



MUSCLE TISSUE

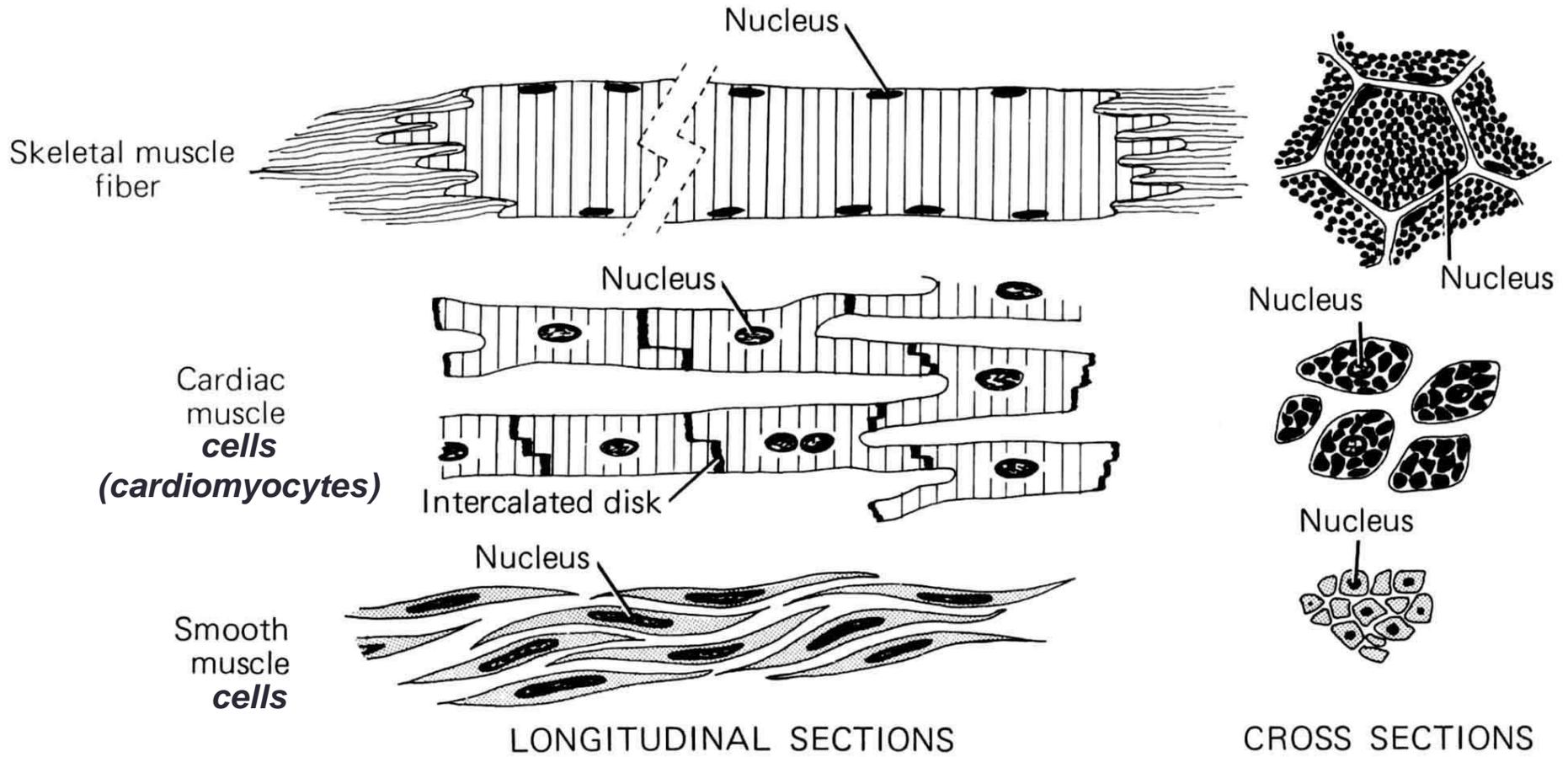
Andrea Felšöová

Muscle tissue

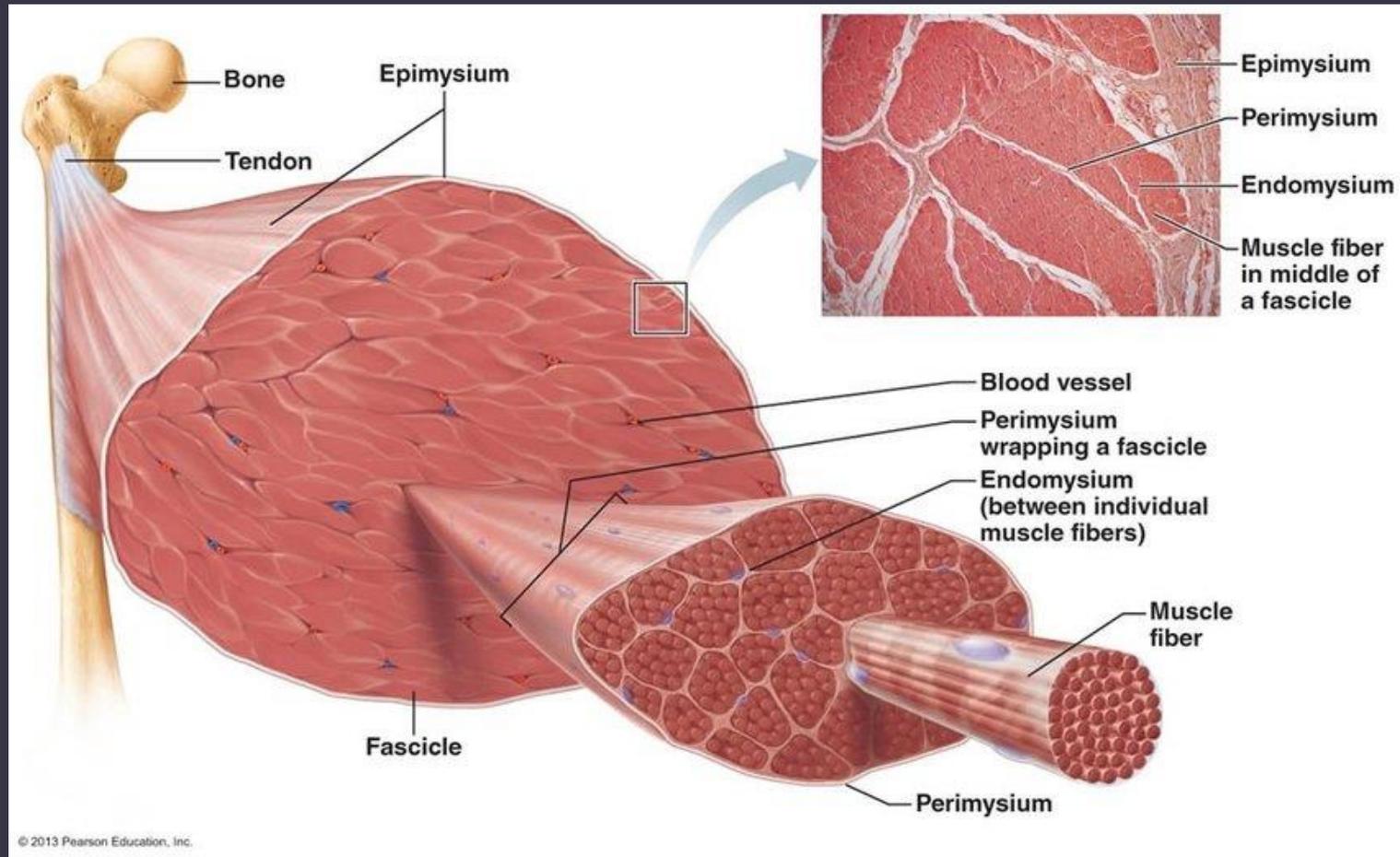
- composed of elongated elements whose basic property is **contractility**
- muscle elements exhibit intercellular contacts
- amount of extracellular matrix is relatively small

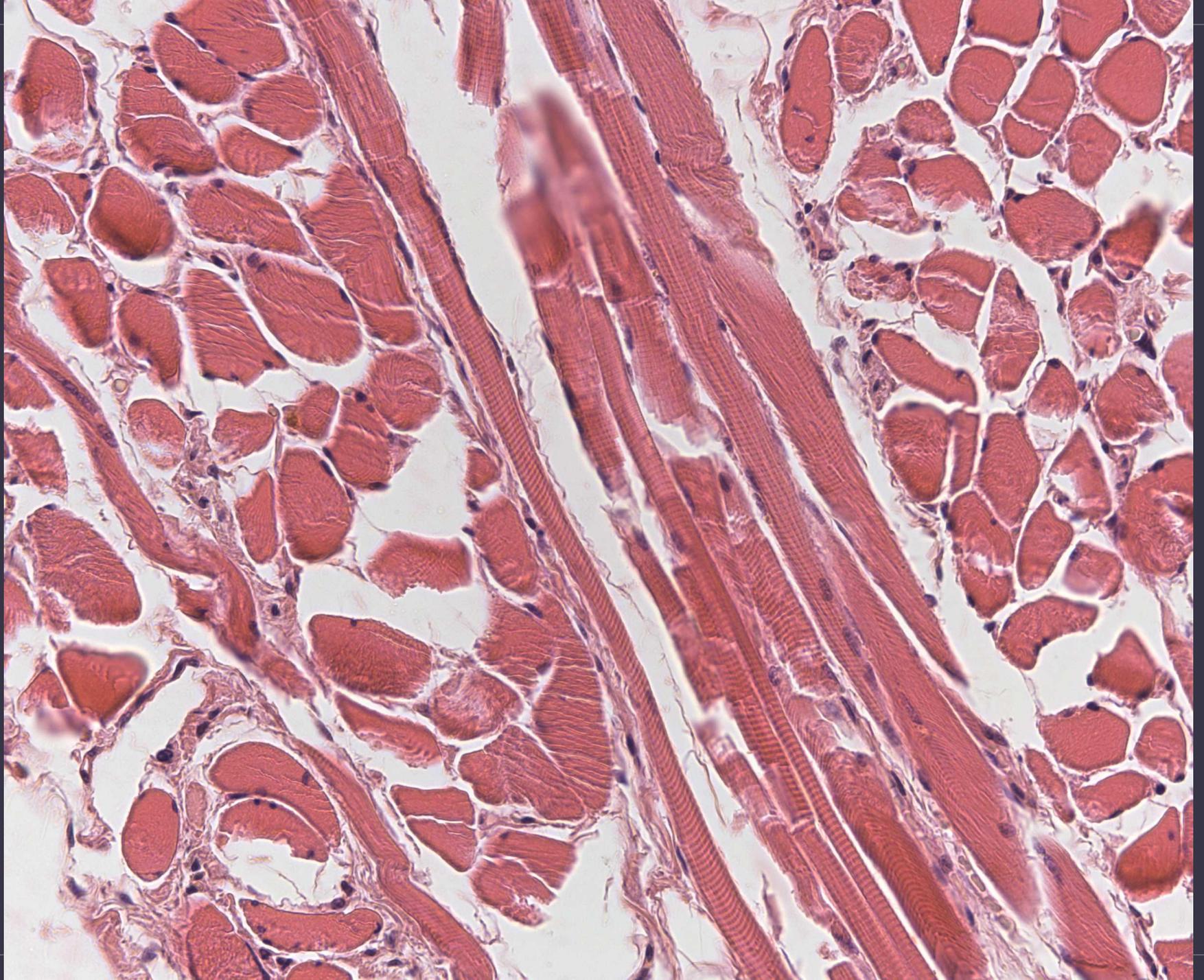
Contraction = interaction of myofilaments

Muscle elements



Striated skeletal muscle





Striated skeletal muscle

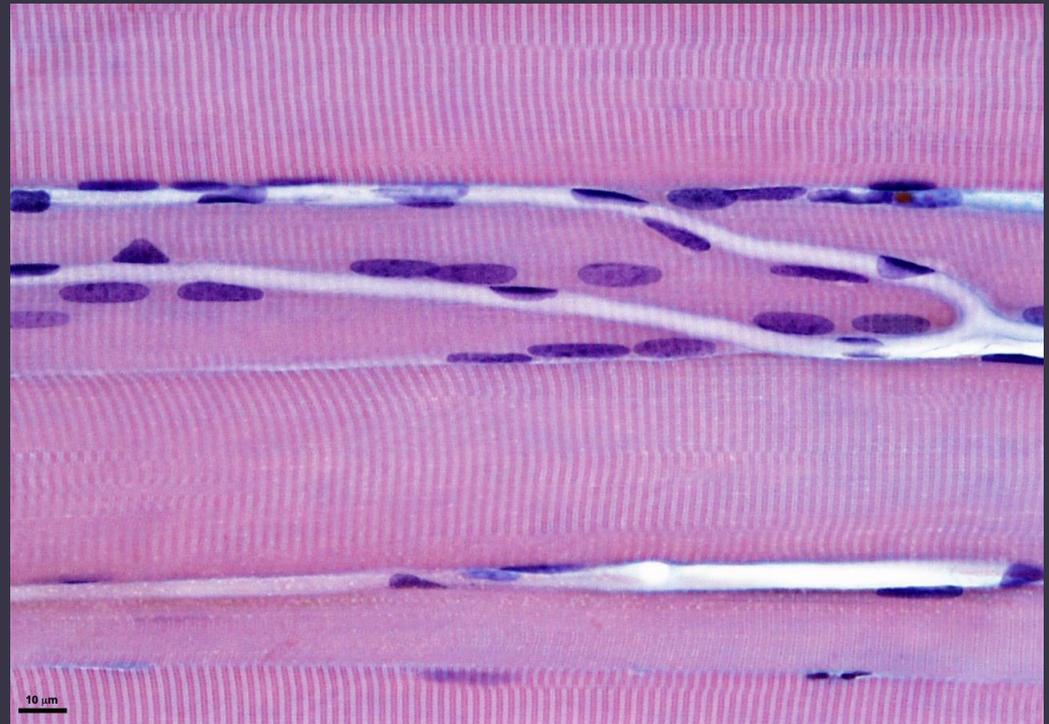
The basic unit is a **muscle fiber** = multinucleated **syncytium**

Various length, diameter 10 to 100 μm

Eosinophilic **sarcoplasm**

Cross-striation in LM

Nuclei are located **beneath**
the sarcolemma

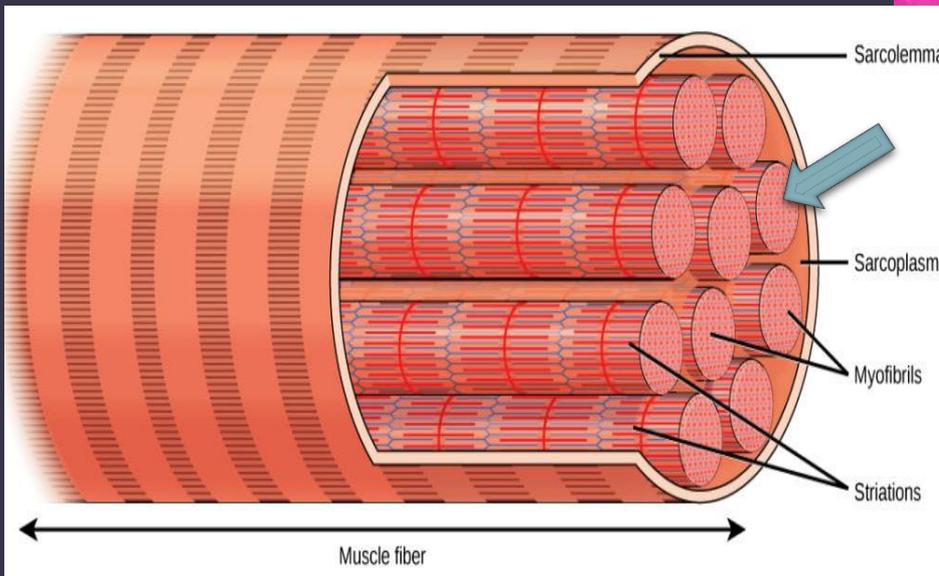


Striated skeletal muscle

Cytoskeletal functional and structural subunit = **myofibril** (\varnothing 1-2 μm)

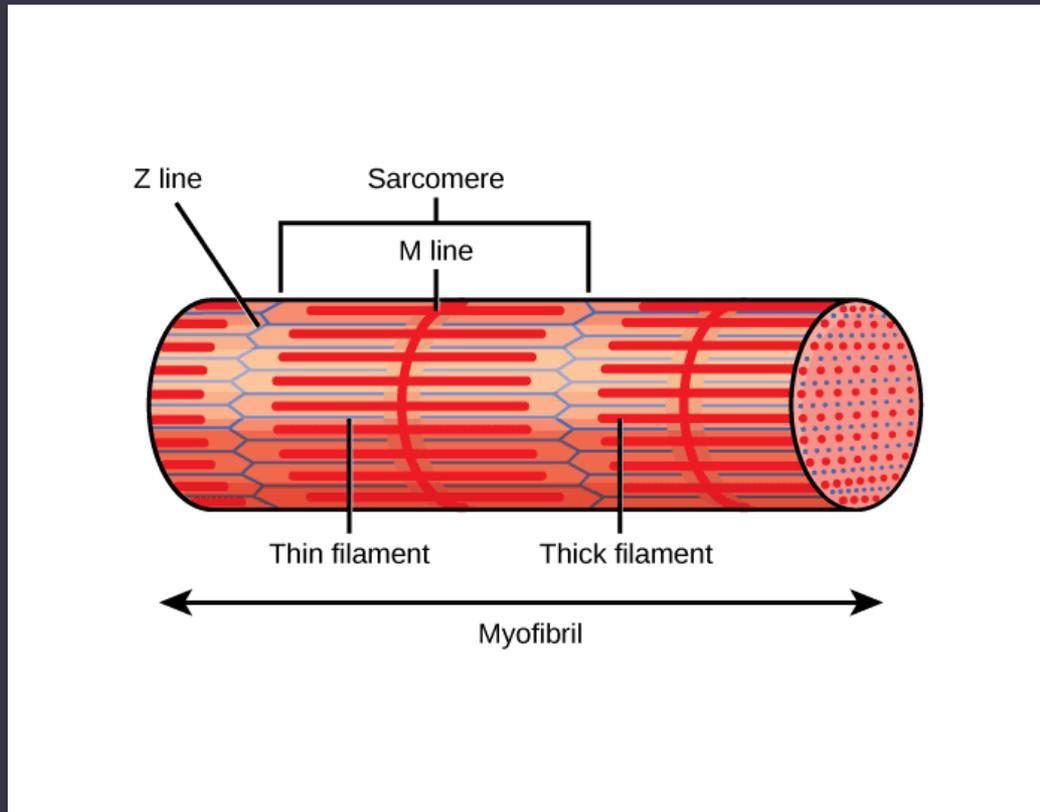
Muscle fiber is filled with longitudinally arrayed **myofibrils**

Each **myofibril** is composed of **myofilaments**



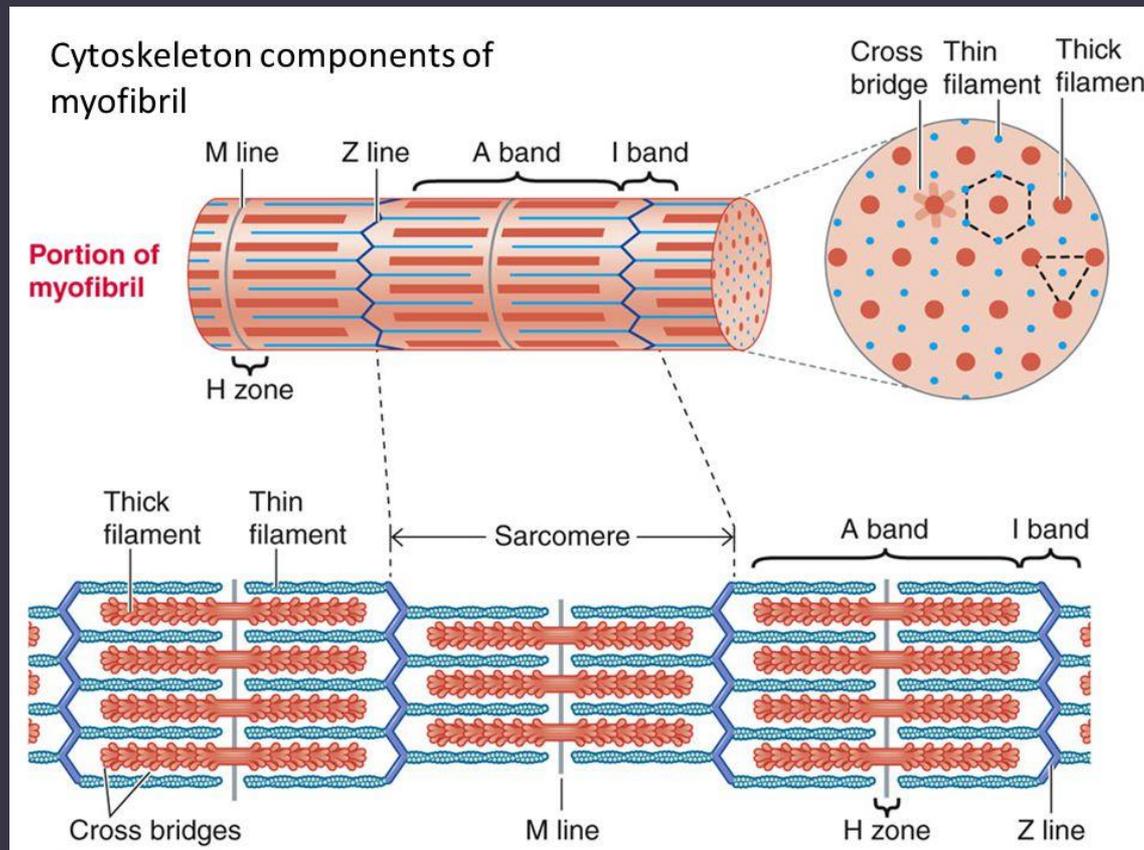
Myofibril and Sarcomere

Sarcomere is the functional unit of **myofibril**



Organization of skeletal muscle

https://www.youtube.com/watch?v=f_tZne9ON7c



M = myofibril

A = A band

I = I band

S = sarcomere

Z = Z line (telofragma)

