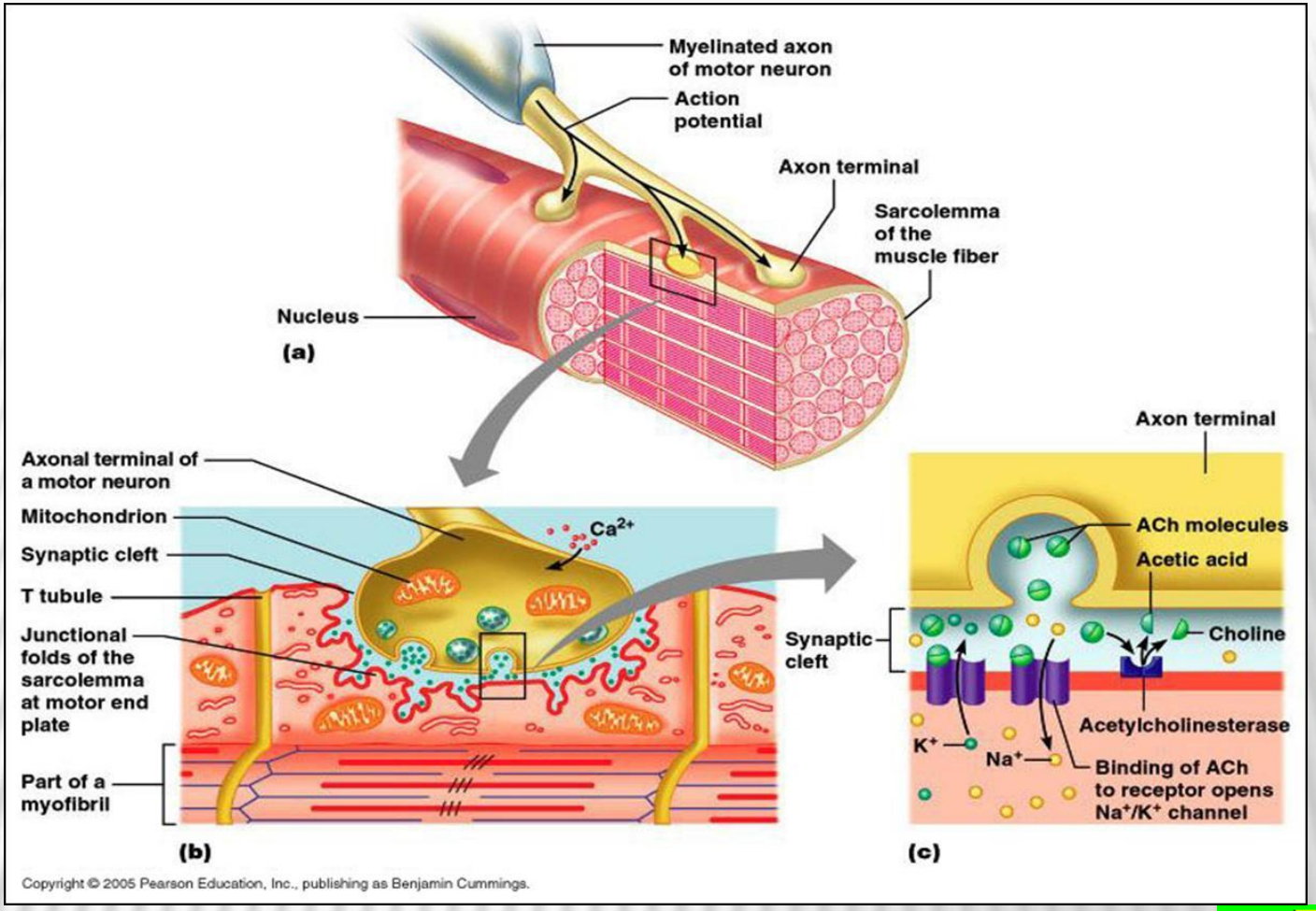
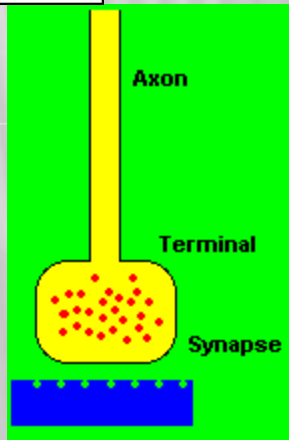
PSK4U

THE NEUROMUSCULAR SYSTEM





REVIEW

- Review of muscle so we can see how the neuromuscular system works
- This is not on today's note

Skeletal Muscle Cell: Cellular System

- A) **Excitation System – Electrical Potential**
  - muscle is an excitable tissue
  - sarcolemma (cell membrane)/ T-Tubules
  - action potential

- B) **Ca^{2+} Regulation System**
  - Sarcoplasmic Reticulum (SR)
  - storage, release, and uptake of Ca^{2+}

- C) **Contractile System (Myofibrils)**
  - Contractile Proteins (Actin & Myosin)
  - Regulatory Proteins (Troponin & Tropomyosin)

Skeletal Muscle Cell: Cellular System

- D) **Metabolic (Energy) System**
  - ATP $\xrightarrow[\text{ATPase}]{}$ ADP + Pi + ENERGY
  - muscle cell needs a constant supply of ATP to contract and produce force.

- E) **Nucleus (Multinucleated)**
  - ability to regenerate (Satellite Cells)
  - ability to adapt and be eliminated to physiological and environmental stimuli

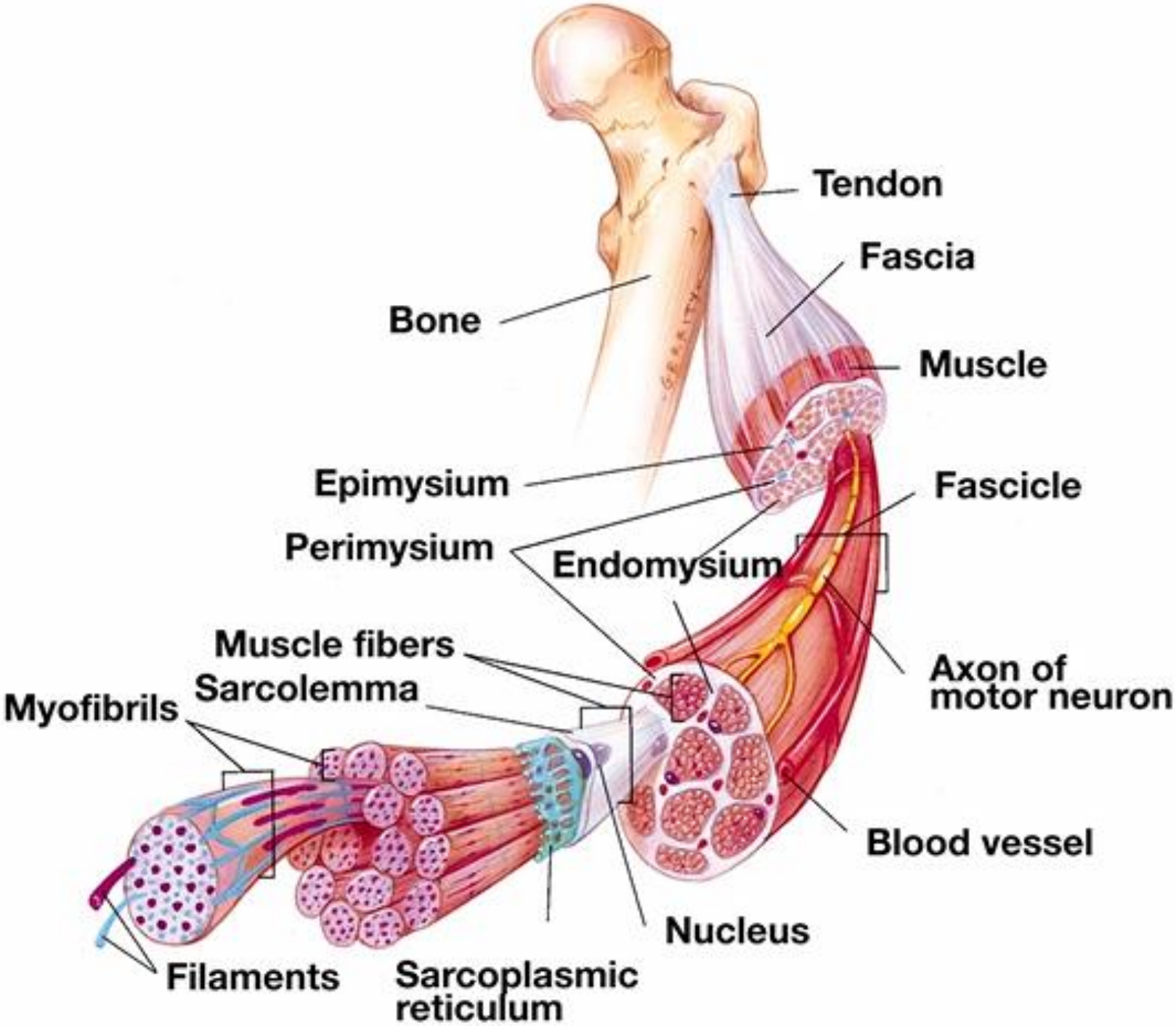
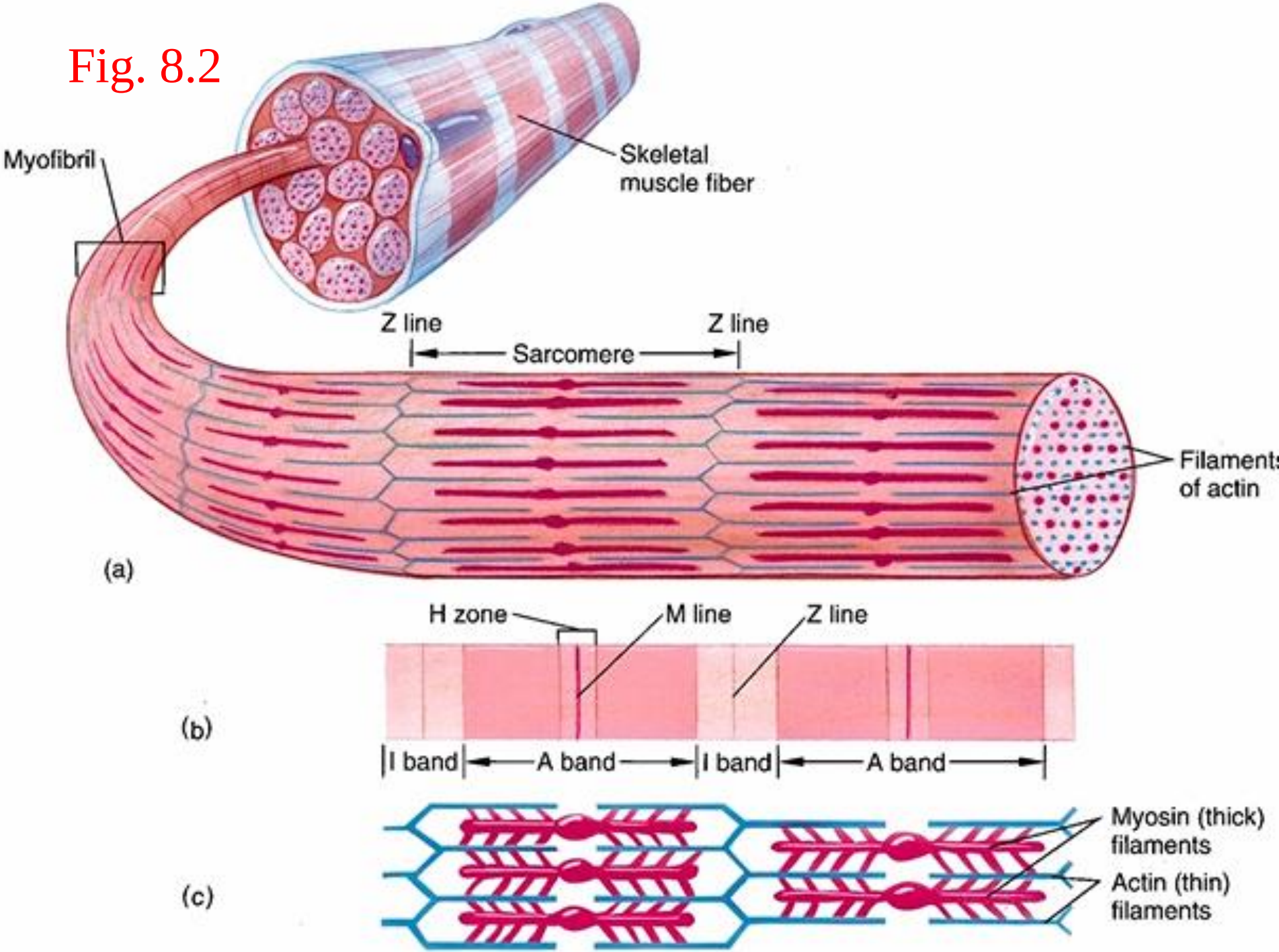
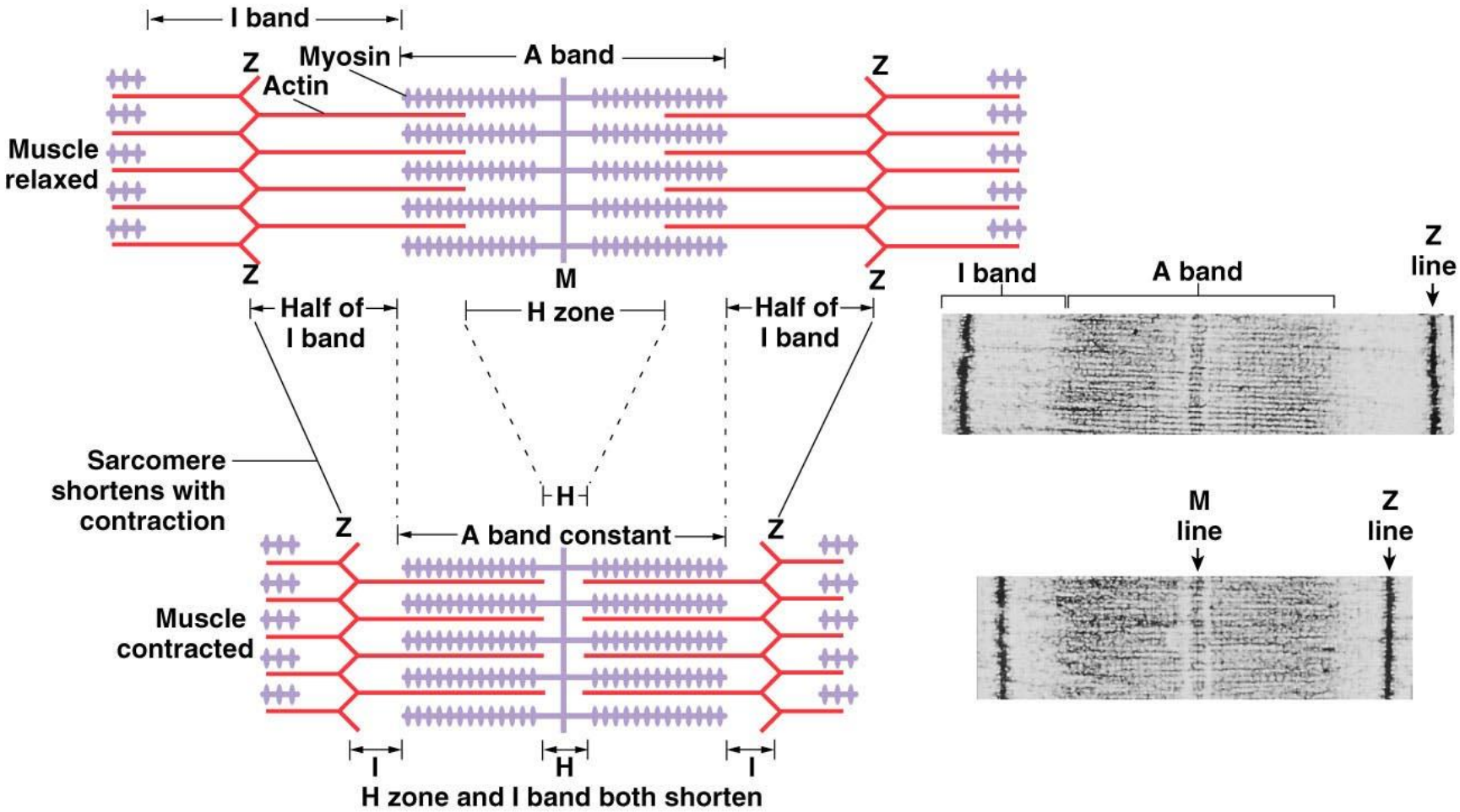

Tendon
Fascia
Bone
Muscle
Epimysium
Fascicle
Perimysium
Endomysium
Muscle fibers
Sarcolemma
Myofibrils
Axon of motor neuron
Blood vessel
Nucleus
Filaments
Sarcoplasmic reticulum

