is greater than any load that can be lifted during isotonic contraction.

Load-velocity relationship

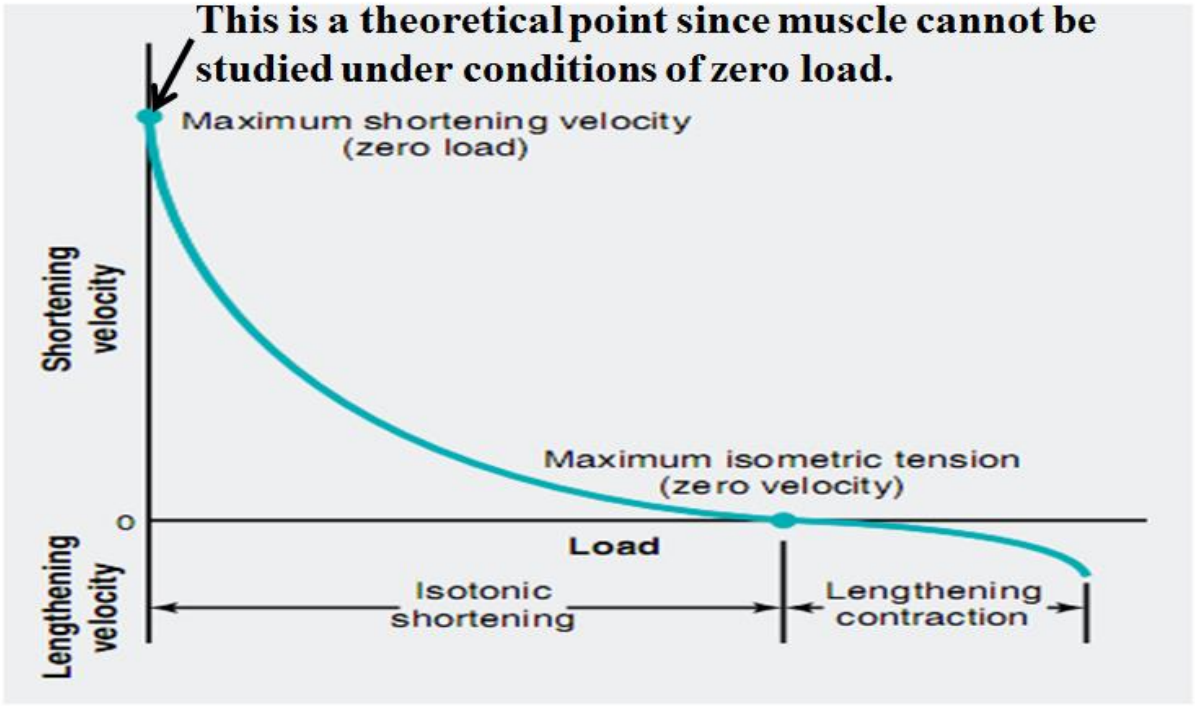
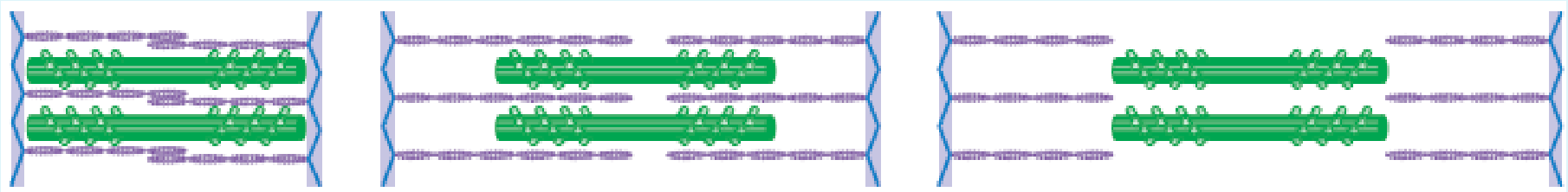


FIGURE 11–22
Velocity of skeletal-muscle fiber shortening and lengthening as a function of load. Note that the force on the cross bridges during a lengthening contraction is greater than the maximum isometric tension.

