# AUGMENTATION OF MUSCLE STRENGTH

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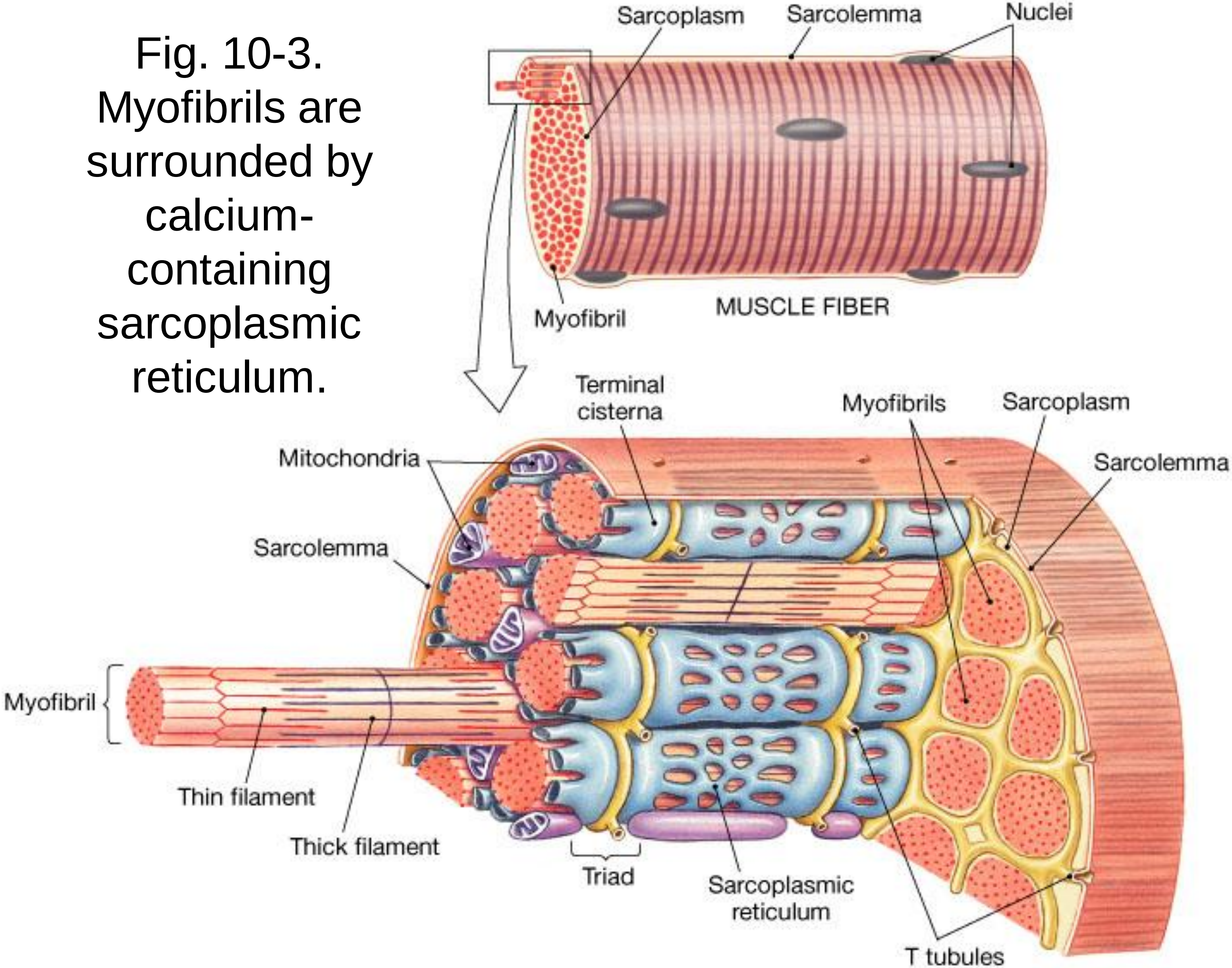
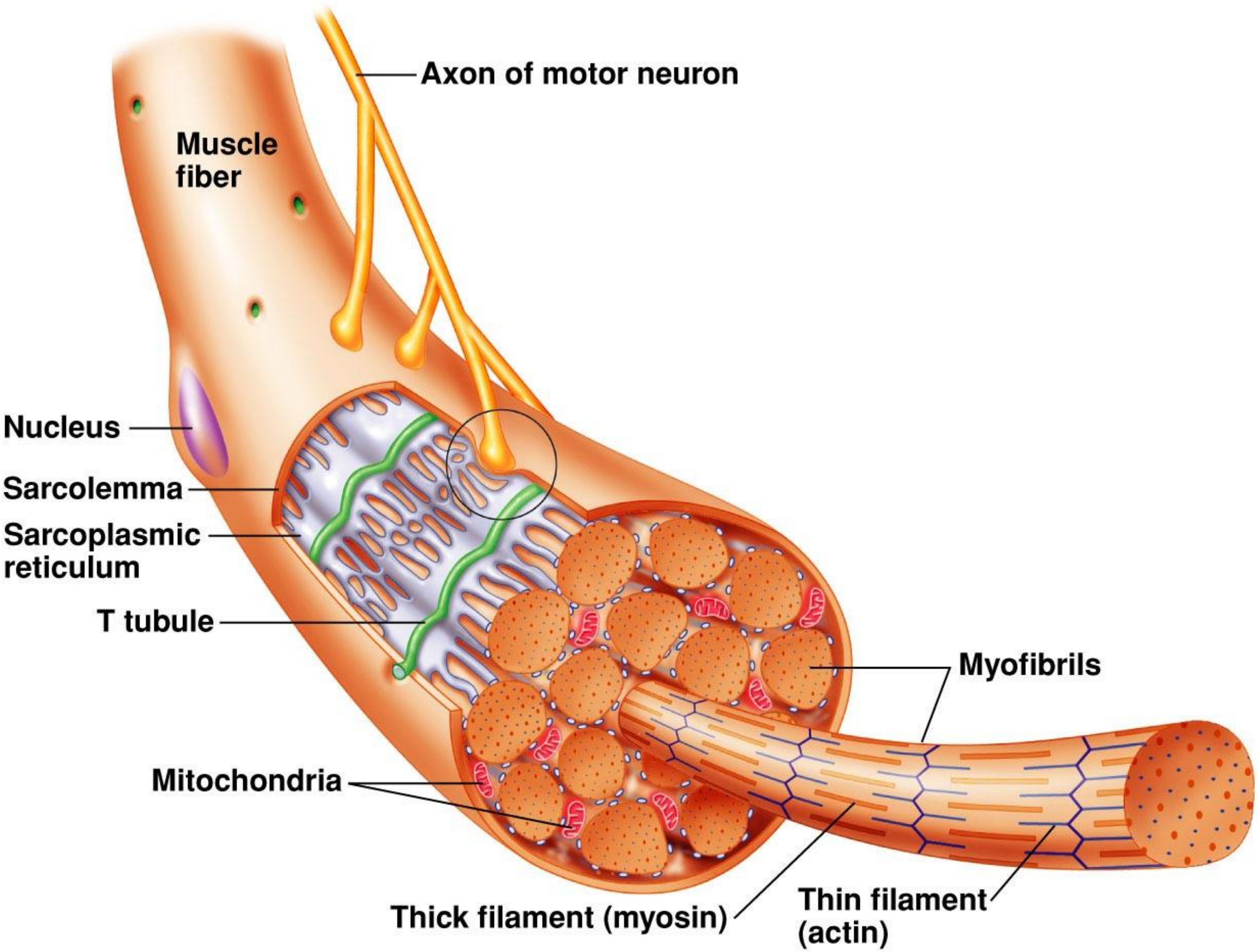
# Learning Objectives

- To describe muscle's macro and micro structures.
- To explain the sliding-filament action of contraction.
- To differentiate among types of muscle fibres.
- To differentiate between physiologically and electrically induced muscle contraction.
- To explain how electrically induced muscle contraction augment muscle strength.

Fig. 10-3. Myofibrils are surrounded by calcium-containing sarcoplasmic reticulum.



# Components of a muscle fiber



# Muscle fiber components

- Sarcolemma: muscle cell membrane
- Sarcoplasma: muscle cell cytoplasm
- Motor end plate: contact surface with axon terminal
- T tubule: cell membrane extension into the sarcoplasm (to reach the myofibrils)
- Cisternae: areas of the ER dedicated to Ca++ storage (located on each side of the T-tubules)
- Myofibrils: organized into sarcomeres

