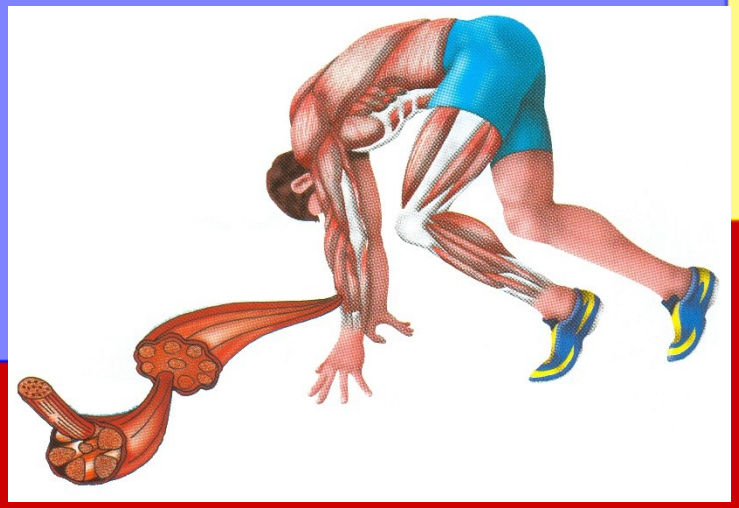
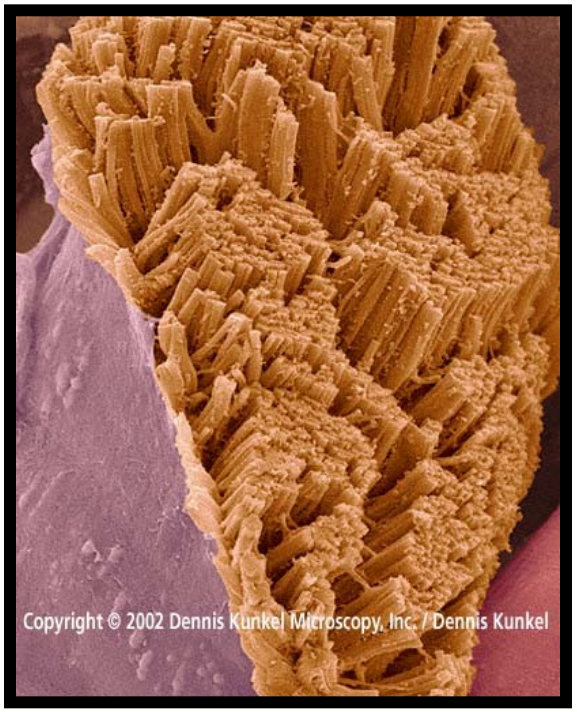
MUSCLES
AND HOW THEY MOVE