5. Length-Tension Relationship

- **Length–tension relationship** for skeletal muscle, indicates how the forcefulness of muscle contraction depends on the length of the sarcomeres before contraction begins.
- The length at which the fiber develops the greatest active tension is termed the optimal length, I_o (resting length). It is about 2 to 2.2 μm



Length-Tension Relationship

- **At length smaller than the resting length**, the actin filaments overlap each other so the number of active sites available for interacting with myosin cross bridges is reduced .
- **At length equal to or slightly greater than the resting length** (corresponding to a sarcomere length of 2-2.2 microns), maximum interaction is possible between the active sites on actin and myosin cross bridges. Hence the active tension developed is also maximum.
- **At length longer than the resting length** the degree of overlap between actin and myosin reduced so their interaction also reduced. Thus, the active tension developed is also less.
- **At length i.e. 180% of the resting length** (a sarcomere length of 3.6 microns), there is no overlap between actin and myosin. Hence the active tension developed is zero .

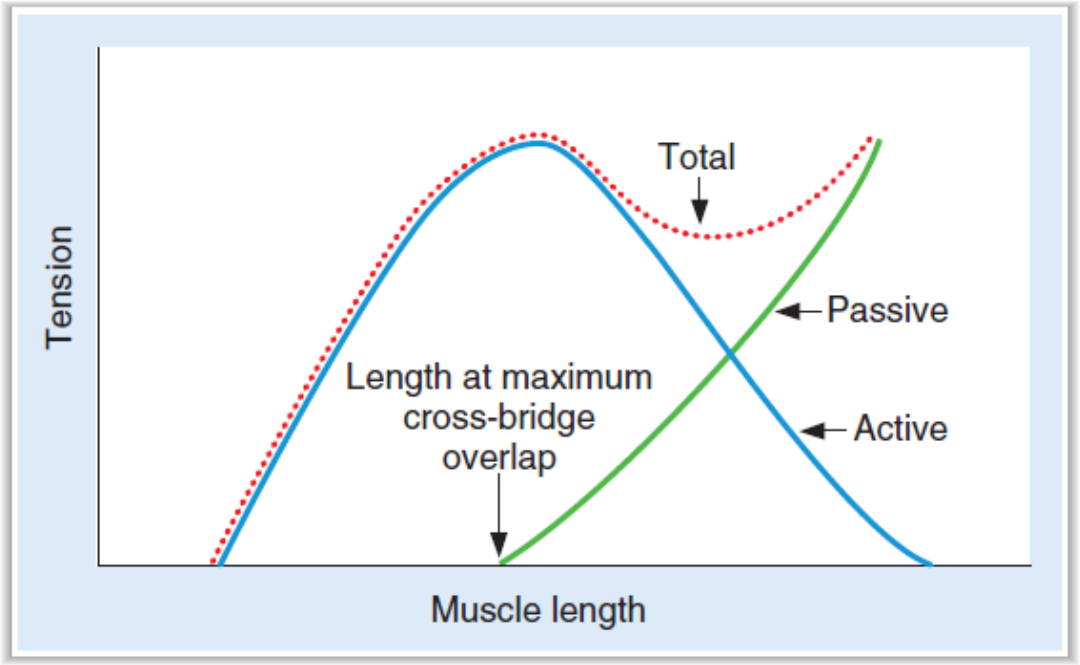


FIGURE 1-14 Length–tension relationship in skeletal muscle.

Length–tension relationship (Figure 1-14)

- measures tension developed during **isometric contractions** when the muscle is set to fixed lengths (preload).

a. **Passive tension** is the tension developed by stretching the muscle to different lengths.
b. **Total tension** is the tension developed when the muscle is stimulated to contract at different lengths.
c. **Active tension** is the difference between total tension and passive tension.

