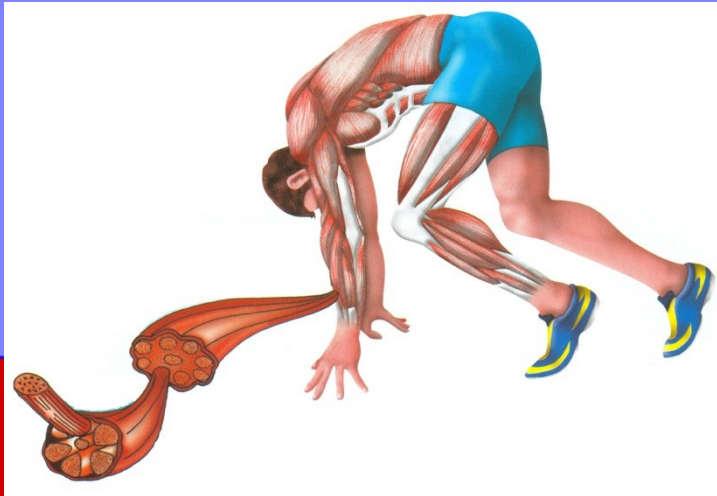




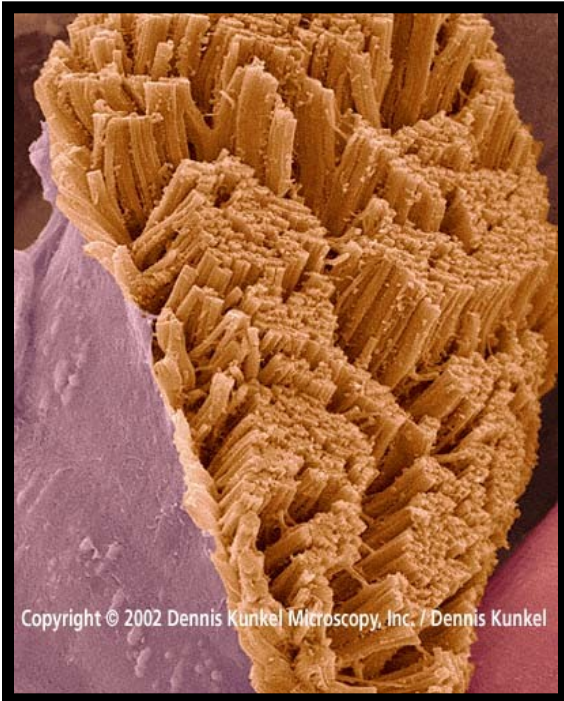
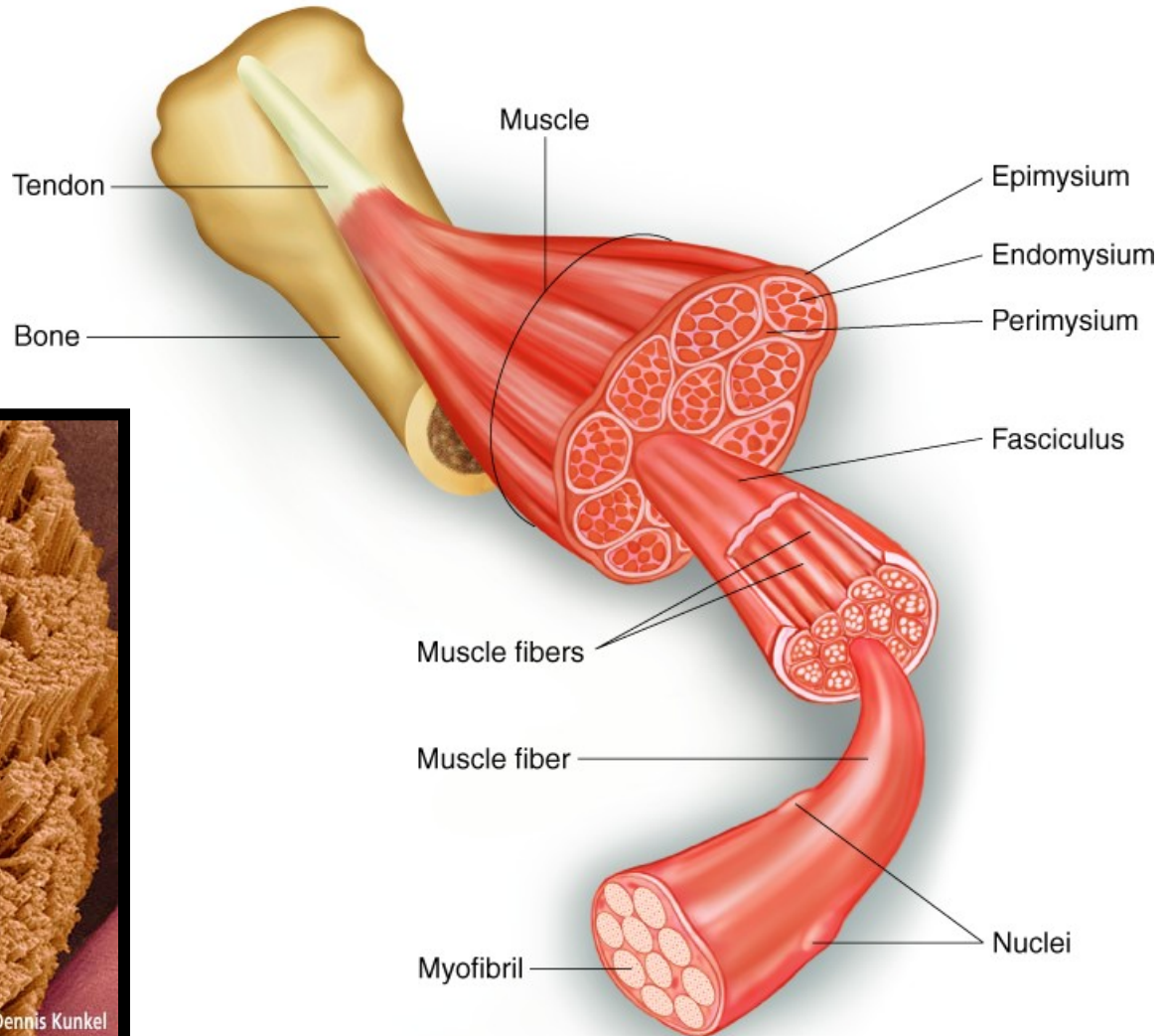
# MUSCLES AND HOW THEY MOVE



