

Muscle Structure and Function

Lecture: Day 2

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Gross Anatomy of Muscle

- 1 muscle = 1 organ
- Each muscle served by a **nerve, artery, & vein (1 or more)**
- Rich **blood supply** – need energy & O₂ to survive
- **Connective tissue sheaths**: wraps each cell and reinforce whole muscle
- **Attachment**
 - (1) directly to bone
 - (2) by **tendons or aponeuroses** to bone, cartilage, or other muscles

Organization of Skeletal Muscle

Muscle

- Muscle cells + blood vessels + nerve fibers
- Covered by **epimysium (connective tissue)**

Fascicle

- Bundle of muscle cells
- Surrounded by **perimysium**

Muscle fiber (cell)

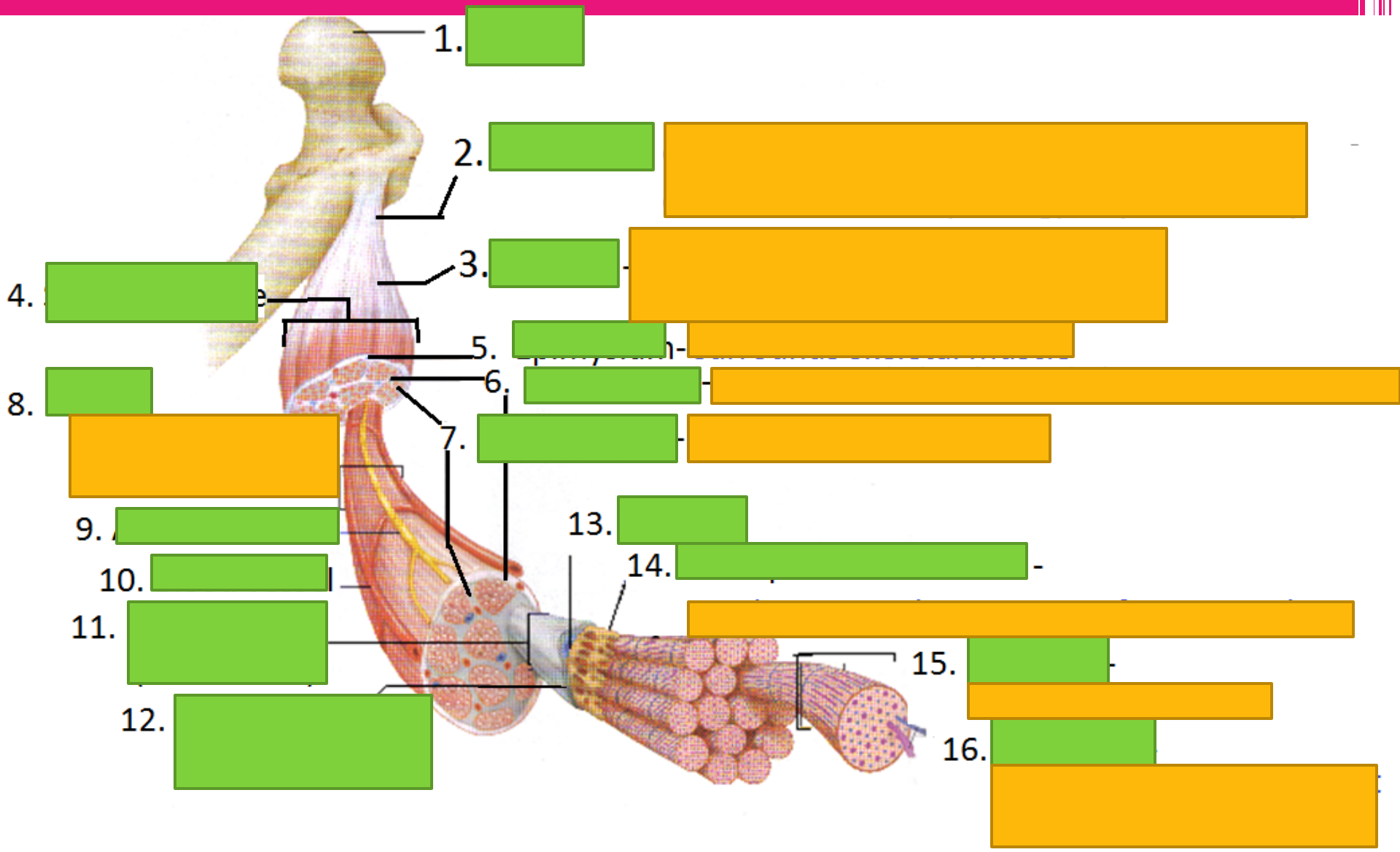
- Surrounded by **endomysium**

Myofibril

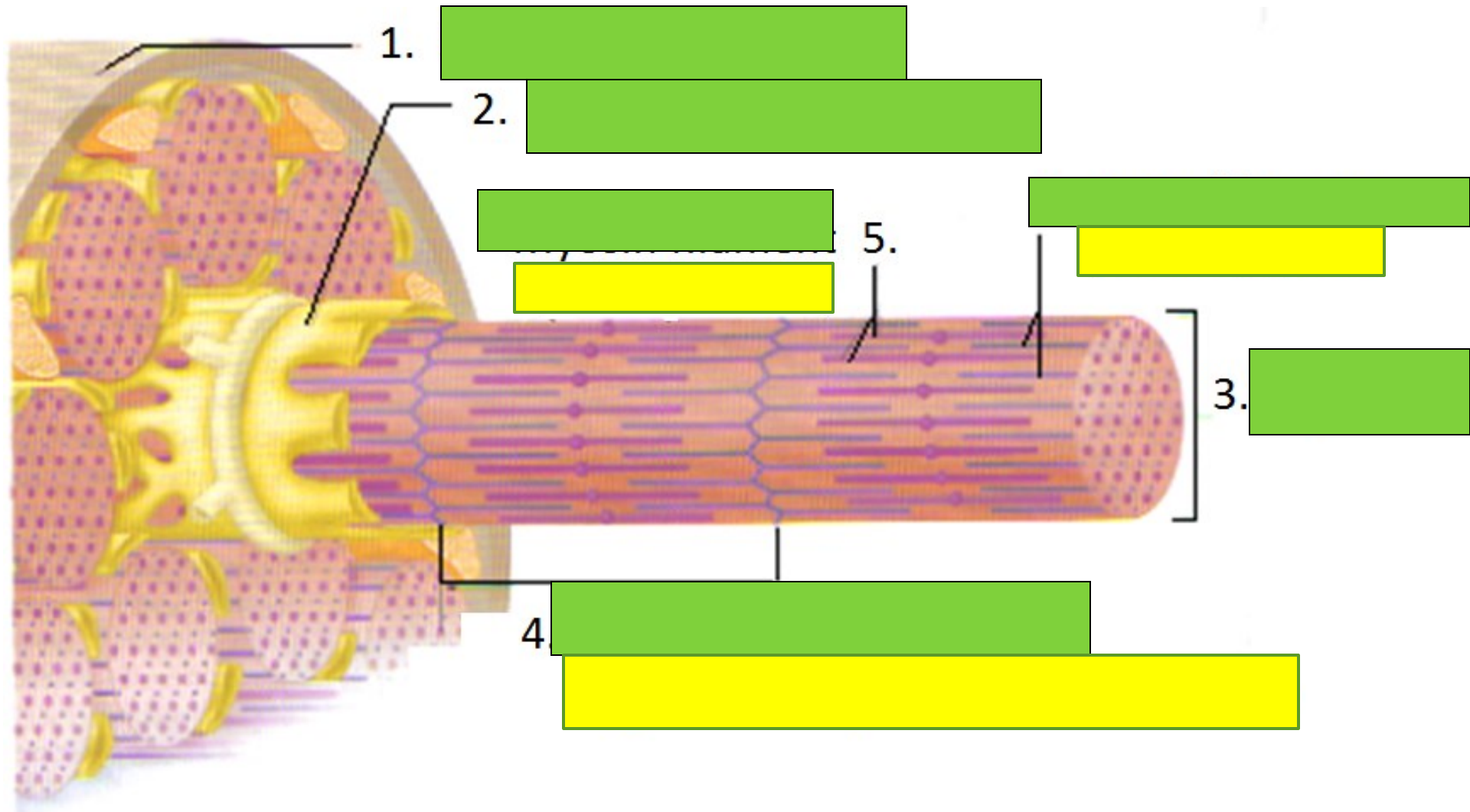
- Complex organelle

Sarcomere

- Contractile unit



Structures of a skeletal muscle fiber



Muscle Fiber Arrangement

Parallel

A



Convergent

B



Pennate

C



Bipennate

D

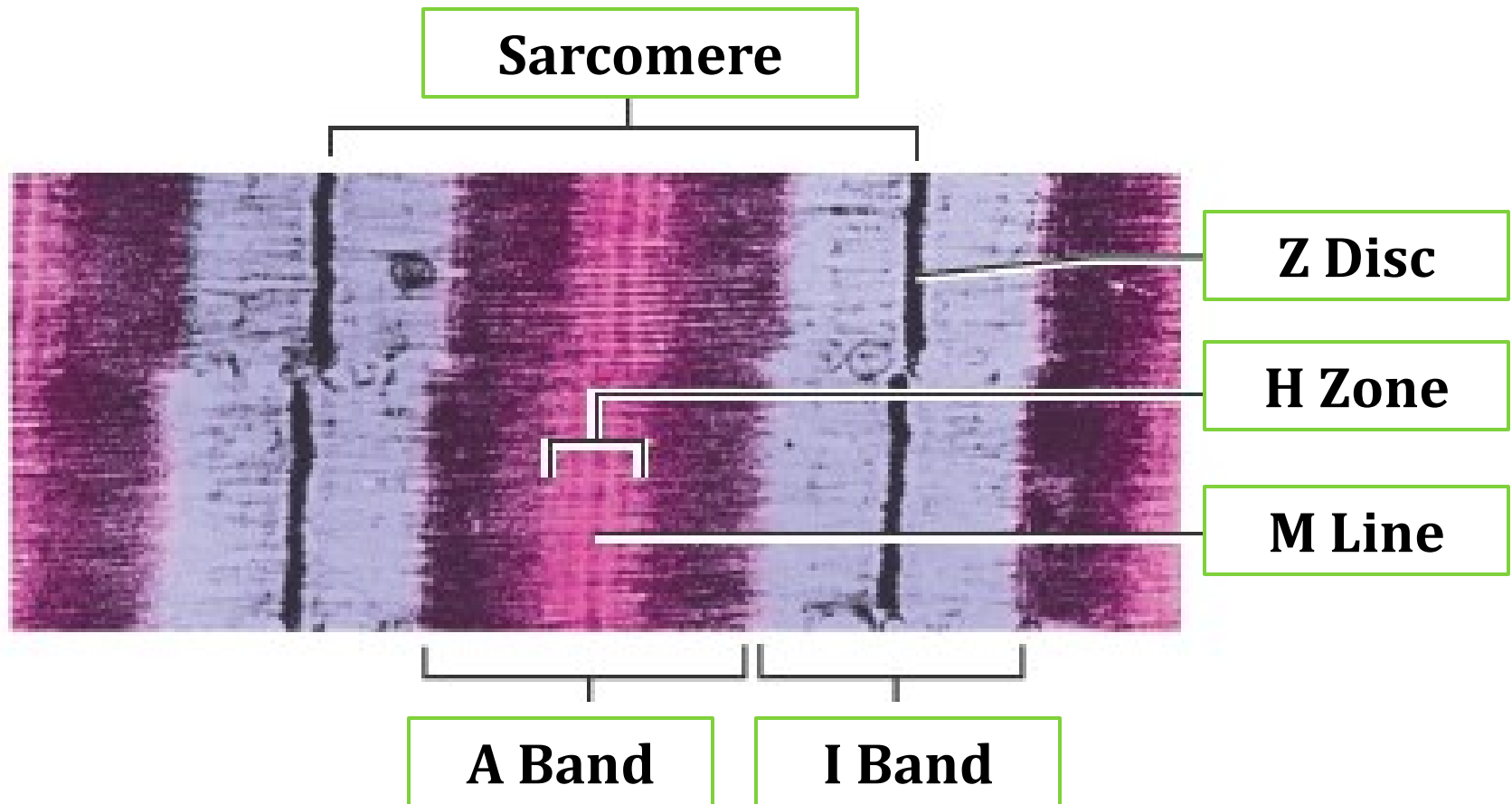


Sphincter

E

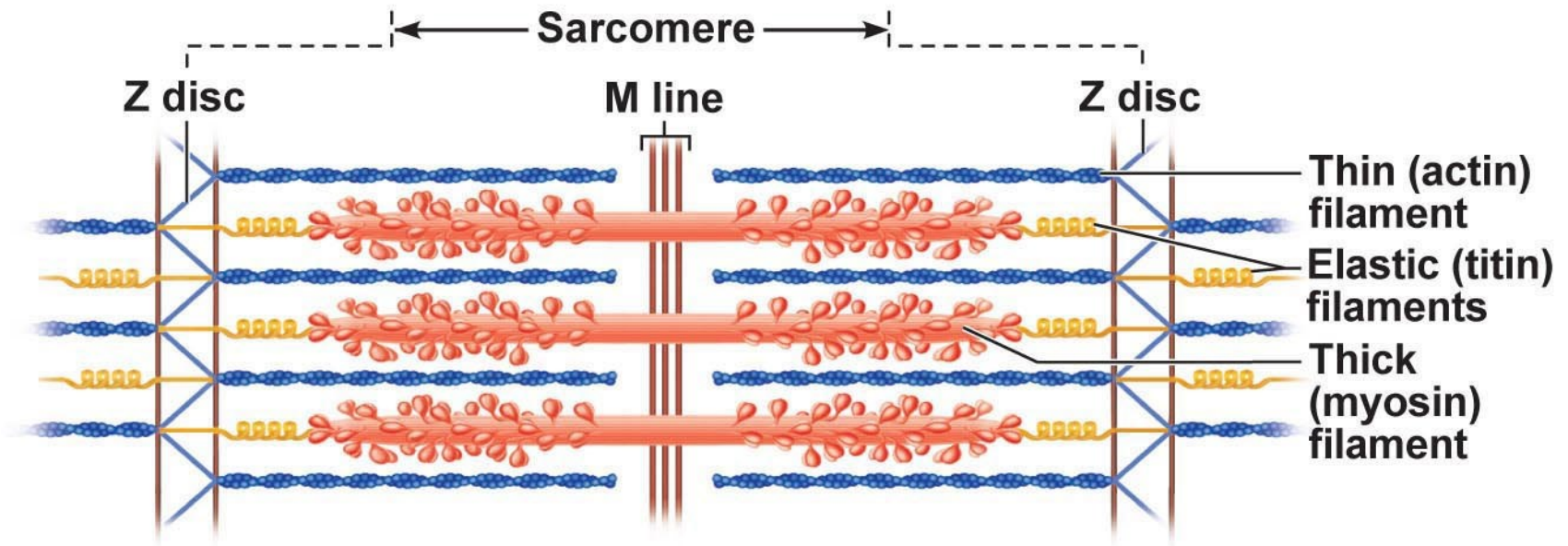


Sarcomere: The repeating patterns formed in muscle striations



Sarcomere