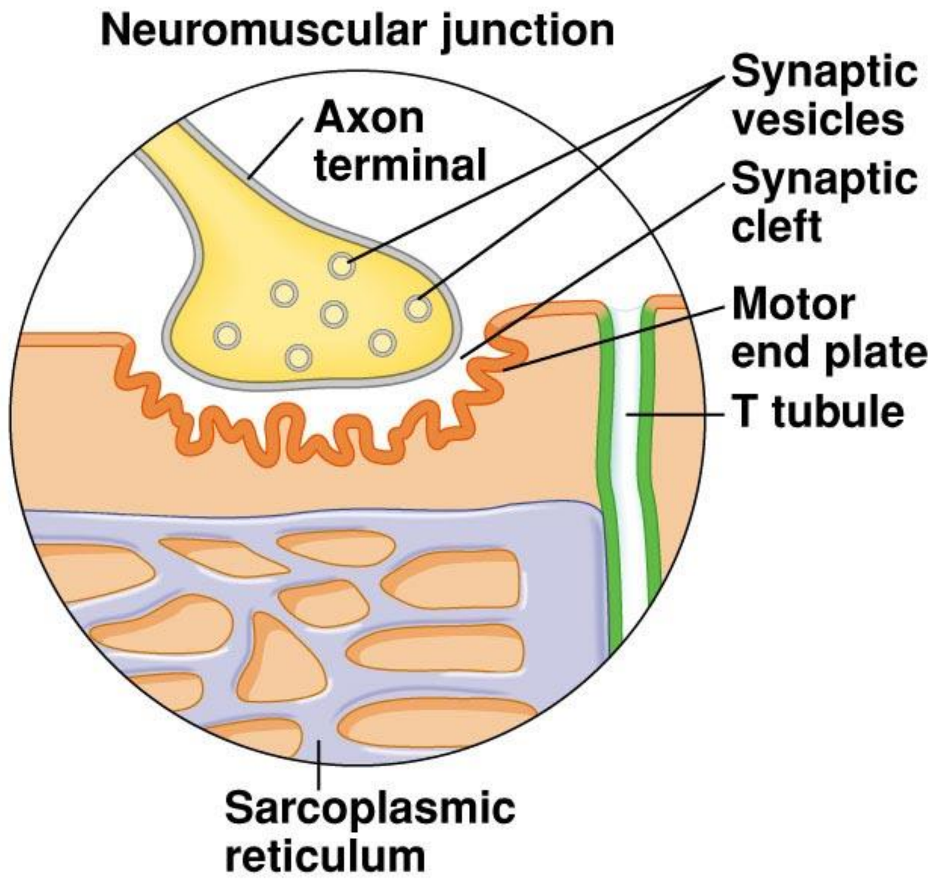
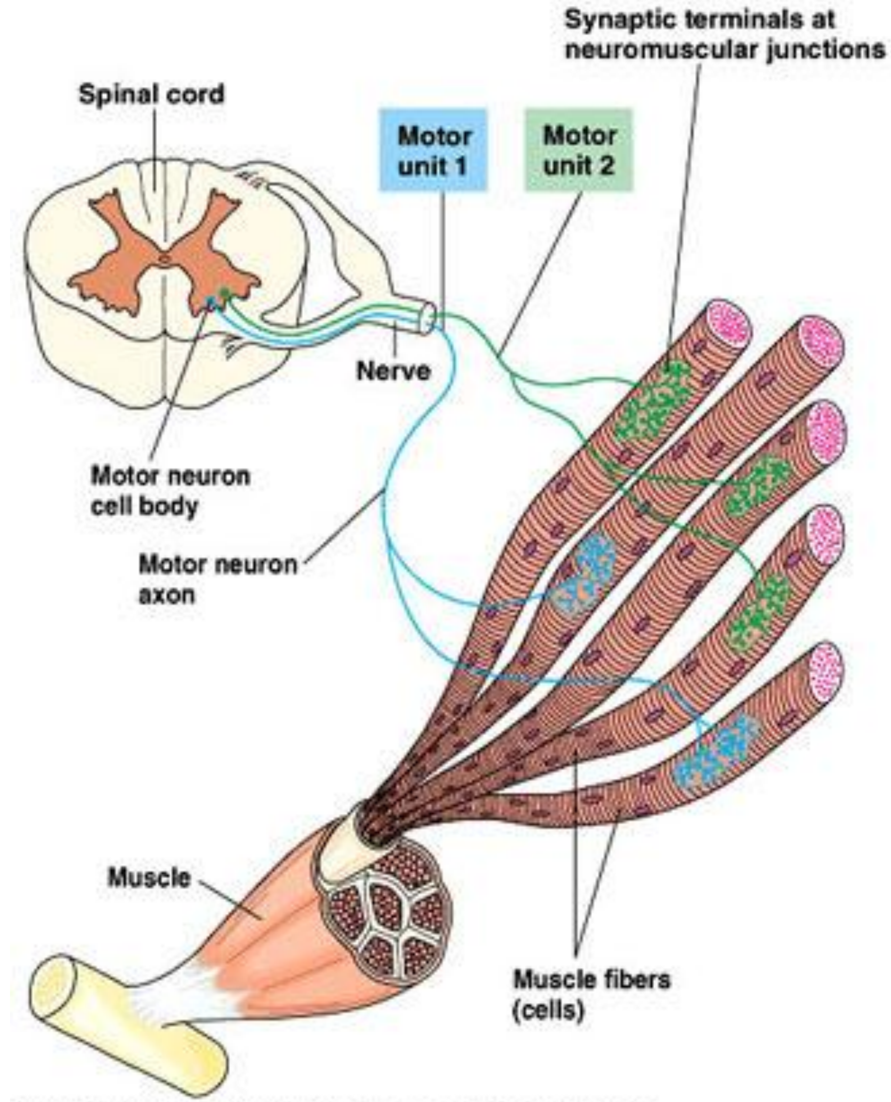




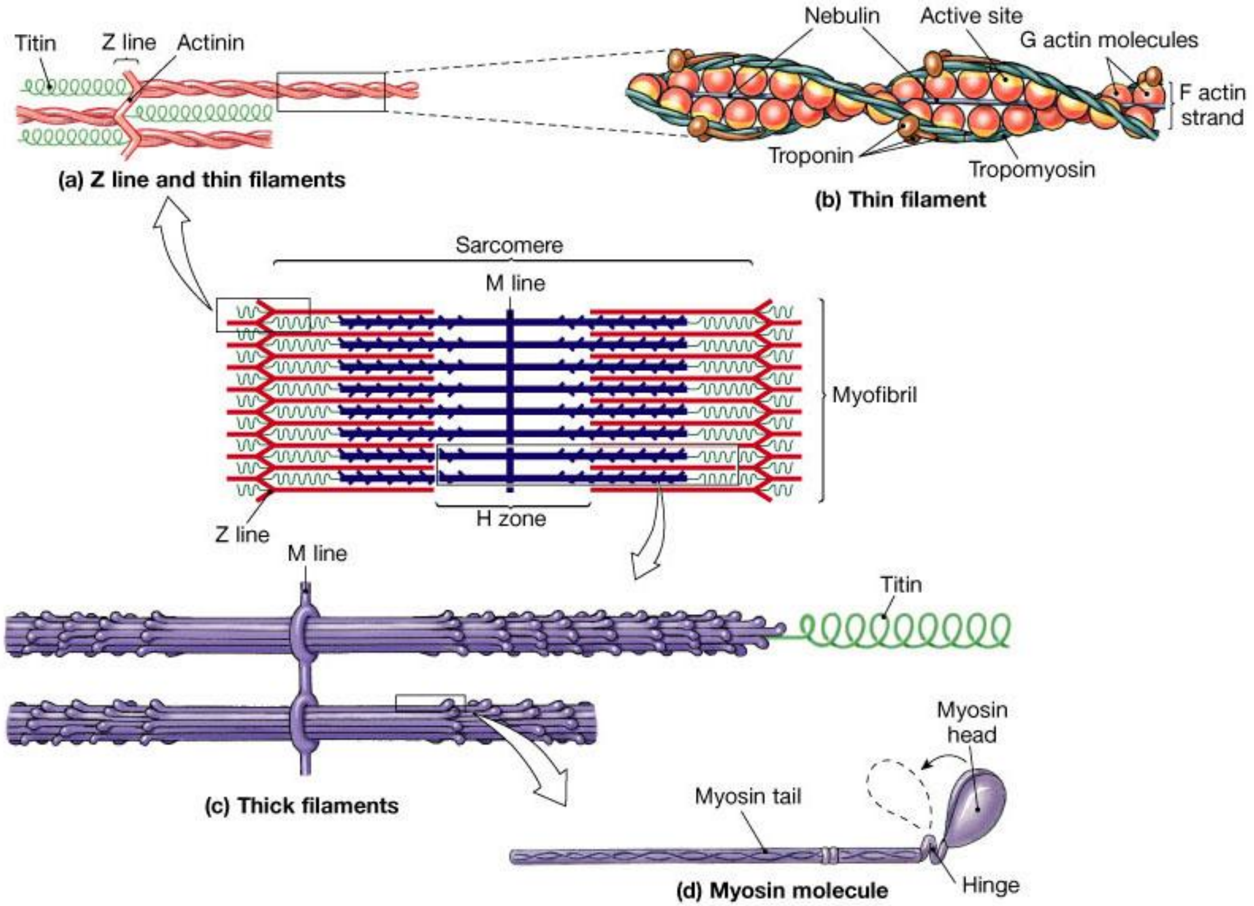

Figure 12.2 (2 of 2)

# Motor units

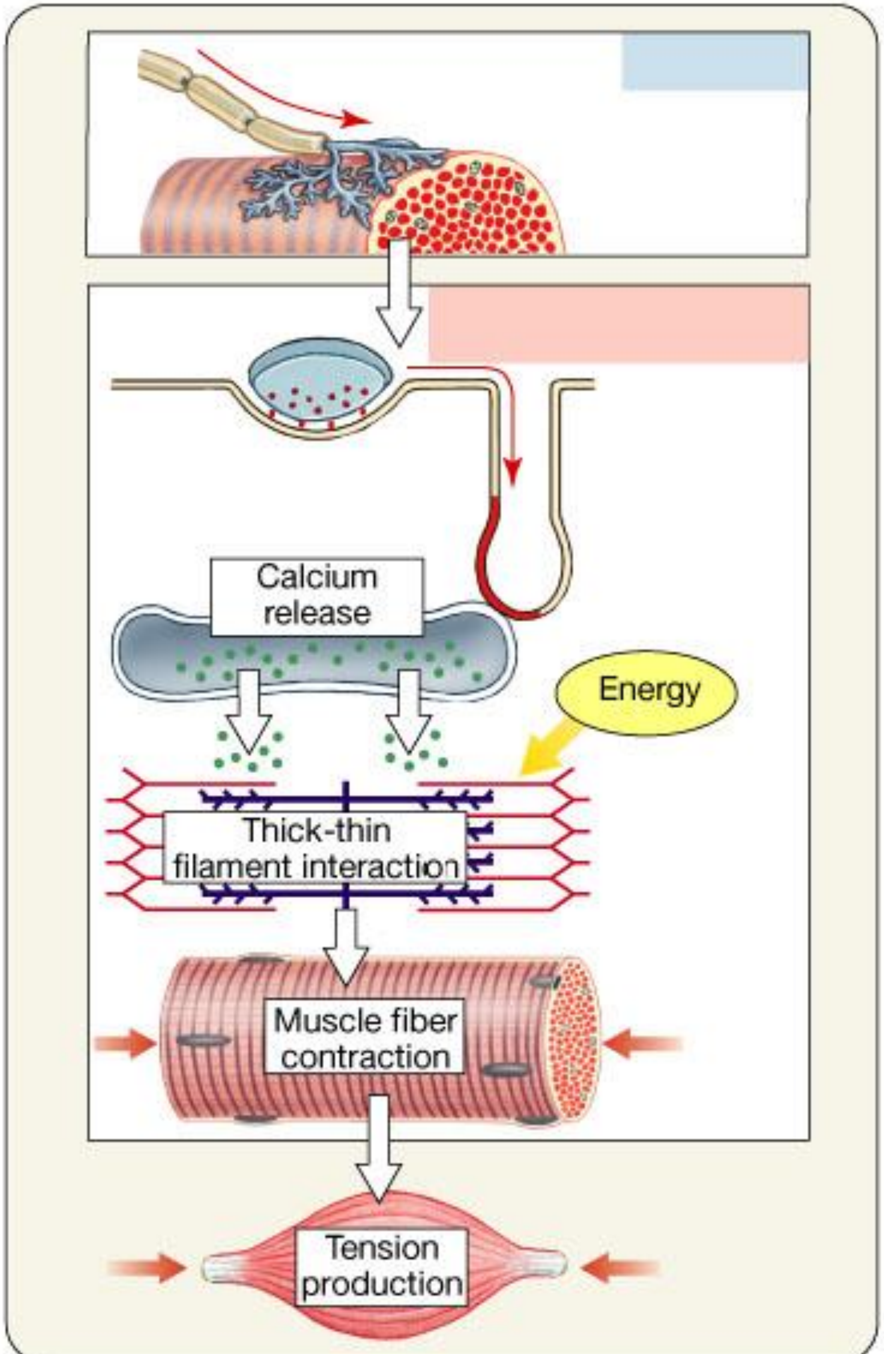
- Motor unit: Composed of one motor neuron and all the muscle fibers that it innervates
- There are many motor units in a muscle
- The number of fibers innervated by a single motor neuron varies (from a few to thousand)
- The fewer the number of fibers per neuron → the finer the movement (more brain power)
- Which body part will have the largest motor units? The smallest?

