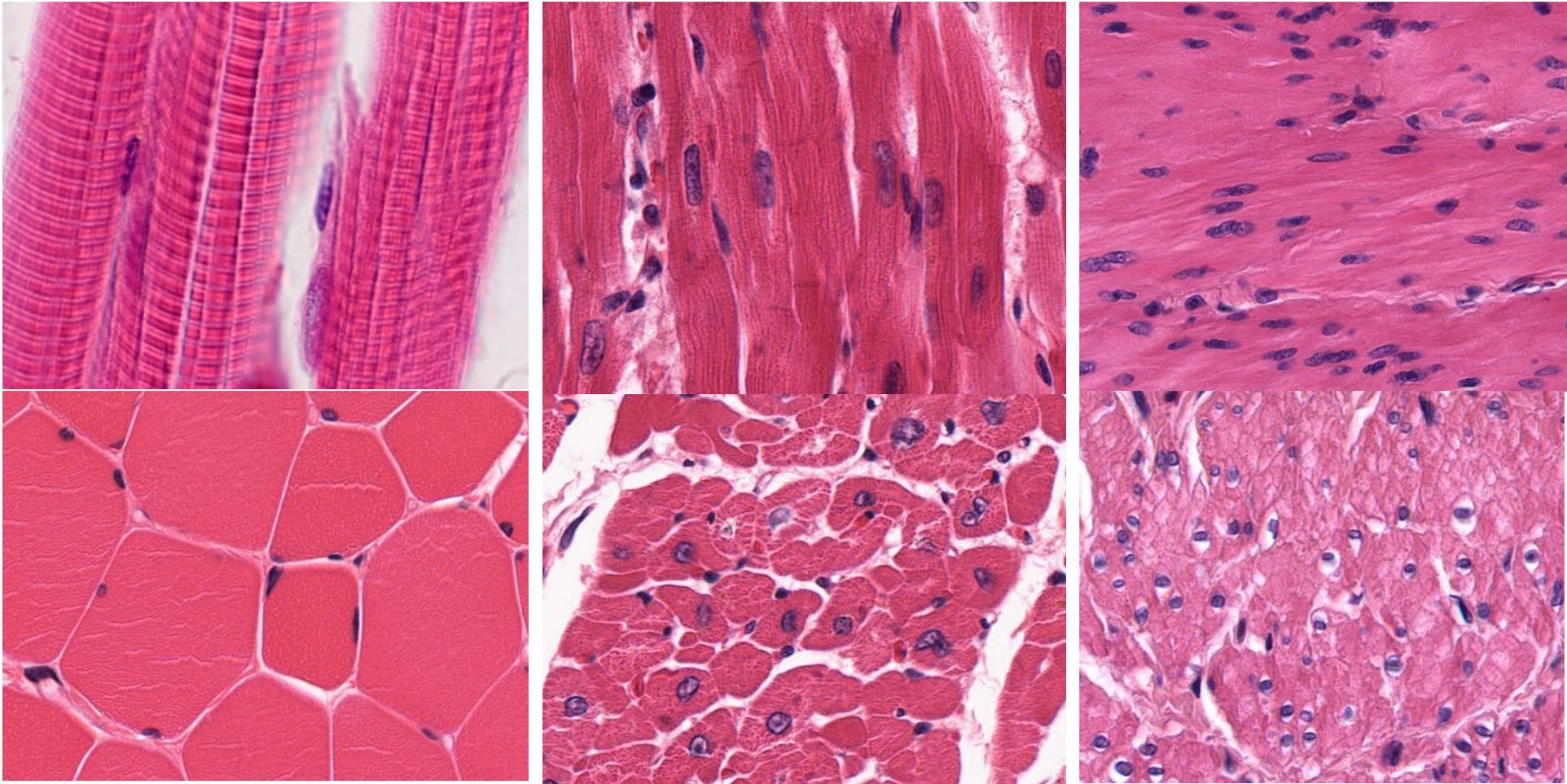


Muscle tissue



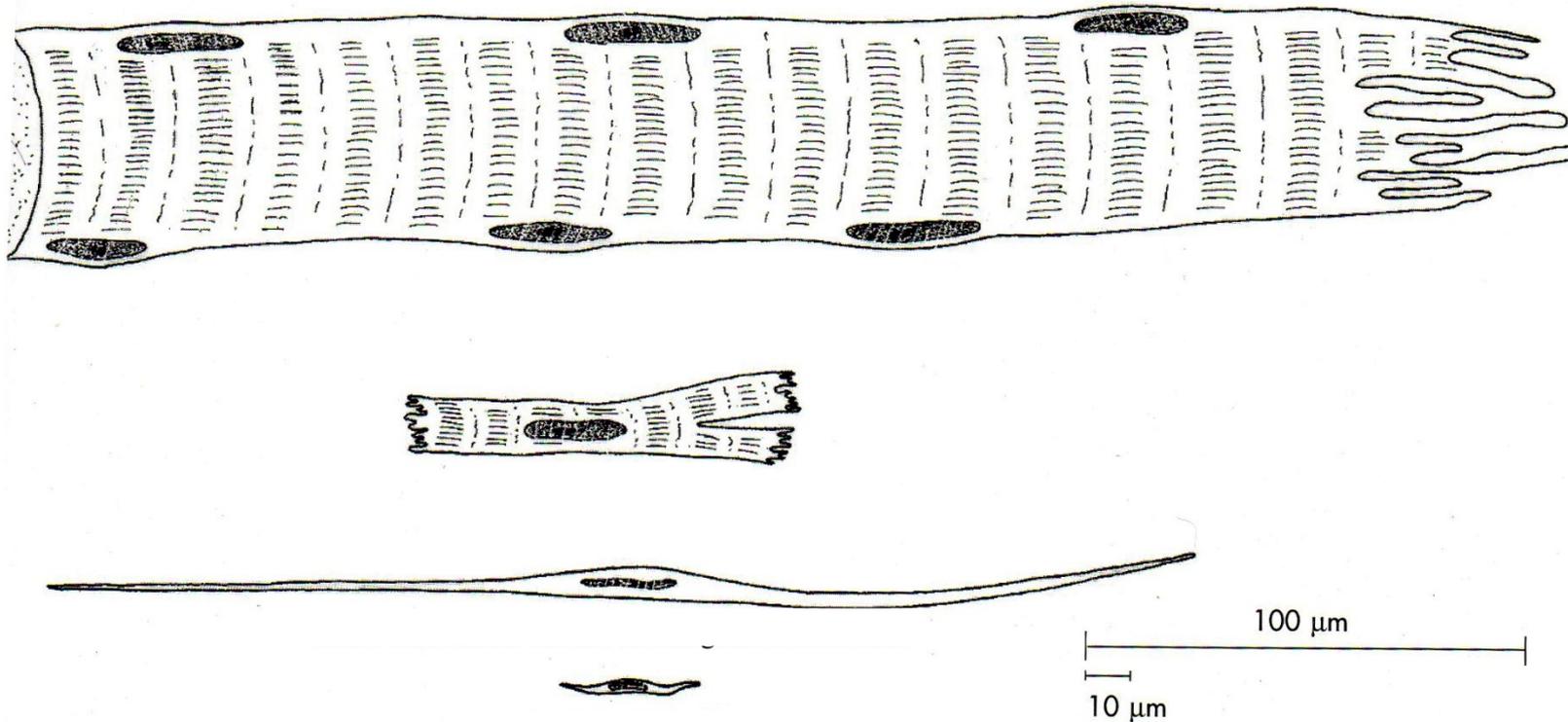
Dr. Emese Pálfi

Semmelweis University

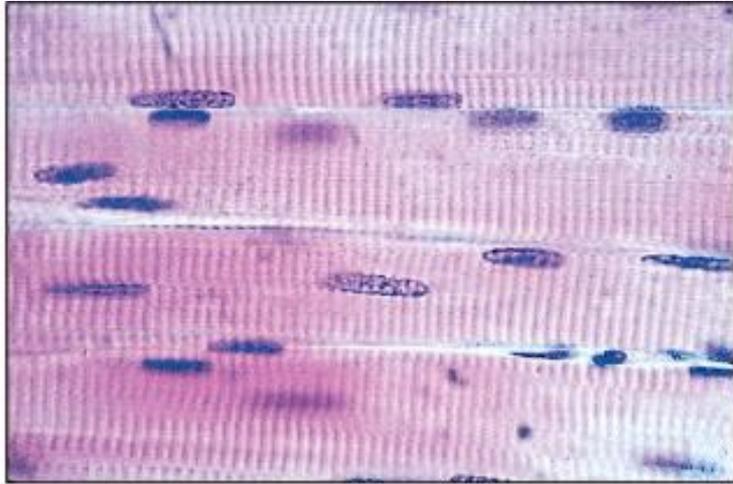
Department of Anatomy, Histology and Embryology

