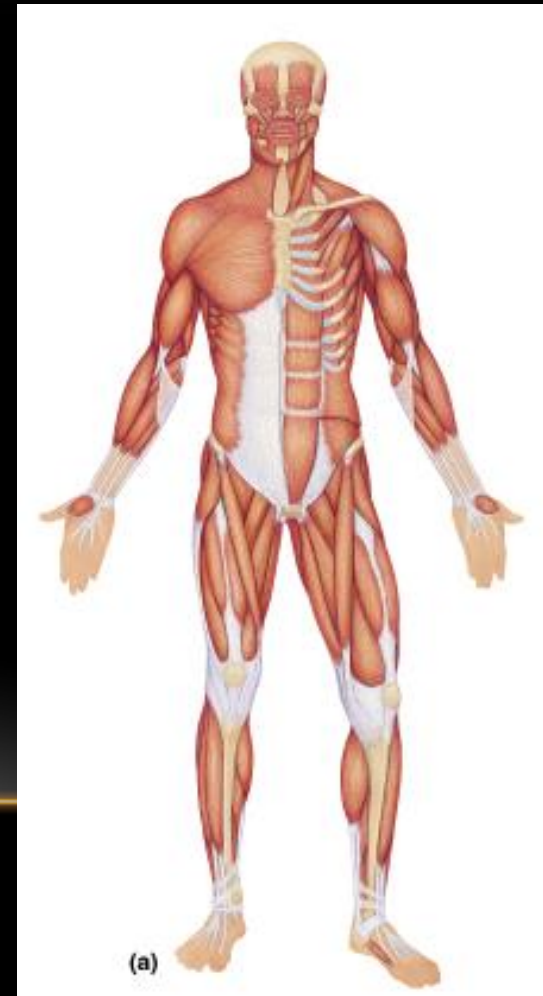


Muscle Tissue

Muscle tissue functions

- Movement
- Posture
- Joint stabilization
- Heat generation



Muscle tissue properties

Contractile

Excitable

Extensible

Elastic



Muscle tissue types

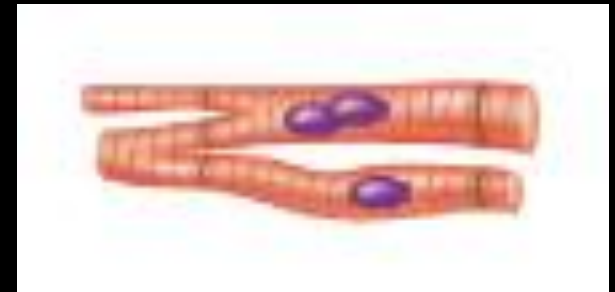
Skeletal

- Striated, voluntary



Cardiac

- Heart, striated, involuntary



Smooth

- Nonstriated, involuntary



Muscle tissue terminology

Fiber = skeletal, cardiac & smooth muscle cell

Myofilaments

- Actin – thin filaments
- Myosin – thick filaments

Sarcolemma – plasma membrane

Sarcoplasm – cytoplasm

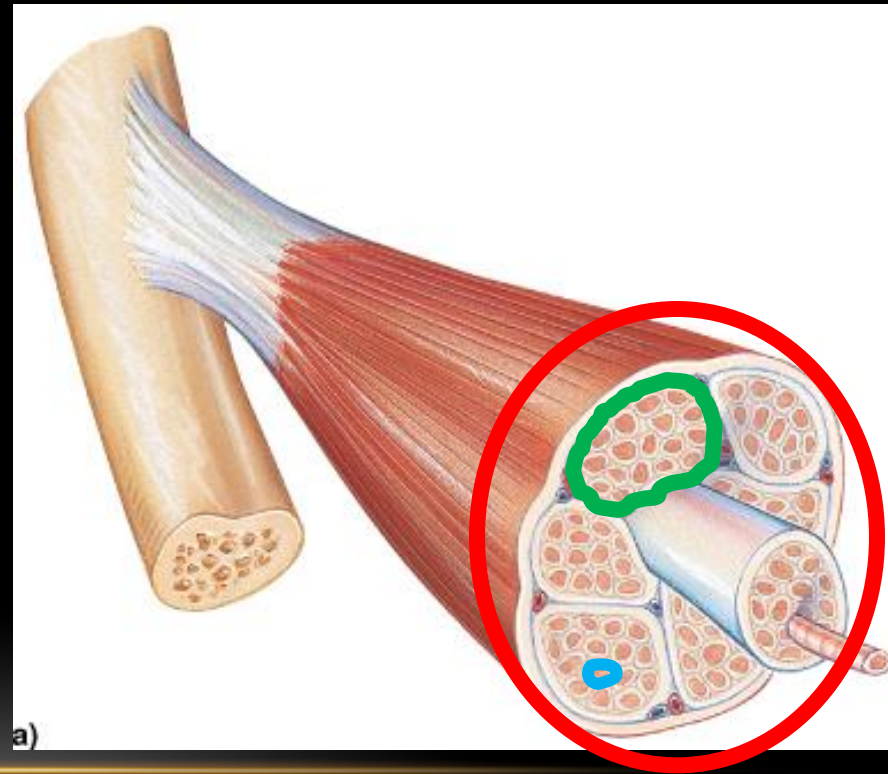
Sarcoplasmic reticulum – endoplasmic reticulum

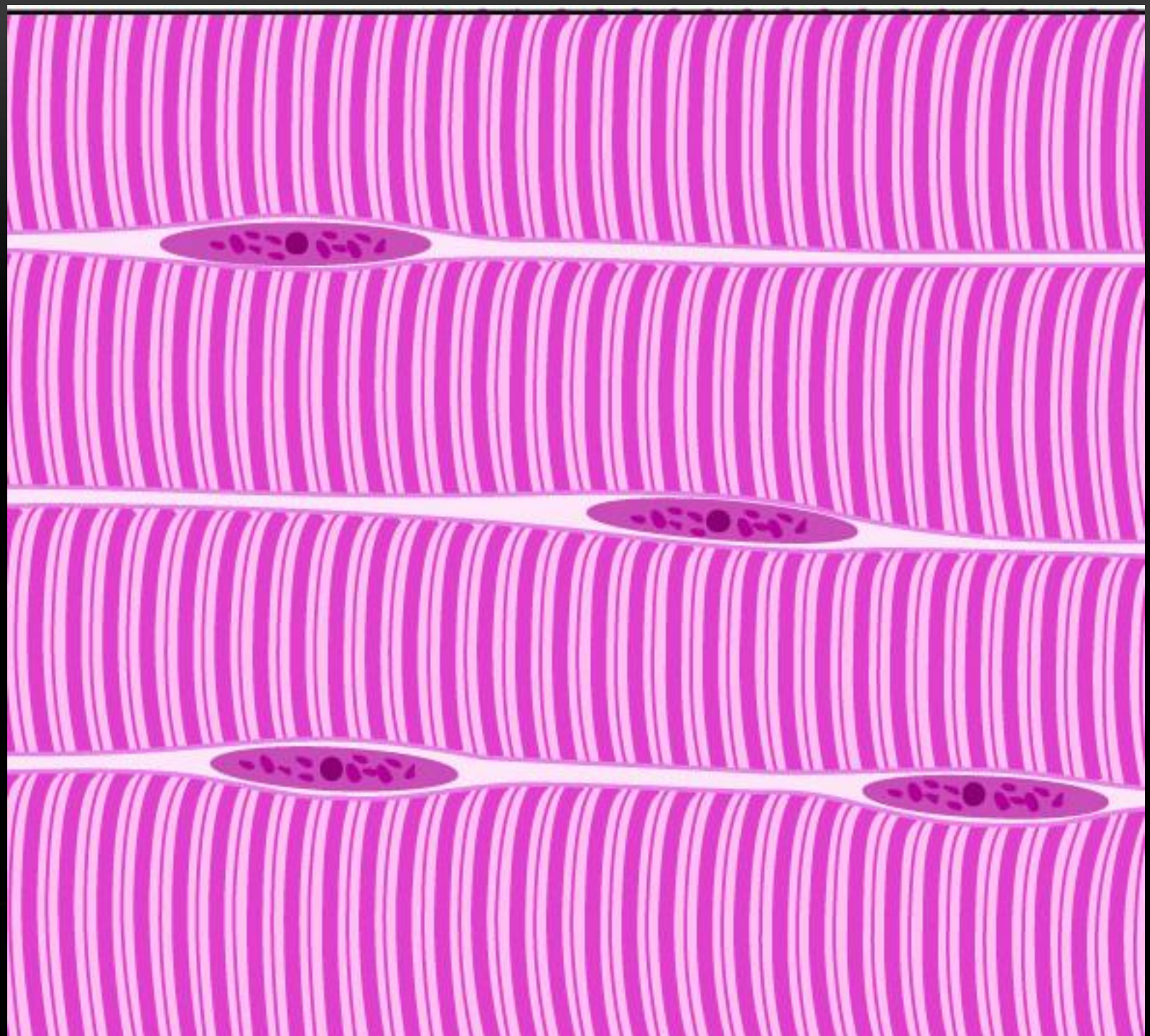
Skeletal muscle CT

Epimysium – surrounds entire muscle/organ = muscle fascia.

