Muscle Tissues

Quit

Muscle

Lecture

- **Slide menu**
- **Interactive presentation**

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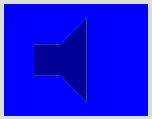

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- Slide 2 – Notes – Skeletal muscle
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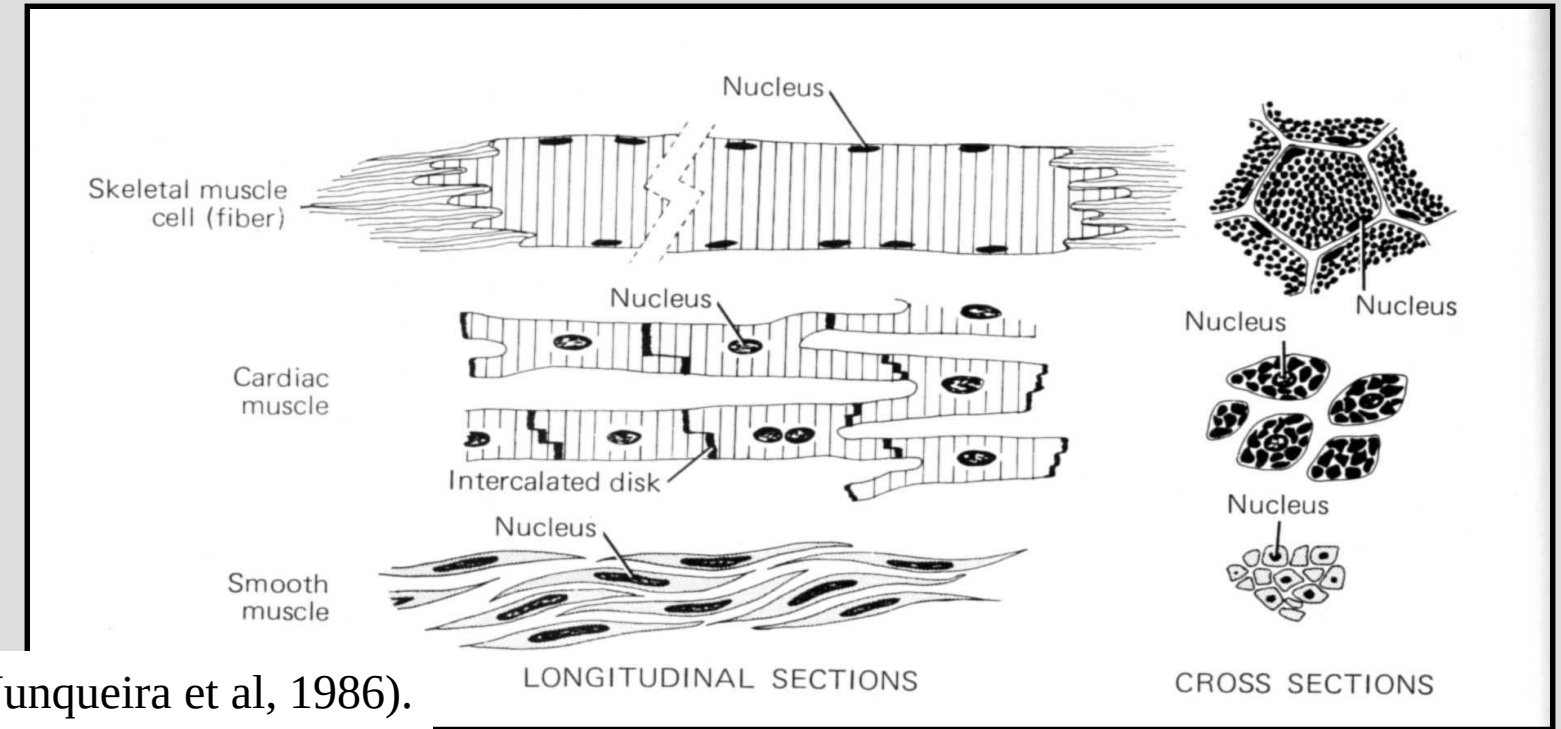
MUSCLE

Specialized for **contraction** allow movement
The cells are called **fibres** because of their length (myo= muscle)
sarcoplasm = protoplasm
sarcolemma = cell membrane
sarcoplasmic reticulum = smooth surfaced EPR
sarcomere = functional unit
sarcosomes = mitochondria
Types:

striated → **Skeletal (voluntary)**
striated → **cardiac (involuntary)**
smooth (involuntary)



(Junqueira et al, 1986).

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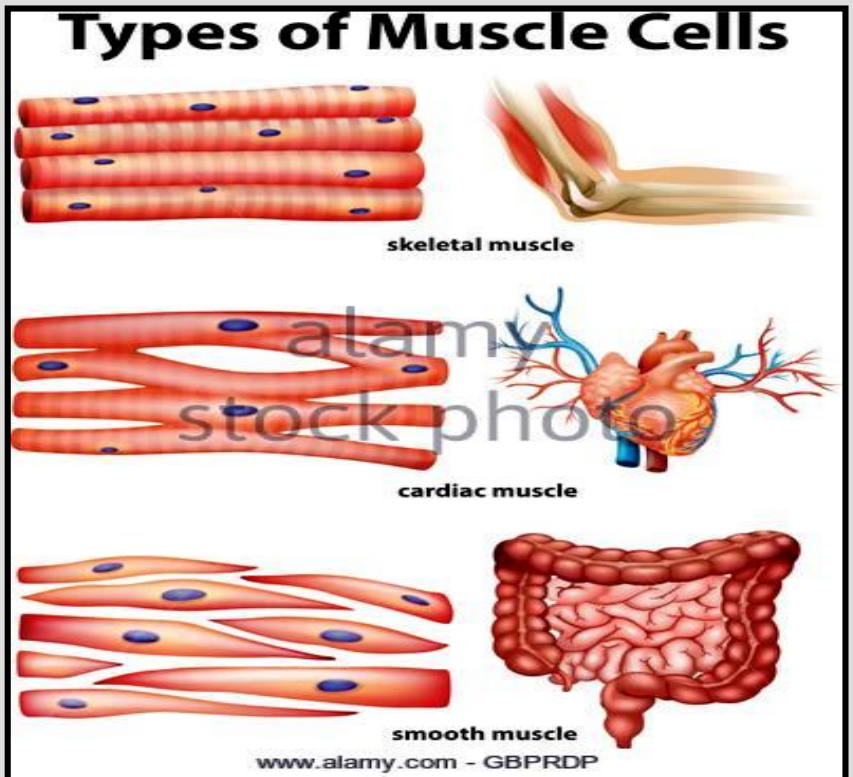
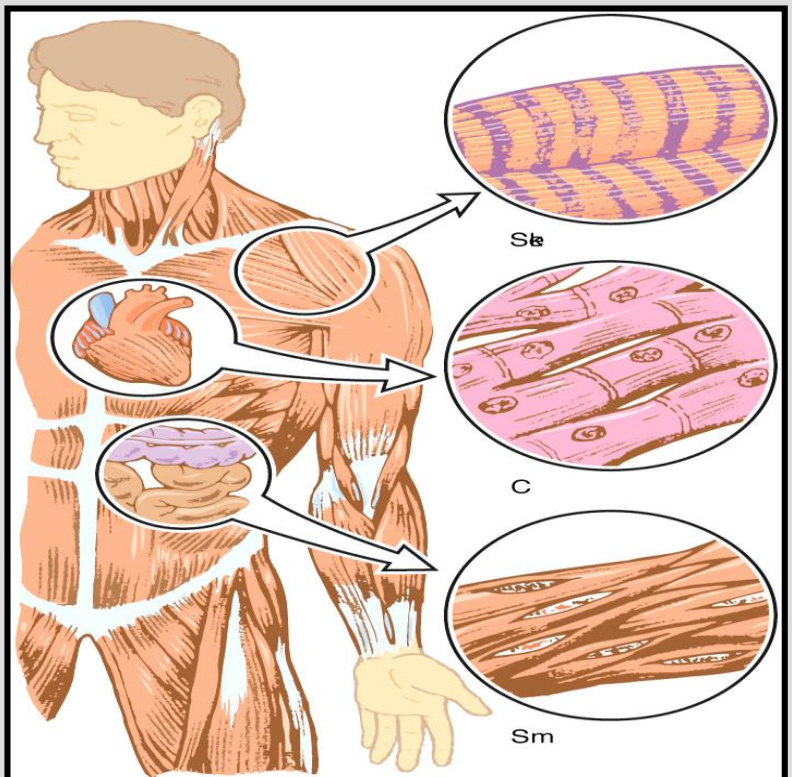
Muscle cells can be placed into three categories:

a. **Smooth Involuntary Muscle**
   i. found in hollow visceral organs such as the gut, uterus and blood vessels
   ii. associated with various exocrine glands.

b. **Striated Involuntary Muscle** - found in the heart (cardiac muscle)
c. **Striated Voluntary Muscle** - makes up the skeletal muscles of the body

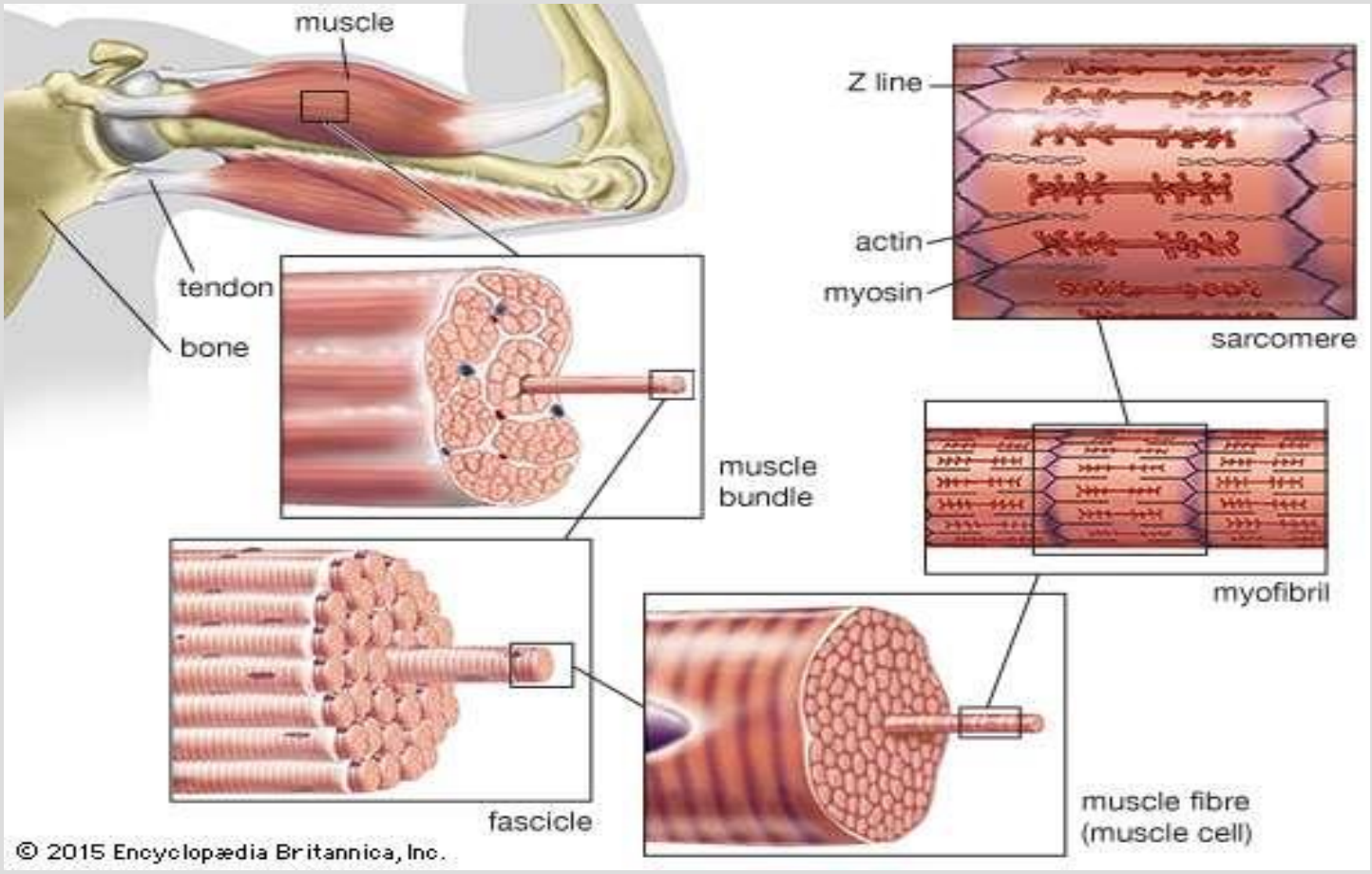




Skeletal Muscle

-known as **striated** or **voluntary muscle**, comprises some **40-50%** of the body mass in adults

- long fibres, the average length of skeletal muscle cells in humans is about 3 cm (**sartorius** muscle up to 30 cm, **stapedius** muscle only about 1 mm). Their diameters vary from 10 to 100µm.



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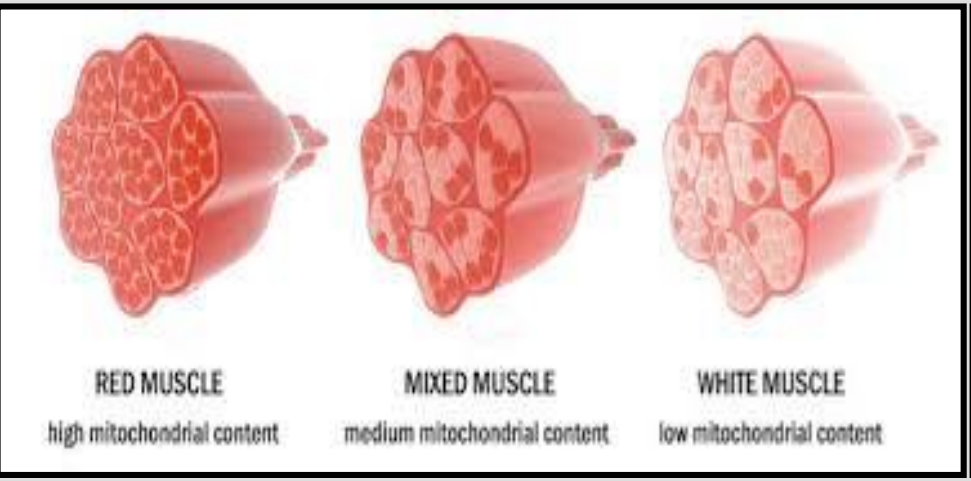
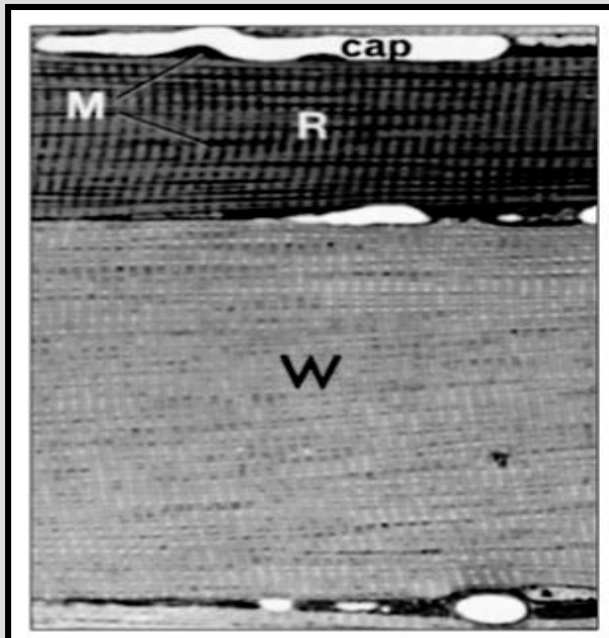
-According to the **myoglobin** content there are:

Red fibres (Type I fibres)
-Red muscle fibres are comparatively **thin.** Contain lots of **myoglobin**
-**Many** mitochondria
-**Slow twitching** (contract slower) – **tire slower**
-Found in limbs, long muscles of the back (long, slow contraction for erect posture).
Red muscles are needed when **sustained** production of **force** is necessary

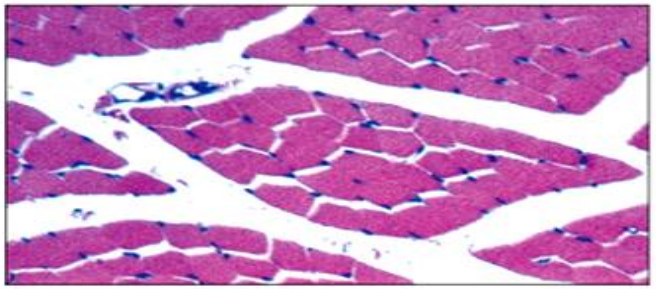
White fibres (Type II fibres)
-are **thicker**, **Less** myoglobin
-**Less** mitochondria
-**Fast twitching,** contraction is **fast** – **tire quickly**
-Found in **extraocular** muscles, digits (for rapid and precise movement)
-Fast twitch fibers can be further categorized into **Type IIa** and **Type IIb** fibers.



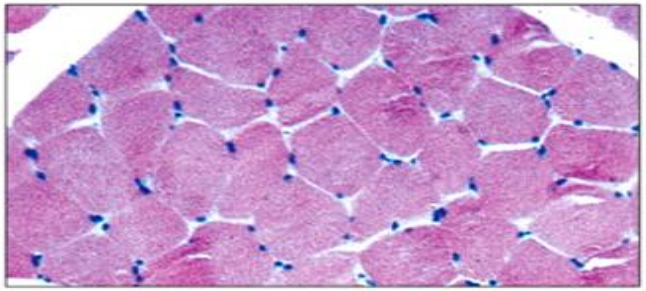
Most muscles have all three in varying ratios

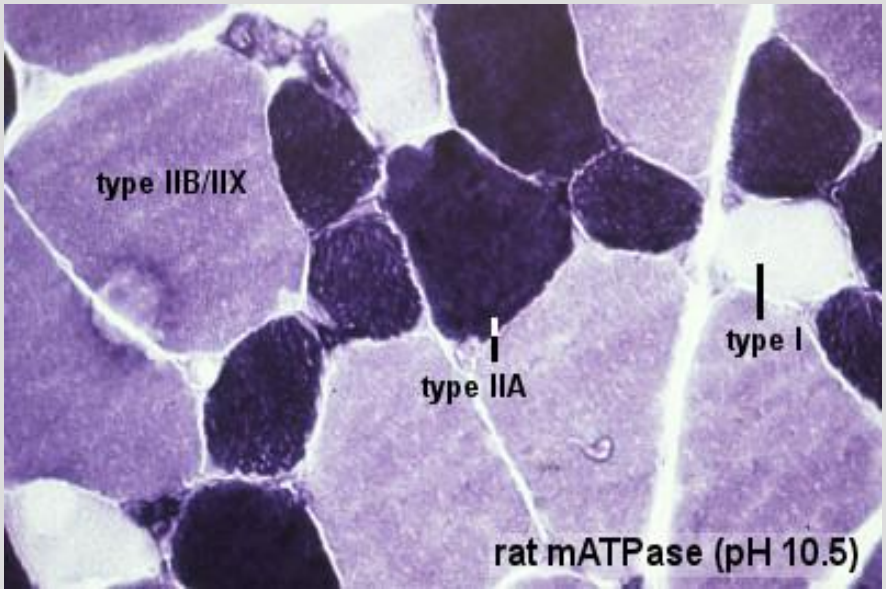


Slow-twitch oxidative muscle fibers
Note smaller diameter, darker color due to myoglobin. Fatigue-resistant.

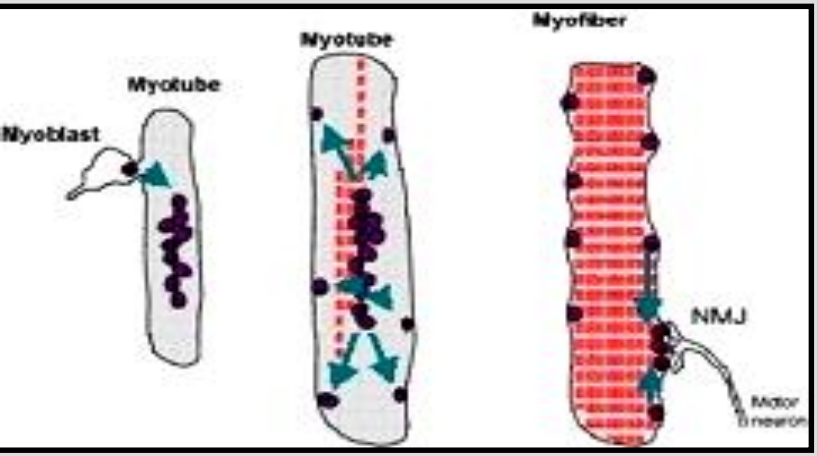


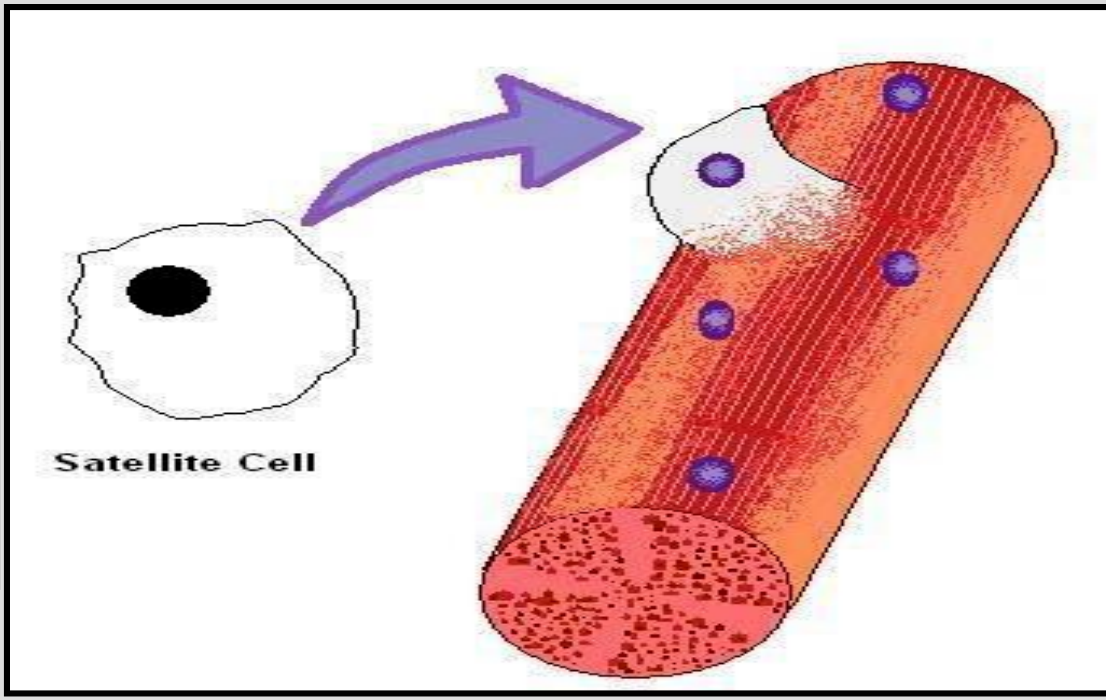
Fast-twitch glycolytic muscle fibers
Larger diameter, pale color. Easily fatigued.