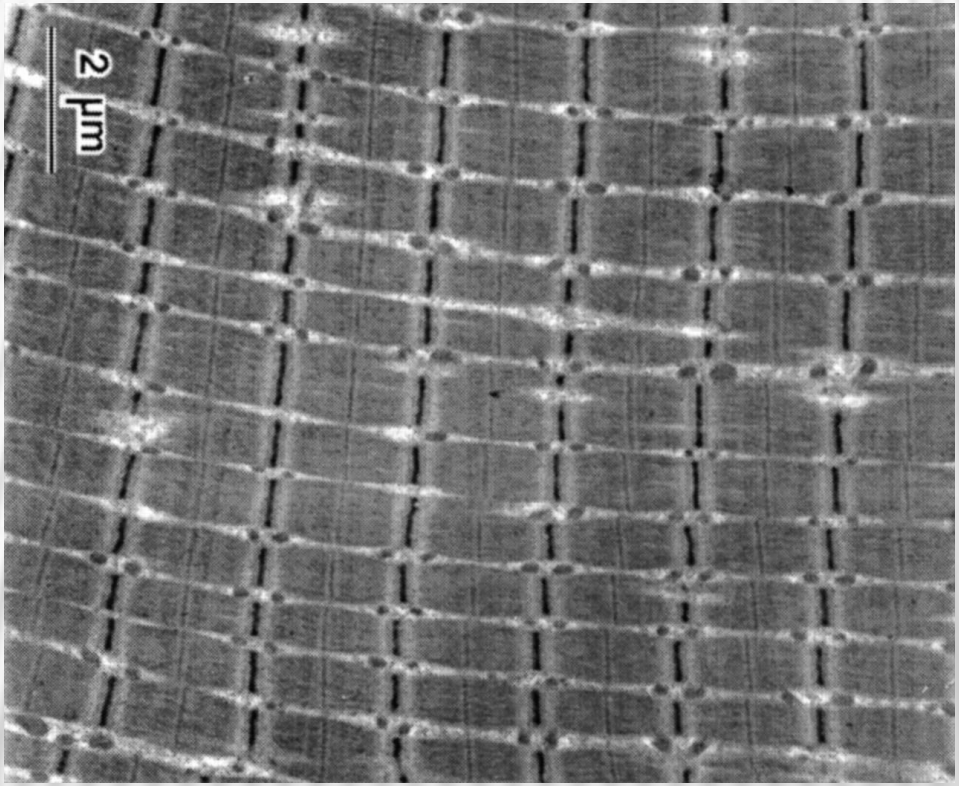
Fig. 8.2


Myofibril
Skeletal muscle fiber
Z line
Z line
Sarcomere
Filaments of actin
(a)
H zone
M line
Z line
(b)
I band
A band
I band
A band
Myosin (thick) filaments
Actin (thin) filaments
(c)

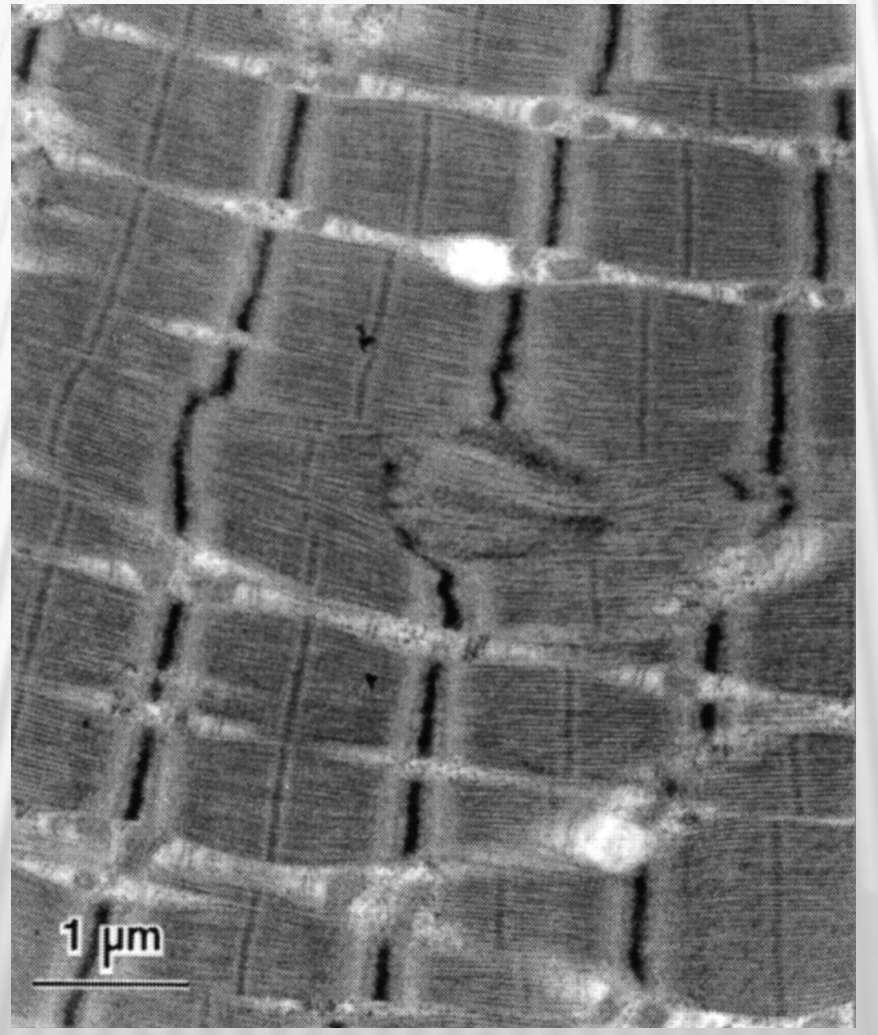
Orientation of Thin & Thick Filaments Within Skeletal Muscle



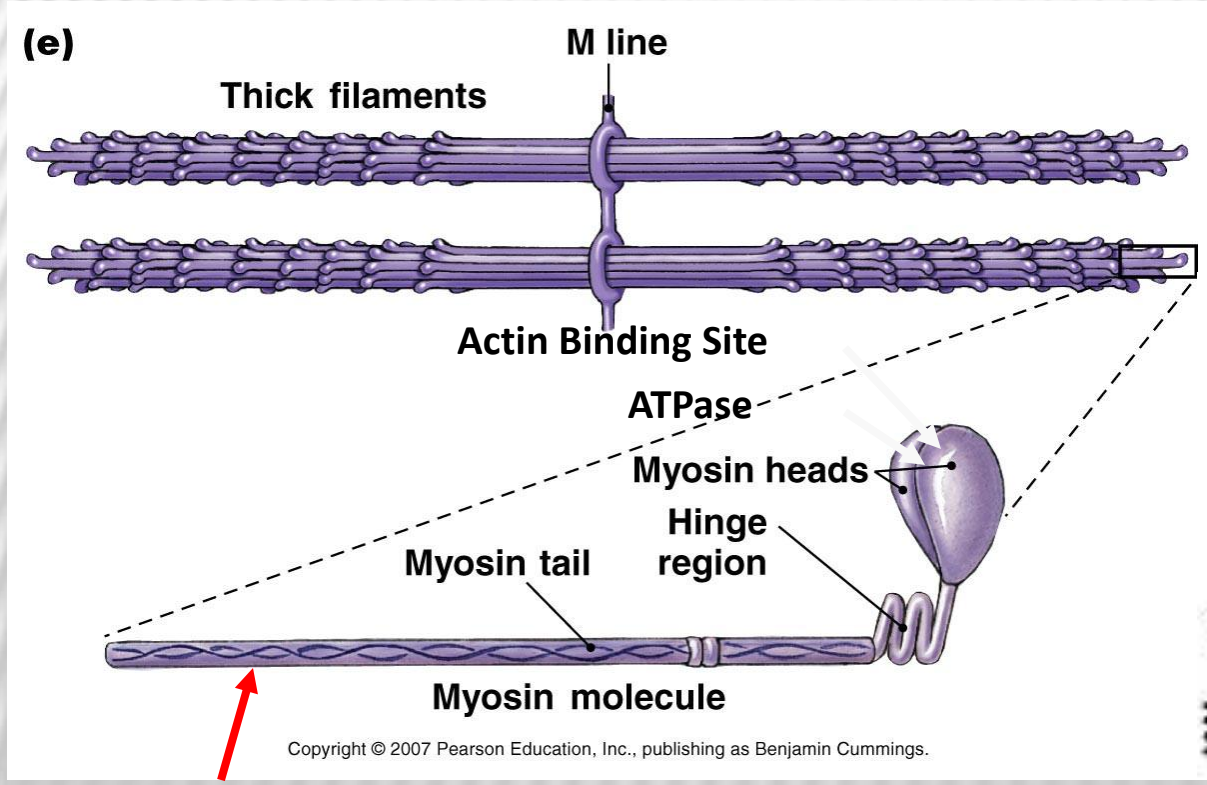
THIS IS HEALTHY MUSCLE TISSUE

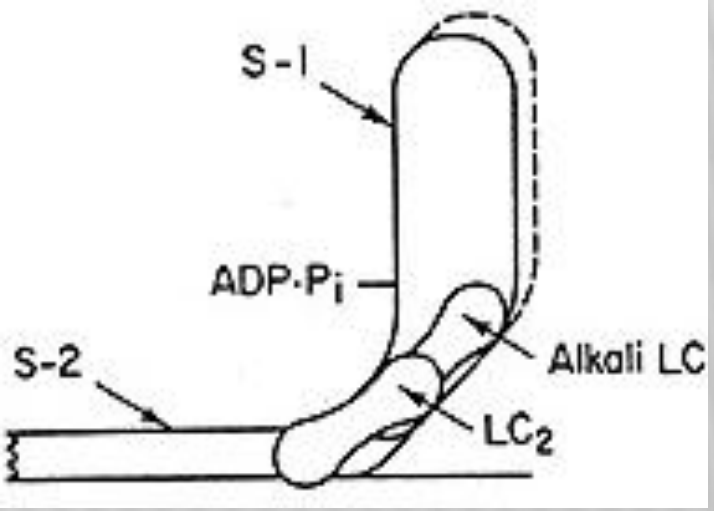


THIS IS A DAMAGED TISSUE



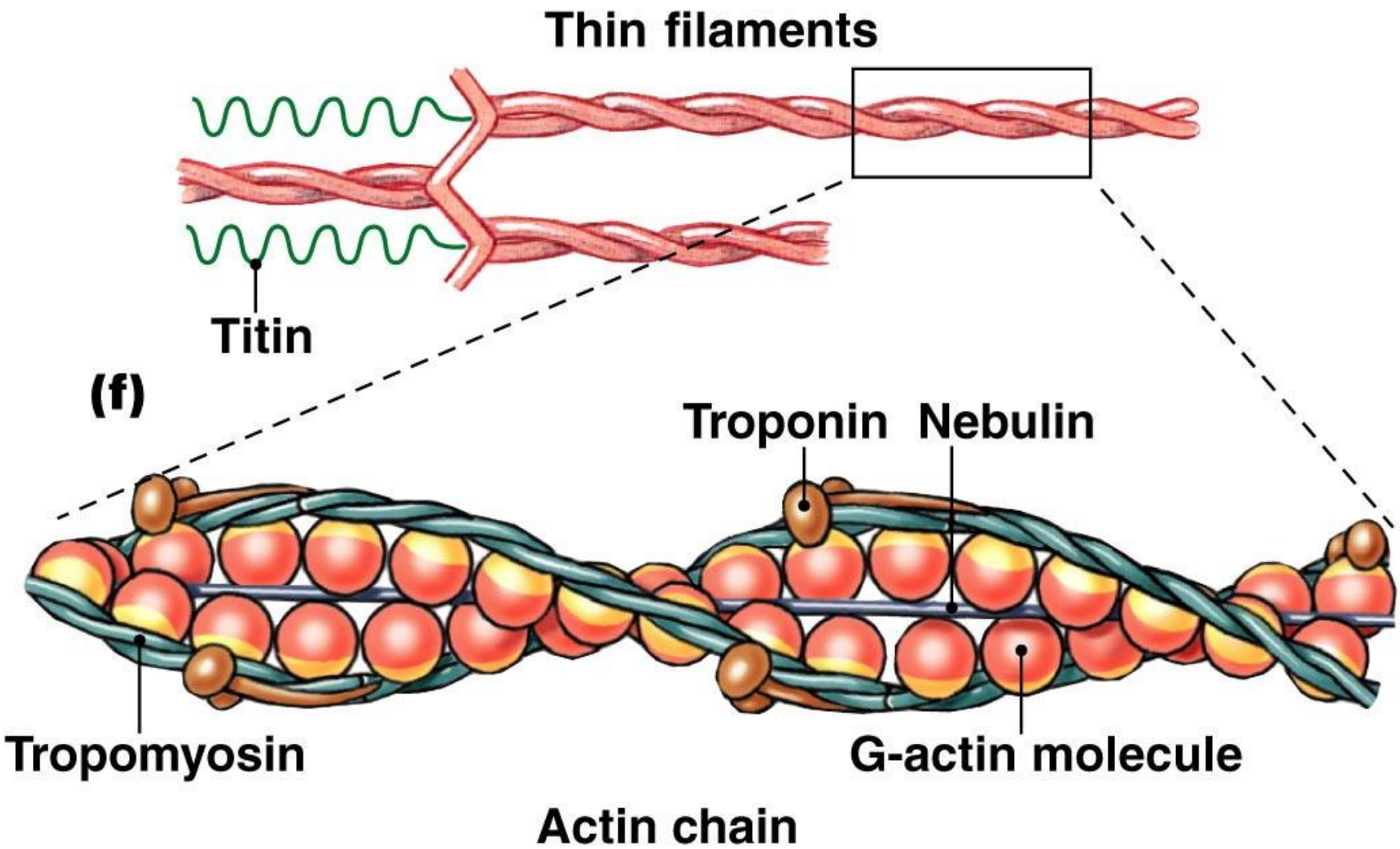
Thick Filament: Myosin Molecule





Thick Filament Backbone

Silverthorn, Prentice-Hall, 2007.



Muscle Fiber Types

Fast fibers

- Type IIx (IIb) fibers
  - Fast-twitch fibers
  - Fast-glycolytic fibers

- Type IIa fibers
  - Intermediate fibers
  - Fast-oxidative glycolytic fibers

Slow fibers

- Type I fibers
  - Slow-twitch fibers
  - Slow-oxidative fibers

MUSCLE FIBER TYPES

Primary factor that differentiates muscle or muscle fiber types:

- **The RATE (speed) of contraction**
  - **Vmax (maximal rate of shortening)**
  - **Fast-Twitch (Type II) – IIx > IIa**
  - **Slow-Twitch (Type I)**
  - **TYPE II > TYPE I**