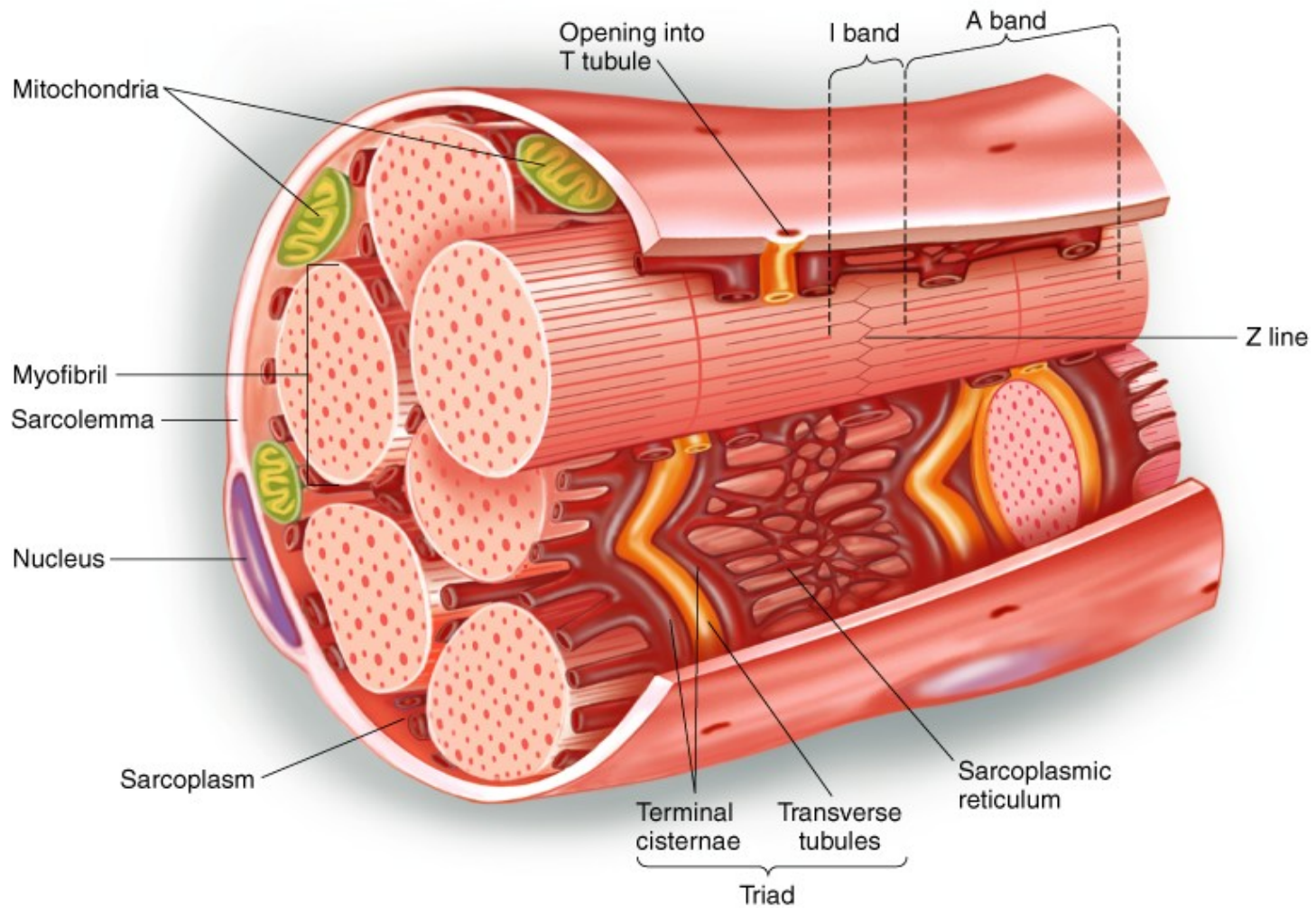
# Learning Objectives

- ◆ learn the basic components of skeletal muscle, muscle fiber
- ◆ discover how muscle functions during exercise
- ◆ consider the differences in fibre types
- ◆ diagnostika svalových vláken

