Muscle Tissues

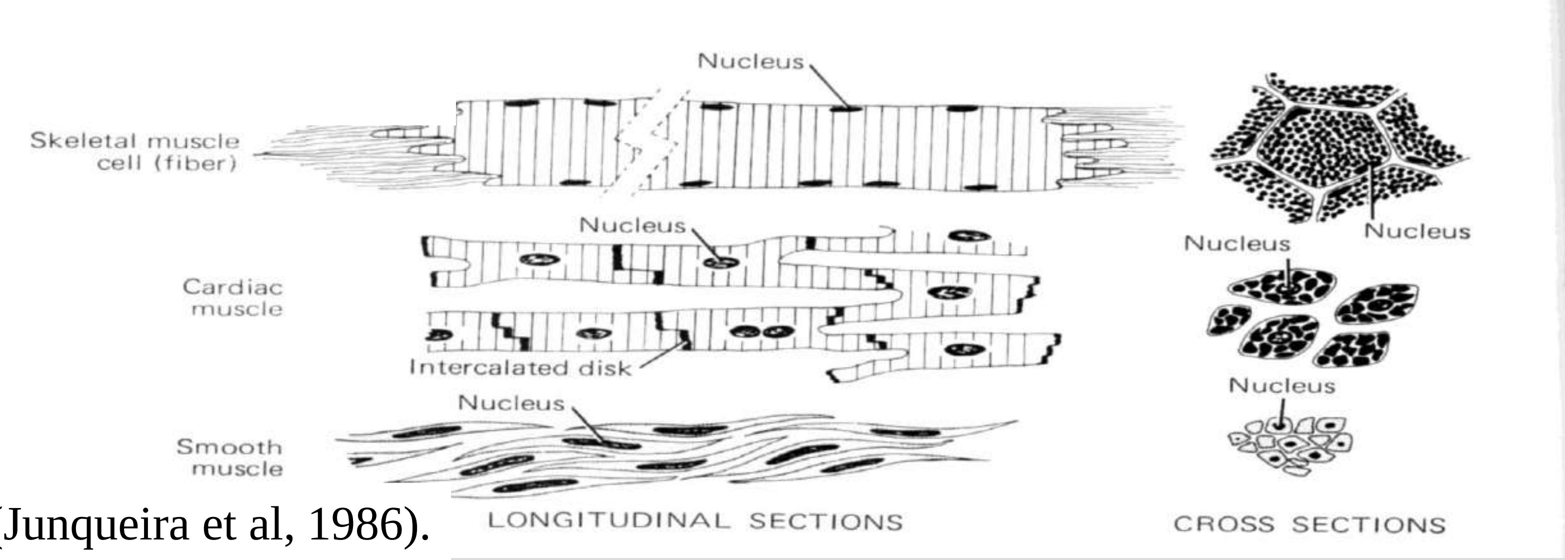
Quit

MUSCLE

Specialized for **contraction** allow movement
The cells are called **fibres** (**myocyte**) because of their length
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).

Muscle cells can be placed into three categories:

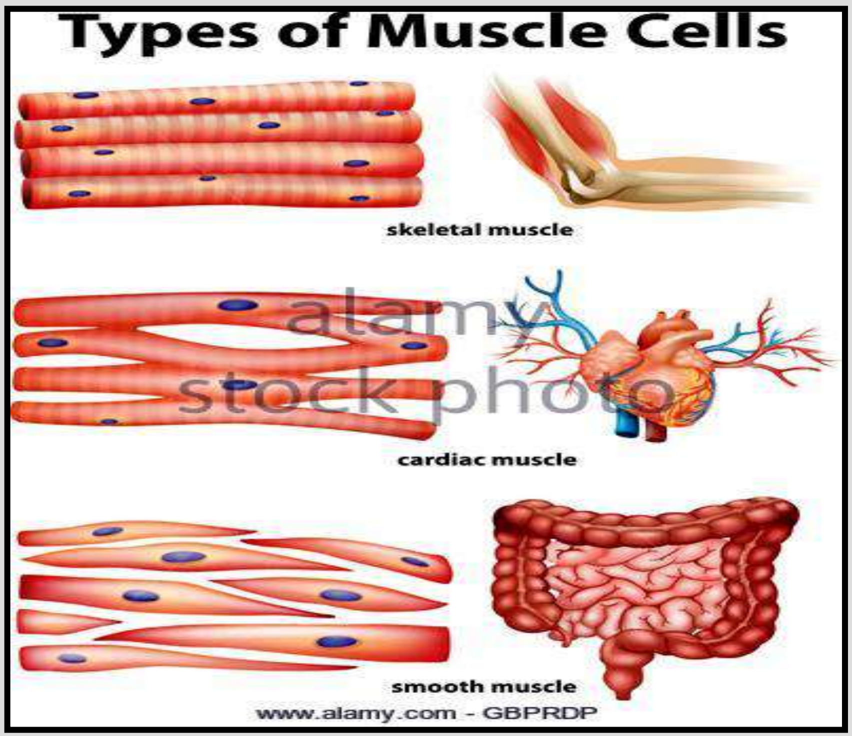
a. **Smooth Involuntary Muscle**

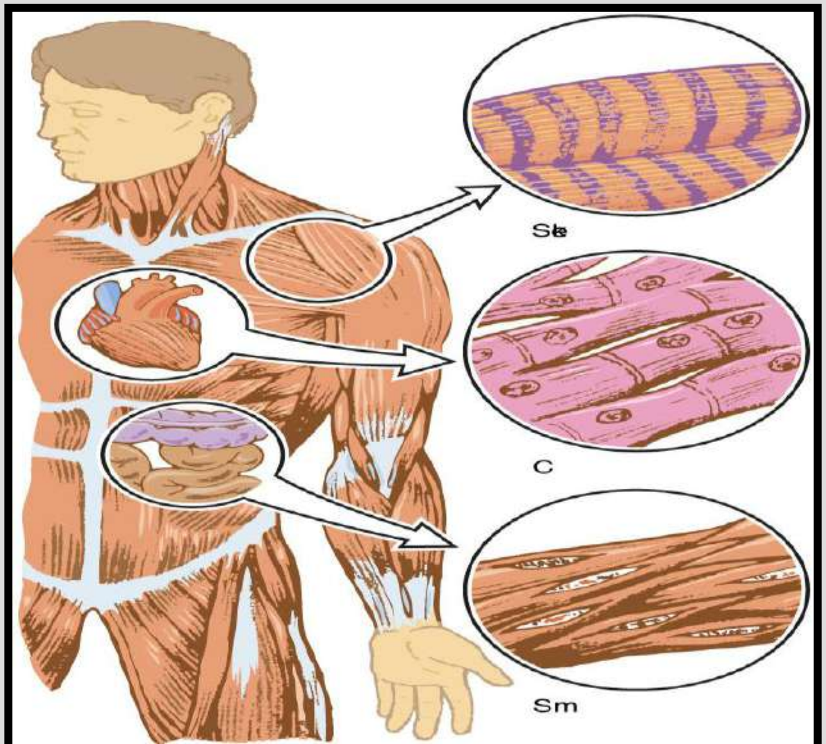
i. found in hollow visceral organs such as the gut, uterus and blood vessels