FAST-TWITCH VS. SLOW-TWITCH

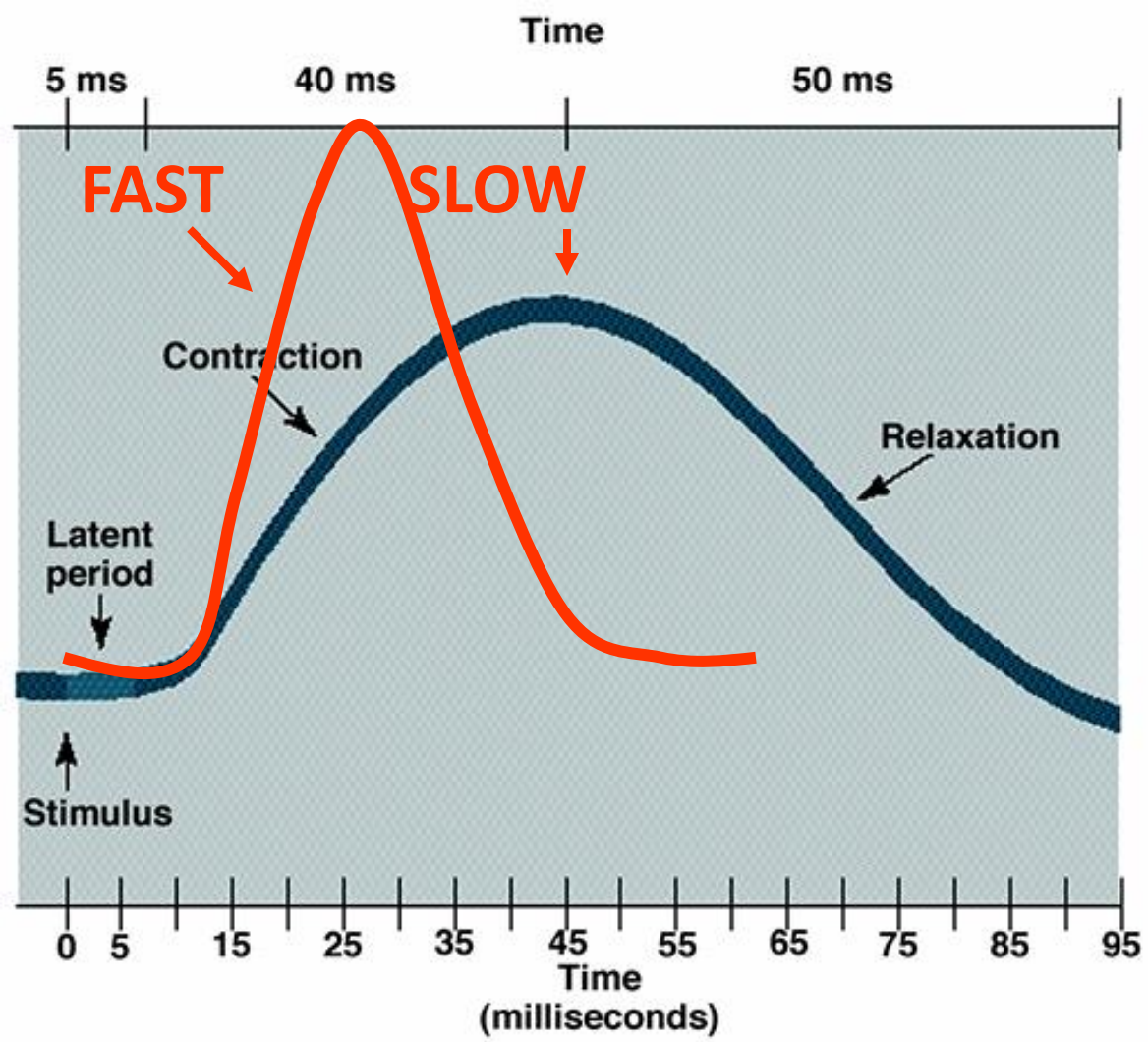


FIG 8.15 Powers

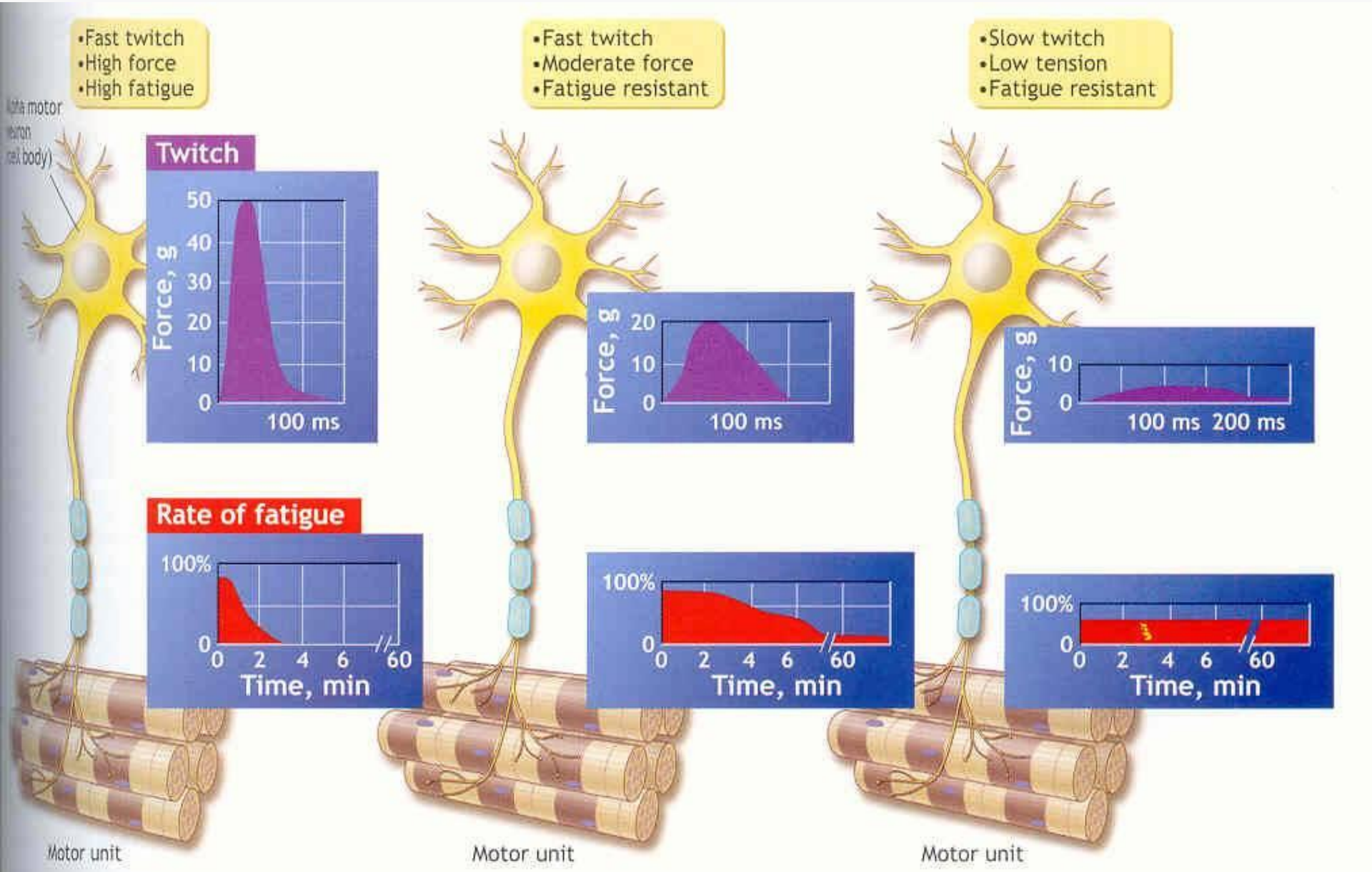


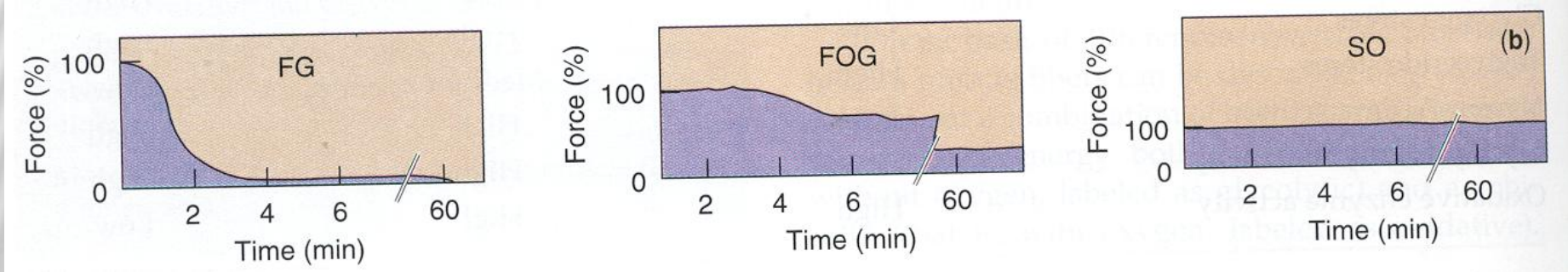
FIGURE 19.13 • Speed, force, and fatigue characteristics of motor units. "Phasic" motor neurons fire rapidly with short bursts; "tonic" motor neurons fire slowly but continuously.

MUSCLE FIBER TYPES

Second factor that differentiates muscle or muscle fiber types:

- FATIGUE Characteristics
  - Fatigue Index

Fast Fatigable (FF) **Fast Resistant (FR)** **Slow (S)**



Muscle Fiber Types

A third factor used to characterized muscle fiber types is the fiber **METABOLIC CHARACTERISTICS**

- **METABOLIC Characteristics**
  - Glycolytic
  - Oxidative
  - measure enzyme activities of representative pathways (Glycolysis, Oxidative Phosphorylation)

  - Fast-Glycolytic (FG)
  - Fast-Oxidative-Glycolytic (FOG)
  - Slow-Oxidative (SO)

Muscle Fiber Types

A fourth factor used to characterized muscle fiber types I the MORPHOLOGICAL characteristics (form and structure of fiber)

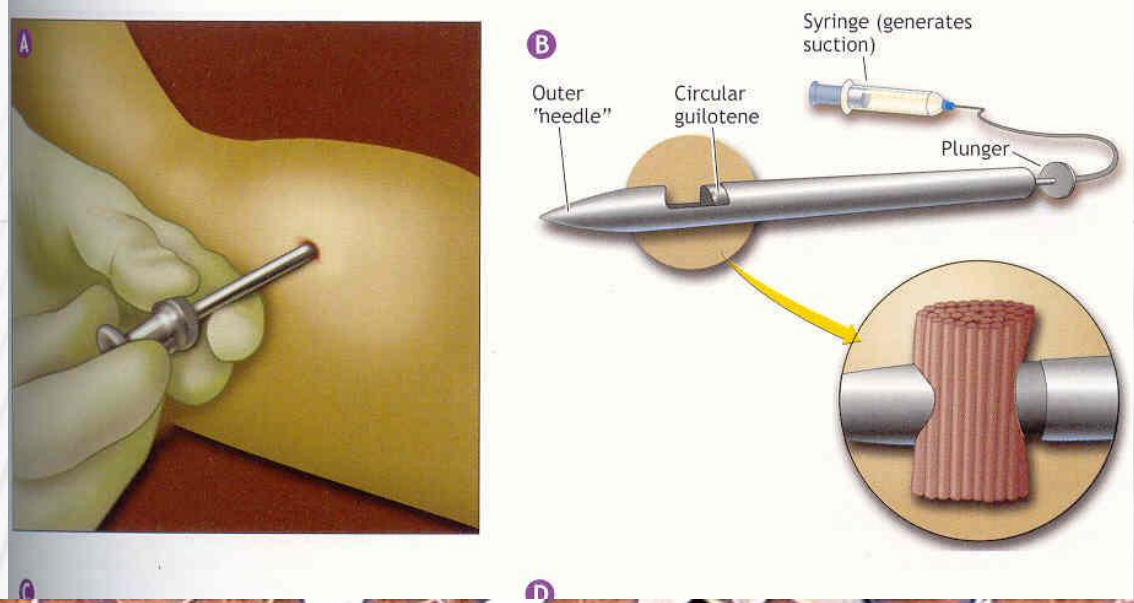
MORPHOLOGICAL CHARACTERISTICS

- muscle fiber diameter (size)
- capillary density (muscle blood flow)
- myoglobin content (cellular O2 transport)
- organelle content (SR, Mitochondria)

Muscle Fiber Types

Characteristic	Fast fibers Type IIb	Type IIa	Slow fibers Type I
Number of mitochondria	Low	High/moderate	High
Resistance to fatigue	Low	High/moderate	High
Predominant energy system	Anaerobic	Combination	Aerobic
ATPase activity	Highest	High	Low
V_{max} (speed of shortening)	Highest	Intermediate	Low
Efficiency	Low	Moderate	High
Specific tension	High	High	Moderate

Table. 8.1 Powers.