# SKELETAL MUSCLE STRUCTURE



# MUSCLE FIBER

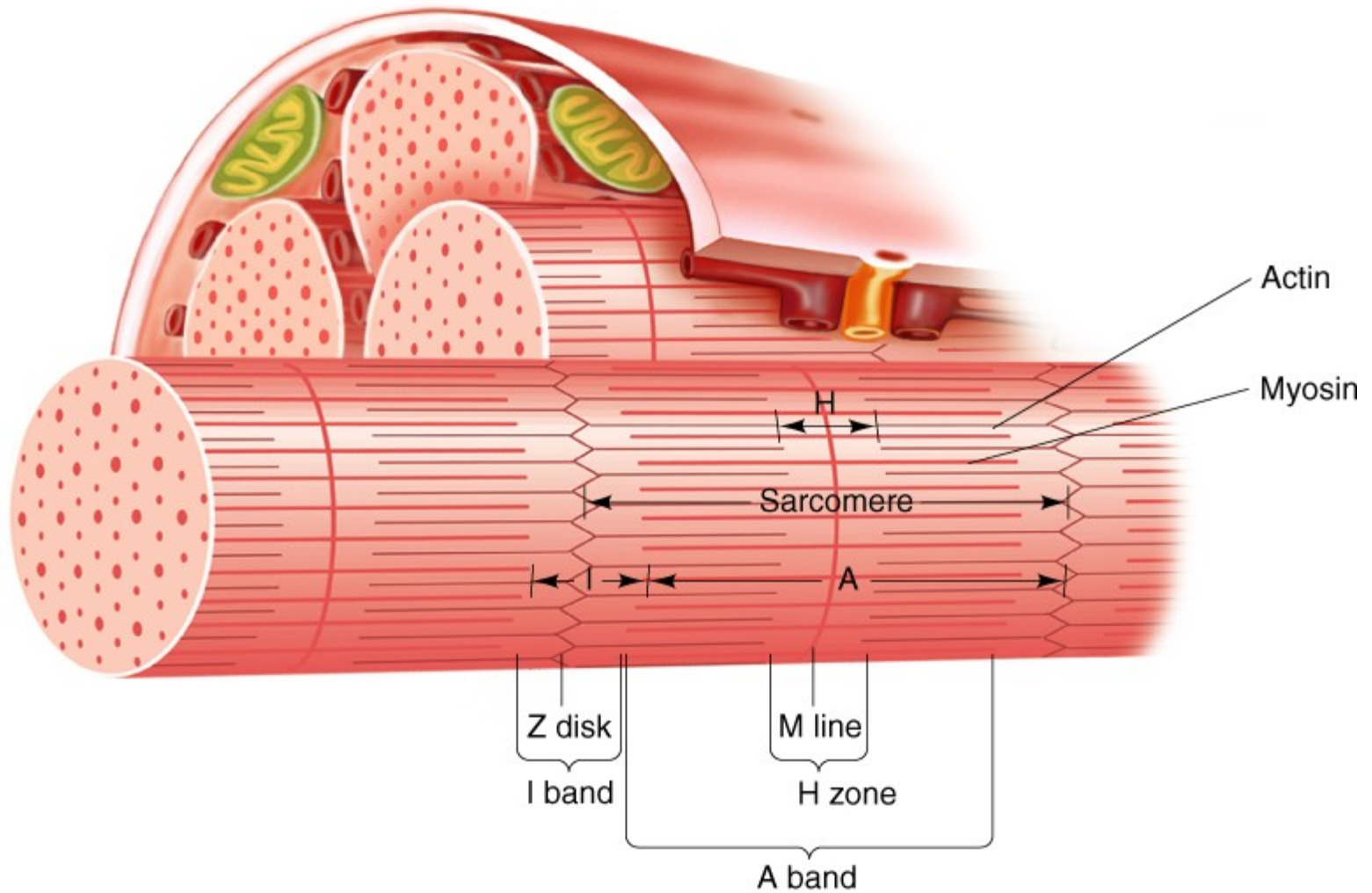


# Key Points

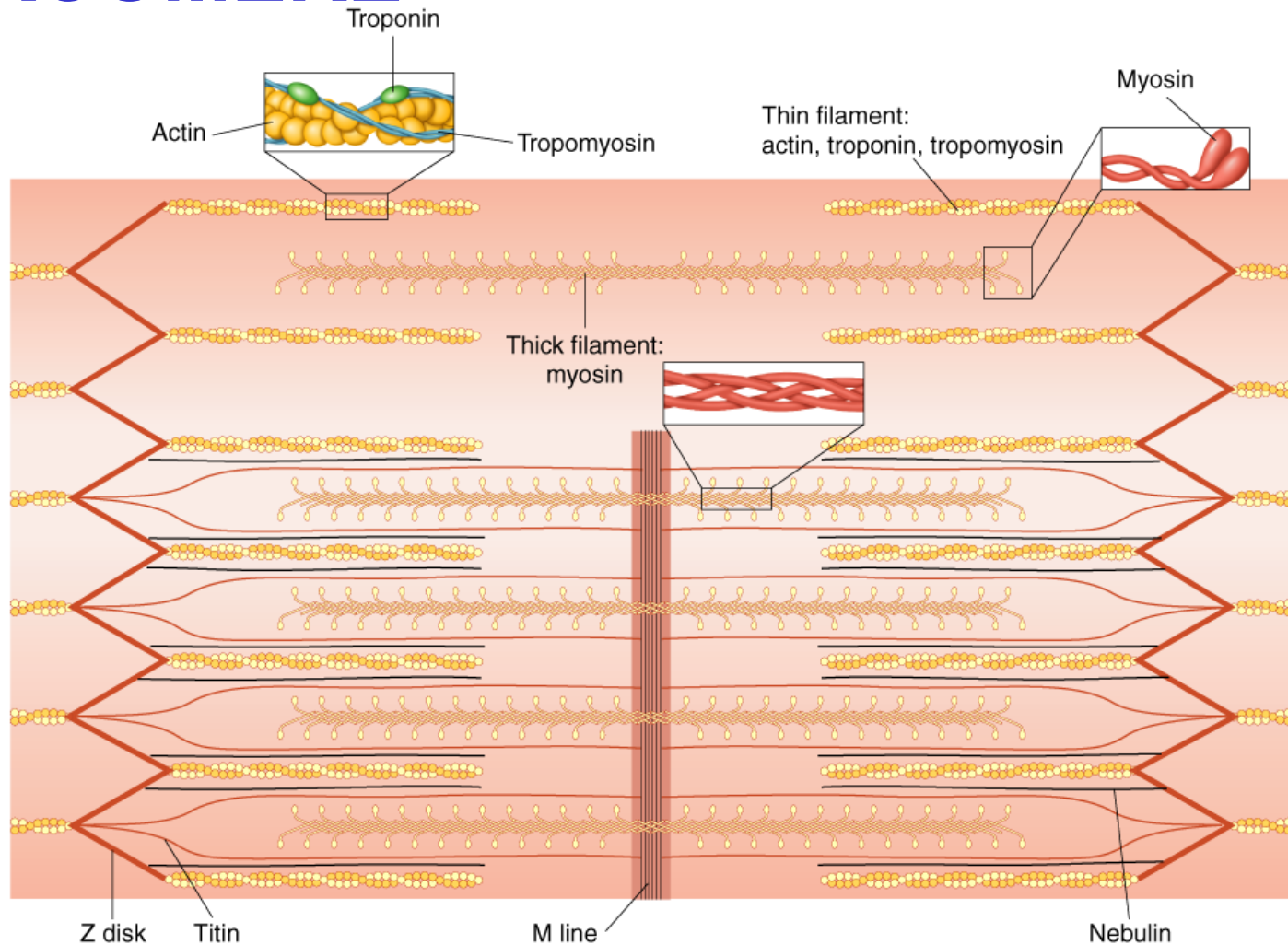
## Muscle Fiber

- ◆ An individual muscle cell is called a muscle fiber.
- ◆ A muscle fiber is enclosed by a plasma membrane called the sarcolemma.
- ◆ The cytoplasm of muscle fiber is called the sarcoplasm.
- ◆ Within the sarcoplasm, the T tubules allow transport of substances through the muscle fiber.
- ◆ The sarcoplasmic reticulum stores calcium.