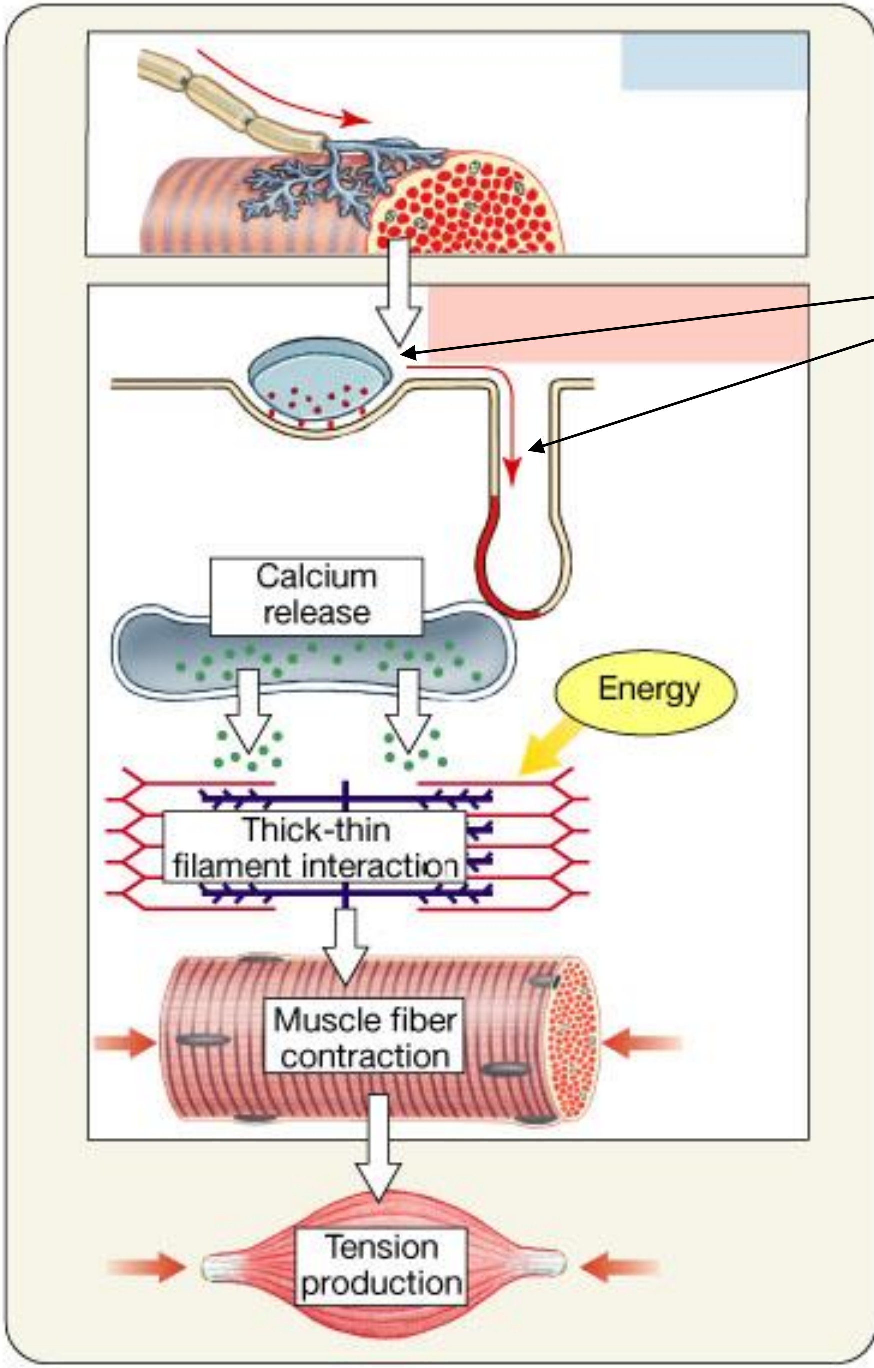


# Fig. 10-7. Review of thin and thick filament structure



# Fig. 10-9. Overview of the process

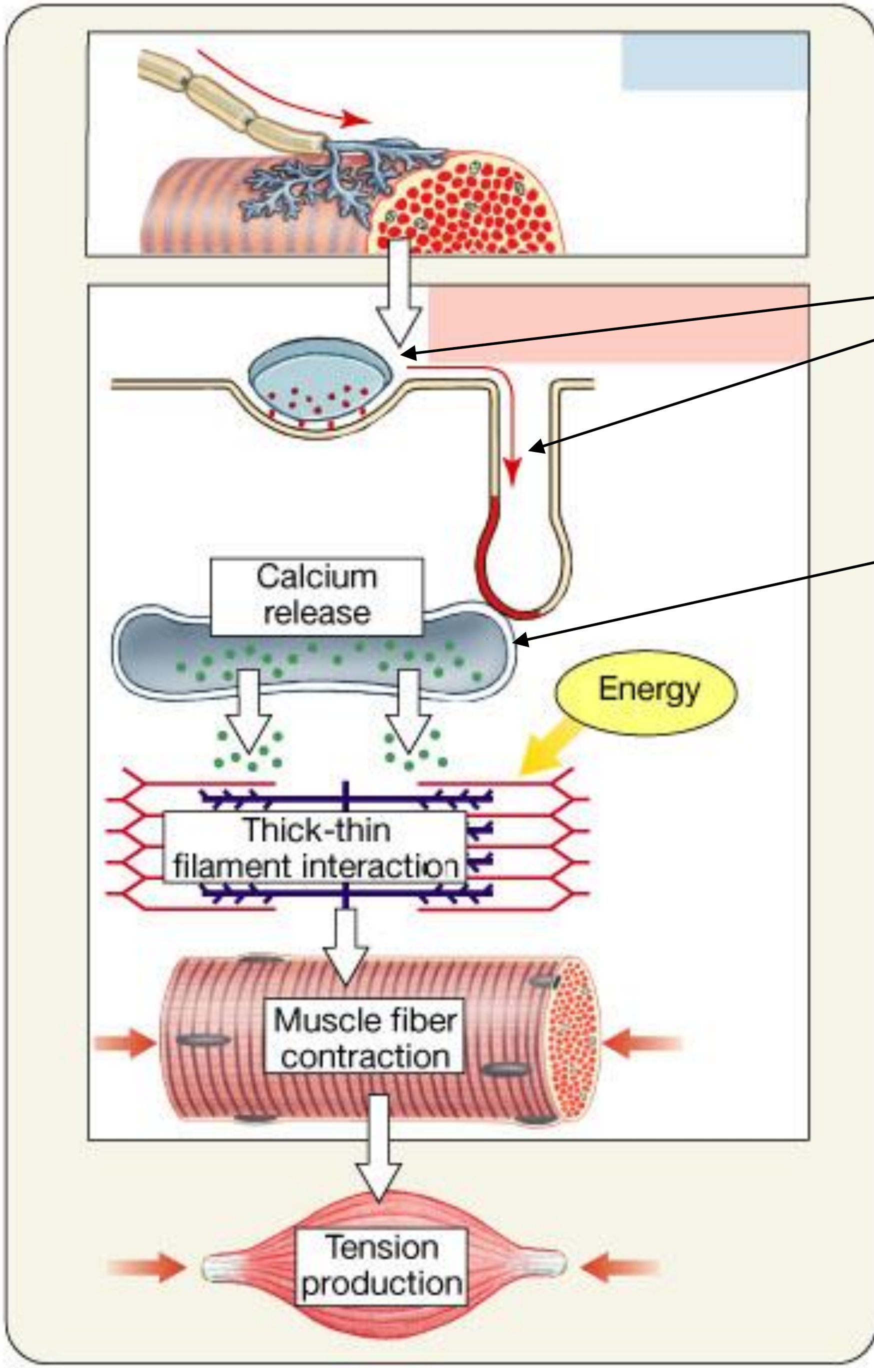







# Fig. 10-9. Overview of the process

The muscle fiber is stimulated.



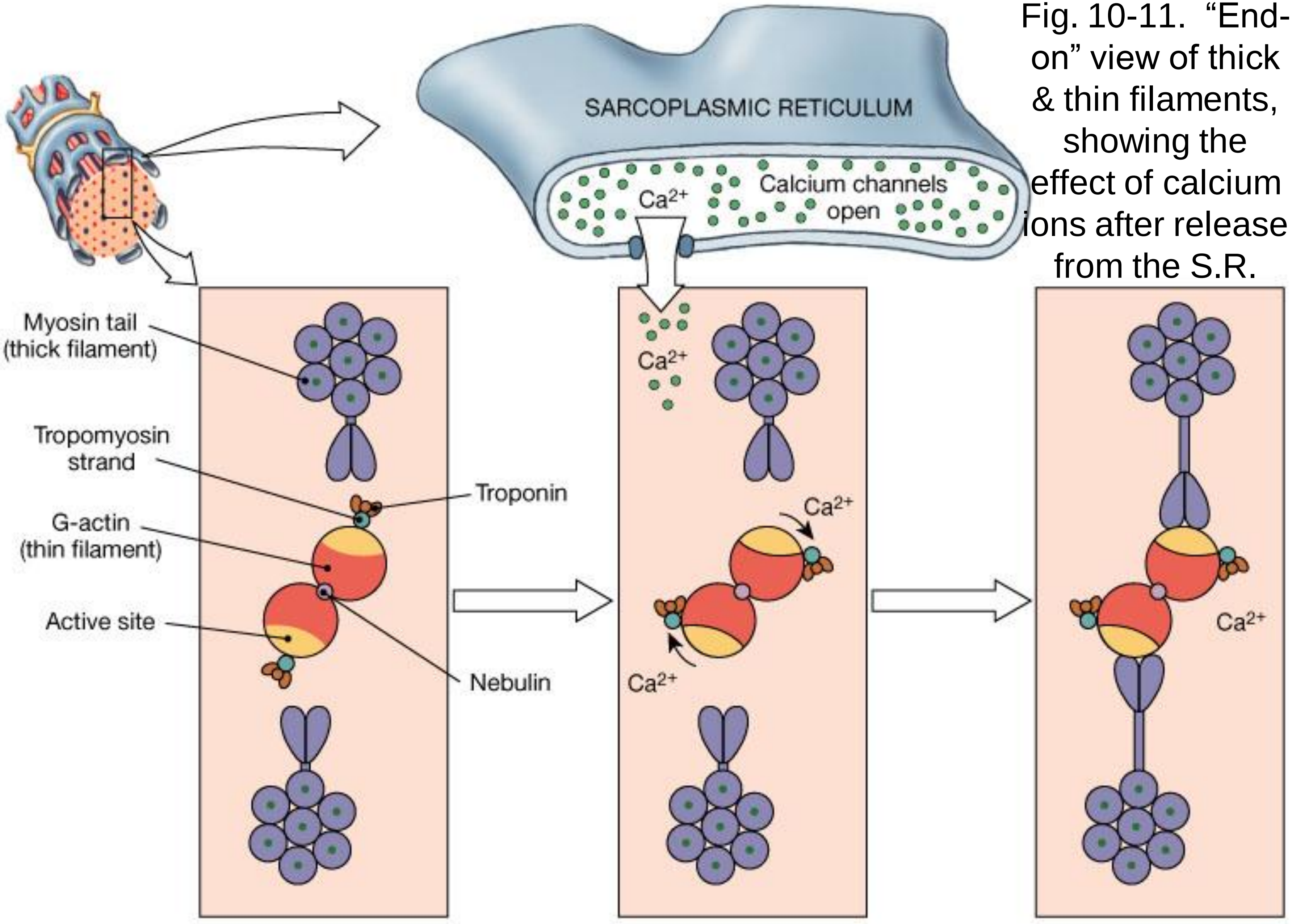


# Fig. 10-9. Overview of the process

The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

Fig. 10-11. "End-on" view of thick & thin filaments, showing the effect of calcium ions after release from the S.R.