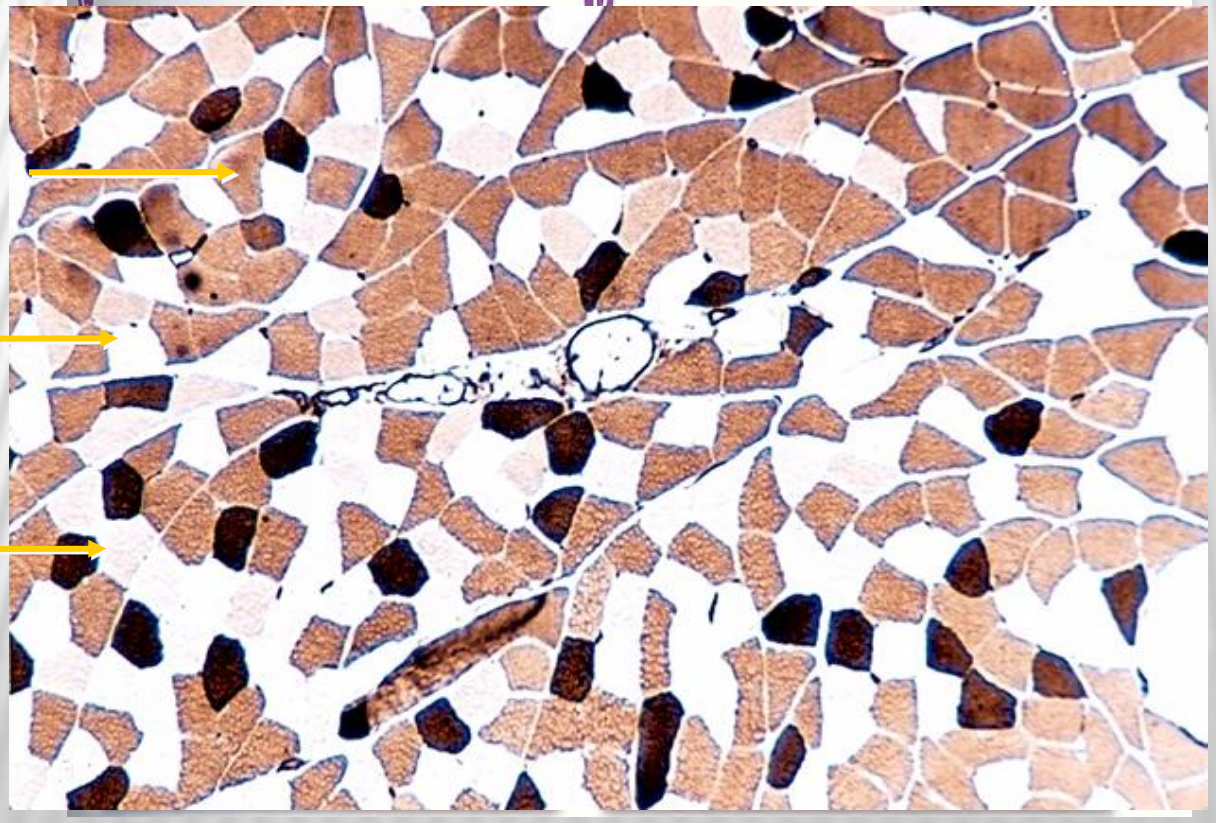


M-ATPase
pH=4.6

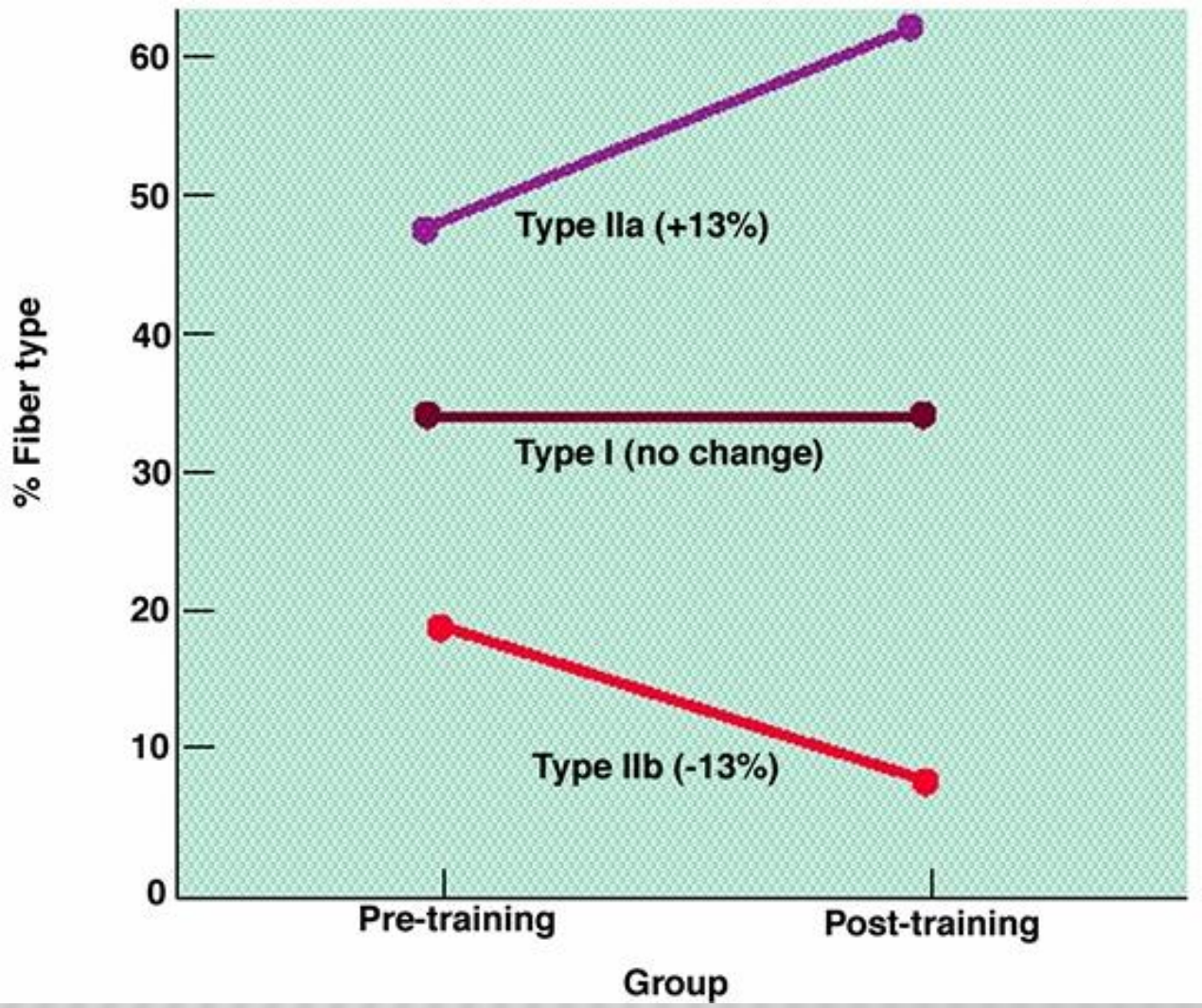
Type IIa

Type IIx

Type I

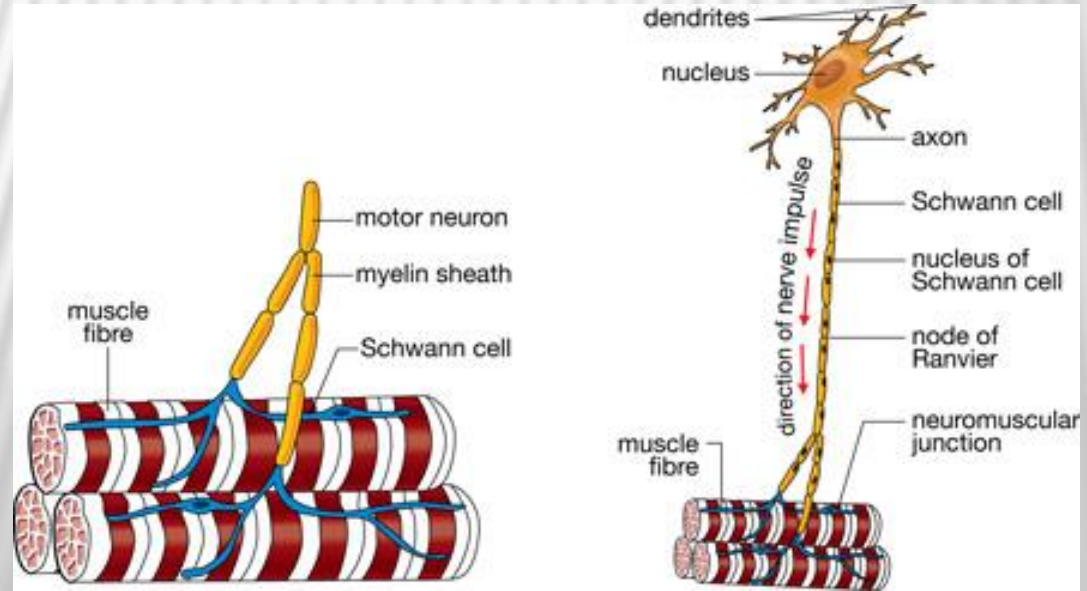


Training-Induced Changes in Muscle Fiber Type



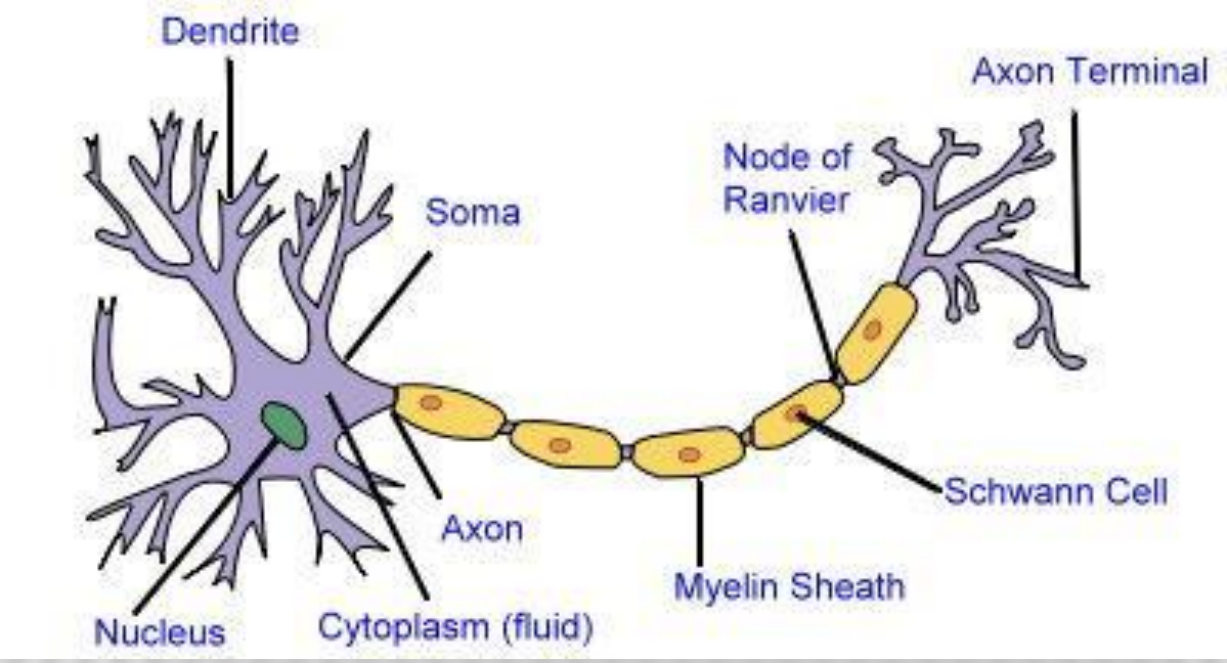
THE NEUROMUSCULAR SYSTEM (P.172)

- - The interrelated workings of the nervous system and the muscles to bring about movement
  - The brain and spinal cord control skeletal (voluntary) muscles through specialized nerves



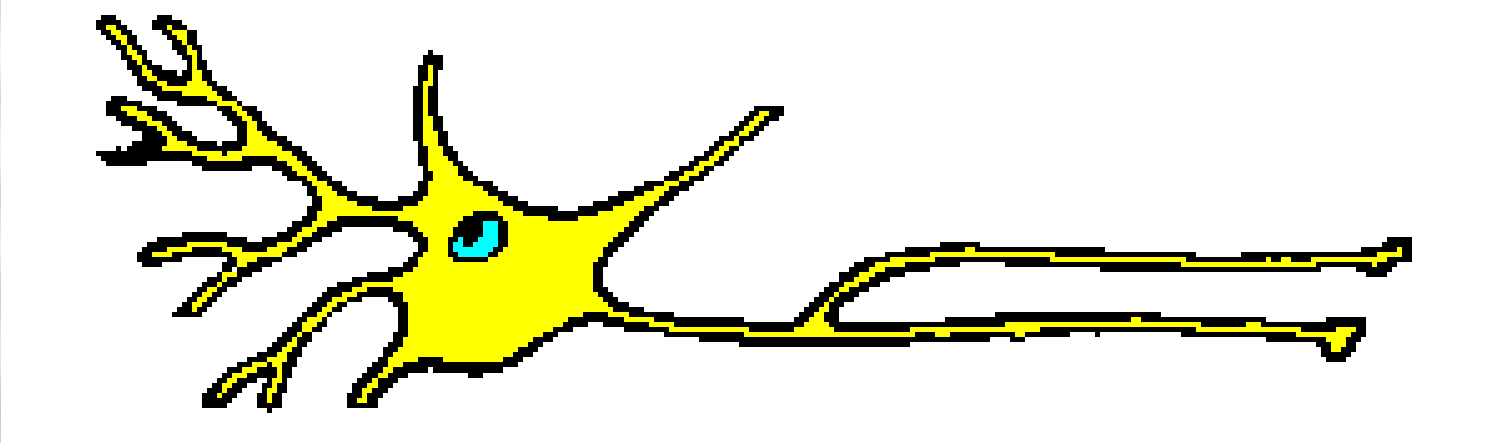
THE NERVE CELL

- Neurons are nerve cells, found in the nervous system.
- These are specialized cells designed to stimulate other cells in the body in order to communicate.



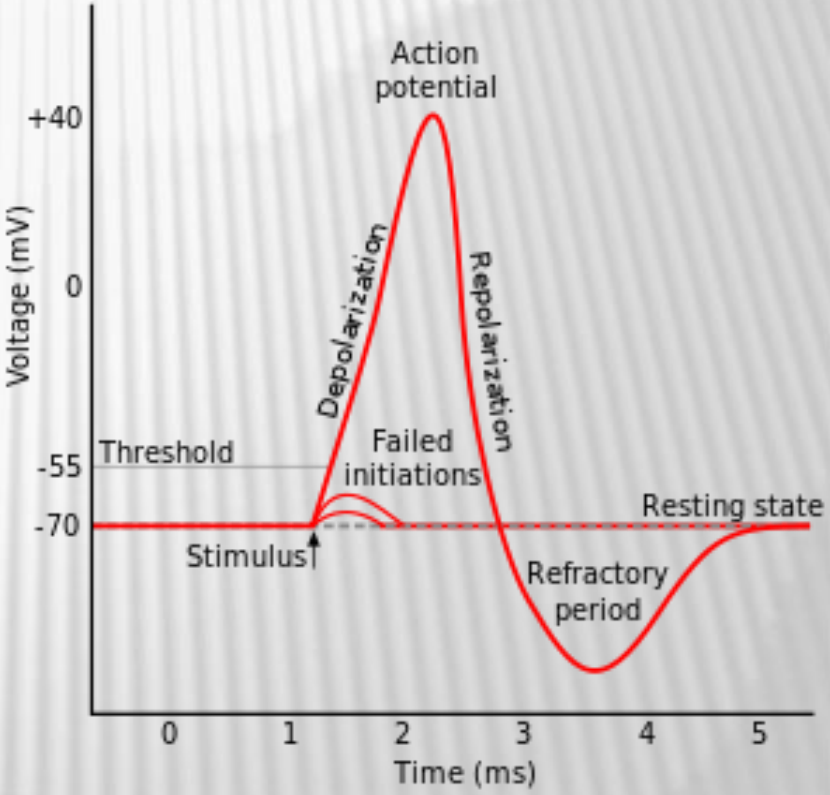
THE NERVE CELL

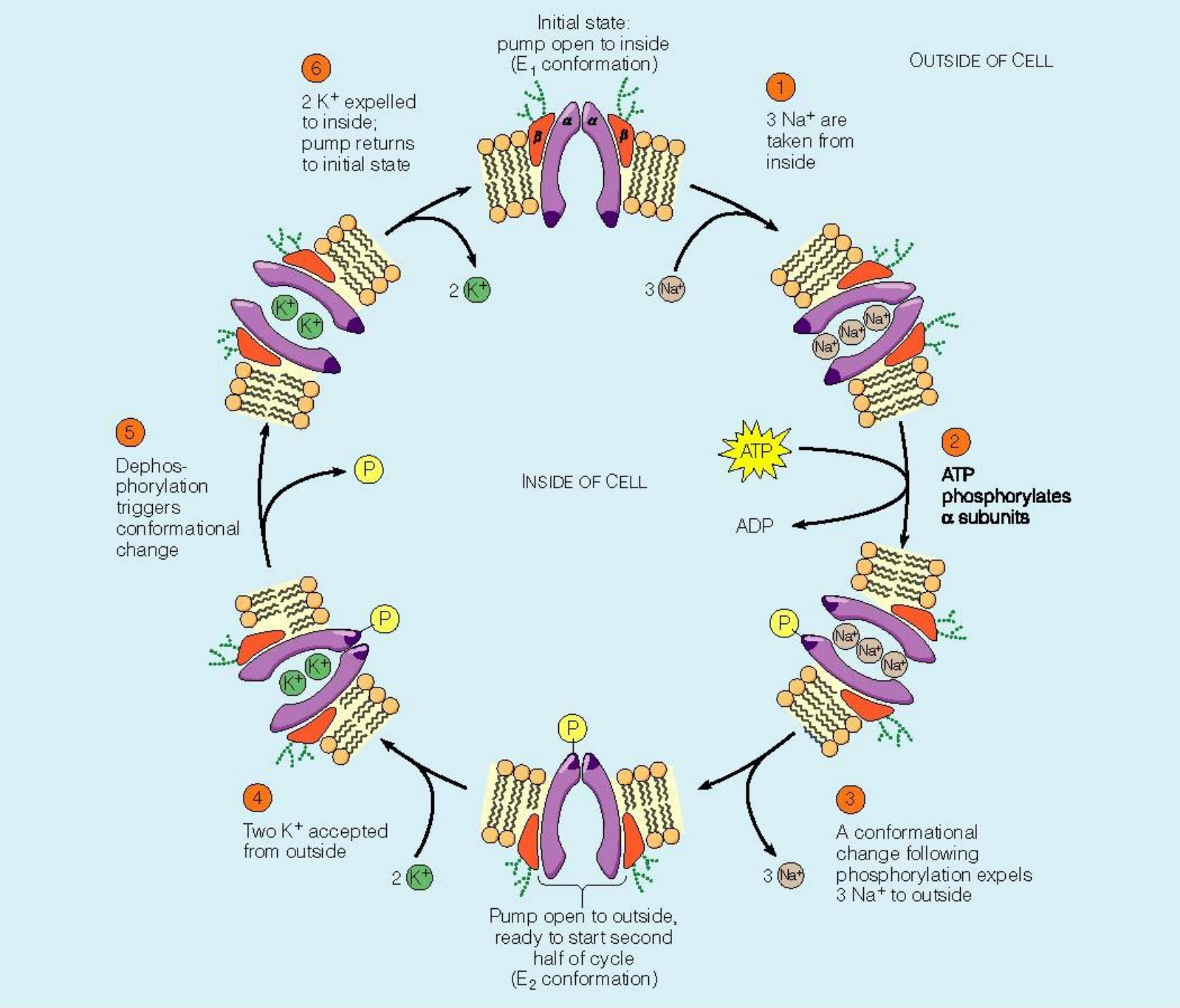
- Neurons are excitable, which means they function by using electrical stimulation.

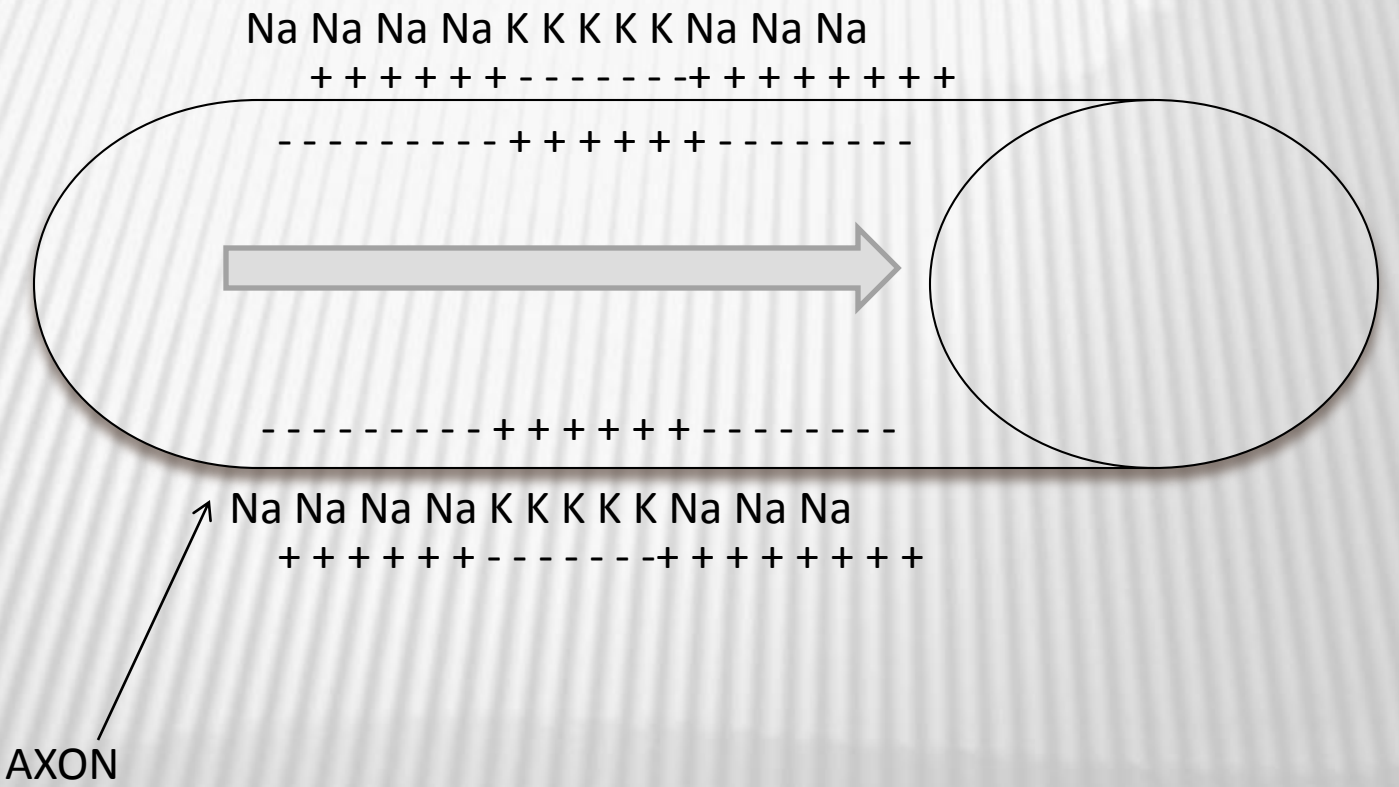


ACTION POTENTIAL

- Action Potential
  - a short-lasting event in which the electrical membrane **potential** of a cell rapidly rises and falls, following a consistent trajectory