H = H band

N = nuclei of muscle fibres

CT = connective tissue cell



A

I

S

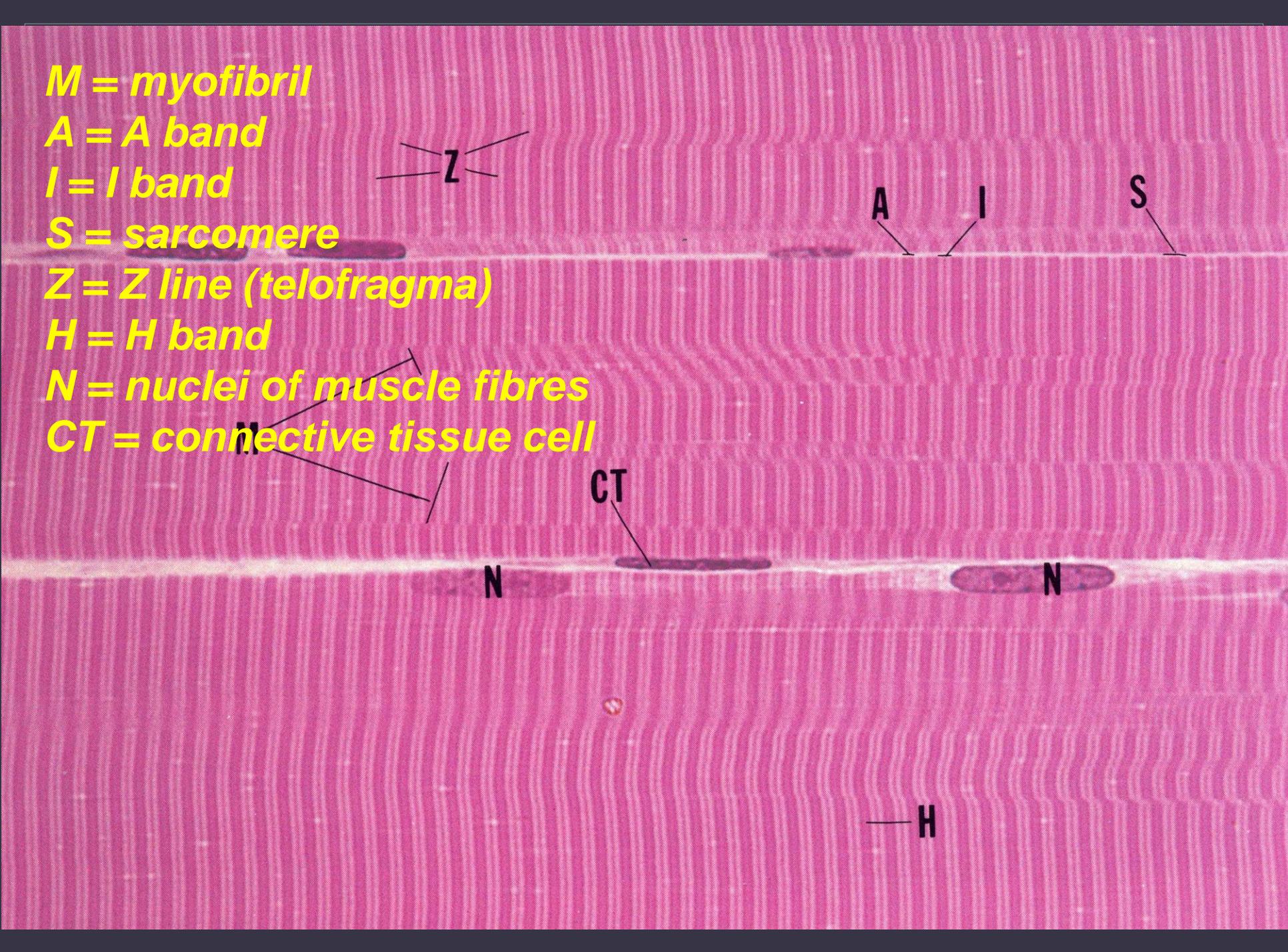
M

CT

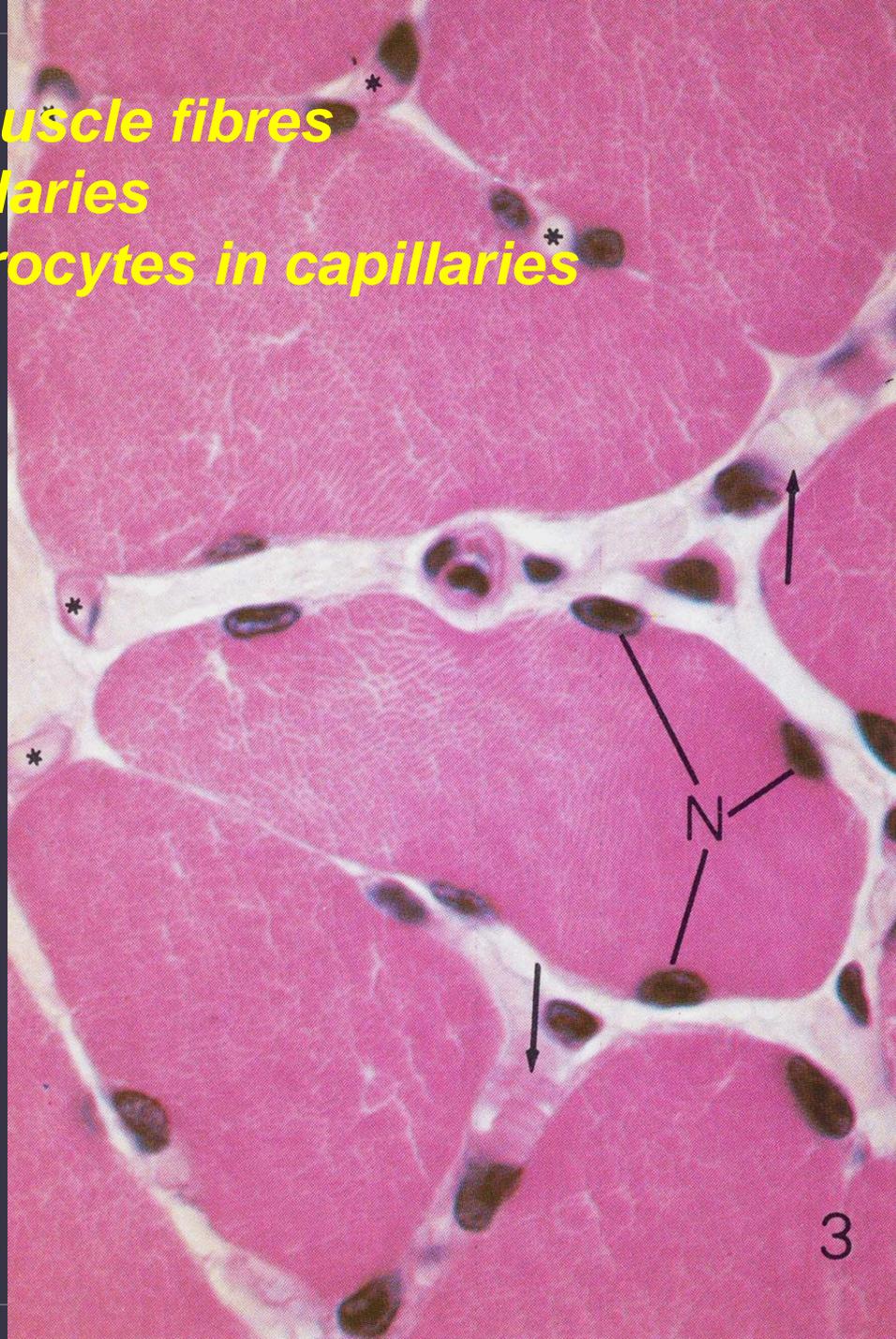
N

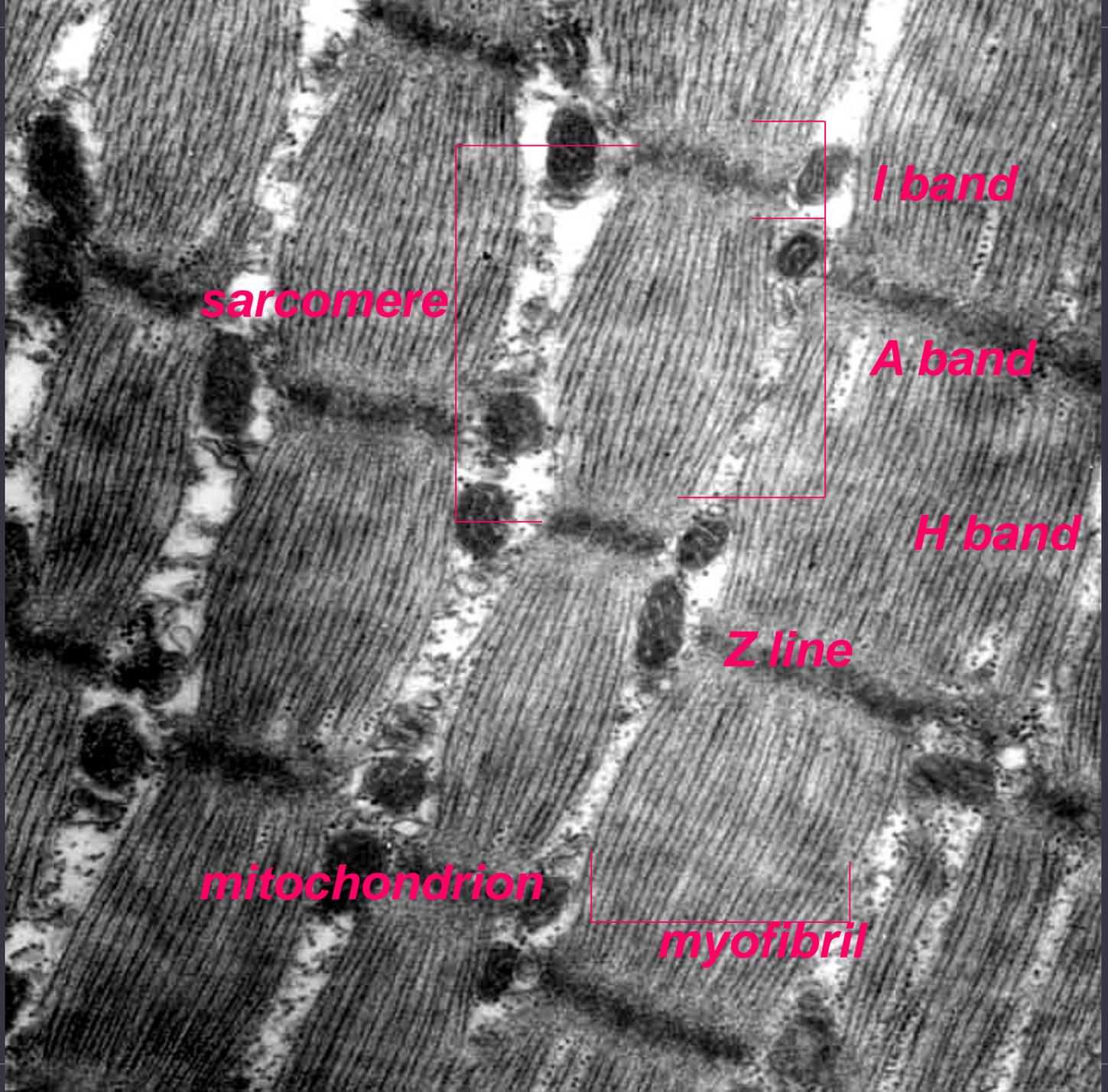
N

H



N = nuclei of muscle fibres
**** = empty capillaries***
arrows = erythrocytes in capillaries





sarcomere

I band

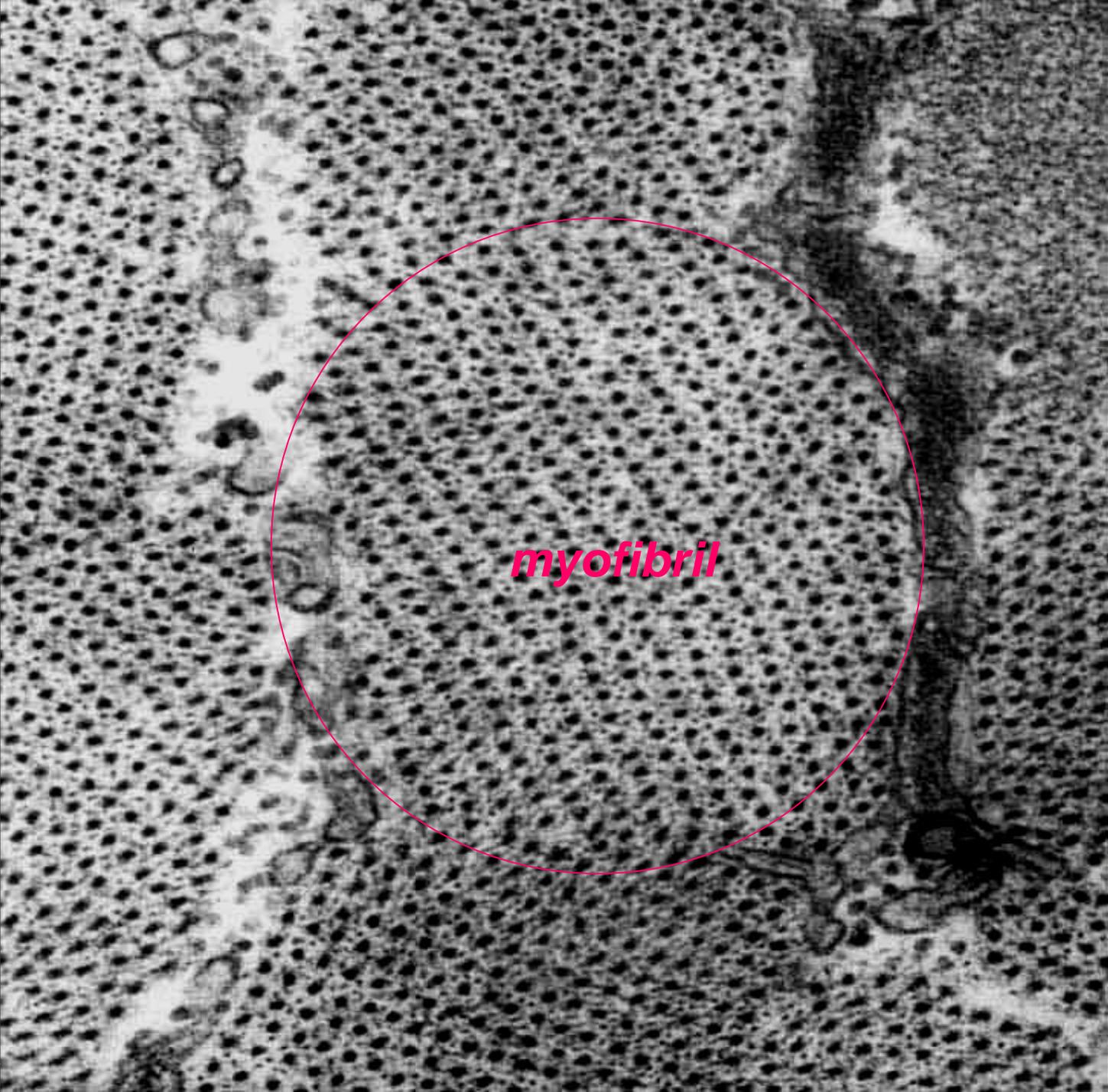
A band

H band

Z line

mitochondrion

myofibril



myofibril

Other components of muscle fiber

Numerous mitochondria - ATP

Prominent **sarcoplasmic reticulum** – repeating series of network around myofibrils = transverse tubular system

T tubule

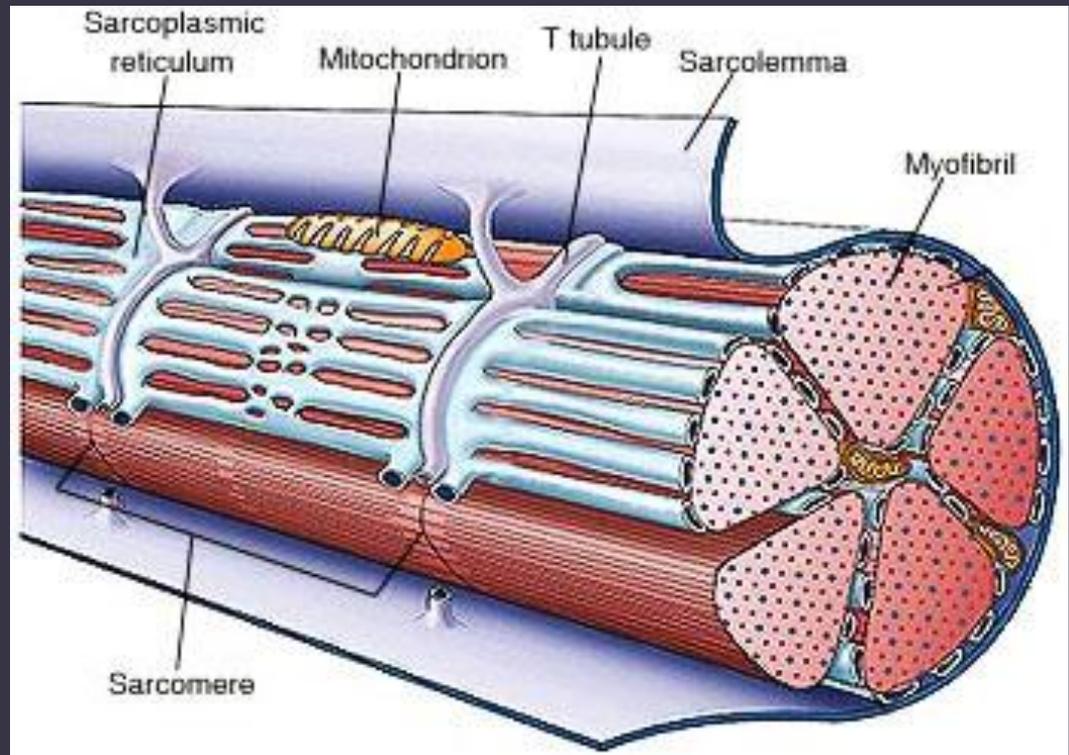
Terminal cisternae
(triad)

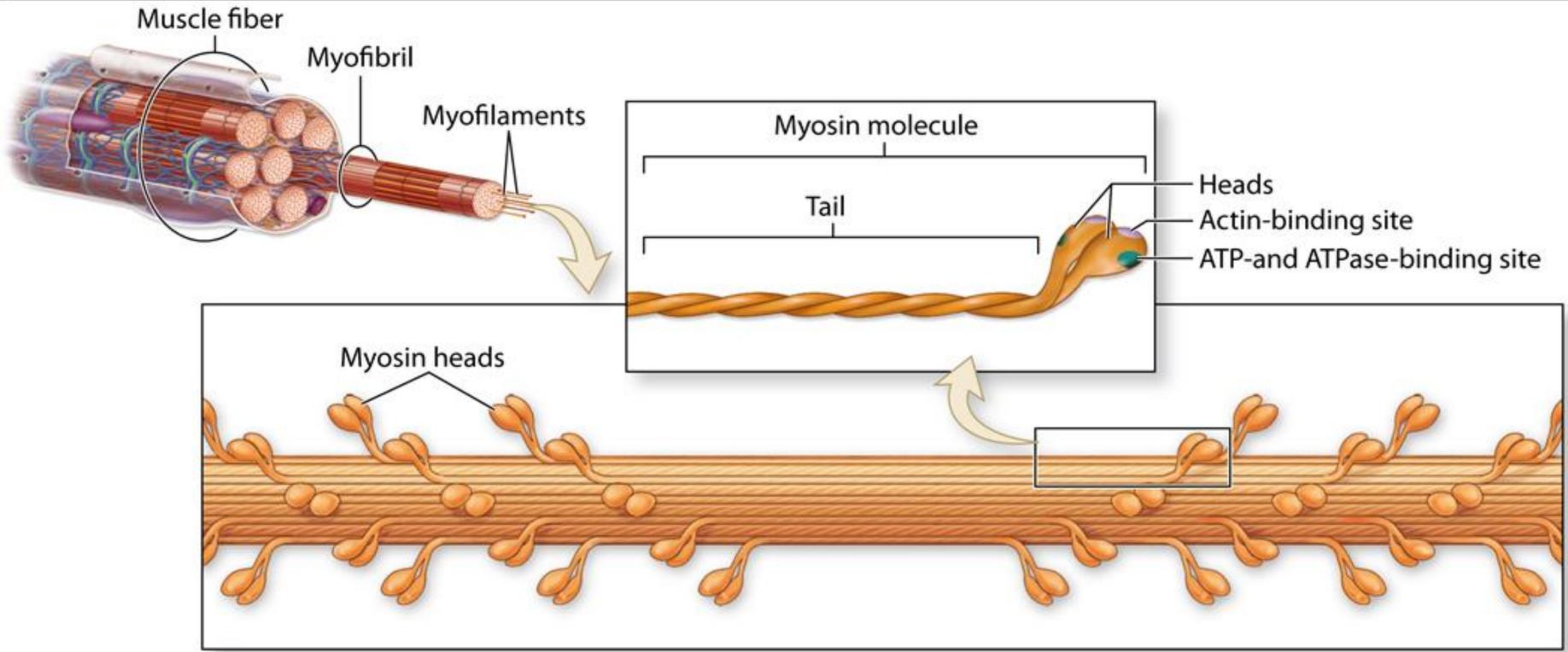
Myoglobin

– oxygen binding protein

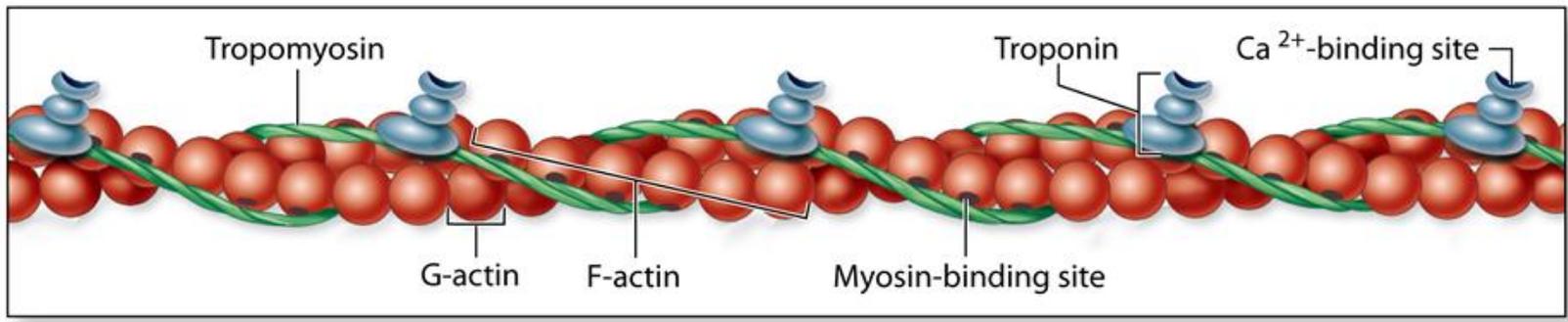
Glycogen inclusions

- anaerobic glycolysis



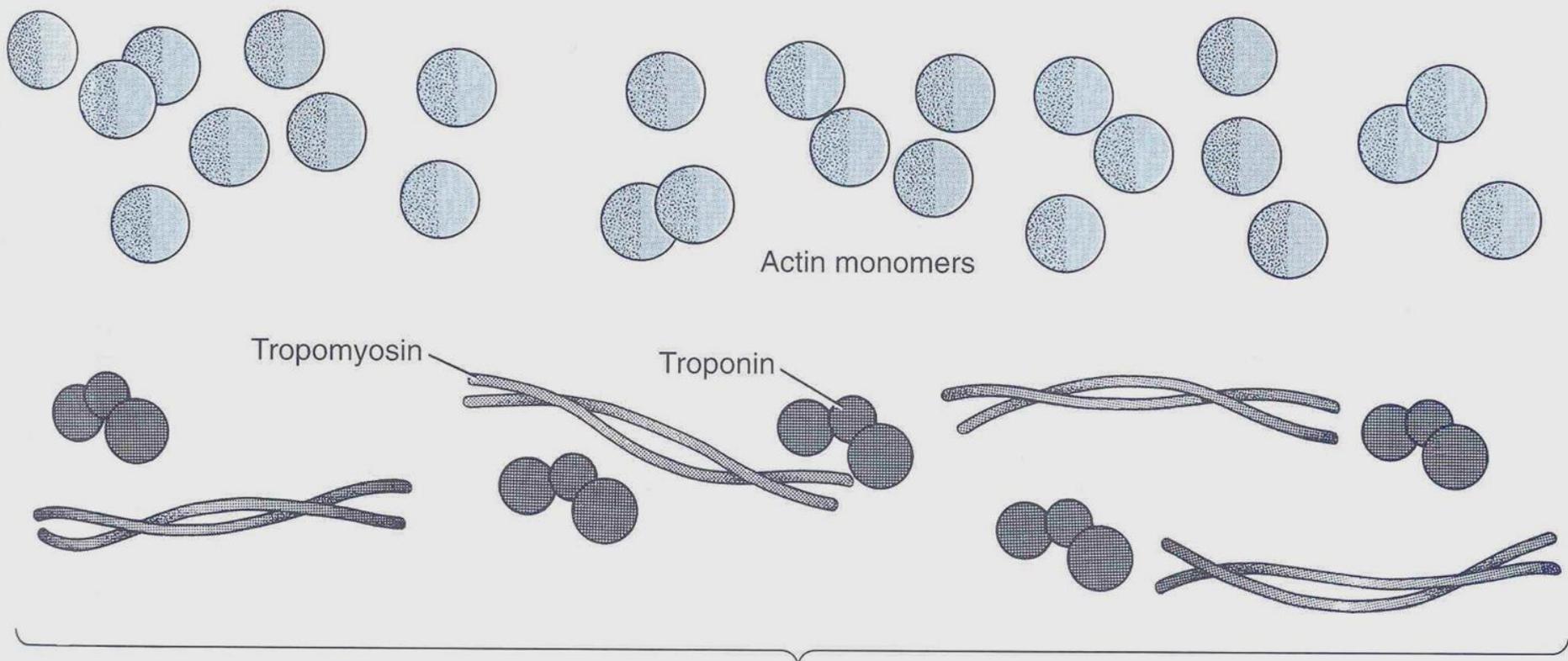


a Thick filament

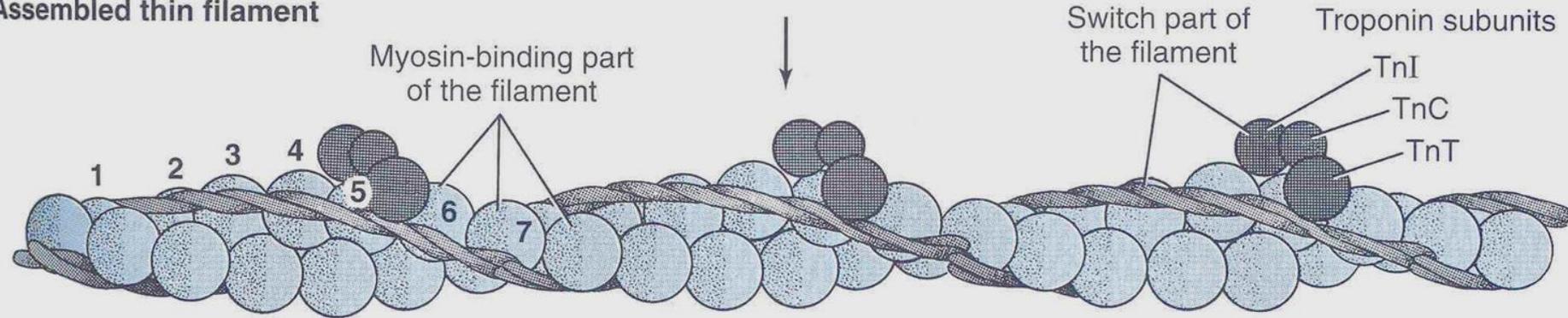


b Thin filament

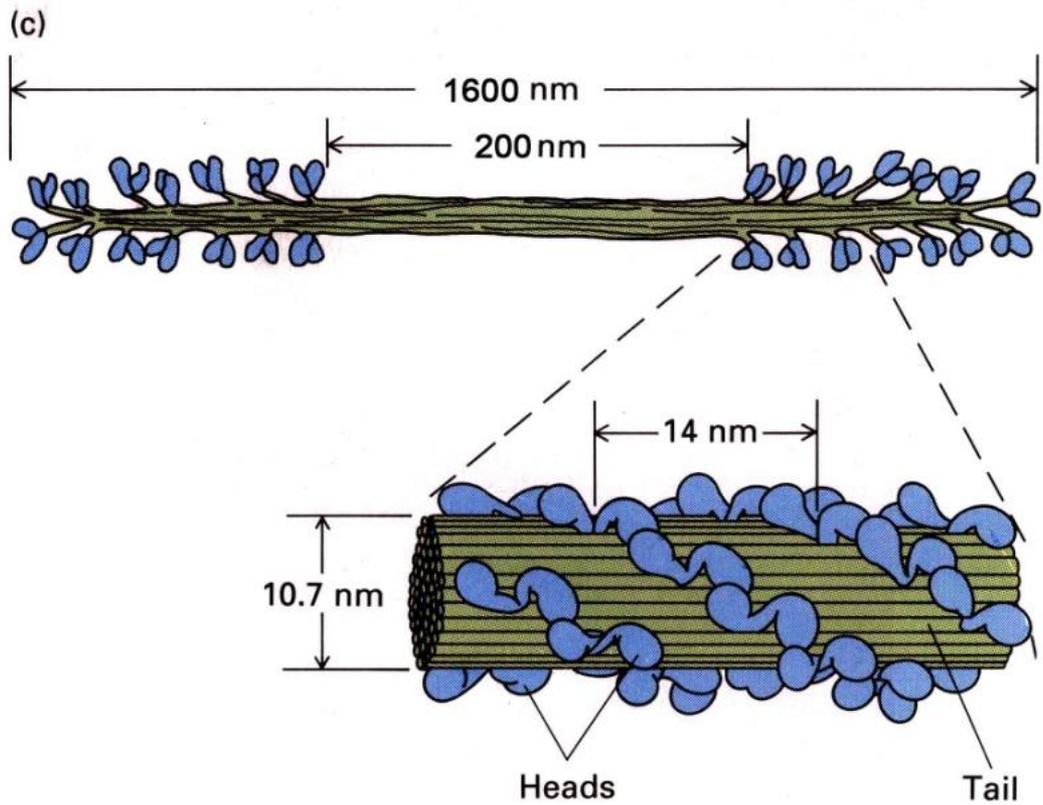
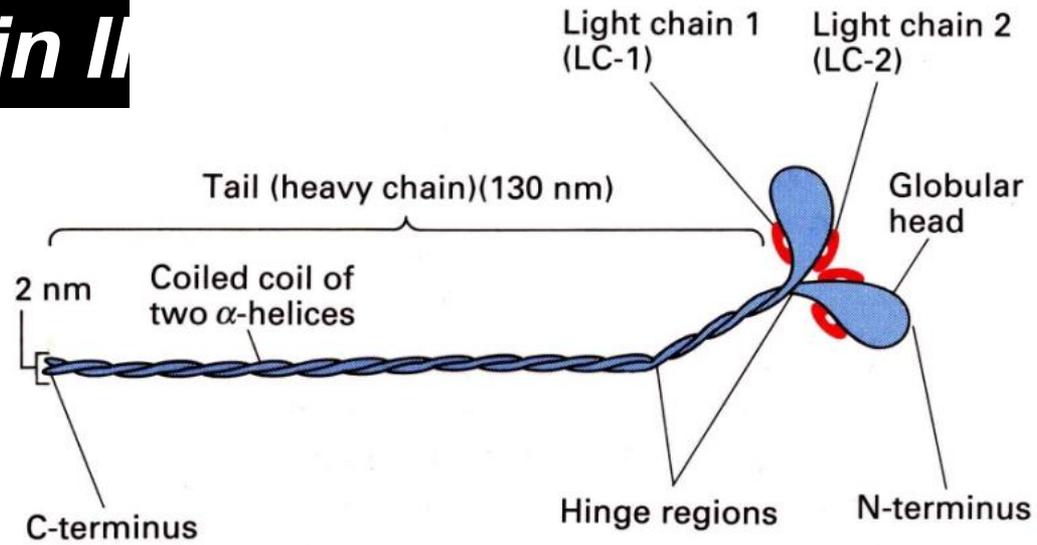
Disassembled components of the thin filament