- During embryonic development **mesodermal cells** differentiate into uninuclear **myoblasts**, which elongate and fuse together to form **myotubes**, which further develop into the mature muscle fibers or **myofibers**. These myofibers are the basic units of skeletal muscle



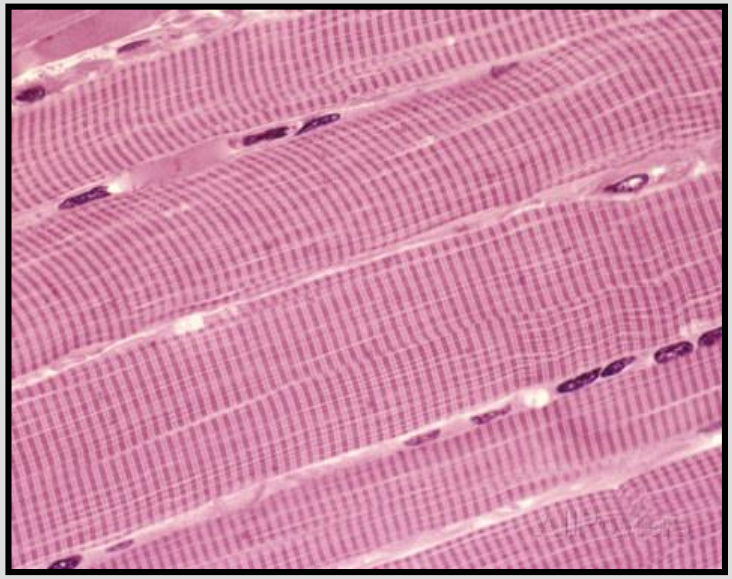


- A further cell-type, known as **satellite cells,** may be found adjacent to the sarcolemma. These are elongated, poorly-differentiated cells that are very difficult to discern in typical preparations, but become active during **repair** and **regeneration** processes after muscle injury.

Structure of skeletal muscle:

Light Microscopy

- Many nuclei - 35/mm
- Nuclei are oval - situated peripheral
- Dark and light bands lie across the fiber
- **No branching**



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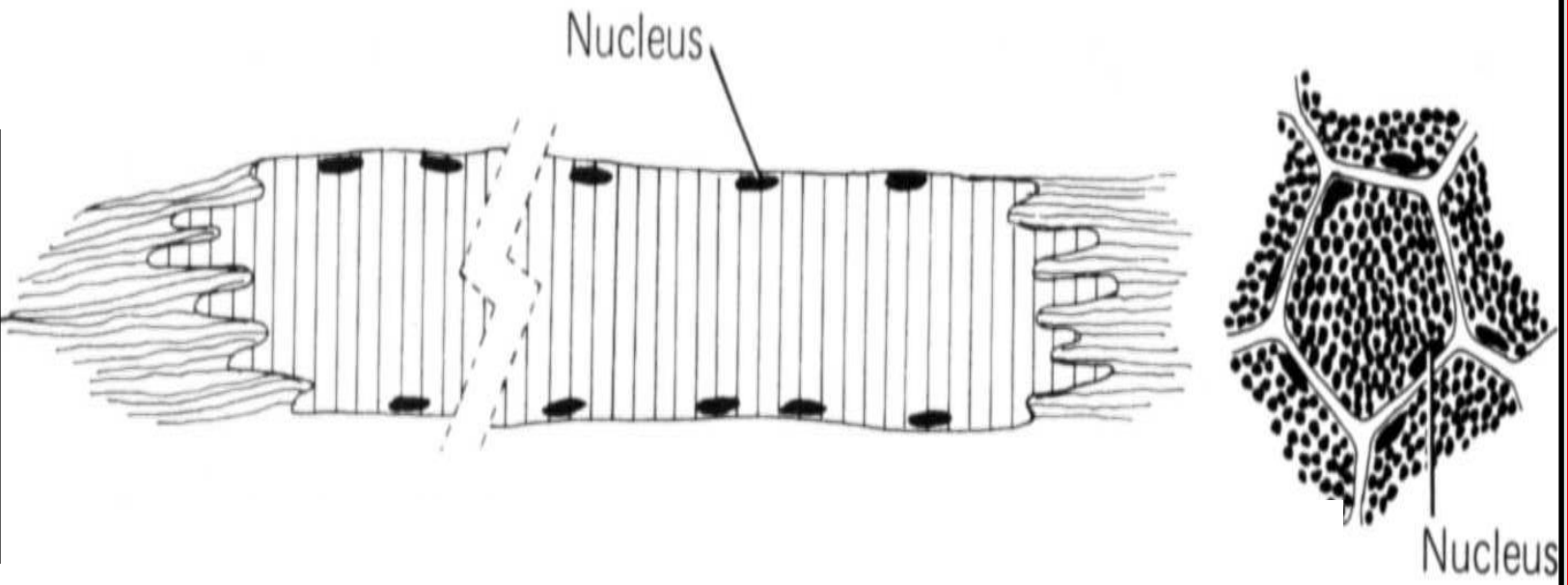
Skeletal muscle



(Junqueira et al, 1986).

This is skeletal muscle. The ← ← show the peripheral nuclei of a skeletal muscle fiber. Notice the cross striations and that the fibers don't have any connections.

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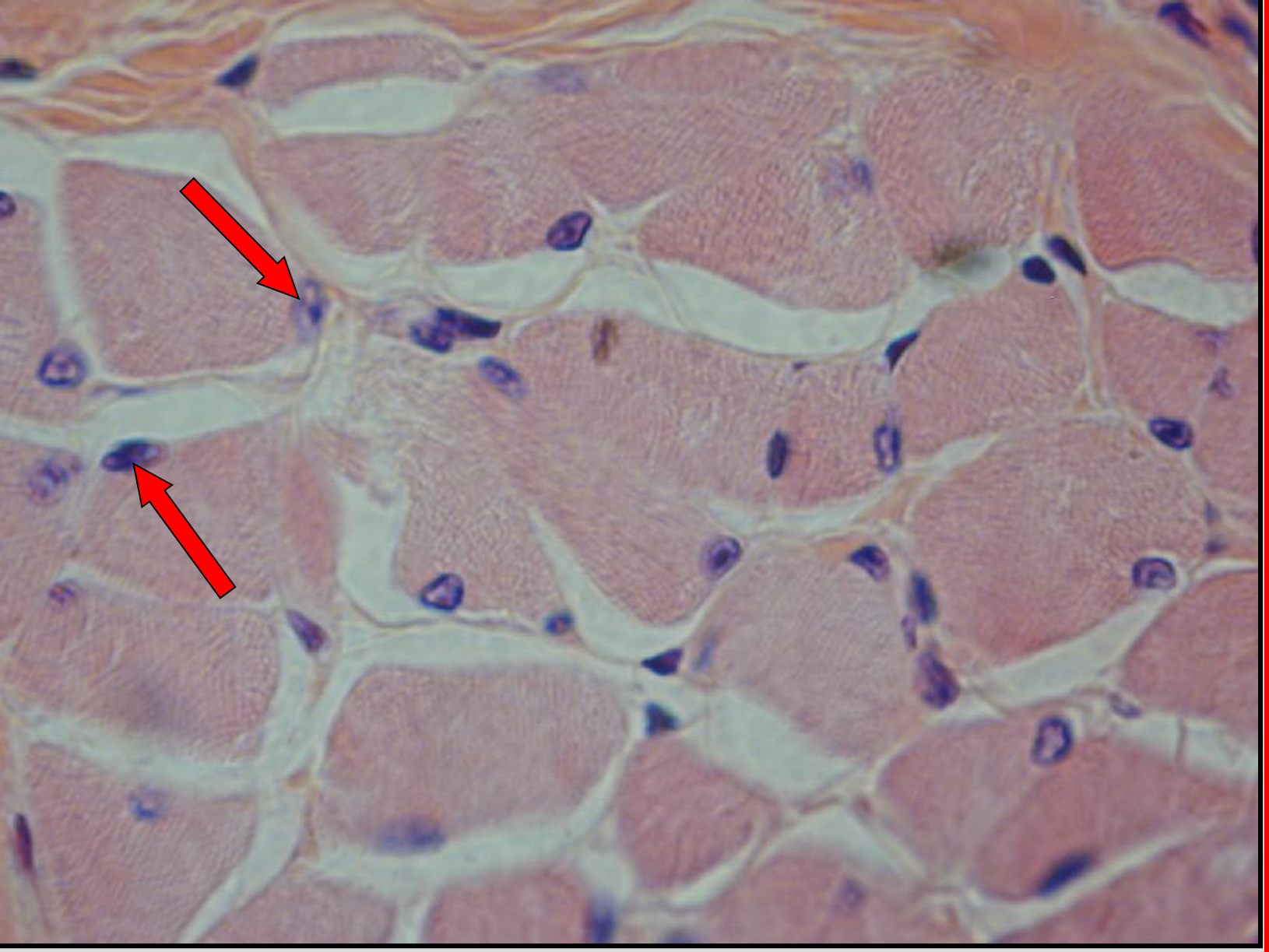

This is a cross section through skeletal muscle. The ↑↓ indicate the peripheral nuclei of skeletal muscle fibers.

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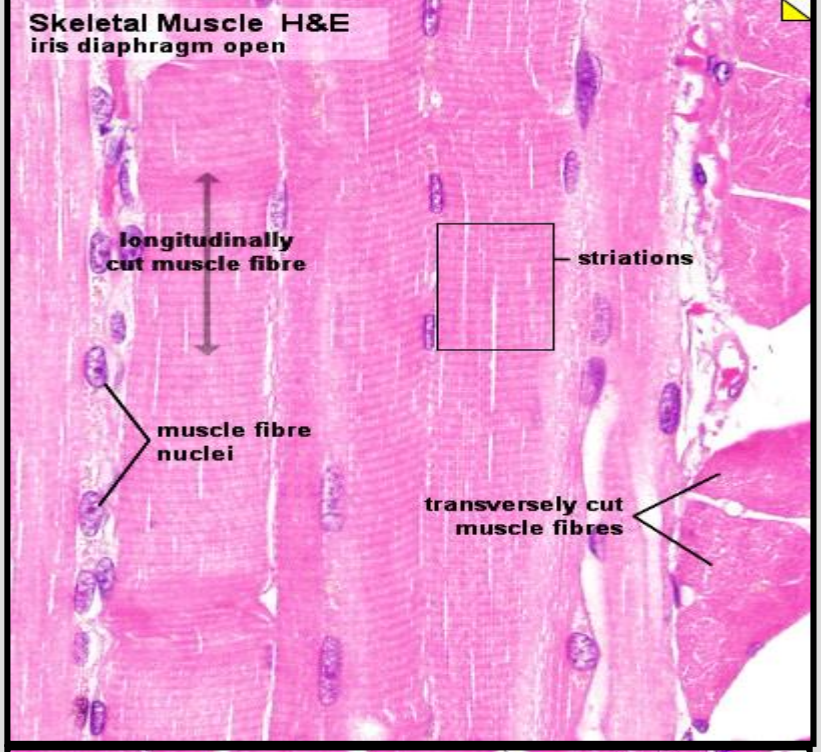
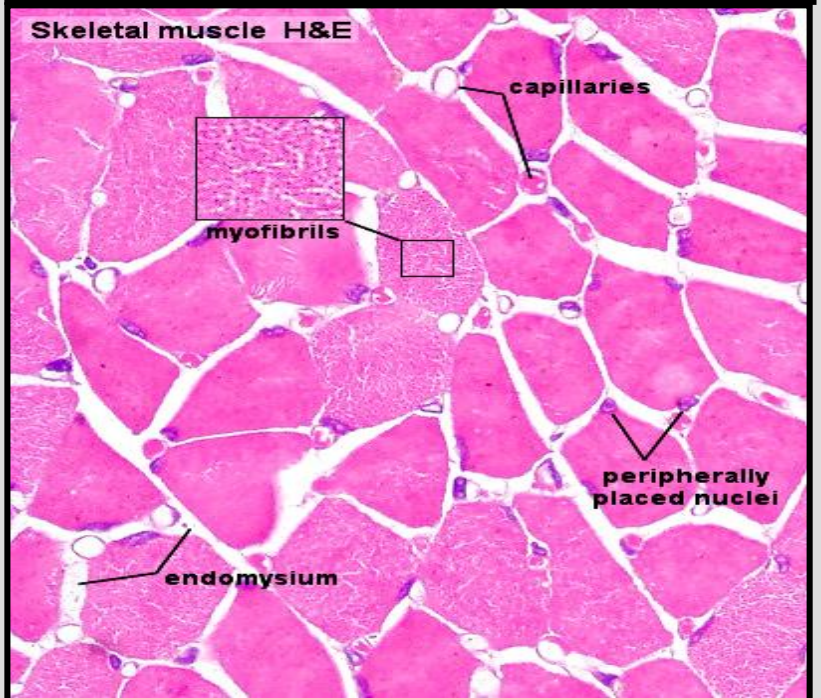
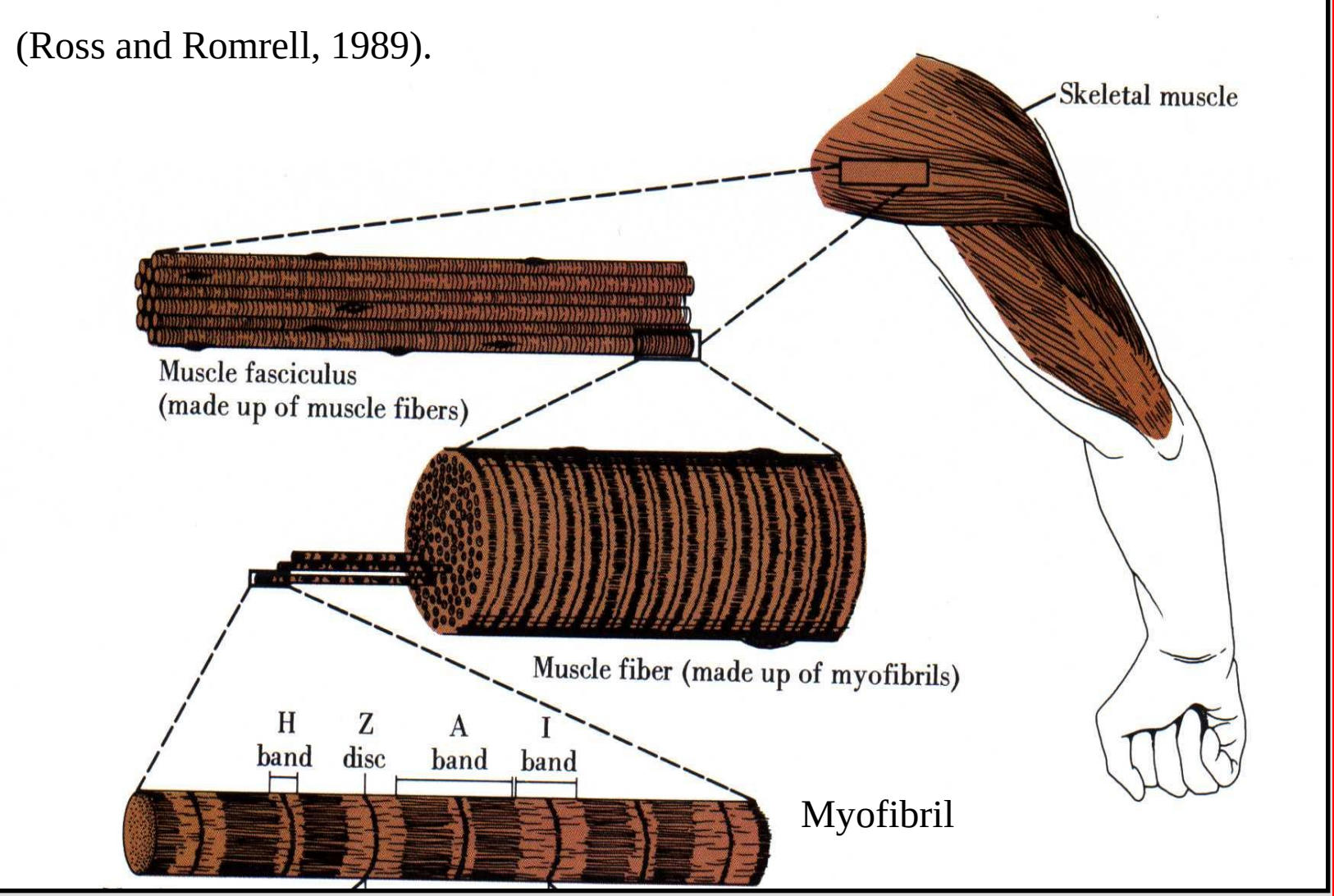
Skeletal Muscle H&E
adipocytes
longitudinally cut
muscle fibres
transversely cut


Skeletal Muscle H&E
iris diaphragm open
longitudinally
cut muscle fibre
striations
muscle fibre
nuclei
transversely cut
muscle fibres

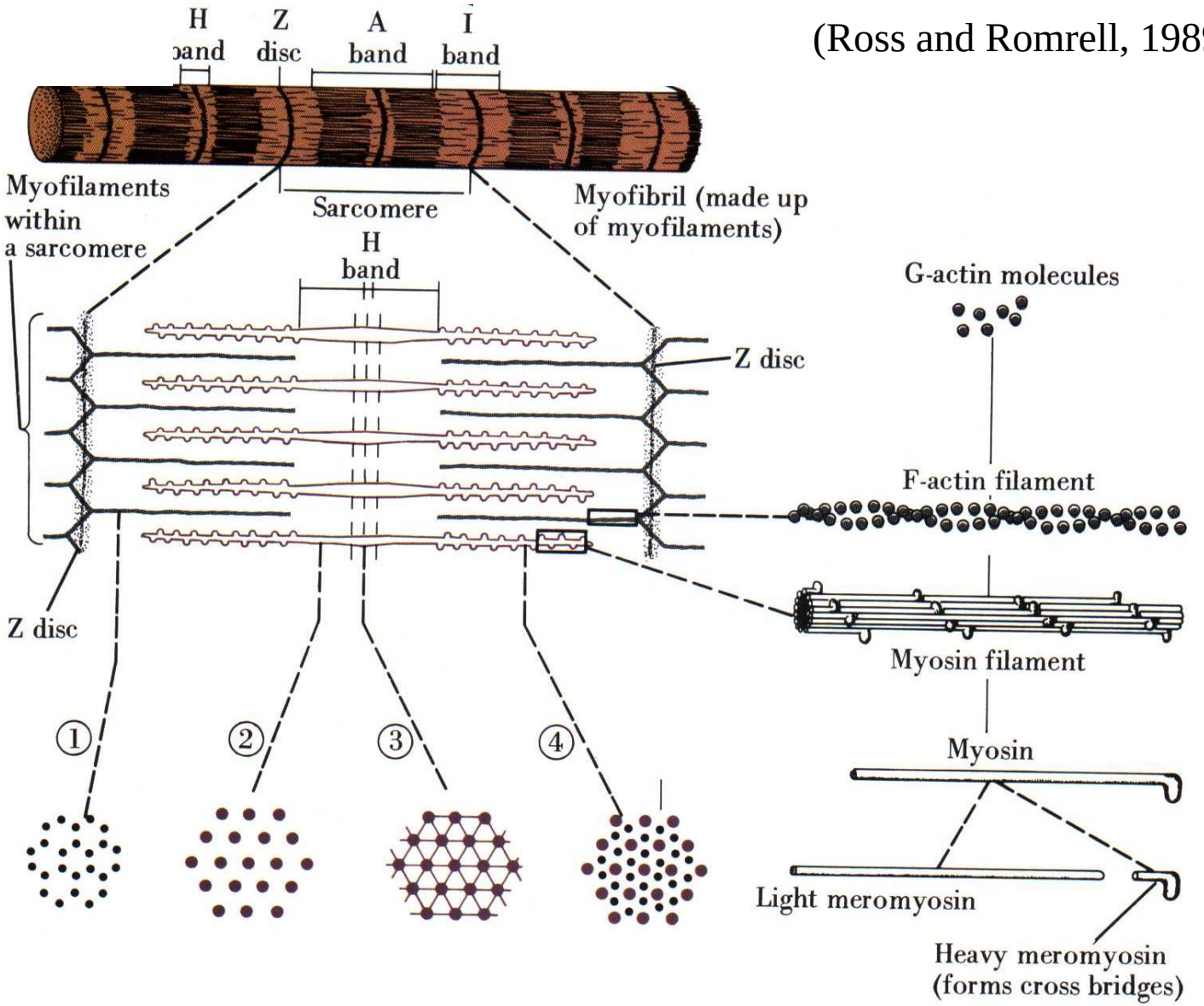

Skeletal muscle H&E
capillaries
myofibrils
peripherally
placed nuclei
endomysium

(Ross and Romrell, 1989).



This is a drawing showing how a number of myofibrils make up a muscle fiber and how a number of fibers make up a **muscle fasciculus** (bundle). A number of these bundles make up a muscle. Notice the A,I and H bands and Z disc (line) across the myofibril.

(Ross and Romrell, 1989).



This drawing shows how the myofilaments (actin + myosin) make up a myofibril. It also shows the different bands across the fibril. Drawings 1,2,3,4 show cross sections through different parts of the fibril.

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The average length of a **sarcomere** (functional unit) is about 2.5 µm (contracted ~1.5 µm, stretched ~3 µm).

