Muscle Tissue

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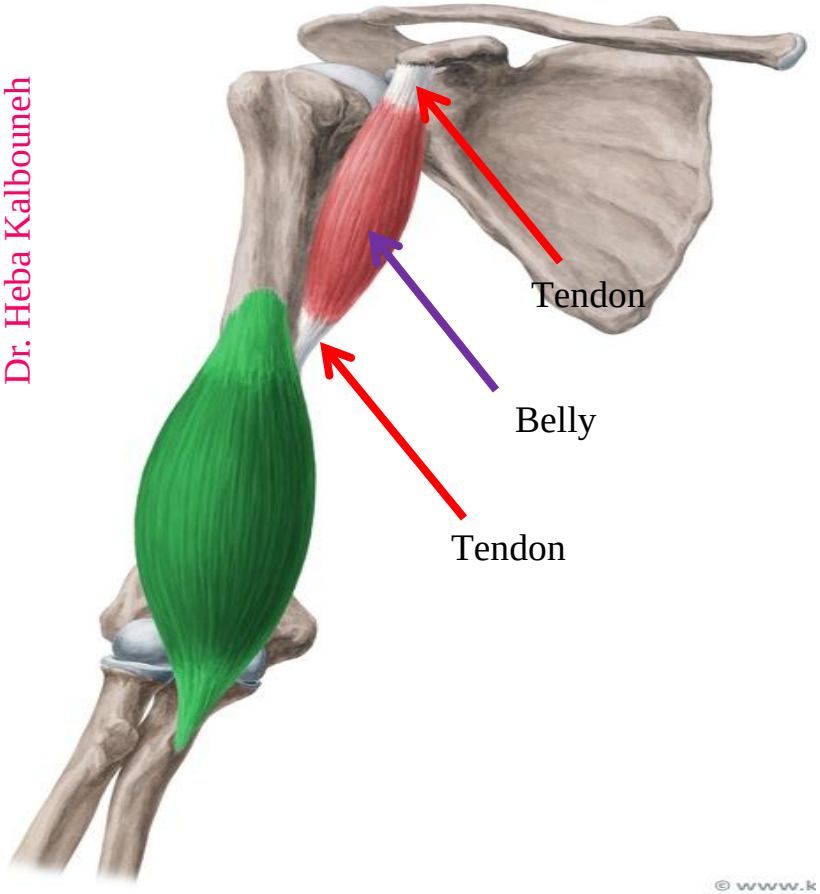
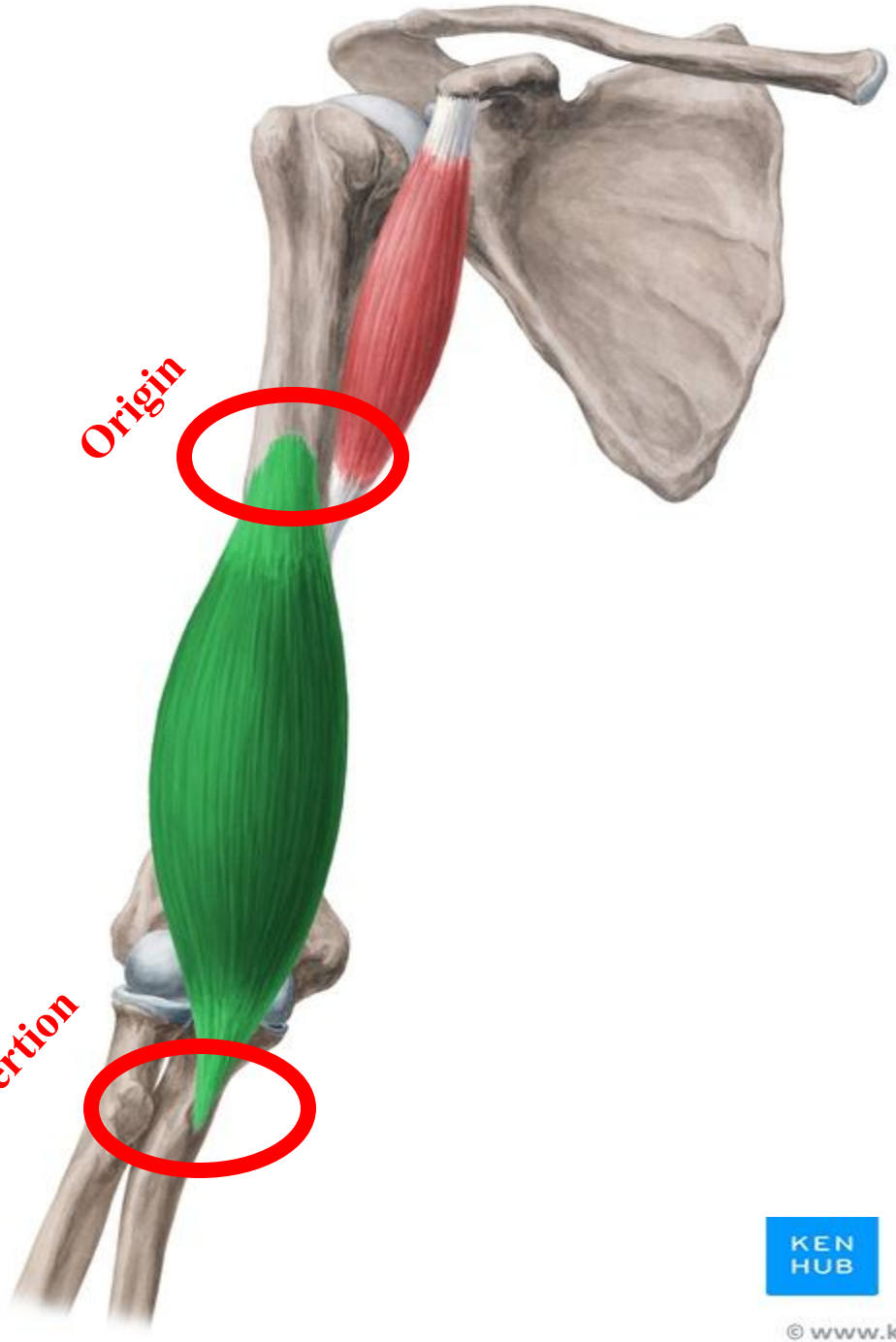
Functions of muscle tissue

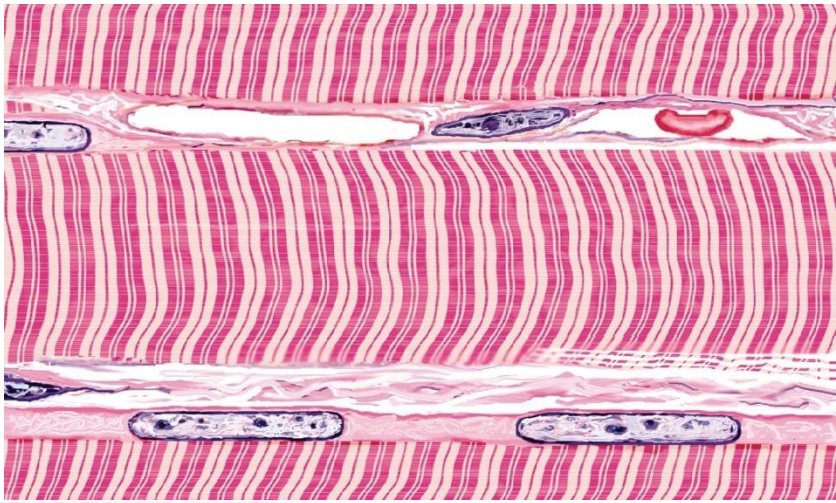
- Movement
- Maintenance of posture
- Joint stabilization
- Heat generation



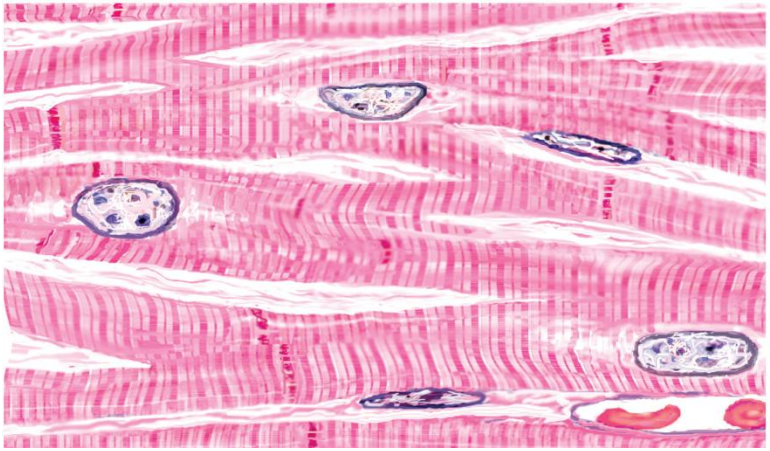


Types of Muscle Tissue

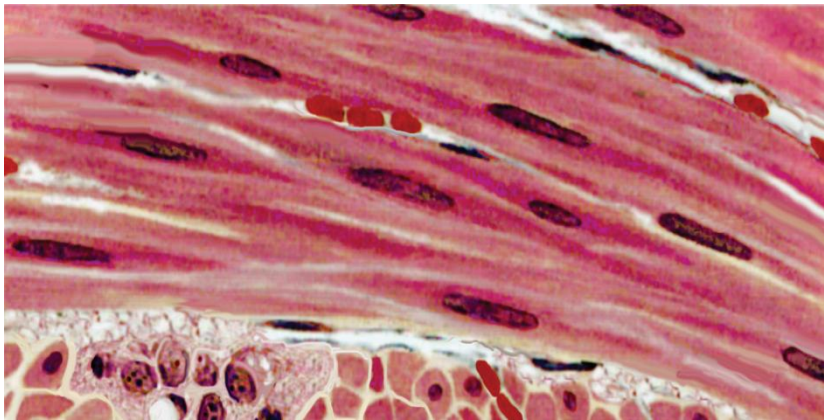
- Skeletal muscle



- Cardiac muscle

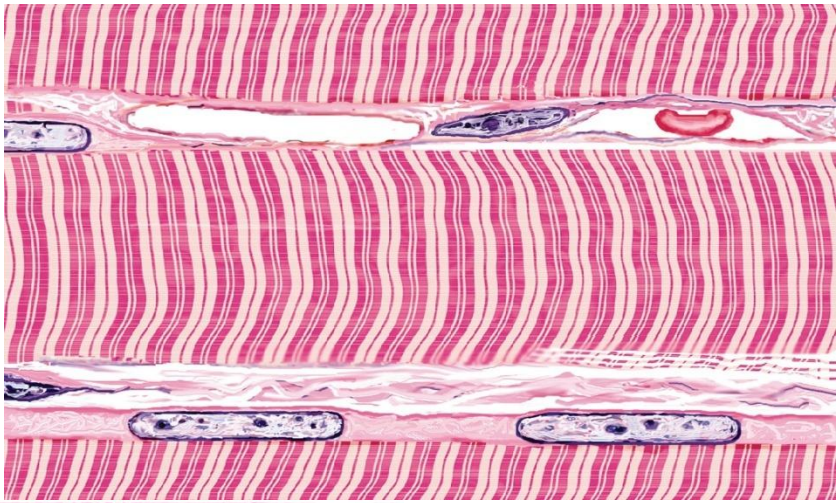


- Smooth muscle



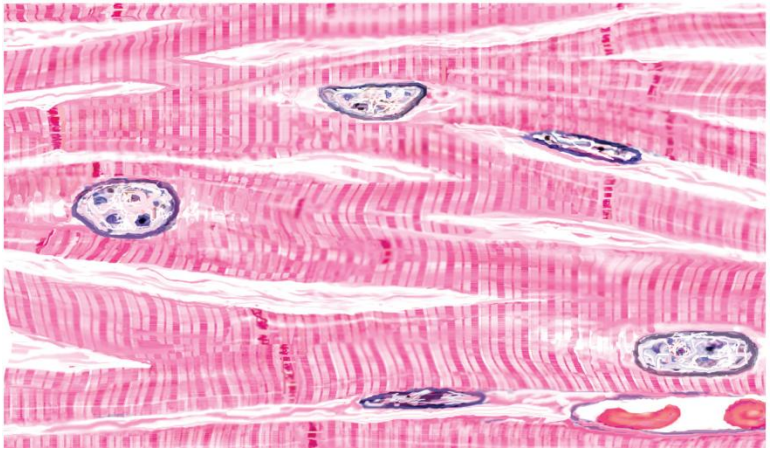
Skeletal

- Attach to and move skeleton
- 40% of body weight
- Fibers = multinucleate cells (embryonic cells fuse)
- Cells with obvious striations
- Contractions are voluntary



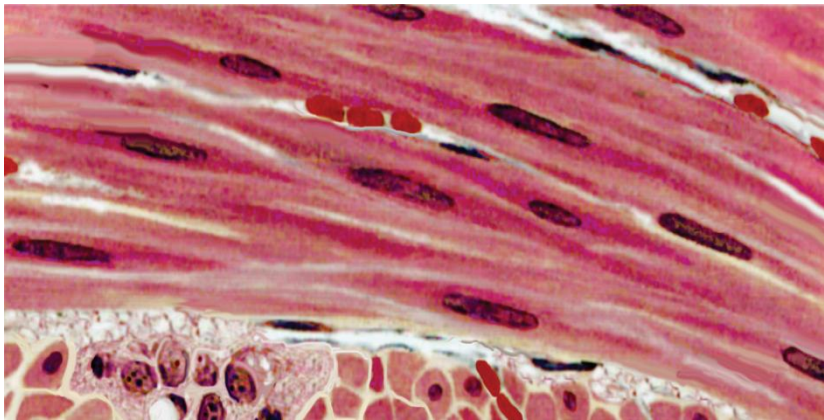
Cardiac: *only in the wall of the heart*

- Cells are striated
- Contractions are involuntary



Smooth: *walls of hollow organs*

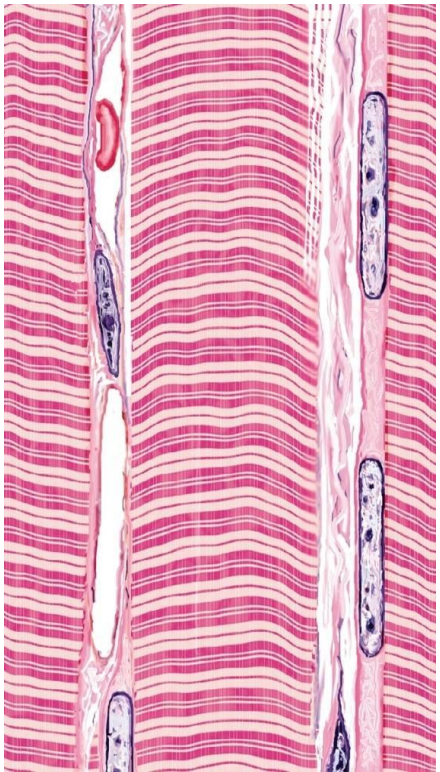
- Lack striations
- Contractions are involuntary



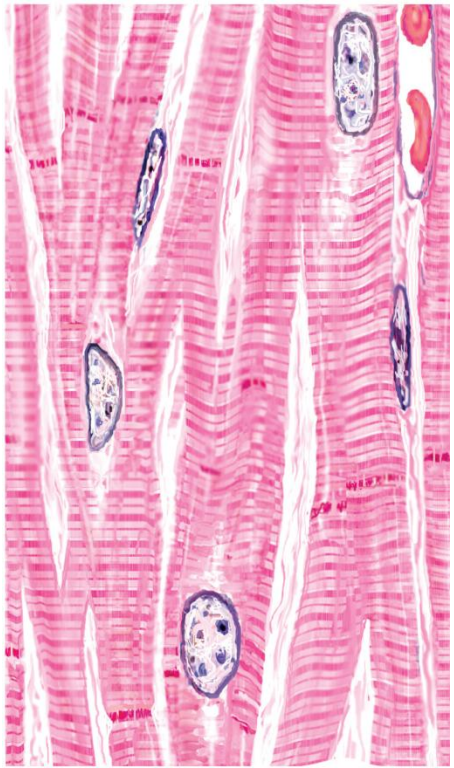
Similarities…

- Their cells are called **fibers** because they are elongated
- Contraction depends on **myofilaments**
  - *Actin*
  - *Myosin*
- Plasma membrane is called **sarcolemma**
  - *Sarkos* = flesh
  - *Lemma* = sheath

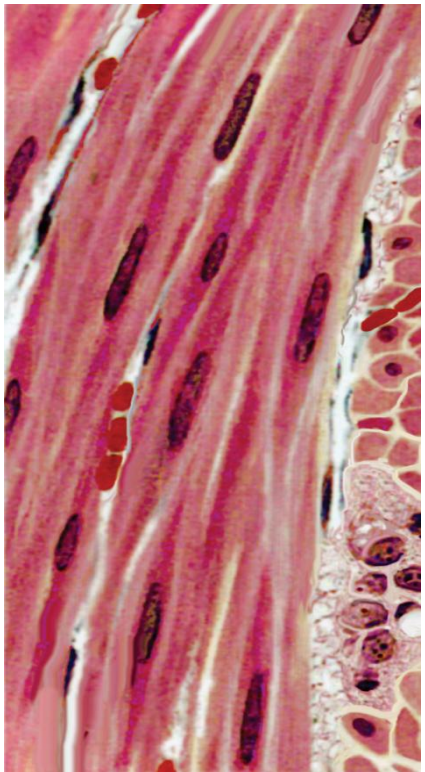
Skeletal muscle



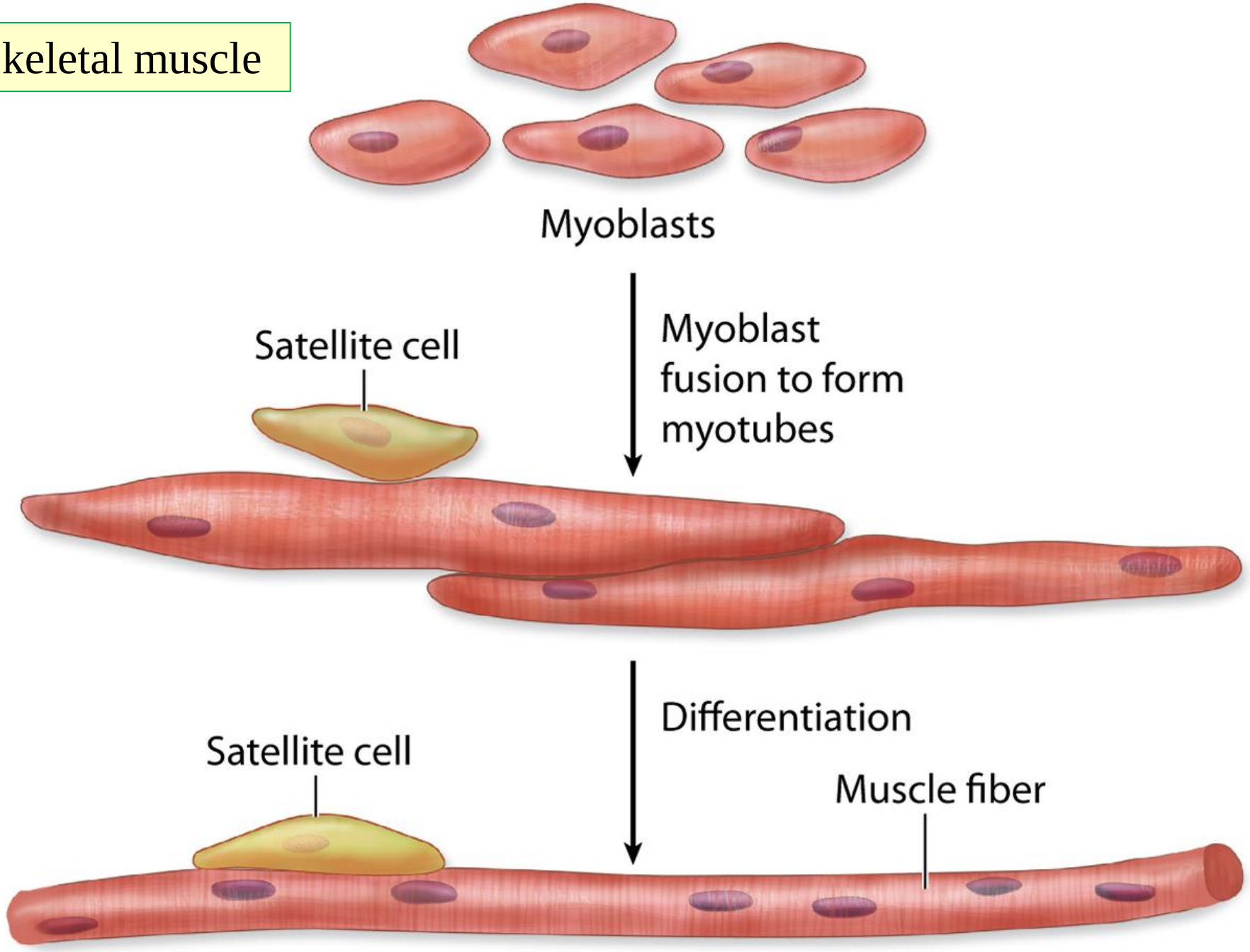
Cardiac muscle



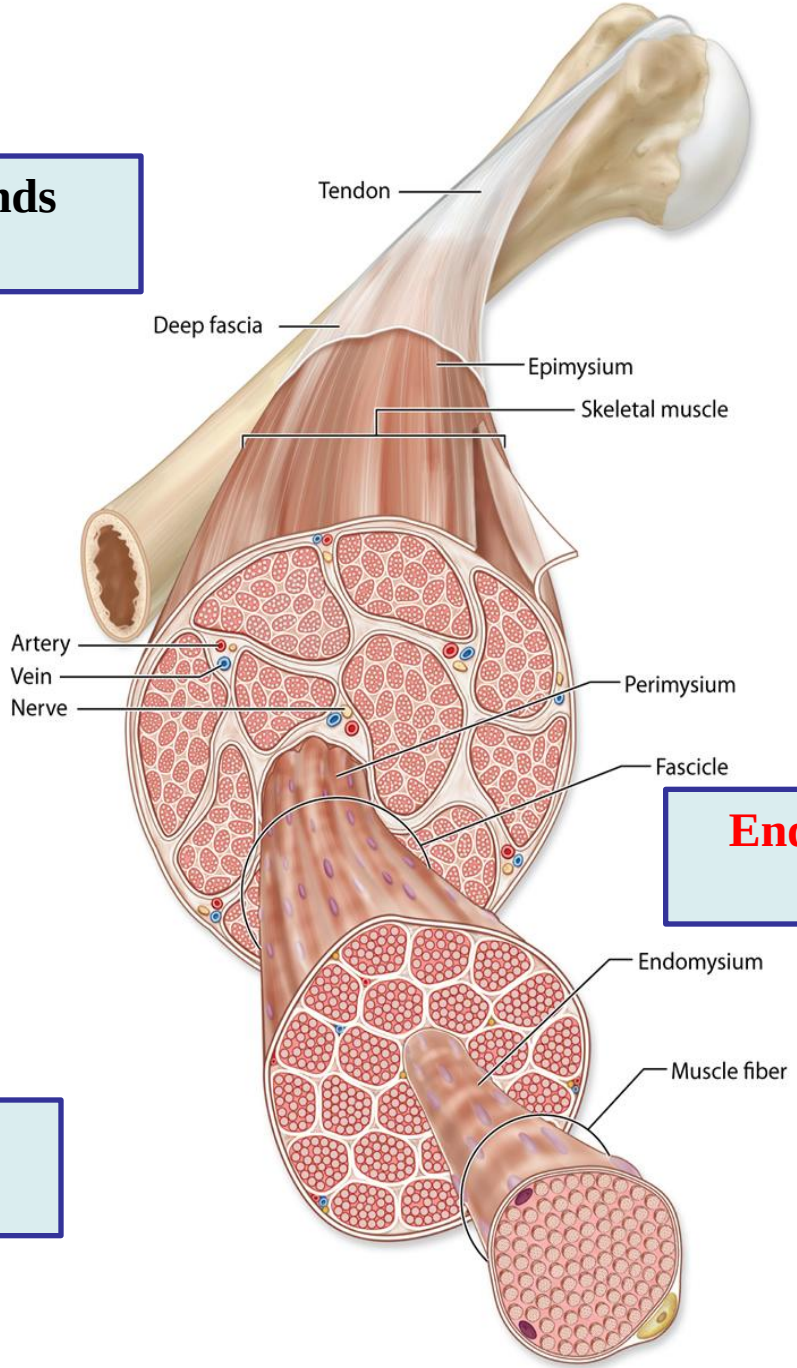
Smooth muscle



Skeletal muscle



Epimysium surrounds whole muscle



Endomysium is around each muscle fiber

Perimysium is around fascicle

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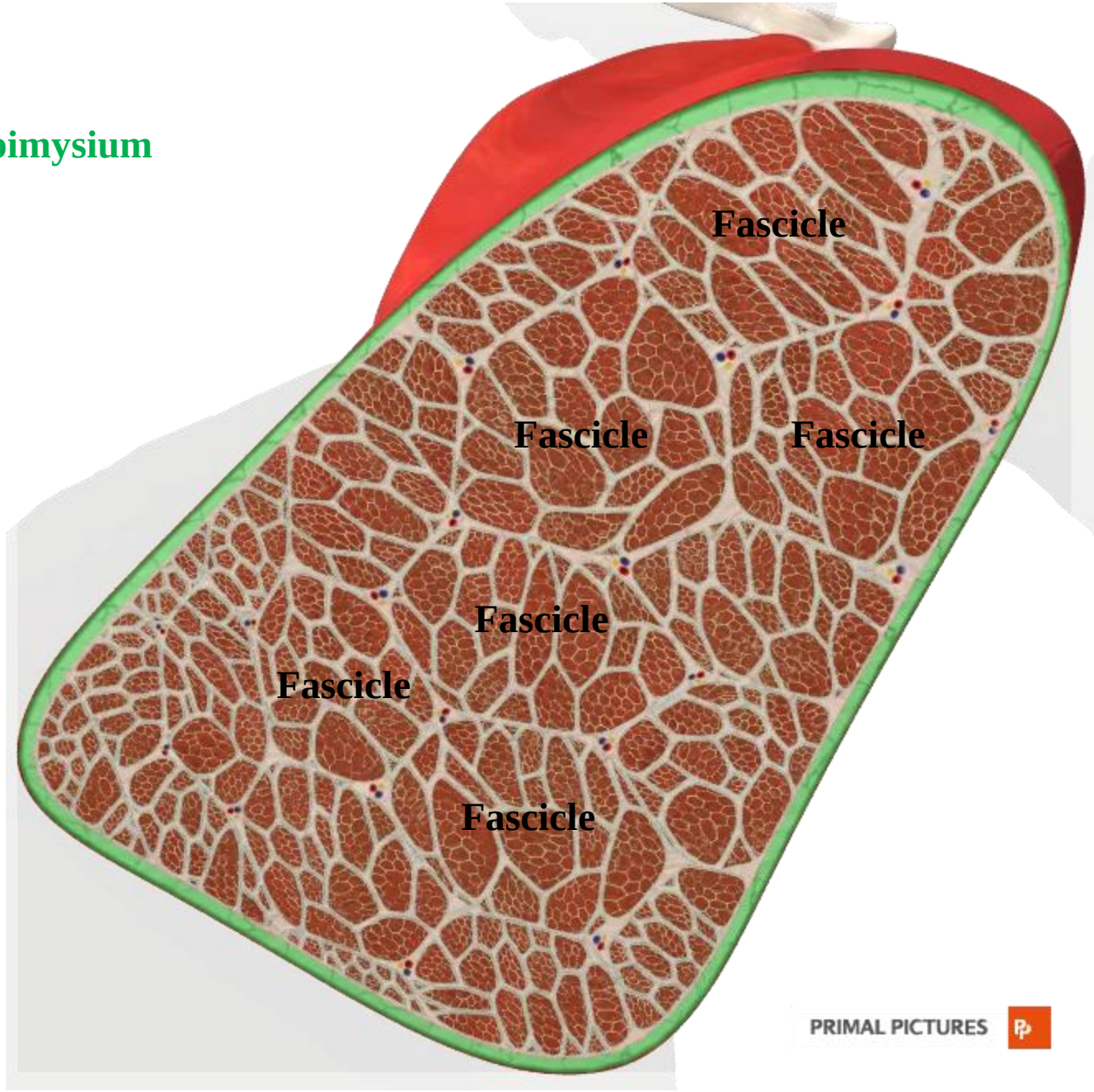
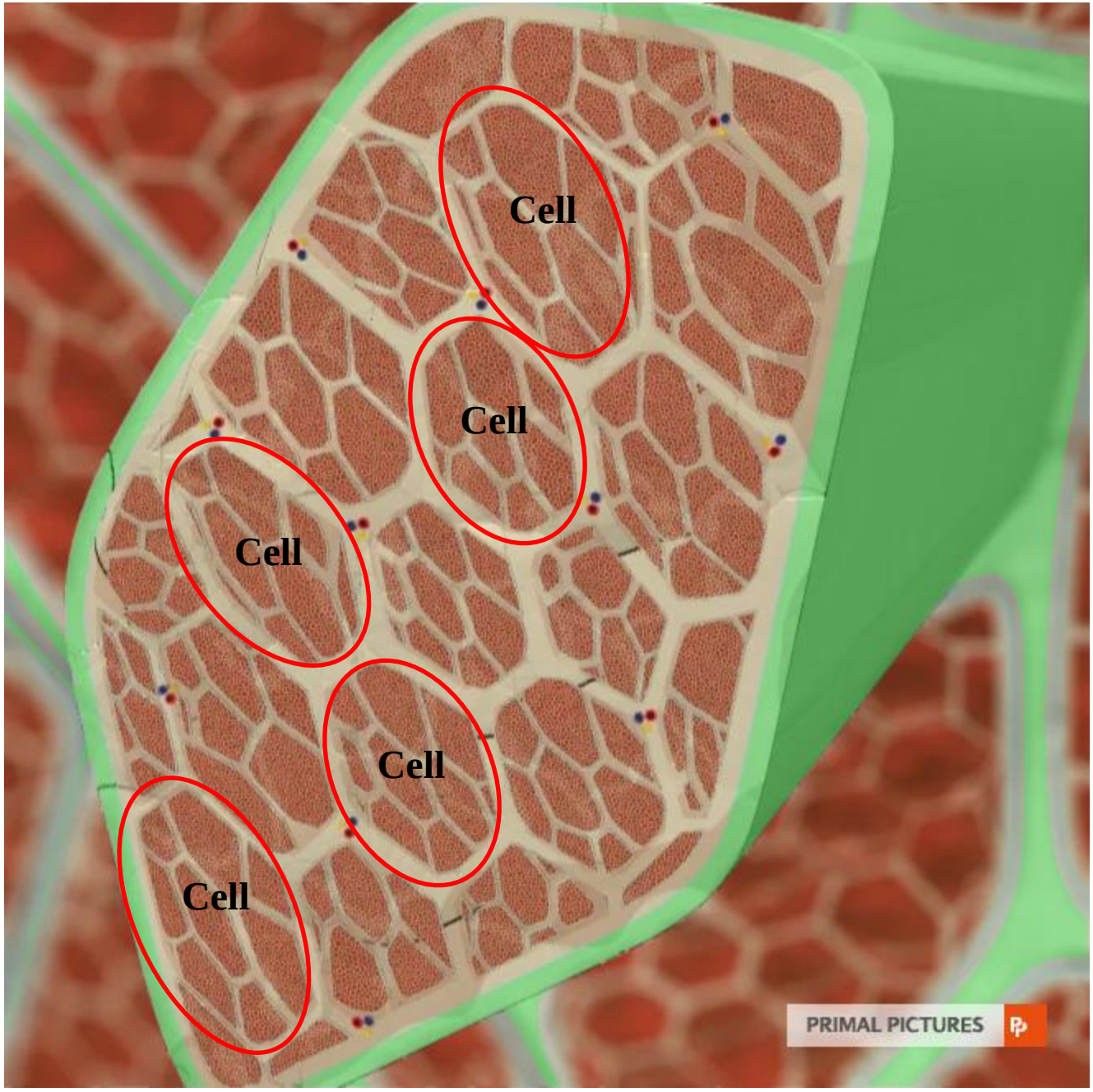
Epimysium



Perimysium



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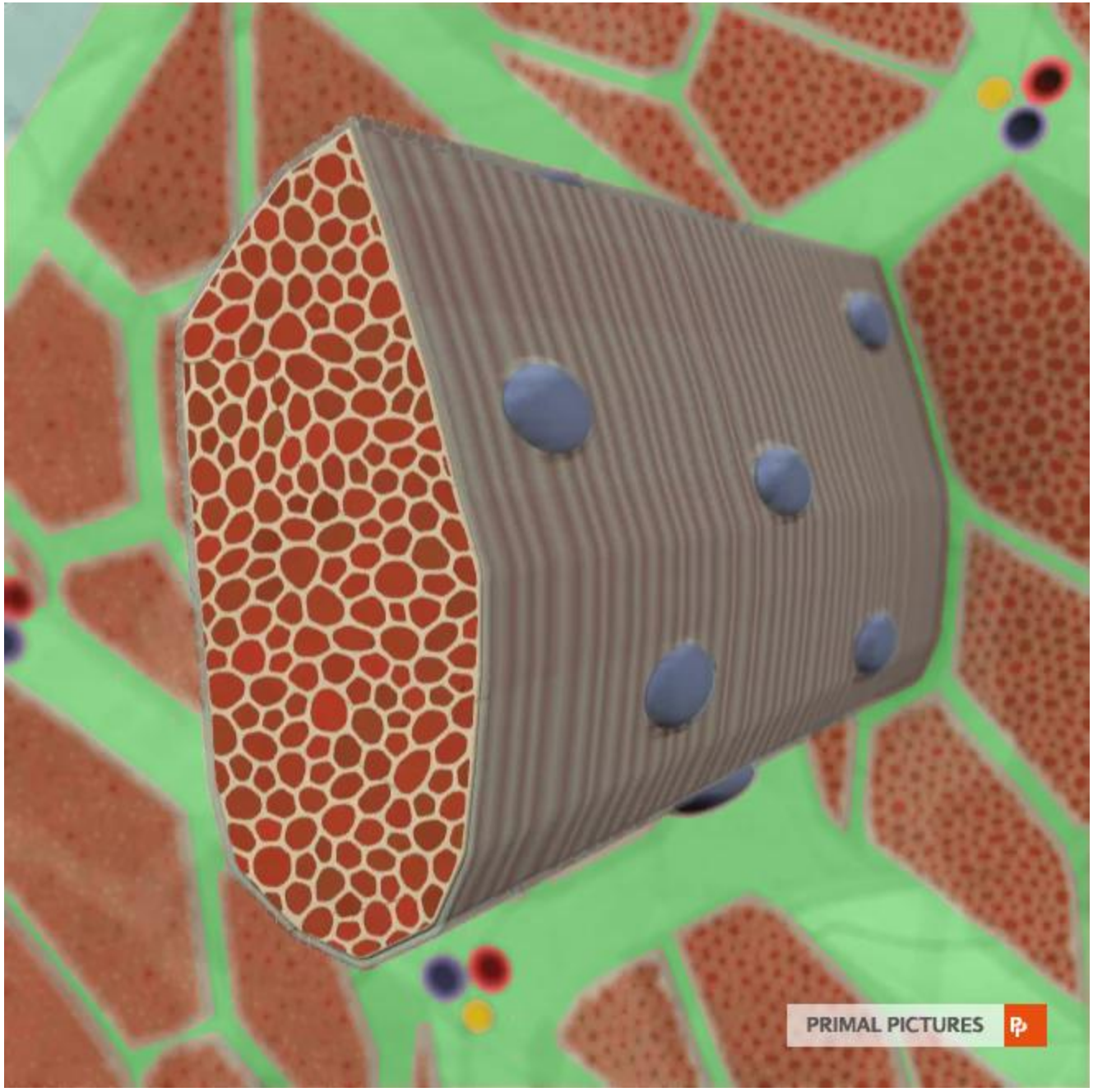
Endomysium