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

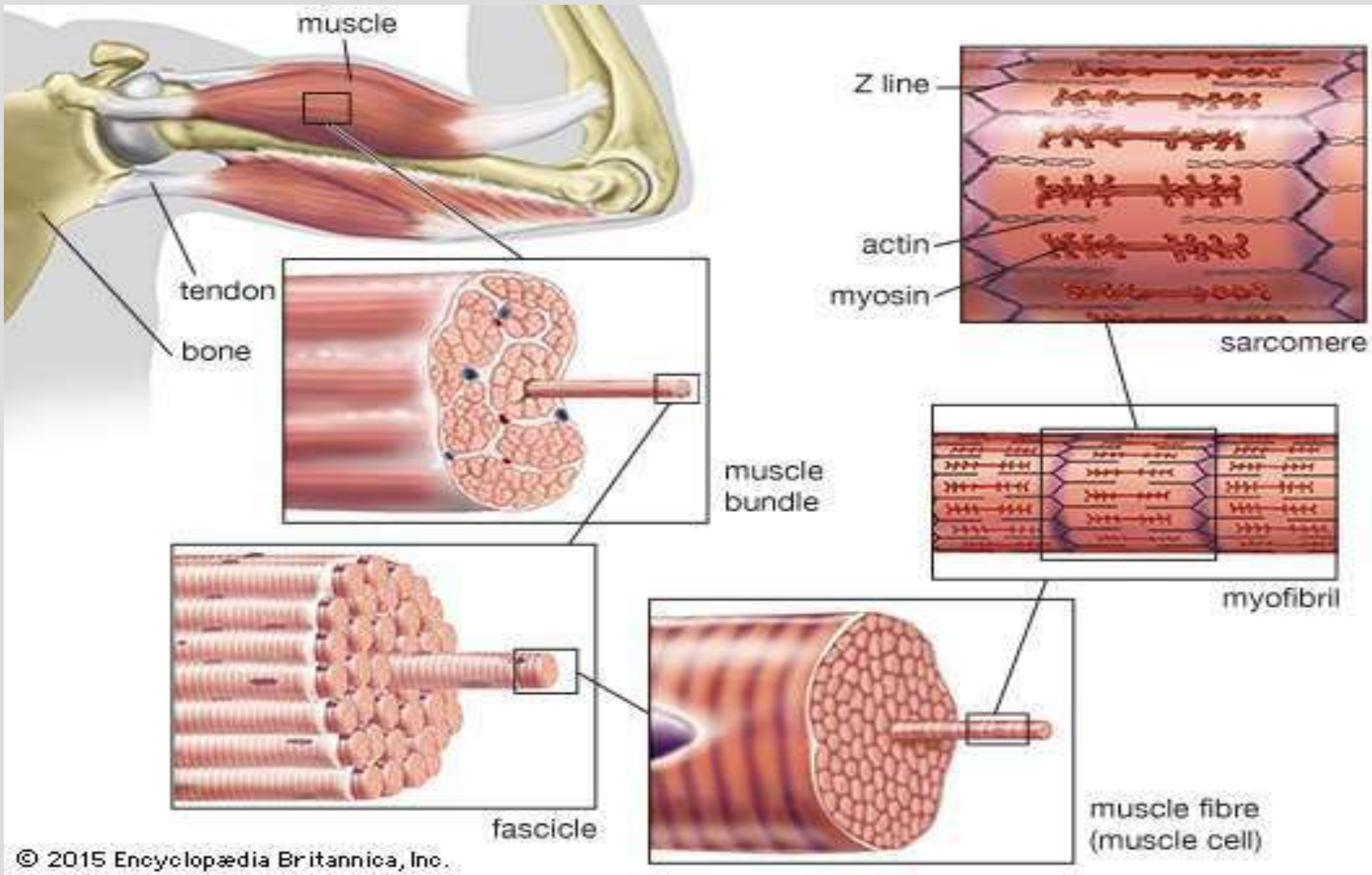




Skeletal Muscle

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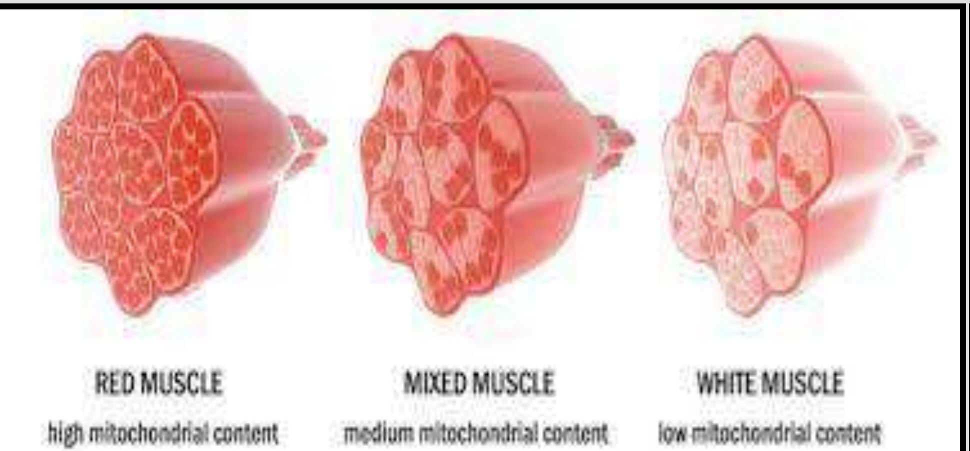
-According to the **myoglobin** content there are:

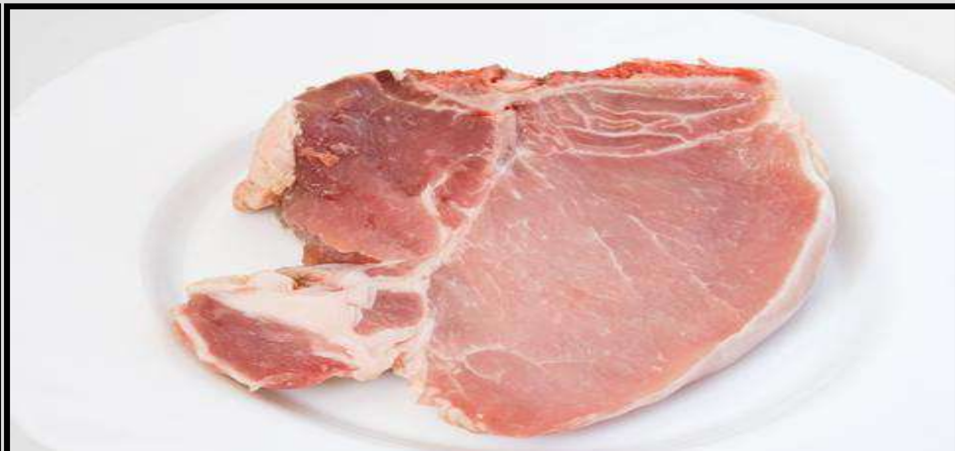
Red fibres (Type I fibres)

