

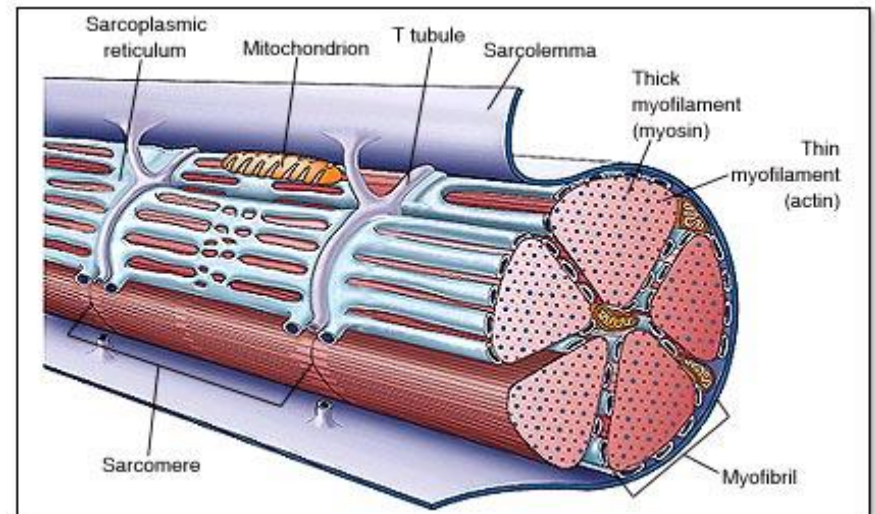
# Meat Technology



**Prof. Dr. Ayla Soyer**  
**Meat SCIENCE**

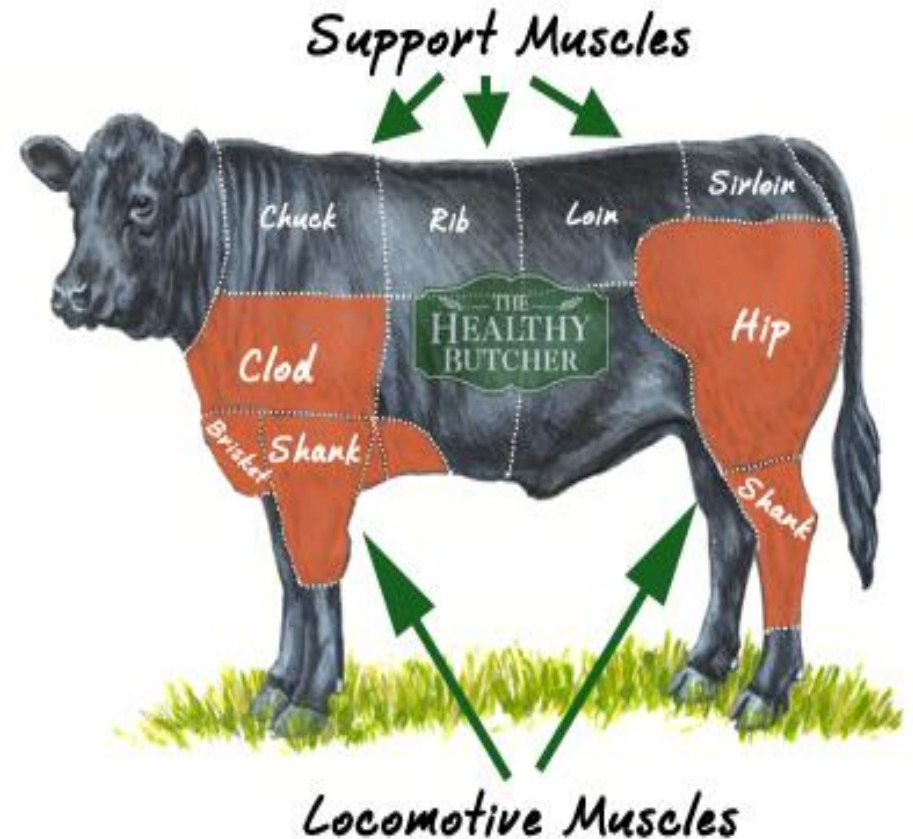
## **Content:**

- \*Muscle structure
- \*Muscle contraction and relaxation
- \*Energy sources for muscle contraction
- \*Muscle composition



# Function of muscle

- Movement
- Maintenance of posture
- Respiration
- Heat generation
- Communication
- Constriction of organs and blood vessels
- Pumping blood



# Properties of muscle tissue

All muscle cells share several properties: contractility, excitability, extensibility, and elasticity:

- **Contractility** is the ability of muscle cells to forcefully shorten.
- **Excitability** is the ability to respond to a stimulus, which may be delivered from a motor neuron or a hormone.
- **Extensibility** is the ability of a muscle to be stretched.
- **Elasticity** is the ability to recoil or bounce back to the muscle's original length after being stretched.

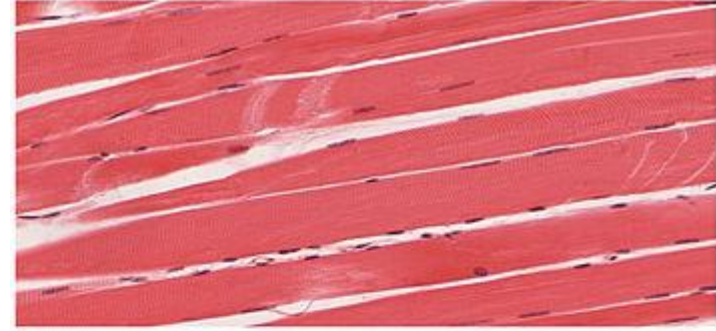
# Classification of muscles

- **Voluntary**
- **Involuntary**

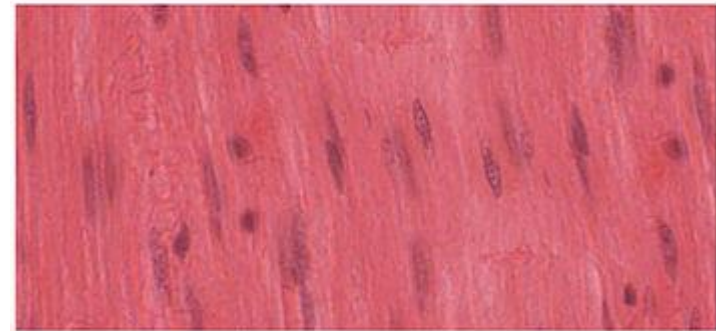
# Types of muscles

Muscle tissue — constitutes the bulk of the carcass of meat animals.

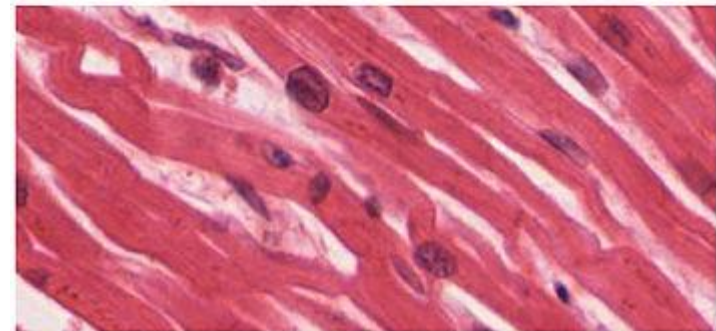
- Skeletal muscle — of principal interest to the meat industry.
- Cardiac muscle — muscle of the heart.
- Smooth muscle — located in arteries and the lymph system as well as the digestive and reproduction systems.



(a)



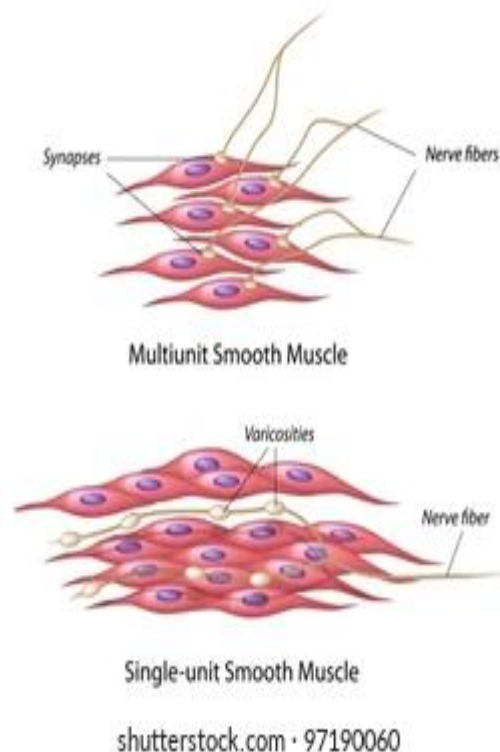
(b)



(c)

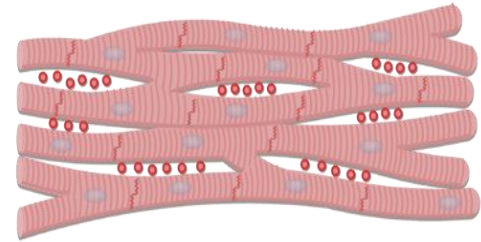
# Smooth muscles

- Involuntary muscles, found in the walls of internal organs and the blood vessels.
- Are not under voluntary control.
- Are spindle shaped and are not striated.
- Interlace to form sheets of smooth muscle tissue.
- Contains one nucleus near cell's center.
- Are found in many internal organs:
  - Stomach
  - Intestines
  - Blood vessel walls



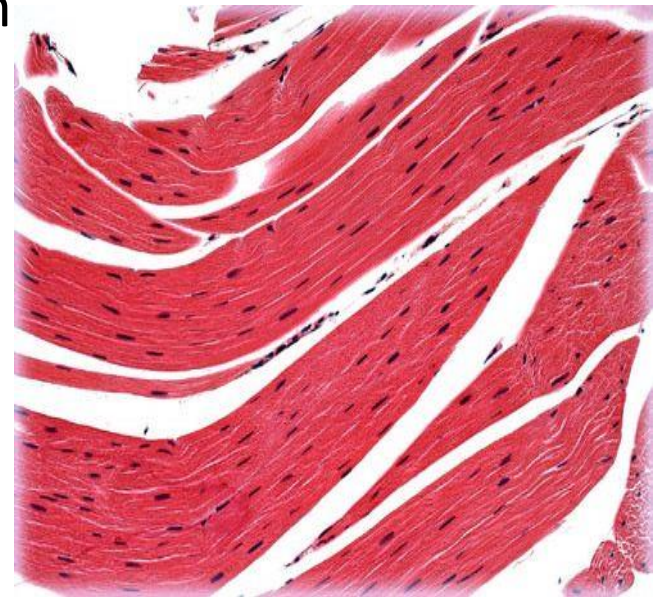
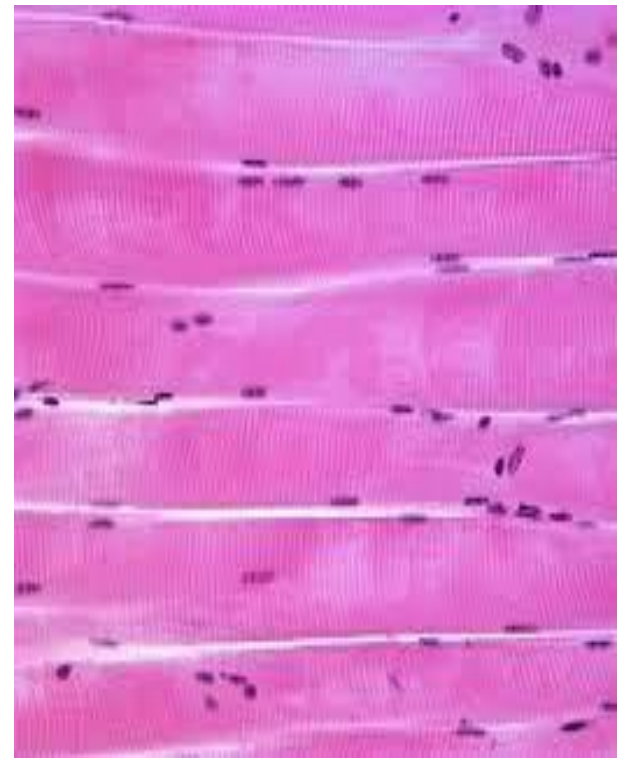
# Cardiac muscles

- Muscles that form a network to make up the heart. Not under control of the brain, but under their own control.
- Only found in the heart.
- Are not under voluntary control.
- Contract without direct stimulation by the nervous system.
- Are faintly striated, branching, mononucleated cells.