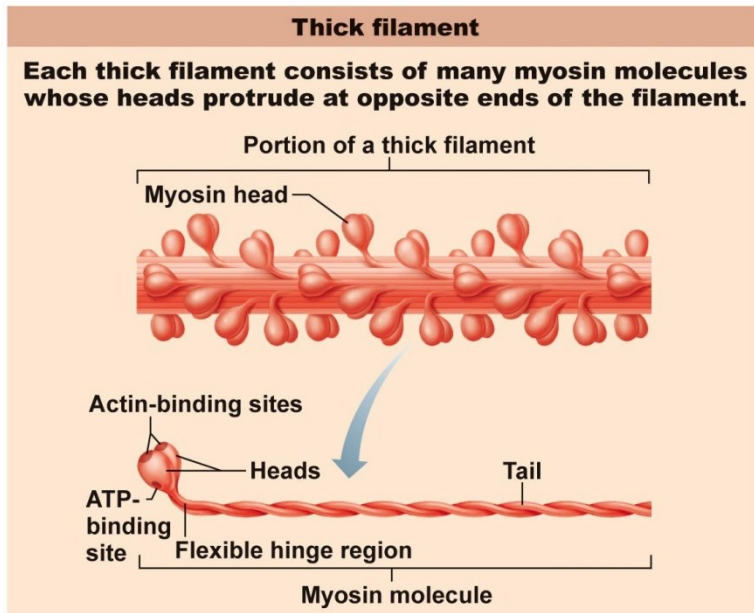
- Protein **myofilaments**:
 - Thick filaments = **myosin** protein
 - Thin filaments = **actin** protein



(d) Enlargement of one sarcomere (sectioned lengthwise). Notice the myosin heads on the thick filaments.

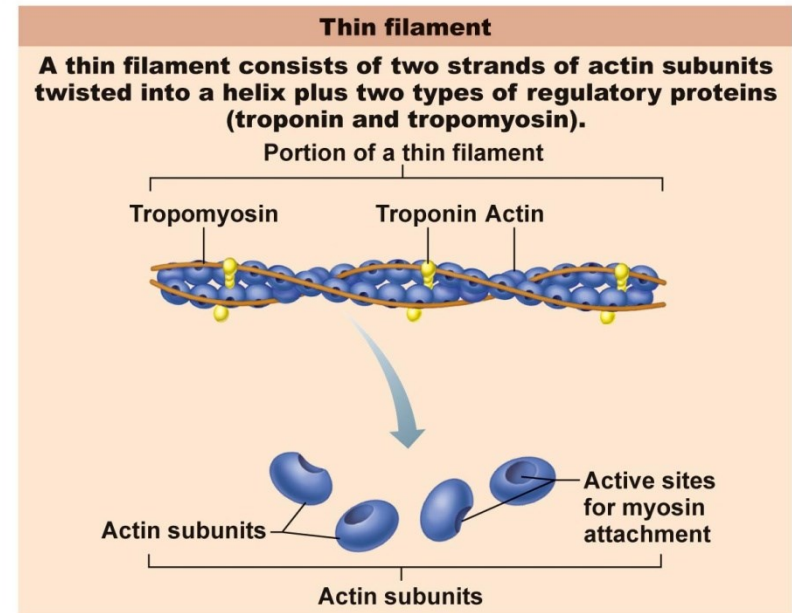
Thick Filaments

- **Myosin head:** forms *cross bridges* with thin filaments to contract muscle cell

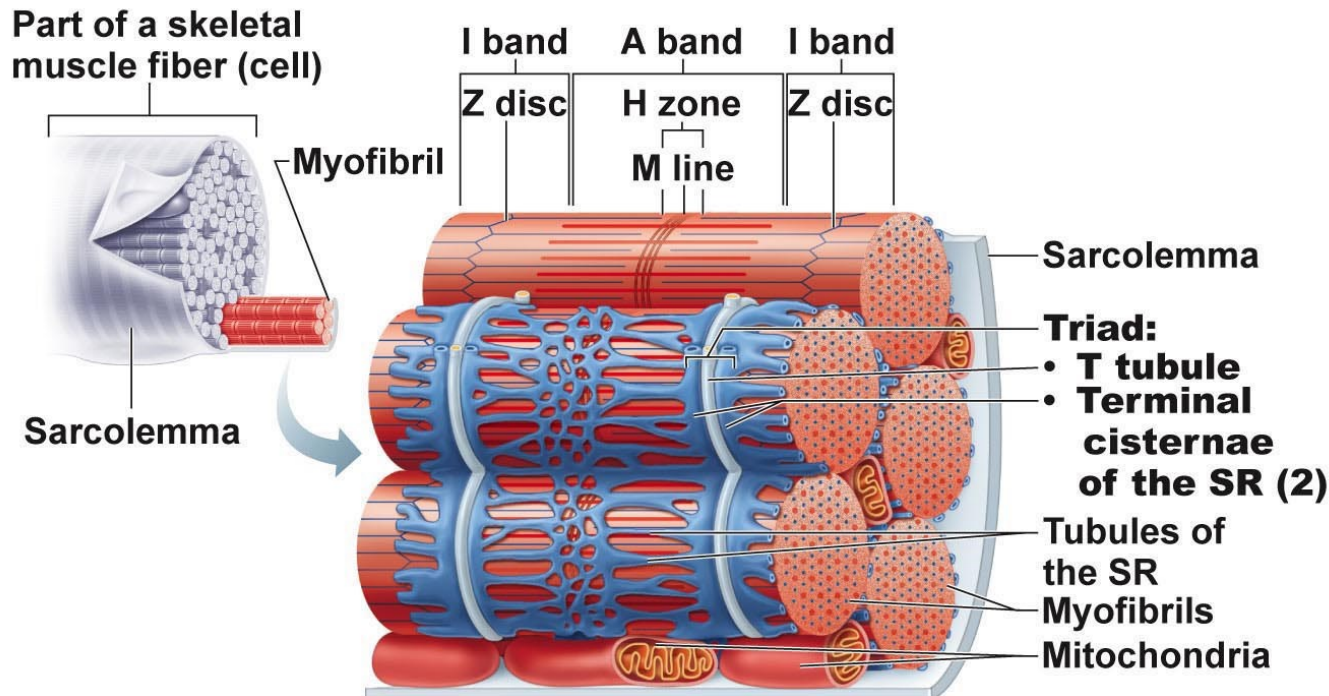


Thin Filaments

- **Tropomyosin:** protein strand stabilizes actin
- **Troponin:** bound to actin and tropomyosin, affected by Ca^{2+}