- 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

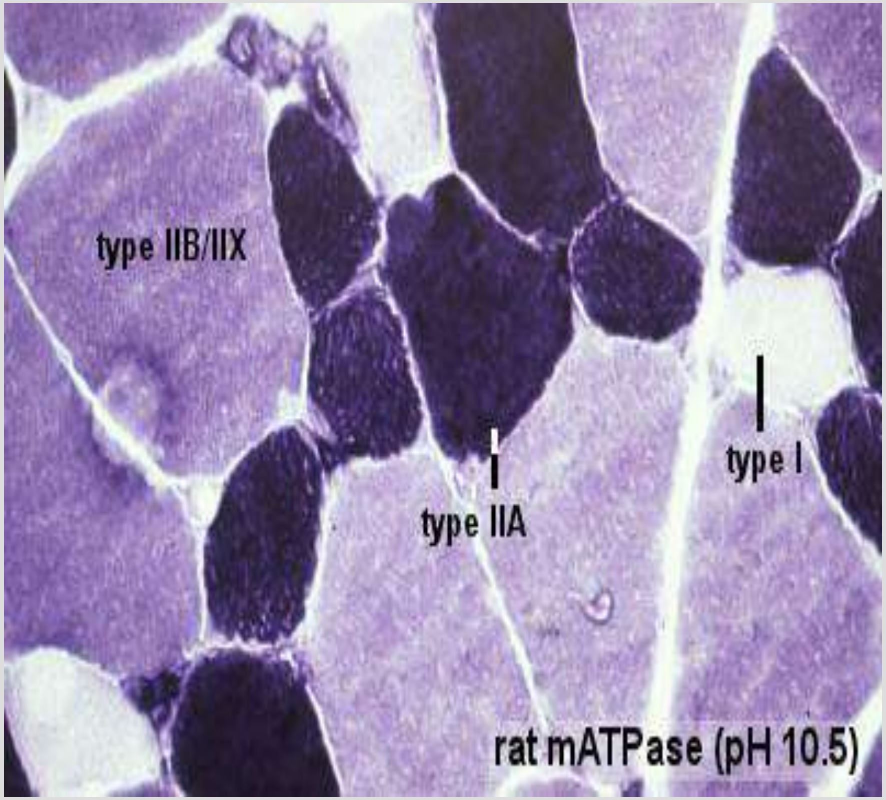
White fibres (Type II fibres)

- 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.



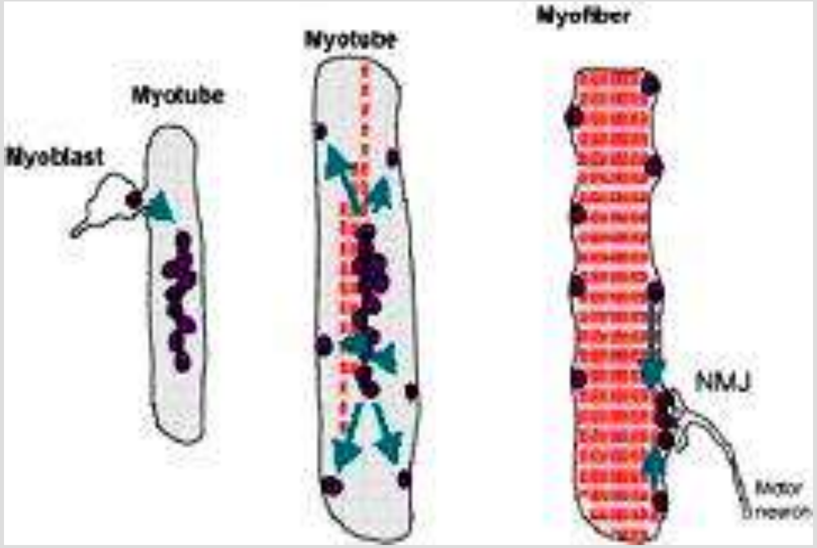


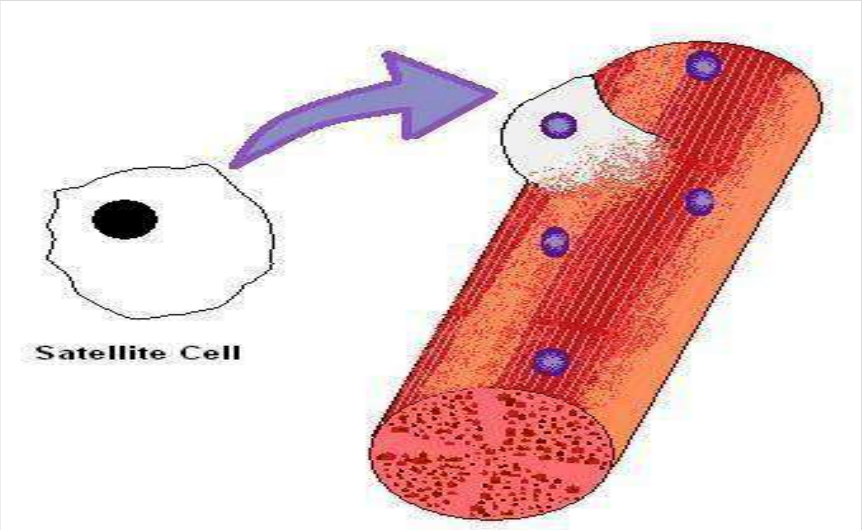
Most muscles have all types in varying ratios



•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

•Mature skeletal muscle cells **can't divide**



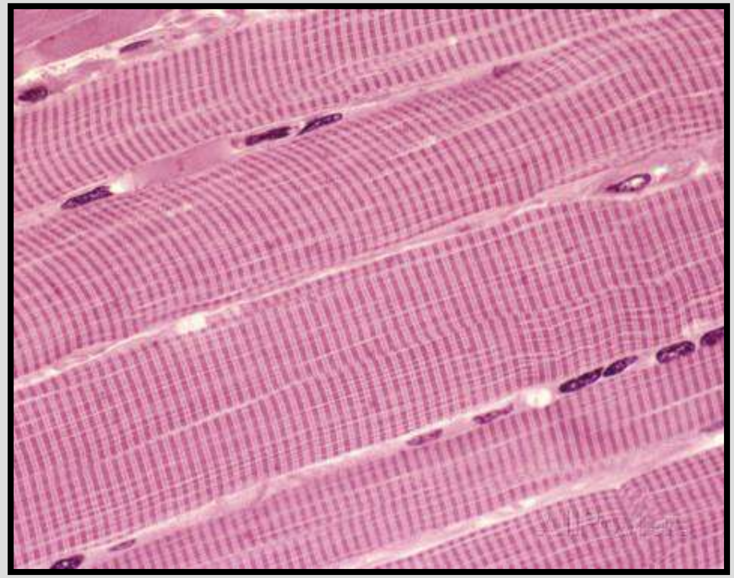


•A further cell-type, known as **satellite cells (myosatellite cells),** may be found adjacent to the sarcolemma. These are elongated, poorly-differentiated cells that are very difficult to discern in typical preparations, but become active by **exercise** or during **repair** and **regeneration** processes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

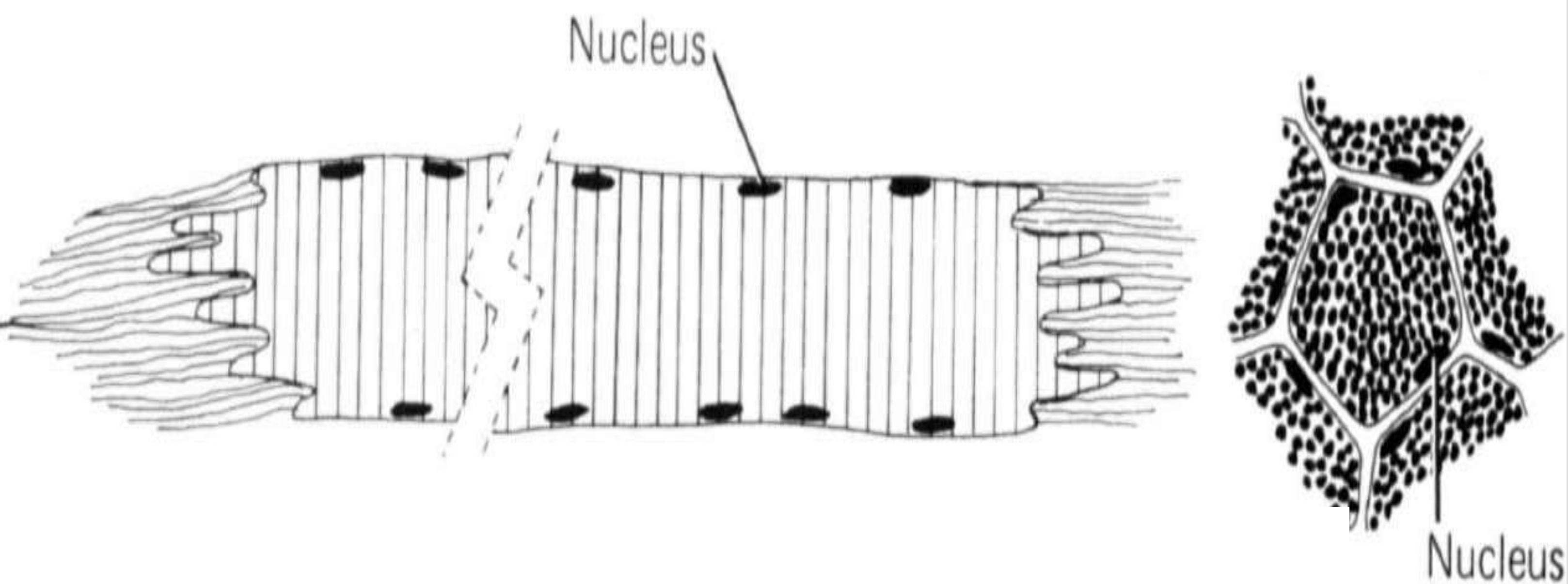
Structure of skeletal muscle:

