Structure of Skeletal Muscle and Mechanism of Contraction

Discussion Topics.

- Introduction
- Anatomy of skeletal muscle
- Sarcoplasmic reticulum
- Excitation contraction coupling
- Sliding filament model
- Energy sources
- Neuromuscular junction

Introduction

- Human body contains over 400 skeletal muscles.
- 40-50 % of total body weight.
- Function of skeletal muscle.
- Body movement
- Maintenance of body posture
- Production of body heat (Thermogenesis)

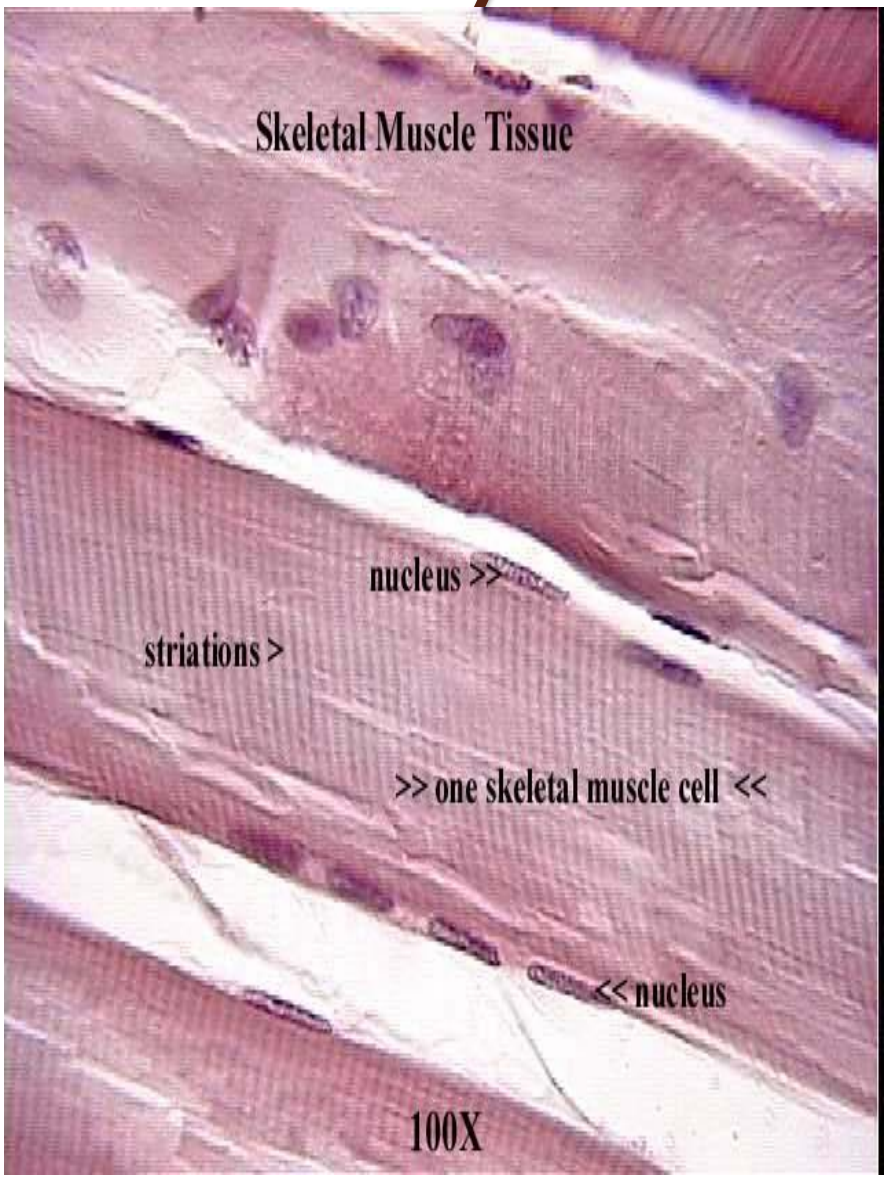
Skeletal muscle characteristics

- Most are attached by tendons to bones
- Cells are multinucleate
- Striated-having visible banding
- Voluntary-subject to conscious control
- Cells are surrounded and bundled by connective tissue.
- An average adult male is made up of 42 % of skeletal muscle
- An average adult female is made up of 36 % (as a percentage of body mass).

Terms

- Sarcolemma= cell membrane
- Sarcoplasm=cytoplasm
- Sarcoplasmic reticulum=endoplasmic reticulum
- Sarcosomes=mitochondria