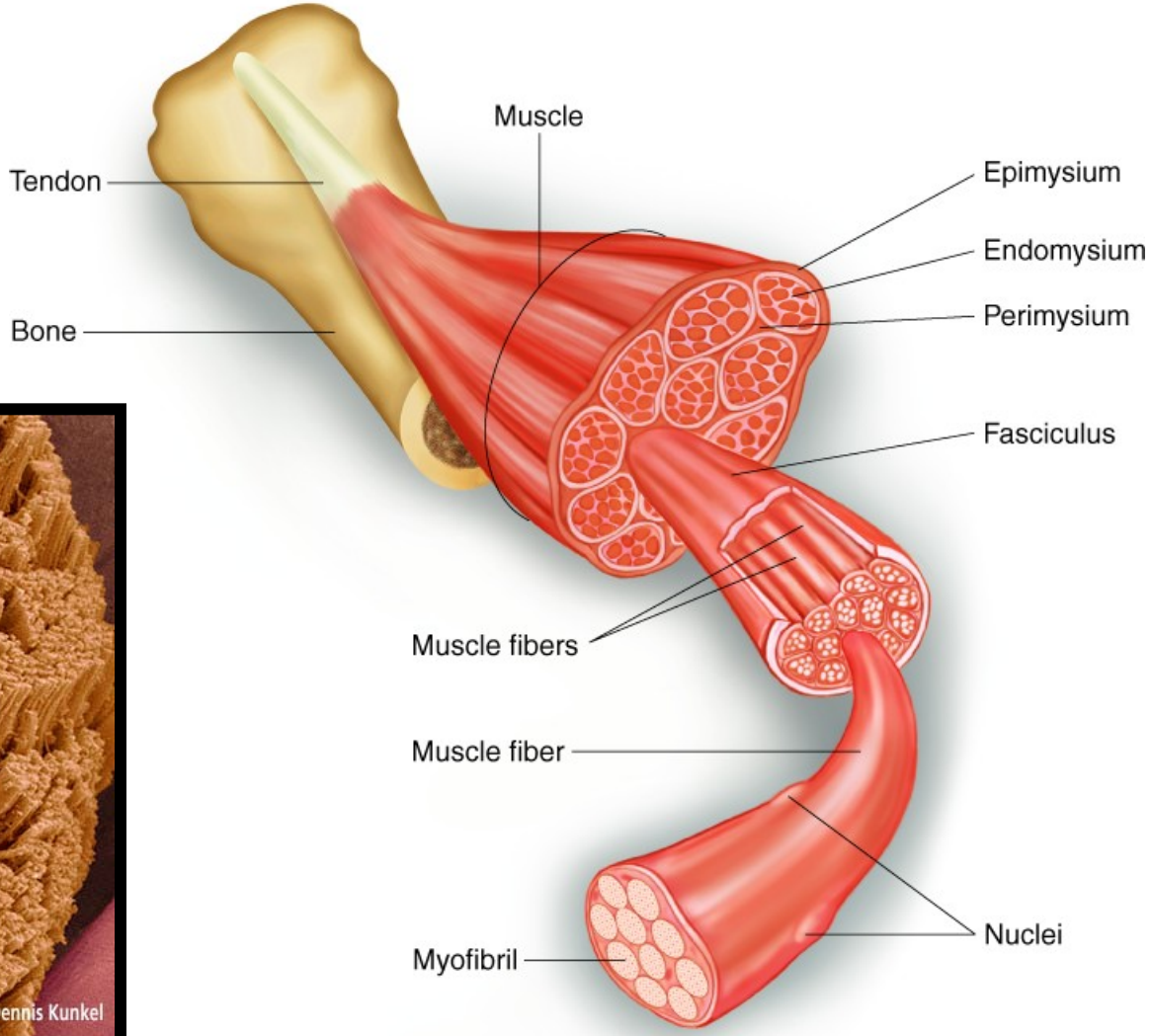


Learning Objectives

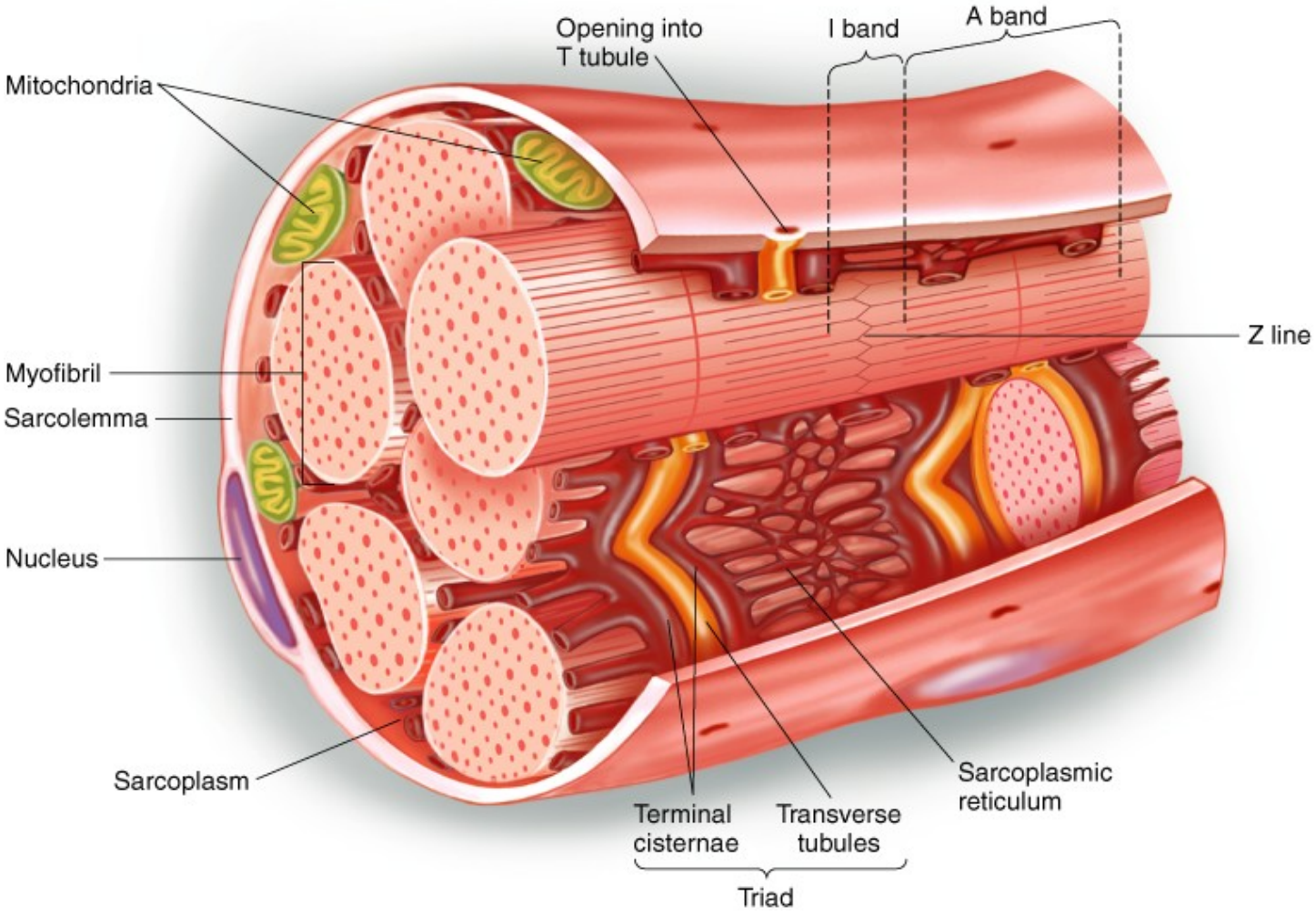
- learn the bacis components of skeletal muscle, muscle fiber
- discover how muscle functions during exercise
- consider the differences in fibre types
- muscle fiber types diagnostics

