MUSCULOSKELETAL SYSTEM (MSK)

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Objectives

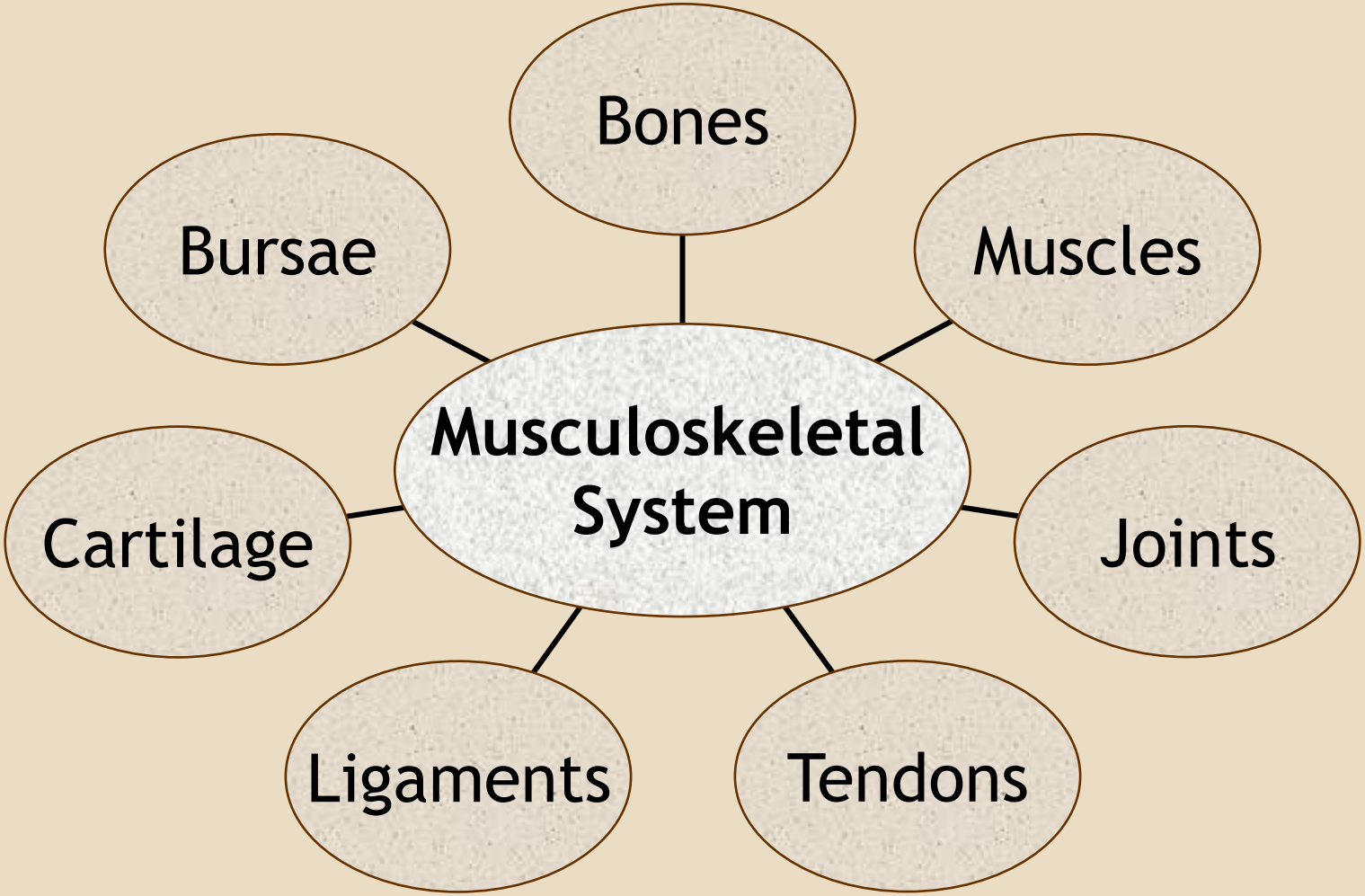
At the end of the class you should able to:

- describe the general functions of muscles
- classify the muscles
- review anatomy of skeletal muscle
- examine the connective tissues associated with the skeletal muscle
- review the intracellular organization of the skeletal muscle

What you need to know?

✓Definition of connective tissue
✓Structure of a typical cells

Musculoskeletal System



THE MUSCULAR PHYSIOLOGY

Introduction

- more than 50% of body weight is muscle
- And muscle is made up of proteins and water
- Only body tissue able to contract
- Body energy converters

Muscle Tissue characteristics

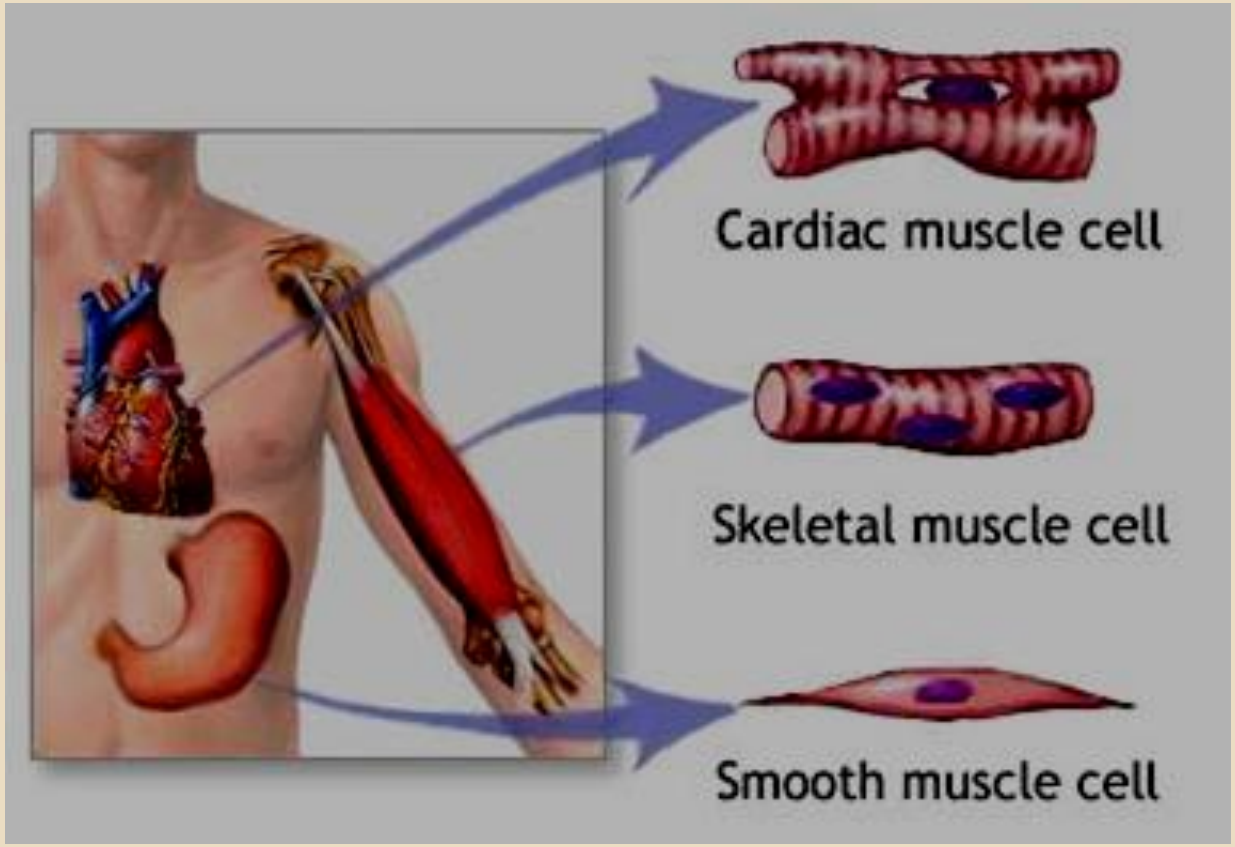
- Excitability
- Contractibility
- Elasticity
- Extensibility
- Atrophy
- Hypertrophy

Muscular system functions

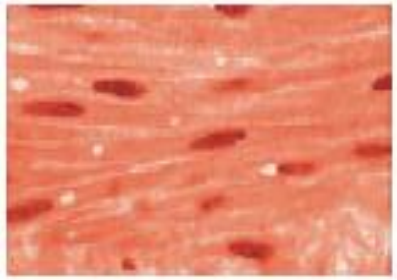
- Body movement (Locomotion)
- Maintenance of posture
- Respiration
  - Diaphragm and intercostals contractions
- Communication (Verbal and Facial)
- Constriction of organs and vessels
  - Peristalsis of intestinal tract
  - Vasoconstriction of vessels and other structures (pupils)
- Heart beat
- Production of body heat (Thermogenesis)

The Muscles - classification

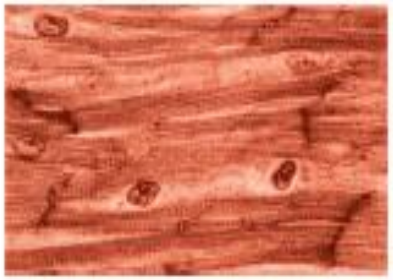
- There are three basic types of muscle
  - Skeletal
  - Cardiac
  - Smooth



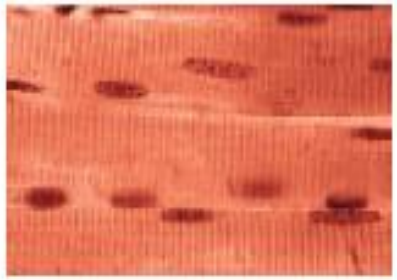
The Muscles - features

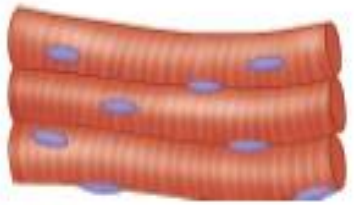


Smooth muscle
- has spindle-shaped, nonstriated, uninucleated fibers.
- occurs in walls of internal organs.
- is involuntary.



Cardiac muscle
- has striated, tubular, branched, uninucleated fibers.
- occurs in walls of heart.
- is involuntary.





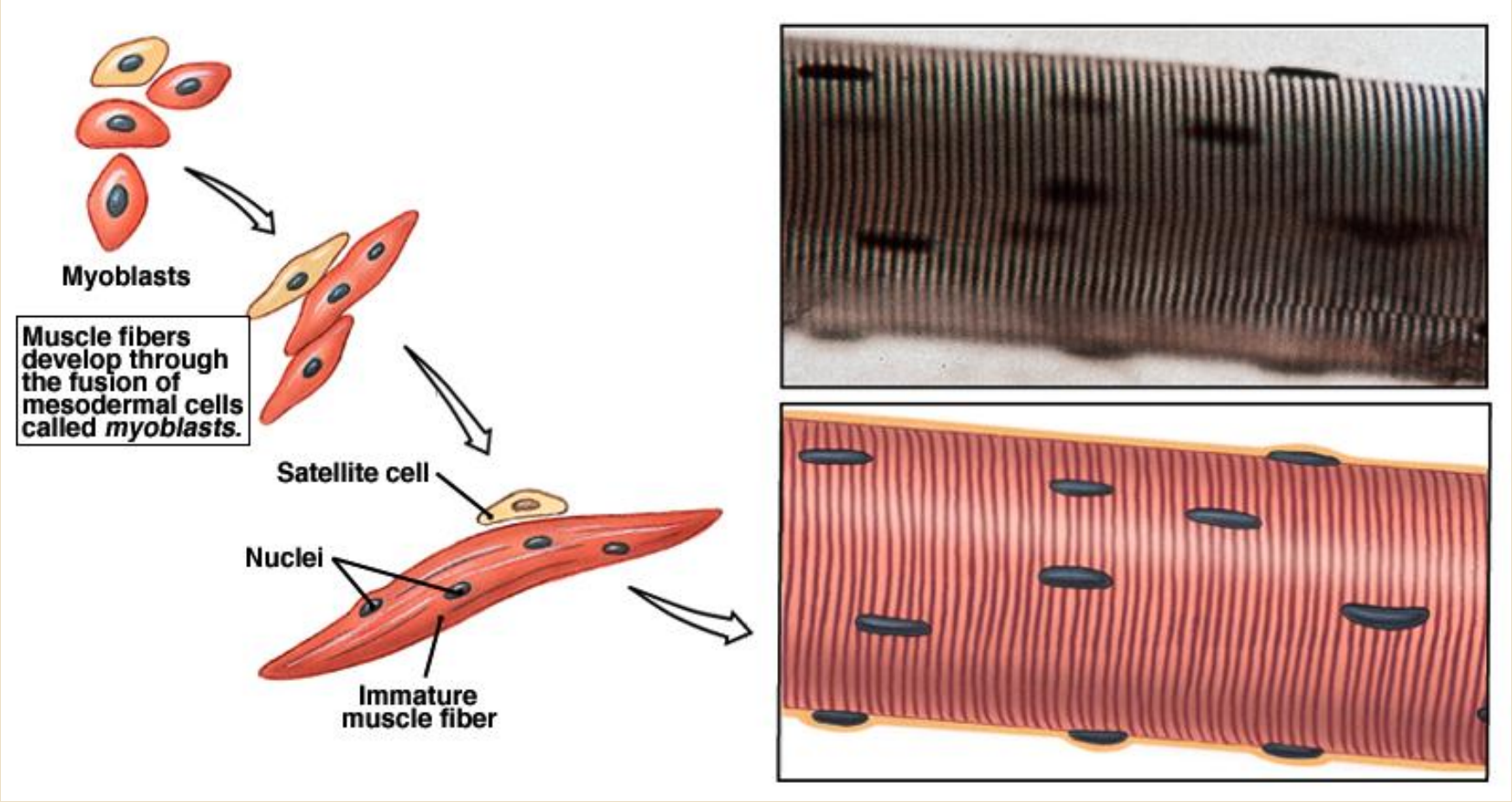
Skeletal muscle
- has striated, tubular, multinucleated fibers.
- is usually attached to skeleton.
- is voluntary.