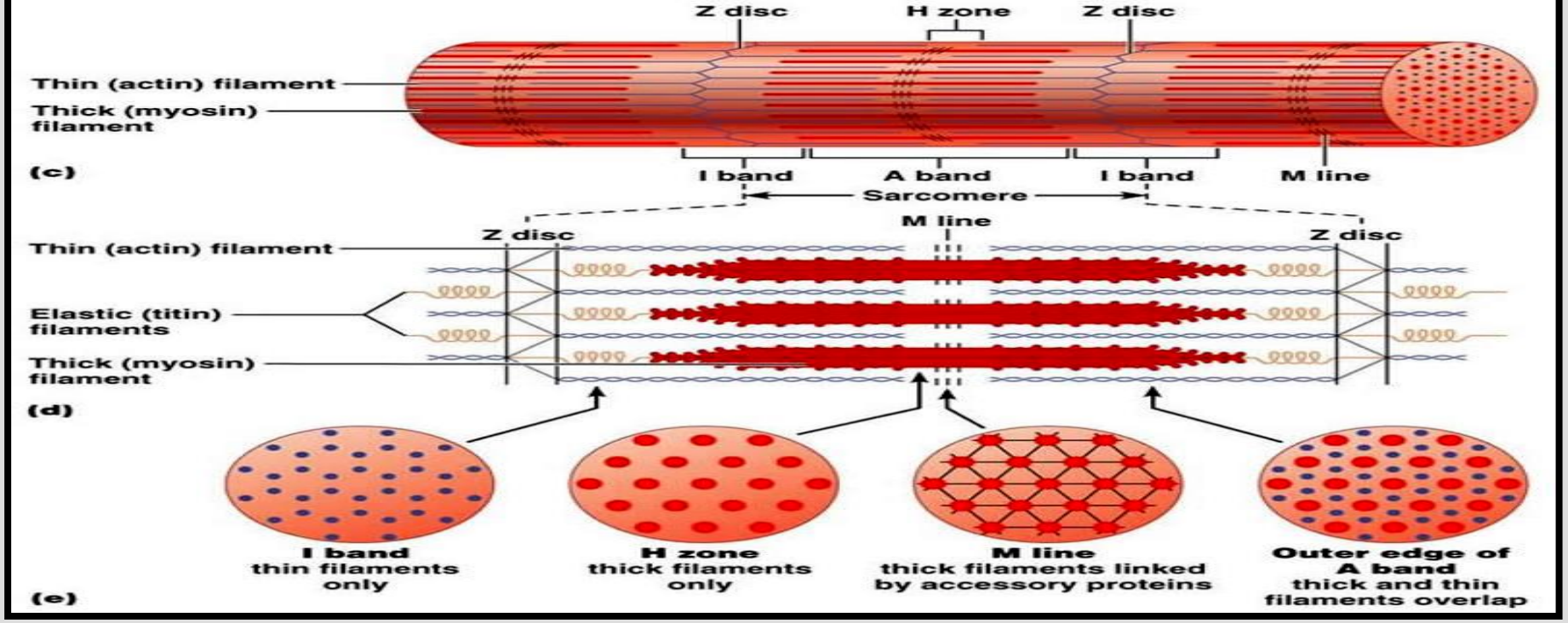
I-band - actin filaments,

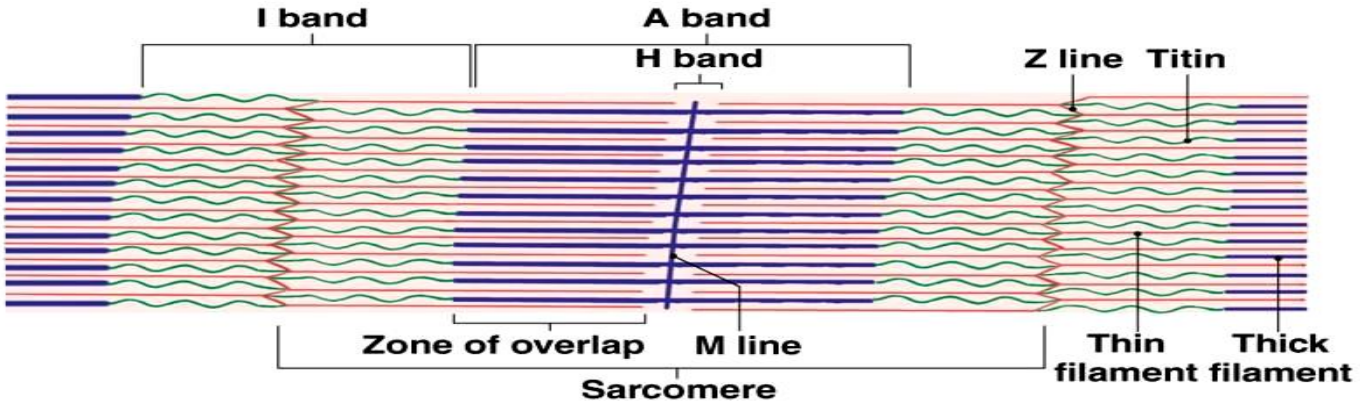
A-band - myosin filaments which may overlap with actin filaments,

H-band - zone of myosin filaments only (no overlap with actin filaments) within the A-band,

Z-line - zone of apposition of actin filaments belonging to two neighboring sarcomeres (mediated by a protein called **alpha-actinin**),

M-line - band of connections between myosin filaments (mediated by proteins, e.g. myomesin, M-protein).





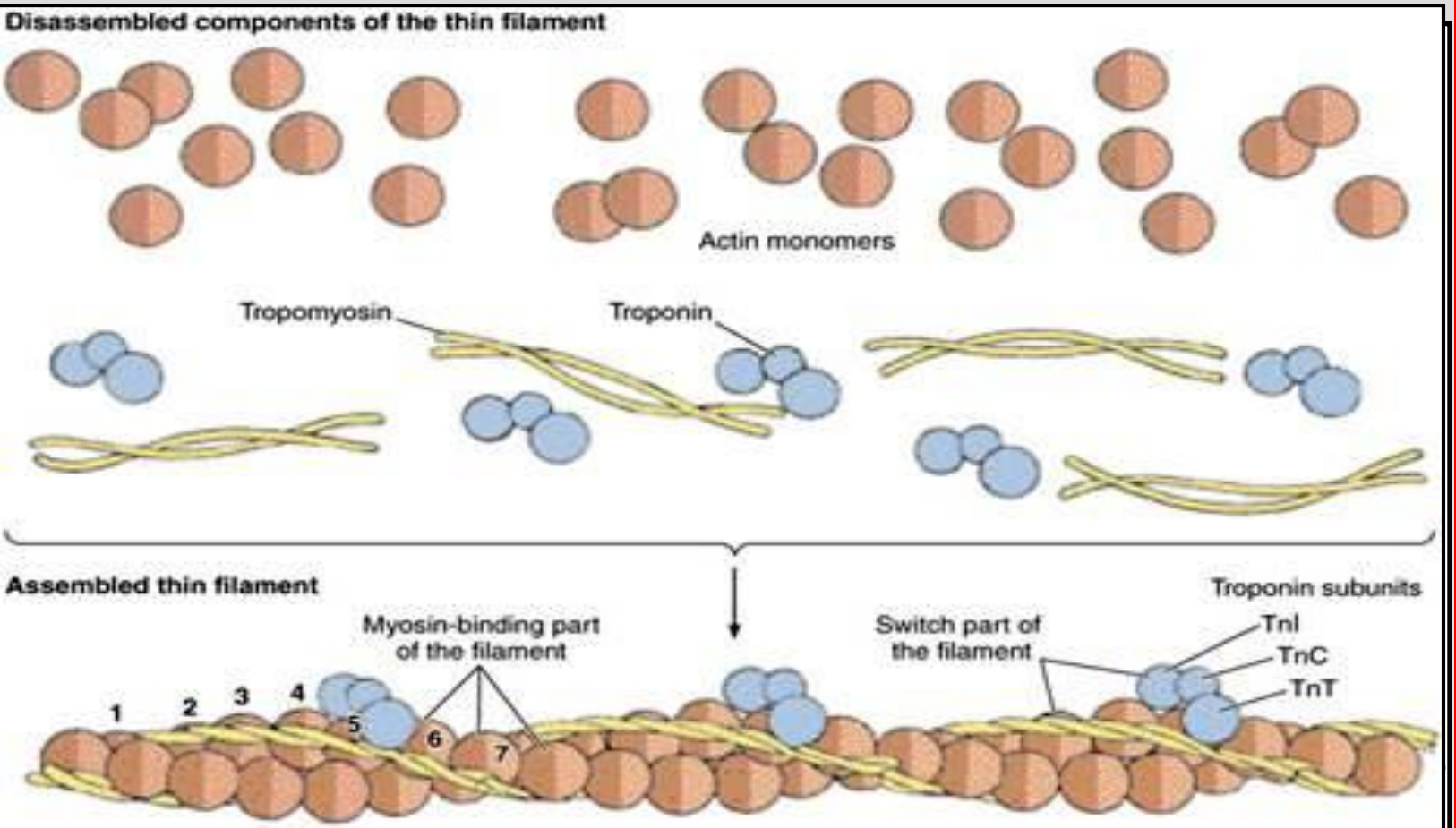
a A longitudinal section of a sarcomere, showing bands

Electron Microscopy

Two types of myofilaments

Actin

- The actin molecule has 3 components:
  - actin monomers
  - tropomyosin - 7 actin molecules long
  - troponin



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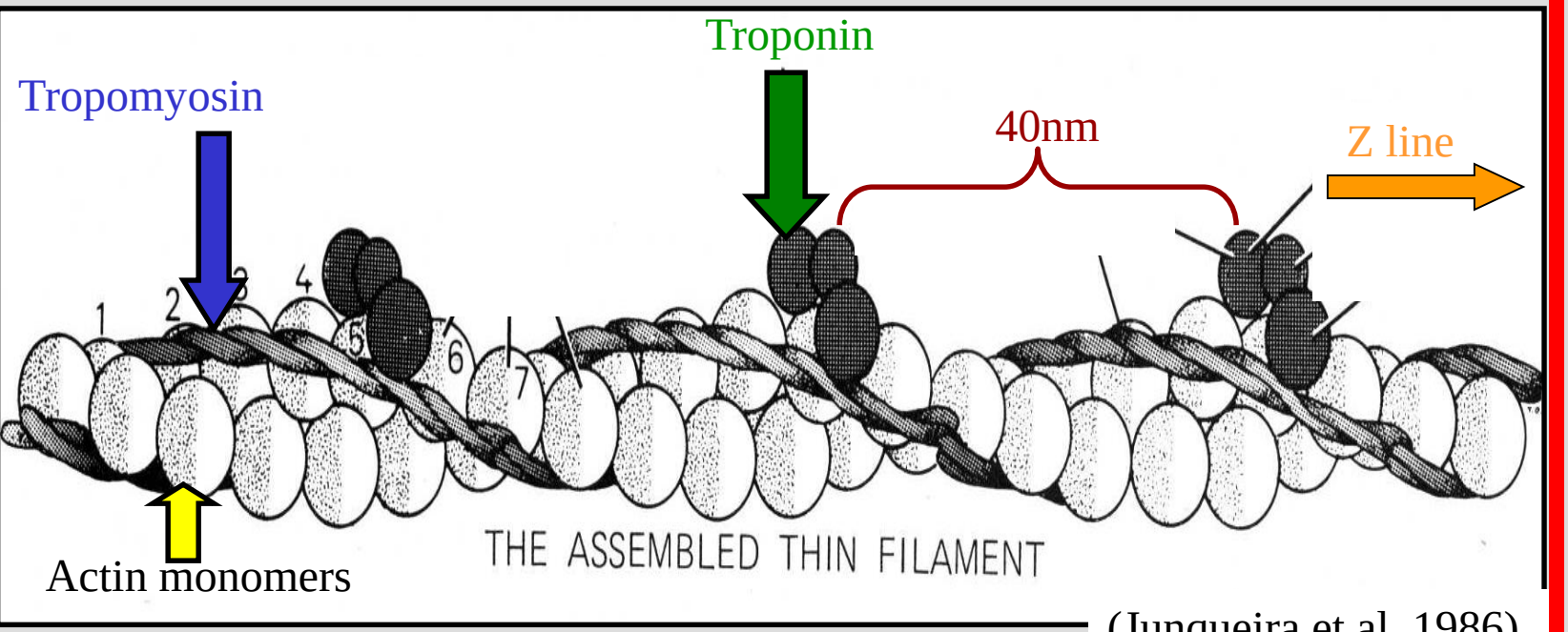
Electron Microscopy

Two types of myofilaments

Actin

- actin monomers form 2 threads that spiral
- tropomyosin - lie in the groove of the spiral
- troponin - attach every 40 nm
- one end attach to the Z line
- other end goes to the middle of the sarcomere
- Z line consists of α actinin



(Junqueira et al, 1986).

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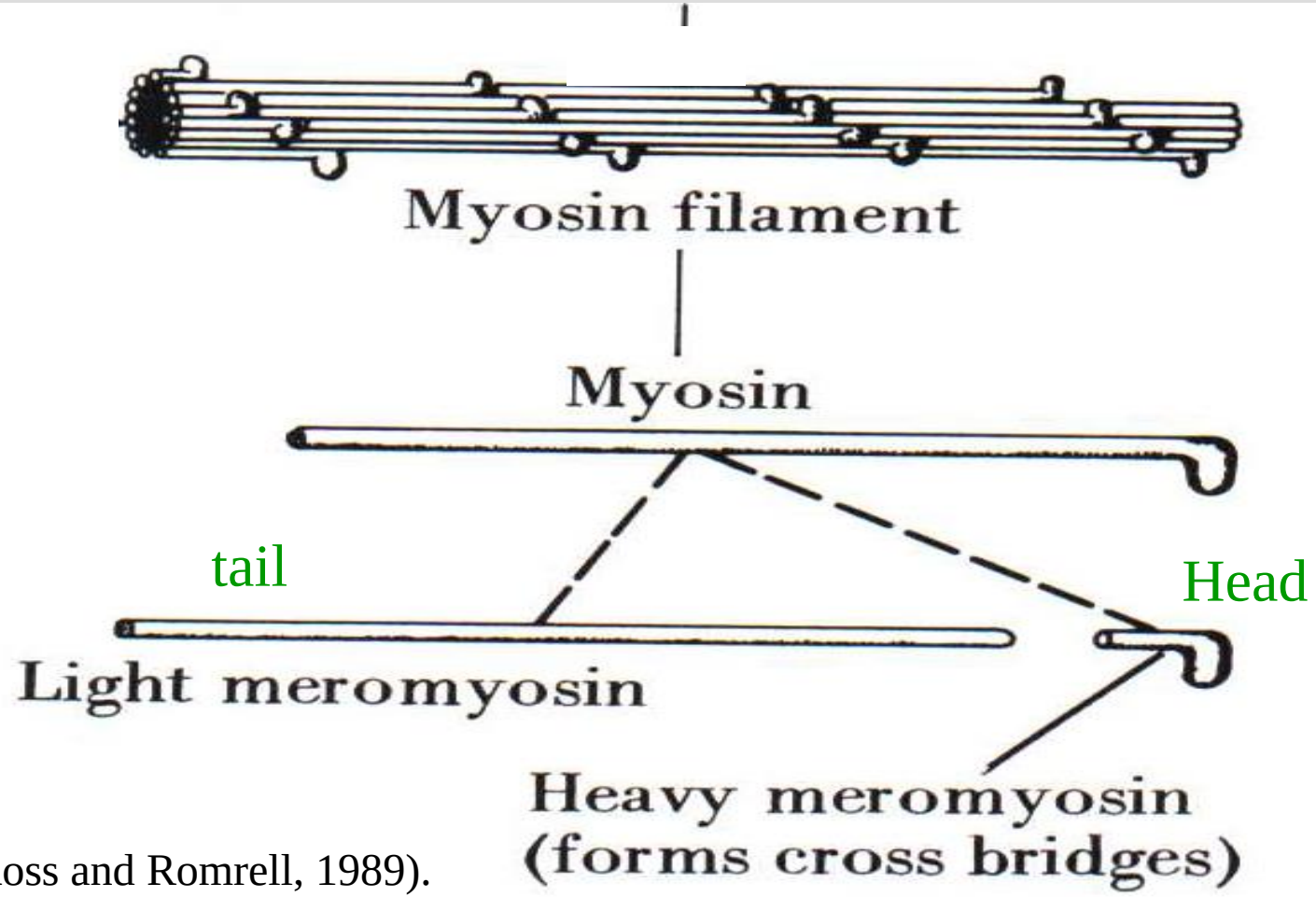
Myosin:

- 15 nm ϕ
- 1,6 μm long
- The molecule has a head and a tail
- tails are parallel
- heads project in a spiral
- in the middle is a thickening



(Ross and Romrell, 1989).

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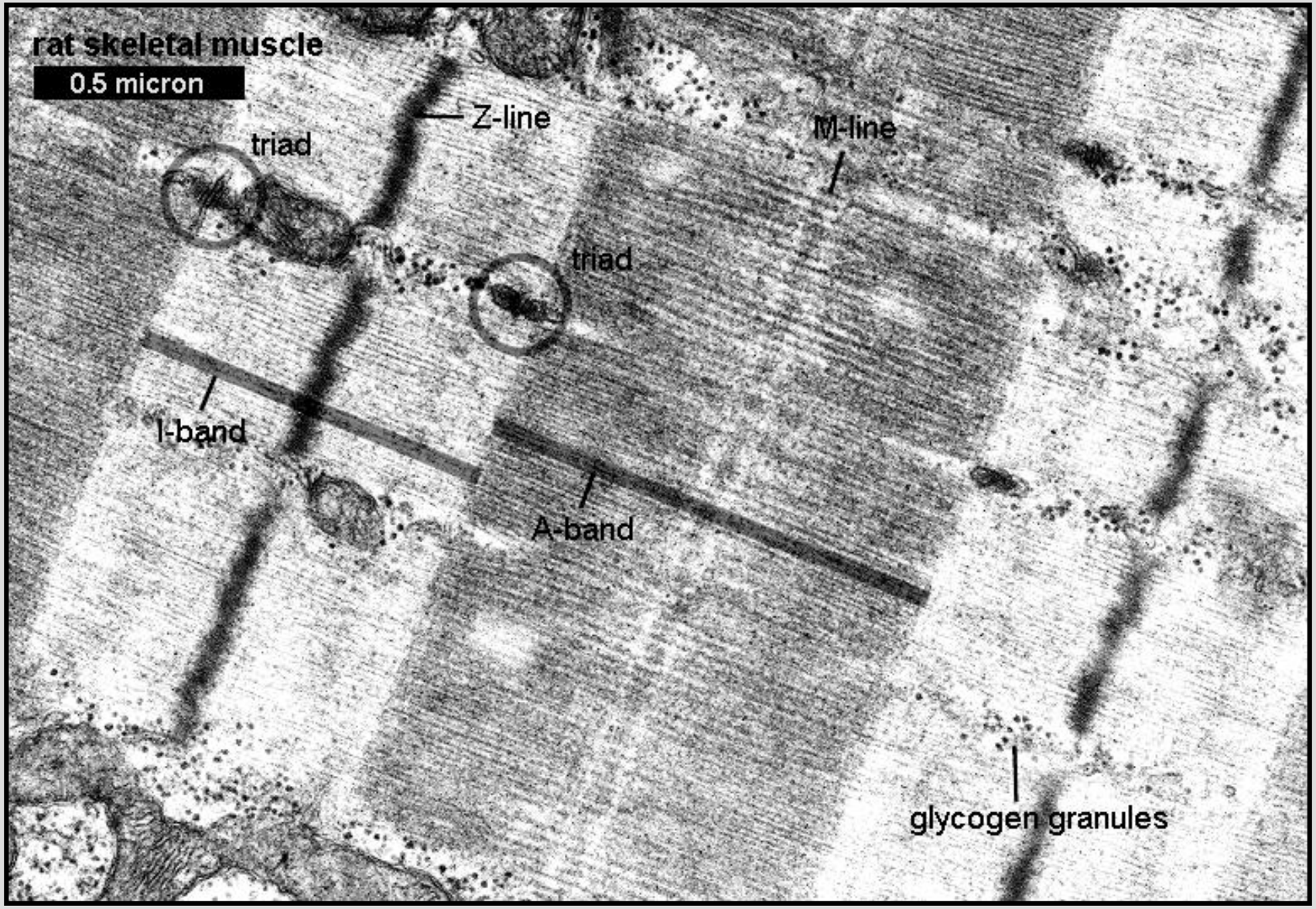
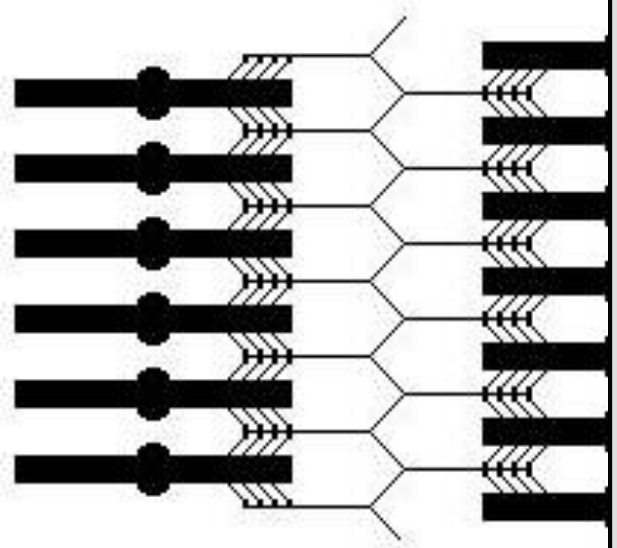
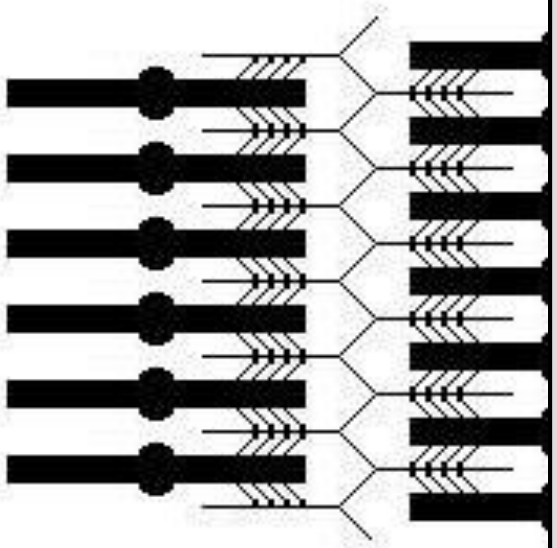

rat skeletal muscle
0.5 micron
Z-line
M-line
triad
triad
I-band
A-band
glycogen granules

Contraction:
A - band stays the same
I - band, H - bands become **narrower**
Myosin heads ratchet on the actin molecule

Relaxed



Contracted state



Notice how the I band changes during contraction. The next 2 slides will show how the I band changes during contraction. To see it go forwards and backwards.