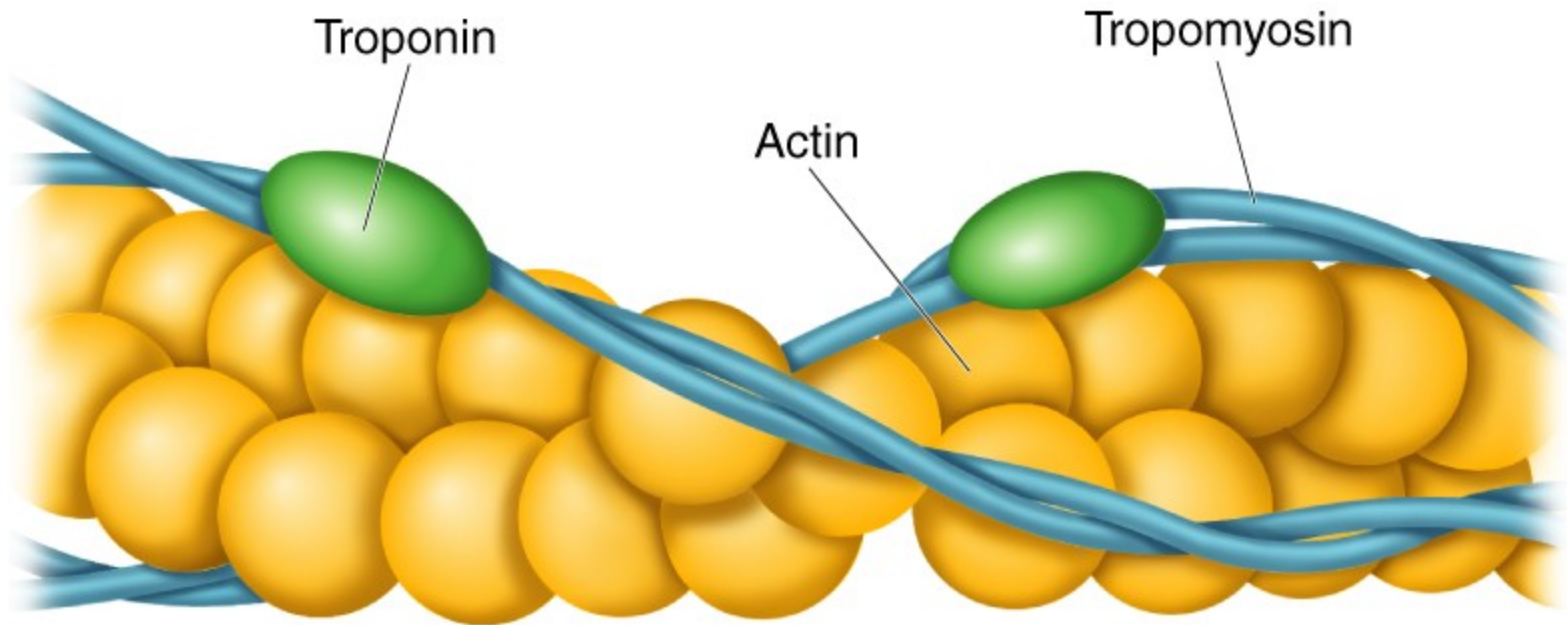
# ARRANGEMENT OF FILAMENTS



# ARRANGEMENT OF FILAMENTS IN A SARCOMERE

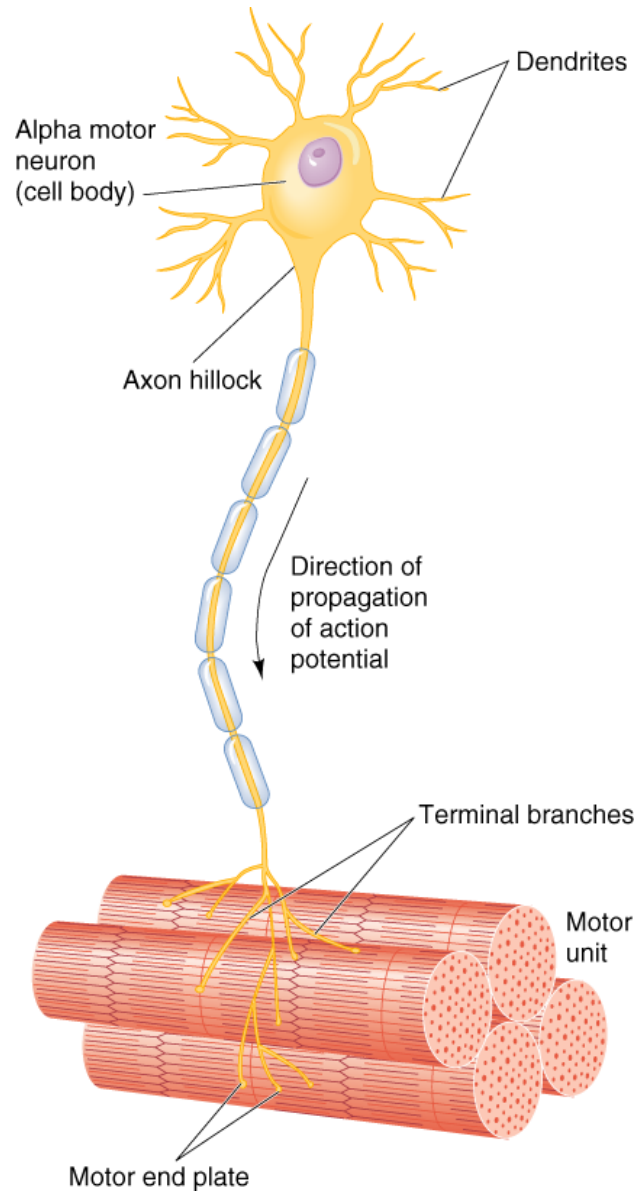


# ACTIN FILAMENT





# MOTOR UNIT



# Key Points

## Myofibrils

- ◆ Myofibrils are the contractile elements of skeletal muscle, with several hundred to several thousand composing a single muscle.
- ◆ Myofibrils are made up of sarcomeres, the smallest functional units of a muscle.
- ◆ A sarcomere is composed of filaments of two proteins, myosin and actin, which are responsible for muscle contraction.
- ◆ Myosin is a thick filament with a globular head at one end.
- ◆ An actin filament – composed of actin, tropomyosin, and troponin – is attached to a Z disk.

# Excitation/Contraction Coupling

1. A motor neuron, with signals from the brain or spinal cord, releases the neurotransmitter acetylcholine (ACh) at the neuromuscular junction.
2. ACh crosses the junction and binds to receptors on the sarcolemma.
3. This initiates an action potential, providing sufficient ACh.
4. The action potential travels along the sarcolemma and through the T tubules to the SR releasing  $\text{Ca}^{2+}$ .
5. The  $\text{Ca}^{2+}$  binds to troponin on the actin filament, and the troponin pulls tropomyosin off the active sites, allowing myosin heads to attach to the actin filament.

