Neuromuscular Junction

Last time...

- Neuromuscular junction
  - Where a neuron meets a muscle fiber (cell)
- Synaptic Cleft, Synaptic Vesicles, Junctional Folds
- Neurotransmitter
  - Acetylcholine
- Degrading Enzyme
  - Acetylcholinesterase

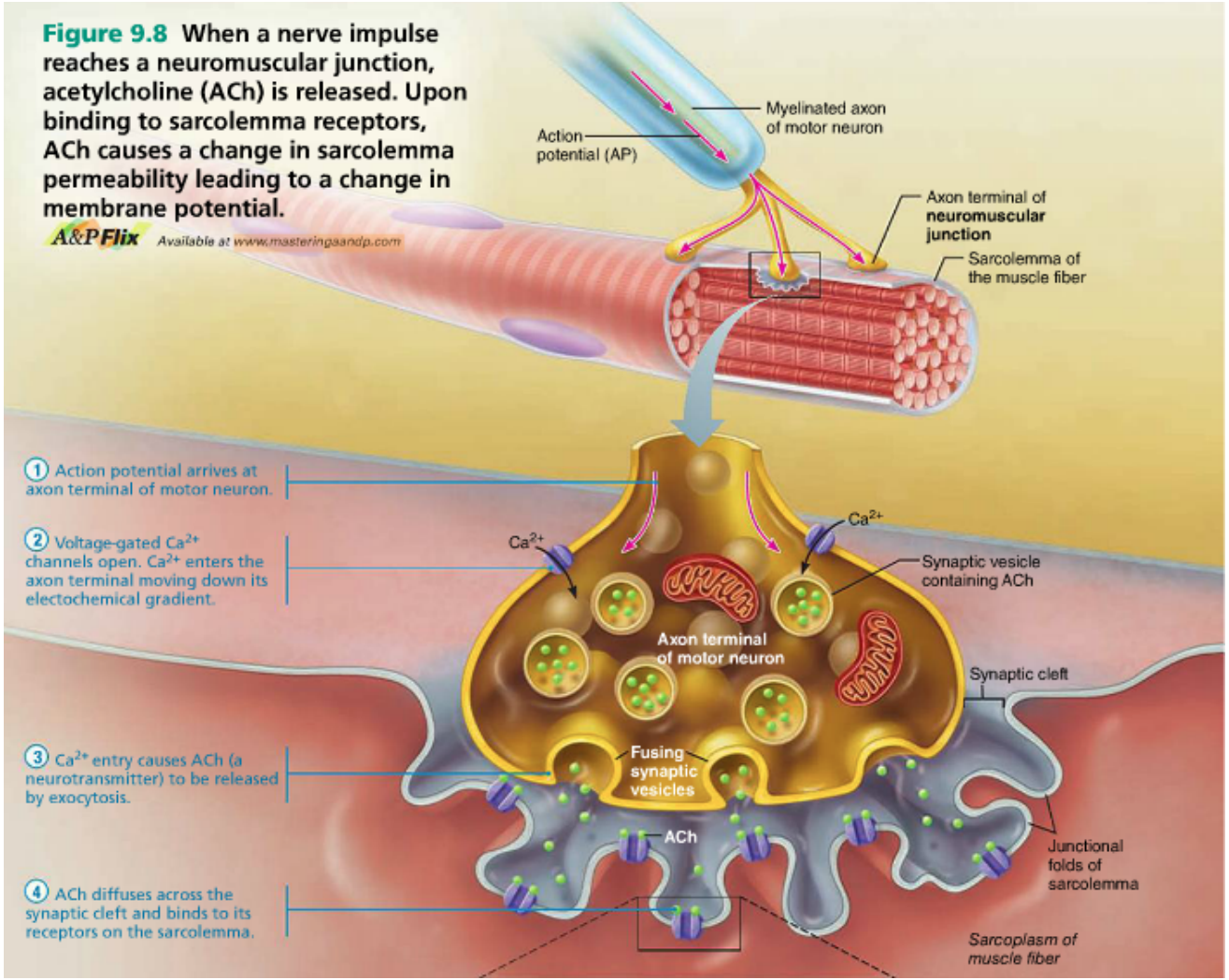
Figure 9.8 When a nerve impulse reaches a neuromuscular junction, acetylcholine (ACh) is released. Upon binding to sarcolemma receptors, ACh causes a change in sarcolemma permeability leading to a change in membrane potential.