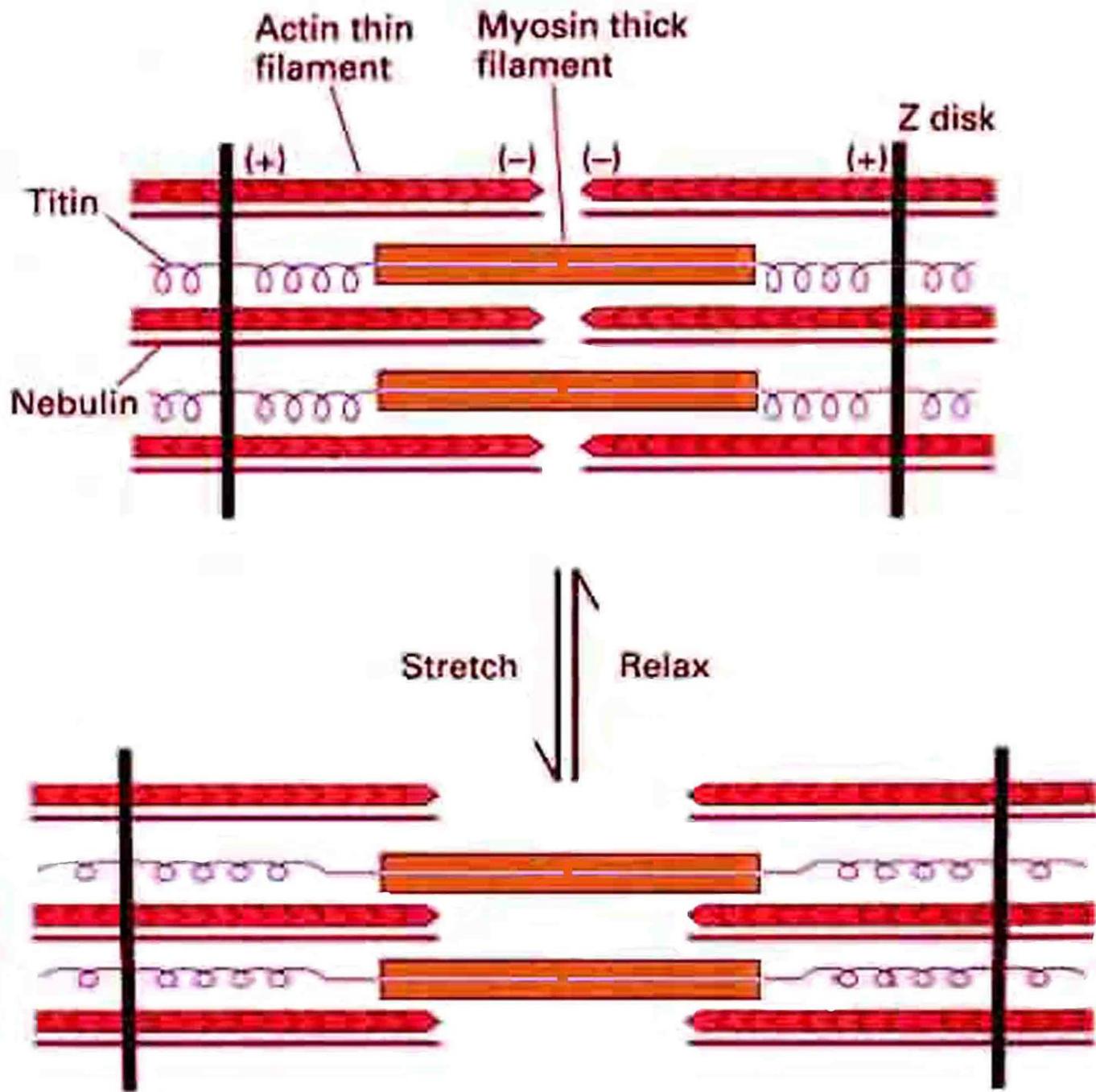


Assembled thin filament

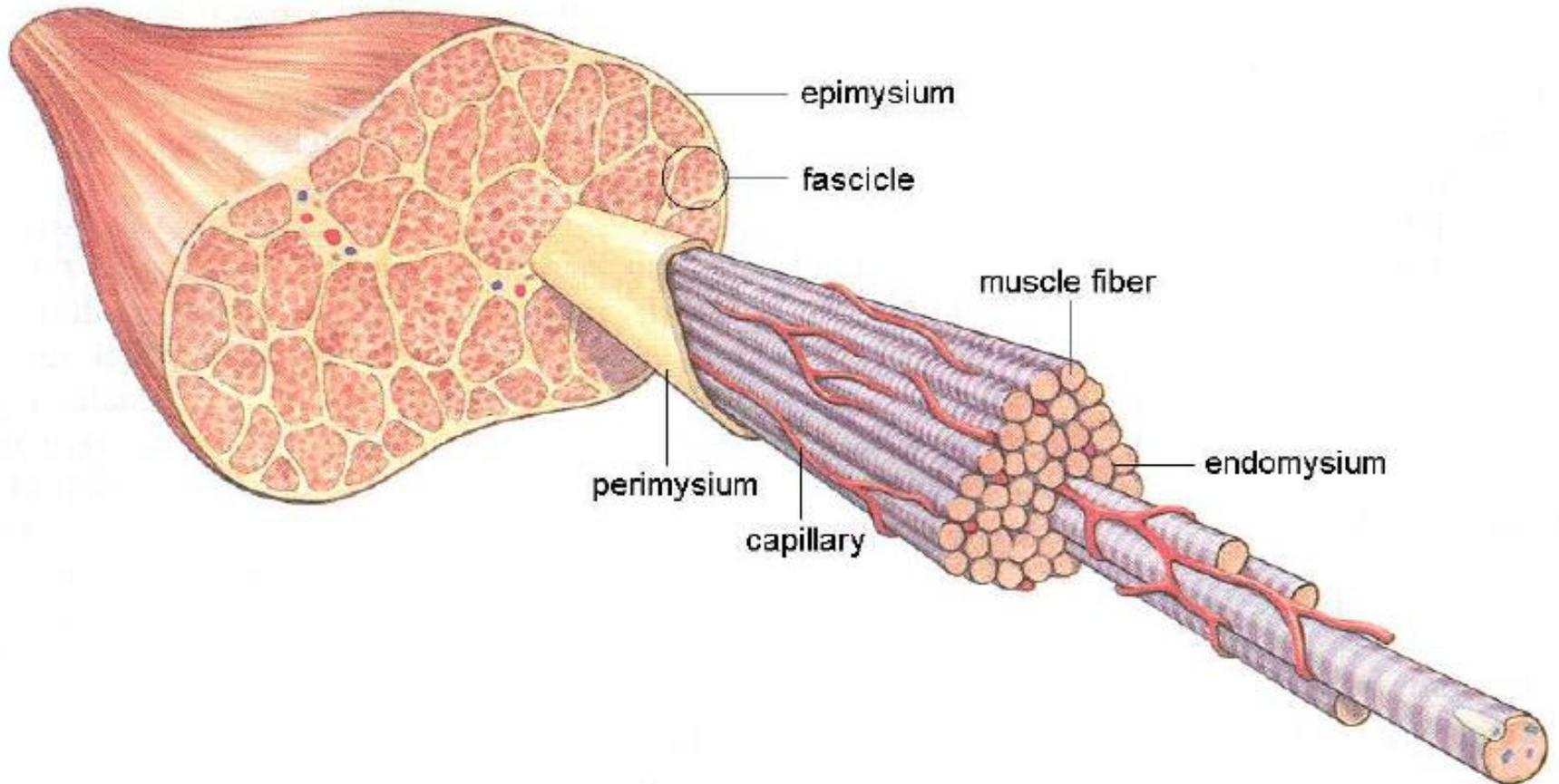


Myosin II





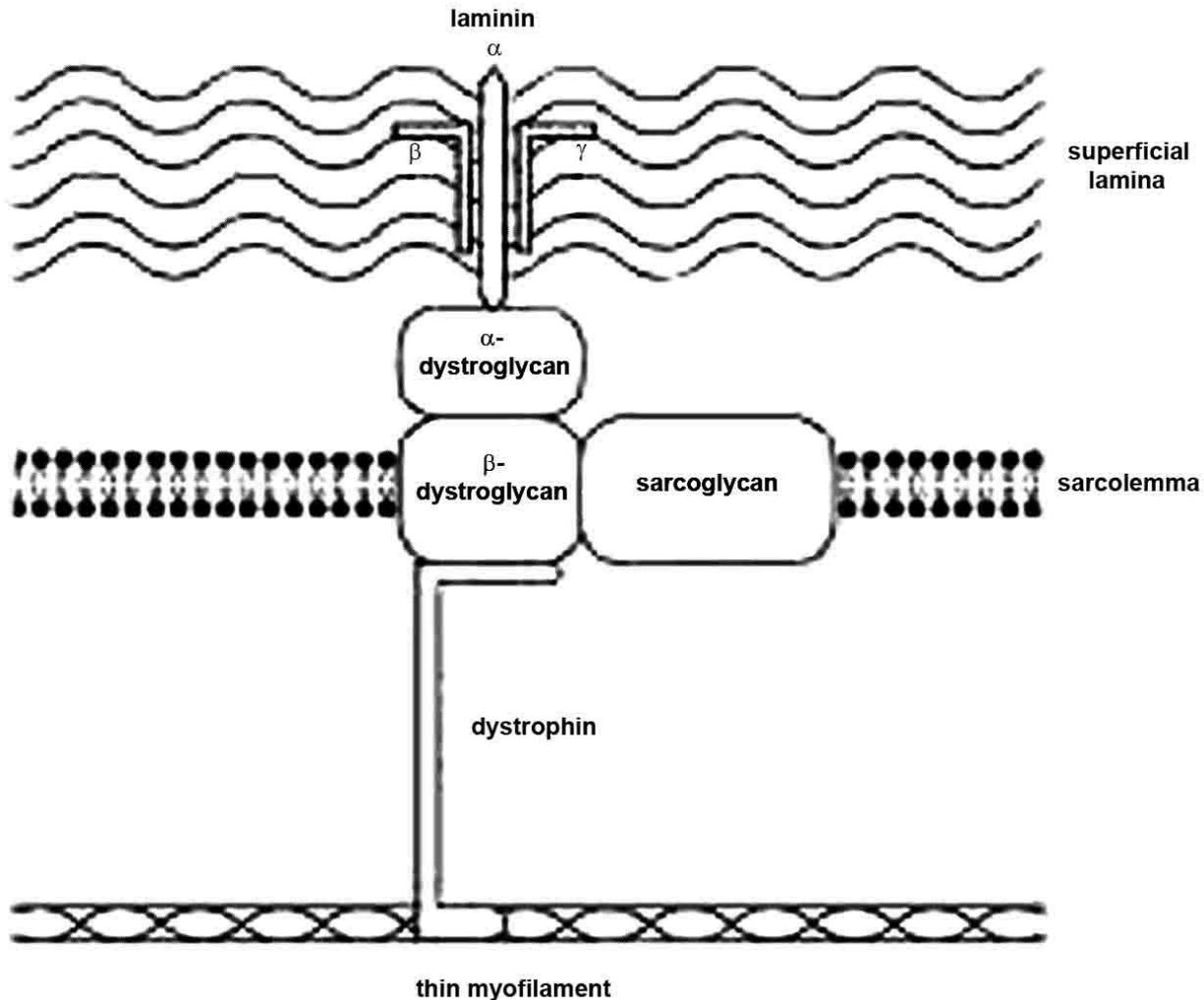
Muscle sheets



contraction of myofibrils must be transmitted to sarcolemma and endomysium
peripheral myofibrils are attached to sarcolemma at Z-line

ZJEDNODUŠENÉ SCHEMA KOSTAMERY („ŽEBROVÍ“)

SIMPLIFIED SCHEME OF A COSTAMERE



costamere
(„ribbing“)

dystrophin
dystroglycan
sarcoglycan
synemin
syncoilin
dystrobrevin
sarcospan

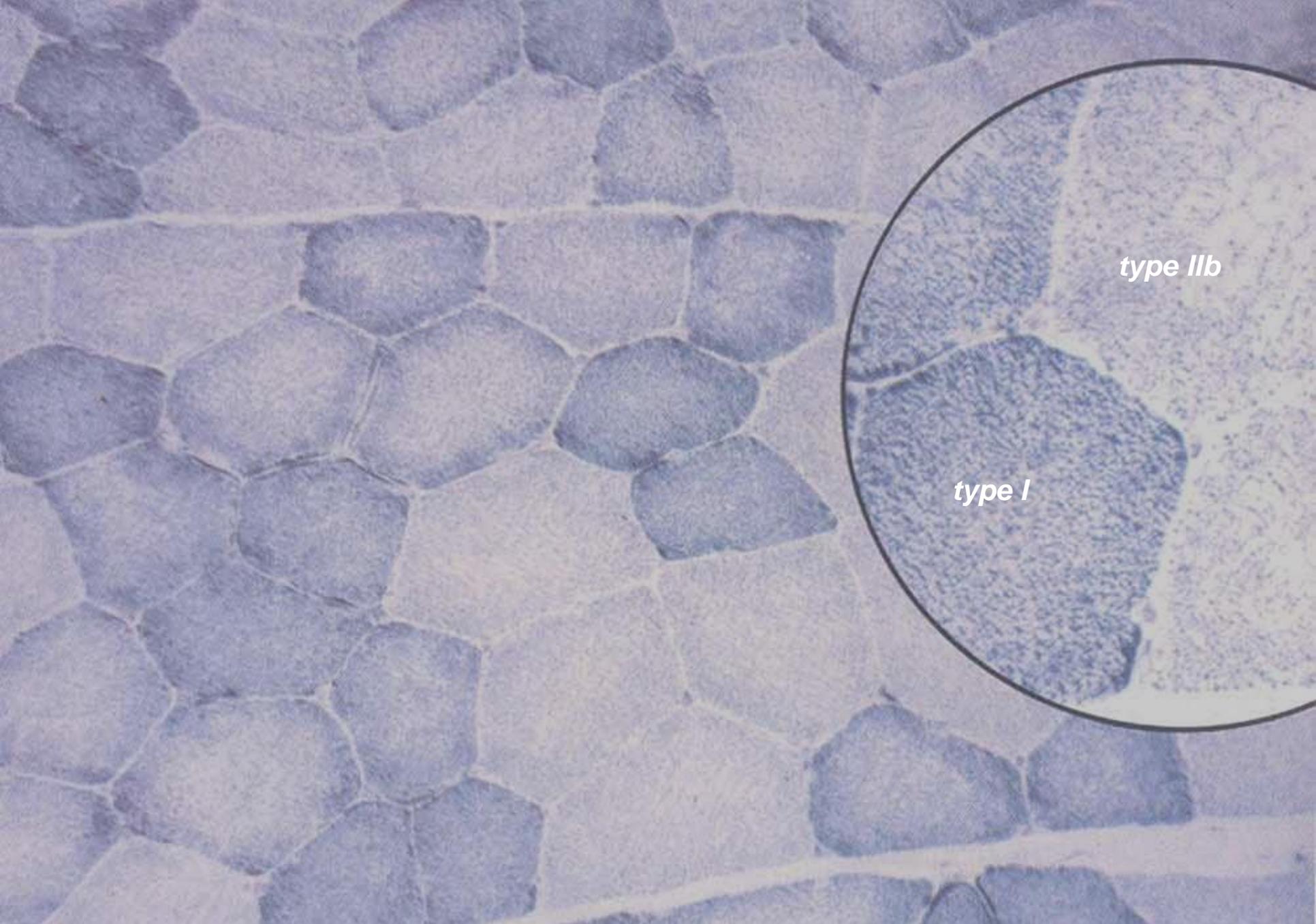
Types of skeletal muscle fibers

Type I fibers = slow oxidative fibers

Type IIa = fast oxidative glycolytic

Type IIb = fast glycolytic



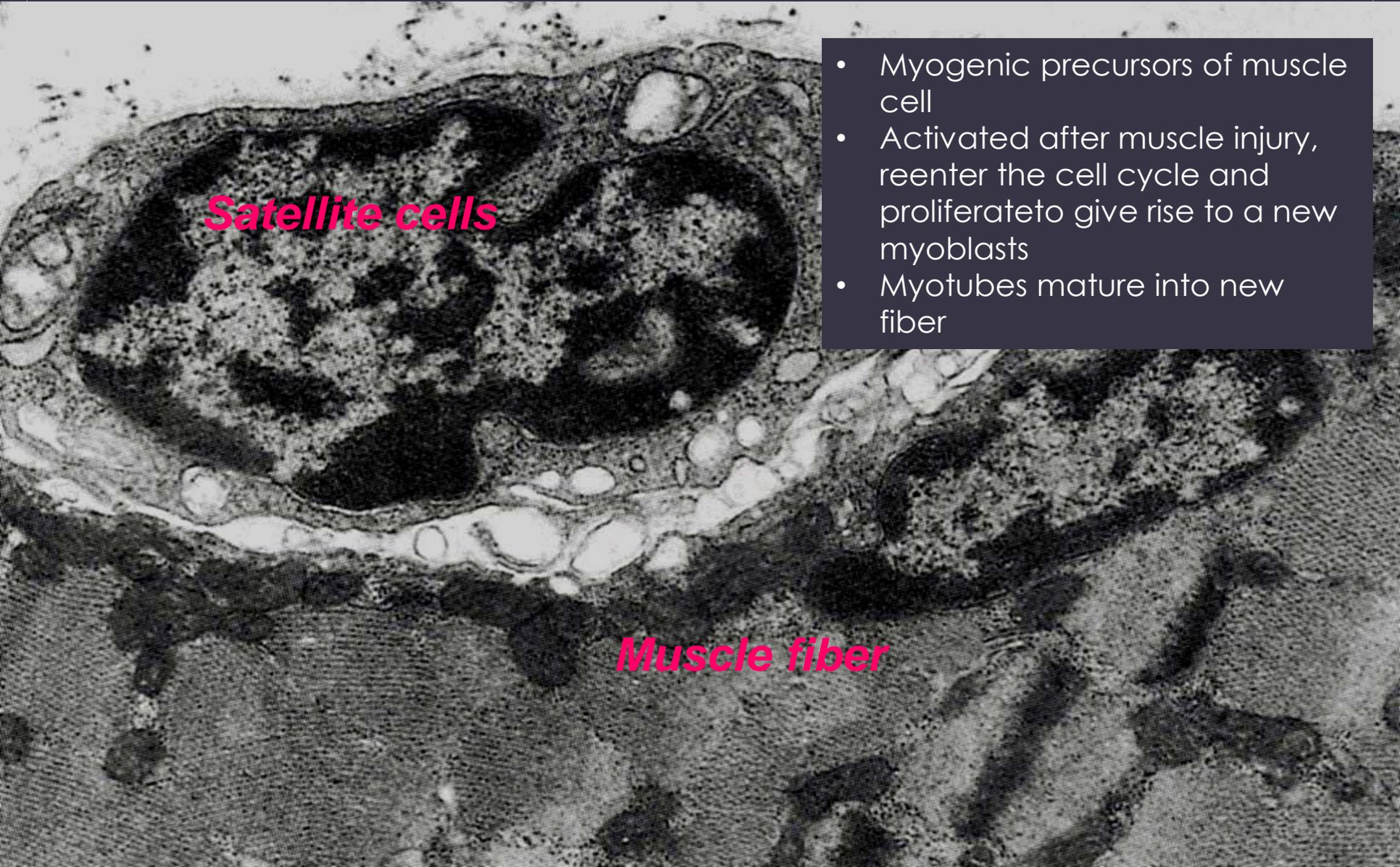


type IIb

type I

Histochemical reaction based on oxidative enzyme activity – succinic dehydrogenase

Regeneration



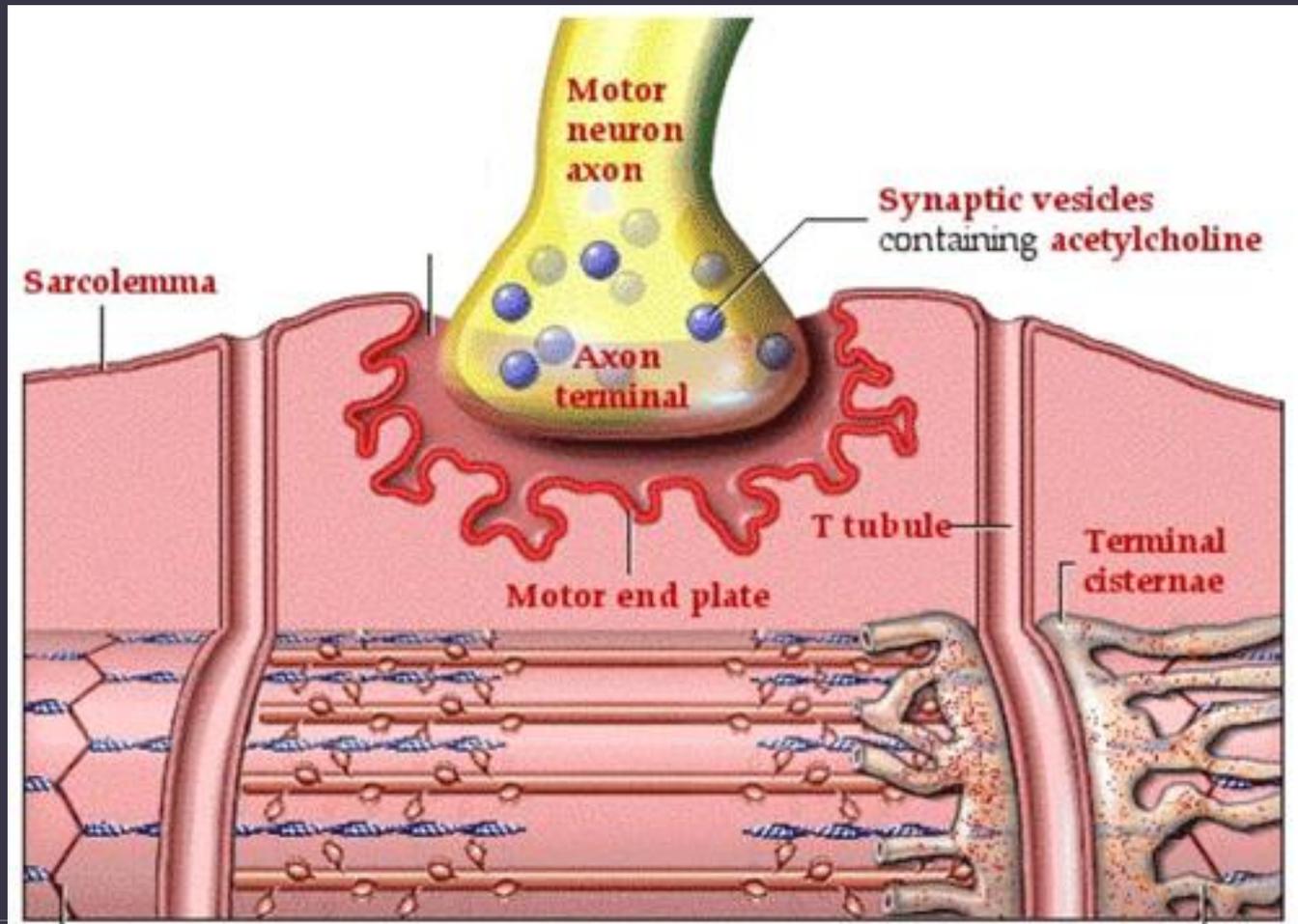
Satellite cells

- Myogenic precursors of muscle cell
- Activated after muscle injury, reenter the cell cycle and proliferate to give rise to a new myoblasts
- Myotubes mature into new fiber

Muscle fiber

Neuromuscular junction and contraction

<https://www.youtube.com/watch?v=sZuy356qkPM>



Cardiac muscle

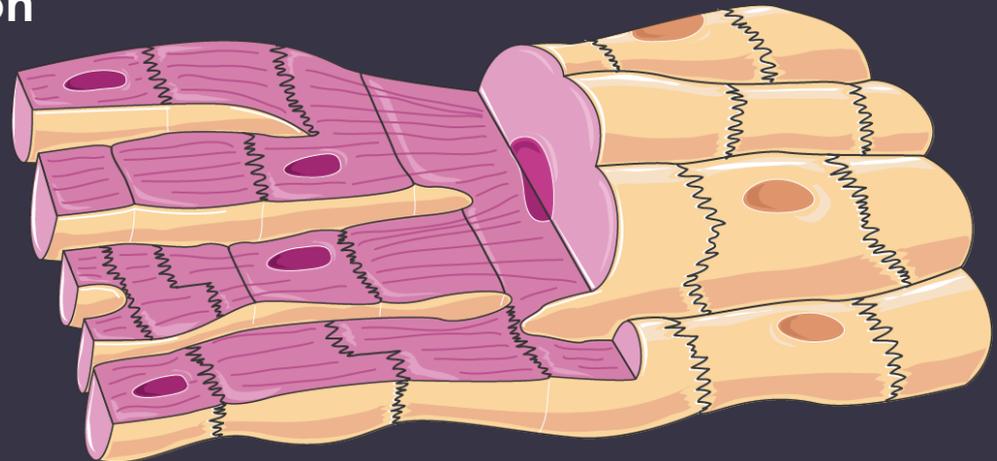
Cardiomyocytes – cylindrical cells arranged end to end