Perimysium – surrounds muscle fascicle.

Endomysium – surrounds individual muscle fiber.





Histology of the Skeletal Muscle Fibres ..1

Long acidophilic multinucleated cells, 10-100 μm diameter, Varied length – up to entire muscle.

Nuclei are located under the sarcolemma (peripheral).

Satellite cells are interposed between the muscle fibre and its external lamina.

Cytoplasm contains longitudinal myofibrils.

Myofibrils extend the entire length of the cell and their parallel arrangement is responsible for the cross-striations.



Histology of the Skeletal Muscle Fibres ..2

Dark bands A (*anisotropic*)

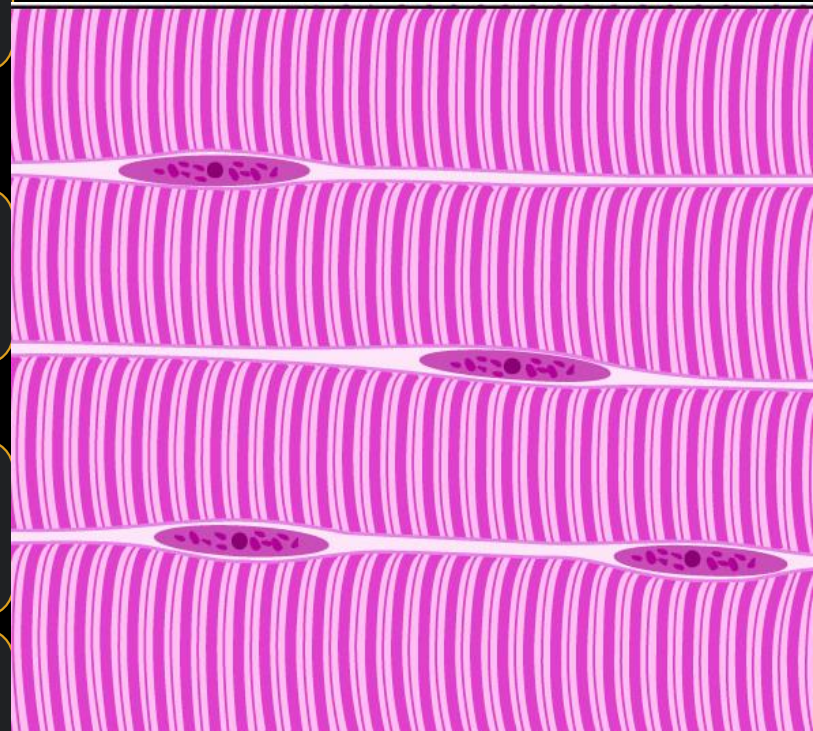
- Bisected by the H band.
- Bisected by the M line.

Light band I (*isotropic*).

- Bisected by the Z line.

The region between 2 successive Z lines
→ Sarcomere.

The sarcomere is the contractile unit of the skeletal muscle fibre.



Histology of the Skeletal Muscle Fibres ..3

The sarcolemma is continued inside the cell as an invagination → T tubules.

T tubules lie in the plane of the junction between A and I bands.

T tubules branch and anastomose.

Each sarcomere has 2 sets of T tubules.

Histology of the Skeletal Muscle Fibres ..4

The sarcoplasmic reticulum is closely related to the T tubule.

The dilated end of the reticulum is called the terminal cisternae → voltage-gated Ca^{++} release channels.

Two of the cisternae are closely related to the tubule → Triad.

The sarcoplasmic reticulum stores intracellular calcium.

- Release of Ca^{++} = contraction
- Sequestering of Ca^{++} = relaxation

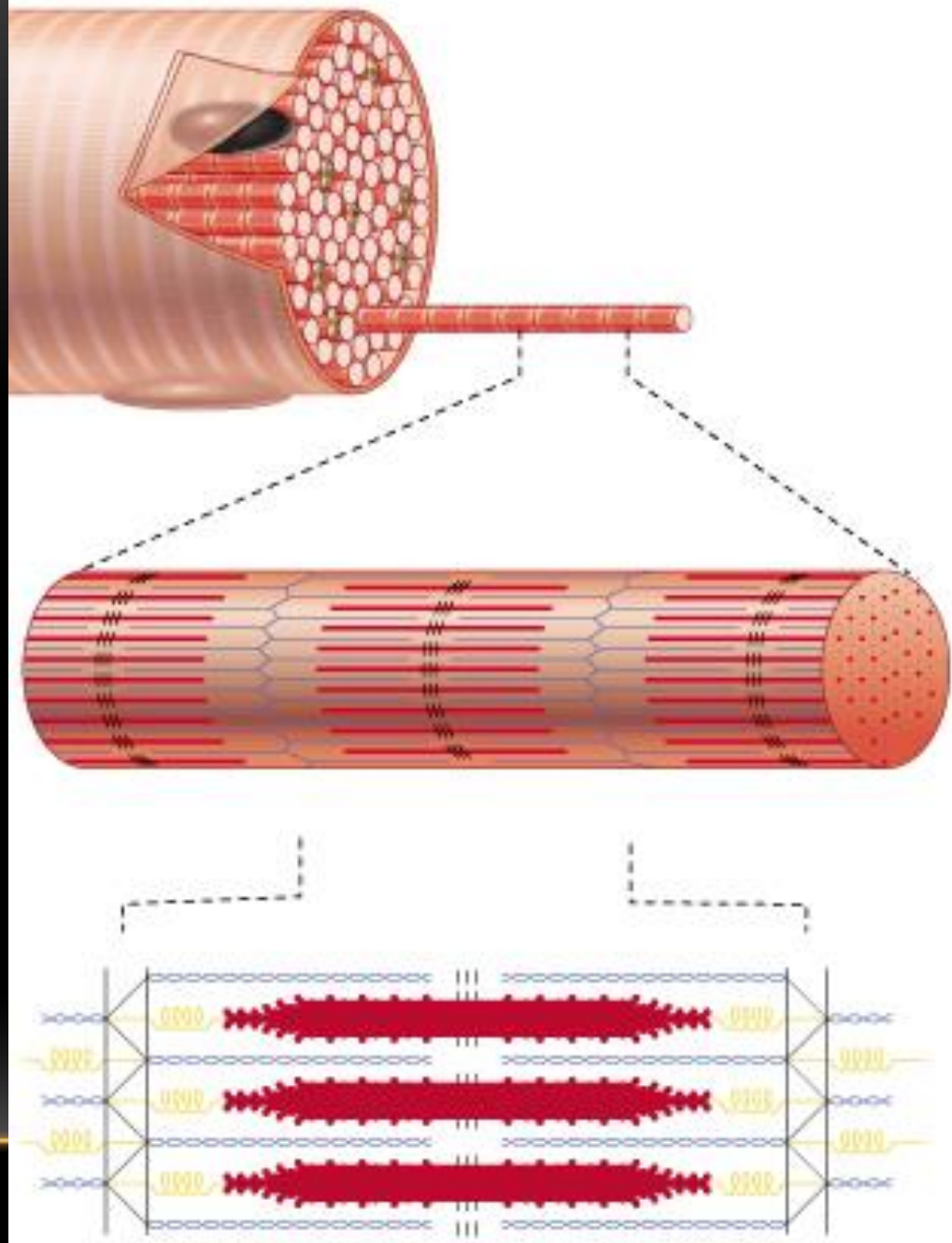
Histology of the Skeletal Muscle Fibres ..5

Myofibrils are kept together by *desmin* and *vemintin*.

The cytoplasm contains mitochondria with interdigitating cristae in different regions.