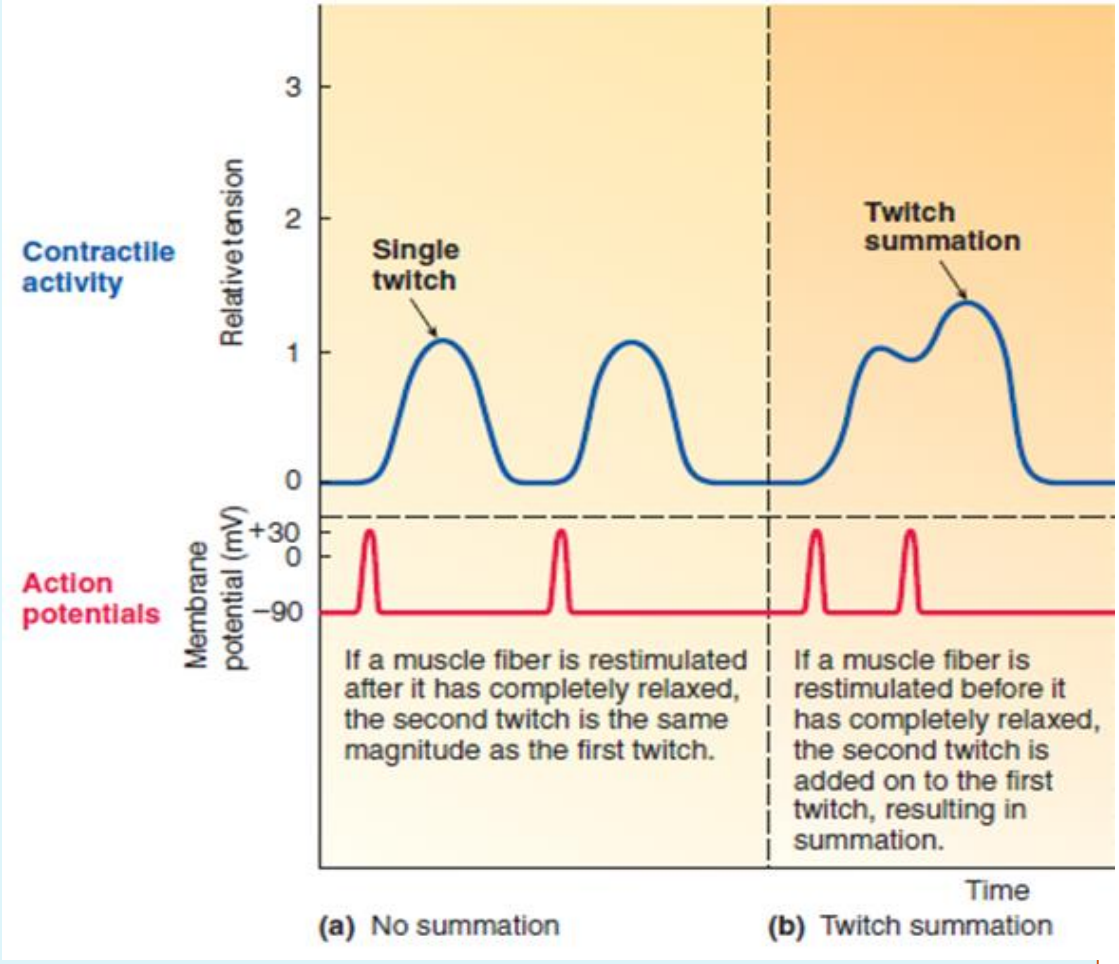
Length-Tension Relationship

- **Passive tension:** Tension developed in the muscle during resting condition.
- **Total tension:** Tension developed in the muscle during isometric contraction.

- **Active tension:**
  - Difference between the passive tension and total tension at a particular length of the muscle.
  - Considered as the real tension that is generated in the muscle during contractile process.
  - Determined by the length-tension curve.

6. Summation of contraction:

- Summation means adding together of individual twitch contraction= Simple means of increasing force of muscle contraction.
- Isometric tension developed in a single fiber or a muscle depends on the frequency of the stimulus applied to it.