The Muscles - control

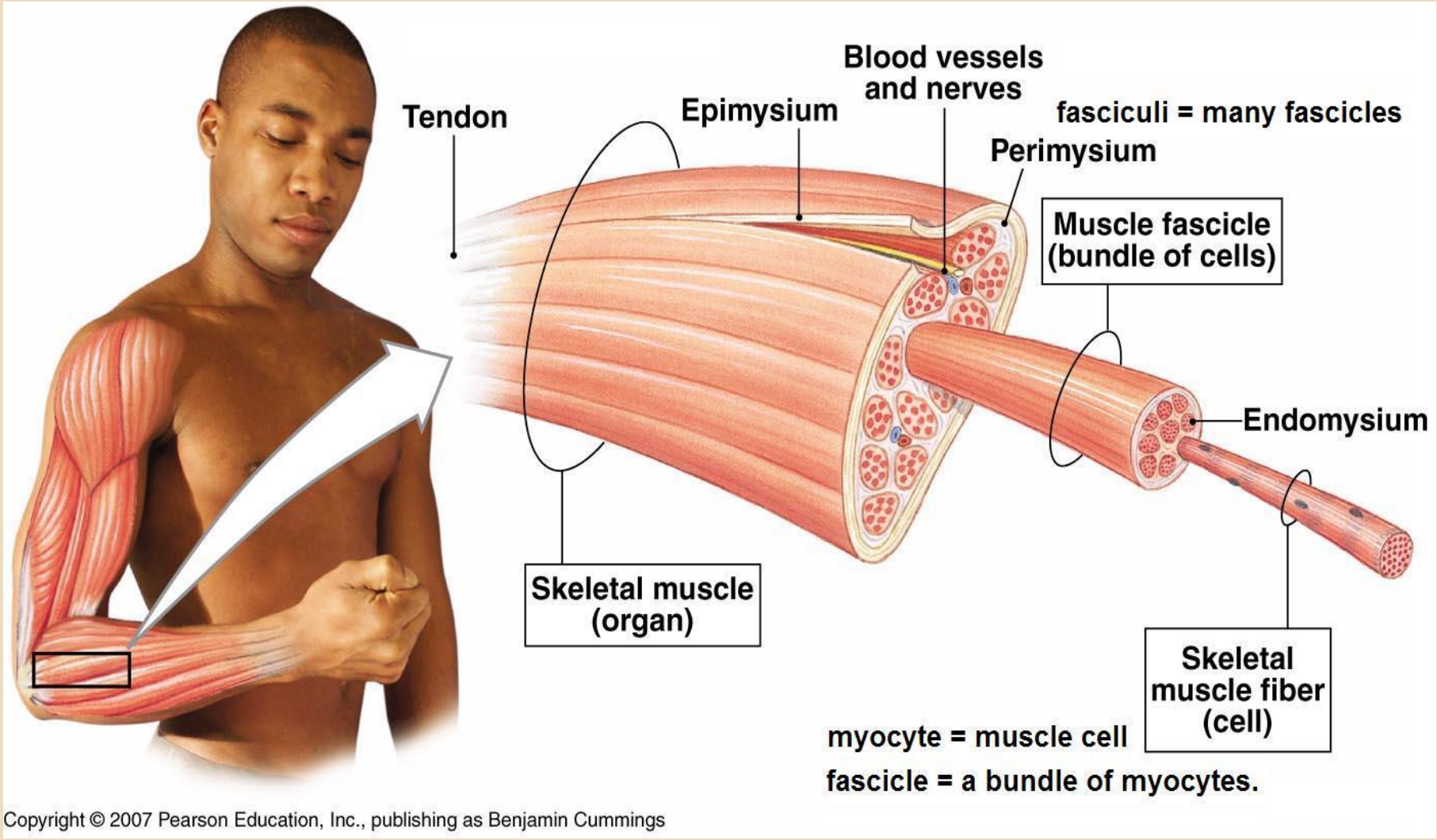
Type of muscle	Nervous control	Type of control	Example
Skeletal	Controlled by CNS	Voluntary	Lifting a glass
Cardiac	Regulated by ANS	Involuntary	Heart beating
Smooth	Controlled by ANS	Involuntary	Peristalsis

The skeletal muscle

Embryologic origin

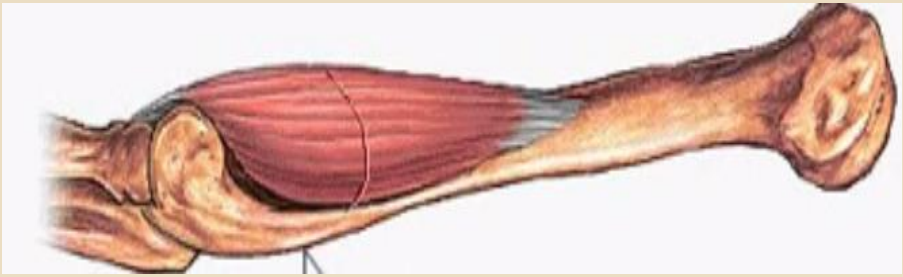


The skeletal muscle: structure



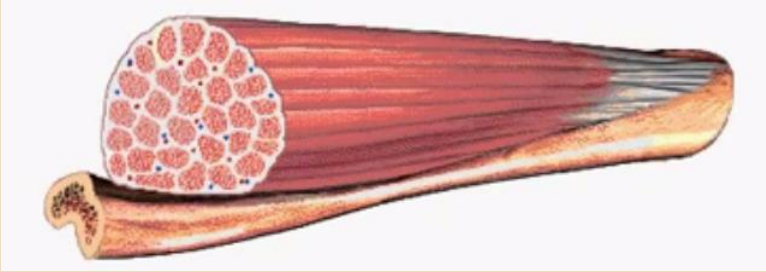
Skeletal muscle: structure contd..

A. Whole skeletal muscle



B. Internal structure of skeletal muscle

- Composed of an orderly arrangement of **connective tissue and contractile cells**



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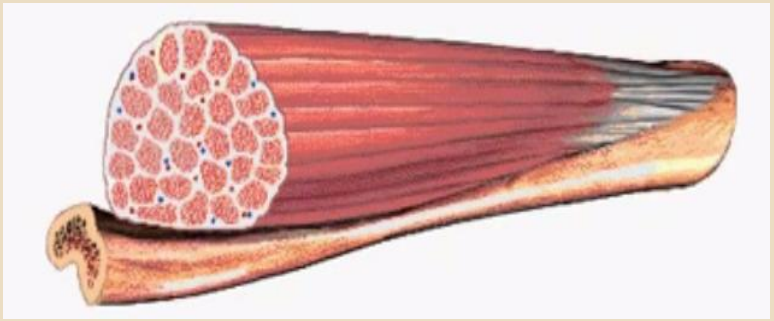
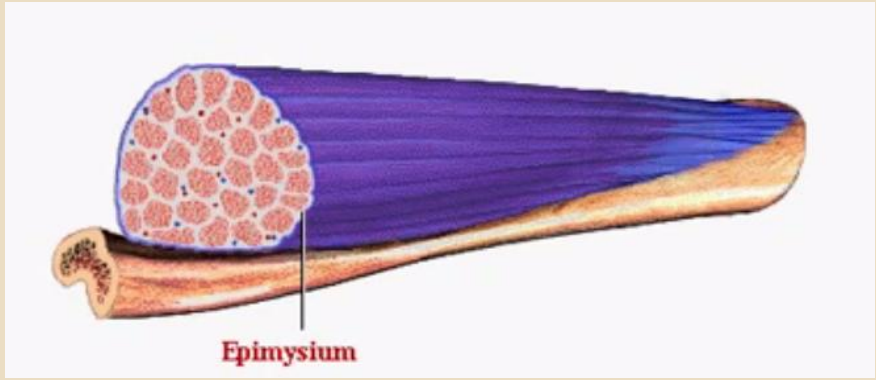
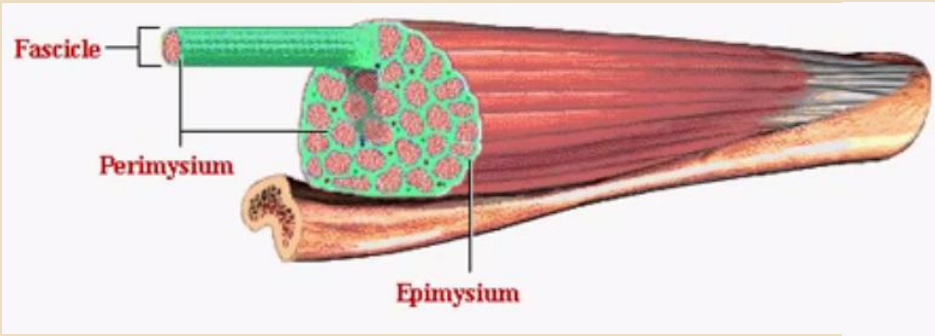
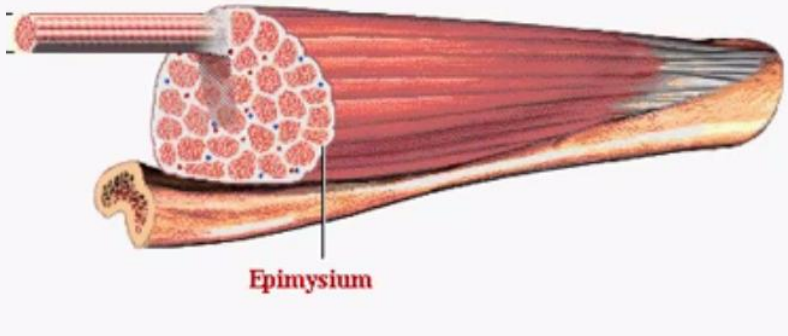