MYOFIBRILS

- Bundles of myofilaments
- Z discs
- A band – actin & myosin overlap
- I band – actin only
- H zone – myosin only
- Sarcomere – Z to Z
- Striations – alignment of myofilaments & myofibrils



Sliding filament theory

Muscle contracts by actin and myosin sliding past each other

Myosin forms cross-bridges that attach to actin

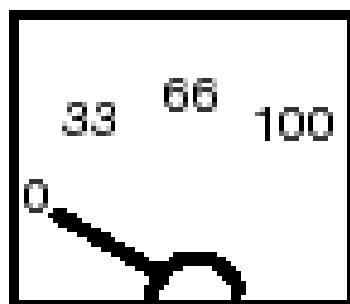
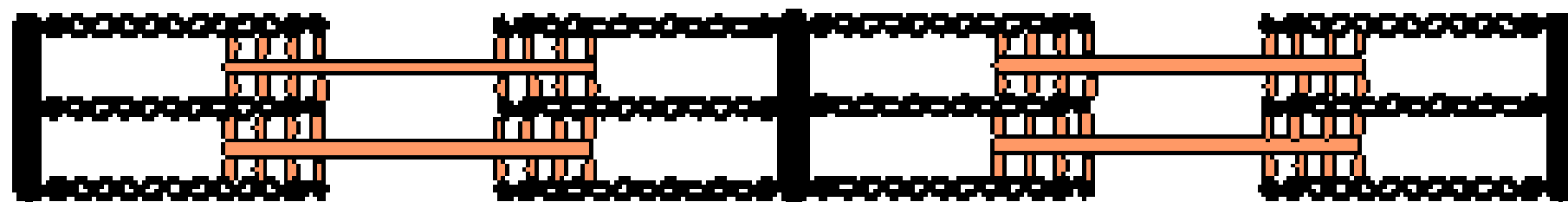
Cross bridges all swing in same direction and pull actin along

Increased overlap of filaments results in contraction of muscle

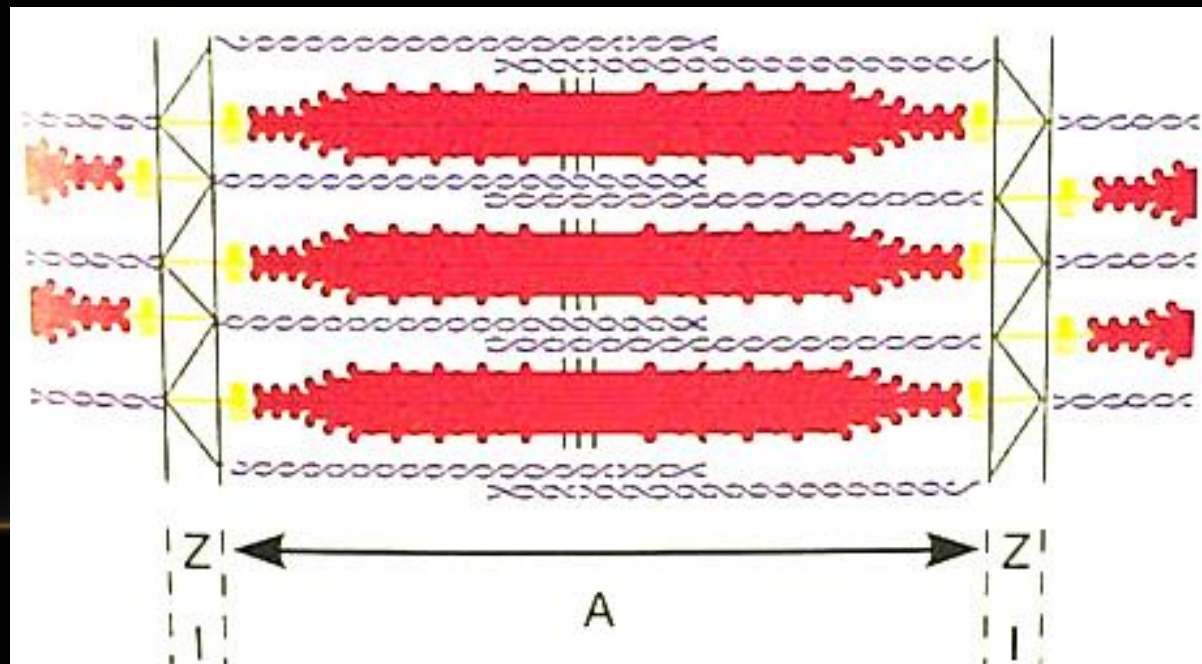
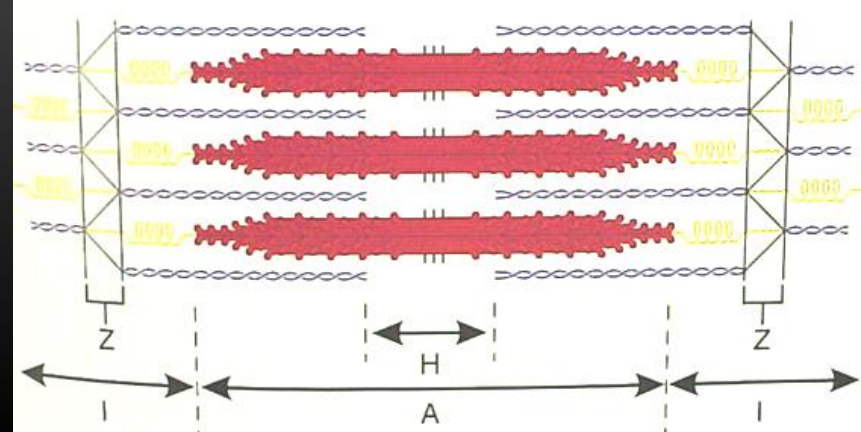
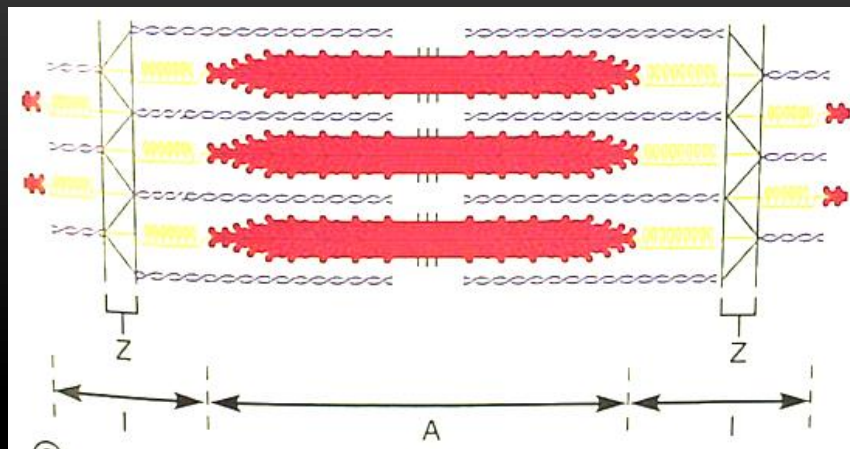
Sliding Filament Theory

During contraction:

- Filaments **DO NOT** shorten.
- Two **Z** disks are brought closer together.
- Thin filaments slide over thick filaments.
- The thin and thick filaments overlap.
- The width of the **I** and **H** bands is reduced.
- The width of the **A** band is **NOT** affected.