Muscle tissue

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



Skeletal muscle

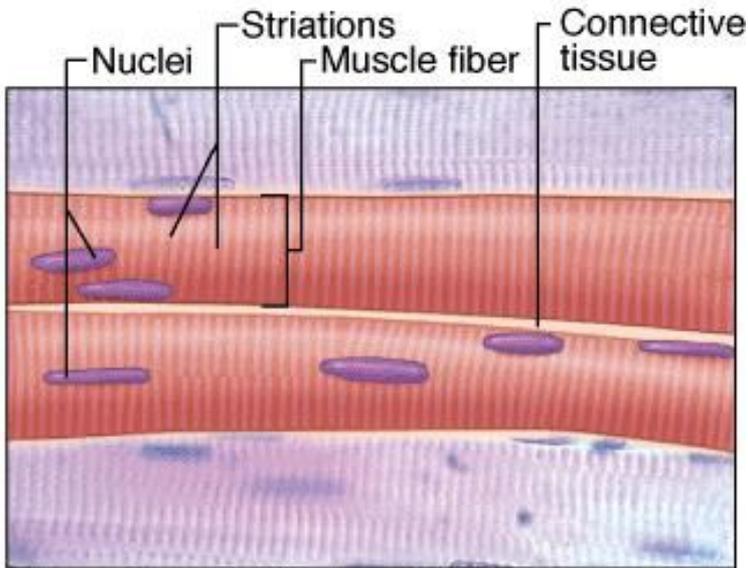


Unit: **muscle fiber**

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

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

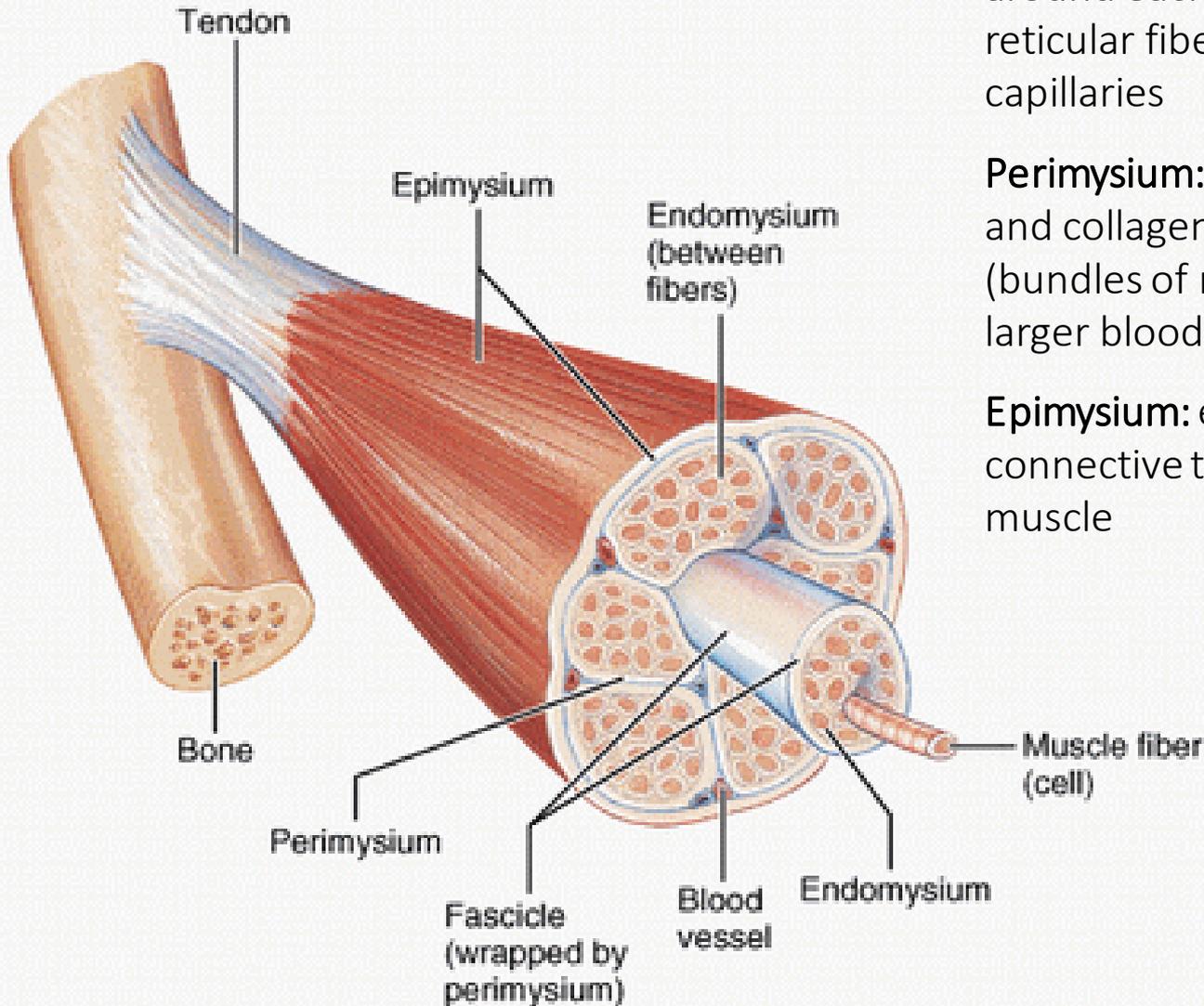
- basal lamina
- myoblast fusion >> syncytium
- flattened oval nuclei (up to 100/muscle fiber)
under the sarcolemma
- many mitochondria
- reserve energy: lipid droplets, glycogen particles
- satellite cells: beneath the basal lamina, regeneration



- 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):

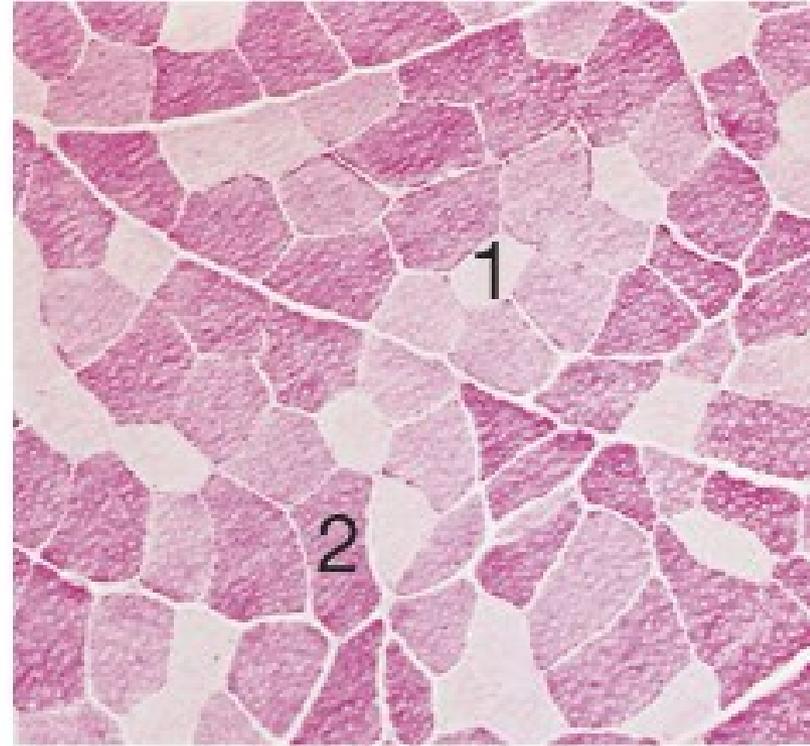
- few mitochondria
 - high glycogen content
 - large diameter
 - few capillaries
 - rapid contraction but fatigue quickly
- m. biceps brachii, m. rectus abdominis, eye muscles*

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

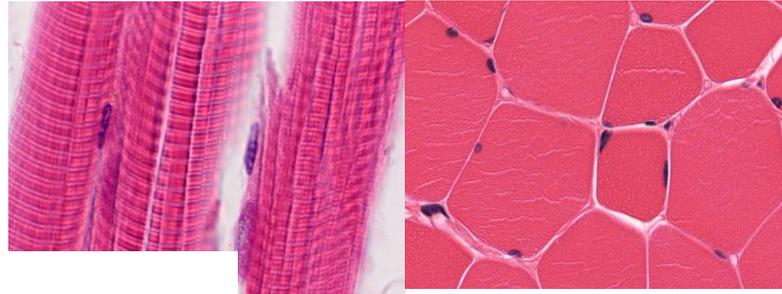


Skeletal muscle

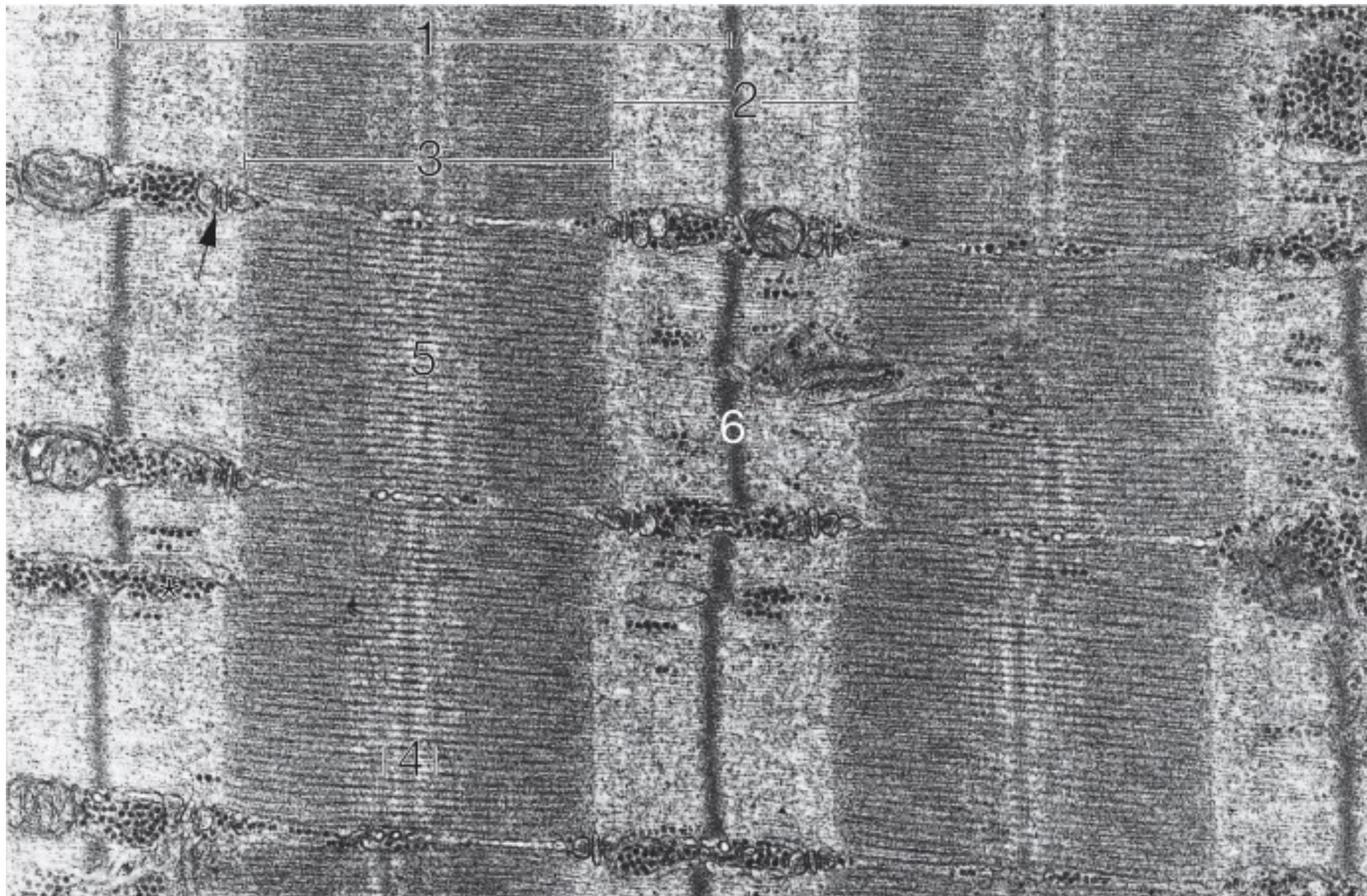
- unit: muscle fibre
- origin and insertion on bony structures
- contraction arises due to nerve stimulation