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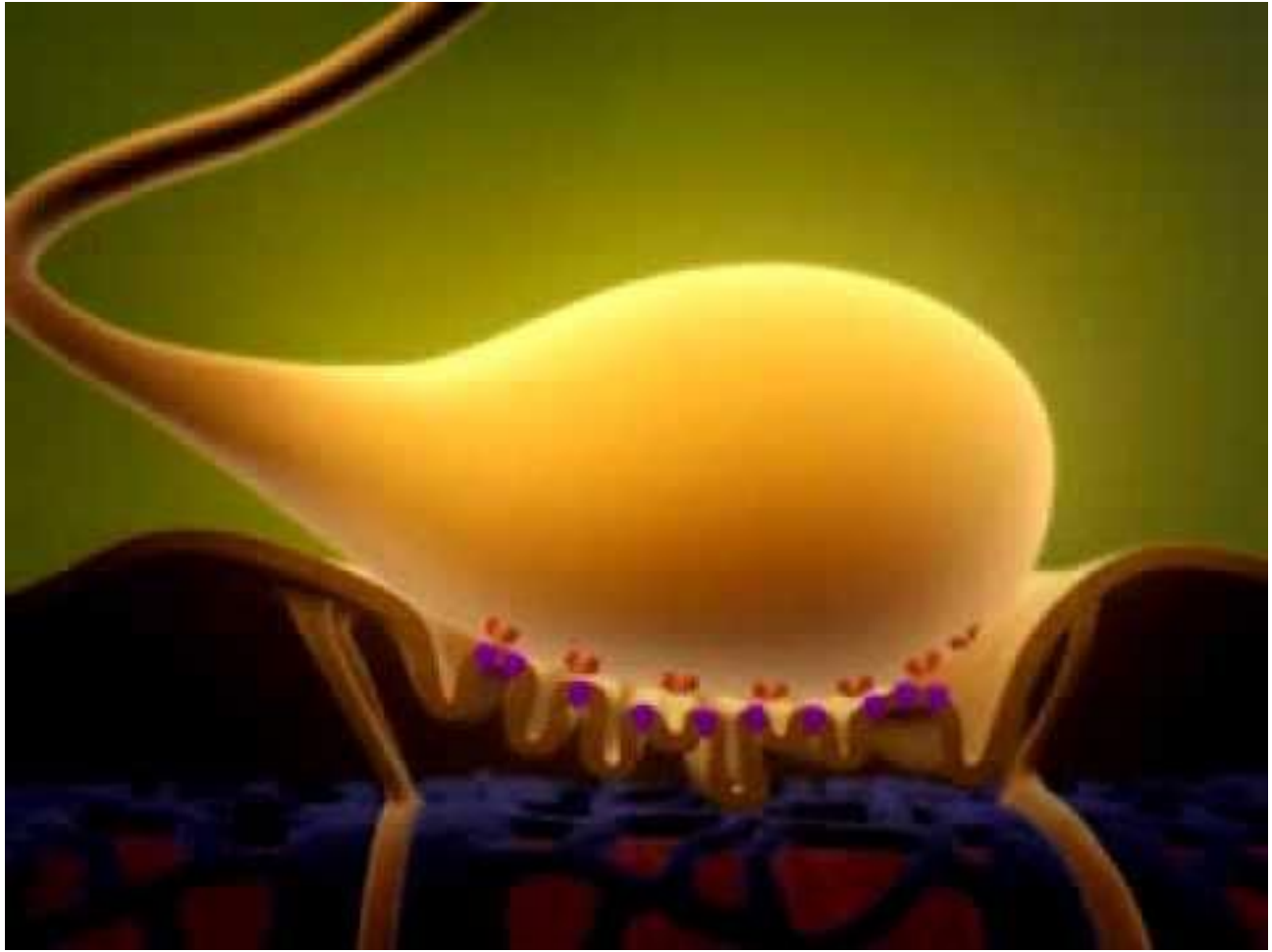
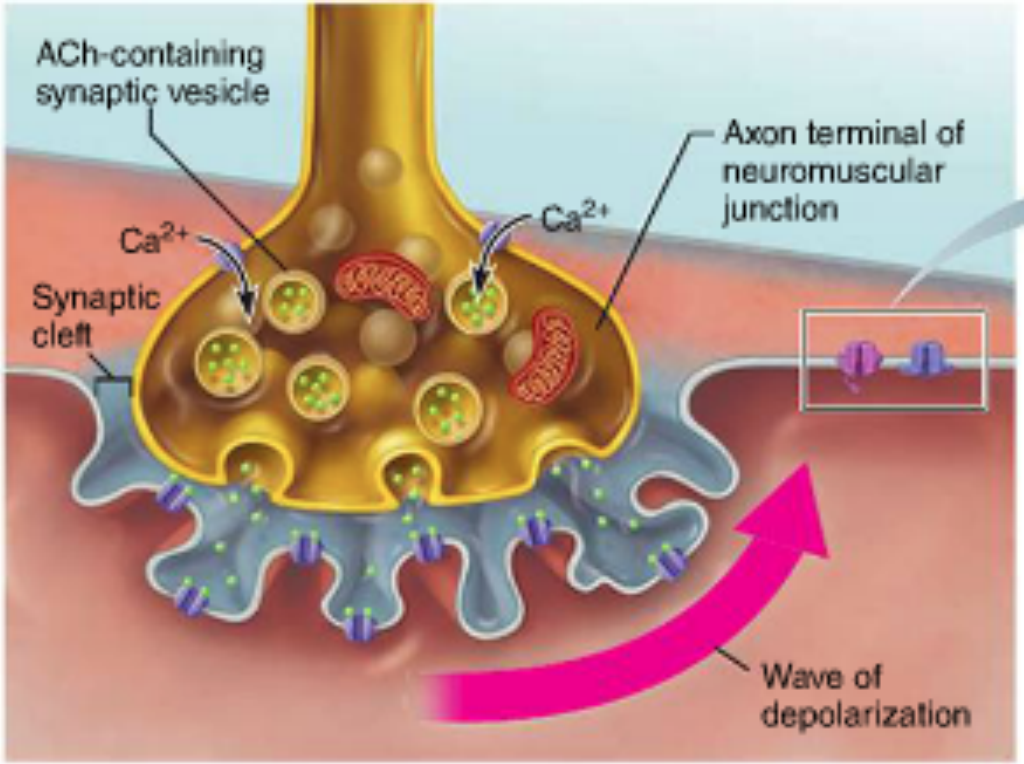
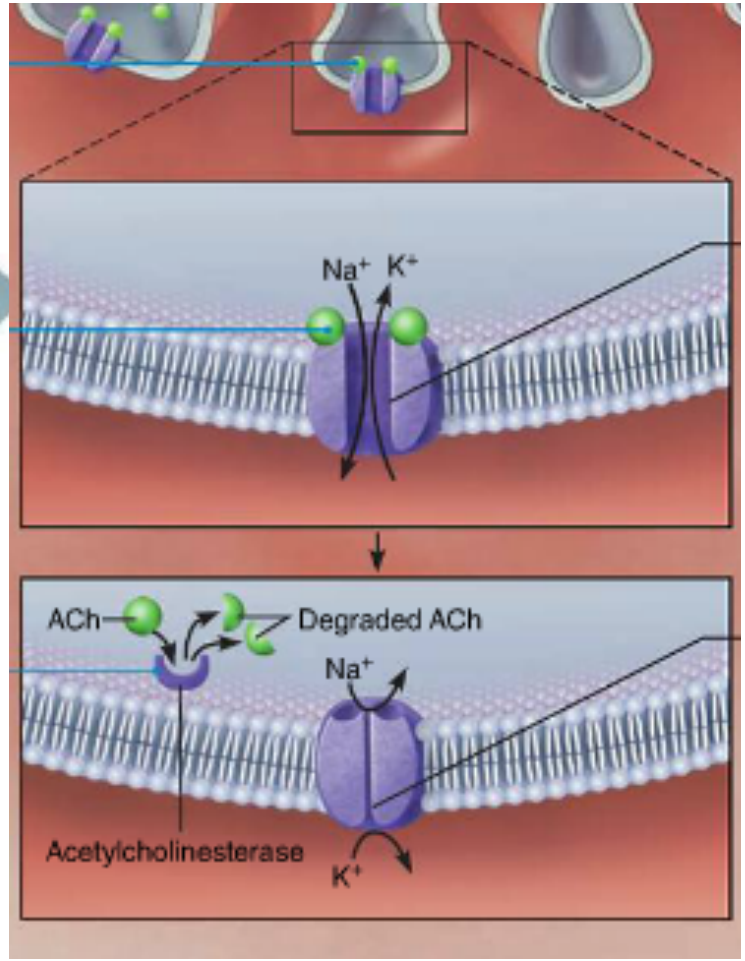
Myelinated axon of motor neuron
Action potential (AP)
Axon terminal of neuromuscular junction
Sarcolemma of the muscle fiber
1 Action potential arrives at axon terminal of motor neuron.
2 Voltage-gated Ca^{2+} channels open. Ca^{2+} enters the axon terminal moving down its electochemical gradient.
3 Ca^{2+} entry causes ACh (a neurotransmitter) to be released by exocytosis.
4 ACh diffuses across the synaptic cleft and binds to its receptors on the sarcolemma.
Ca^{2+}
Ca^{2+}
Synaptic vesicle containing ACh
Axon terminal of motor neuron
Mitochondrion
Mitochondrion
Synaptic cleft
Fusing synaptic vesicles
ACh
Junctional folds of sarcolemma
Sarcoplasm of muscle fiber