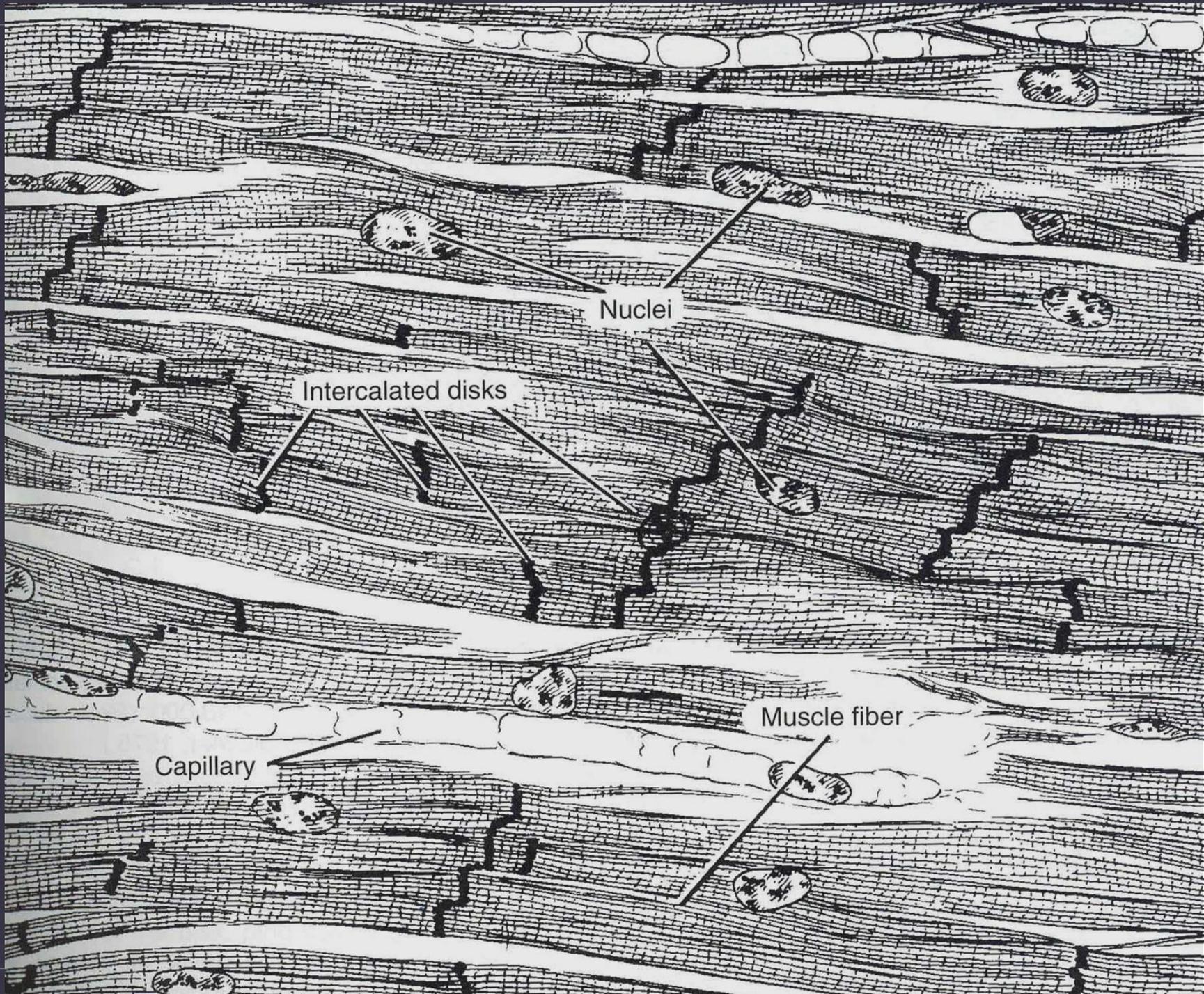
Intercalated discs = specialized attachment sites between adjacent cells

Nucleus lies in the center of cell

Large **mitochondria** and **glycogen** stores

Spontaneous **rythmic contraction**



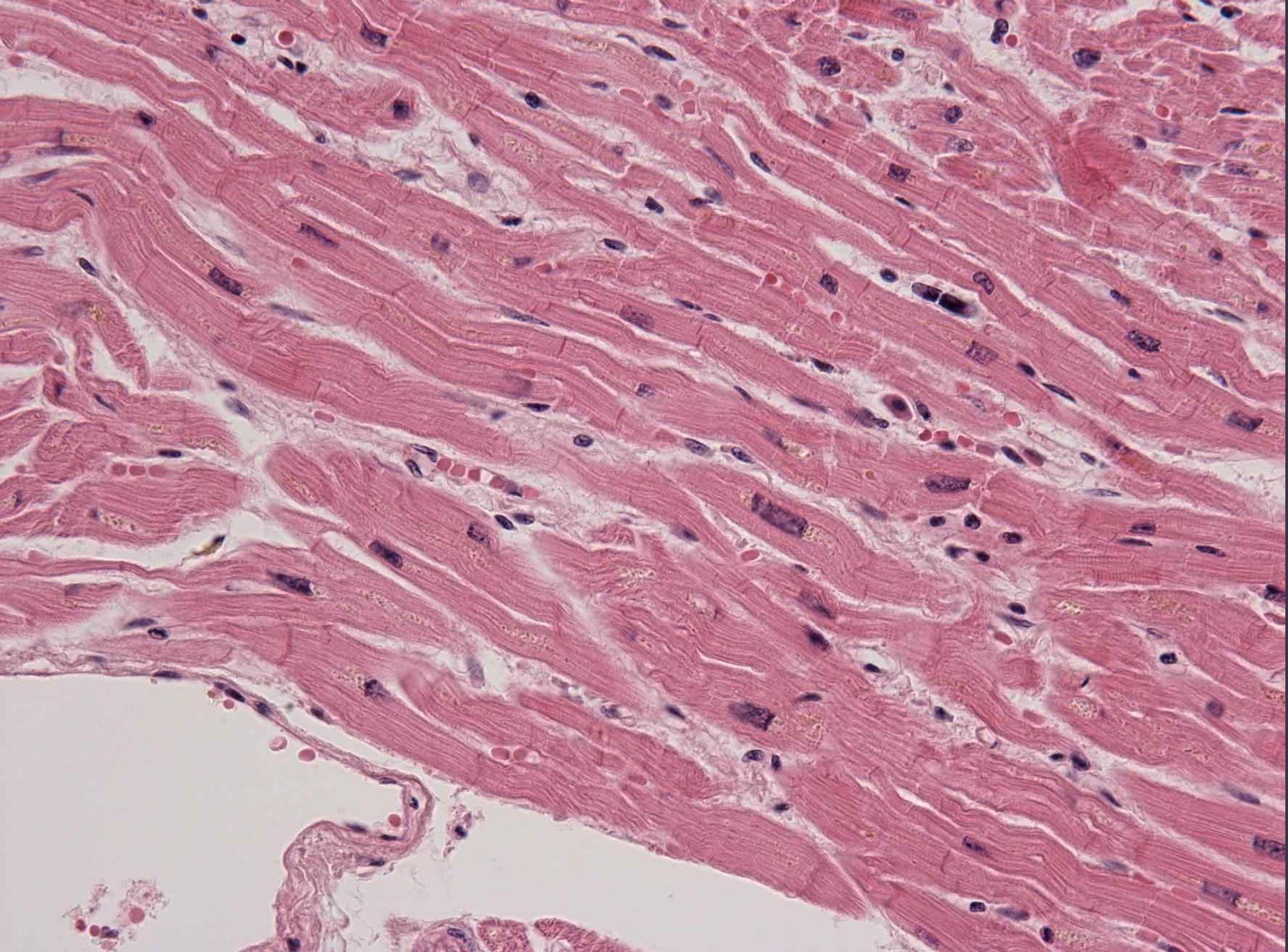


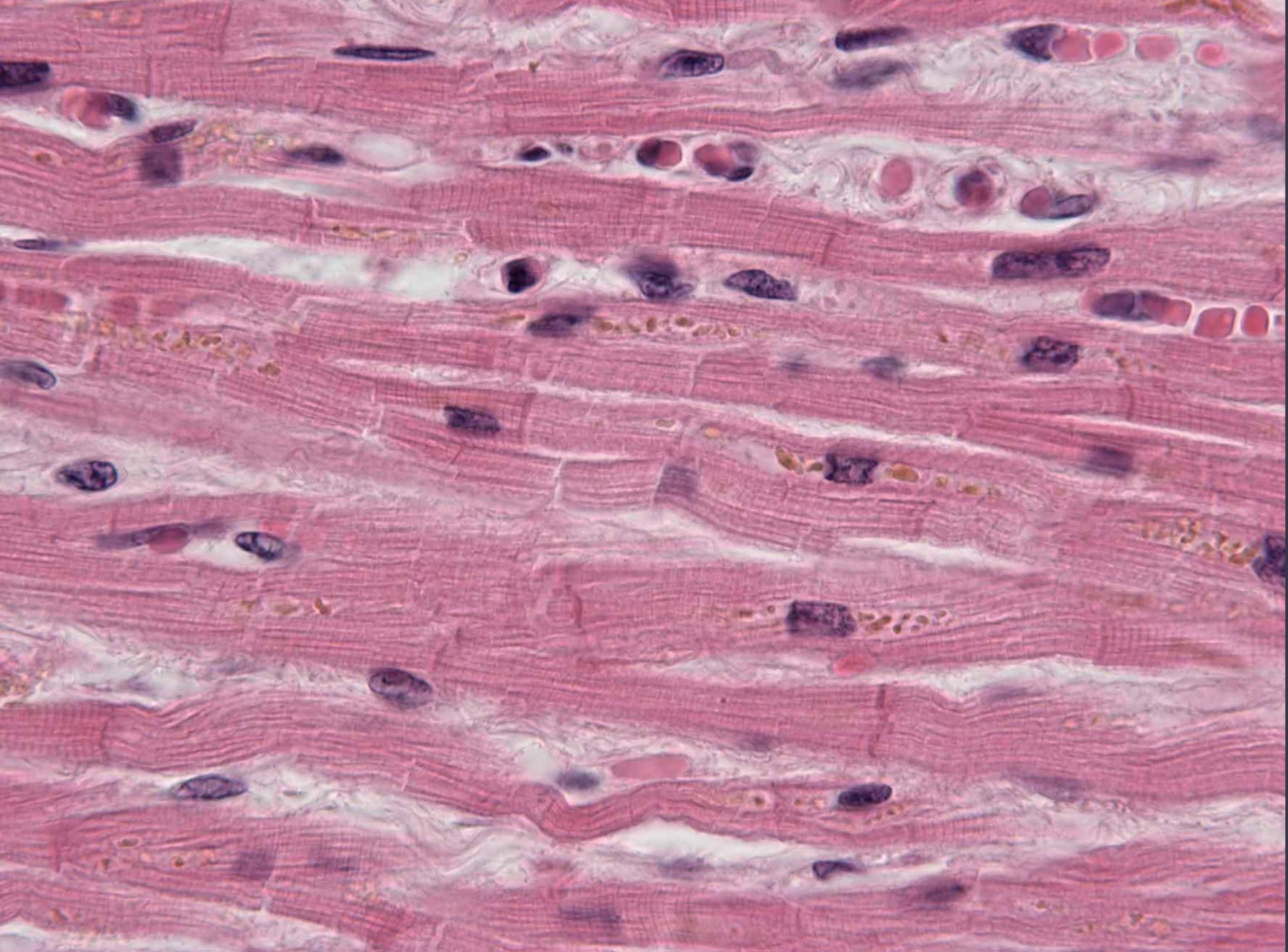
Nuclei

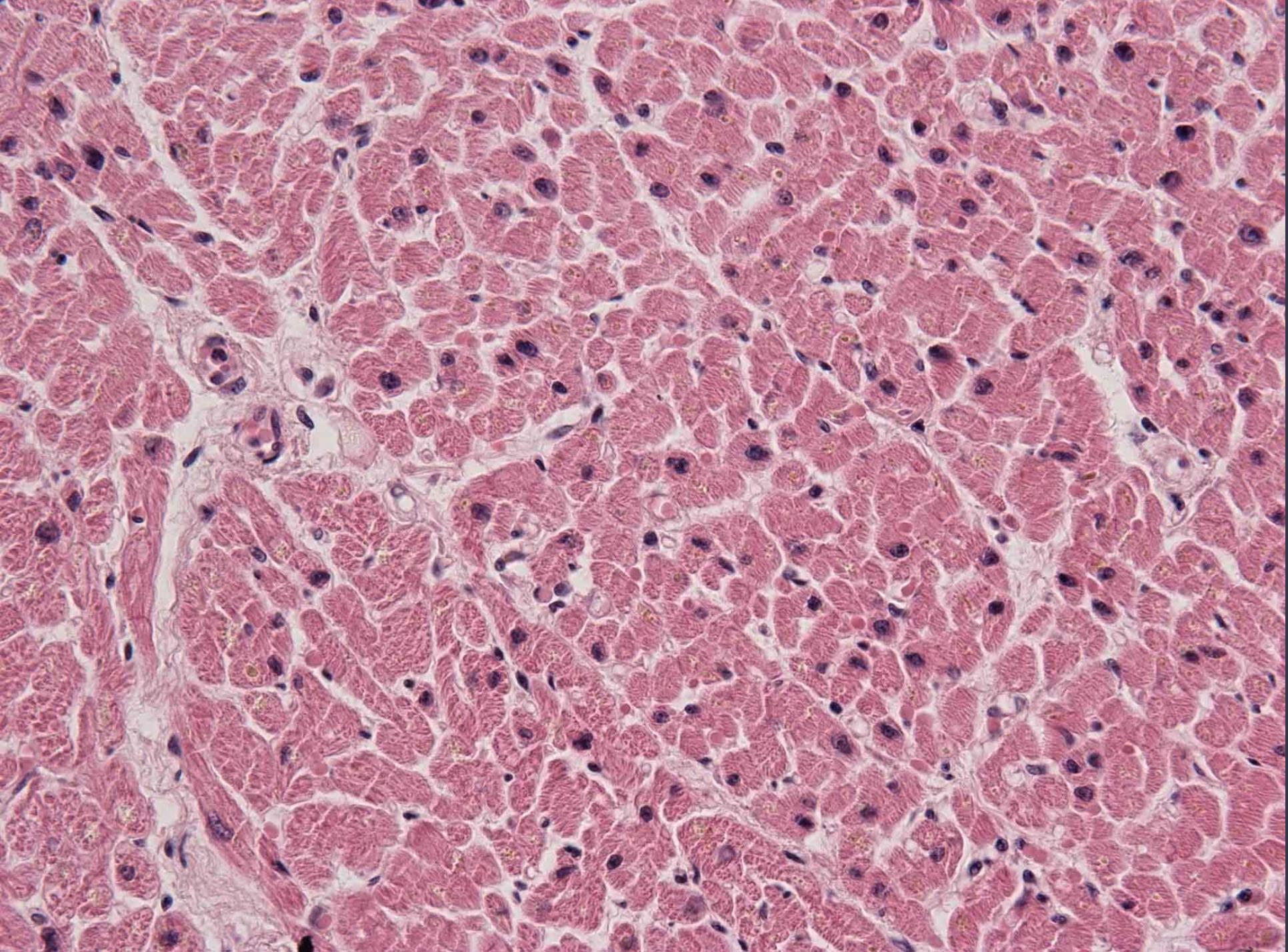
Intercalated disks

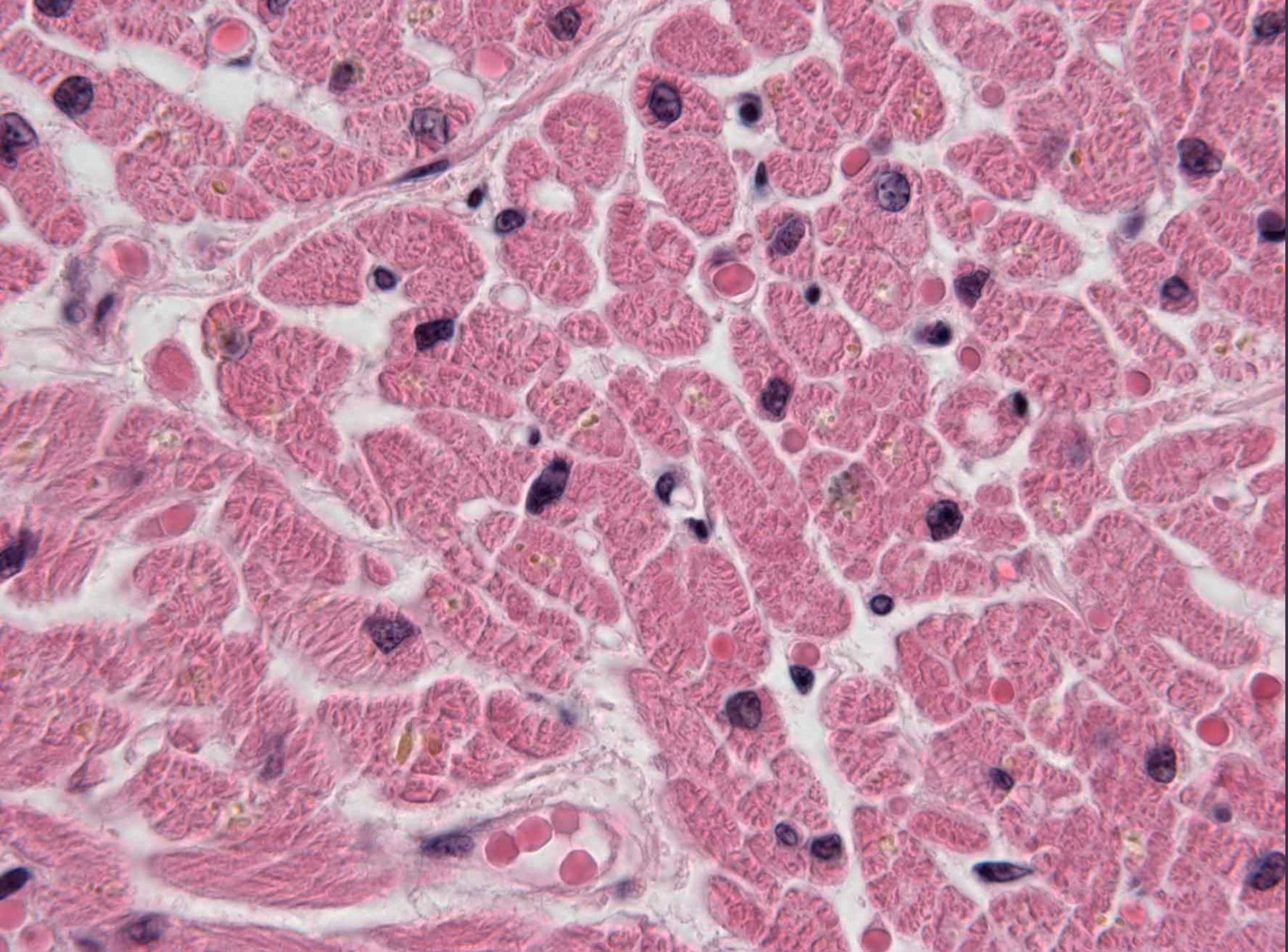
Capillary

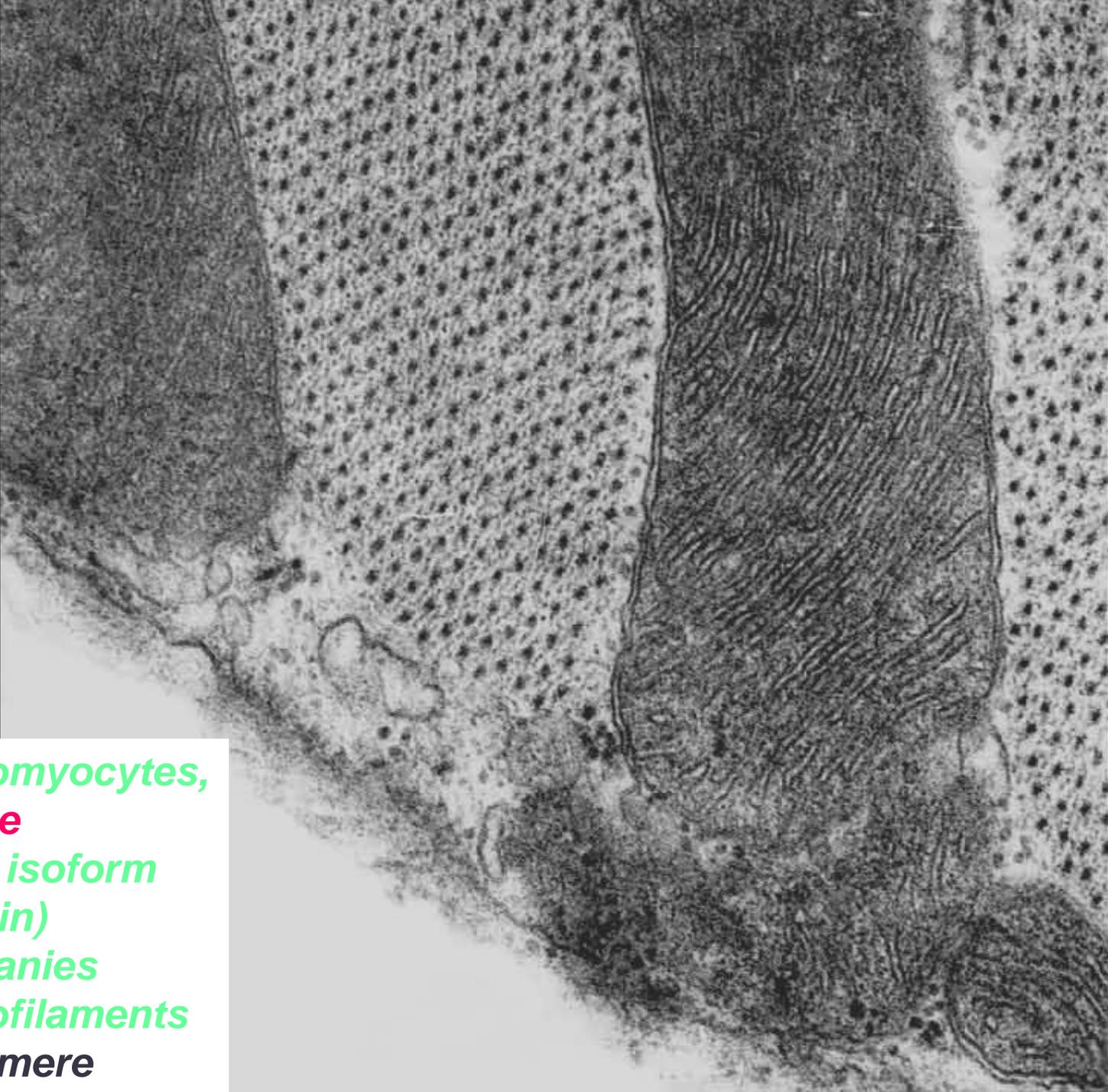
Muscle fiber



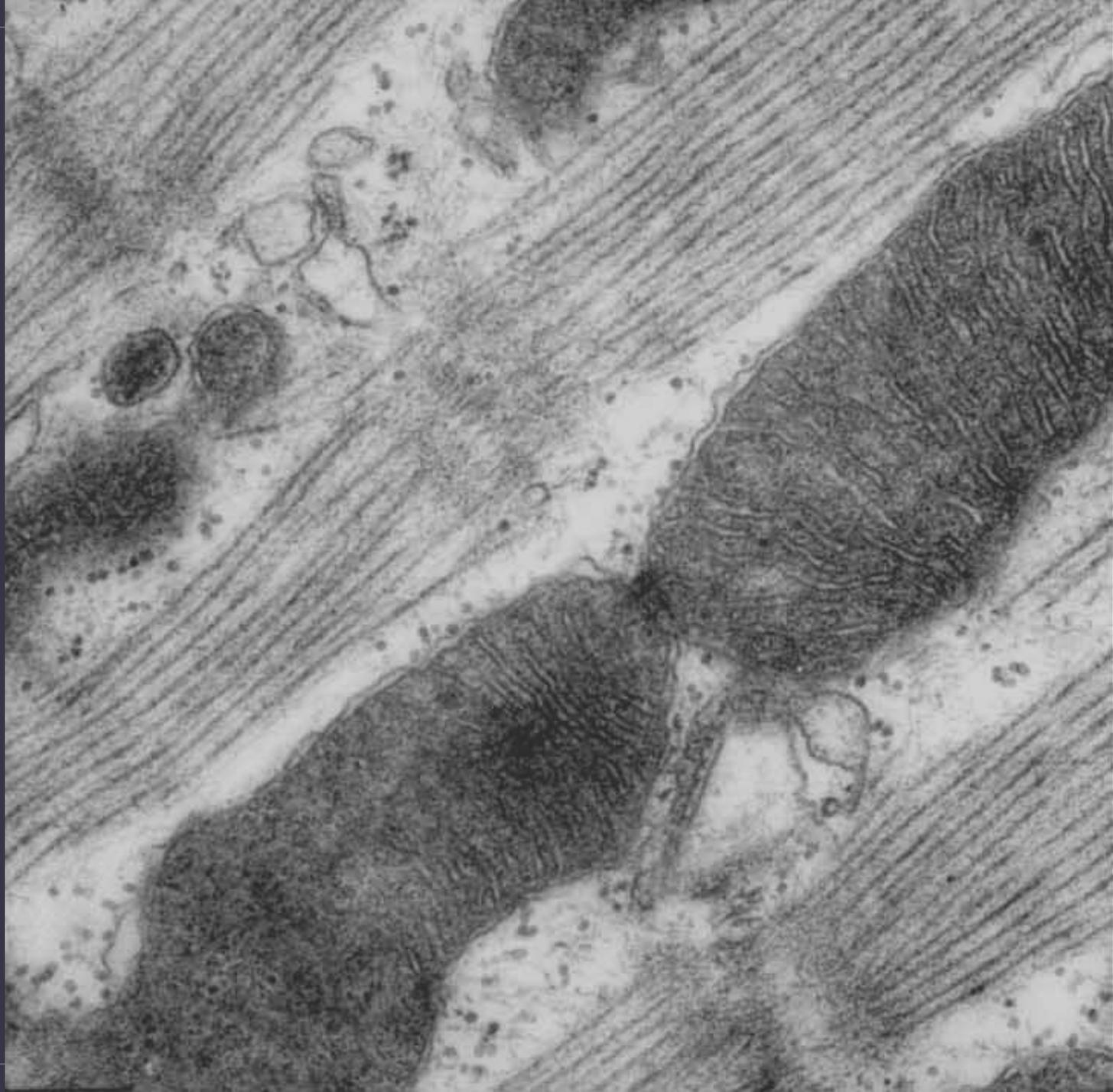








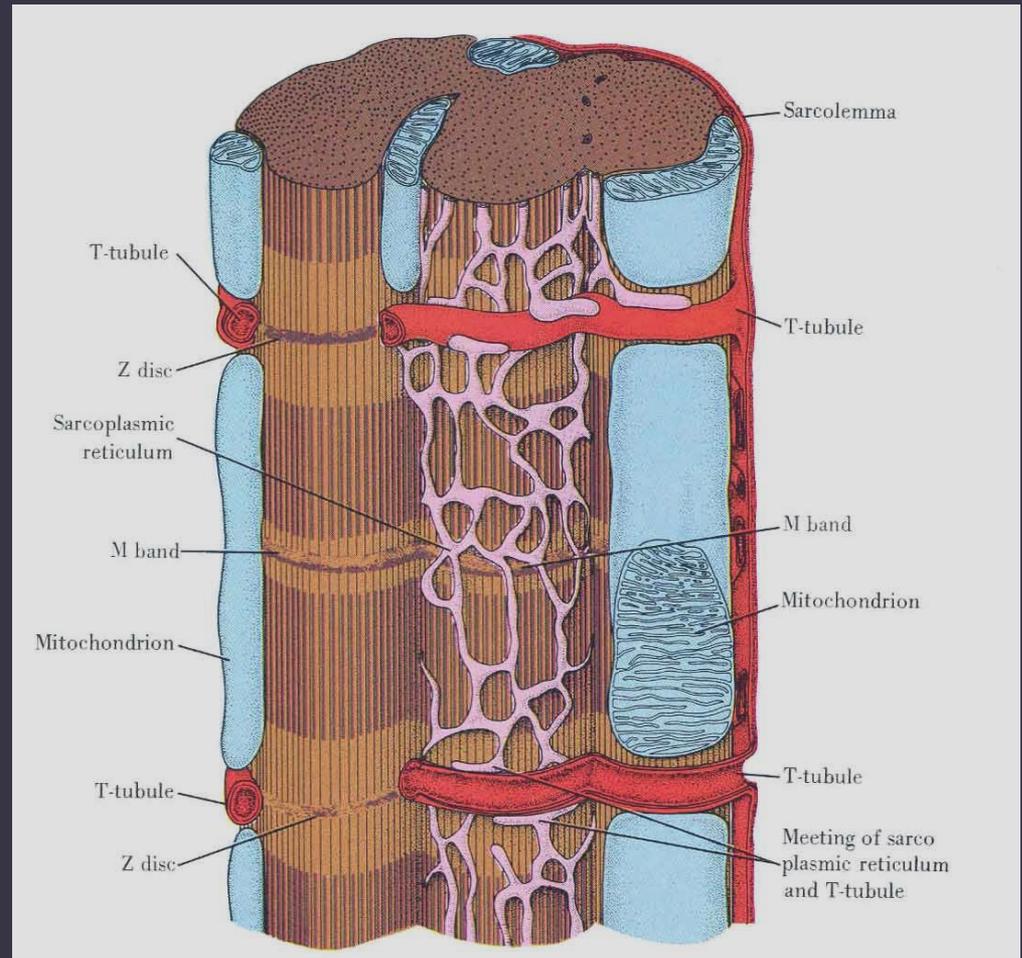
in cardiomyocytes,
nebullette
(smaller isoform
of nebulin)
accompanies
thin myofilaments
in sarcomere