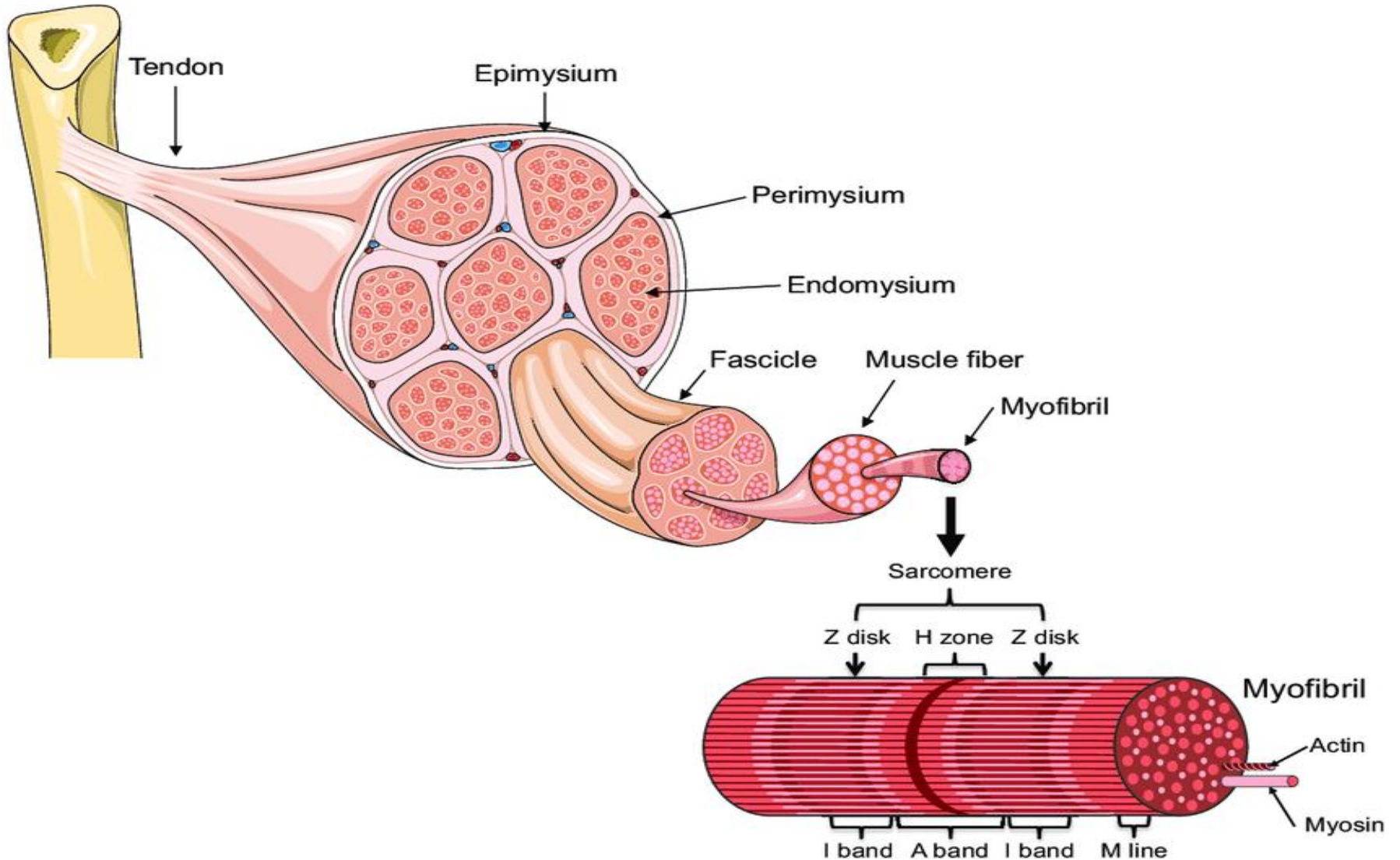
# Skeletal muscles

- made of elongated cells called
- **MUSCLE FIBERS**
- Have a striped appearance.
- Are voluntary muscles
- This is a majority of the muscle tissue in the body.
- Are grouped into dense bundles called **FASCICLES**
- Are large and have more than one nucleus
- Most are voluntary





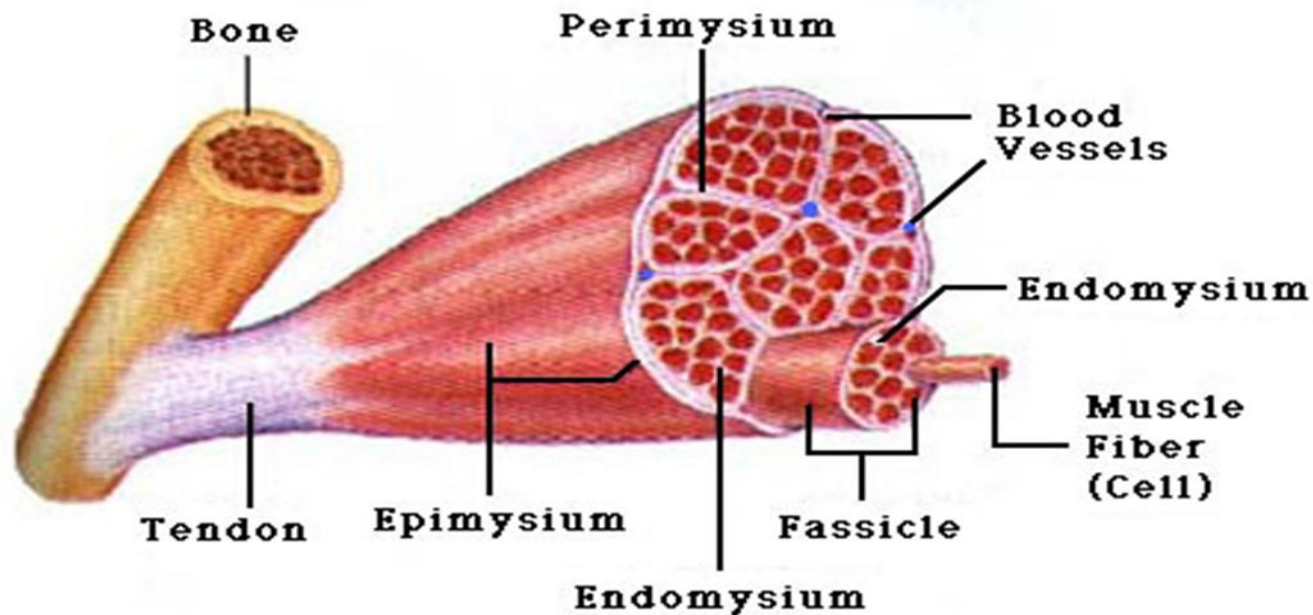
# Skeletal muscle organization



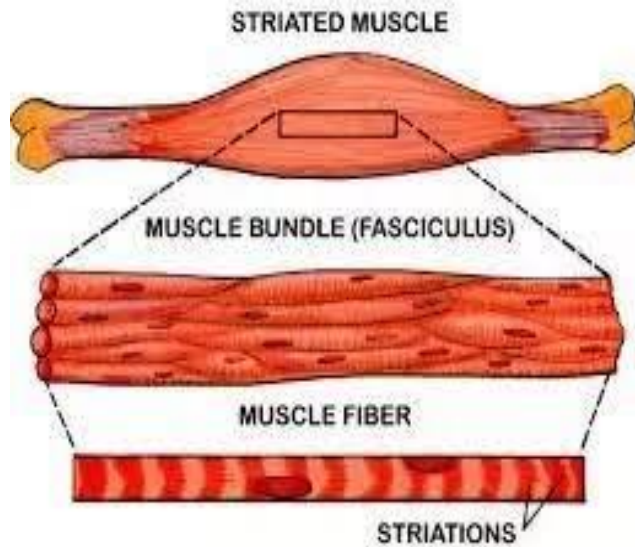
# Structure of skeletal muscle:

## *Connective tissue covering*

- Epimysium
- Perimysium
- Endomysium



# Skeletal muscle structure



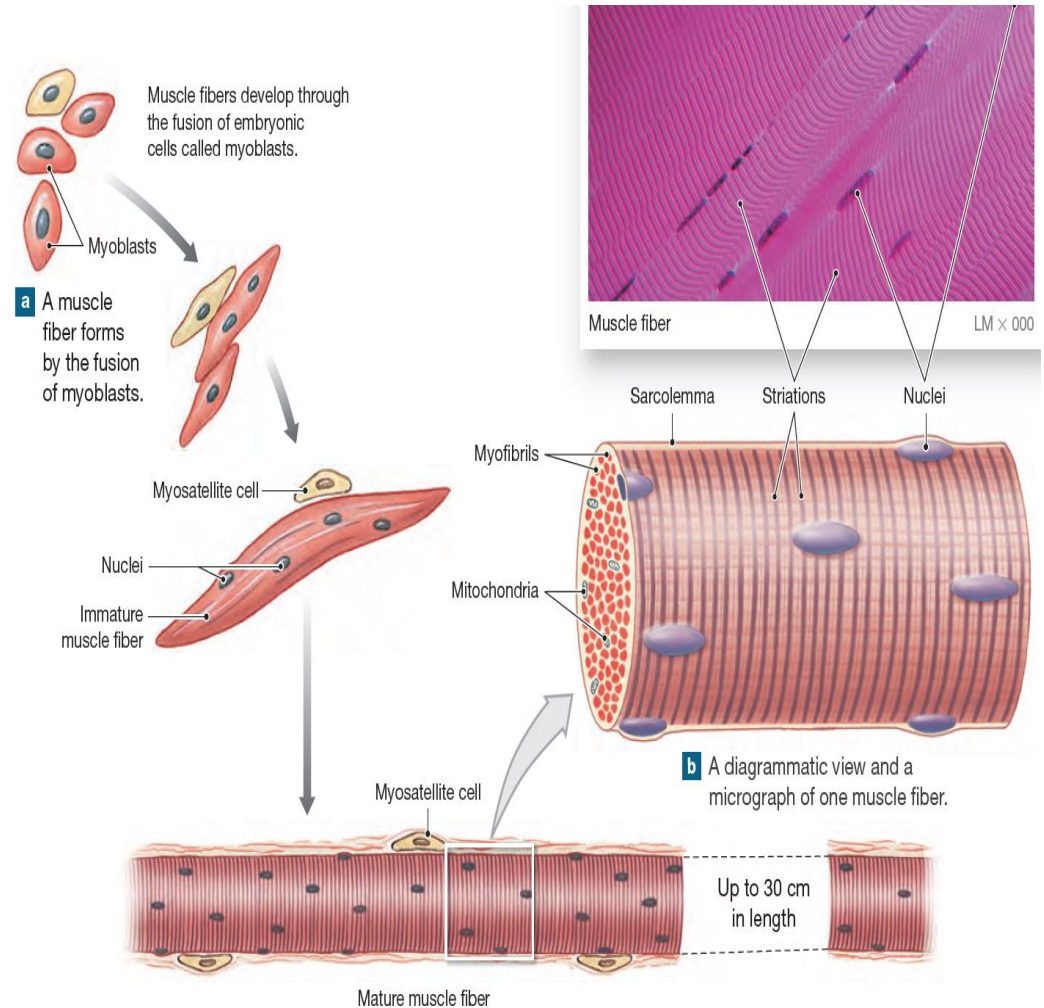
- Composed of muscle cells (fibers), connective tissue, blood vessels, nerves.
- Fibers are long, cylindrical, and multinucleated.
- Tend to be smaller diameter in small muscles and larger in large muscles , 1 mm – 4 cm in length.