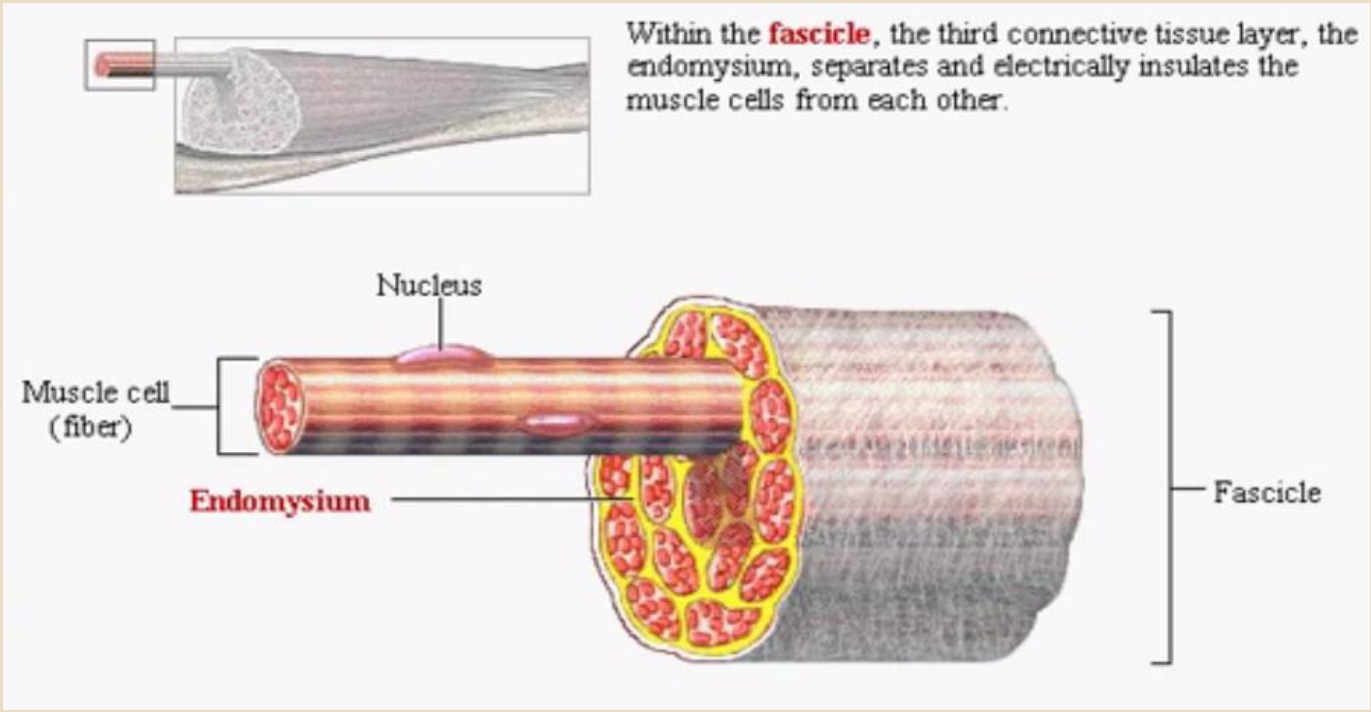






Internal structure of skeletal muscle

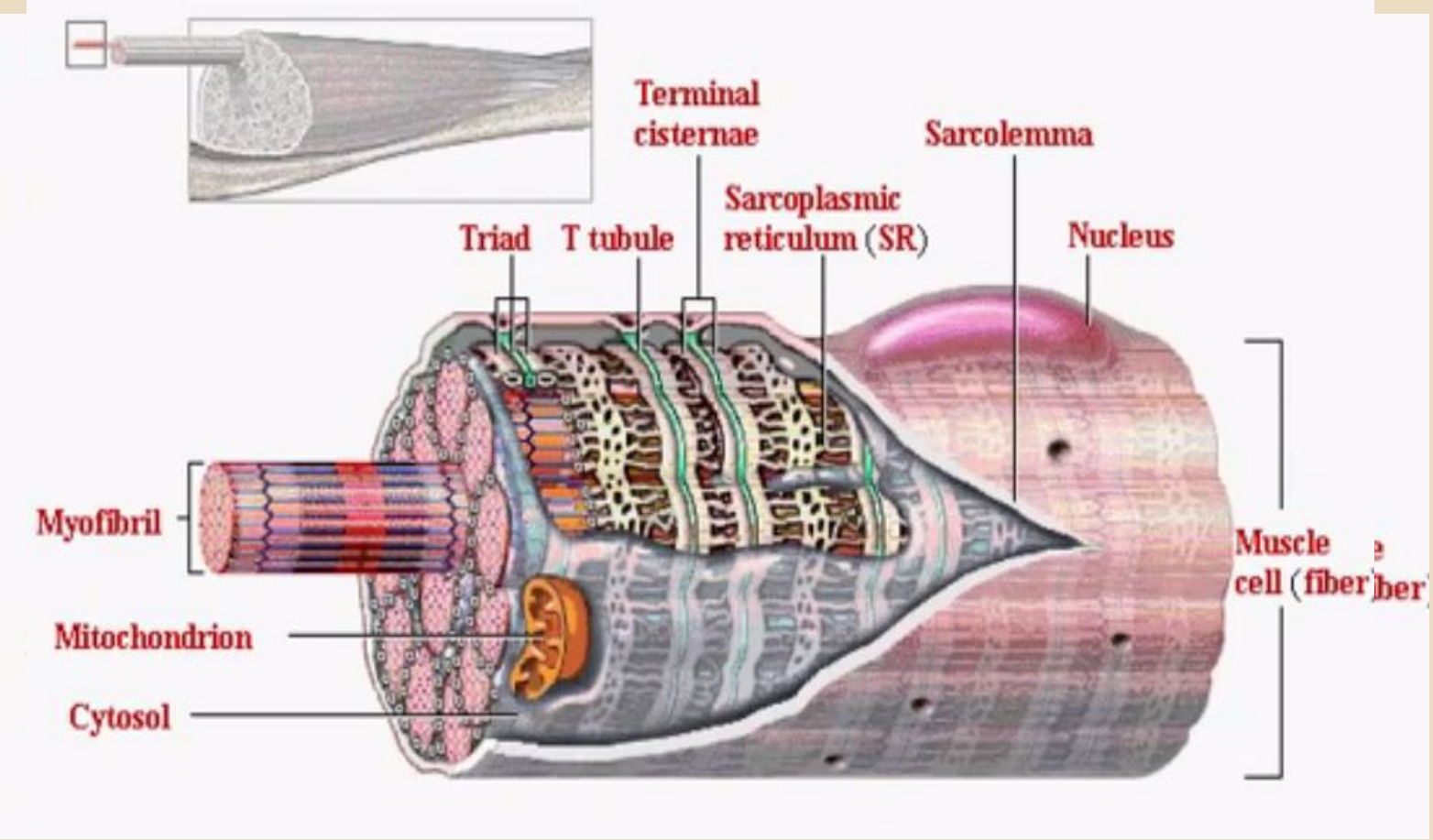
Internal structure of a fascicle



Internal structure of skeletal muscle

contd..

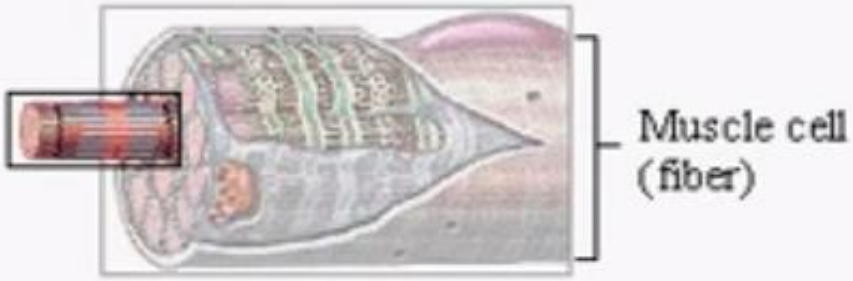
Internal structure of a skeletal muscle cell (fiber)



Internal structure of skeletal muscle

contd..

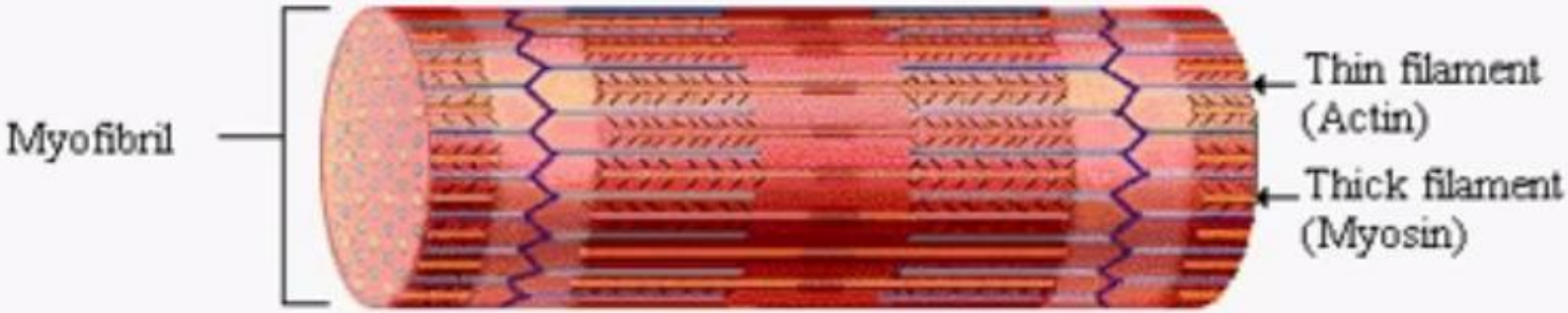
Structure of a myofibril



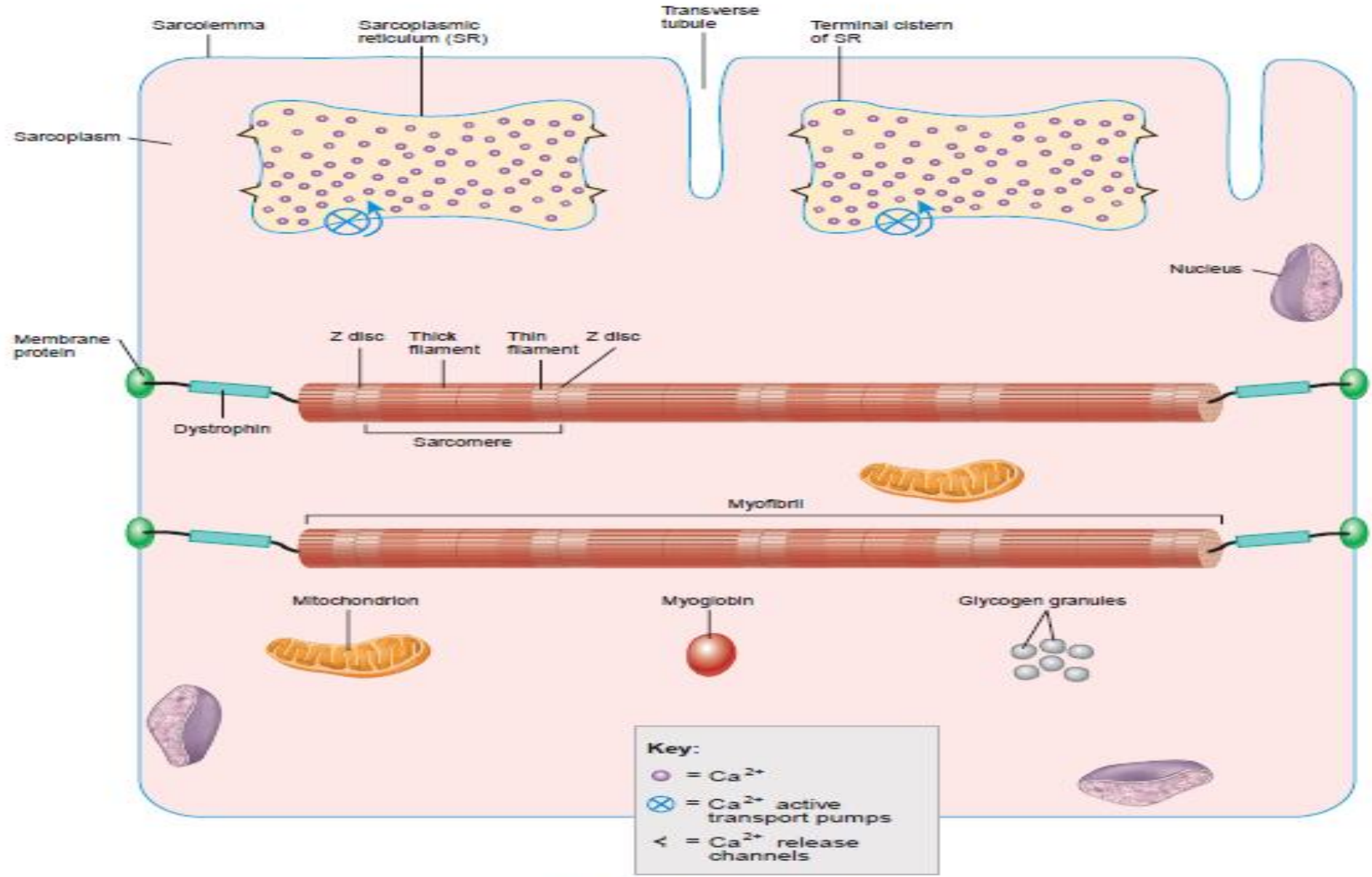
The **myofibrils** are composed of individual contractile proteins called **myofilaments**.

There are two types of myofilaments:

- The thin filament is composed mainly of the protein actin.
- The thick filament is made up chiefly of the protein myosin.



Simplest representation of a muscle cell



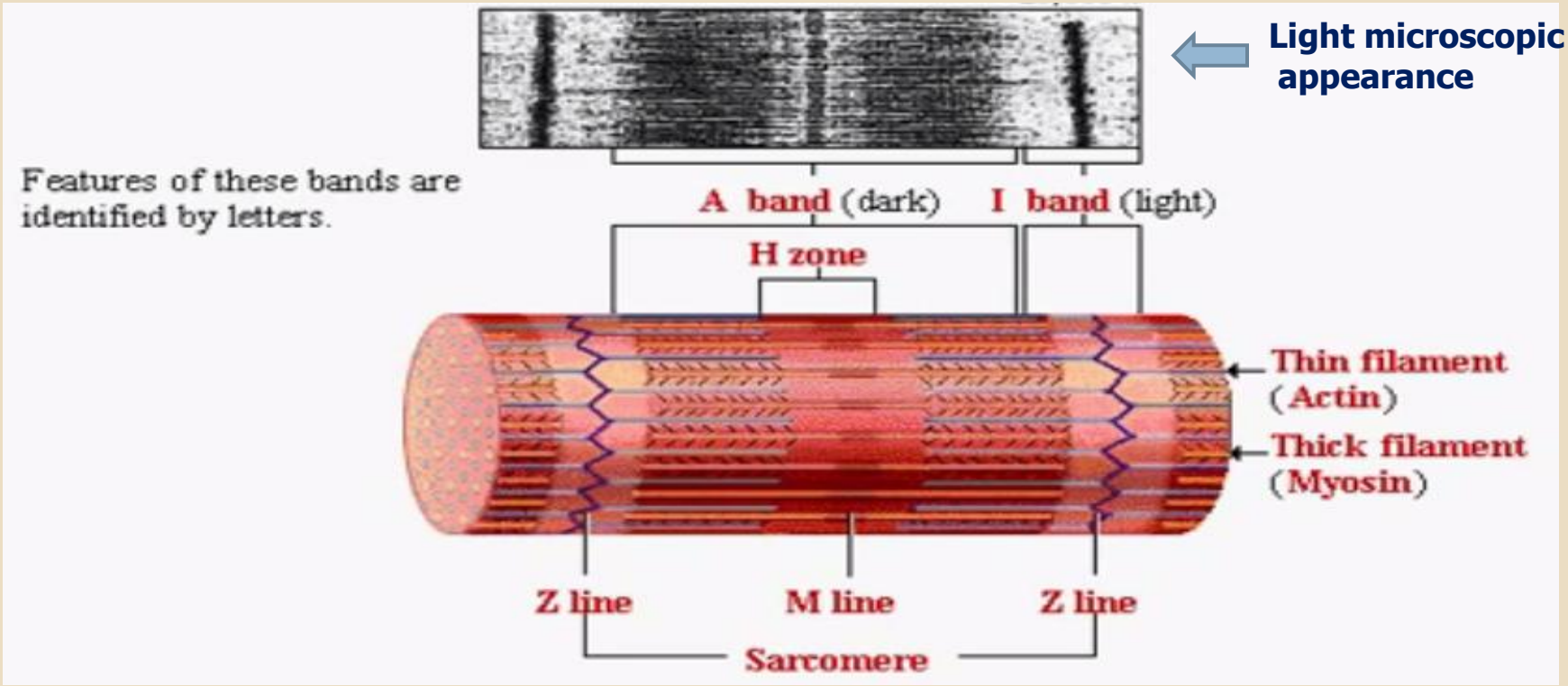
(d) Simplistic representation of a muscle fiber