7. Staircase Phenomenon (Treppe)

- Muscle stimulated rapidly but below tetanizing frequency
- Second contraction occurs during the relaxation phase of 1st one that results higher amplitude
- There is progressive increase in force of contraction for the 1st few contractions, until a maximum uniform tension per contraction is reached.
- **Cytoplasmic Ca^{++} conc. remains elevated**
- **Heat production decreases sarcoplasmic viscosity & facilitated enzymatic activity**

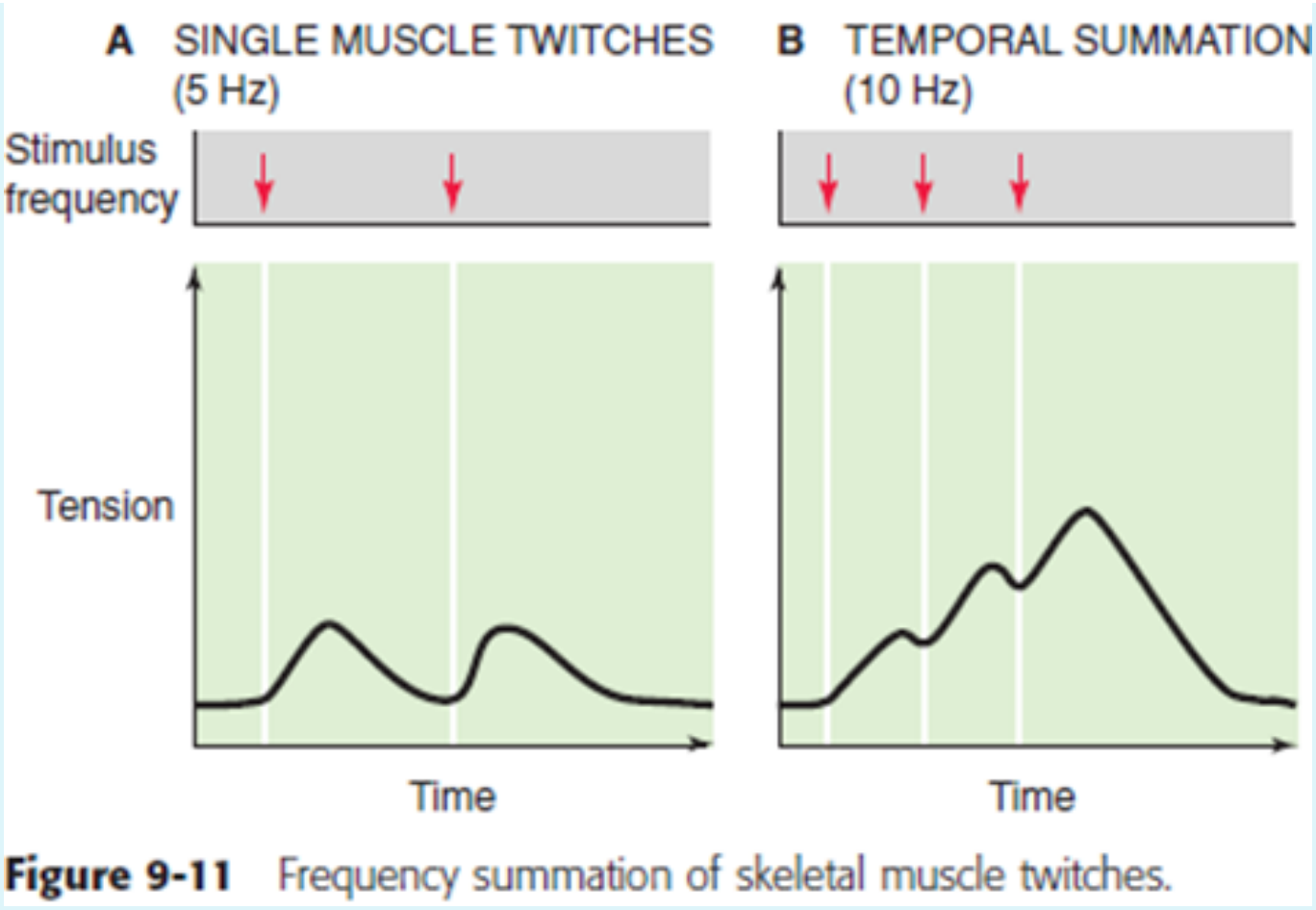


Figure 9-11 Frequency summation of skeletal muscle twitches.