% Tension Developed



The Neuromuscular Junction

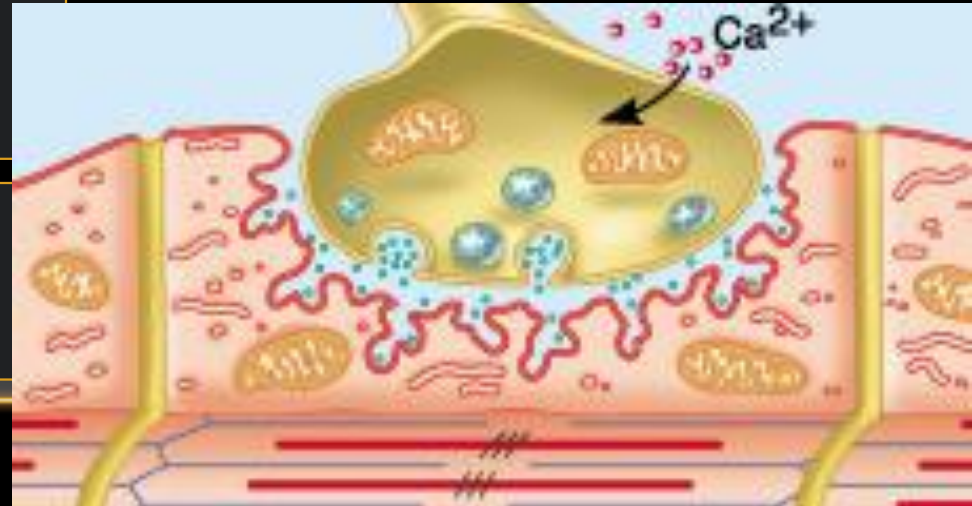
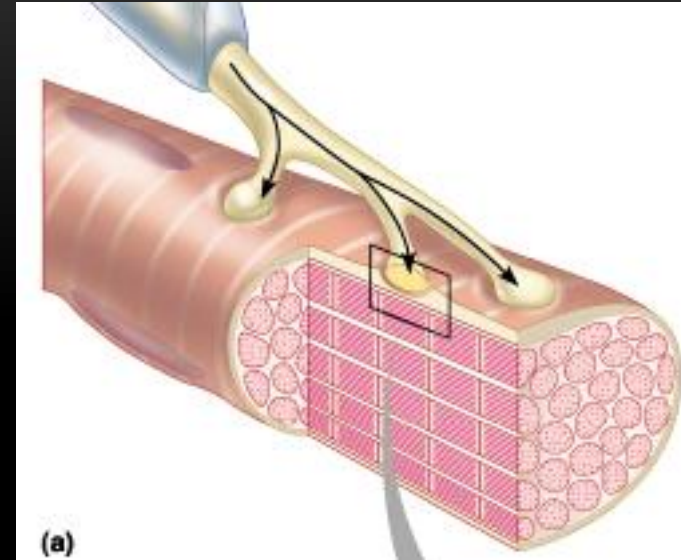
Axon terminal

- Mitochondria
- Synaptic vesicles – ACh

Synaptic cleft

Motor end plate

- AChR
- AP to muscle fiber



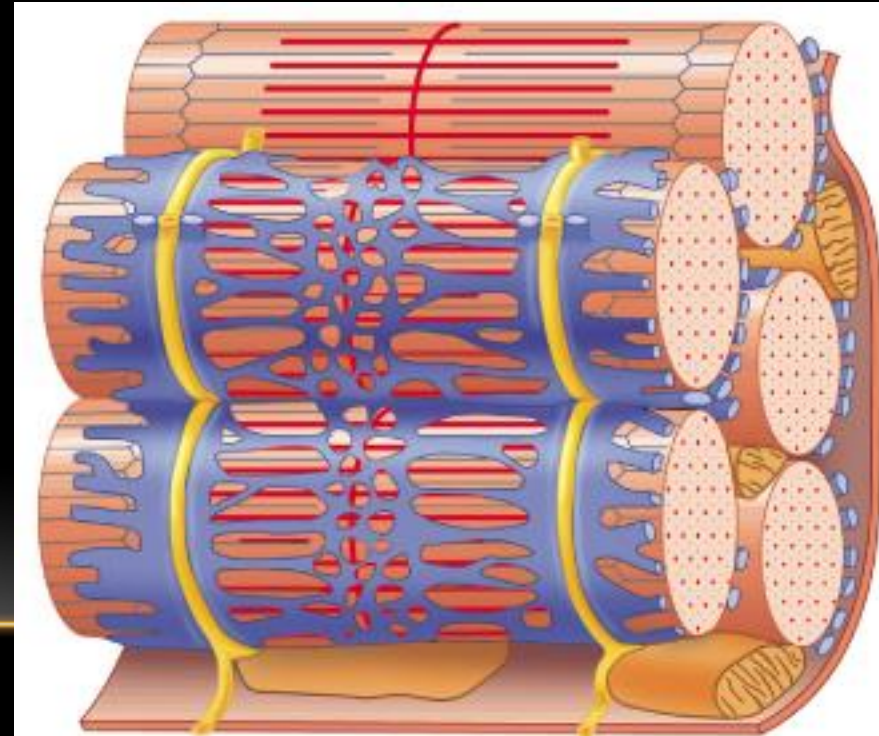
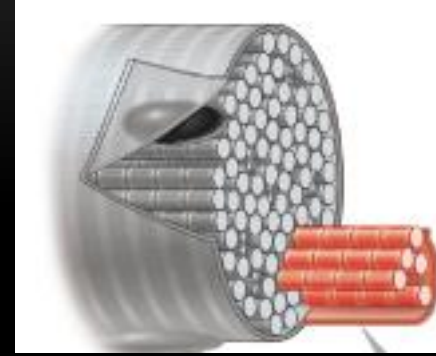
T tubules

Invaginations of sarcolemma

Runs between myofibrils

Conducts electrical impulses from sarcolemma

Excites SR to release Ca^{++}

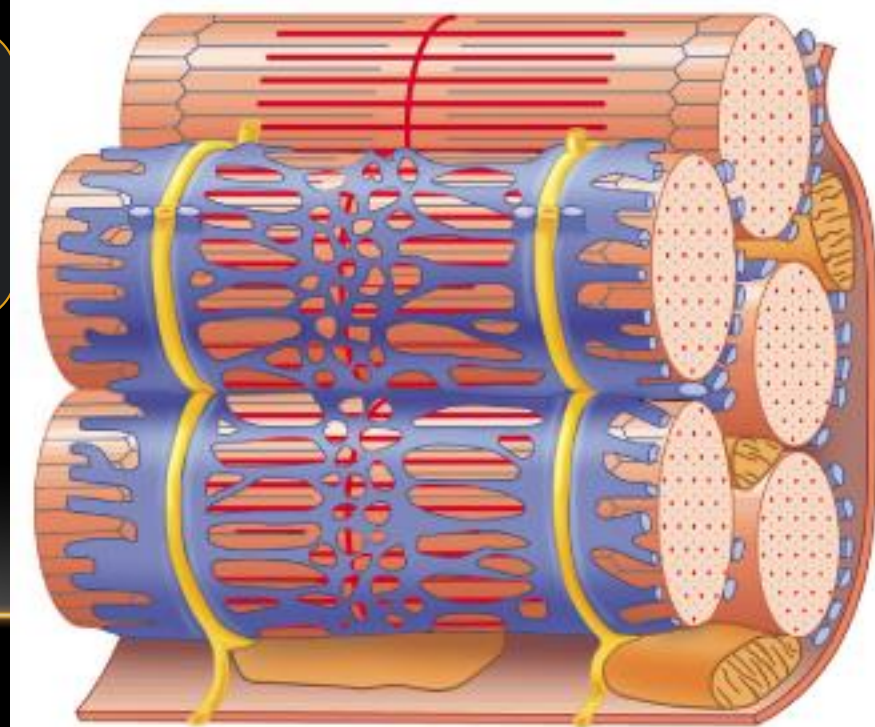
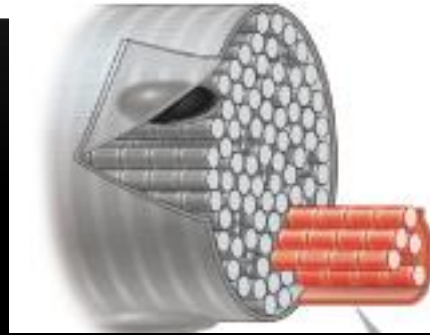