Depolarization

- ACh binds to a gated ion channel in the sarcolemma. ← KEY
- When ACh binds, it opens the channel allowing more Na+ to flow inside the cell.
  - Na+ enters faster than K+ can leave.
  - Causes the interior of the sarcolemma to become less negative
    - depolarization
    - end plate potential

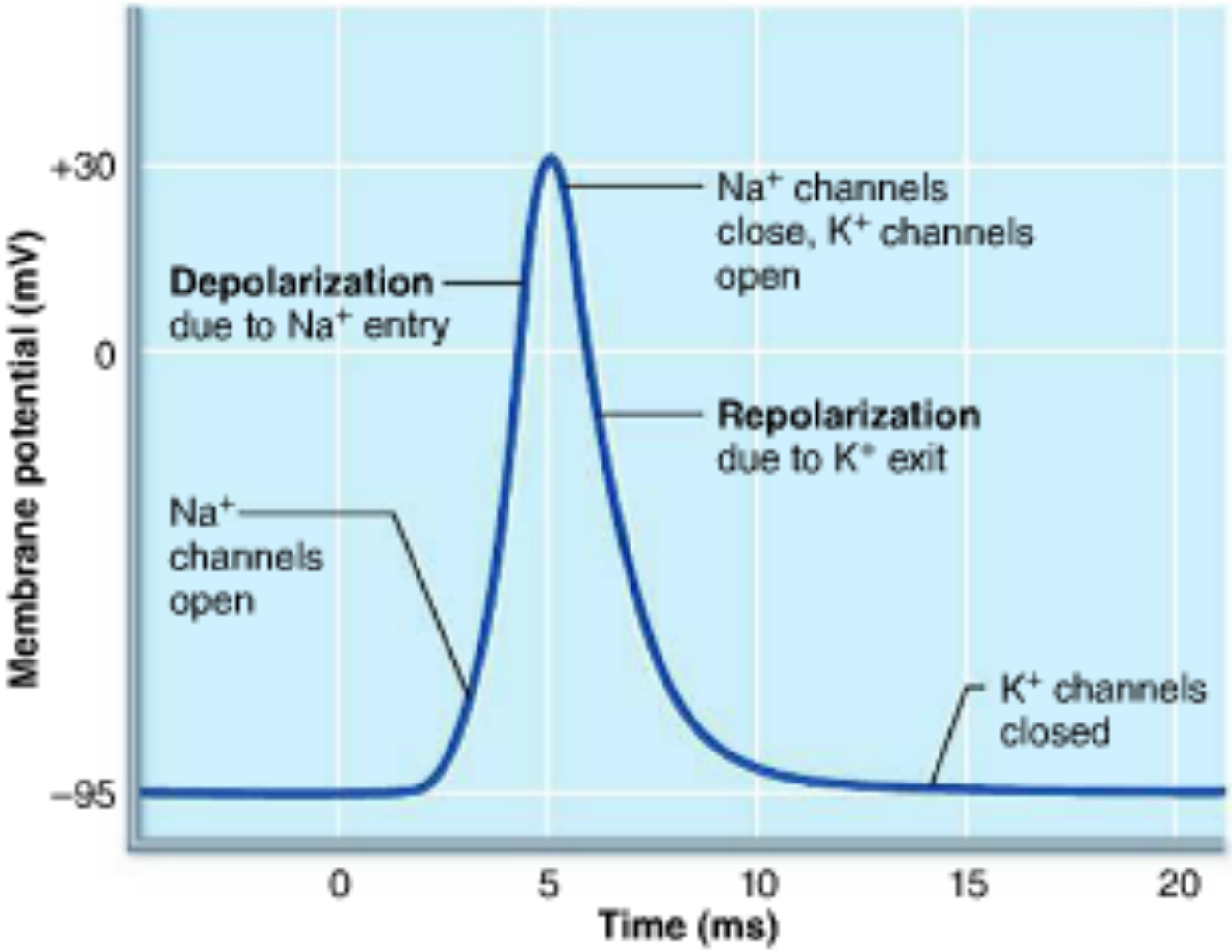



ACh-containing synaptic vesicle
Axon terminal of neuromuscular junction
Ca^{2+}
Ca^{2+}
Synaptic cleft
Wave of depolarization


