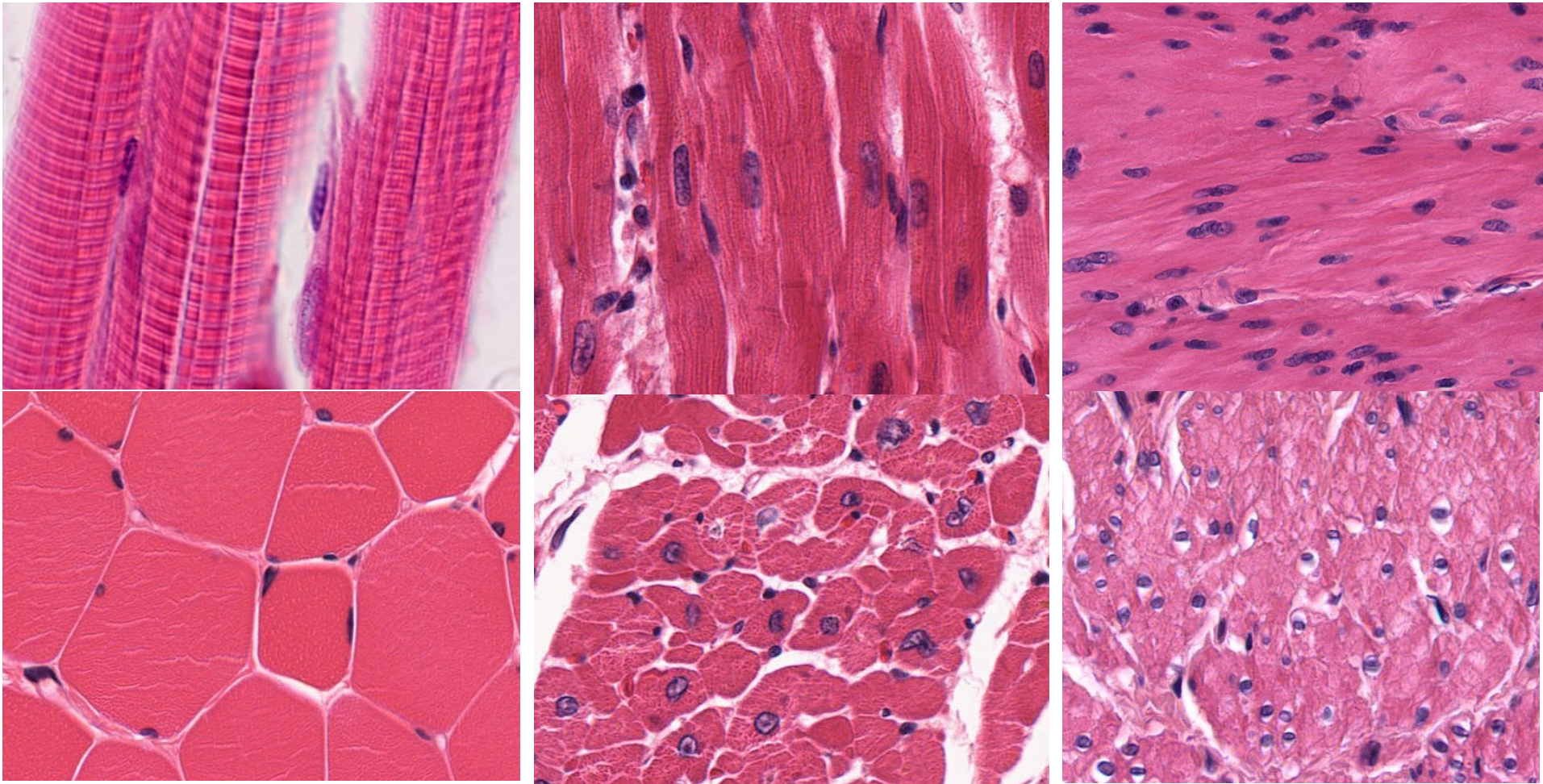


# Muscle tissue



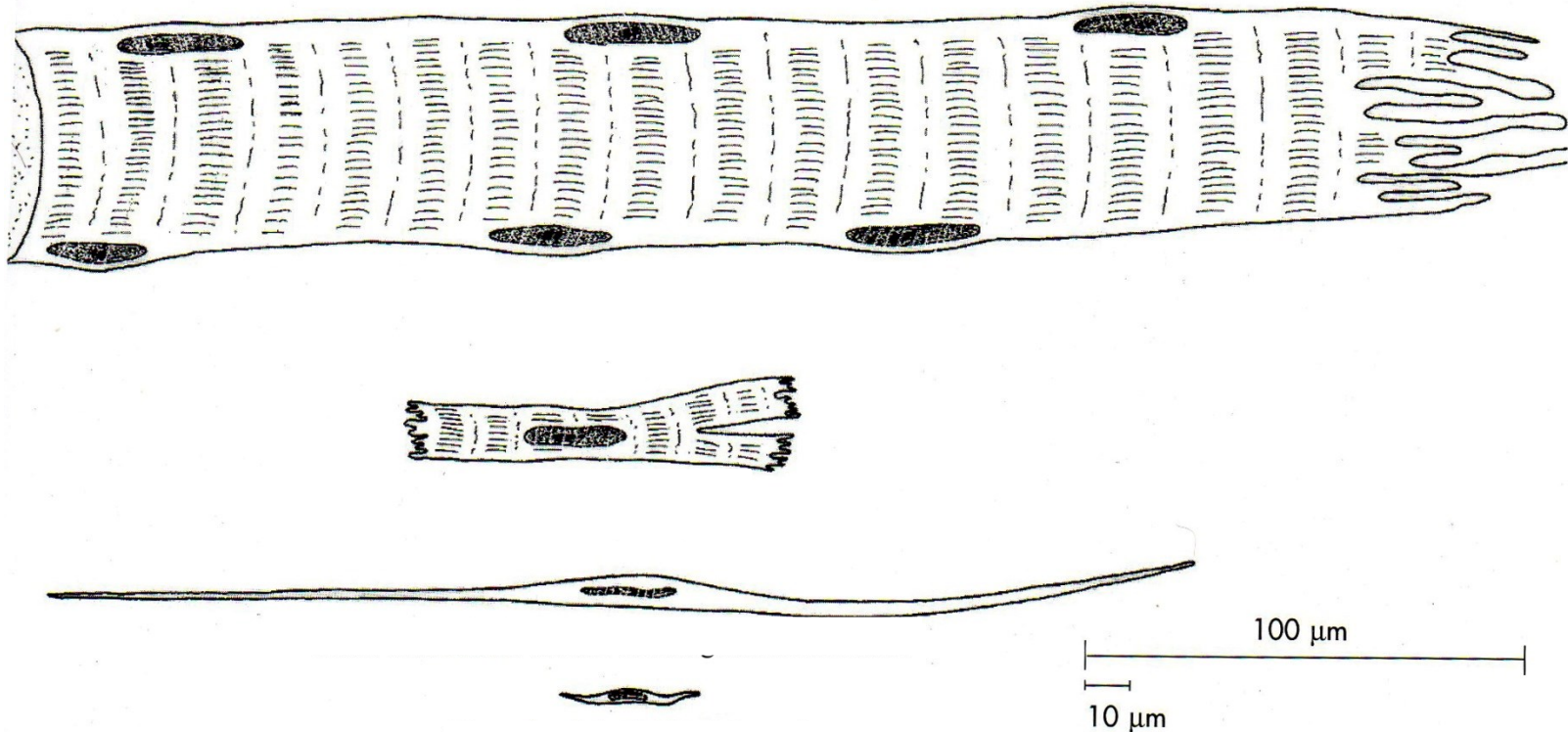
Dr. Emese Pálfi

Semmelweis University

Department of Anatomy, Histology and Embryology

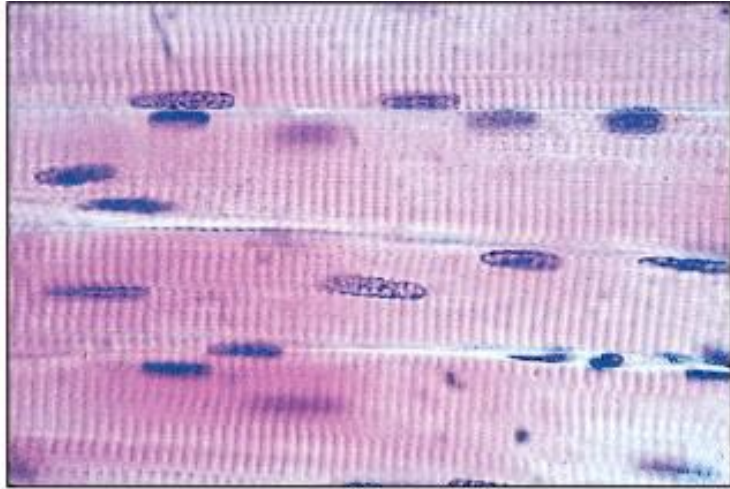
# Muscle tissue

- converting chemical energy into mechanical work >> well developed in muscle tissue
- skeletal component: actin  
contractile element: myosin