Sarcoplasmic reticulum

SR surrounds each myofibril

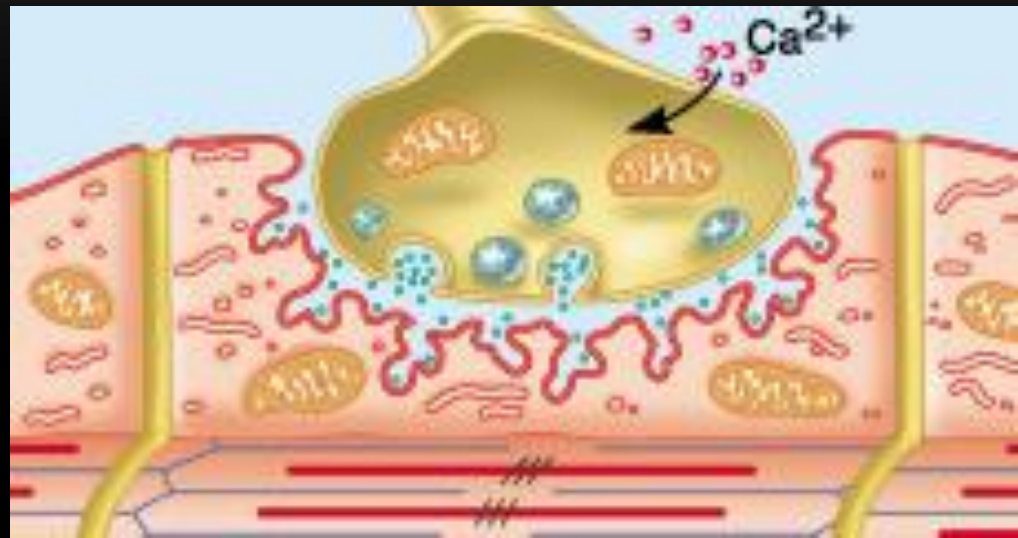
Stores Ca^{++}

- Release Ca^{++} for contraction
- Ca^{++} uptake for relaxation



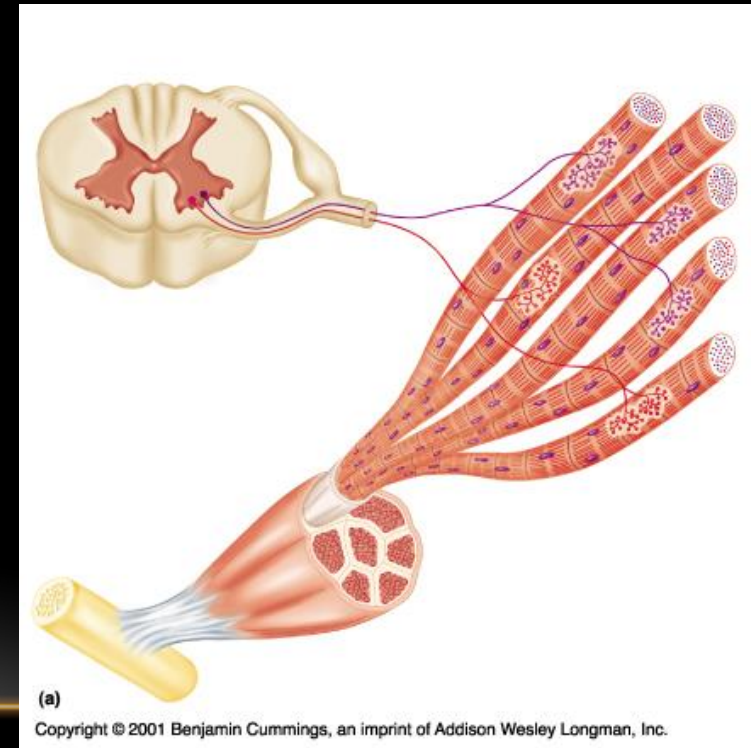
Muscle contraction

- AP to axon terminal
- ACh released
- AChR activated
- Muscle excited
- Excitation travels down t-tubule
- SR releases Ca^{++}
- Ca^{++} activates sliding filament process
- Muscle contracts

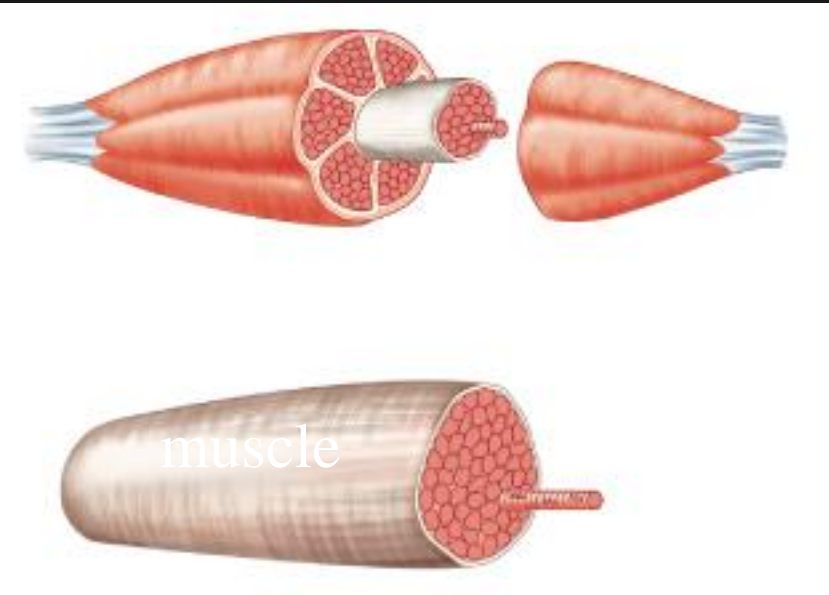


MOTOR UNIT

- Definition: a motor neuron and all the muscle fibers it innervates.
- When a motor neuron fires, all muscle fibers in the motor unit contract.
 - All or none principle
- A motor unit may contain hundreds to four muscle fibers (average ~ 150)
- Each muscle fibers receives one NMJ