SKELETAL MUSCLE STRUCTURE





MUSCLE FIBER

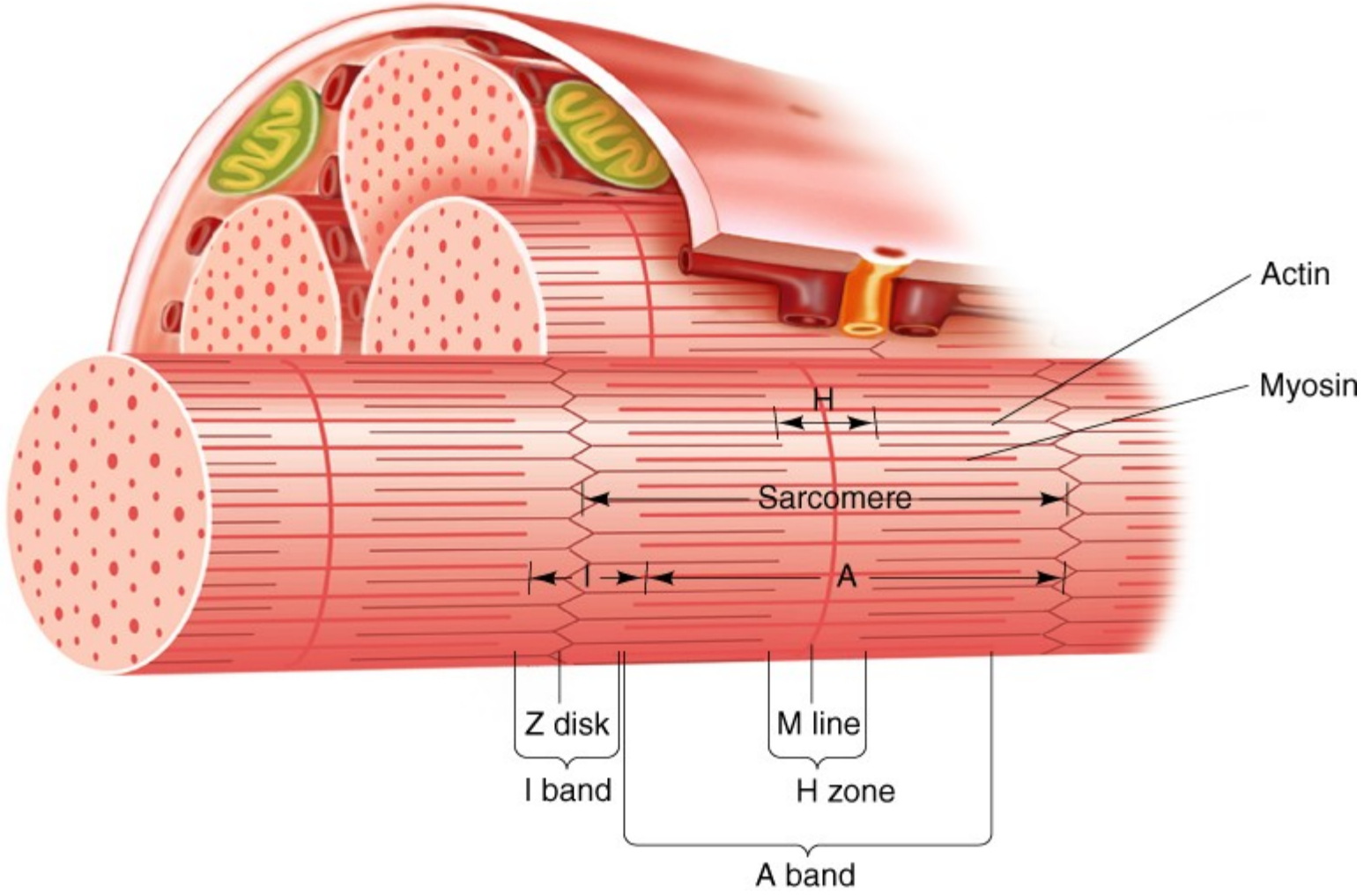


Key Points

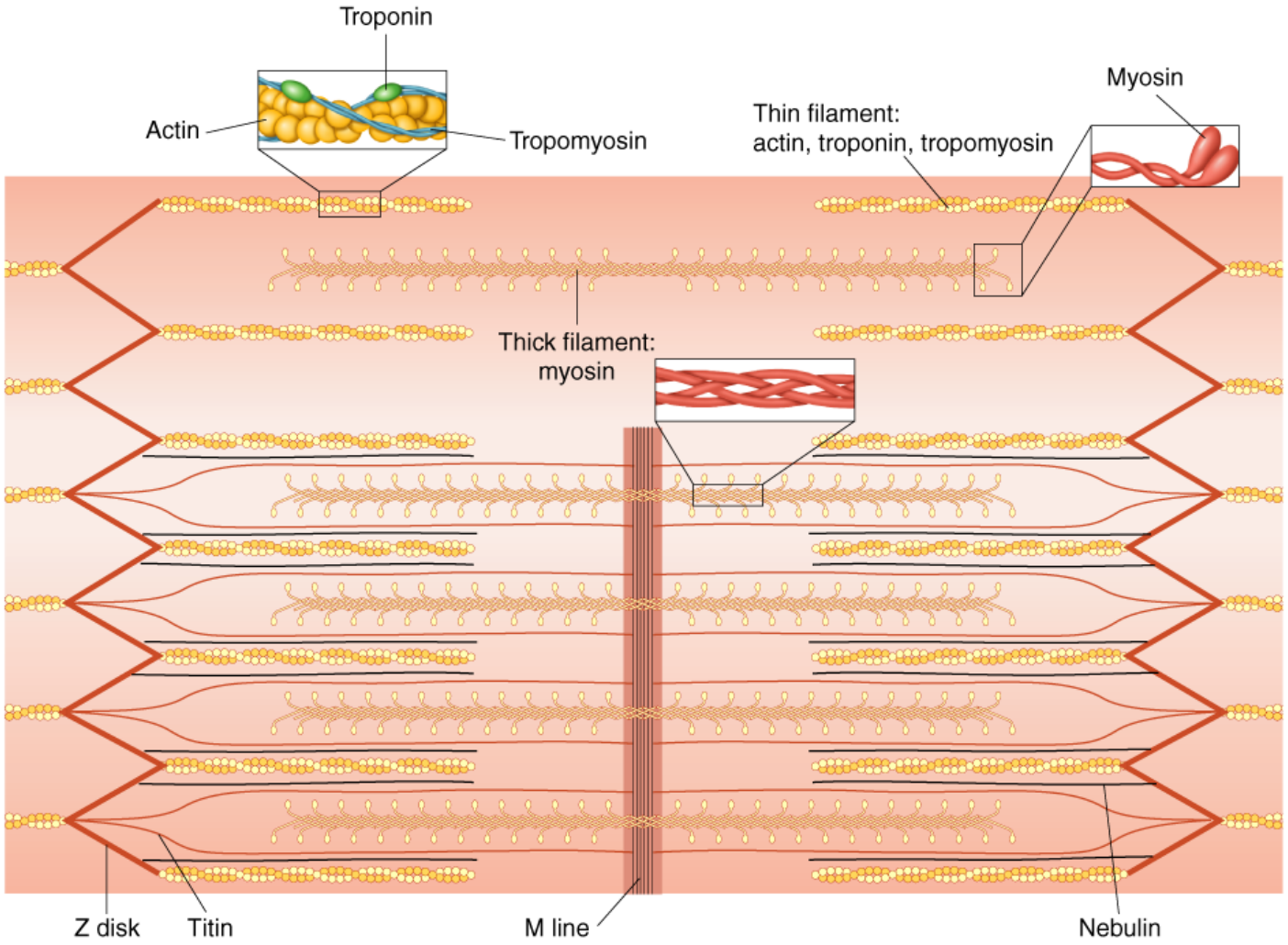
Muscle Fiber

- 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 throught the muscle fiber.
- The sarcoplasmic reticulum stores calcium.

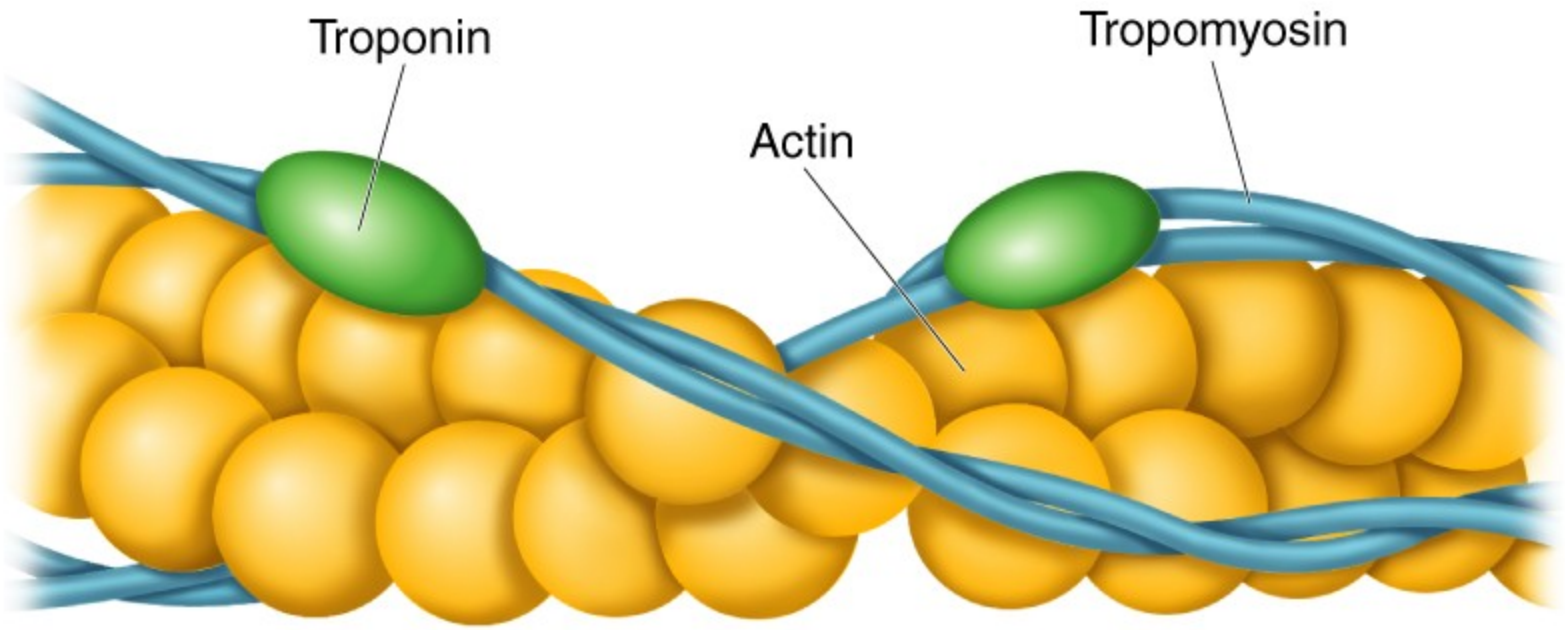
ARRANGEMENT OF FILAMENTS



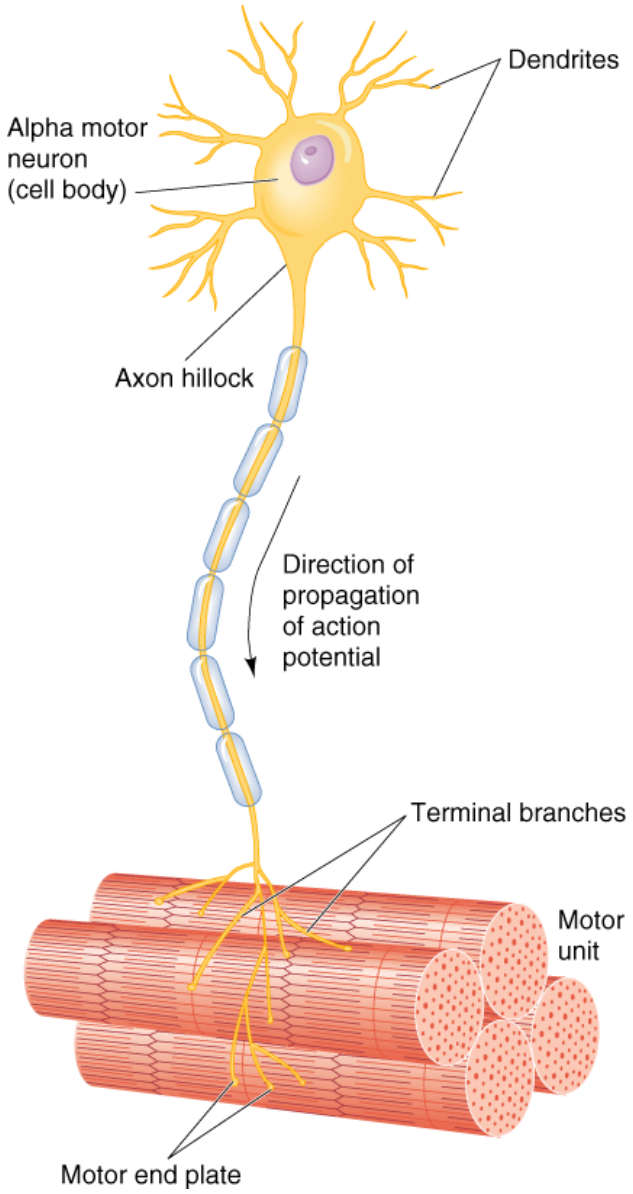
ARRANGEMENT OF FILAMENTS IN A SARCOMERE



ACTIN FILAMENT



MOTOR UNIT


Dendrites
Alpha motor neuron (cell body)
Axon hillock
Direction of propagation of action potential
Terminal branches
Motor unit
Motor end plate