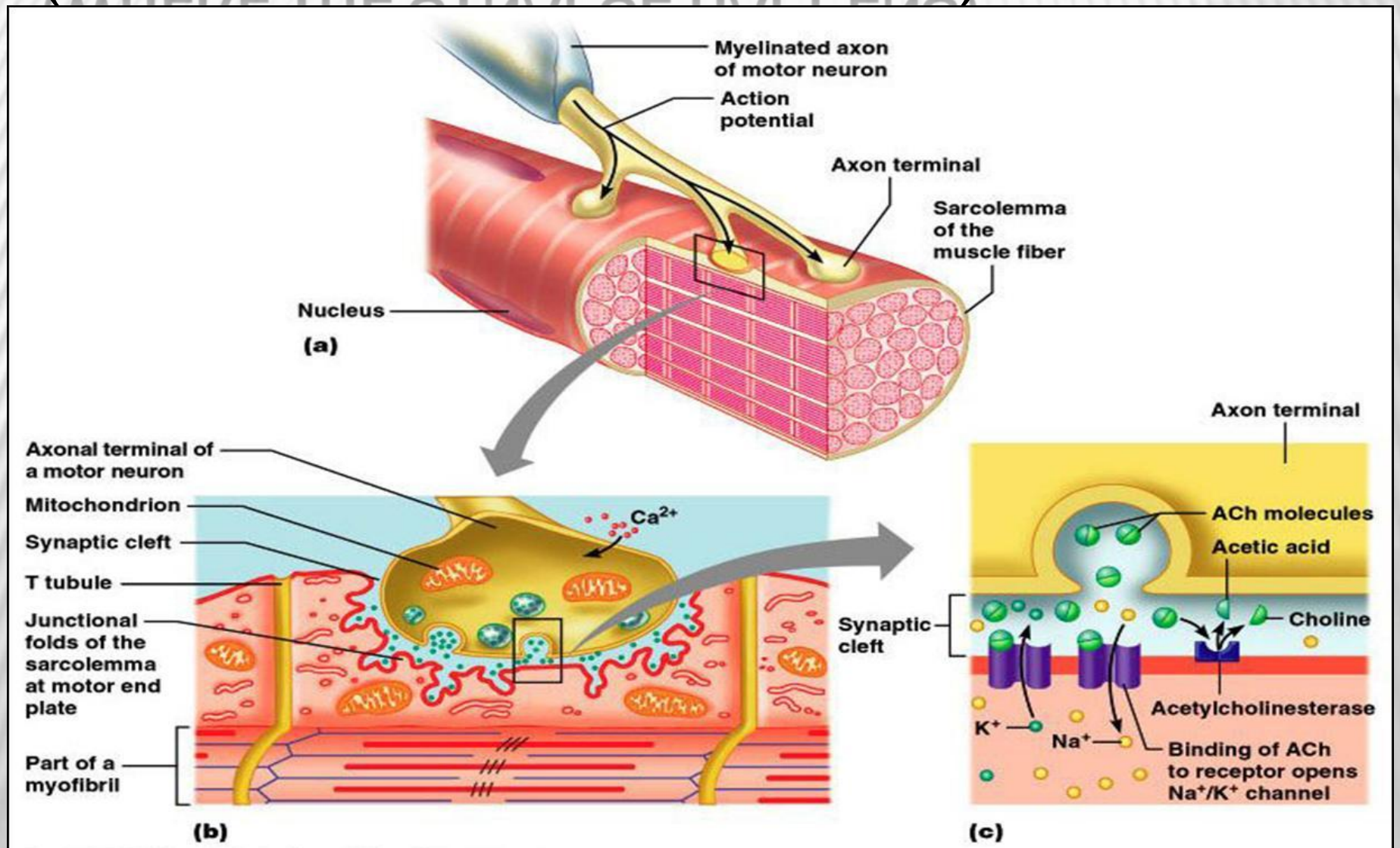





Na Na Na Na K K K K K Na Na Na
+ + + + + + - - - - - - -+ + + + + + + +
- - - - - - - - - + + + + + + - - - - - - - -
- - - - - - - - - + + + + + + - - - - - - - -
Na Na Na Na K K K K K Na Na Na
+ + + + + + - - - - - - -+ + + + + + + +
AXON

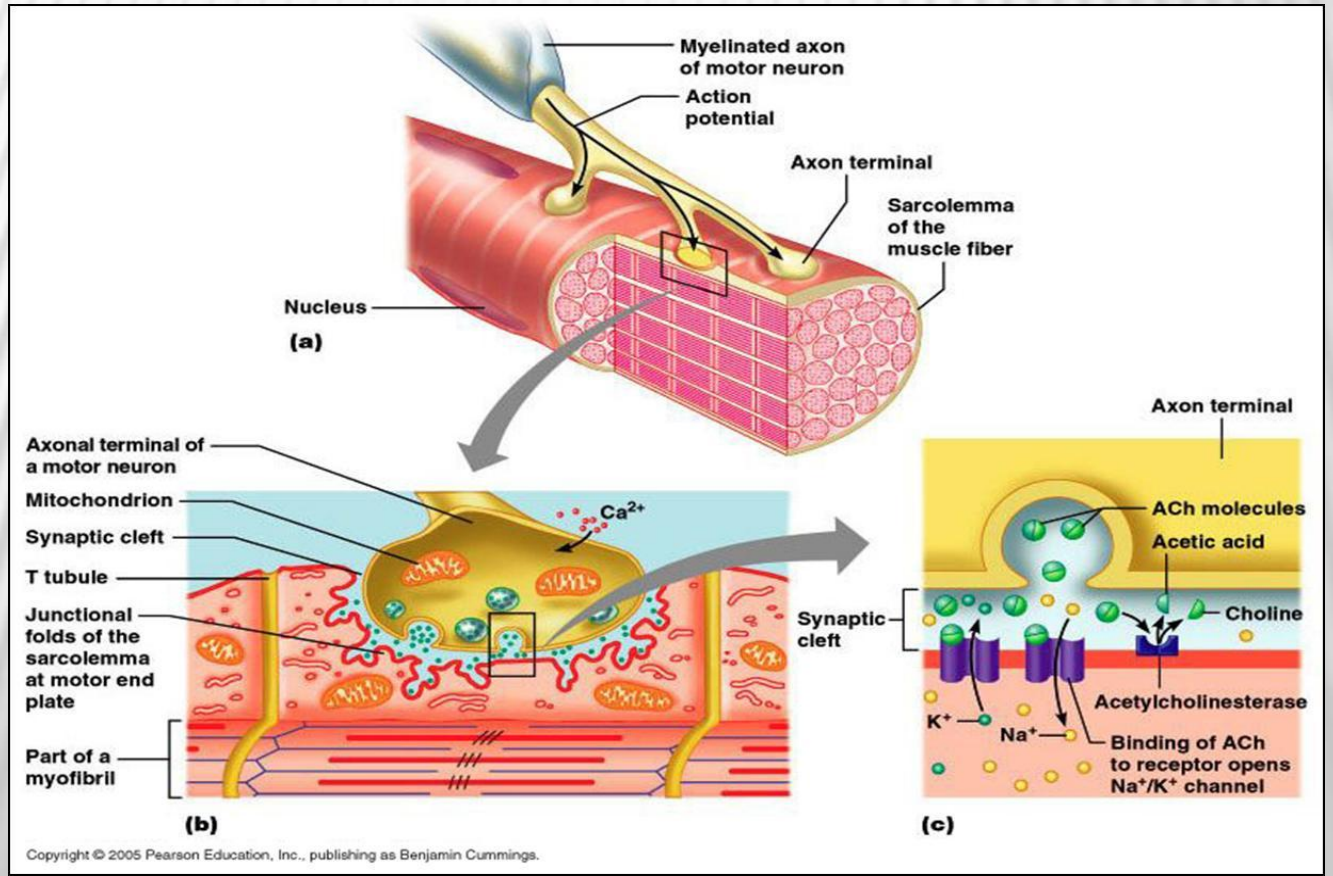
- Action Potential
- https://www.youtube.com/watch?v=ifD1YG07fB8

NEUROMUSCULAR JUNCTION (WHERE THE SYNAPSE HAPPENS)