striated muscle cells

# Skeletal muscle structure

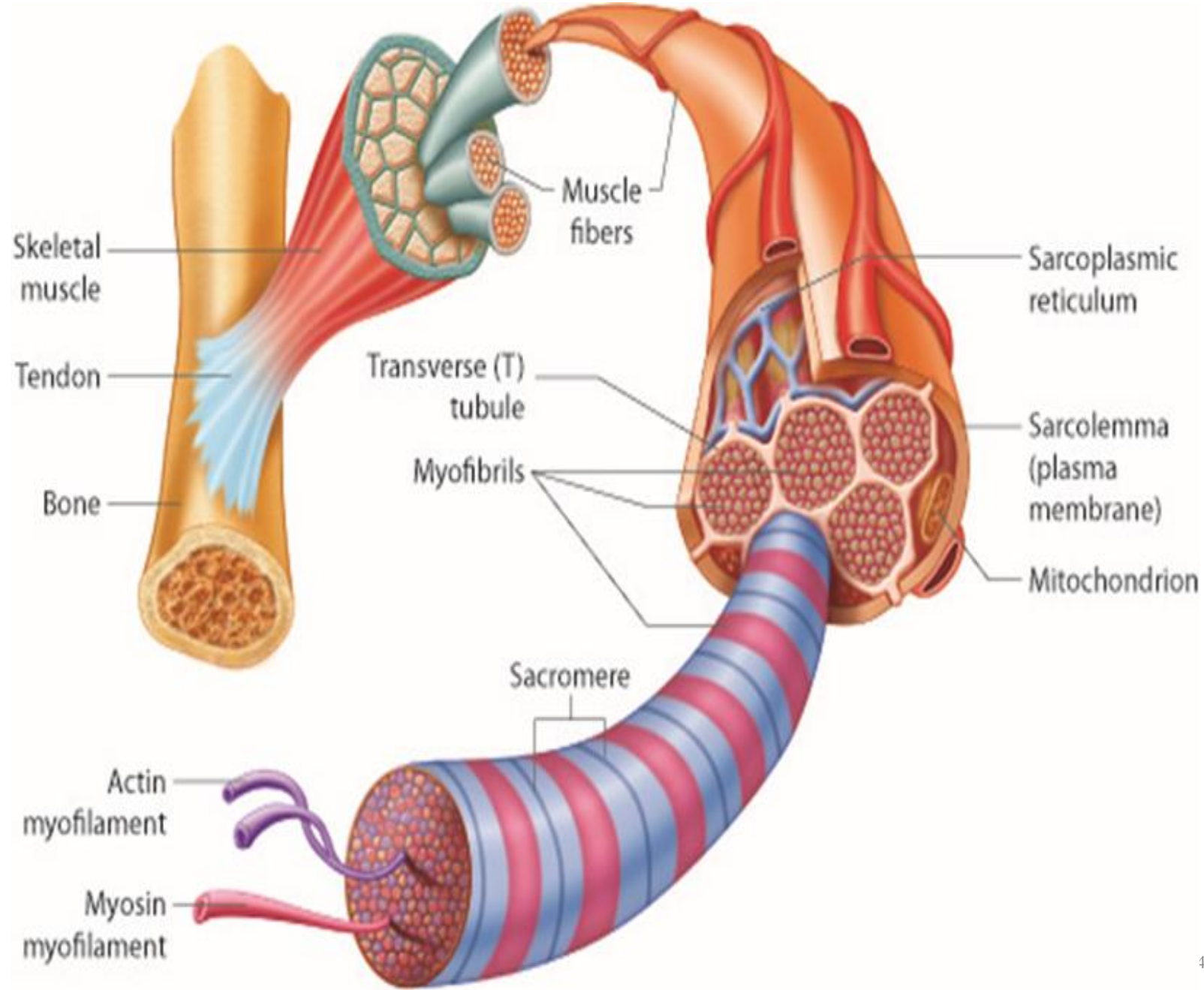
- Developed from myoblasts; numbers remain constant
- Striated appearance
- Nuclei are peripherally located



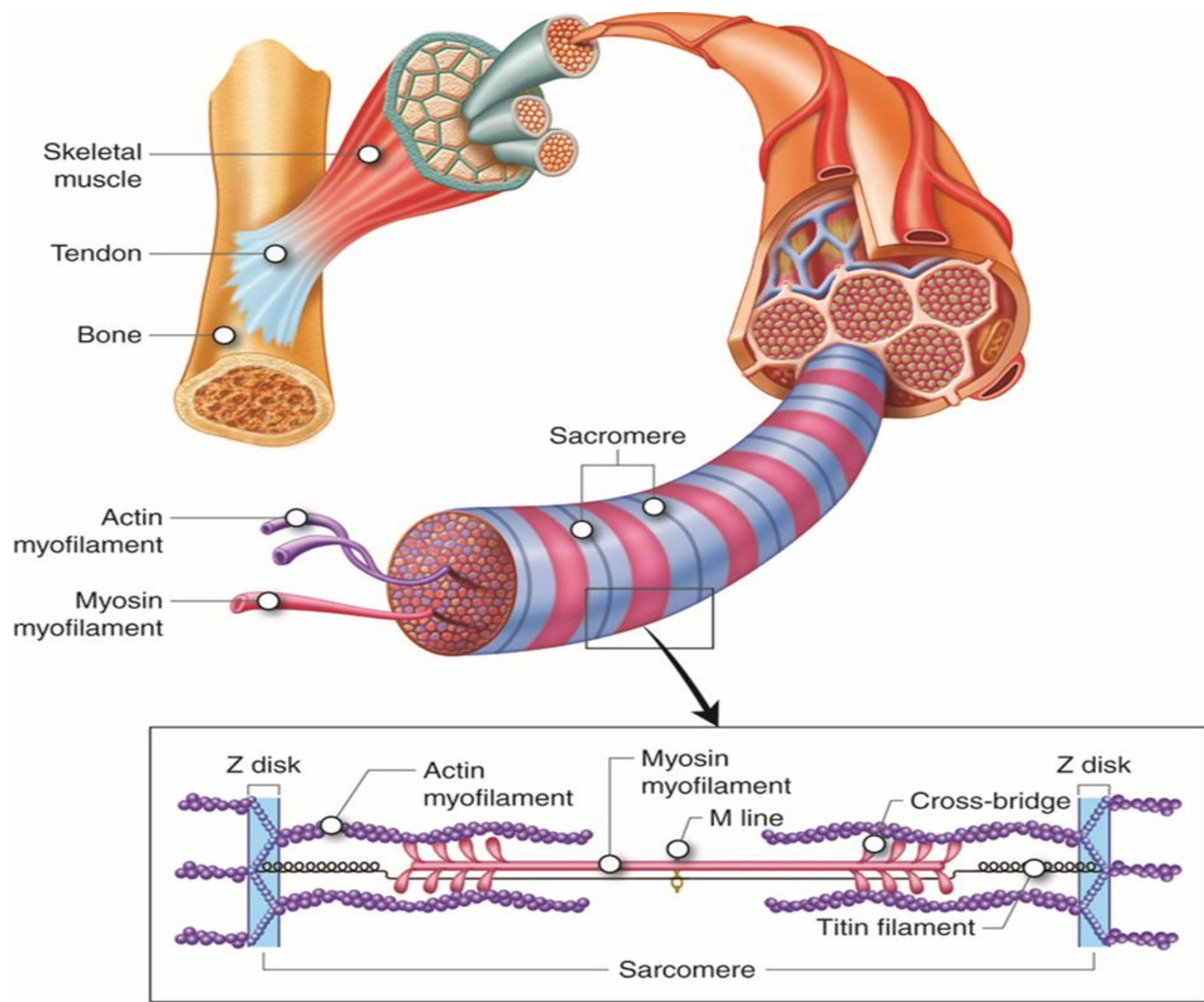
# Muscle fiber anatomy

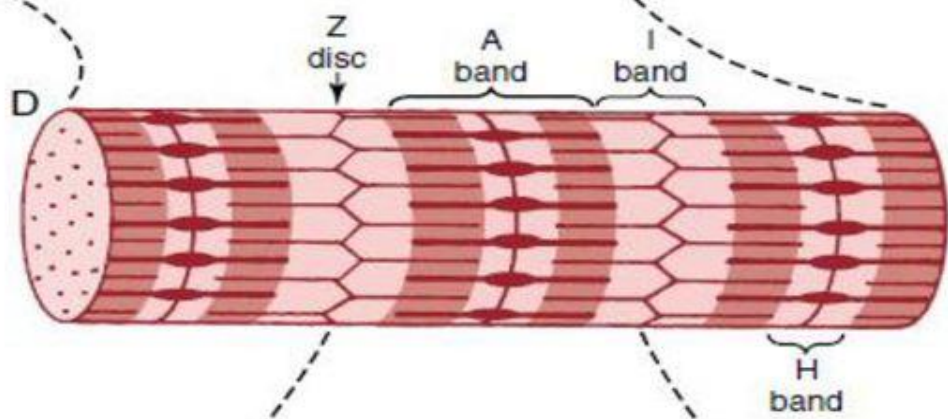
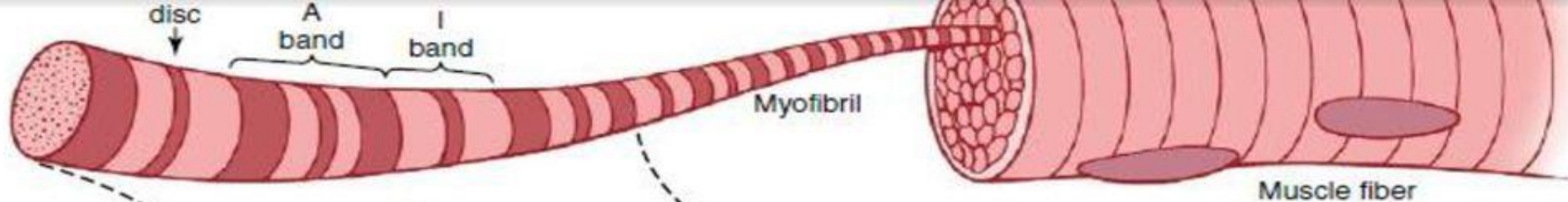
- **Sarcolemma**- cell membrane
  - Surrounds the **sarcoplasm** (cytoplasm of fiber)
    - Contains many of the same organelles seen in other cells.
    - An abundance of the oxygen-binding protein **myoglobin**
  - Punctuated by openings called the **transverse tubules (T-tubules)**
- **Myofibrils**-cylindrical structures within muscle fiber
  - Are bundles of protein filaments (= **myofilaments**)
    - Two types of myofilaments
      - **Actin filaments** (thin filaments)
      - **Myosin filaments** (thick filaments)