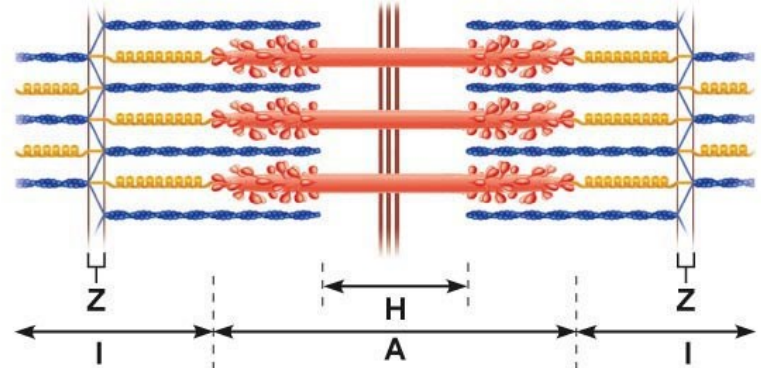
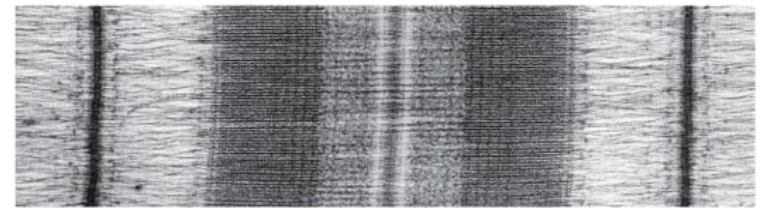
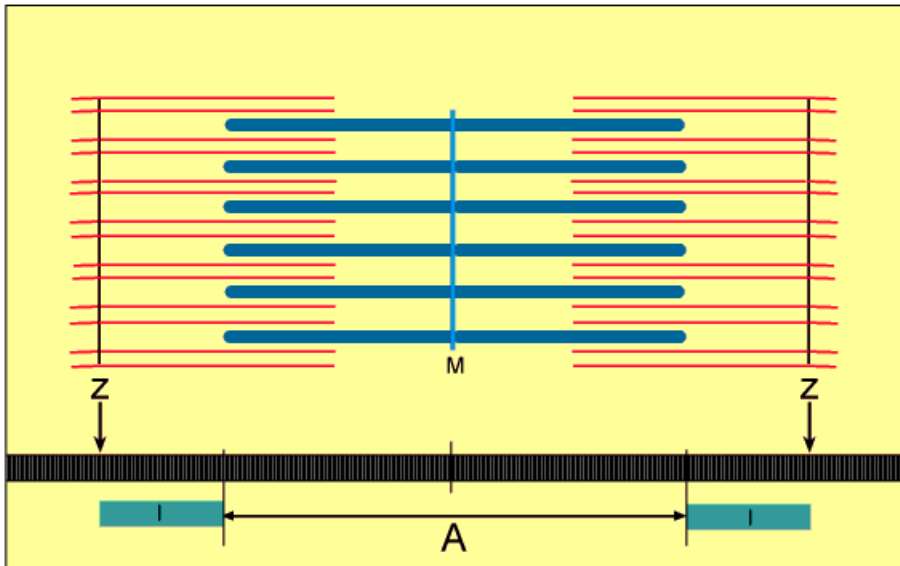


- **Sarcoplasmic Reticulum (SR)**: specialized smooth ER, surrounds each myofibril
 - Stores and releases **calcium**
- **T Tubule**: part of sarcolemma, conducts nerve impulses to every sarcomere
 - Triggers release of calcium from SR

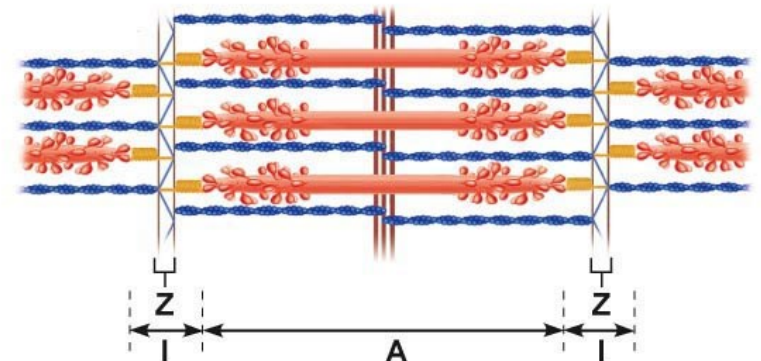


Sliding Filament Model

- **During contractions:** **thin filaments** slide past **thick** ones so they overlap more
- Sarcomere shortens