Light Microscopy

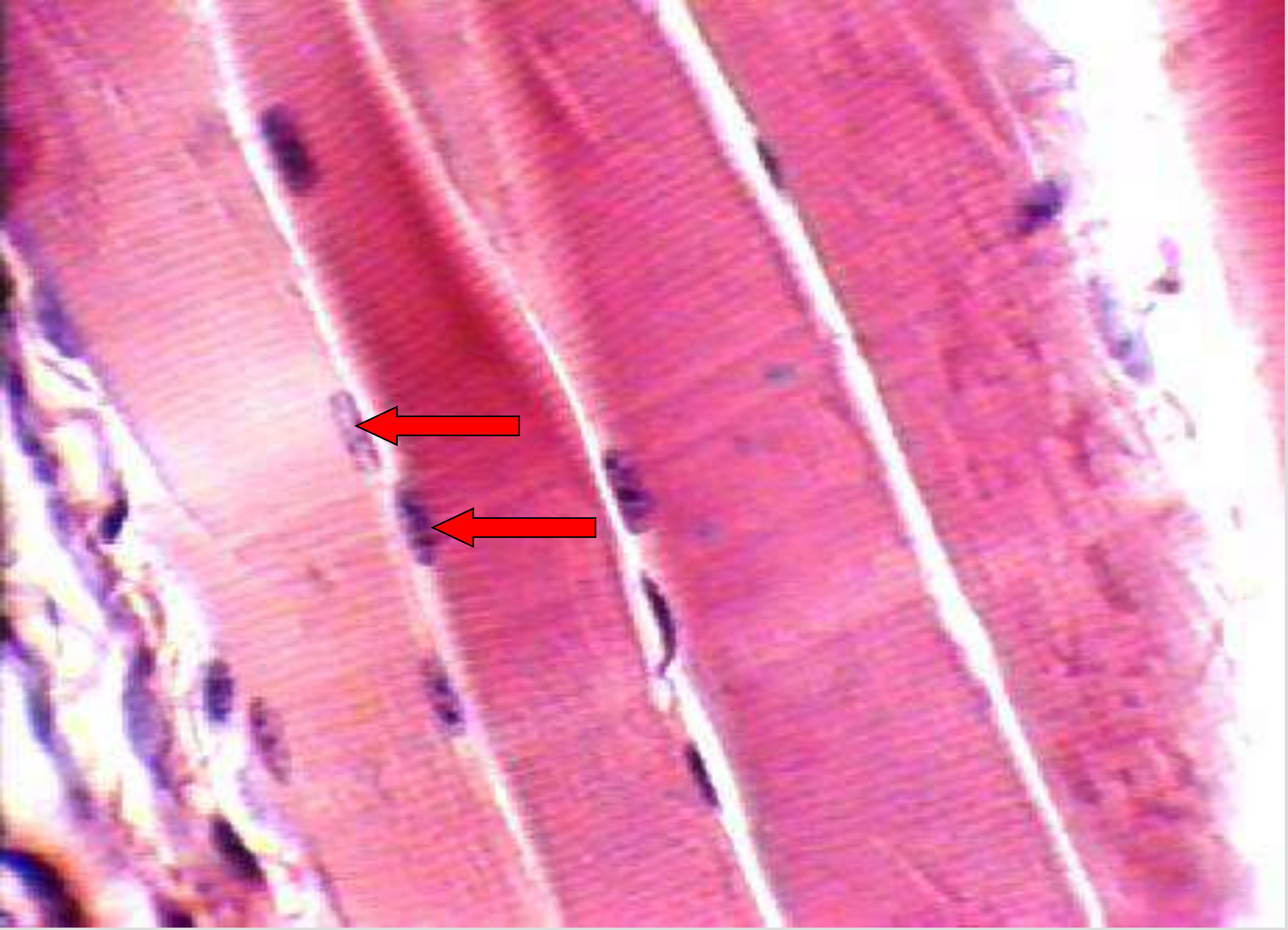
- Many nuclei - 35/mm
- Nuclei are oval - situated peripheral
- Dark and light bands lie across the fiber
- **No branching**