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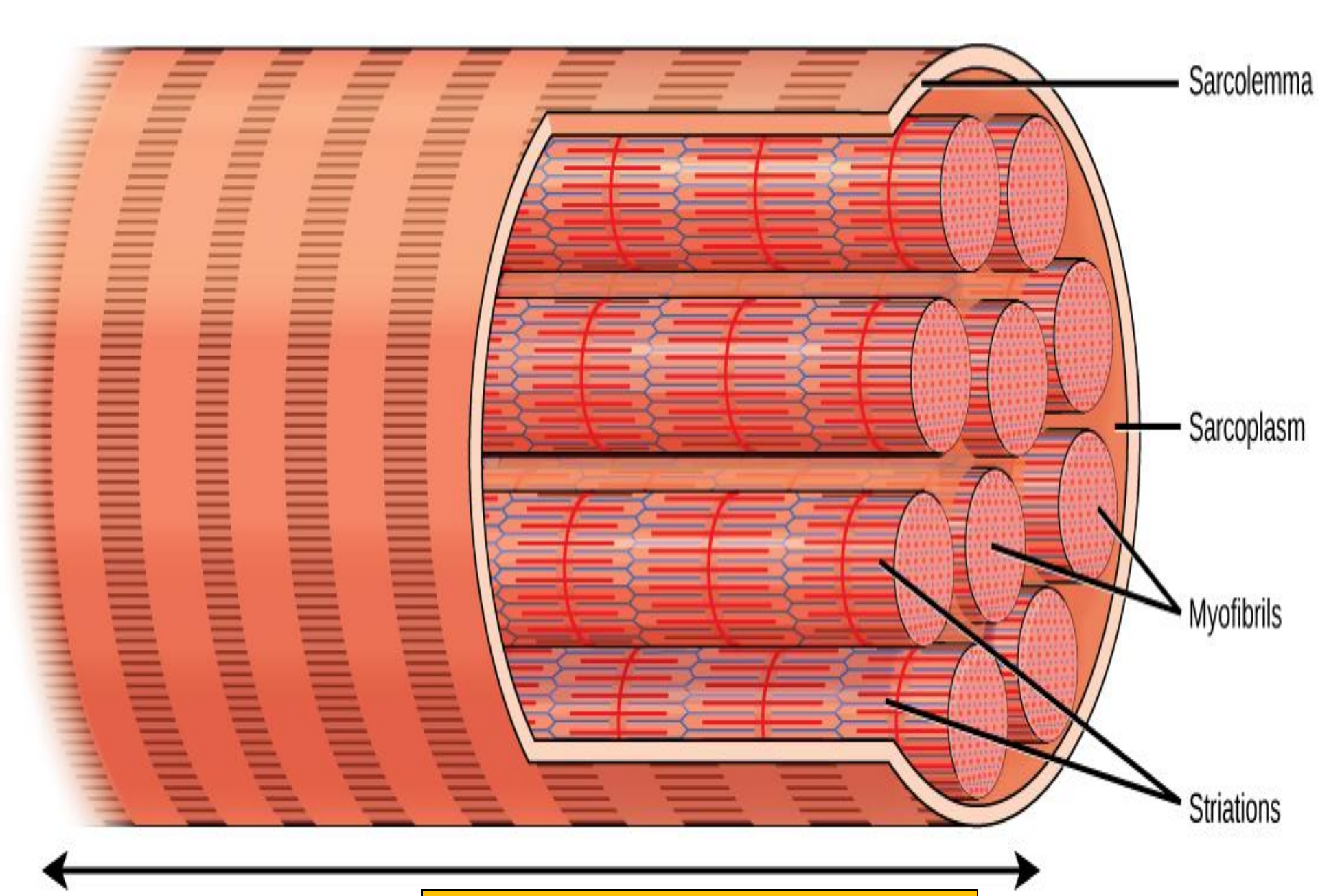


Muscle fiber= muscle cell= myofiber

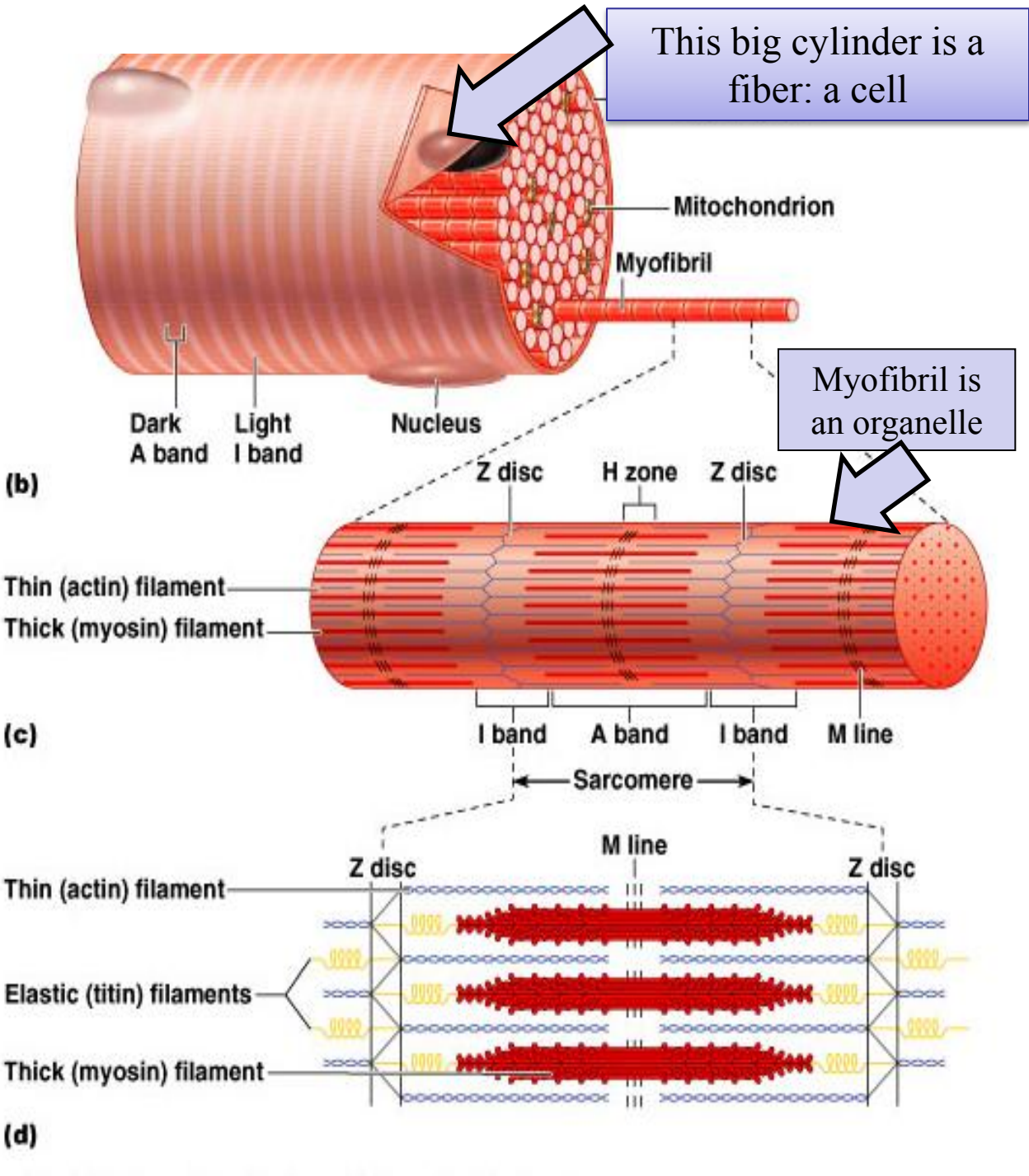
Skeletal muscle

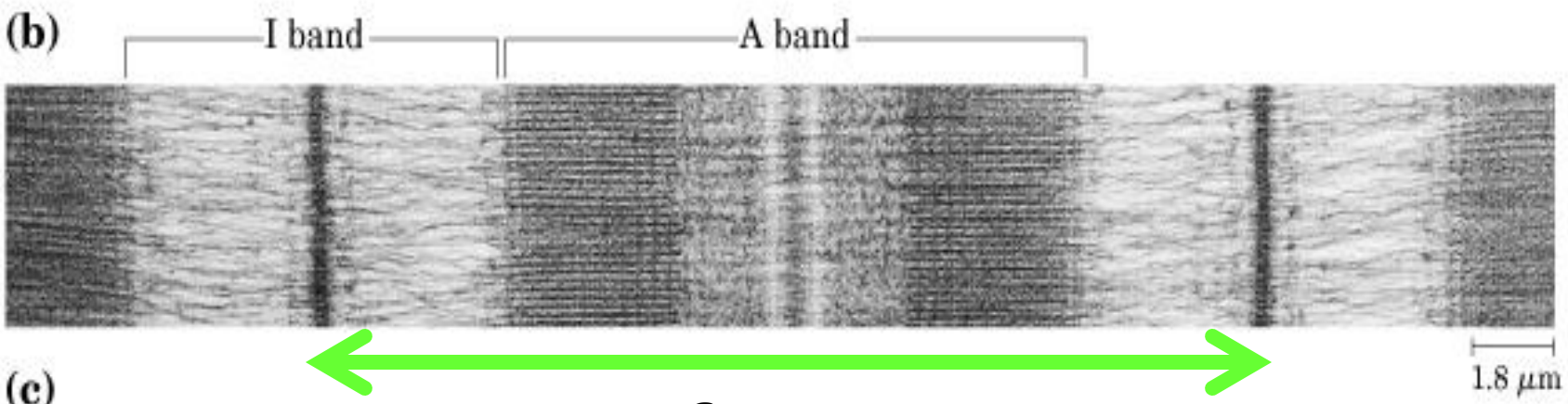
Fibers (each is one cell) have striations

Myofibrils
are organelles of the cell, are made up of **myofilaments**

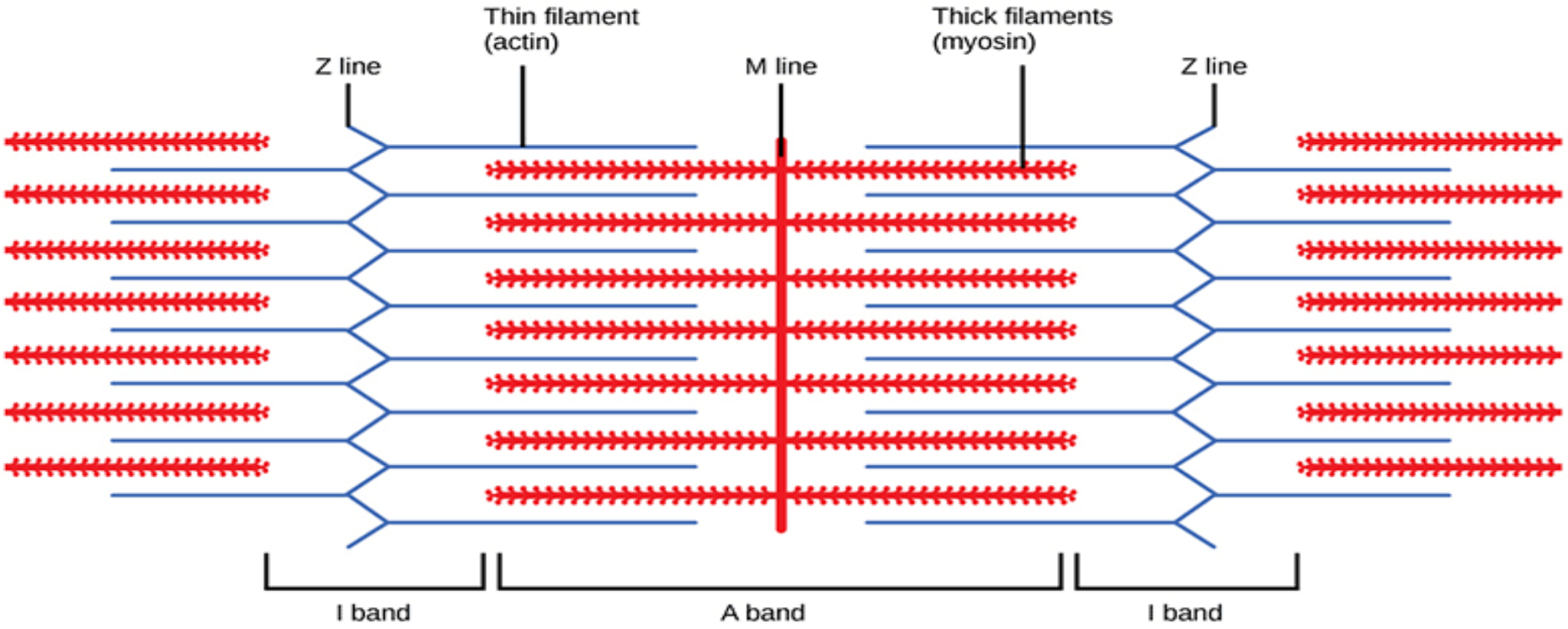
Myofibrils
are long rows of repeating sarcomeres

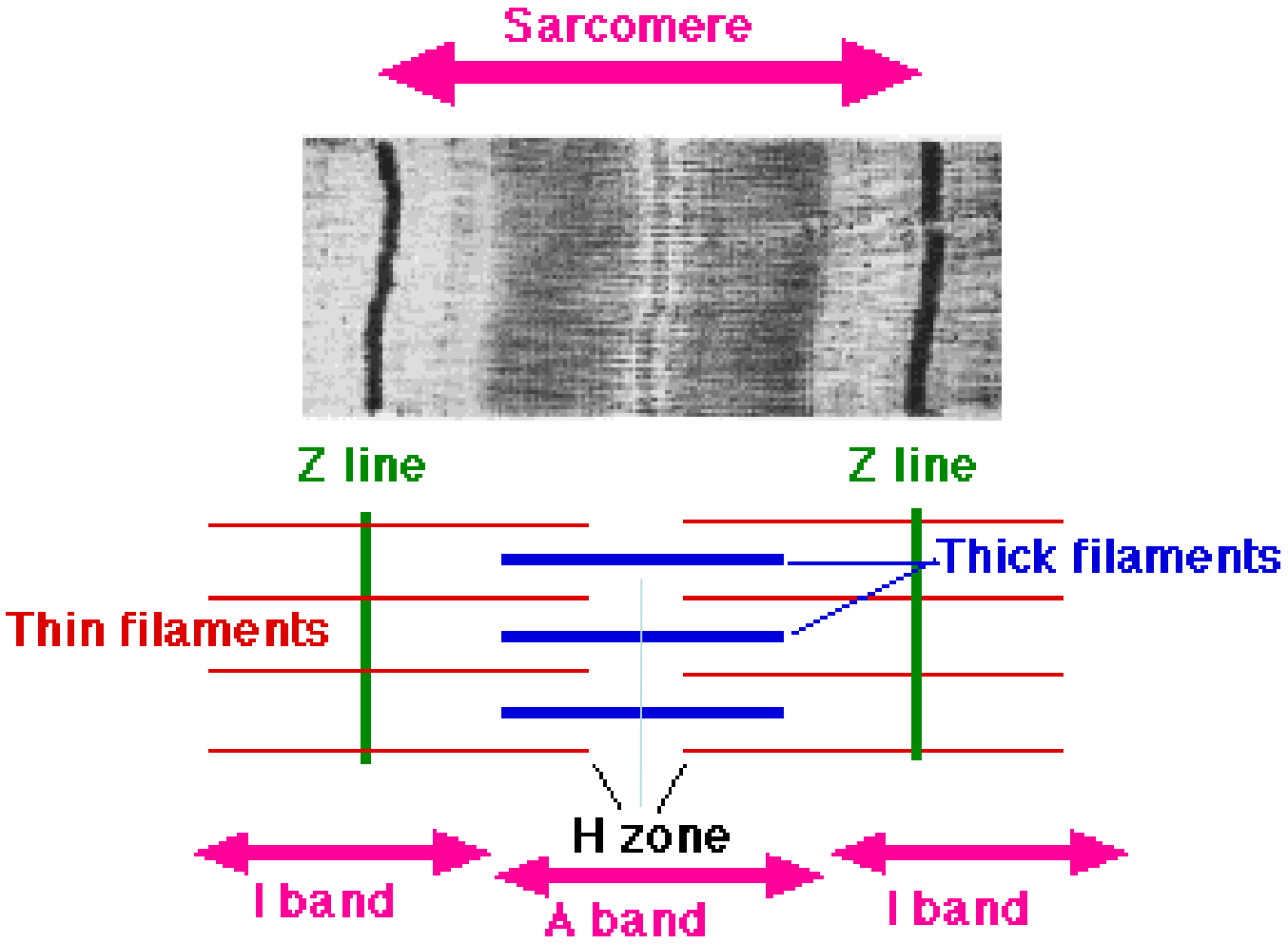
Sarcomere:
Basic unit of contraction
Boundaries: **Z discs** (or lines)




(b)
I band
A band
1.8 μm
(c)

Sarcomere


Thin filament
(actin)
Thick filaments
(myosin)
Z line
M line
Z line
I band
A band
I band



M line provides an attachment to myosin filaments
Z line provides an attachment to actin filaments

A band is the darker band of the myofibril containing myosin filaments

H band is the lighter section in the middle of the A band where only myosin is present

I band is the lighter band containing only the actin filaments

Myofibrils are made of **myofilaments**

Contractile unit of striated muscle

Structures between Z lines

- 2 halves of I bands
- A band
- H zone
- M line
- Myofilaments

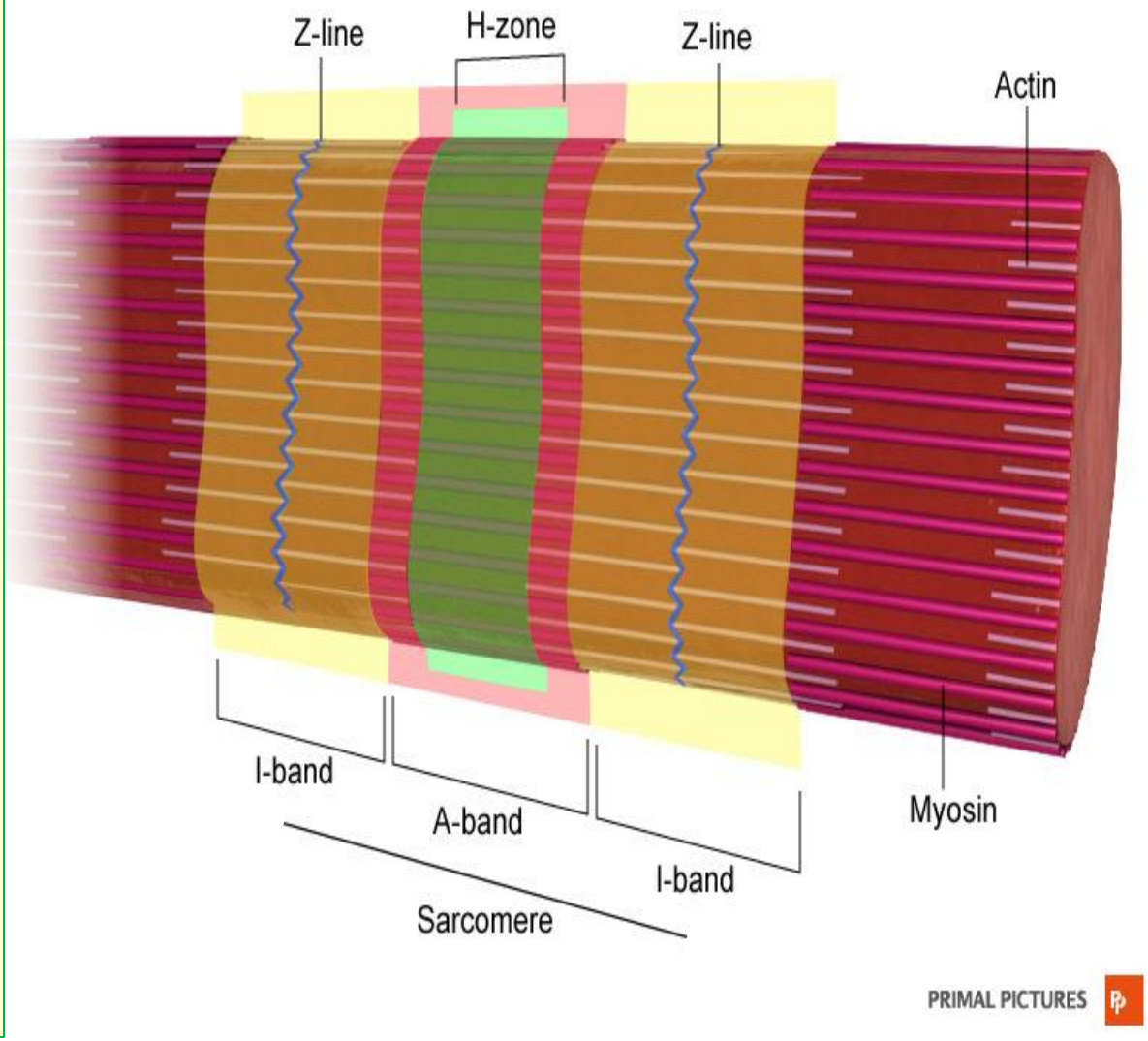
Actin

Myosin

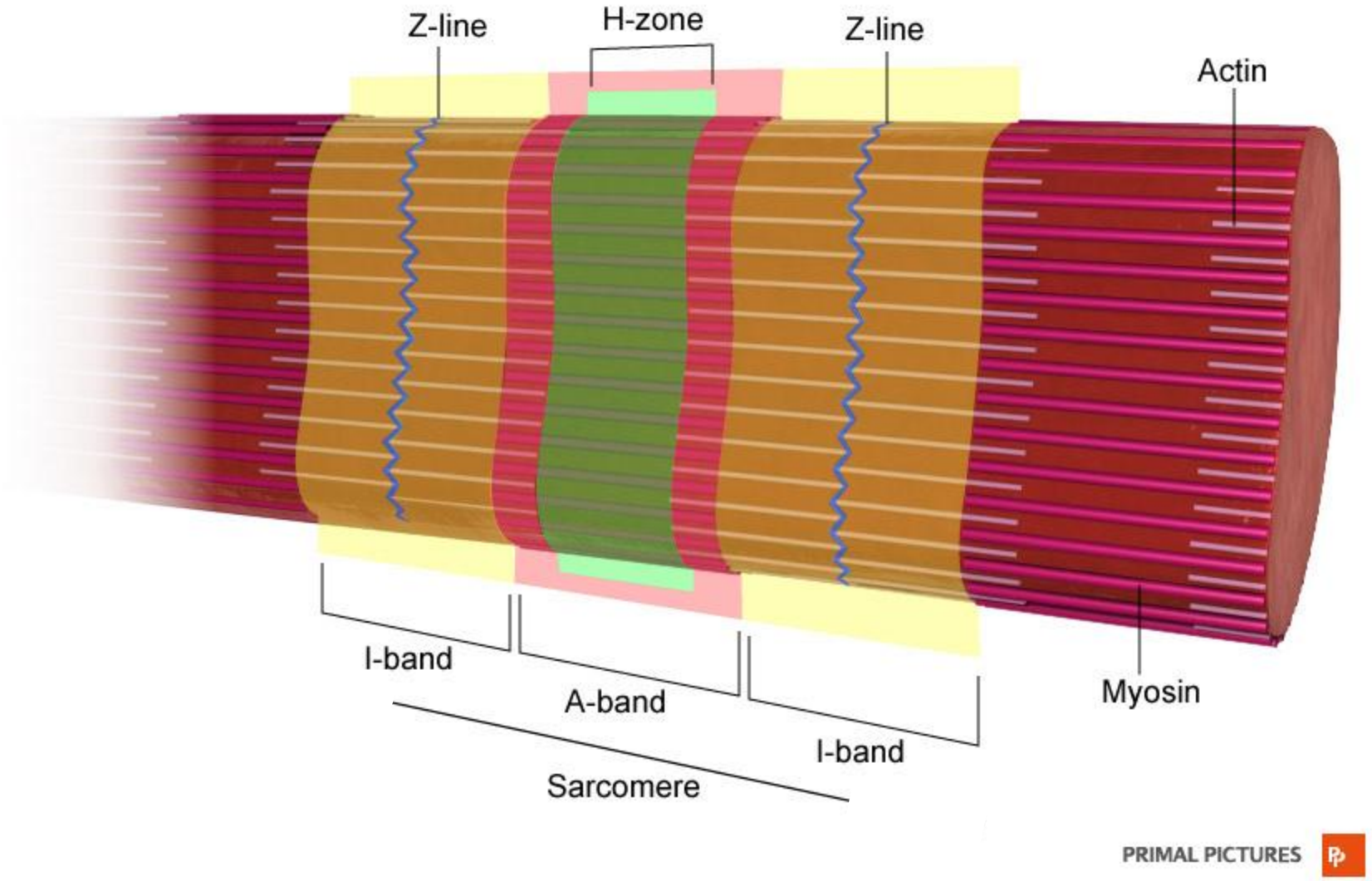
Other structural proteins

- **Titin (myosin-associated) supports myosin filaments and anchor them to Z line (elastic)**
- Nebulin (actin-associated)- binds actin filaments to α actinin
- Myomesin (at M line)
- actinin (at line)
- Vimentin (Z line)
- Dystrophin (cell Z line)
- Desmin (Z membrane)

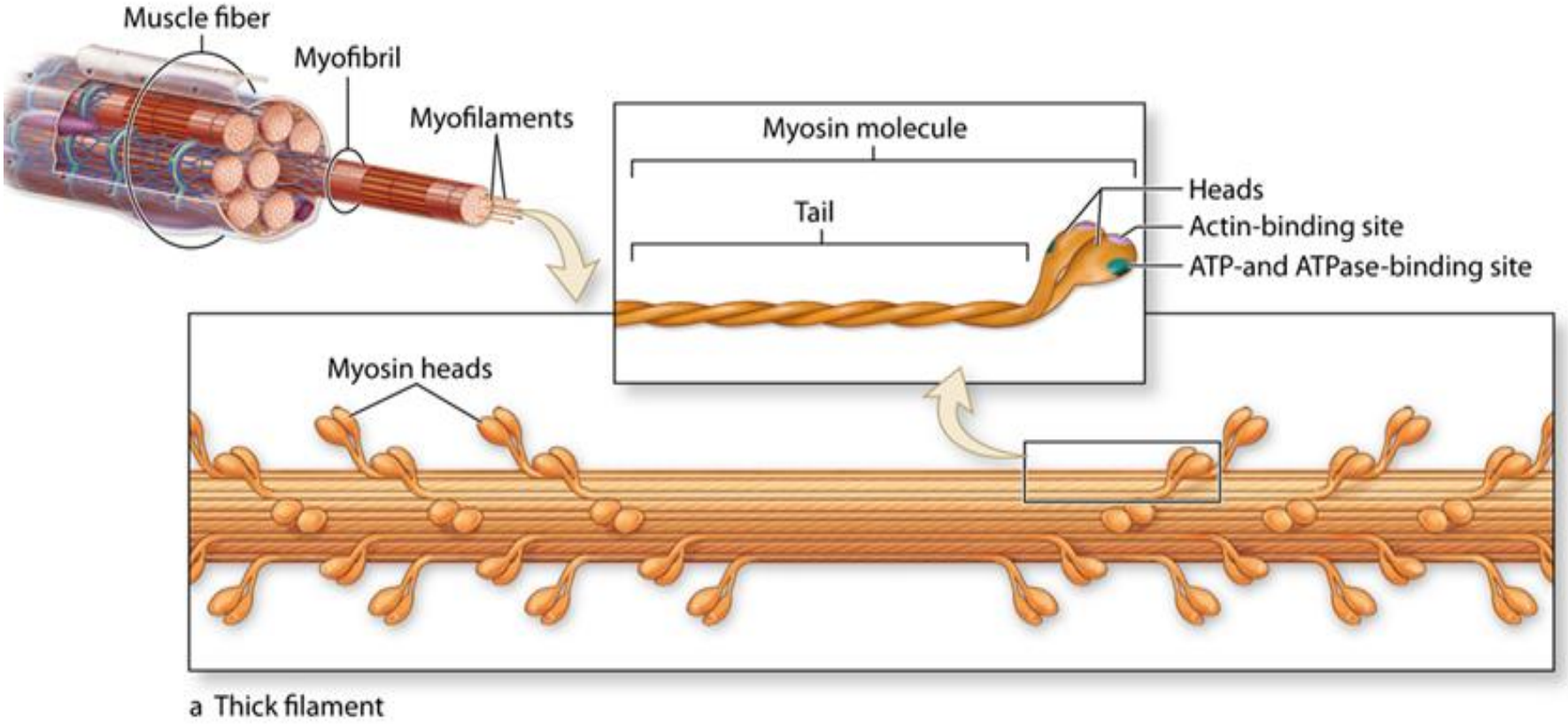
Read only



Myofibril is a long row of repeating sarcomeres



Thick filament

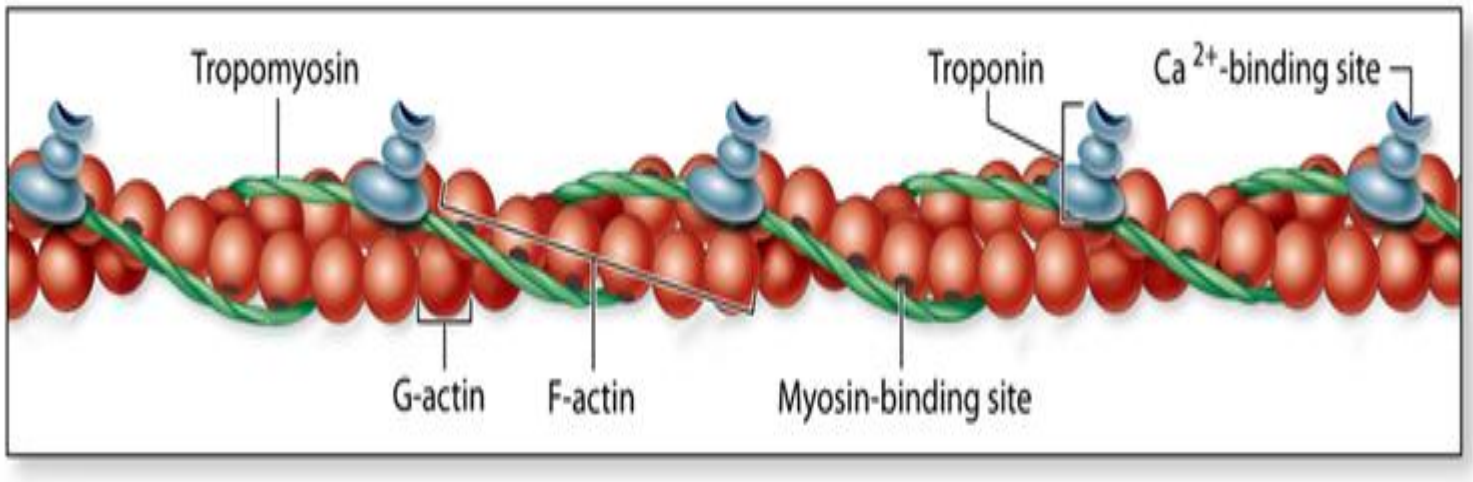


Myosin is composed of 2 identical heavy chains and two pairs of light chains

heavy chains are twisted together as tail

The four light chains form a head at one end of each heavy chains

Thin filament



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- Actin filaments are composed of two thin helical twisted strands composed of G-actin monomers
- Contain a myosin binding site
- Are anchored to the Z line by alpha-actinin
- Associated with:

A- **Tropomyosin**: coil of two peptide chains located in the groove between the two twisted actin strands