# Organization of a muscle fiber



# Organization of a muscle fiber

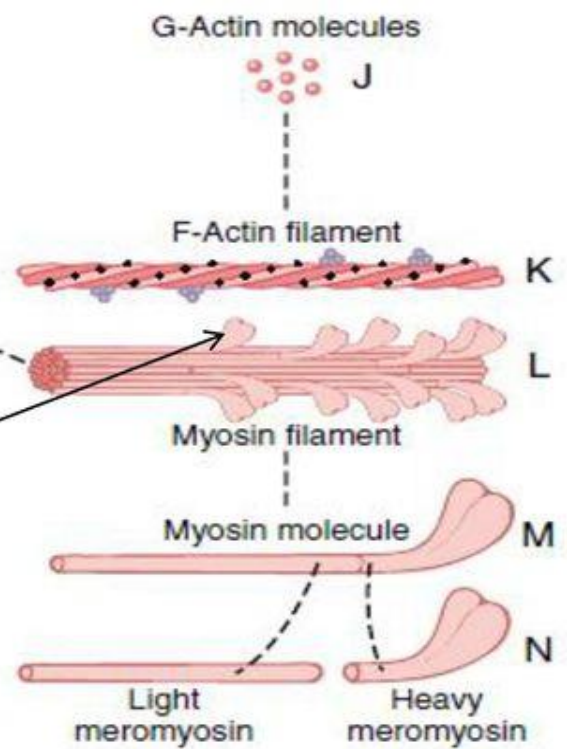
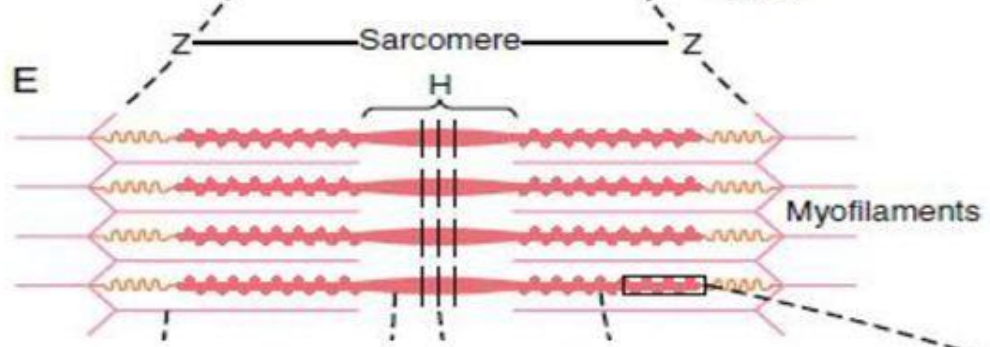




**3000 Actin**

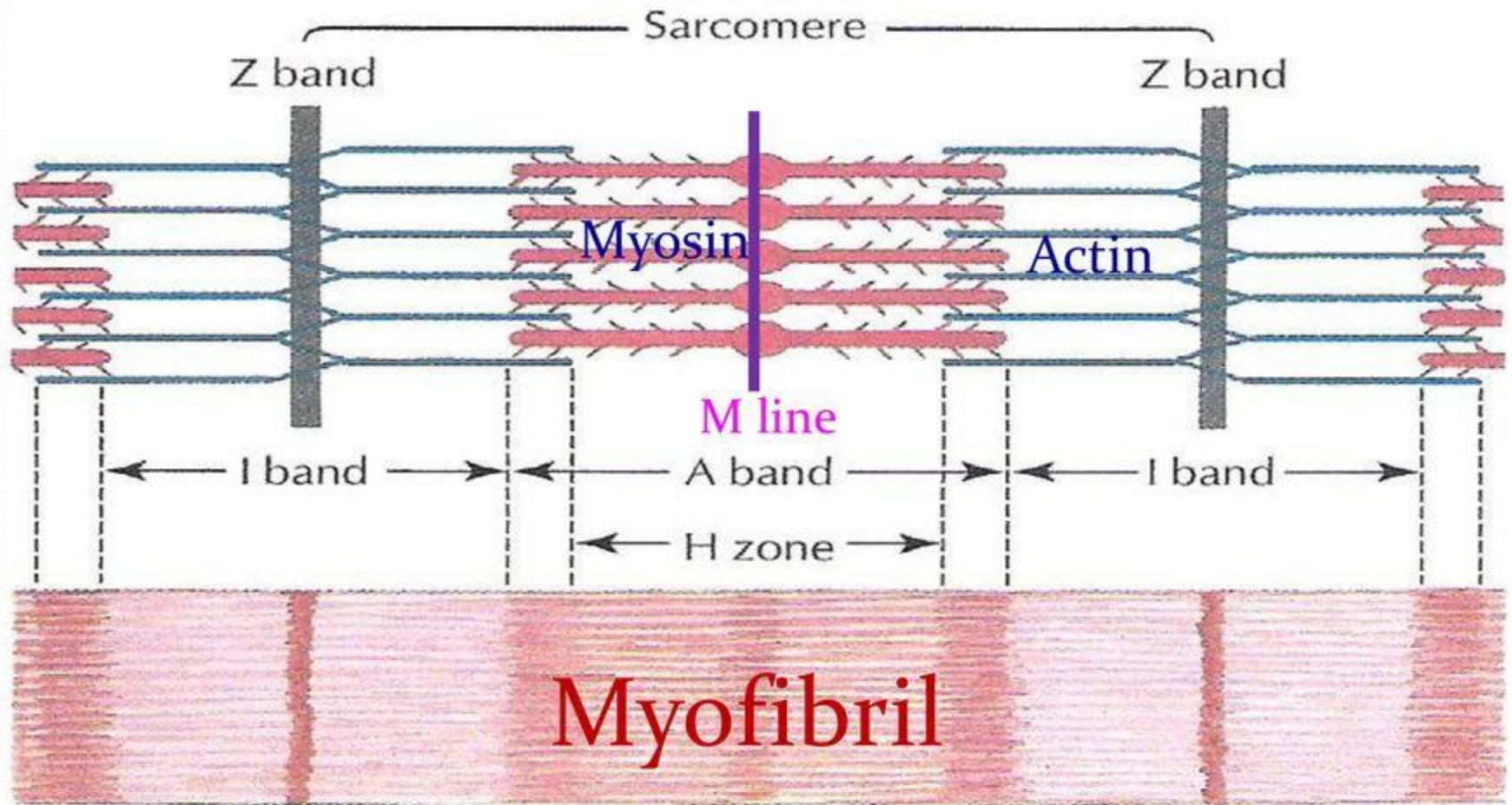
**1500 Myosin**

Responsible for the actual muscle contraction

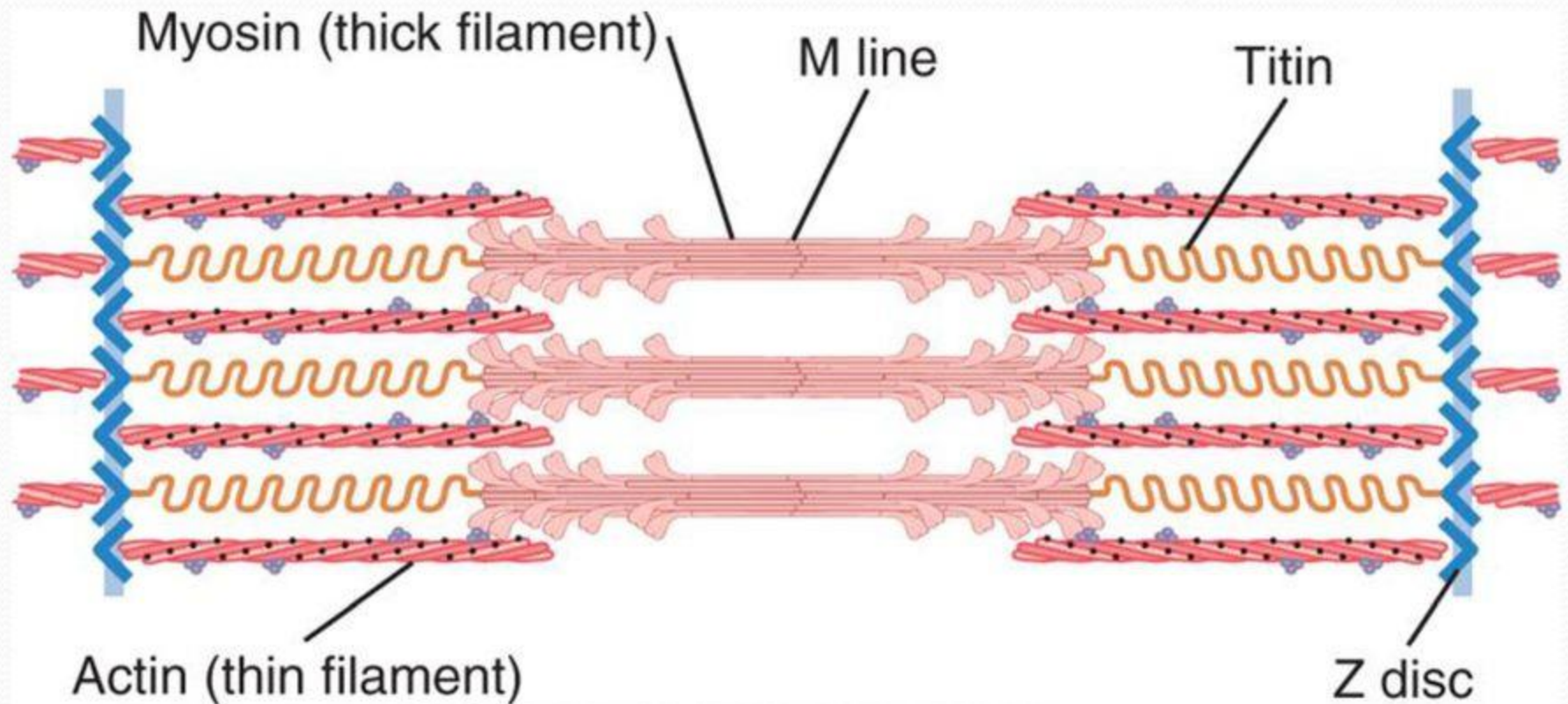


*Cross-bridges*





The light and **dark** bands give skeletal and cardiac muscle their striated appearance.



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Fig. 6.3 Organization of proteins in a sarcomere

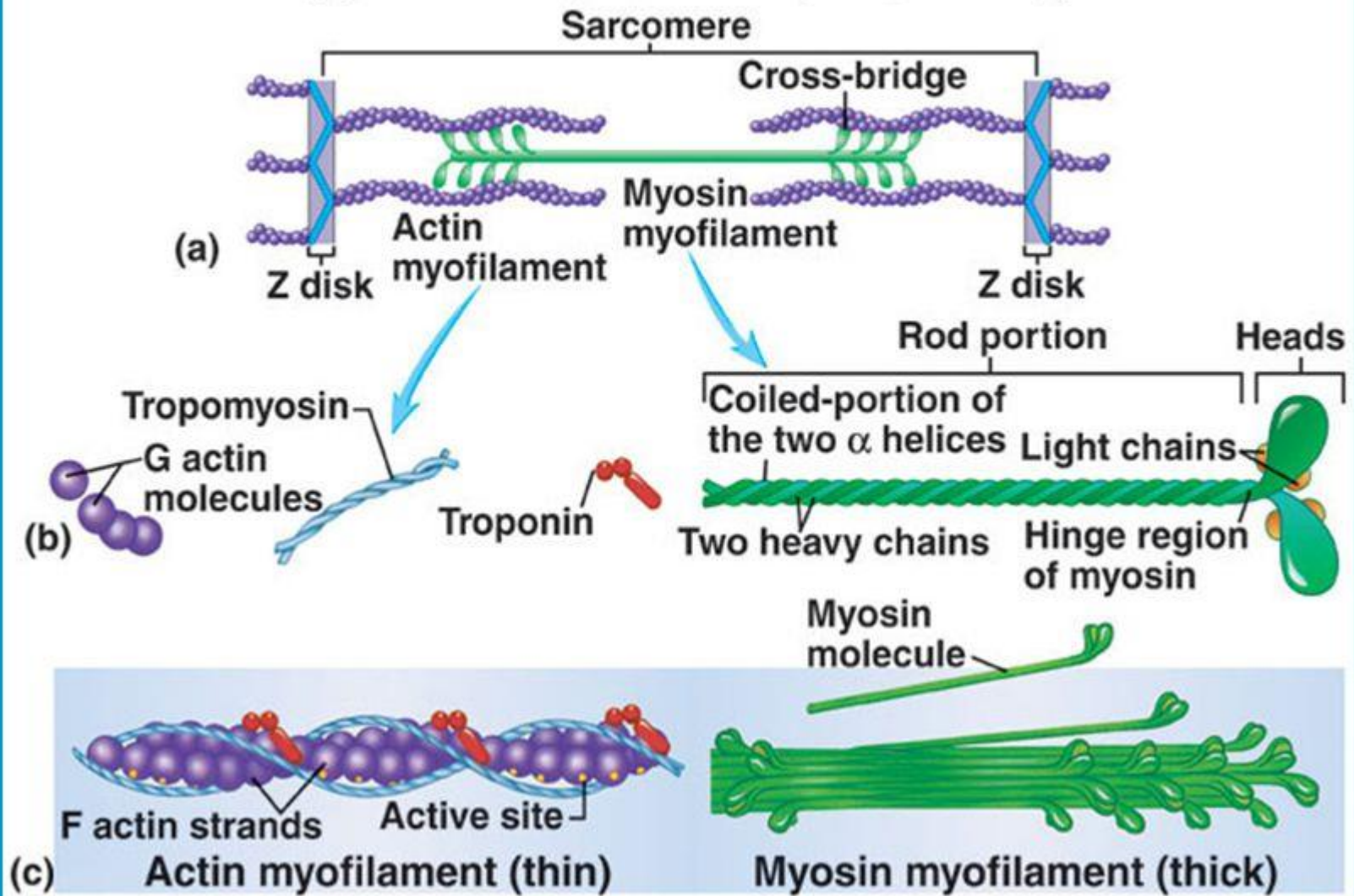
➤ **Titin** filaments keep the myosin and actin filaments in place.