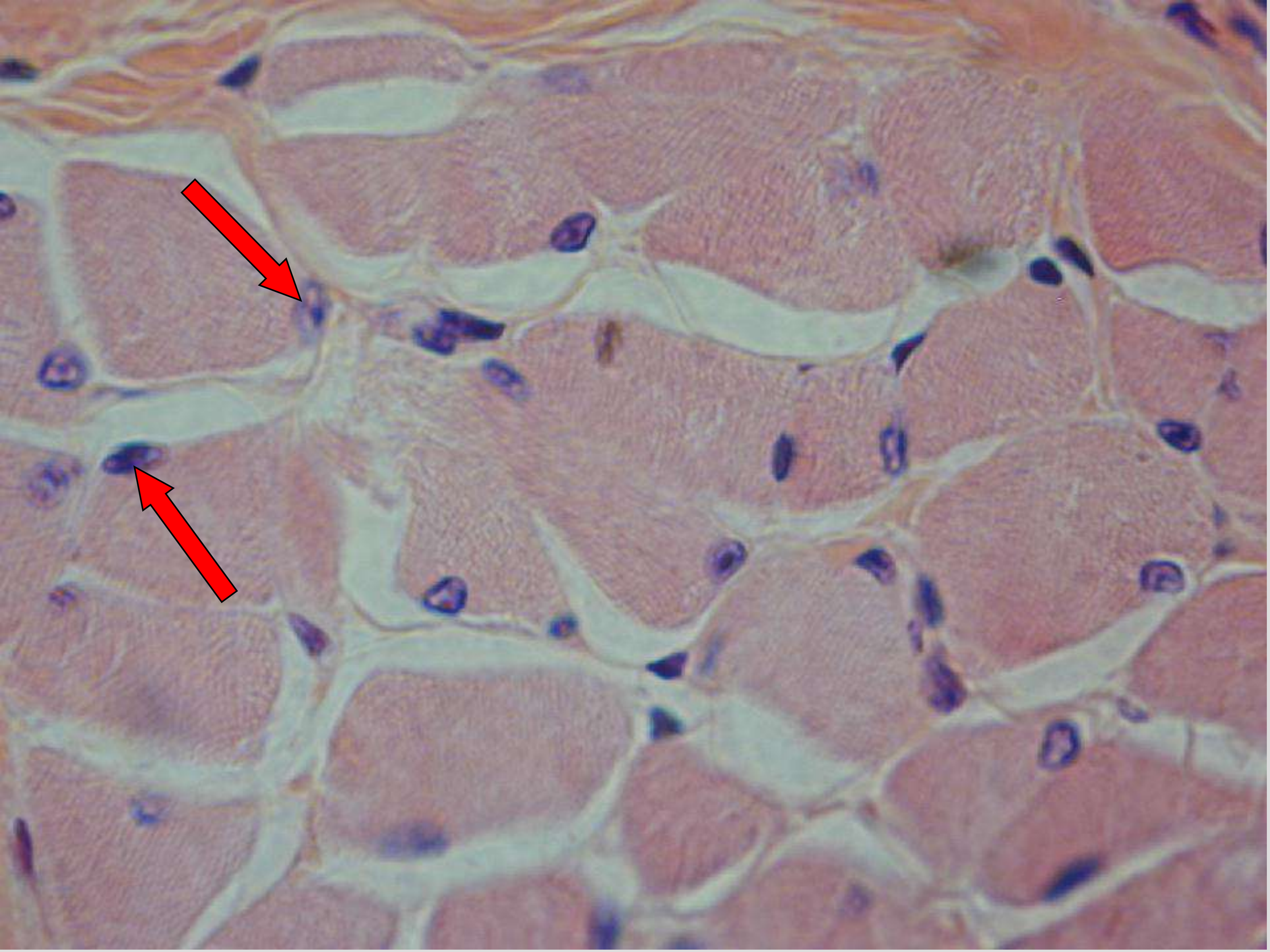
Skeletal muscle



(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.



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

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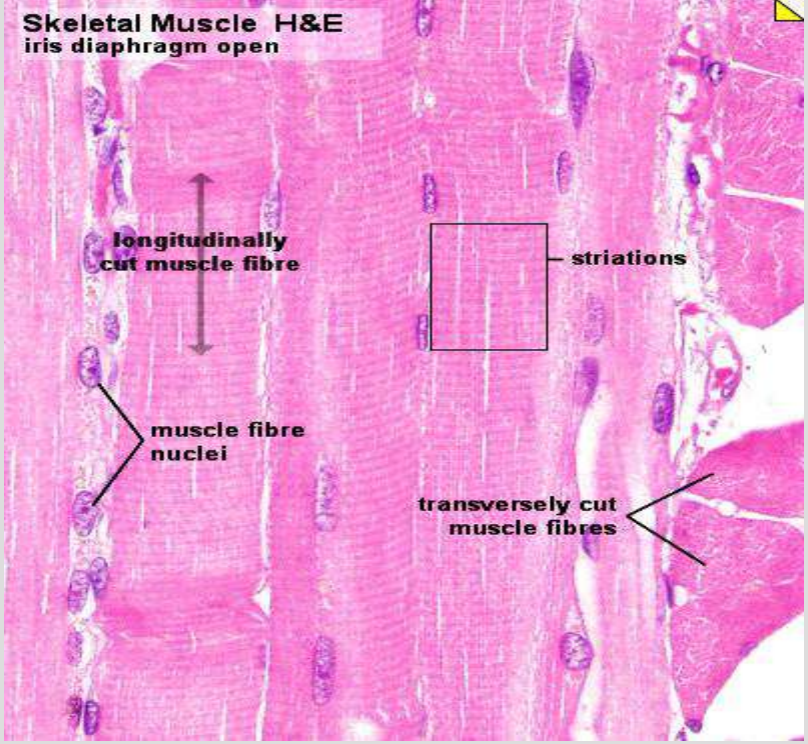
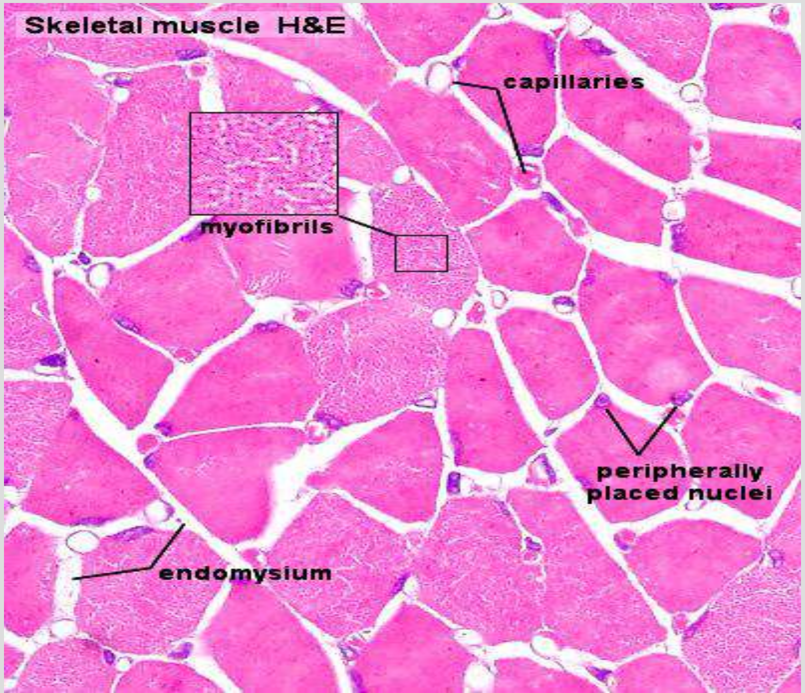
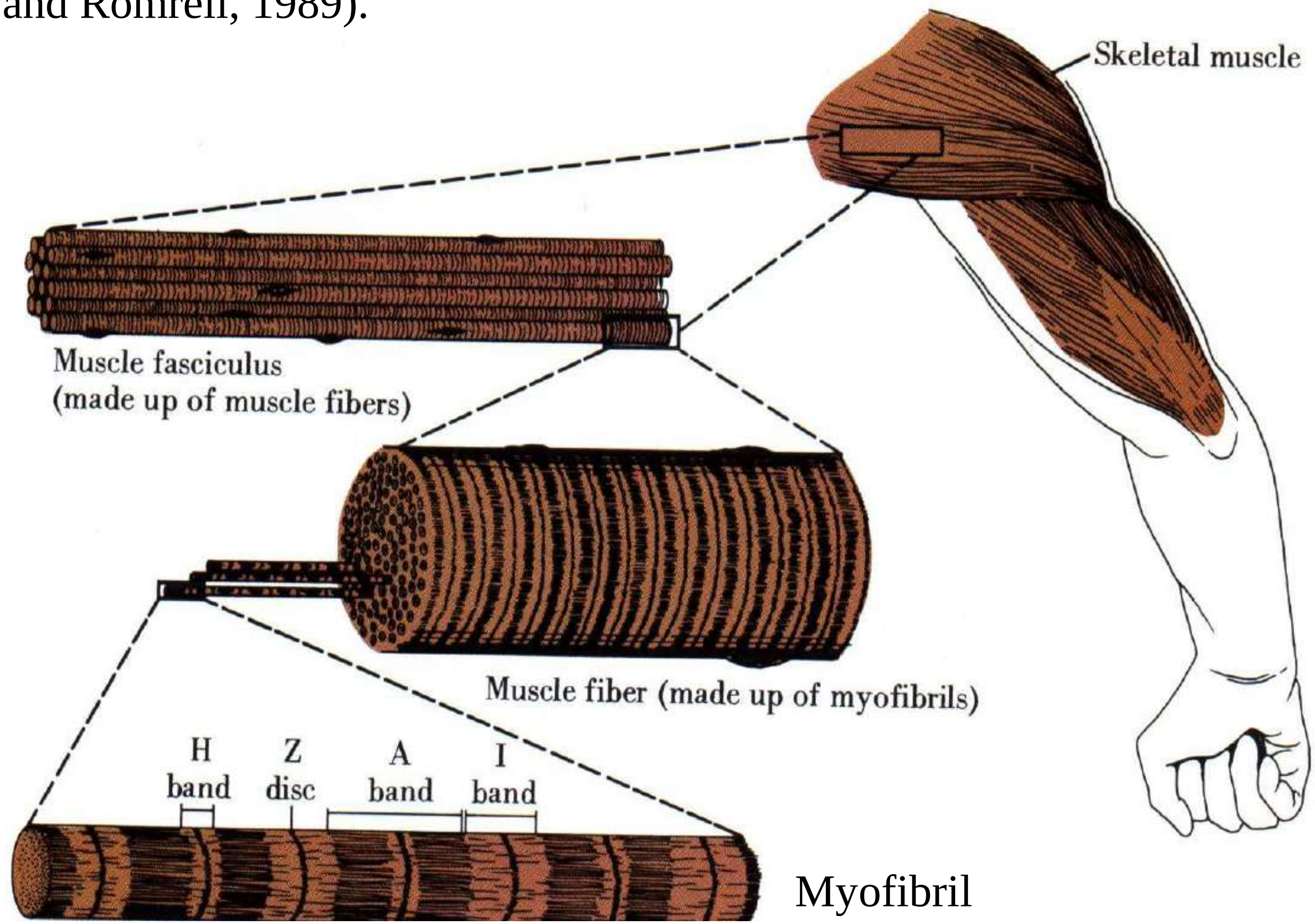
Skeletal Muscle H&E
adipocytes
longitudinally cut
transversely cut
muscle fibres