Key Points

Myofibrils

- Myofibrils are the contractile elemets 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 sarkomere 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

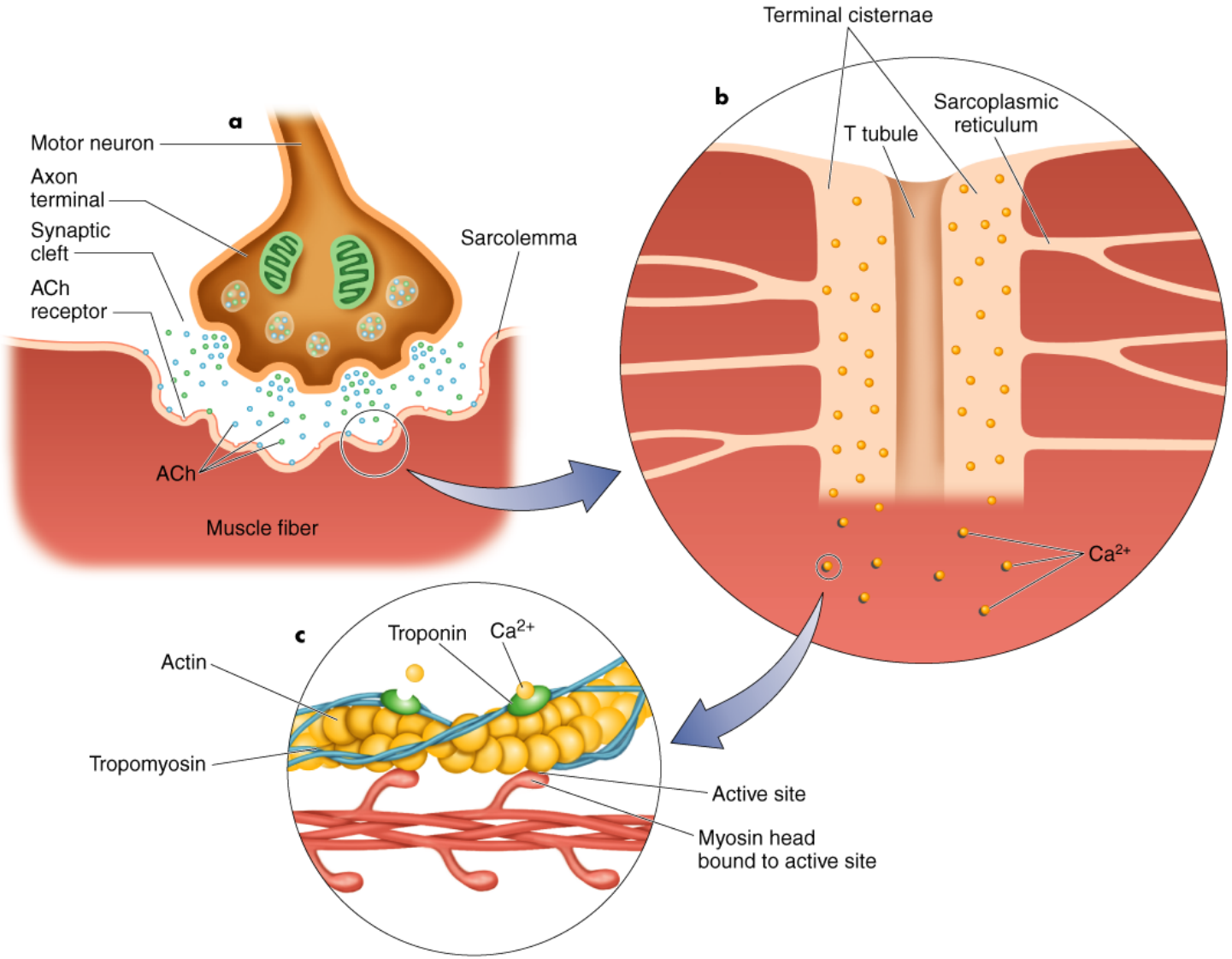
1. A motor neuron, with signals from the brain or spinal cord, releases the neurotransmitter acetylcholine (Ach) at the neuromuscular junction.
2. ACh crosses the junction and binds to receptors on the sarcolemma.
3. This initiates an action potential, providing sufficient ACh.
4. The action potential travels along the sarcolemma and through the T tubules to the SR releasing Ca^{2+}.
5. The 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)