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

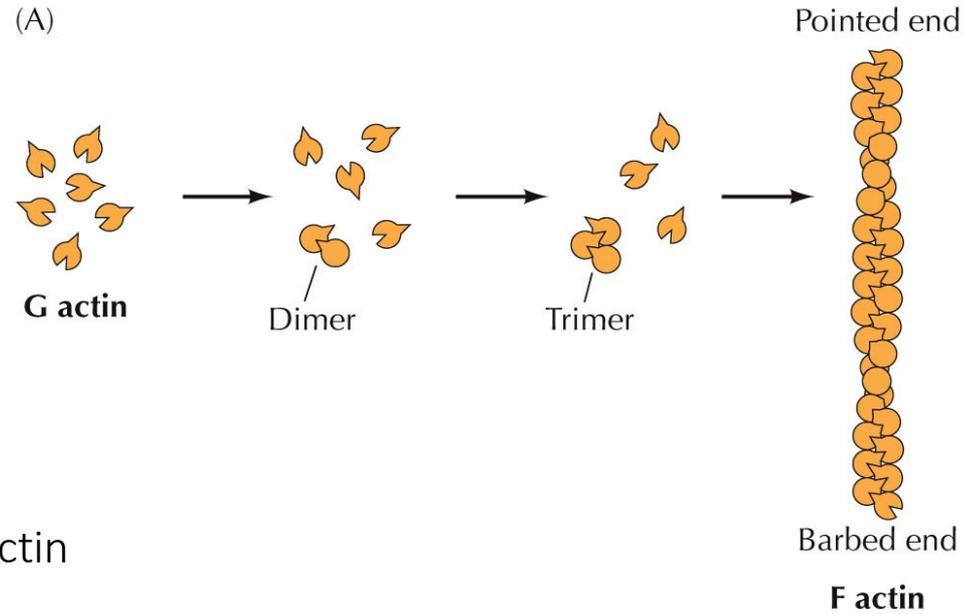
1. Actin (thin filament)

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)

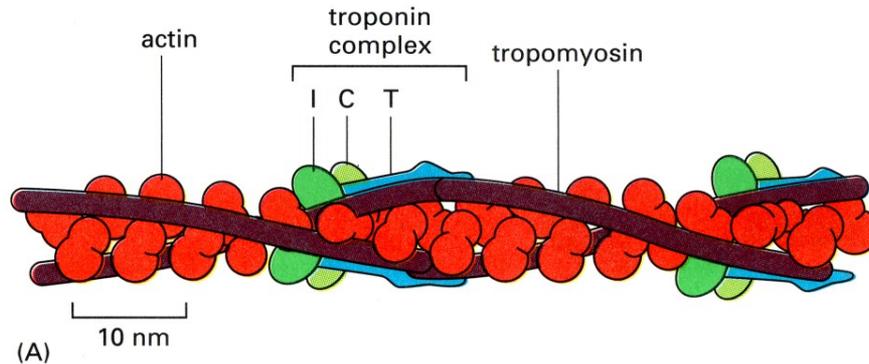
blocks the myosin binding site on the actin

3. Troponin complex

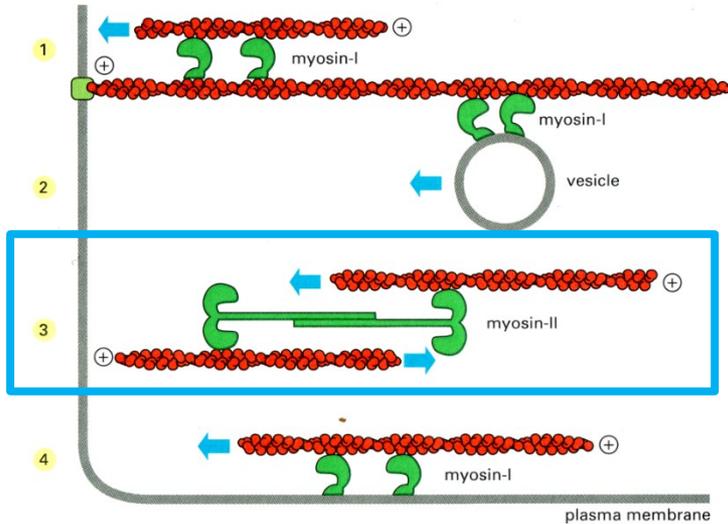
TnT - binds the complex to tropomyosin

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)

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

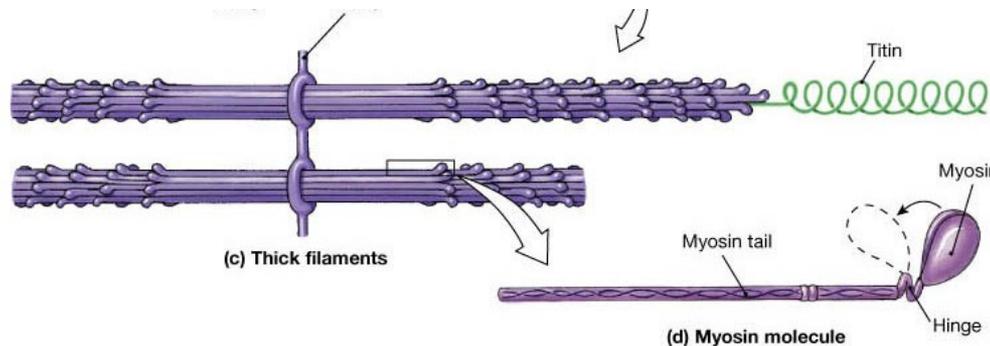
$l = \sim 1,5 \mu\text{m}$

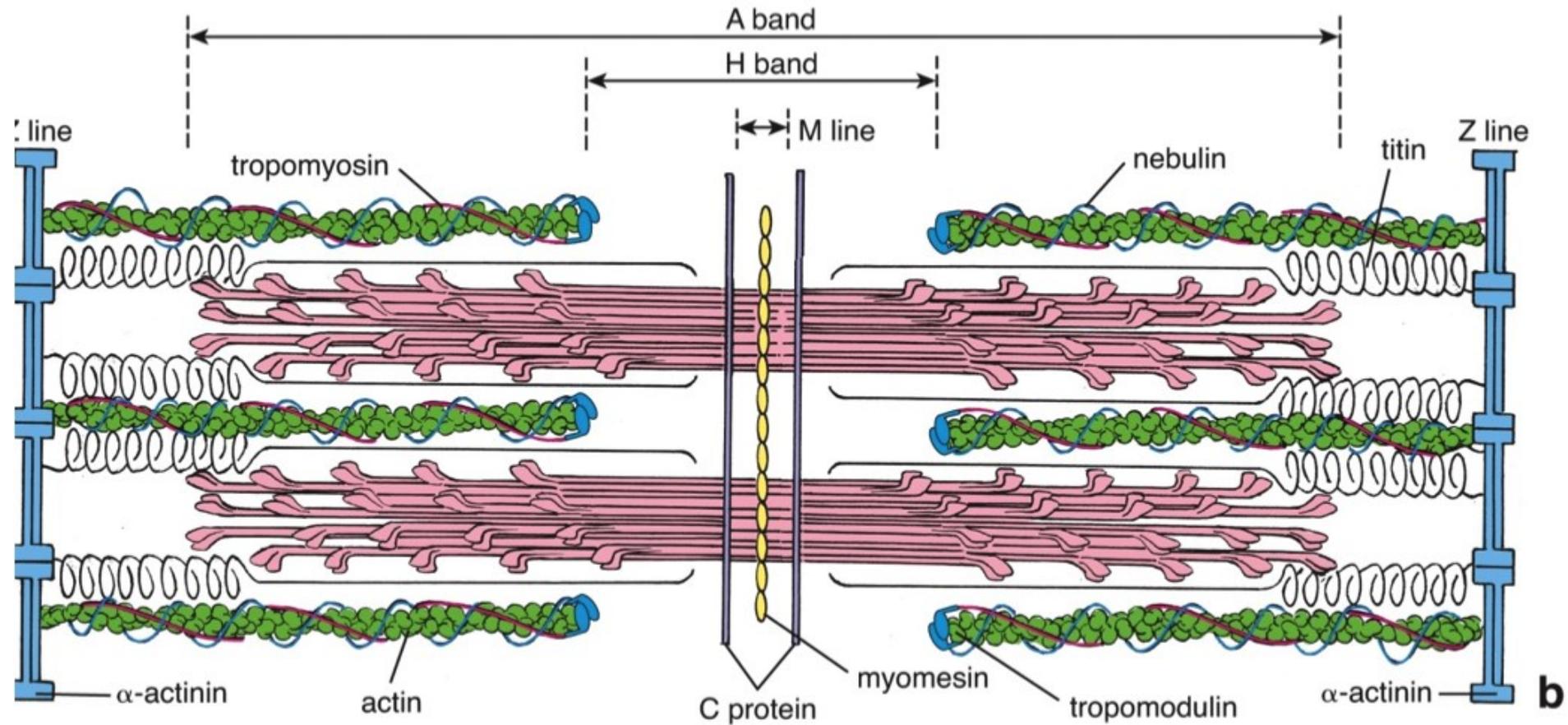
Main component: bundle of myosin filaments (~ 350 myosin molecules)

- 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

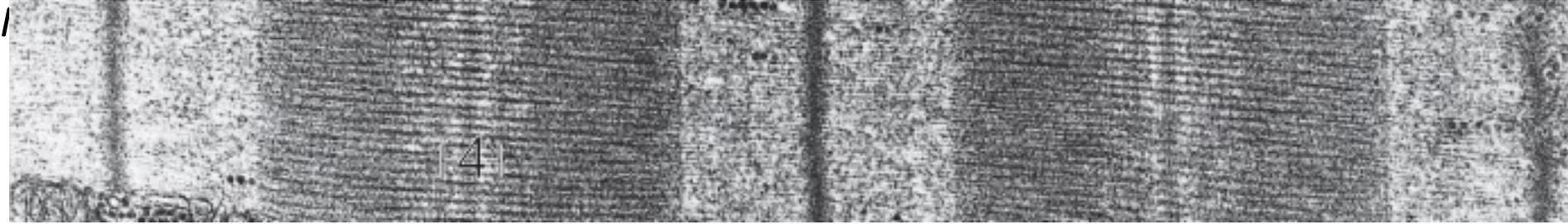
Sarcomer: (2-3 μm) between 2 Z lines

A-band: anisotropic, thicker, dark
1.5 μm long, 15 nm thick
predominantly myosin + overlapping actin filaments
length remains unchanged during contraction