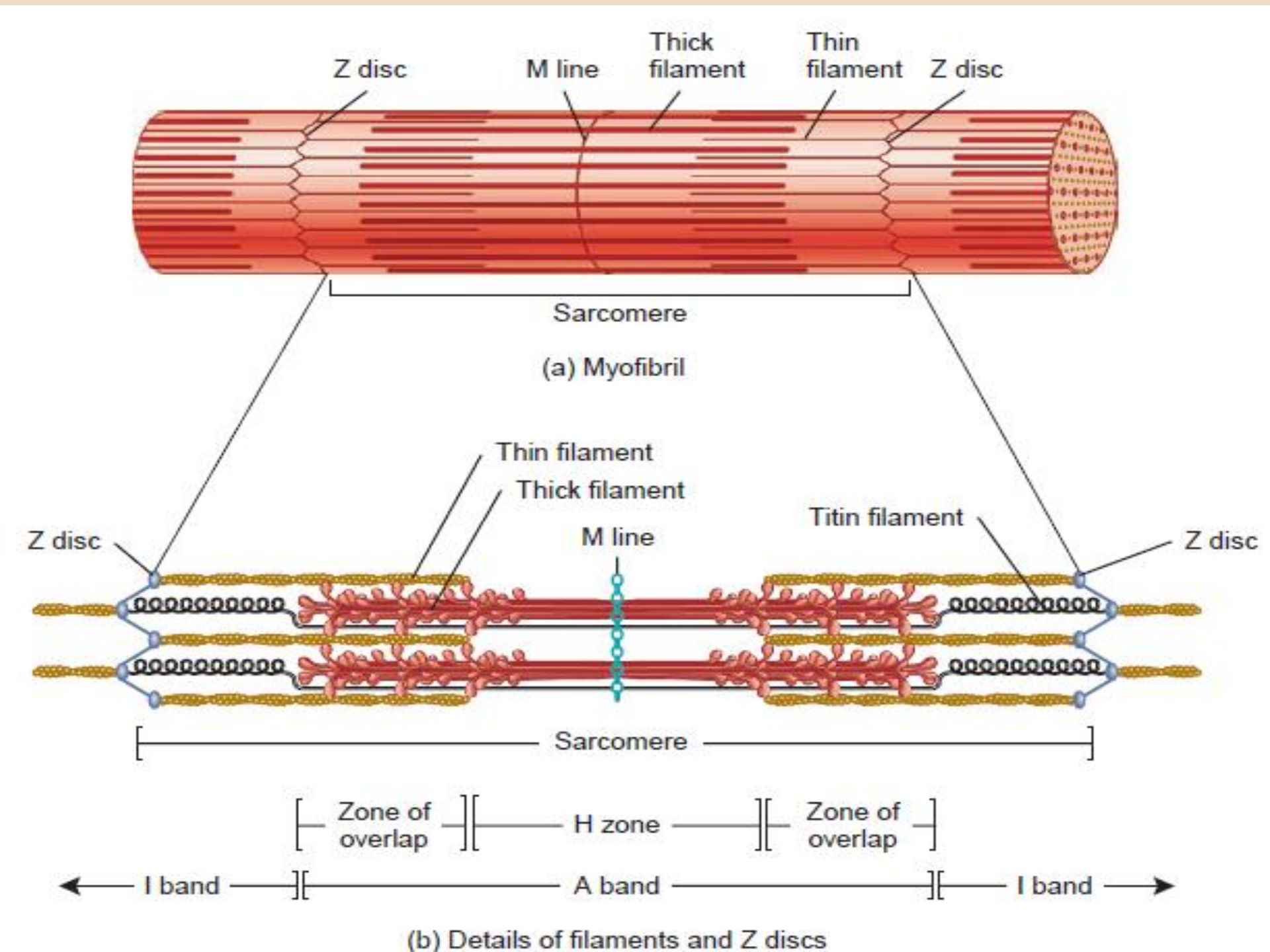
Sarcomere

Arrangement of myofilaments

➢The arrangement of thick & thin myofilaments forms light and dark alternating bands (striations) along the myofibril

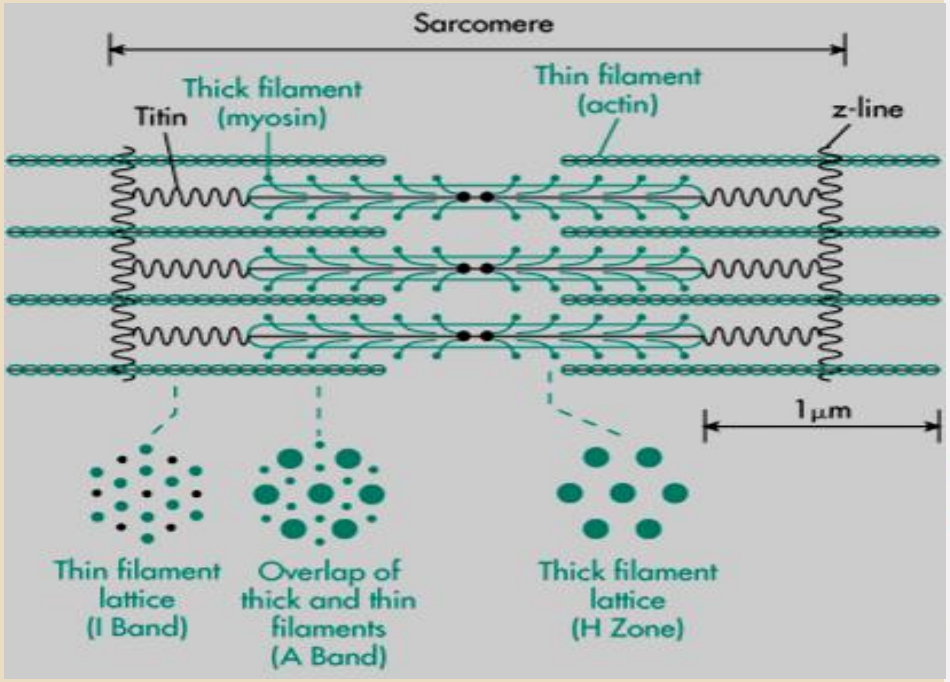
Sarcomere: The structural between to Z lines and functional unit for contraction of skeletal muscle

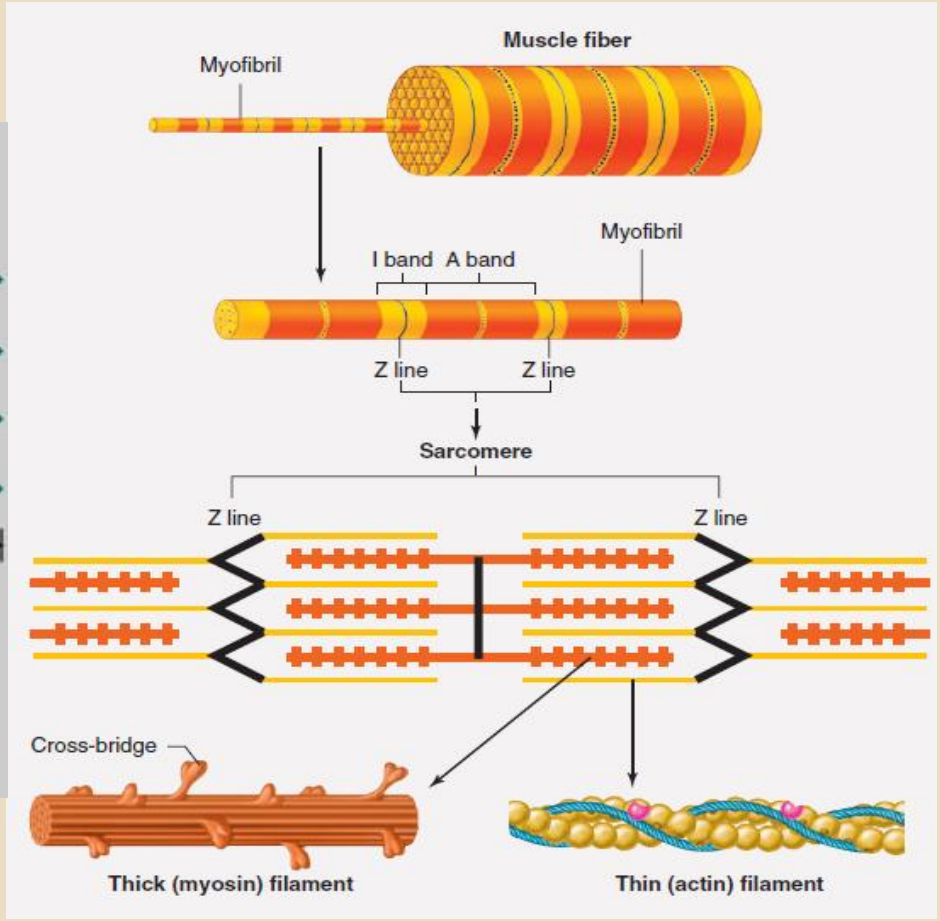



Z disc
M line
Thick filament
Thin filament
Z disc
Sarcomere
(a) Myofibril
Thin filament
Thick filament
Titin filament
Z disc
M line
Z disc
Sarcomere
Zone of overlap
H zone
Zone of overlap
I band
A band
I band
(b) Details of filaments and Z discs

Sarcomere contd…

Arrangement of myofilaments: The electron microscopic appearance





The skeletal muscle fibre proteins

1. Contractile proteins:

- Actin and myosin

2. Regulatory proteins:

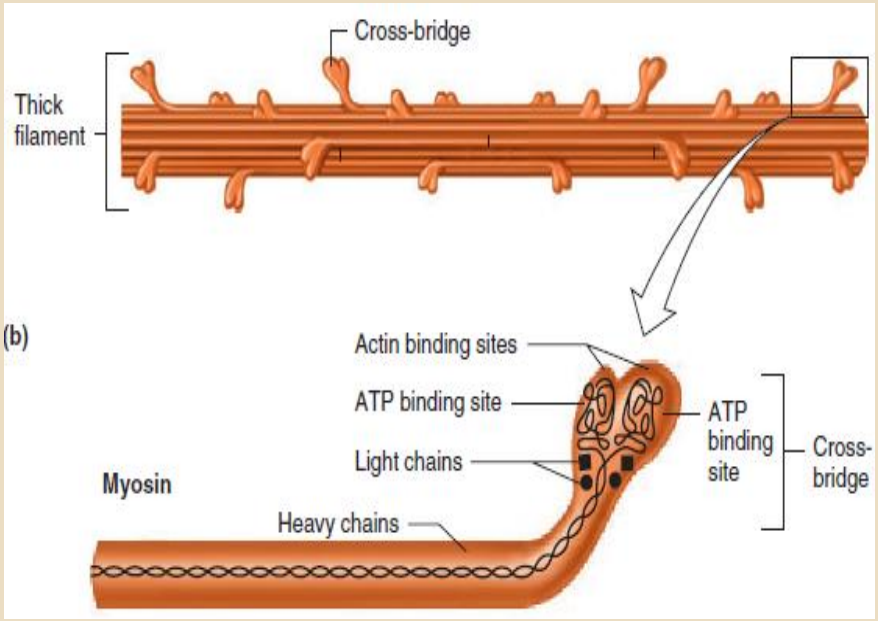
- Tropomyosin and troponin

3. Structural proteins:

- Alpha-actinin, myomesin, titin, nebulin, dystrophin

Thick Filament: the myosin

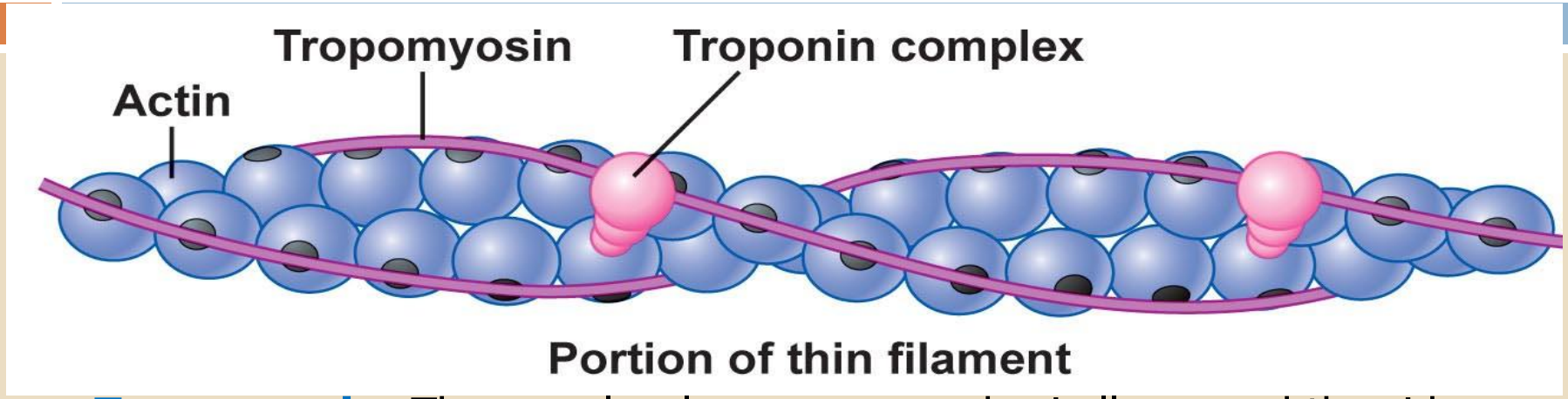
- Forms **A-band; surrounded by six thin filaments**
- The myosin molecule (myosin-II) is composed of two large polypeptide **heavy chains** & four **light chains.**
- These polypeptides combine to form a molecule that consists of two globular **heads** (heavy & light chains) & a **long tail** formed by the two twisted heavy chains