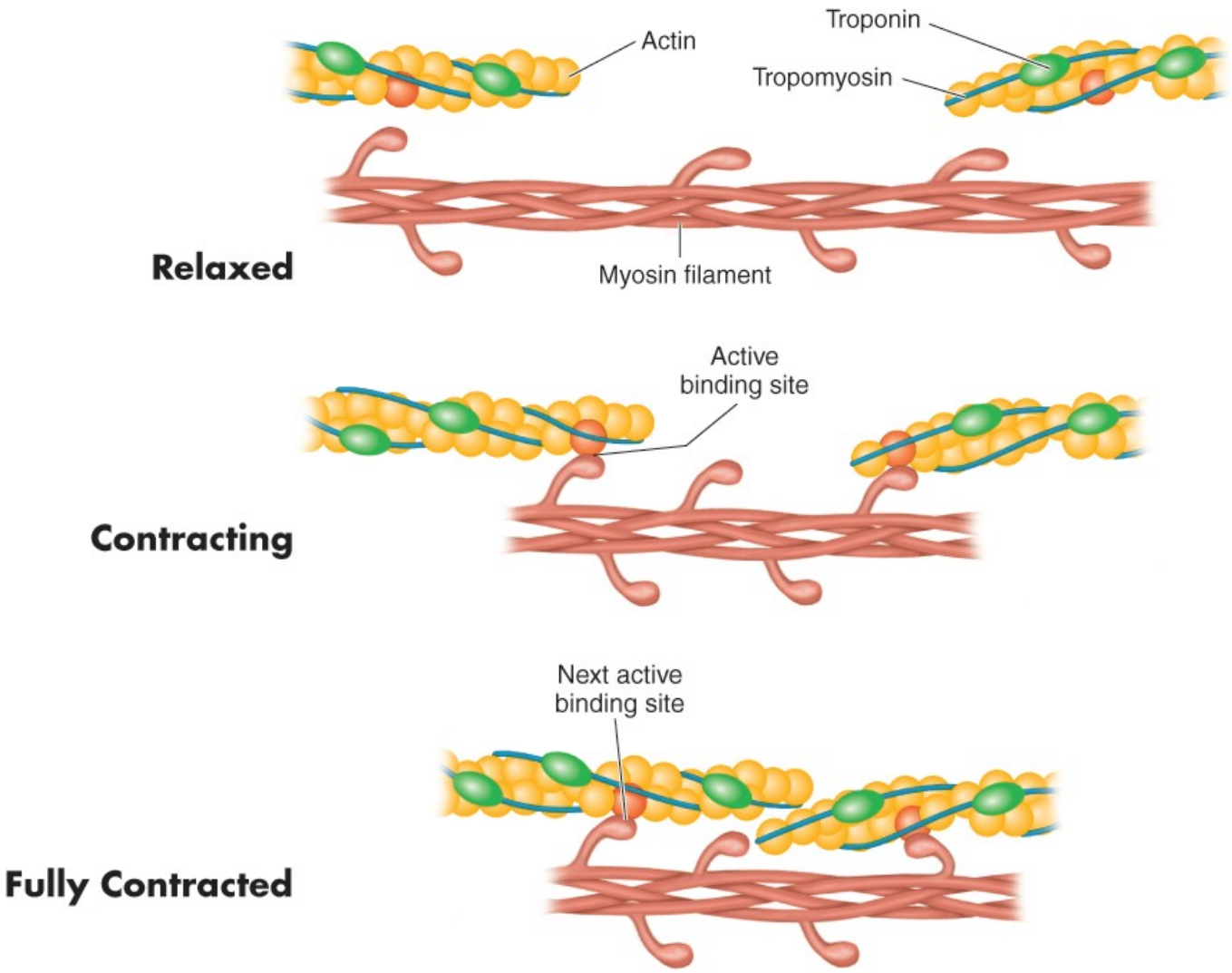
Excitation/Contraction Coupling

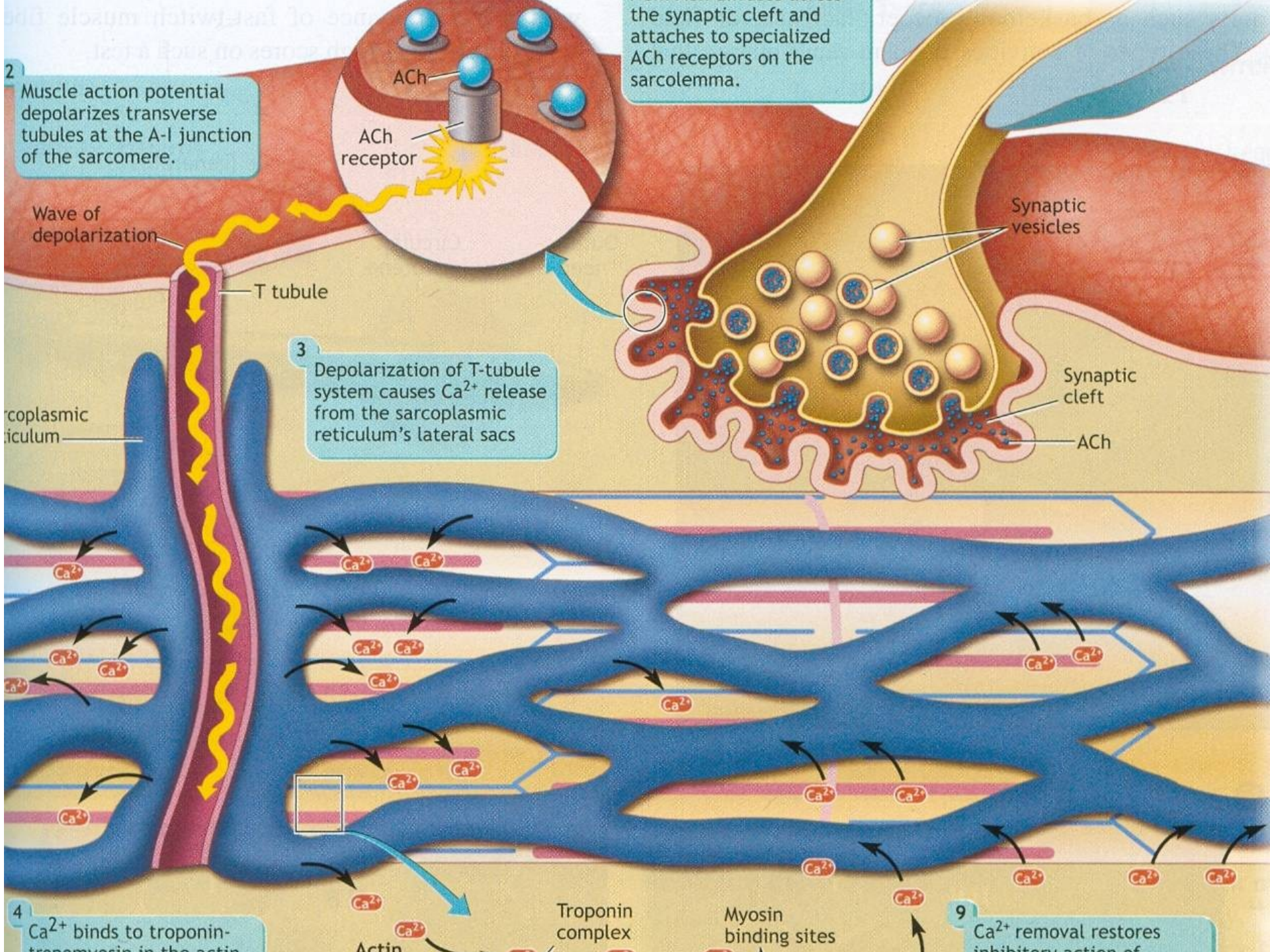
6. Once a strong binding state is extablished with actin, the myosin head tilts, pulling the actin filament (power stroke).
7. The myosin head binds to ATP, and ATPase found on the head splits ATP into ADP and P_i, releasing energy.
8. Muscle action ends when calcium is actively pumped out of the sarcoplasm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

EVENTS LEADING TO MUSCLE ACTION



CONTRACTING MUSCLE FIBER




the synaptic cleft and attaches to specialized ACh receptors on the sarcolemma.
2
Muscle action potential depolarizes transverse tubules at the A-I junction of the sarcomere.
ACh
ACh receptor
Wave of depolarization
T tubule
Synaptic vesicles
Synaptic cleft
ACh
3
Depolarization of T-tubule system causes Ca^{2+} release from the sarcoplasmic reticulum's lateral sacs
rcoplasmic iculum
Ca^{2+}
4
Ca^{2+} binds to troponin-
Troponin complex
Myosin binding sites
9
Ca^{2+} removal restores

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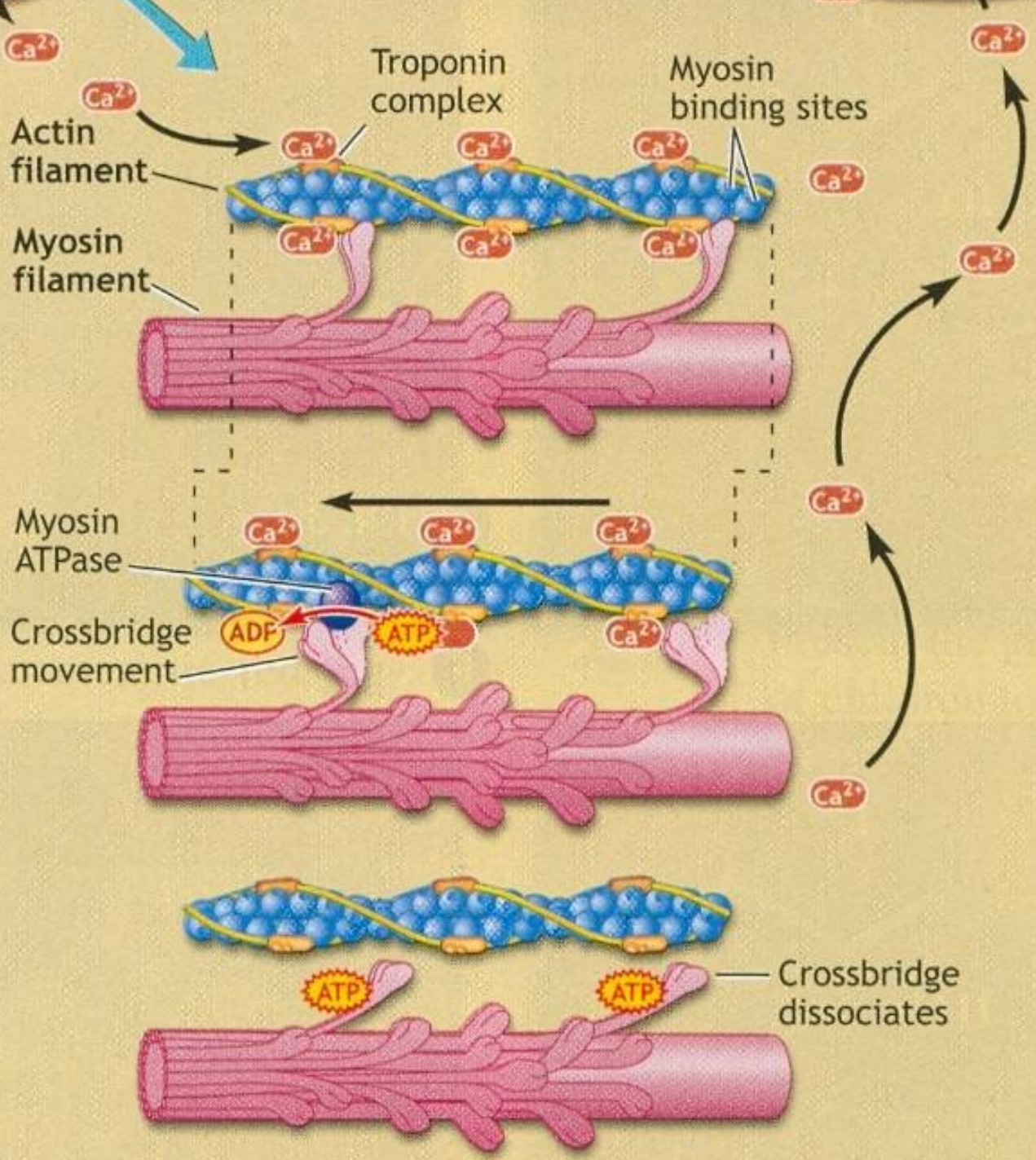