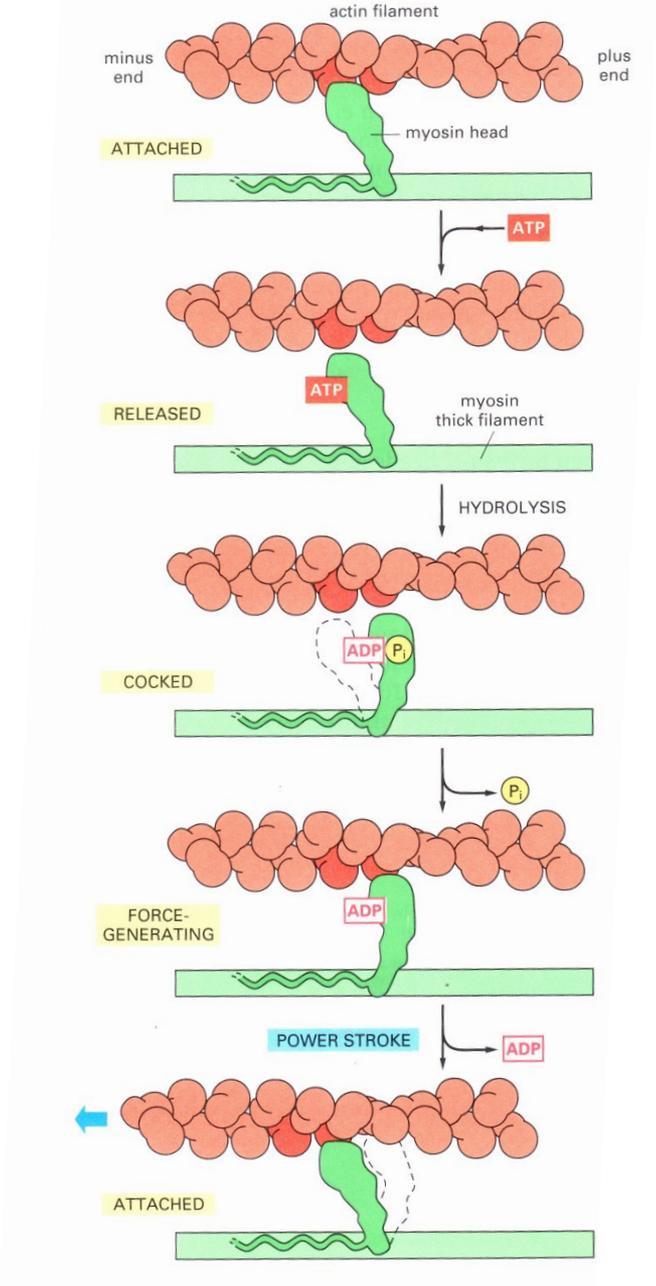
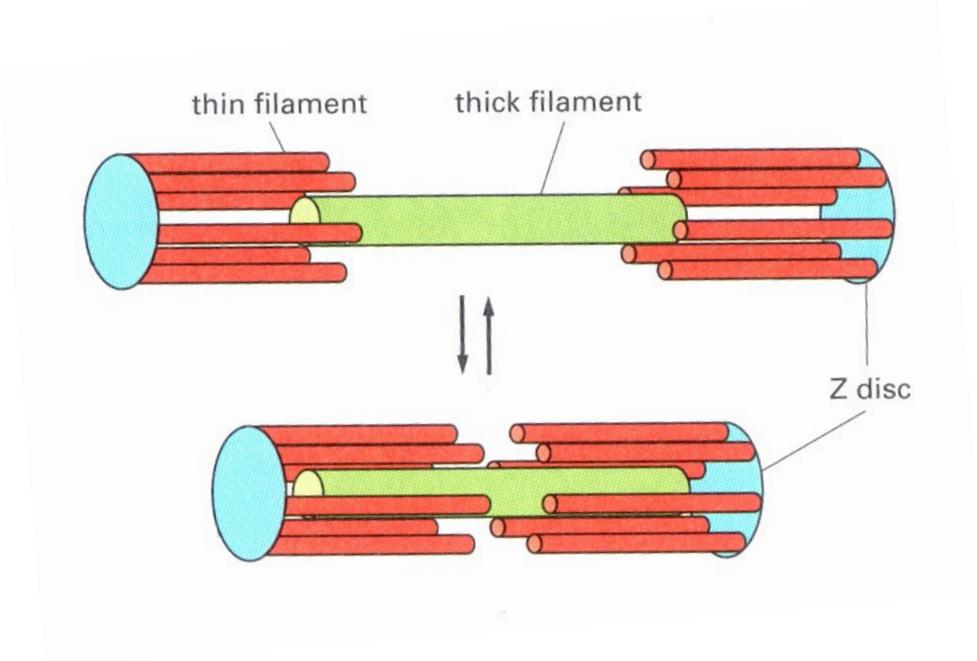
I-band: isotropic, thinner, brighter
1 μm long, 7 nm thick
predominantly actin
shortens during contraction

Z-line: α -Actinin
desmin

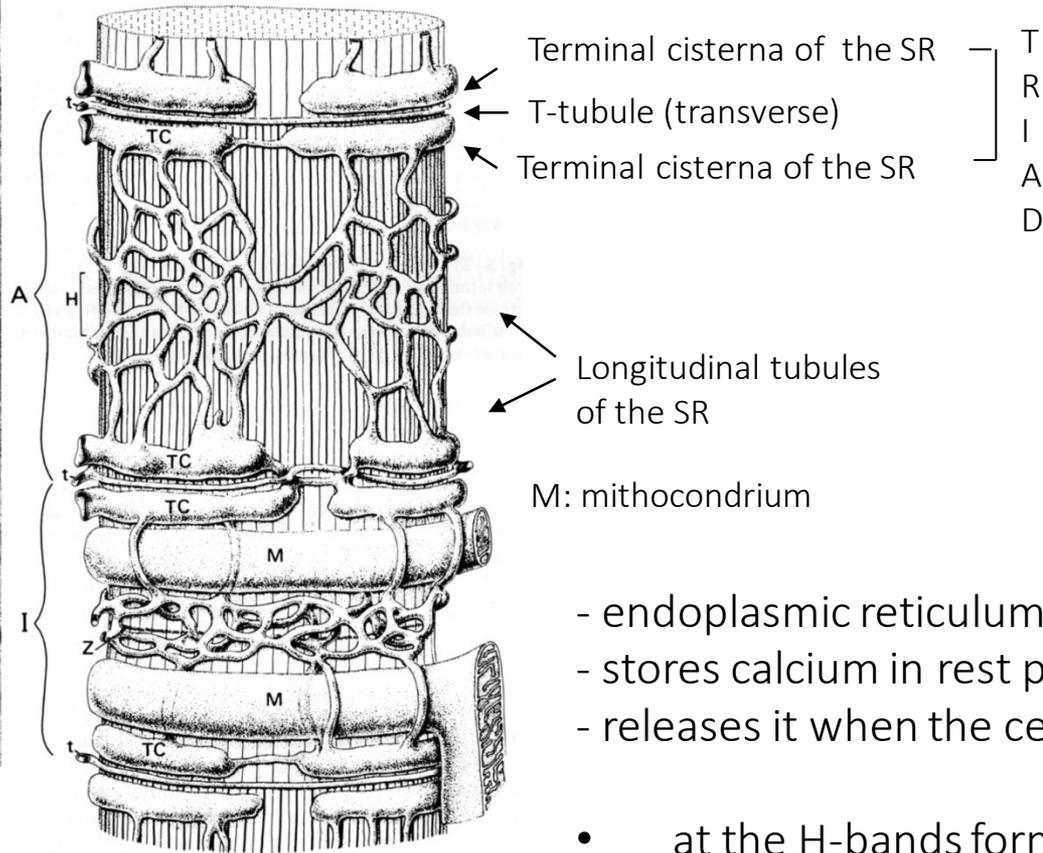
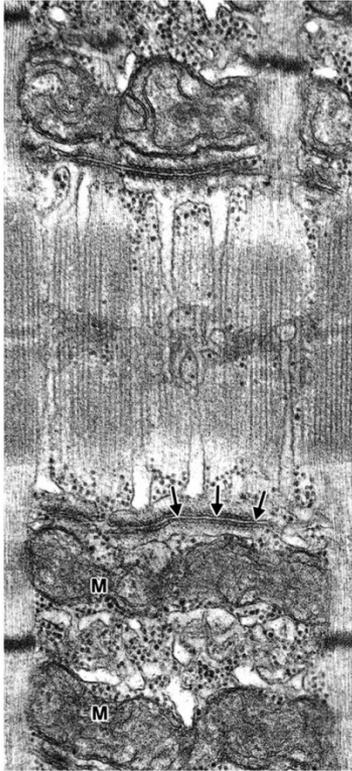
H-band: a bright area in the middle of the A-band
only myosin



Sliding filament hypothesis



Sarcoplasmic reticulum (SR)



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

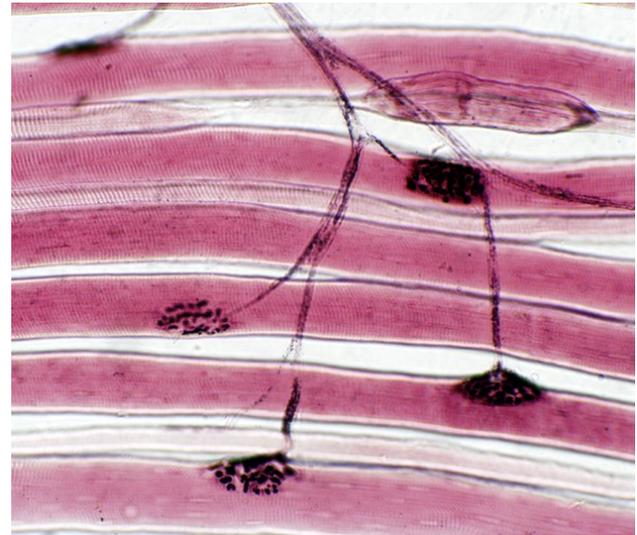
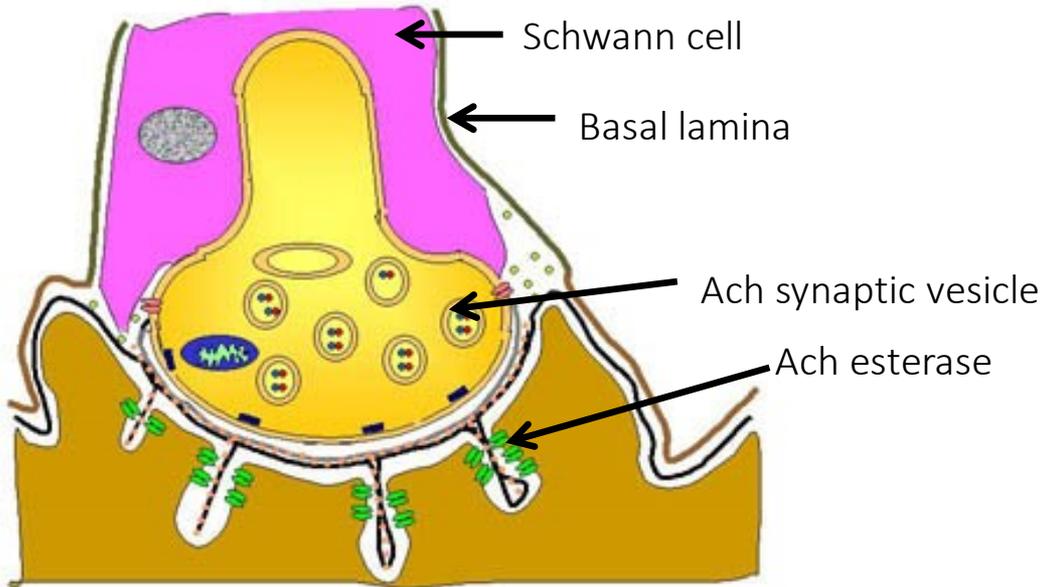
- at the H-bands forms a network
- Terminal cisterns (junctional reticulum)
- T-Tubulus: invagination of cell membrane