Functions:

- **heads serve as "cross bridge"**
  a) **Actin binding site: where myosin comes in contact with actin**
  b) **ATPase (catalytic site): that hydrolyzes ATP**

Thin Filaments (actin, tropomyosin & troponin)



- **Tropomyosin:** These molecules are wrapped spirally around the sides of the F-actin helix.
  - In the resting state, the tropomyosin molecules lie on top of the active sites of the actin strands, so that attraction cannot occur between the actin and myosin filaments to cause contraction.
- **Troponin:** are actually complexes of three loosely bound protein subunits
  - Troponin I: has a strong affinity for actin,
  - Troponin T: affinity for tropomyosin,
  - Troponin C: affinity for calcium ions, to initiate the contraction process

- Form the **I band**
- **Actin, tropomyosin & troponin** arrange themselves to form the thin filament (i.e., actin filament) with 2 chains of globular units that form a long spiral chain.
- Each thin filament contains 300 to 400 actin molecules and 40 to 60 tropomyosin molecules.

a) Actin: - thinner and stretch from Z- lines to the edge of the H-zone.
- two types

i) "G" actin (globular): Attached to each one of the G-actin molecules is one molecule of ADP. It is believed that these ADP molecules are the active sites on the actin filaments with which the cross-bridges of the myosin filaments interact to cause muscle contraction

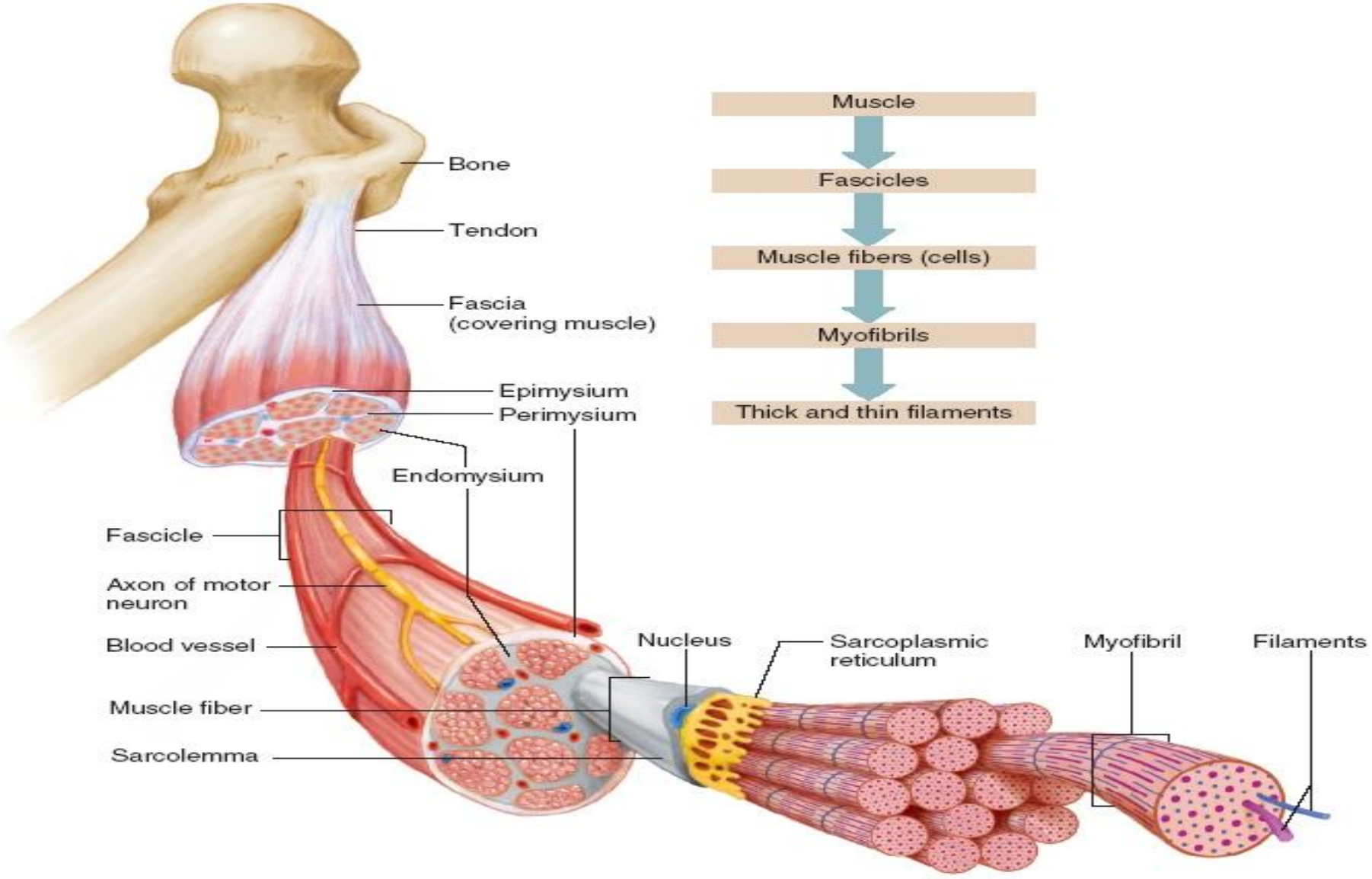
ii) "F" actin (fibrous): formed by polymerisation of G-actin with liberation of energy. The backbone of the actin filament is a doublestranded F-actin protein molecule

- **Regulatory proteins:** help switch the muscle contraction process on and off. Eg.: Tropomyosin & troponin.

- **Structural proteins:** keep myofilaments in proper alignment and connect with extracellular matrix.

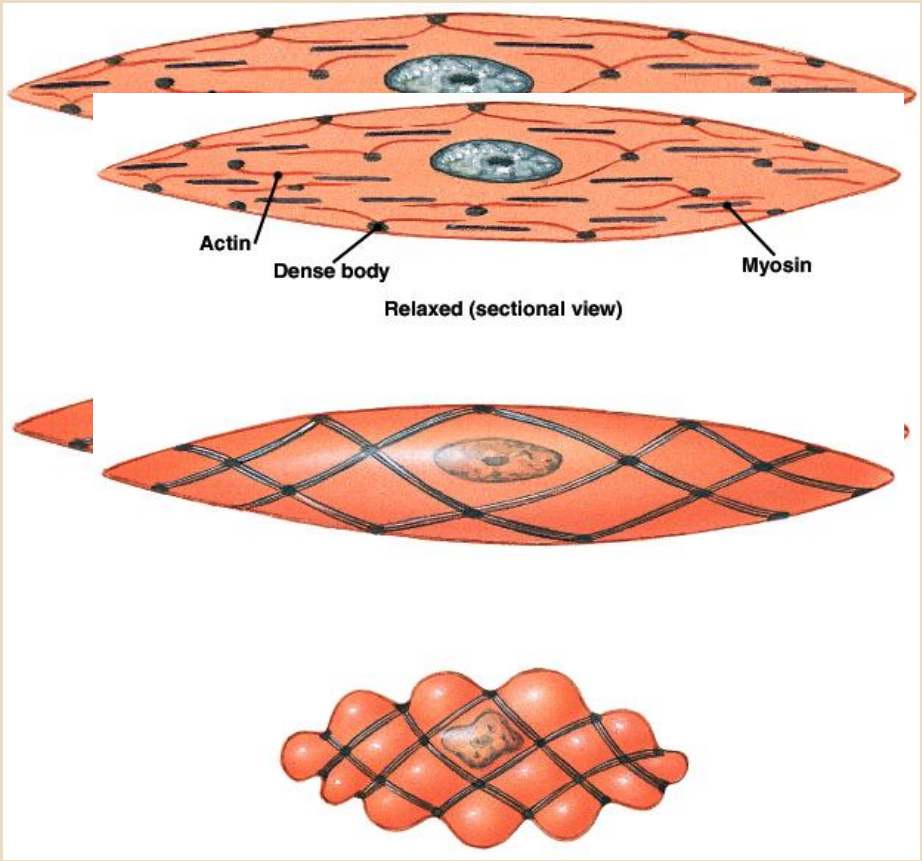
Structural proteins	Proteins that keep the thick and thin filaments of the myofibrils in proper alignment, give the myofibrils elasticity and extensibility, and link the myofibrils to the sarcolemma and extracellular matrix.
Titin	A structural protein that connects a Z disc to the M line of the sarcomere, thereby helping to stabilize the position of the thick filament. Because it can stretch and then spring back unharmed, titin accounts for much of the elasticity and extensibility of myofibrils.
α-actinin	A structural protein of the Z discs that attaches to actin molecules of thin filaments and to titin molecules.
Myomesin	A structural protein that forms the M line of the sarcomere; it binds to titin molecules and connects adjacent thick filaments to one another.
Nebulin	A structural protein that wraps around the entire length of each thin filament; it helps anchor the thin filaments to the Z discs and regulates the length of the thin filaments during development.
Dystrophin	A structural protein that links the thin filaments of the sarcomere to integral membrane proteins in the sarcolemma, which are attached in turn to proteins in the connective tissue matrix that surrounds muscle fibers. It is thought that dystrophin helps reinforce the sarcolemma and that it helps transmit tension generated by sarcomeres to tendons.

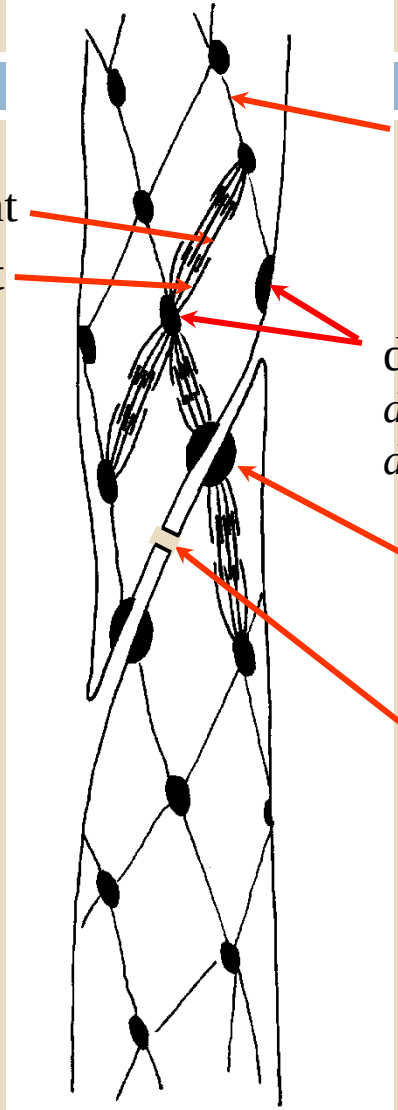
Summary: Organization of skeletal muscle




THANK YOU!