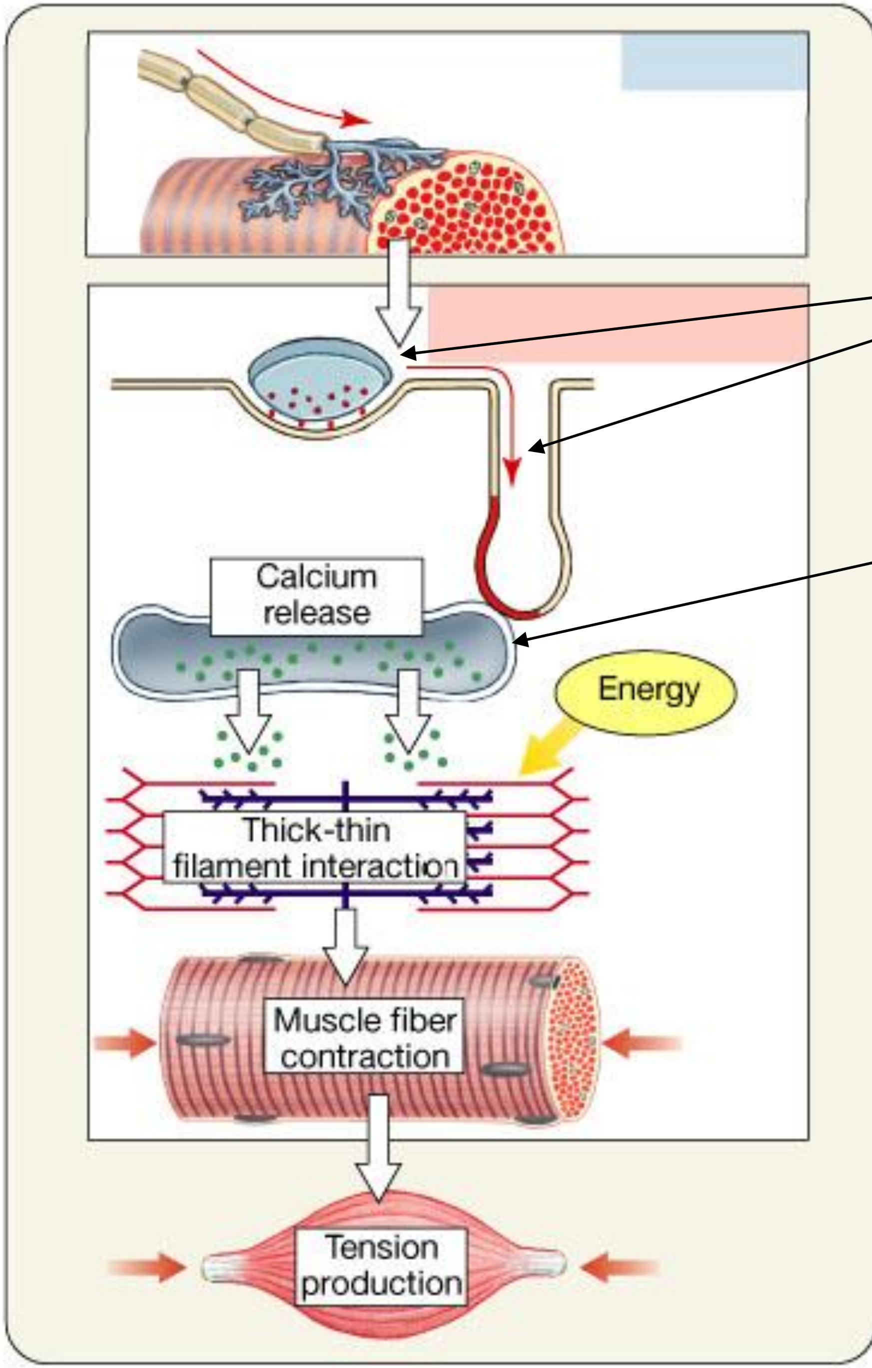



(a) Resting state

(b) Active site exposure

(c) Cross-bridge formation

# Fig. 10-9. Overview of the process

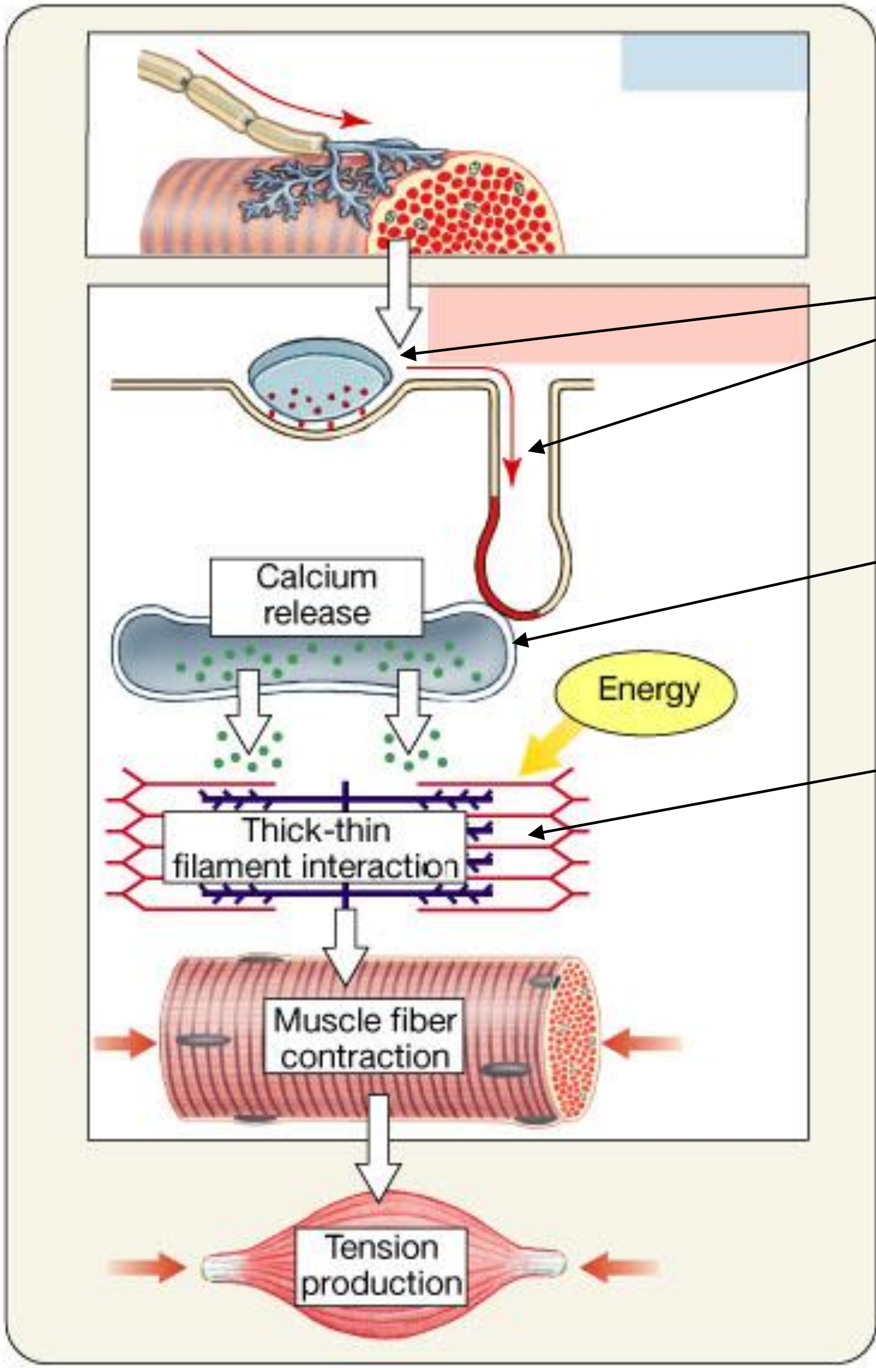





The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

# Fig. 10-9. Overview of the process





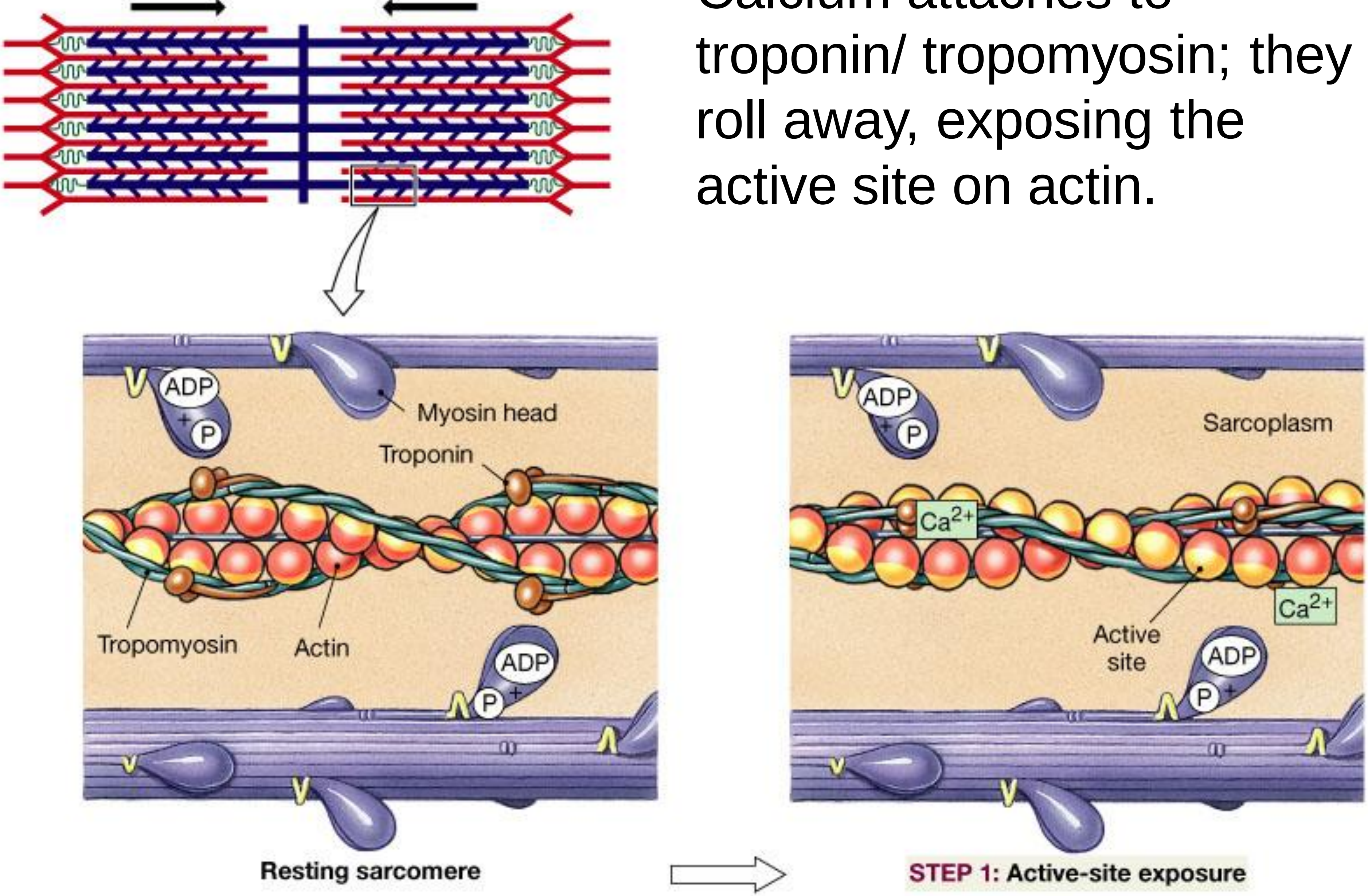

The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

Thin filaments move to middle of sarcomere.

Fig. 10-12