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

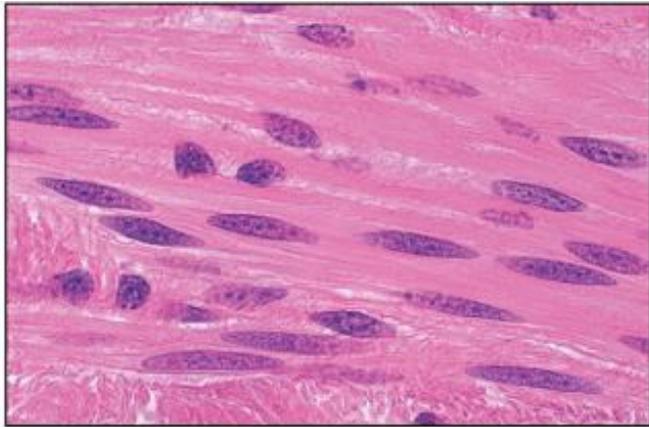
Motor unit

Neuromuscular junction/motor end plate

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



Smooth muscle

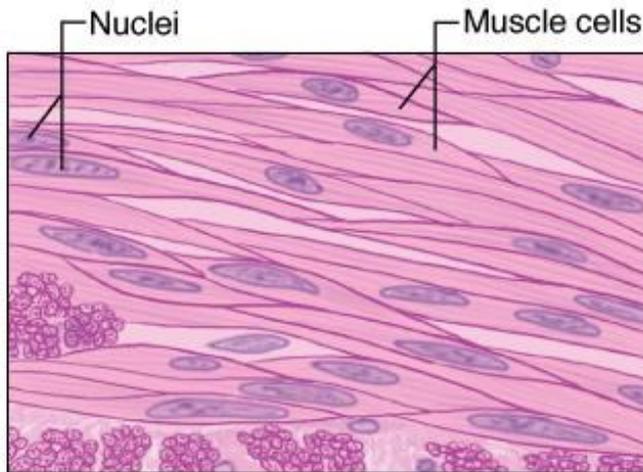


Unit: **smooth muscle cell** (myocyte)

d = 3-8 μm

l = 15-800 μm

- 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

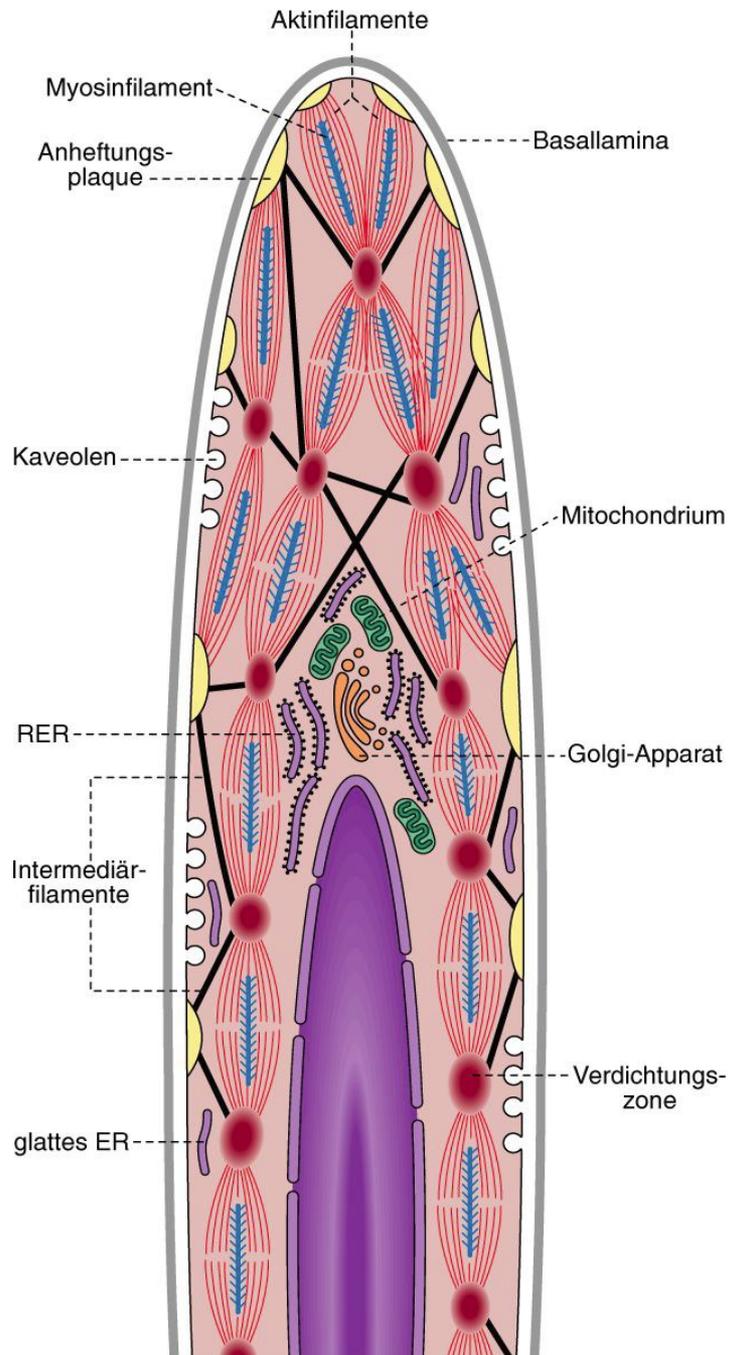
c Smooth muscle

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

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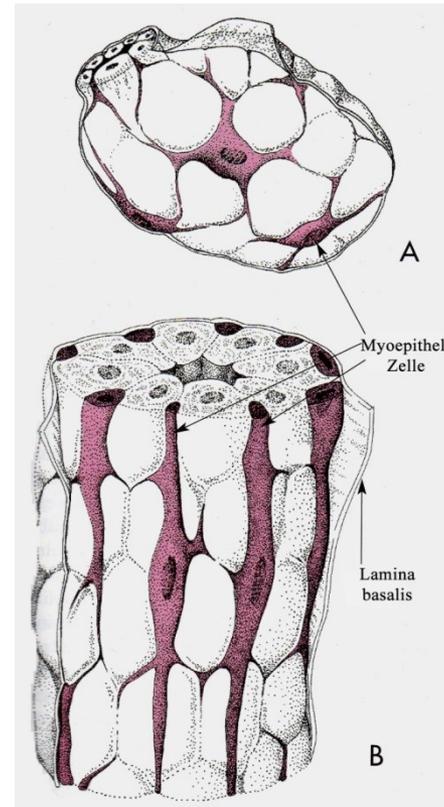
Can be organized in lamelles, bundles.

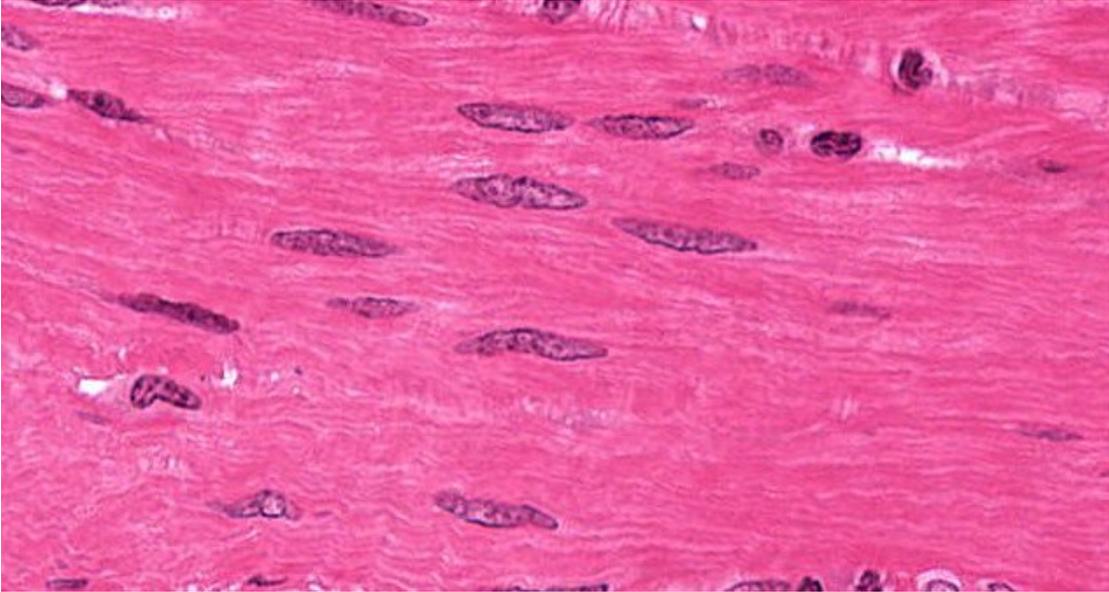
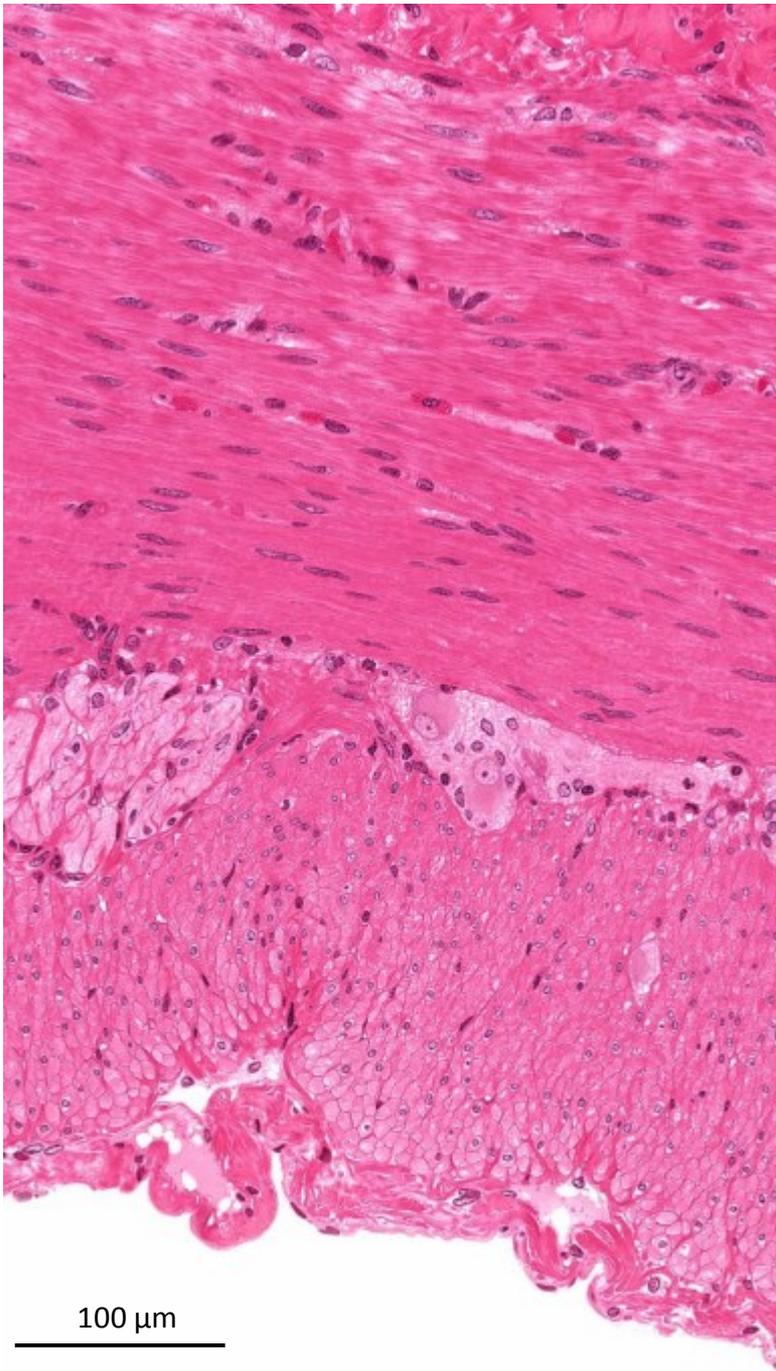
In the wall of tubular organs (gastrointestinal tract, airways, genital tract, vessels) and in the eye and skin can be also found.