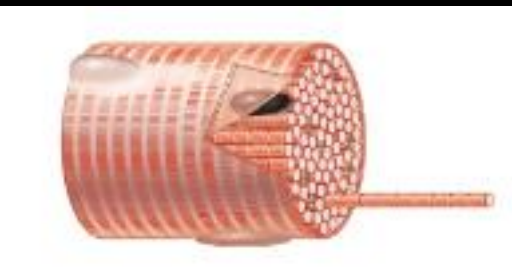


SUMMARY: SKELETAL MUSCLE FIBERS



muscle

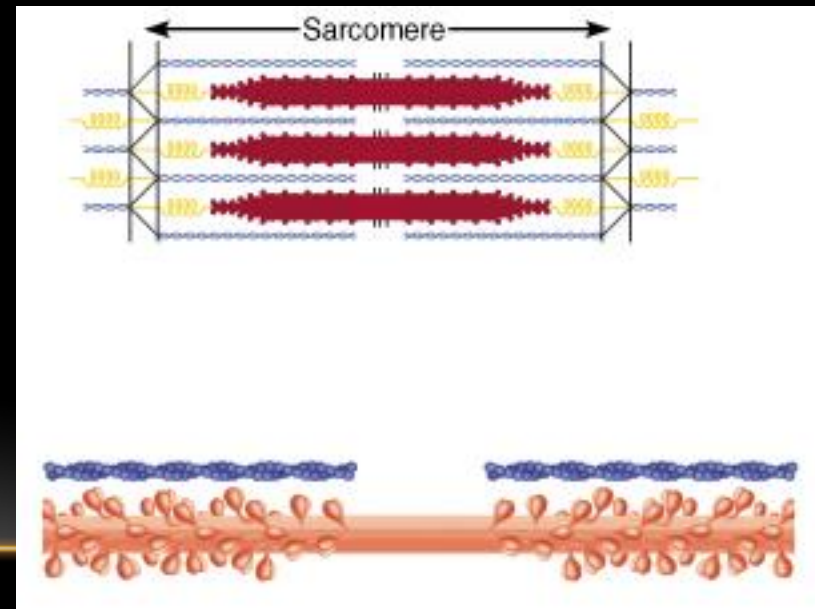
fascicle



fiber

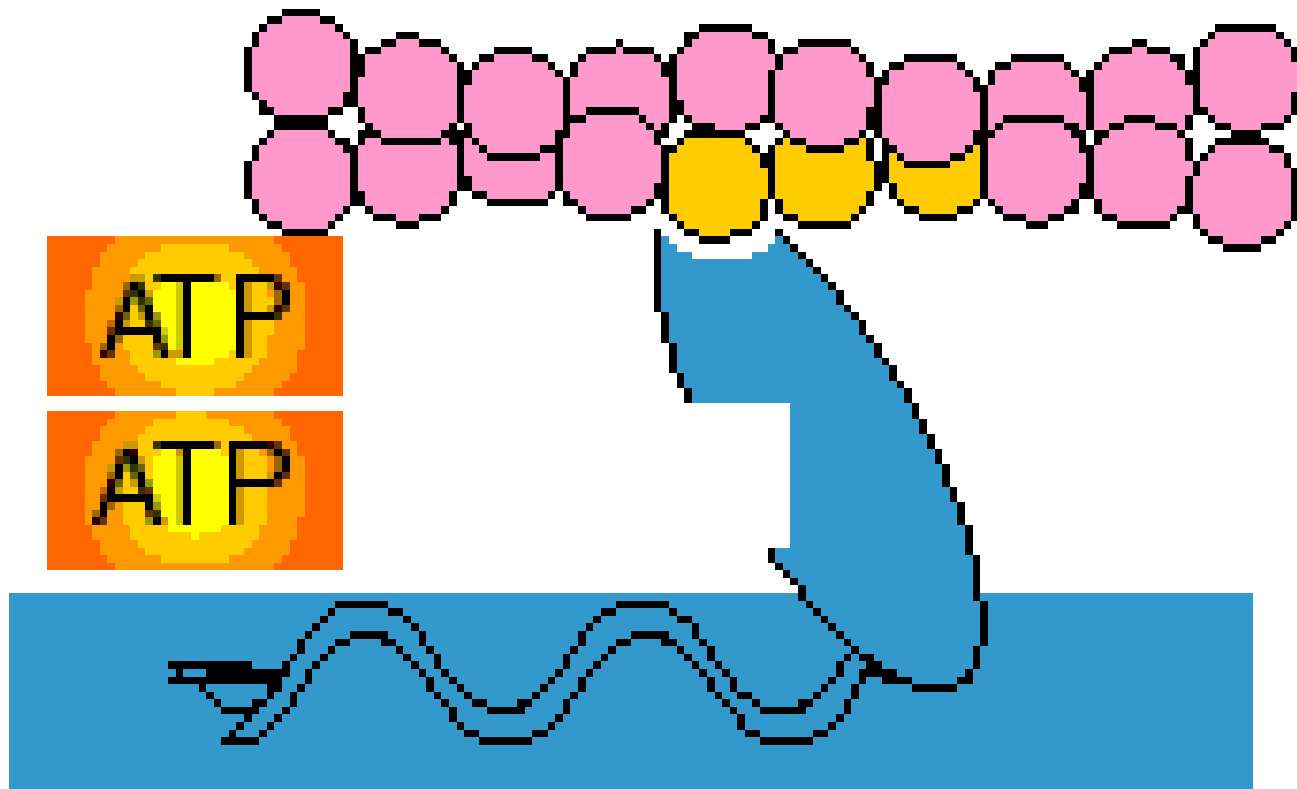


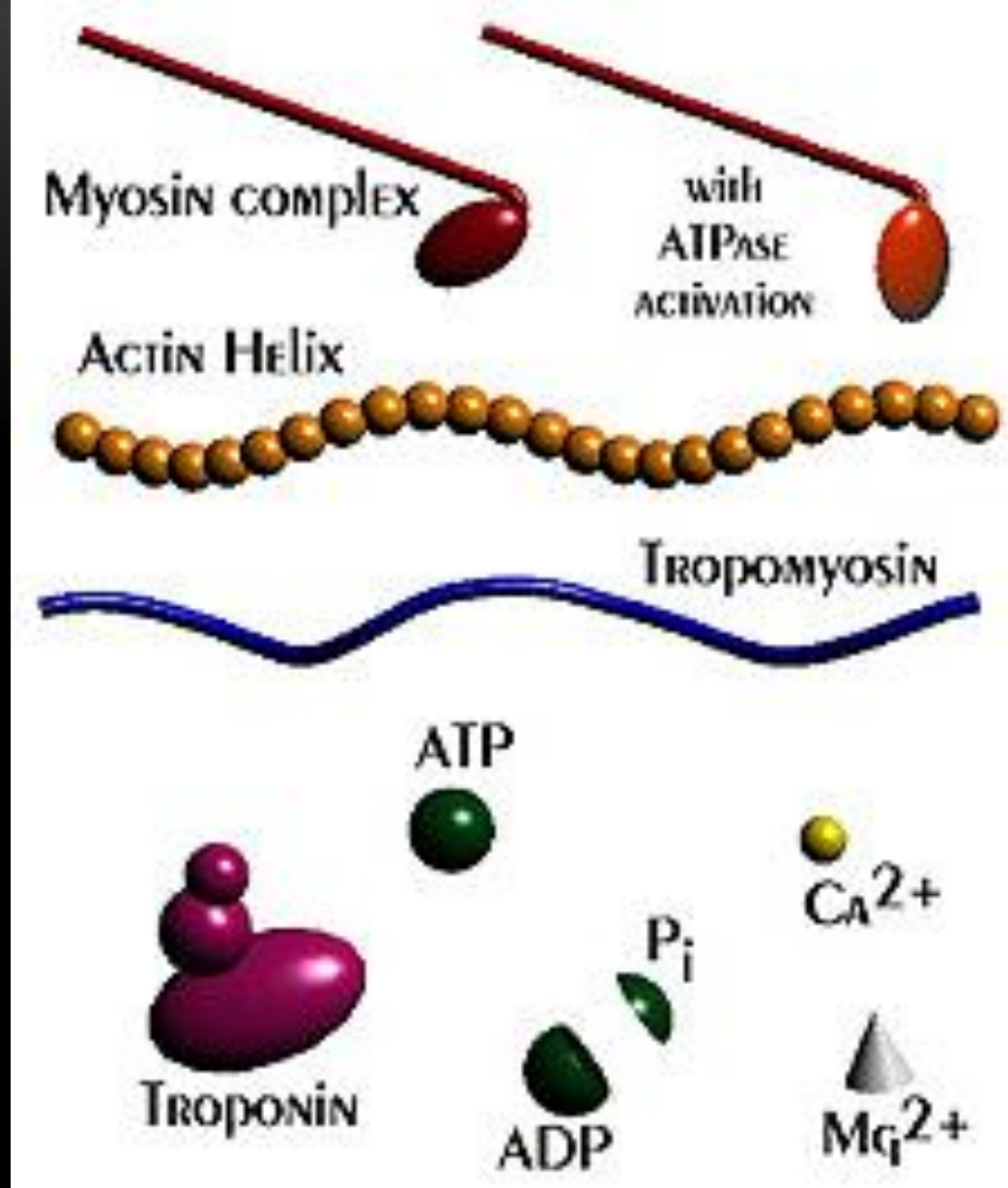
myofibril



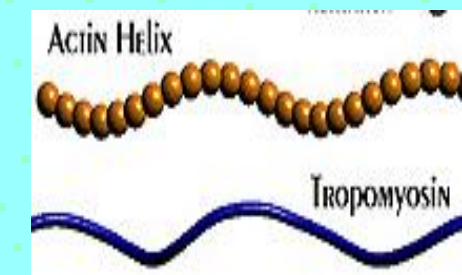
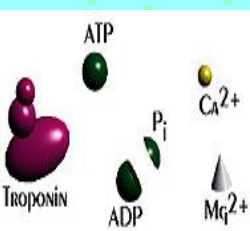
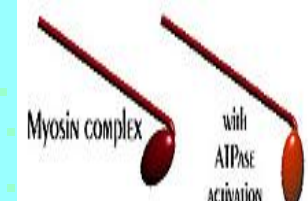
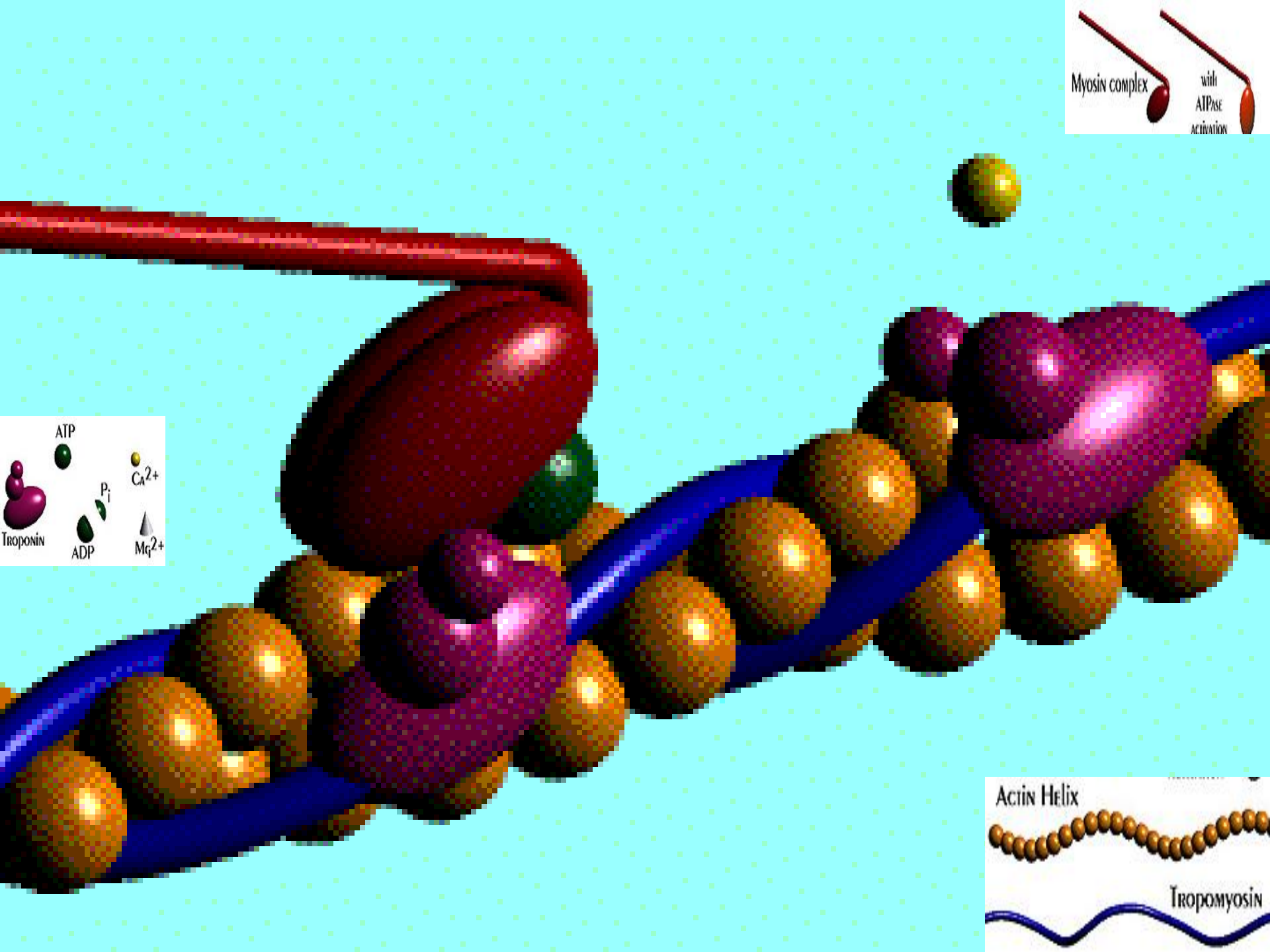
Myofilaments :actin & myosin