Anatomy of skeletal muscle

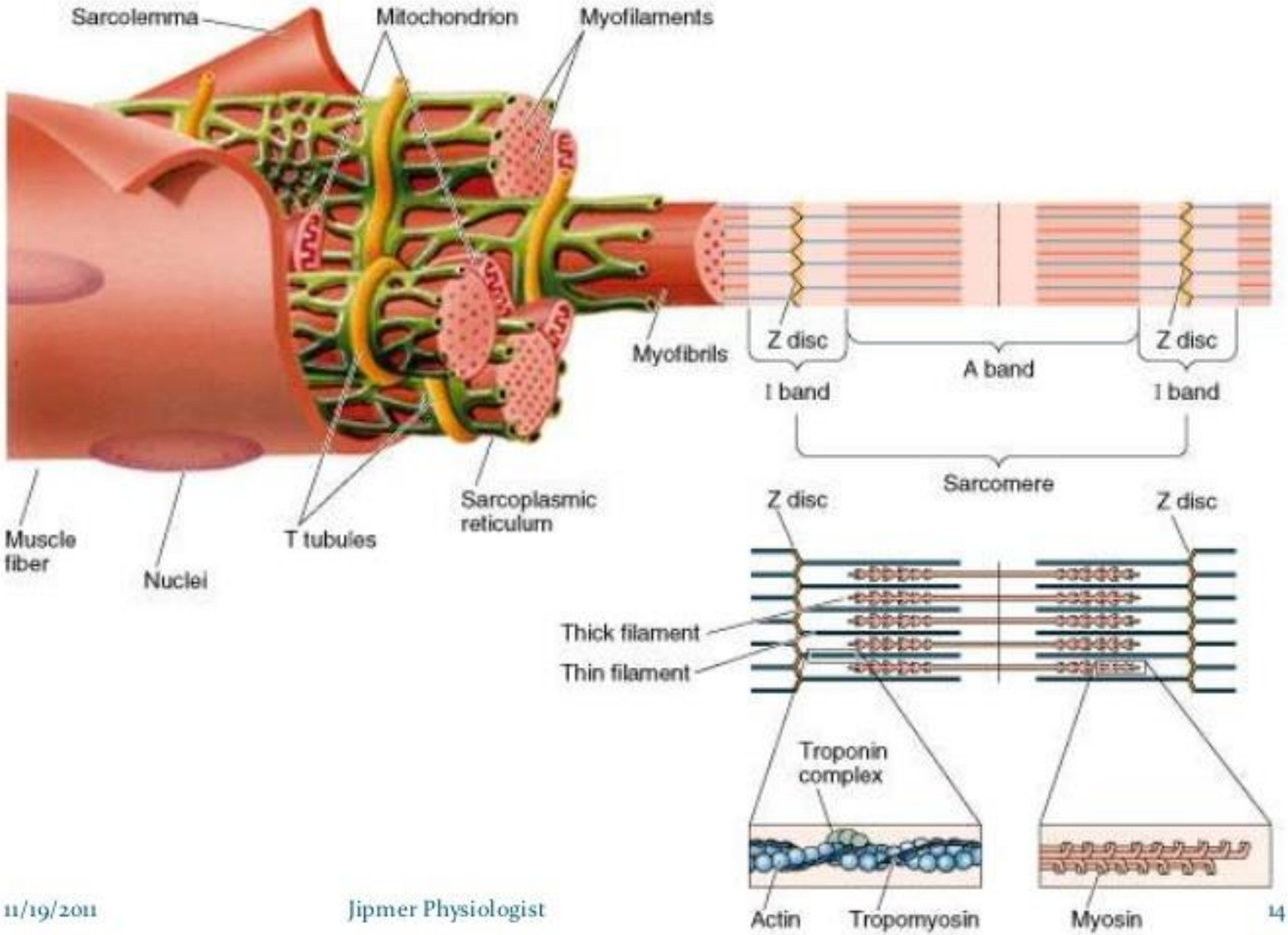


- Composed of muscle cells(fibers), connective tissue, blood vessels, nerves.
- fibers are long, cylindrical and multinucleated.
- 1mm-4cm in length.
- Striated appearance.
- Nuclei are pheripherally located.
- Develop from myoblasts.

Muscle fiber Anatomy.

- Sarcolemma-cell membrane.
  Surrounds sarcoplasm- cytoplasm of fiber.
  Invaginates into cytoplasm of muscle cell forming membranous tubule called transverse tubule (T- tuble)
- Myofibrils- cylindrical structures within muscle fibers.
  Are bundles of protein filaments called myofilaments.
  Two types of myofilaments.
  Actin filaments-thin filaments.
  Myosin filaments-thick filaments.
- When myofibrils' shorten muscle shorten.