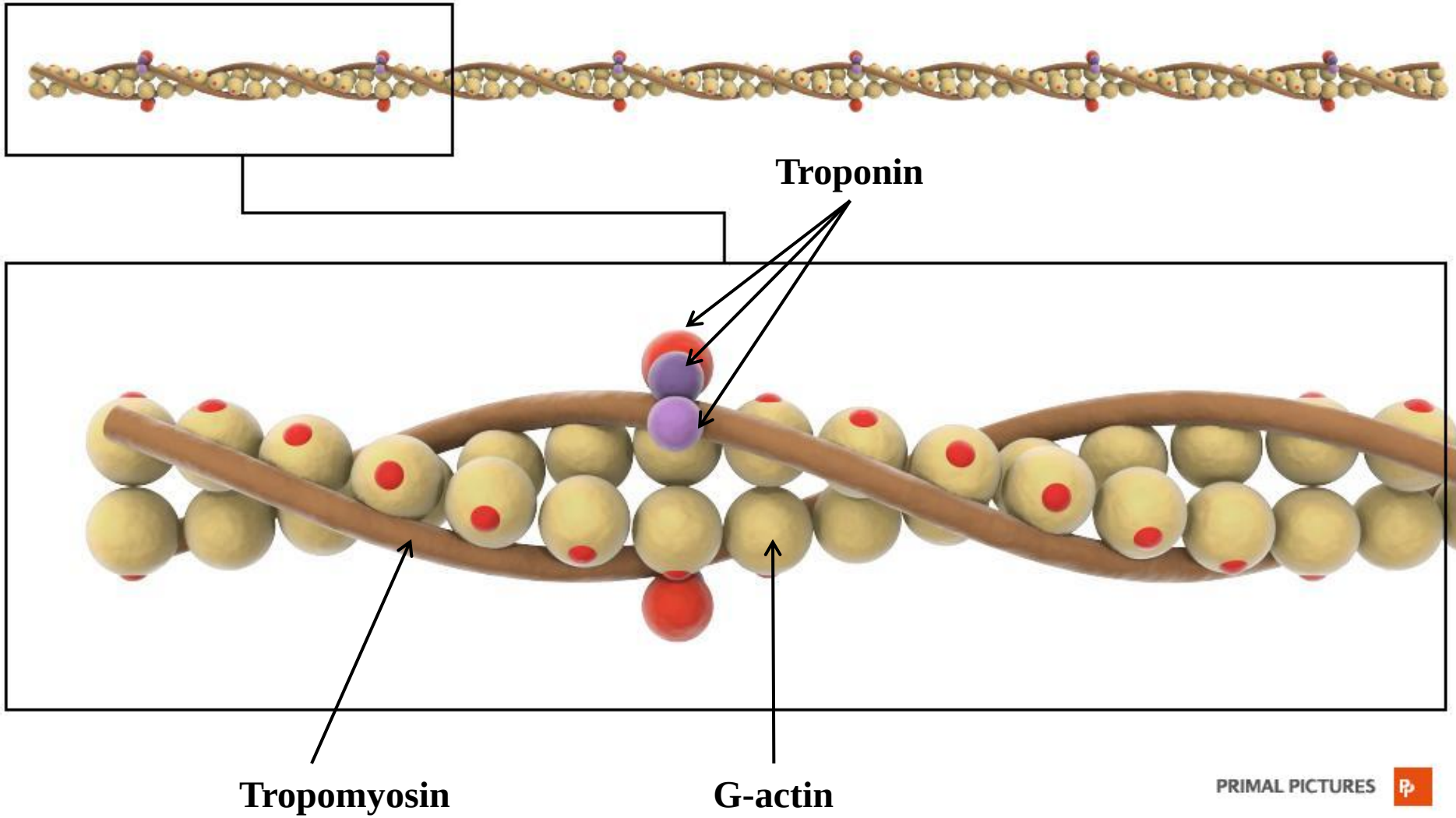
B- **Troponin** a complex of 3 subunits :

Tropomyosin

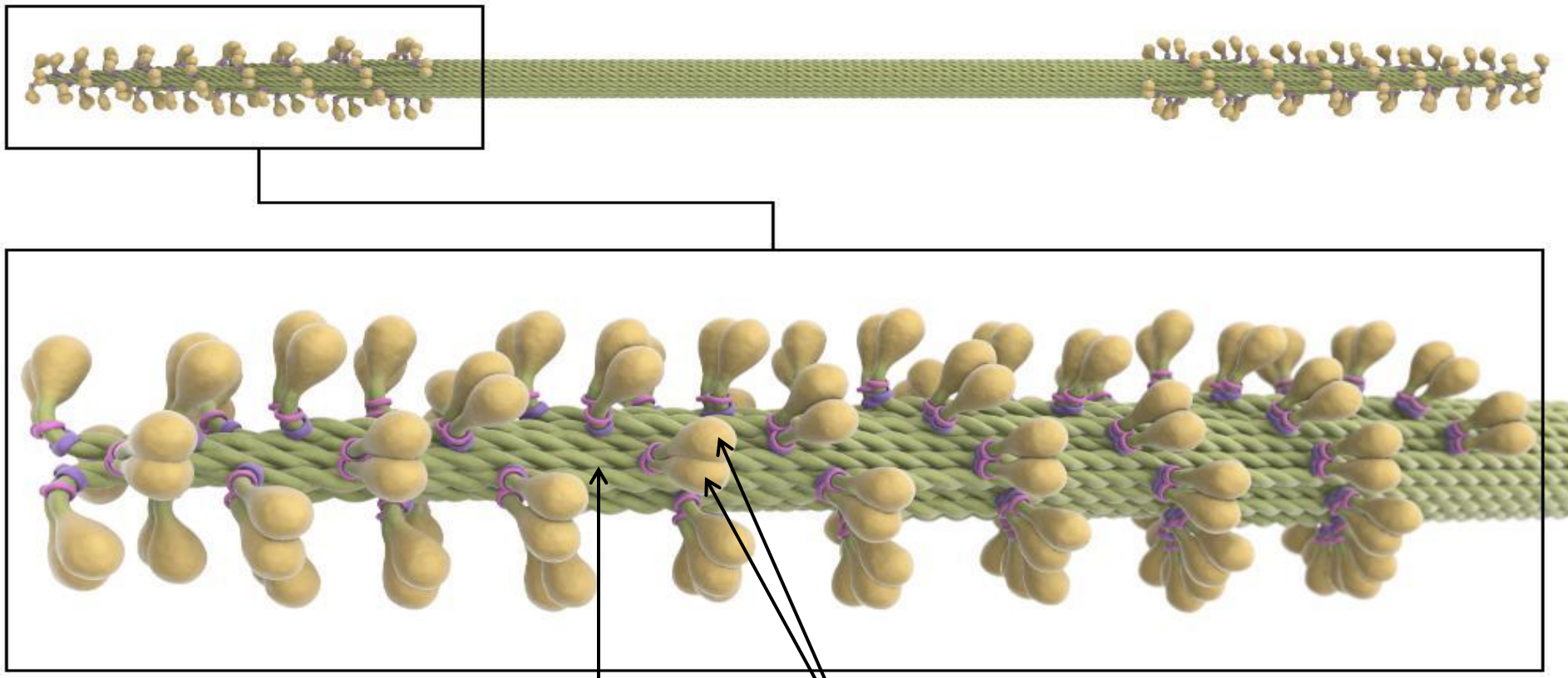
Calcium ion

Regulatory subunit

Thin filament

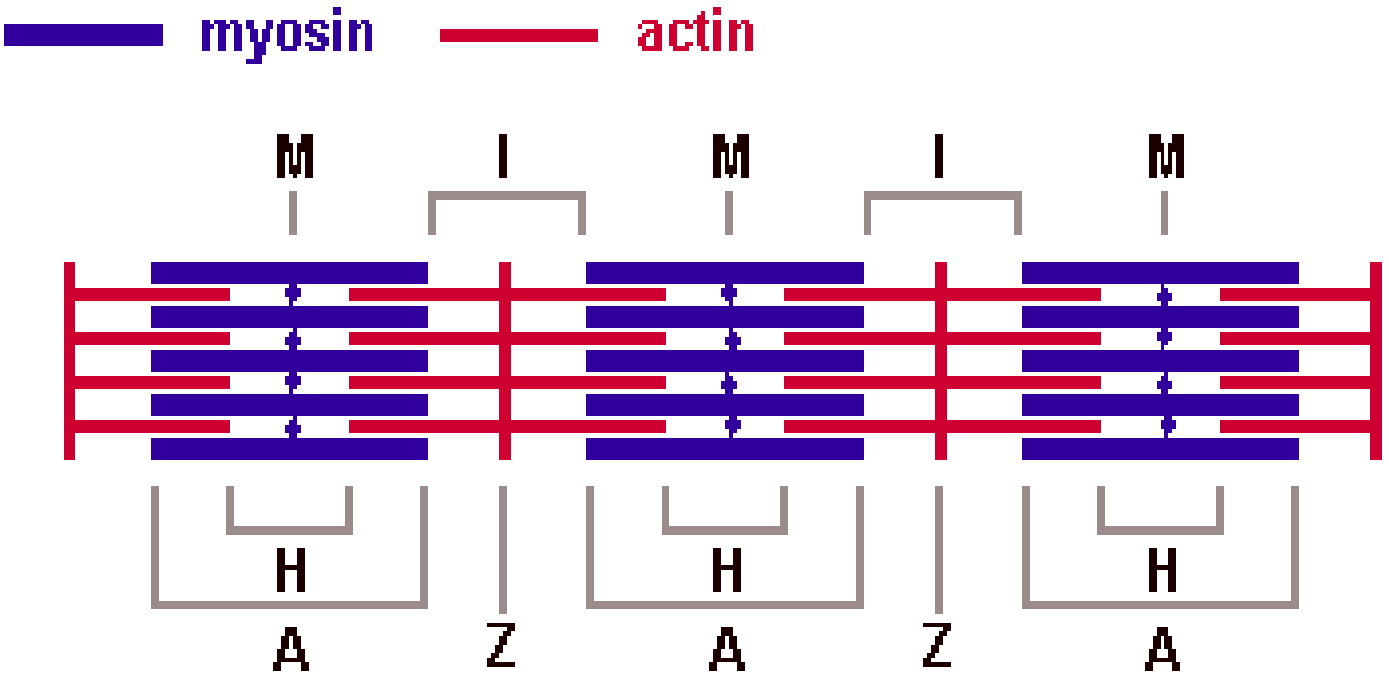


Thick filament

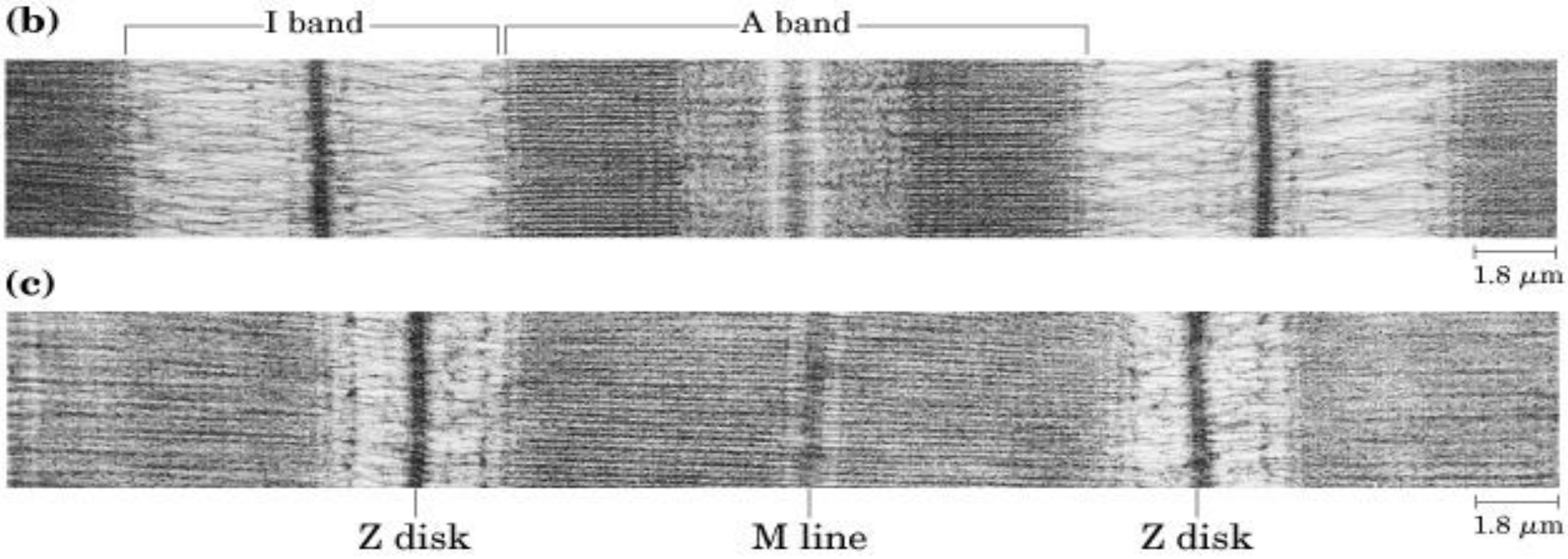


Sliding Filament Model

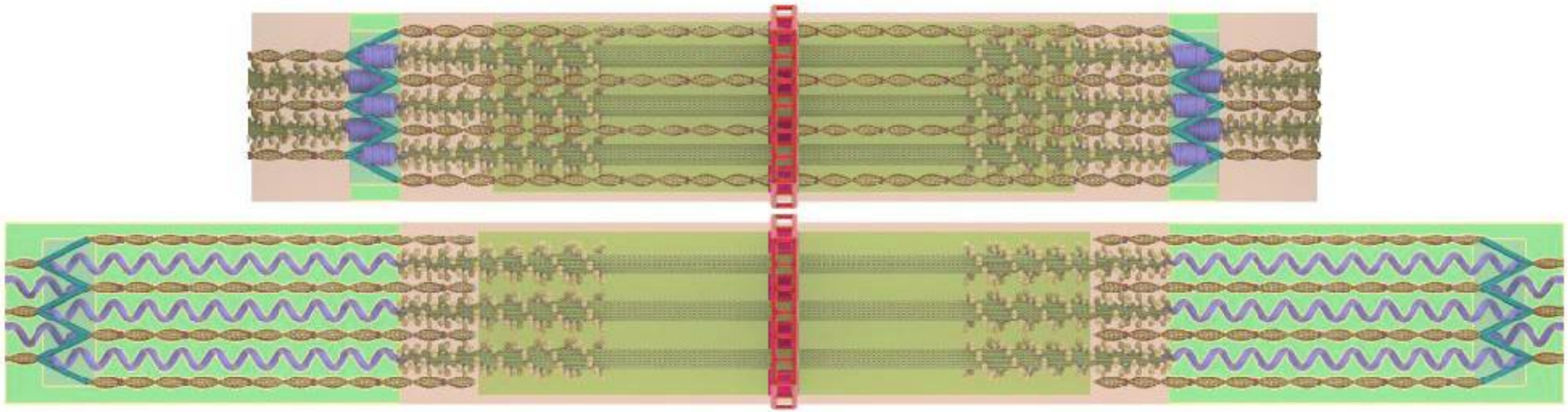
Note: Z lines move closer together; I **band** and **H band** become smaller during contraction



Bands and lines in the contractile apparatus of skeletal muscle

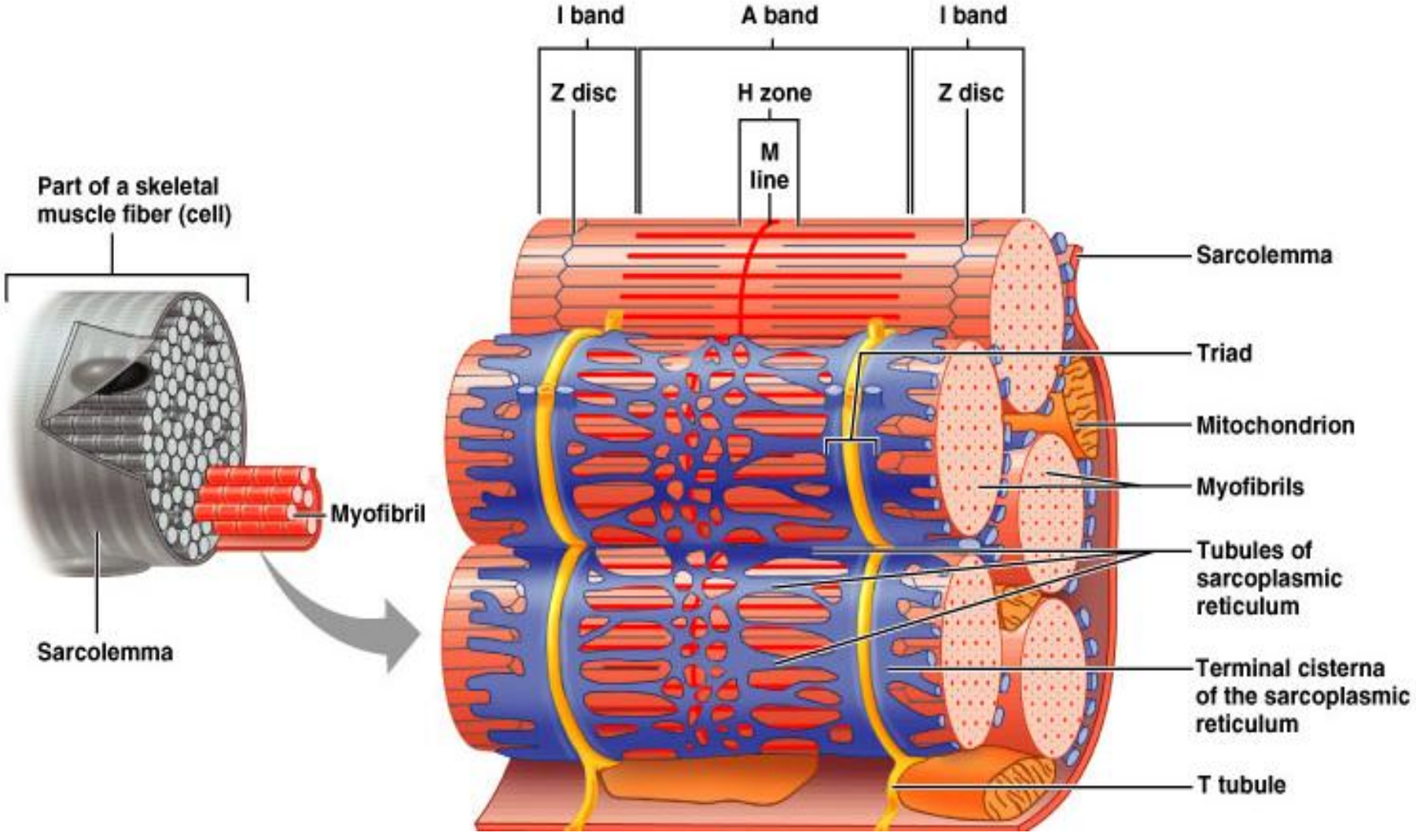


Contracted sarcomere



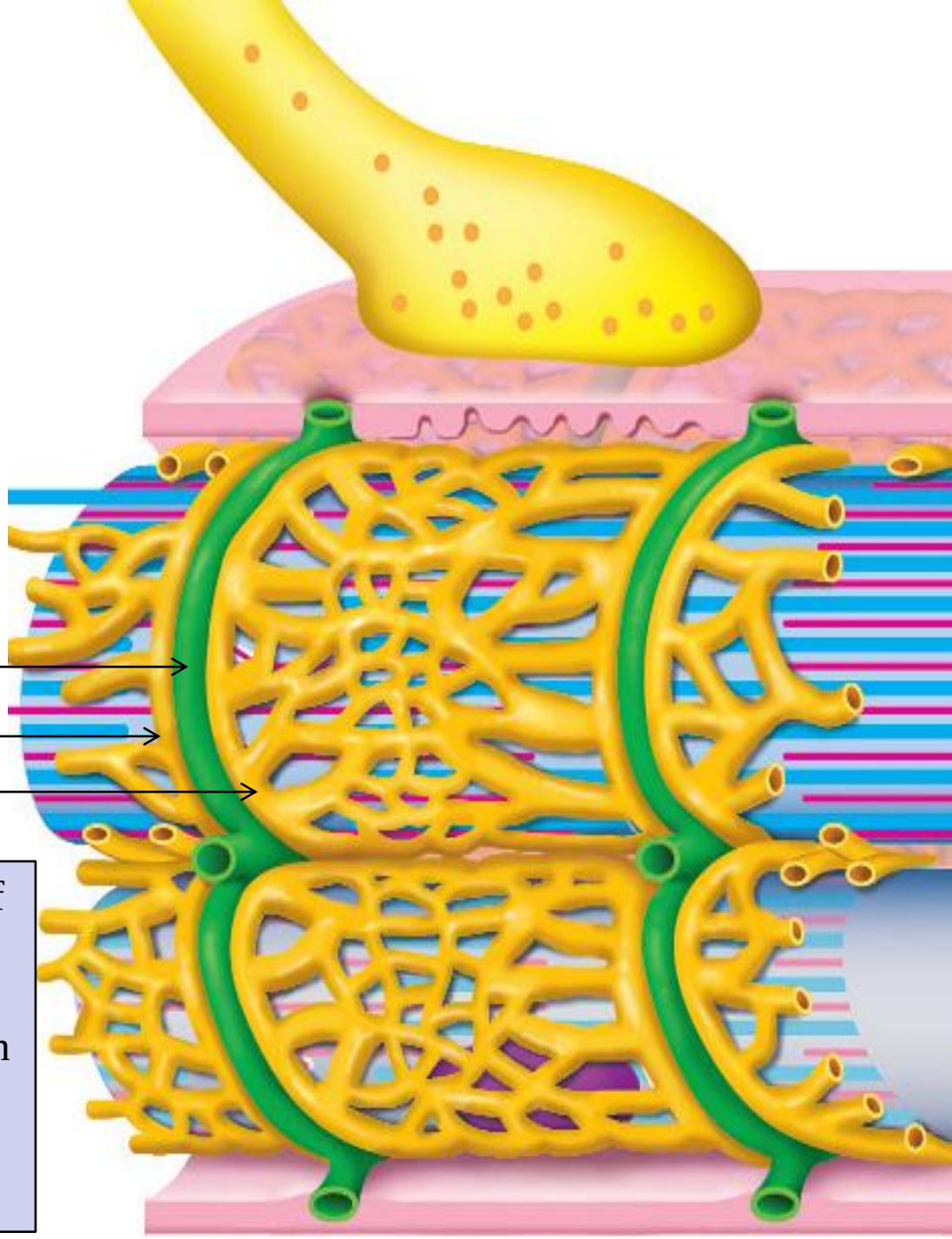
Relaxed sarcomere

- Sarcoplasmic reticulum is smooth ER
- T tubules are continuous with sarcolemma, therefore whole muscle (deep parts as well) contracts simultaneously

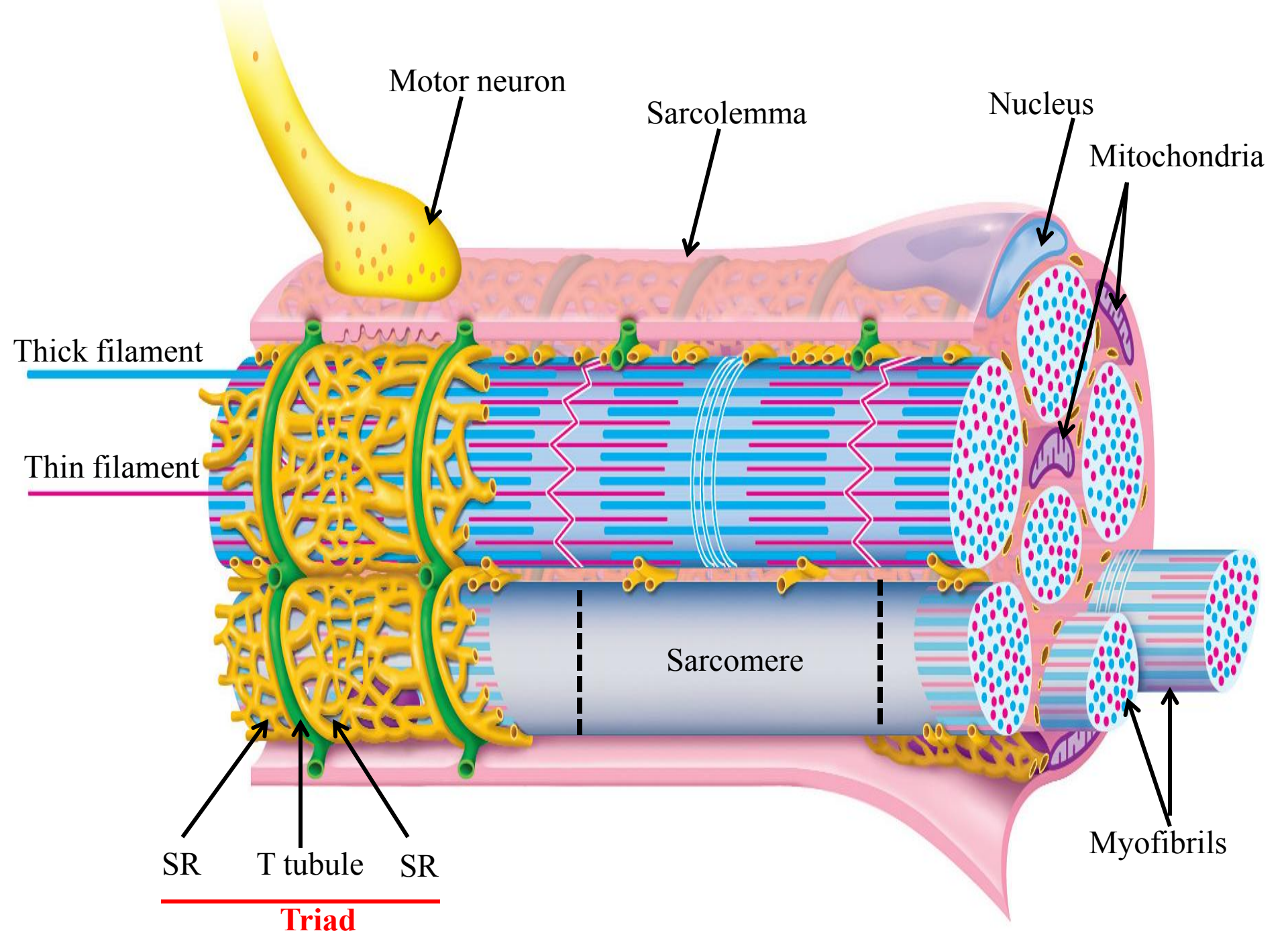


A **T-tubule** (or **transverse tubule**) is a deep invagination of the sarcolemma

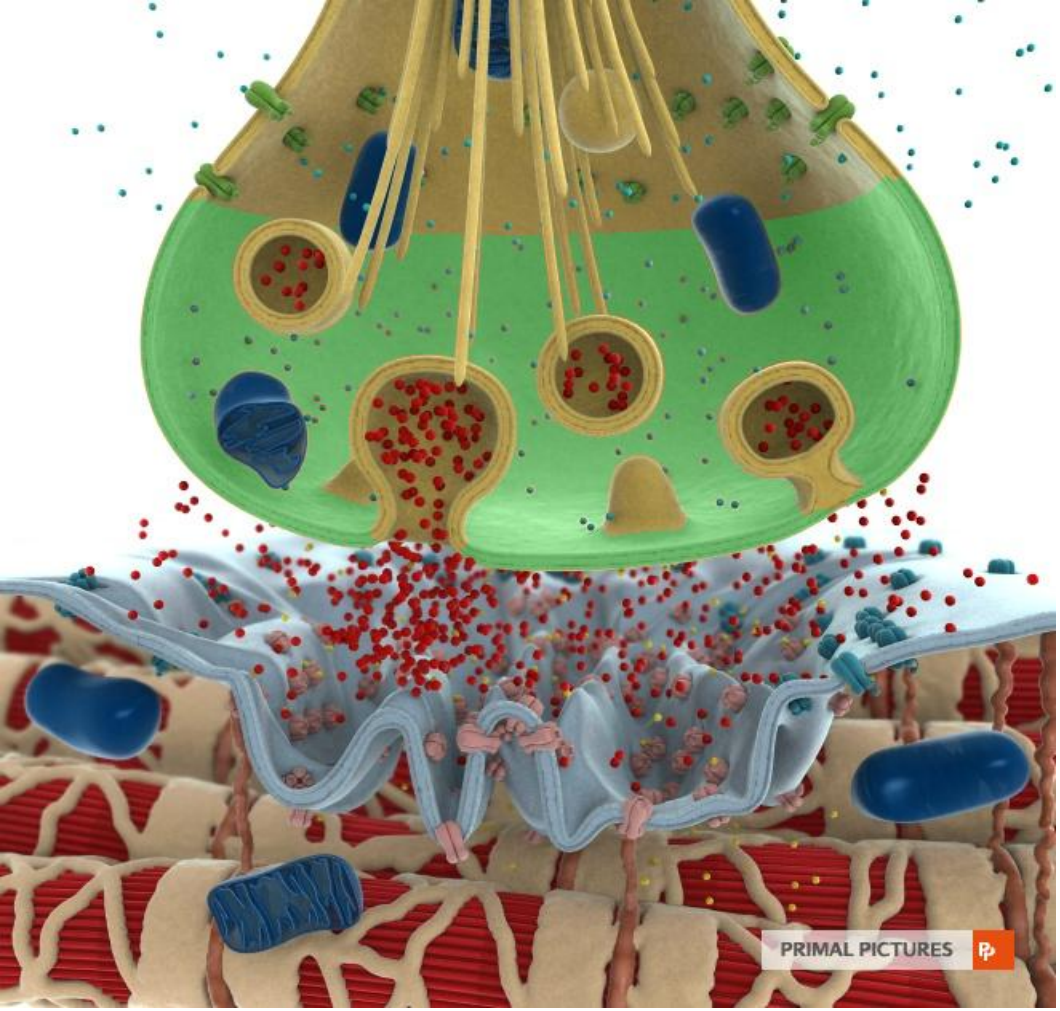
T-tubules permit the conduction of electrical impulses



Terminal cisternae are enlarged areas of the sarcoplasmic reticulum surrounding the transverse tubules.
They store calcium and release it when an action potential courses down the transverse tubules, eliciting muscle contraction


Motor neuron
Sarcolemma
Nucleus
Mitochondria
Thick filament
Thin filament
Sarcomere
SR
T tubule
SR
Triad
Myofibrils

Neuromuscular Junction

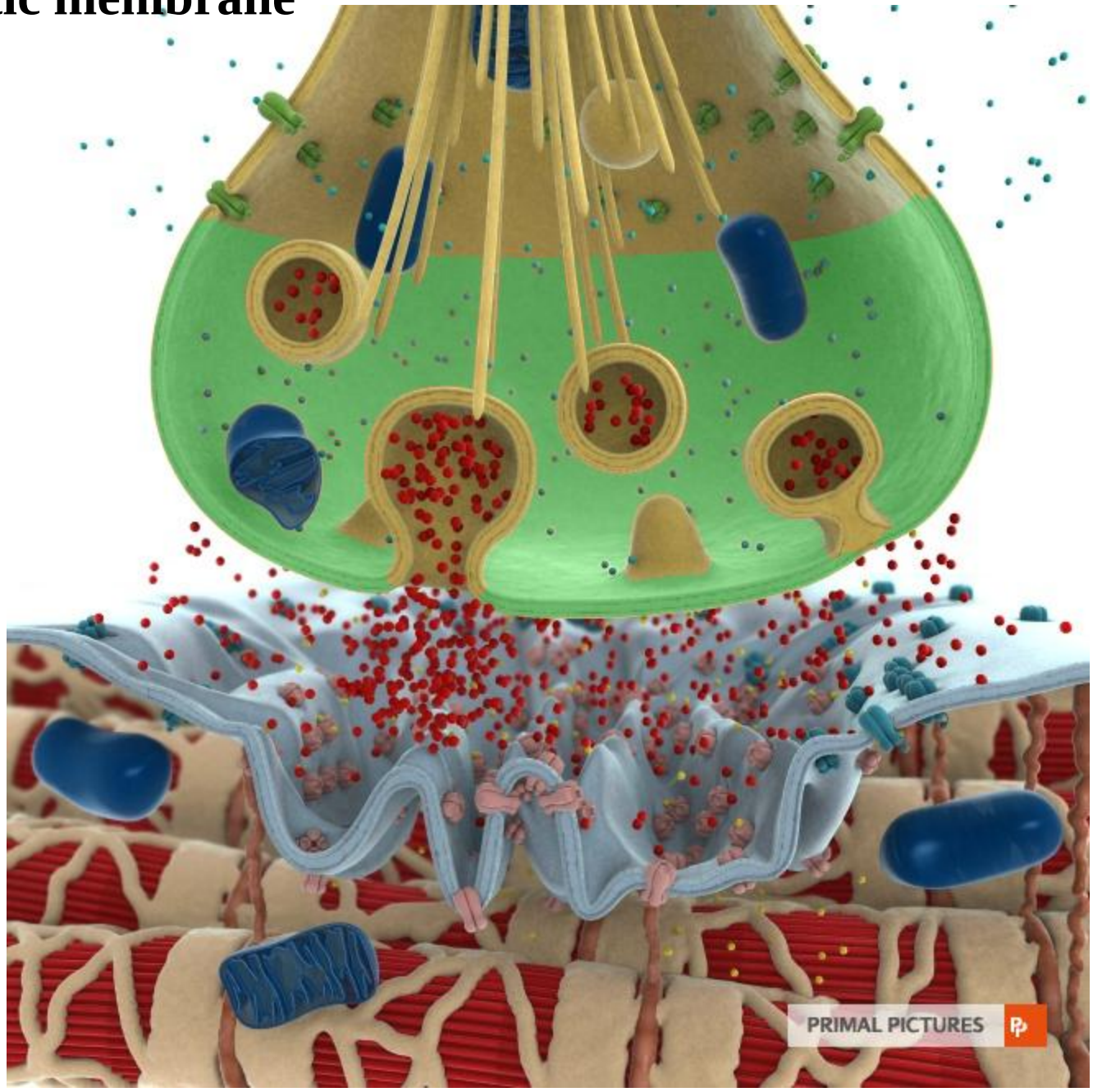


Motor neurons innervate muscle fibers
Motor end plate is where they meet
Neurotransmitters are released by nerve signal: this initiates calcium ion release and muscle contraction