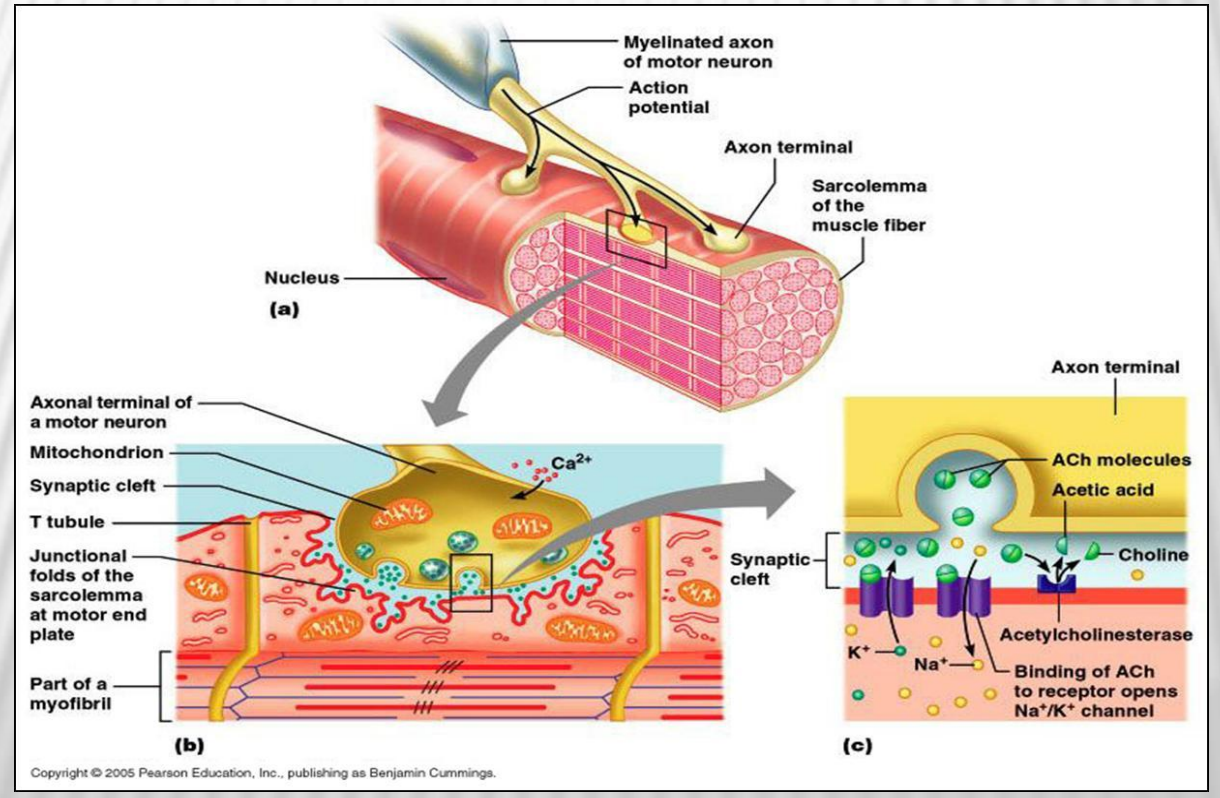
NEUROMUSCULAR JUNCTION - STEPS

1. Action potential travels down the Axon and depolarizes the axon terminal



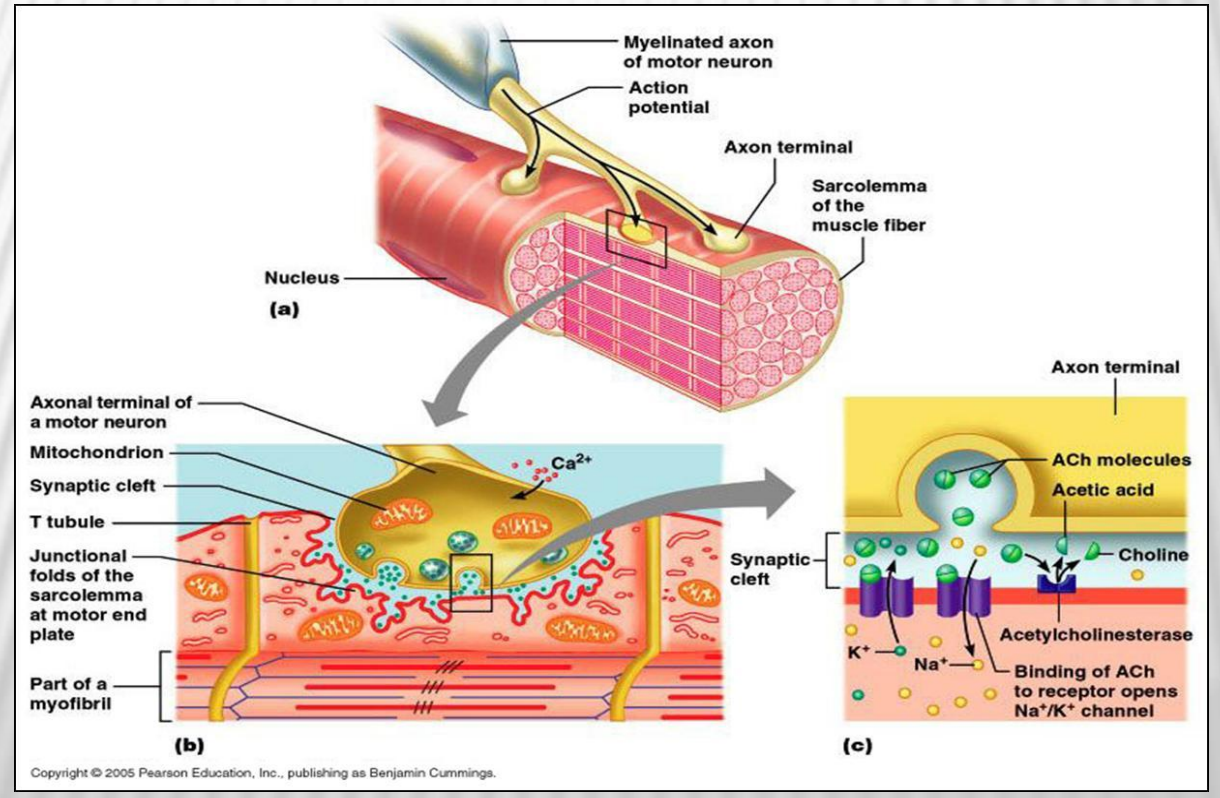
NEUROMUSCULAR JUNCTION - STEPS

2. The depolarization opens voltage gated Ca^{2+} channels and Ca^{2+} enters the cell



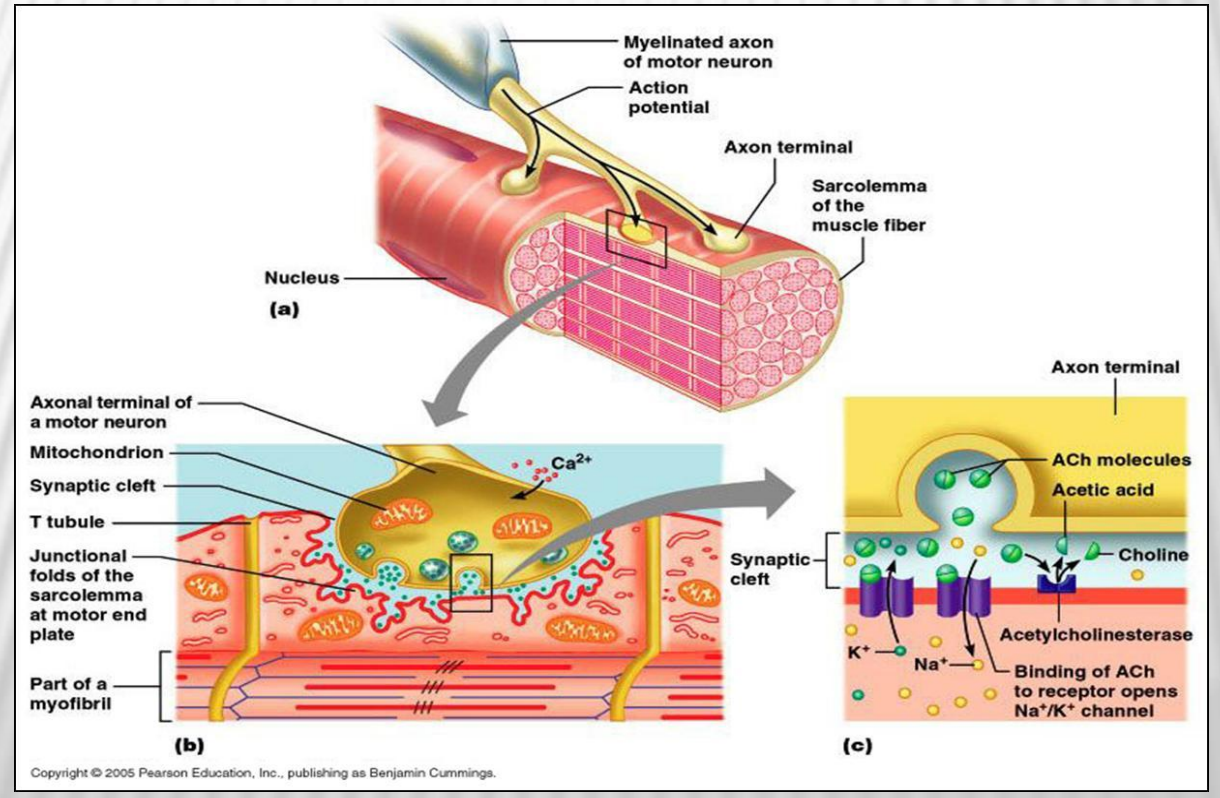
NEUROMUSCULAR JUNCTION - STEPS

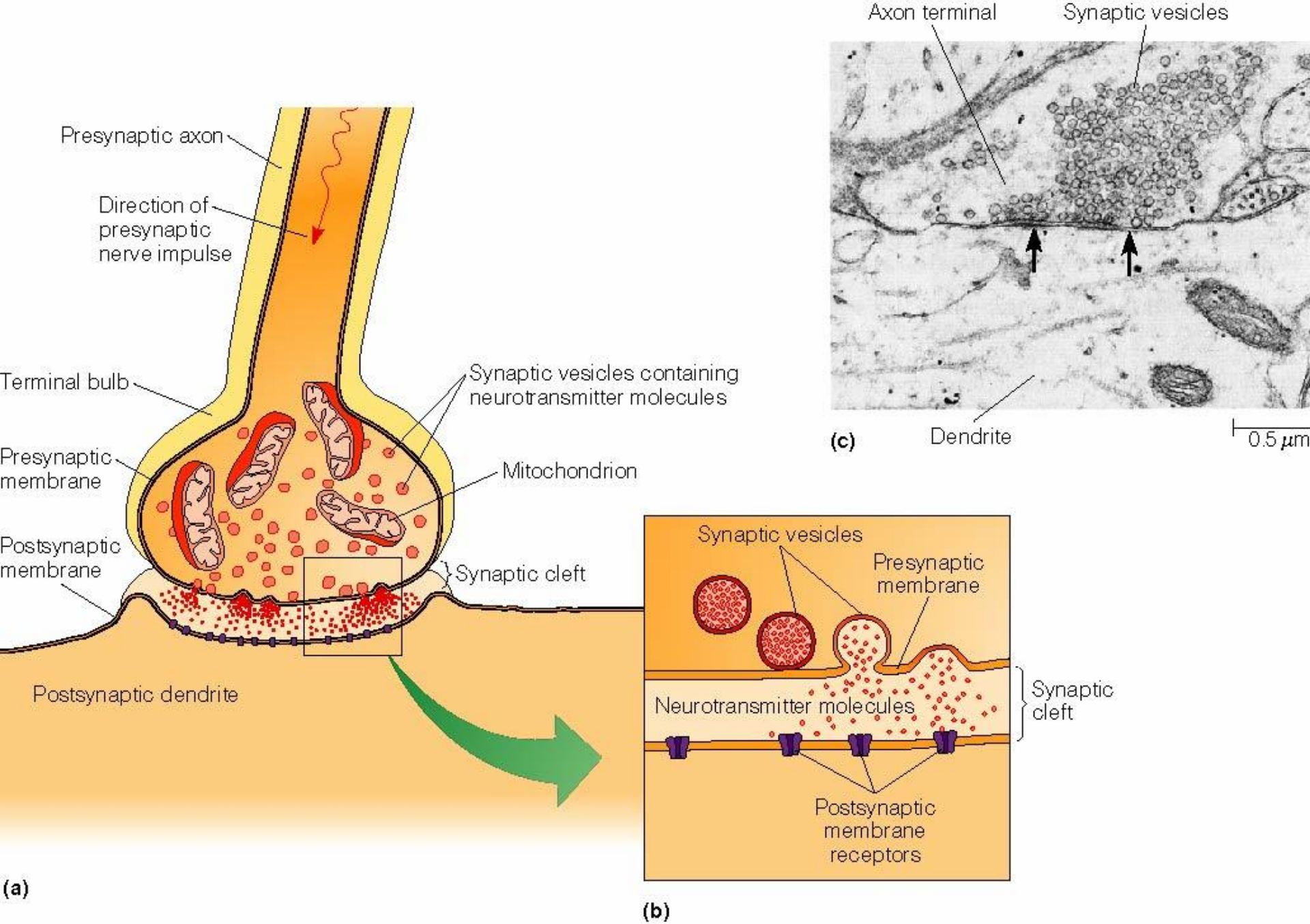
3. Calcium entry triggers exocytosis of synaptic vessels neurotransmitter (acetylcholine - ACh)



NEUROMUSCULAR JUNCTION - STEPS

4. Neurotransmitter diffuses across the synaptic cleft and binds on receptors



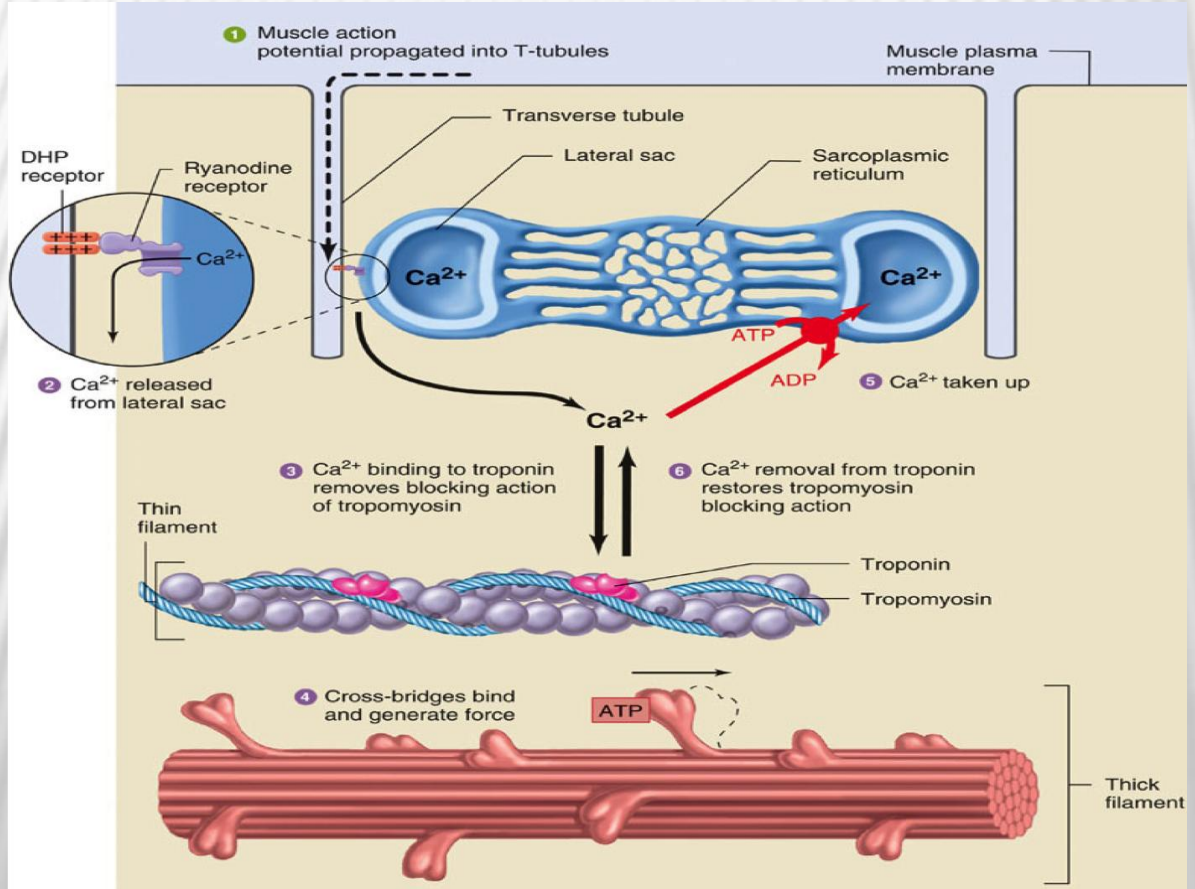


EXCITATION – CONTRACTION COUPLING

- The physiological process of converting an electrical stimulus to a mechanical response.
- It is the link (transduction) between the action potential generated in the sarcolemma and the start of a muscle contraction