Sarcoplasmic reticulum

Single network extending between two adjacent Z-lines

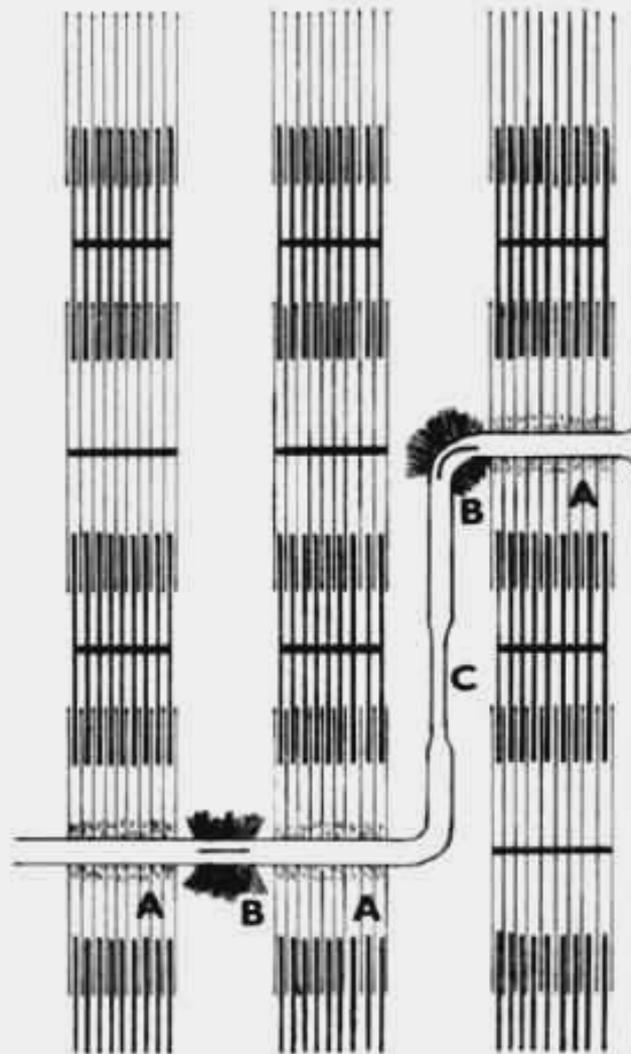
Terminal cisternae form **diad** with T tubules at the level of Z-line





T tubule
diad

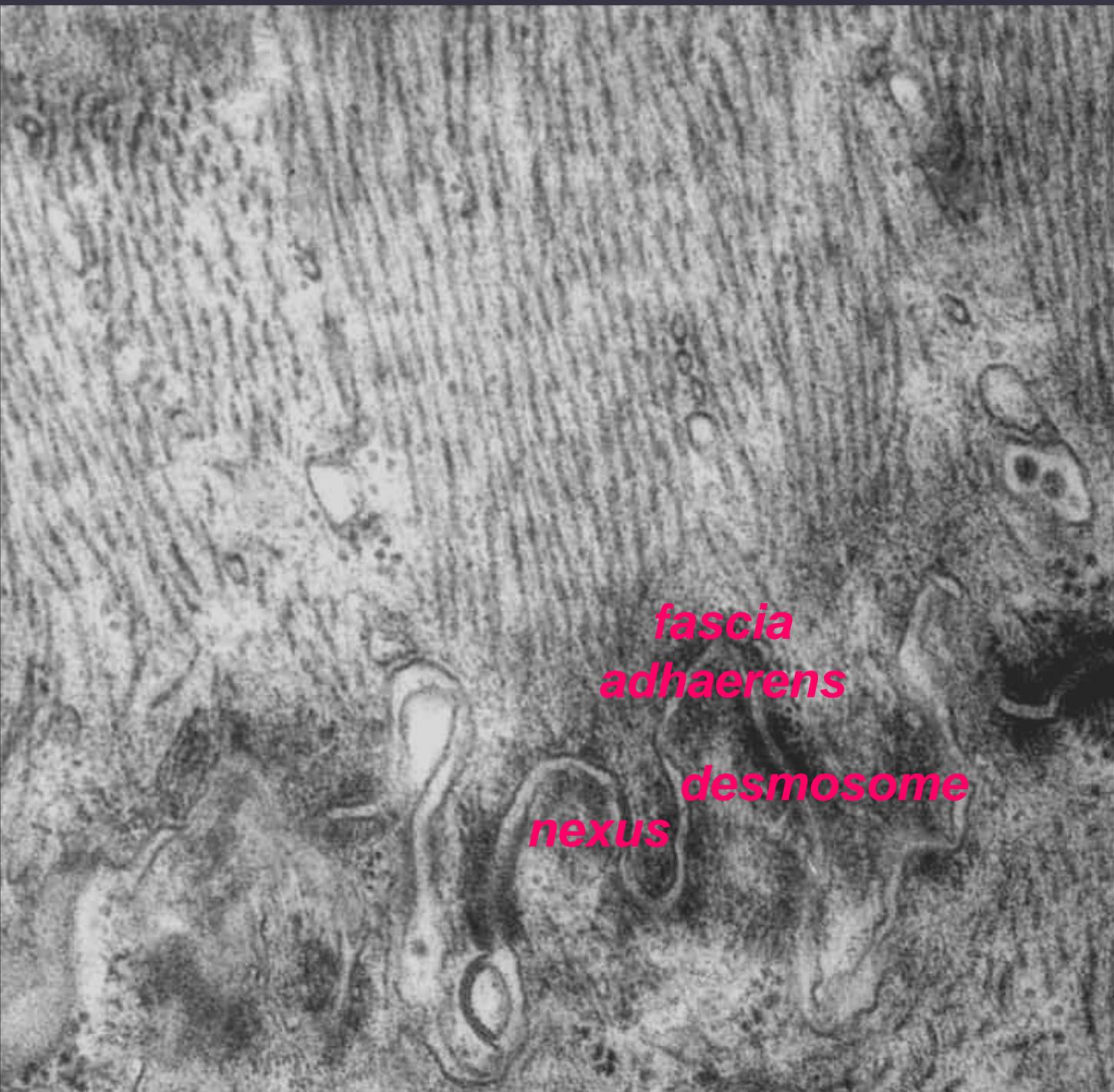
INTERCALATED DISC



A – fascia adhaerens

B – macula adhaerens (desmosome)

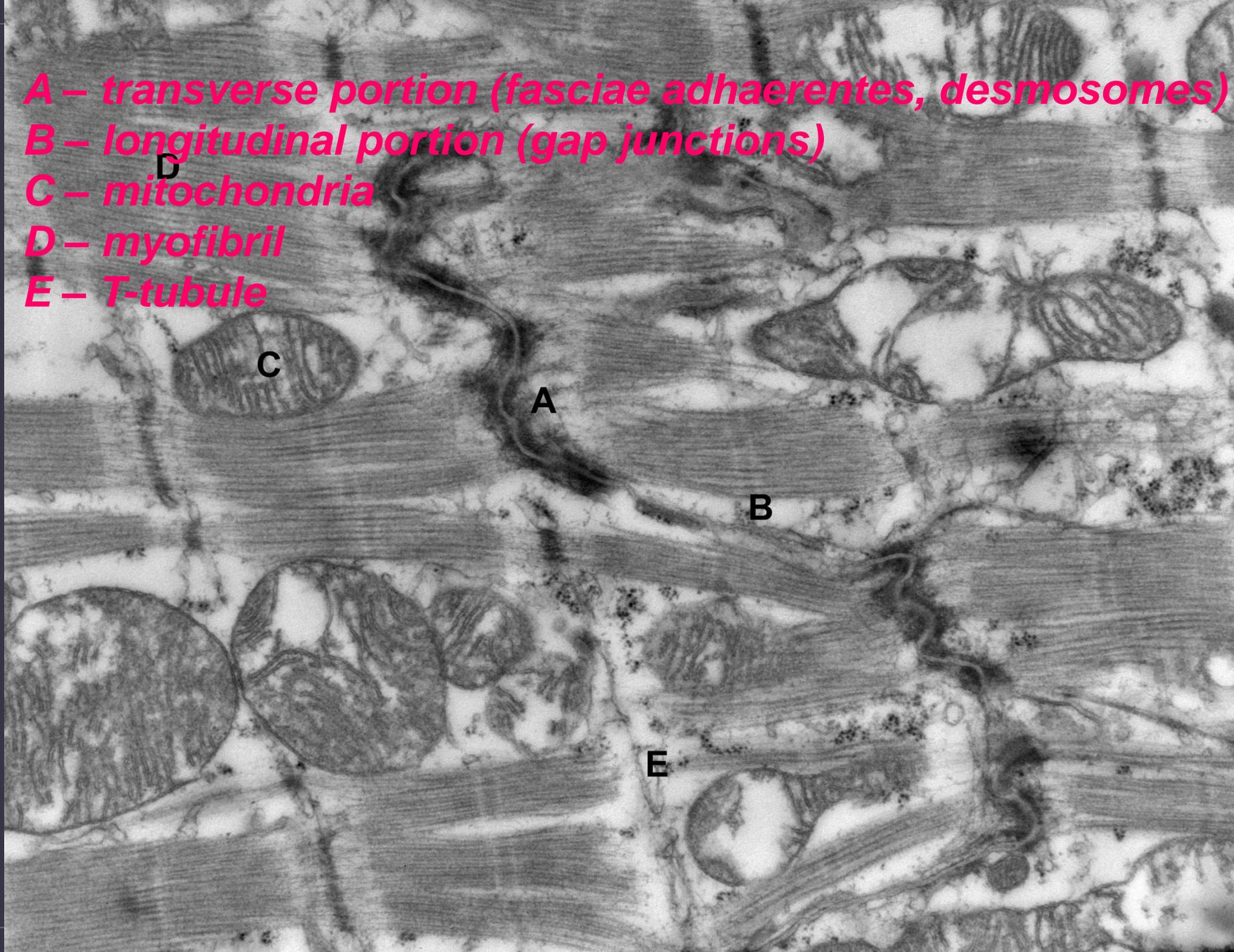
C – gap junction (nexus)

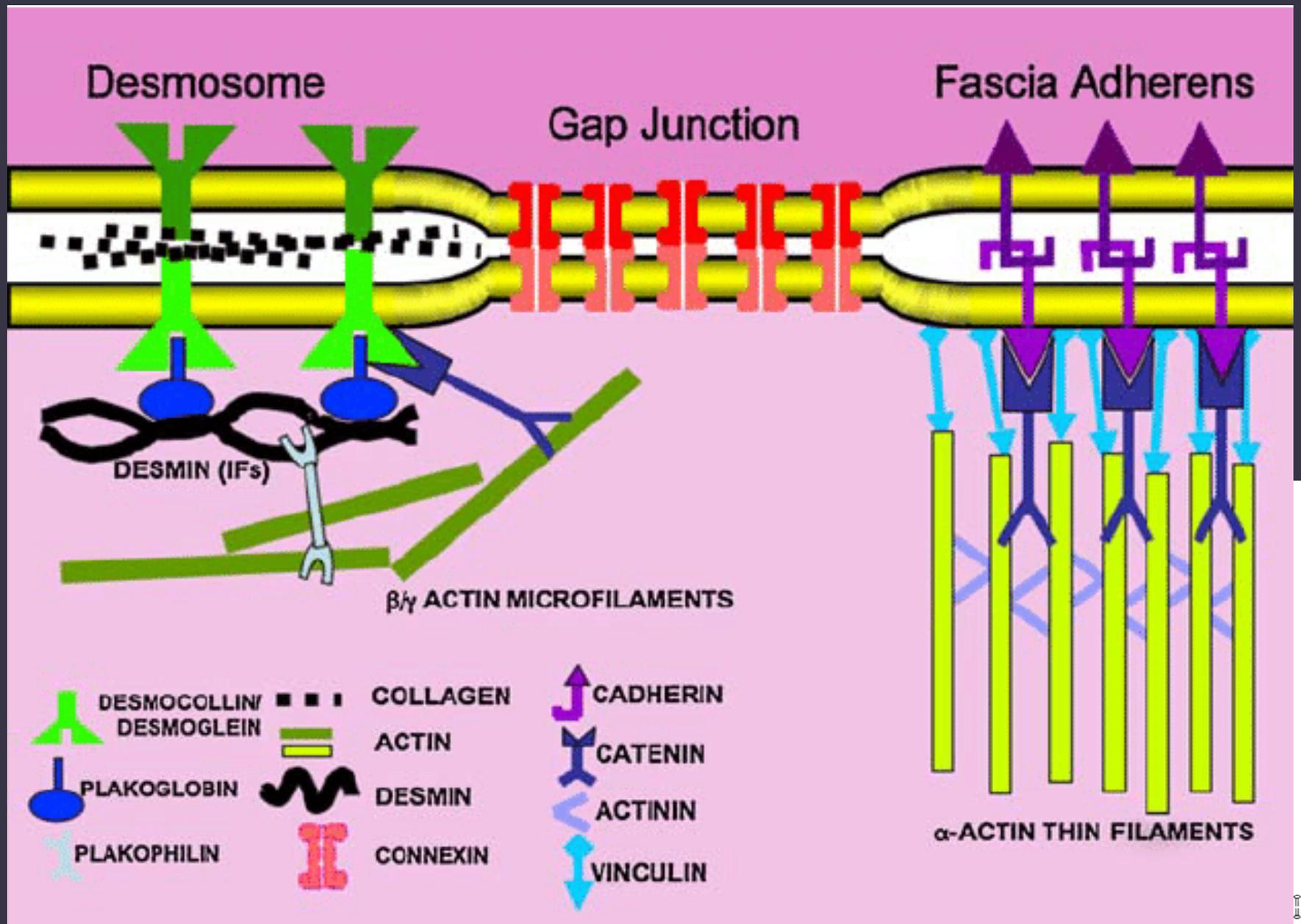


*fascia
adhaerens*

*desmosome
nexus*

- A – transverse portion (fasciae adhaerentes, desmosomes)**
- B – longitudinal portion (gap junctions)**
- C – mitochondria**
- D – myofibril**
- E – T-tubule**





← Long axis of the cell →

Hypothetical
integral
membrane
protein

Intercalated
disk

Vinculin

Actin
filaments

α -Actinin

(+)

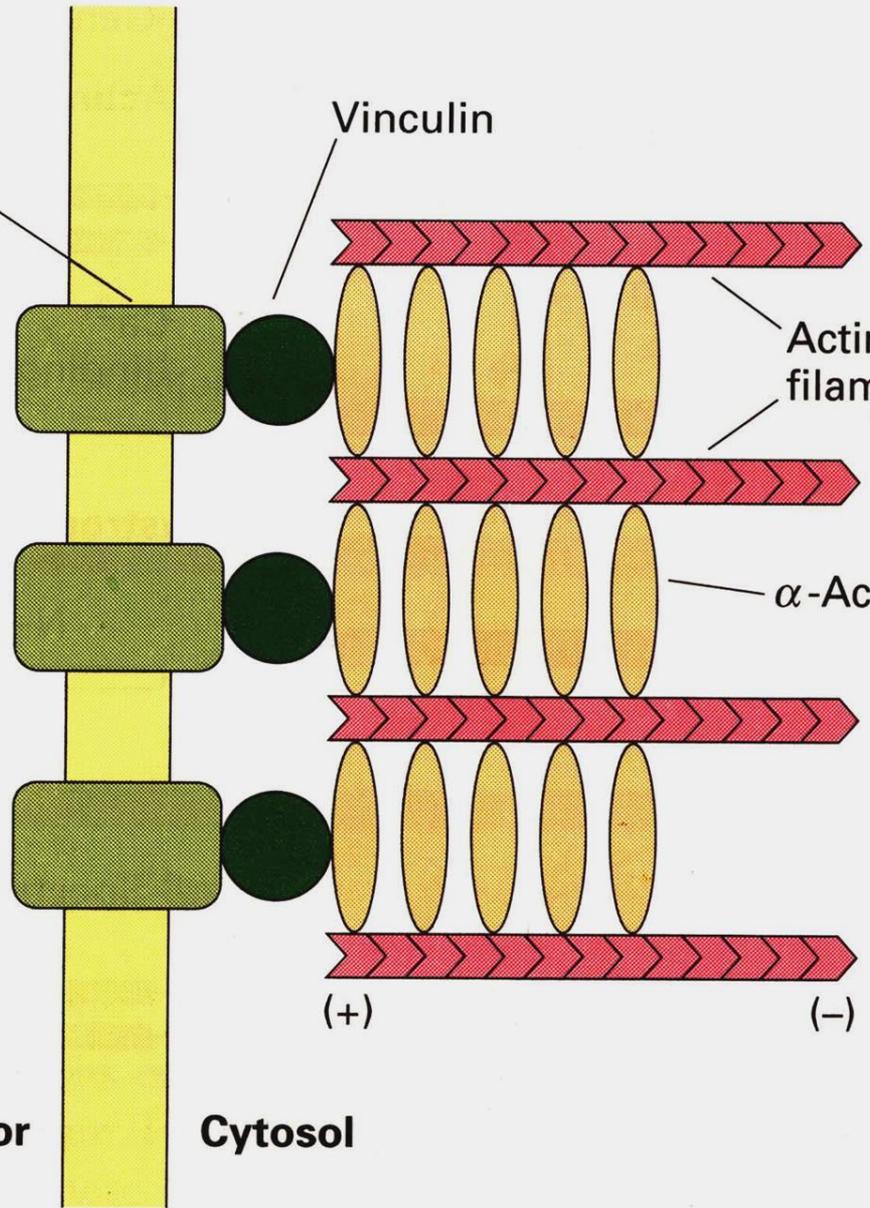
(-)

Exterior

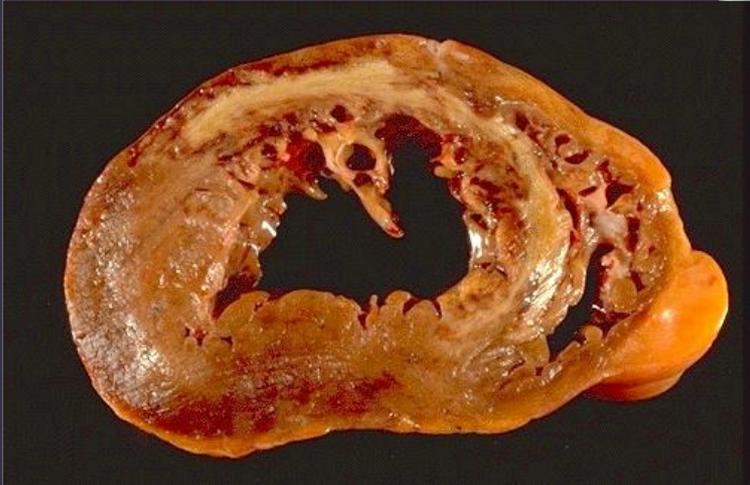
Cytosol

Plasma
membrane

*in cardiomyocytes,
vinculin
shares the role
with dystrophin
in the costamere*



Regeneration



Smooth muscle

Elongated fusiform cells with **nuclei** located **in the centre**

Gap junctions

Dense bodies – cytoplasmic densities

Network of **intermediate filaments** – desmin (and vimentin)

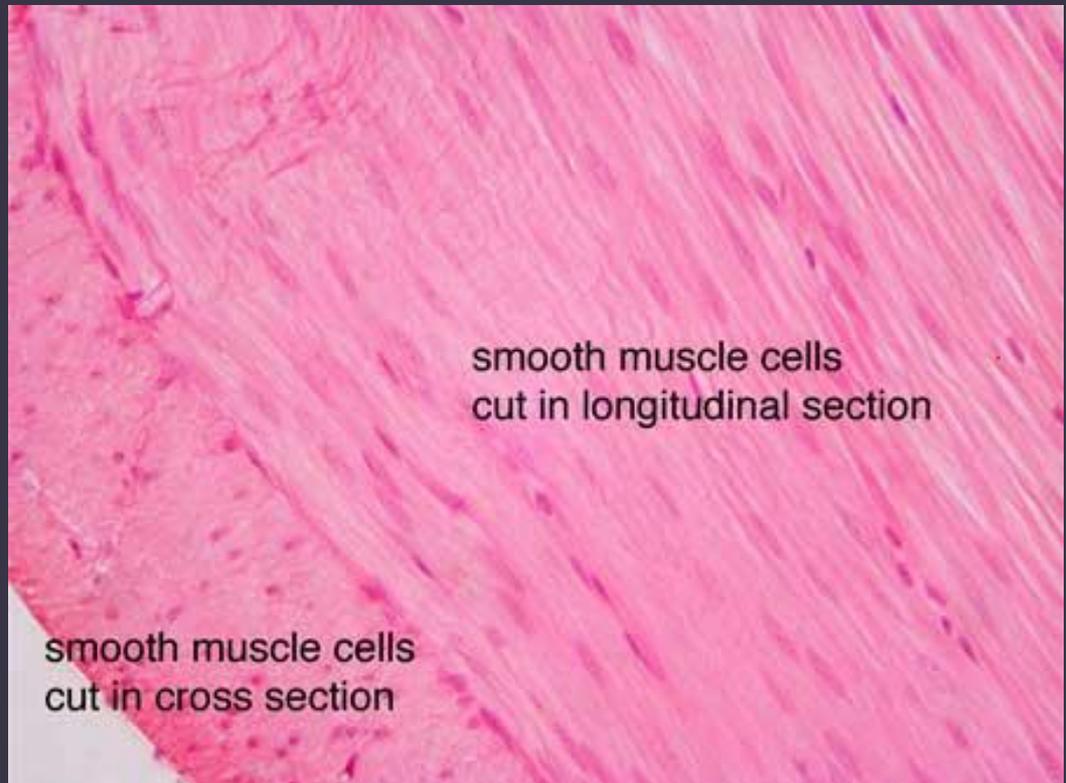
basic unit: **SMOOTH MUSCLE CELL**
spindle-shaped element with one nucleus
slow contraction without any voluntary control