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Key Points

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 Ca^{2+} ions.
- 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

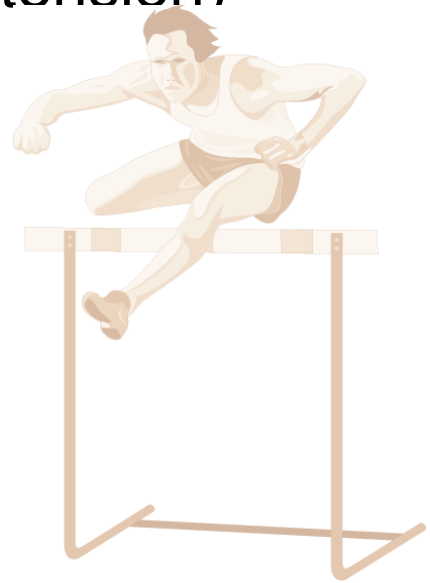
- Once myosin binds with actin, the myosin head tills and pulls the actin filament so they slide across each other.
- Muscle action ends when calcium is pumped out of the sarcoplasm to the sarcoplasmic reticulum for storage.
- Energy for muscle action is provided when thy myosin head binds to the ATP.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

Slow-oxidative Muscle Fibers - I

- 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

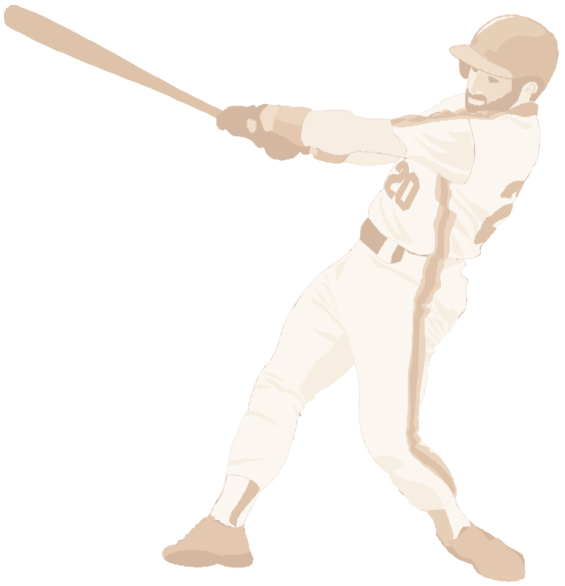
Fast-oxydative-glycolytic Muscle Fibers - II_a

- 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-glycolitic Muscle Fibers - II_x

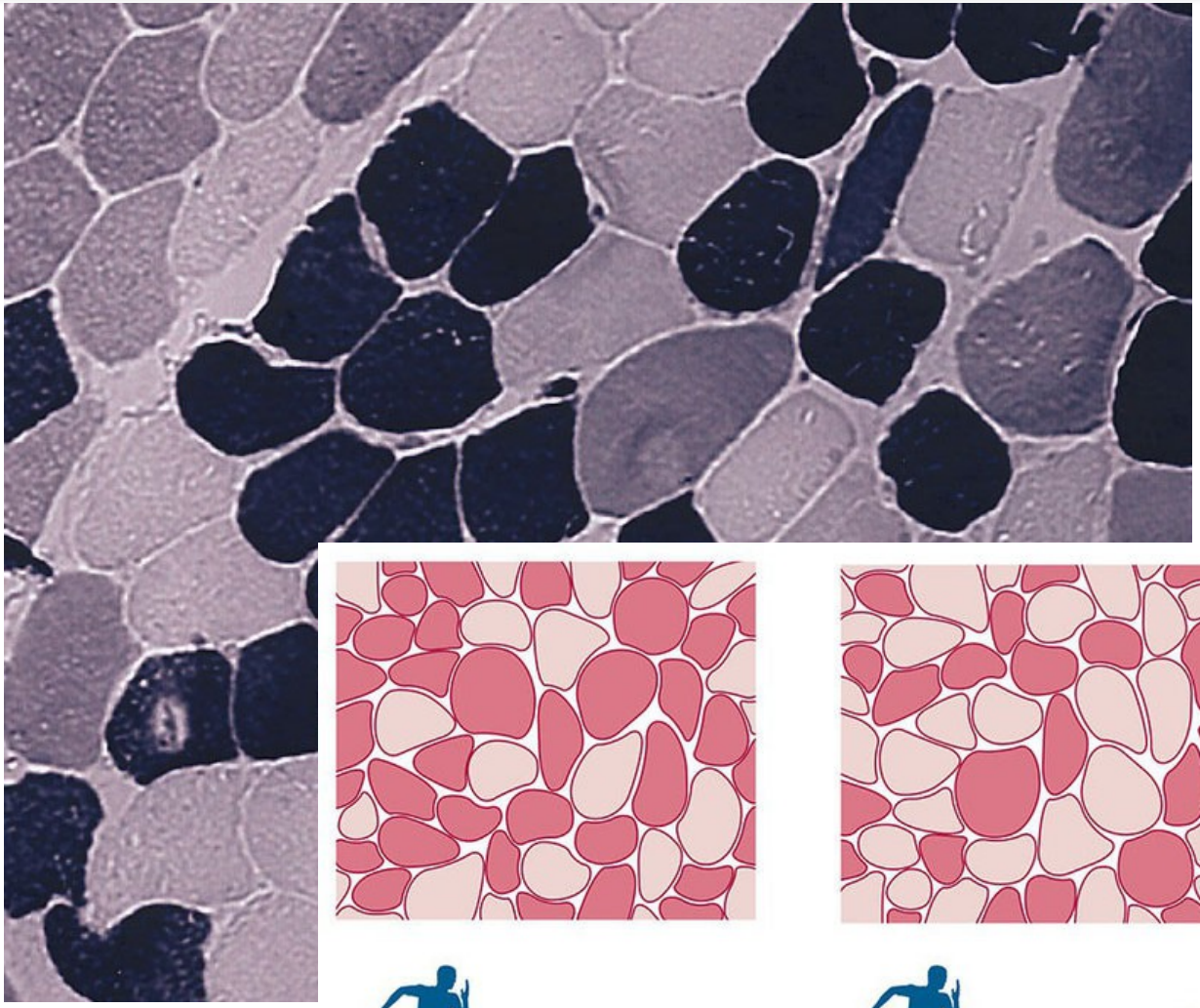
- Low aerobic (oxidative) capacity and fatigue resistance
- High anaerobic (glycolytic) capacity and motor unit strength
- Fast contractile speed (50 ms to reach peak tension)
- 300–800 fibers per motor neuron