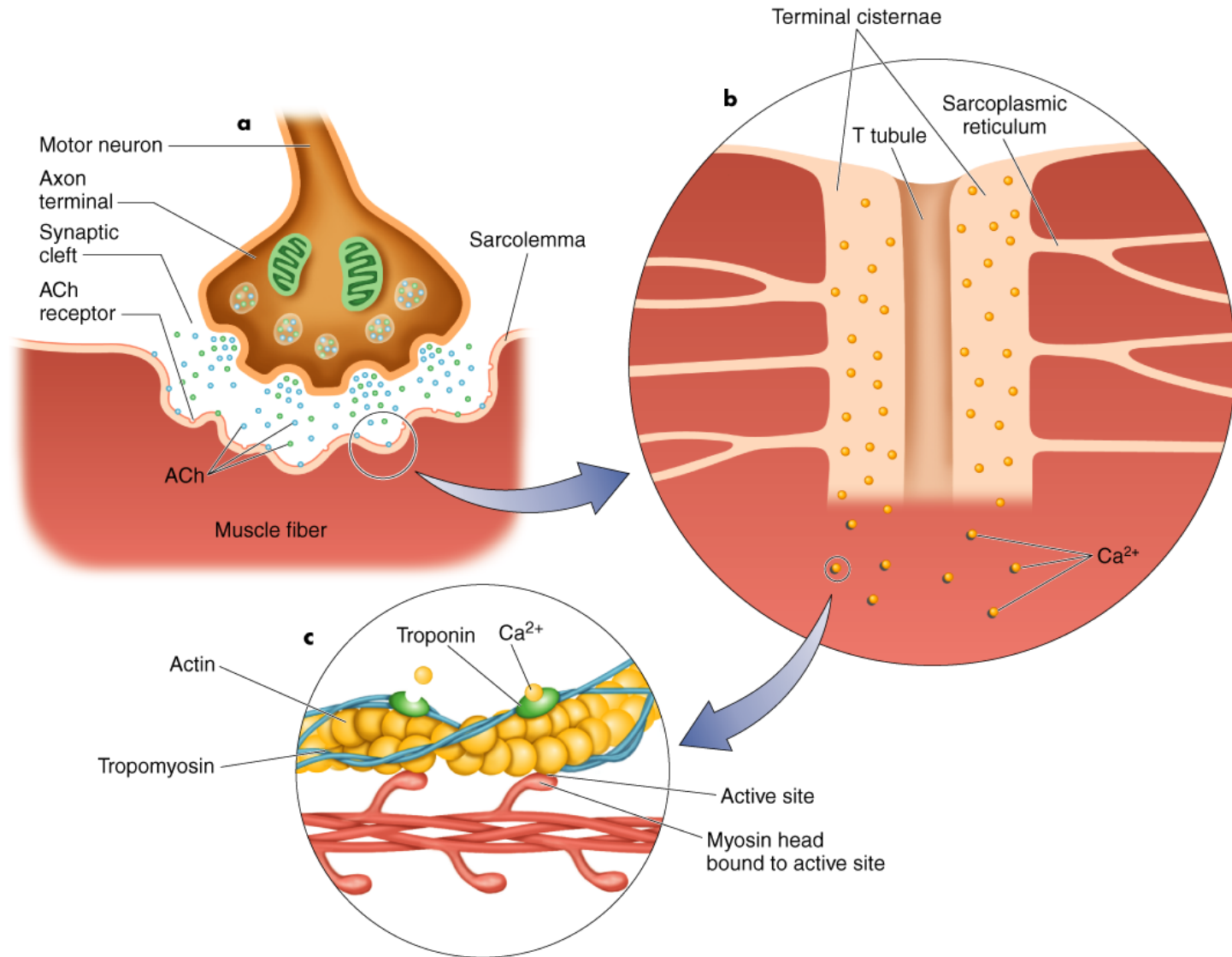
*(continued)*

# Excitation/Contraction Coupling

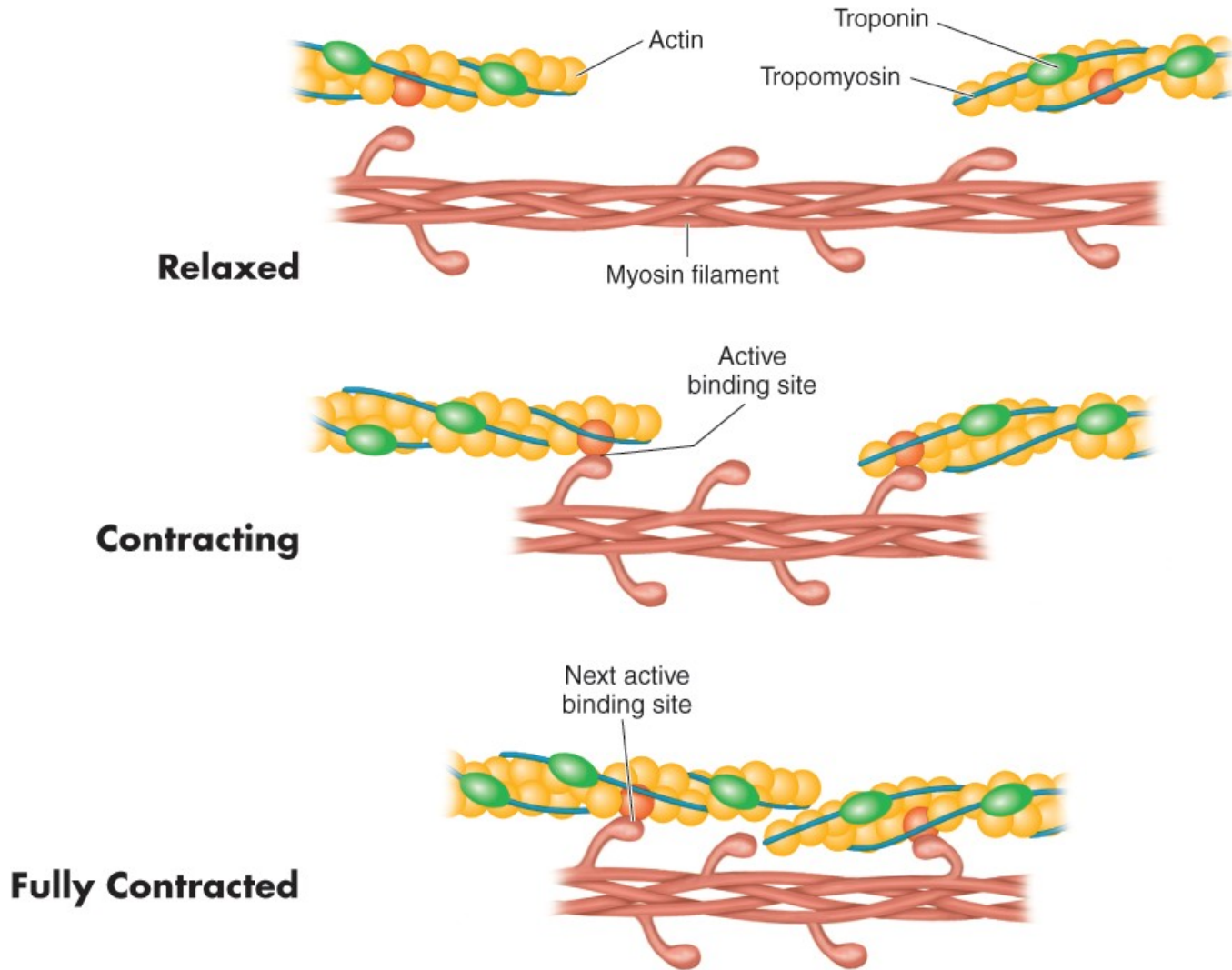
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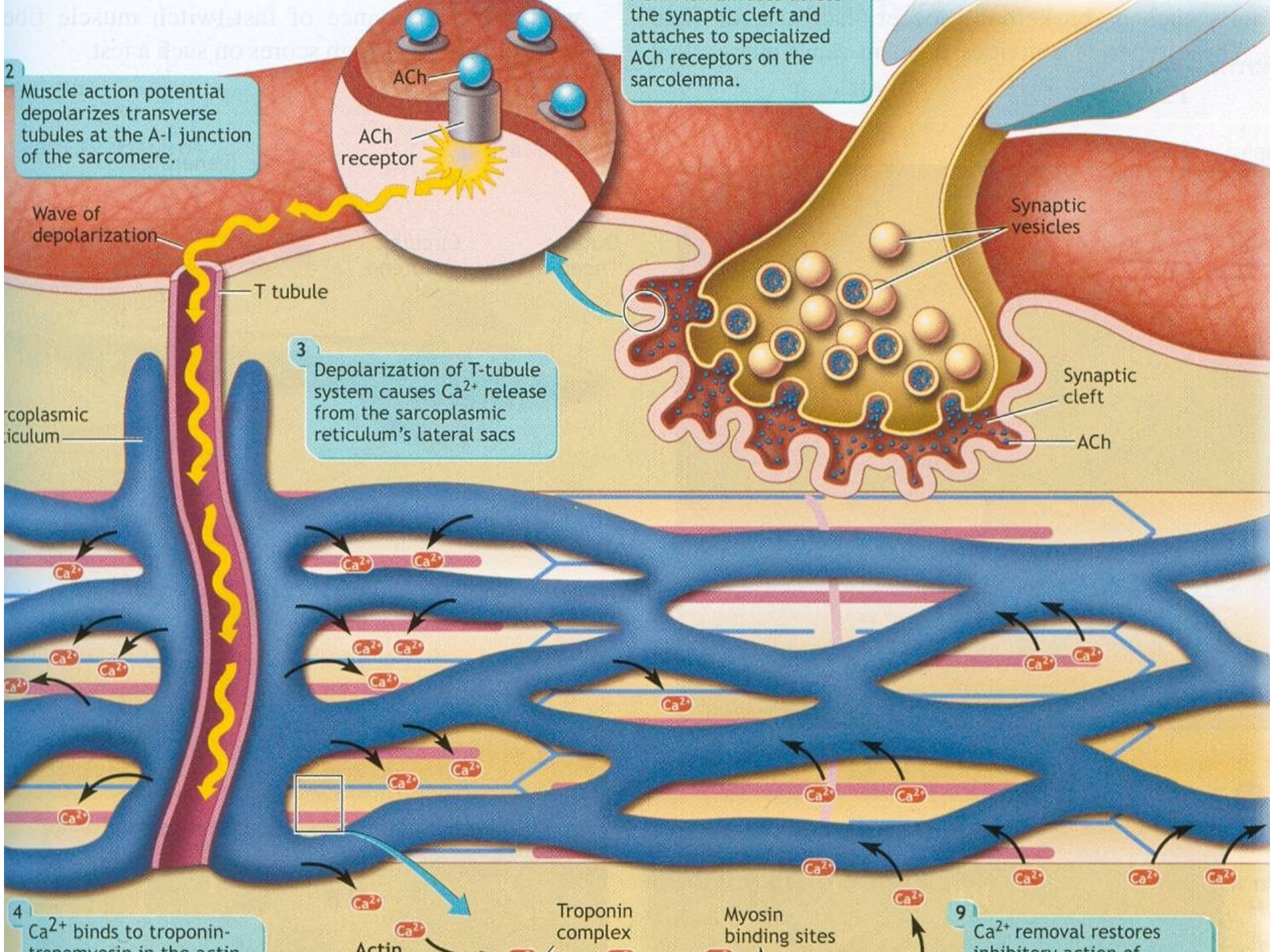
6. Once a strong binding state is established with actin, the myosin head tilts, pulling the actin filament (power stroke).
7. The myosin head binds to ATP, and ATPase found on the head splits ATP into ADP and  $P_i$ , releasing energy.
8. Muscle action ends when calcium is actively pumped out of the sarcoplasm back into the sarcoplasmic reticulum for storage.

# EVENTS LEADING TO MUSCLE ACTION



# CONTRACTING MUSCLE FIBER





1 Muscle action potential depolarizes transverse tubules at the A-I junction of the sarcomere.

the synaptic cleft and attaches to specialized ACh receptors on the sarcolemma.