8. Tetanization

- Muscle when stimulated repeatedly at a very high frequency resulting continuous contractile activity without relaxation lead to Tetanic contraction (Tetanus)
- Reason: with each stimulus there is fresh release of Ca^{2+}, so that after few stimuli, Ca^{2+} concentration reaches its maximum in cytoplasm
- Strength of contraction of an intact muscle made up of many different motor units can be increased by:

(1) increasing the number of motor neurons activated, thereby increasing the number of motor units contracting (**Spatial recruitment)**

(2) increasing the frequency of action potentials of motor neuron, thereby eliciting summation or tetanus of those muscle fibers in the motor unit (**Temporal recruitment)**

Effect of repetitive stimulation on muscle contraction

Incomplete/
Clonus/

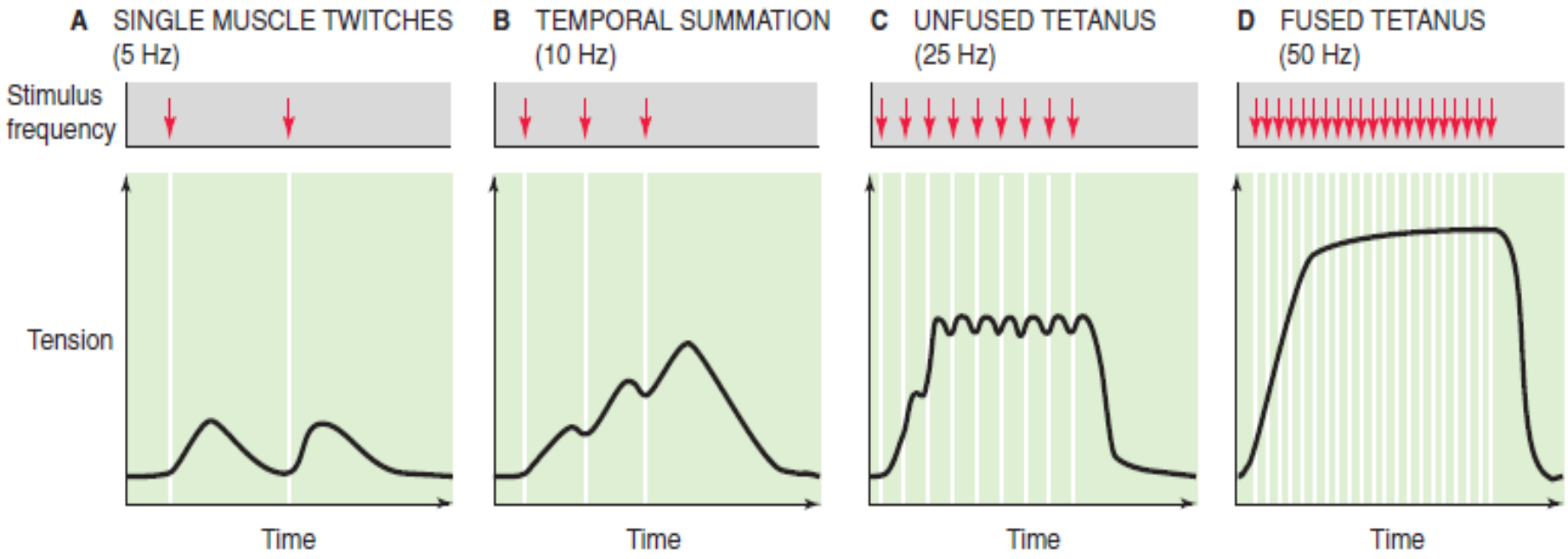
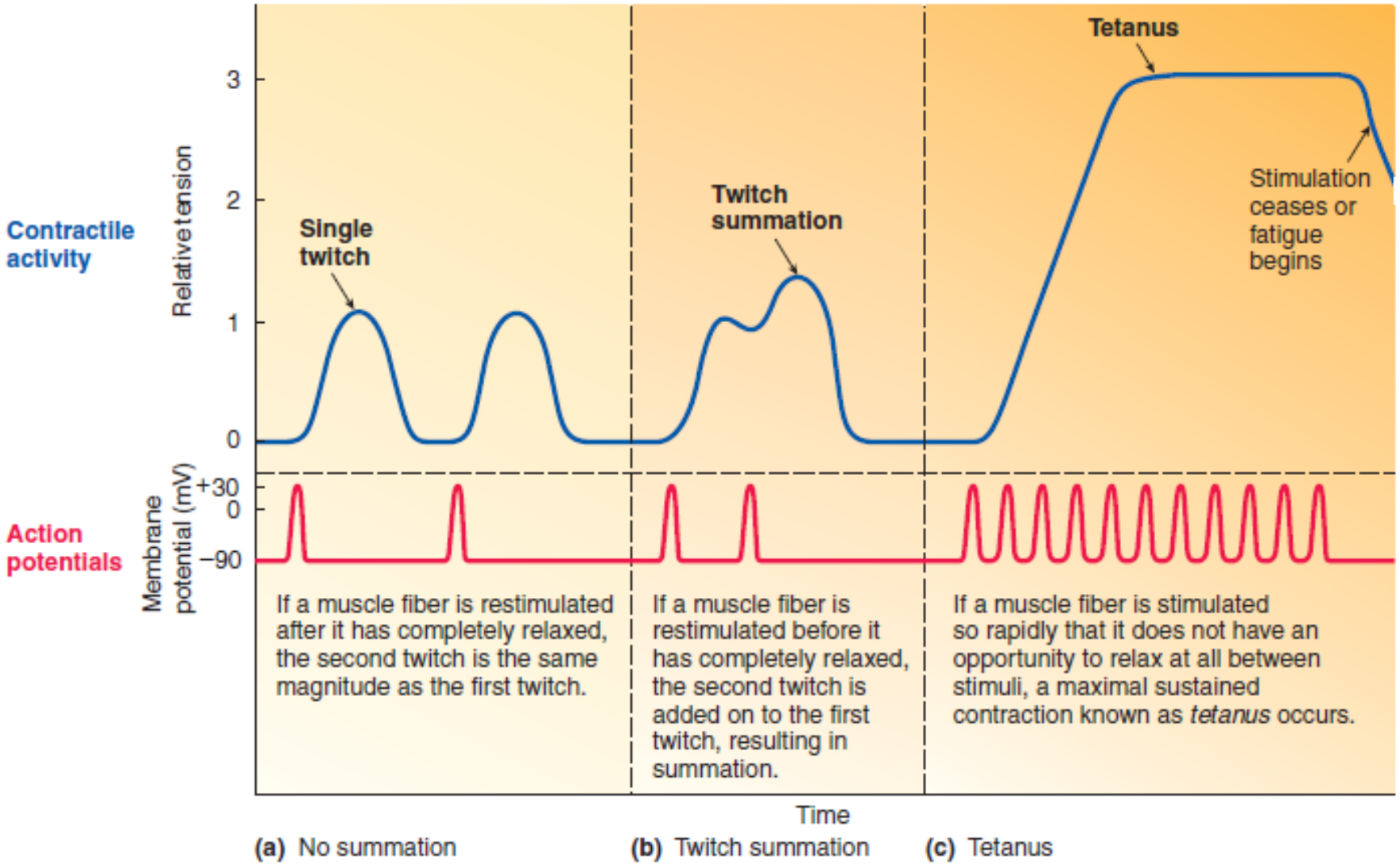