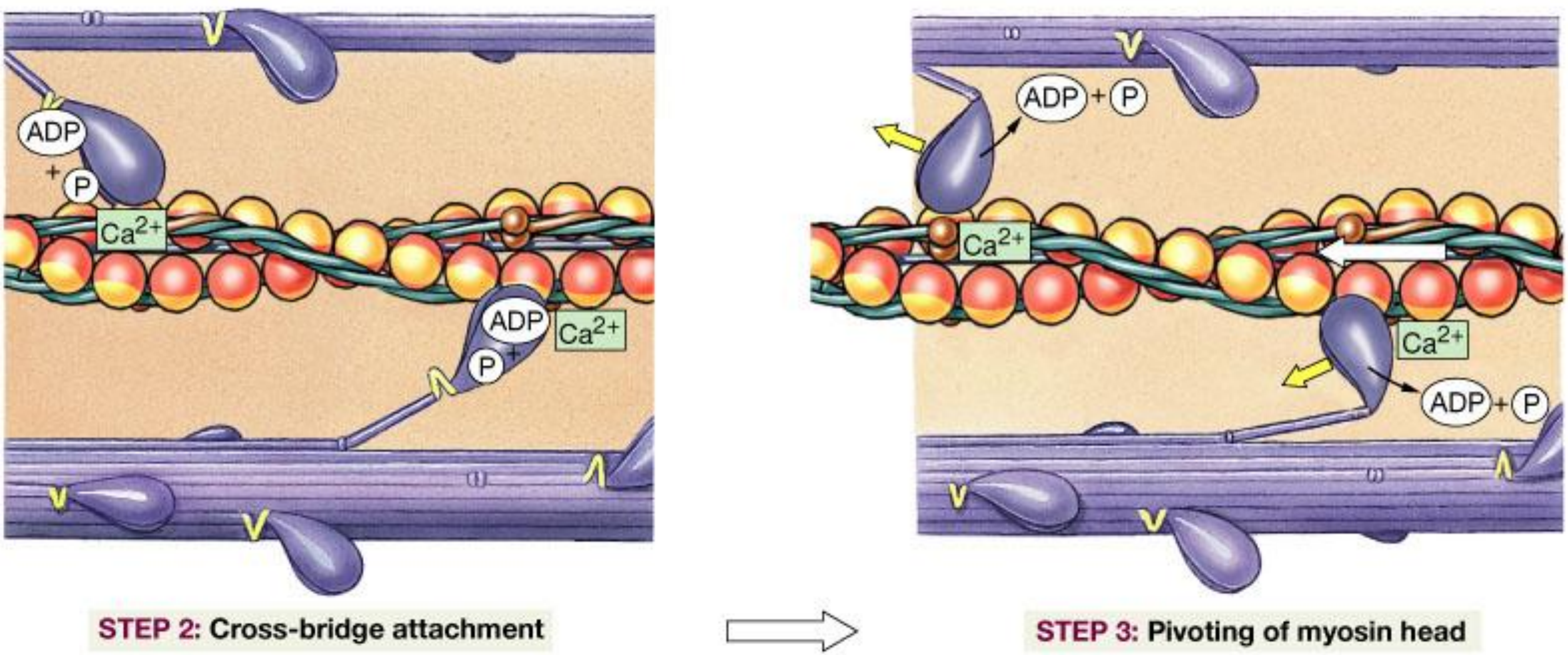
Calcium attaches to troponin/ tropomyosin; they roll away, exposing the active site on actin.



# Fig. 10-12

Myosin cross-bridges attach to active site on actin.

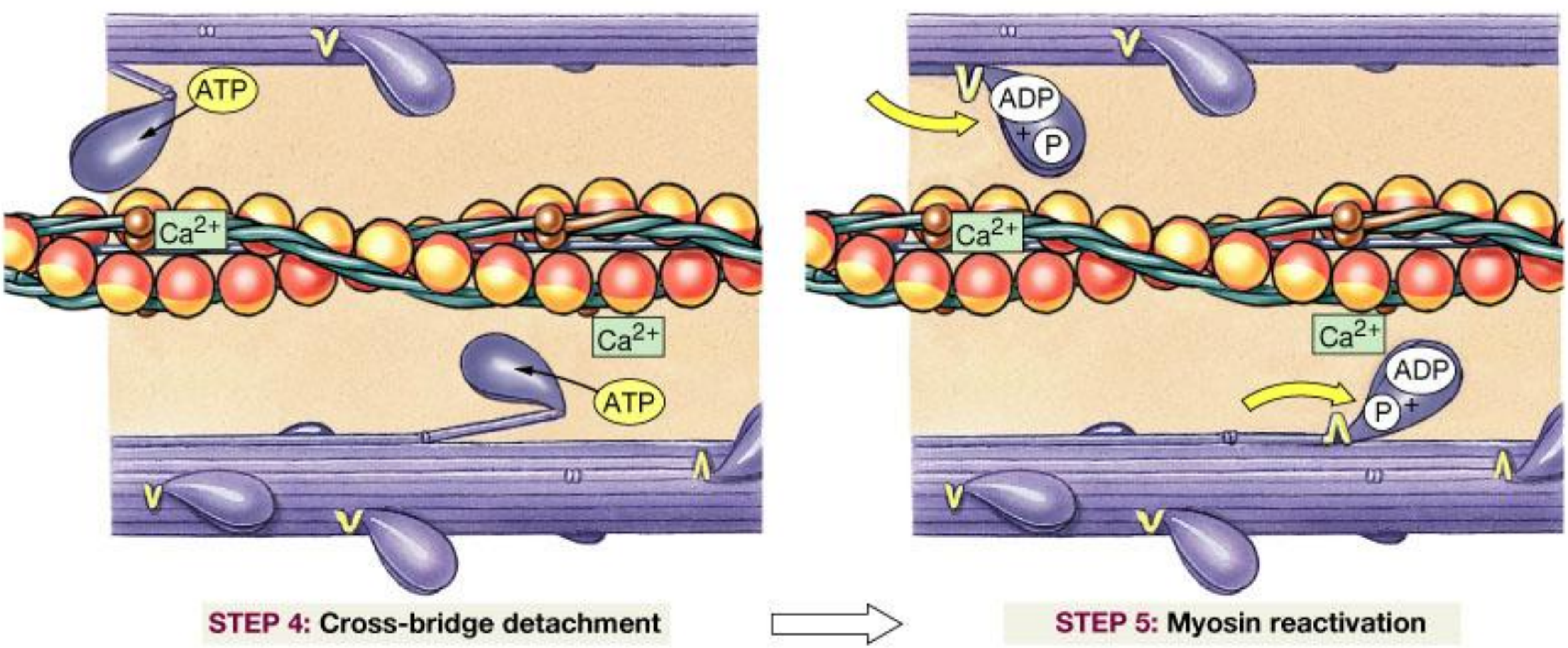
After attachment, the cross-bridges pivot, pulling the thin filaments.



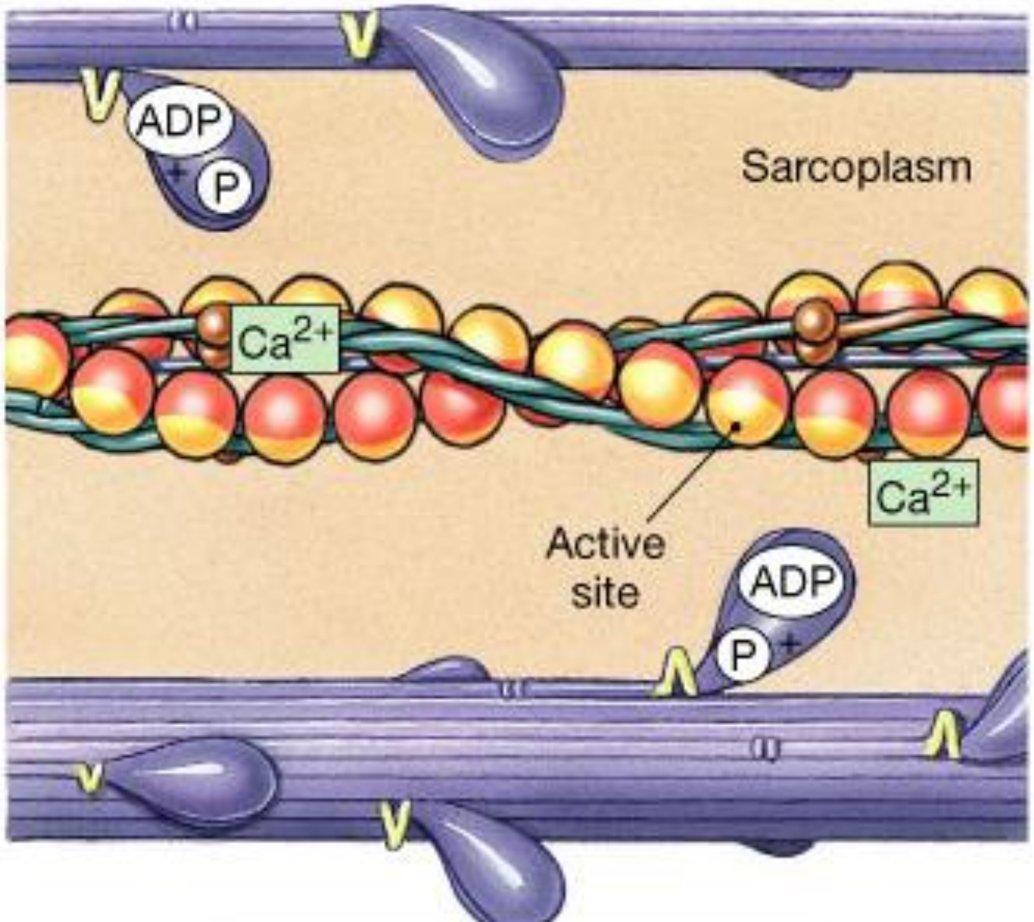
# Fig. 10-12

A fresh ATP replaces the $ADP+P_i$, allowing myosin and actin to detach.