# Skeletal muscle

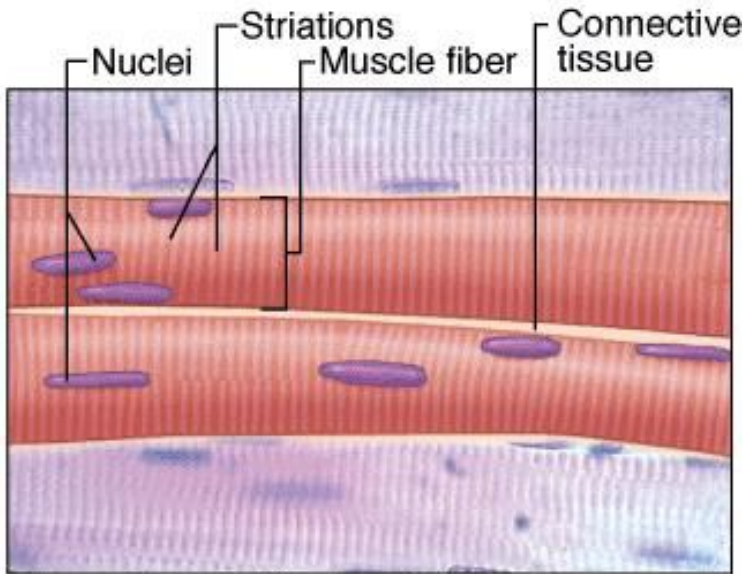


Unit: **muscle fiber**

$d = 5-10 \mu\text{m}$

$l = 1-2 \text{ mm}-50 \text{ cm}$

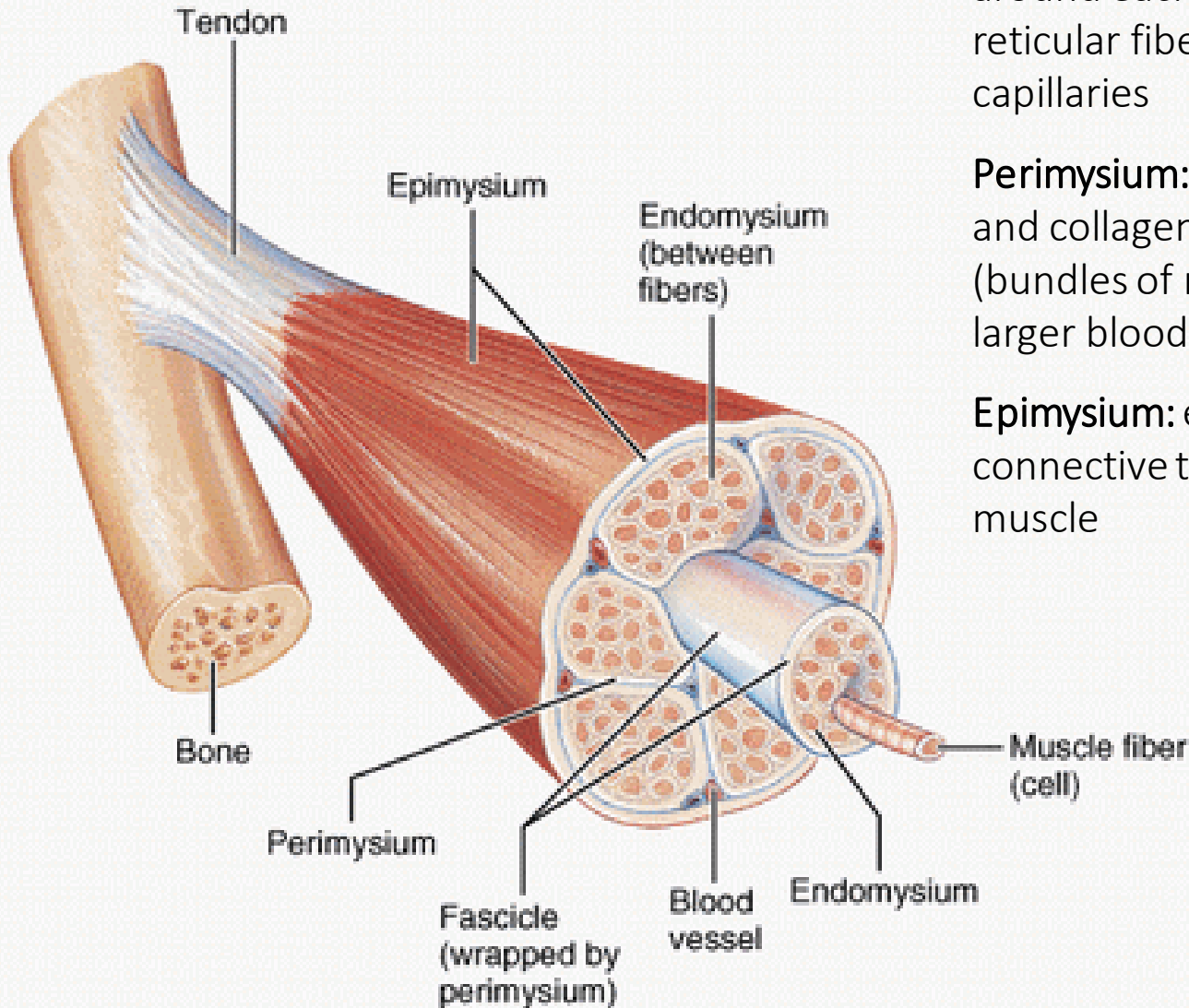
- basal lamina
- myoblast fusion >> syncytium
- flattened oval nuclei (up to 100/muscle fiber) under the sarcolemma
- many mitochondria
- reserve energy: lipid droplets, glycogen particles
- satellite cells: beneath the basal lamina, regeneration



- fast
- voluntary control
- produces great force in a short time

**a** Skeletal muscle

# Organization of skeletal muscle



**Endomysium:** loose connective tissue around each muscle fiber (basal lamina, reticular fibers, fibroblast), containing capillaries

**Perimysium:** connective tissue (elastic and collagen fibers) around each fascicle (bundles of muscle fibers) and route for larger blood vessels

**Epimysium:** external sheath of dense connective tissue surrounding the entire muscle

### Fast / glycolytic / white muscle fiber (1):

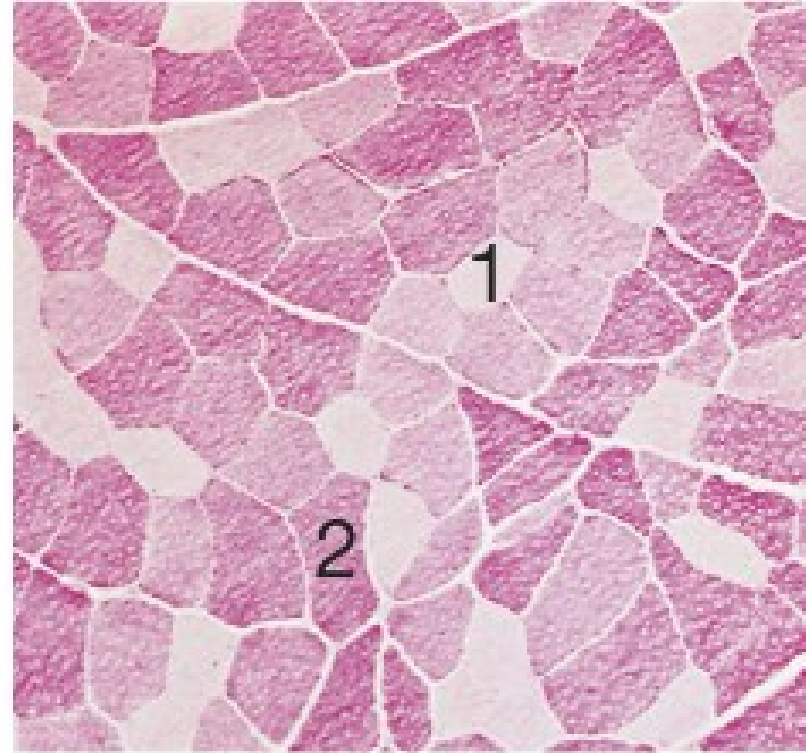
- few mitochondria
  - high glycogen content
  - large diameter
  - few capillaries
  - rapid contraction but fatigue quickly
- m. biceps brachii, m. rectus abdominis, eye muscles*

### Slow / oxidative / red muscle fiber (2):

- many large mitochondria
  - high lipid content
  - low glycogen content
  - small diameter
  - darker appearance due to the many myoglobin and capillaries
  - continuous contractions over prolonged periods,
- m. masseter, diaphragm, core muscles*

### Intermediate / oxydative-glycolitic muscle fiber:

- myoglobin rich
- many capillaries
- oderate glycogen content
- mall and medium diameter
- rapid contraction, with medium fatigue

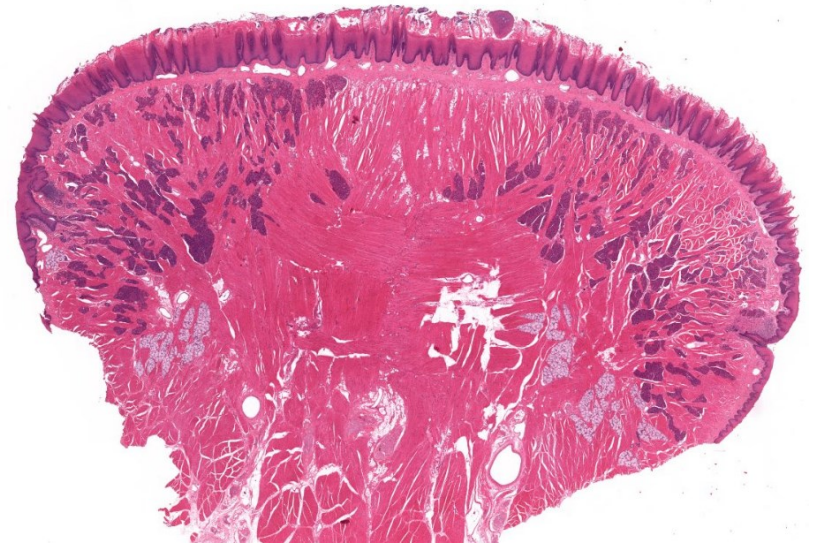
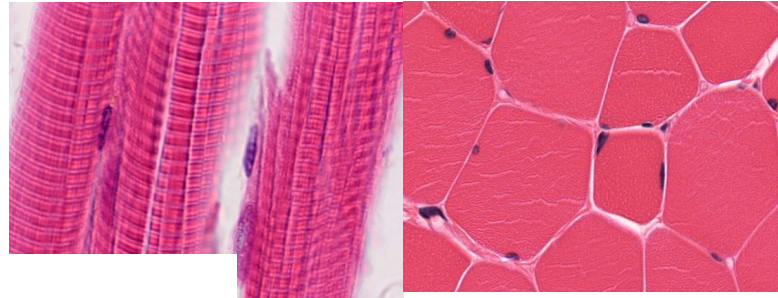


## Skeletal muscle

- unit: muscle fibre
- origin and insertion on bony structures
- contraction arises due to nerve stimulation

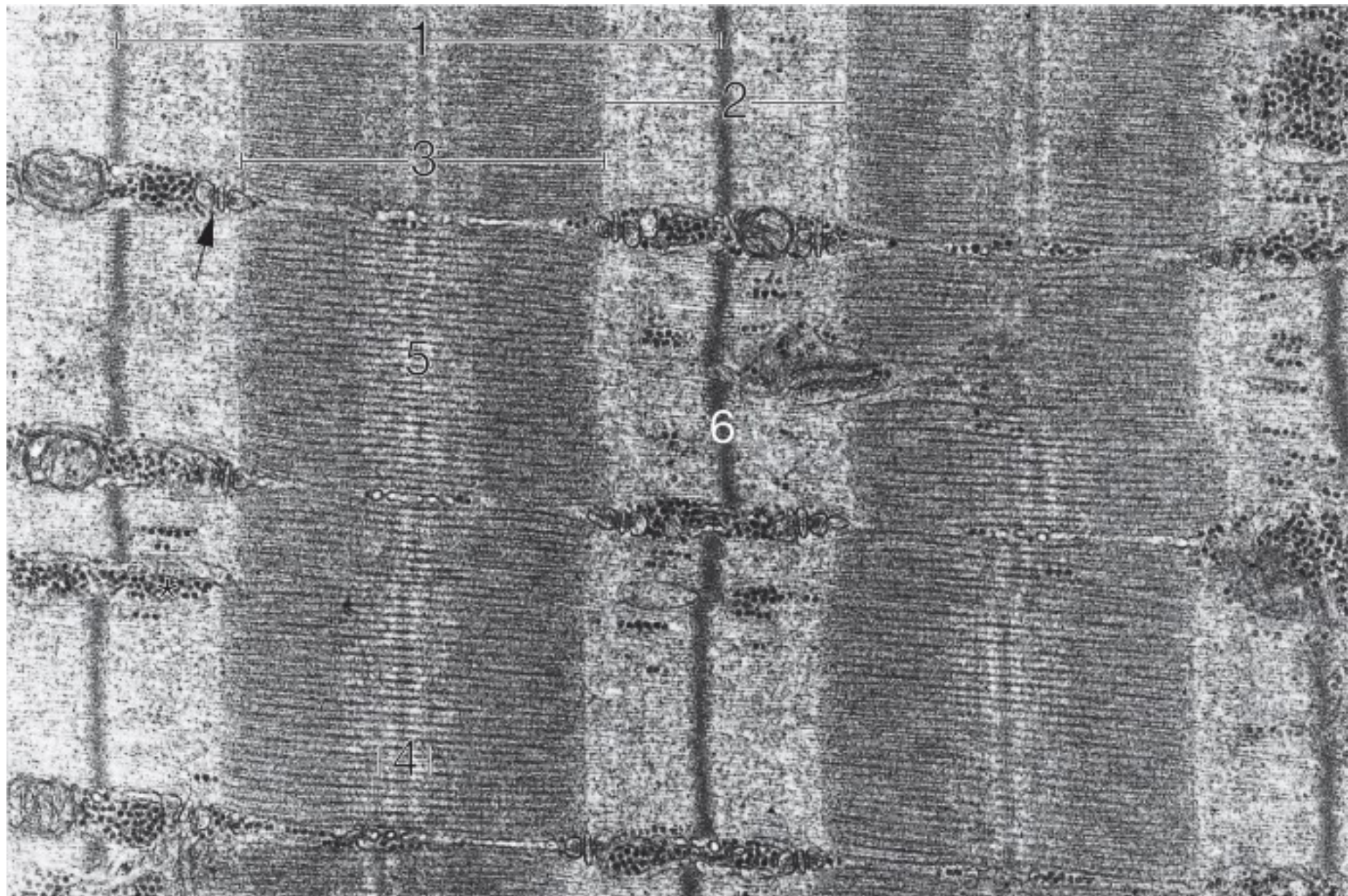
## Visceral

- internal muscles of the tongue, upper third of oesophagus
- unit: muscle fibre
- independent from skeletal elements
- contraction arises due to nerve stimulation