# Muscle proteins

- Contractile proteins
  - Actin- thin myofilament
  - Myosin- thick myofilament
- Regulatory proteins
  - Tropomyosin
  - Troponin
- Attachment proteins
  - Titin, nebulin, alpha actinin, dystropin

# Structure of Actin and Myosin

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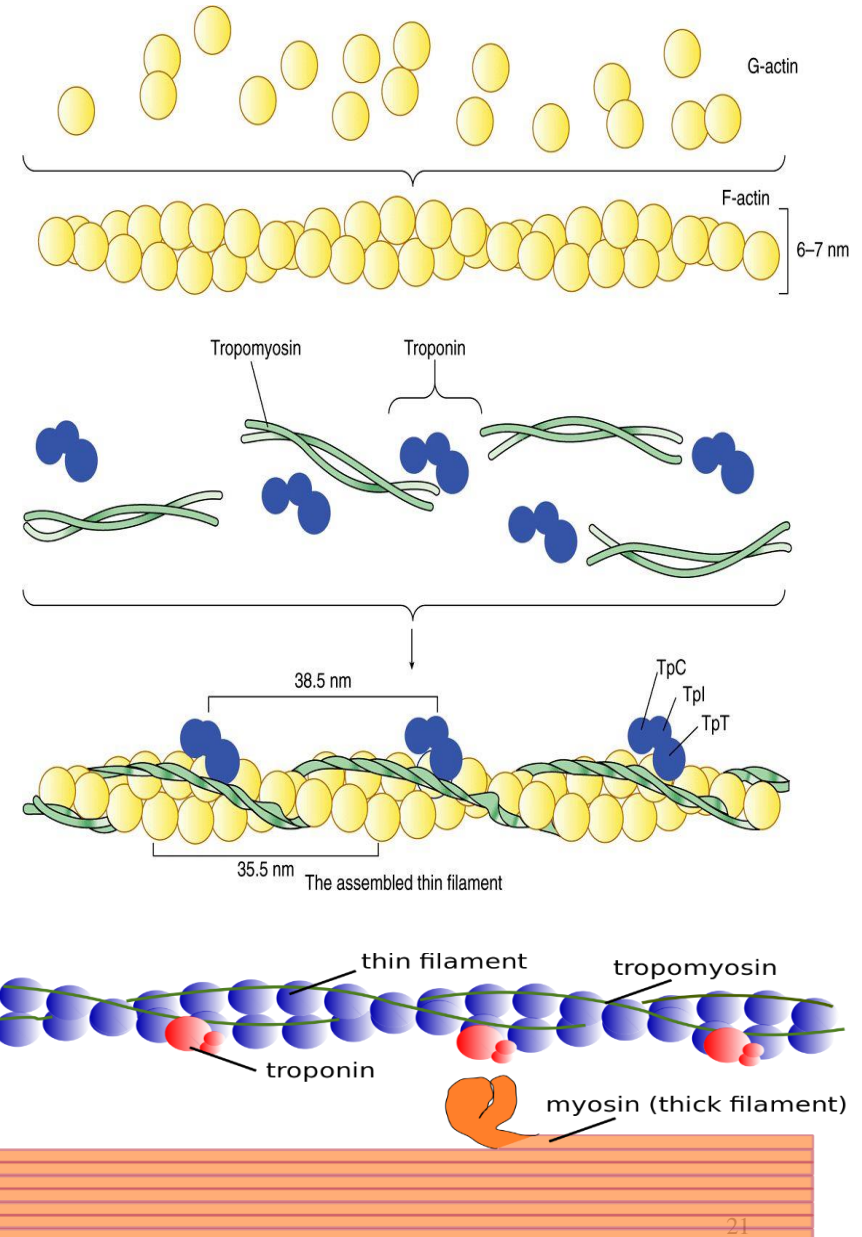
# Thin myofilament

Composed of three major proteins:

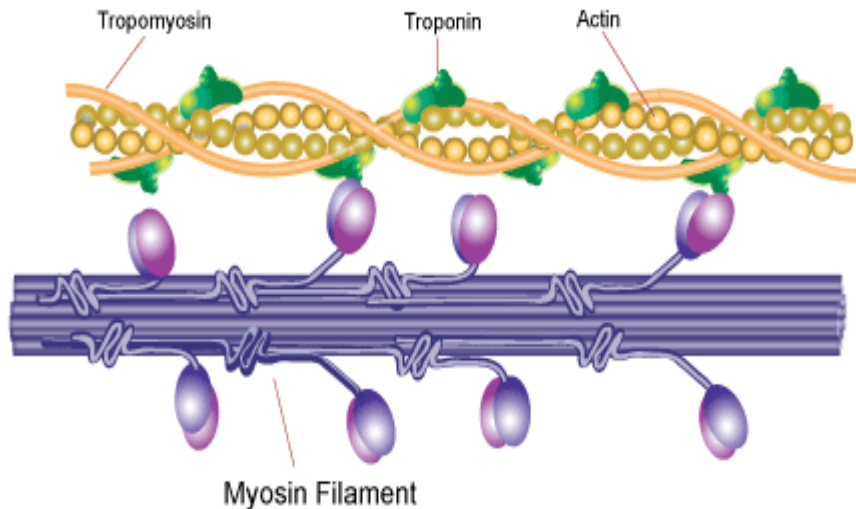
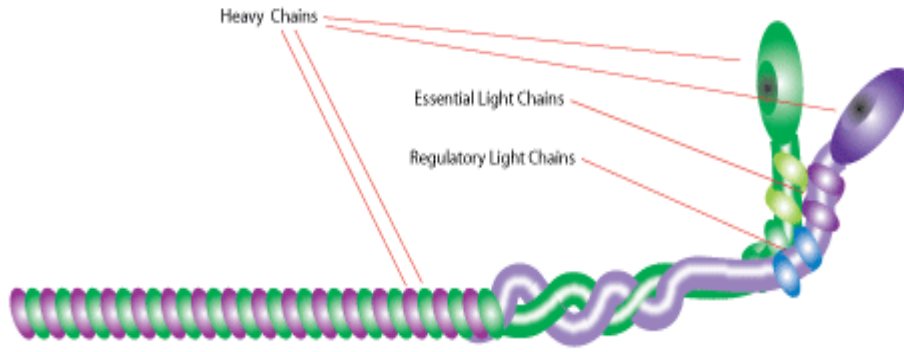
1. **F (fibrous) actin**
2. **Tropomyosin**
3. **Troponin**

- **Tropomyosin:** an elongated protein winds along the Groove of the F actin double helix.
- **Troponin** is composed of three subunits:
  - Tn-A: binds to actin
  - Tn-T: binds to tropomyosin
  - Tn-C: binds to calcium ions

# Thin filaments



# Myosin (thick) myofilament



- Many elongated myosin molecules shaped like golf clubs.
- Single filament contains roughly 300 myosin molecules.
- Molecule consists of two heavy myosin molecules wound together to form a rod portion lying parallel to the myosin myofilament and two heads that extend laterally.
- Myosin heads
  - Can bind to active sites on the actin molecules to form cross-bridges. (actin binding site)
  - Attached to the rod portion by a hinge region that can bend and straighten during contraction.
  - Have ATPase activity

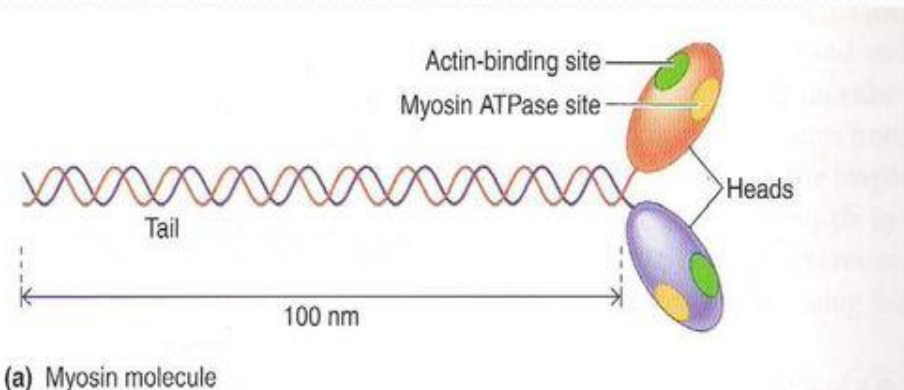
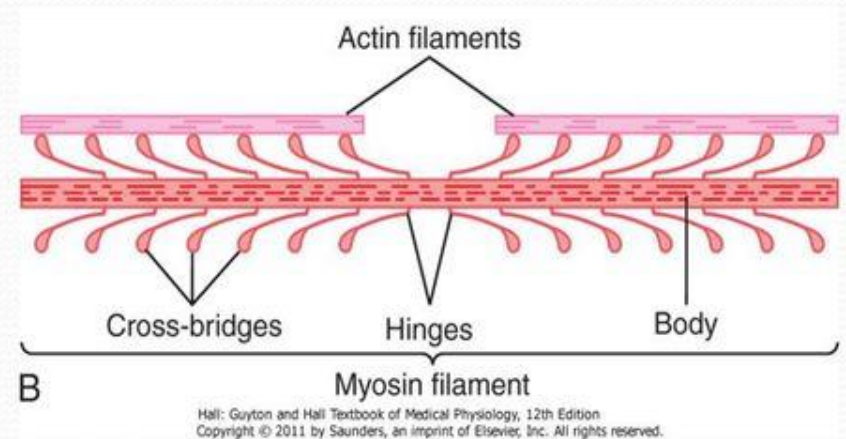
**Myosin filaments** are composed of multiple myosin molecules.