3 Depolarization of T-tubule system causes  $Ca^{2+}$  release from the sarcoplasmic reticulum's lateral sacs

4  $Ca^{2+}$  binds to troponin-tropomyosin in the actin

9  $Ca^{2+}$  removal restores inhibitory action of

Wave of depolarization

T tubule

Sarcoplasmic reticulum

ACh

ACh receptor

Synaptic vesicles

Synaptic cleft

ACh

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

Troponin complex

Myosin binding sites

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

$Ca^{2+}$

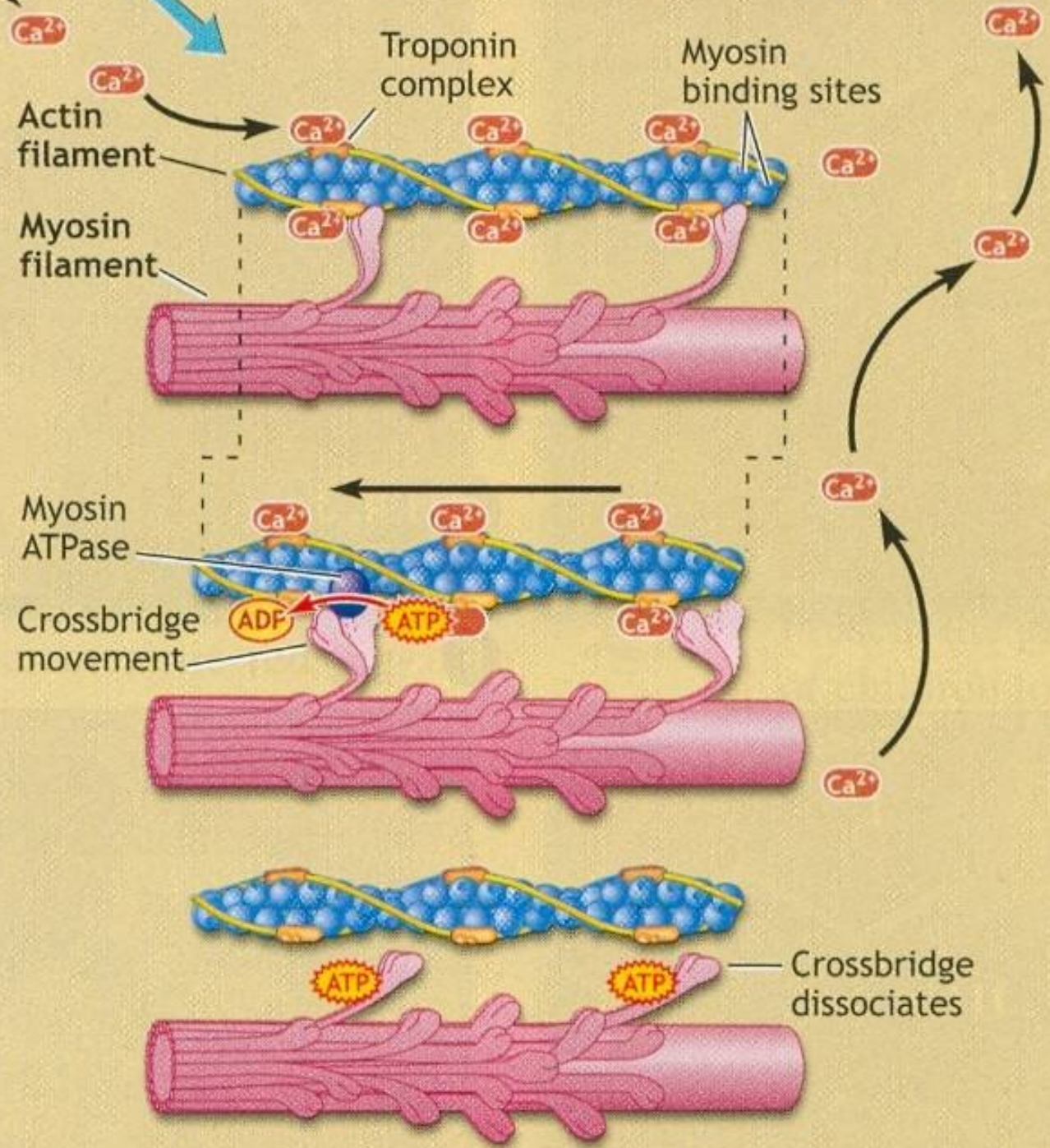
$Ca^{2+}$

$Ca^{2+}$

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# Key Points

## Muscle Fiber Action

- ◆ Muscle action is initiated by a nerve impulse.
- ◆ The nerve release Ach, which allows sodium to enter and depolarized, an action potential occurs which releases stored  $\text{Ca}^{2+}$  ions.
- ◆  $\text{Ca}^{2+}$  ions bind with troponin, which lifts the tropomyosin molecules off the active sites on the actin filament. These open sites allow the myosin heads to bind to them.

# Key Points

## Muscle Fiber Action

- ◆ Once myosin binds with actin, the myosin head tucks and pulls the actin filament so they slide across each other.
- ◆ Muscle action ends when calcium is pumped out of the sarcoplasm to the sarcoplasmic reticulum for storage.
- ◆ Energy for muscle action is provided when the myosin head binds to the ATP. ATPase on the myosin head splits the ATP into a usable energy source.

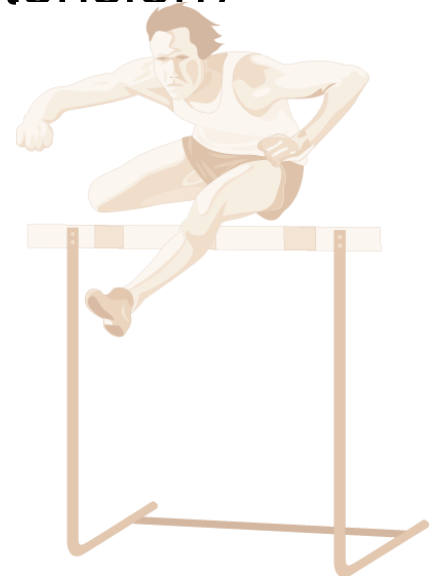
# Slow-Twitch (ST) Muscle Fibers

- ◆ High aerobic (oxidative) capacity and fatigue resistance
- ◆ Low anaerobic (glycolytic) capacity and motor unit strength
- ◆ Slow contractile speed (110ms to reach peak tension) and myosin ATPase
- ◆ 10–180 fibers per motor neuron



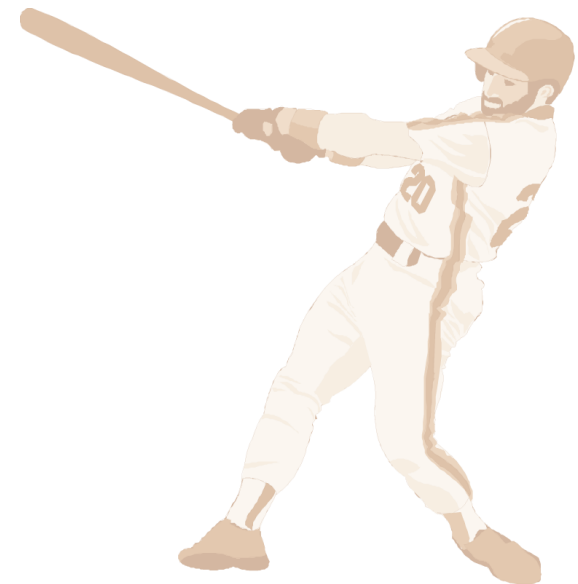
# Fast-Twitch (FT<sub>a</sub>) Muscle Fibers

- ◆ Moderate aerobic (oxidative) capacity and fatigue resistance
- ◆ High anaerobic (glycolytic) capacity and motor unit strength
- ◆ Fast contractile speed (50 ms to reach peak tension)
- ◆ 300–800 fibers per motor neuron



# Fast-Twitch ( $FT_b/FT_x$ ) Muscle Fibers

- ◆ Low aerobic (oxidative) capacity and fatigue resistance
- ◆ High anaerobic (glycolytic) capacity and motor unit strength
- ◆ Fast contractile speed (50 ms to reach peak tension)
- ◆ 300–800 fibers per motor neuron