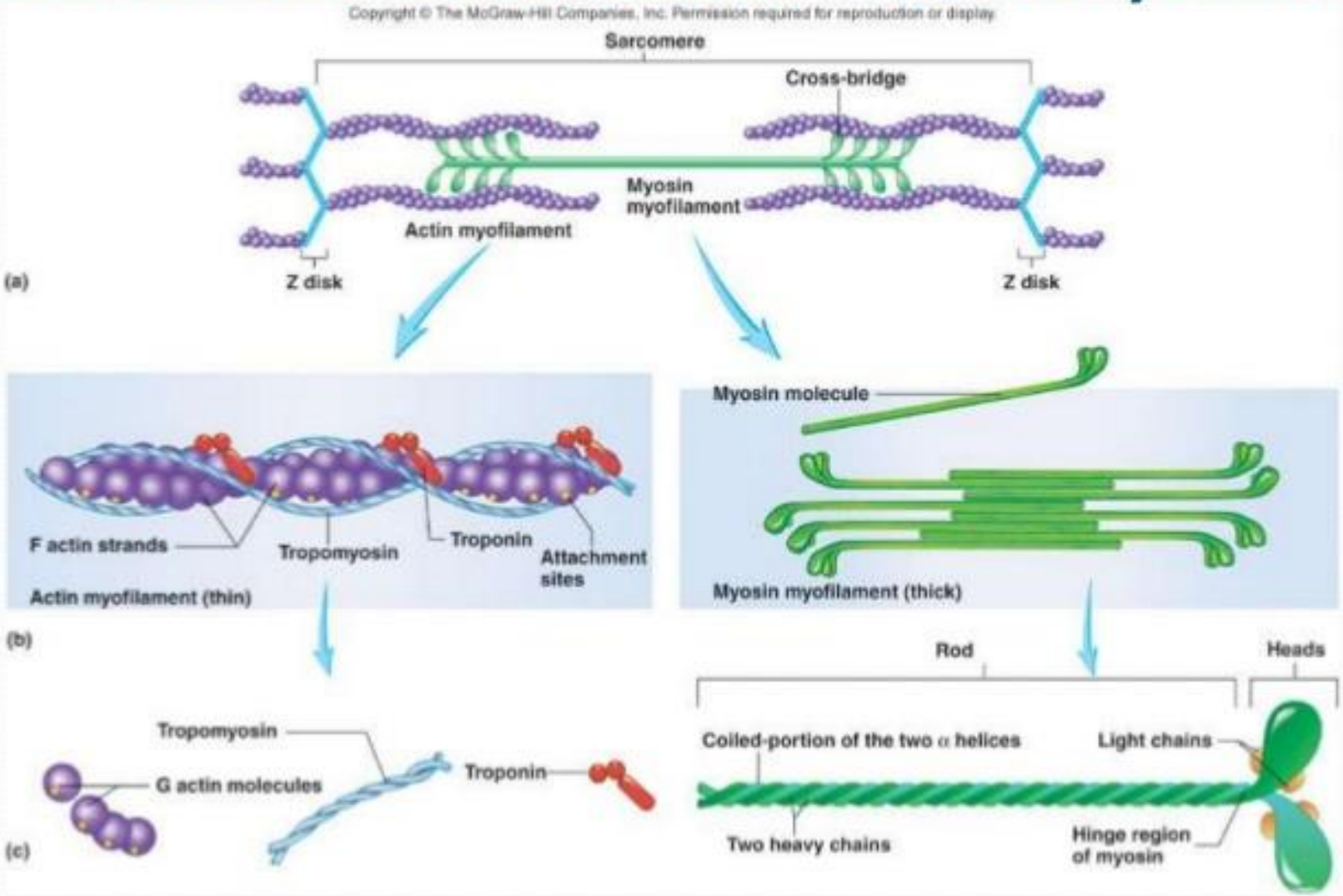
► Organization of a Muscle Fiber



Muscle proteins

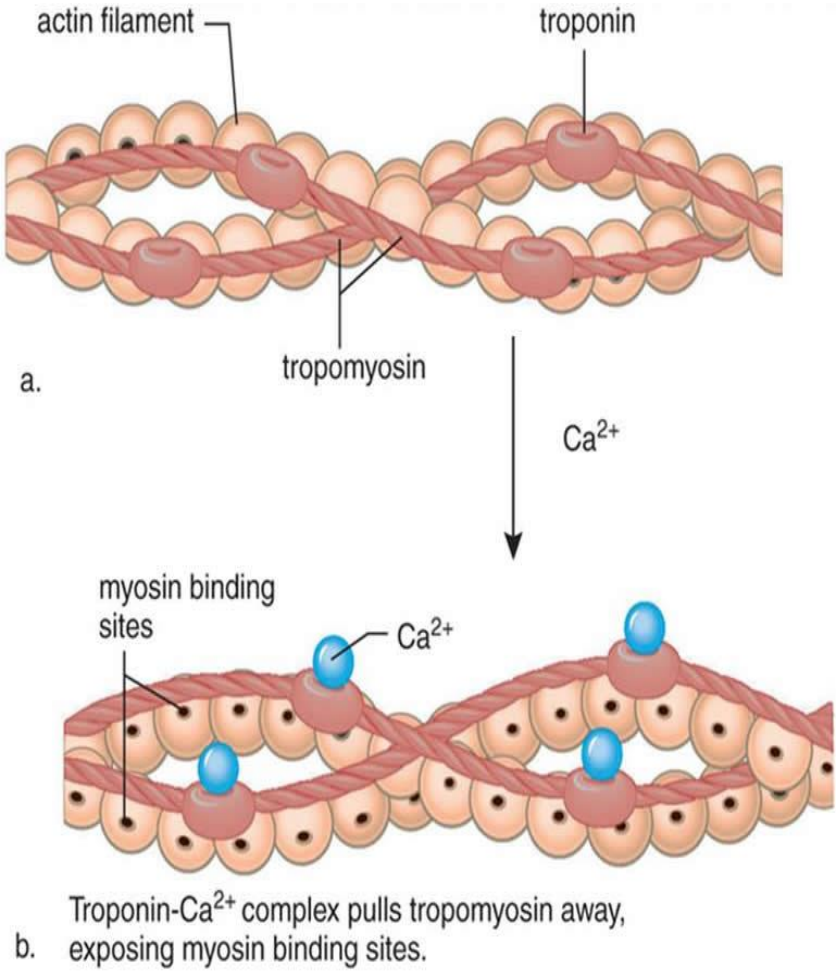
- Contractile proteins.
  - Actin-thin filament
  - Myosin-thick filament
- Regulatory proteins
  - Tropomyosin
  - Troponin
- Attachment proteins
  - Titin, nebulin, aplha actinin.

Structure of Actin and Myosin

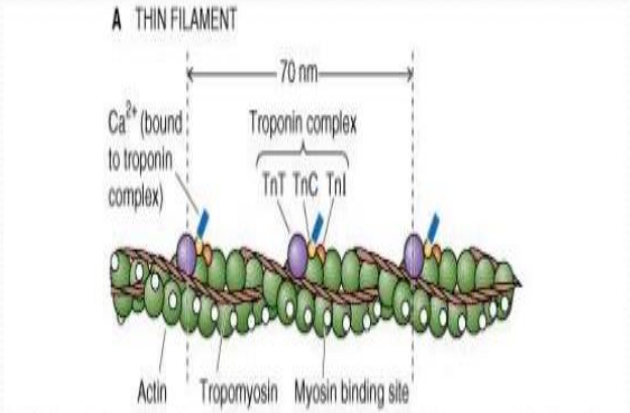


Actin- Thin Myofilaments

- Composed of three major proteins.
  1. F (fibrous) actin
  2. Tropomyosin
  3. Troponin
- Two strands of fibrous (F) actin form a double helix. Extending the length of myofilament.
- Composed of G actin monomers each of which has myosin-binding site.
- Actin site can bind myosin during muscle contraction.



- Tropomyosin- an elongated protein winds along the groove of the F actin double helix.
- Troponin is composed of three sub-units:
- Tn-A: binds to actin
- Tn- T: binds to tropomyosin
- Tn-I: binds to calcium ions.



Myosin- thick filament

- Single filament contains roughly 300 myosin molecules.
- Molecule consists of two heavy myosin molecules wound together to form a rod portion lying parallel to myosin filament and two heads that extends laterally.
- Myosin heads:

1. Can bind to active sites of actin molecule to form cross bridges.

2 atached to rod portion by hinge region that can bend and straighten during contraction.

3 have ATPase activity.