Each Myosin molecule has:

- (1) Head
- ( 2 ) Tail
- (3) Hinge (joint )

Each myosin head contains:

- (1) Actin binding site
- (2) Myosin ATPase site

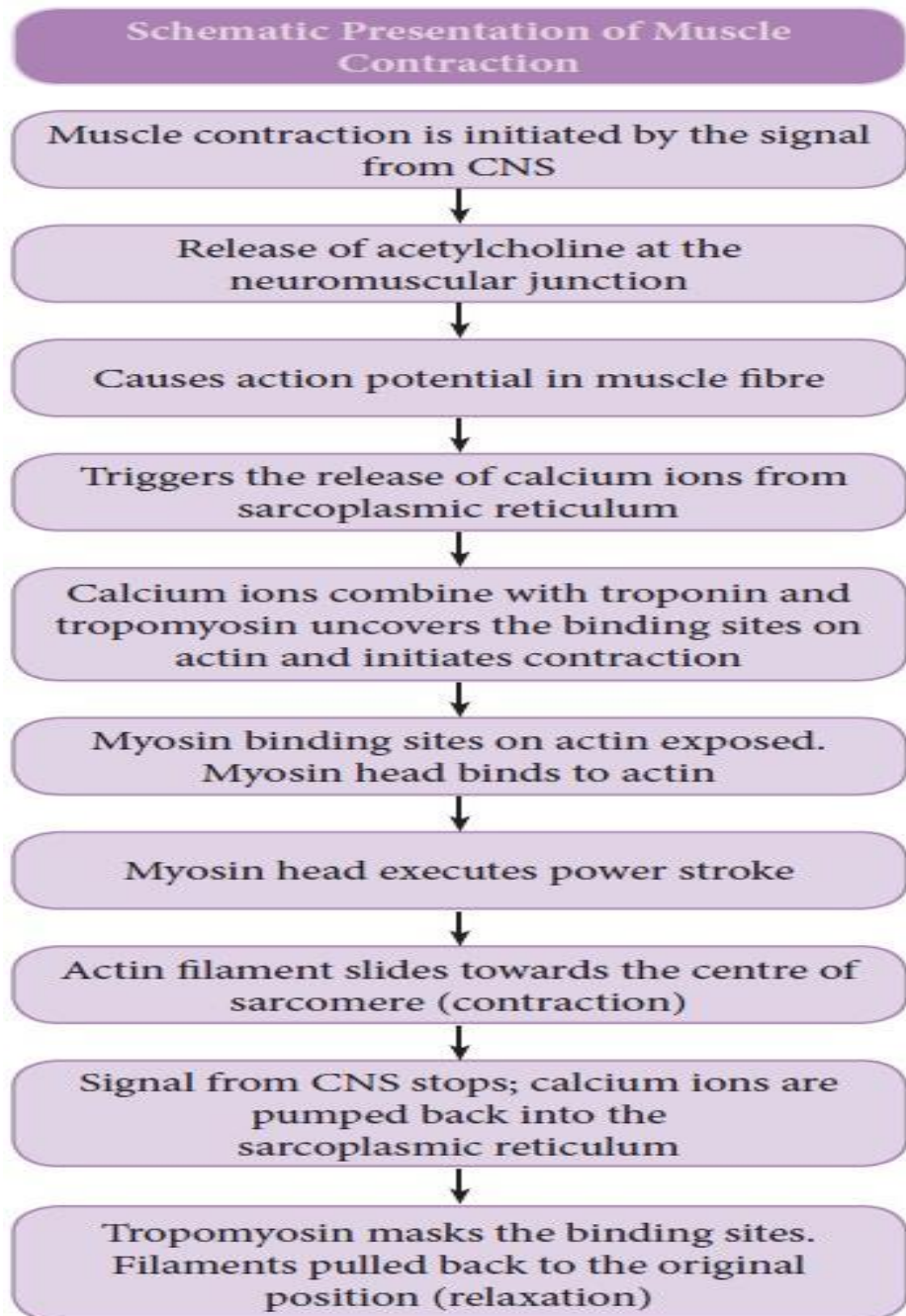


# Muscle contraction and relaxation

- Sliding filament theory in 1954, Andrew F. Huxley and Rolf Niedergerke proposed the sliding-filament theory to explain muscle contraction.
- According to this theory, overlapping actin and myosin filaments of fixed length slide past one another in an energy requiring process, resulting in muscle contraction.
- The contraction of muscle fibre is a remarkable process that helps in creating a force to move or to resist a load.
- The force which is created by the contracting muscle is called muscle tension.
- Contraction is the creation of tension in the muscle which is an active process
- Relaxation is the release of tension created by contraction.

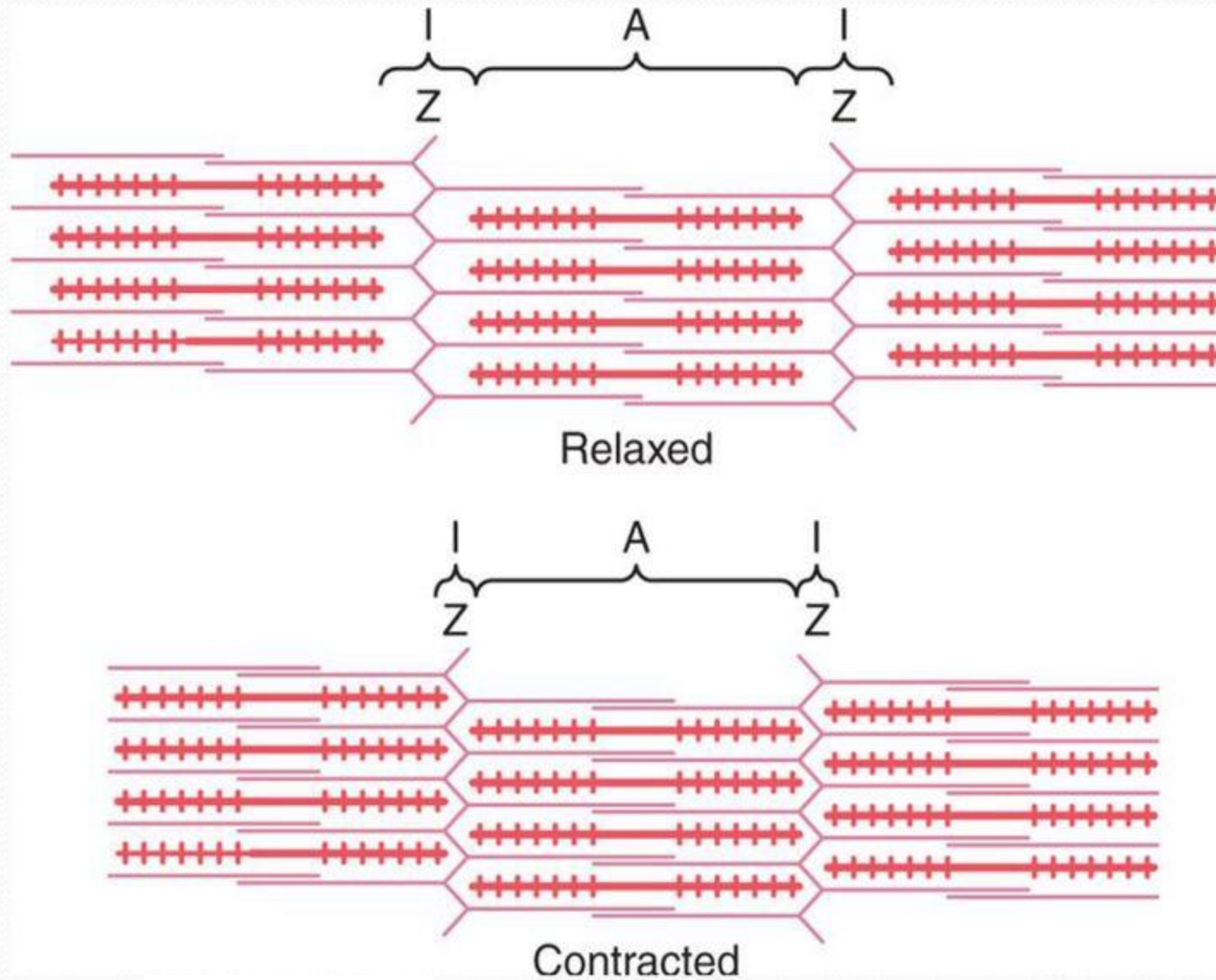


# Muscle contraction



# Molecular Mechanism of Muscle Contraction

Muscle  
Contraction  
Occurs by a  
Sliding Filament  
Mechanism



Relaxed and contracted states of a myofibril.

# Excitation-Contraction Coupling

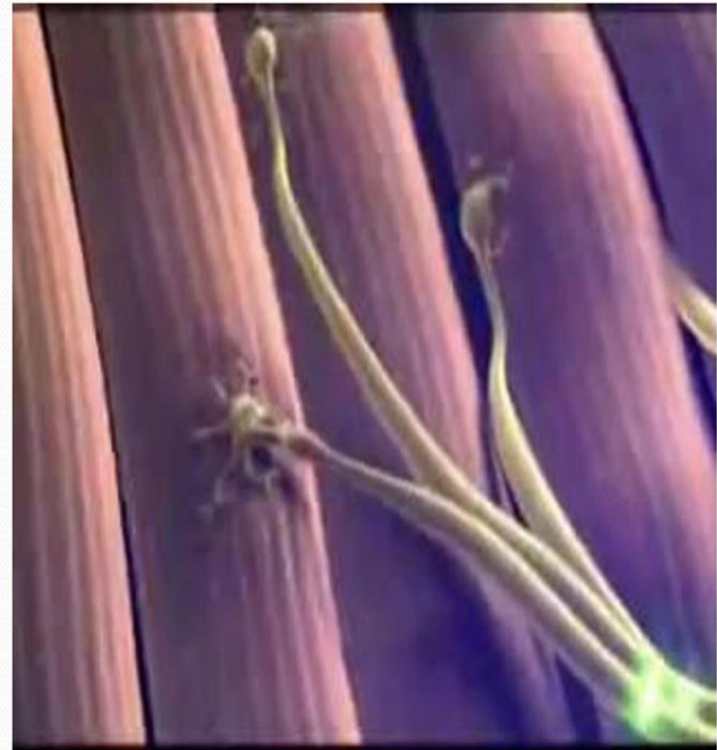
Mechanism where an action potential causes muscle fiber contraction involves:

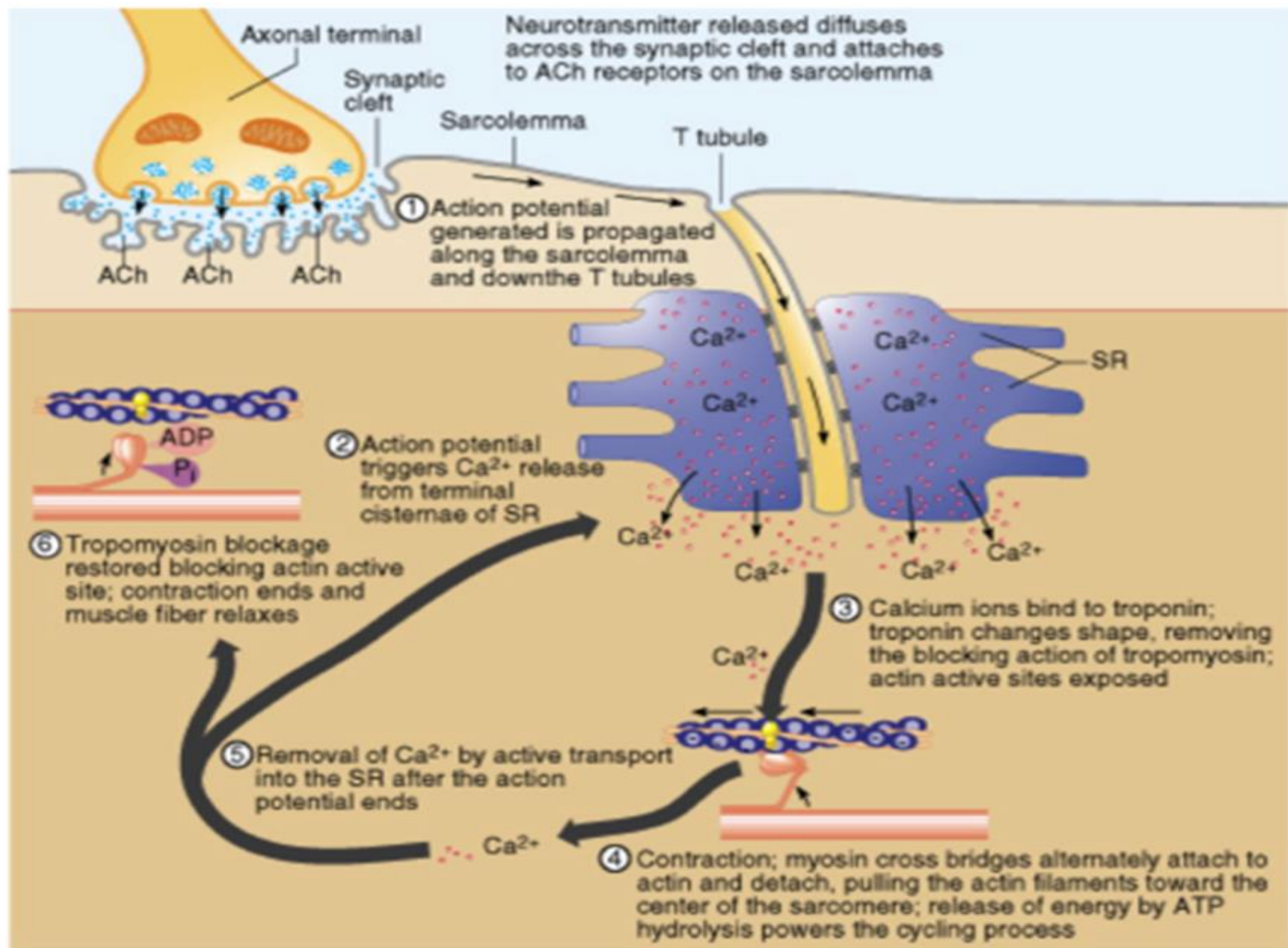
- Sarcolemma
- Transverse or T tubules
- Terminal cisternae
- Sarcoplasmic reticulum
- $\text{Ca}^{+2}$
- Troponin