Characteristics	<i>Red Fibres</i>		<i>White Fibres</i>
	Type I	Type IIa	Type IIb
Vascularization	Rich	Rich	Poorer
Innervation	Small nerve fibres	Intermediate	Larger nerve fibres
Fibre Diameter	Smaller	Intermediate	Larger
Contraction	Slow, repetitive, weak (soleus, muscles of the back)	Fast (leg muscles)	Fast, strong (extra-ocular muscles)
Fatiguability	Difficult	Intermediate	Easy
Sarcoplasmic reticulum	Not extensive	Intermediate	Extensive
Mitochondria	Rich	Rich	Few
Myoglobin	Rich	Rich	Poor
Glycogen content	Low	Intermediate	High
ATPase activity	Low	High	High
Major source of ATP	Oxidative phosphorylation	Oxidative phosphorylation	Anaerobic glycolysis





KEY FOR THE NEXT FIGURE

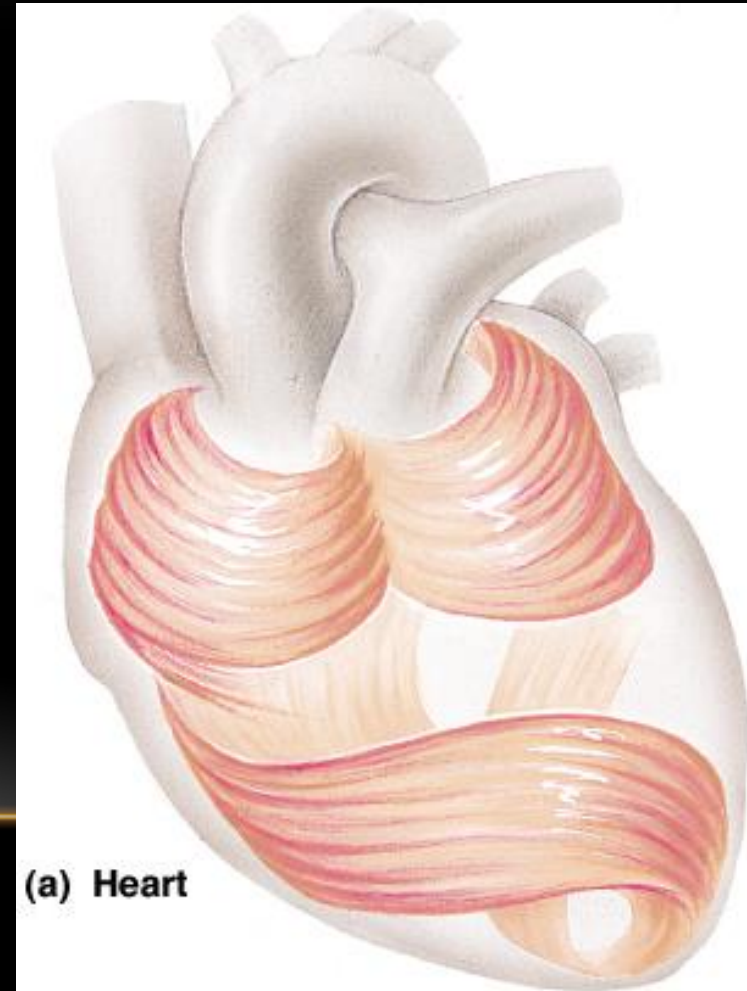


Cardiac muscle

Only in heart and roots of major vessels

Striated

No NMJ



(a) Heart

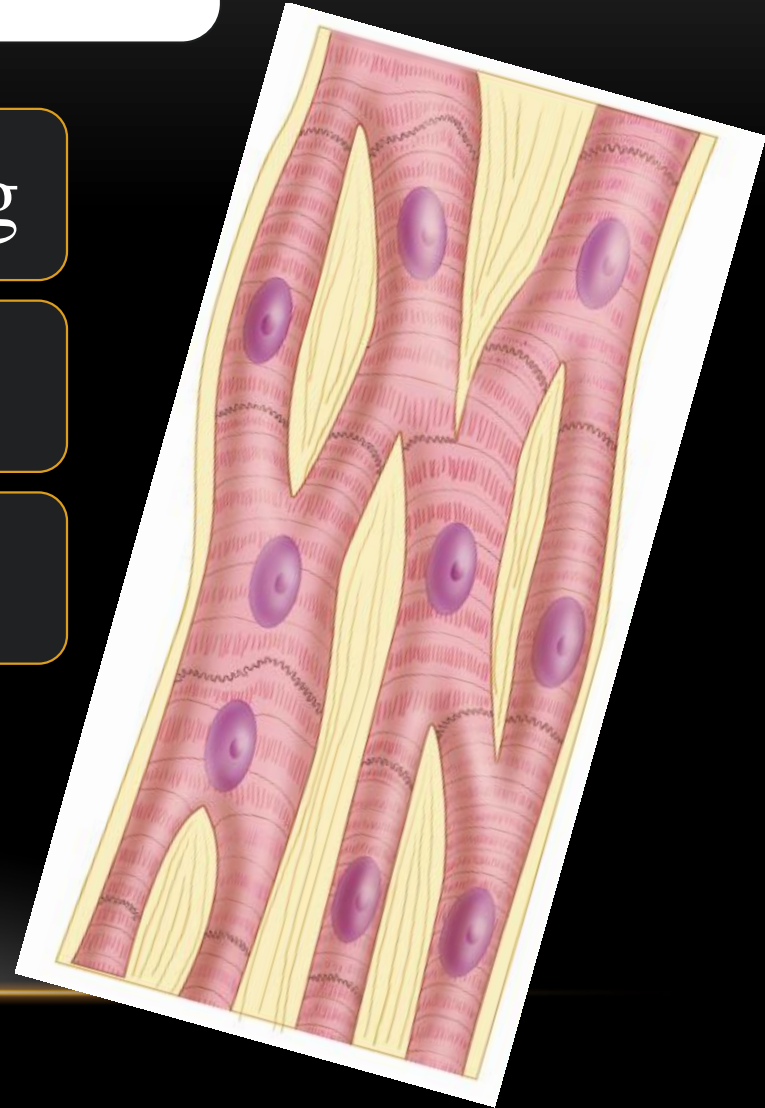
Cardiac muscle cells

15 μm wide X 100 μm long

Branched

Intercalated discs

- Desmosomes
 - adhesion
- Gap junctions
 - transmit electrical impulses



Cardiac muscle cells

Central 1-2 nuclei

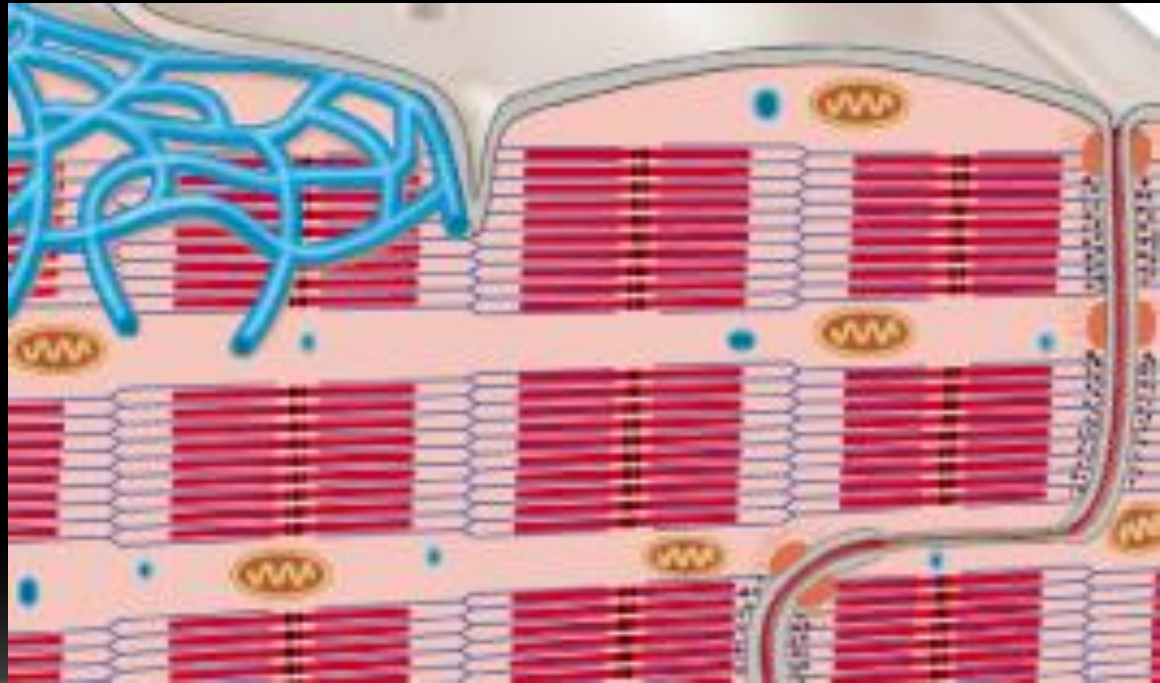
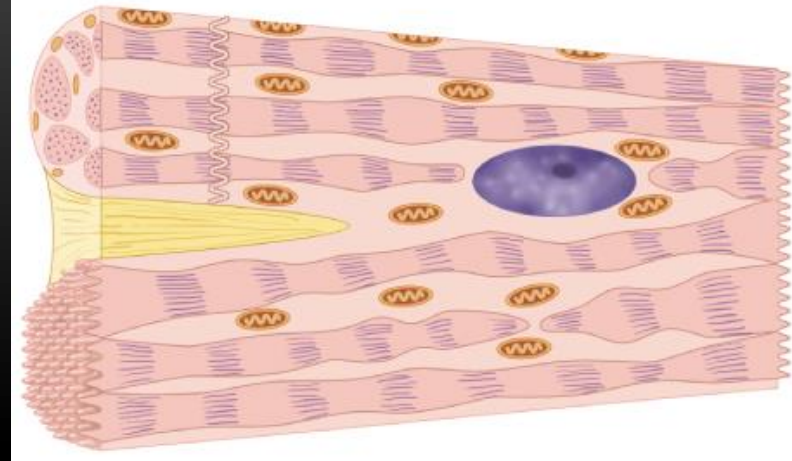
Mitochondria – numerous, Less SR

Fewer T tubules than skeletal muscles

Diad

Sarcomeres

- A band
- I band
- Z disc
- H zone
- Striated



Cardiac muscle is intrinsically contractile but is regulated by autonomic and hormonal stimuli.

The myofibrils separate to pass around the nucleus, leaving a perinuclear clear area (not always evident).

This clear area is occupied by organelles, especially mitochondria.

individual muscle fibres are surrounded by endomysium.

Numerous capillaries are found in the connective tissue around cardiac muscle fibres.

Specialized fibres, called **Purkinje fibres**, arise from the atrioventricular node and travel along the interventricular septum toward the apex of the heart, sending branches into the ventricular tissue.

Purkinje fibres are of larger diameter than ordinary cardiac fibres:

- Fewer myofibrils
- Well-defined clear area around the nucleus.
- Conduct impulses at a rate about four times faster than that of ordinary cardiac fibres.
- Serve to coordinate the contraction of the atria and ventricles.