# Sarcomer



# Actin

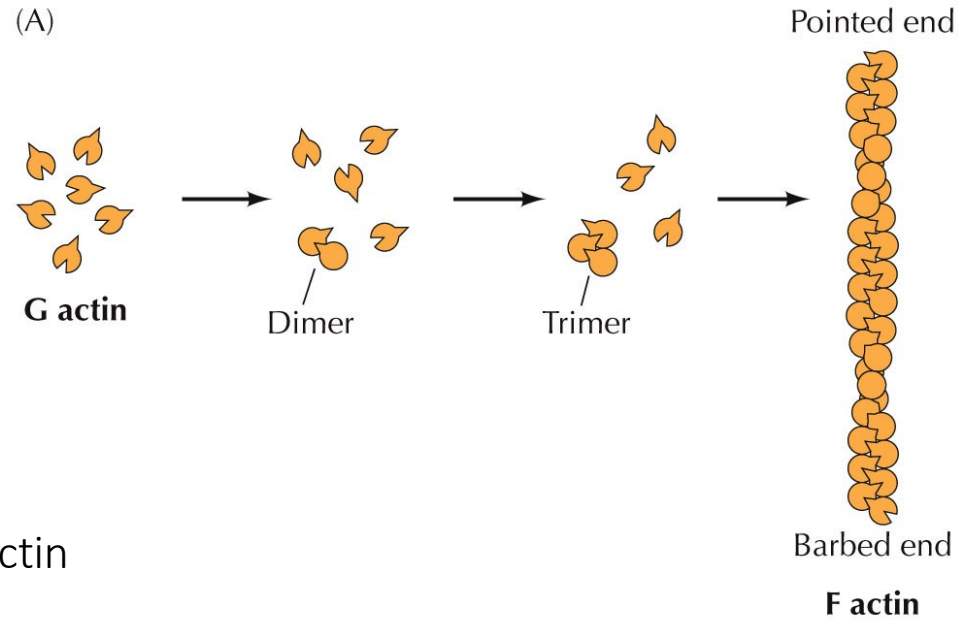
## 1. Actin (thin filament)

G-Actin (globular) = actin monomer

- ATP binding site
- myosin head binding site

F-actin (filamentary)

- $d = \sim 6\text{-}8\text{ nm}$ ,  $l = \sim 1\text{ }\mu\text{m}$
- treadmilling



## 2. Tropomyosin (filamentous protein)

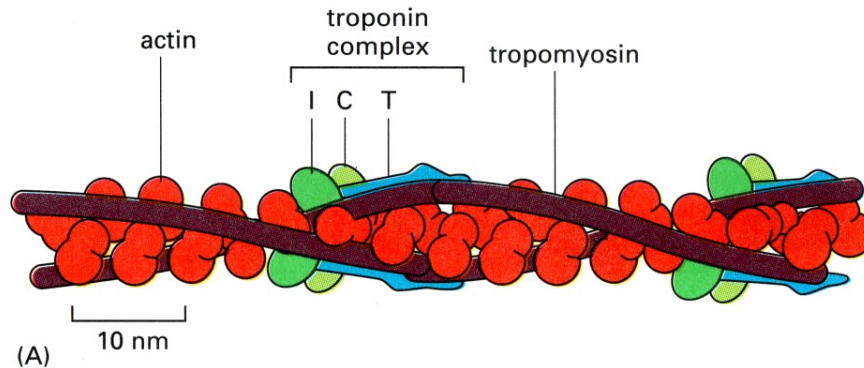
blocks the myosin binding site on the actin

## 3. Troponin complex

TnT - binds the complex to tropomyosin

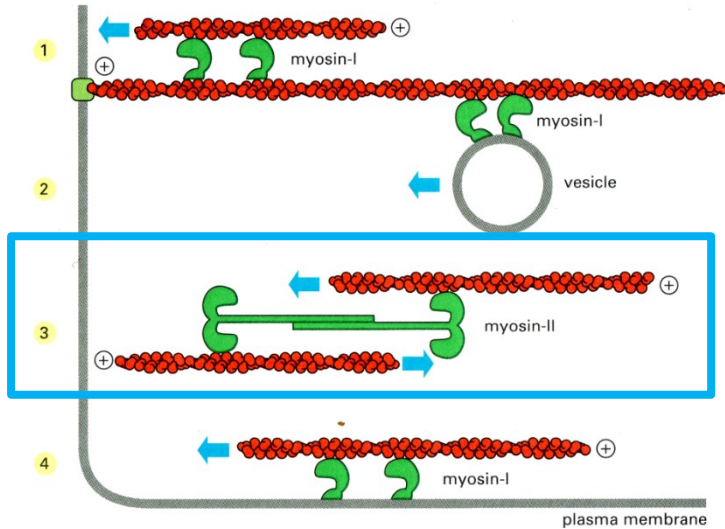
TnC - can bind calcium

TnI - inhibits the binding of myosin heads to actin in resting state





# Myozin



## Myozin I Myozin II

1. Moves the actin filaments relative to each other (Myosin I)
2. Vesicular transport (Myosin I)
3. Contraction (Myosin II): sliding the actin filaments relative to one another
4. Movement of the actin filament relative to the membrane (Myosin I)

## Myosin II (thick filament)

$d = \sim 15 \text{ nm}$

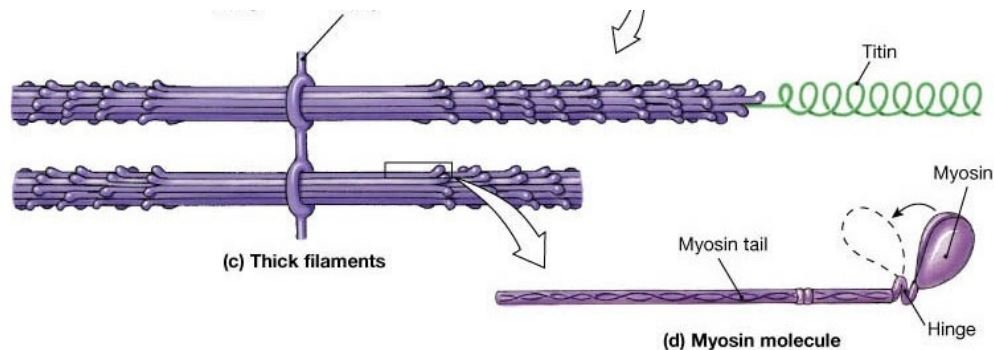
$l = \sim 1,5 \mu\text{m}$

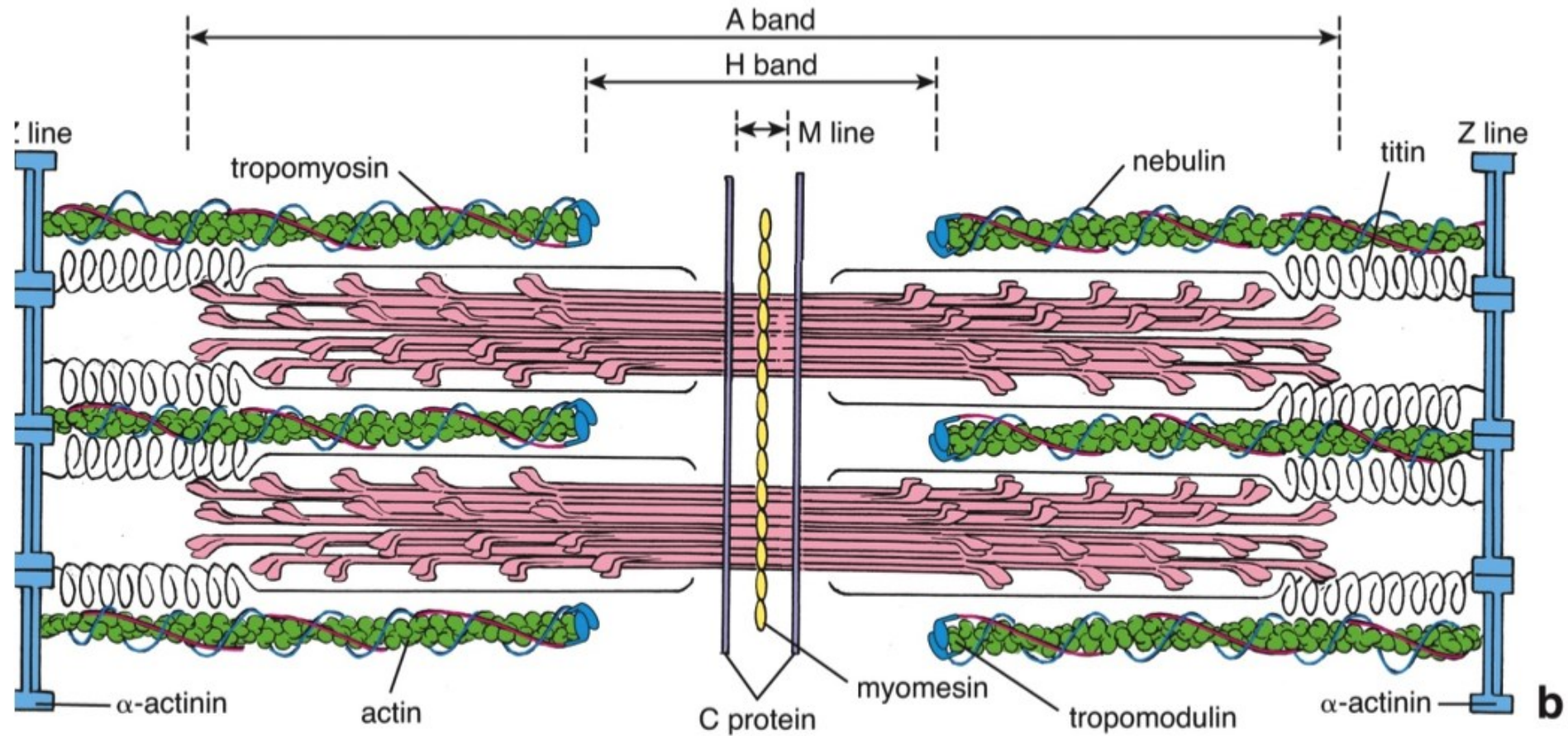
Main component: bundle of myosin filaments ( $\sim 350$  myosin molecules)