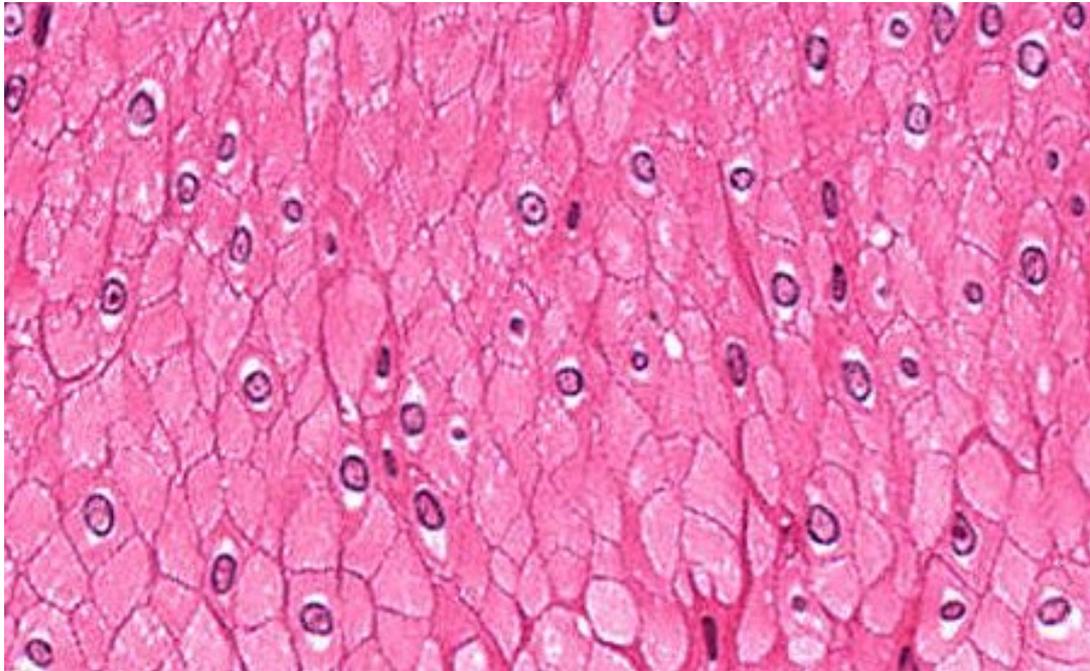
- Actin >> Myosin
- Gap Junction >> Stimulation (spontaneous activity!)

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

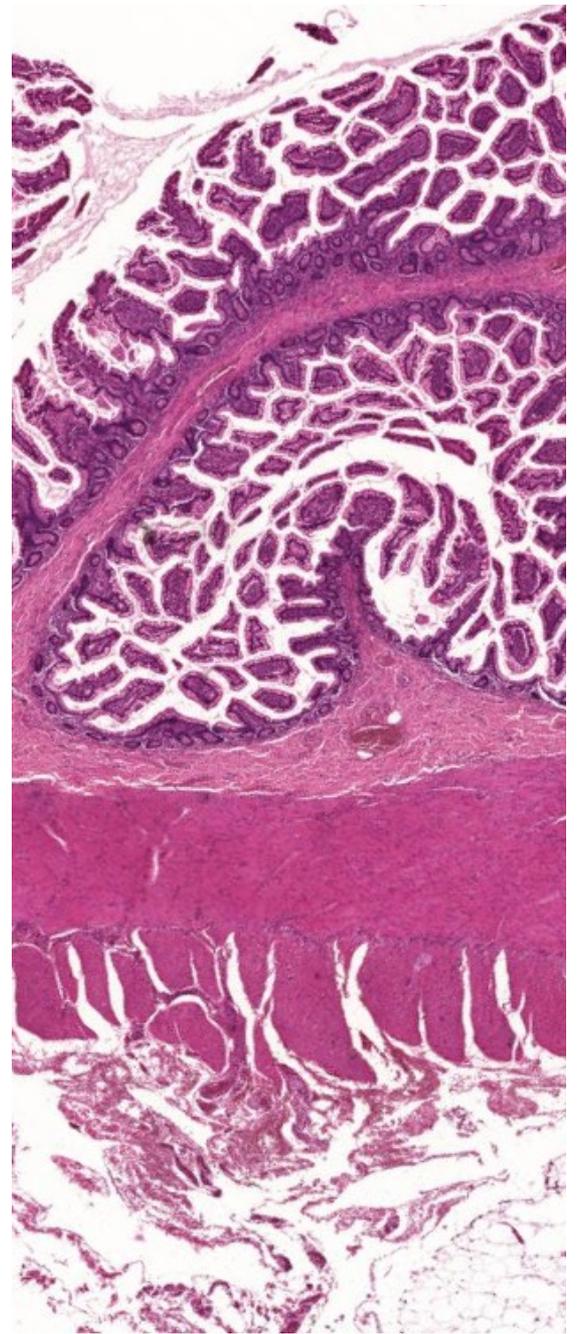
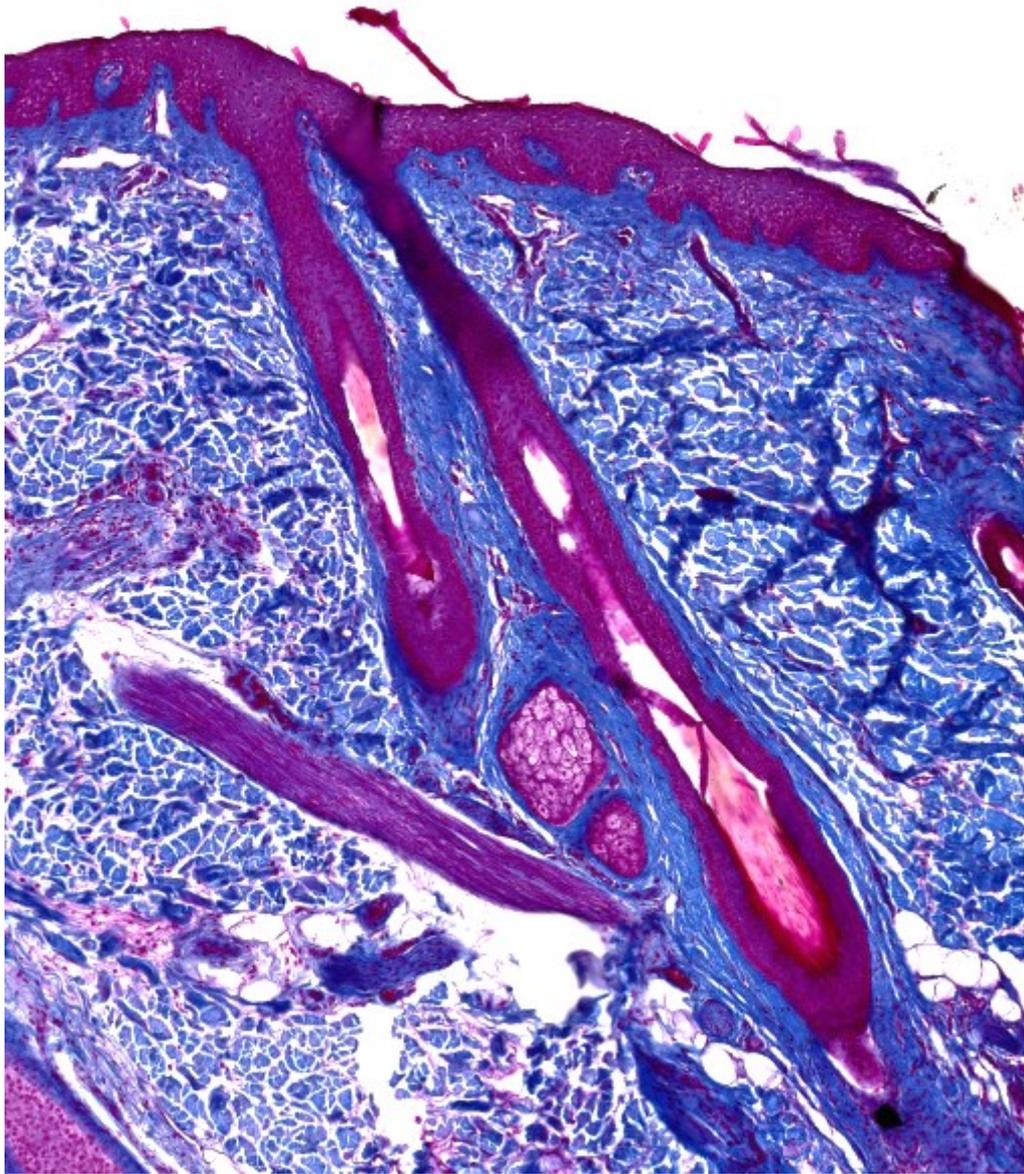