Na^+ K^+
ACh
Degraded ACh
Na^+
Acetylcholinesterase
K^+

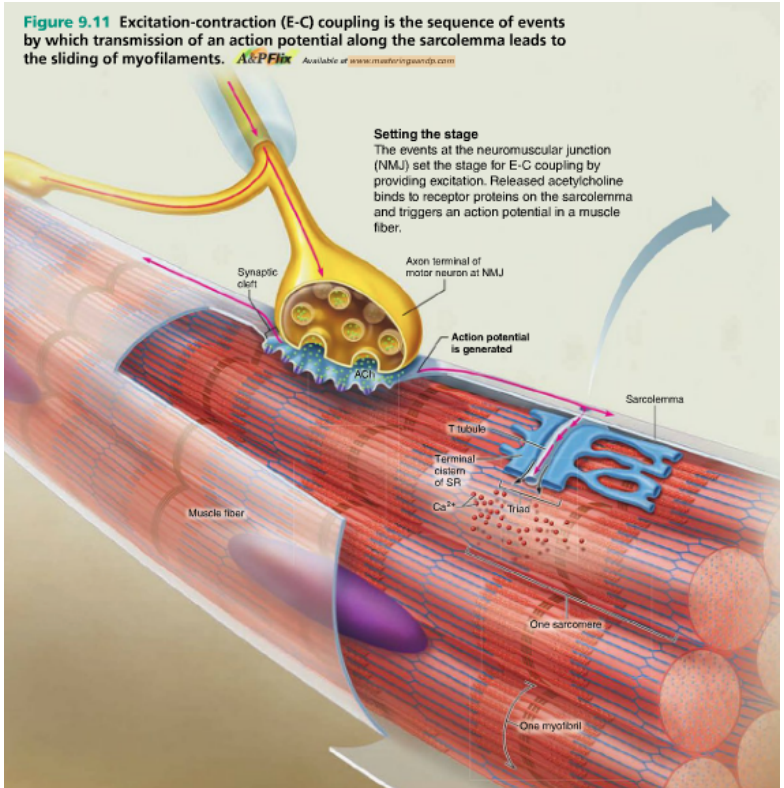
Repolarization

- AChE degrades ACh, closing the Na+ channels.
- As the Na+ channels close, K+ channels open.
  - K+ will rush out of the cell due to the high amount of positive charges inside the cell
- Restores the sarcolemma to its polarized state.

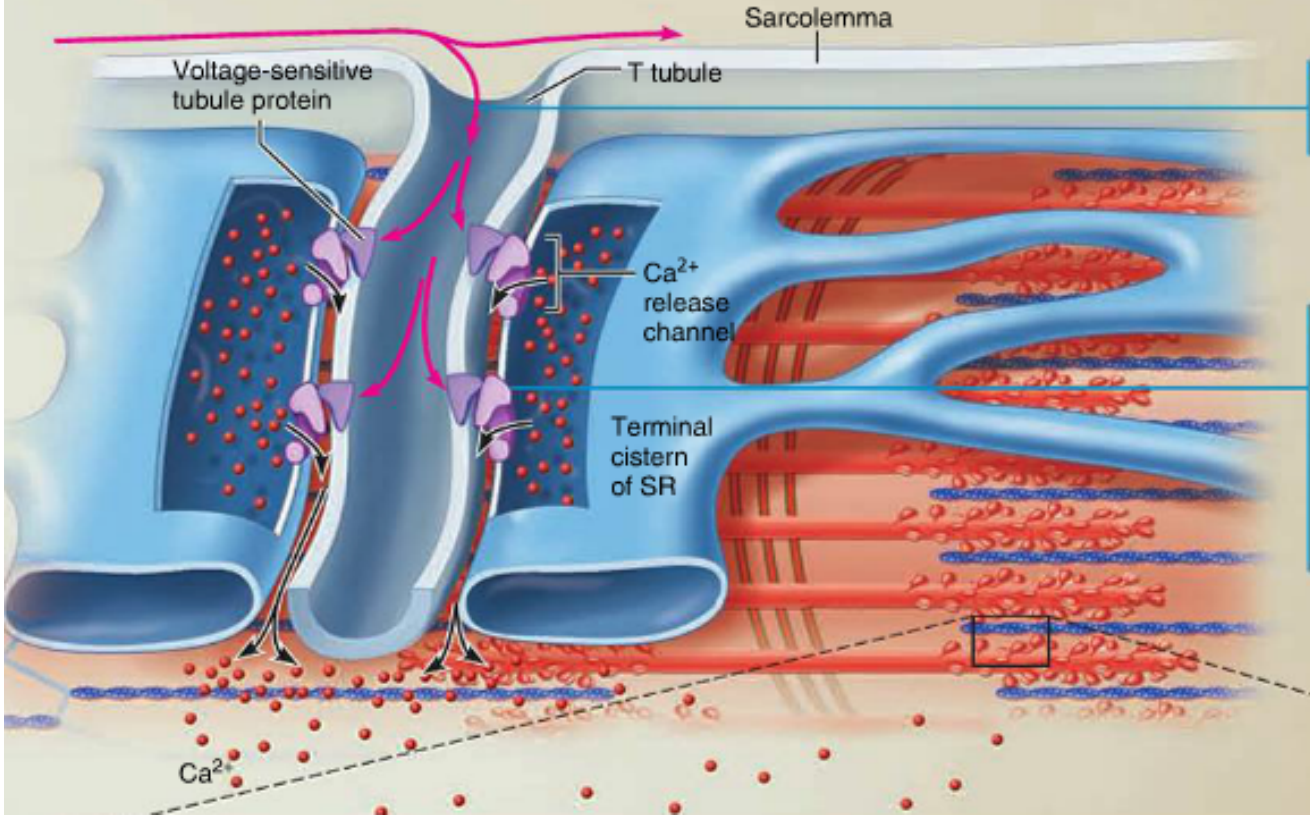

+30
0
−95
Membrane potential (mV)
Depolarization
due to Na+ entry
Na+ channels
close, K+ channels
open
Repolarization
due to K+ exit
Na+
channels
open
K+ channels
closed
0
5
10
15
20
Time (ms)

Excitation-Contraction Coupling

The sequence of events by which transmission of an action potential along the sarcolemma leads to myofilament sliding (contraction).