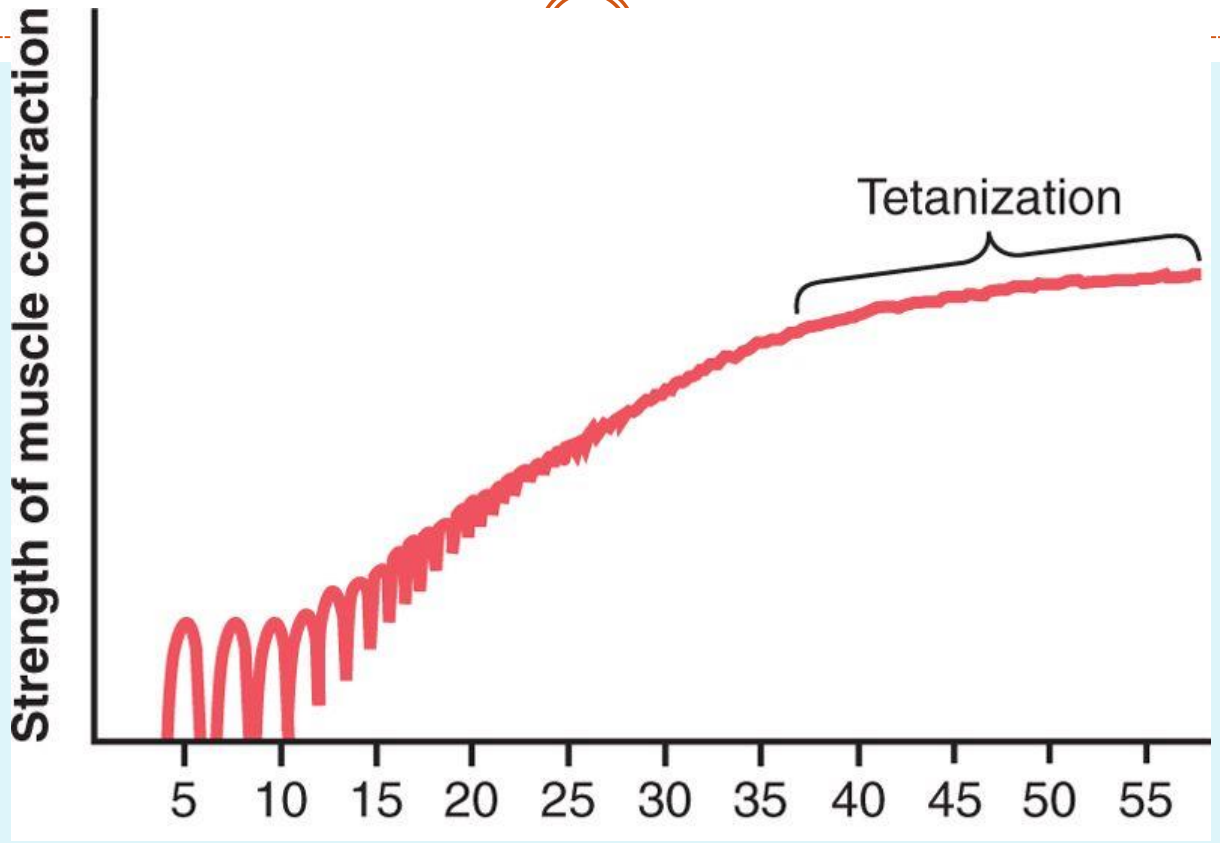
Figure 9-11 Frequency summation of skeletal muscle twitches.