- ATP-dependent motor protein moves to the (+) end of the actin

## Myosin molecule

- 2 heavy chains form tail and globular end (head)
- head: ATPase activity
- 2 light chains - neck area
- neck is movable  $\gg$  joint region





**Nebulin** - determination the length of the actin

**Titin** - provides elasticity and resistance for muscle fibers

**b**

**Sarcomer:** (2-3  $\mu\text{m}$ ) between 2 Z lines

**A-band:** anisotropic, thicker, dark  
1.5  $\mu\text{m}$  long, 15 nm thick  
predominantly myosin + overlapping actin filaments  
length remains unchanged during contraction

**I-band:** isotropic, thinner, brighter  
1  $\mu\text{m}$  long, 7 nm thick  
predominantly actin  
shortens during contraction

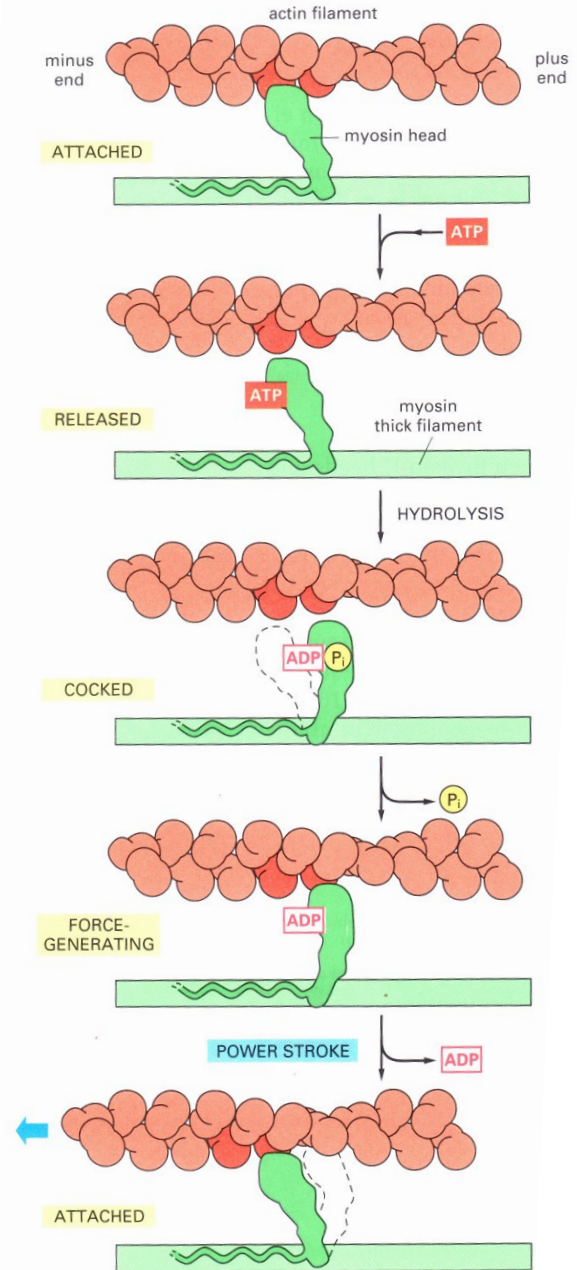
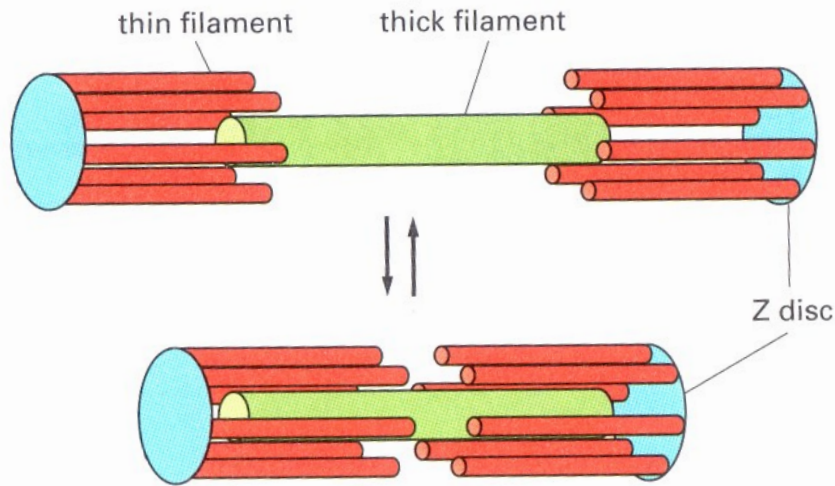
**Z-line:**  $\alpha$ -Actinin  
desmin

**H-band:** a bright area in the middle of the A-band  
only myosin

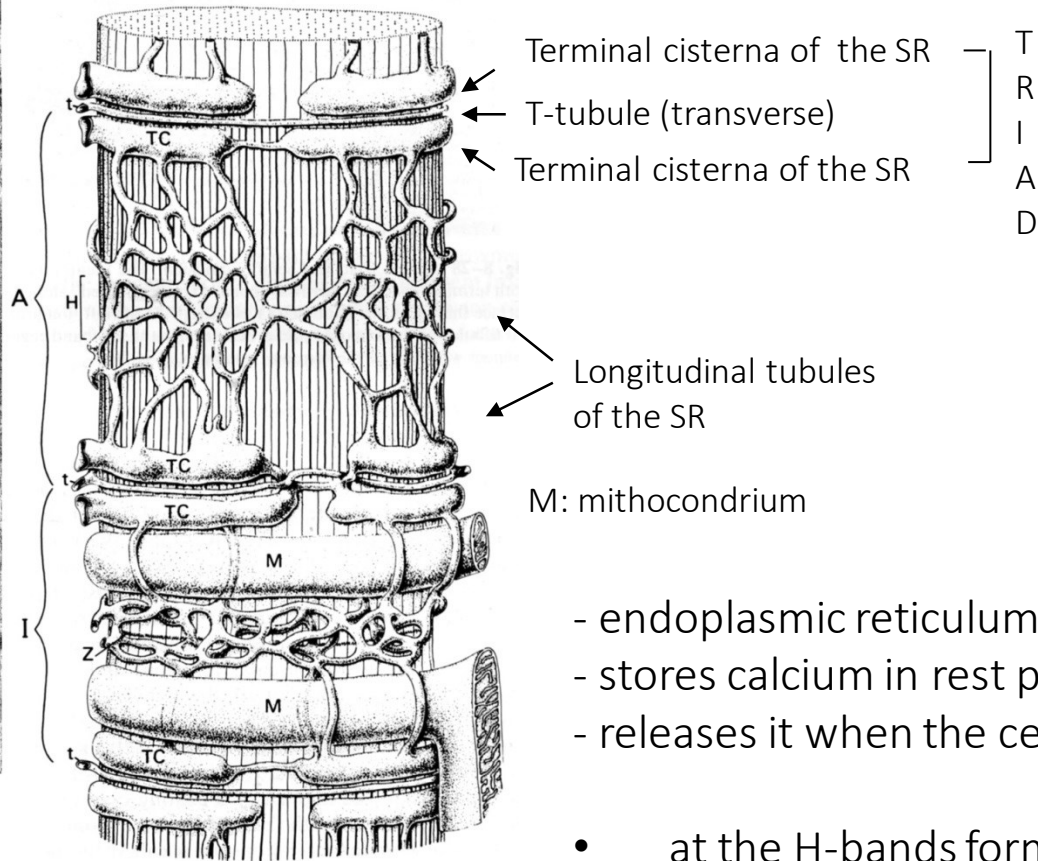
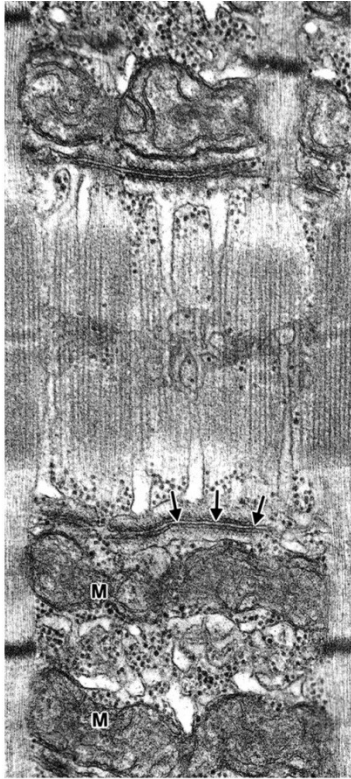




# Sliding filament hypothesis



# Sarcoplasmic reticulum (SR)



- endoplasmic reticulum with smooth surface
- stores calcium in rest phases
- releases it when the cells are excited

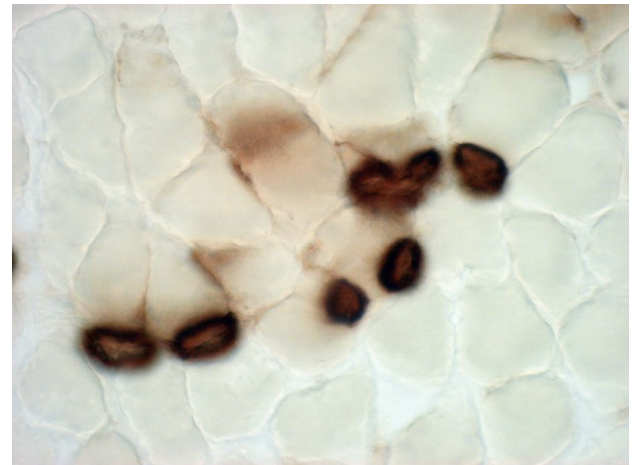
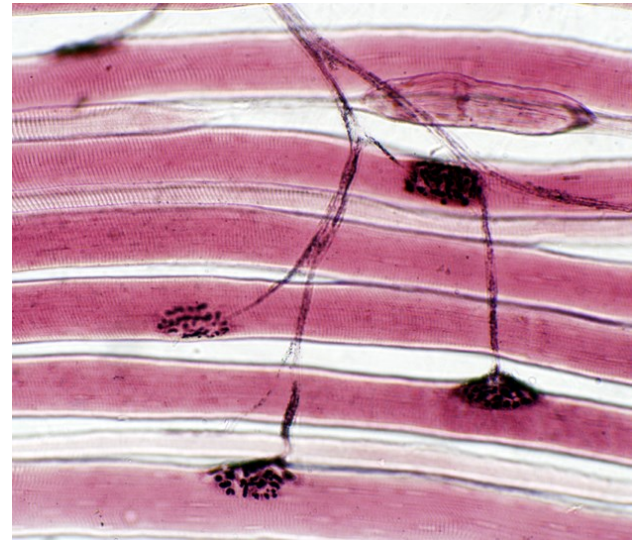
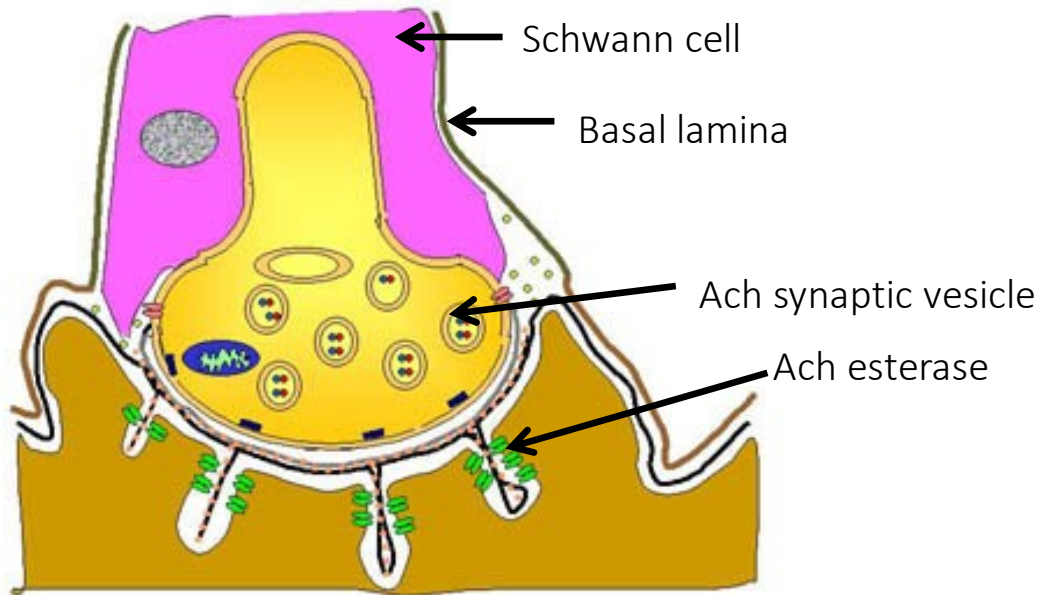
- at the H-bands forms a network
- Terminal cisterns (junctional reticulum)
- T-Tubulus: invagination of cell membrane