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.

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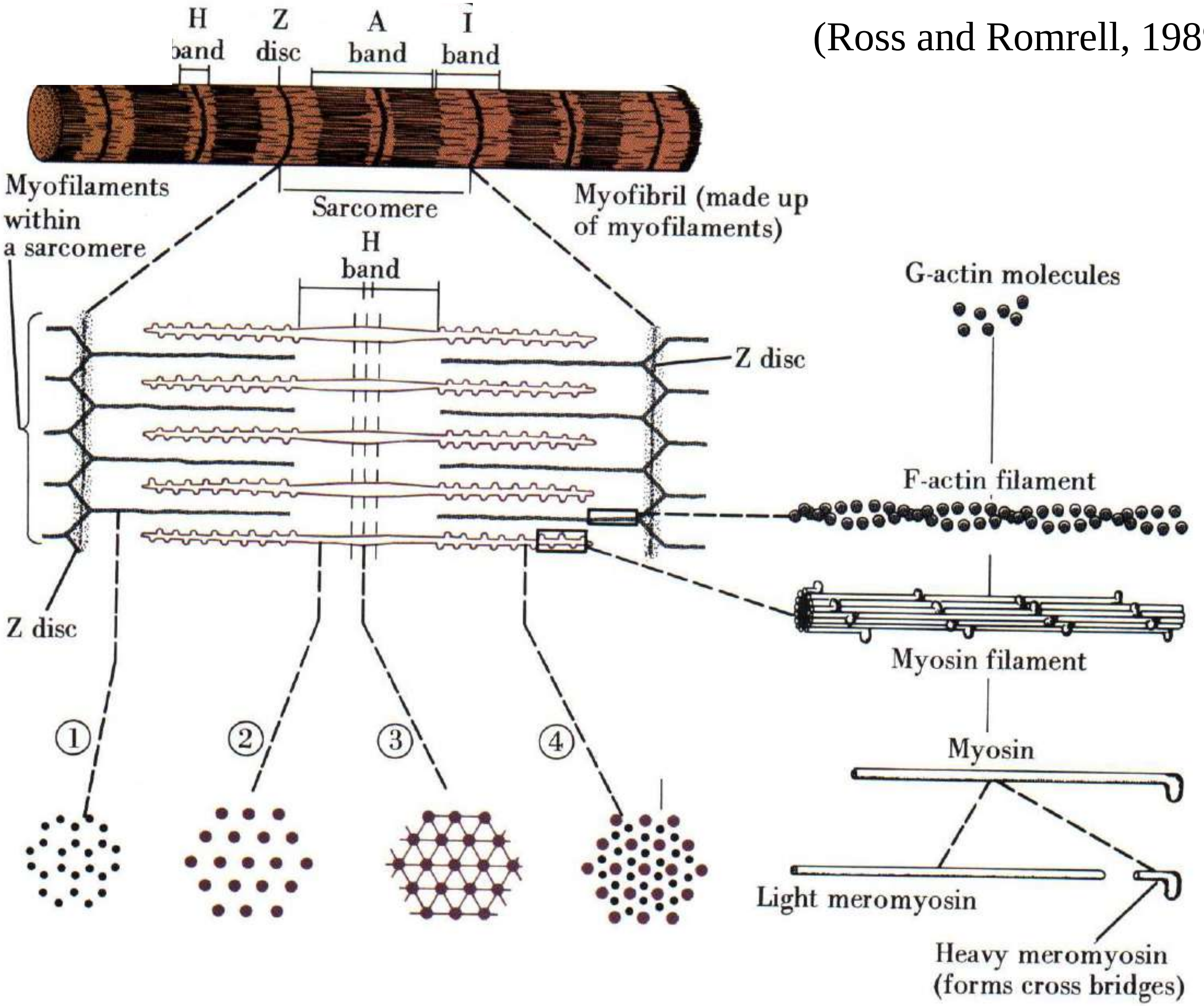
(Ross and Romrell, 1989).



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.