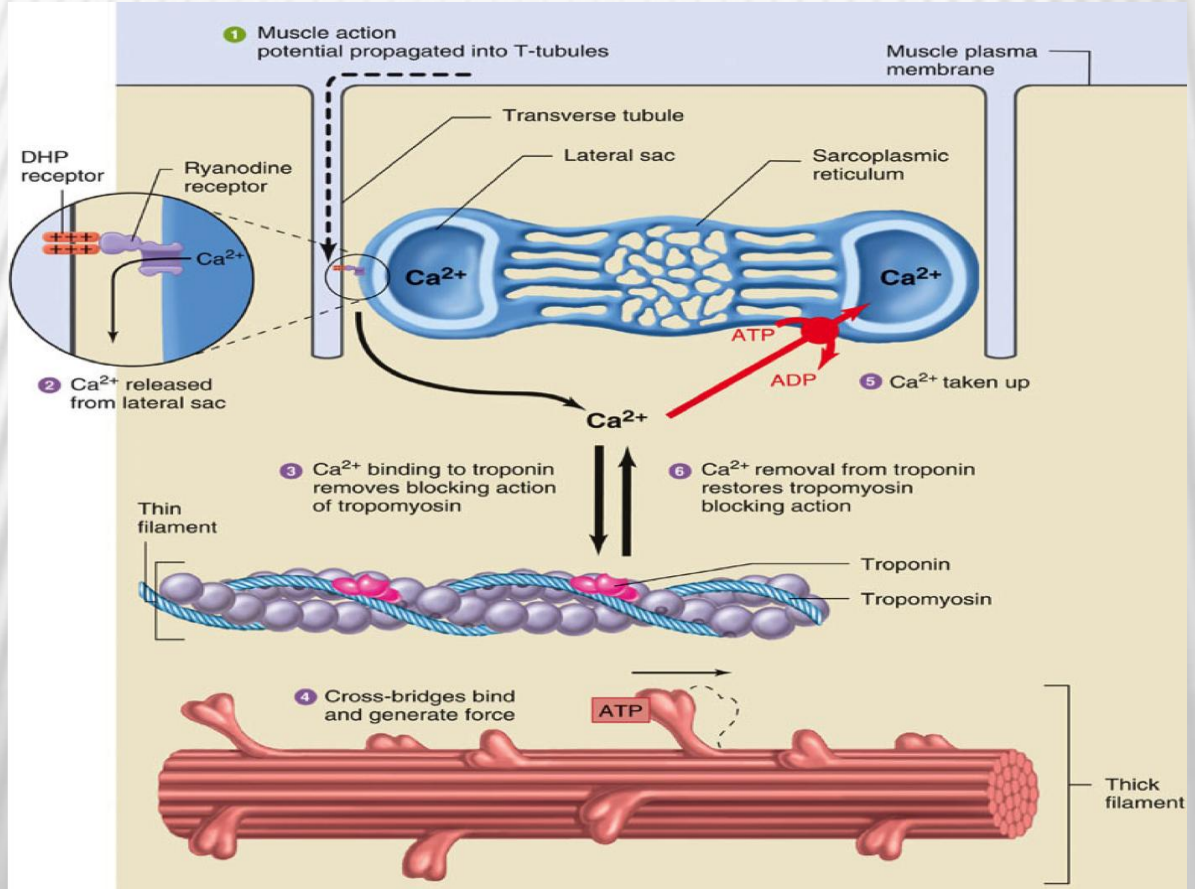
STEPS

1. Muscle action potential propagation into – T-tubules



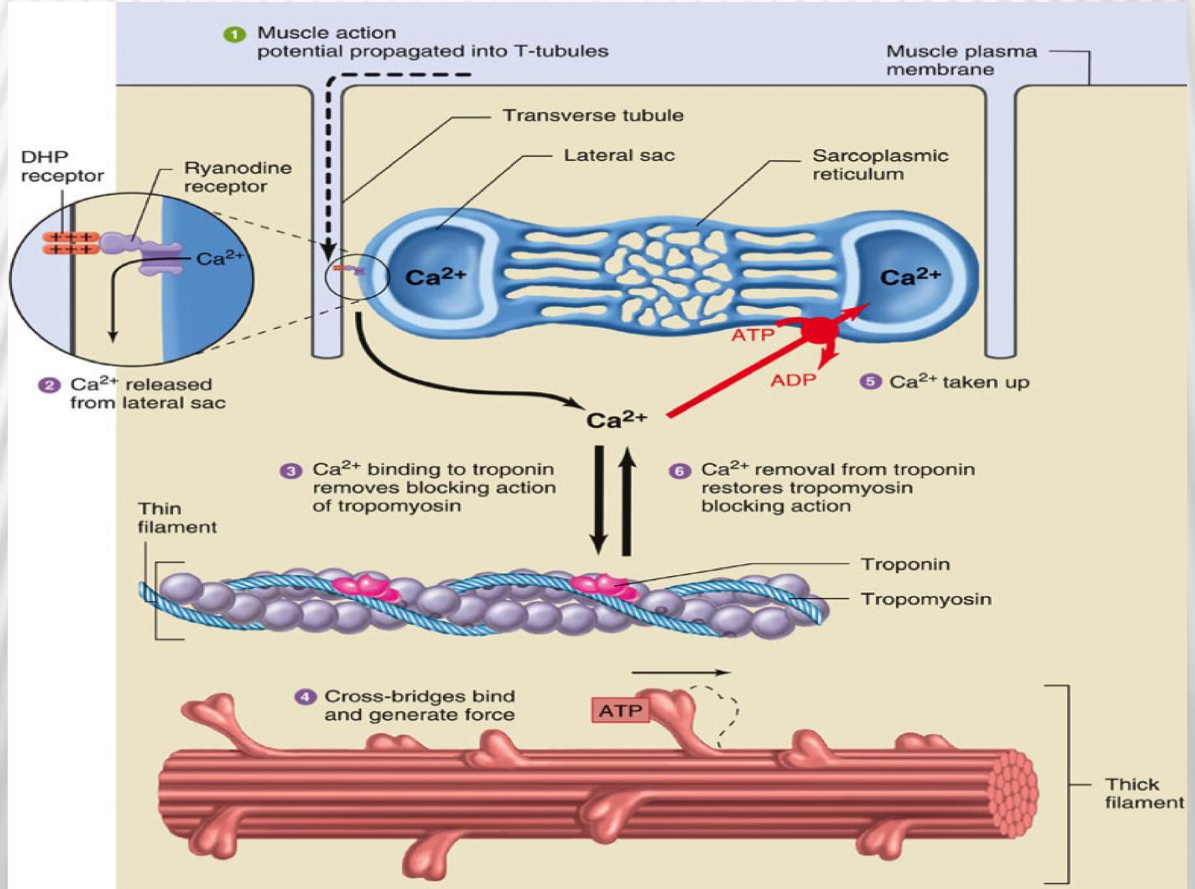
STEPS

2. Ca^{2+} released from sarcoplasmic reticulum



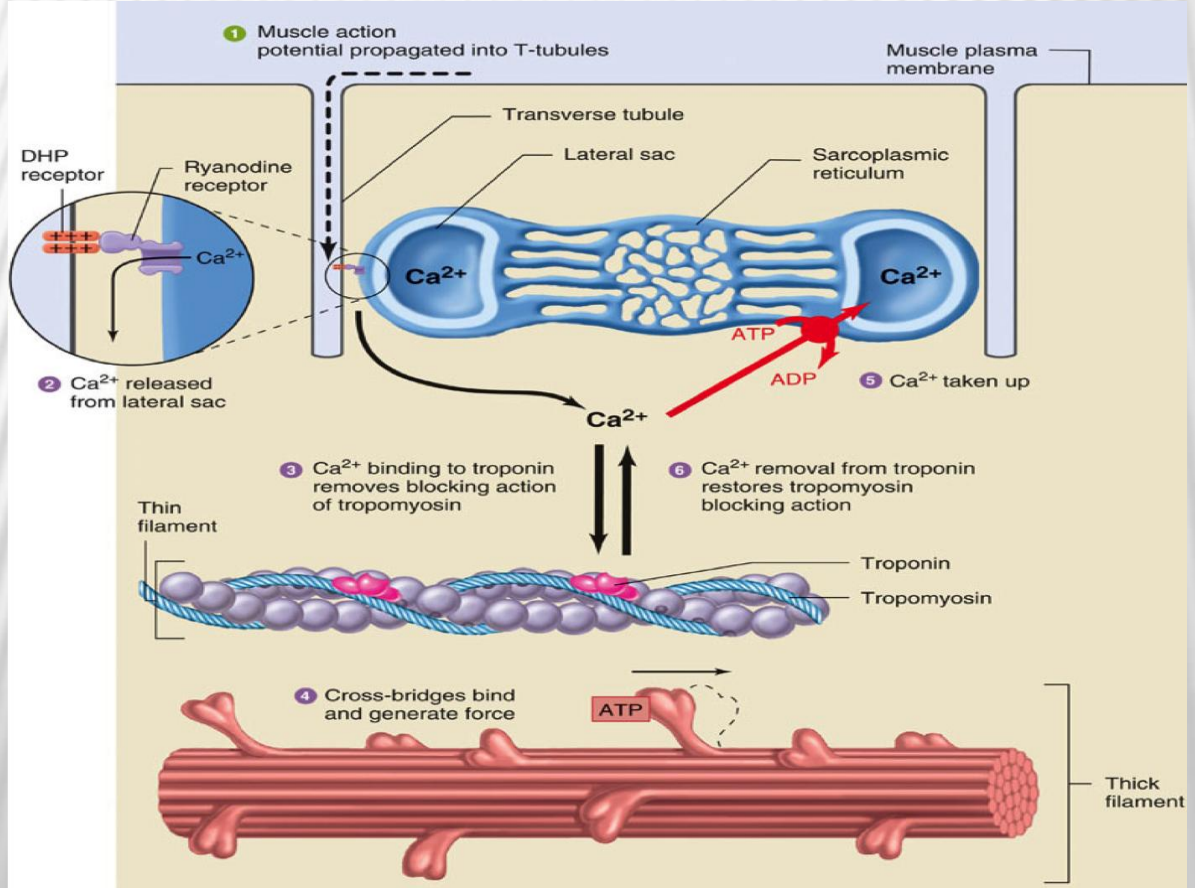
STEPS

3. Ca^{2+} binds to troponin and removes blocking action for tropomyosin



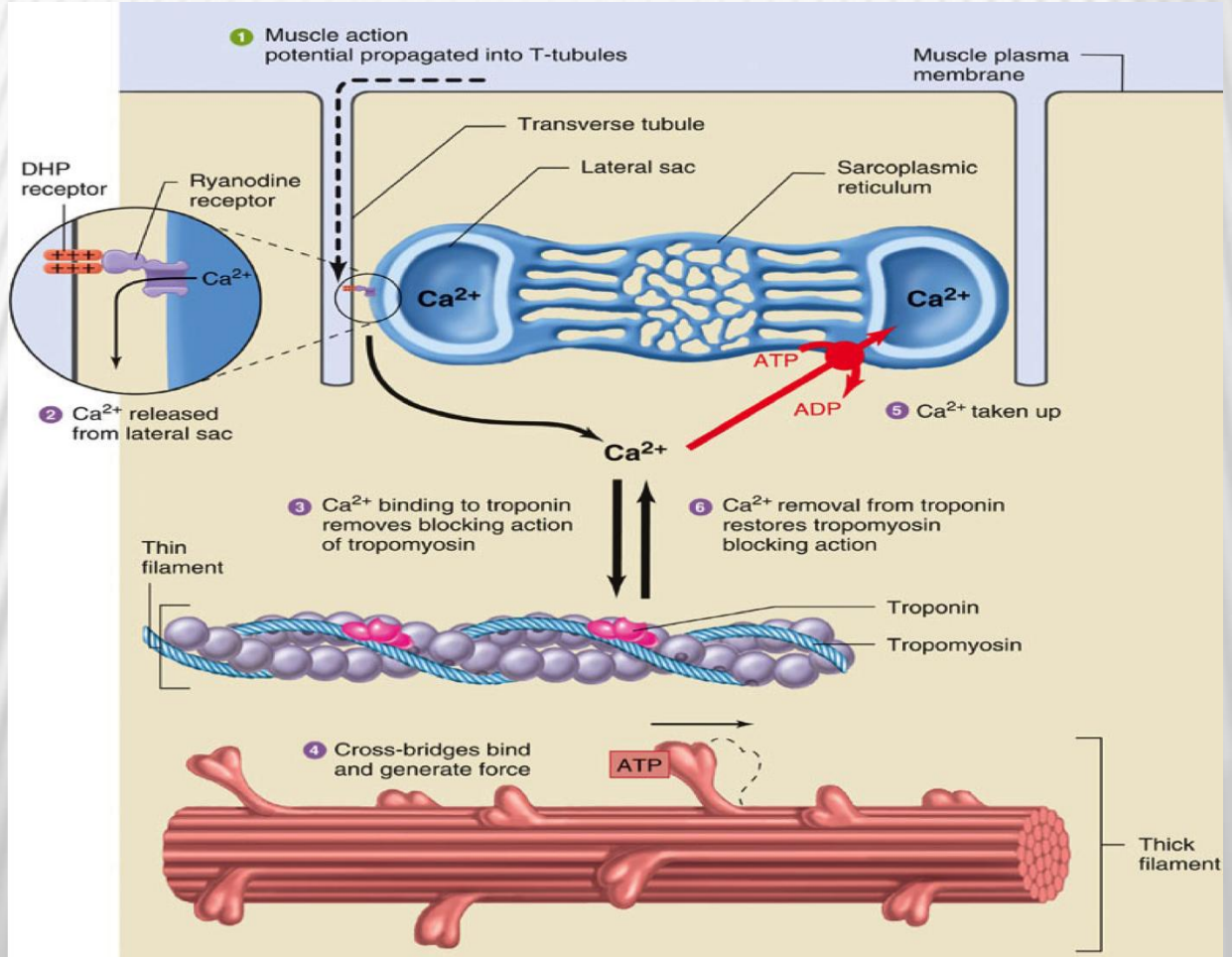
STEPS

4. Cross –bridges bind and generate force (muscle shortens)



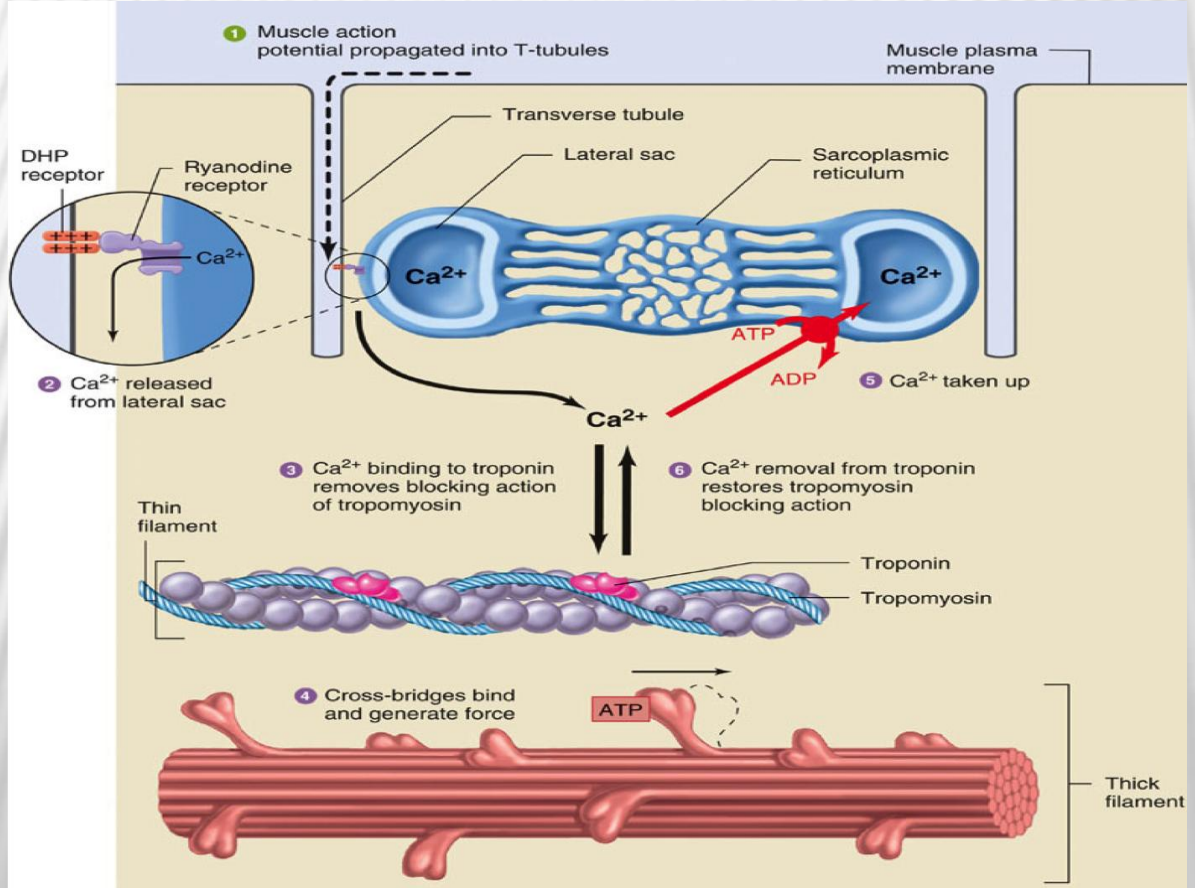
STEPS

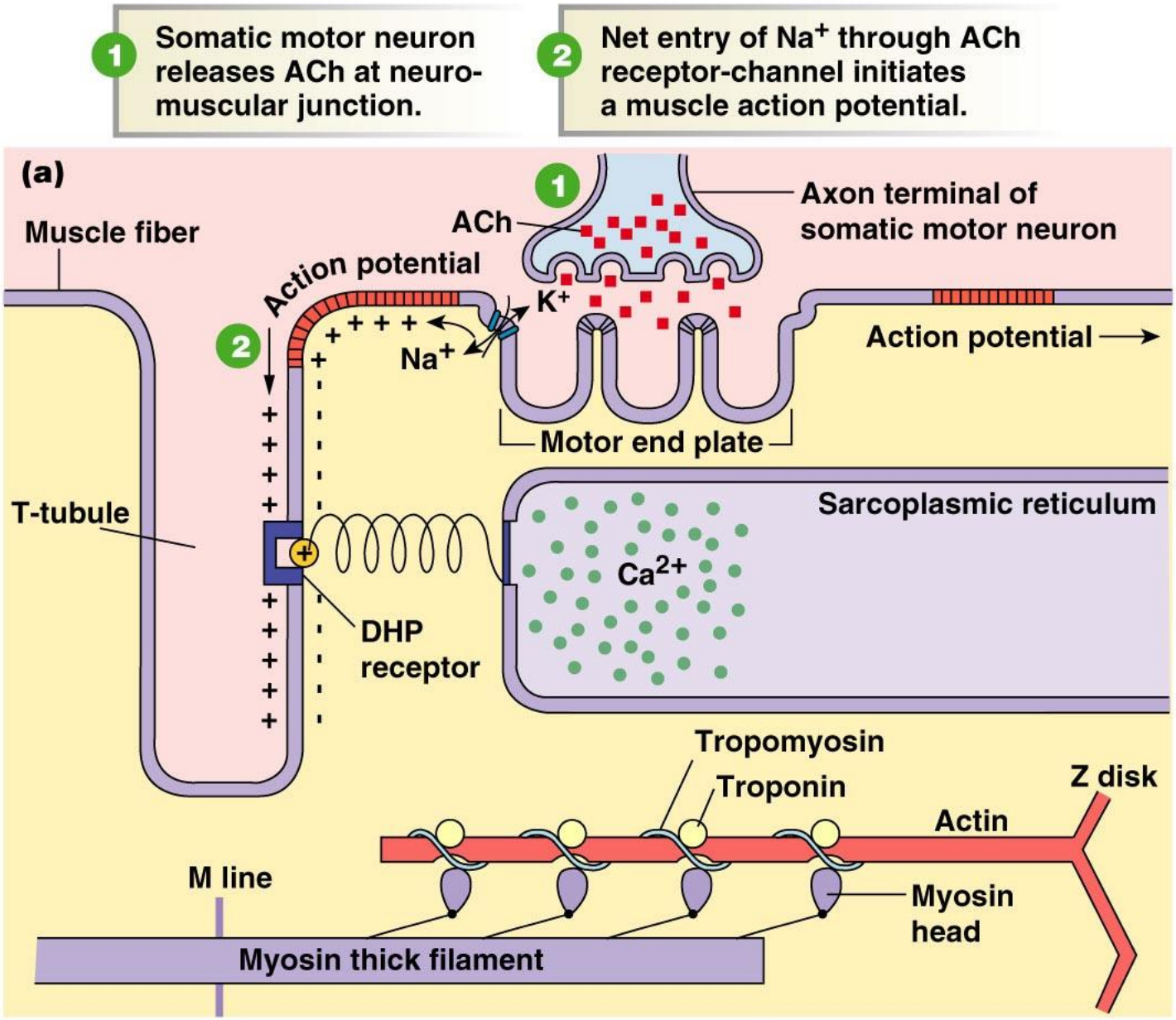
5. Ca^{2+} taken back up

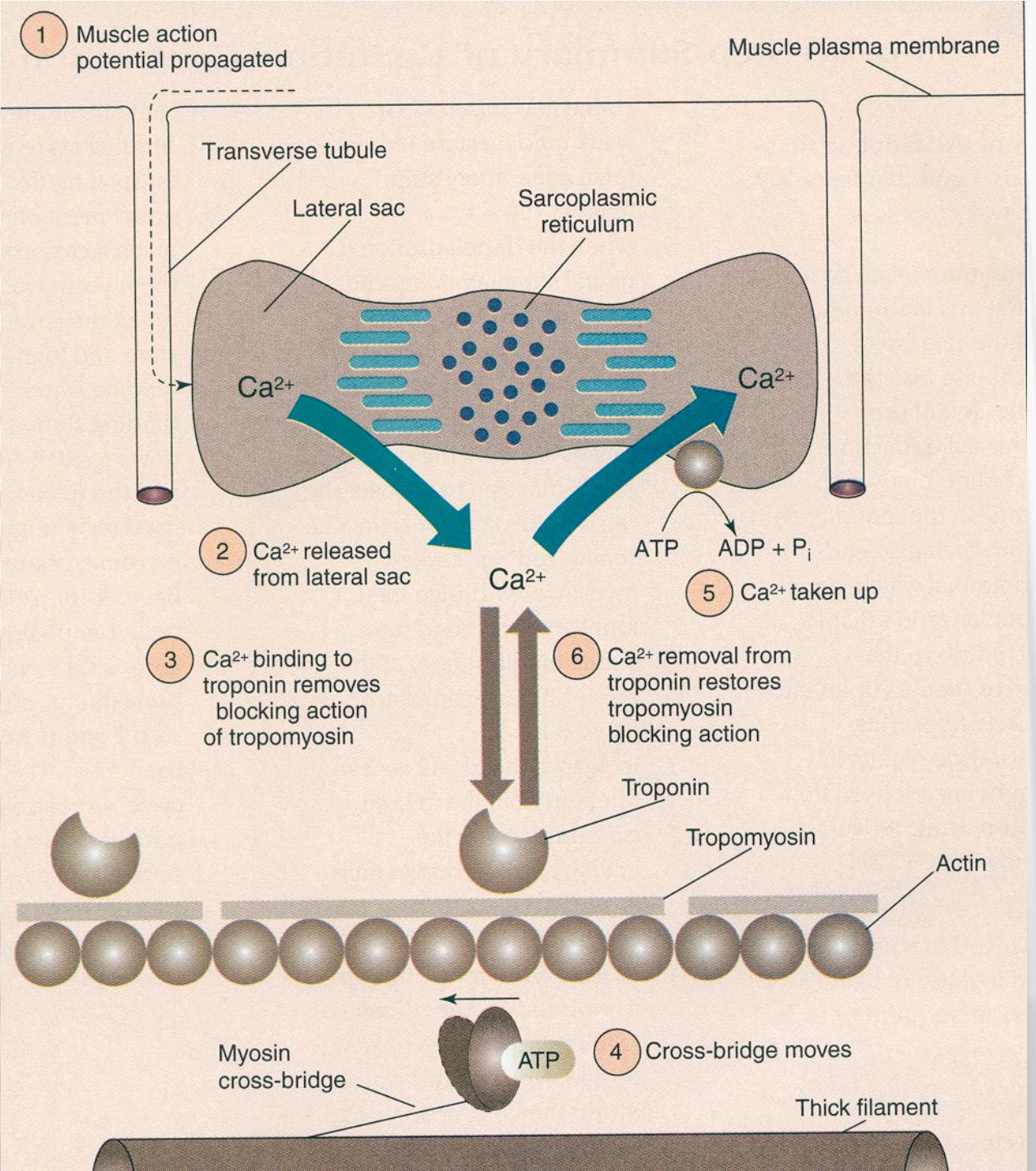


STEPS

6, Ca^{2+} removal from troponin restores tropomyosin blocking agent.