25 μm



25 μm



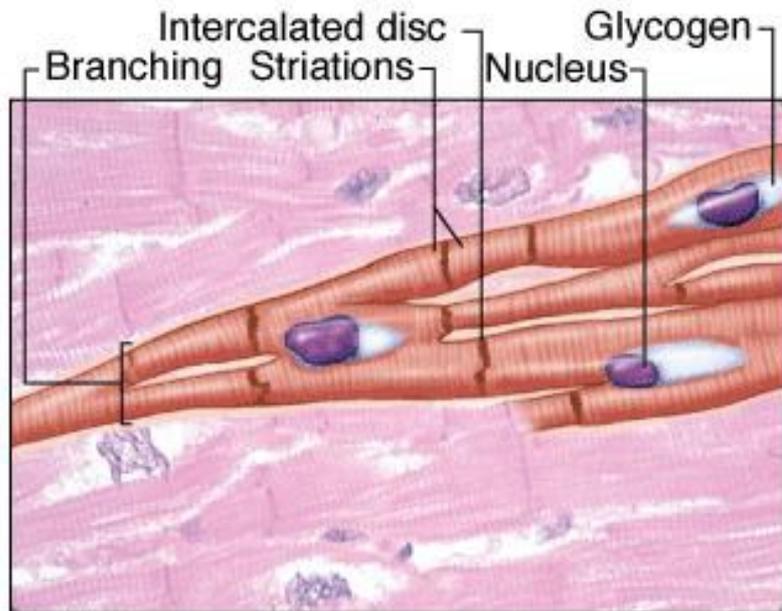
Cardiac muscle



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

l= 50-120 μm d= 15-20 μm

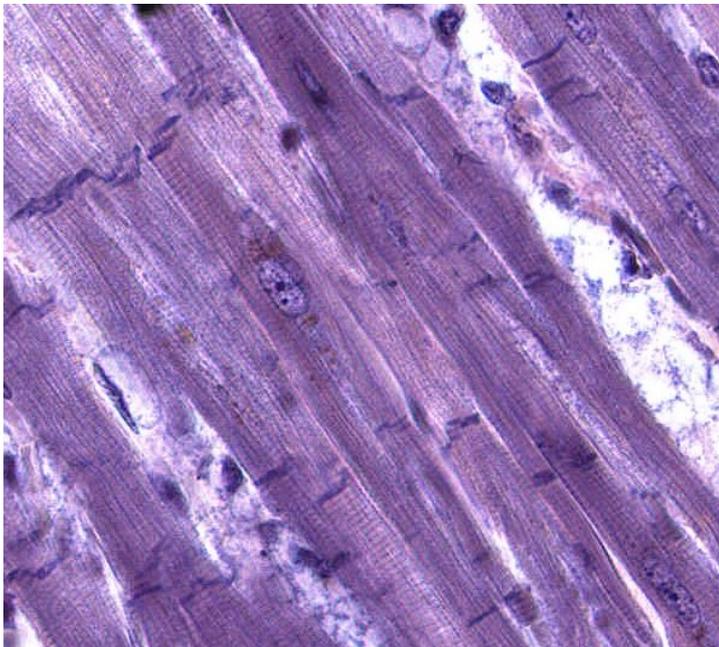
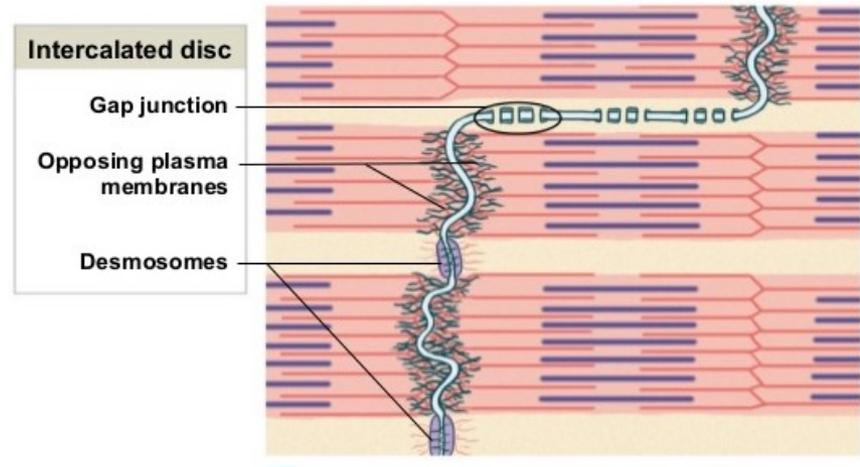
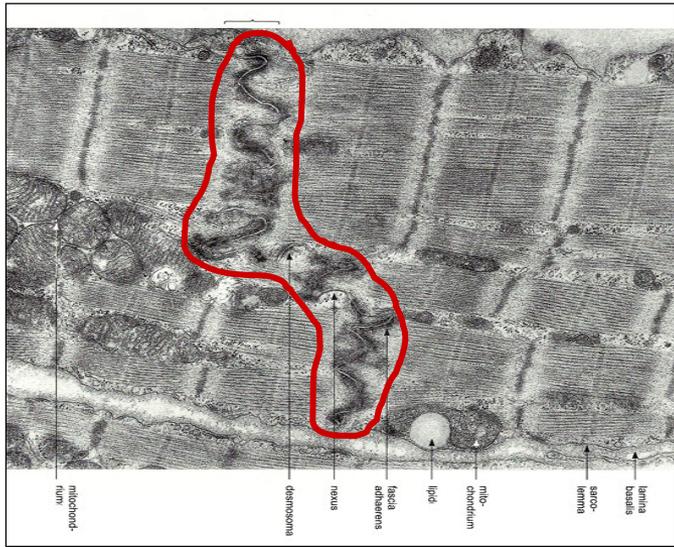
- Y-shaped cells with interdigitating cell extensions
- intercalated discs: end to end junctions between individual cardiac muscle cells
- 1 nucleus, centrally located
- 1-2 nucleoli
- eosinophilic cytoplasm
- cross striated
- glycogen and lipid droplets, lipofuchsin granules
- tireless, works for life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

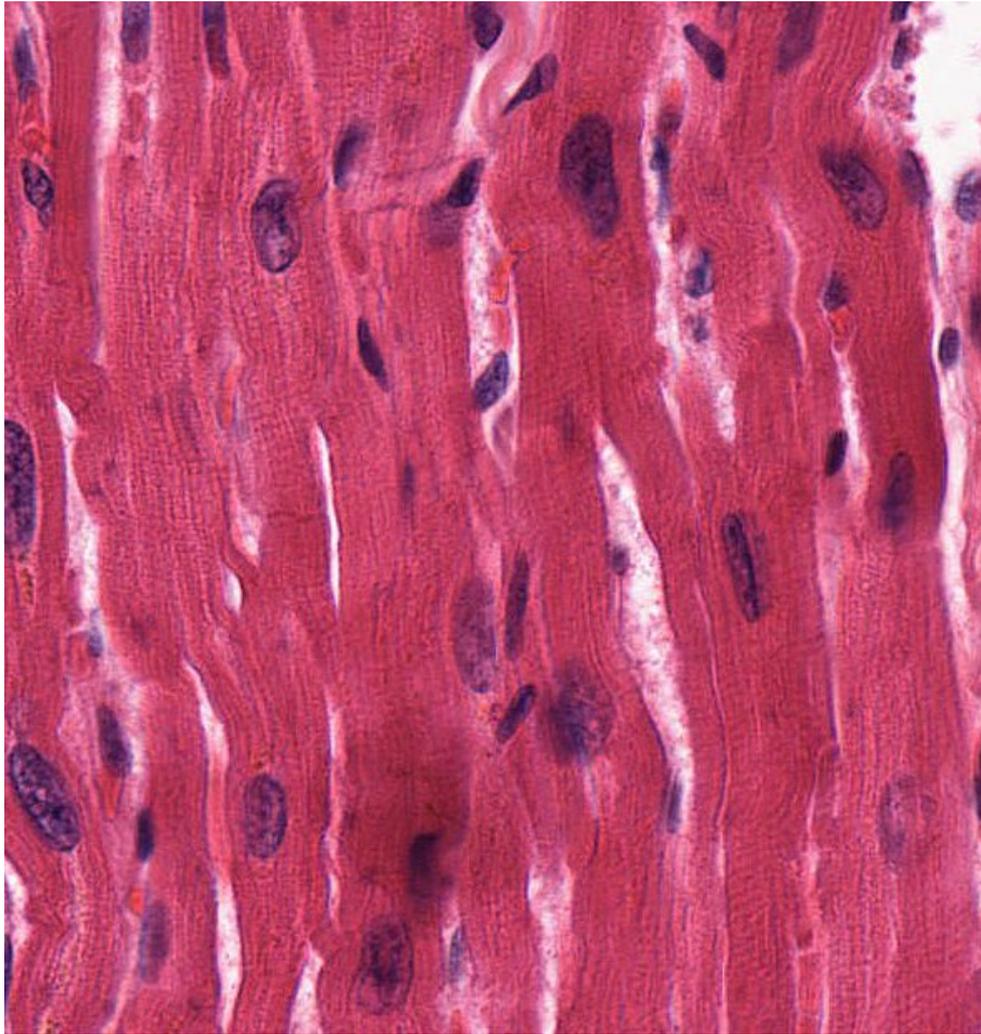
fascia adherens, desmosomes

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

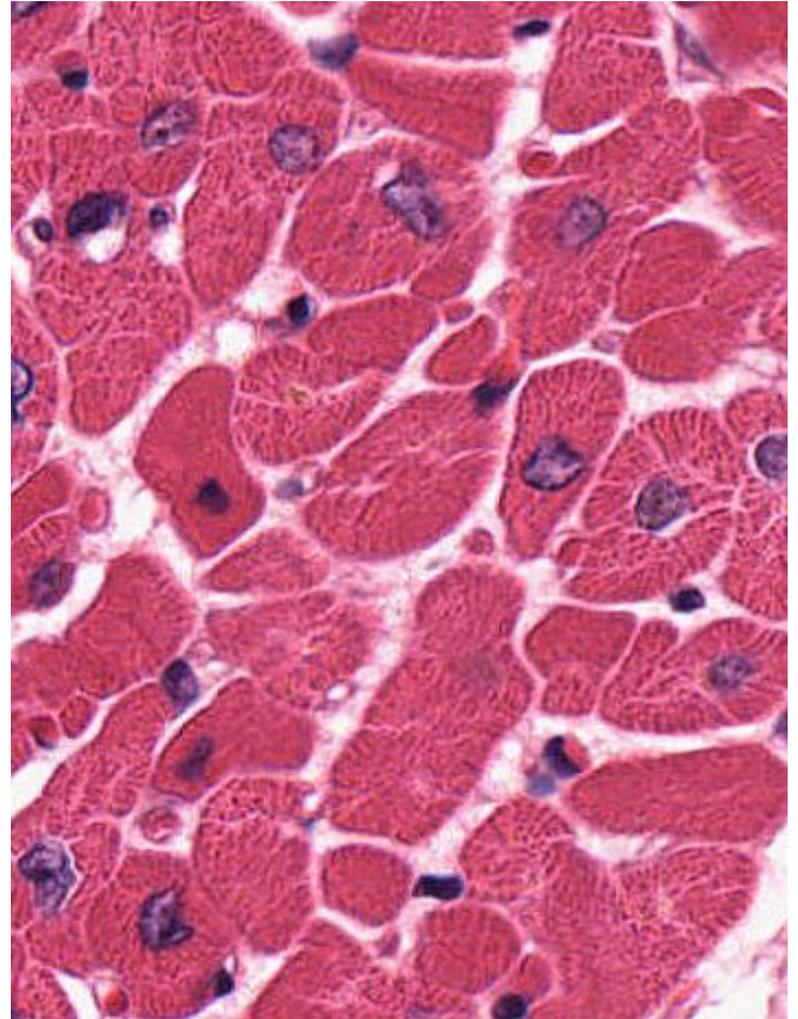
longitudinal parts:

nexus or gap junction (connexin 43)

rapid excitation conduction from cell to cell (functional syncytium)



