Muscle contraction – *force summation*

Force summation: increase in contraction intensity as a result of the additive effect of individual twitch contractions

(1) Multiple fiber summation:

- results from an ***increase in the number of motor units*** contracting simultaneously (fiber recruitment)
- **Size principle**

increasing the motor unit size ⇒ ↑↑ tension

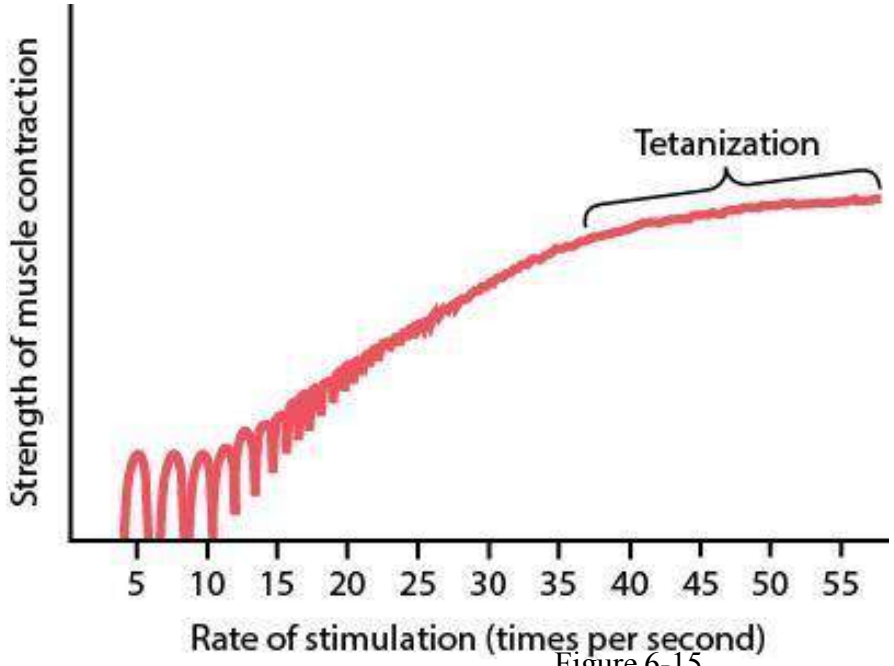


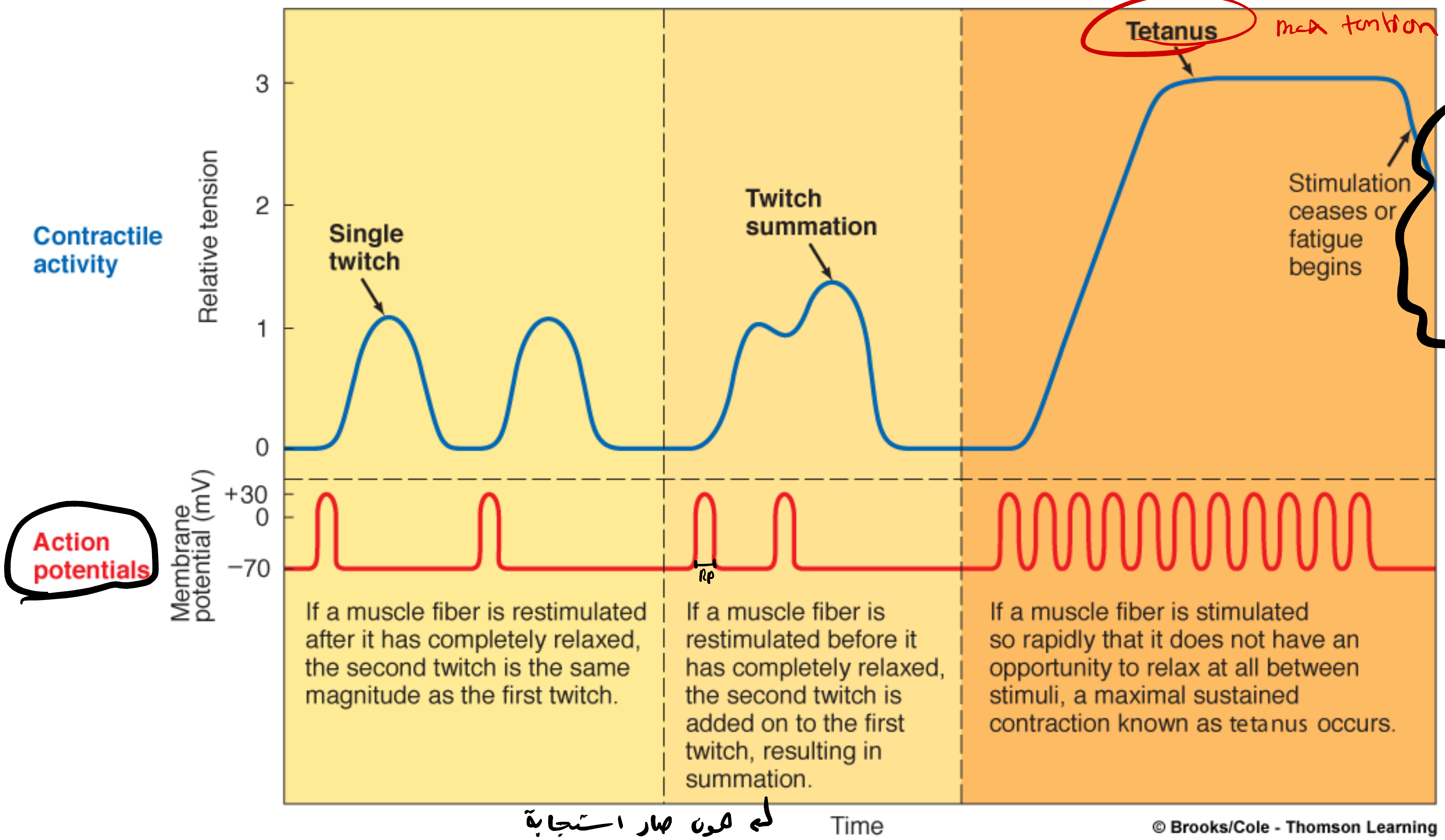
Figure 6-15

(2) Frequency summation: results from an ***increase in the frequency of contraction*** of a single motor unit

High frequency stimulation Tetany and summation

Summation causes an increase in intra cellular Ca^{2+} → Increase in tension

continous contraction [هنا مثلا العضلات إلي بتخلينا واقفين بتعمل constant contraction]



* If muscle is stimulated before complete relaxation has occured, the new twitch will sum with the previous one.

لهون صار استجابة لأنه الـ stimulus اجا بعد الـ Refractory period

Summary

Determinants of Whole-Muscle Tension in Skeletal Muscle

- **Number of Fibers Contracting** ⇒ علاقة طردية مع الـ tension — number of fibers
- Number of motor units recruited*
- Number of muscle fibers per motor unit
- Number of muscle fibers available to contract (size of muscle)
- **Tension Developed by Each Contracting Fiber** ⇒ شو بحدد الـ tension اللي بولدلي إياه fiber واحد
- Frequency of stimulation (twitch summation and tetanus)*
- Length of fiber at onset of contraction (length–tension relationship) ⇒ optimal length has the ↑ tension
  أي زيادة أو نقصان عن الـ optimal length بقلل الـ tension
- Extent of fatigue (عكسي مع الـ tension) ⇒ ↑ fatigue → ↓ tension
- Type of fiber (fatigue-resistant oxidative (slow) or fatigue-prone glycolytic (fast))
- Thickness of fiber (strength training and testosterone)
  ↑ thickness → ↑ myosin / actin binding site → ↑ tention

The Staircase Effect (Treppe)

* لو العضلة صارلها فترة منا عاملة Contraction ، لو عملت بعدها Contraction بكون الـ tension قليل بعدين بصير يزيد الـ tension شوي شوي زي الدرج

- When a muscle begins to contract after a long period of rest, its initial strength of contraction is smaller than the strength of muscle later.