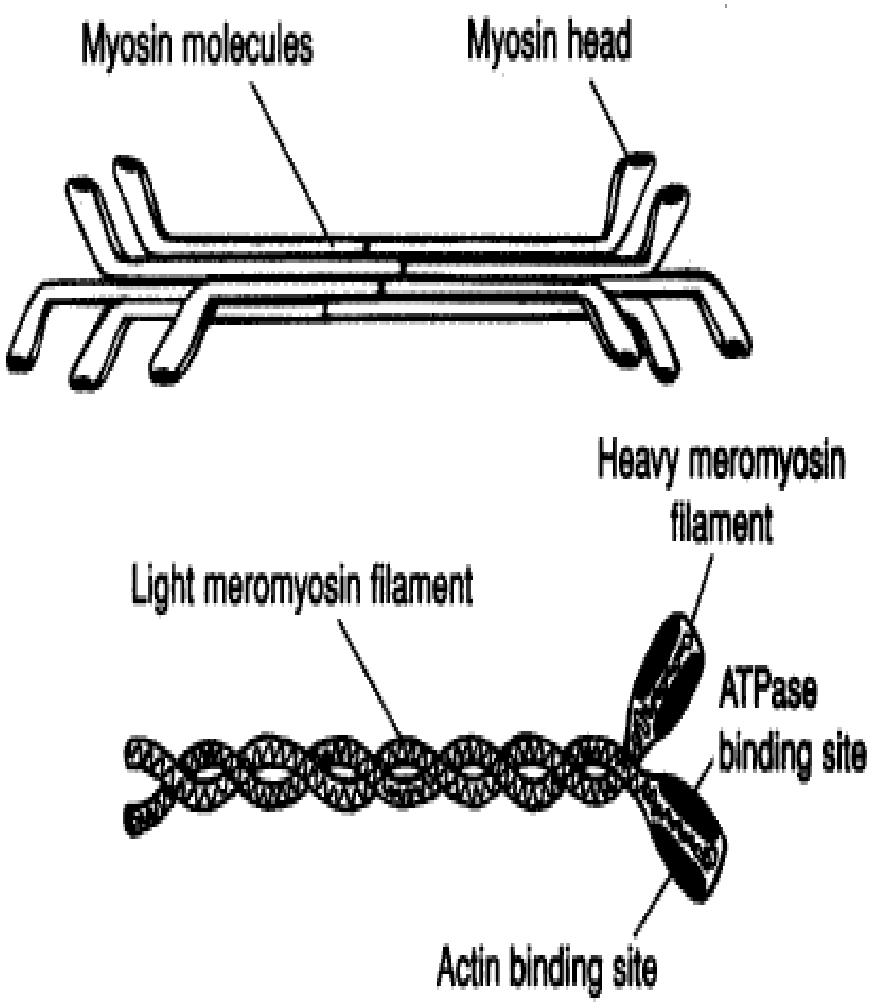
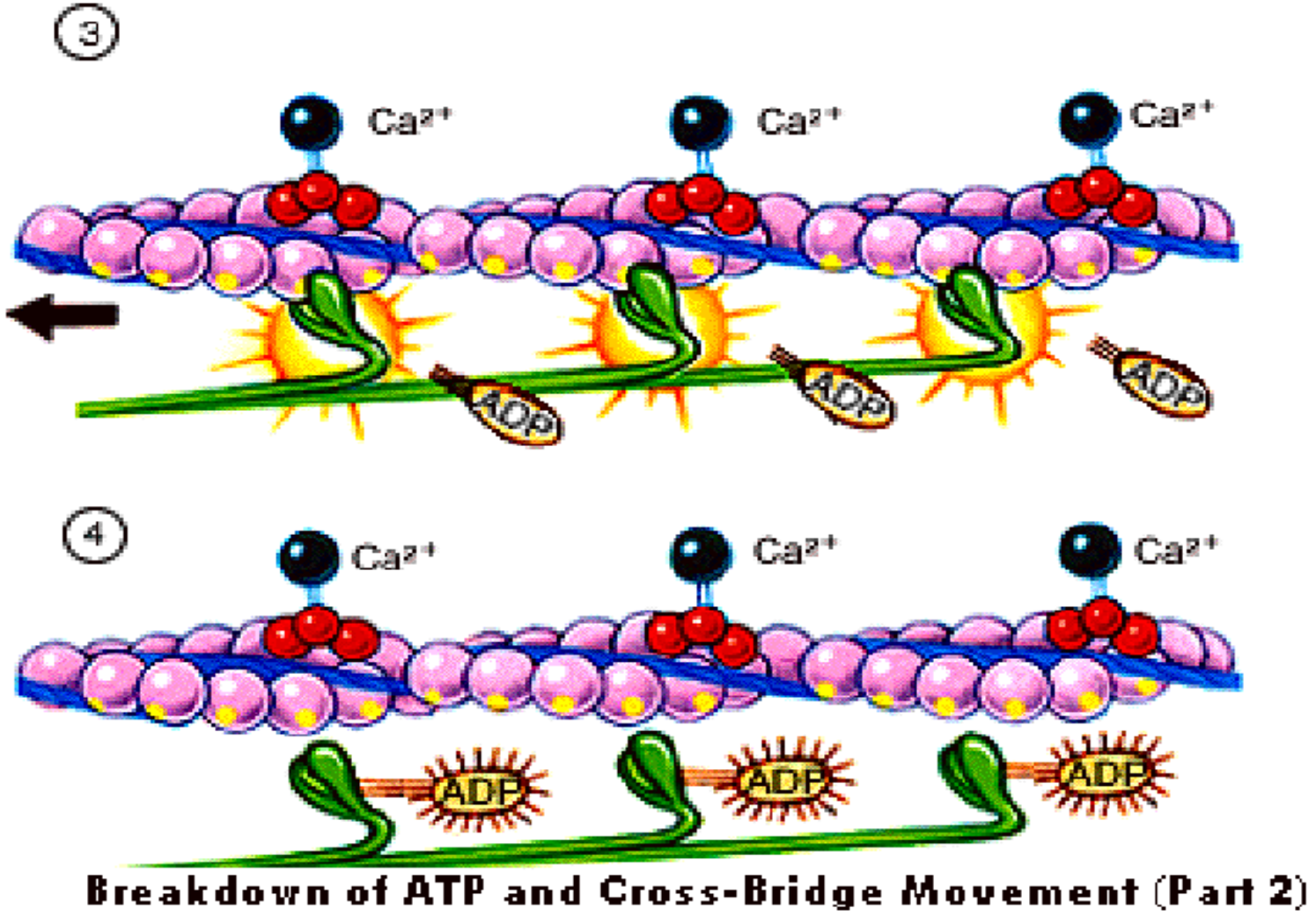


Figure 7-1. Structure of thick myofilaments.

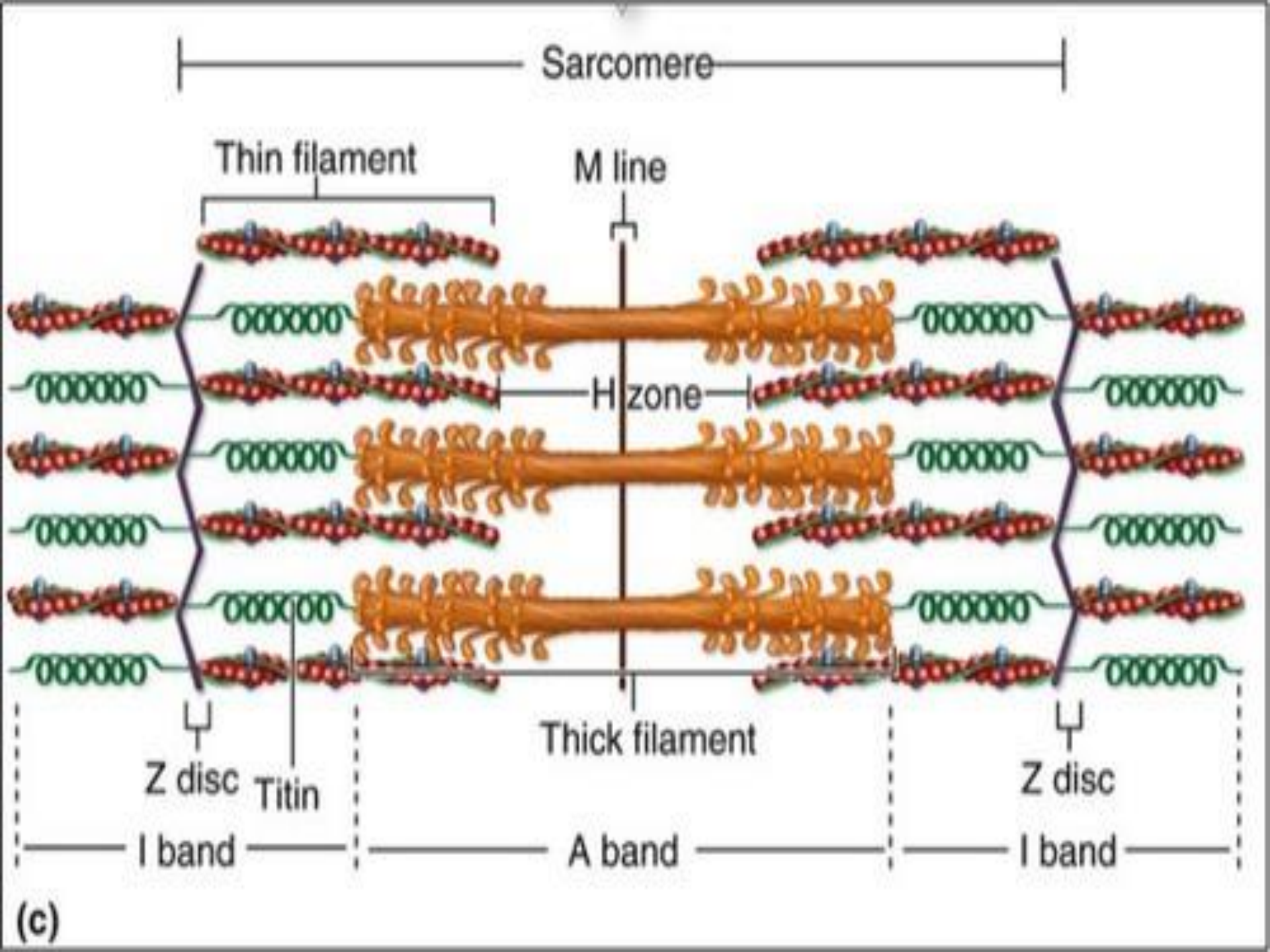
Interaction of thin and thick filaments



Breakdown of ATP and Cross-Bridge Movement (Part 2)