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Muscle Animation
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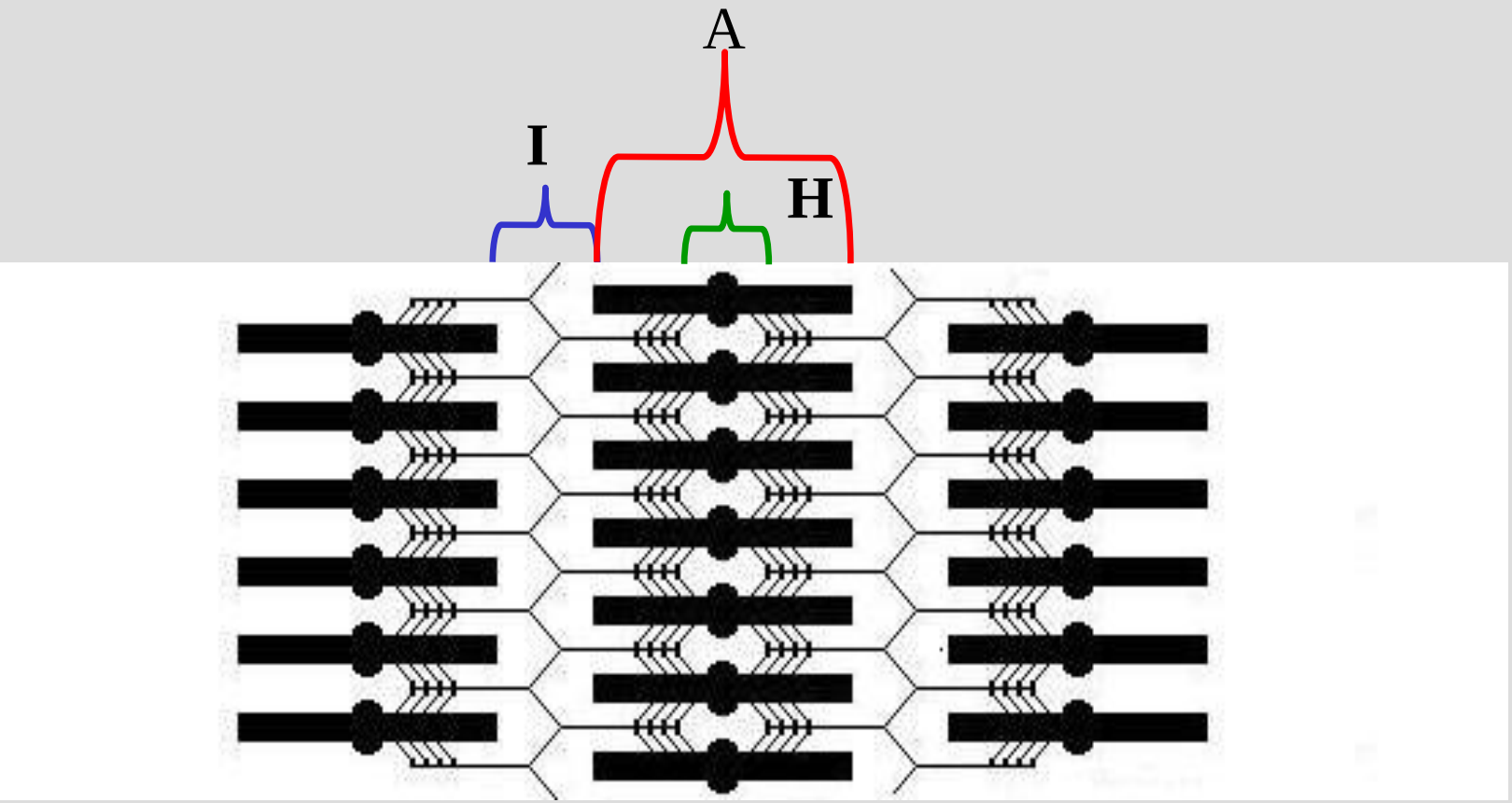

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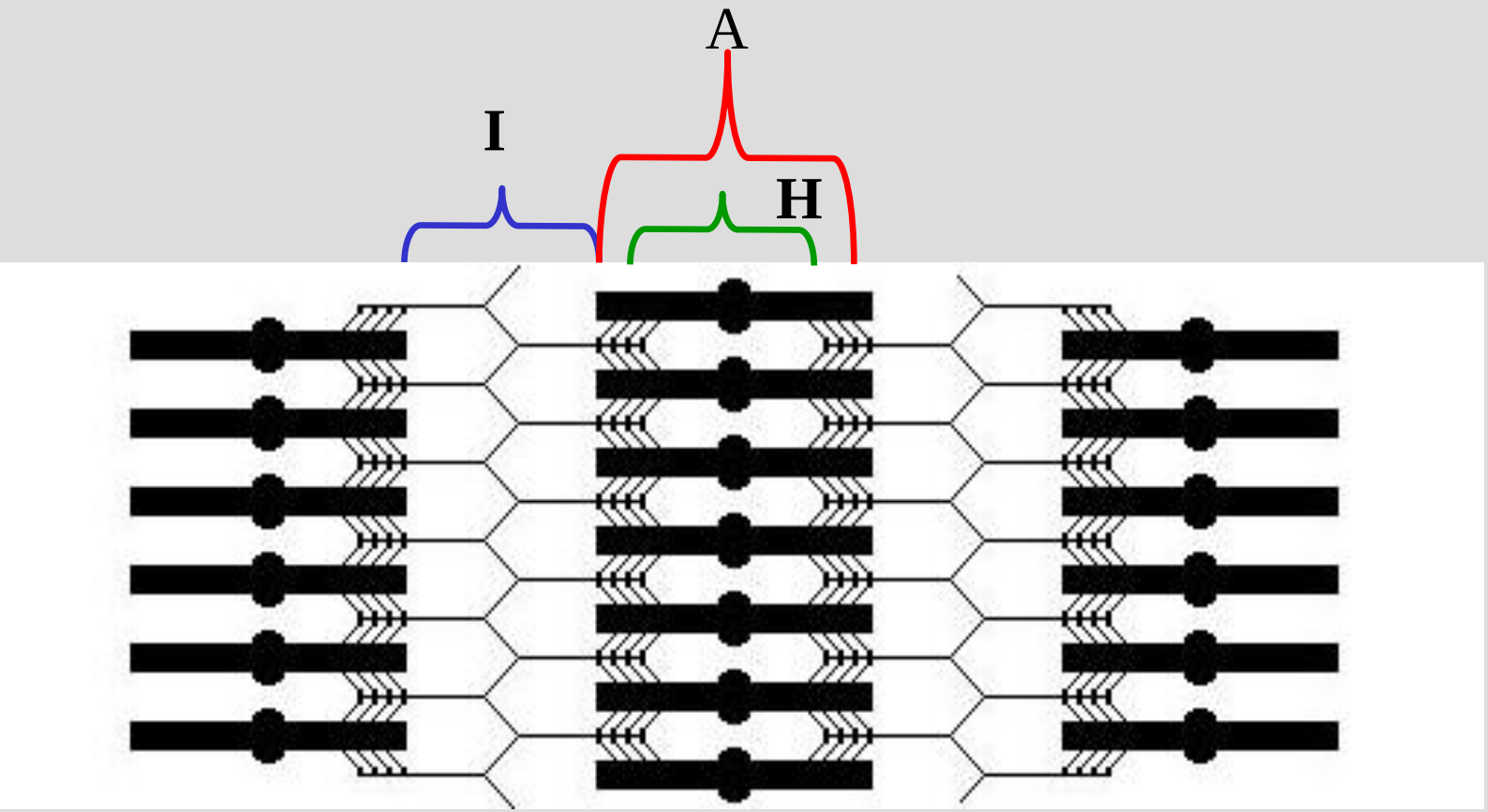

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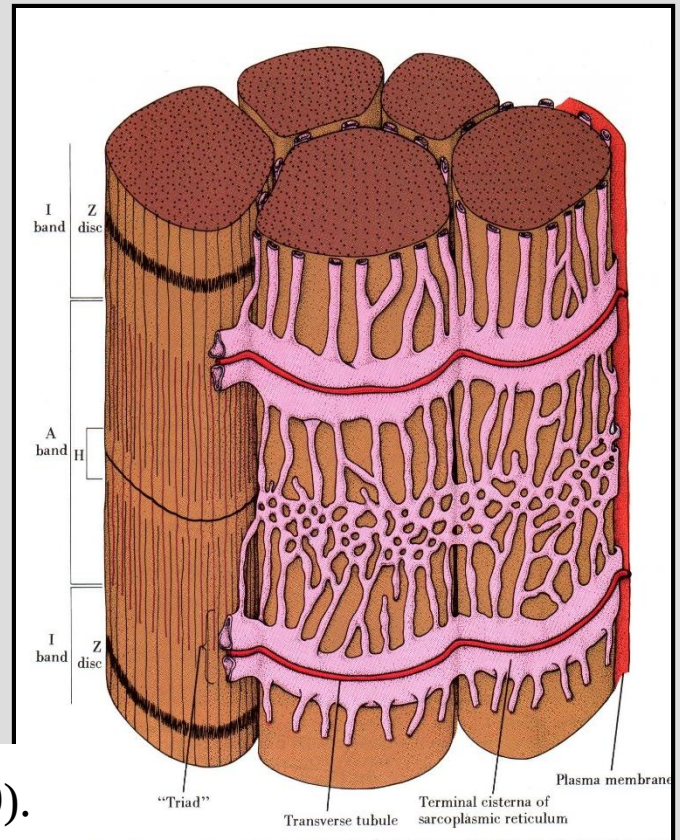
Sarcolemma:
- 9 nm thick
- invaginate to form **T-tubule**
- myofibrils - attach to the sarcolemma

Sarcoplasmic Reticulum:
- specialized smooth EPR, regulates muscle contraction
- ***Consists of T-tubules, terminal cisternae and sarcotubules***
- It is speculated that there are gap junctions between the T-tubule and terminal cisterna
- An impulse is carried into the fiber by the T-tubule from where it goes to the rest of the sarcoplasmic reticulum



(Ross and Romrell, 1989).

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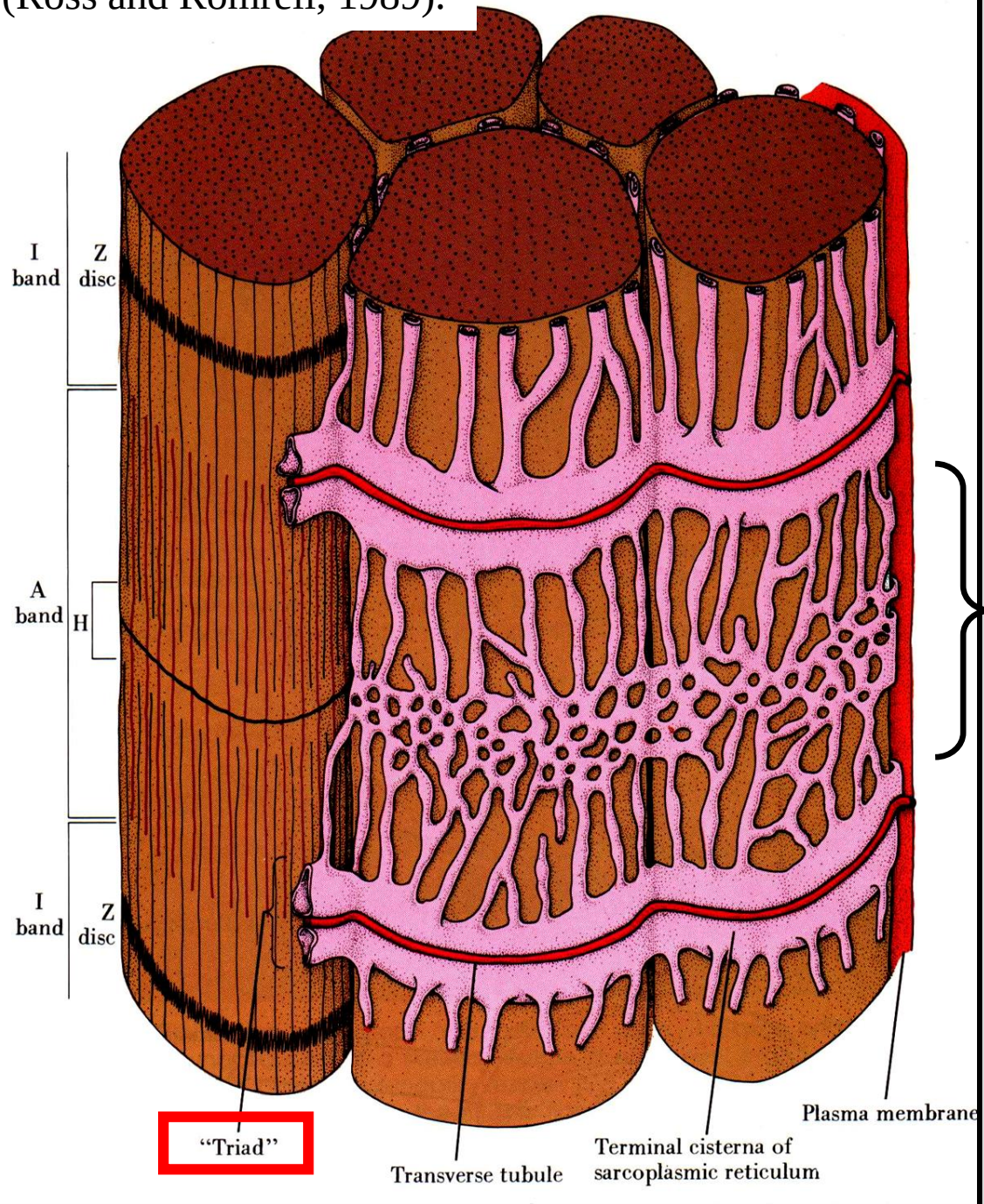
(Ross and Romrell, 1989).



Identify:

T tubule,

Terminal cisternae and

Sarcotubules

The level at which the T tubule lies

Sarco tubules

Slide 13

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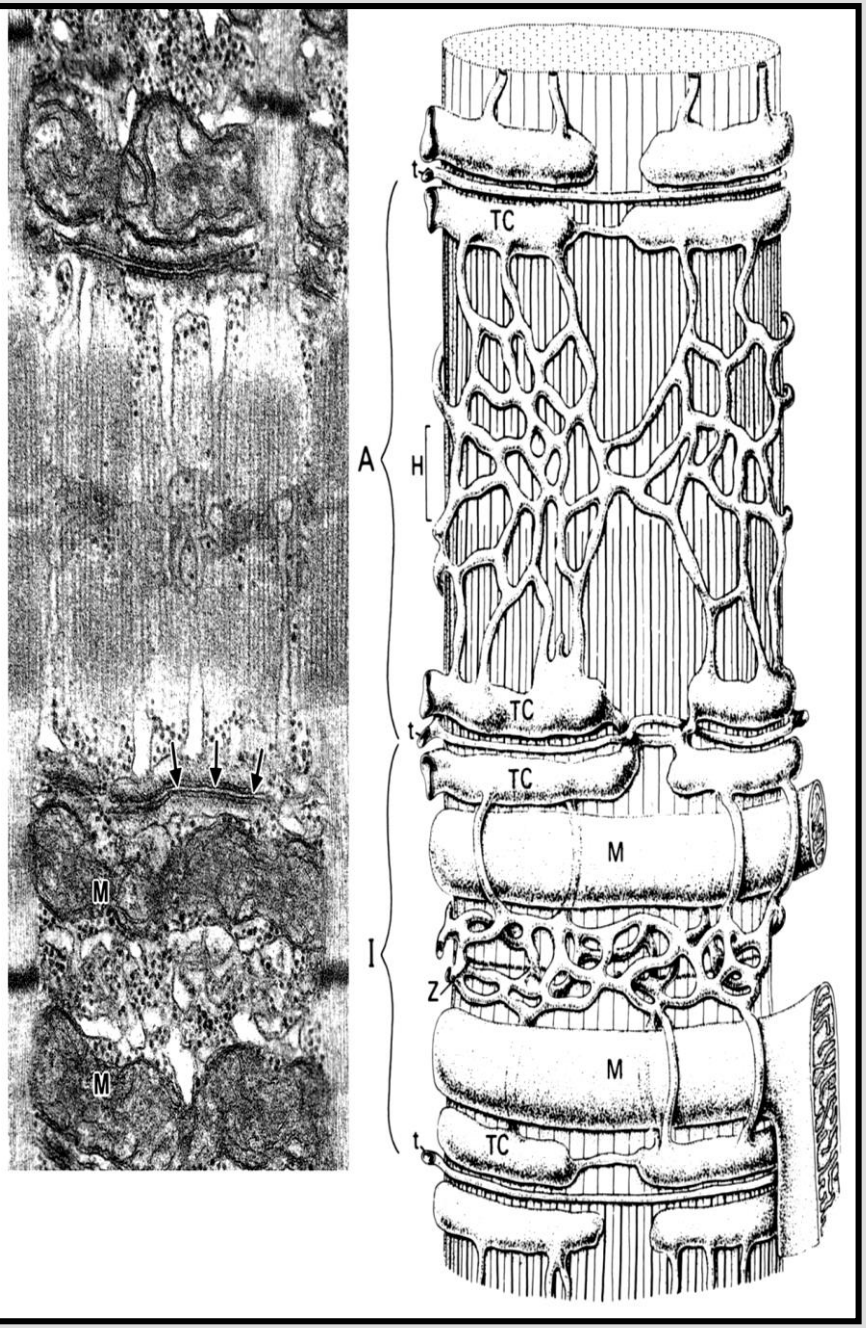
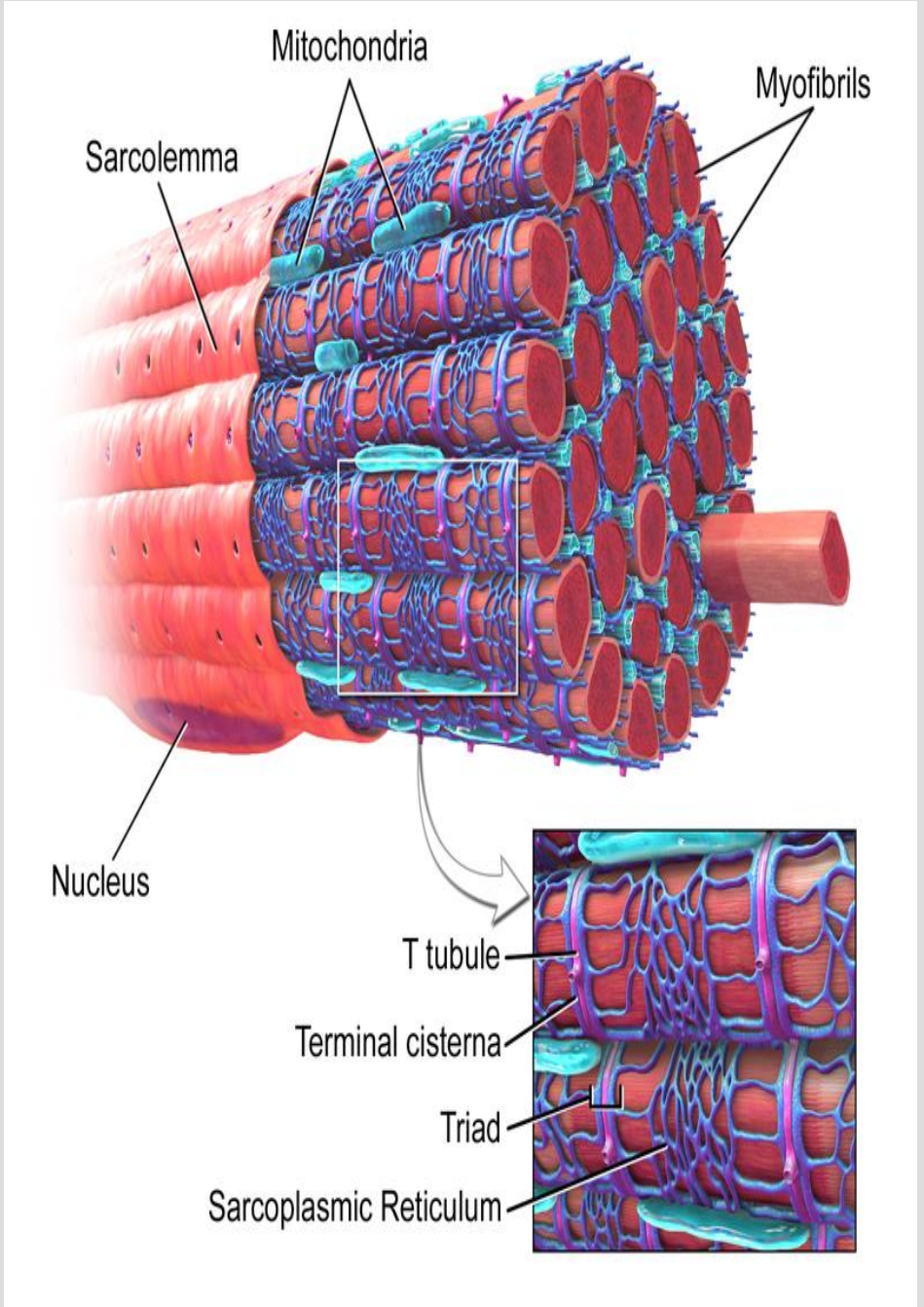
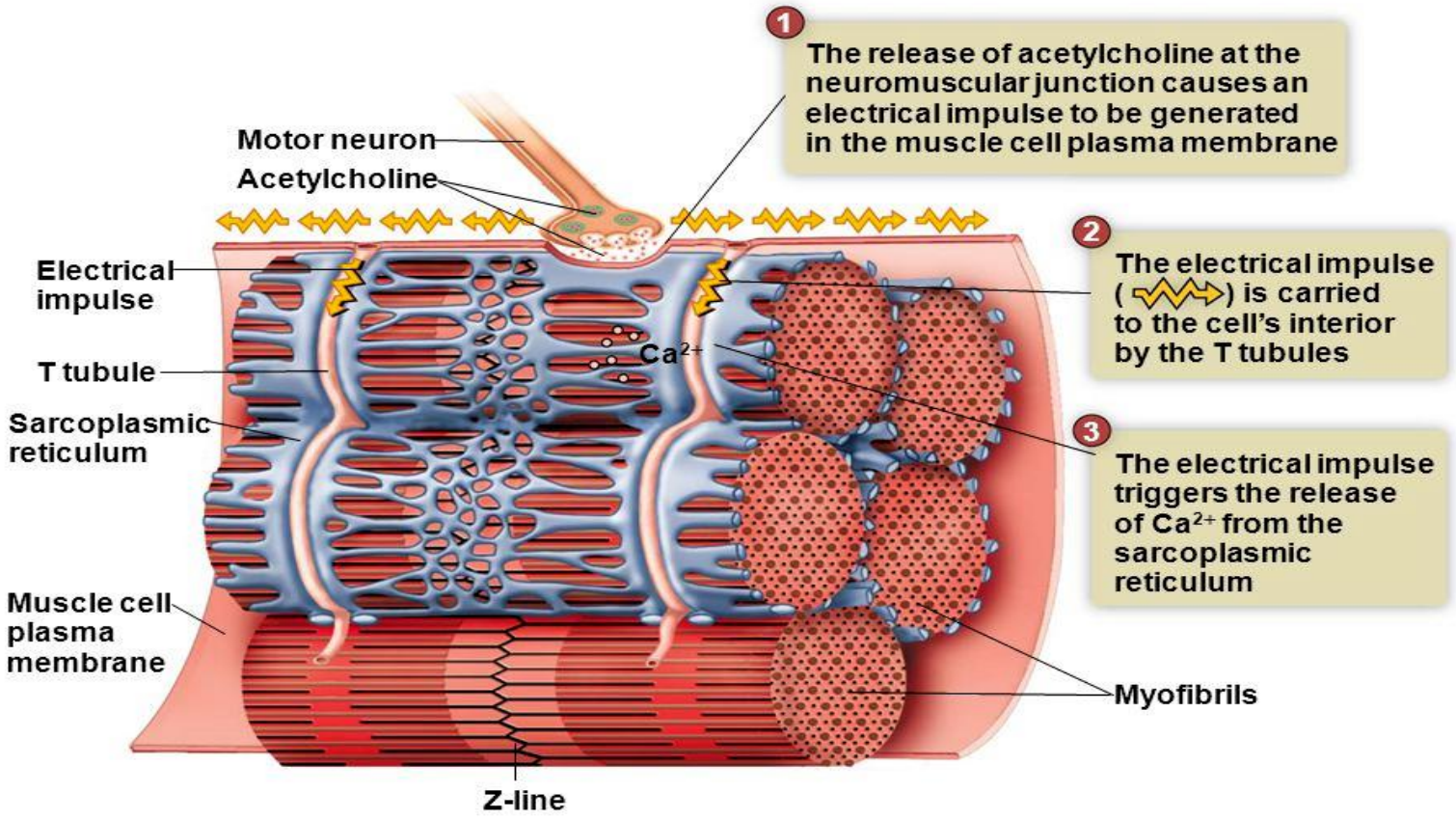