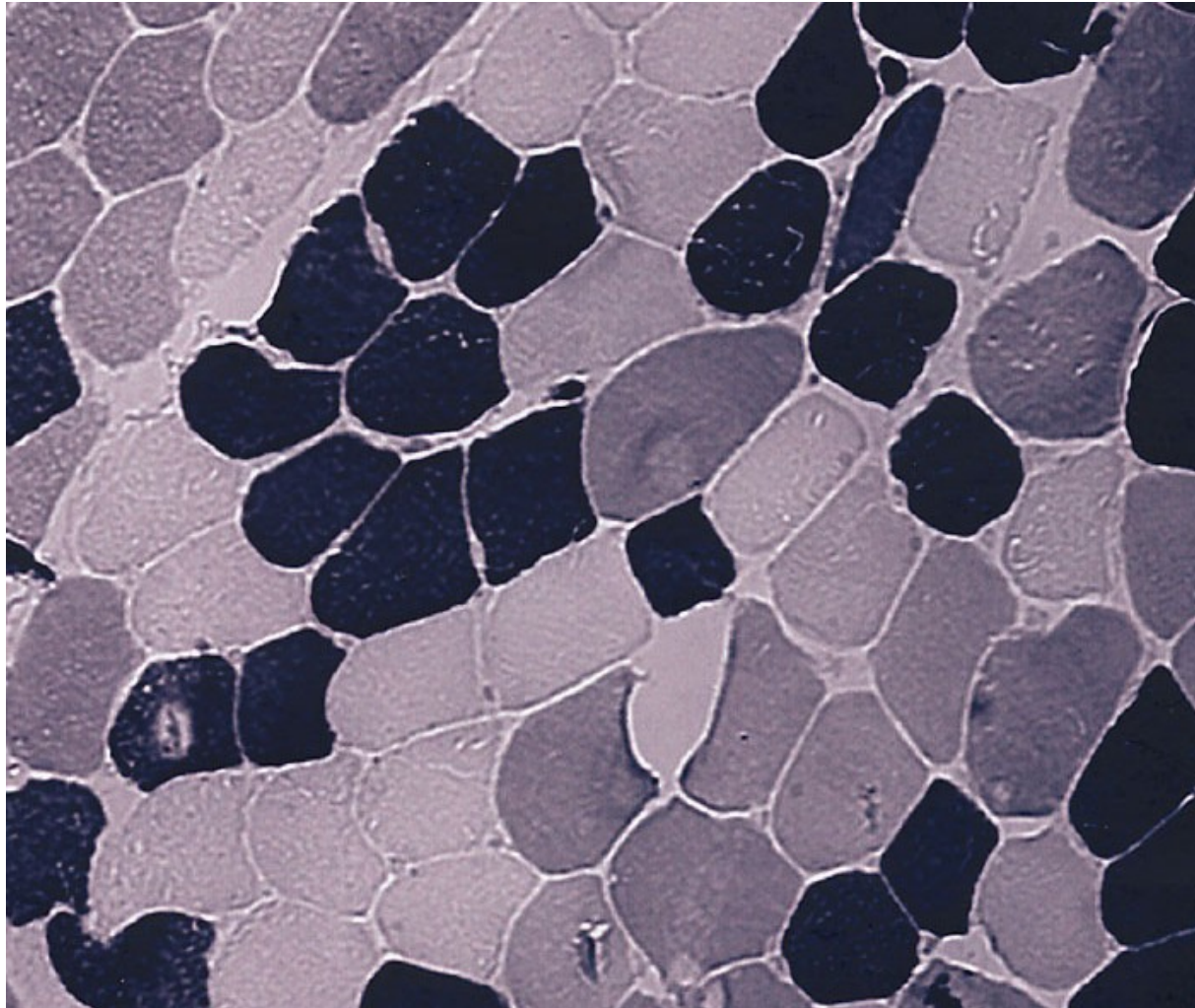


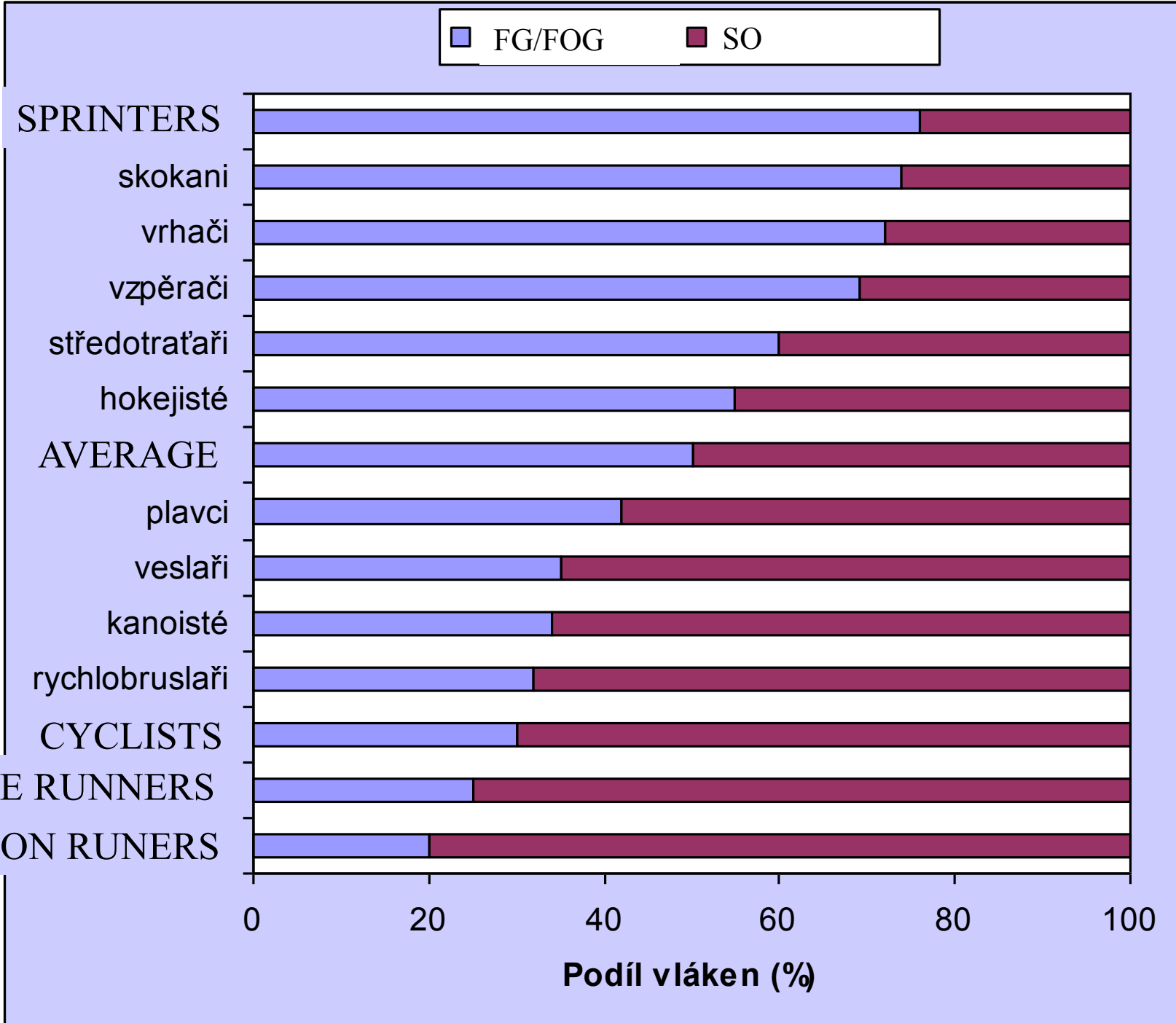
# Characteristic of muscle fibers

	Slow-Twitch (ST) SO	Fast-twitch (FTa) FOG	Fast-Twitch (FTx) FG
--	------------------------	--------------------------	-------------------------

<b>Contractile speed</b>	<b>slow</b>	<b>fast</b>	<b>fast</b>
<b>Contractile force</b>	<b>low</b>	<b>moderate</b>	<b>high</b>
<b>Fatigue resistance</b>	<b>high</b>	<b>moderate</b>	<b>low</b>
<b>Glycogen capacity</b>	<b>low</b>	<b>high</b>	<b>high</b>
<b>Diameter</b>	<b>small</b>	<b>moderate</b>	<b>big</b>
<b>Mitochondrials density</b>	<b>high</b>	<b>high</b>	<b>low</b>
<b>Capilars density</b>	<b>high</b>	<b>high</b>	<b>low</b>
<b>Activity of ATPase</b>	<b>low</b>	<b>high</b>	<b>high</b>
<b>Glycolytic capacity</b>	<b>low</b>	<b>high</b>	<b>high</b>

# SLOW- AND FAST-TWITCH FIBERS





DISTANCE RUNNERS  
MARATHON RUNNERS



# DIAGNOSTIC OF MUSCLE FIBERS

muscle biopsy

▶ magnetic resonance imaging

▶ 1MR (one-repetition maximum) and subsequent exercise with 80%.