Stimulus (T-tubule) →  $\text{Ca}^{2+}$  released from SR →  $\text{Ca}^{2+}$  binds TnC → tropomyozin moves further → actin + myozinhead binds together

# Motor unit

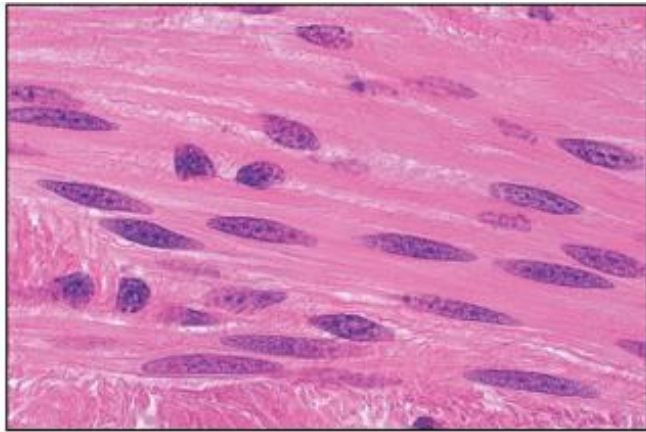
## Neuromuscular junction/motor end plate

**Motor unit:** motorneuron (spinal cord or brainstem) and the innervated muscle cells. The contraction is voluntary.





# Smooth muscle

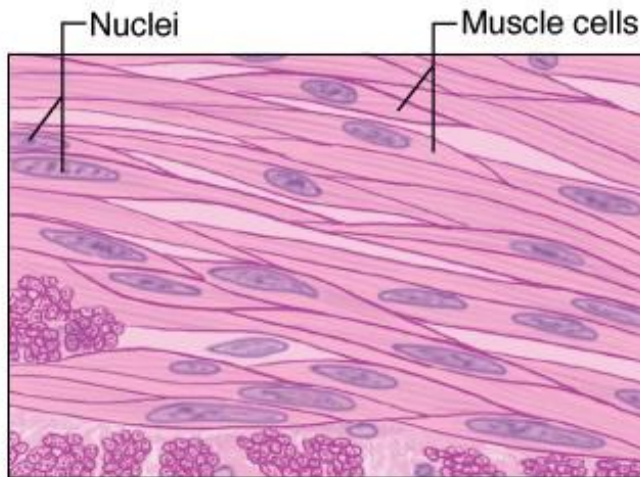


Unit: **smooth muscle cell** (myocyte)

d = 3-8  $\mu\text{m}$

l = 15-800  $\mu\text{m}$

- basal lamina
- non-striated: contractile elements-myofilaments (not arranged in the ordered manner)
- mononuclear, rod-shaped nucleus, central
- cytoplasm: intensively eosinophilic
- produce collagen and elastic fibers



slow but permanent contraction

high power

low energy consumption

is innervated by the vegetative (autonomous) nervous system

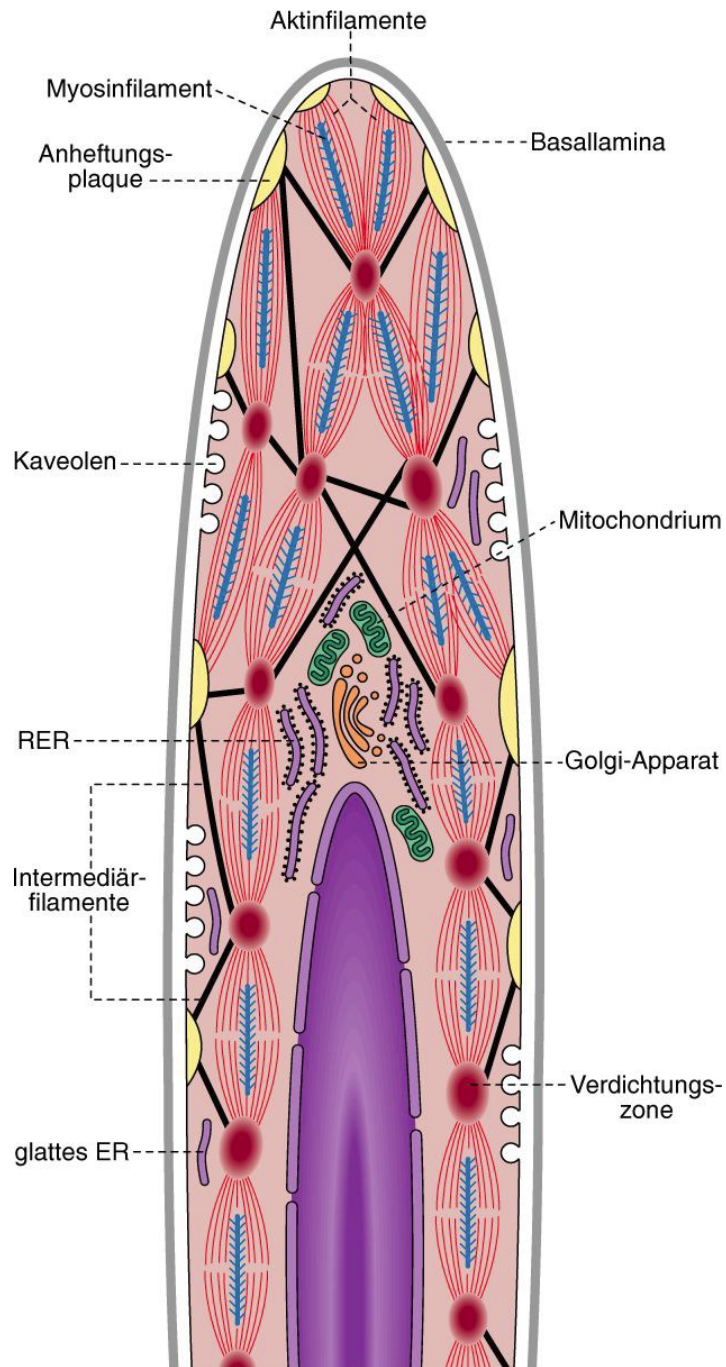
Can be organized in lamelles, bundles.

In the wall of tubular organs (gastrointestinal tract, airways, genital tract, vessels) and in the eye and skin can be also found.

## c Smooth muscle

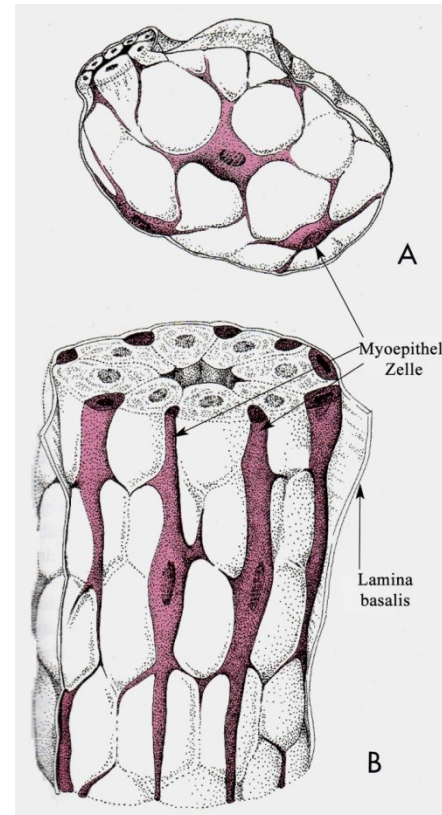
Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition*: <http://www.accessmedicine.com>