- That is, the strength of contraction increases to a plateau, a phenomenon called the *staircase effect*, or *treppe.*
- it is believed to be caused primarily by increasing calcium ions in the cytosol because of the release of more and more ions from the sarcoplasmic reticulum with each successive muscle action potential

Energy for muscle contraction

- Most of the energy required for muscle contraction is used to trigger the walk-along mechanism whereby the cross-bridges pull the actin filaments, but small amounts are required for the following:
- (1) pumping calcium ions from the sarcoplasm into the sarcoplasmic reticulum after the contraction is over; and
- (2) pumping sodium and potassium ions through the muscle fiber membrane to maintain an appropriate ionic environment for the propagation of muscle fiber action potentials
- The concentration of ATP in the muscle fiber, about 4 millimolar, is sufficient to maintain full contraction for only 1 to 2 seconds at most. The ATP is split to form ADP, which transfers energy from the ATP molecule to the contracting machinery of the muscle fiber

Energy for muscle contraction

ADP rephosphorylation and generation of newer ATP

- The first source of energy that is used to reconstitute the ATP is the substance *phosphocreatine*, which carries a high-energy phosphate bond similar to the bonds of ATP. Therefore, phosphocreatine is instantly cleaved, and its released energy causes bonding of a new phosphate ion toto reconstitute the ATP.
- Glycolysis Rapid enzymatic breakdown of the glycogen to pyruvic acid and lactic acid liberates energy that is used to convert ADP to ATP; the ATP can then be used directly to energize additional muscle contraction
- *Oxidative metabolism*, which means combining oxygen with the end products of glycolysis and with various other cellular foodstuffs to liberate ATP. *More than 95% of all energy used by the muscles for sustained long-term contraction is derived from oxidative metabolism.*

Mechanisms of excitation-contraction coupling and relaxation in cardiac muscle.

gap junction

ATP, Adenosine triphosphate.
RyR, ryanodine
receptor Ca2+ release channel;
SERCA, sarcoplasmic reticulum
Ca2+-ATPase