Smooth Muscle: structure





thick filament

thin filament

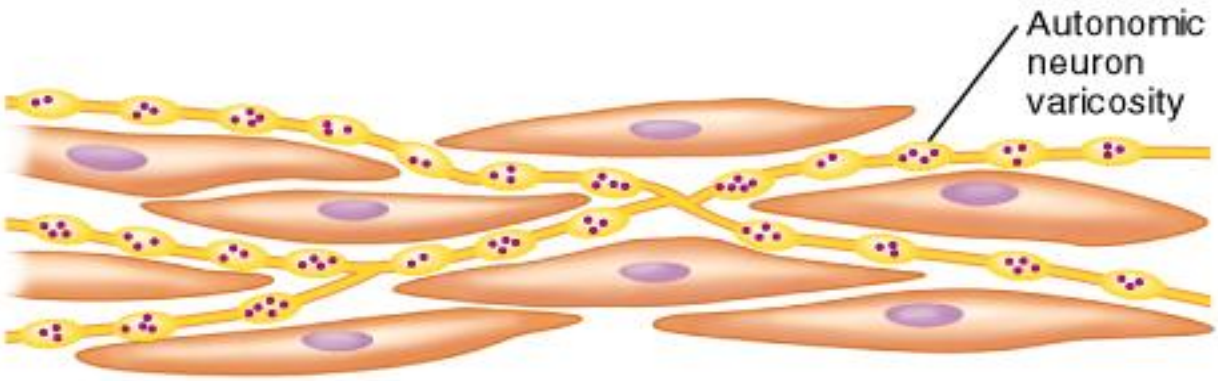
intermediate filament *(form structural backbone)*

dense body *(membrane dense area analogous to Z discs)*

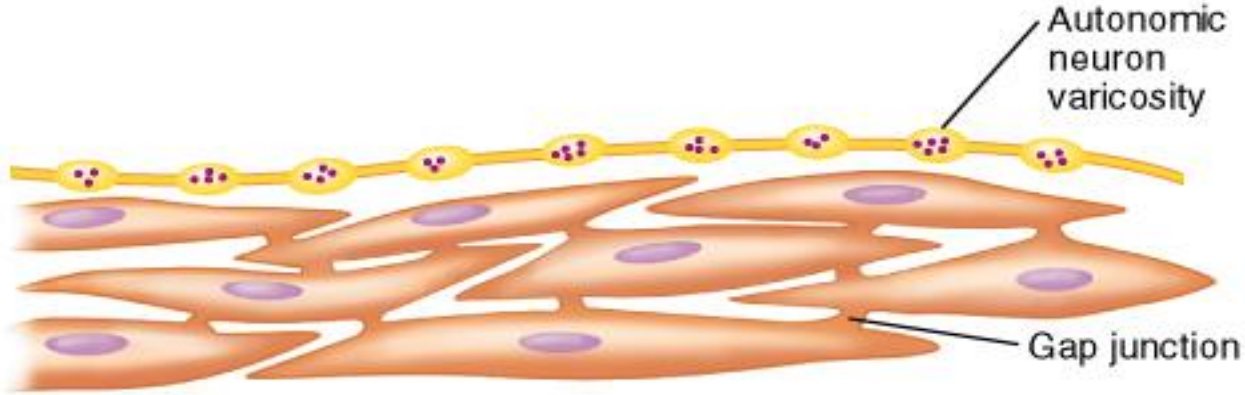
mechanical junction (*coupling cells*)

gap junction *(electrical coupling)*

Smooth Muscle: types

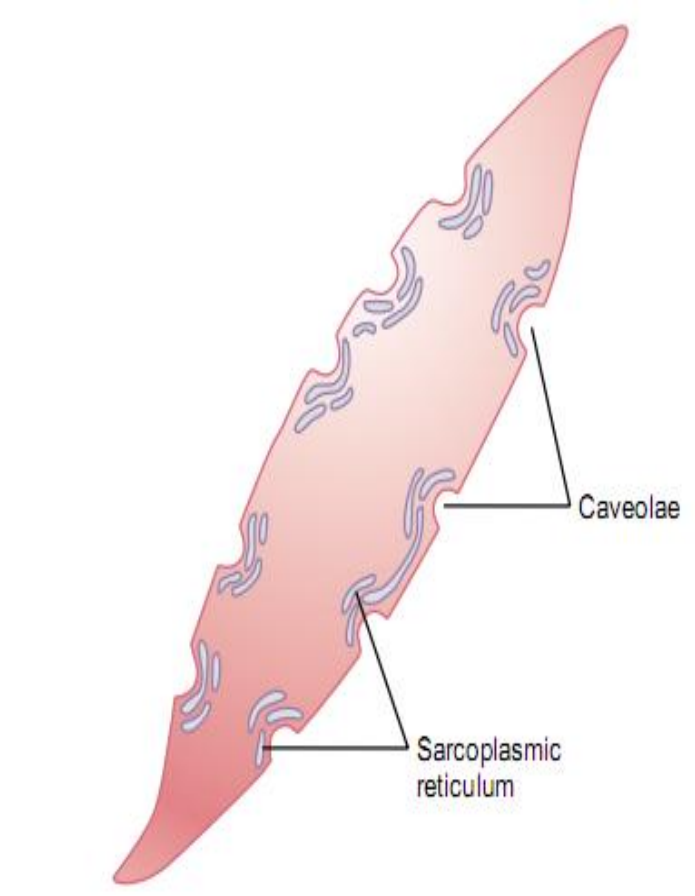


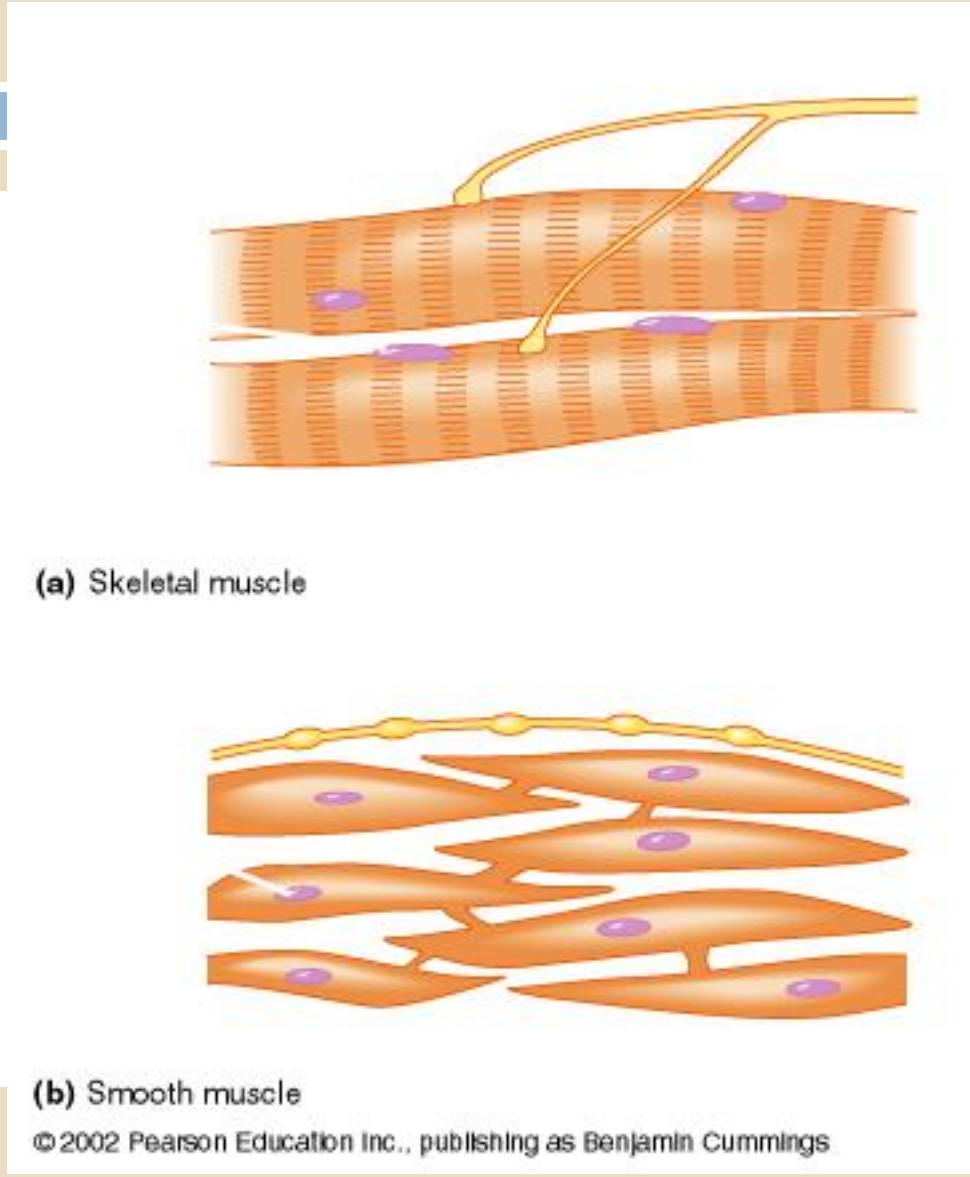
(a) Multi-unit smooth muscle



(b) Single-unit smooth muscle

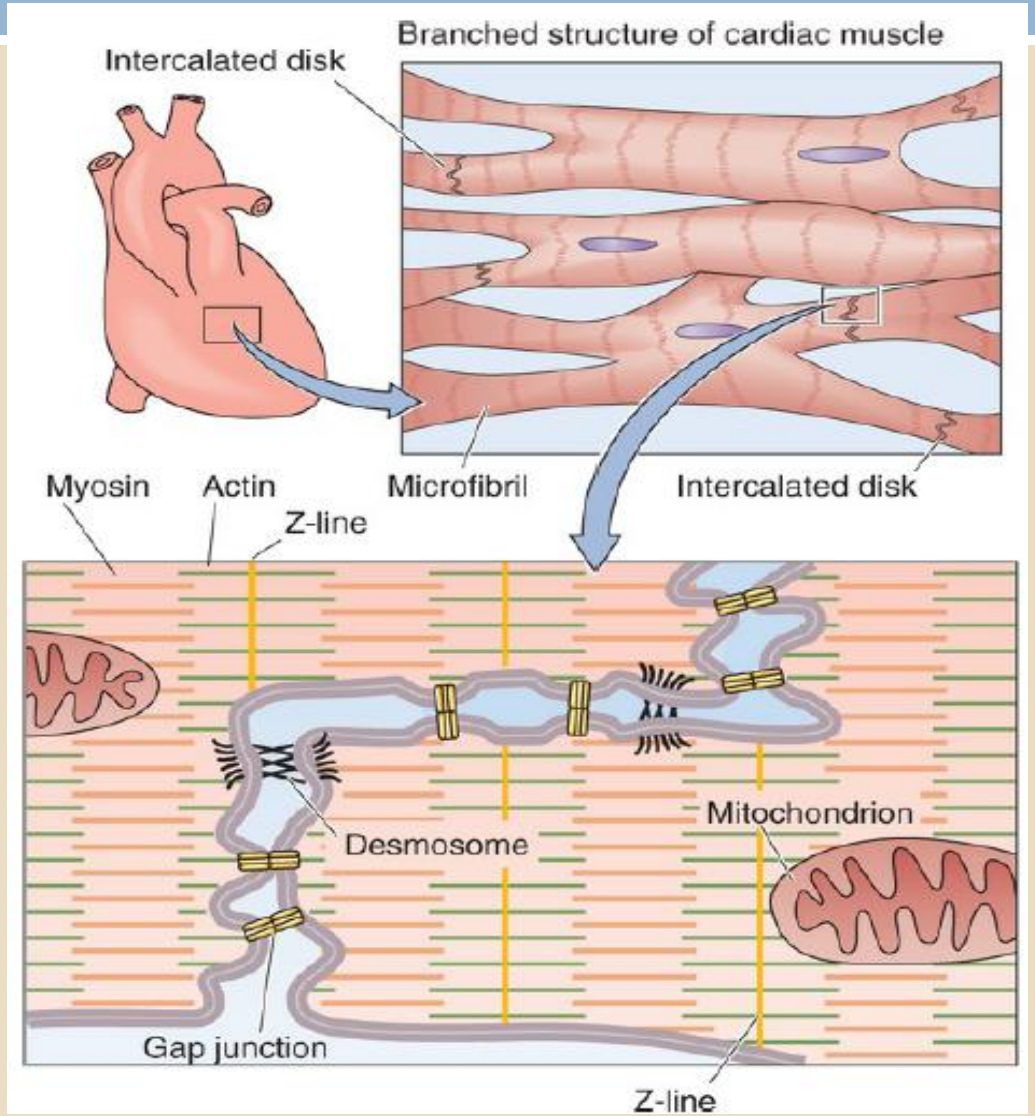
Smooth Muscle: arrangement



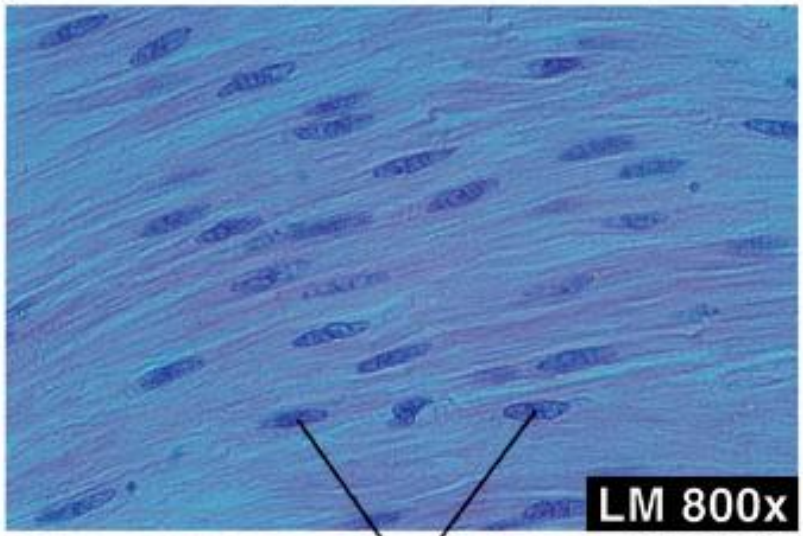


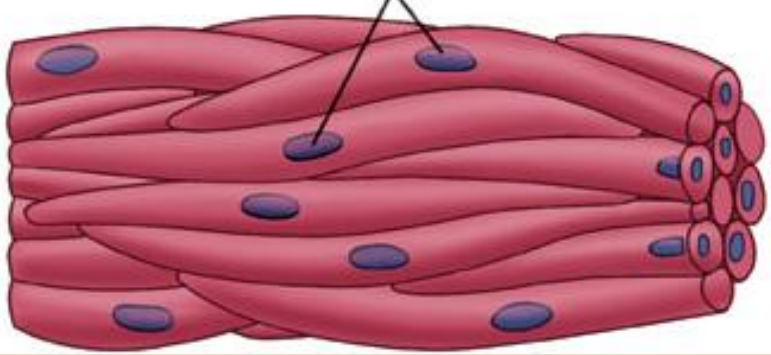
Cardiac Muscle

- Found only in the heart
- Composed of **interconnecting, branching fibers** that are striated
- Each cell has a single nucleus similar to skeletal muscle
- Contains **actin and myosin similar to smooth muscle**.
- Abundant mitochondria
  - Depends on aerobic metabolism
  - It cannot sustain an oxygen debt and still function efficiently
- No motor units
  - Not every cardiac muscle cell is innervated by a nerve in order to stimulate contraction