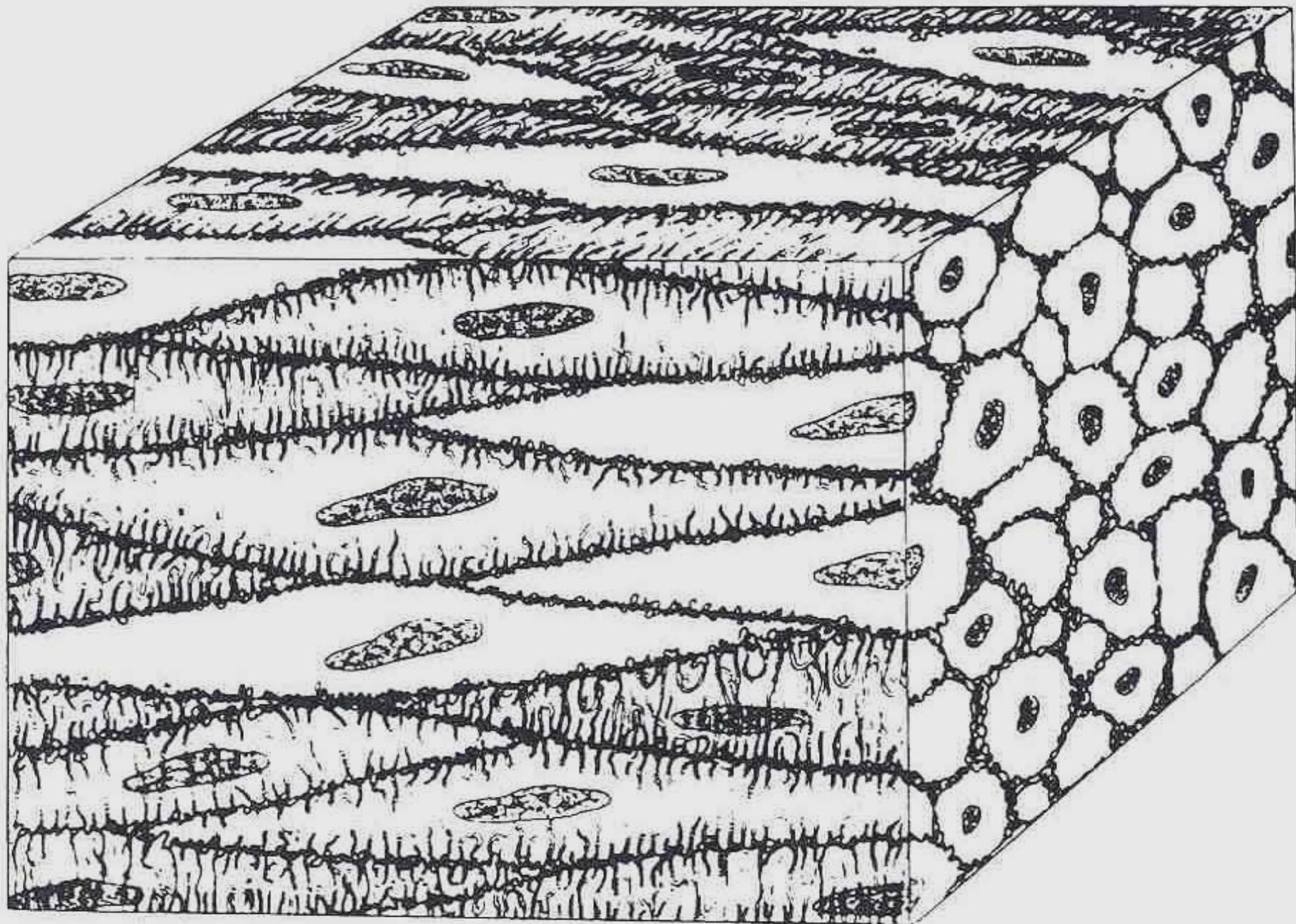
length: 15 to 500 micrometers

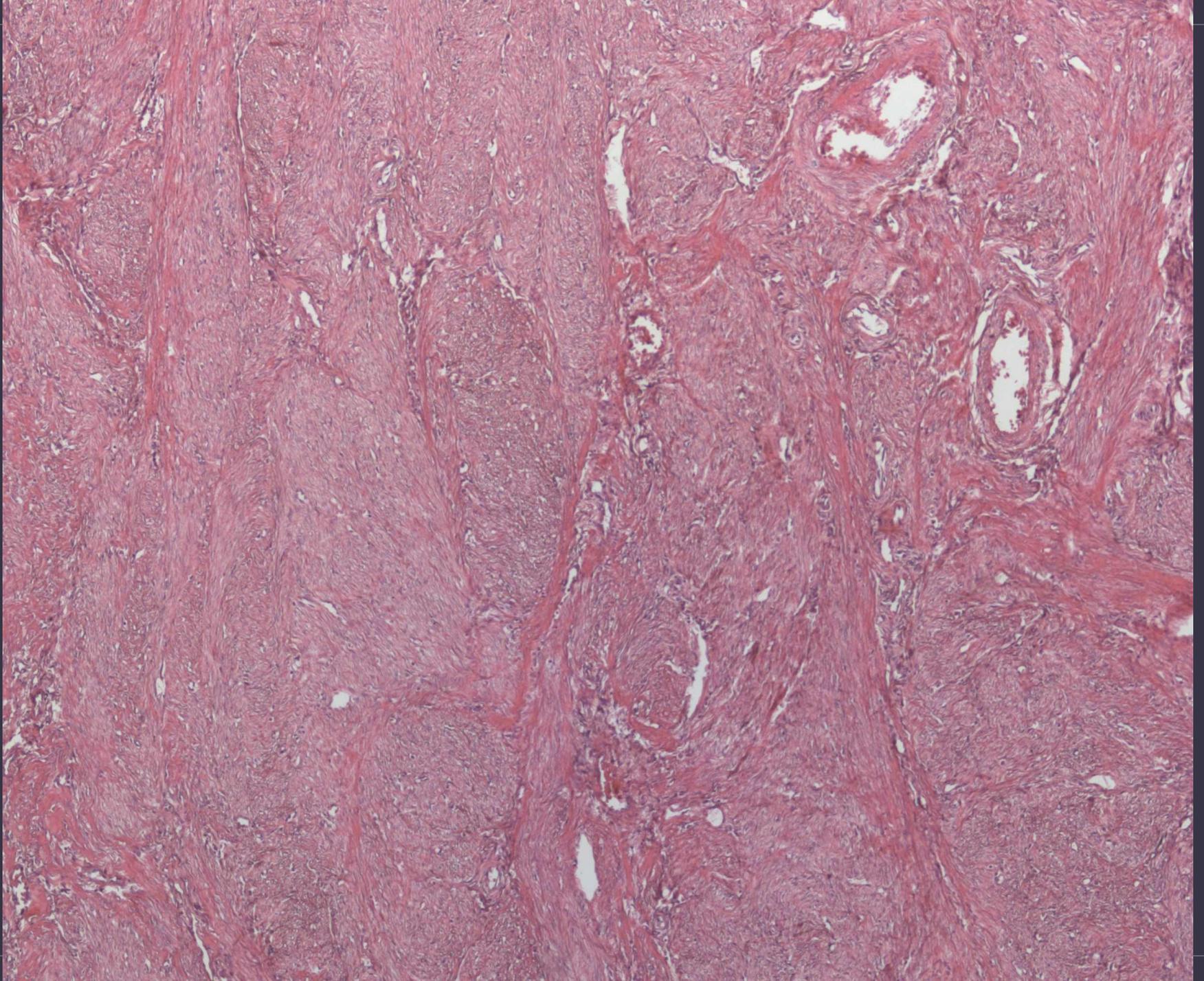
diameter: approx. 6 micrometers

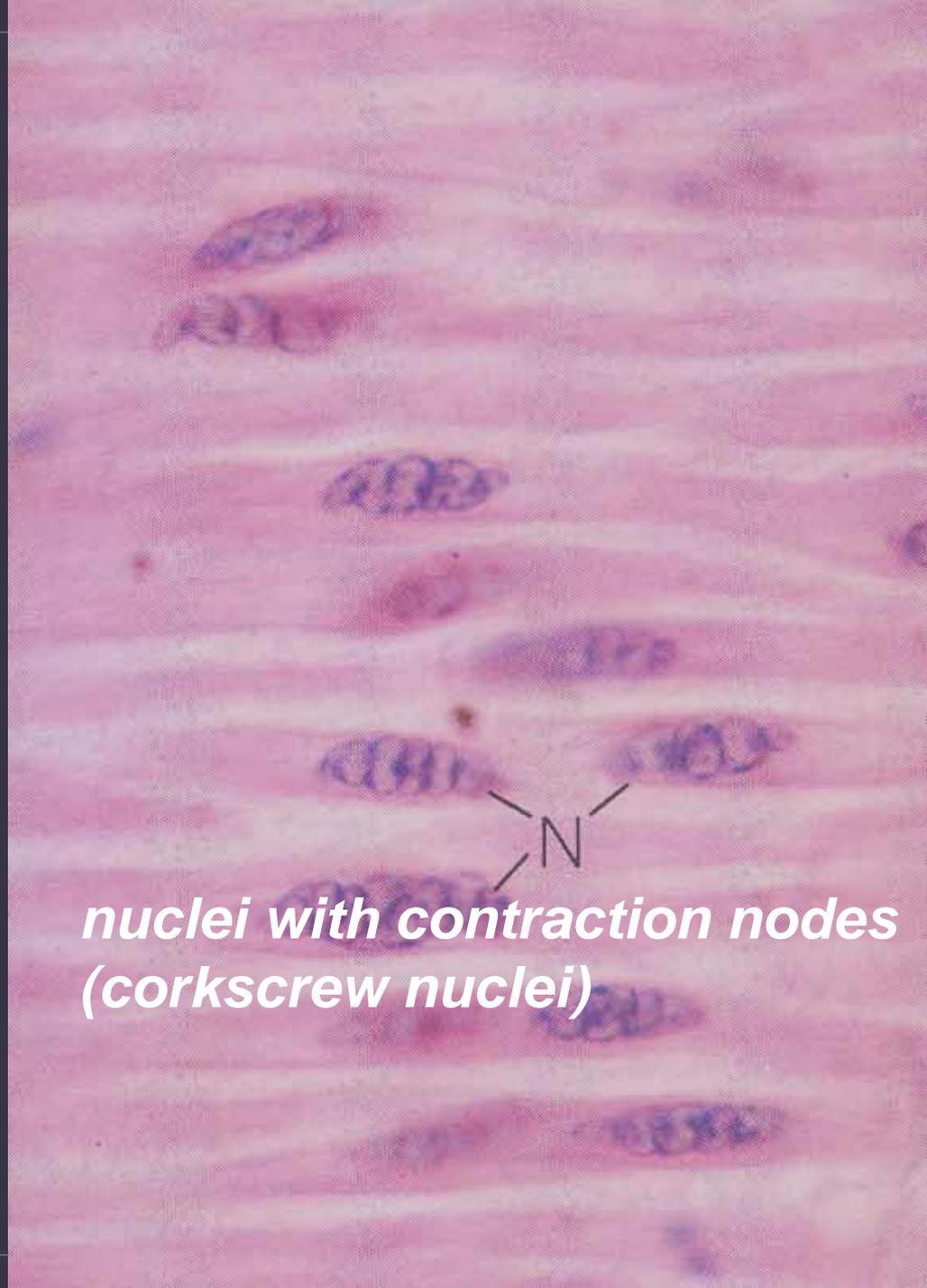
nucleus situated in the centre

myofilaments arranged irregularly (**NO MYOFIBRILS**)

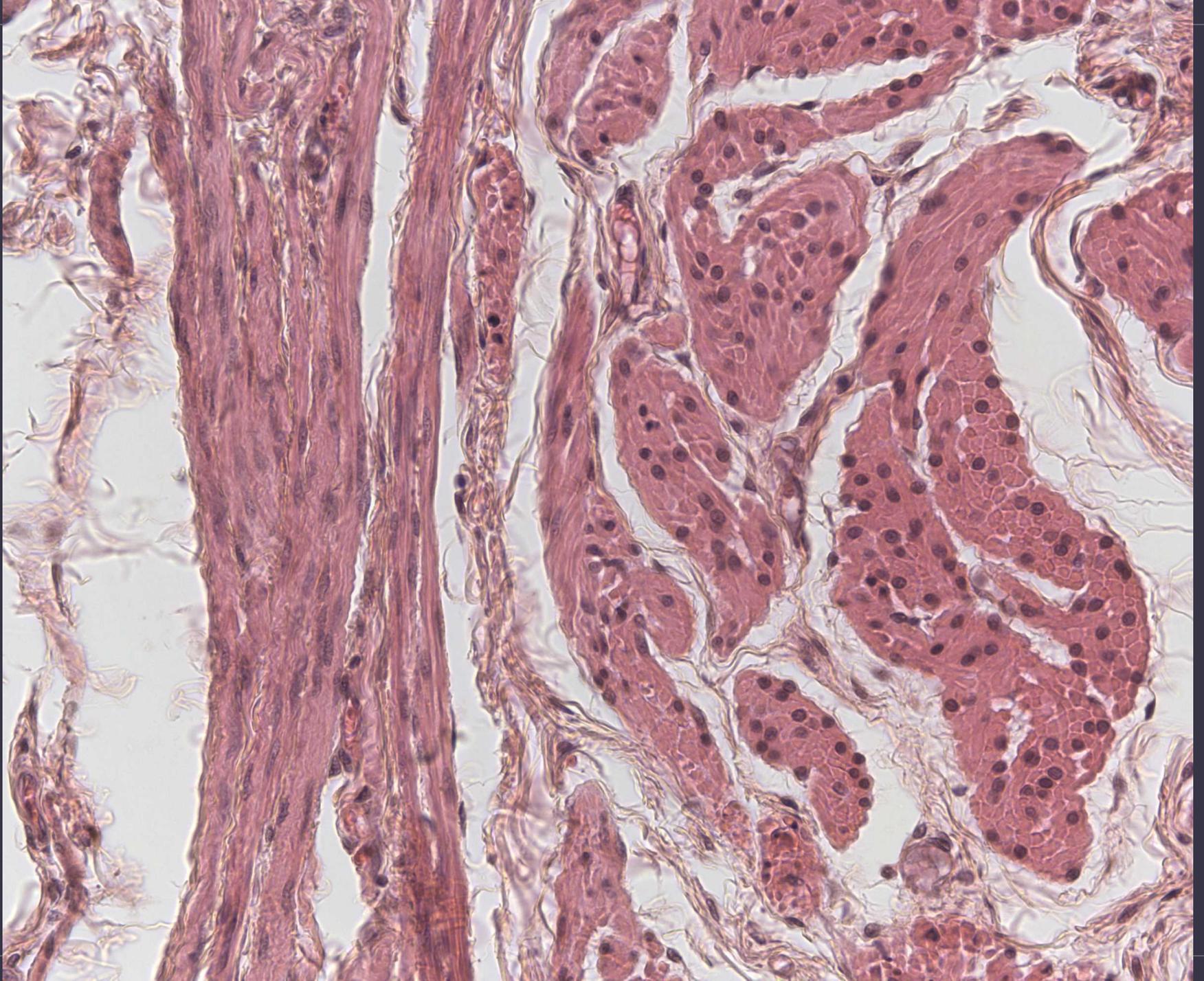








***nuclei with contraction nodes
(corkscrew nuclei)***

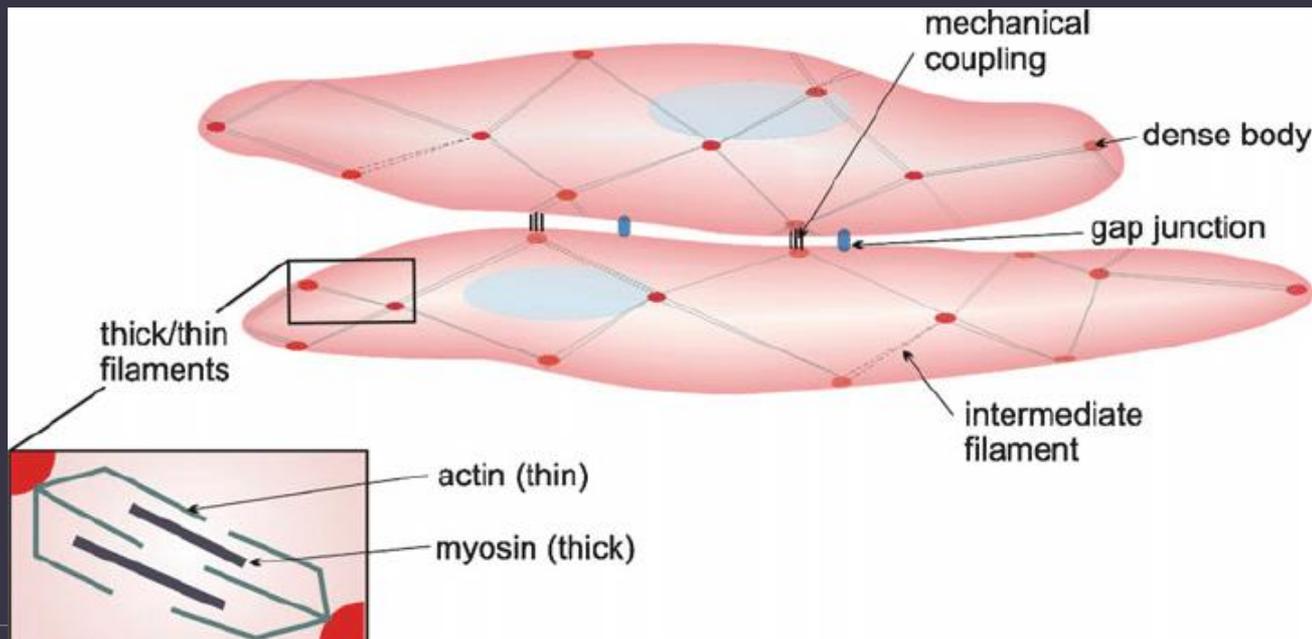


Dense bodies and contractile network

Thin myofilaments are anchored into dense bodies

Intracellular network of anchoring points is joined to intermediate desmin filaments

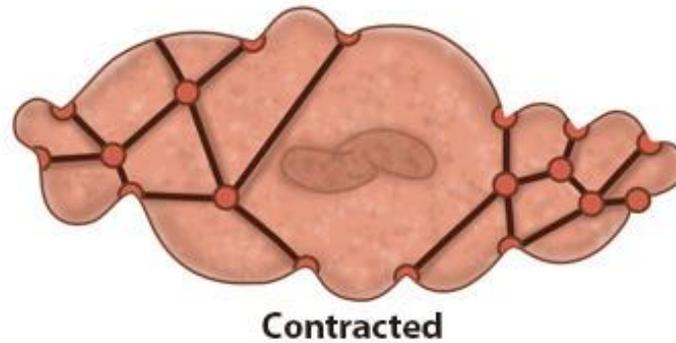
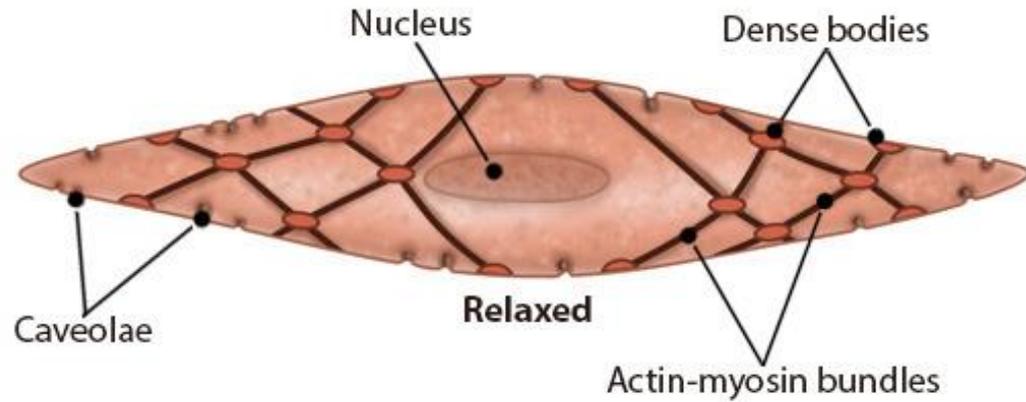
Thin myofilaments have no troponin complex





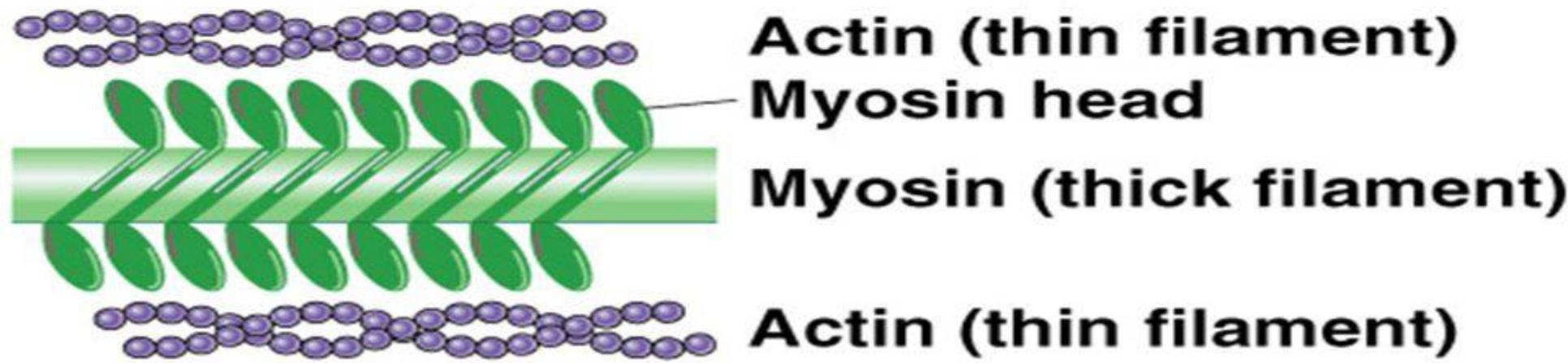
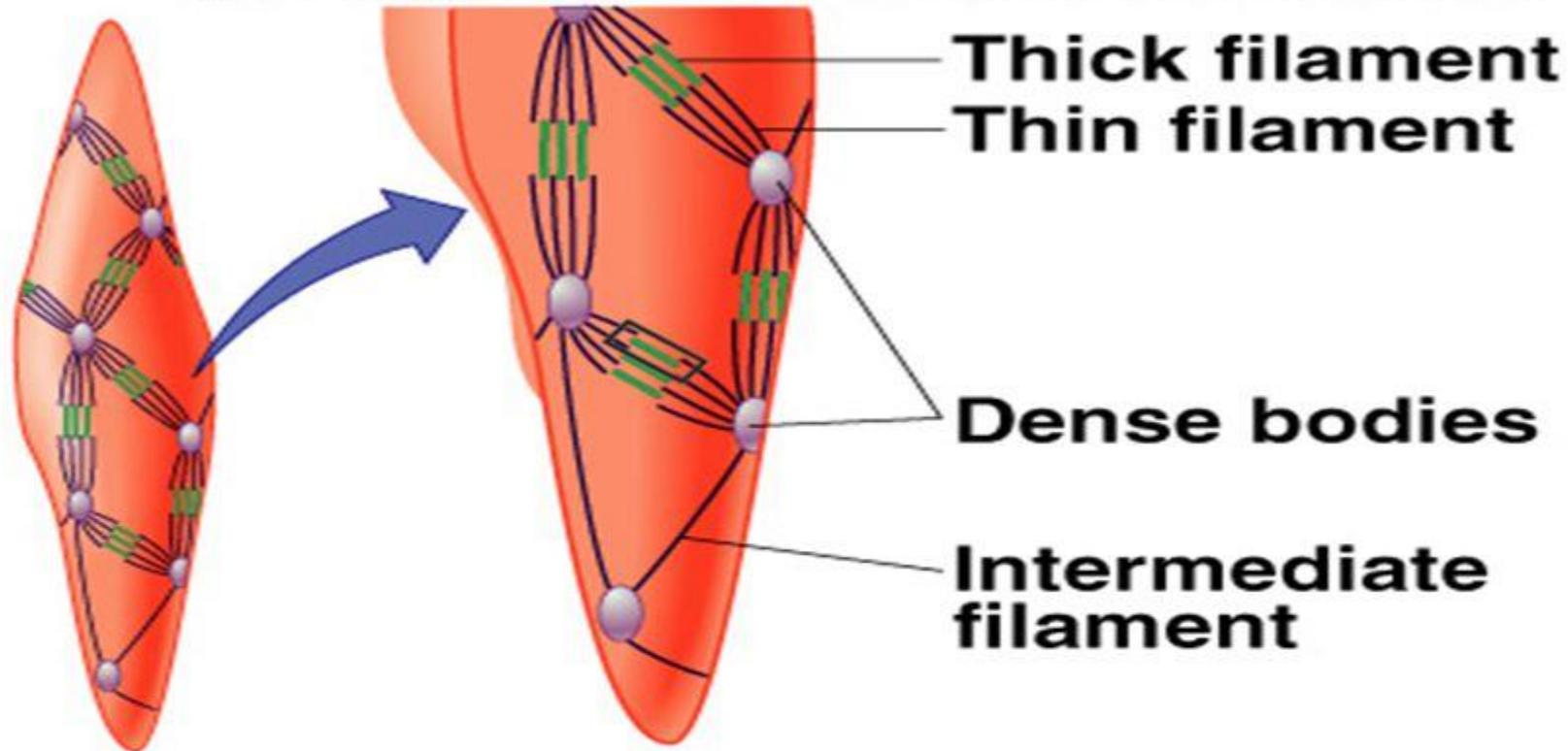
dense body

Contraction



Structure of Smooth Muscle

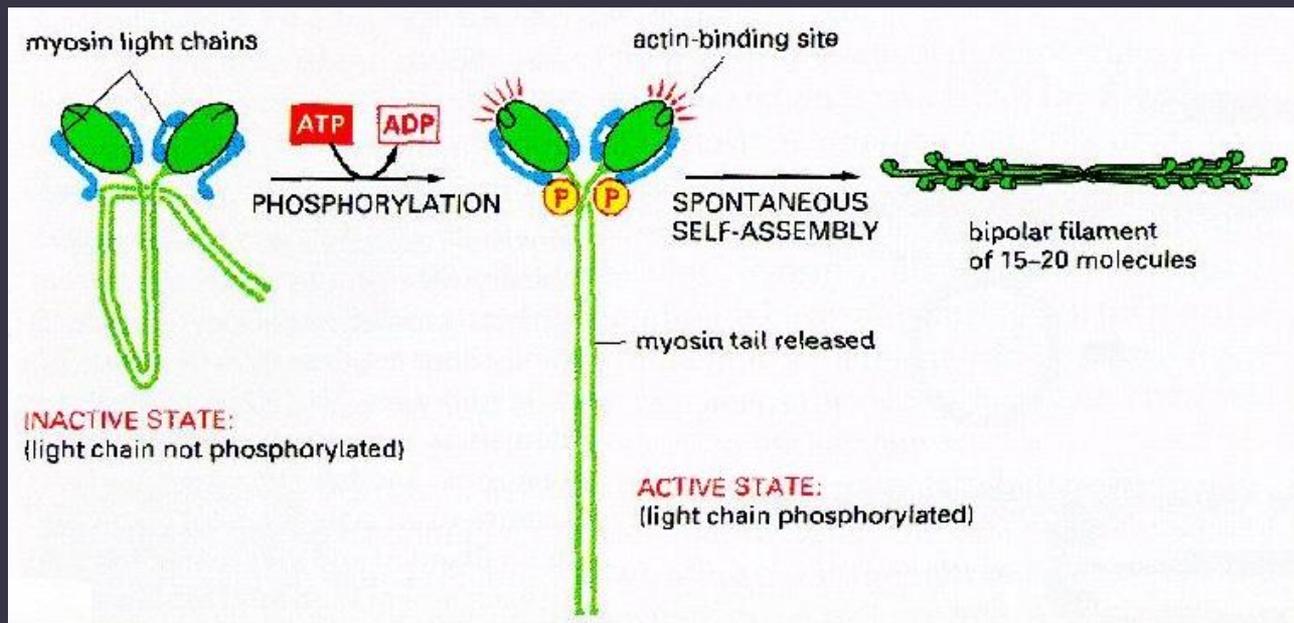
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Thick filaments – myosin II

In the resting state the actin-binding site is inactivated, myosin II is folded

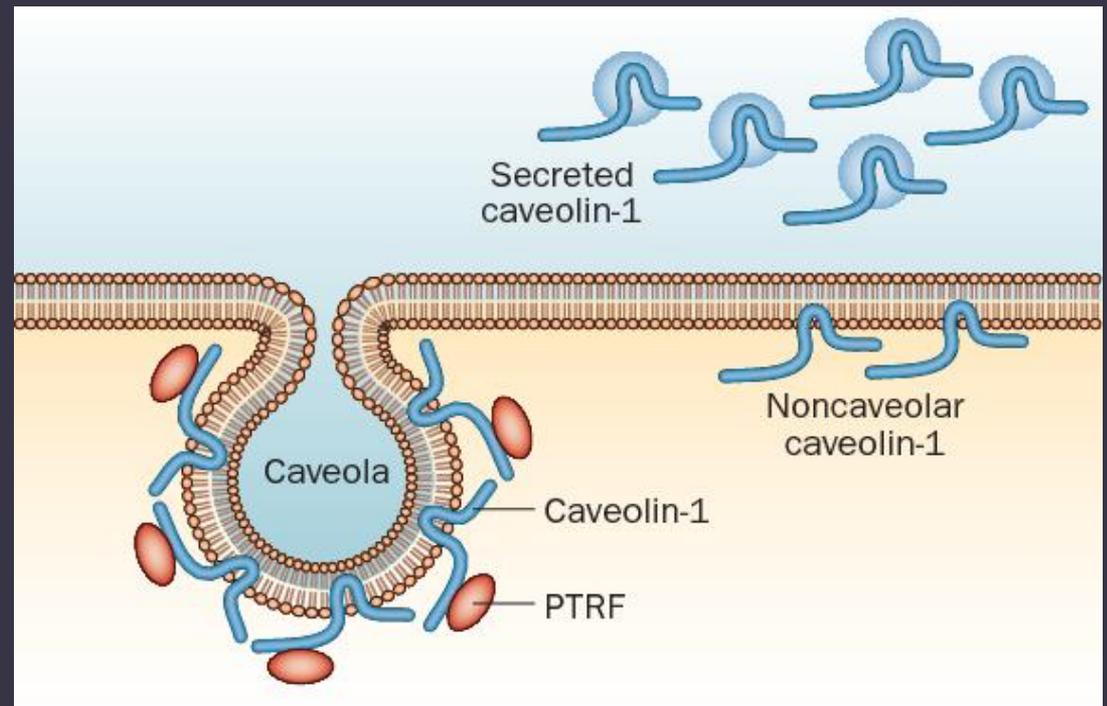
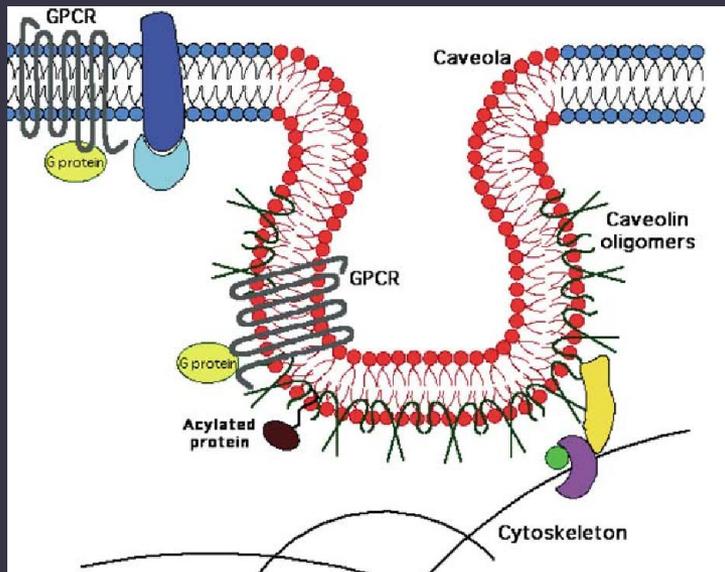
After the phosphorylation by **myosin light chain kinase**, actin-binding site of the myosin head is activated and binds to actin. In the presence of ATP, the myosin head bends and produces a contraction.