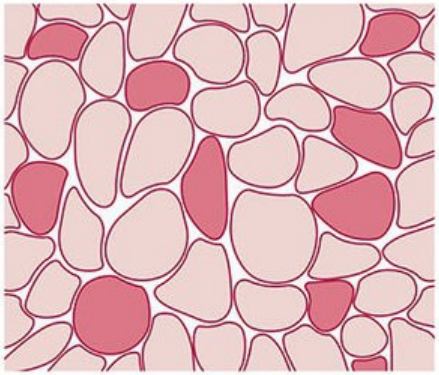


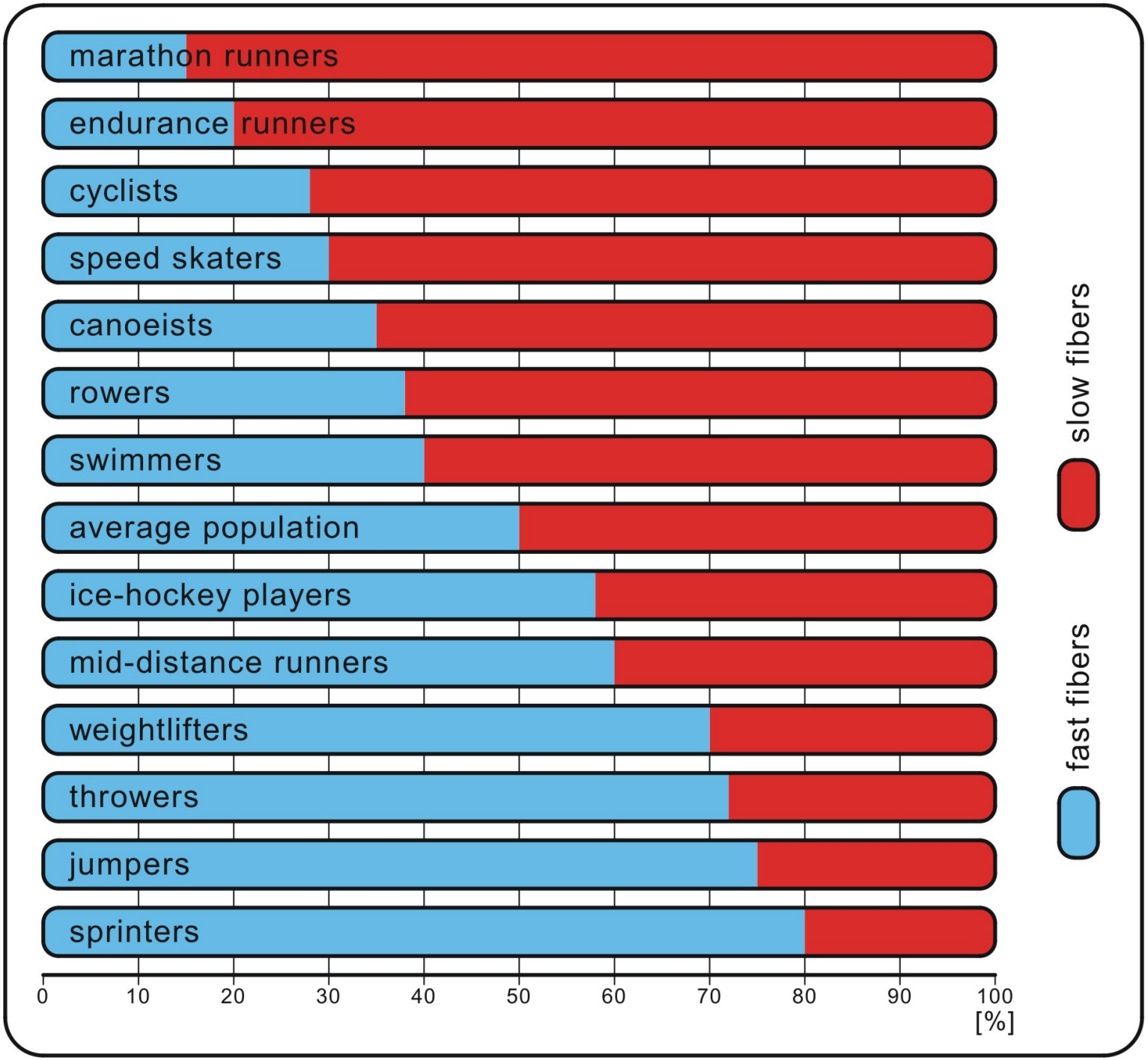
Characteristic of muscle fibers

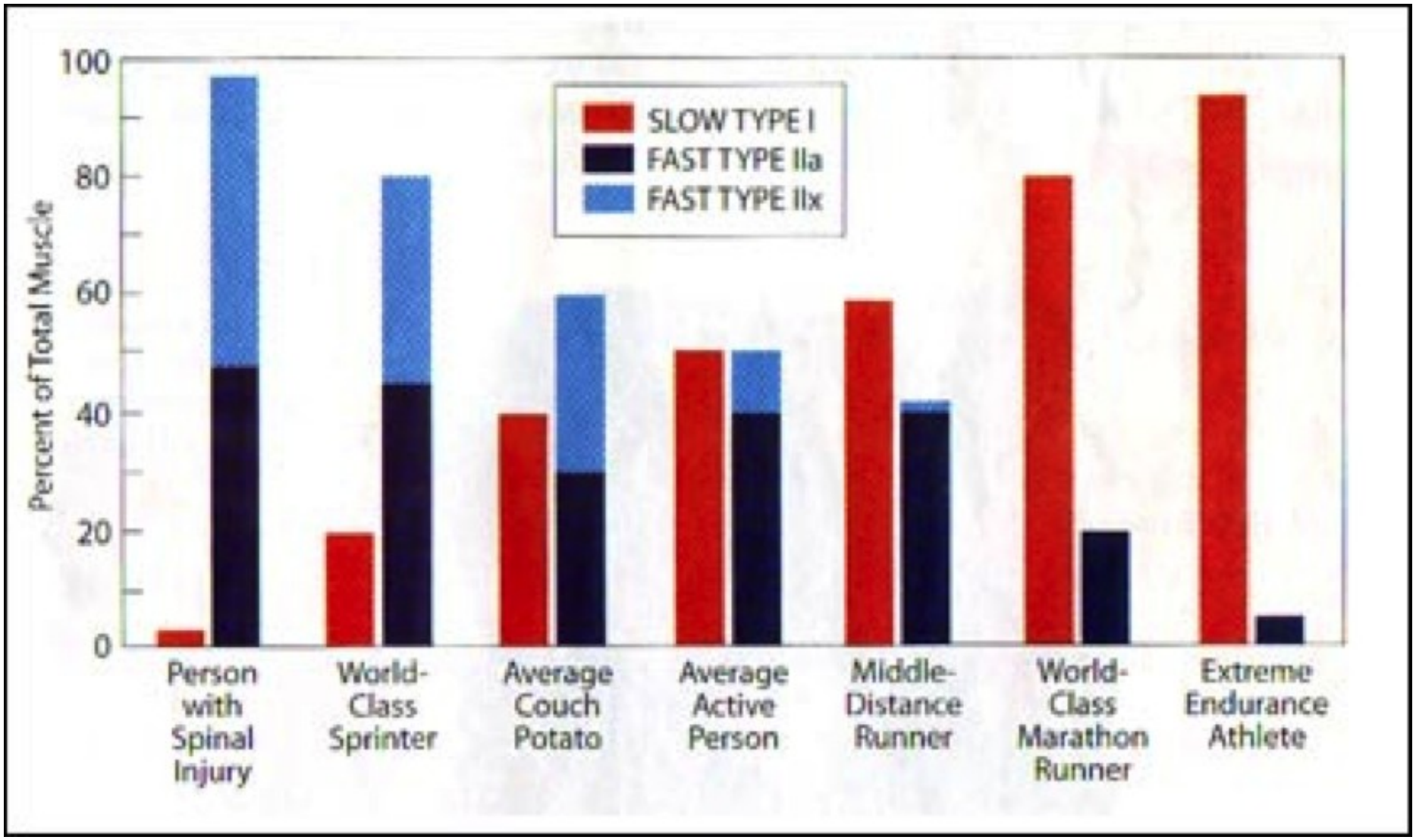
	Slow-oxidative SO (I)	Fast-oxidative-glyco FOG (IIa)	Fast-glycolytic FG (IIx)
Contractile speed	**slow**	**fast**	**fast**
Contractile force	**low**	**moderate**	**high**
Fatigue resistance	**high**	**moderate**	**low**
Glycogen capacity	**low**	**high**	**high**
Diameter	**small**	**moderate**	**big**
Mitochondrials density	**high**	**high**	**low**
Capilars density	**high**	**high**	**low**
Activity of ATPase	**low**	**high**	**high**
Glycolytic capacity	**low**	**high**	**high**