25μm



25 μm

Conduction system

Sinus node

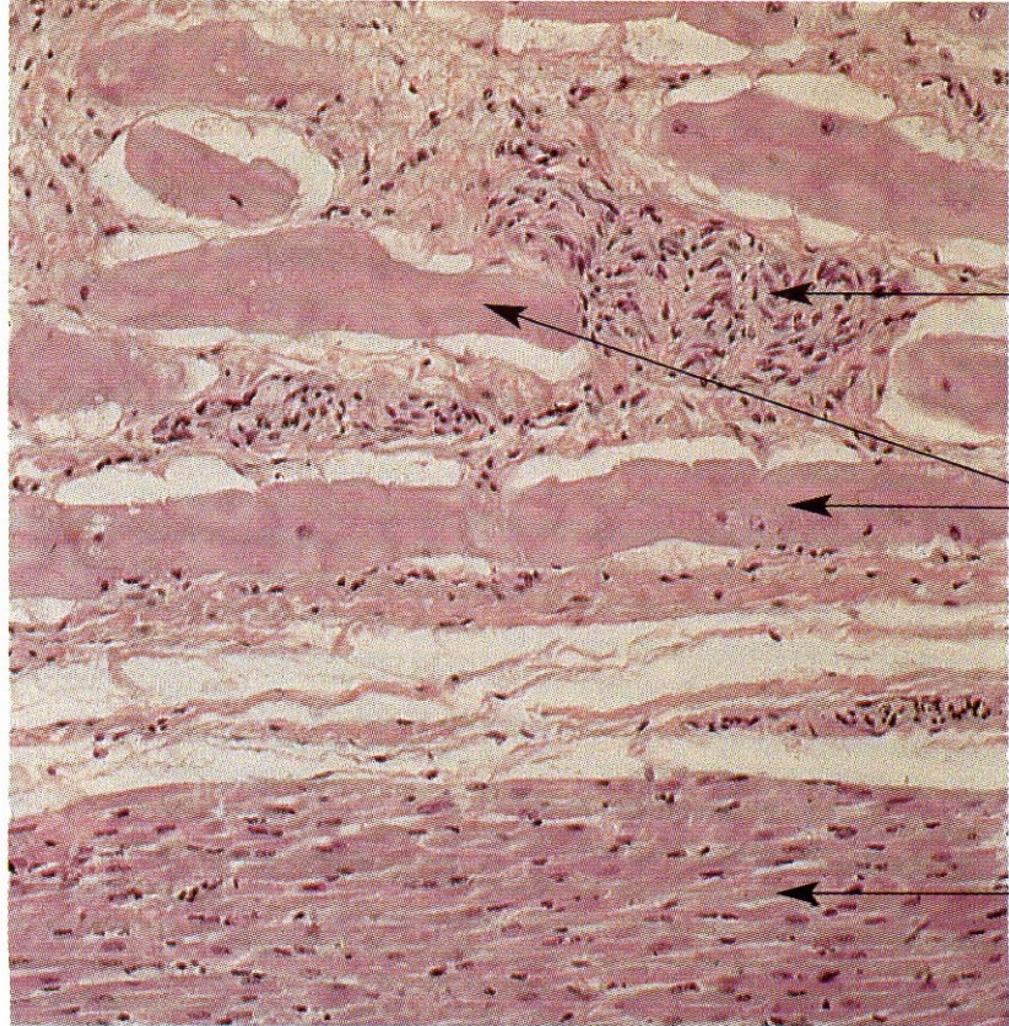
- P-cells
- nexus

AV node

- transient cells
- less nexus (stimulation delay)

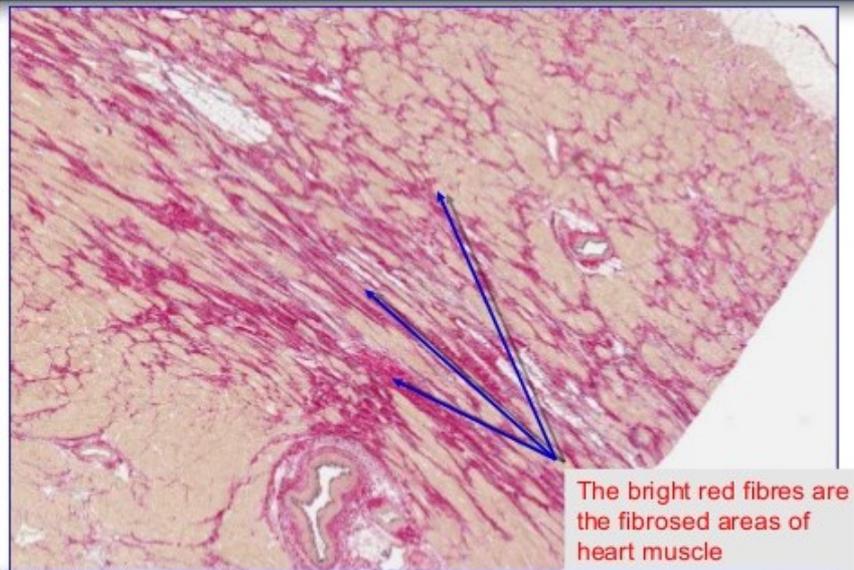
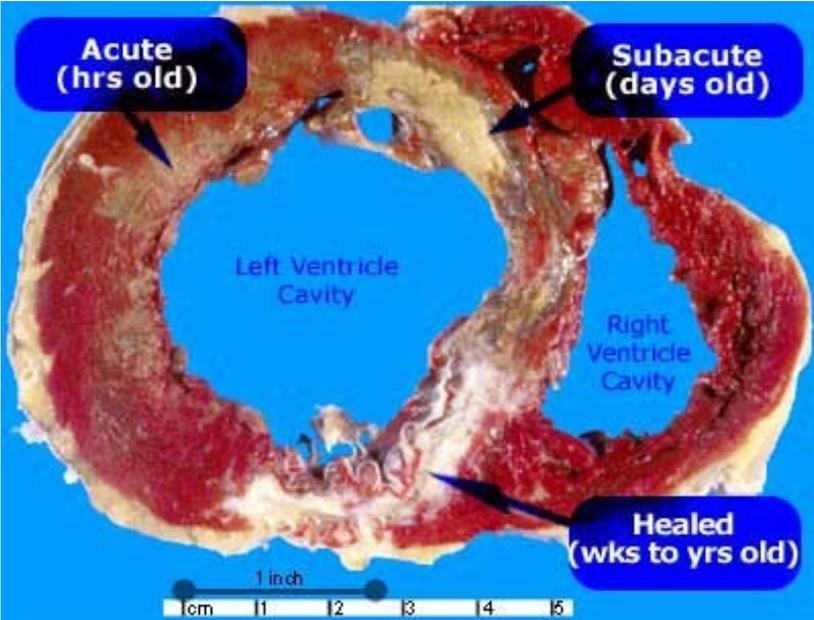
Purkinje fibres

- 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

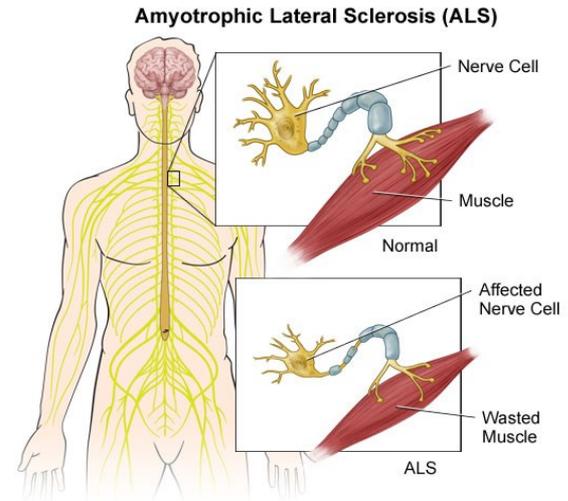
Heart attack



Muscle atrophy/Amyotrophy



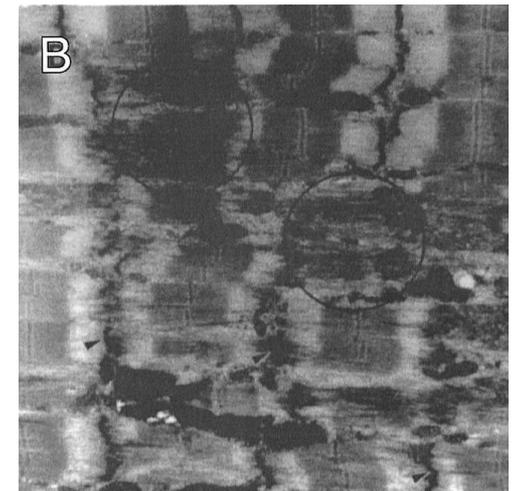
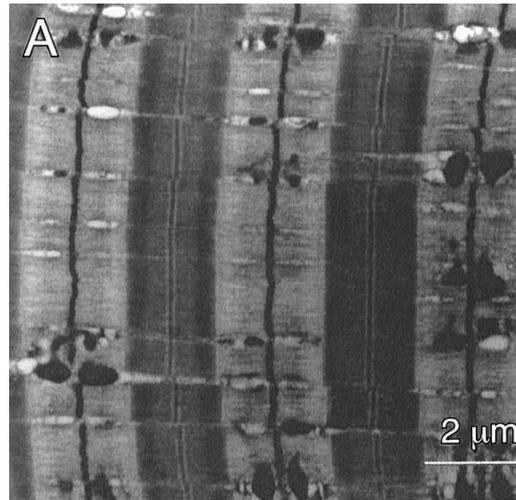
Amyotrophic lateral sclerosis (ALS)



Hypertrophy



Muscle soreness



Literature

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Dr Puskár: the cytoskeleton and cell movement

Alberts: Molecular biology of the cell (Third edition 1994, Garland Publishing Inc.)

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www.histologyguide.com

Welsch: Histologie

Quatar Cardiovascular Research Center