Energy from the splitting of the fresh ATP allows repositioning of the myosin head.



# Fig. 10-12

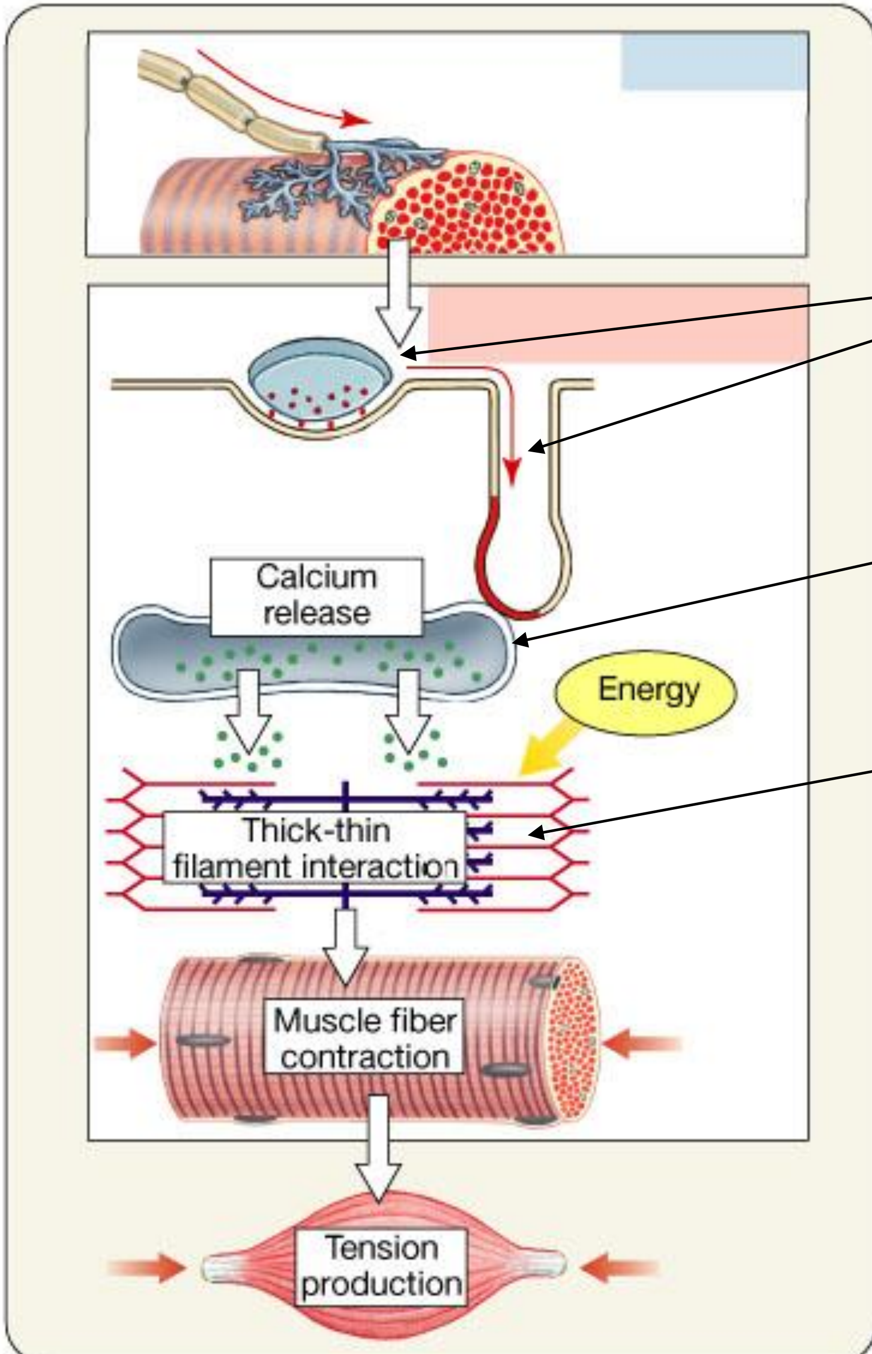



STEP 1: Active-site exposure



This leads back to Step 1, which continues the cycle as long as calcium ions are attached to troponin/tropomyosin.

# Fig. 10-9. Overview of the process



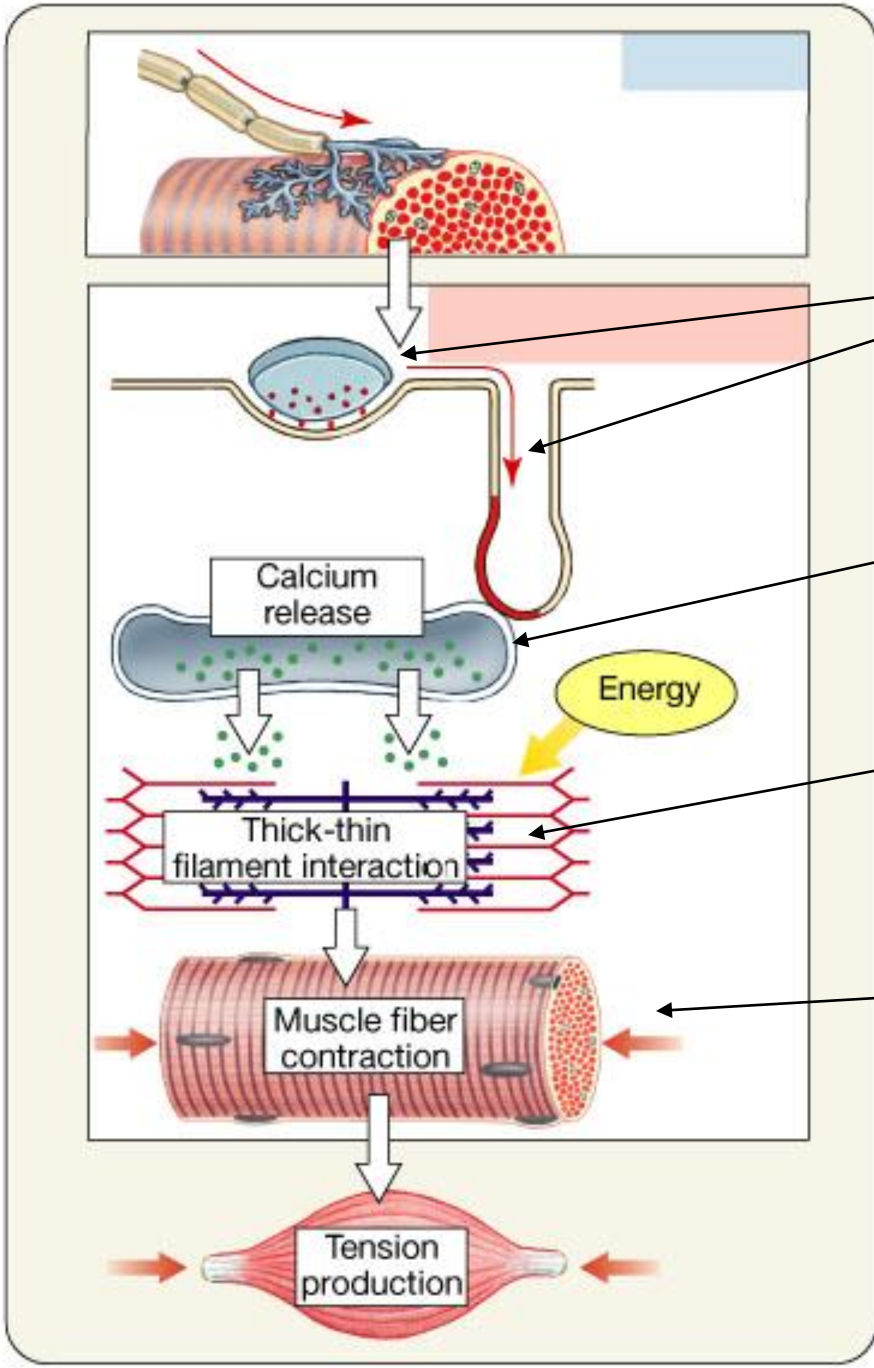



The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

Thin filaments move to middle of sarcomere.