Sarcomere: Z disk to Z disk

- Repeating functional units of myofibril.
  about 10,000 sarcomeres per
  myofibril.
  each is about 2 um long.
- Differences in size, density and distribution of thick and thin filaments give the muscle fiber a banded or striated appearance.
- A bands: a dark band
- M line: protein to which myosin attaches
- H zone: thick but no thin filaments
- I bands: a light band
  thin but no thick filaments
  extend from A band of one sarcomere to A band of
  next sarcomere
- Z disc: filamentous network of protein.
- Titin filaments: elastic chains of amino acids; keep thick and thin filament in proper alignment.


Sarcomere
Thin filament
M line
H zone
Thick filament
Z disc
Titin
Z disc
I band
A band
I band
(c)

Sarcoplasmic Reticulum (SR)

- SR is an elaborate, smooth endoplasmic reticulum,
  runs longitudinally and surrounds each
  myofibril.
  forms chambers called terminal
  cisternae on either sides of T-tubule.
- A single T-tubule and 2 terminal cisternae form a triad.
- SR stores calcium when muscles not contracting.
- When stimulated calcium released into sarcoplasm.
- SR membranes have calcium pumps that function to pump calcium out of sarcoplasm back into SR after contraction.

Sarcoplasmic Reticulum (SR)

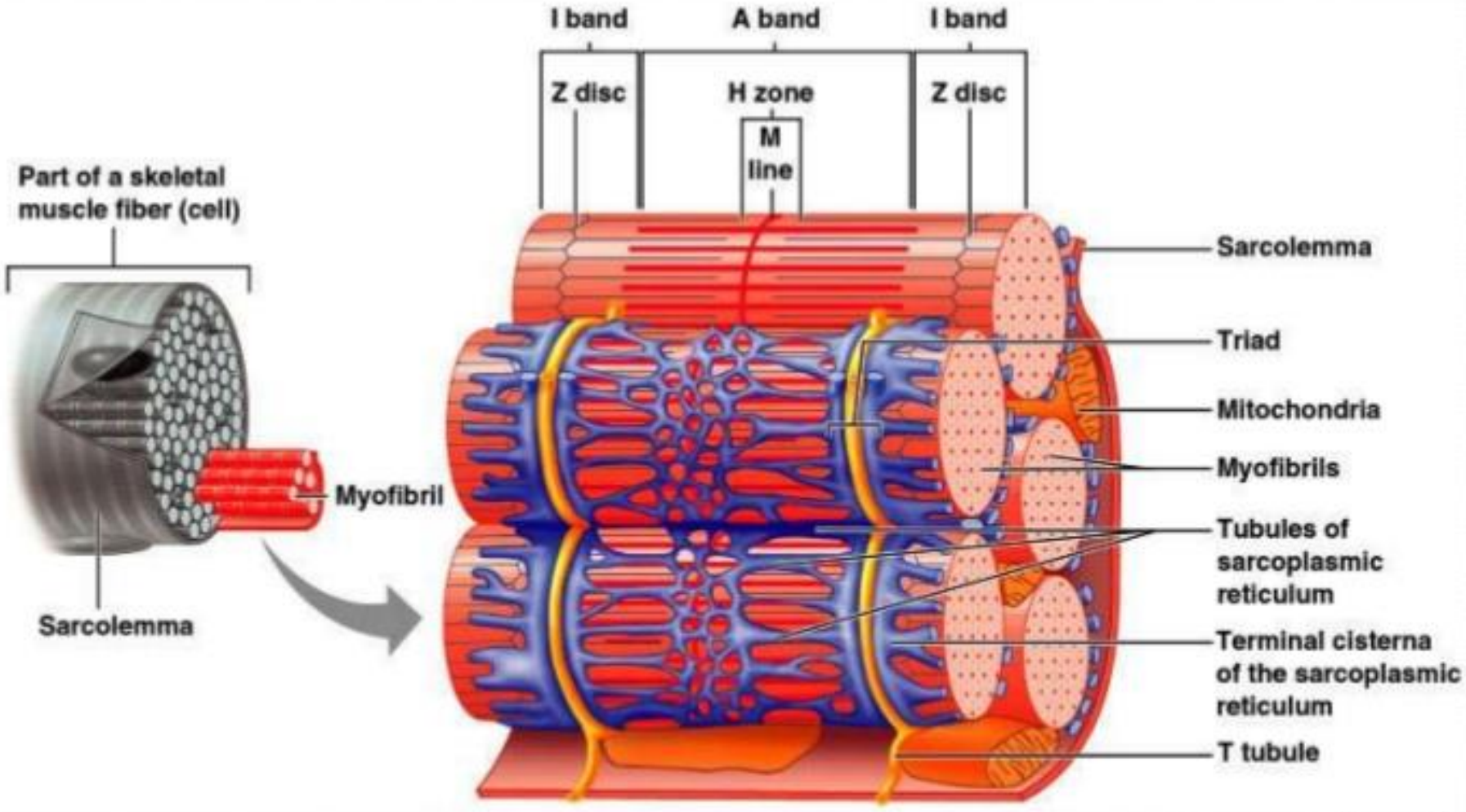
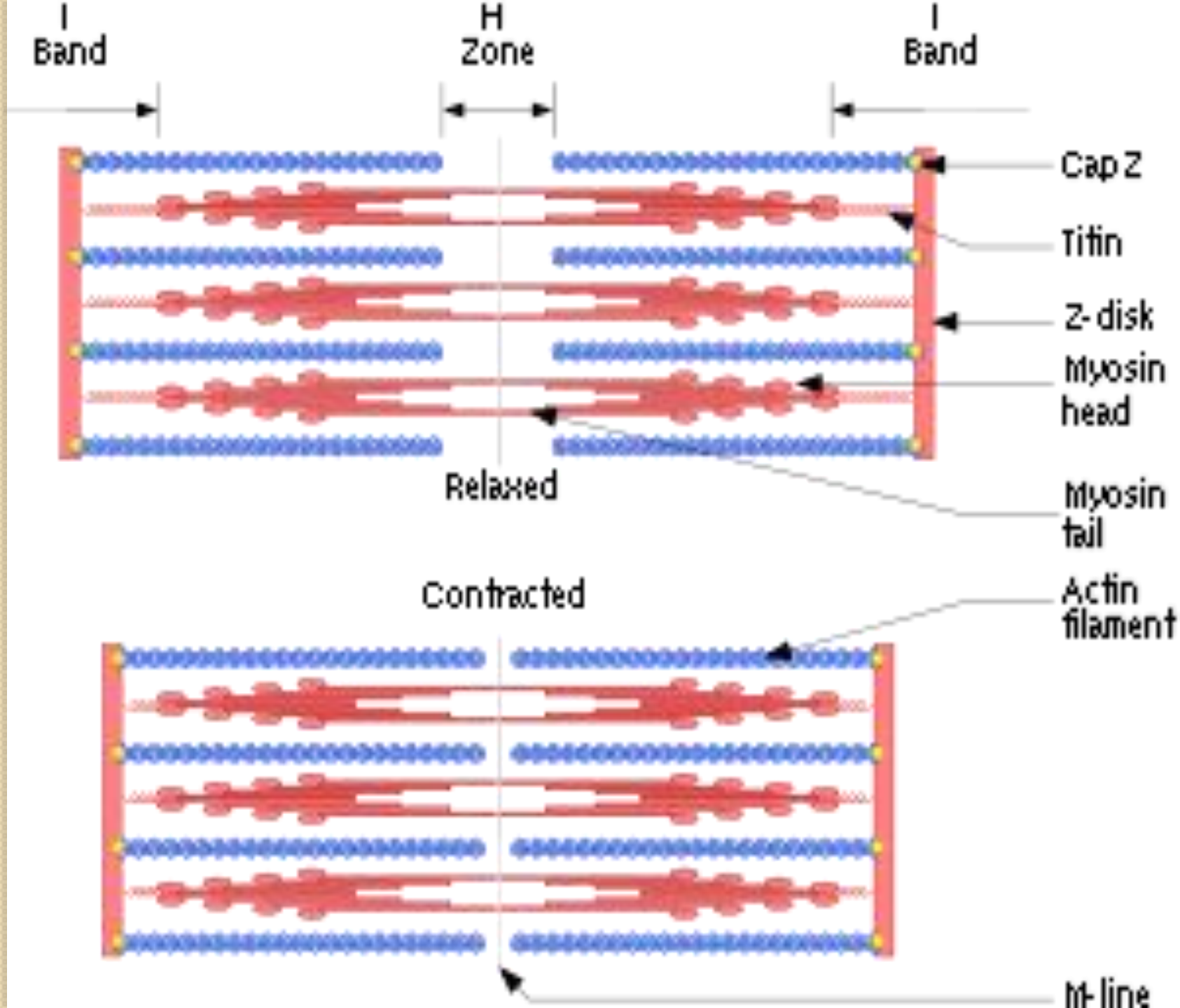