Transmission of impulses from nerve endings to skeletal muscle

fibers occurs via:

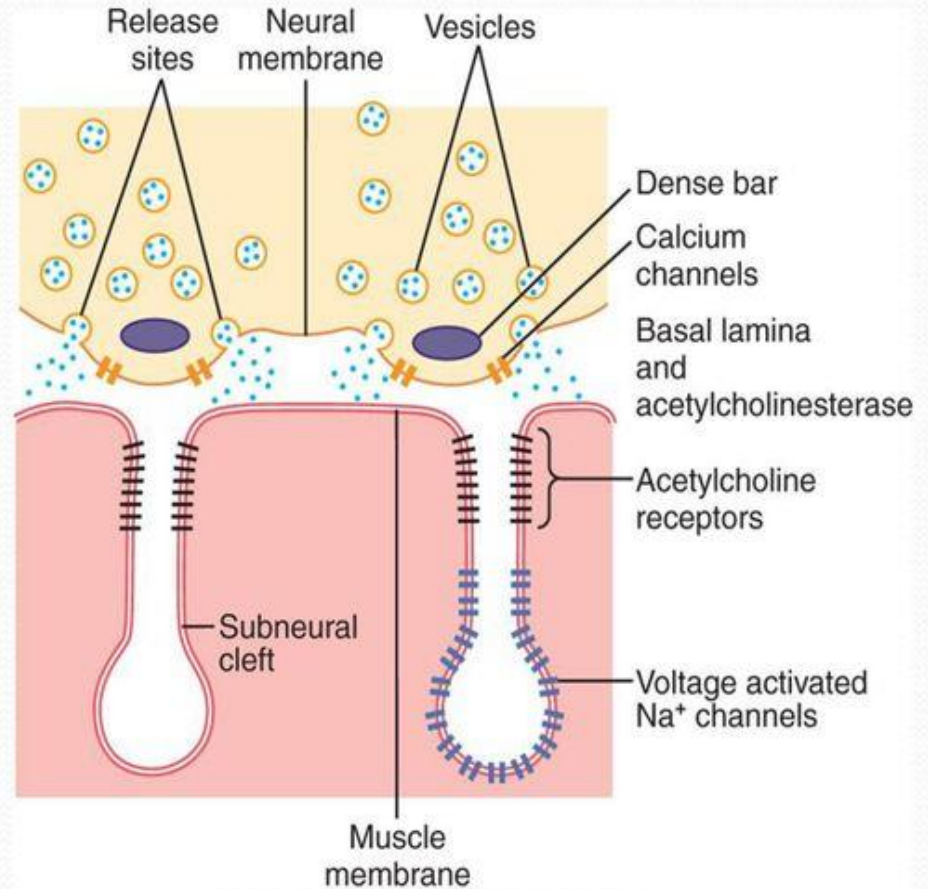
THE NEUROMUSCULAR JUNCTION (NMJ)





# Secretion of Acetylcholine by the Nerve Terminals

- 125 vesicles of Ach are released.
- *Voltage-gated calcium channels.*
- Acetylcholine receptors  
(Ach-gated ion channels).
- *Voltage-gated Na<sup>+</sup> channels.*



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Fig. 7.2

# Spread of the AP via Transverse Tubules

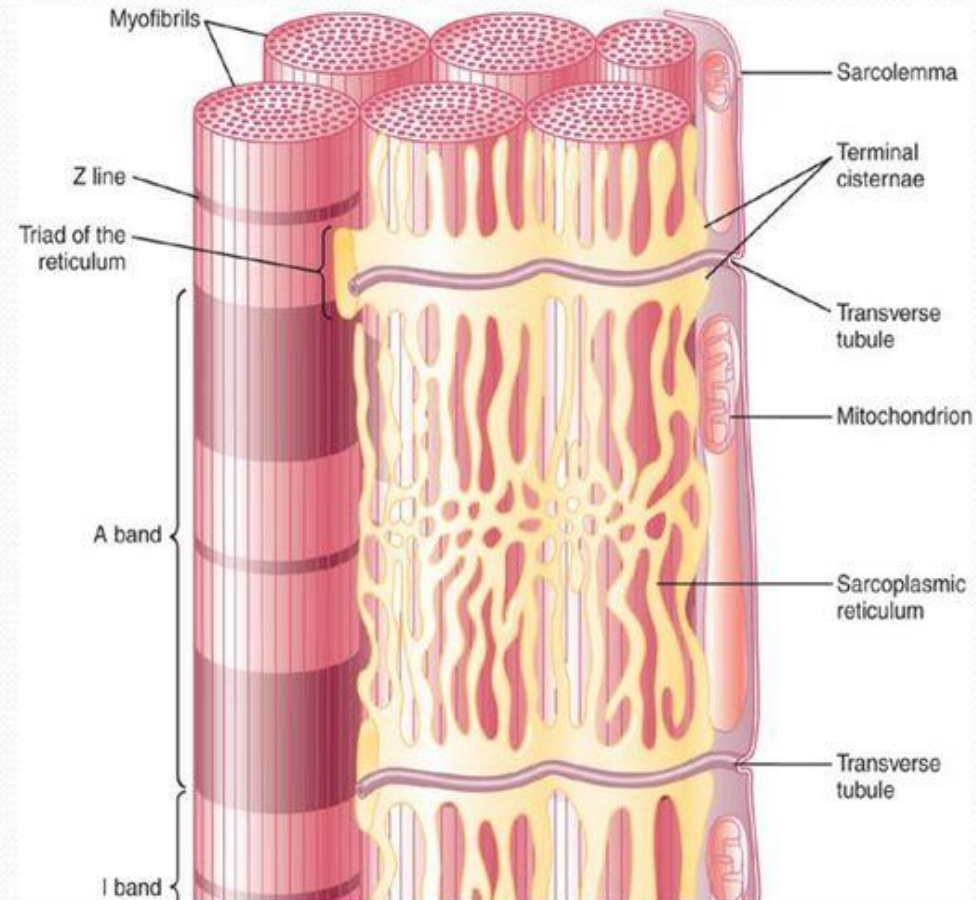
## Excitation-Contraction Coupling

### T-Tubule-Sarcoplasmic Reticulum System.

- **T-tubules** are small and run transverse to the myofibrils.

- The **sarcoplasmic reticulum** is composed of 2 parts:

- (1) large chambers called terminal cisternae
- (2) long longitudinal tubules



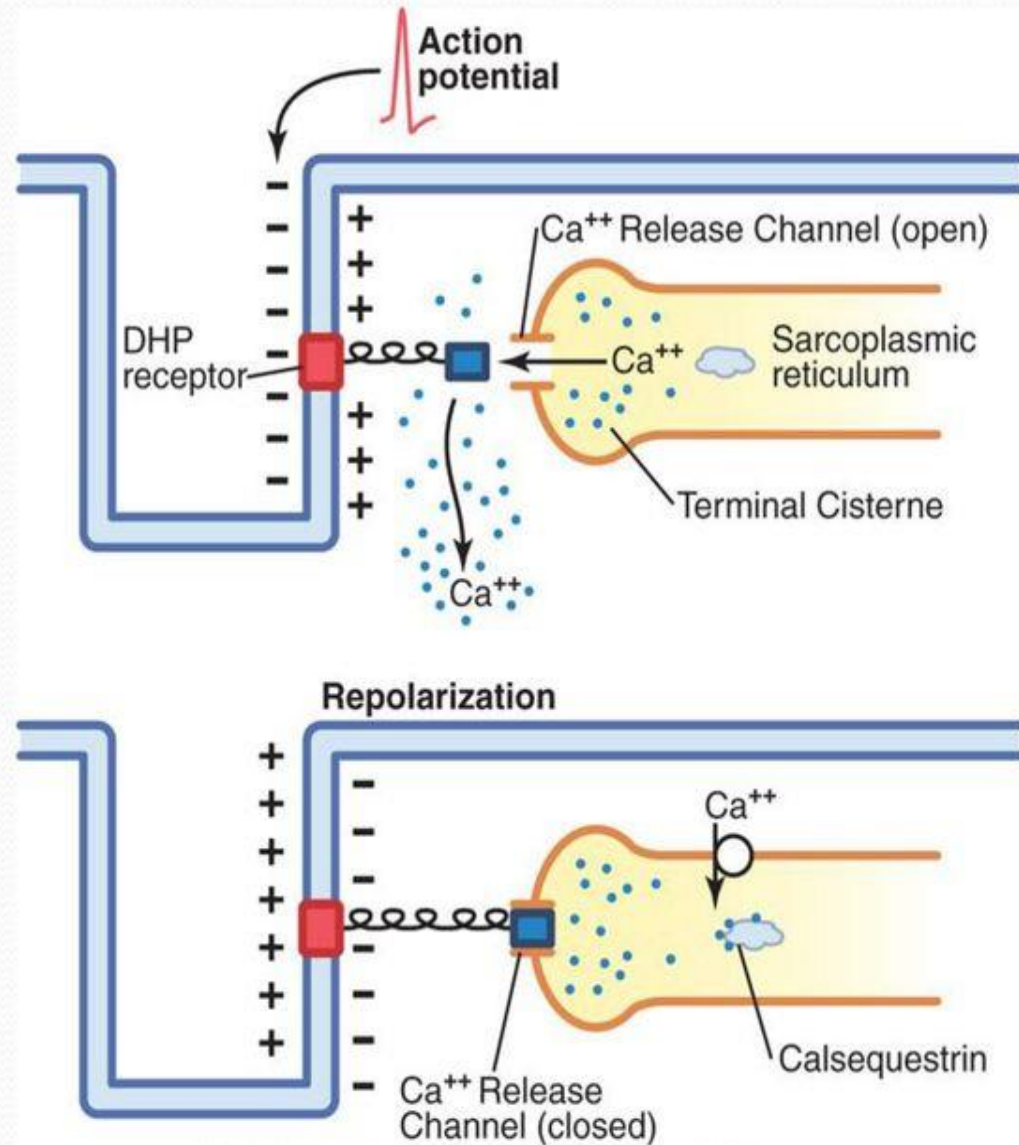
The T tubule action potentials cause  $\text{Ca}^{++}$  release inside the muscle fiber in the immediate vicinity of the myofibrils, and this  $\text{Ca}^{++}$  then cause contraction. This overall process is called *excitation-contraction coupling*.