M
M
A
H
I
Z
TC
TC
TC
M
M
TC


Mitochondria
Myofibrils
Sarcolemma
Nucleus
T tubule
Terminal cisterna
Triad
Sarcoplasmic Reticulum

Nerves: (motor)
The axon of a motor neuron branches and ends in **motor end plates** (**myoneural junction)** on the fiber
The excitatory transmitter at the motor end plate is **acetylcholine**

Figure 6.6



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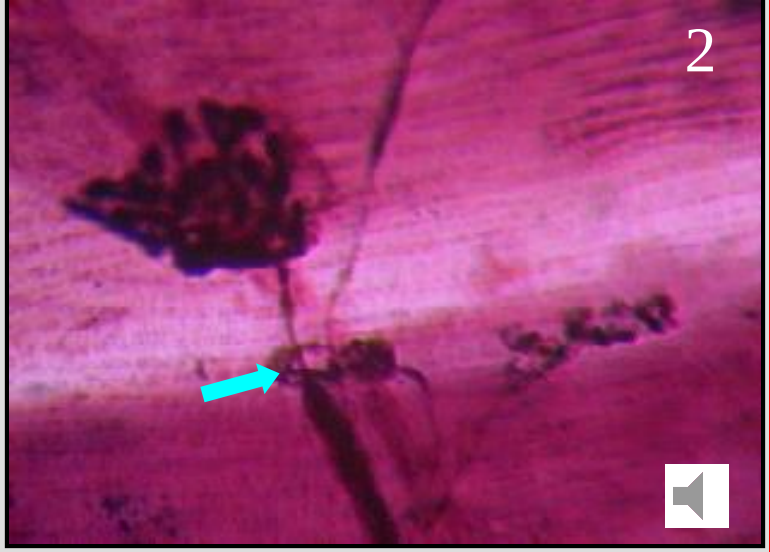

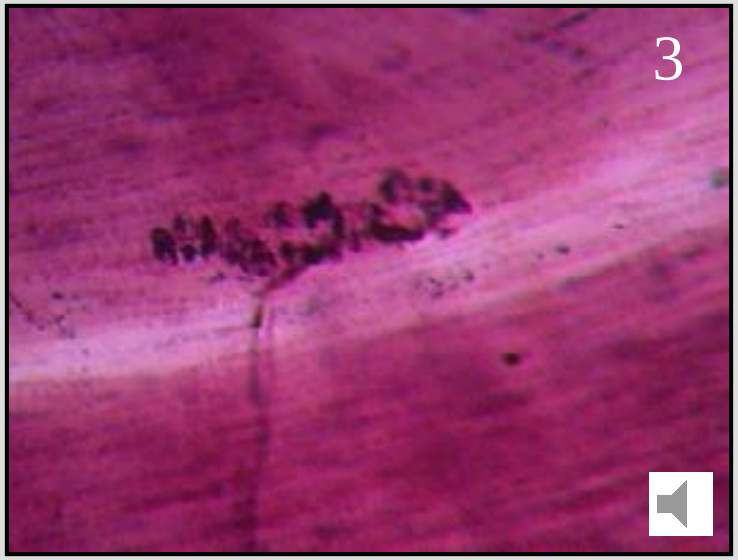

This is the motor end plate. Slide 1 shows a low magnification. The ↓↓ indicate 2 motor end plates. The → in slide 2 shows where the myelin sheath ends. Slide 3 shows a single motor end plate.

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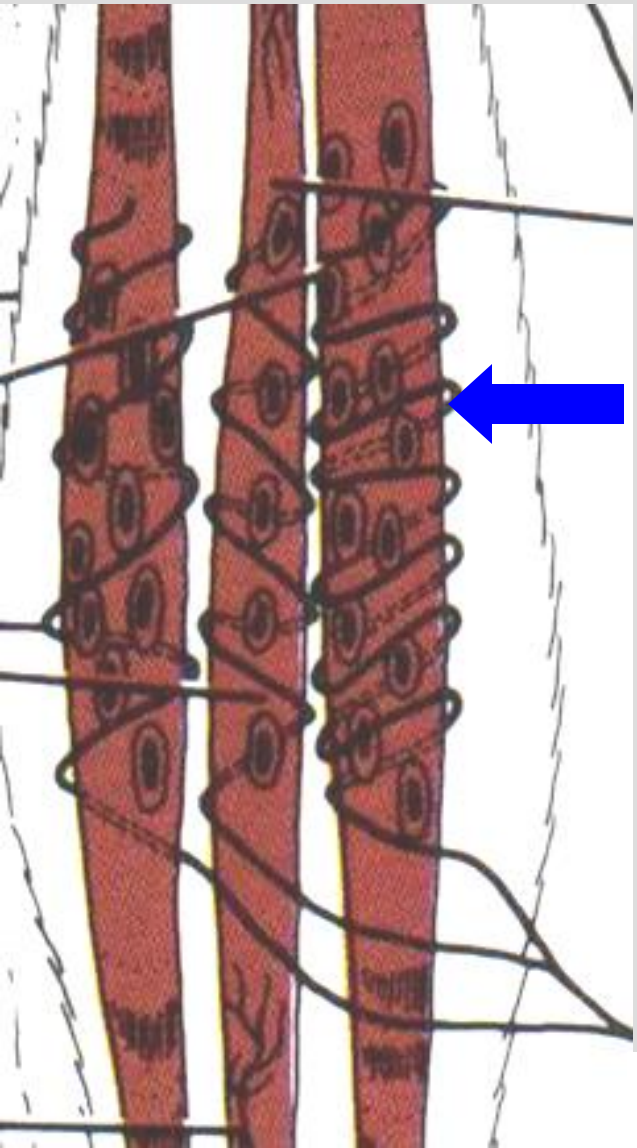
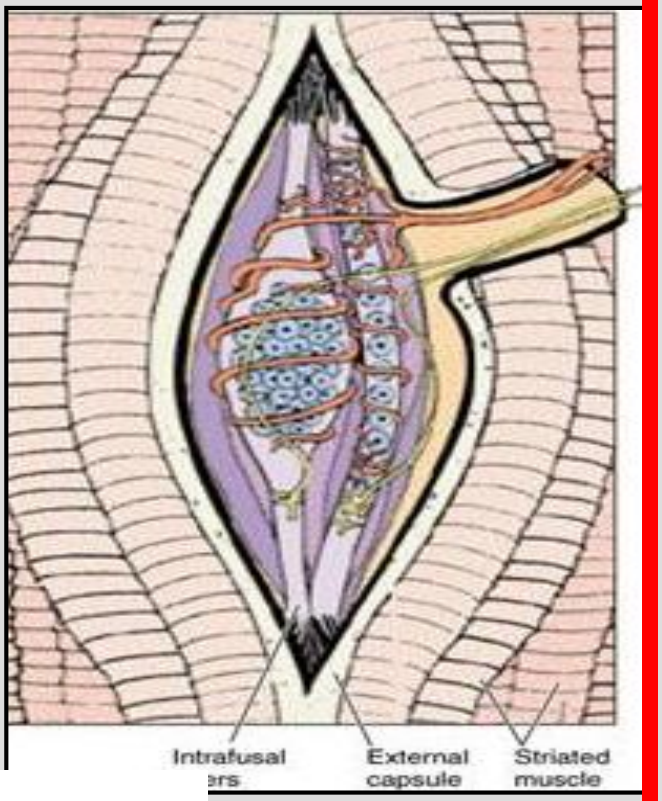
Nerves: sensory

- Specialized fusiform sensory organ called **spindles** (function as **stretch receptors**) form sensory receptors in muscles telling the brain how far the muscle has stretched



Stretch receptor

A number of small specialised **intrafusal muscle fibres** (nuclear bag fibres and nuclear chain fibres) are surrounded by a capsule of connective tissue.



(Ross and Romrell, 1989).

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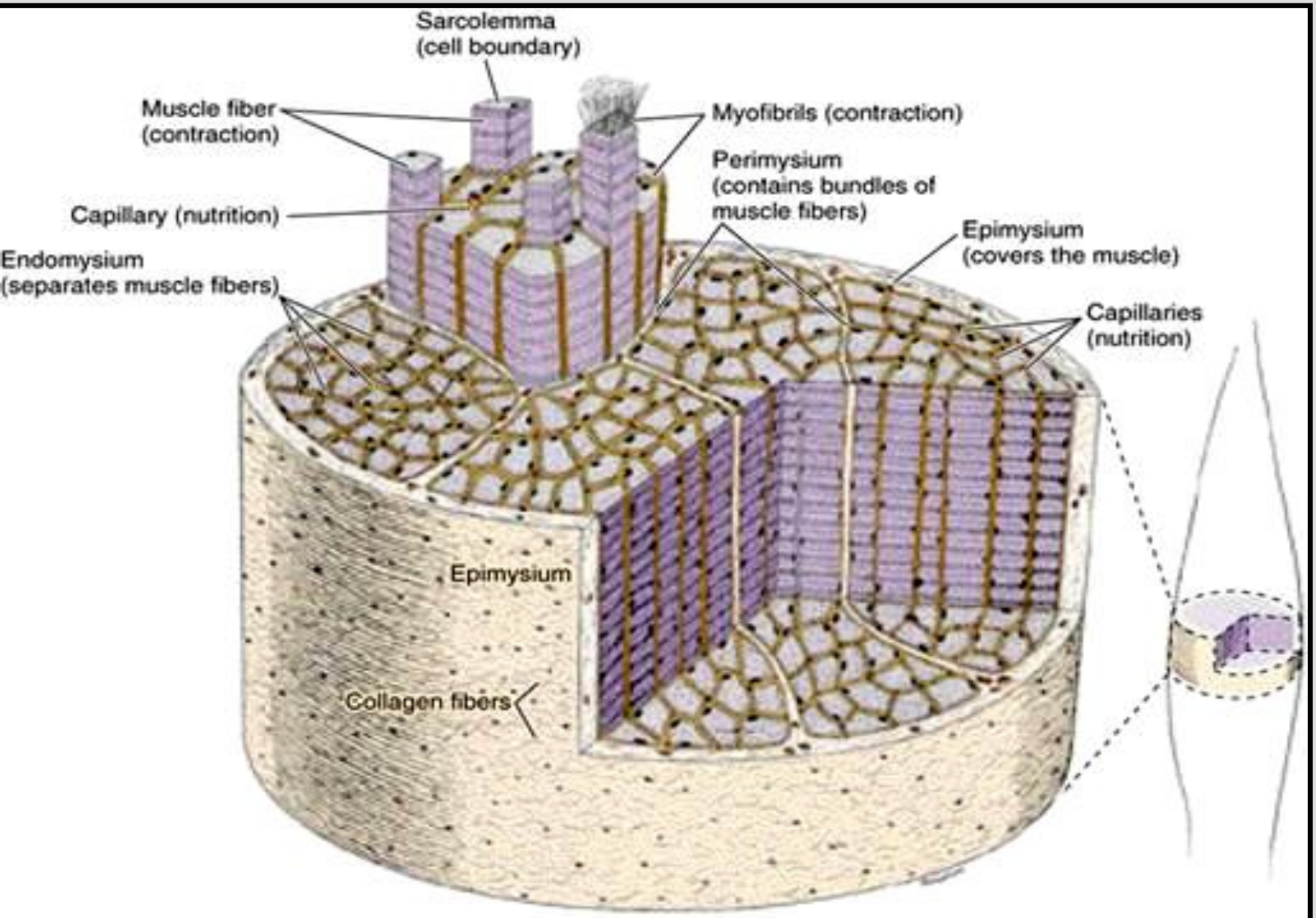
Connective tissue coverings of the muscle

- Endomysium around fibres, perimysium around bundles (fascicle) and epimysium around the whole muscle
- blood vessels and nerves lie in these connective tissue coverings.
- The CT goes over into a tendon or aponeurosis which attaches to the periosteum



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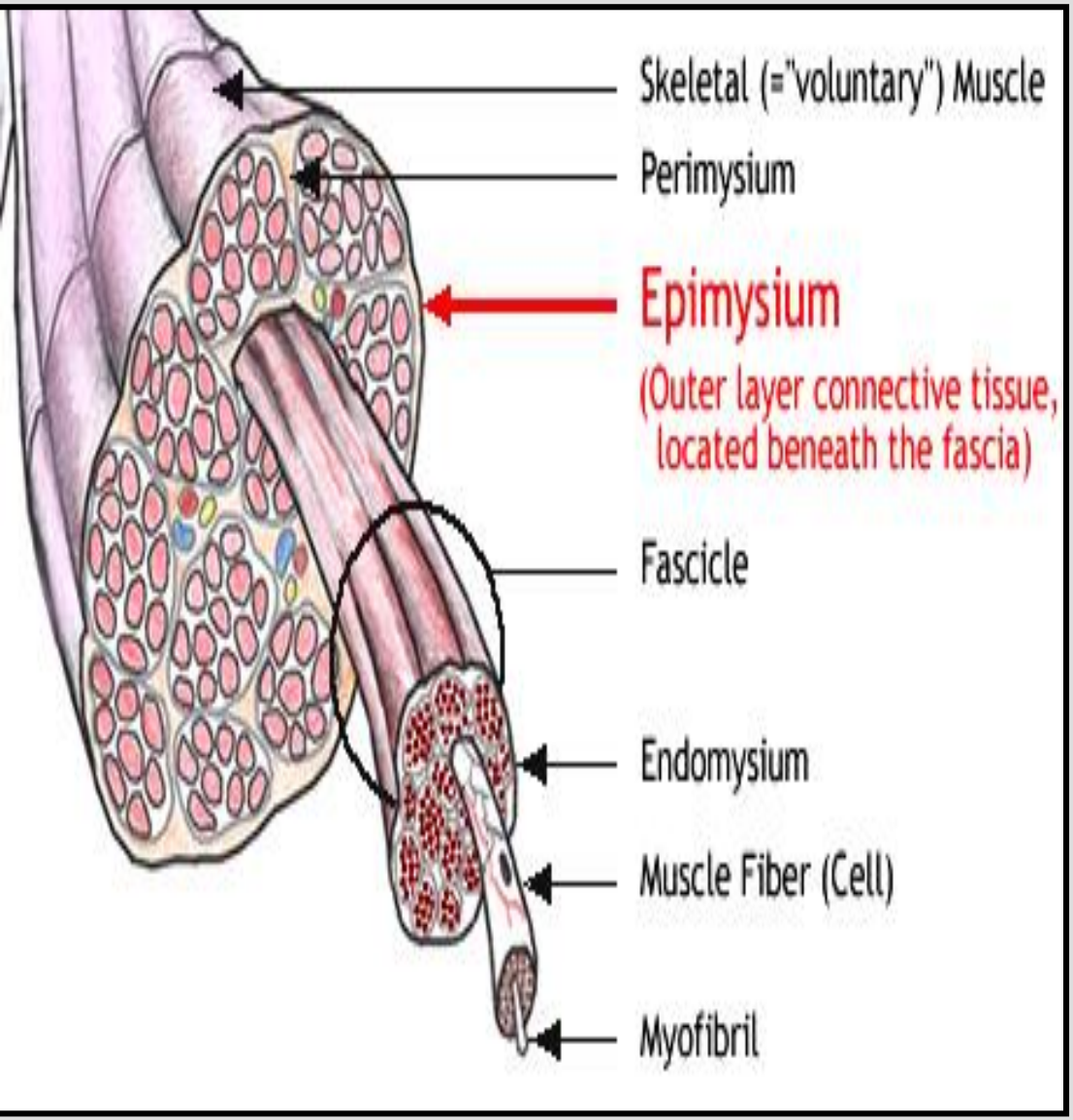
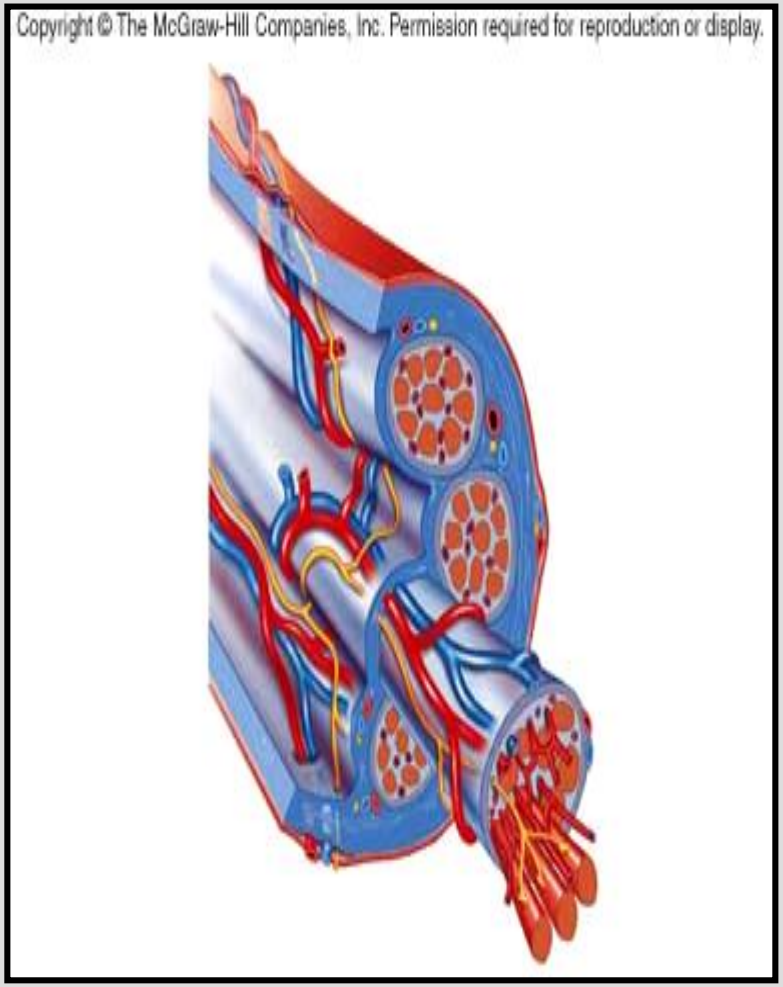

Skeletal (="voluntary") Muscle
Perimysium
Epimysium
(Outer layer connective tissue, located beneath the fascia)
Fascicle
Endomysium
Muscle Fiber (Cell)
Myofibril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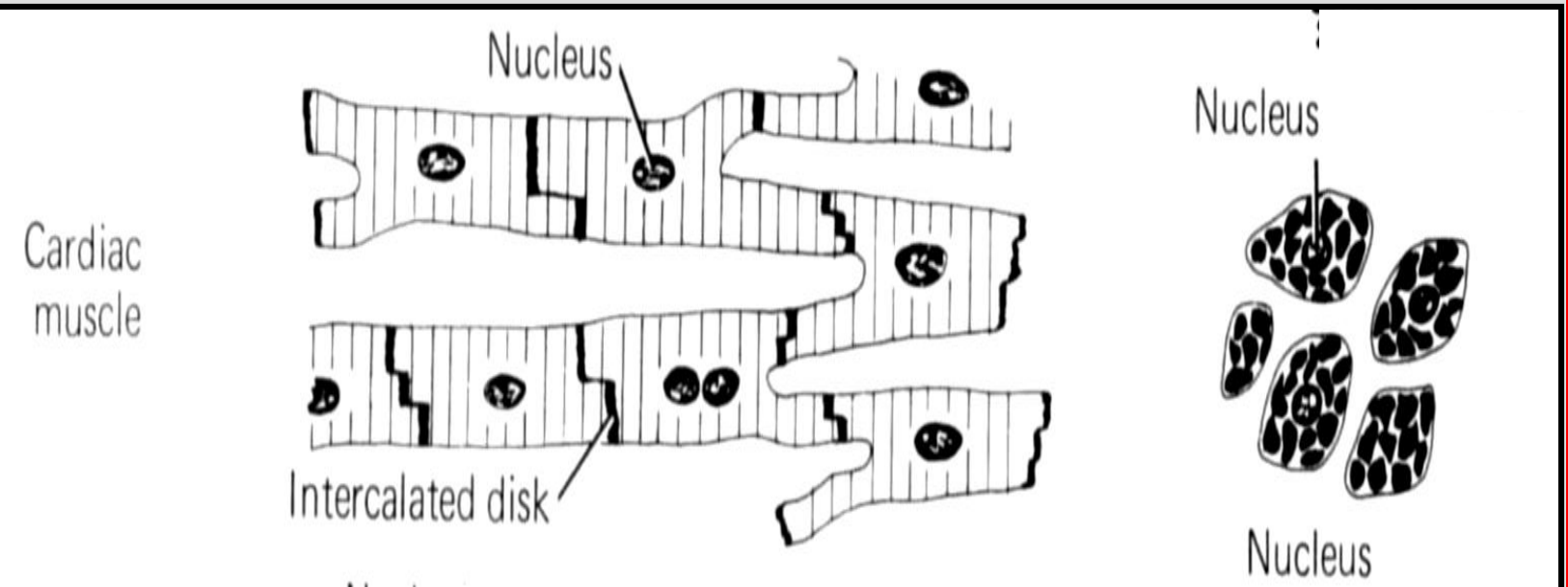
Cardiac Muscle