① Fully relaxed sarcomere of a muscle fiber

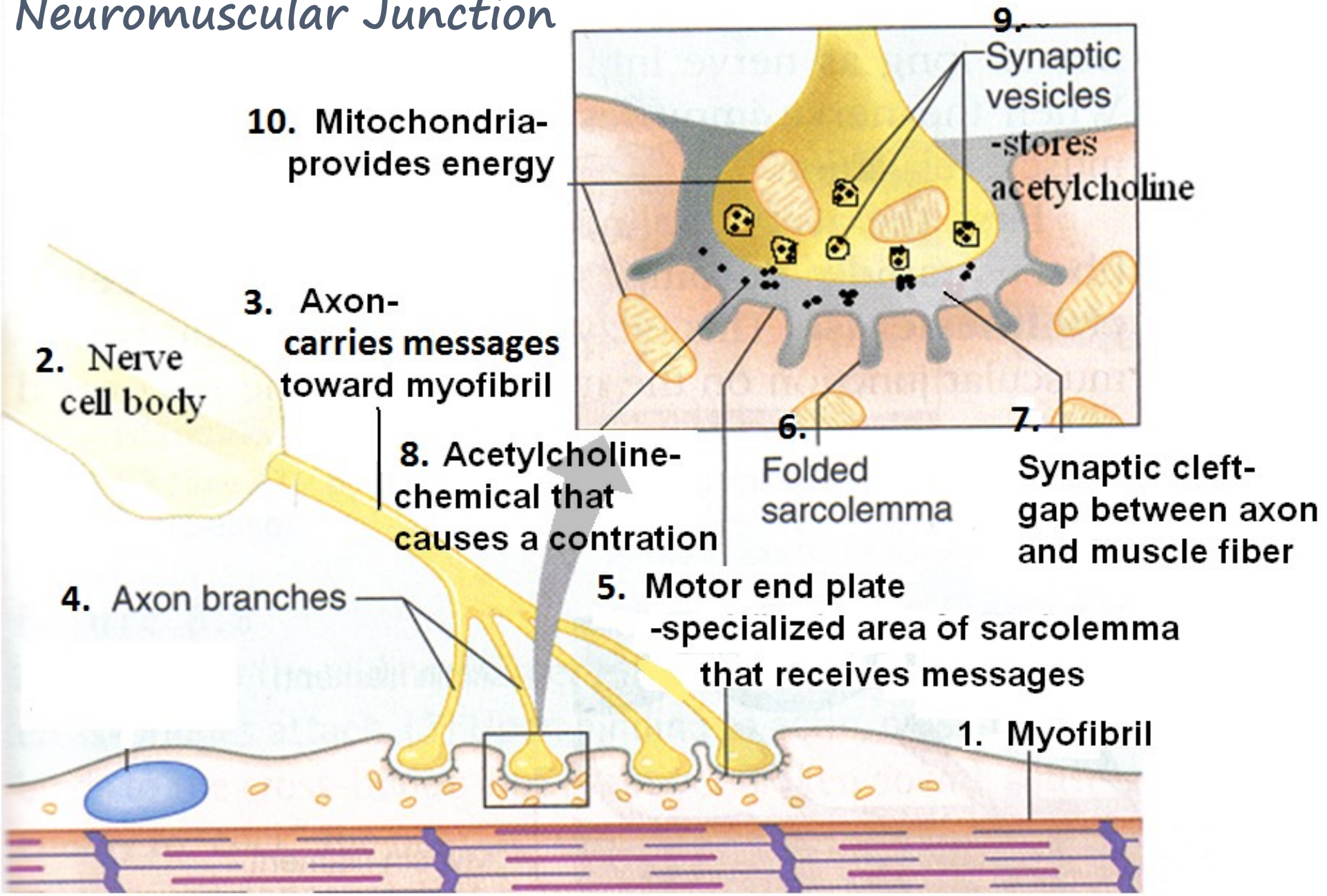


② Fully contracted sarcomere of a muscle fiber

Neuromuscular Junction

- Connects the nervous system to the muscular system through synapses between nerve and muscle fibers
 - Directs **action potentials** = basically a small impulse that set off the chain of events that lead to muscle contractions
- Acetylcholine is the neurotransmitter that motor neurons use to control skeletal muscle contraction
 - Synthesized in the cytoplasm of motor neuron

Neuromuscular Junction

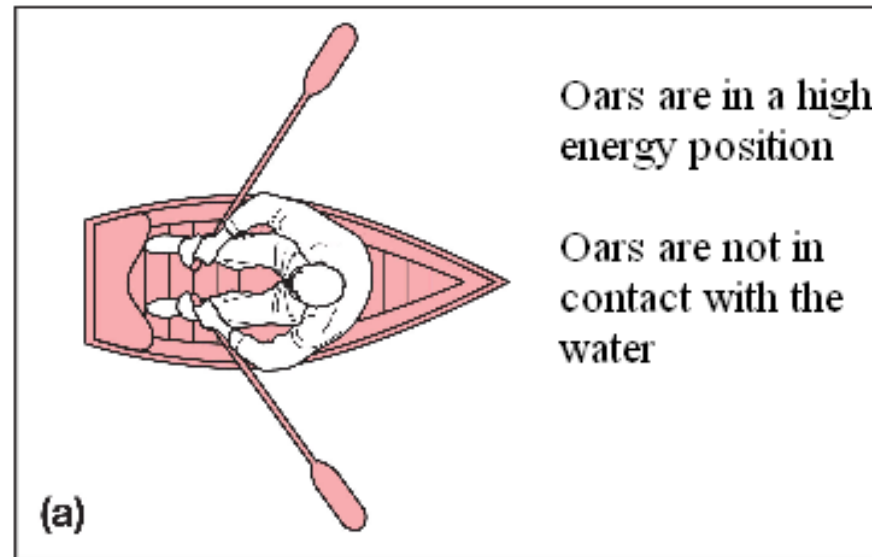
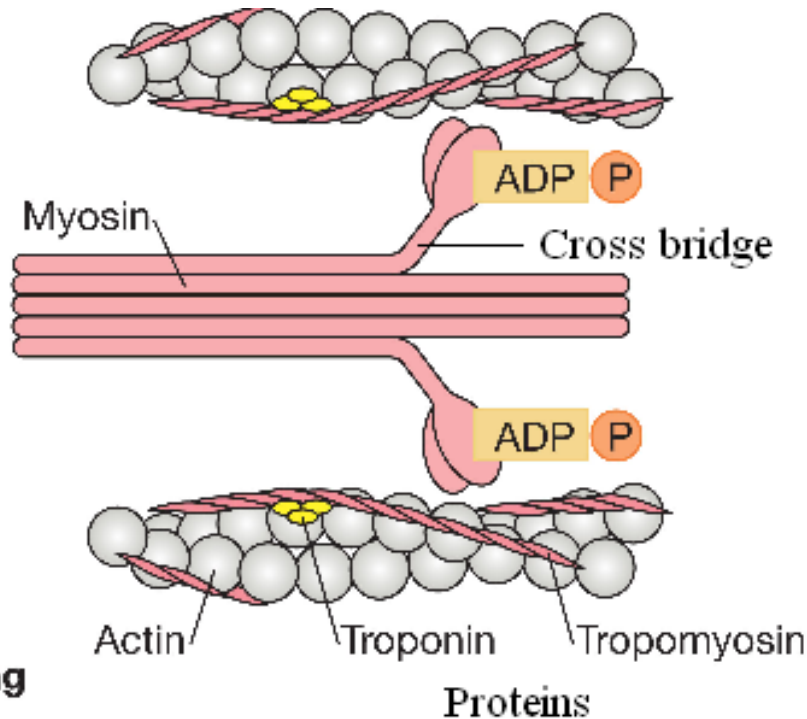


Sliding Filament theory - method by which muscles are thought to contract

- **Boat** = Myosin (thick filament)
- **Oar** = Myosin side arm
- **Water** = Actin (thin filament)
- **Life ring** = Calcium