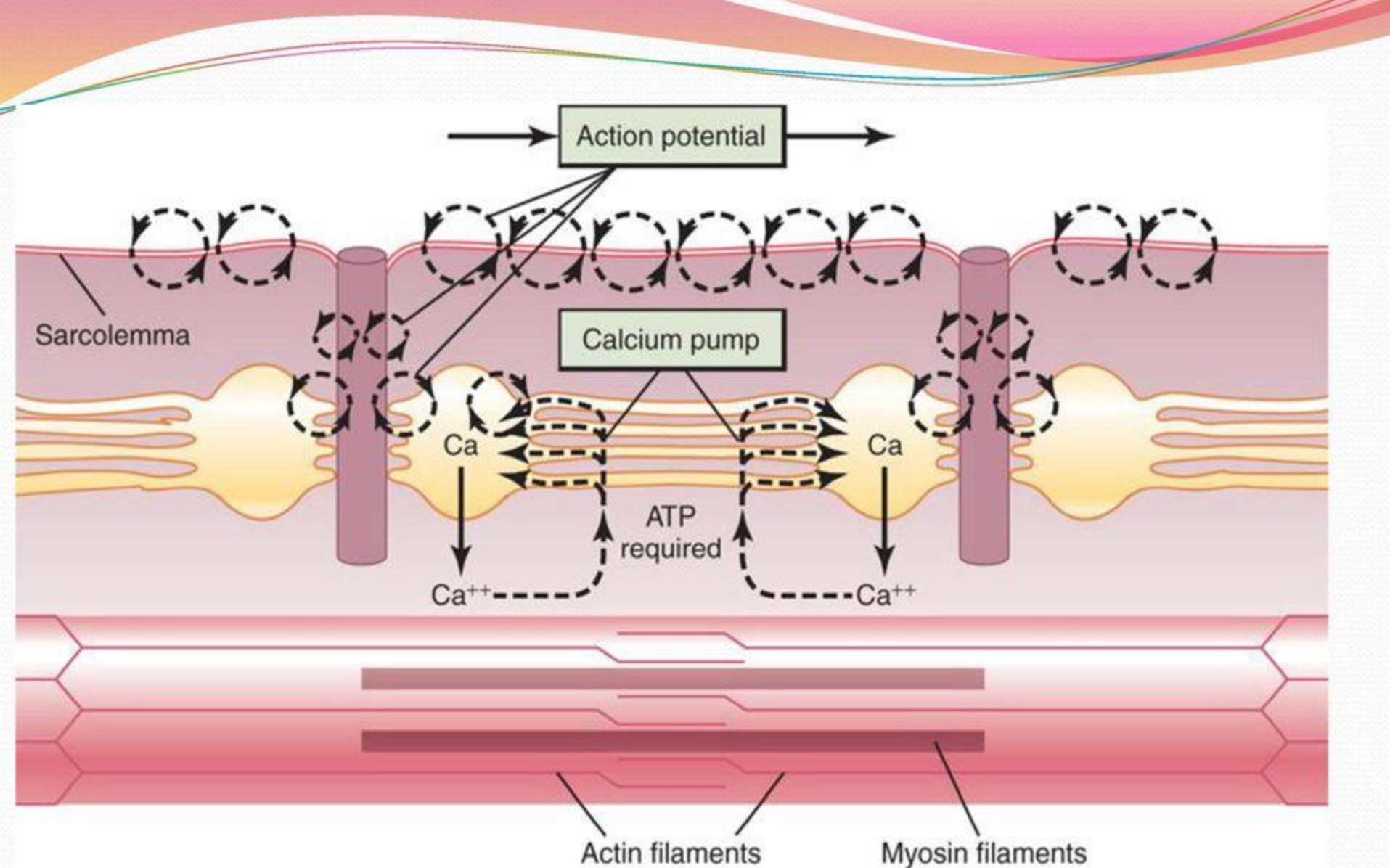
# Release of Calcium Ions by the Sarcoplasmic Reticulum

➤ As the AP reaches the T-tubule, the voltage change is sensed by **dihydropyridine receptors (DHP)** linked to calcium release channels (Ryanodine receptors) which triggers the release of  $\text{Ca}^{++}$  initiating contraction.

➤ **Calcium pump** removes calcium ions after contraction occurs.

➤ Calcium binds to **calsequestrin**.





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Fig. 7.7 Excitation-contraction coupling in the muscle showing (1) an AP that causes the release of Ca ions from the sarcoplasmic reticulum and then (2) re-uptake of the calcium ions by the calcium pump.



## Destruction of the Released Acetylcholine

- Most of the Ach is destroyed by the enzyme **acetylcholinesterase** into acetate ion and choline.

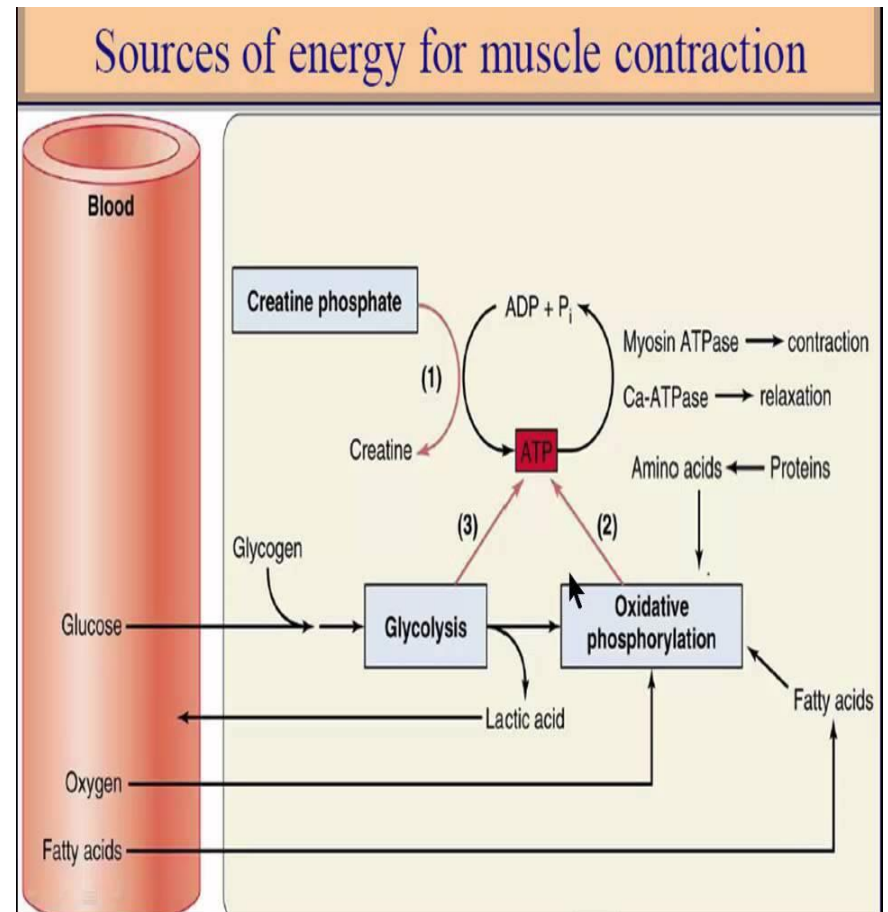
[choline is reabsorbed actively into the neural terminal to be reused to form new acetylcholine]

- A small amount diffuses out of the synaptic space.

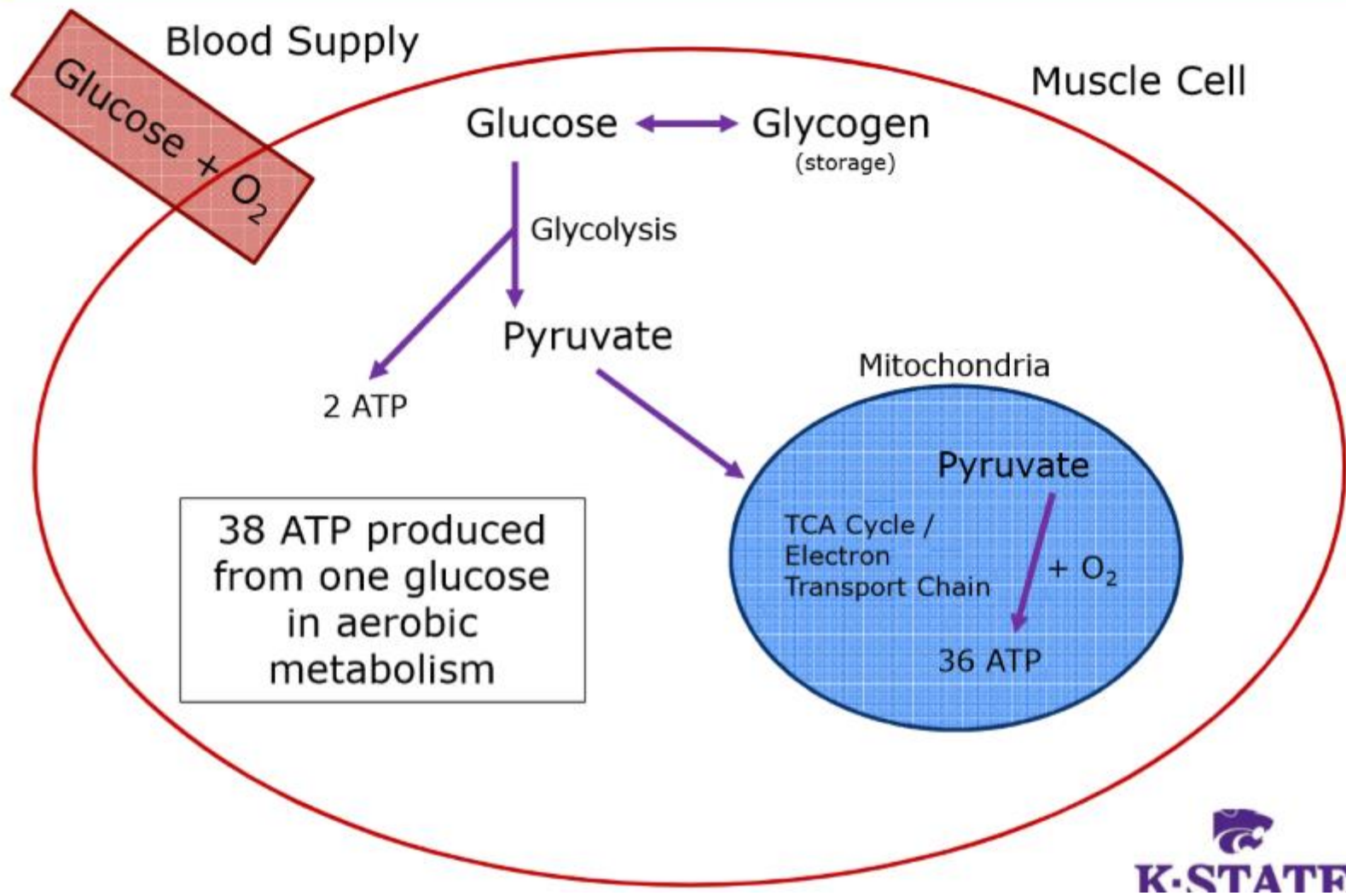
# Energy for muscle contraction

- ATP is required for muscle contraction
  - Myosin ATPase breaks down ATP as fiber contracts

- Sources of ATP
  - Phosphocreatine (PC)
  - Glycolysis
  - Oxidative phosphorylation



# Normal aerobic conditions



# Normal anaerobic conditions

## NORMAL ANAEROBIC CONDITIONS