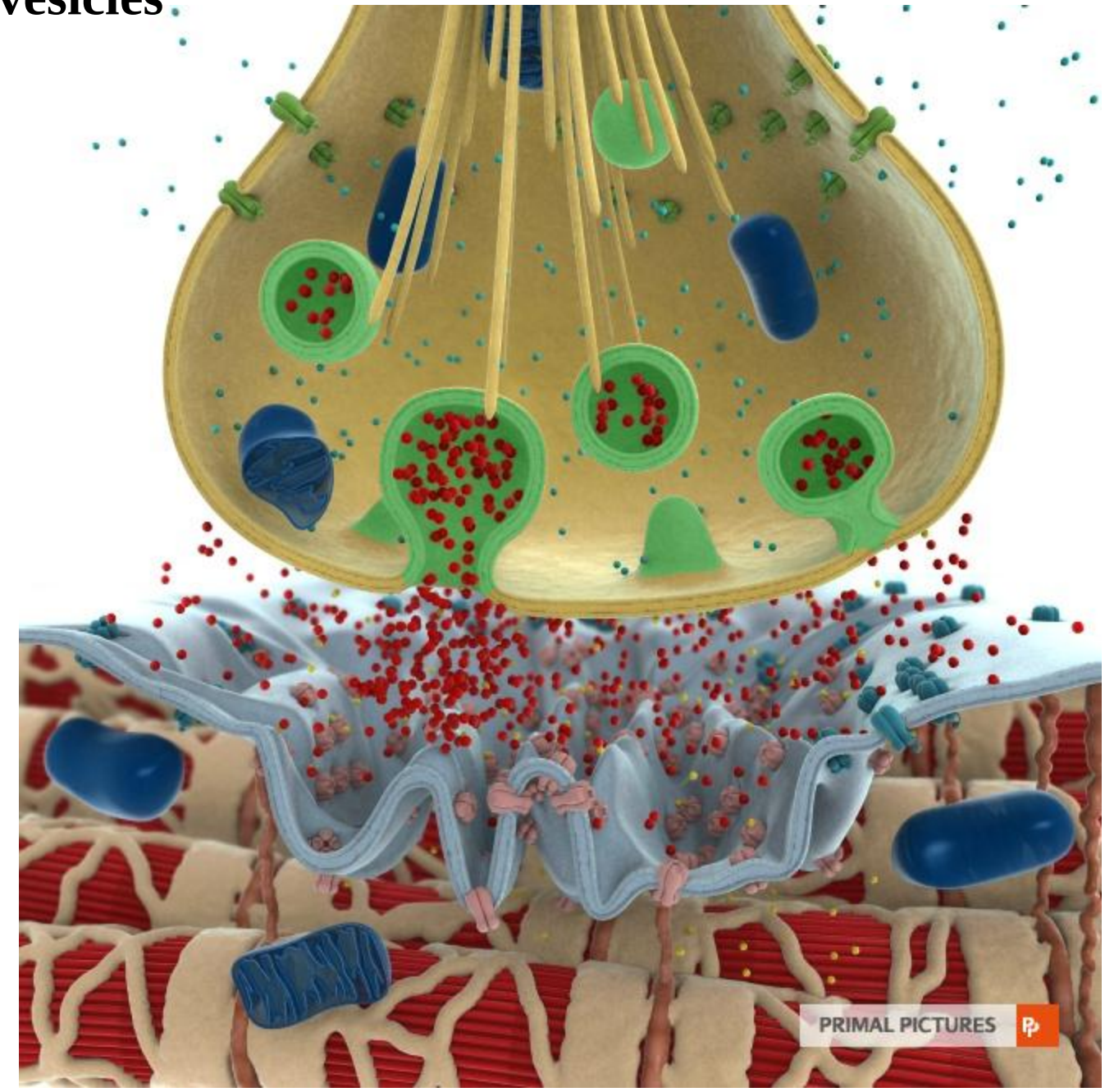
Motor Unit: a motor neuron and all the muscle fibers it innervates (these all contract together)

- Average is 150, but range is one to several hundred muscle fibers in a motor unit
- The finer the movement, the fewer muscle fibers /motor unit
- The fibers are spread throughout the muscle, so stimulation of a single motor unit causes a weak contraction of the entire muscle

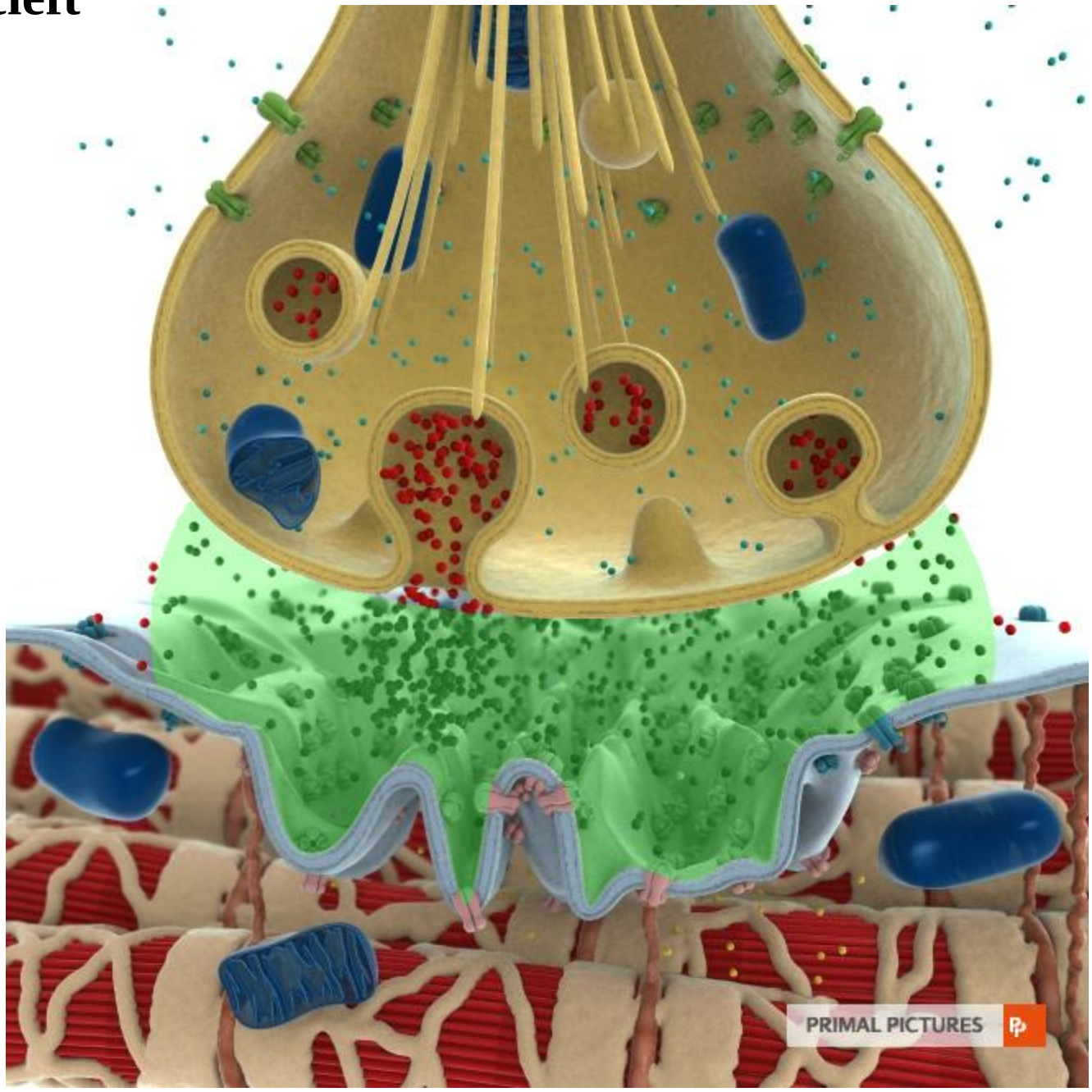
Presynaptic membrane



Synaptic vesicles

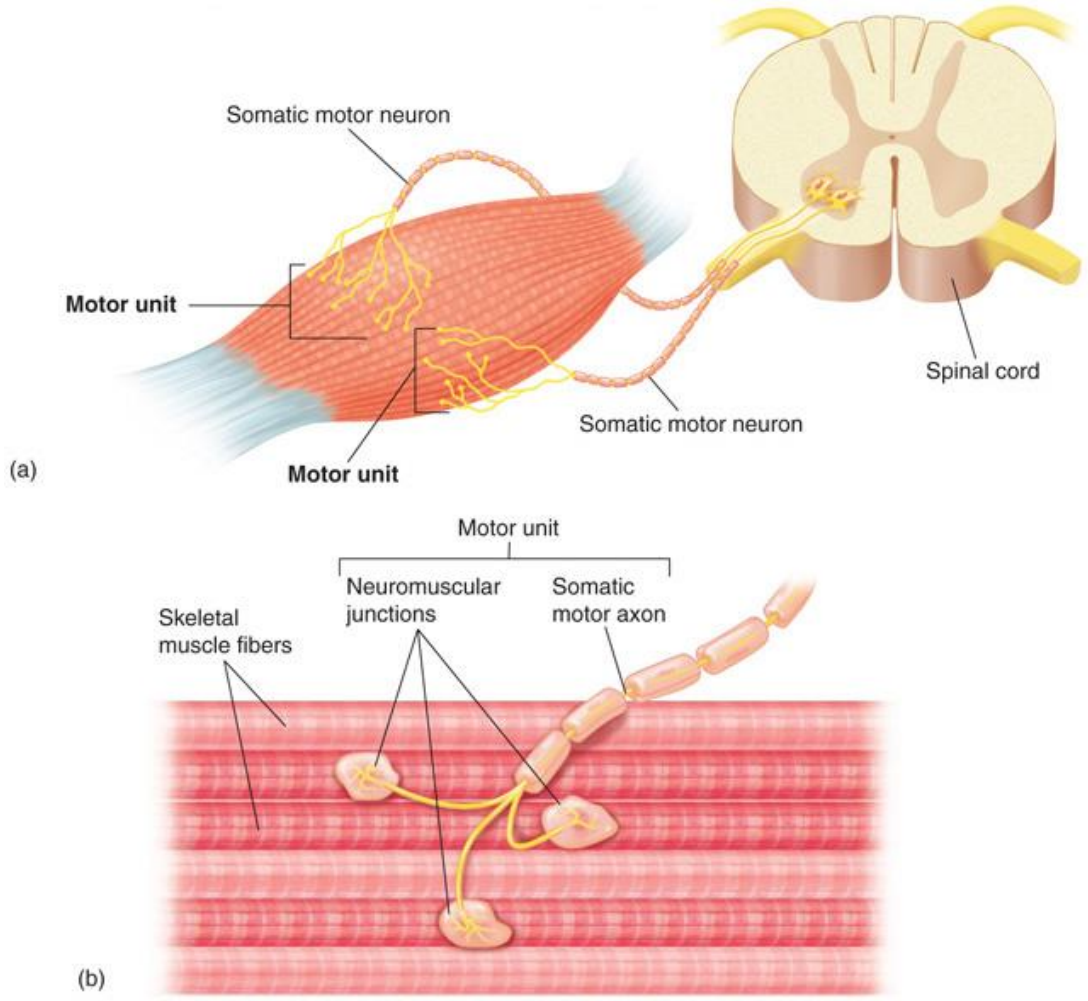


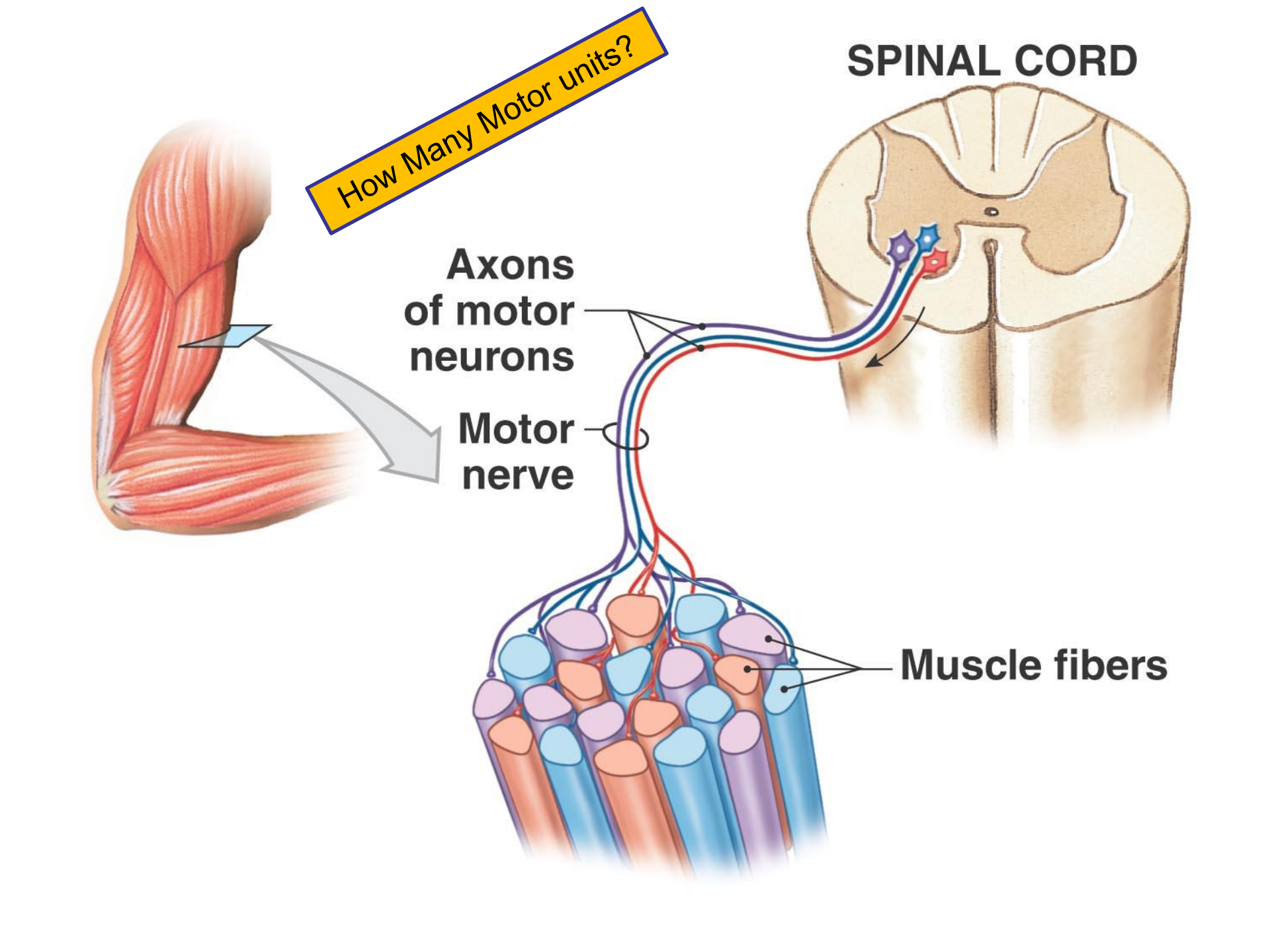
Synaptic cleft

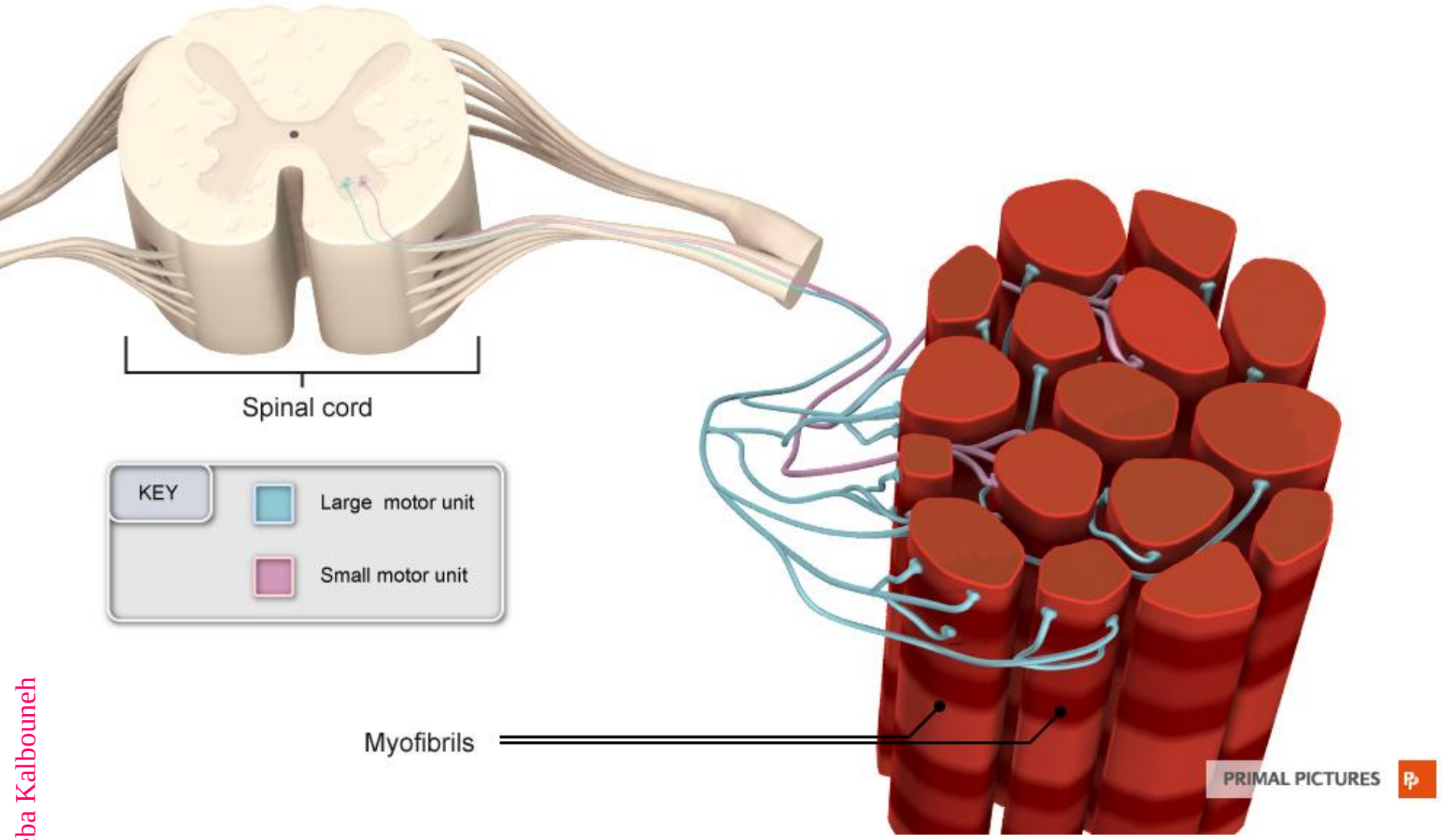


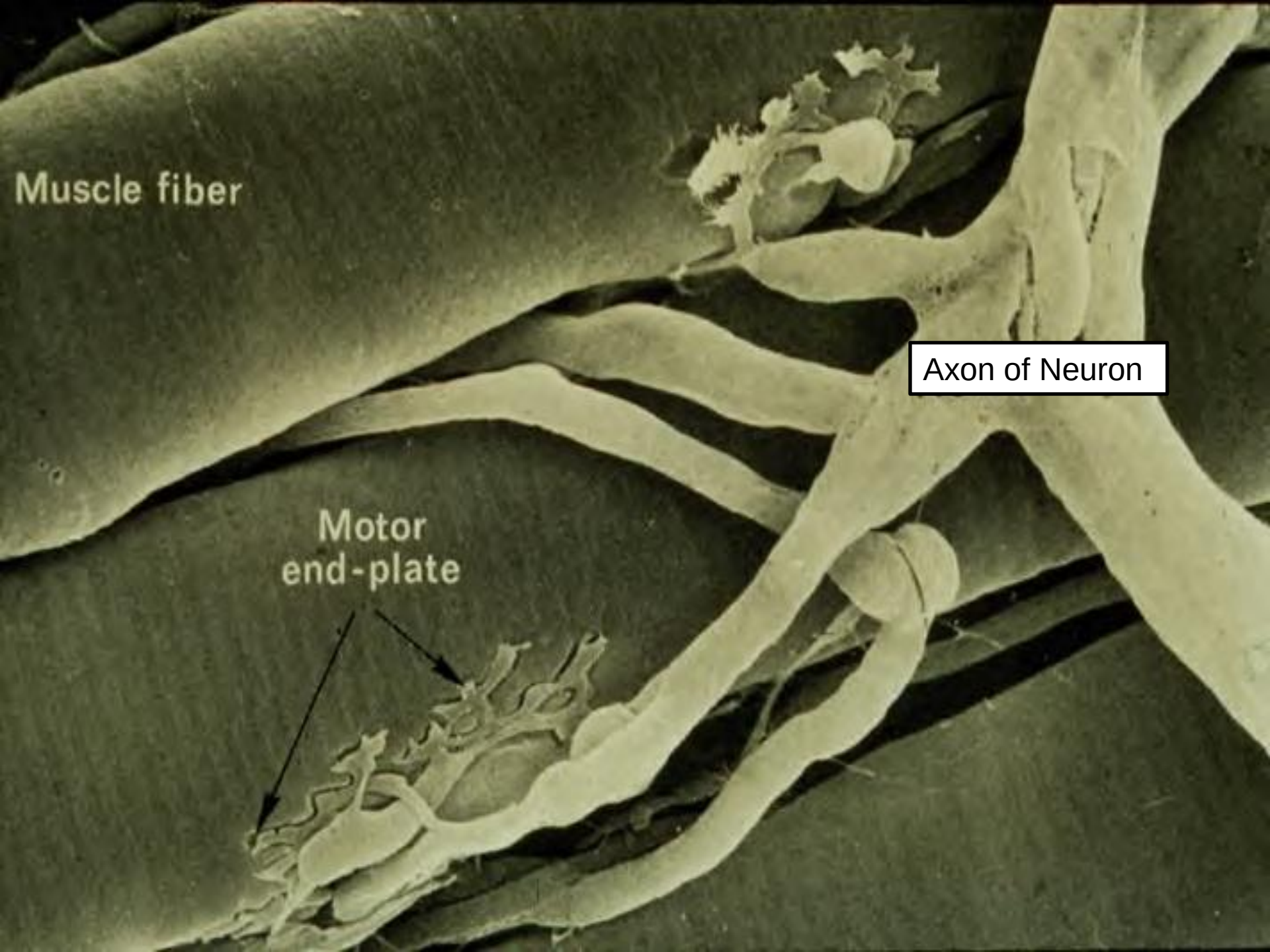
Motor Unit

- Each motor neuron branches to innervate a variable # of muscle fibers
- A motor unit includes each motor neuron and all fibers it innervates




How Many Motor units?
SPINAL CORD
Axons
of motor
neurons
Motor
nerve
Muscle fibers




Muscle fiber
Axon of Neuron
Motor
end-plate

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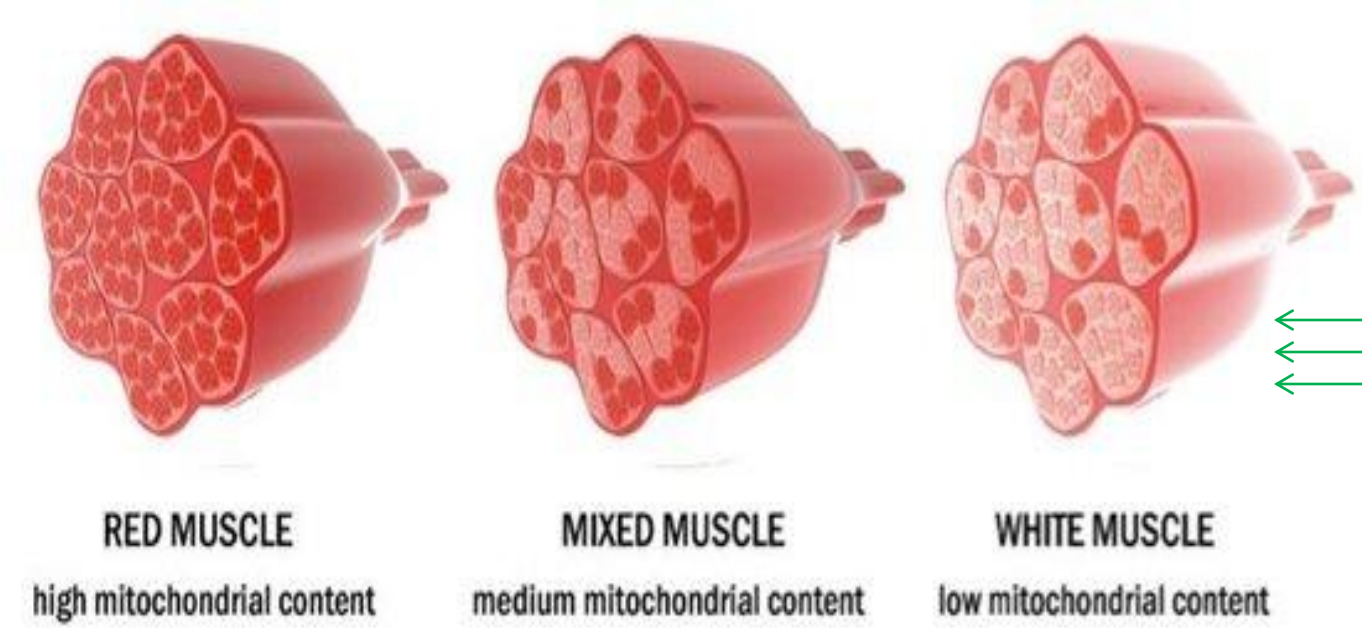
Types of skeletal muscle fibers

- Fast, slow and intermediate
- Whether or not they predominantly use oxygen to produce ATP
  - Oxidative – aerobic (use oxygen)
  - Glycolytic – make ATP by glycolysis (break down of sugars without oxygen=anaerobic)
- Fast fibers: “white fibers” – large, predominantly anaerobic, fatigue rapidly (rely on glycogen reserves); most of the skeletal muscle fibers are fast
- Slow fibers: “red fibers” – half the diameter, 3X slower, but can continue contracting; aerobic, more mitochondria, myoglobin
- Intermediate: in between



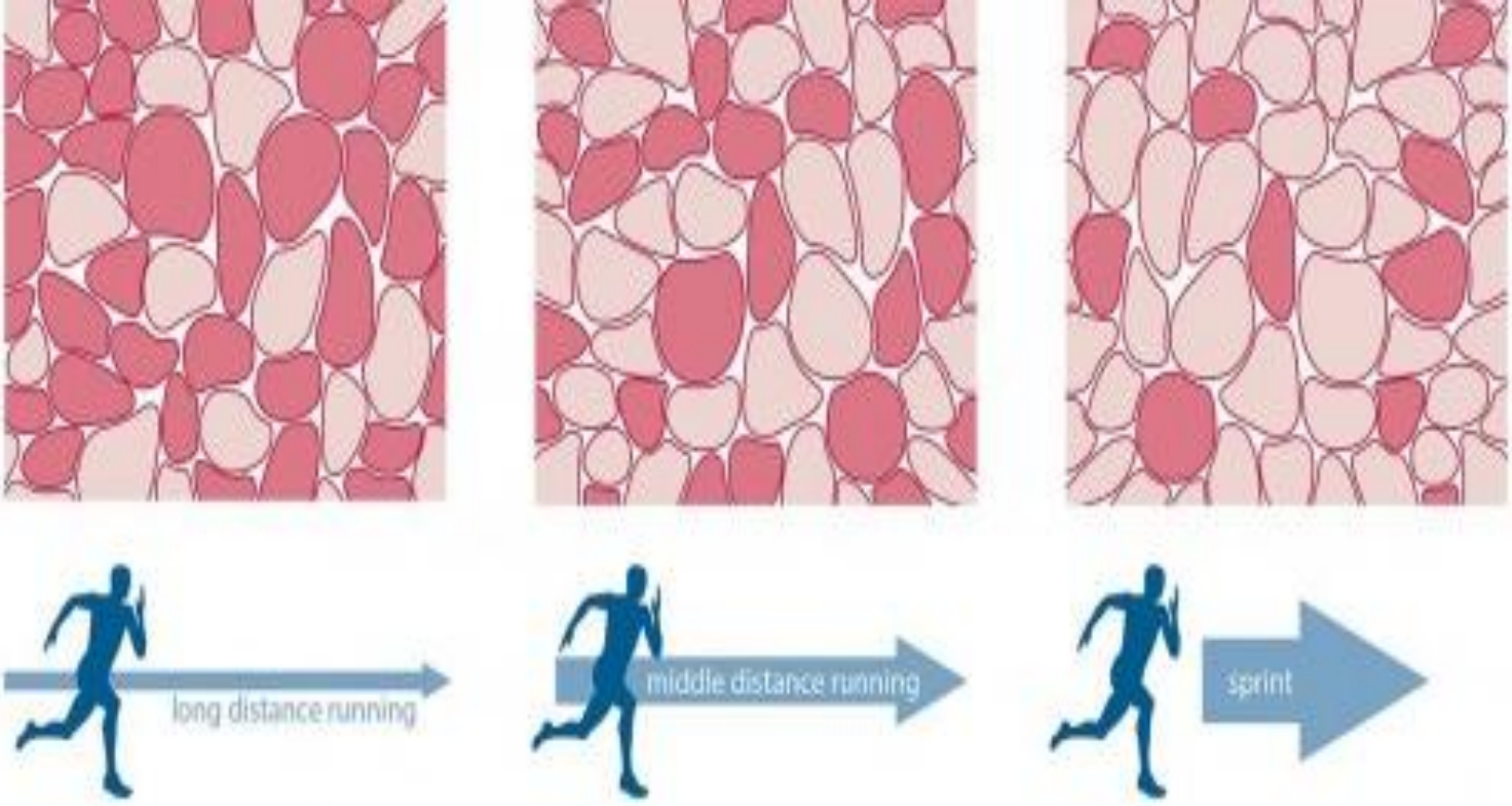
Some have to be designed for rapid and powerful contractions
Some have to be suited for slower and longer contractions
Other muscles are designed to be somewhere in the middle of them

SLOW TWITCH VS FAST TWITCH MUSCLE FIBRES

By: Chirag Navadia @Me

FEATURES	TYPE I MUSCLE FIBER	TYPE II MUSCLE FIBER
FORCE OF CONTRACTION	Slow	Fast
RED COLOR	High (aka Red Fibers)	Low (aka White Fibers)
MITOCHONDRIA & MYOGLOBIN	High	Low
OXIDATIVE CAPACITY	High	Low
CAPILLARY DENSITY & FATIGUE RESISTANCE	High	Low
MAIN SOURCE OF ENERGY	Triglycerides	Glycogen & Creatine Phosphate
DURATION OF USE	Long	Short
GLYCOGEN & GLYCOLYTIC CAPACITY	Low	High
POWER	Stamina	Strength
HIGH AMOUNT IN...	Postural Muscles (Axial)	Peripheral Muscles
INCREASED IN...	Marathon Runner (Gastrocnemius) Swimmer (Post. Deltoid)	Sprinter (Gastrocnemius) Pole Vaulting, Shot Putter


Red Turtle



Left – Red Fiber Dominant, Marathoner
Right – White fiber Dominant, Sprinter
Middle – Perfect, Bodybuilder

Human muscles are generally pink

What do you think that means?

Human muscles are mostly pink because they are a mixture of fast and slow muscle fibers
However genetics and athletic training play a very important role in the development of muscle fibers

Chicken legs are dark meat because they are red muscles

A chicken breast which is white muscle that is infrequently used but has to generate large amounts of force when used

General notes ☺

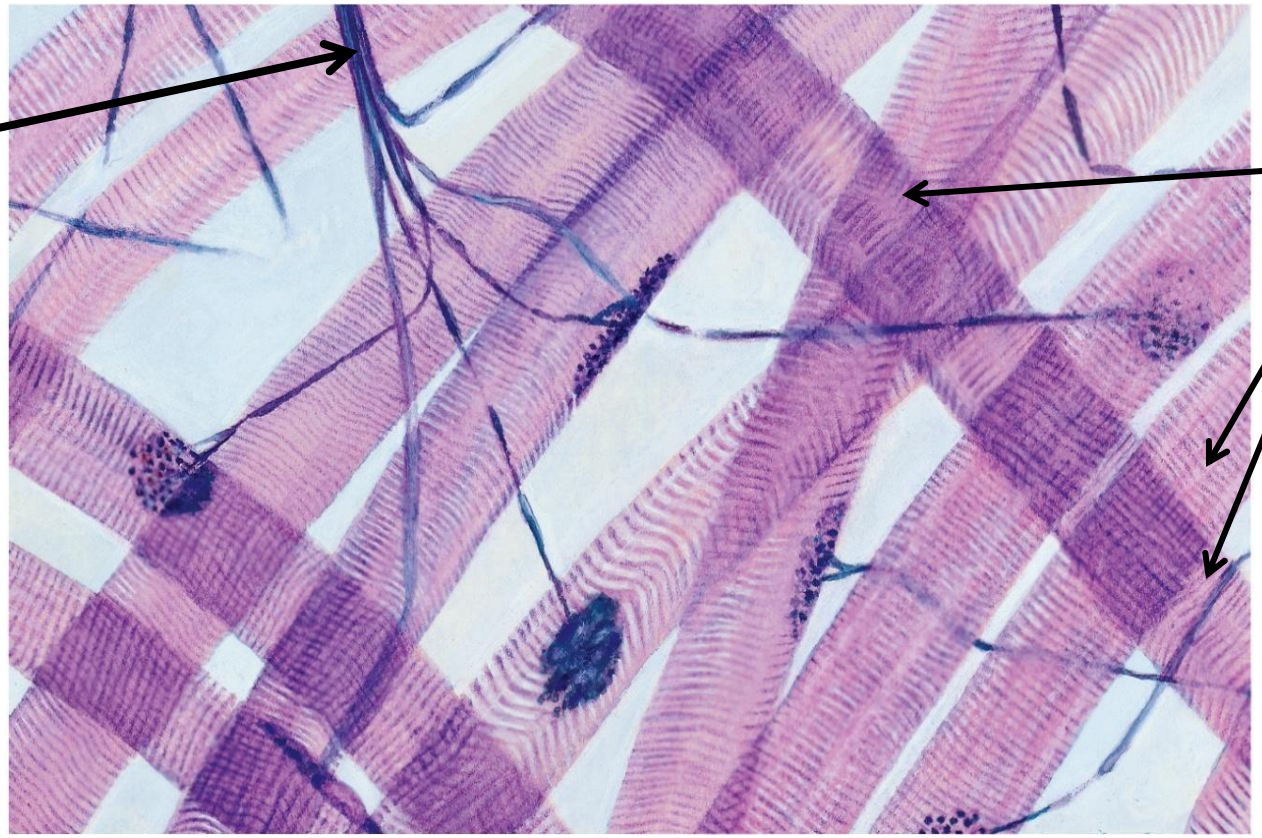
For those of you that have never fished before, take a look to the left

On most type of fish fillets there are different colors to their muscles
These different colors indicate the true purpose of the muscles

To summarize

- **Red muscles** contain mostly slow muscle fibers
- They appear red because they contain a large amount of blood to supply mitochondria with oxygen
- They also appear red because they contain myoglobin, a chemical that helps hold excess oxygen
- Chicken legs are "dark meat" because they are red muscles

- **White muscle** contains mostly fast muscle fibers
- They contain small amounts of myoglobin and contain small amount of blood
- This is similar to a chicken breast which is white muscle that is infrequently used but has to generate large amounts of force when used



Note:
increased size is
hypertrophy

increased number of cells is
hyperplasia

All muscle fibers of a motor unit are of the same type.