Smooth Muscle





- Characteristics
  - Not striated
  - Dense bodies instead of Z disks as in skeletal muscle
    - Have noncontractile intermediate filaments
  - Ca^{2+} required to initiate contractions
- Types
  - Visceral or unitary
    - Function as a unit
  - Multiunit
    - Cells or groups of cells act as independent units

Smooth Muscle

In comparison to skeletal muscle fibers

- Smooth muscle fibers are shorter and thinner
- They have a single, centrally located nucleus
- Lack striations
  - Although smooth muscle fibers do contain actin and myosin, the filaments are thin and randomly arranged so that it lacks striations
- No T-tubules
- A poorly developed sarcoplasmic reticulum

Smooth Muscle

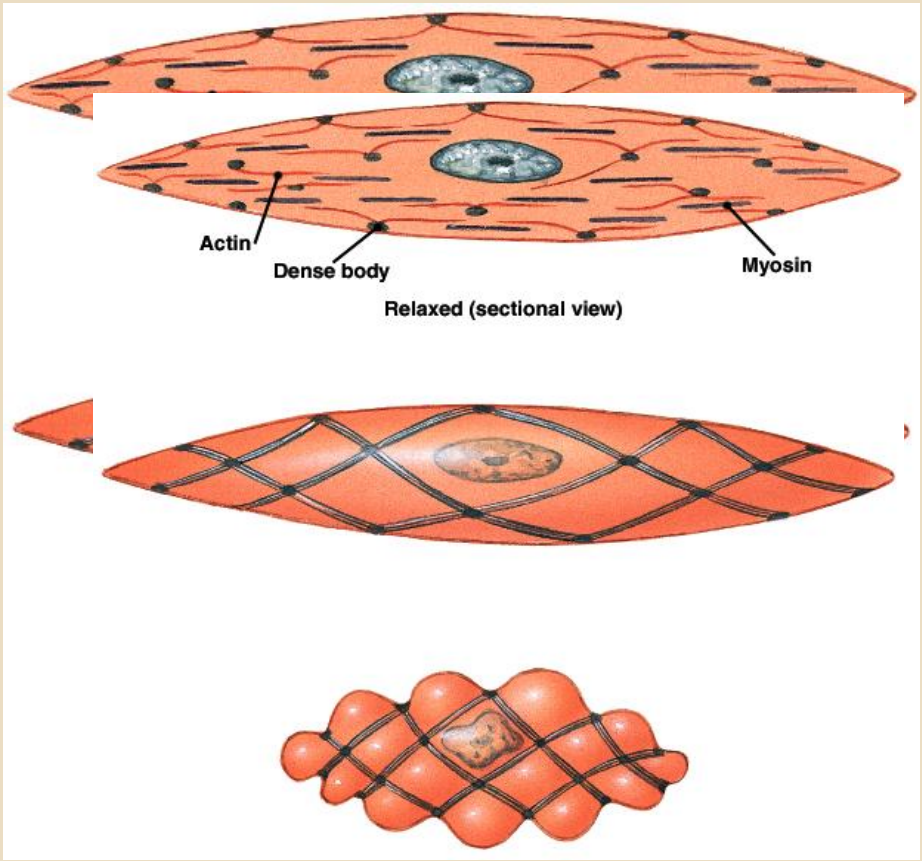
- Smooth muscle fibers contract in a similar manner to skeletal muscles with a few important functional similarities and differences.
  - **Similarities**
    - Both contractile mechanisms depend on the action of actin and myosin;
    - Both are triggered by membrane impulses and the release of calcium ions; and
    - Both require ATP.

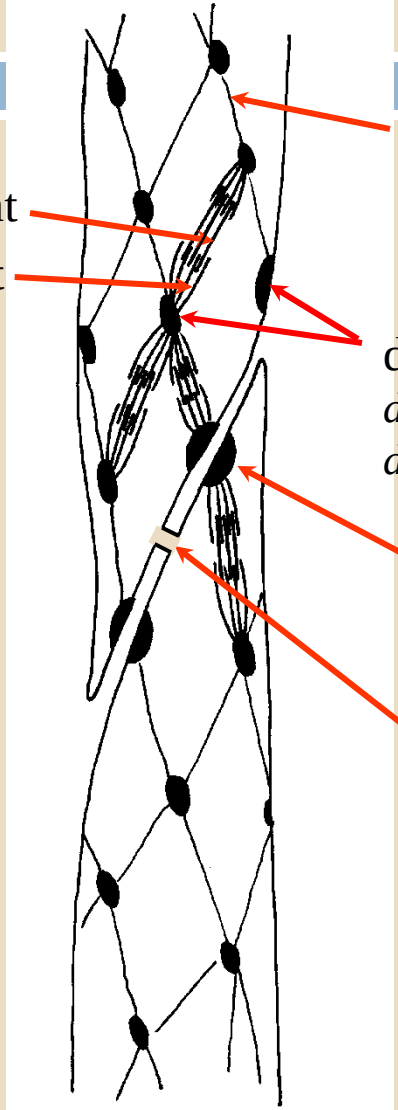
Smooth Muscle

Differences in smooth muscle include

- Actin has **no troponin**, the protein that binds to myosin in skeletal muscle. Rather smooth muscle has a calcium binding protein called **calmodulin**. This protein activates the actin and myosin cross-bridge formation.
- Most of the calcium required for contraction comes into the cell by diffusion **from the extracellular fluid.**
- Smooth muscle is **more resistant to fatigue** and produces a slower, longer lasting contraction than skeletal muscle.
- It is more energy efficient than skeletal muscle in that it can maintain a more forceful contraction for a longer period of time with the same amount of ATP.

Smooth Muscle: structure





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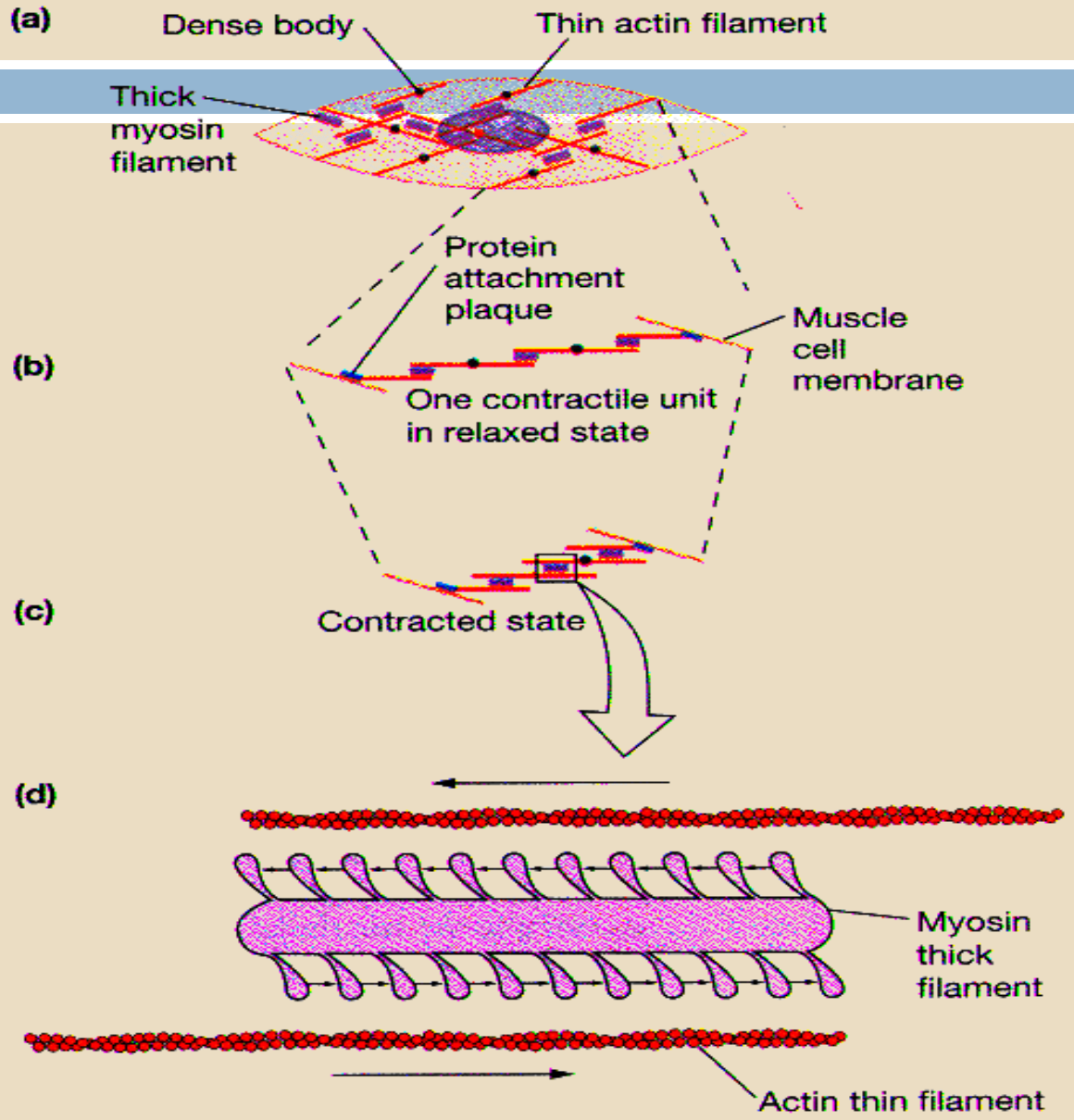
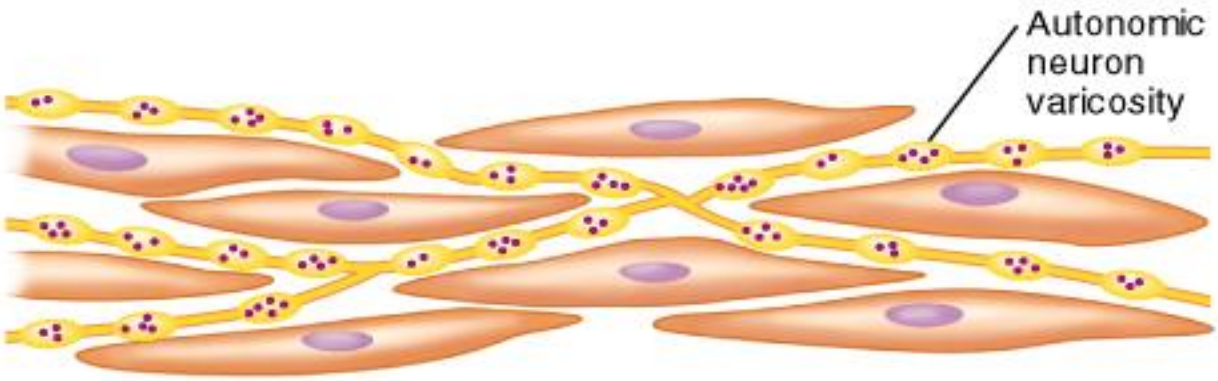

(a)
Dense body
Thin actin filament
Thick
myosin
filament
Protein
attachment
plaque
Muscle
cell
membrane
(b)
One contractile unit
in relaxed state
(c)
Contracted state
(d)
Myosin
thick
filament
Actin thin filament

Smooth Muscle: types



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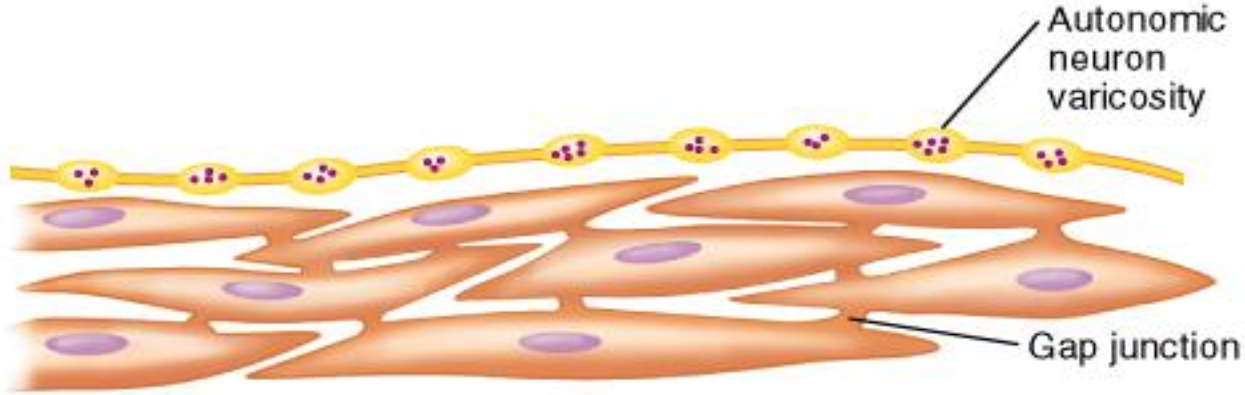