- Cardiac muscle, the myocardium, consists of muscle cells, **cardiomyocytes**
- Fibres anastomose through cross bridges
- Fibres are **short** and **branched**, connected end to end at **intercalated discs**
- also **striated**
- contract **automatically**
- Cardiac muscle does **not** contain cells equivalent to the **satellite cells** of skeletal muscle. Therefore cardiac muscle **cannot regenerate**

Light microscopic Structure:

- Short fibres connected at ***intercalated*** **discs**
- 85 - 100 μm long
- 15 μm ϕ
- same bands as in skeletal muscle
- **1 or 2 nuclei** - oval and **central**
- in perinuclear area is a sarcoplasmic reticulum
- intercalated discs lie at the *Z line*



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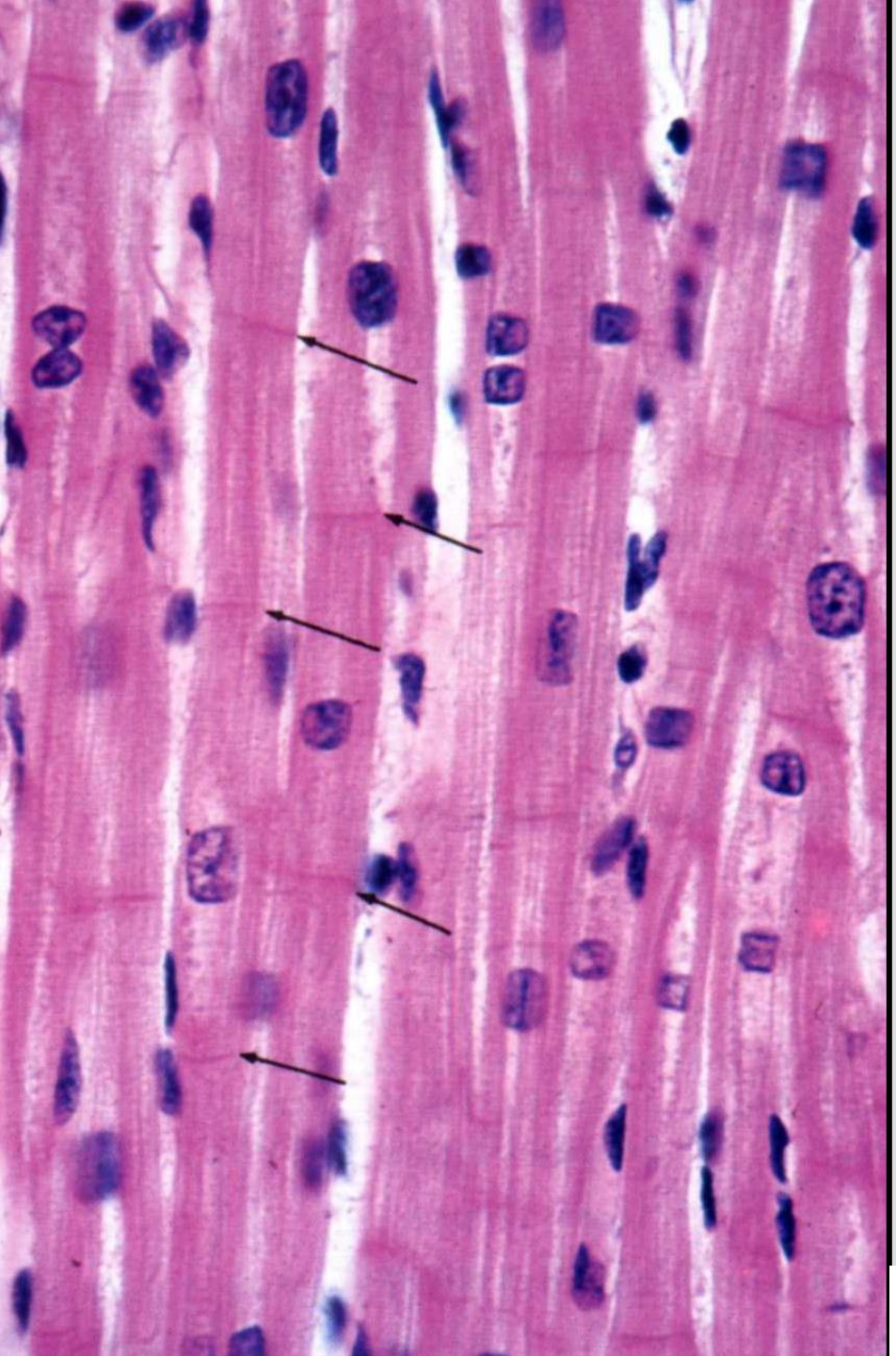

This is cardiac muscle. Notice the centrally placed nuclei and the cross bridges linking fibers. Between lie endomysium and capillaries. The ← indicate the intercalated discs.

(Ross and Romrell, 1989).

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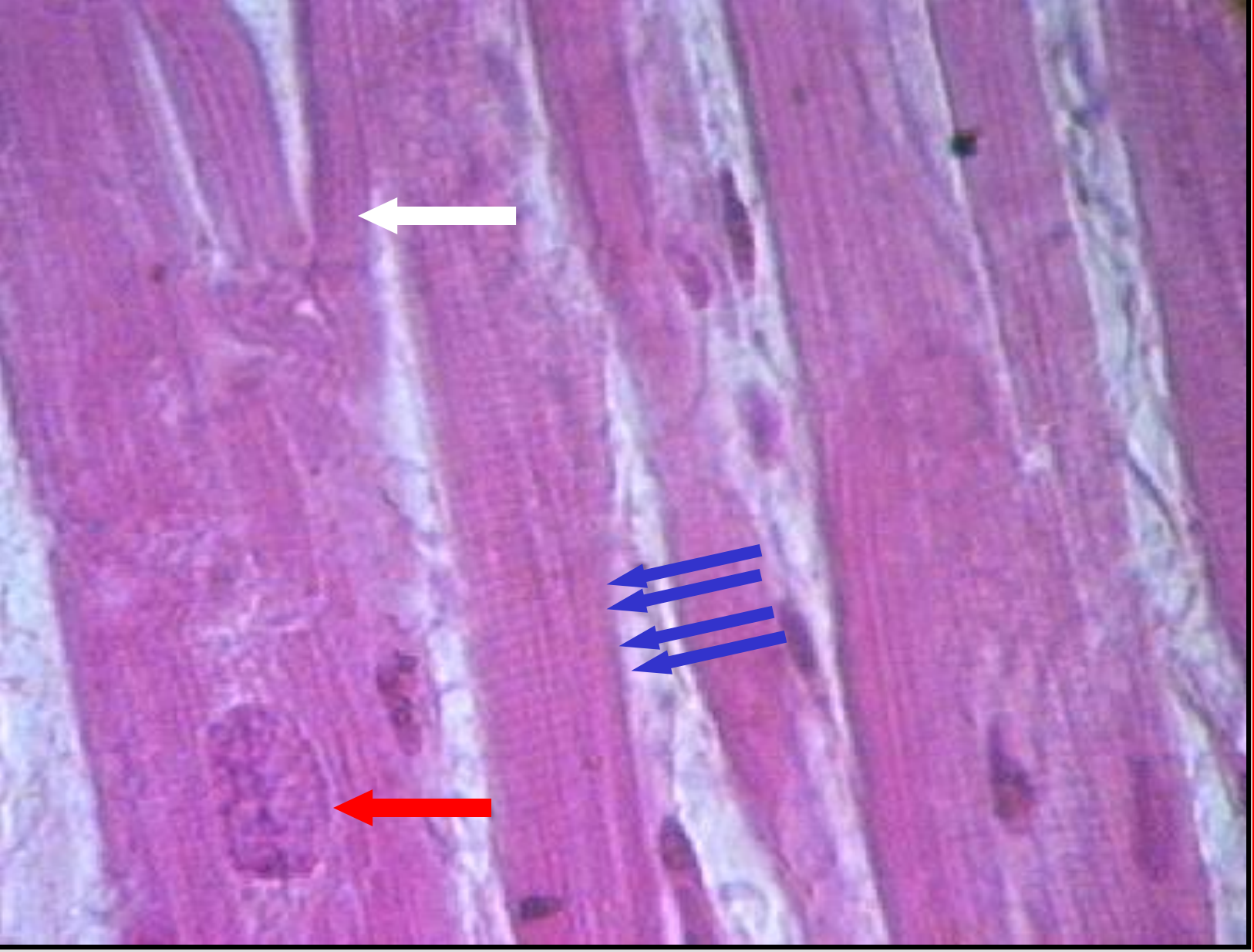
Quit



This is cardiac muscle. The ← indicate a central oval nucleus. The ← indicate a cross bridge. The ← indicate cross striations.

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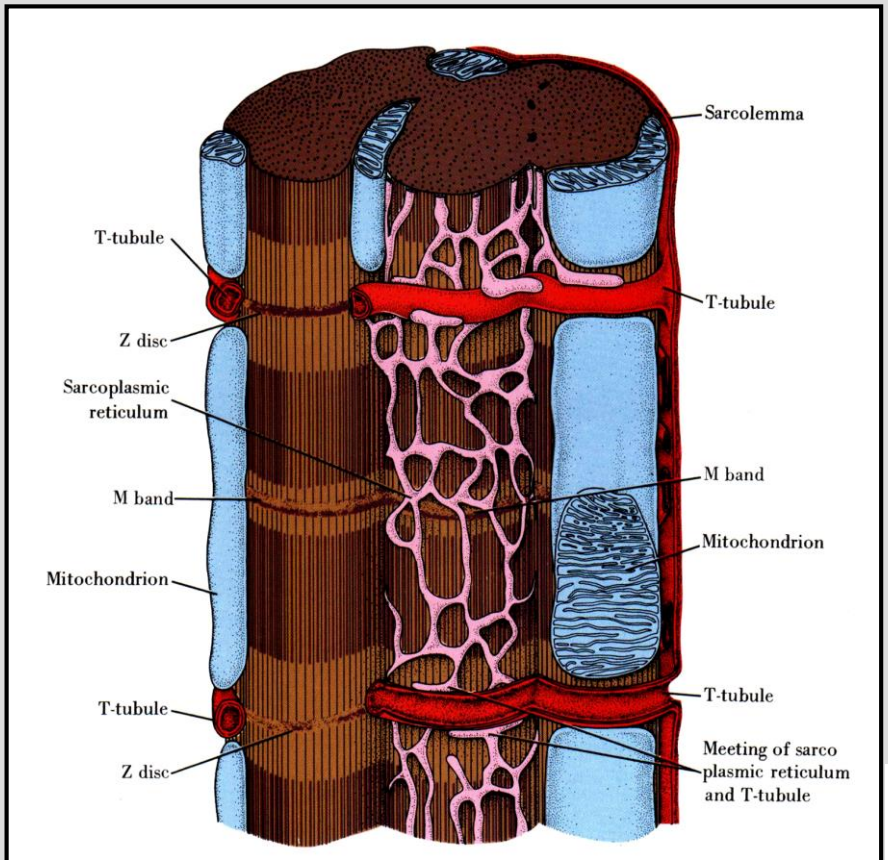
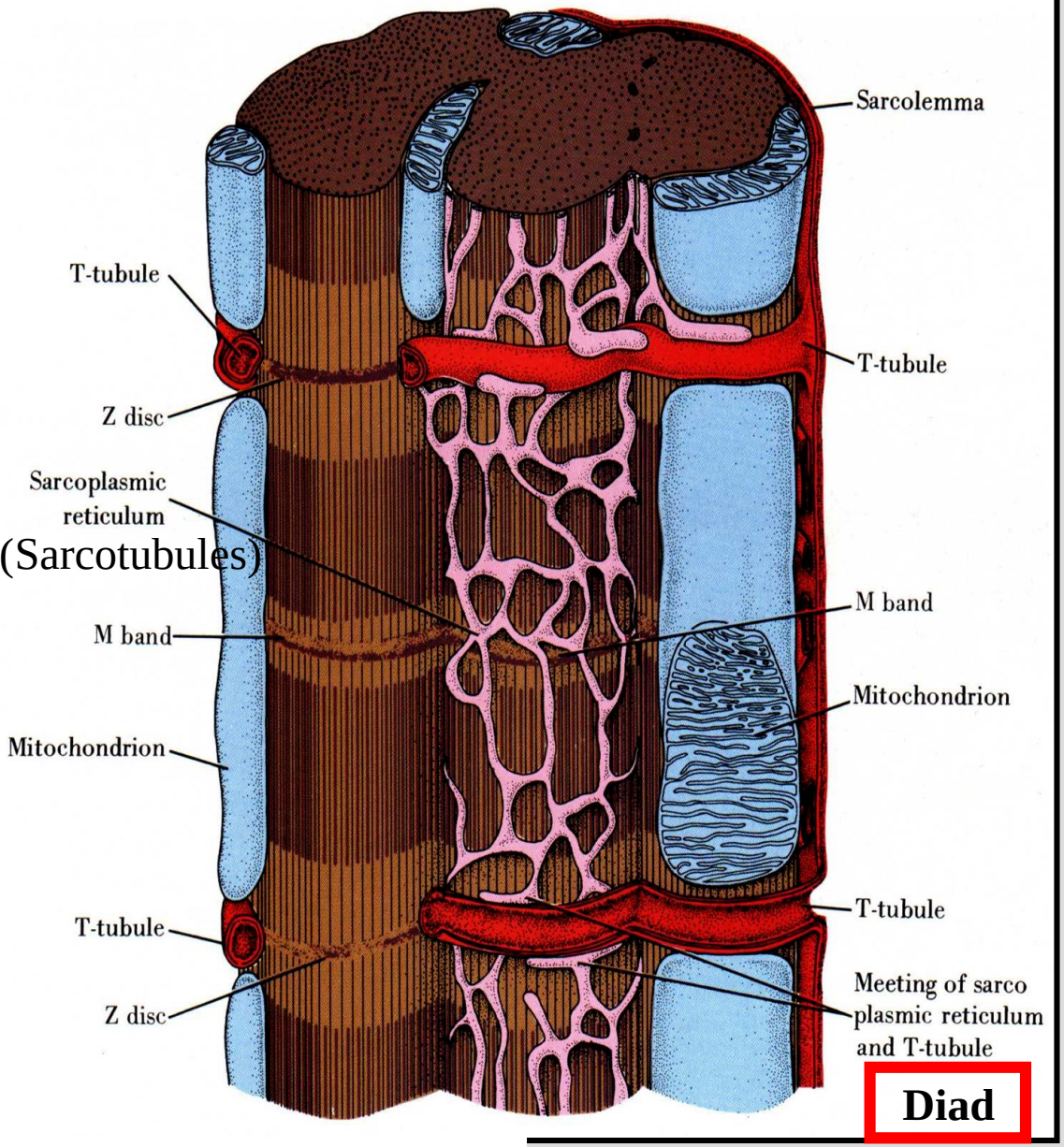
***Electron microscopic structure*:**

- Between myofibrils lie the mitochondria
- **2.5 μm long mitochondria**
- **dense** cristae
- and are as **long** as the sarcomere
- fibres have **more glycogen** than skeletal muscle fibres
- myofilaments, actin and myosin are the same as in skeletal muscle

- the sarcoplasmic reticulum differs in that there is no **terminal cisterna**. The sarcotubules end in **little feet** that sit on the **T-tubule**



(Ross and Romrell, 1989).



(Ross and Romrell, 1989).

Identify:

T tubule,

Sarcotubules

How the sarcotubules end on the T tubule.

The level at which the T tubule lies

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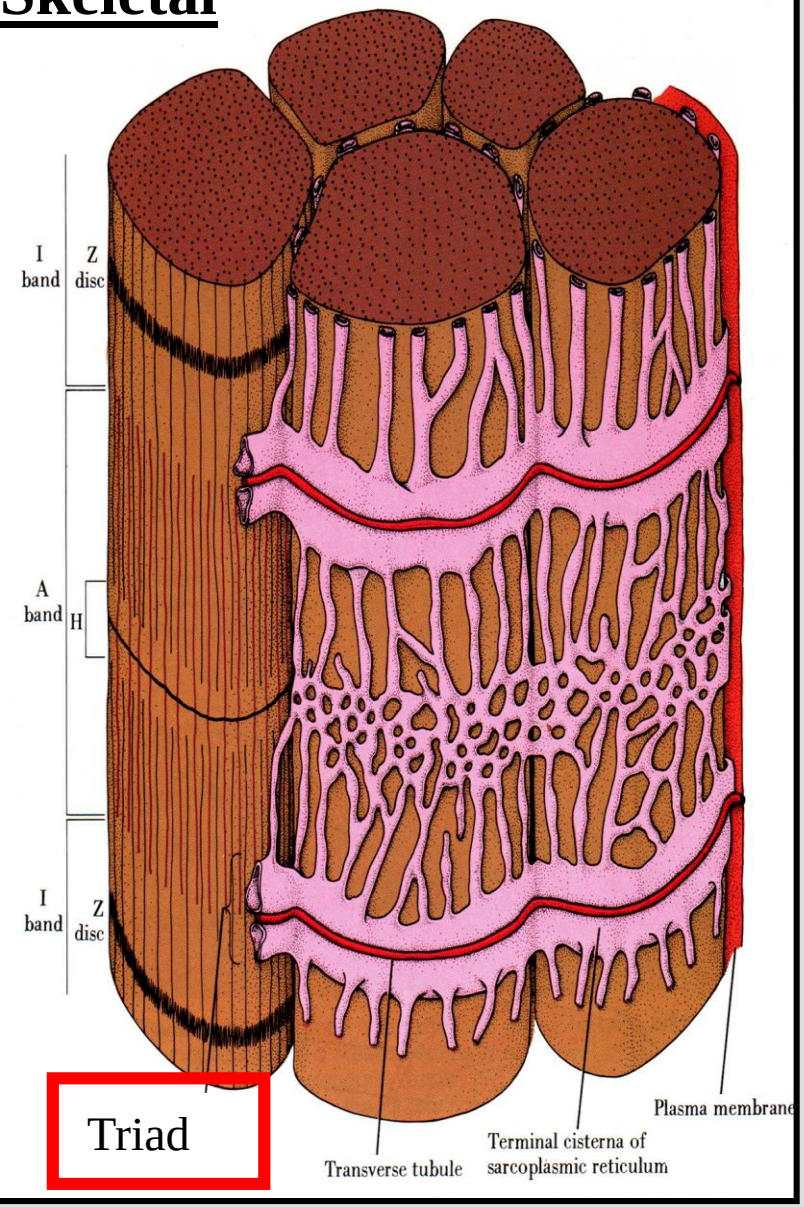
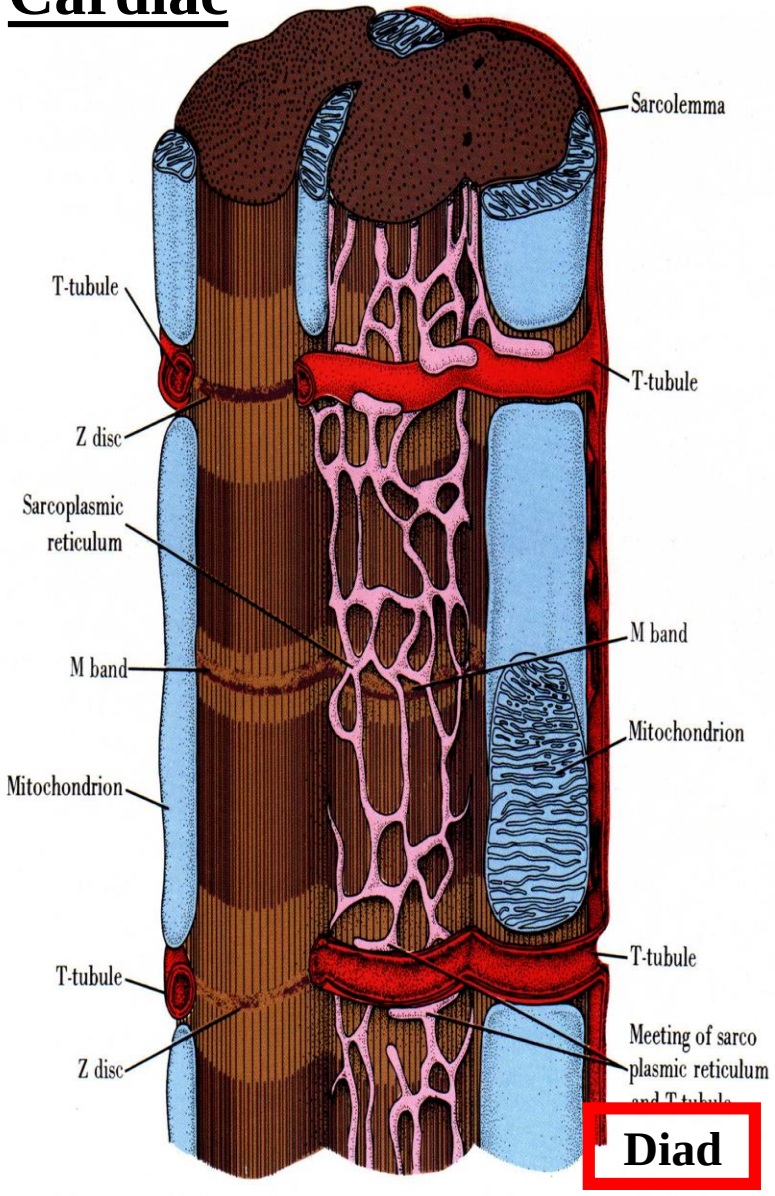
Skeletal

(Ross and Romrell, 1989).