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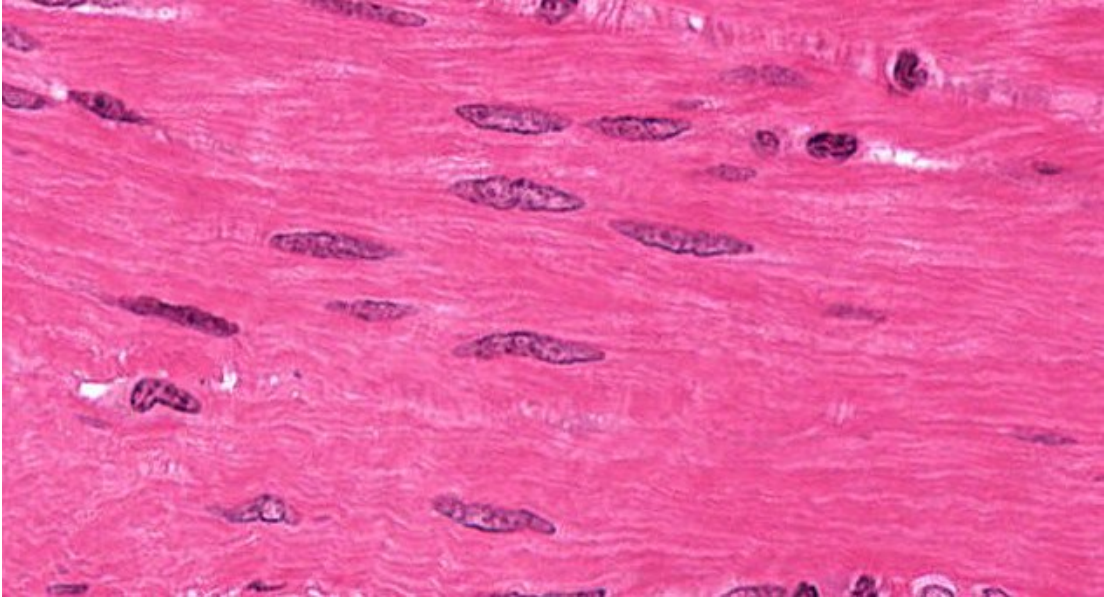
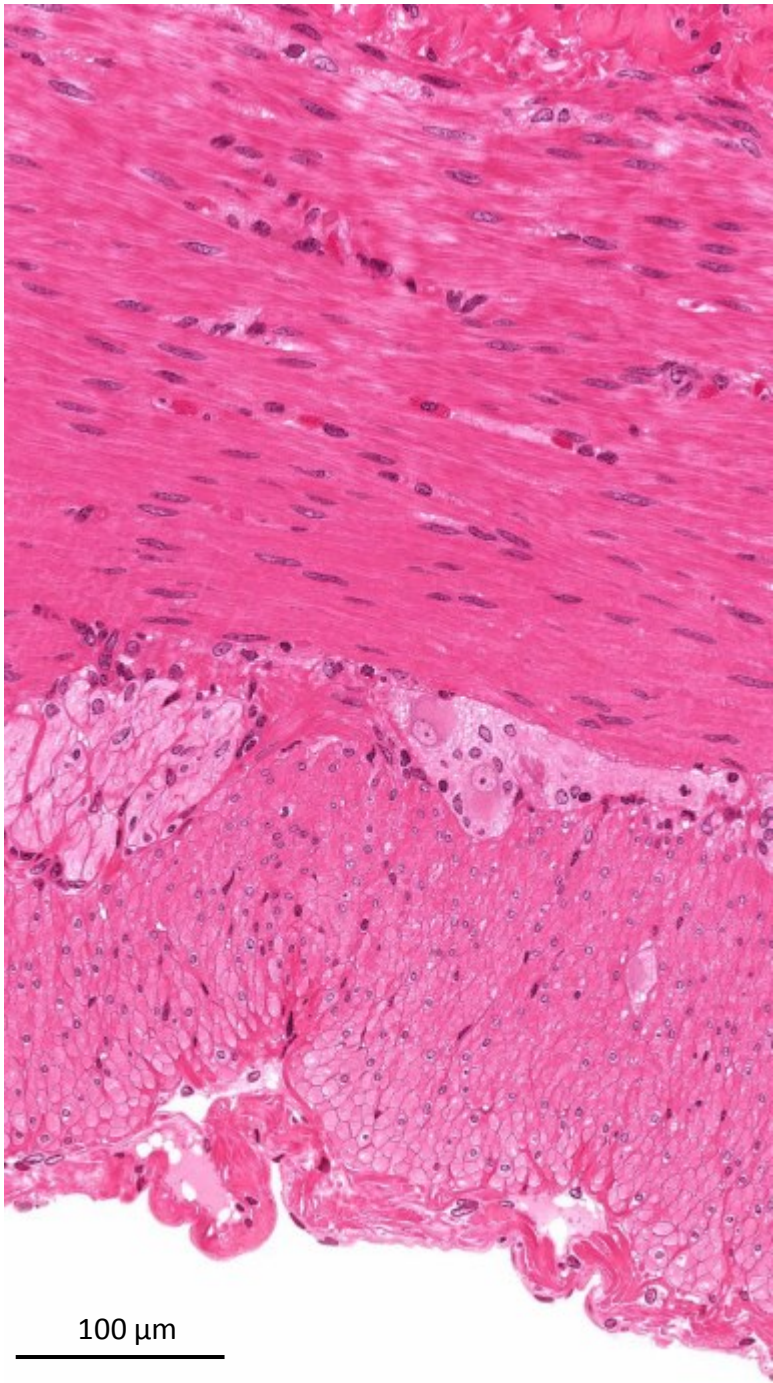


- Actin >> Myosin
- Gap Junction >> Stimulation (spontaneous activity!)

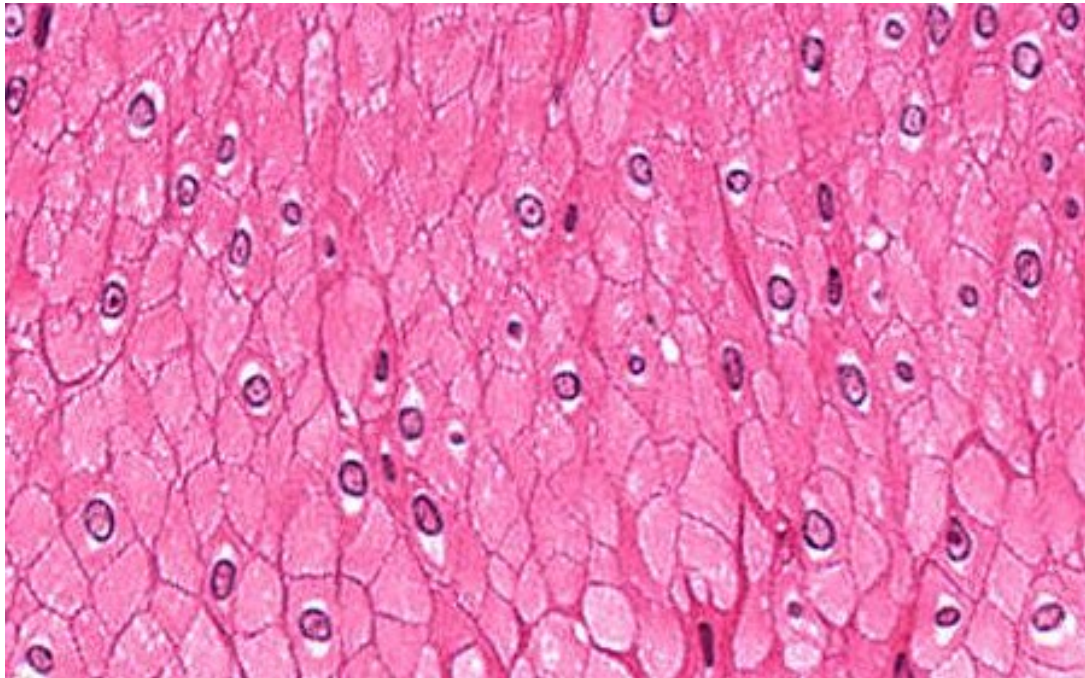
**Myofibroblast:** matrixproduction (collagen, laminin, fibrillin, elastin and proteoglycanes)  
**Myoepithel cells**





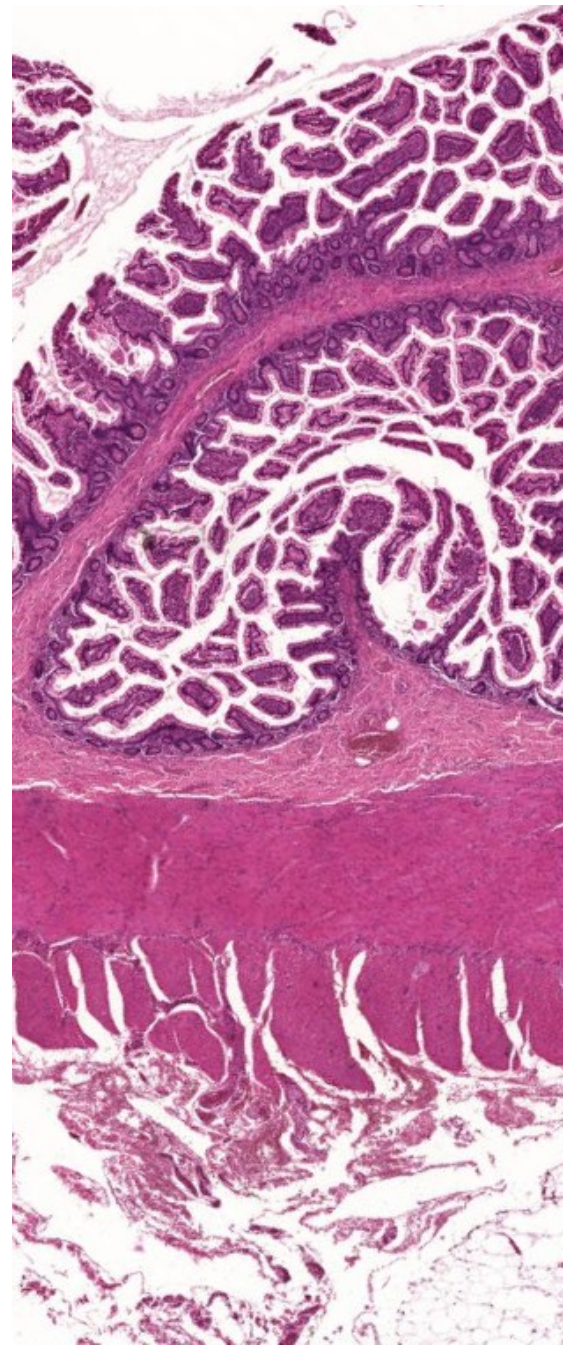
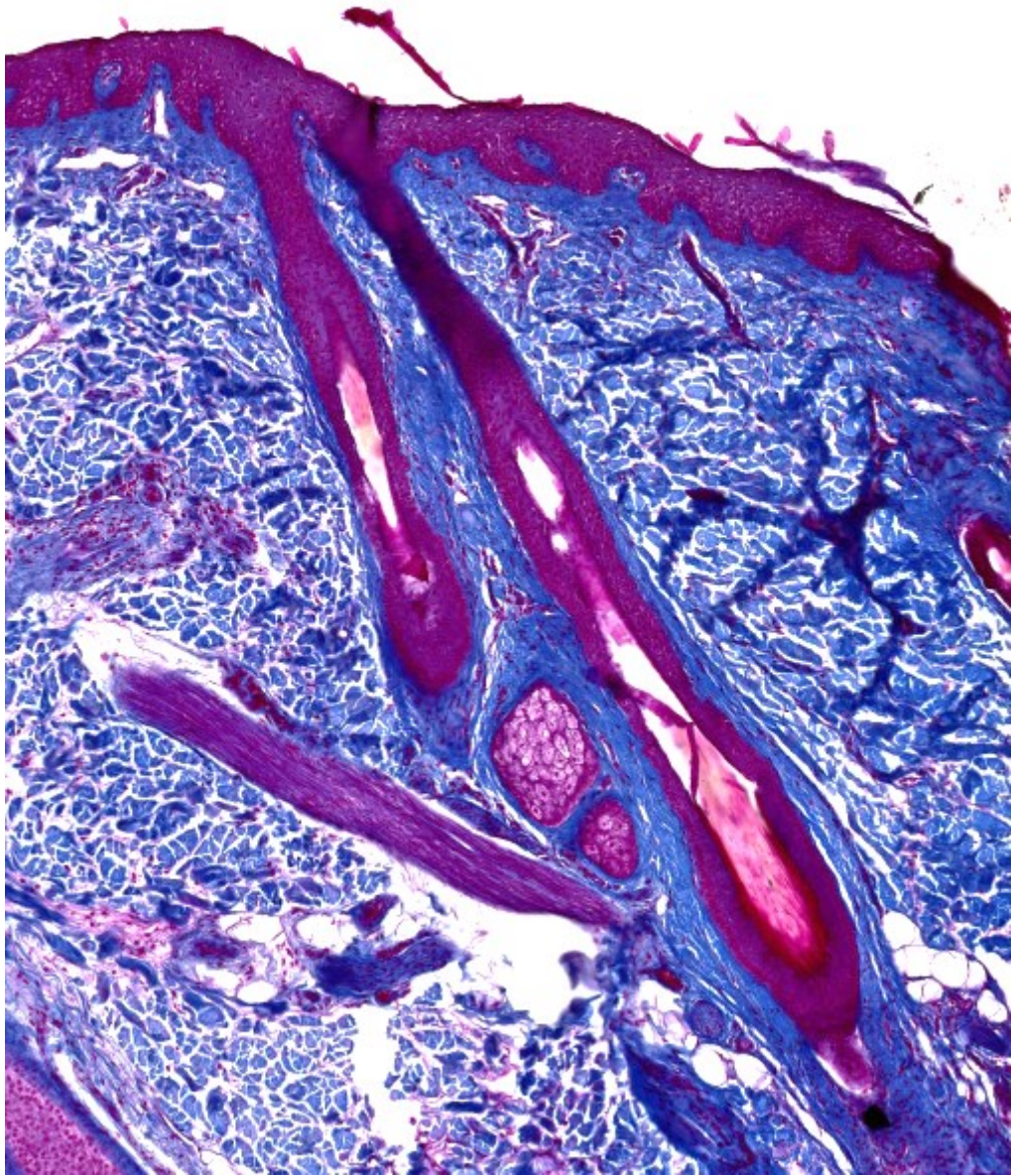