Smooth muscle

Six major locations

- Blood vessels
- Respiratory system
- Digestive system
- Urinary system
- Reproductive system
- Eye (lens and iris)

Siding filament theory applies

- Actin & myosin
- No myofibrils – no striations

Smooth muscle fibers

Spindle shaped

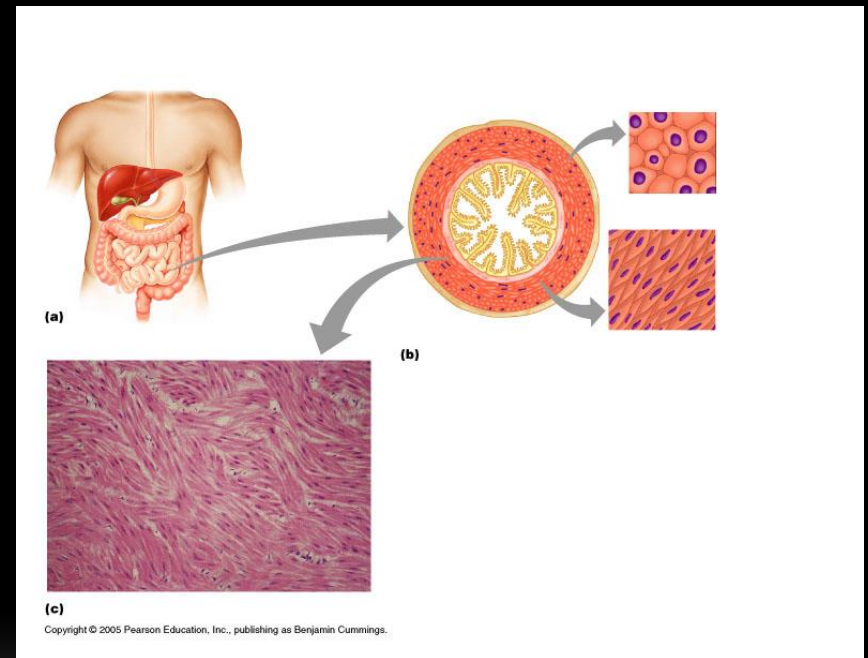
- 2-10 μm diameter
- 20-500 μm long

Nonstriated

Central nucleus

Arranged in sheets

- Usually in layers around a tube
- Peristalsis - waves of contraction to propel contents along tube



Smooth muscle properties

Slower to contract vs. skeletal muscle

Slower to relax vs. skeletal muscle

Can maintain contraction longer

Resistant to fatigue

Unconscious control

- ANS – autonomic nervous system
- Stretch
- Hormones

Also, smooth muscle nuclei often have a corkscrew shape in longitudinal section due to contraction of the muscle fibre during fixation.

In cross section, smooth muscle appears as profiles of various sizes, depending on whether the cut went through the thick central part or tapered end of any individual fibre. Nuclei are seen only in the thicker profiles.

Distinguishing feature of smooth muscle is its ability to secrete connective tissue matrix.

In the walls of blood vessels and the uterus in particular, smooth muscle fibres secrete large amounts of collagen and elastin.

Smooth muscle organization

Single unit innervation

- Smooth muscle fibers connected by gap junctions
- Network receives single innervation
- Coordinated contraction

Multiunit innervation

- Each fiber innervated
- Locations
 - Iris of eye
 - Arrector pili muscle of skin

Comparison of the 3 types of muscles

Feature	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 cisterns	Poorly defined, some small terminals	Some sER (not involved in calcium storage)
T Tubule	Yes: involved in triad formation	Yes: involved in dyad formation	No
Cell Junctions	No	Intercalated disks	Nexus (gap junctions)
Contraction	Voluntary “all or none”	Involuntary: rhythmic and spontaneous	Involuntary: slow and forceful
Calcium Control	Calcequestrin in terminal cisterns	Calcium for extracellular sources	Caveolae
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