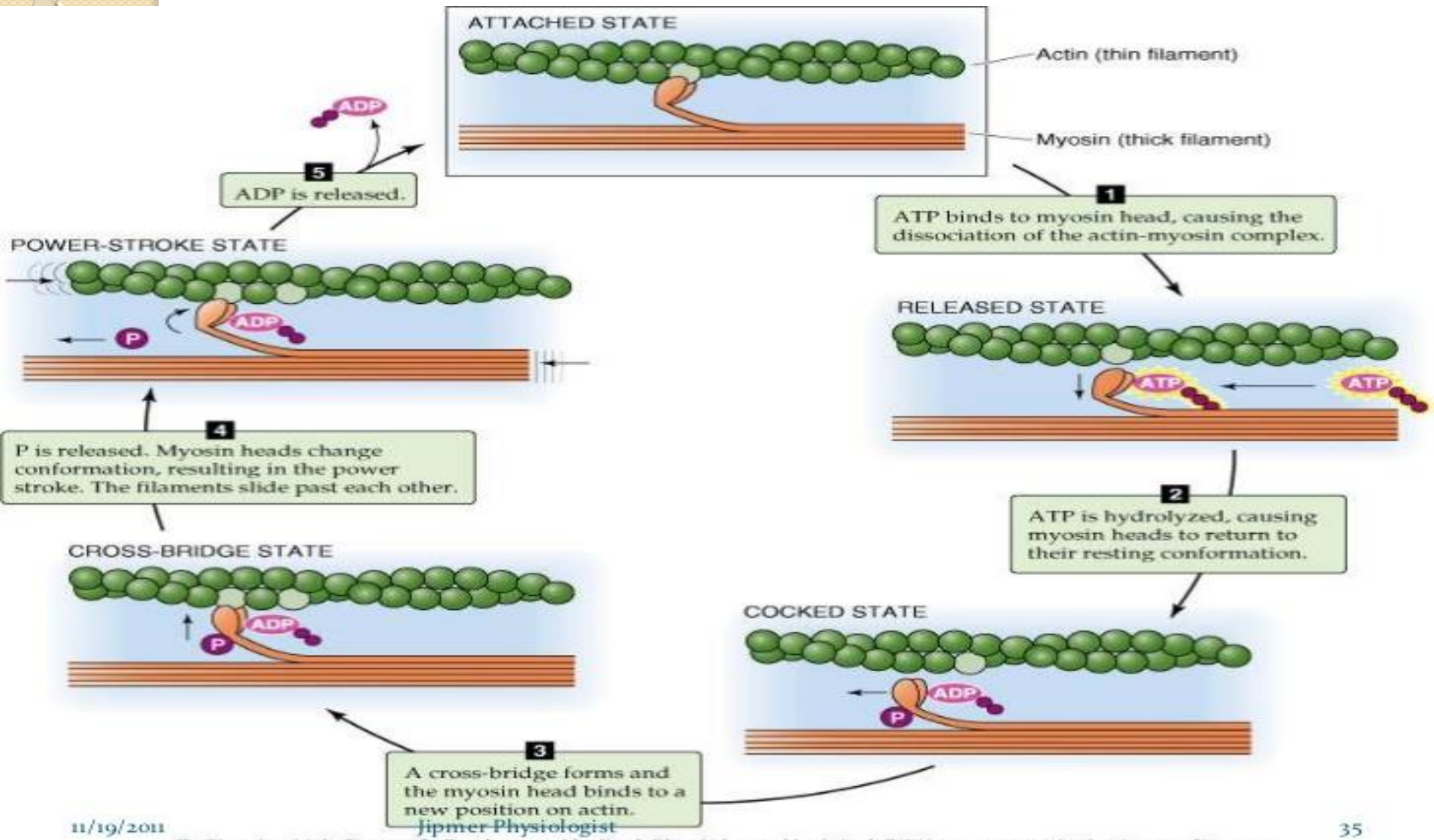
Figure 9.5

Sliding Filament Theory

- Thin filaments slide past the thick ones so that the actin and myosin filaments overlap to a greater distance.
- In the relaxed state, thin and thick filaments overlap only slightly.
- Upon stimulation, myosin heads bind to actin and sliding begins.
- Reduction in distance between Z-lines of sarcomere.
- Formation of cross bridges between actin and myosin filaments.