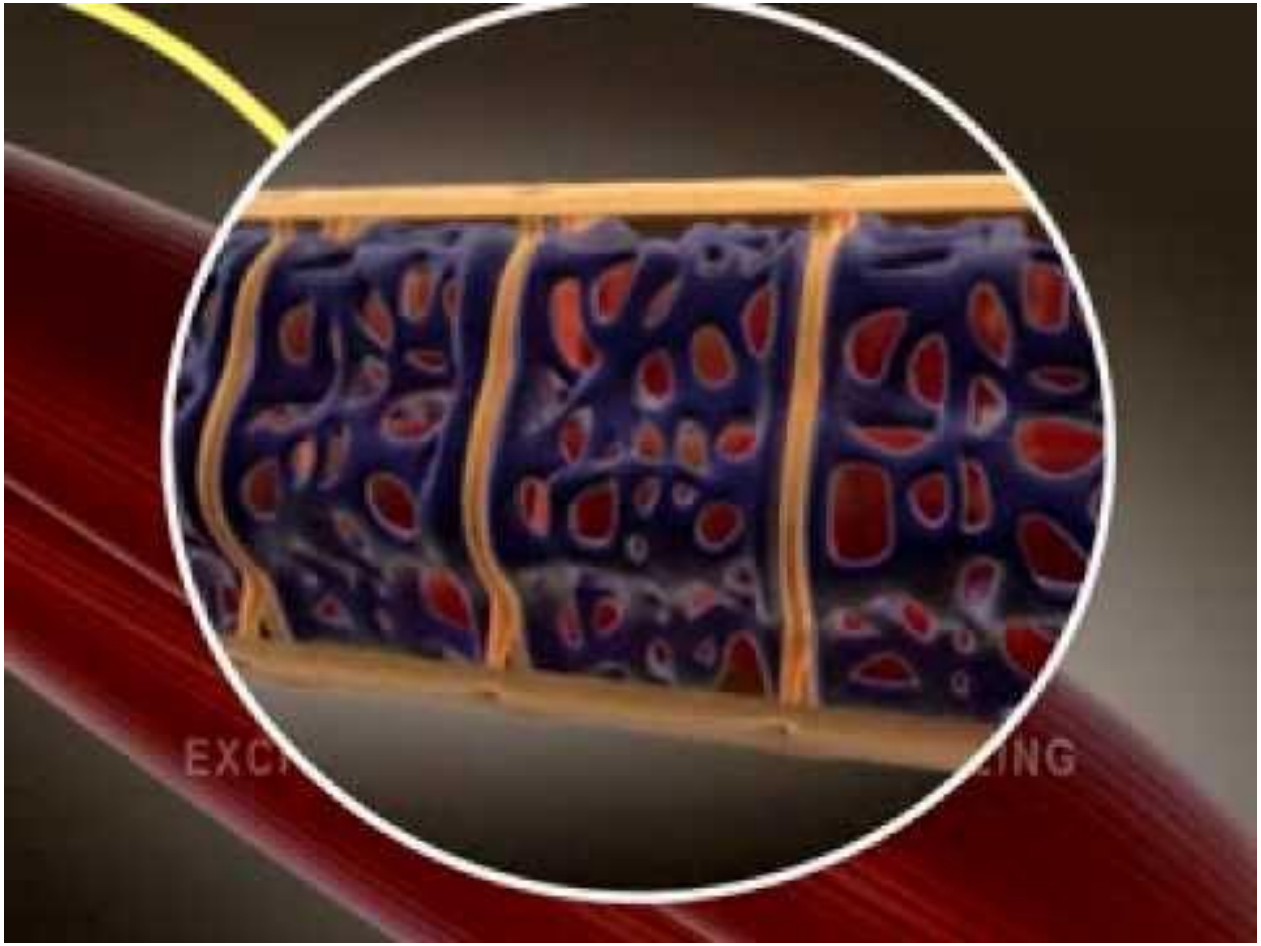


Steps in E-C Coupling:



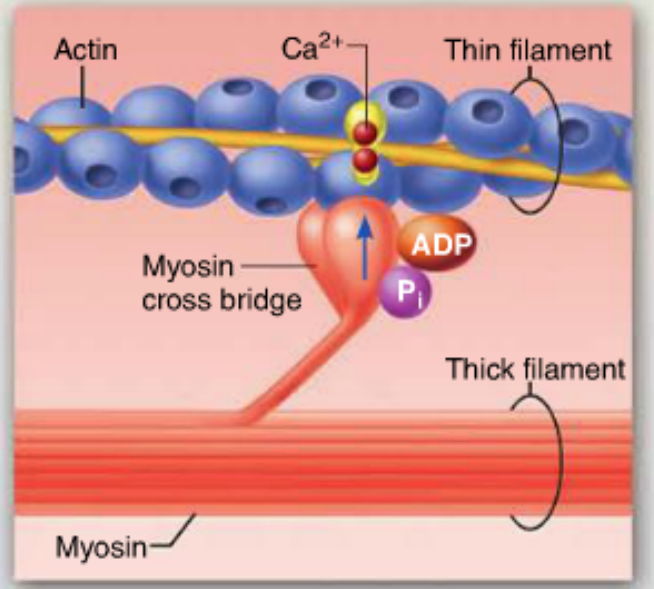
1 The action potential (AP) propagates along the sarcolemma and down the T tubules.