25  $\mu\text{m}$



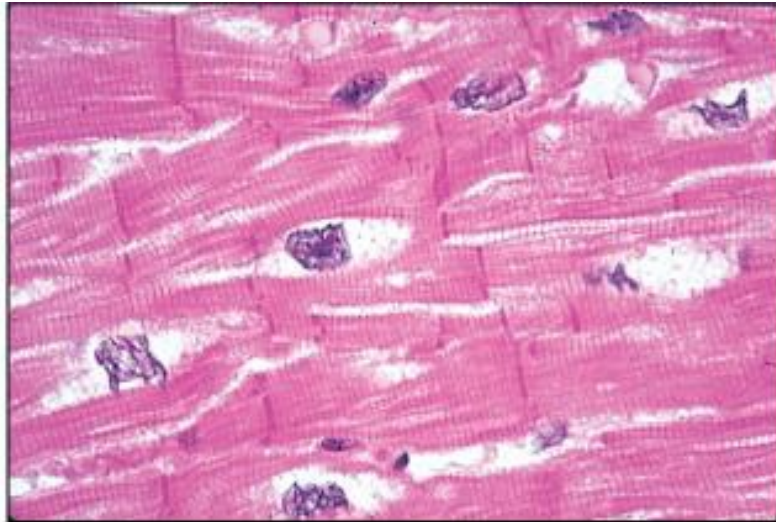
25  $\mu\text{m}$







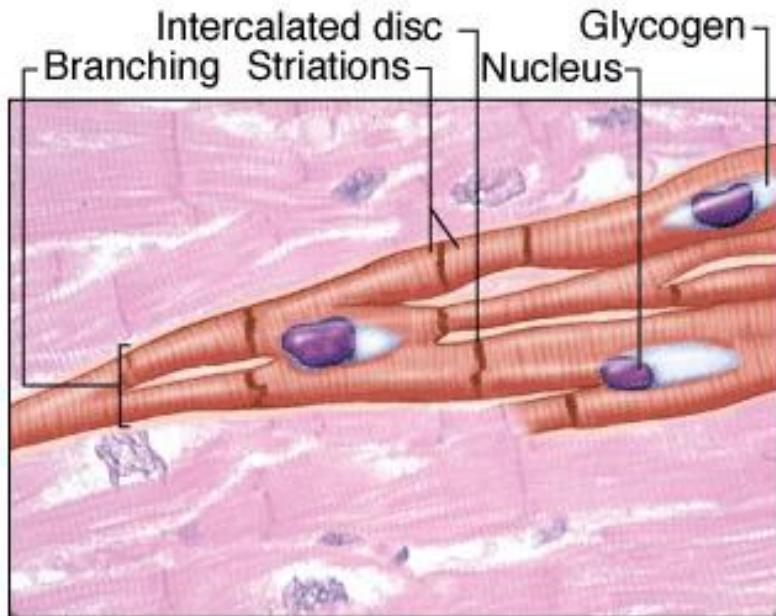
# Cardiac muscle



Unit: **cardiac muscle cell** (functional syncytium)

l= 50-120  $\mu\text{m}$  d= 15-20  $\mu\text{m}$

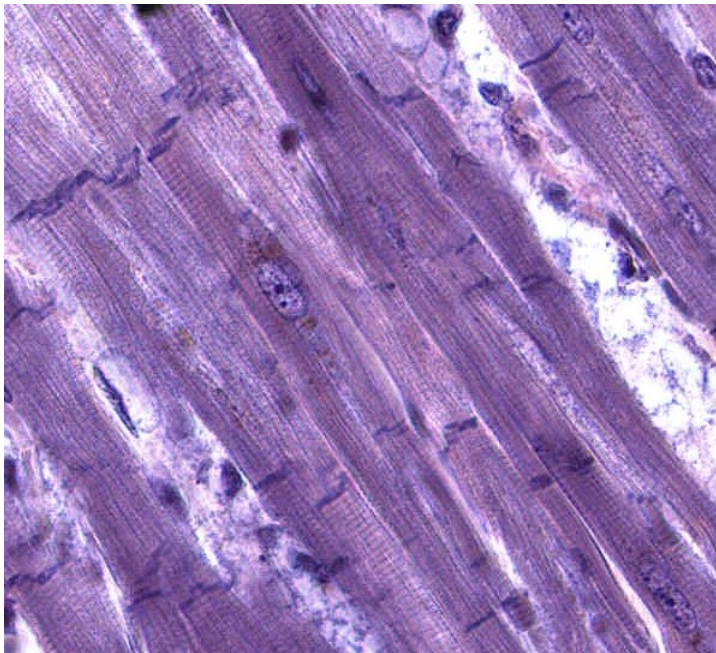
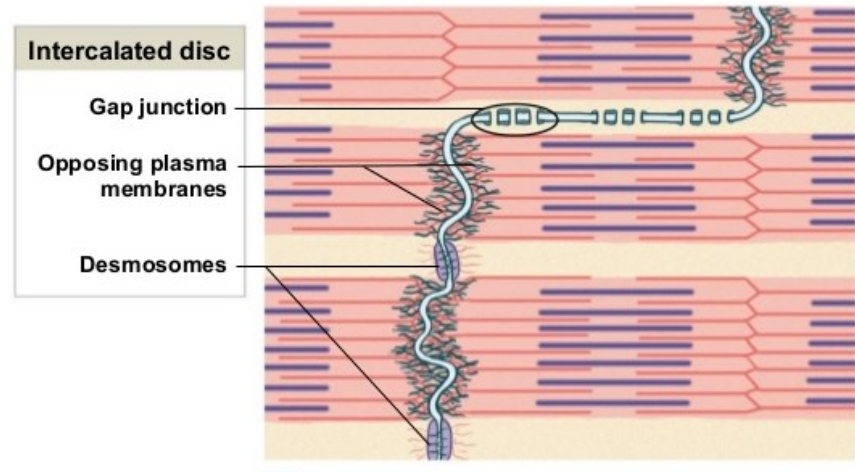
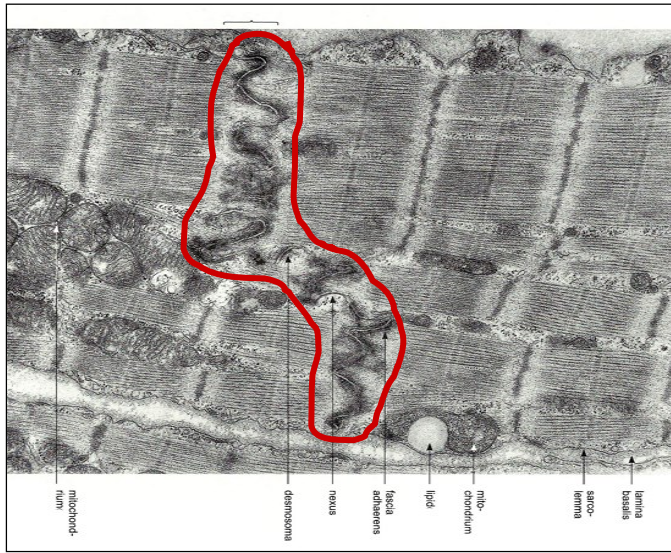
- Y-shaped cells with interdigitating cell extensions
- intercalated discs: end to end junctions between individual cardiac muscle cells
- 1 nucleus, centrally located
- 1-2 nucleoli
- eosinophilic cytoplasm
- cross striated
- glycogen and lipid droplets, lipofuchsin granules
- tireless, works for life
- in the atriums: hormone production



## Purkinje fibers:

modified cardiac muscle cells  
glycogen rich

# Intercalated disc - Eberth line



20µm

mechanical and electrical connection between cells

- LM: a transverse line

EM: step like appearance

transverse parts:

fascia adherens, desmosomes

anchoring the I-strips "Z-line"; cell adhesion with cadherins

longitudinal parts:

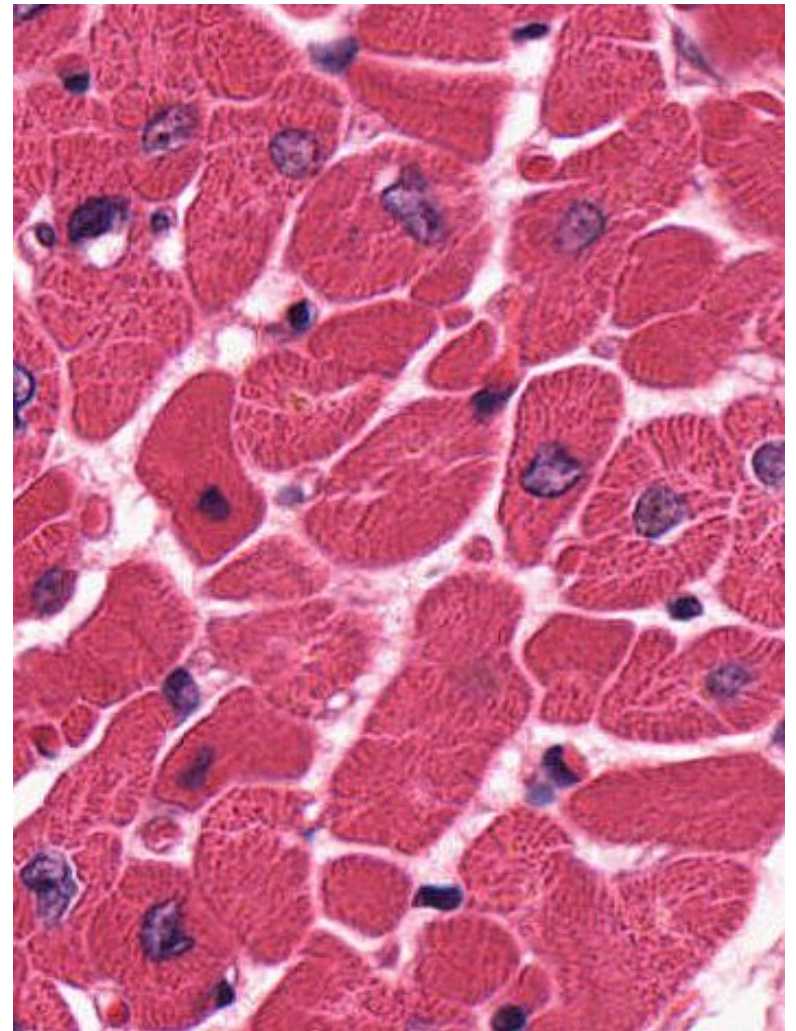
nexus or gap junction (connexin 43)

rapid excitation conduction from cell to cell (functional syncytium)