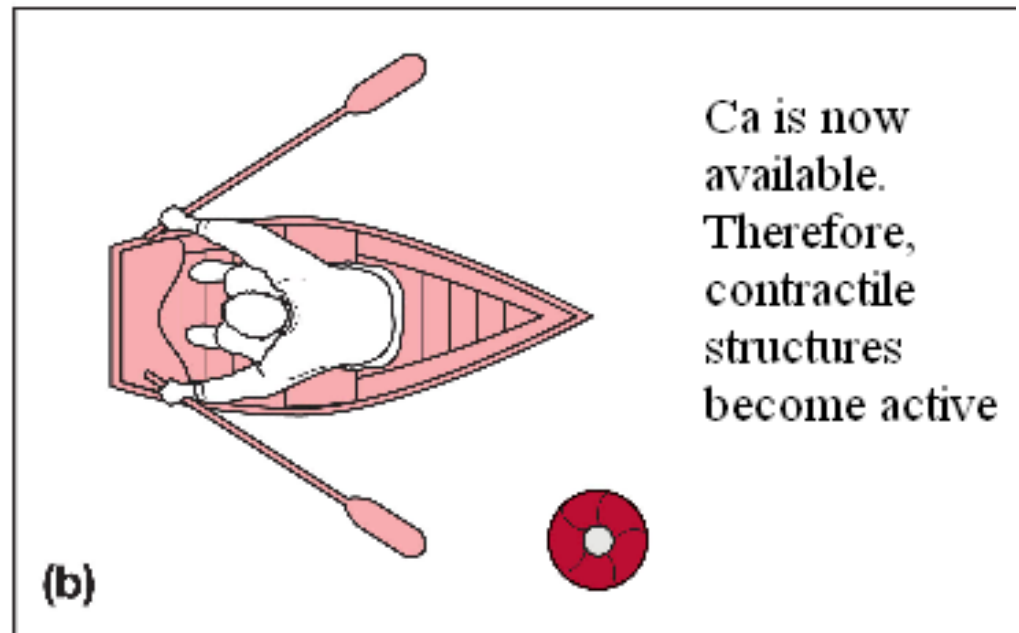
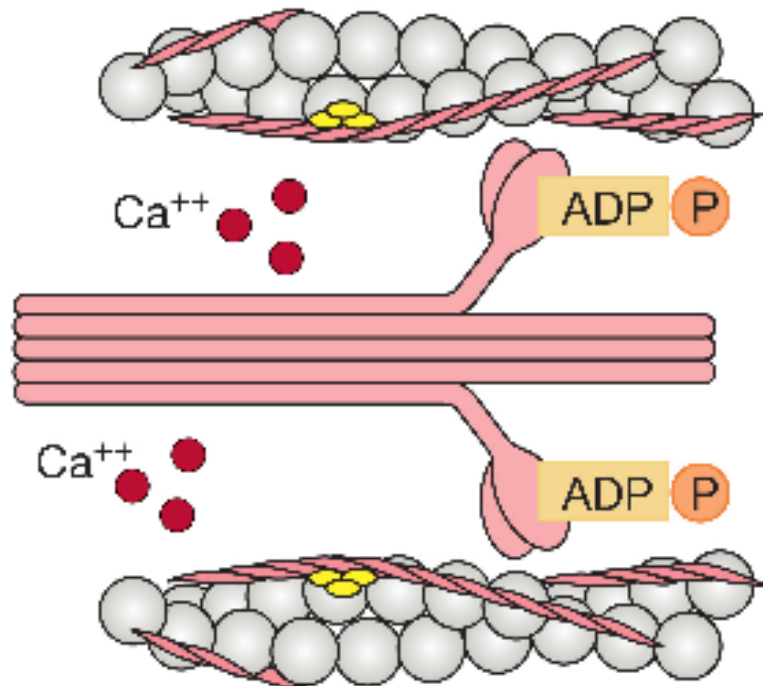
Resting State

1. ATP is bound to myosin side arm.
2. ATP splits into ADP + P (high energy)



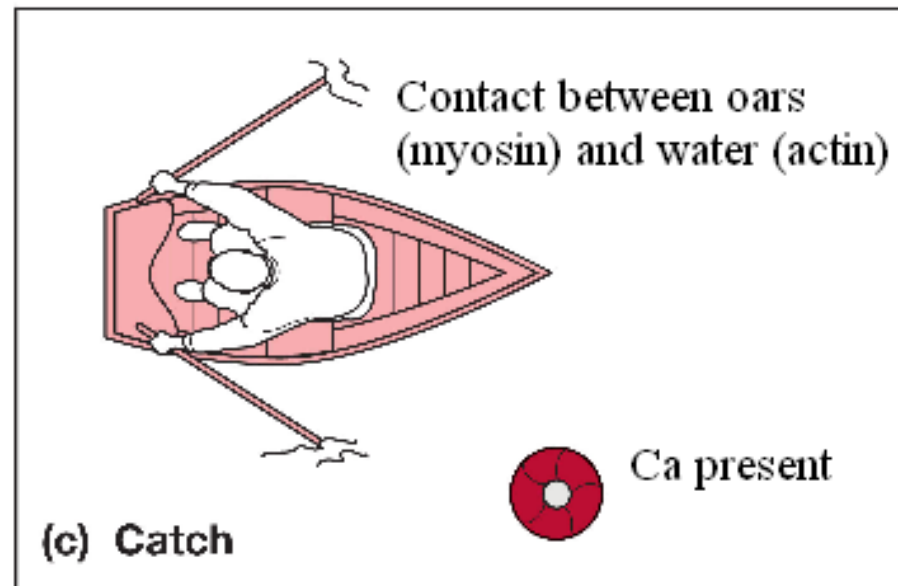
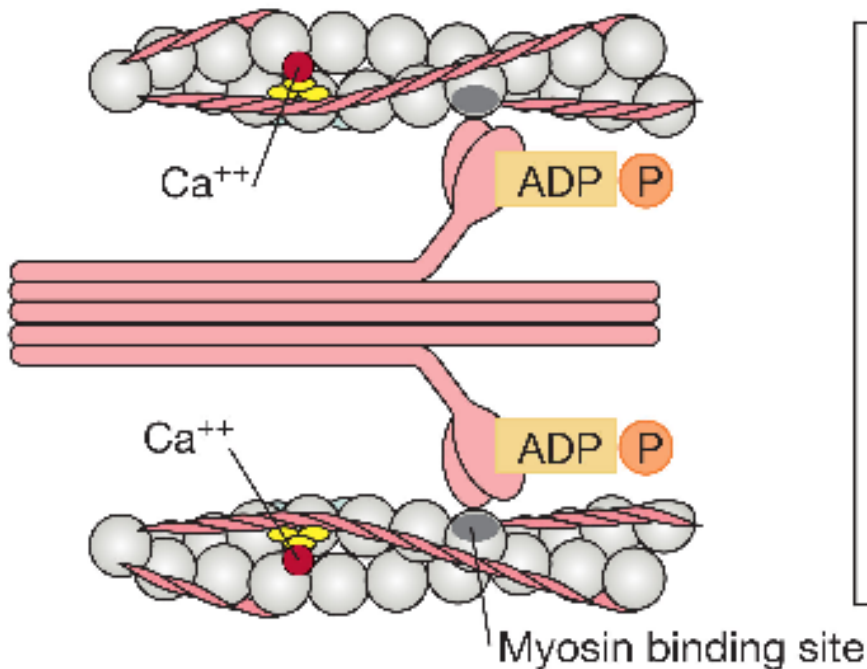
Step 1: Action Potential

1. A nerve action potential releases **acetylcholine** into the synaptic cleft opening the Na^+ channels.
2. Action potential spreads across sarcolemma releasing **Calcium** into sarcoplasm