2 Calcium ions are released. Transmission of the AP along the T tubules of the triads causes the voltage-sensitive tubule proteins to change shape. This shape change opens the Ca^{2+} release channels in the terminal cisterns of the sarcoplasmic reticulum (SR), allowing Ca^{2+} to flow into the cytosol.

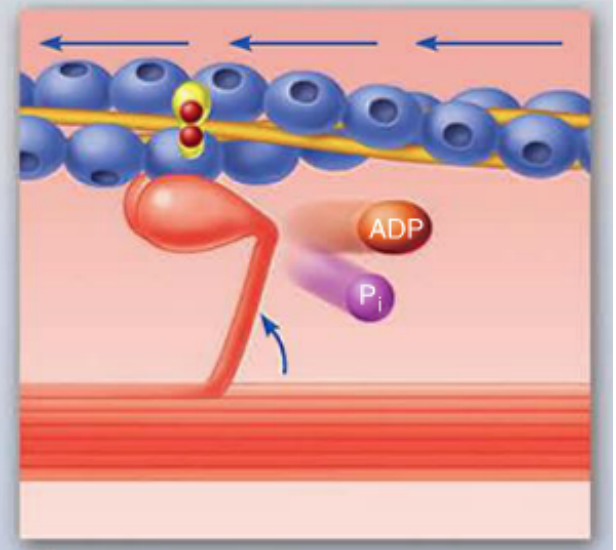


Cross-Bridge Cycling

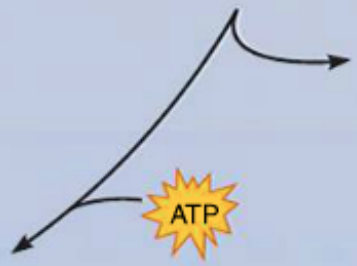
- Relaxed Muscle
  - Low Ca+2 levels
  - Troponin has locked tropomyosin into position so that it blocks the G Actin active spots
- Contraction
  - Ca+2 levels increase
  - Ca+2 binds to troponin, shifting the tropomyosin
    - Active sites exposed
    - Cross-bridging can now occur



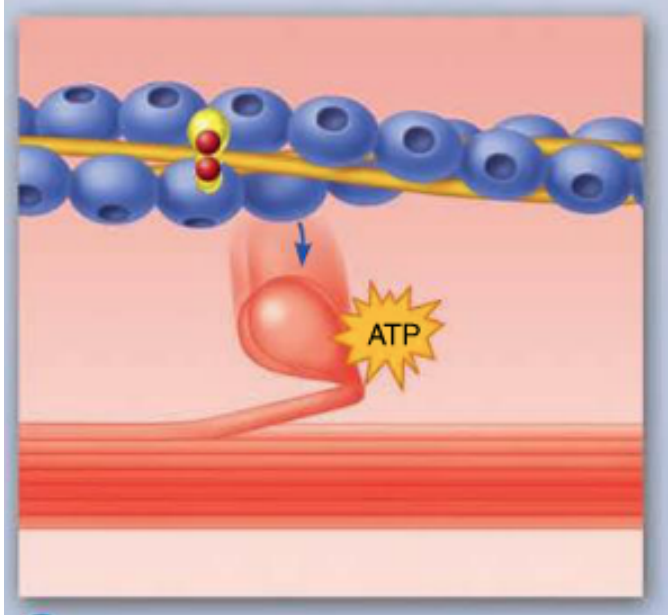
(1) **Cross bridge formation.** Energized myosin head attaches to an actin myofilament, forming a cross bridge.



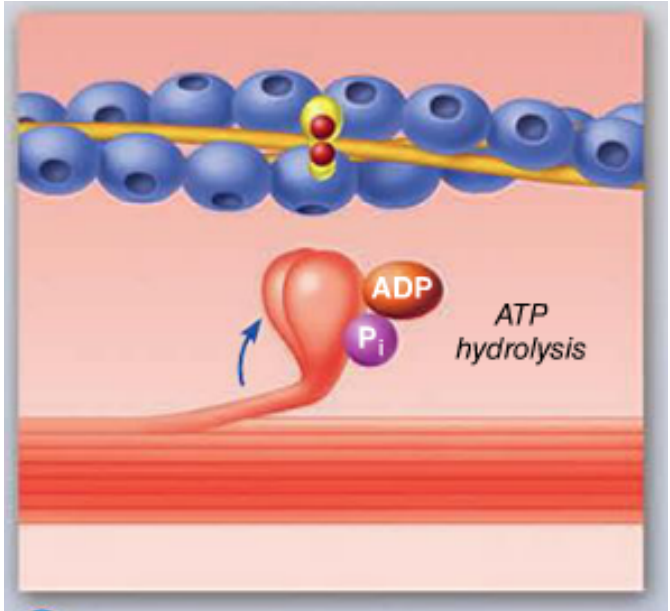
(2) **The power (working) stroke.** ADP and P_i are released and the myosin head pivots and bends, changing to its bent low-energy state. As a result it pulls the actin filament toward the M line.