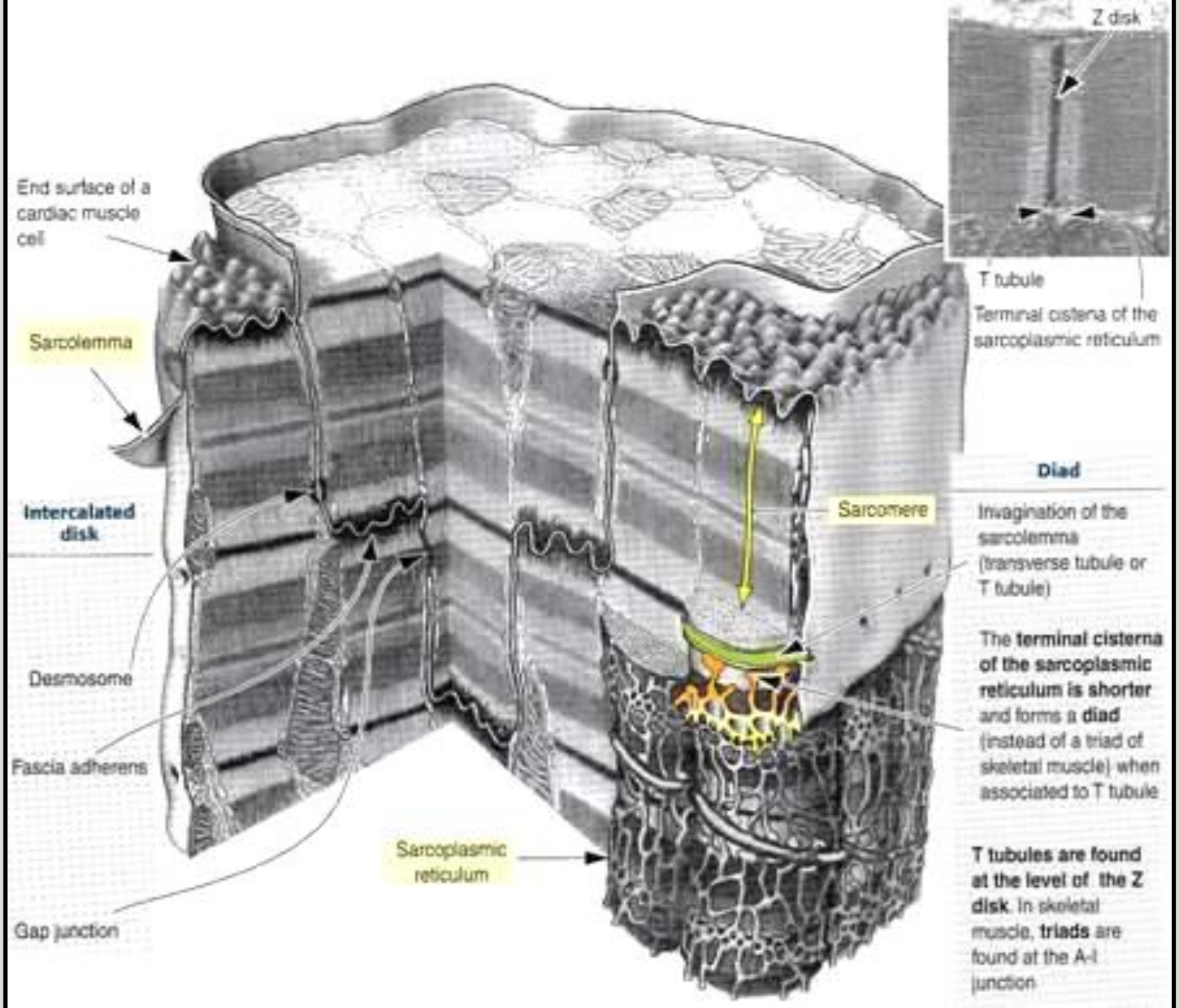


Cardiac

(Ross and Romrell, 1989).

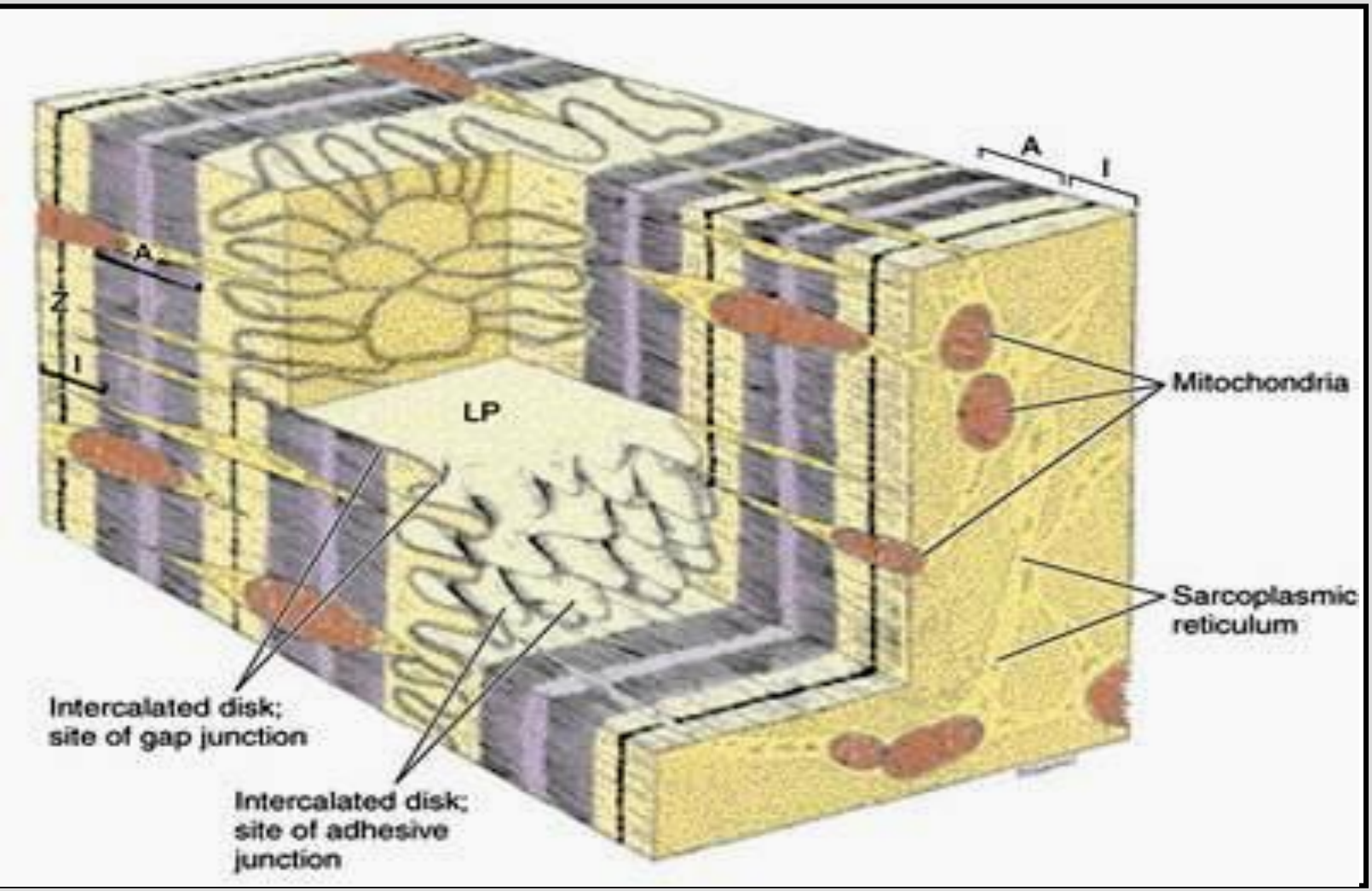


Sarcoplasmic reticulum of skeletal and cardiac muscle. Notice that the T tubules lie at different levels in the two muscle types. (junction of A and I bands for skeletal muscle - Z line for cardiac). Terminal cisterna absent from cardiac muscle


End surface of a cardiac muscle cell
Sarcolemma
Intercalated disk
Desmosome
Fascia adherens
Gap junction
Sarcoplasmic reticulum
Sarcomere
Z disk
T tubule
Terminal cisterna of the sarcoplasmic reticulum
Diad
Invagination of the sarcolemma (transverse tubule or T tubule)
The terminal cisterna of the sarcoplasmic reticulum is shorter and forms a diad (instead of a triad of skeletal muscle) when associated to T tubule
T tubules are found at the level of the Z disk. In skeletal muscle, triads are found at the A-I junction

Intercalated Disc:

- on Z lines
- fibres interdigitate



Notice the tongue and groove folds → for stronger attachment between cardiac muscle fibers in the intercalated disc.

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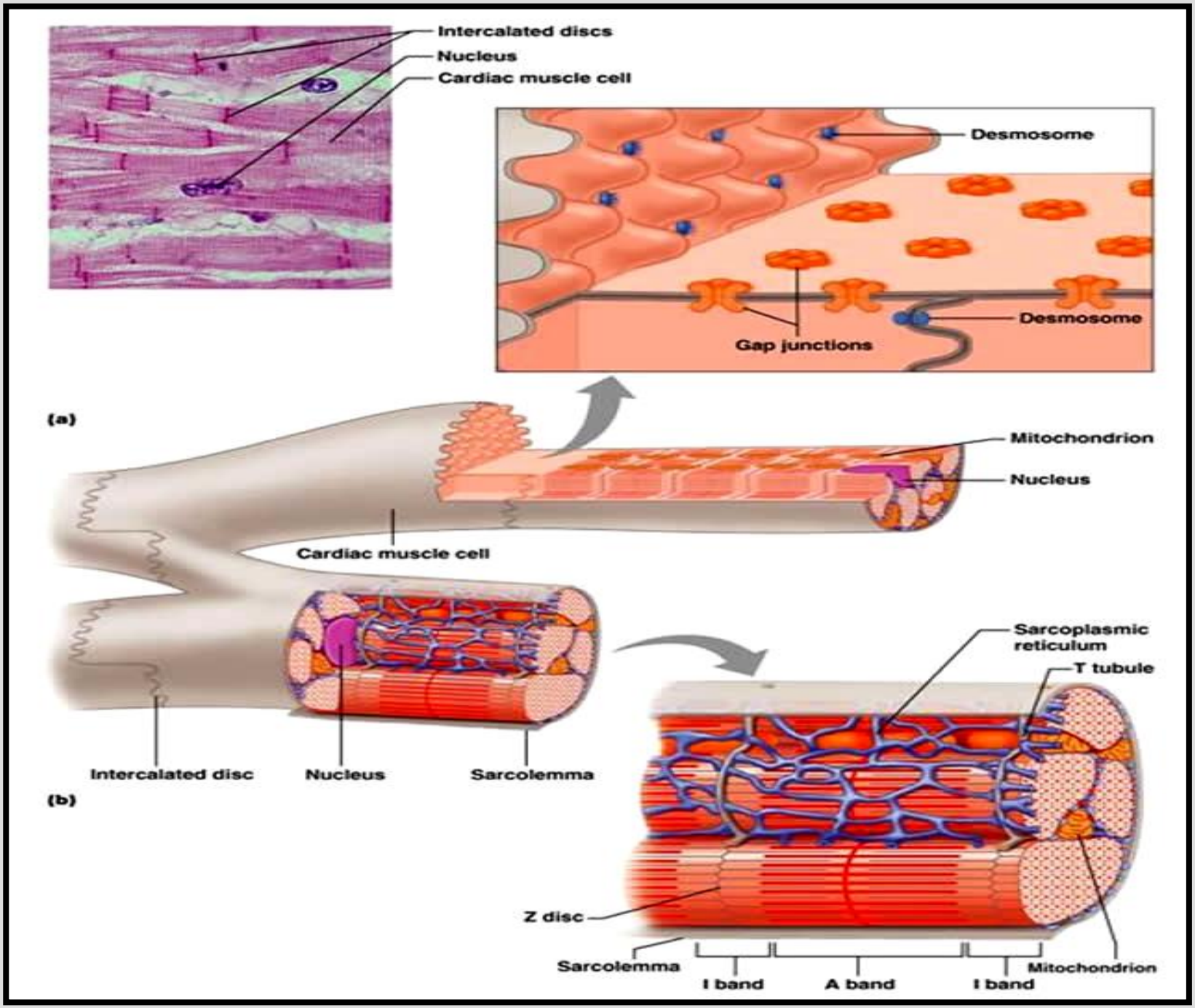
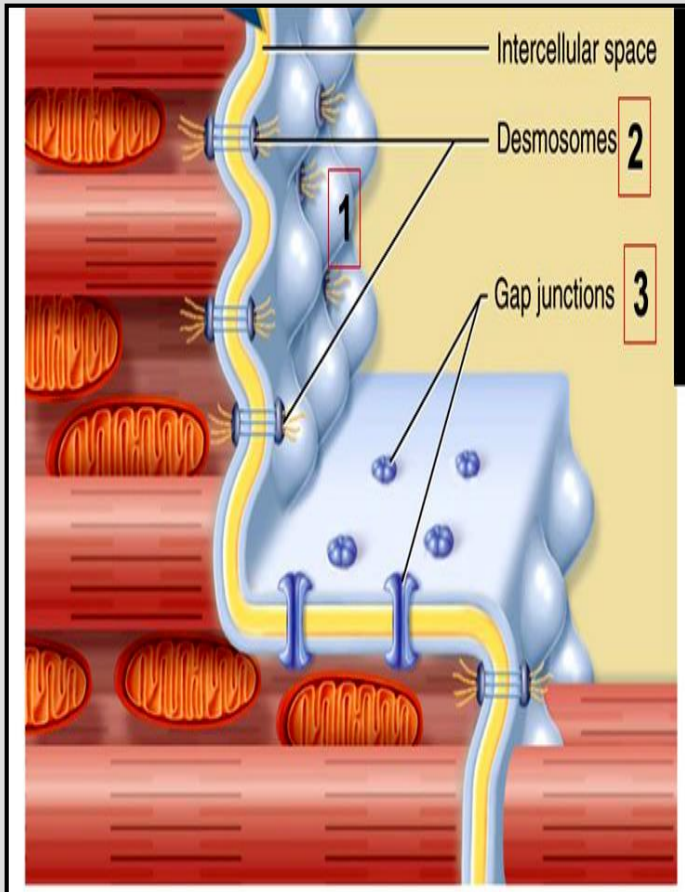

Intercalated discs
Nucleus
Cardiac muscle cell
Desmosome
Desmosome
Gap junctions
(a)
Mitochondrion
Nucleus
Cardiac muscle cell
Intercalated disc
Nucleus
Sarcolemma
(b)
Sarcoplasmic reticulum
T tubule
Z disc
Sarcolemma
I band
A band
I band
Mitochondrion



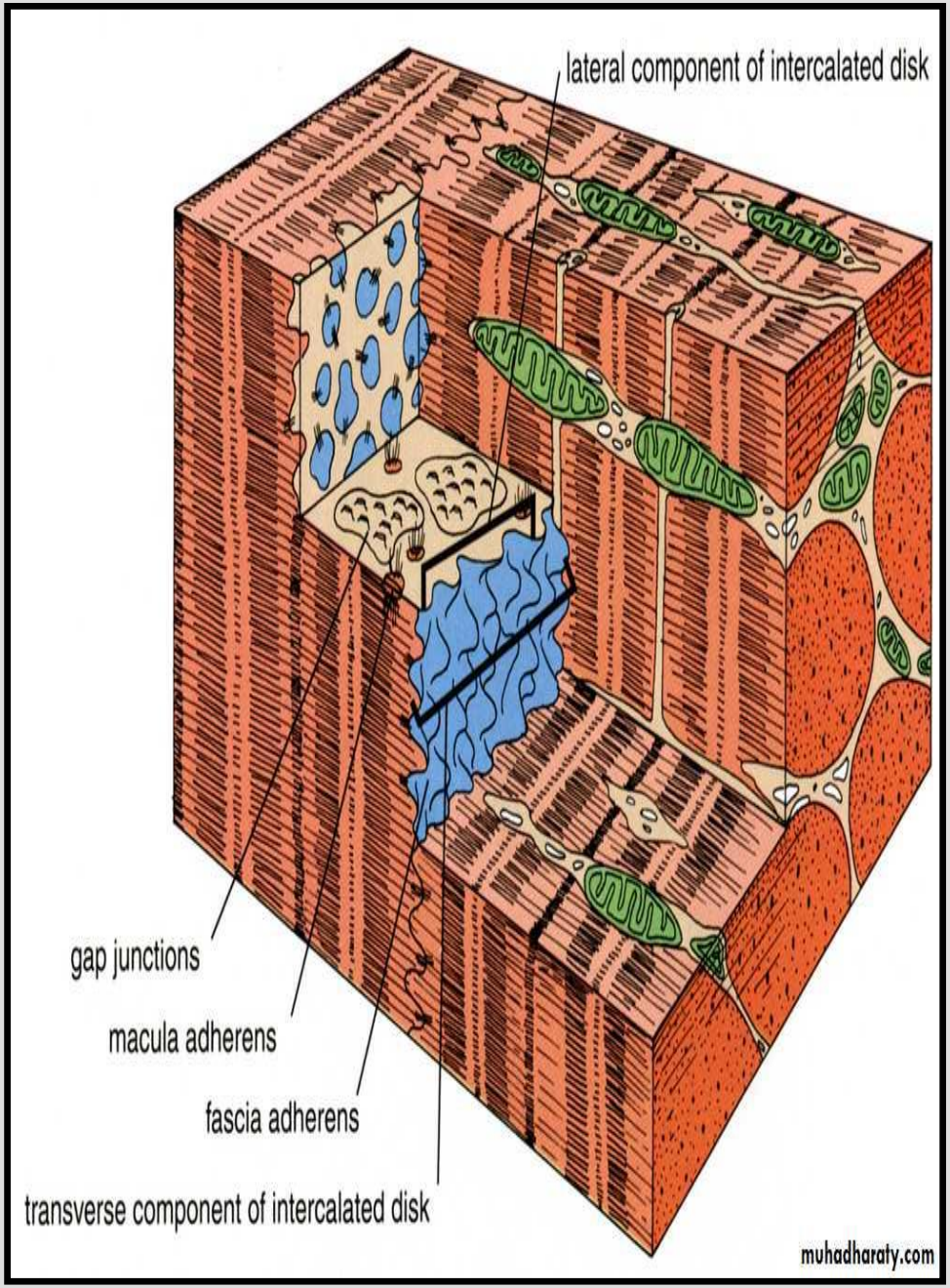
Structure of an intercalated disc

(c) **1-- interdigitating folds**

2—mechanical junctions– two types; fascia adherens and desmosomes

3—electrical (gap) junctions--

19-70



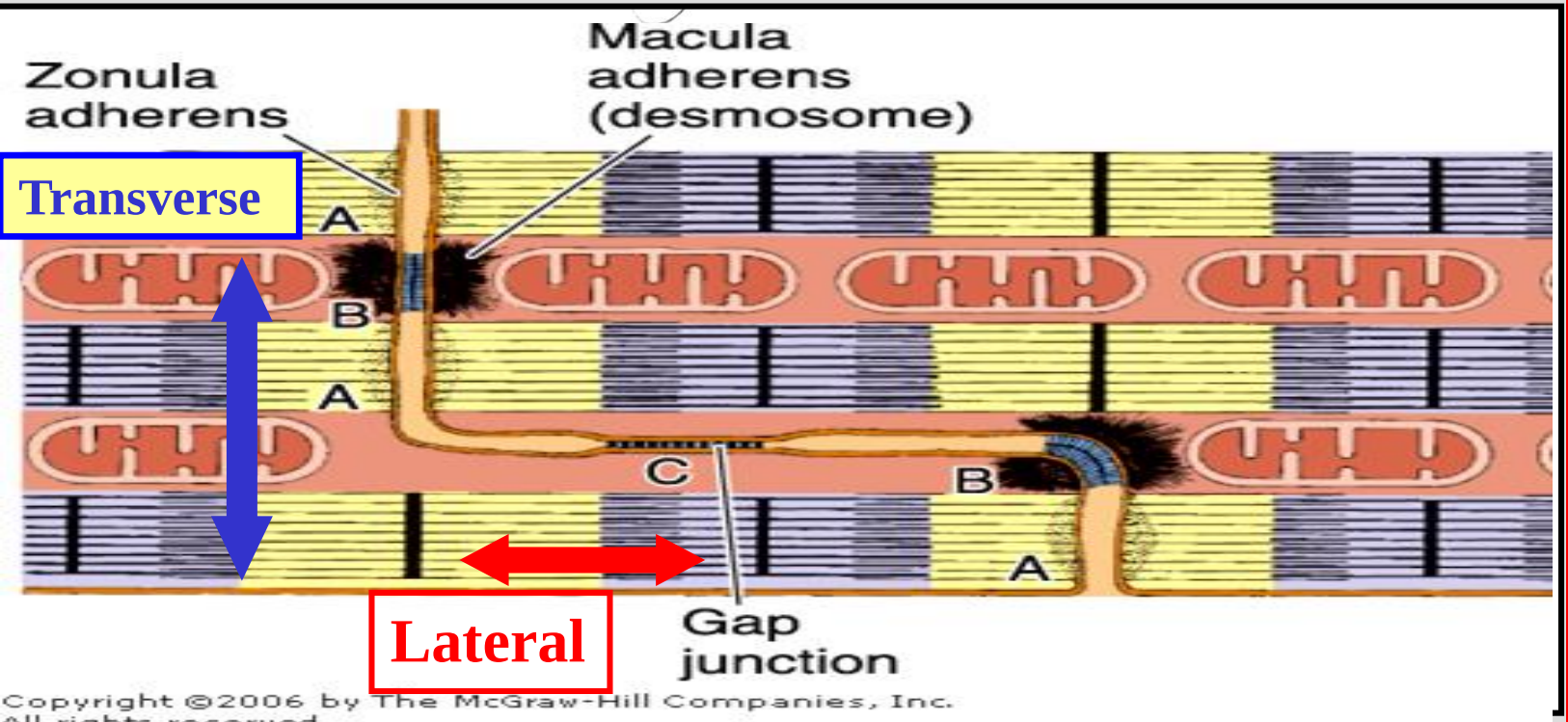
3 types of junctions in the disc

Transverse Part:

- **zonula (fasciae) adherents (A)**
  - ***hold** cardiac muscle cells
  - ***anchor** thin filaments
- **desmosomes (macula adherentes) (B)**
  - ***rivets** to **prevent** the cells from **pulling apart**

Lateral Part:

- **Gap junctions (nexus) (C)**
  - * for **impulse transfer** (electrical communication between cardiac muscle cells)
- **desmosomes** (macula adherentes) **(B)**