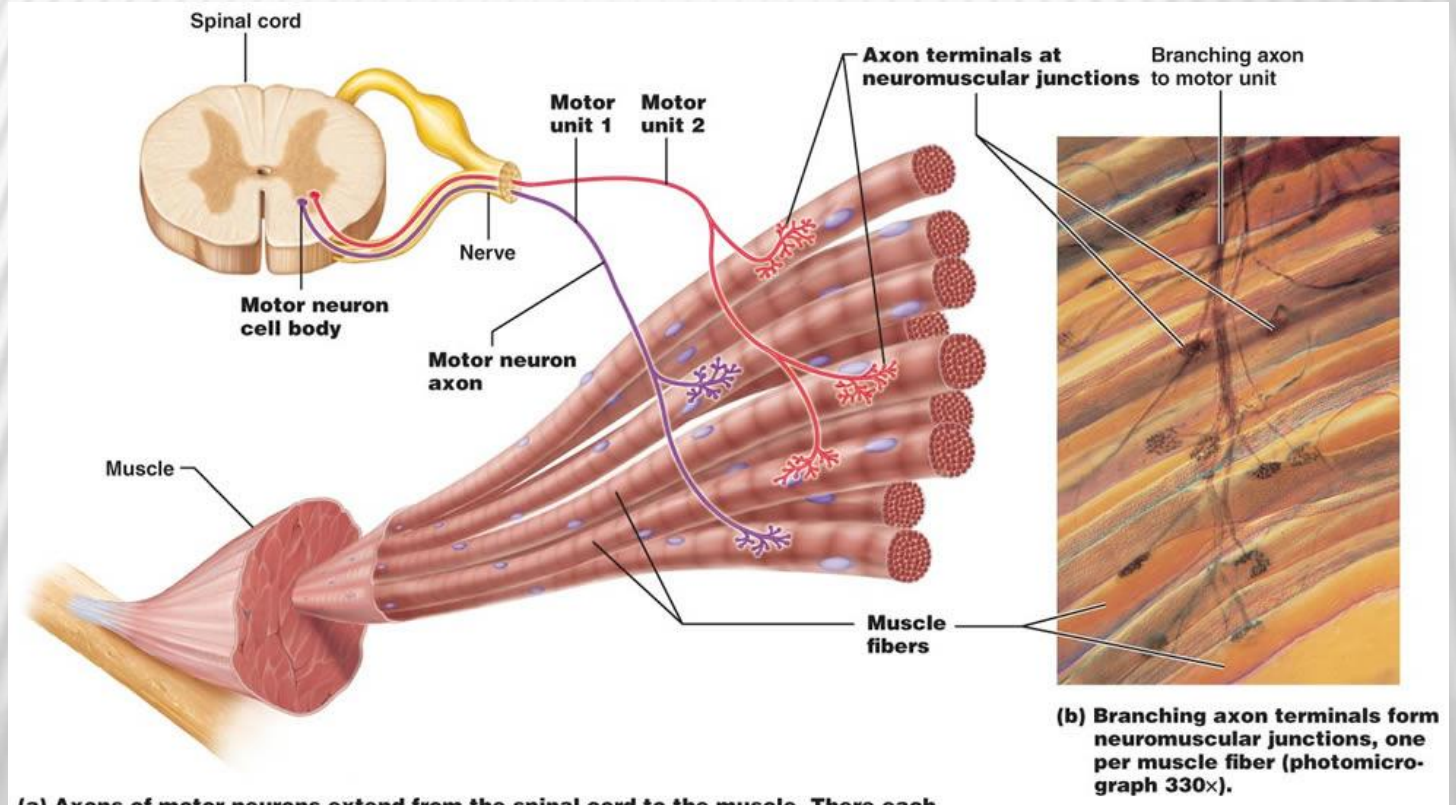


STEPS IN EXCITATION-CONTRACTION (RELAXATION) COUPLING

- Sites of peripheral fatigue (i.e. beyond the neuromuscular junction and in the muscle itself

MOTOR UNIT

- A motor unit consists of a motor neuron, axon, and the muscle fibres it stimulates



(b) Branching axon terminals form neuromuscular junctions, one per muscle fiber (photomicrograph 330×).

(a) Axons of motor neurons extend from the spinal cord to the muscle. There each axon divides into a number of axon terminals that form neuromuscular junctions with muscle fibers scattered throughout the muscle.

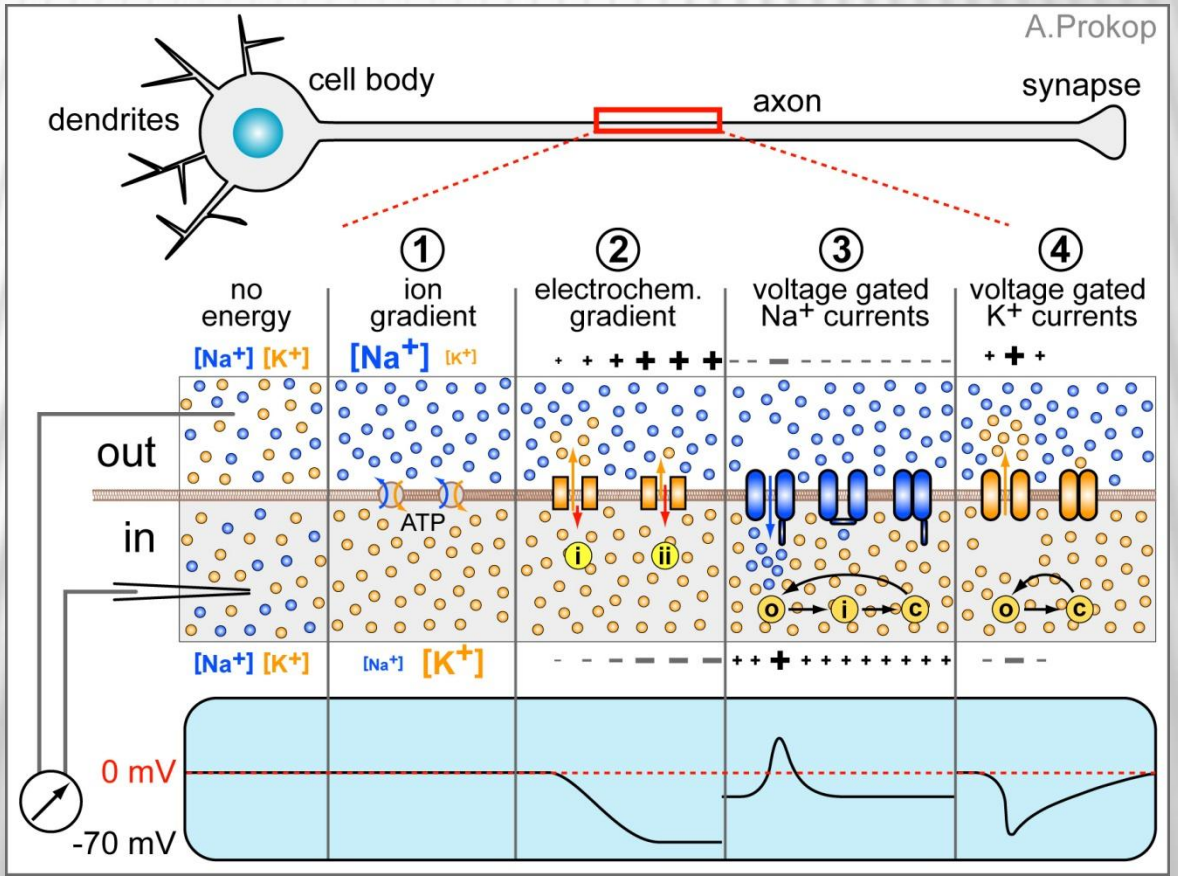
MOTOR UNIT

- Some motor units are attached to just a few muscle fibres while others in large muscles are attached to 100's

- In order to do a one rep max, all motor units must be recruited.

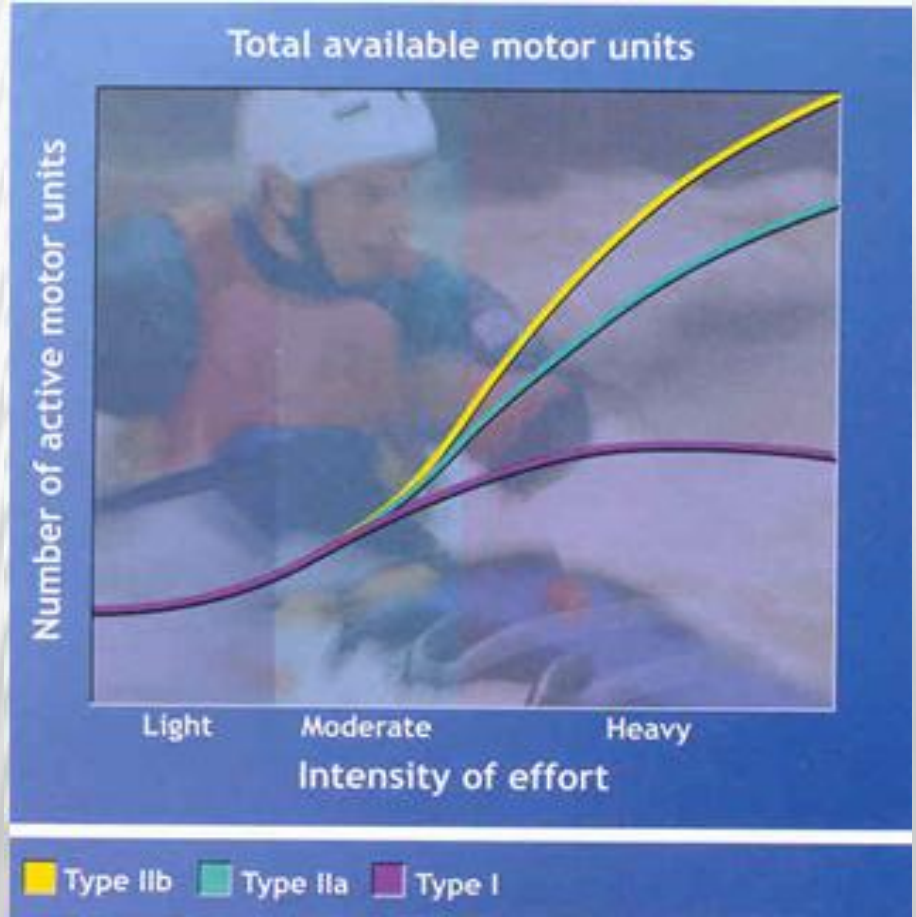
MOTOR UNIT

- Nerve impulses come in waves.
  - **Single wave and muscle contraction is called a twitch**



MOTOR UNITS

- Slow twitch muscle motor units generally are smaller as they have fewer muscle fibres.

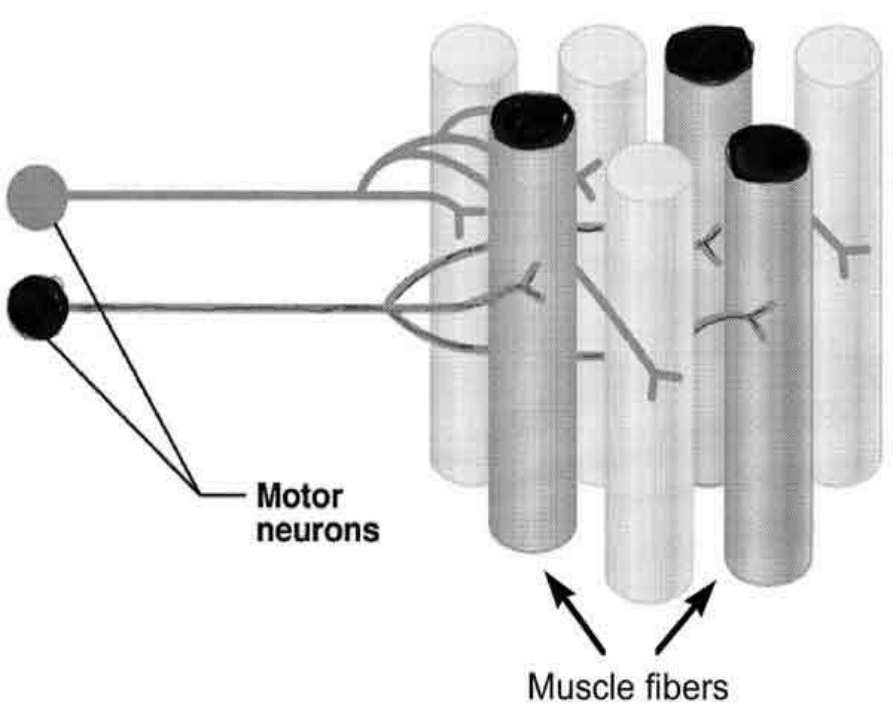


ALL-OR-NONE PRINCIPLE

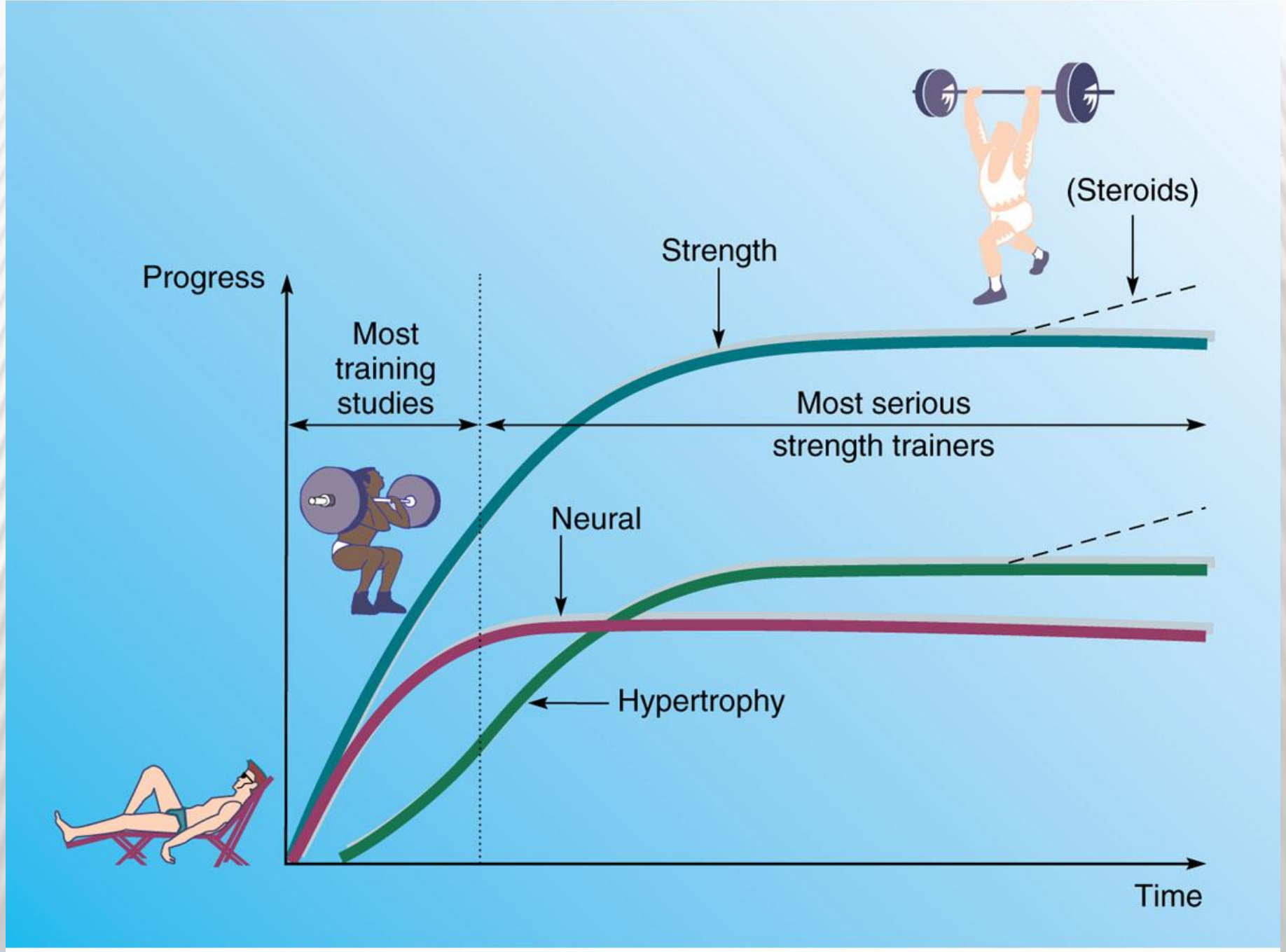
- When a motor unit is stimulated to contract, all the muscle fibres will contract to their fullest potential. Either they all fire or they all don't fire.

MOTOR UNIT

- motor neuron and the muscle fibers it innervates
- smallest amount of muscle that can be activated voluntarily



- recruitment of motor units is the most important means of controlling muscle force
- To increase force:
  - Recruit more motor units
  - Increase frequency



- **Neural factors**
  - -Increased ability to activate motor units
  - -Strength gains in initial 4-20 weeks

- **Muscular enlargement**
  - -Mainly due enlargement of fibers (hypertrophy)
  - -Long-term strength training

HIGH INTENSITY – SHORT DURATION TRAINING

- Nerve–muscle connections
  - Increased recruitment of additional motor units, which respond in a simultaneous fashion to improve force production
  - There is an increased activation of synergistic muscles to assist force production for strength, power, speed and hypertrophy.

HIGH INTENSITY – SHORT DURATION TRAINING

- Nerve–muscle connections
  - Neural pathways linking to target muscles become more efficient at transmitting the message (stimulus).

HIGH INTENSITY – SHORT DURATION TRAINING

- Timing of Neural Stimulus
  - The timing of contractions becomes more co-ordinated, especially with power, speed and strength training, in order to meet the force generation required to move loads.

HIGH INTENSITY – SHORT DURATION TRAINING

- Summation of motor units
- The ability to summate (fire a lot of impulses in target muscles all at once) is improved with strength and power training because they require maximum activation of target muscles to create maximum force.

LONGER DURATION TRAINING

- No real Neural changes

- As the duration of training lengthens slow twitch (endurance) fibres become increasingly dominant. Aerobic fitness, anaerobic fitness and muscular endurance training all improve the function of slow twitch fibres.