# Fig. 10-9. Overview of the process



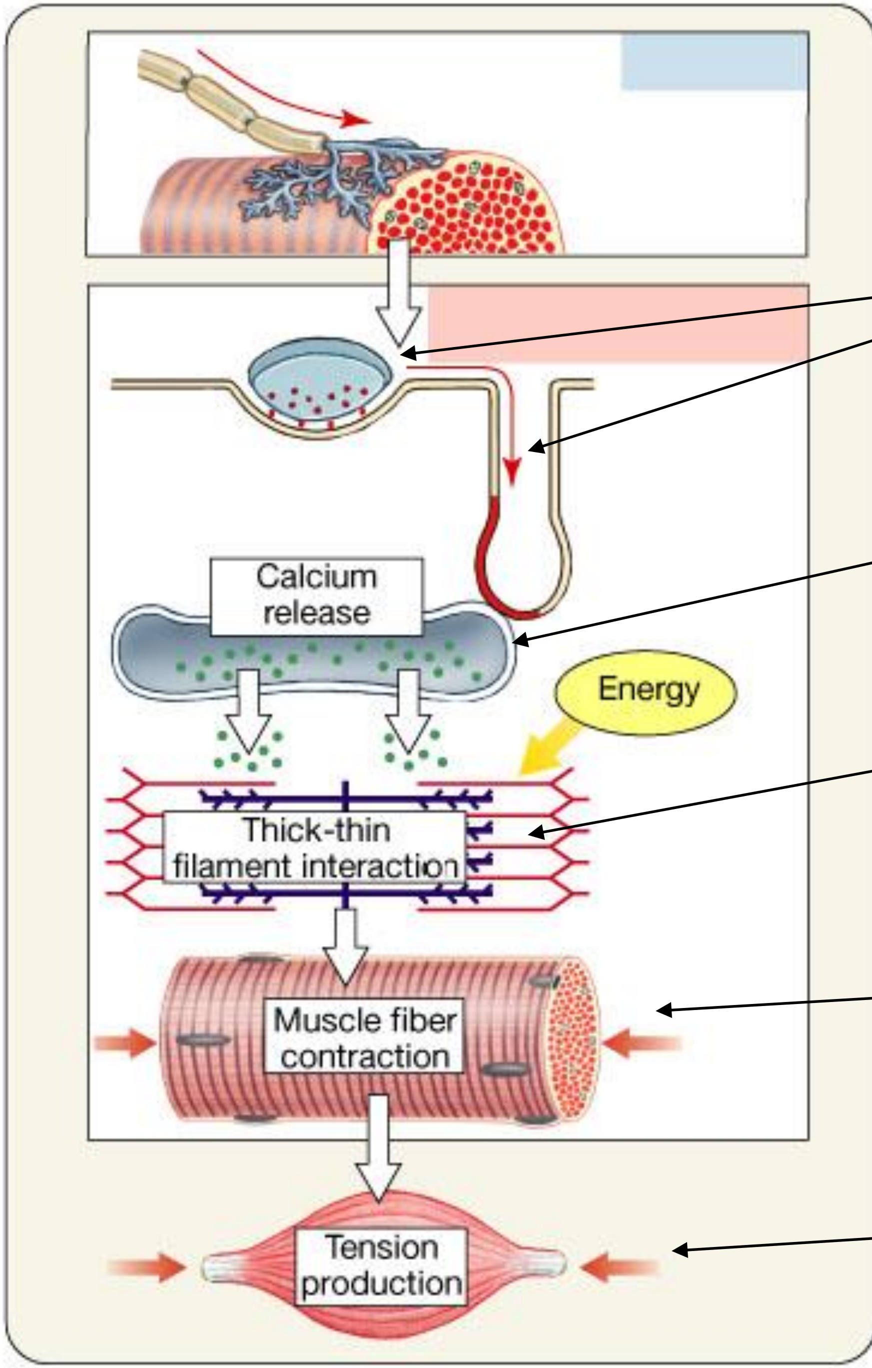

The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

Thin filaments move to middle of sarcomere.

Muscle fiber contracts.

# Fig. 10-9. Overview of the process






The muscle fiber is stimulated.

$Ca^{2+}$ ions are released.

Thin filaments move to middle of sarcomere.

Muscle fiber contracts.

Muscle tension increases.

# Contractile Properties

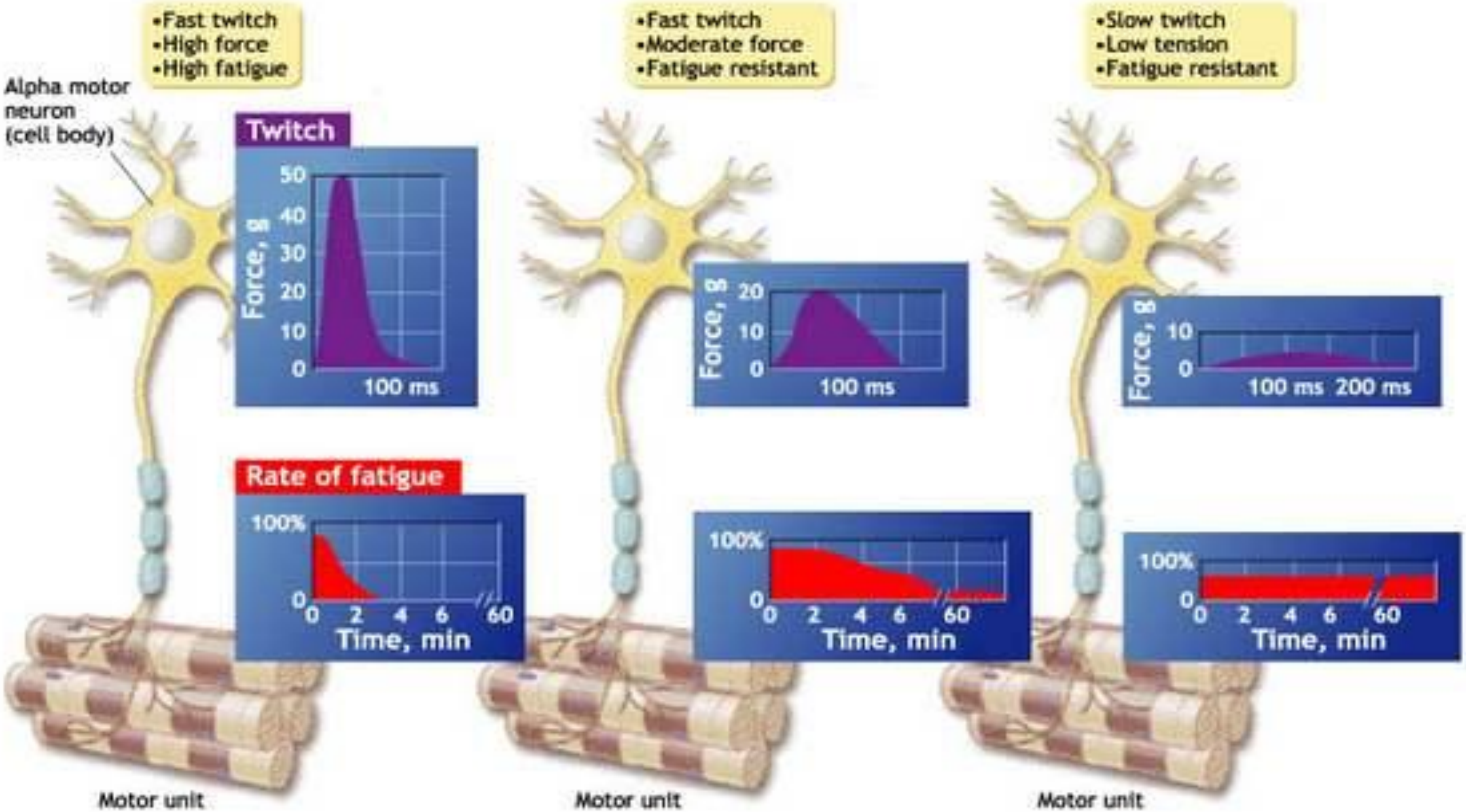



**Figure 19.13.** Speed, force, and fatigue characteristics of motor units. "Phasic" motor neurons fire rapidly with short bursts; "tonic" motor neurons fire slowly but continuously.

## ► Table 17.2 - Structural and Functional Characteristics of Muscle Fibers

| | Type I | Type II | |
|---|---|---|---|
| CONTRACTILE: | ST | FTa | FTb |
| METABOLIC: | SO | FOG | FG |
| **STRUCTURAL ASPECTS** | | | |
| Muscle fiber diameter | Small | Largest | Large |
| Mitochondrial density | High | High | Low |
| Capillary density | High | Medium | Low |
| Myoglobin content | High | Medium | Low |
| **FUNCTIONAL ASPECTS** | | | |
| Twitch (contraction) time | Slow | Fast | Fast |
| Relaxation time | Slow | Fast | Fast |
| Force production | Low | High | High |
| Fatigability | Fatigue-resistant | Fatigable | Most fatigable |
| **METABOLIC ASPECTS** | | | |
| Phosphocreatine stores | Low | High | High |
| Glycogen stores | Low | High | High |
| Triglyceride stores | High | Medium | Low |
| Myosin-ATPase activity | Low | High | High |
| Glycolytic enzyme activity | Low | High | High |
| Oxidative enzyme activity | High | High | Low |

# Contractile Properties

- ✓Slow twitch (I) fibers innervated by alpha 2 motor neurons, smaller of the two α motor neurons.

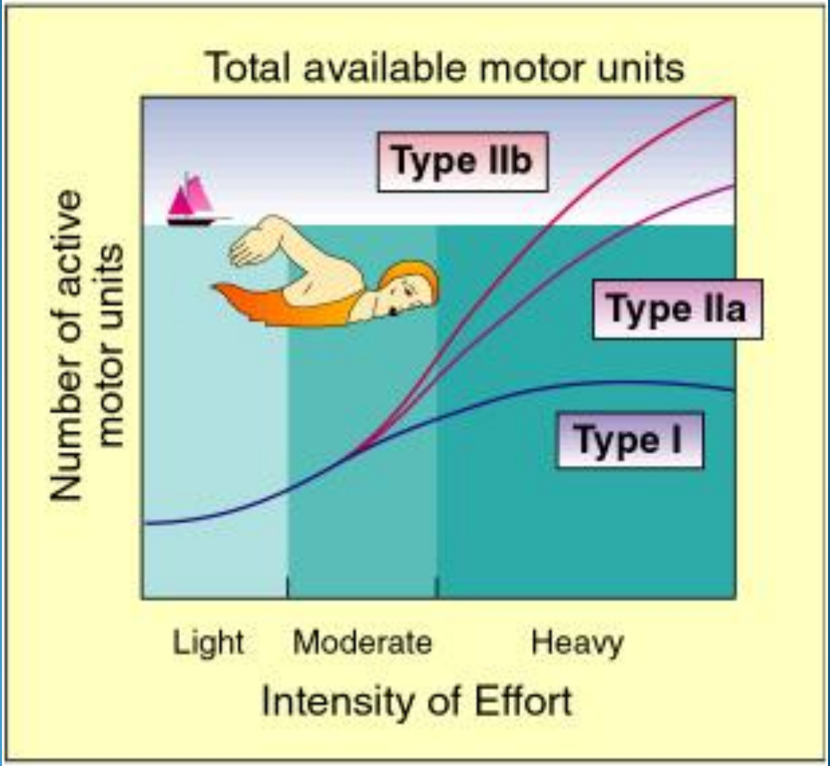
- ✓Fast twitch (II) fibers innervated by alpha 1 motor neurons, larger of the two α motor neurons.

- ✓Fast twitch (II) fibers have higher excitation threshold and faster conduction velocity.