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

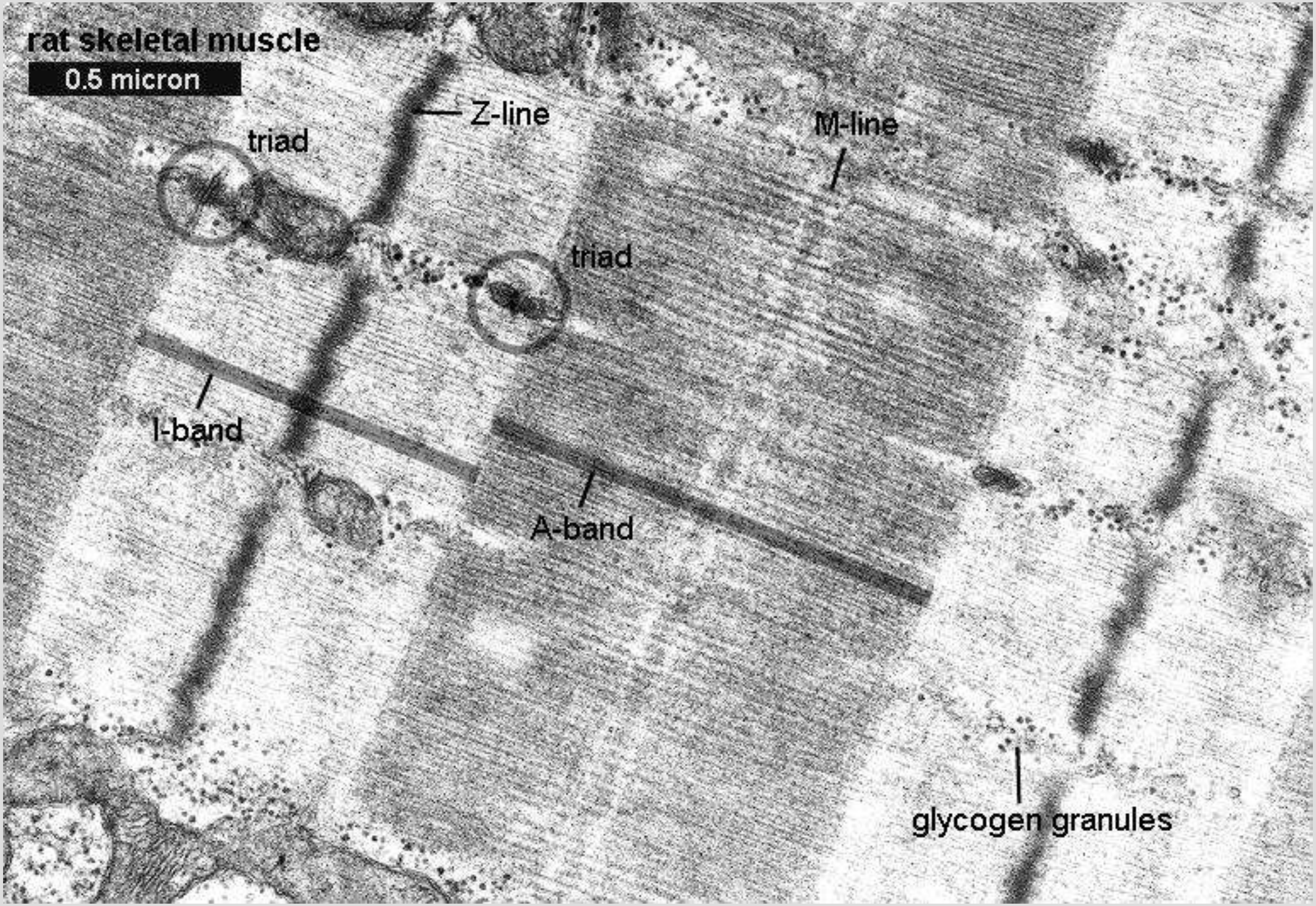
I-band - actin filaments,

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,

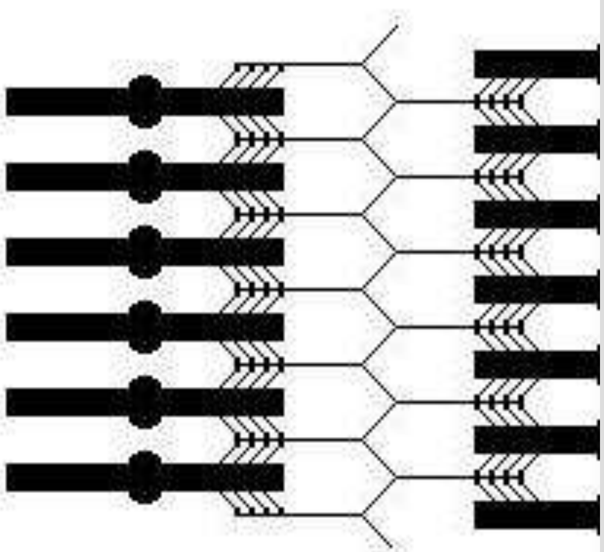
Z-line - zone of apposition of actin filaments belonging to two neighbouring sarcomeres (mediated by a protein called alpha-actinin),

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

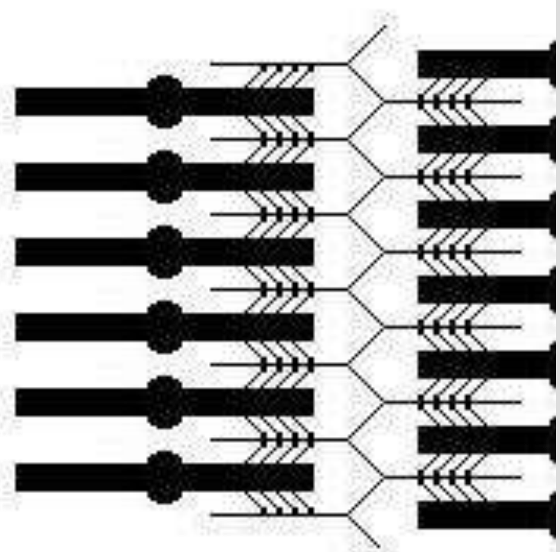

rat skeletal muscle
0.5 micron
Z-line
triad
M-line
triad
I-band
A-band
glycogen granules