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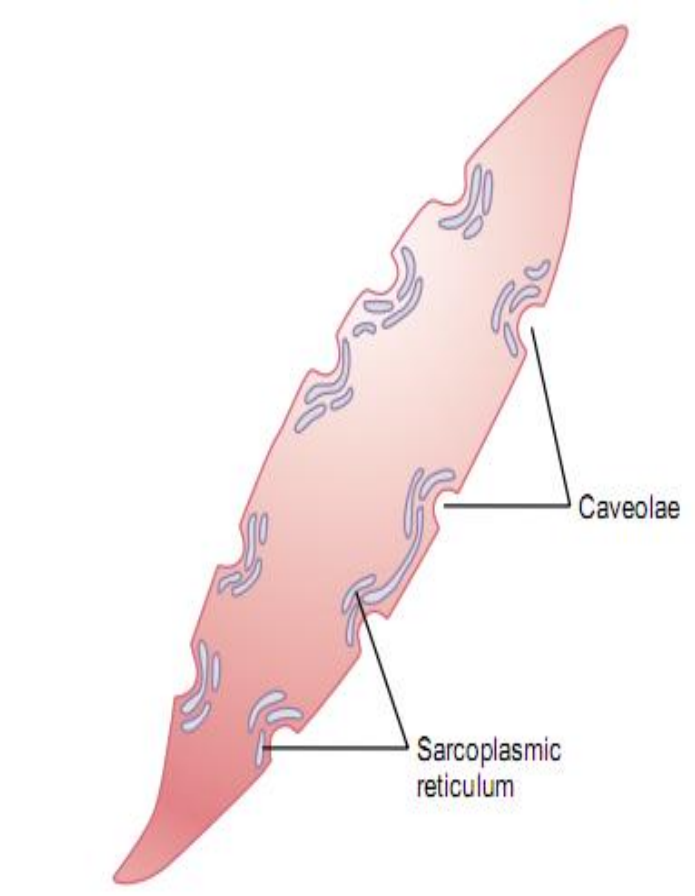
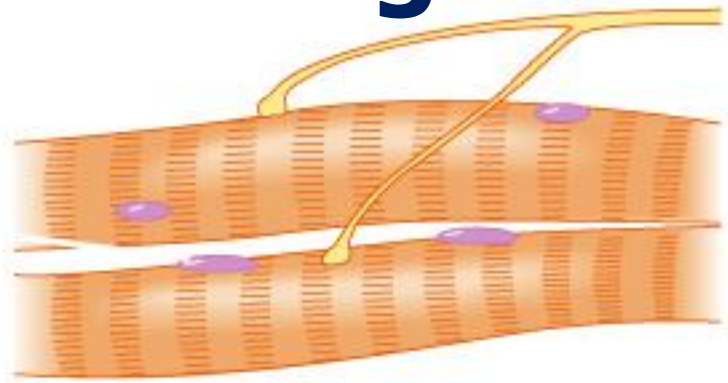
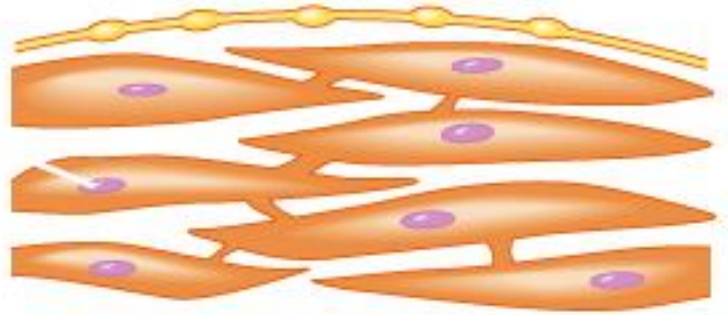
Smooth Muscle: arrangement





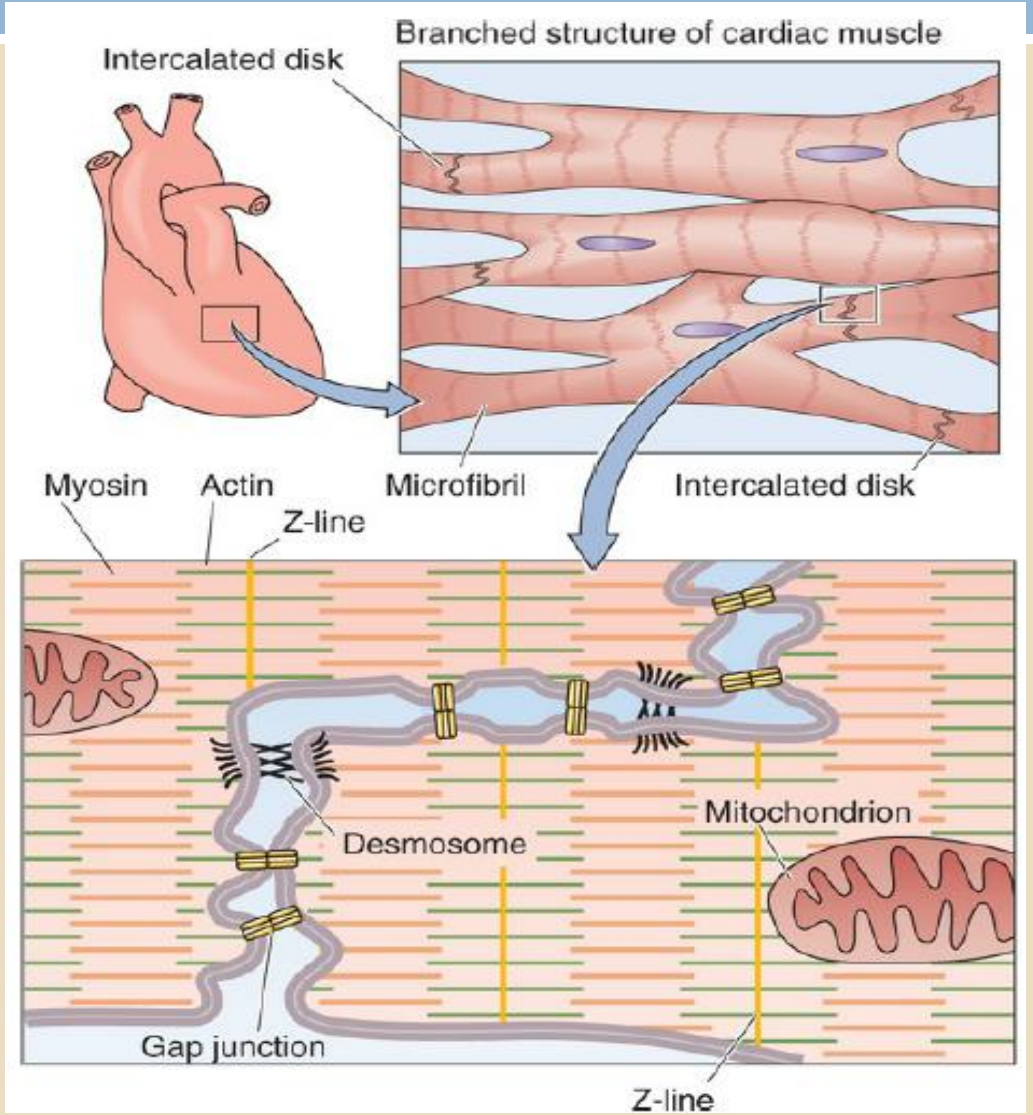
(a) Skeletal muscle



(b) Smooth muscle

Cardiac Muscle

- Found only in the heart
- Composed of **interconnecting, branching fibers** that are striated
- Each cell has a single nucleus similar to skeletal muscle
- Contains **actin and myosin similar to smooth muscle**.
- Abundant mitochondria
  - Depends on aerobic metabolism
  - It cannot sustain an oxygen debt and still function efficiently
- No motor units
  - Not every cardiac muscle cell is innervated by a nerve in order to stimulate contraction



Cardiac Muscle

- **Extensive system of T-tubules**
  - Release large quantities of calcium ions
- **Well developed sarcoplasmic reticulum**
  - Terminal cisternae contain less calcium than in skeletal muscle
  - Strength of the cardiac muscle contraction depends largely on the influx of calcium from the extracellular space in addition to that released from the T-tubules and sarcoplasmic reticulum
- **Contains intercalated disks**
  - Membrane junctions that hold adjacent cells together and transmit the contraction force to each cell
- **Gap Juntions**
  - Most important intercellular junction that allow interchange and communication between the sarcoplasm of connected cardiac muscle cells

Sarcotubular System

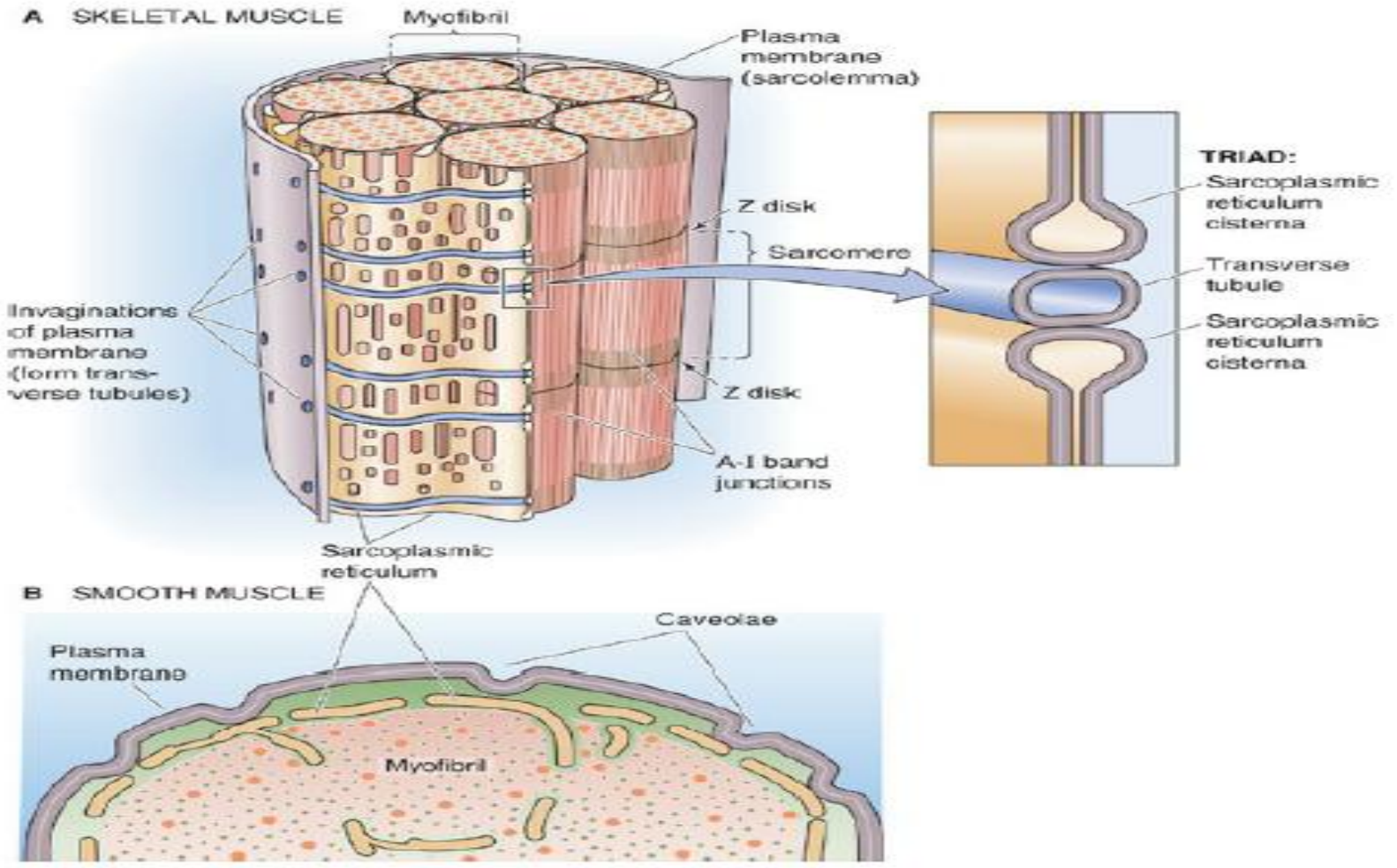


Figure 9-2 Plasma membrane invaginations. **A**, The transverse tubules (T tubules) are extensions of the plasma membrane, penetrating the muscle cell at two points in each sarcomere: the junctions of the A and I bands. **B**, Smooth muscle cells have rudimentary invaginations of the plasma membrane, called caveolae, contacting the sarcoplasmic reticulum.