- ✓ All or none principle: each muscle fiber either contracts completely or not at all
- ✓ Amount of force: depends on how many motor units are activated
- ✓ **Muscle tone:**

Even at rest, some motor units are active: tense the muscle even though not causing movement: "resting tone"

Muscle hypertrophy

Weight training (repeated intense workouts): increases diameter and strength of "fast" muscle fibers by increasing production of:

Mitochondria
Actin and myosin protein
Myofilaments containing these contractile proteins
The myofibril organelles these myofilaments form

Fibers enlarge (hypertrophy) as number and size of myofibrils increase

Muscle fibers (=muscle cells) don't increase in number but increase in diameter producing large muscles

Muscle atrophy

loss of tone and mass from lack of stimulation

Muscle becomes smaller and weaker

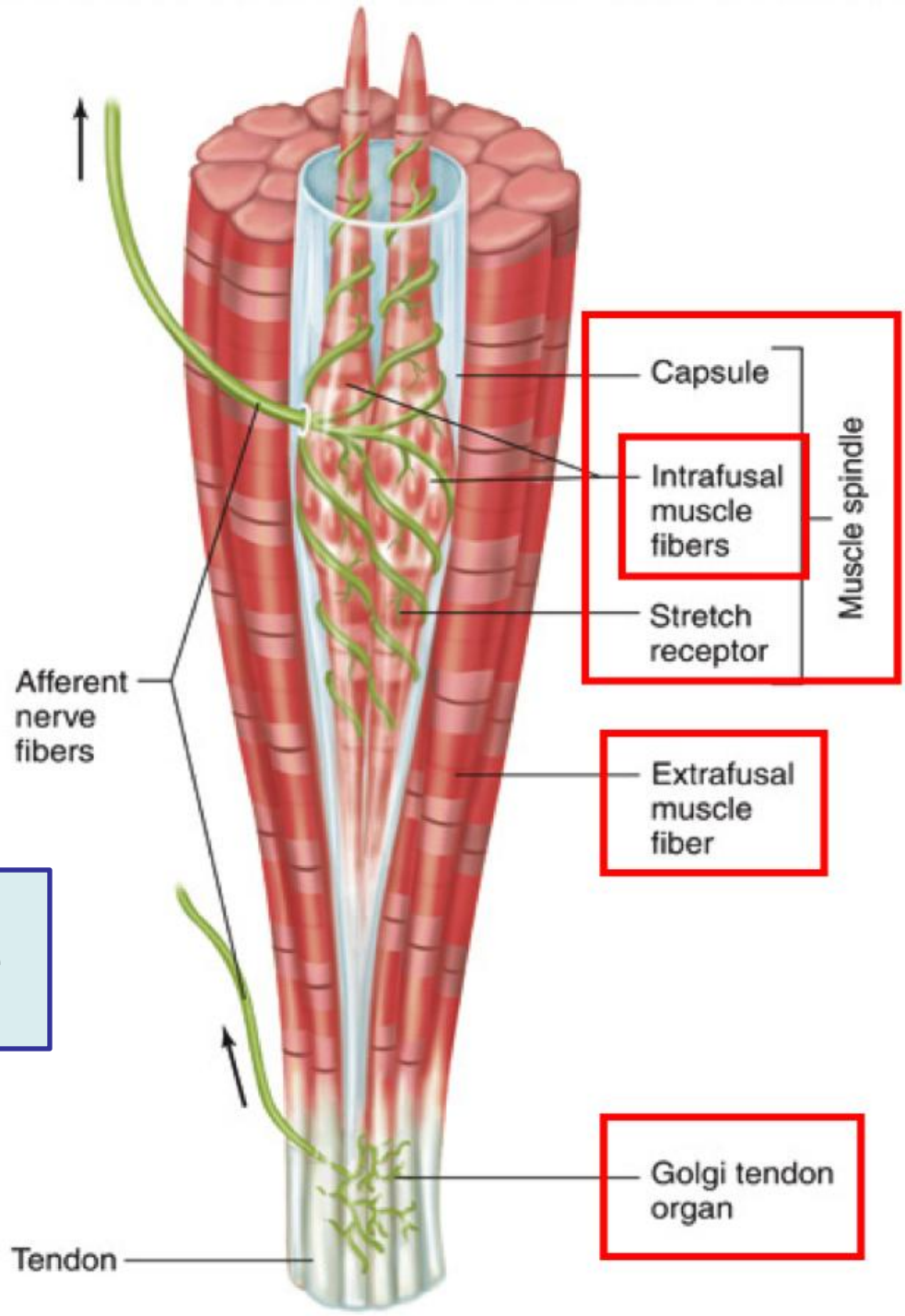
Muscle atrophy can occur after long periods of inactivity.

Muscle spindles are sensory receptors within the belly of a muscle that primarily detect changes in the length of this muscle.

They convey length information to the central nervous system via sensory neurons

This information can be processed by the brain to determine the position of body parts

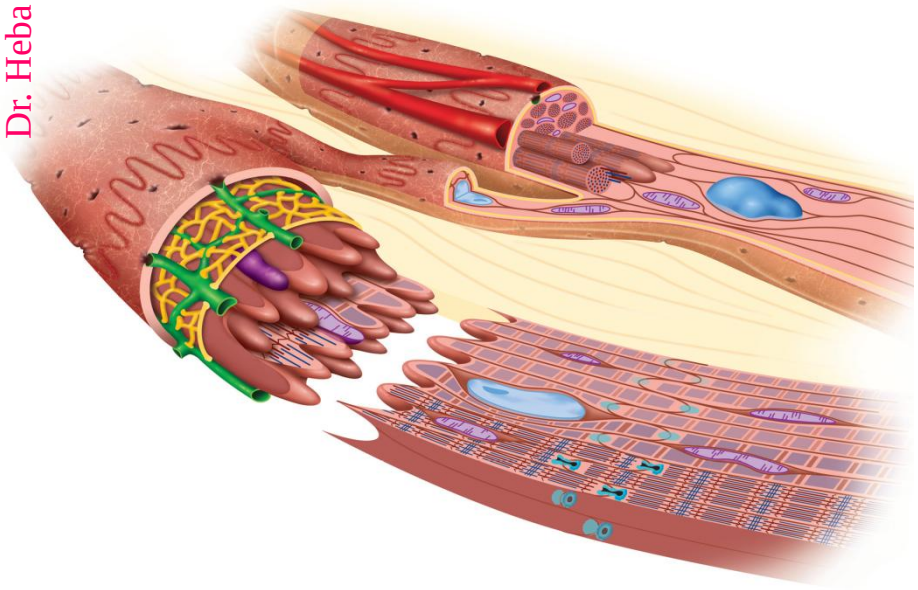
Each muscle spindle consists of an encapsulated cluster of small striated muscle fibers ("**intrafusal muscle fibers**")

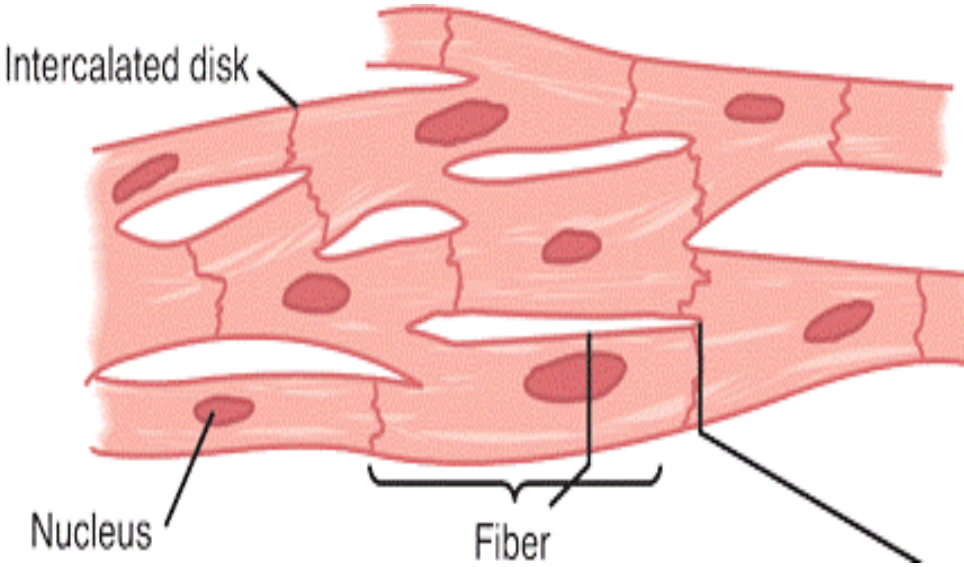


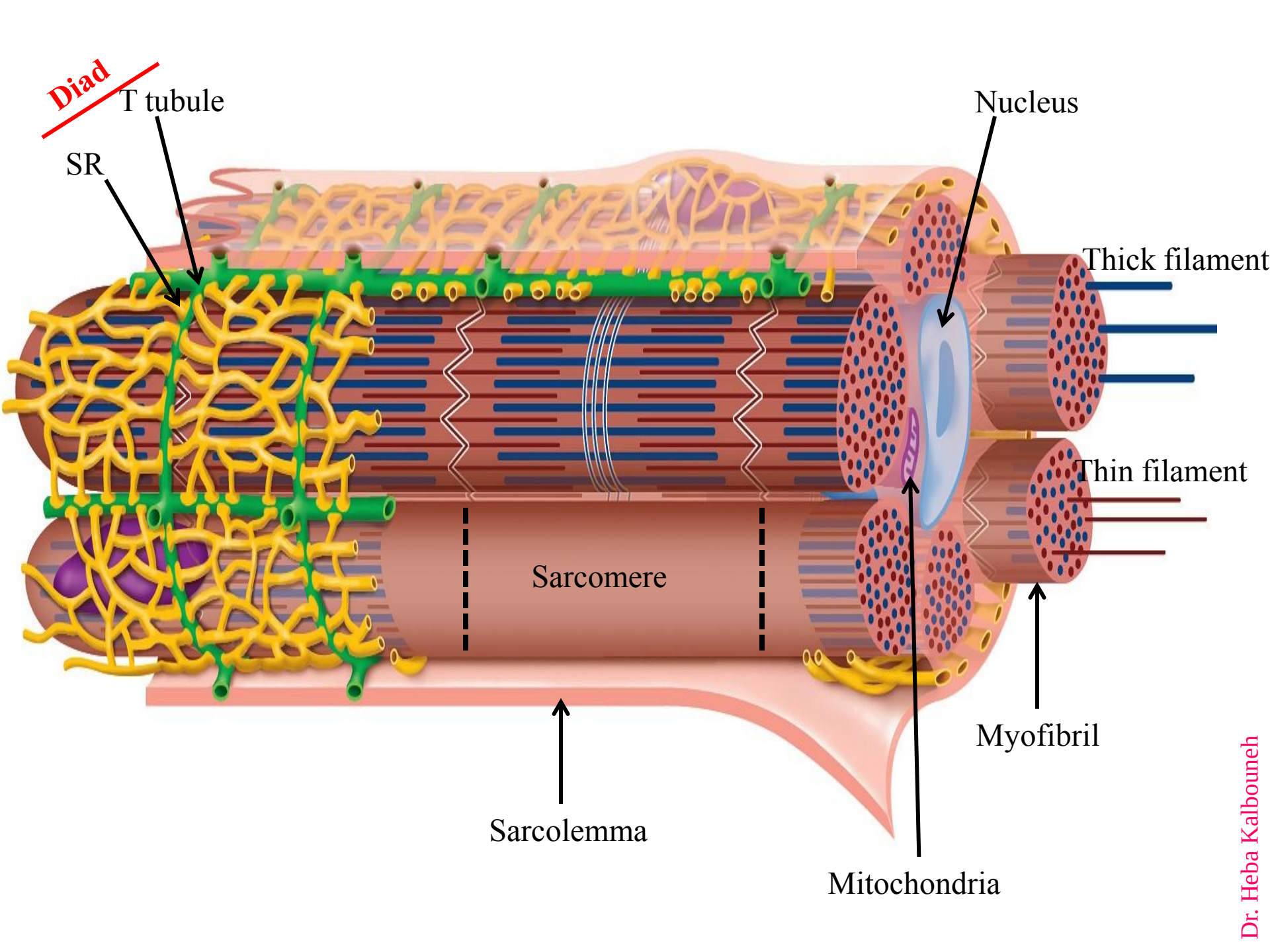
Cardiac Muscle

- ✓Striated (same contractile machinery)
- ✓Self-excitatory and electrically coupled
- ✓Rate of contractions modulated by autonomic nervous system
- ✓1 or 2 centrally placed nuclei
- ✓Branched fibers with intercalated discs

Cardiac muscle does not contain cells equivalent to the satellite cells of skeletal muscle. Therefore cardiac muscle <u>cannot regenerate</u>





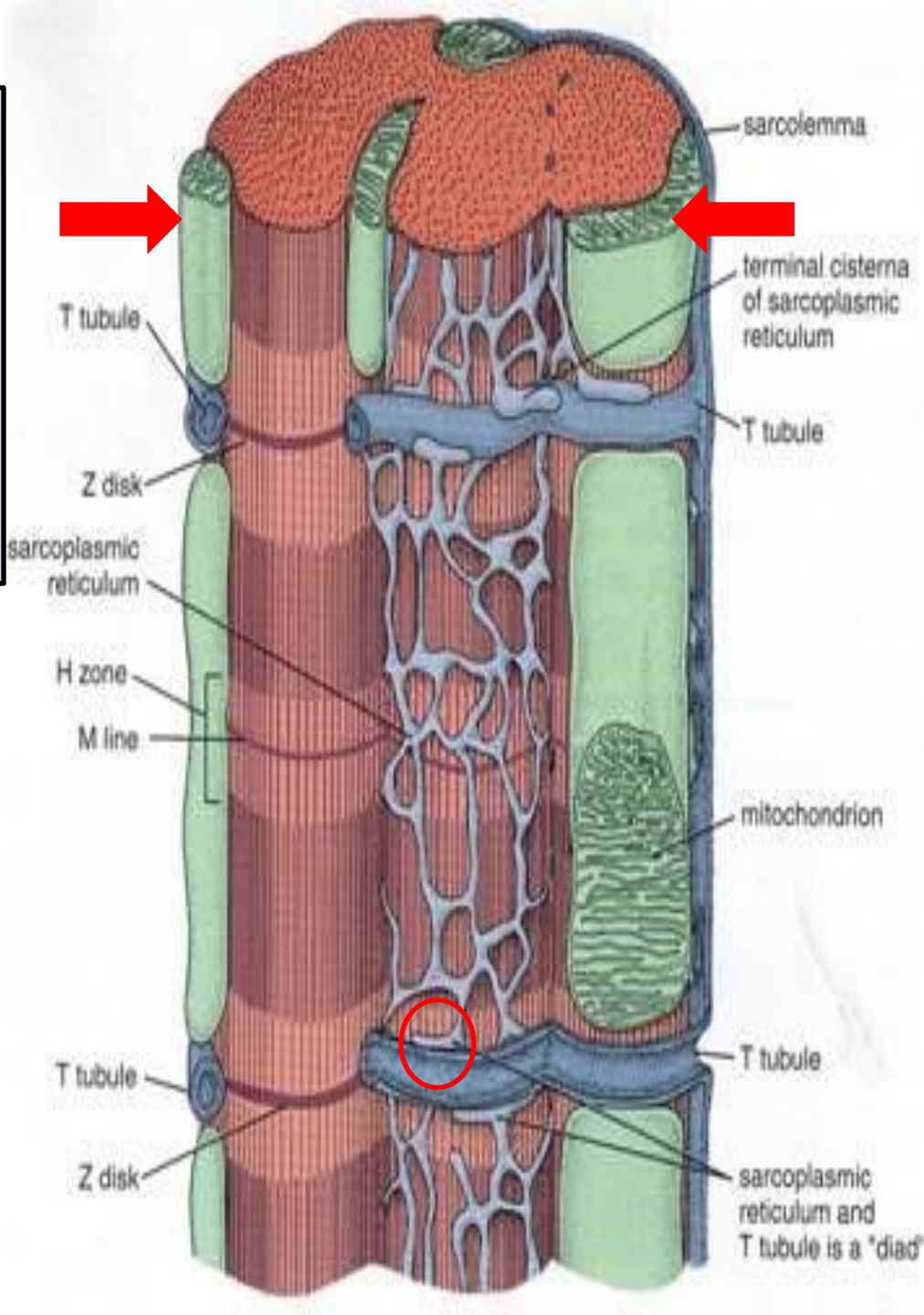


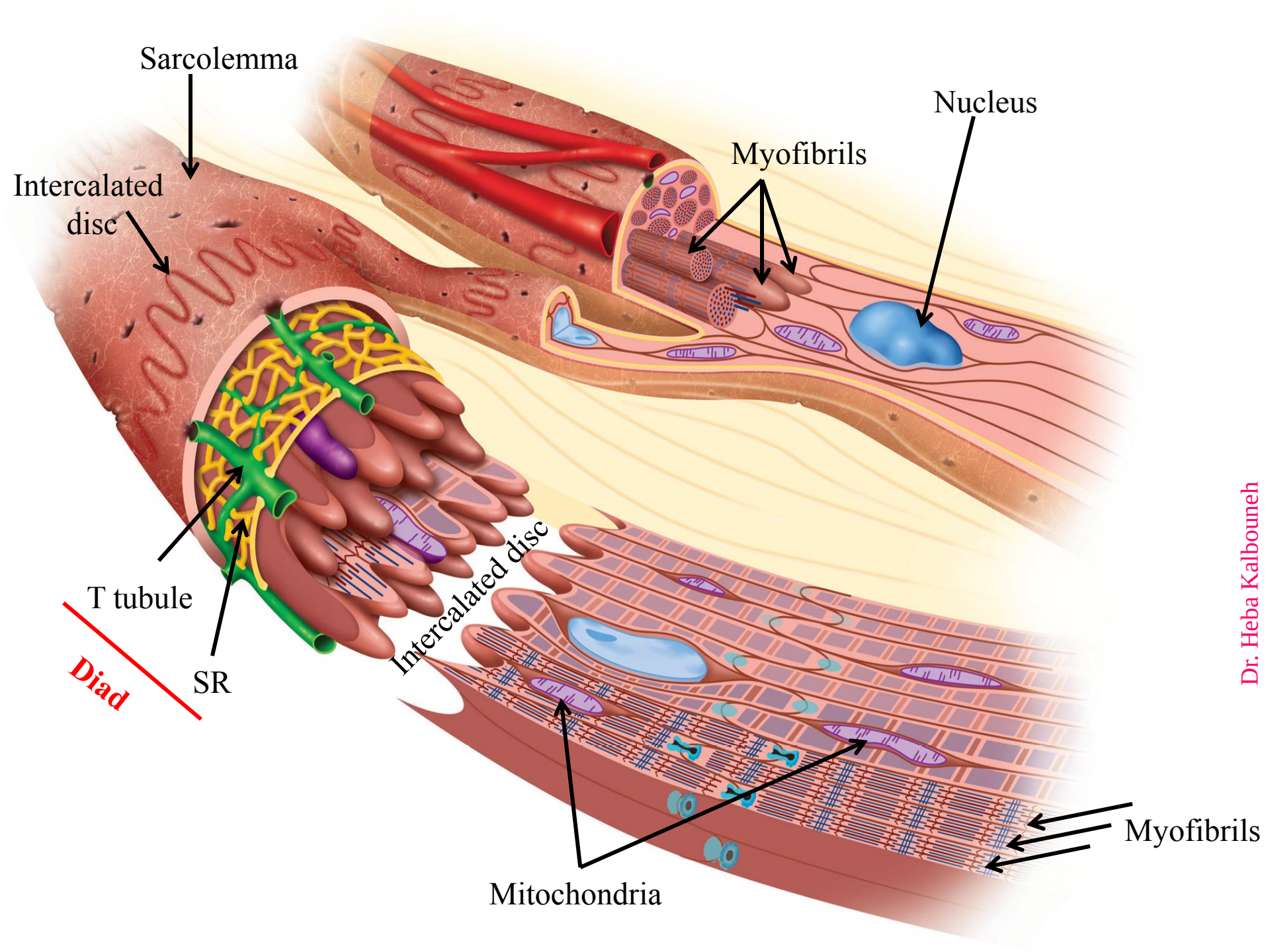
The **diad** is a located at the sarcomere Z-line.

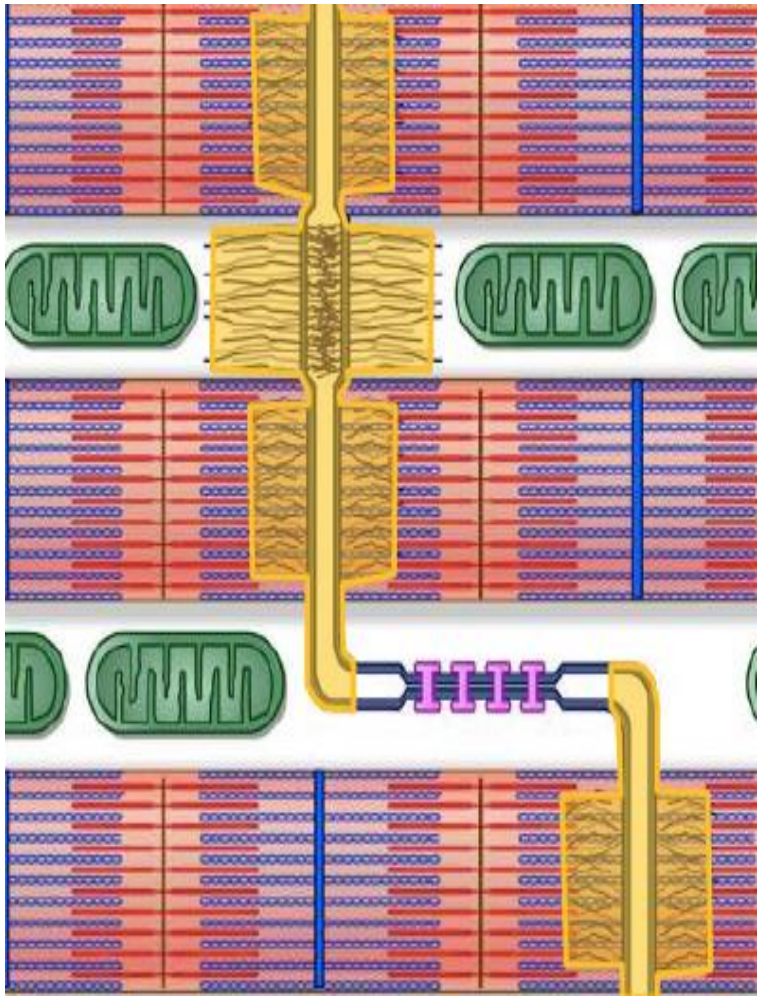
It is composed of a single t-tubule paired with a terminal cisterna of the sarcoplasmic reticulum

T tubules are about 2x larger in diameter than in skeletal muscle

Numerous mitochondria (up to 40% of cell volume)





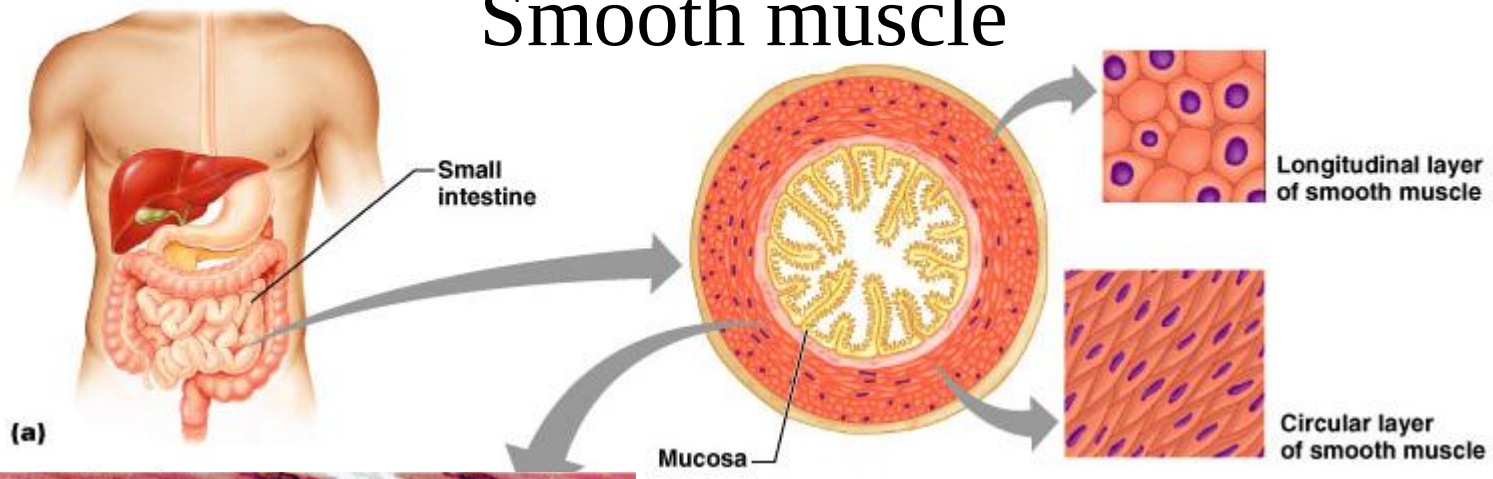


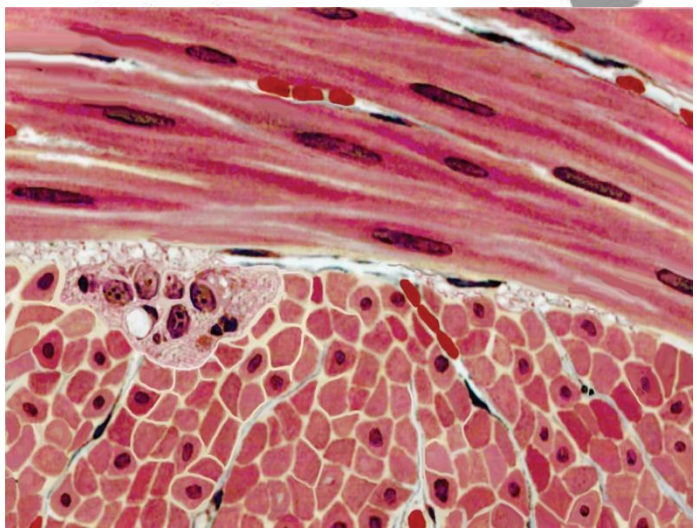
Intercalated discs - junctions between cells where force is delivered. It is a fascia adherens like site (like zonula adherens-disc).

Macula adherens (desmosomes) - anchor intermediate filaments in the same orientation as the fascia adherens

Gap junctions - allow cells to contract simultaneously. Lined up side by side

Smooth muscle

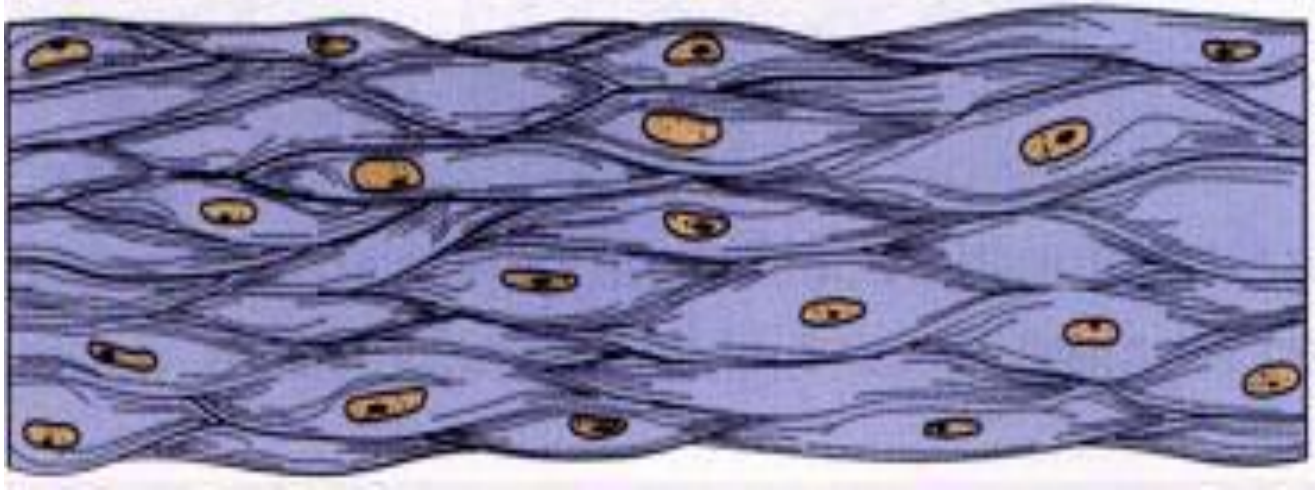




- Muscles are spindle-shaped cells
- One central nucleus
- Grouped into sheets: often running perpendicular to each other
- Peristalsis
- No striations (no sarcomeres)
- Contractions are slow, sustained and resistant to fatigue
- Does not always require a nervous signal: can be stimulated by stretching or hormones
- Gap junctions

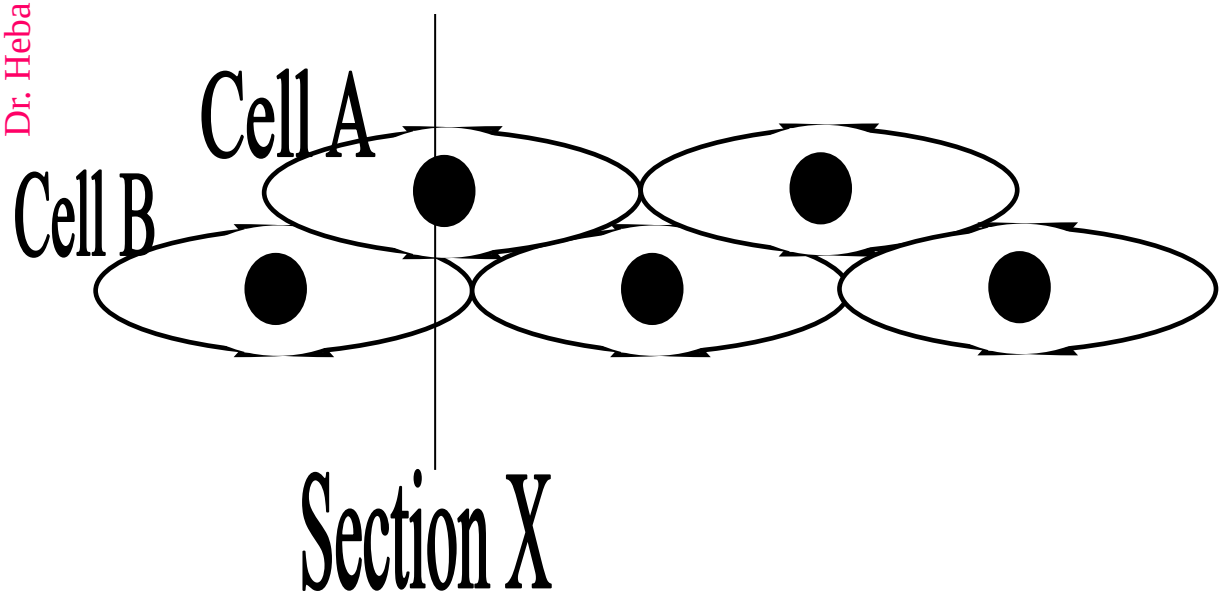
6 major locations:

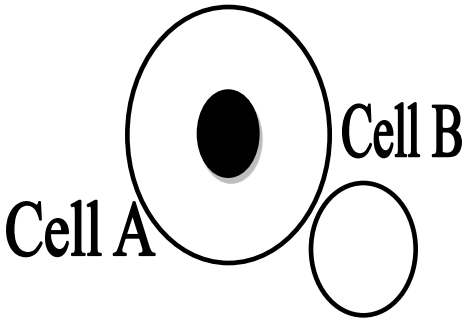
1. inside the eye 2. walls of vessels 3. respiratory tubes
4. digestive tubes 5. urinary organs 6. reproductive organs



Longitudinal section

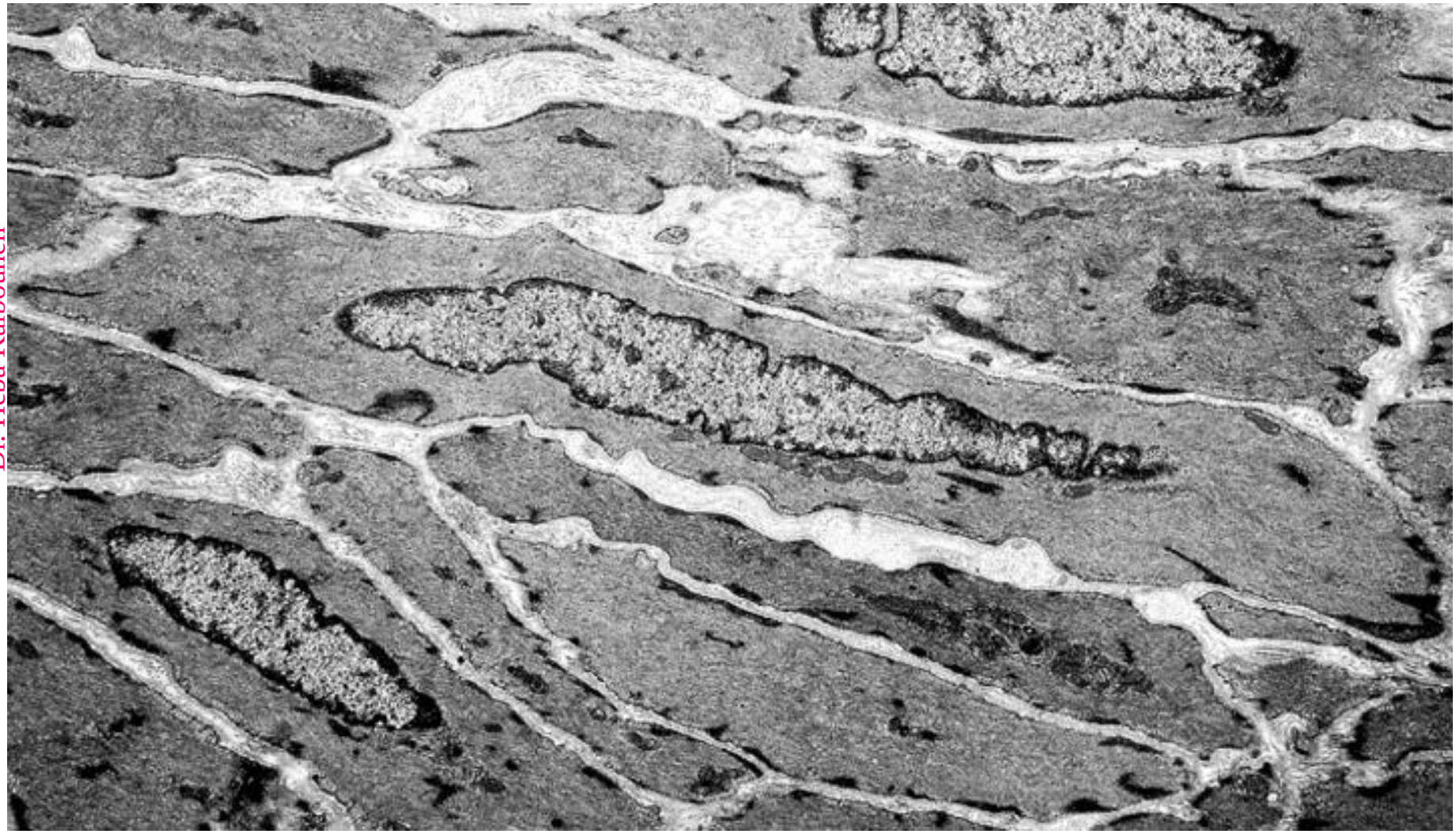
Cross section





Ultrastructure of Smooth Muscle:

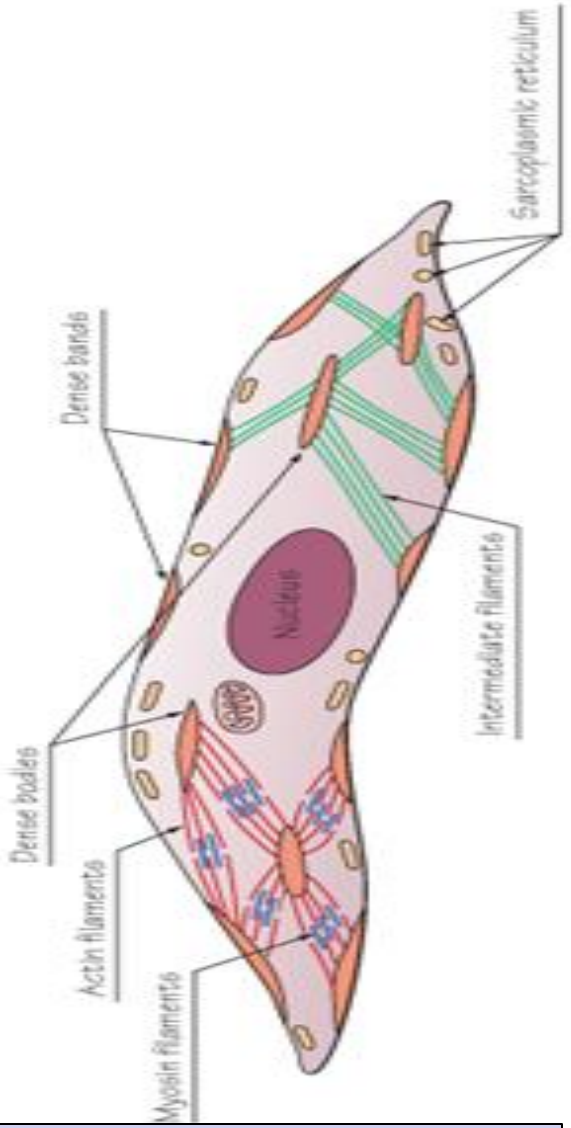
- actin and myosin filaments
- intermediate filaments of desmin (also vimentin in vascular smooth muscle)
- membrane associated and cytoplasmic dense bodies containing α actinin (similar to Z lines)
- relatively active nucleus (smooth muscle cells make collagen, elastin, and proteoglycans)



The myofilaments of smooth muscle are arranged differently and appear less organized

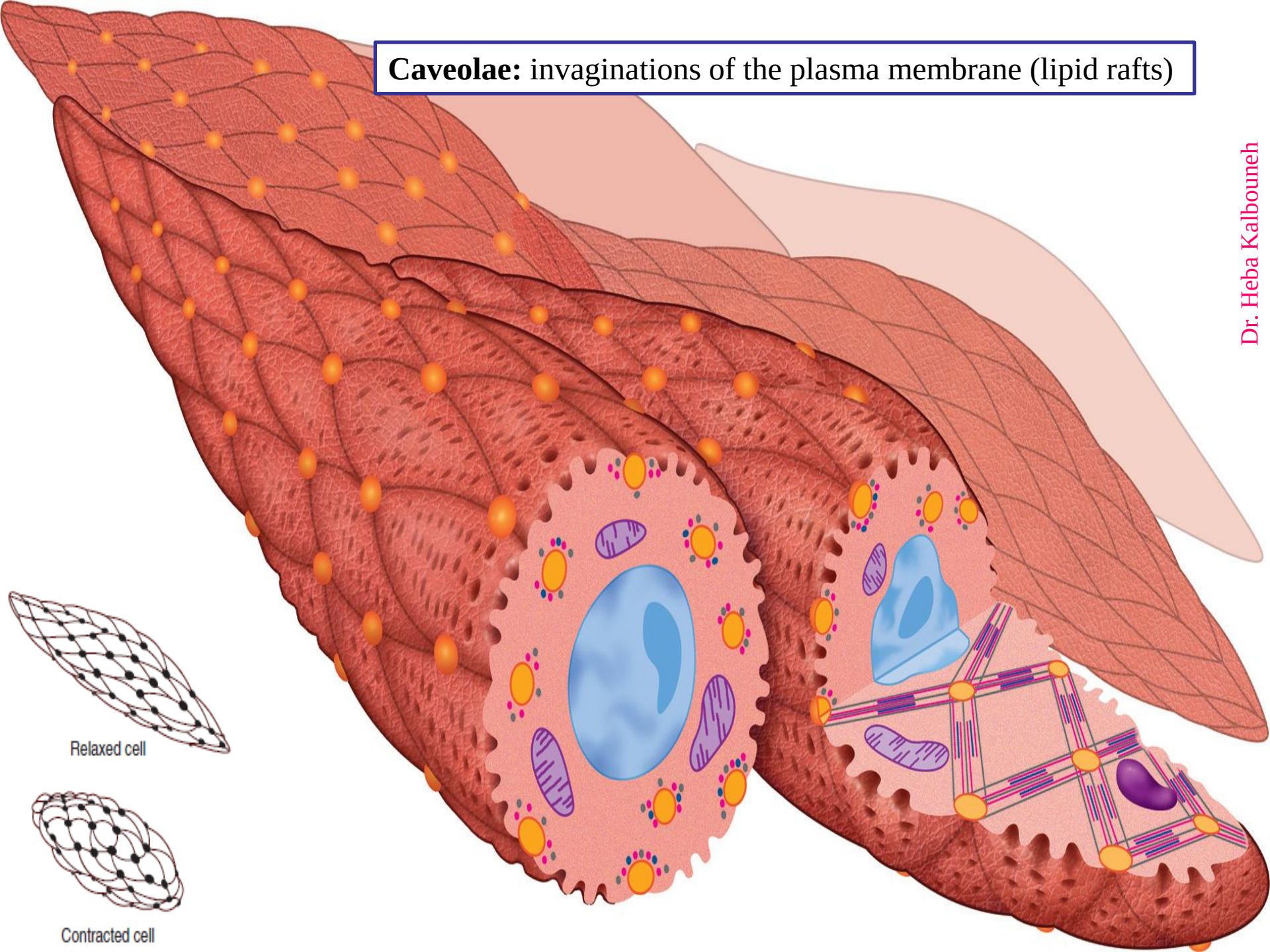
Thin filaments attach to **dense bodies** located on the cytoplasmic surface of the plasma membrane and deep in the cytoplasm (intracytoplasmatic dense bodies)

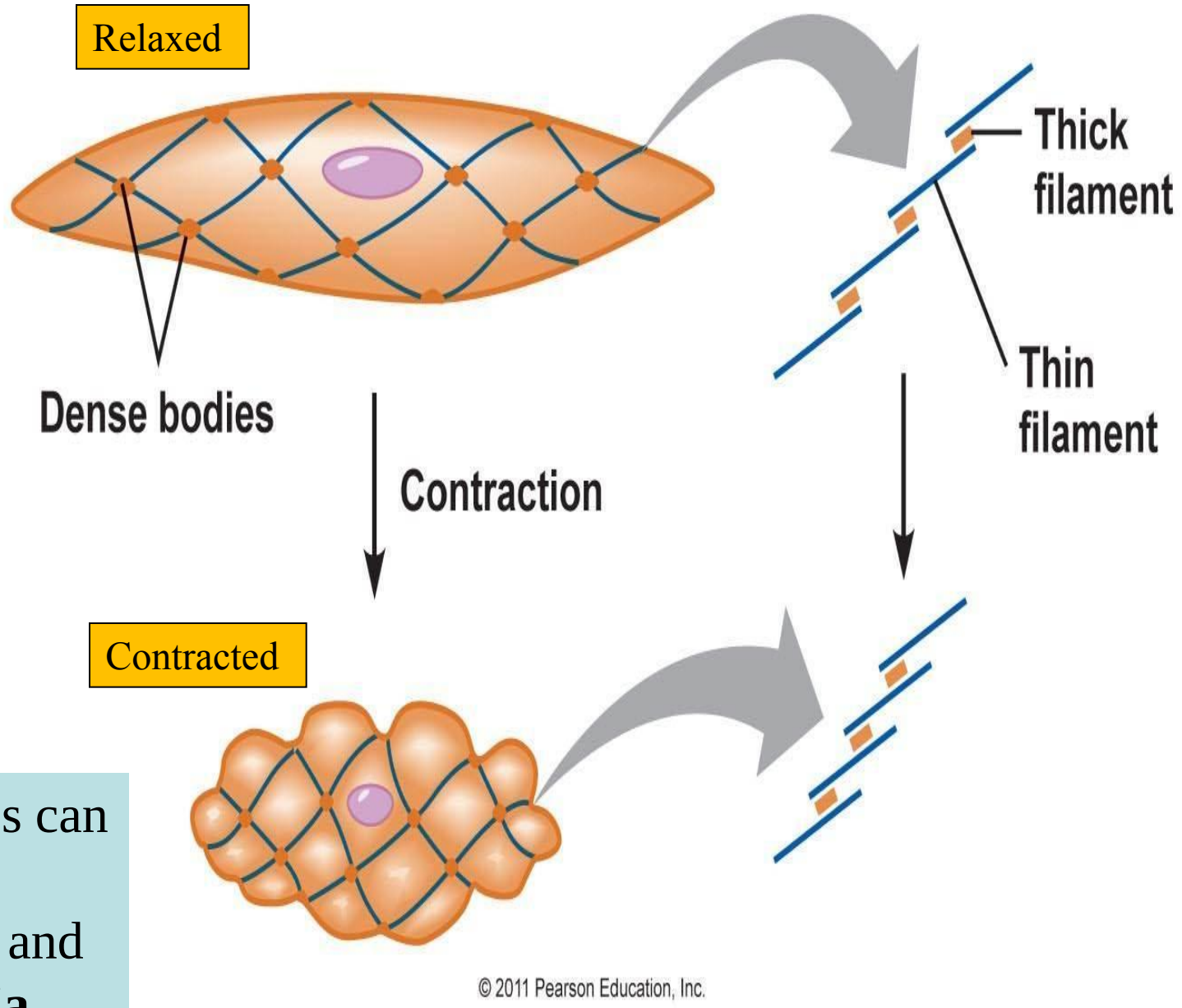
Dense bodies contain α-actinin for thin filament attachment



Dense bodies at the membrane are also attachment sites for intermediate filaments and for adhesive junctions between cells. This arrangement of both the cytoskeleton and contractile apparatus allows the multicellular tissue to contract as a unit, providing better efficiency and force

Caveolae: invaginations of the plasma membrane (lipid rafts)





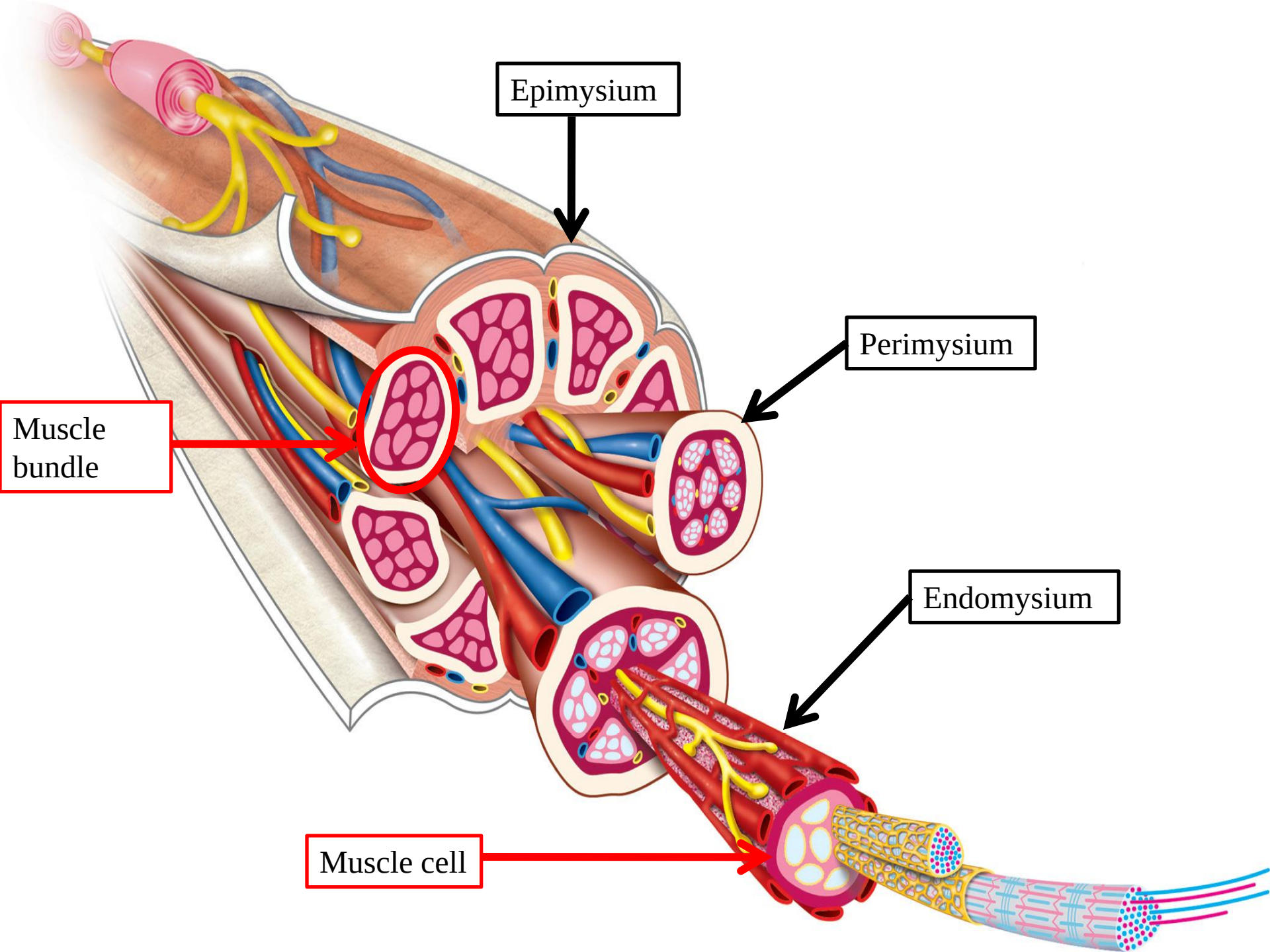
Smooth muscles can undergo **Hypertrophy** and **Hyperplasia**

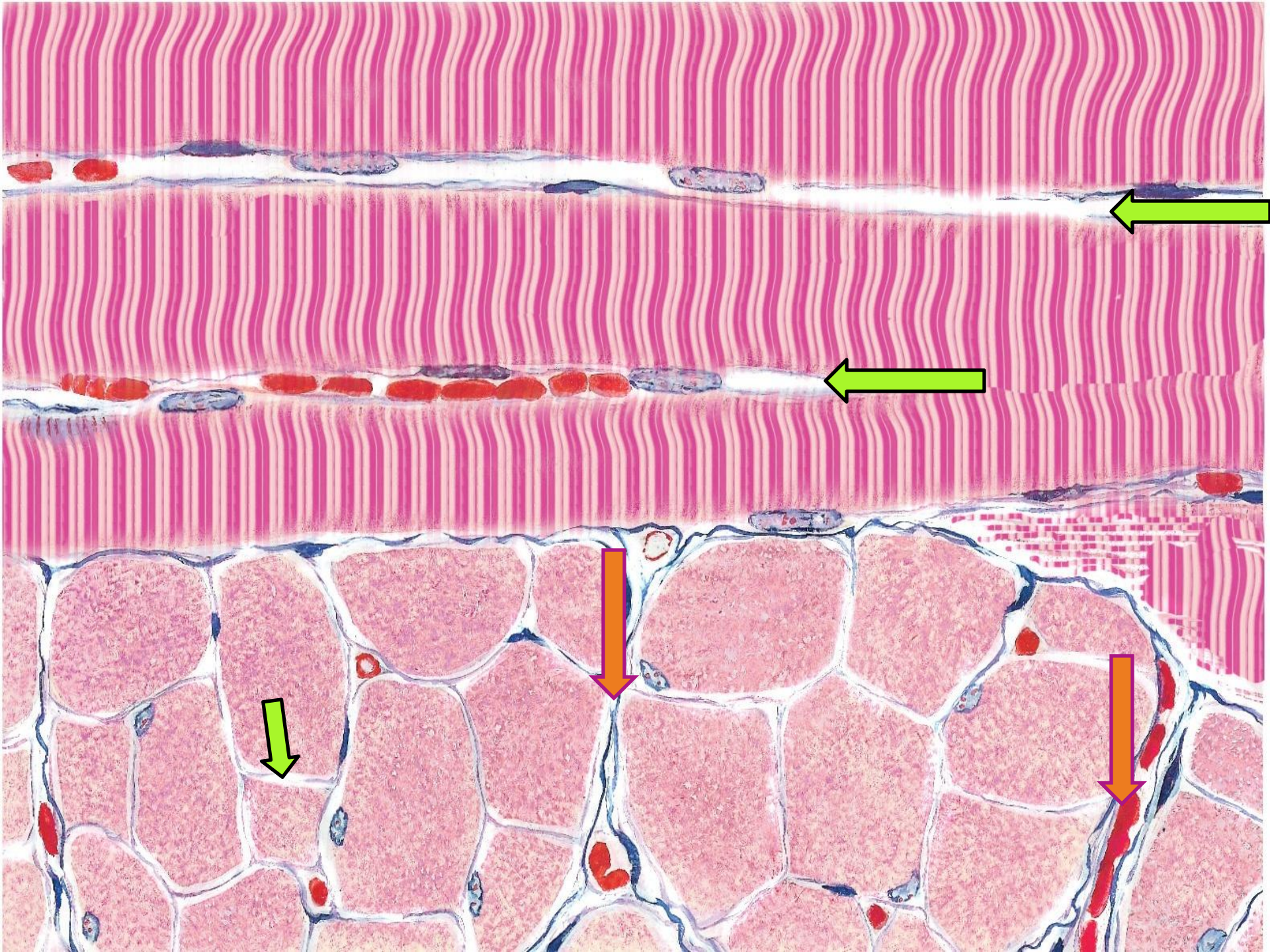
Muscle tissue

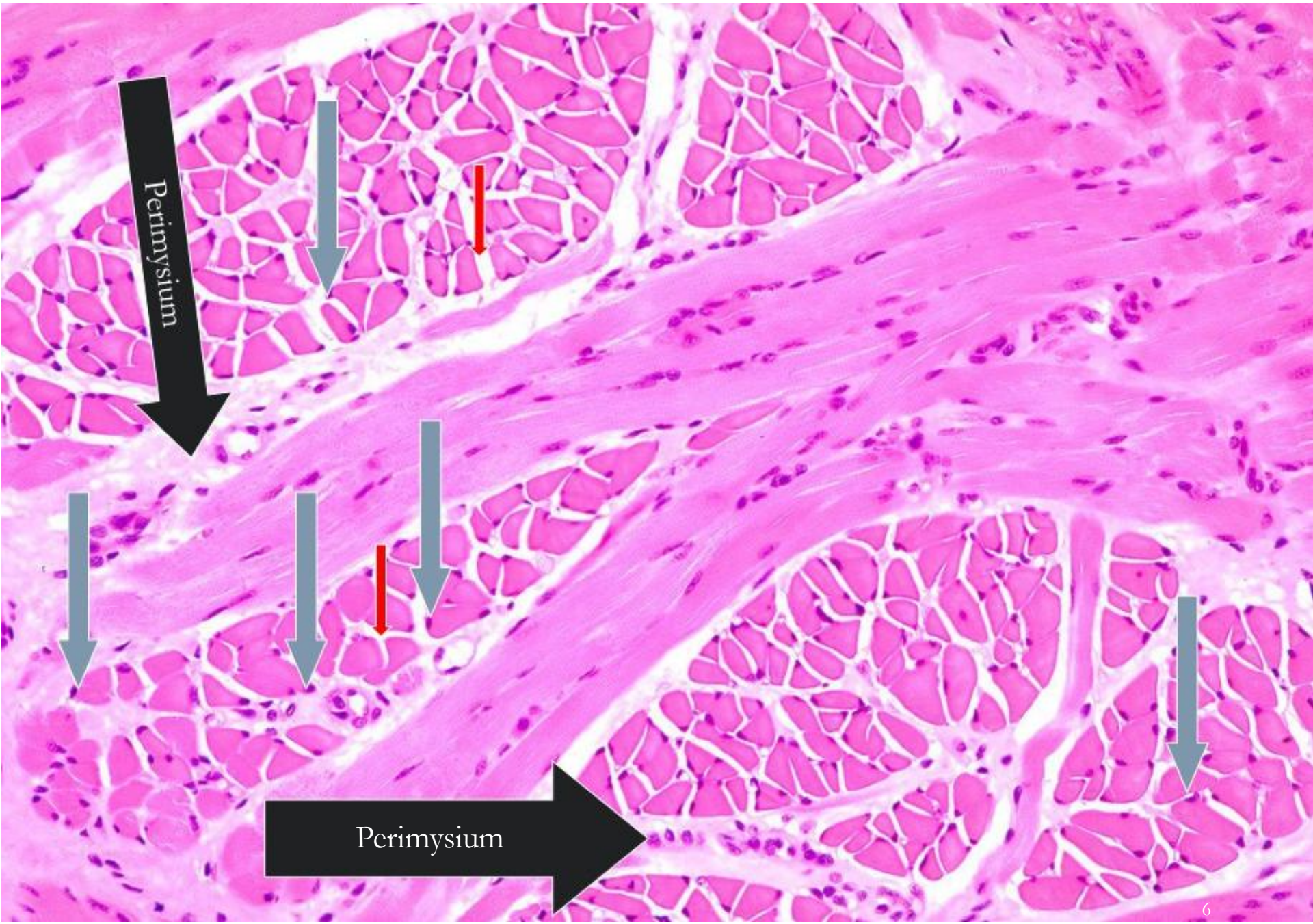
Practical part

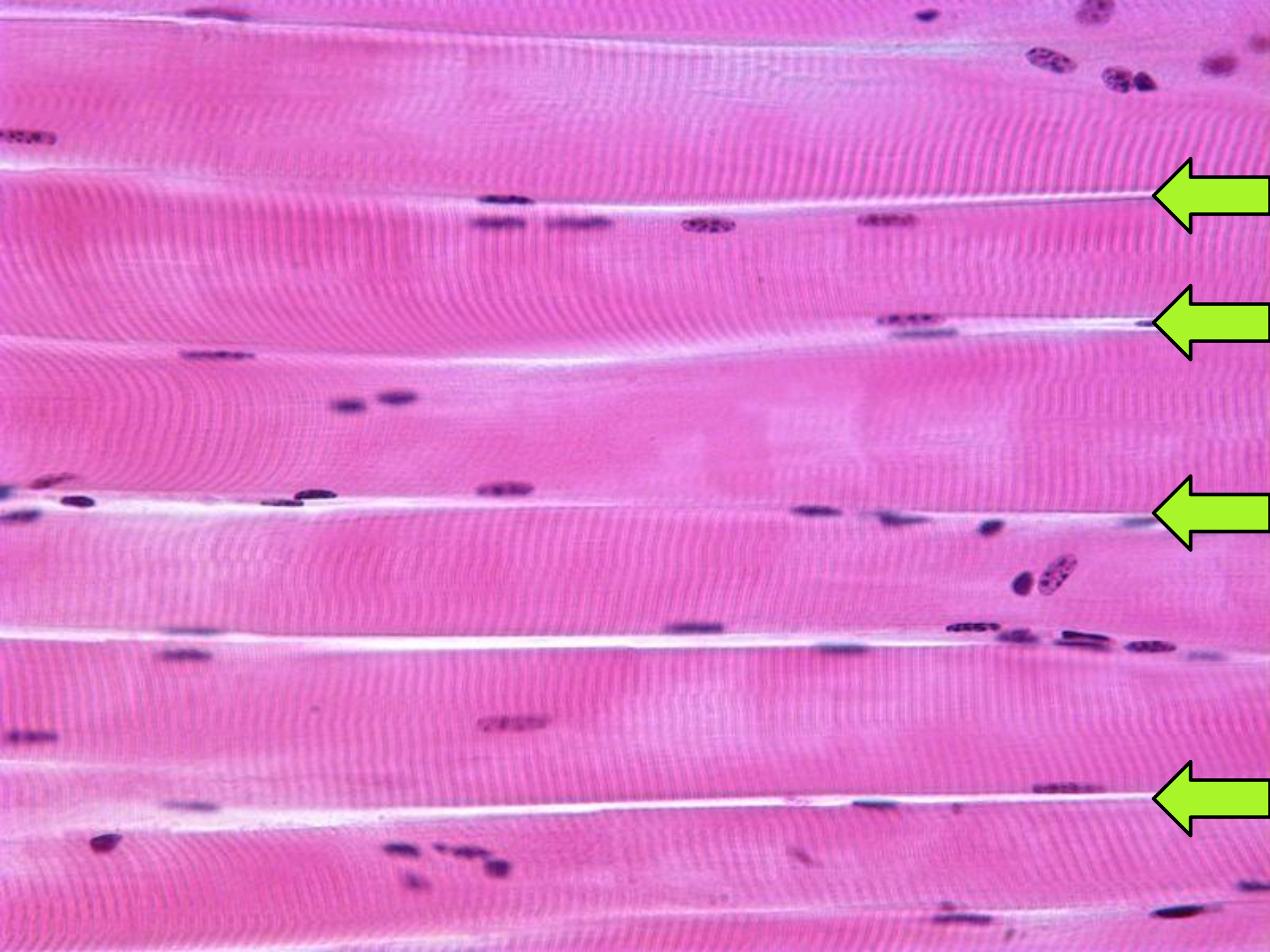
Dr. Heba Kalbouneh
Associate Professor of Anatomy and Histology