Very high frequency



● **FIGURE 8-18 Twitch summation and tetanus.**

Frequency summation & tetanization



Both **frequency summation & tetanus** are examples of **temporal recruitment**—as same fibers are contracted by firing of same motor neurons but with alter frequency

9. Post-Tetanic Potentiation

- When a single stimulus is applied to a muscle immediately after tetanic contraction is over, the amplitude of contraction is higher than that of a single twitch.

- Higher cytosolic Ca^{++} level is responsible for this.

Energy Sources in Skeletal Muscle

- **Adenosine Tri-phosphate**
- **Creatine Phosphate**
- **Oxygen Debt:** extra amount oxygen taken up by the body above the basal O2 consumption.
- **Muscle Fatigue**
- **Rigor Mortis**
- **Heat Production in Muscles**
- **Fiber Types in Skeletal Muscle**

Table 28.1: Differences between type I and II muscle fibers.

	Type I	Type II
1. Other names	Slow; red; oxidative	Fast; white; glycolytic
2. Contraction velocity	Slow	Fast
3. Myosin ATPase	Low	High
4. Ca^{2+}-pumping capacity of SR	Low	High
5. Rate of fatigue	Slow	Fast
6. Fiber diameter	Moderate	Large
7. Size of motor unit	Small	Large
8. Glycogen content	Low	High
9. Glycolytic capacity	Low	High
10. Oxidative capacity	High	Low
11. Mitochondria	Numerous	Less
12. Myoglobin content	High	Low
13. Capillaries	Many	Few
14. Primary source of ATP production	Oxidative phosphorylation	Glycolysis

Applied Aspects

- **Muscular Dystrophy**
- **Myopathies**
- **Myotonia**
- **Focal Dystonias**
- **Muscle Sprain**
- **Muscle Cramp**