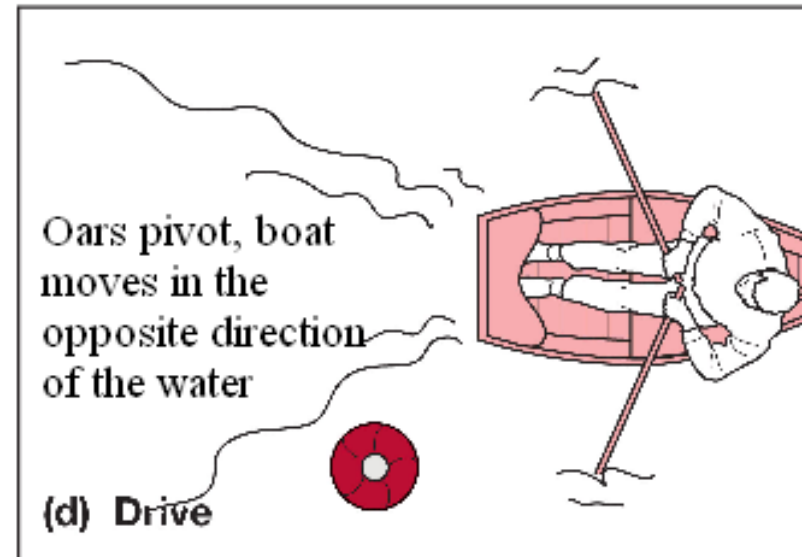
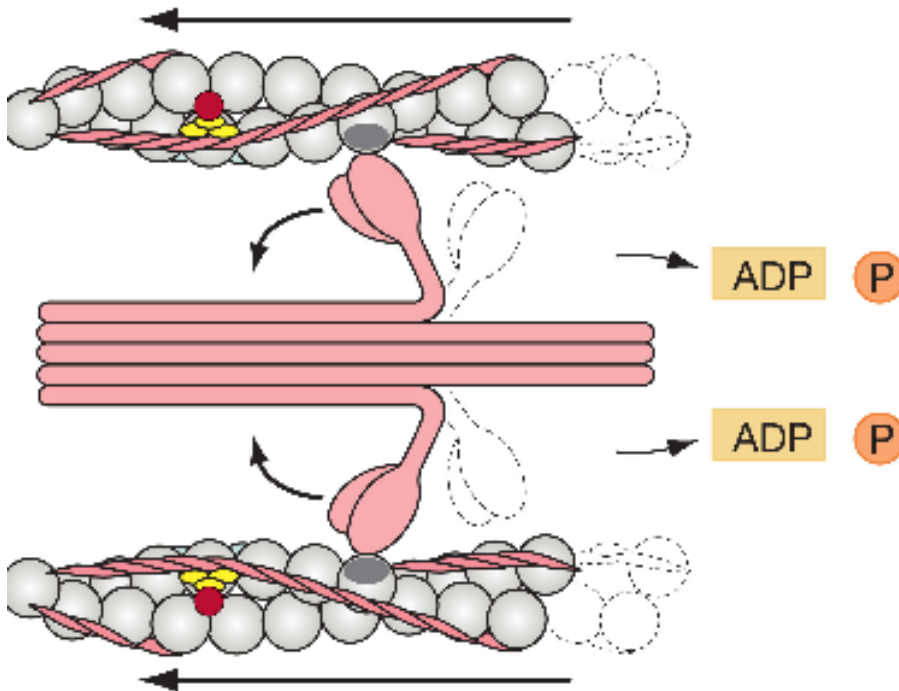
Step 2 Myosin-actin binding

1. **Calcium** binds to **troponin**
2. A shape change in **troponin** moves **tropomyocin** out of the way of actin binding site
3. **Actin** and **myosin** bind using energy from cleaved ATP.



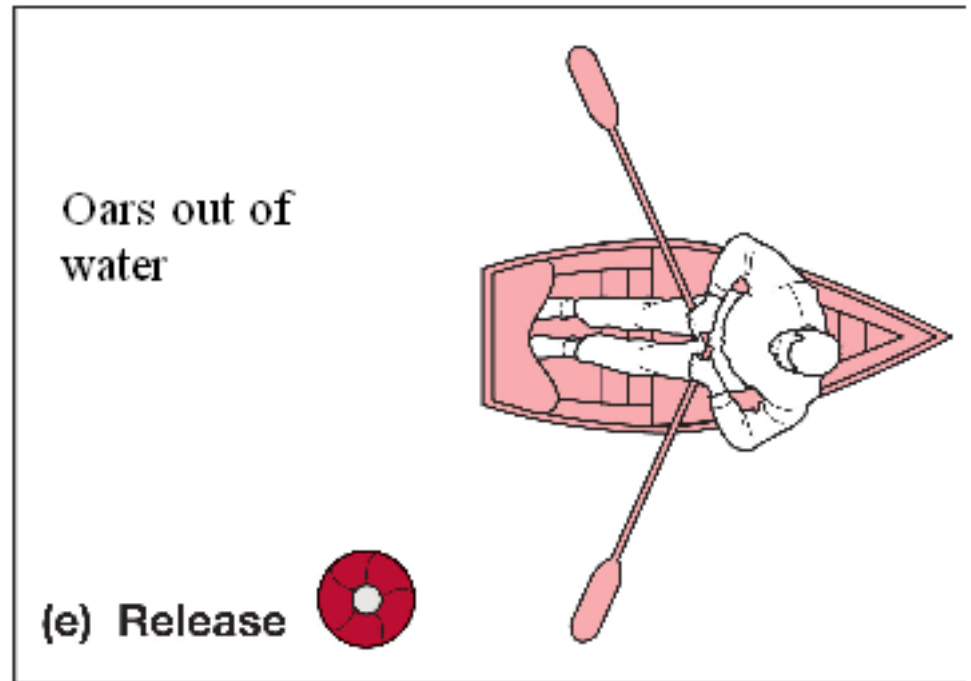
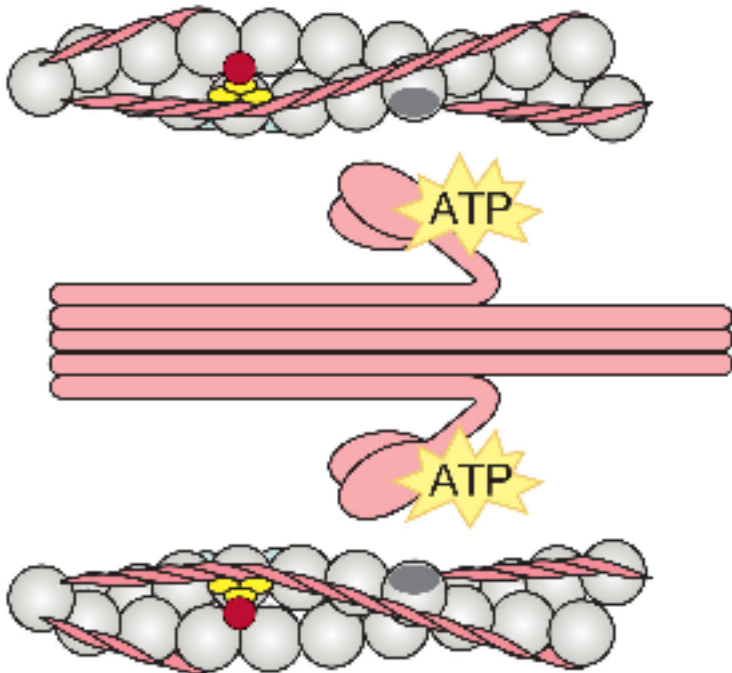
Step 3 Powerstroke

1. Side arm pivots so **myosin** and **actin** slide by each other shortening the sarcomere.
2. ADP and P released (low energy)