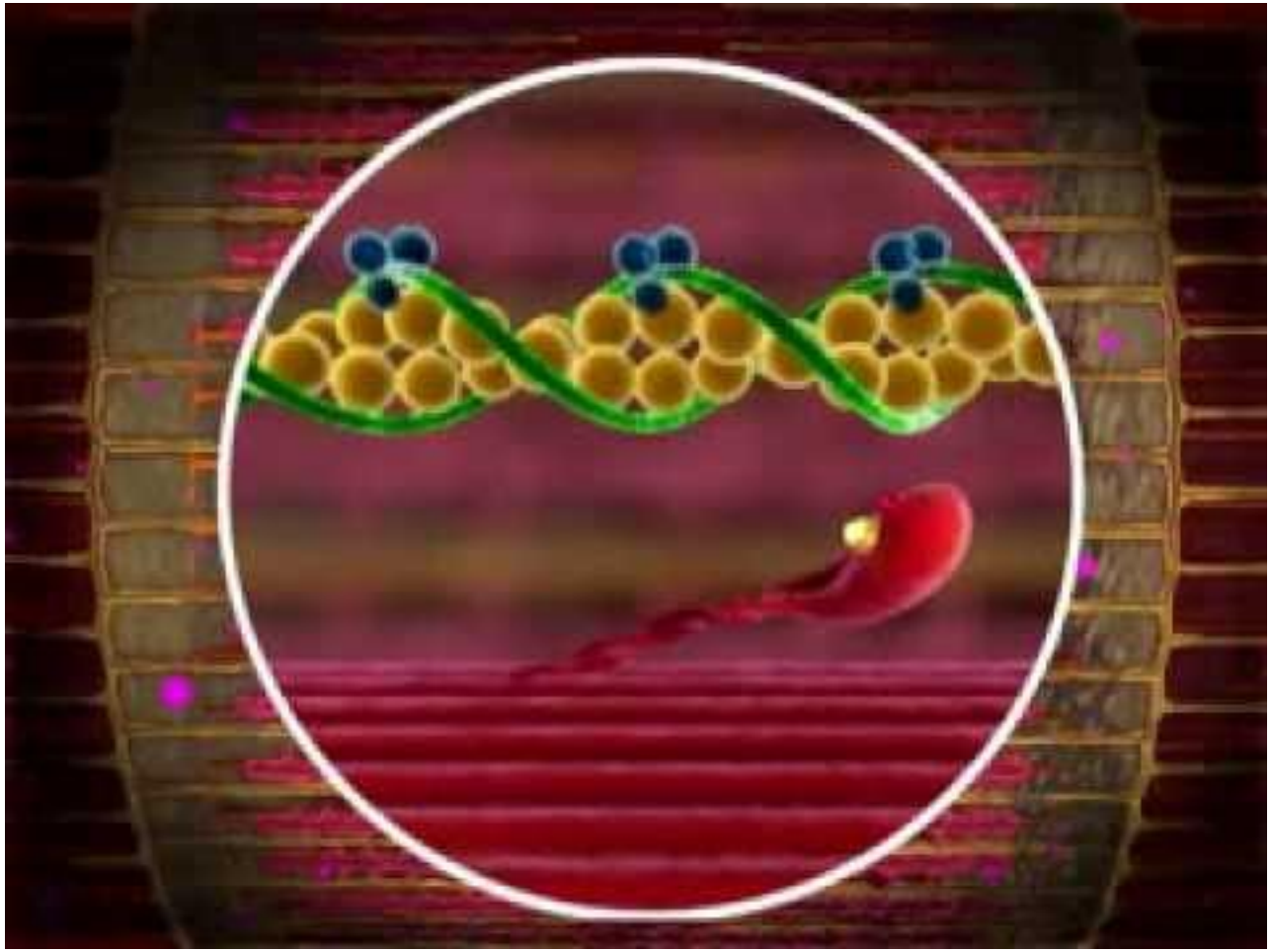
In the absence of ATP, myosin heads will not detach, causing rigor mortis.



(3) **Cross bridge detachment.** After ATP attaches to myosin, the link between myosin and actin weakens, and the myosin head detaches (the cross bridge "breaks").



(4) **Cocking of the myosin head.** As ATP is hydrolyzed to ADP and P_i, the myosin head returns to its prestroke high-energy, or "cocked," position.*



Today's Assignment

Create a flow chart of muscle contraction:

- Begin at the neuromuscular junction and end when the sarcomere has returned to it's relaxed state.
  - You need to be sure if there something happening that you include how it happened (stimulus, neurotransmitter, attachment of a molecule, transmission, etc.)