SLOW- AND FAST-TWITCH FIBERS






marathon runners
endurance runners
cyclists
speed skaters
canoeists
rowers
swimmers
average population
ice-hockey players
mid-distance runners
weightlifters
throwers
jumpers
sprinters
0
10
20
30
40
50
60
70
80
90
100
[%]
slow fibers
fast fibers


Percent of Total Muscle
100
80
60
40
20
0
SLOW TYPE I
FAST TYPE IIa
FAST TYPE IIx
Person with Spinal Injury
World-Class Sprinter
Average Couch Potato
Average Active Person
Middle-Distance Runner
World-Class Marathon Runner
Extreme Endurance Athlete

DIAGNOSTIC OF MUSCLE FIBERS

muscle biopsy

- magnetic resonance imaging

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

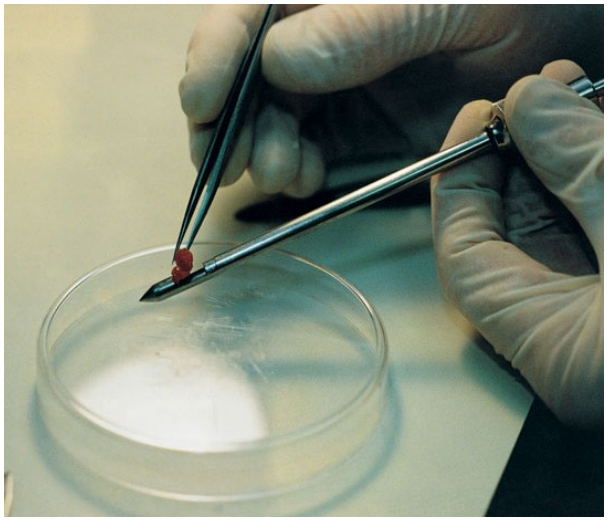
  (1RM) is a functional test of the maximum weight that can be lifted just one time=100%

  < 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.

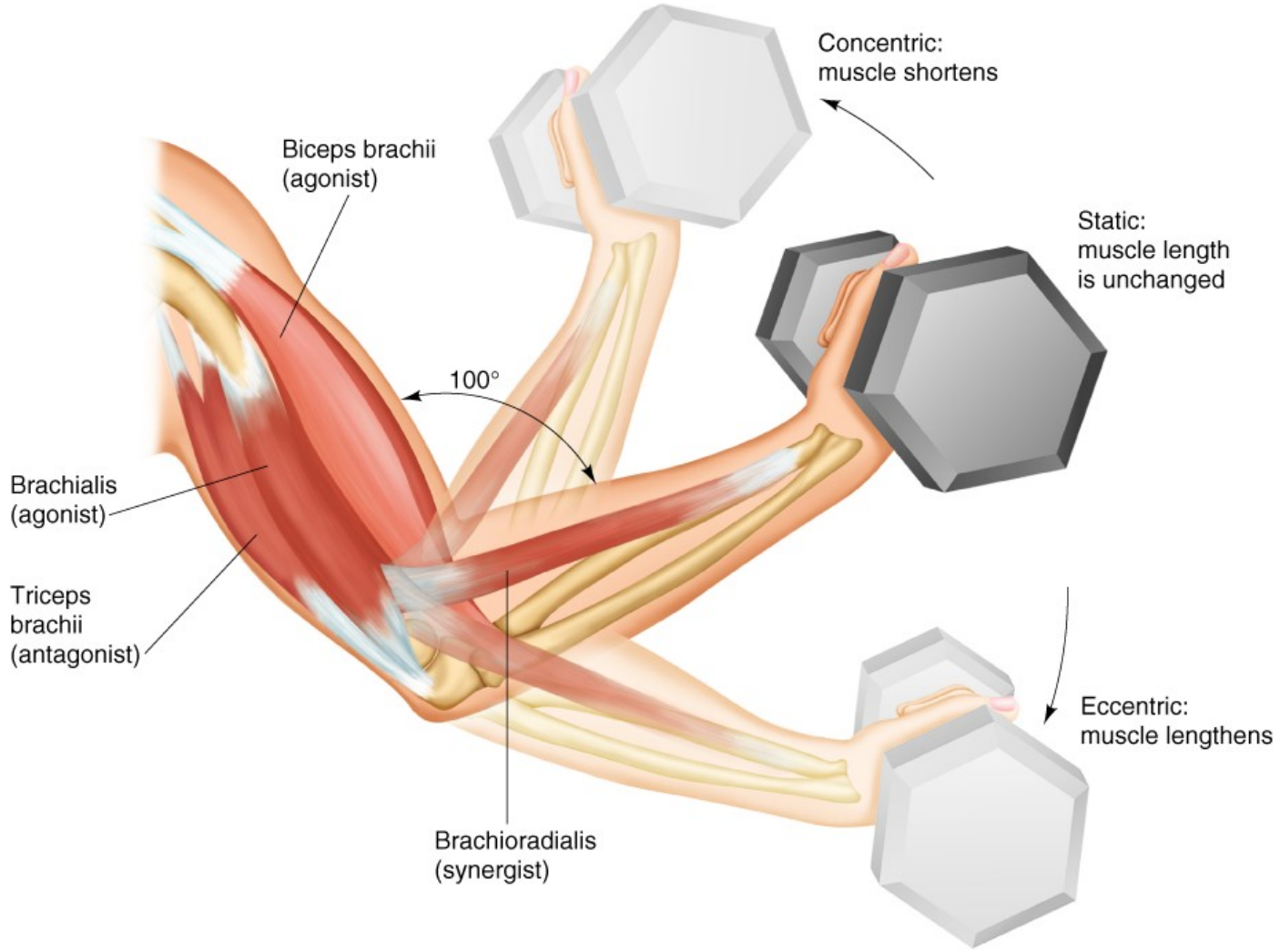
Functional Classification of Muscles

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 strenght testing

- Dynamometry menas testing of muscles strenght.
- Strenght is defined as a peak force of 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 strenght is usually measured as the peak force produced by a maximum voluntary isometric contraction.
- Dynamometers convert the deformation produced by tension or pressure into srenght (N)
- The dynamometric measurements shoul be made at standardised positions.

ISOKINETIC DYNAMOMETRY

- Isokinetic strenght is usually measured as force produced by a constant velocity contraction.
- Dynamometers convert the deformation produced by tension or pressure into srenght (N), peak torque, total work, avarege work
- The dynamometric measuremen standardised positions.