Caveolae

Specialized invaginations of sarcolemma

Role in the **entry of Ca_2 ions** into the cell

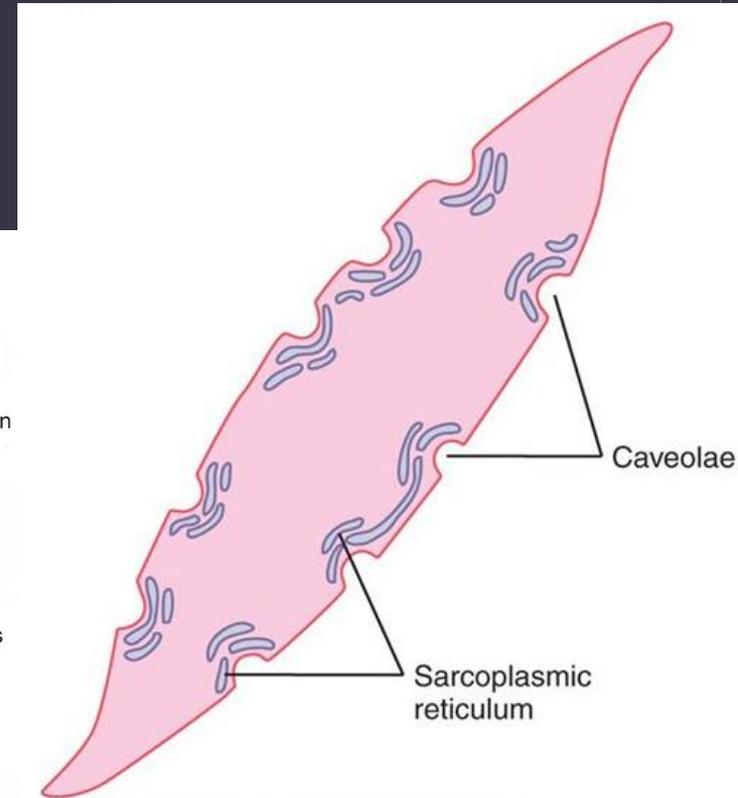
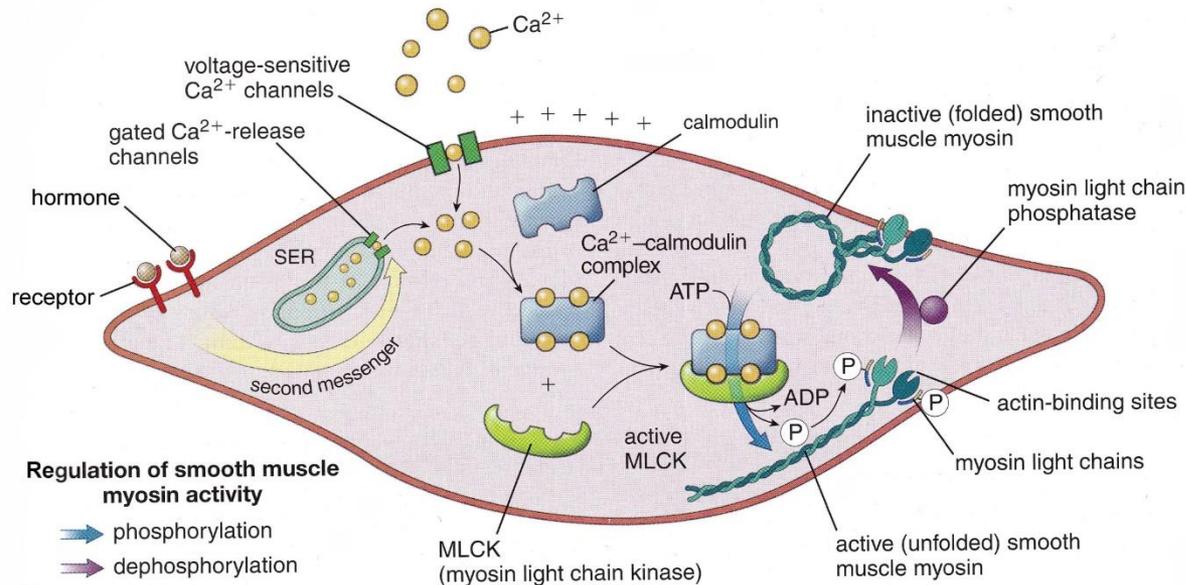


Organelles

Well-developed smooth endoplasmic reticulum

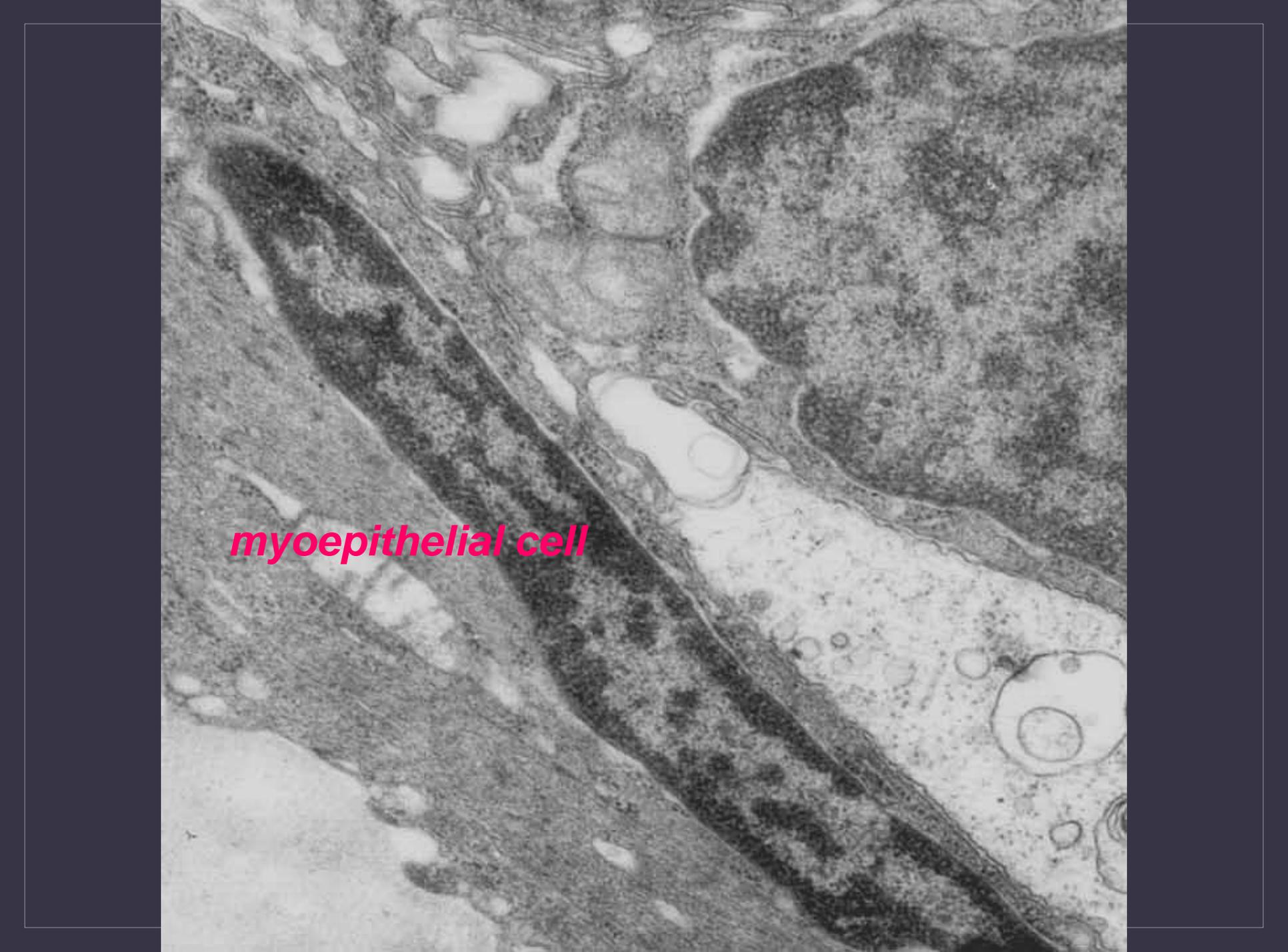
None T tubules!

Well-developed rER and GA –
production of connective tissue matrix



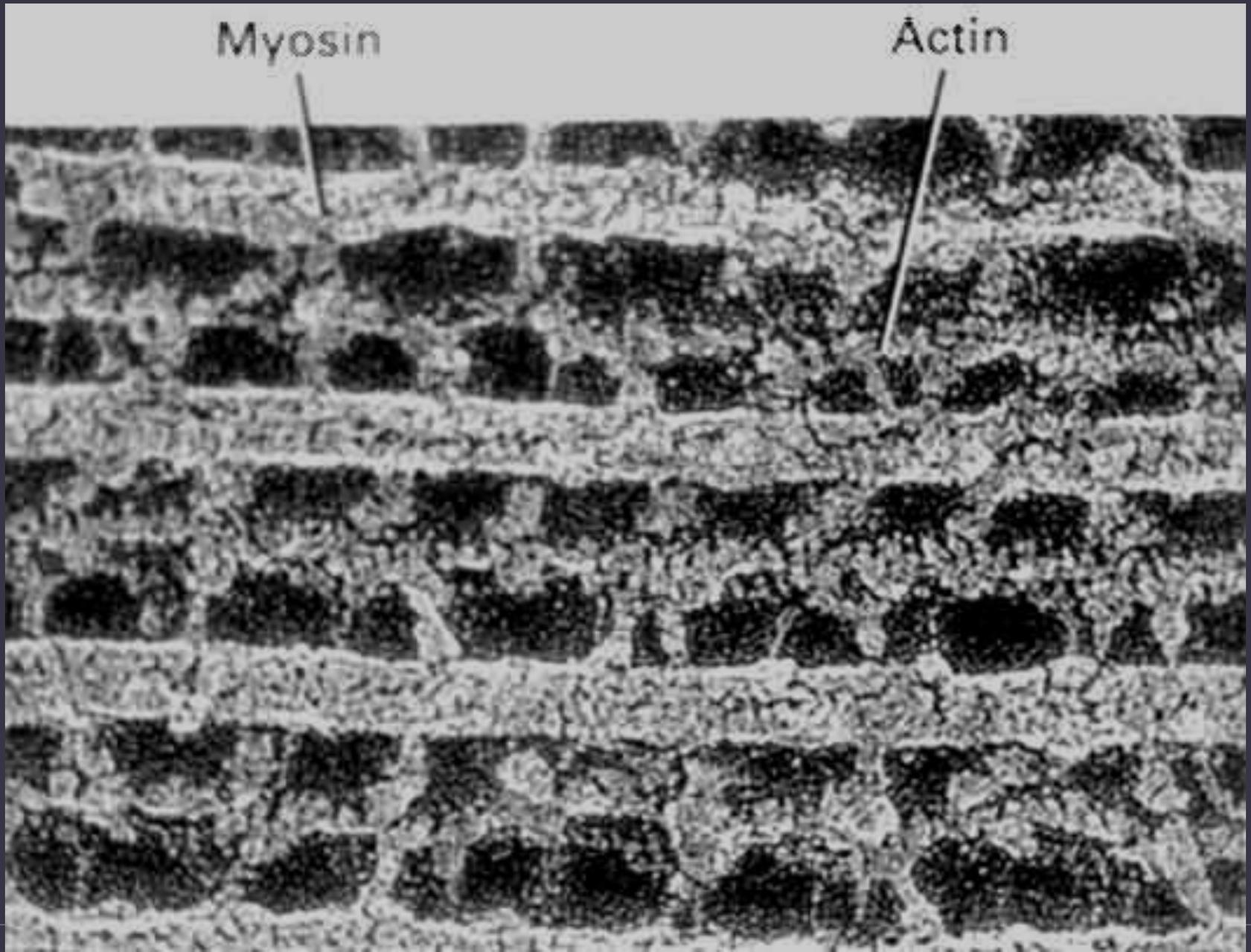
Contractile non-muscle elements

- *myoepithelial cells (glands)*
- *myofibroblasts (connective tissue proper)*
- *pericytes (capillaries, smallest venules)*
- *mesangial cells (kidneys)*
- *myoid cells (testes)*
- *contractile interstitial cells in alveolar septa (lungs)*

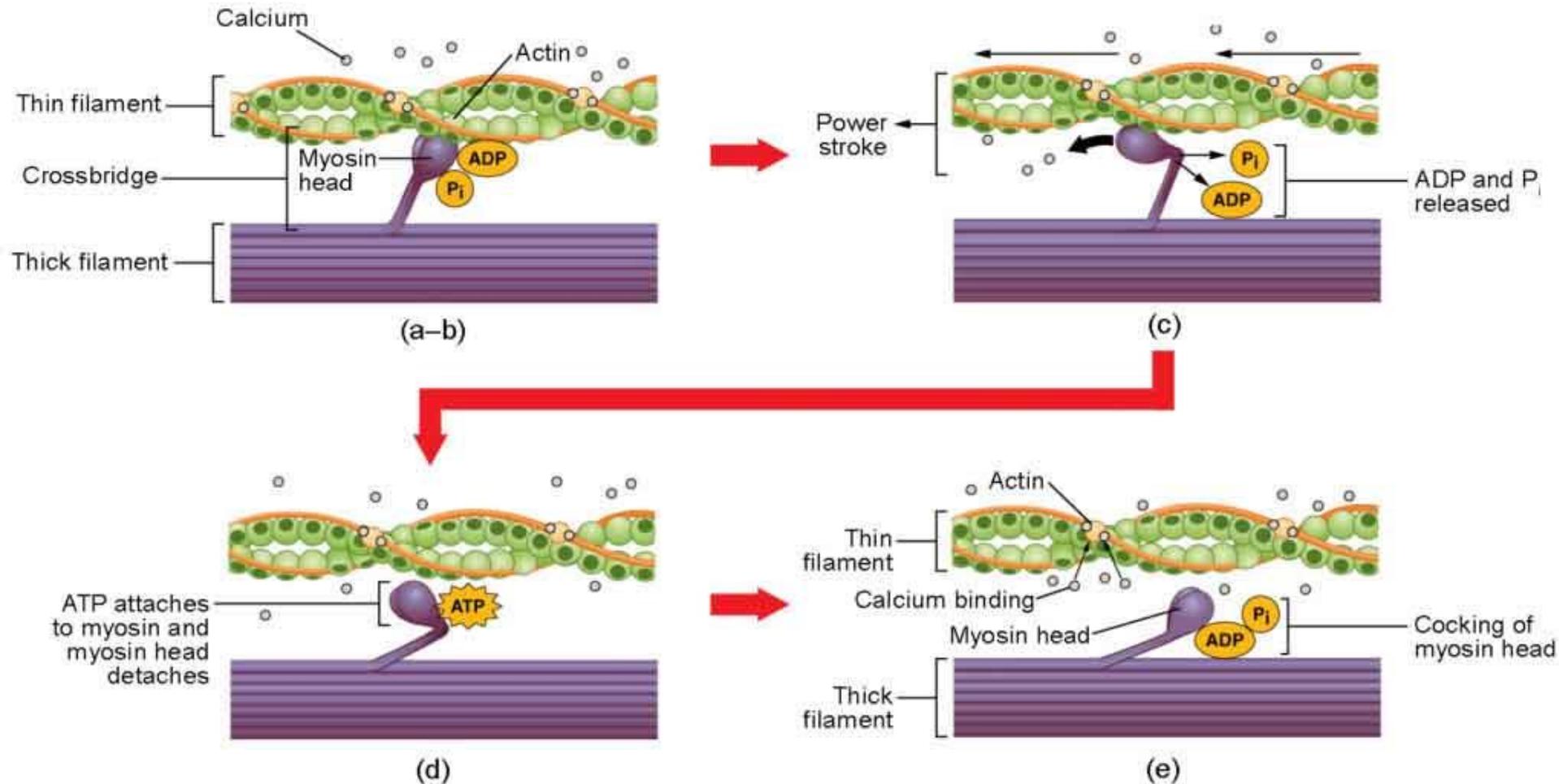
This electron micrograph shows a myoepithelial cell, which is a specialized cell found in glandular tissues. The cell is characterized by its elongated, spindle-like shape and the presence of numerous mitochondria, which are visible as dark, oval structures with internal cristae. The cytoplasm is densely packed with these organelles. The cell is situated between an epithelial layer and a basement membrane, which is visible as a thin, dark line. The overall appearance is that of a contractile cell with a high metabolic rate, typical of its role in surrounding and supporting glandular units.

myoepithelial cell

Mechanism of muscle contraction

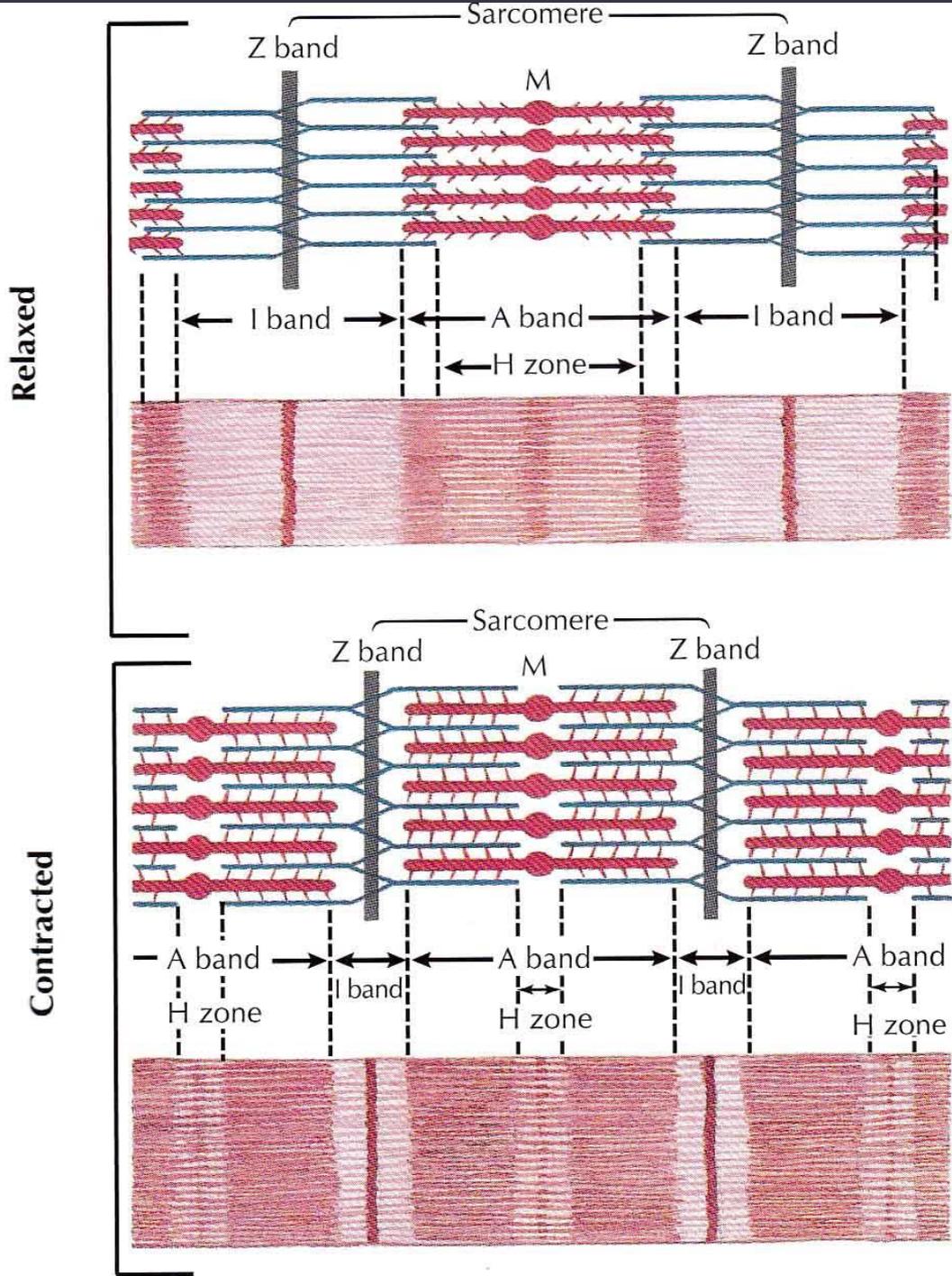


Striated muscle (skeletal and cardiac)



- 1) ATP available and bound to myosin, Ca^{2+} not available – resting state**
- 2) splitting ATP to ADP and P_i without release of splitting products, Ca^{2+} available, TnI unlocks binding site and myosin binds to actin (actin is required as a co-factor for release of splitting products)**
- 3) released energy pushes lever arms by nearly 7 nm**
- 4) binding new ATP to myosin weakens actin-myosin bridge, the cycle repeats until Ca^{2+} is available**

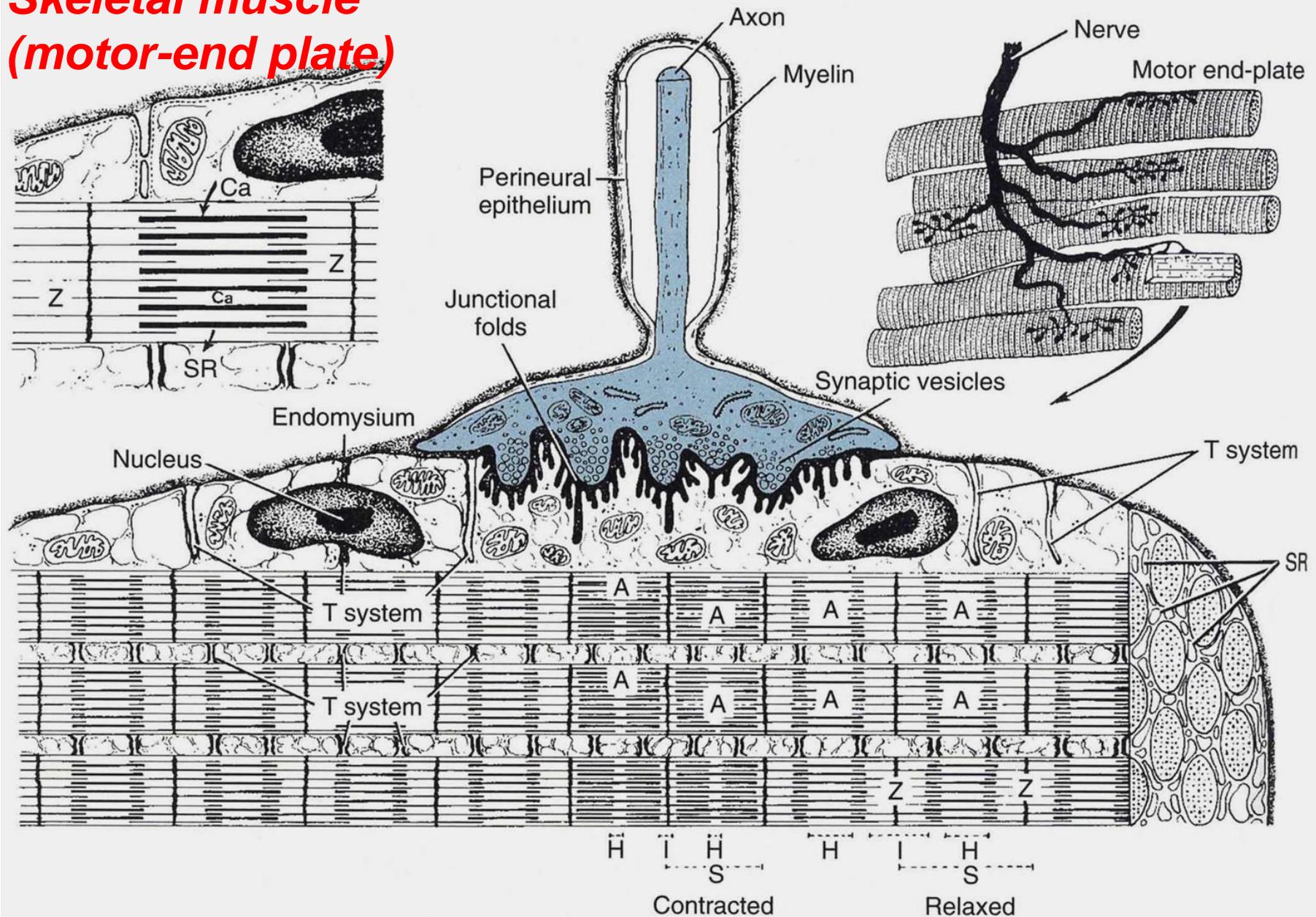
RIGOR MORTIS: ATP not available, Ca^{2+} available - myosin heads remain linked to actin