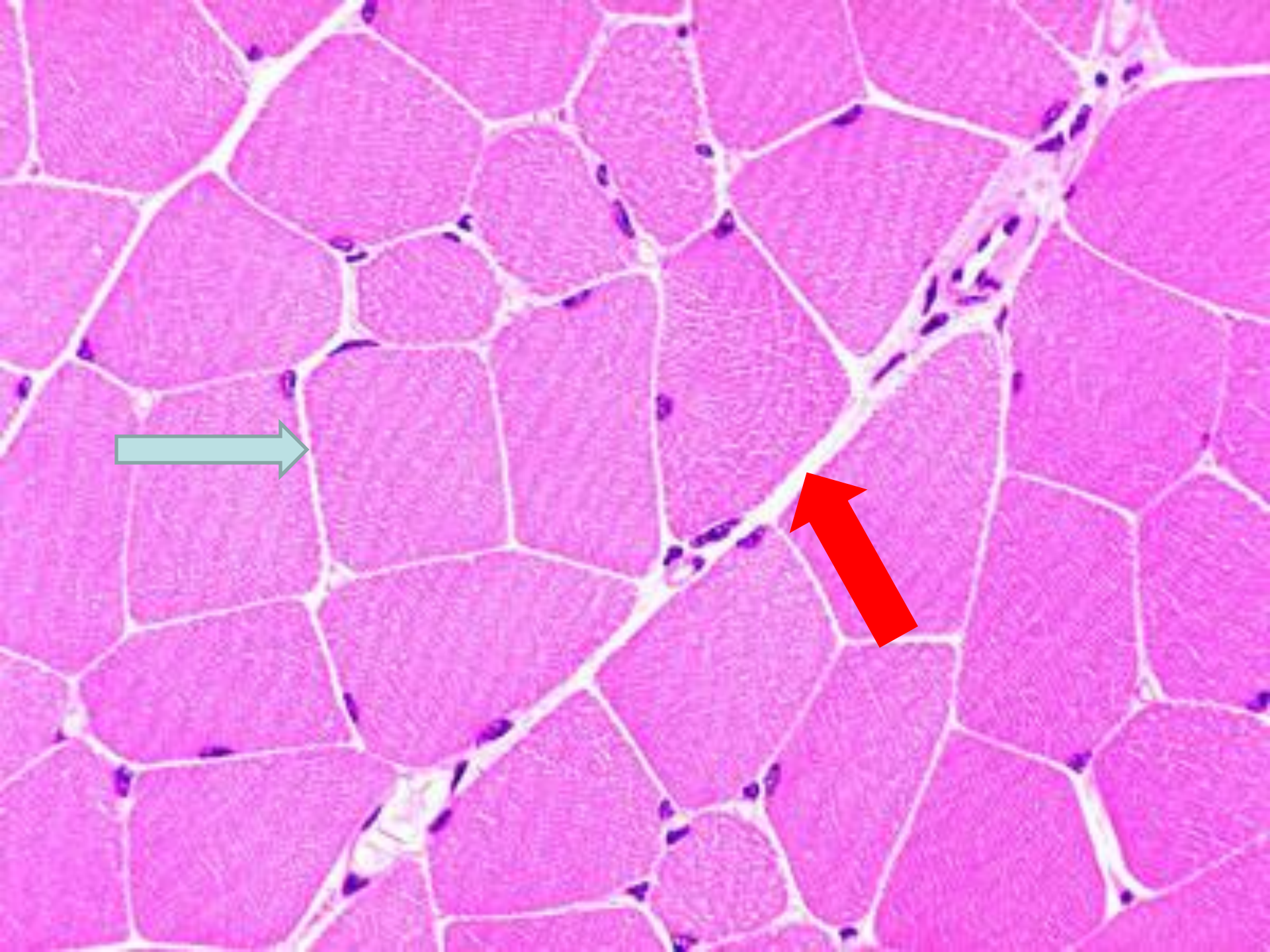
Skeletal muscle

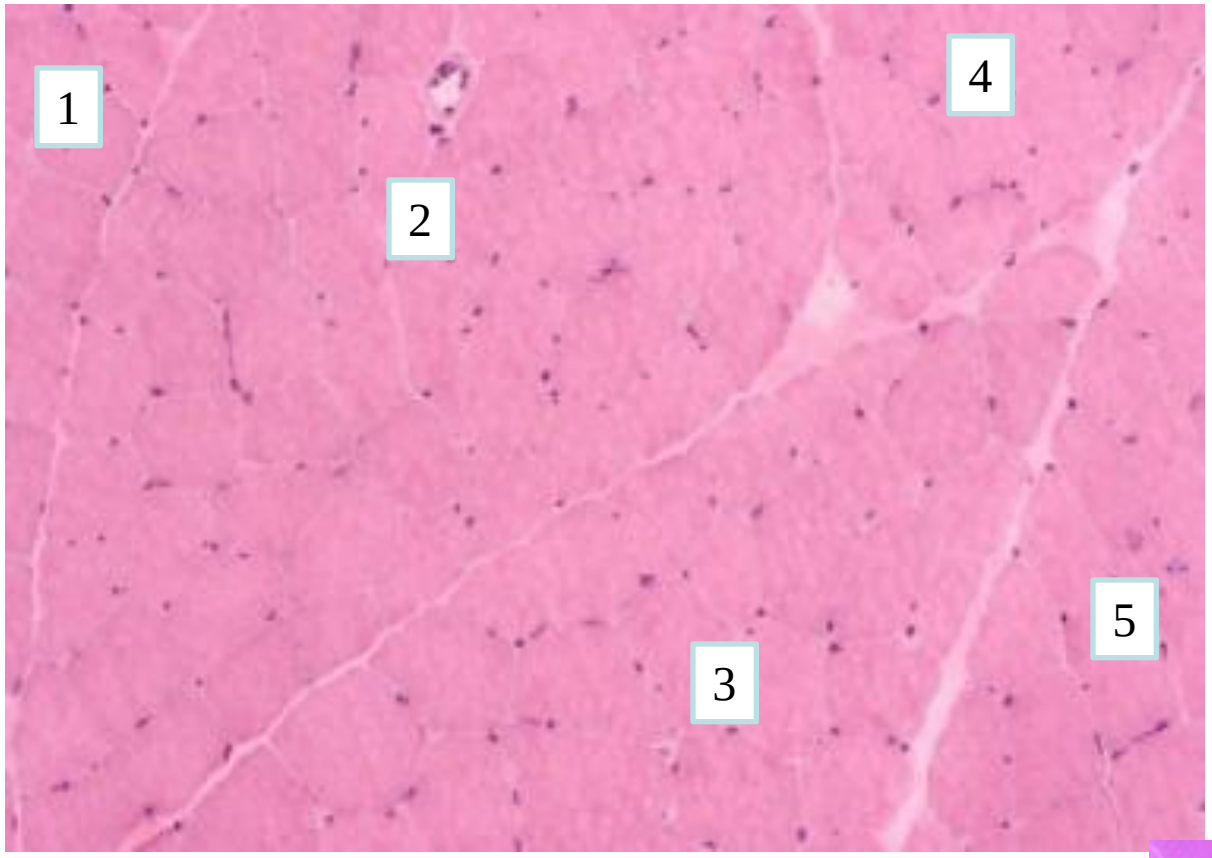

Epimysium
Perimysium
Muscle bundle
Endomysium
Muscle cell



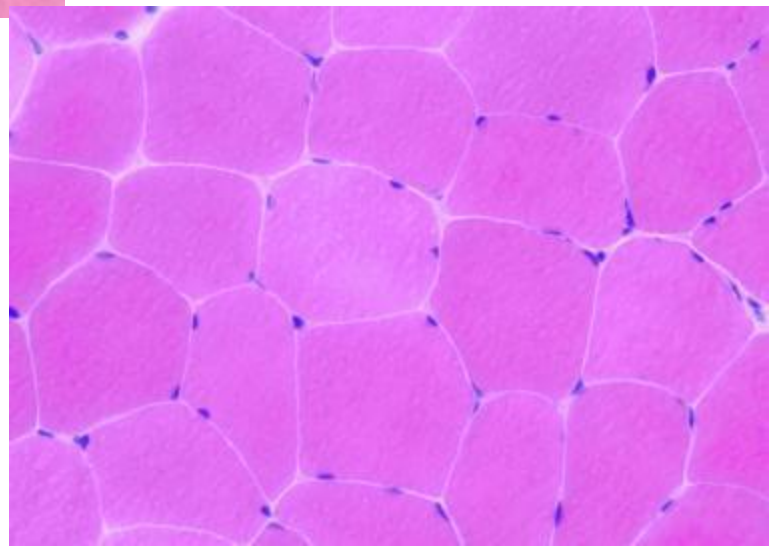

Perimysium
Perimysium

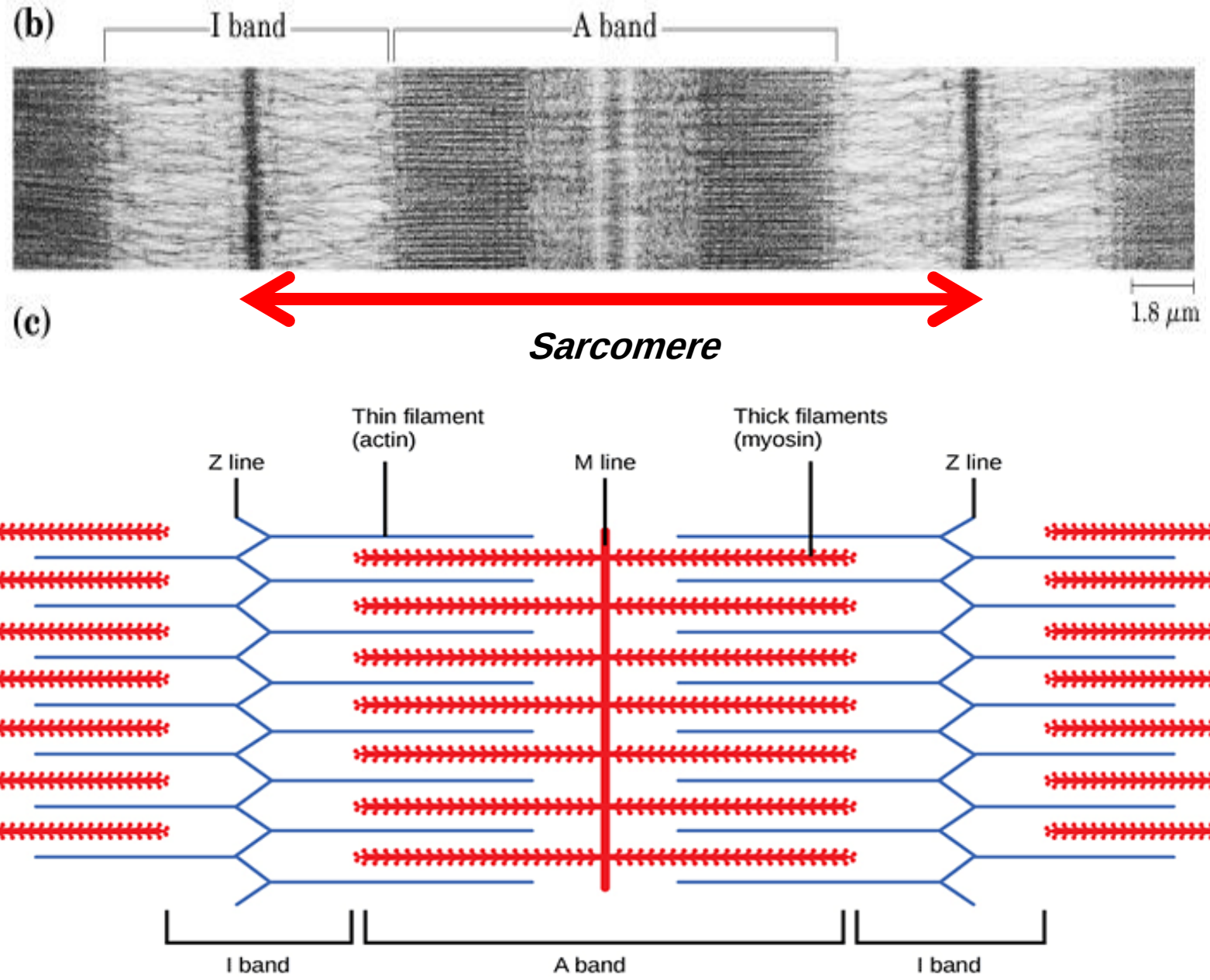


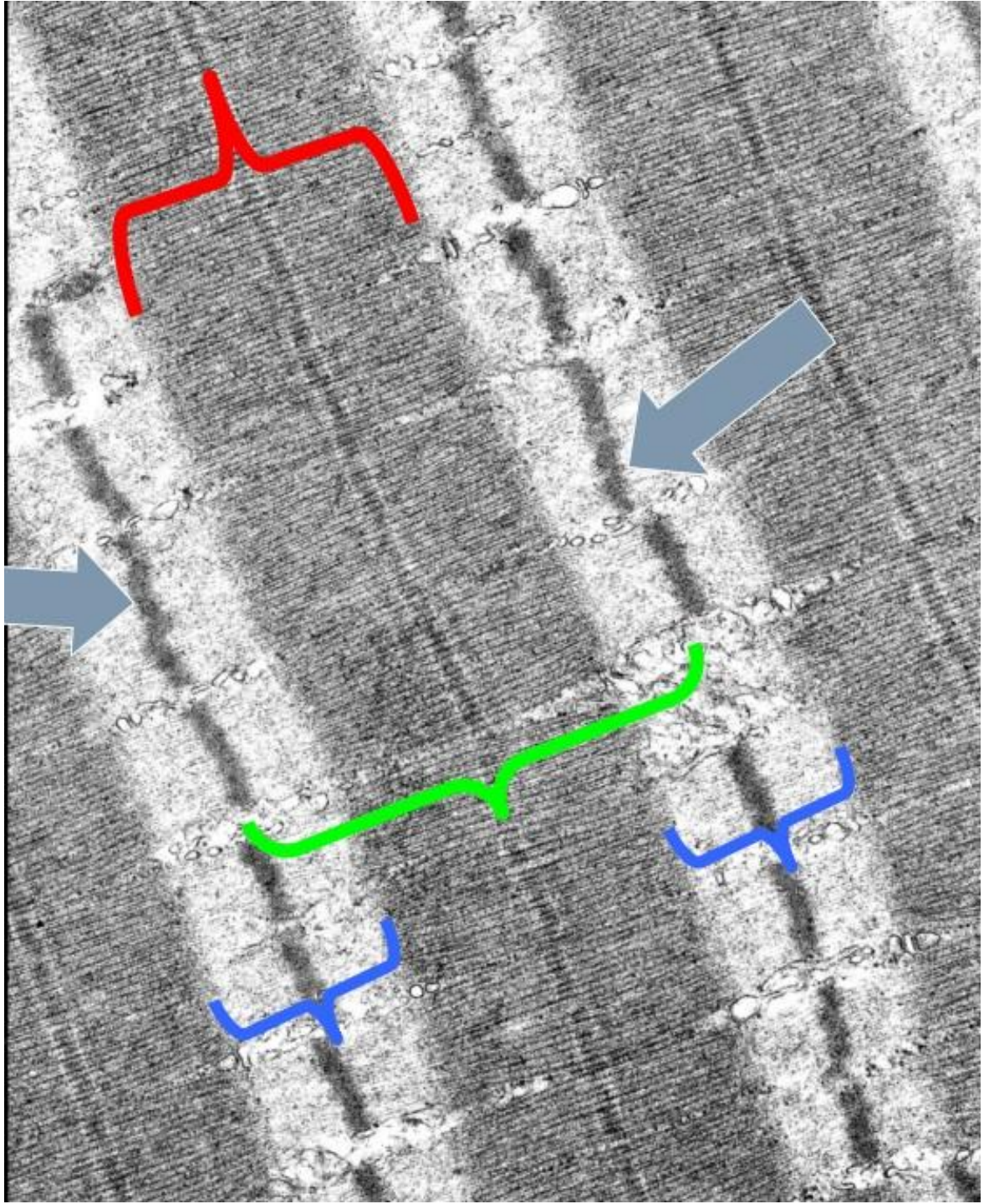


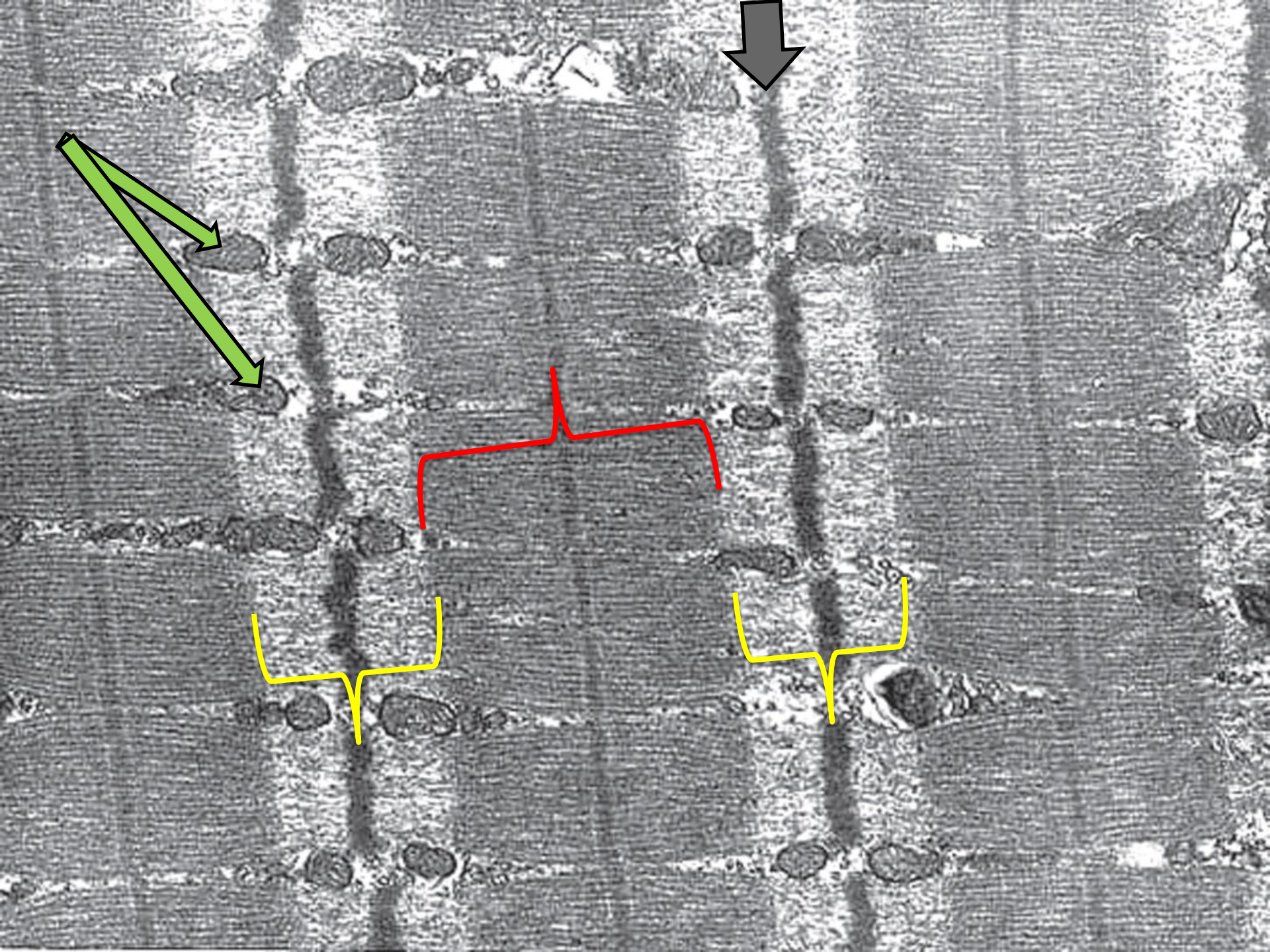


How many fascicles in this section??

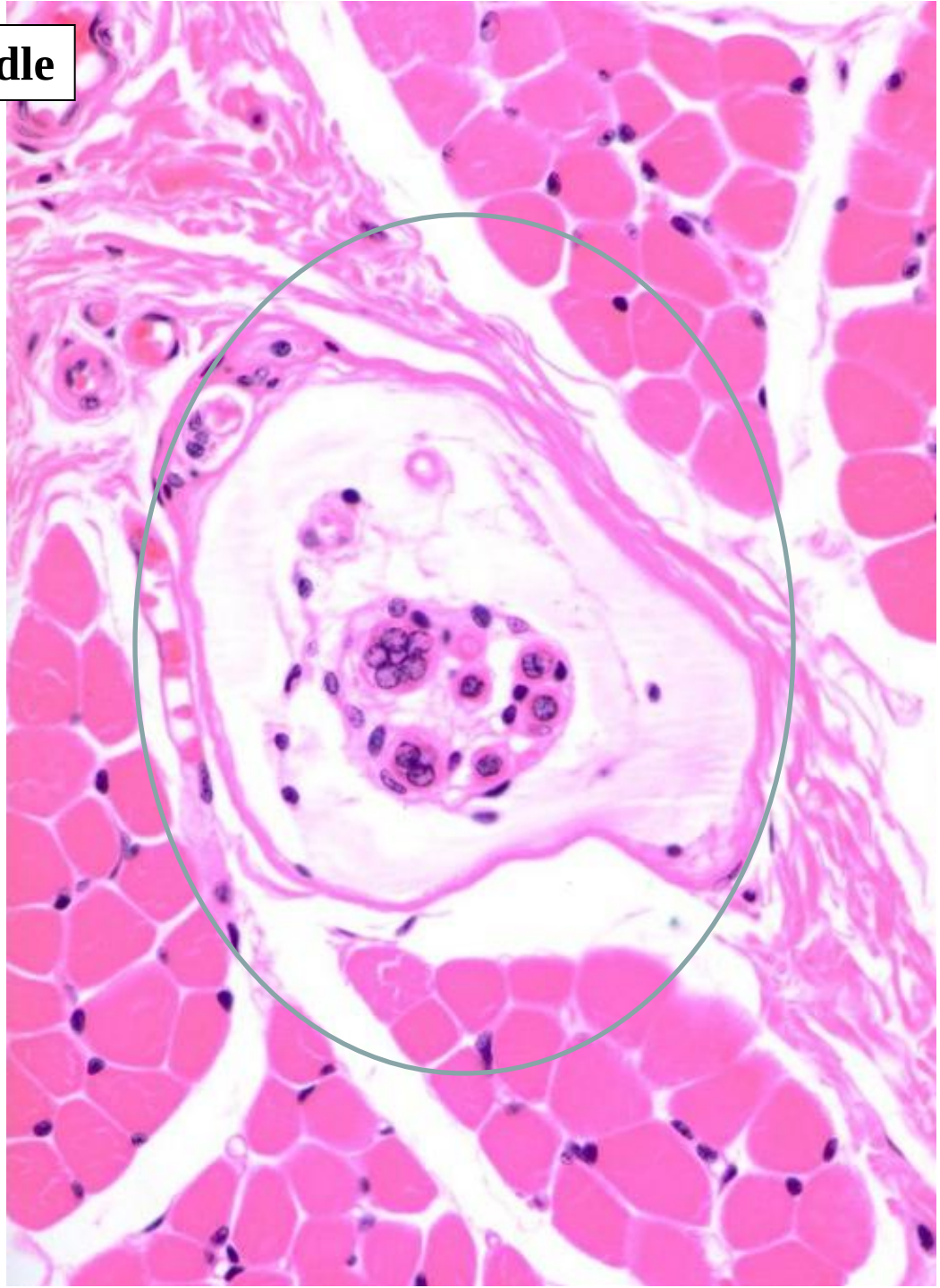



(b)
I band
A band
1.8 μm
(c)
Sarcomere
Thin filament
(actin)
Thick filaments
(myosin)
Z line
M line
Z line
I band
A band
I band