I Band
H Zone
I Band
Cap Z
Titin
Z-disk
Myosin head
Myosin tail
Relaxed
Contracted
Actin filament
M-line

Mechanism Of Theory



Calcium Release: Excitation/Contraction Coupling

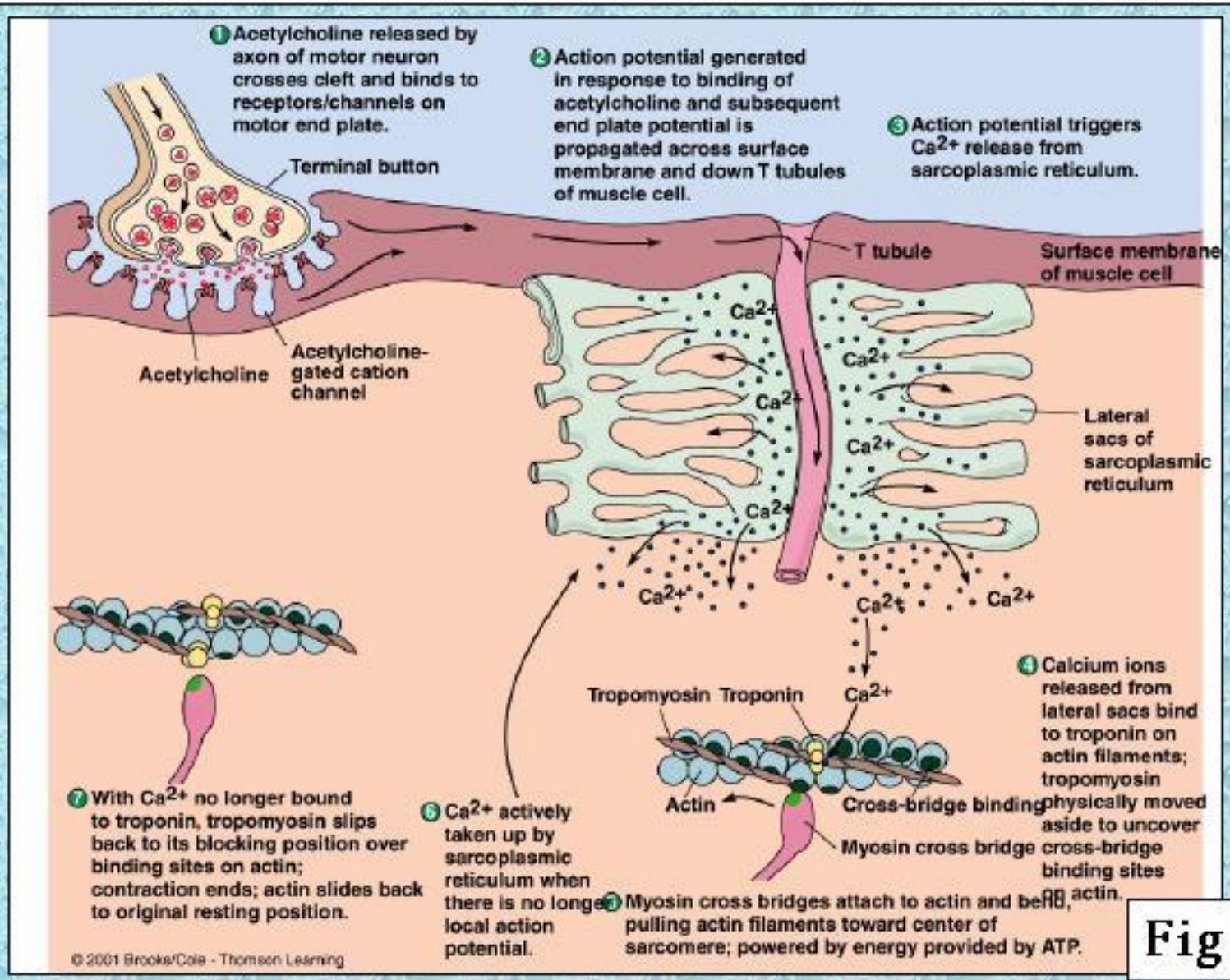


Fig 8-12

Energy Sources

- ATP provides immediate energy for muscle contraction from 3 sources:

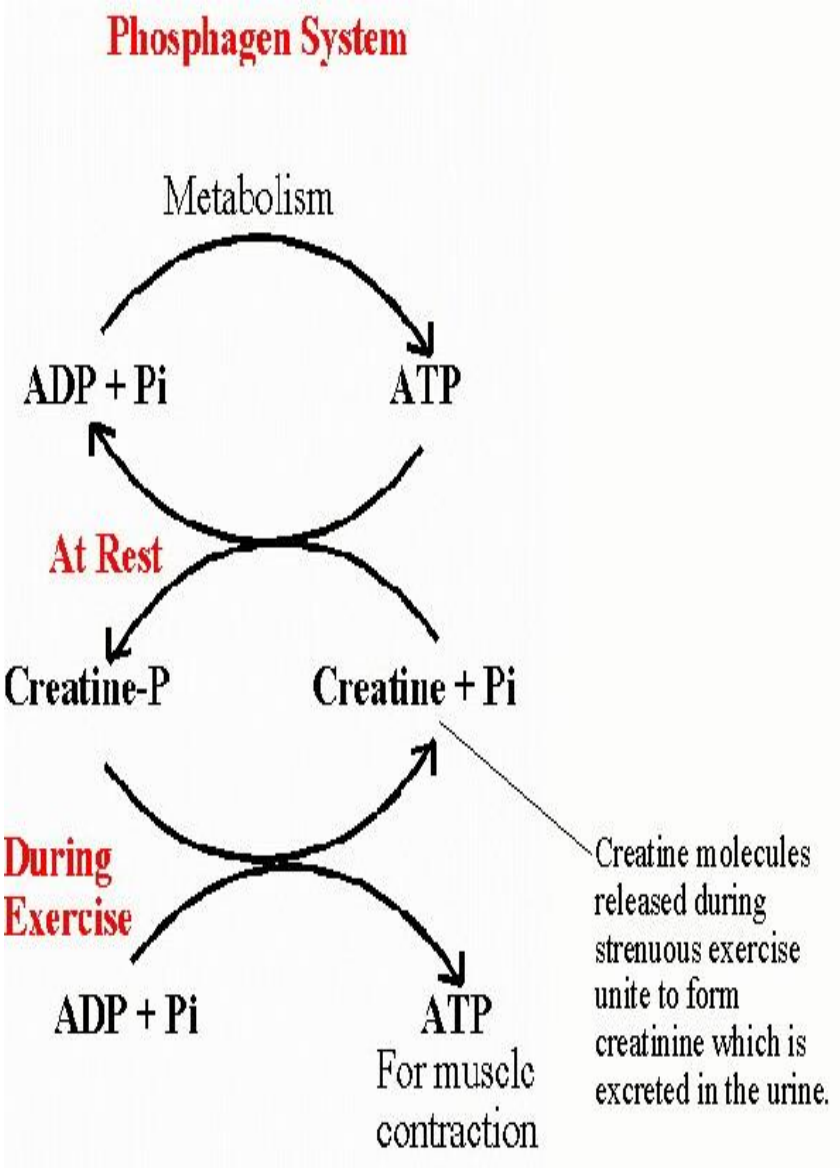
1. Creatine phosphate:
   - During resting conditions stores energy to synthesize ATP.