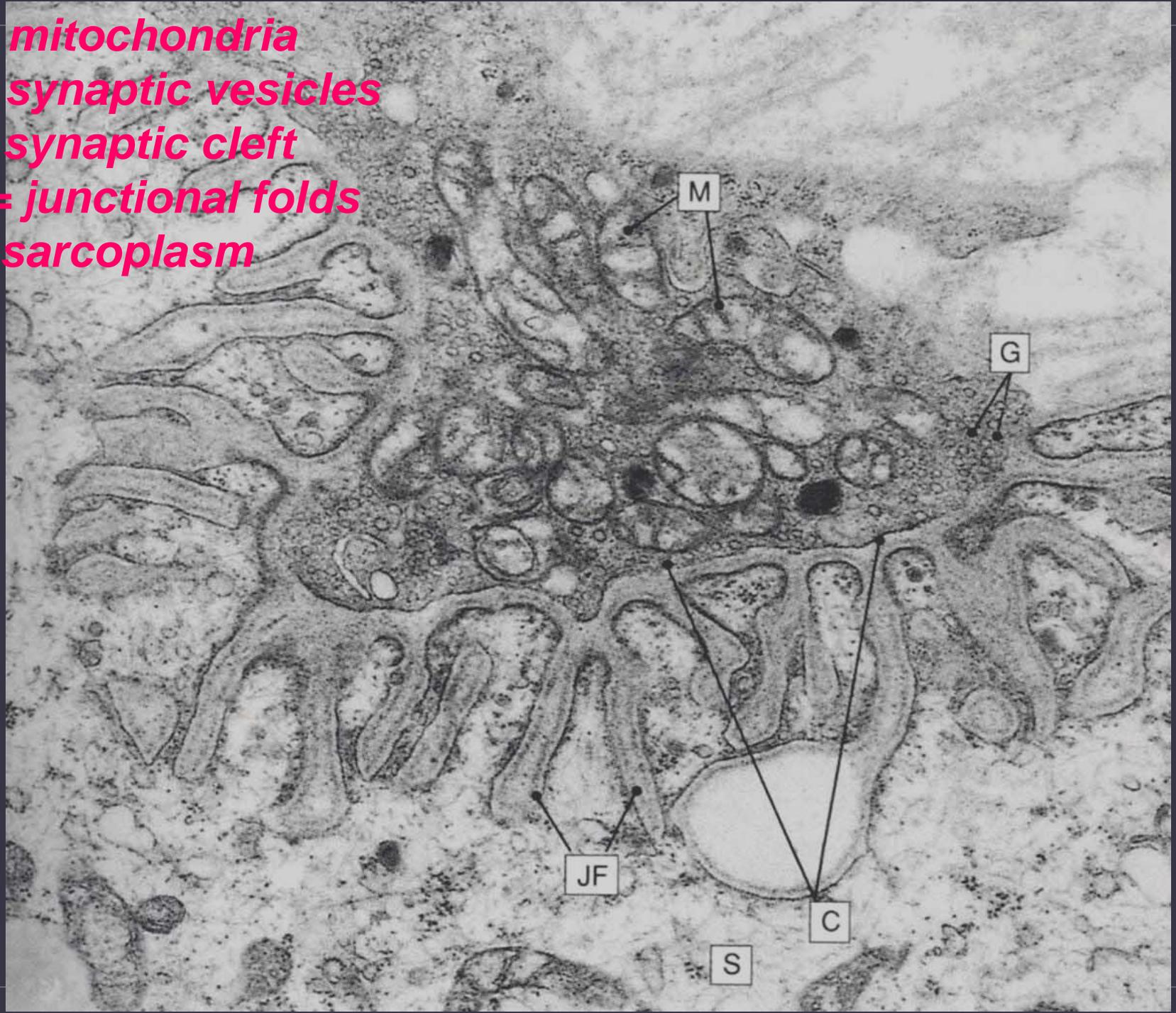
*Ovalle W.K.,
Nahirney P.C.:
Netter's Essential
Histology. 2nd Ed.,
Elsevier 2013*

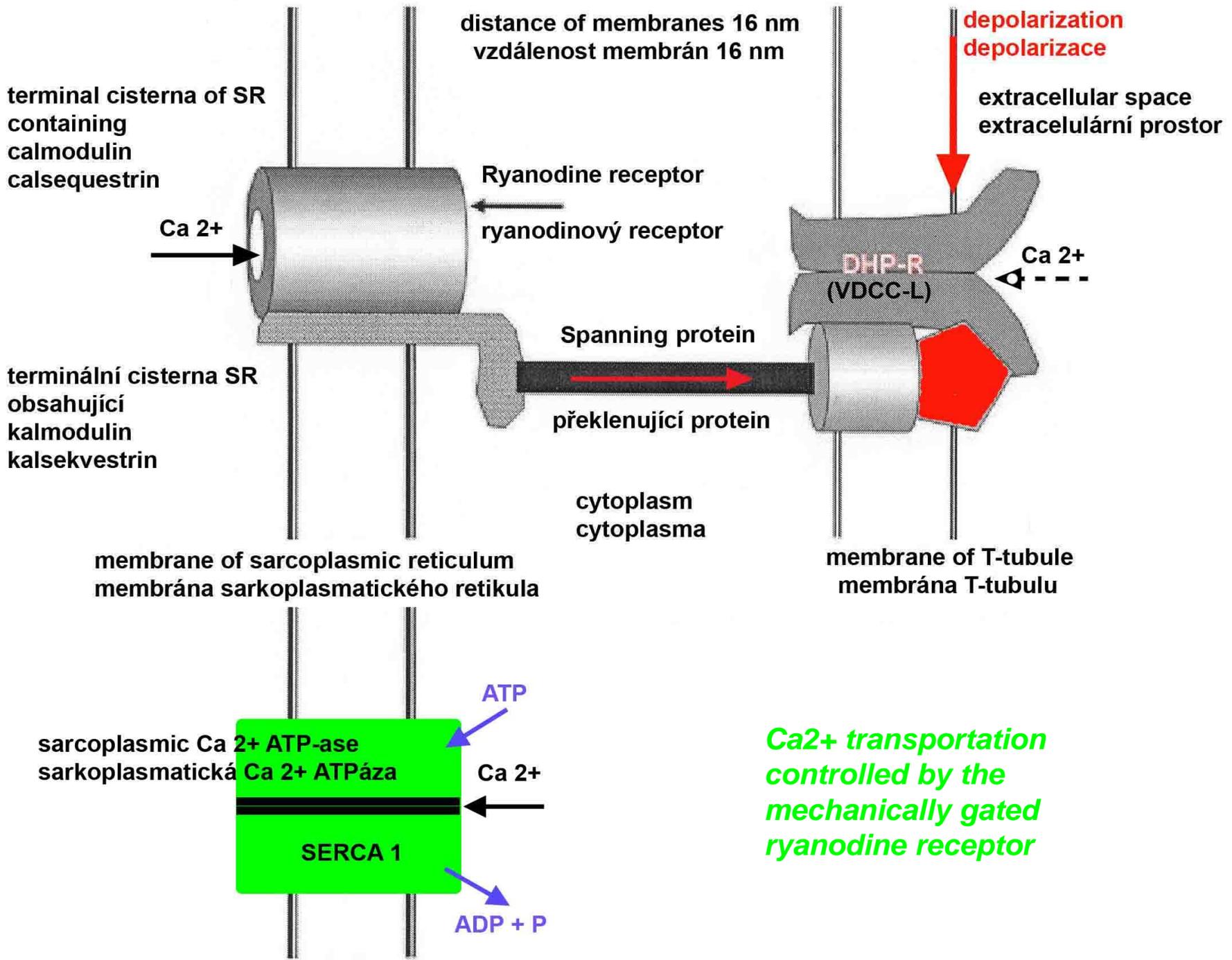
Regulation of muscle contraction

Skeletal muscle (motor-end plate)



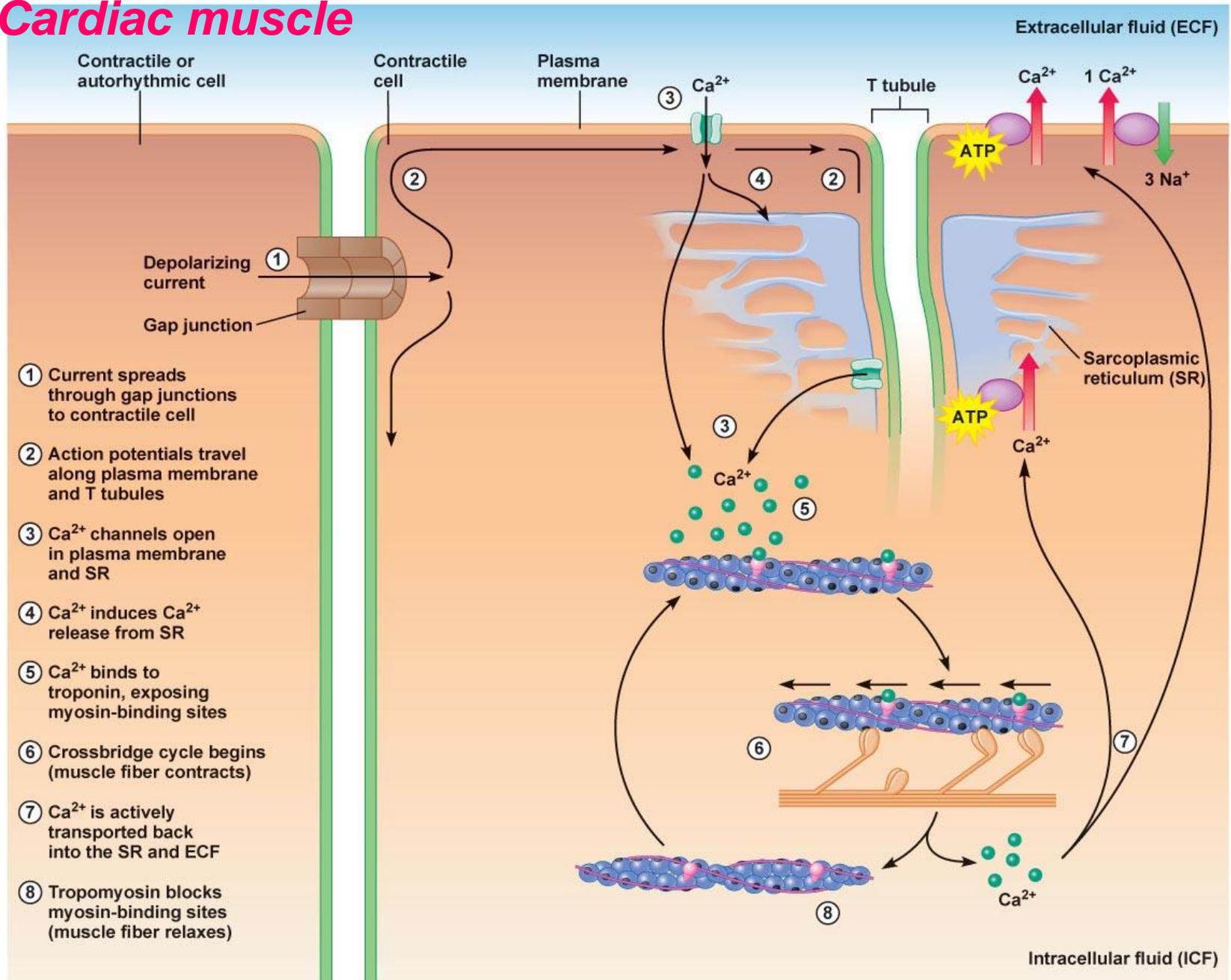
M = mitochondria
G = synaptic vesicles
C = synaptic cleft
JF = junctional folds
S = sarcoplasm





Ca²⁺ transportation controlled by the mechanically gated ryanodine receptor

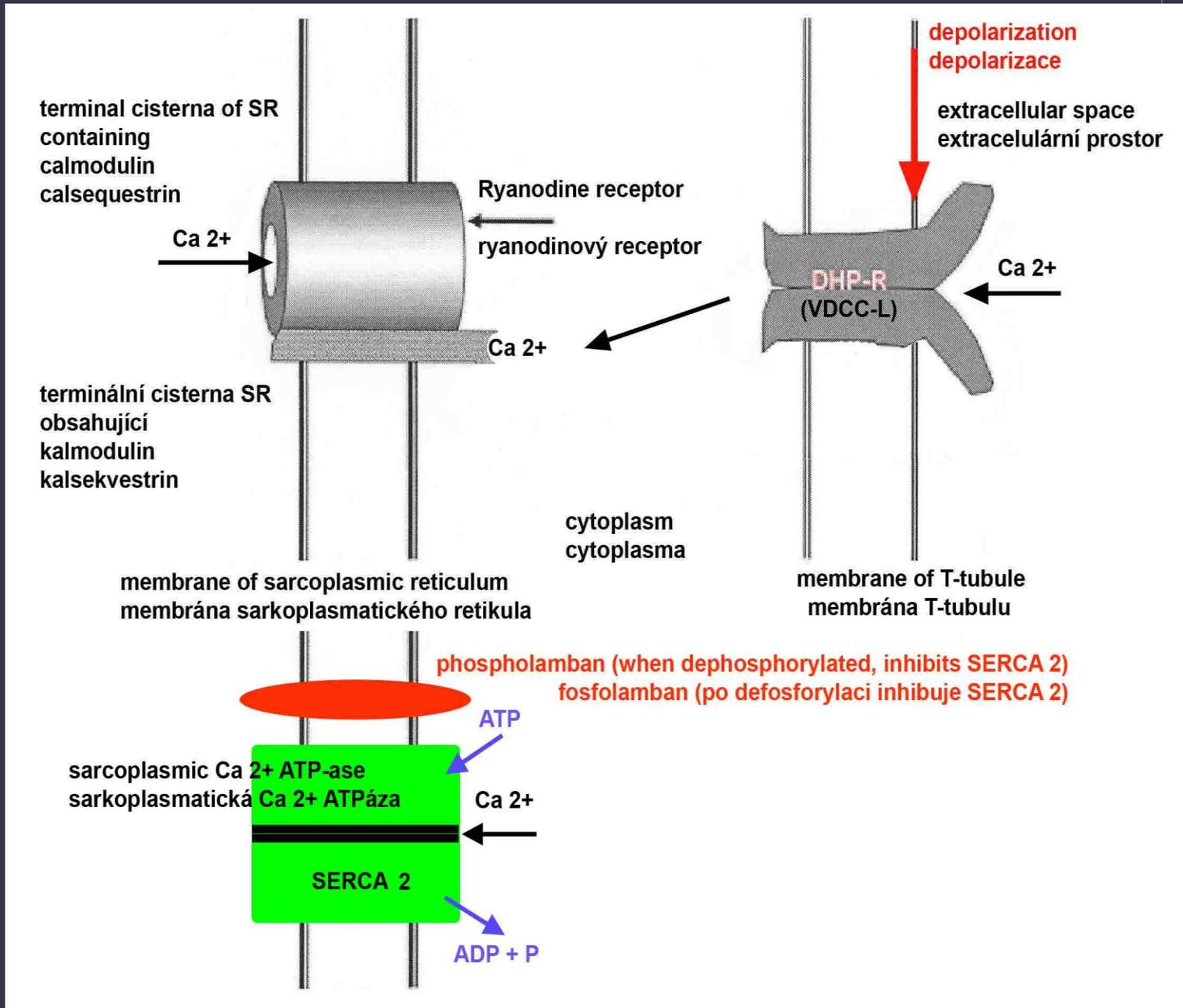
Cardiac muscle



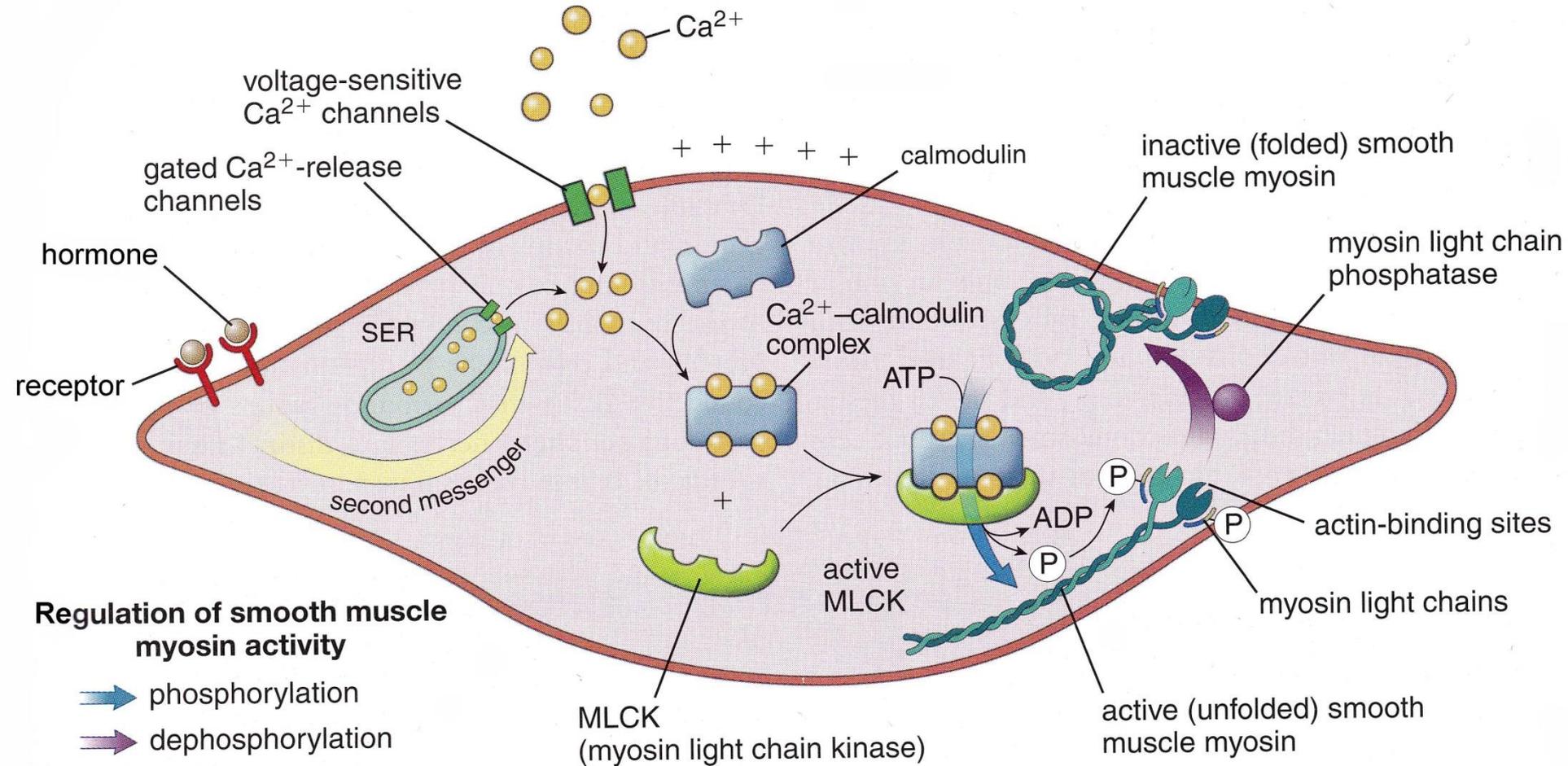
transport of Ca^{2+} is controlled by the Ca^{2+} -gated ryanodine receptor

calstabin 2 closes the channel

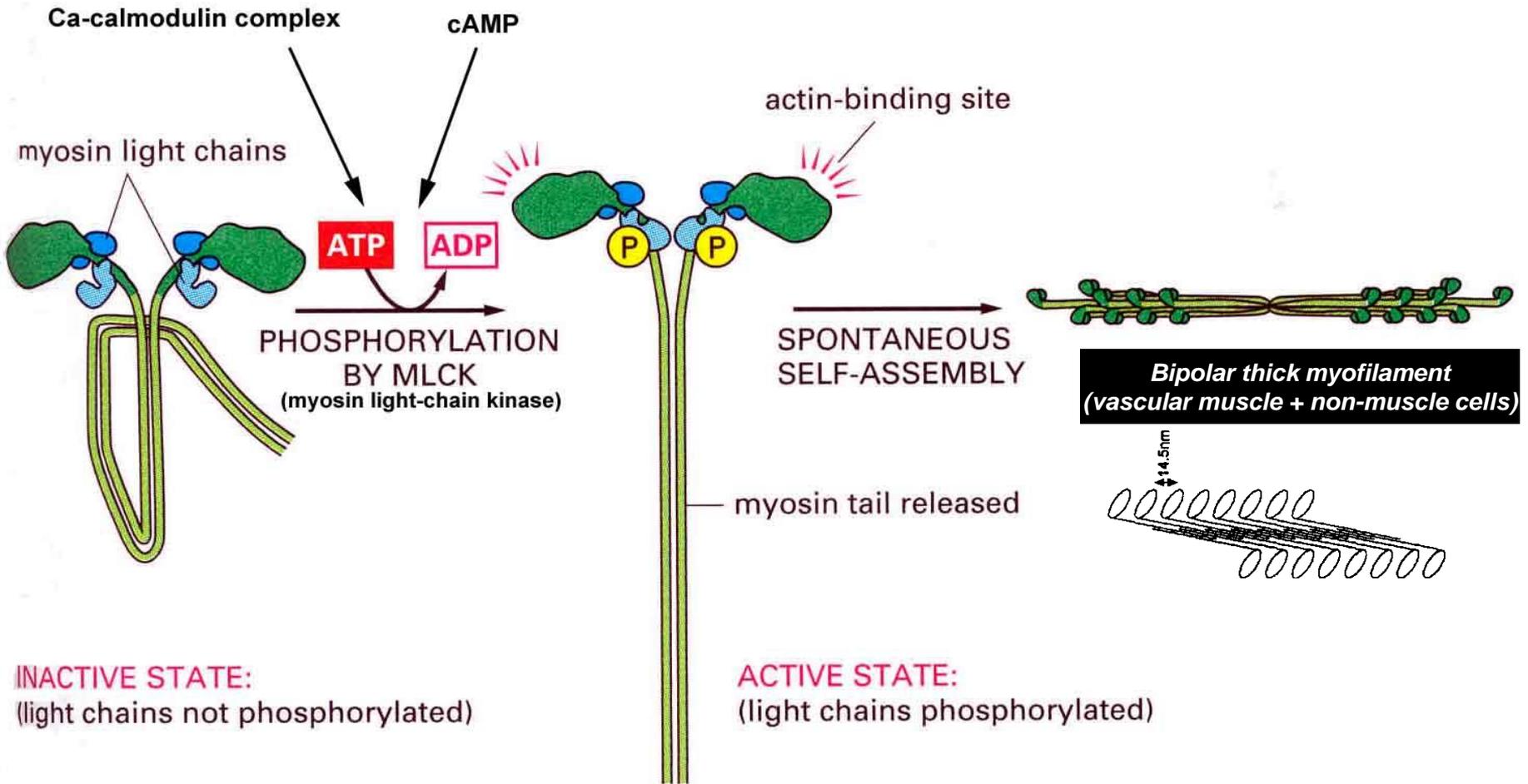
Ca^{2+} "leak" causes an abnormal contraction (arrhythmia)



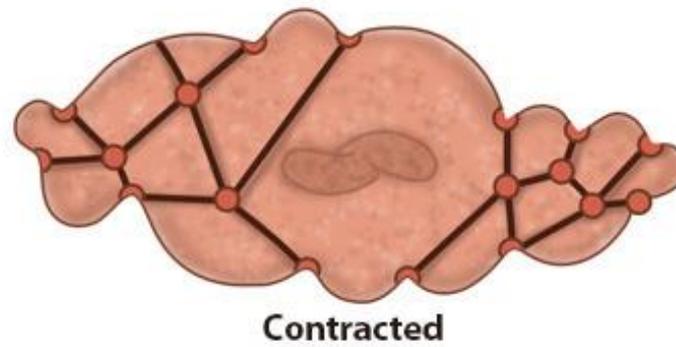
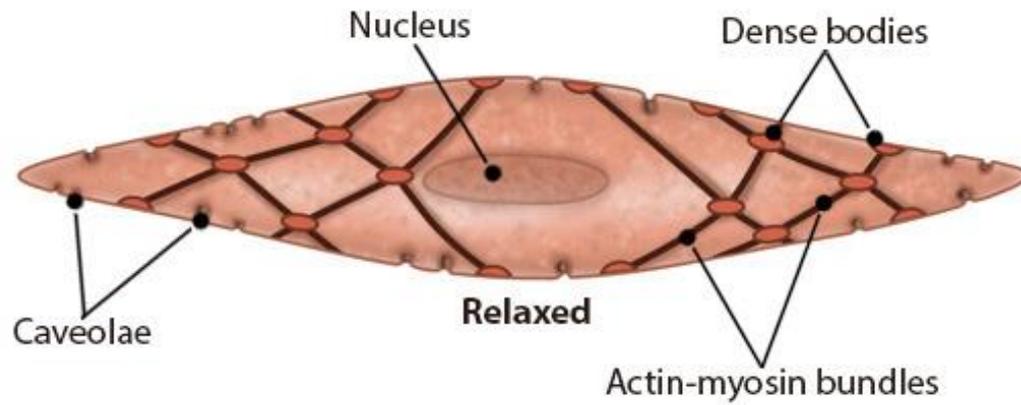
Smooth muscle



Contraction of smooth muscle and non-muscle cells



interaction of actin and myosin then proceeds just as in cross-striated muscle



Thank you for your attention