(1RM) is a functional test of the maximum weight that can be lifted just one time=100%

< 8 rep. predominance FG/FOG

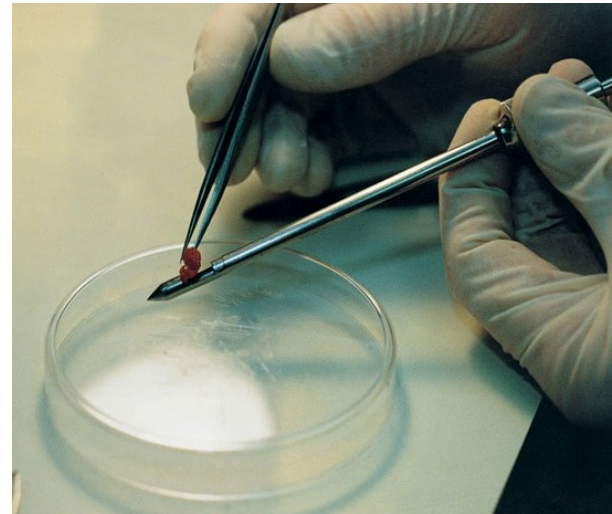
8-12 rep. 50%:50%

> 12 rep. predominance SO

▶ Bocso test (jump test)

# Muscle Biopsy

- ◆ Hollow needle is inserted into muscle to take a sample.
- ◆ Sample is mounted, frozen, thinly sliced, and examined under a microscope.
- ◆ Allows study of muscle fibers and the effects of acute exercise and exercise training on fiber composition.



# Key Points

## Slow- and Fast-Twitch Muscle Fibers

- ◆ Skeletal muscles contain both ST and FT fibers.
- ◆ ATPase in FT fibers acts faster providing energy for muscle action more quickly than ATPase in ST fibers.
- ◆ FT fibers have a more highly developed sarcoplasmic reticulum enhancing calcium delivery.

*(continued)*

# Key Points

## Slow- and Fast-Twitch Muscle Fibers

- ◆ Motor units supplying FT fibers are larger (e.g., more fibers per motor neuron) than those supplying ST fibers; thus, FT motor units can recruit more fibers.
- ◆ ST fibers have high aerobic endurance and are suited to low-intensity endurance activities.
- ◆ FT fibers are better for anaerobic or explosive activities.

# Functional Classification of Muscles

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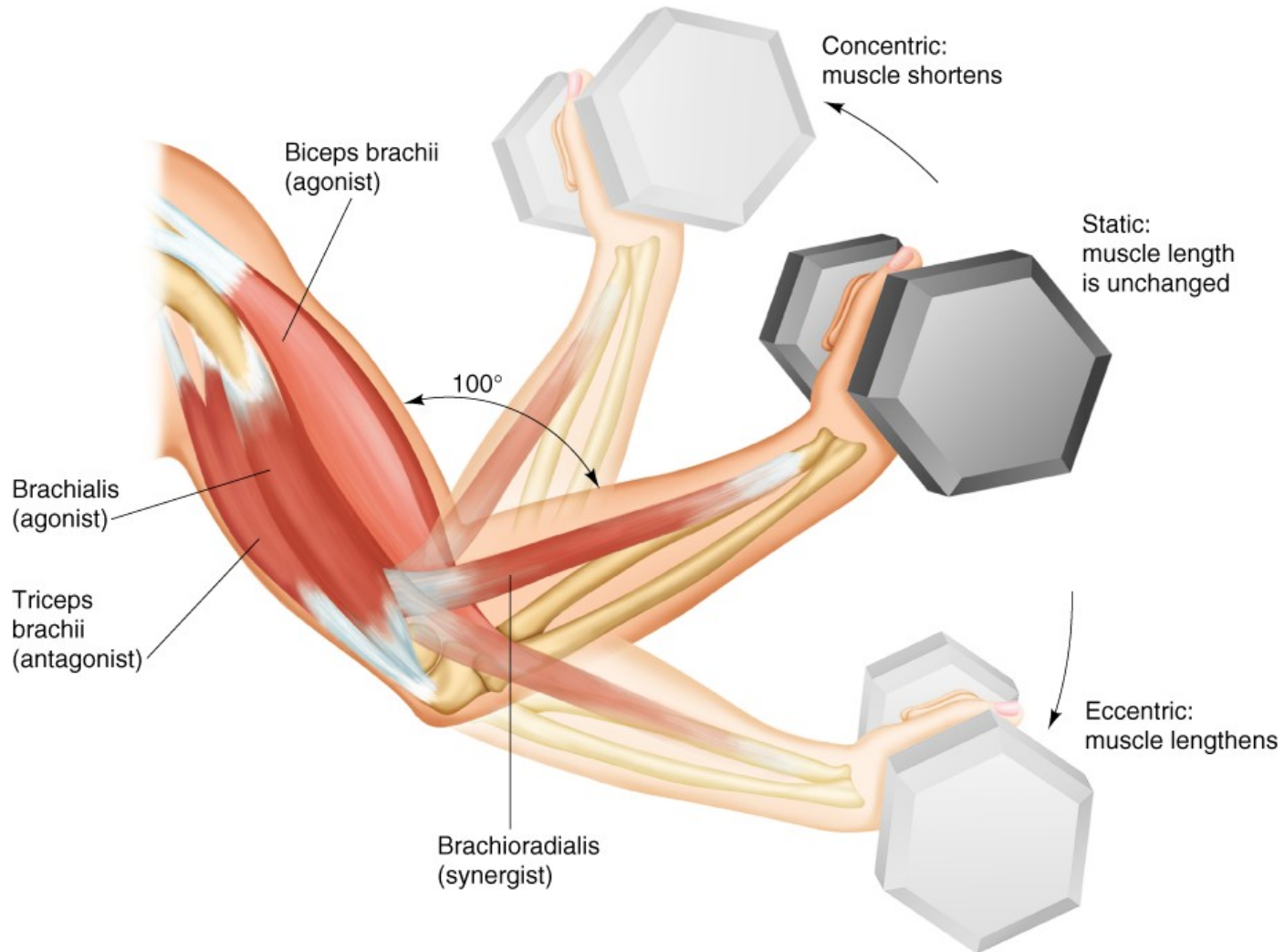
***Agonists*** – prime movers, responsible for the movement

***Antagonists*** – oppose the agonists to prevent overstretching of them

***Synergists*** – assist the agonists and sometimes fine-tune the direction of the movement



# TYPES OF MUSCLE ACTION



# Factors Influencing Force Generation

- ◆ Number of motor units activated
- ◆ Type of muscle fibers (FT or ST)
- ◆ Muscle size
- ◆ Initial muscle length
- ◆ Joint angle
- ◆ Speed of muscle action (shortening or lengthening)



# DYNAMOMETRY – muscle strength testing

- ◆ Dynamometry means testing of muscle strength.
- ◆ Strength is defined as a peak force or torque development during a maximum voluntary contraction under a given set of conditions.
- ◆ For the International System of Units (SI) units for force and torque are the Newton (N) and the Newton meter (N.m)





# ISOMETRIC DYNAMOMETRY

- ◆ Isometric strength is usually measured as the peak force produced by a maximum voluntary isometric contraction.
- ◆ Dynamometers convert the deformation produced by tension or pressure into strength (N)
- ◆ The dynamometric measurements should be made at standardised positions.





MINISTERSTVO ŠKOLSTVÍ,  
MLÁDEŽE A TĚLOVÝCHOVY



OP Vzdělávání  
pro konkurenceschopnost



INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

# Thank you for your attention.

Projekt: Zvyšování jazykových kompetencí pracovníků FSpS MU  
a inovace výuky v oblasti kinantropologie, reg. č.: CZ.1.07/2.2.00/15.0199