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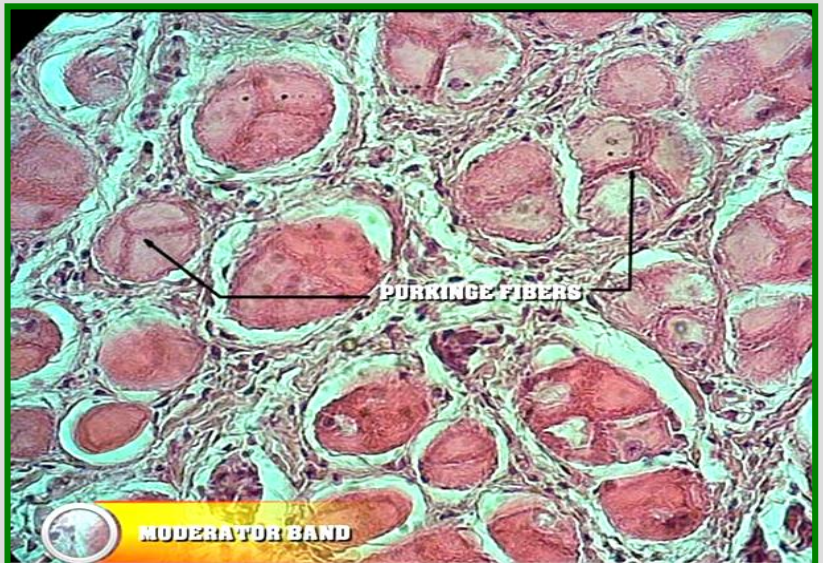
Mechanism of Contraction:

- slide - ratchet like in skeletal muscle
- certain fibres are modified for conduction, **specialised cardiac muscle** cells organized into nodes to transmit the impulse to various parts called **cardiac conducting cells** (***Purkinje cells***)
- Impulses spread from cell to cell through gap junctions



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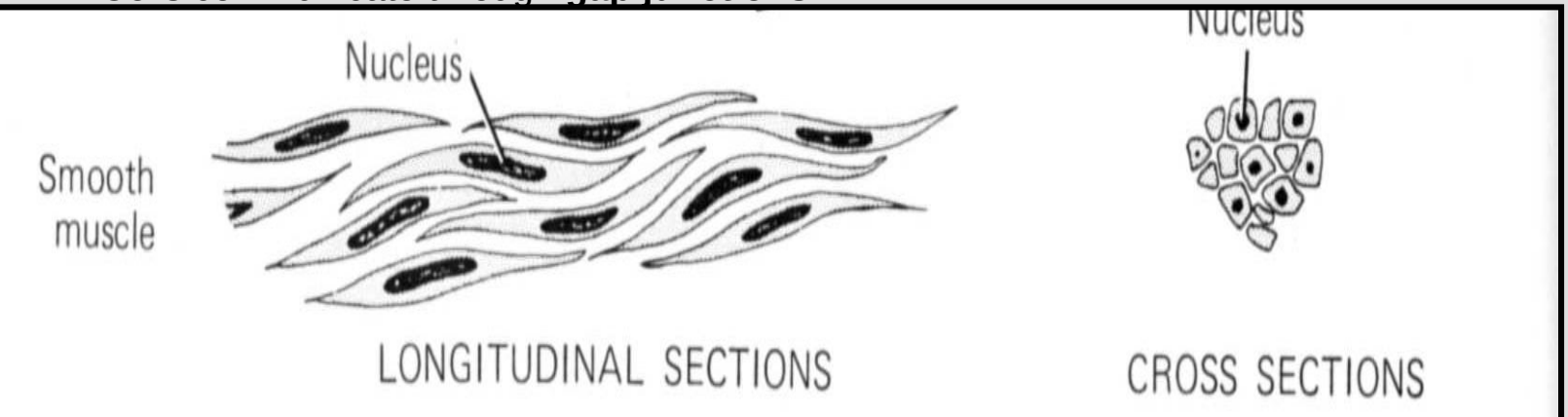
Smooth Muscle

Light microscopic Structure:

- cells – **variable size** - **spindle shaped** -The largest smooth muscle cells occur in the uterus during pregnancy (12x600 µm). The smallest are found around small arterioles (1x10 µm)
- nucleus lies in the **widest widest part** of the fiber
- when the fiber contract the nucleus become **folded**
- 30 - 200 µm long
- between fibres lie **endomysium**

Electron microscopic structure:

- Mitochondria, ribosomes, golgi, rough EPR
- myofilaments are present but **no sarcomeres** and **no Z lines**
- thin filaments - **actin** and tropomyosin (7nmØ)
- thick *filaments* - **myosin** (17nmØ)
- intermediate filaments (10 nmØ)
- actin and myosin **overlap** more than in skeletal muscle and can therefore contract more
- A rudimentary sacroplasmic reticulum is present in the form of invaginations on the surface called **caveolae**
- So there are **no T-tubules**
- Cells communicate through **gap junctions**.



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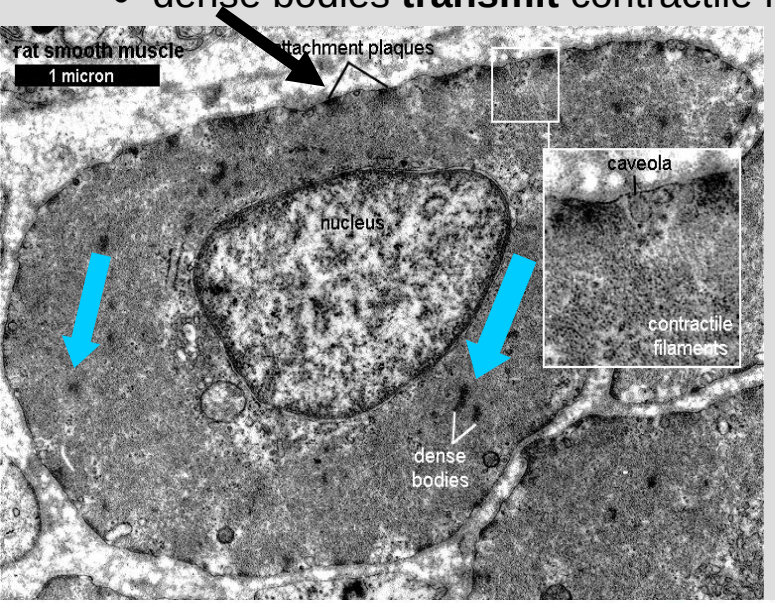
Dense bodies

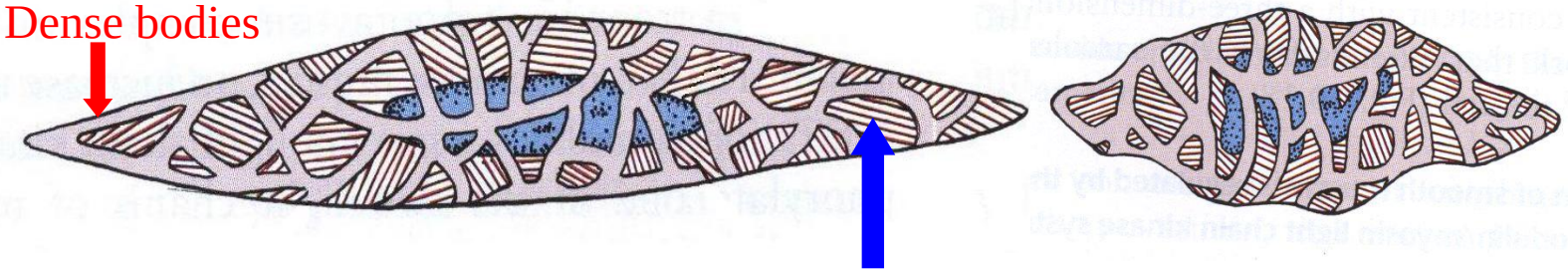
- Filaments are attached to **dense bodies** (**plaque**) which take the place of the Z line in skeletal muscle
- There are two types of dense bodies - **cytoplasmic** and **membrane**
- contains a percentage *actinin* (like the Z line)
- dense bodies **transmit** contractile force to adjacent fibres



The ↓ indicate a dense body on the membrane.

The ↓↓ indicate dense bodies in the cytoplasm.

The drawings show how the filaments attach to the
dense bodies and how the filaments pull the dense bodies
closer during contraction.



Relaxed

Contracted

(Ross and Romrell, 1989).

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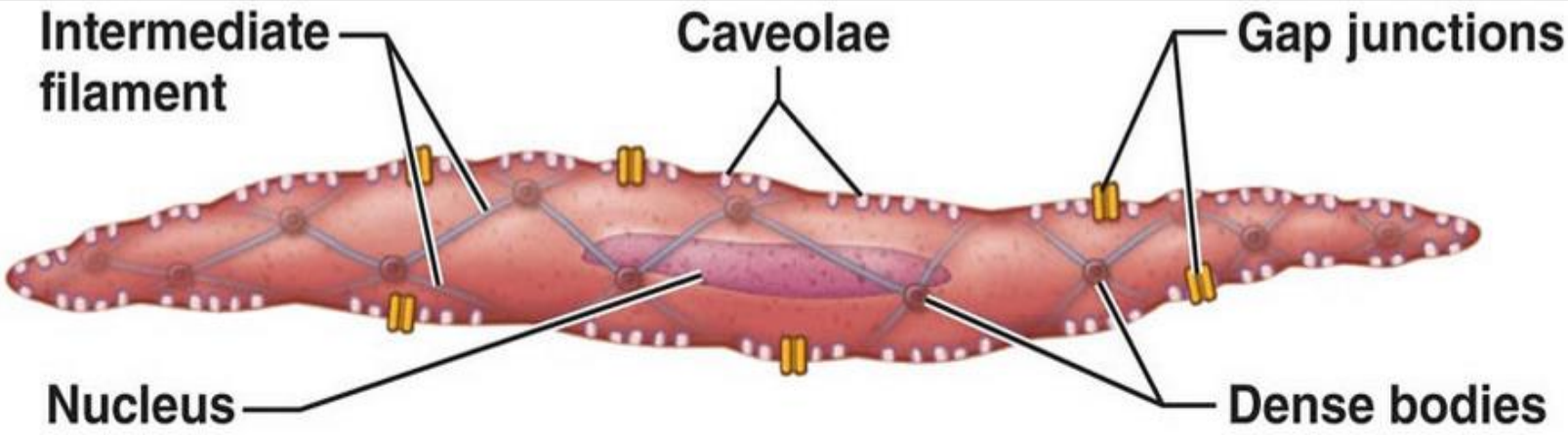
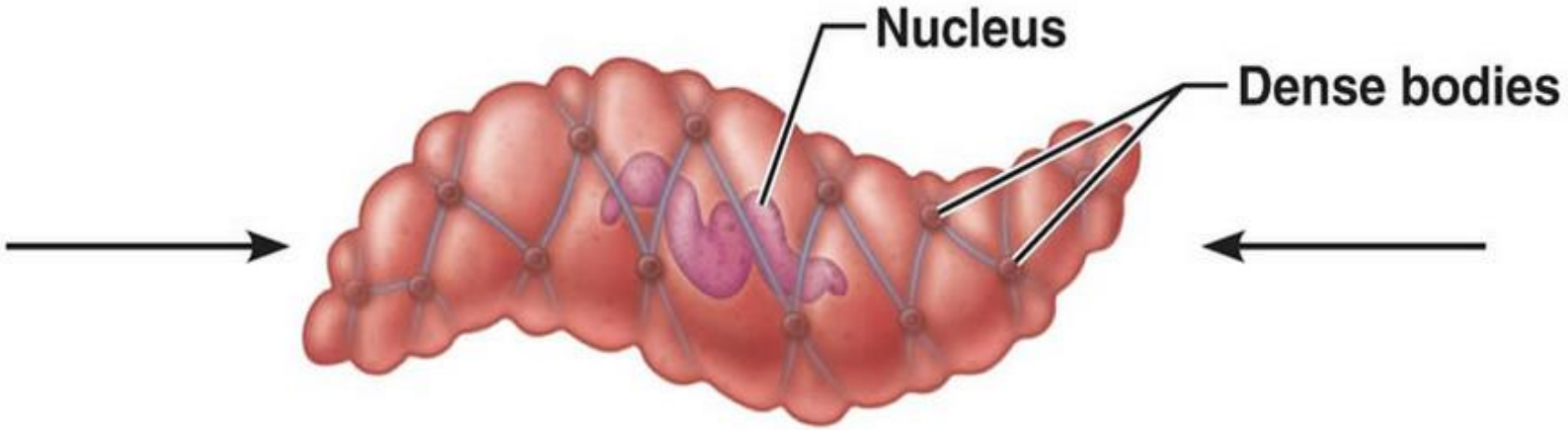


(a) Relaxed smooth muscle fiber (note that gap junctions connect adjacent fibers)



(b) Contracted smooth muscle fiber

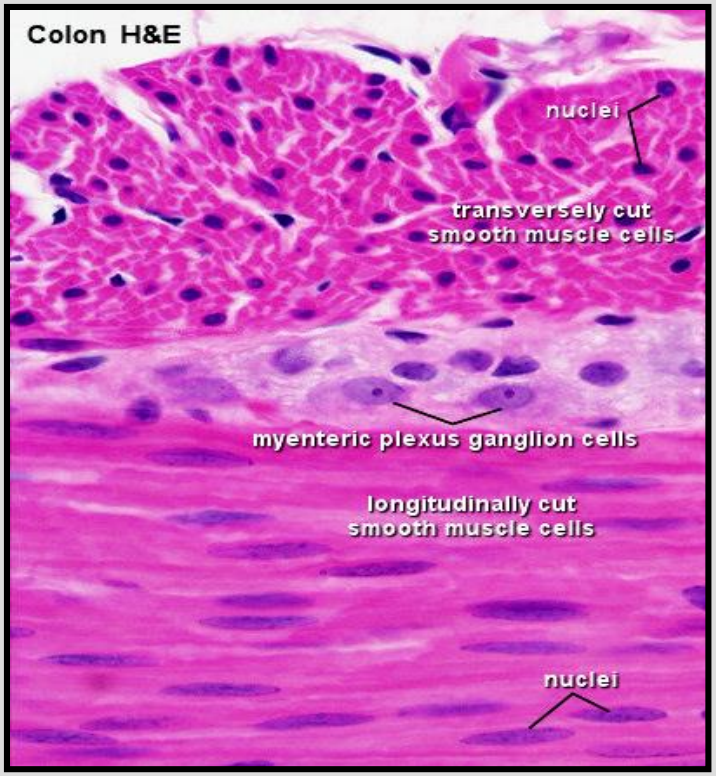
Arrangement:

- Fibres can be single or in groups
- normally arranged in sheaths
- In the GIT are 2 or 3 layers

Nerve supply:

2 types:

- Where it is arranged in layers a few fibres are innervated **together**
- impulse spread through the gap junctions between fibres (slow contraction)
- In the iris and the vas deferens each fiber is **individually** supplied (quick contraction)



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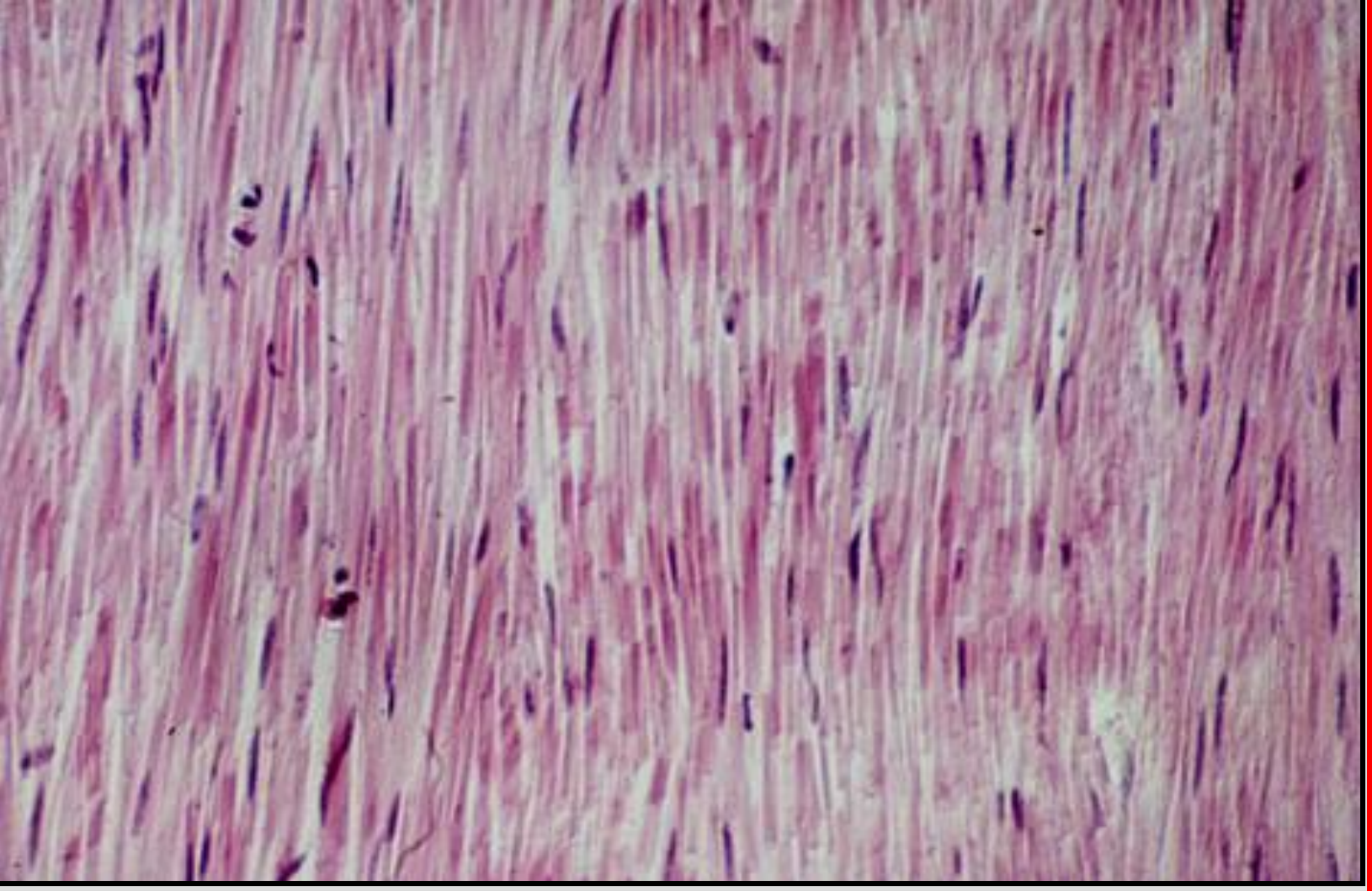

This is low magnification of smooth muscle.

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This is a higher magnification of smooth muscle. Notice the elongated (sigar shaped) ↑ nuclei.

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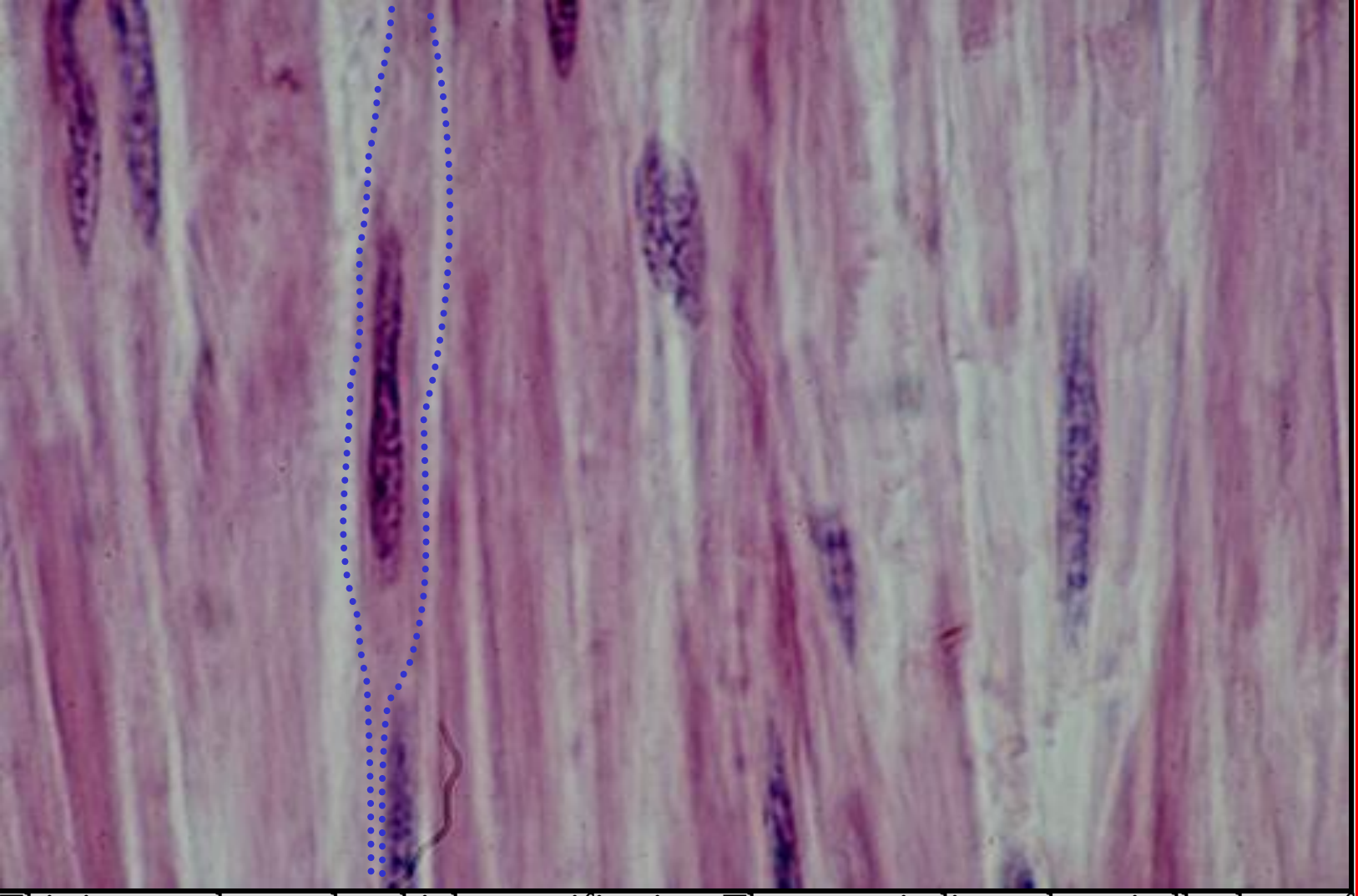

This is smooth muscle – high magnification. The ..... indicate the spindle shape of the smooth muscle fiber. Notice the elongated nuclei.

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