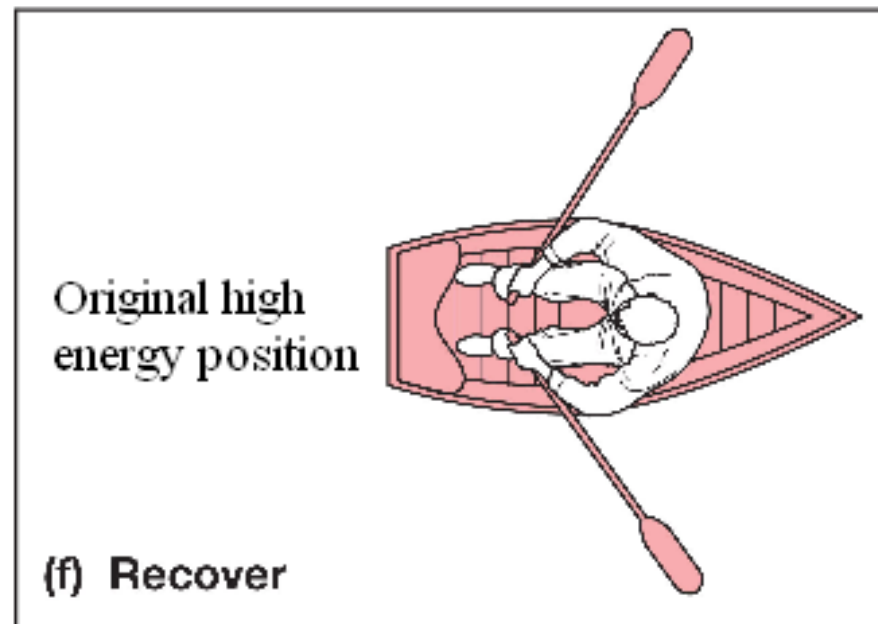
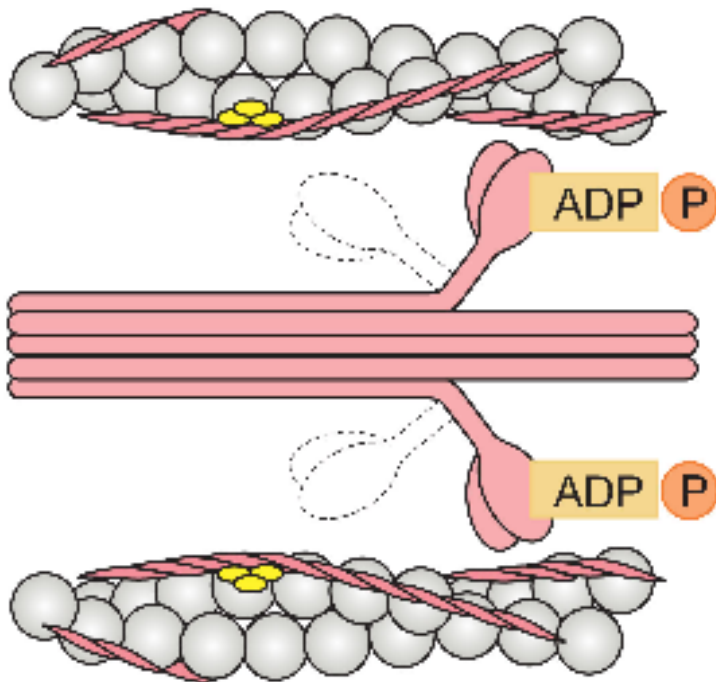
Step 4 ATP Binding Actin-myosin release

1. A different ATP molecule binds to active site.
2. Actin released



Step 5 ATP cleavage

1. Return to high energy state
2. Cycle will repeat if Ca still available.

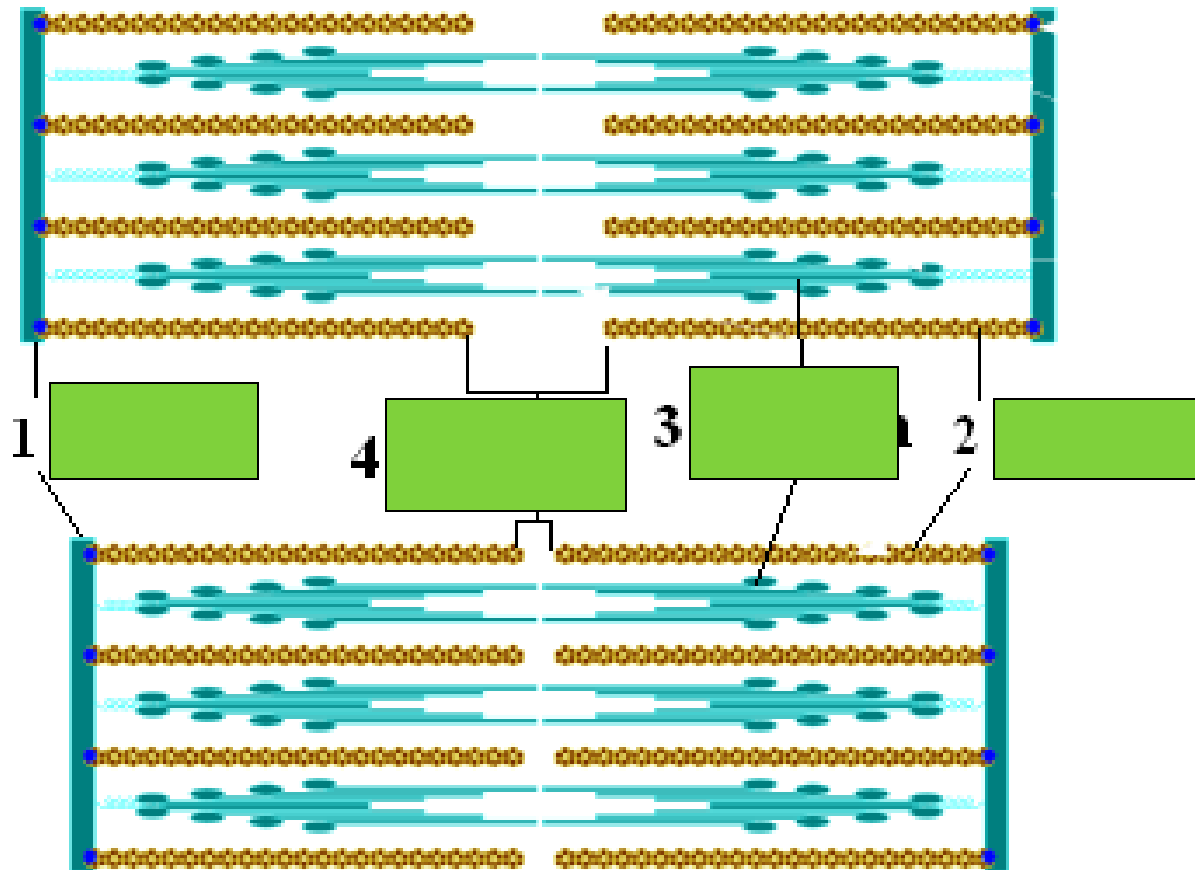


Think it over

- The boat (myosin) does not move far in one cycle, a muscle contraction requires many cycles
 - **If a muscle is contracted what happens if a new molecule of ATP is not available?**
 - **Muscle stays contracted- cramps**
- Why does rigor mortis occur? (Hint: What chemical is no longer available to the body?)
 - **ATP is not available to control calcium release so contractions are continuous 6-8 hours after death.**
 - **Body relaxes 16-24 hours as enzymes break down contractile structures.**

Sarcomere summary

Relaxed sarcomere



Contracted sarcomere

• SF Animation 2

Focus Questions:

What chemical exposes the binding site for actin and myosin?

- *Calcium*

What is the source of energy for a contraction?

- *ATP*

What is the name of the step in which the actin filament is actively contracted?

- *Powerstroke*

What chemical must be present in order for the actin and myosin filaments to separate?

- *ATP*