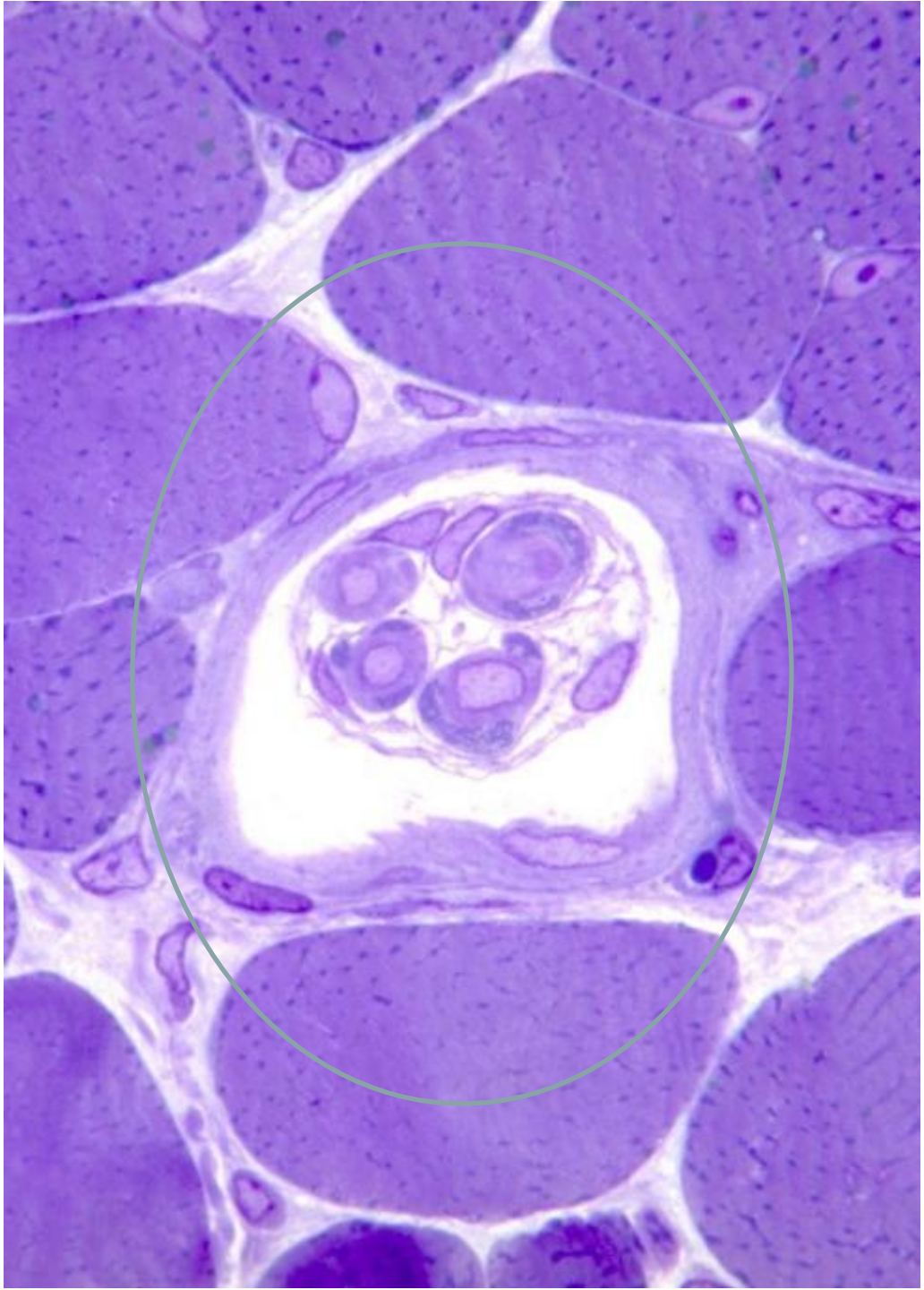


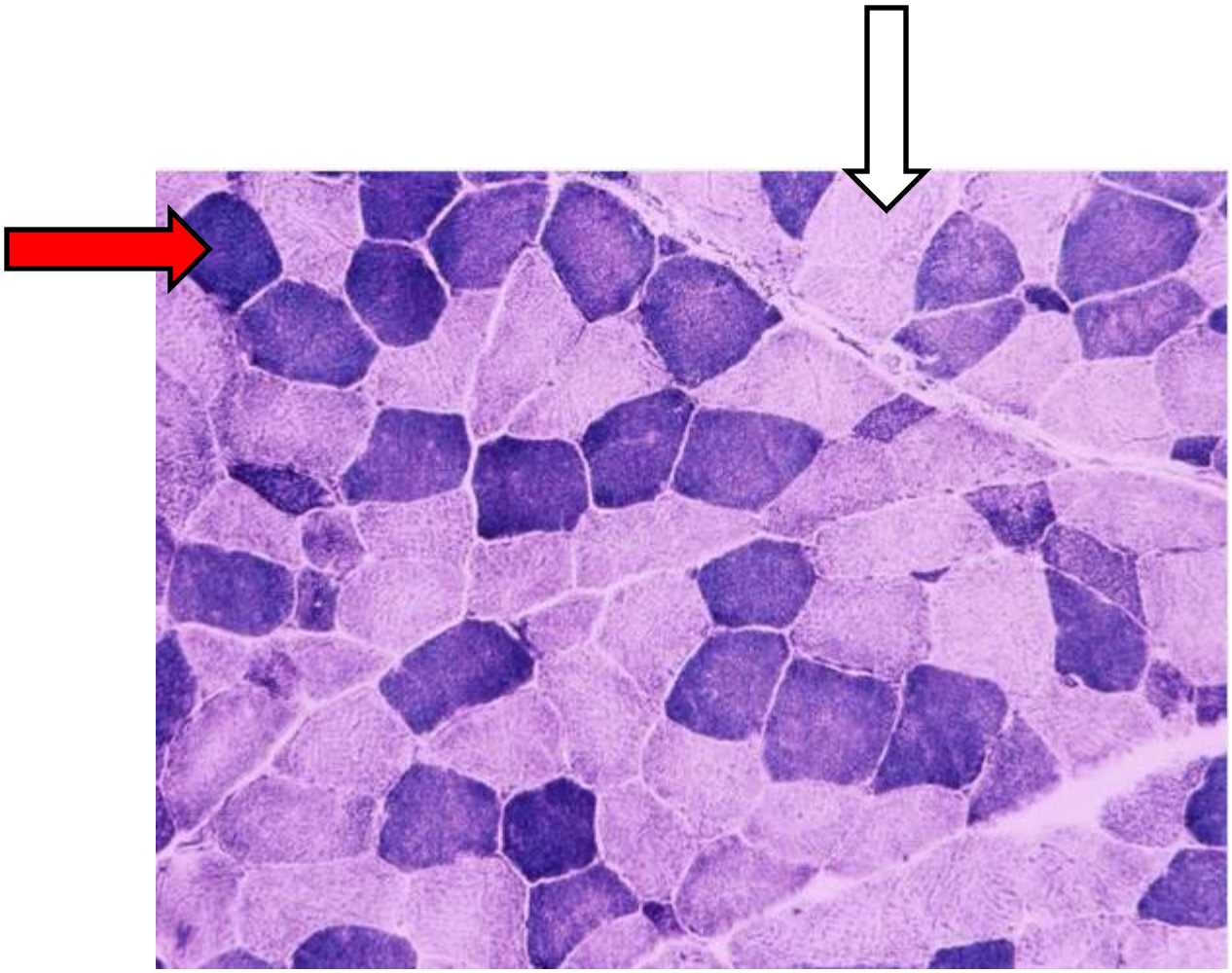


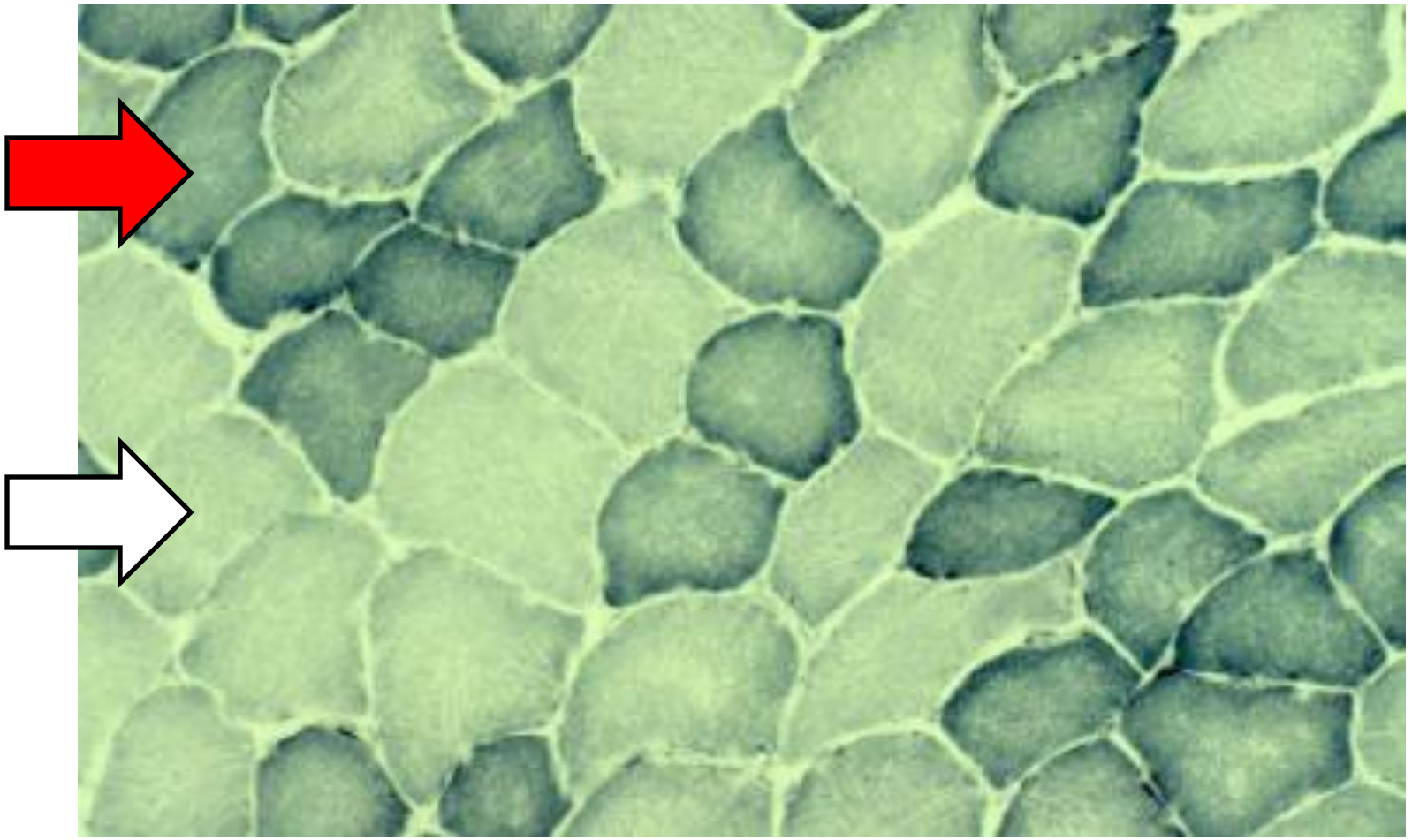
Muscle spindle



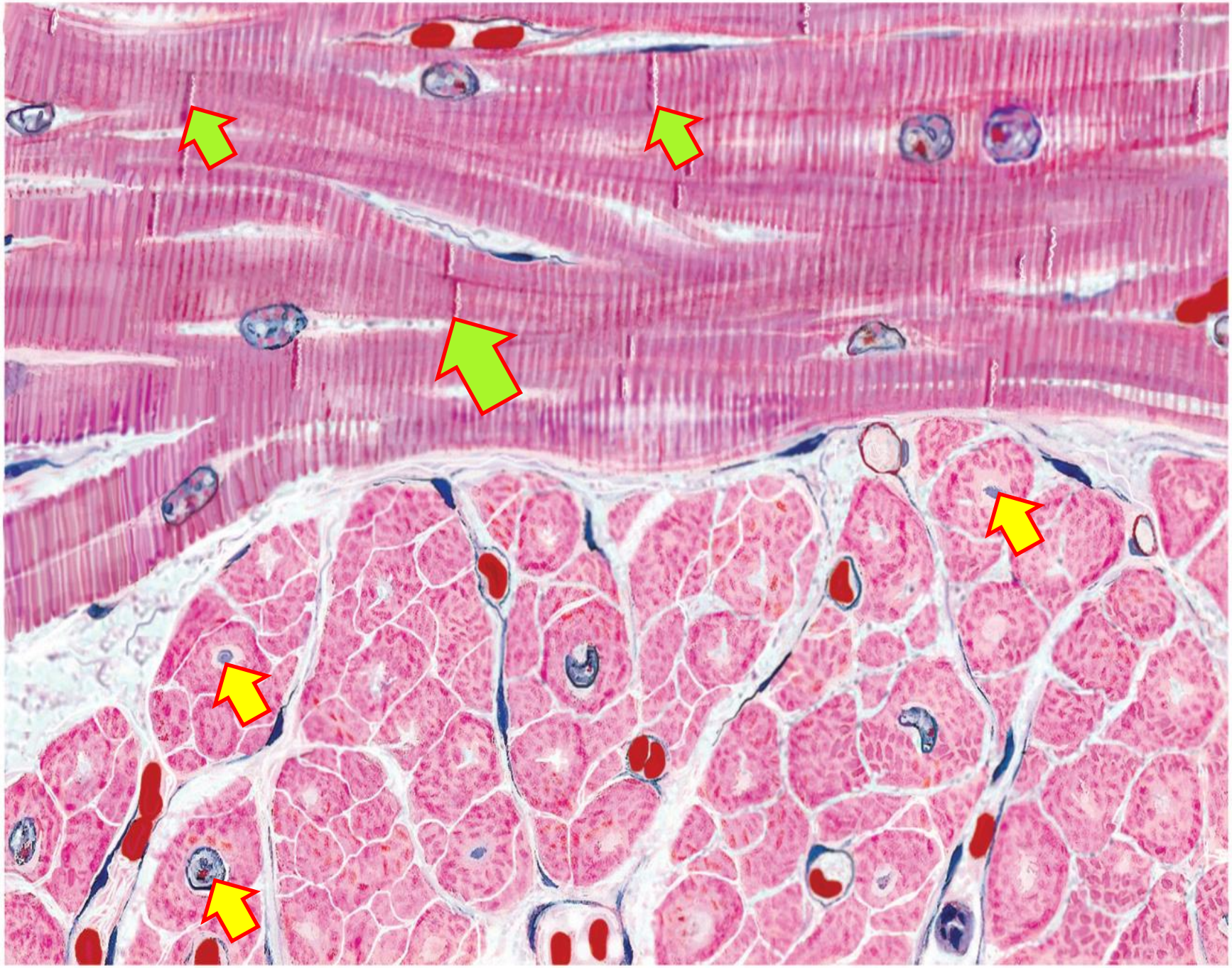
Muscle spindle

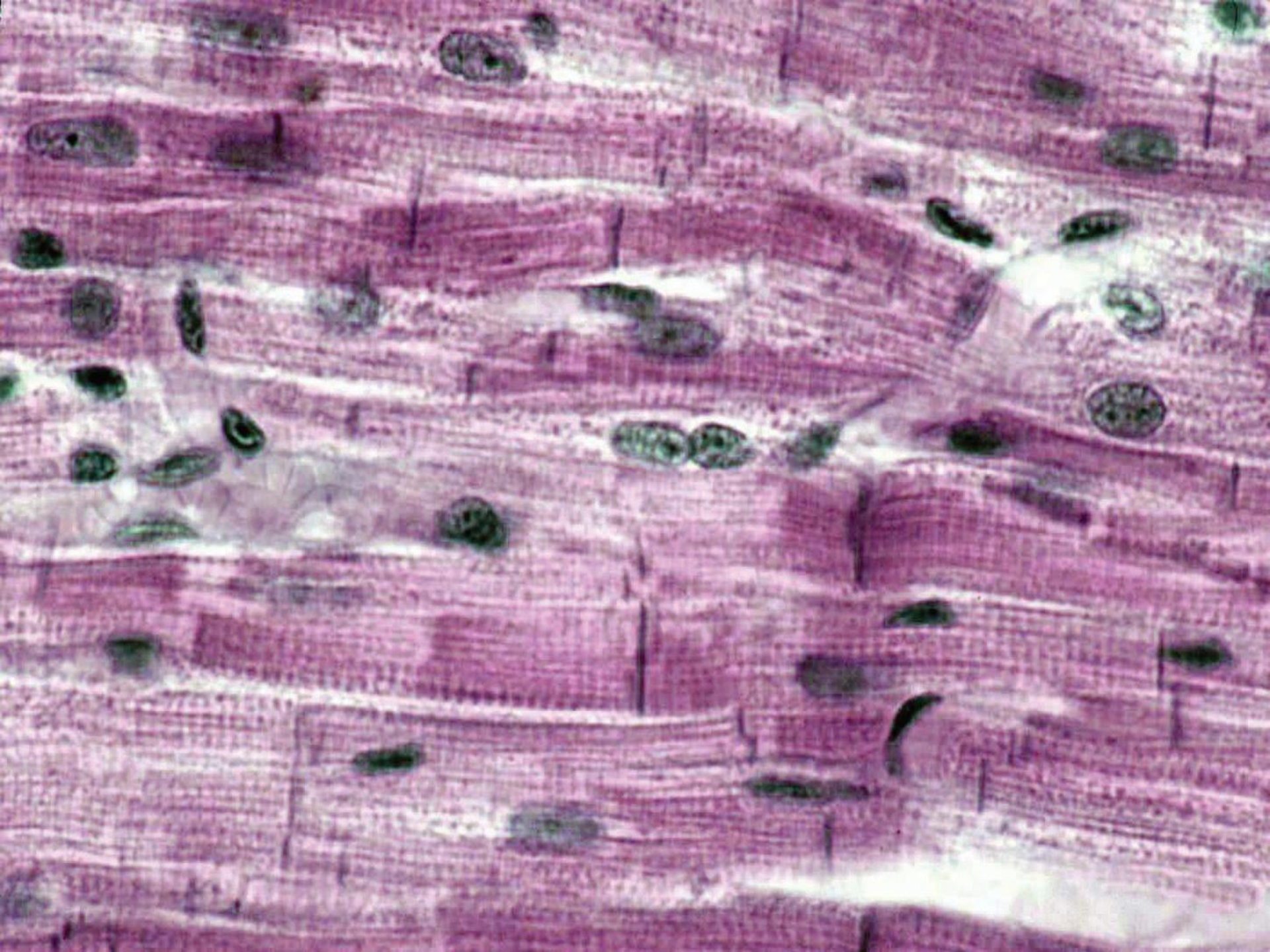


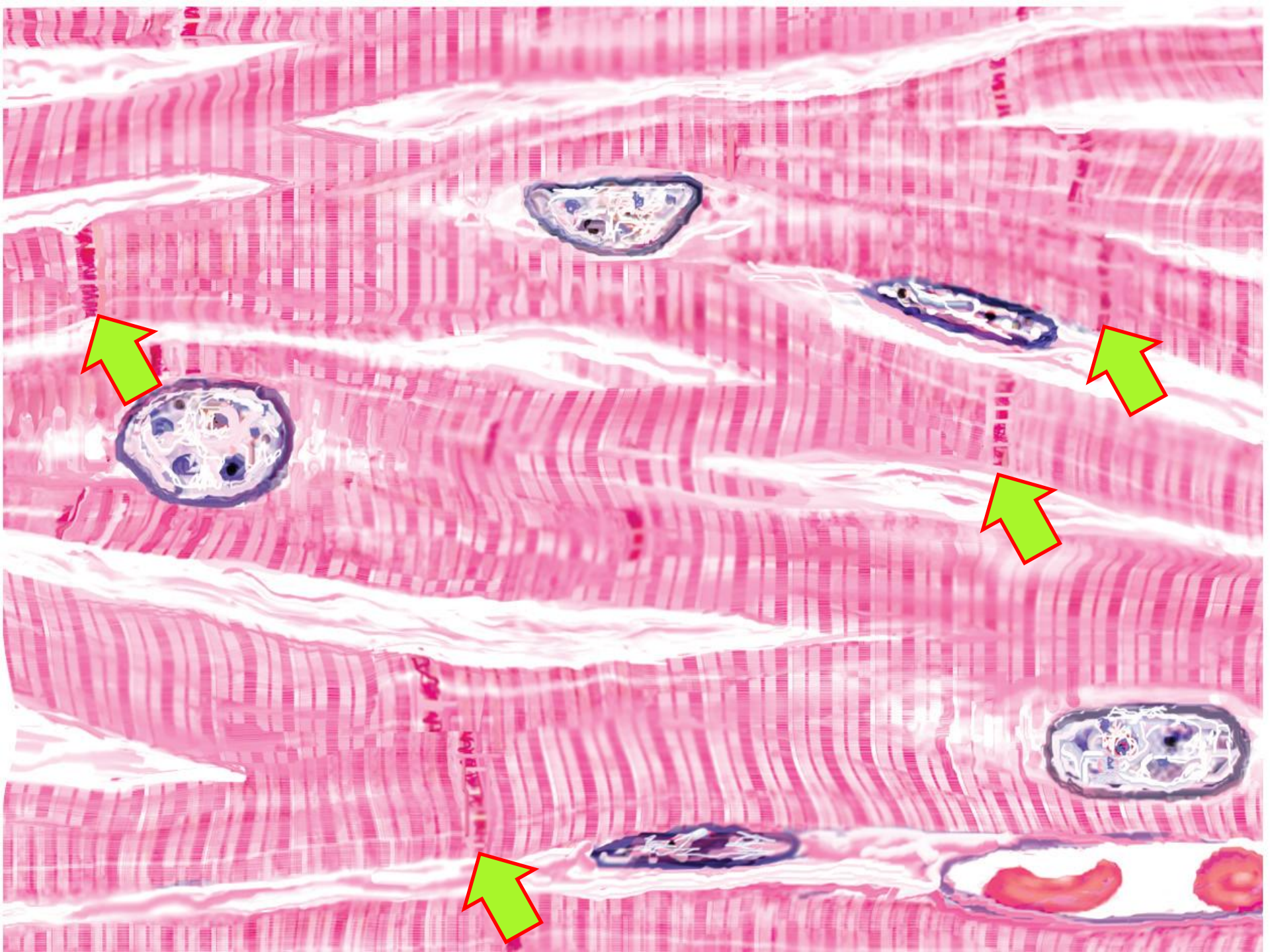


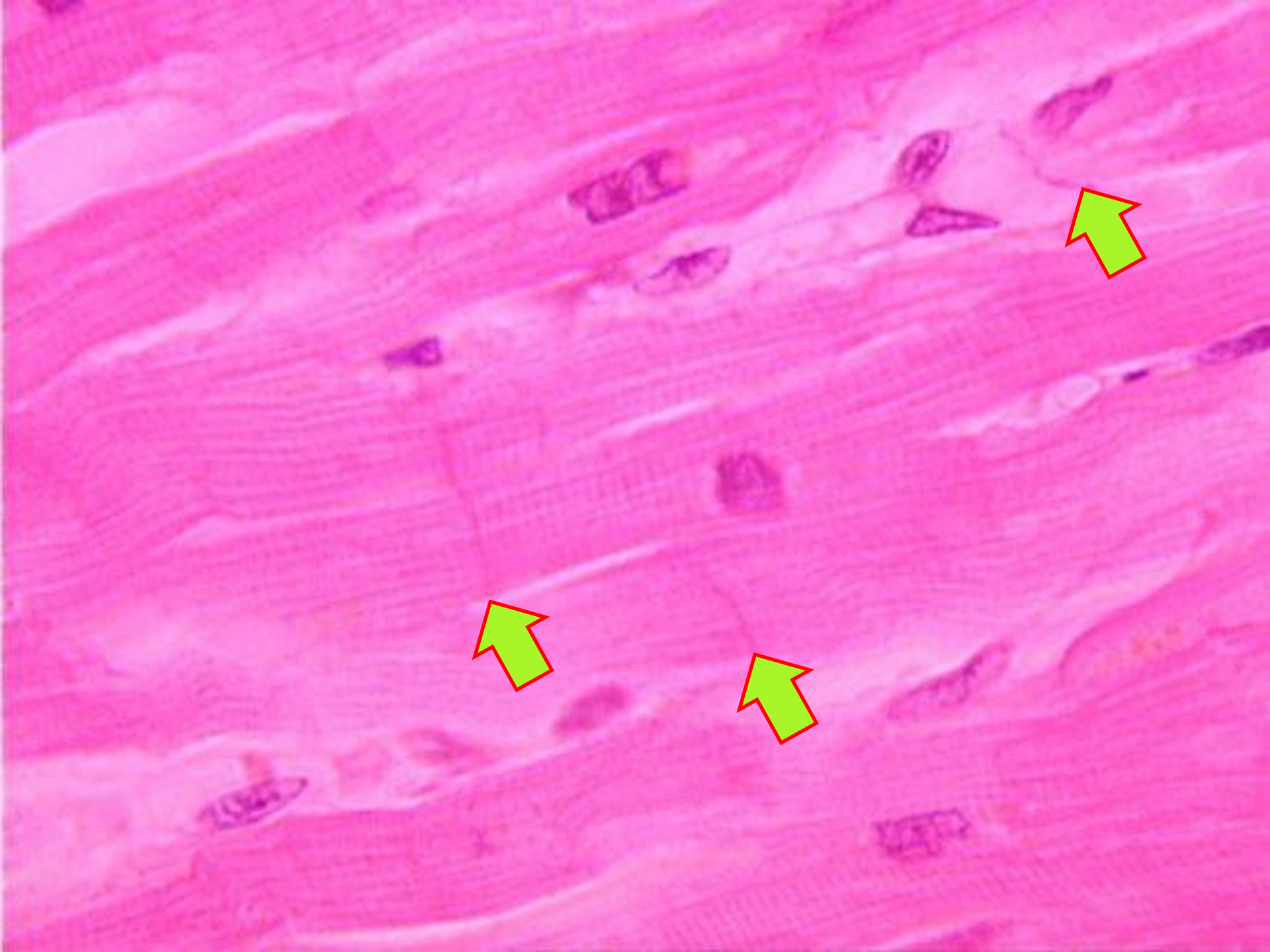


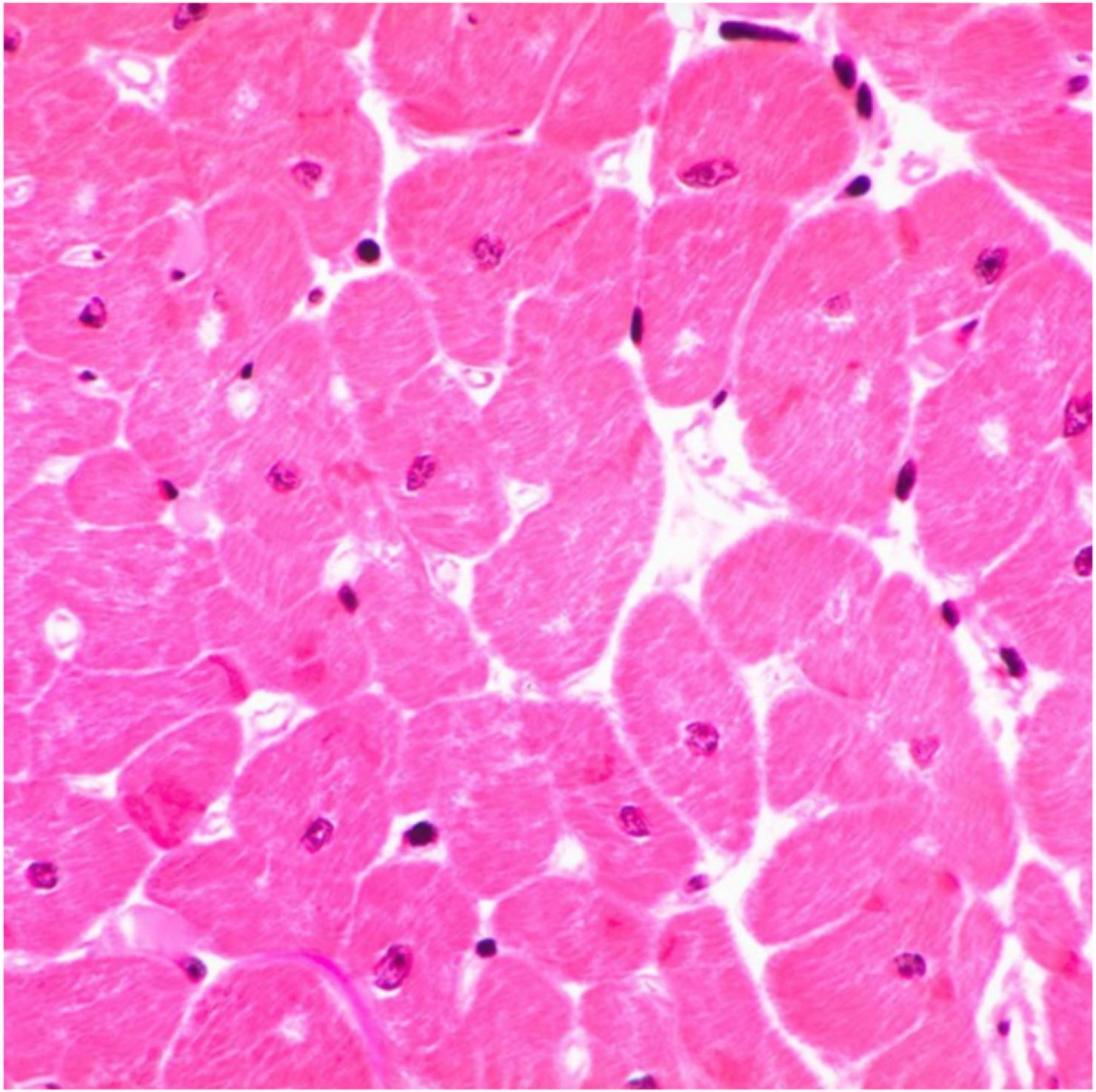
Cardiac muscle

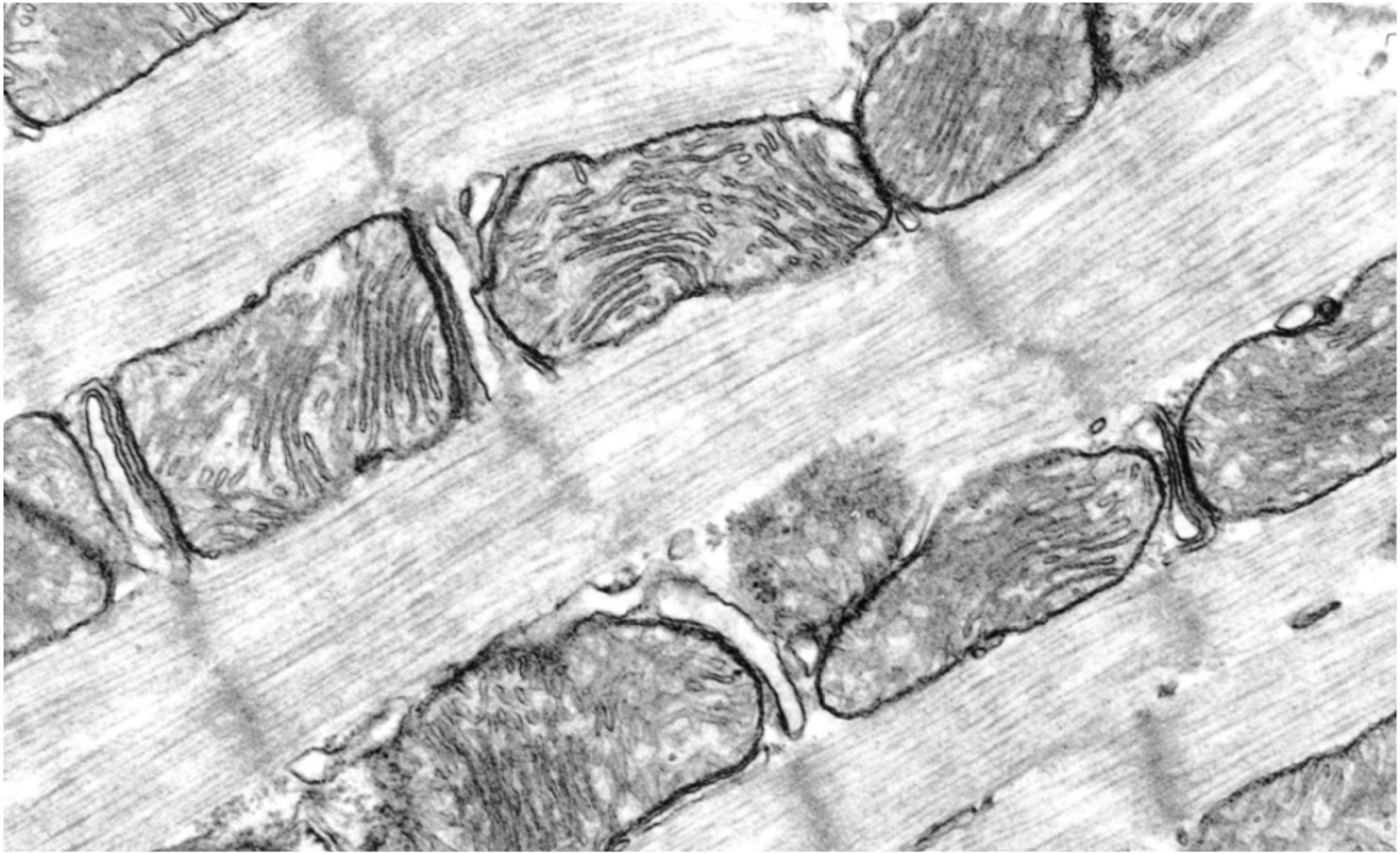


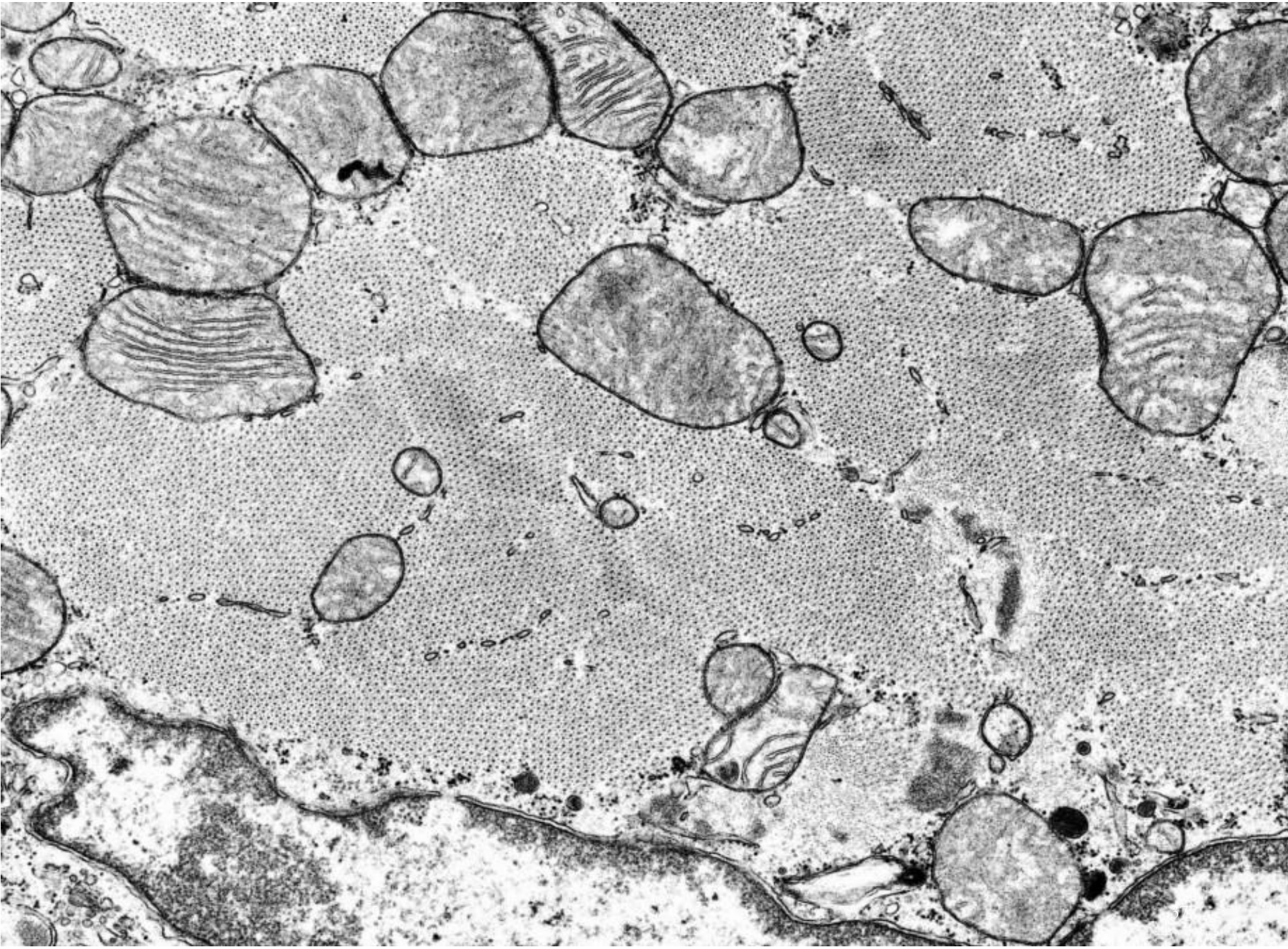




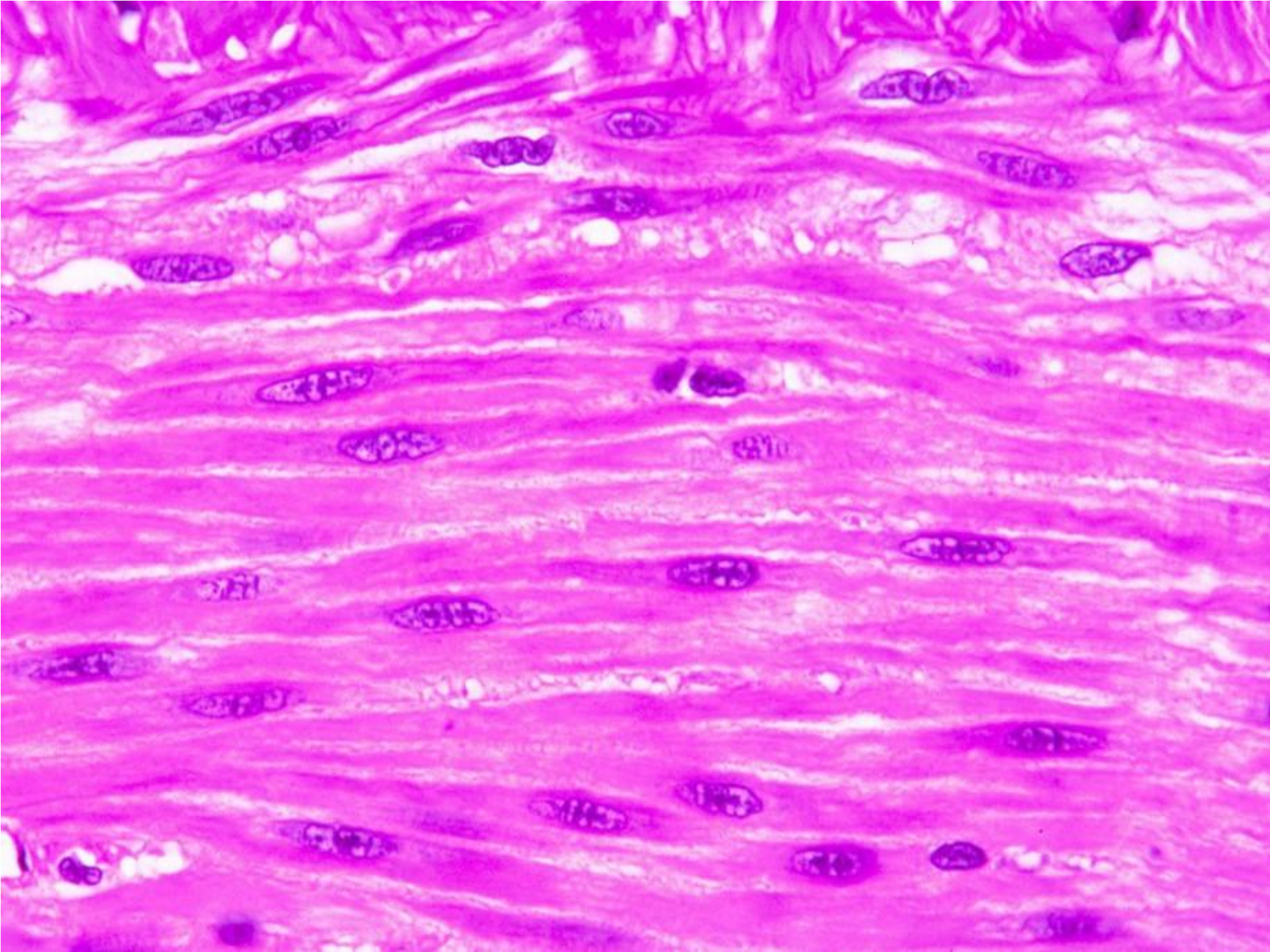




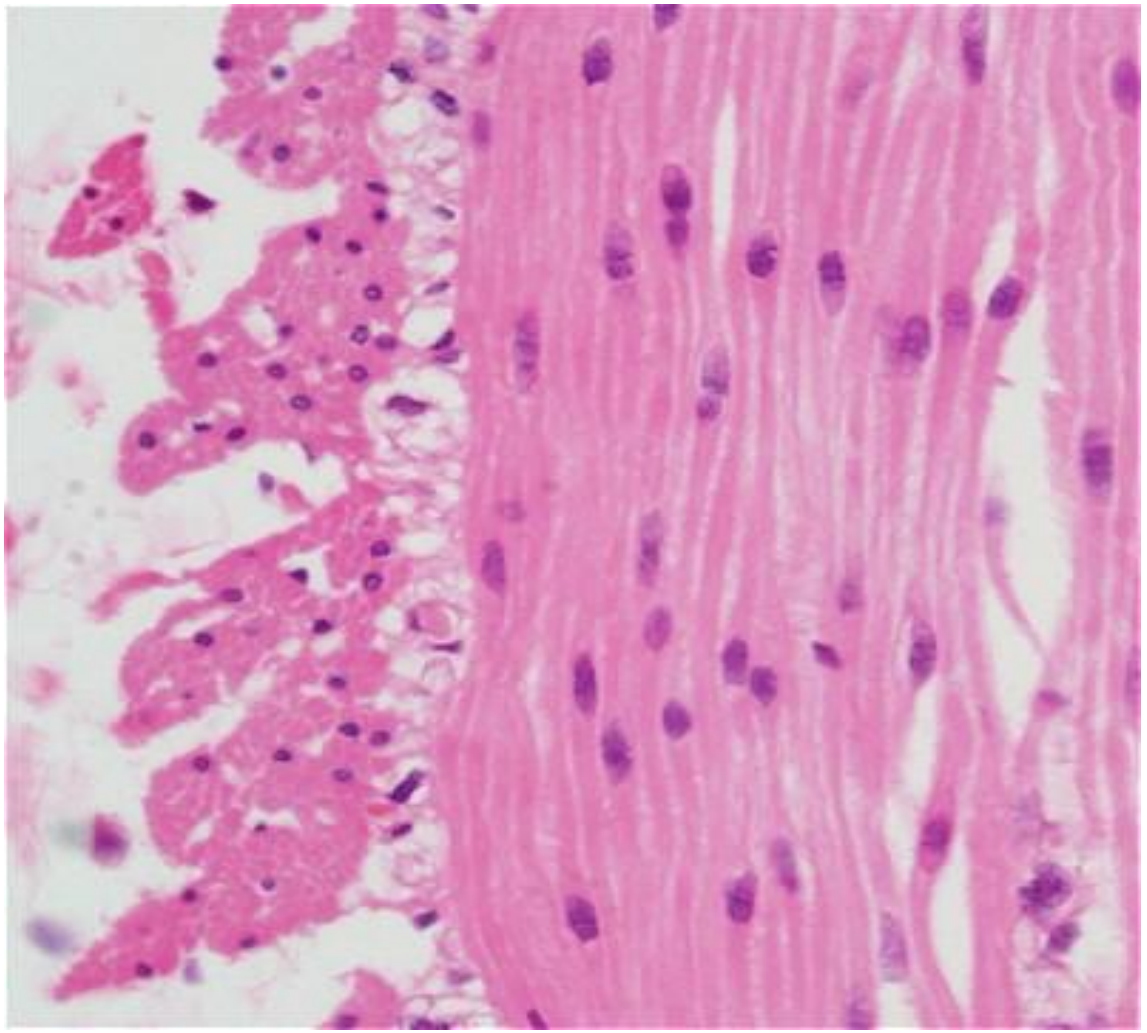


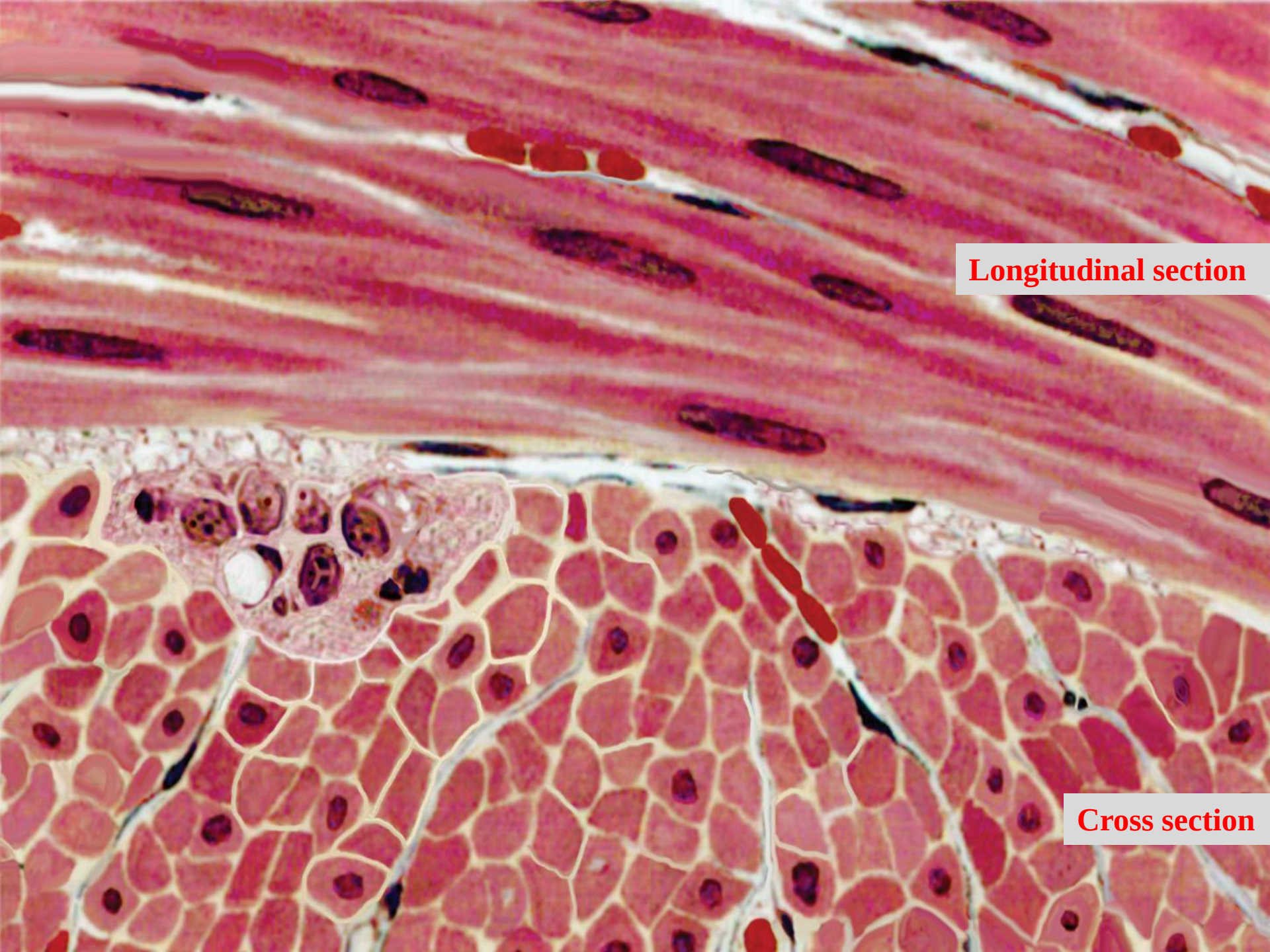


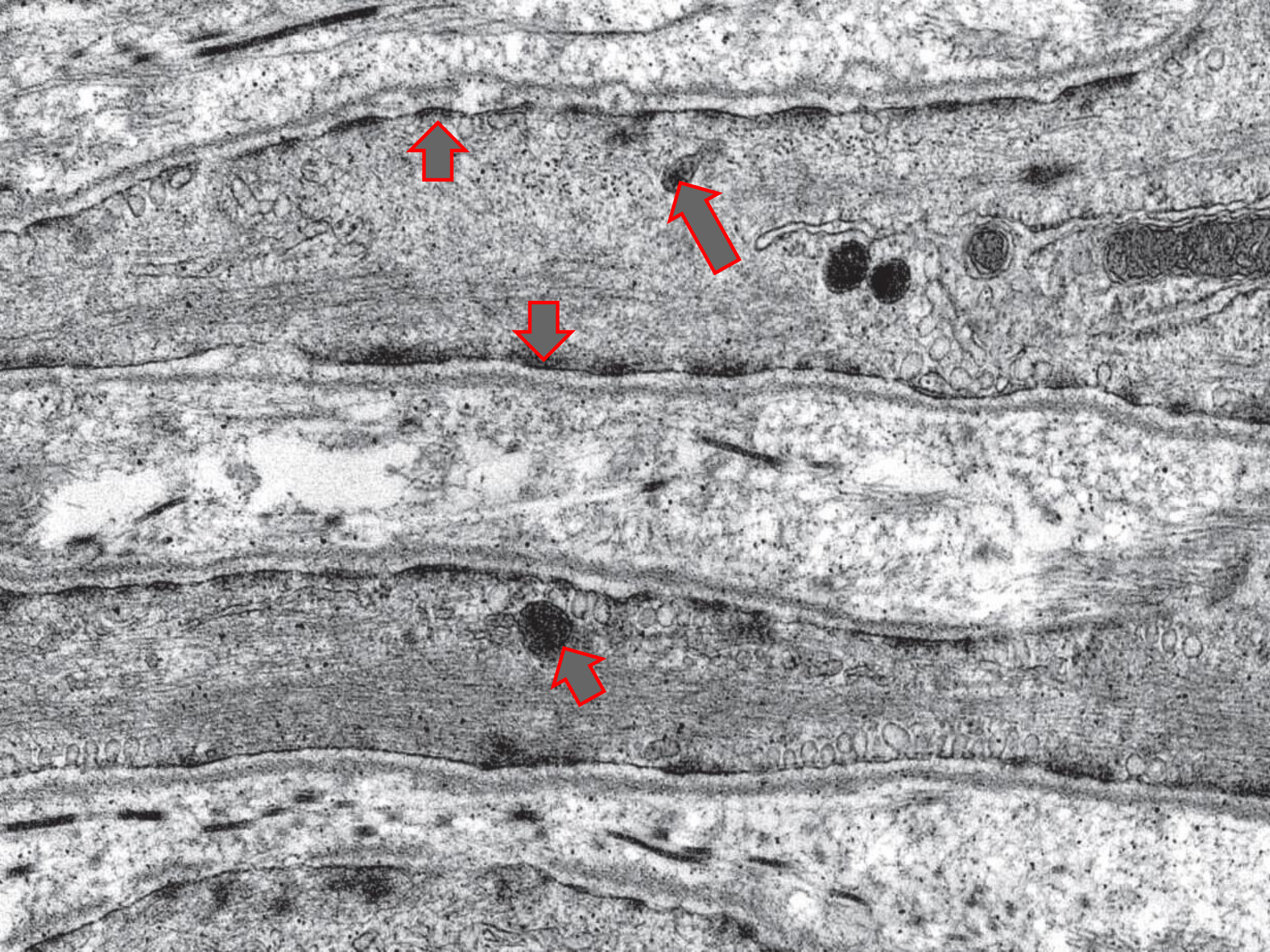
Smooth muscle



Cross section Longitudinal section




Longitudinal section
Cross section



Comparison of the 3 types of muscles

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Sarcomere	Yes	Yes	No
Nuclei	Multinucleated, peripherally located	1 or 2 centrally located	One, centrally located
Sarcoplasmic Reticulum	Well developed with terminal cisterna	Less developed, some small terminals	Rudimentary sER (not involved in calcium storage)
T Tubule	Yes: involved in triad formation	Yes: involved in diad formation	No
Cell Junctions	No	Intercalated disks	Nexus (gap junctions)
Contraction	Voluntary “all or none”	Involuntary: rhythmic and spontaneous	Involuntary: slow, often spontaneous, wavelike and rhythmic
Calcium Binding	Troponin C	Troponin C	Calmodulin
Regeneration	Limited, via satellite cells	No-very poor	Yes, via mitosis
Nerve Fibres	Somatic motor	Autonomic	Autonomic
Connective Tissue	Epimysium; perimysium and endomysium	Connective tissue sheaths and endomysium	Connective tissue sheaths and endomysium
Distinctive Features	Long, cylindrical, many peripheral nuclei	Branched cells, intercalated disks, central nucleus	Fusiform cells, no striations, central nucleus