2. Anaerobic respiration:
   - Occurs in absence of oxygen and results in breakdown of glucose to yield ATP and lactic acid.

3. Aerobic respiration:
   - Requires oxygen and breaks downglucose to produce ATP, carbondioxide and water.
   - More efficient then anaerobic.

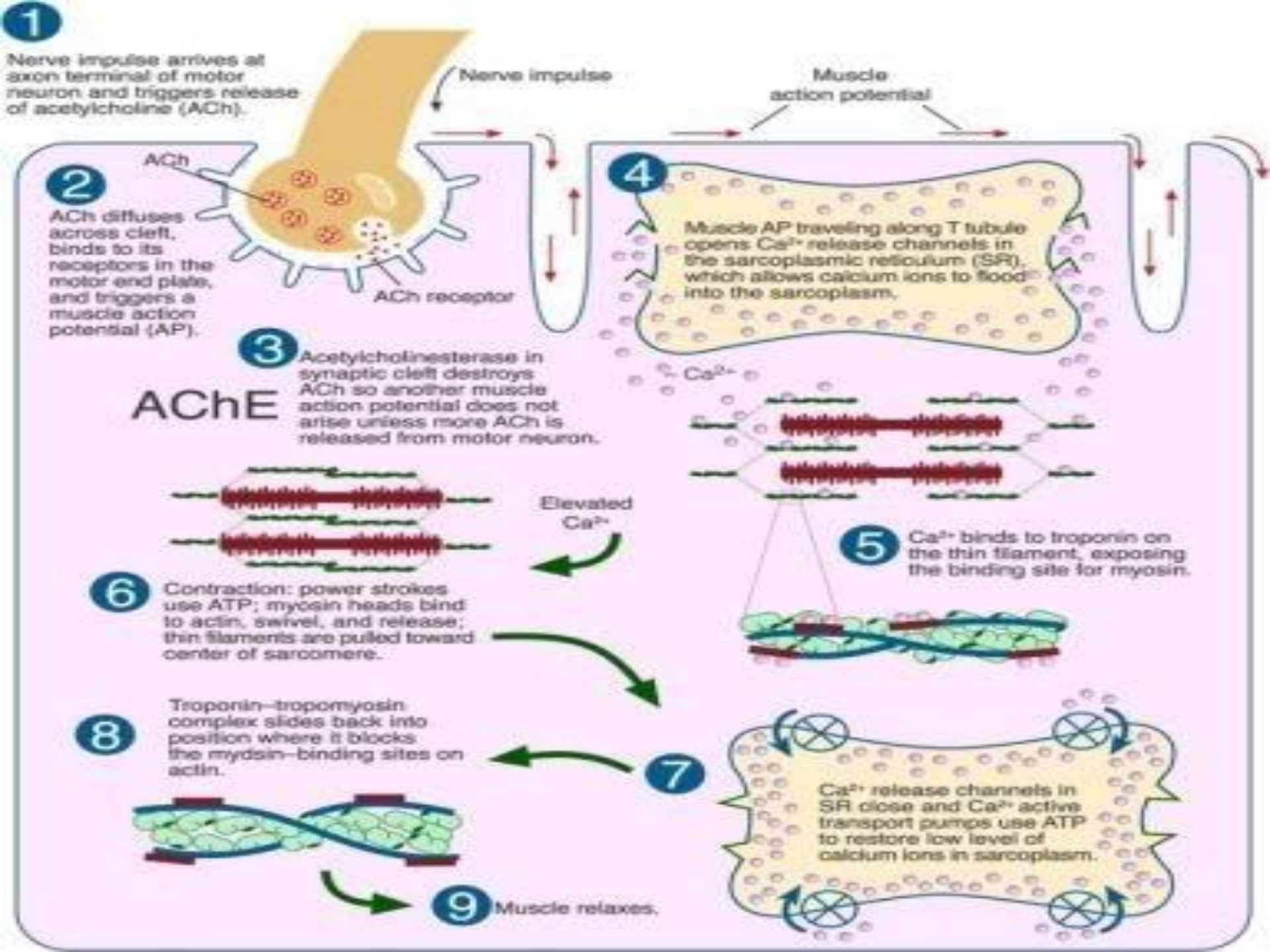
Direct Phosphorylation

- Muscle cells contain creatine phosphate(cp).
- CP is a high energy molecule.
- After ATP is depleted ADP is left.
- CP transfers energy to ADP to regenerate ATP.
- CP supplies are exhausted in about 20 seconds.



NEUROMUSCULAR JUNCTION

- The **neuromuscular junction** connects the nervous system to the muscular system via synapses between efferent nerve fibres and muscle fibres , also known as muscle cells.
- As an action potential reaches the end of a motor neuron, voltage-dependent calcium channels open allowing calcium to enter the neuron.
- motor neurons release acetylcholine (ACh), a small molecule neurotransmitter, which diffuses through the synapse and binds nicotinic acetylcholine receptors (nAChRs) on the plasma membrane of the muscle fiber, also known as the sarcolemma.
- The binding of ACh to the receptor can depolarize the muscle fiber, causing a cascade that eventually results in muscle contraction.


1
Nerve impulse arrives at axon terminal of motor neuron and triggers release of acetylcholine (ACh).
Nerve impulse
Muscle action potential
ACh
2
ACh diffuses across cleft, binds to its receptors in the motor end plate, and triggers a muscle action potential (AP).
ACh receptor
4
Muscle AP traveling along T tubule opens Ca^{2+} release channels in the sarcoplasmic reticulum (SR), which allows calcium ions to flood into the sarcoplasm.
Ca^{2+}
3
AChE
Acetylcholinesterase in synaptic cleft destroys ACh so another muscle action potential does not arise unless more ACh is released from motor neuron.
Elevated Ca^{2+}
5
Ca^{2+} binds to troponin on the thin filament, exposing the binding site for myosin.
6
Contraction: power strokes use ATP; myosin heads bind to actin, swivel, and release; thin filaments are pulled toward center of sarcomere.
8
Troponin–tropomyosin complex slides back into position where it blocks the myosin-binding sites on actin.
7
Ca^{2+} release channels in SR close and Ca^{2+} active transport pumps use ATP to restore low level of calcium ions in sarcoplasm.
9
Muscle relaxes.


THANK U