25μm



25 μm



# Conduction system

## Sinus node

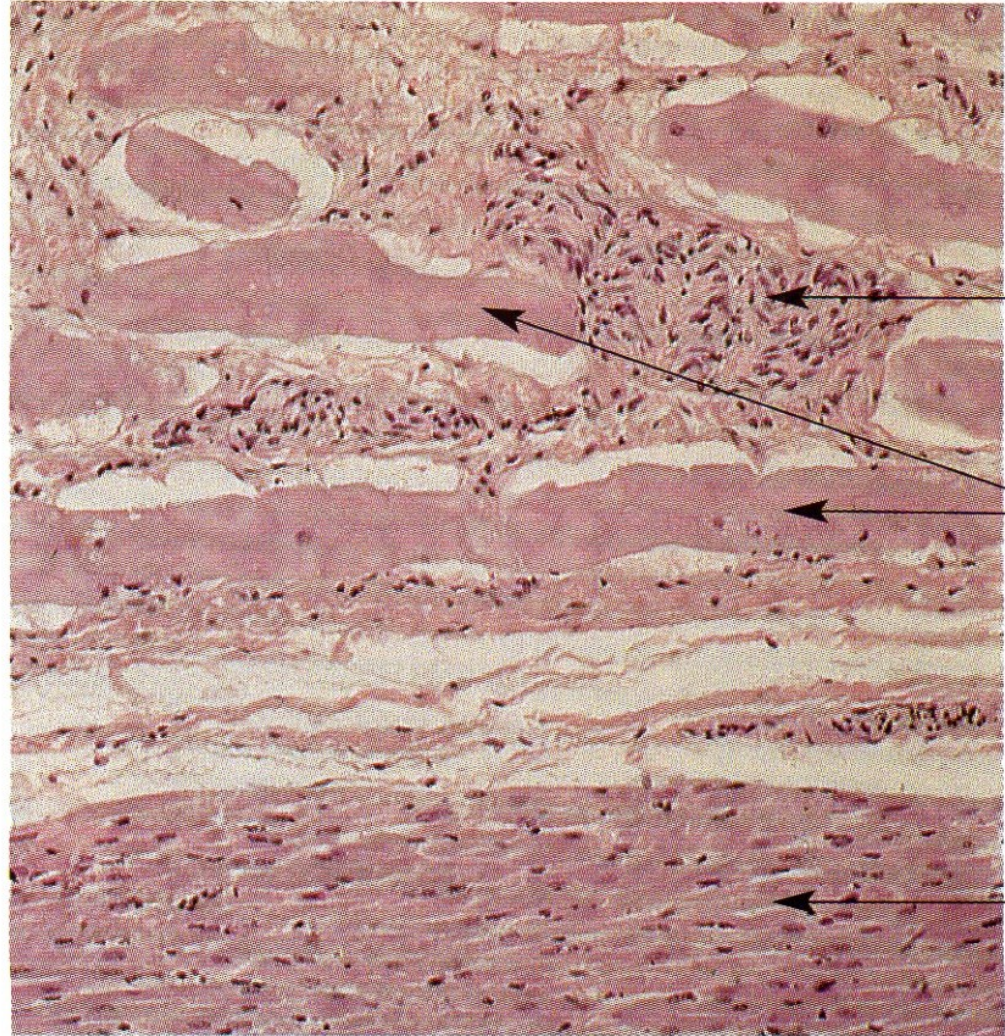
- P-cells
- nexus

## AV node

- transient cells
- less nexus (stimulation delay)

## Purkinje fibres

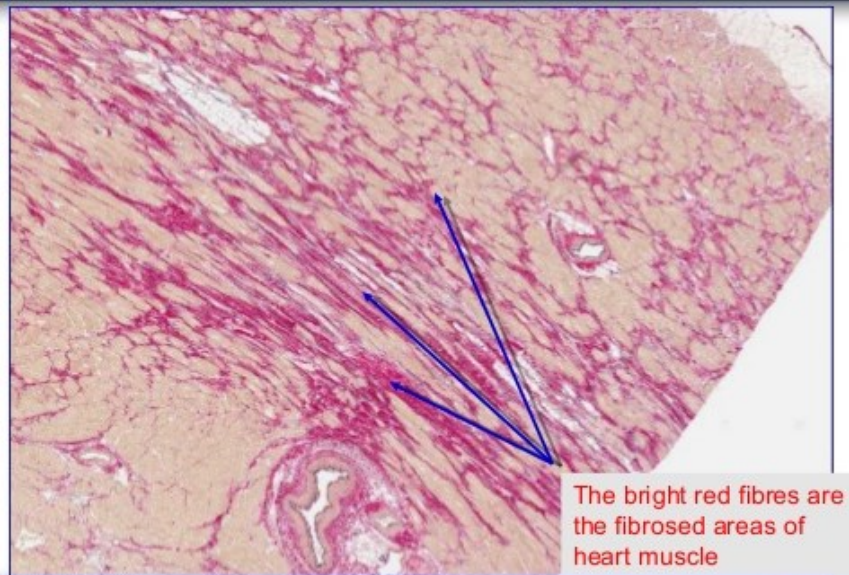
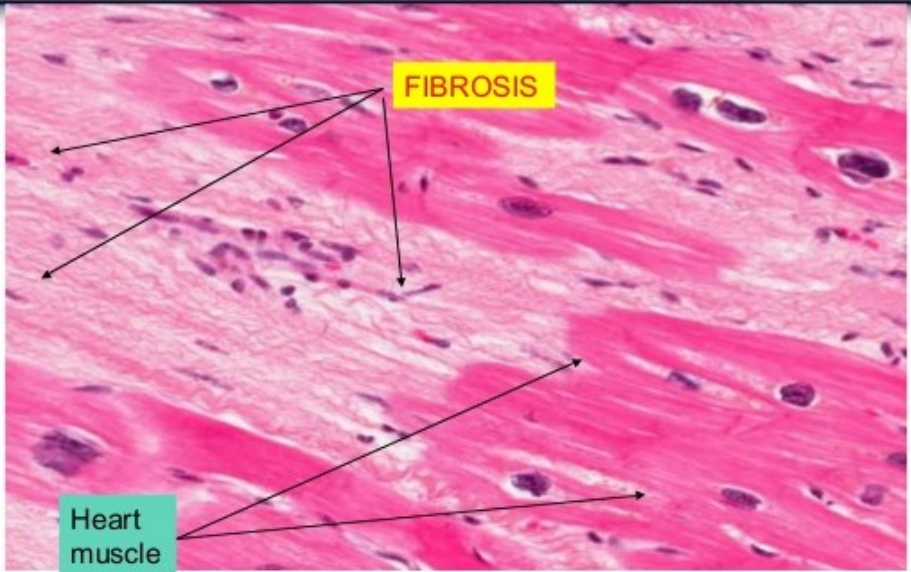
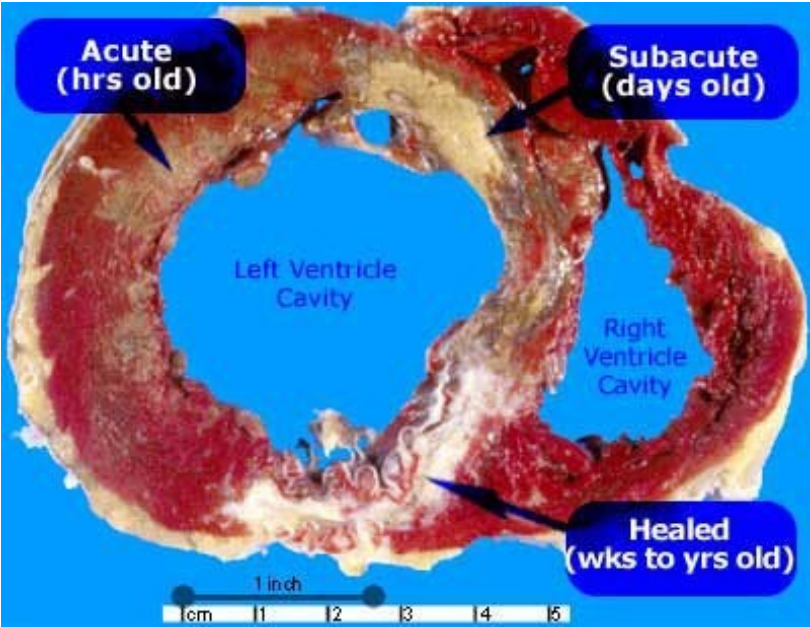
- distal parts of the excitation conduction system
- large (short but thick) cells
- more nuclei
- rich in glikogen
- no T-tubules
- many gap junctions
- high acetilecolinesterase activity





# Clinical relevance

## Heart attack

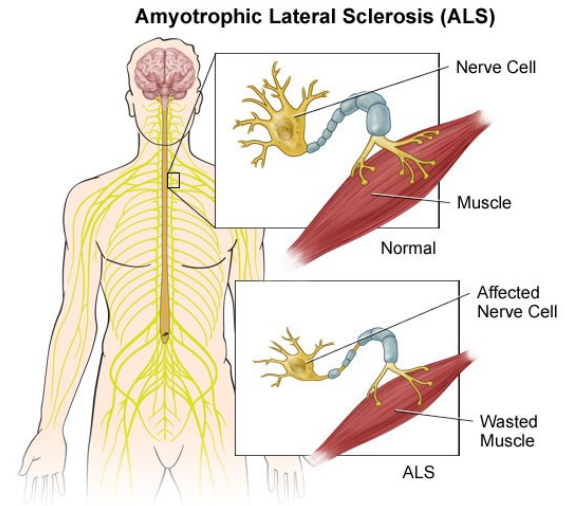




# Muscle atrophy/Amyotrophy



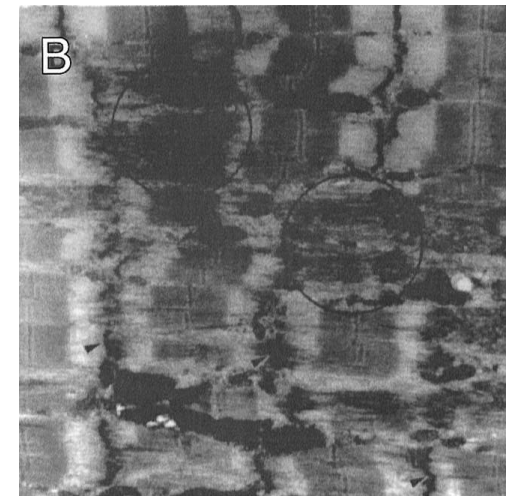
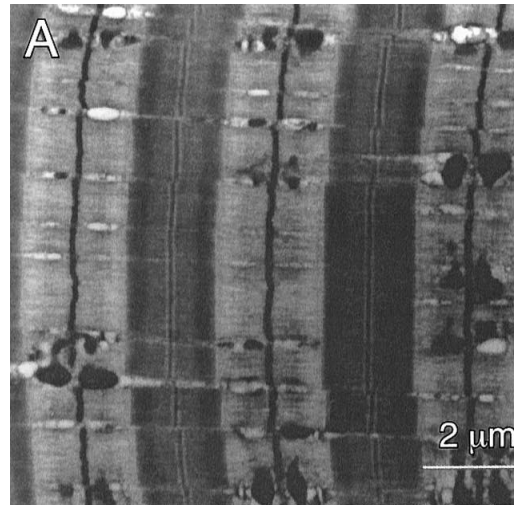
# Amyotrophic lateral sclerosis (ALS)



# Hypertrophy



# Muscle soreness





# Literature

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Dr Puskár: the cytoskeleton and cell movement

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[www.histologyguide.com](http://www.histologyguide.com)

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Quatar Cardiovascular Research Center