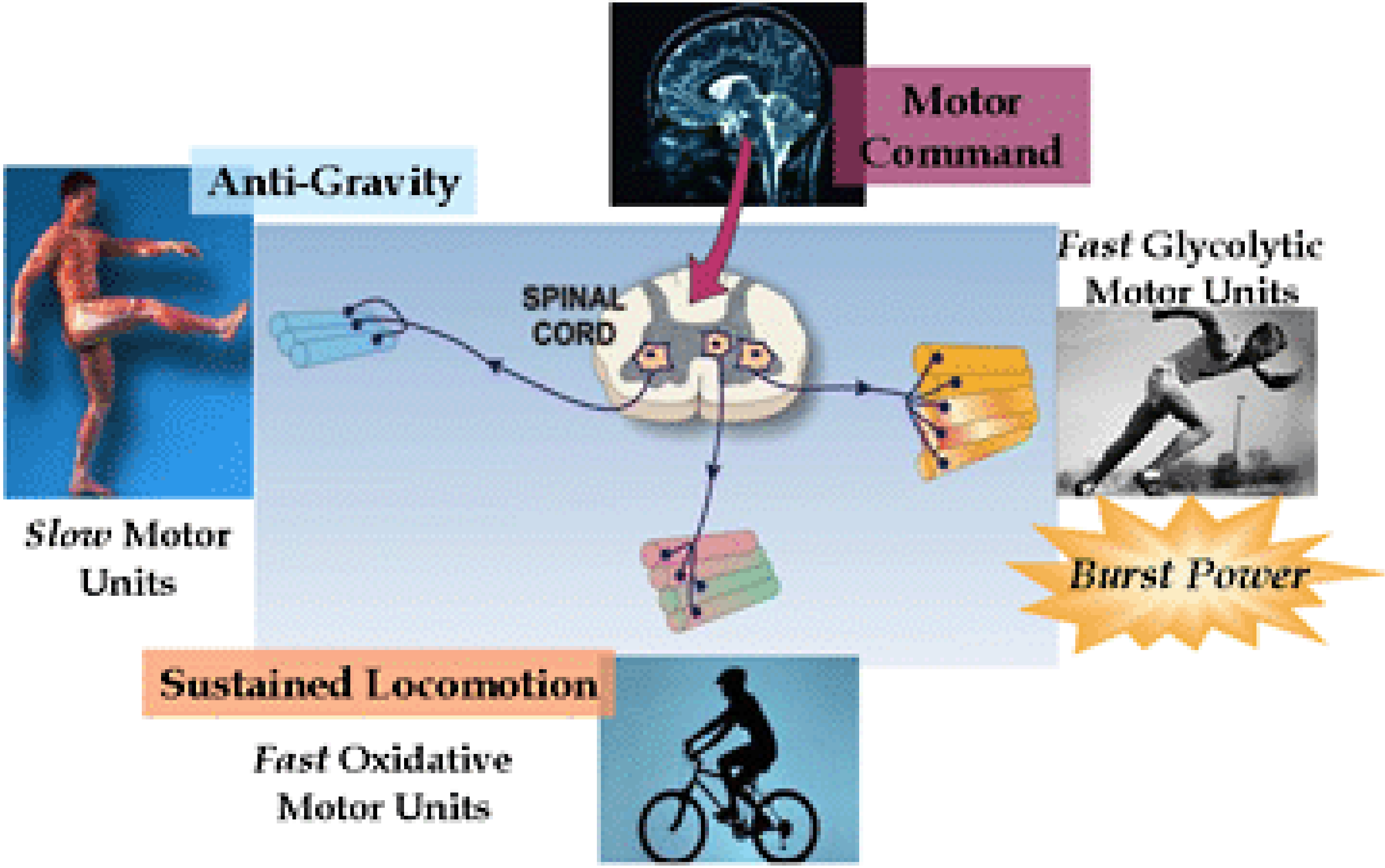
# Motor Unit Recruitment

- ✓Motor neurons recruited in order of size.
- ✓Smallest alpha motor neurons, α2, which belong to slow twitch recruited first.
- ✓Largest alpha motor neurons, α1, which belong to fast twitch recruited last

12.10. Recruitment of slow-twitch and fast-twitch muscle fibers.



# Motor Units and Musculoskeletal System I



# ELECTRICALLY INDUCED MUSCLE CONTRACTIONS

- ✓synchronous firing of all motor neurons.
- ✓Large diameter, fast twitch muscle fibers are recruited first.
- ✓This reversed order because large diameter motor neuron (type II) is more easily stimulated,
- ✓Muscle contraction is the immediate effect while muscle strengthening represent the long term effects

# PHYSIOLOGICALLY VERSUS ELECTRICALLY INDUCED MUSCLE CONTRACTIONS

| Physiologically induced contractions | Electrically induced contractions |
| --- | --- |
| Small diameter, slow twitch muscle fibers are recruited first | Large diameter, fast twitch muscle fibers are recruited first. |
| Contractions and recruitment are asynchronous to decrease muscle fatigue. | Contractions and recruitment are synchronous, based on the frequency. |
| GTOs protect muscles from too much force production. | GTOs cannot override the developing tension. |

# STRENGTH AUGMENTATION

***Strength gains through NMES may be due to;***

✓placement of an increased functional load on the muscle.

It is necessary to expose the subject to a stress that is greater than the stress that is normally encountered during everyday life.

✓ Selective recruitment of type II muscle fibers.

Electrical current depolarizes larger-diameter nerves first, type II fibers are brought into the contraction sooner and fatigue first.

Muscle weakness after immobilization can be explained as transform of type I fiber to type II fiber.

NMES seems to transfer type II to type I fiber which is essential for normal voluntary muscle contraction

Selective recruitment of type II fibers supports the use of NMES as opposed to voluntary exercise in diminishing the deleterious effects.

Near maximal volitional effort is needed to elicit contraction in type II motor units which is difficult, if not impossible for some patients.

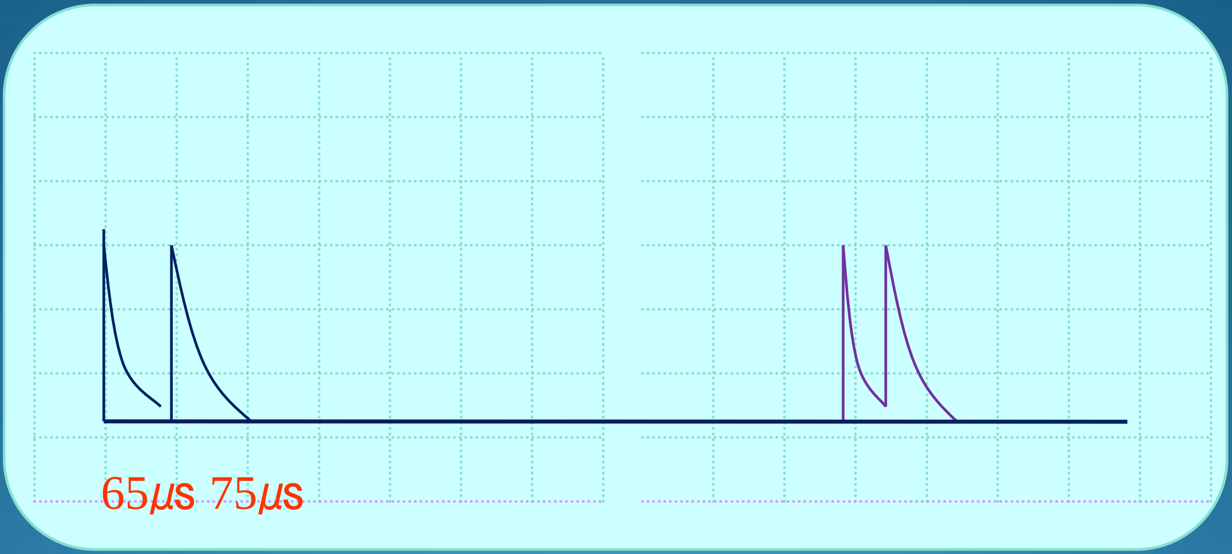
So, NMES is superior for muscle strength gains as compared with voluntary exercise in patients with muscle weakness

NMES must be capable of producing strong tetanic contraction and yet activate a low pain response

HVPGS is extensively used to initiate and facilitate voluntary contraction of muscle through;

- ✓ Retard the effects of atrophy.
- ✓ Muscle reeducation.
- ✓ Reduction of edema.
- ✓ Augmentation of muscle strength.

# Twin-peak monophasic pulse of very short duration ,a high voltage output and very high peak current.




Pulse Duration : 100 μs (Very Short)

Interpulse Interval : 9900 μs (Very Long)

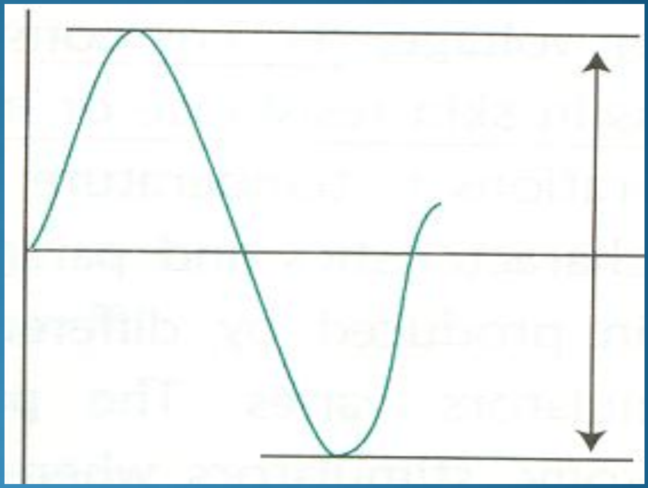
Duty Cycle : A + B = 10000 μs (10 ms)

Peak Amplitude : 500 V

Peak Current : 400 mA (Very High)

# Pulse Amplitude

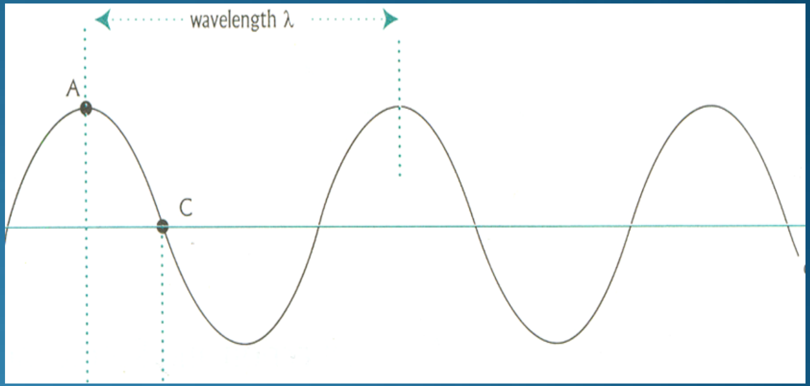
Increasing the intensity of the electrical stimulus causes the current to reach deeper recruiting more nerve fibers.



The force of the muscle contraction is linearly correlated to intensity of current.

# Pulse Frequency

At pulse rate of less than 15 pps, there are distinguishable muscle contractions for each pulse.



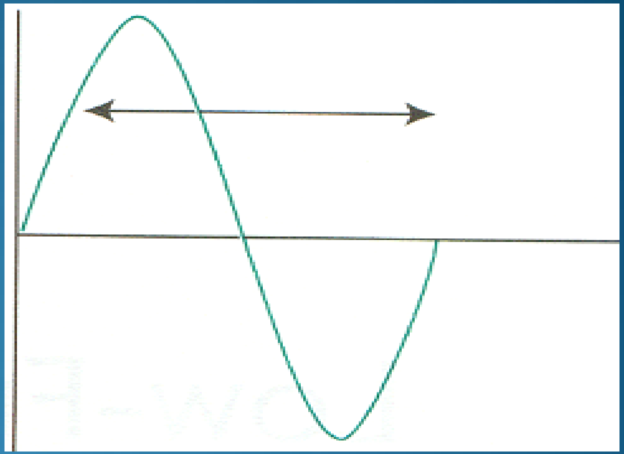

There is sufficient time for the muscle fibers to return to their length before the next pulse begin.

At 15 and 25 pps Summation starts and continues until the muscle reaches the stage of tetany

As the pulse frequency increases, the amount of summation increases

# Phase Duration

Short phase durations require greater amplitude to evoke an action potential than phases of longer durations.



The optimal phase duration to elicit maximal muscle contractions is 300 to 500 (µ.sec).


THANK YOU