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

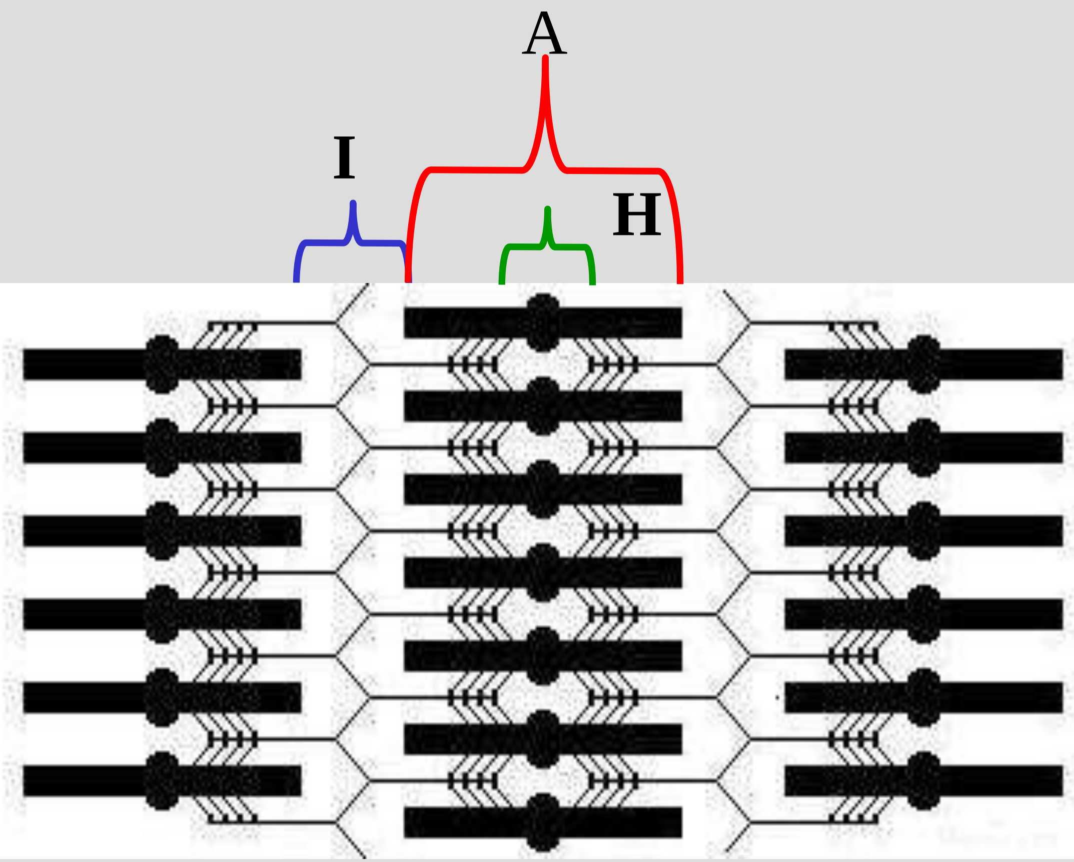
Relaxed



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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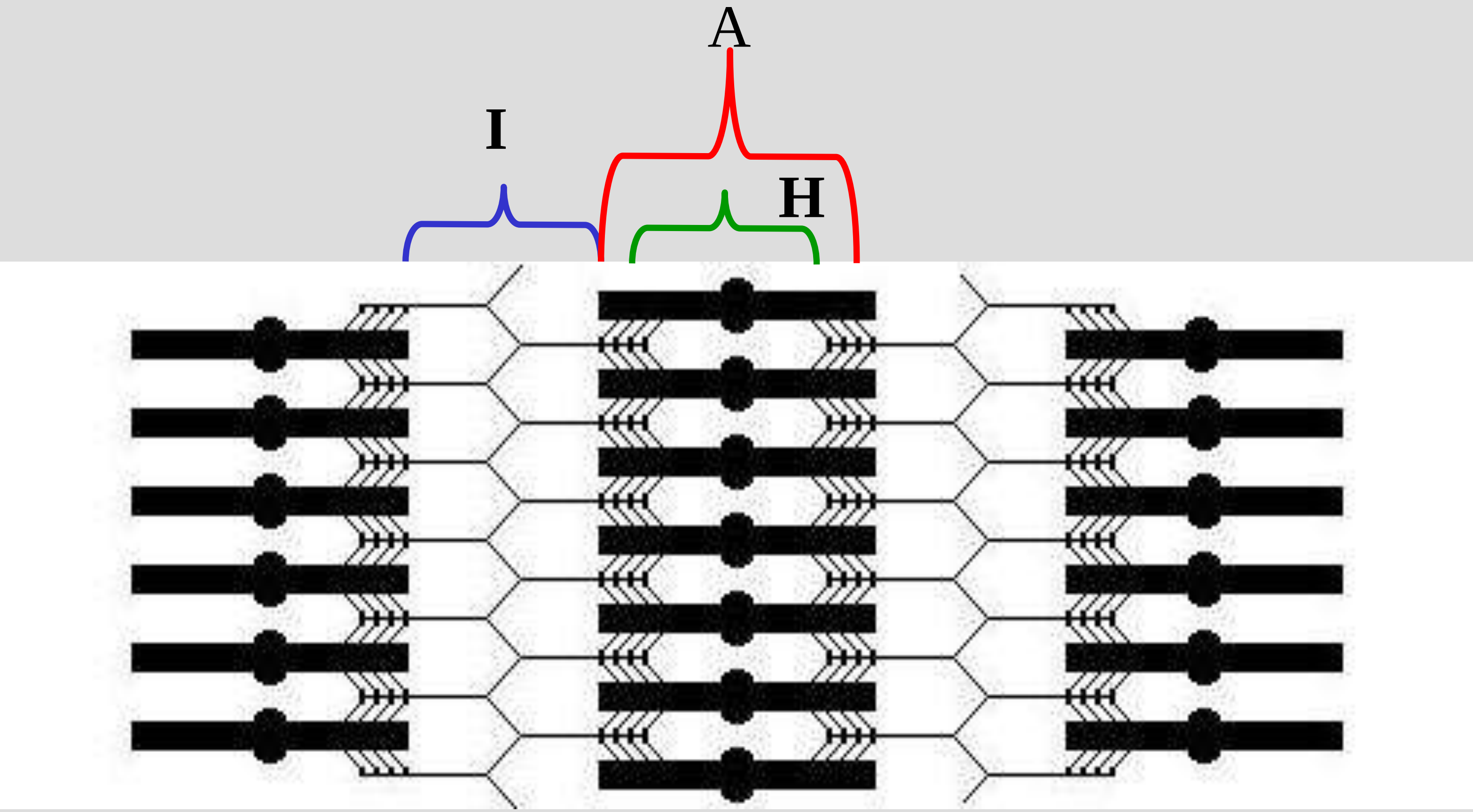
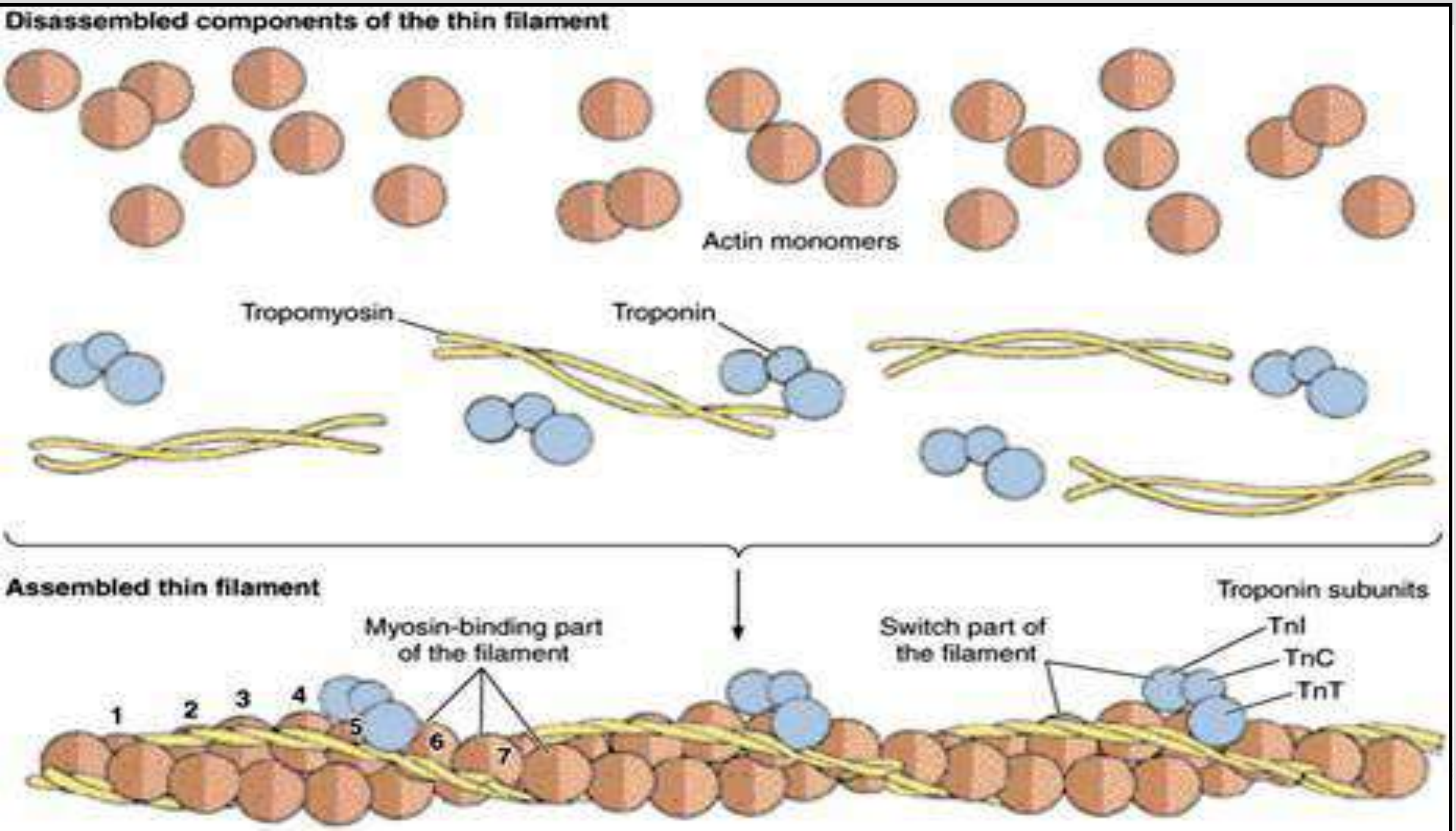

A
I
H

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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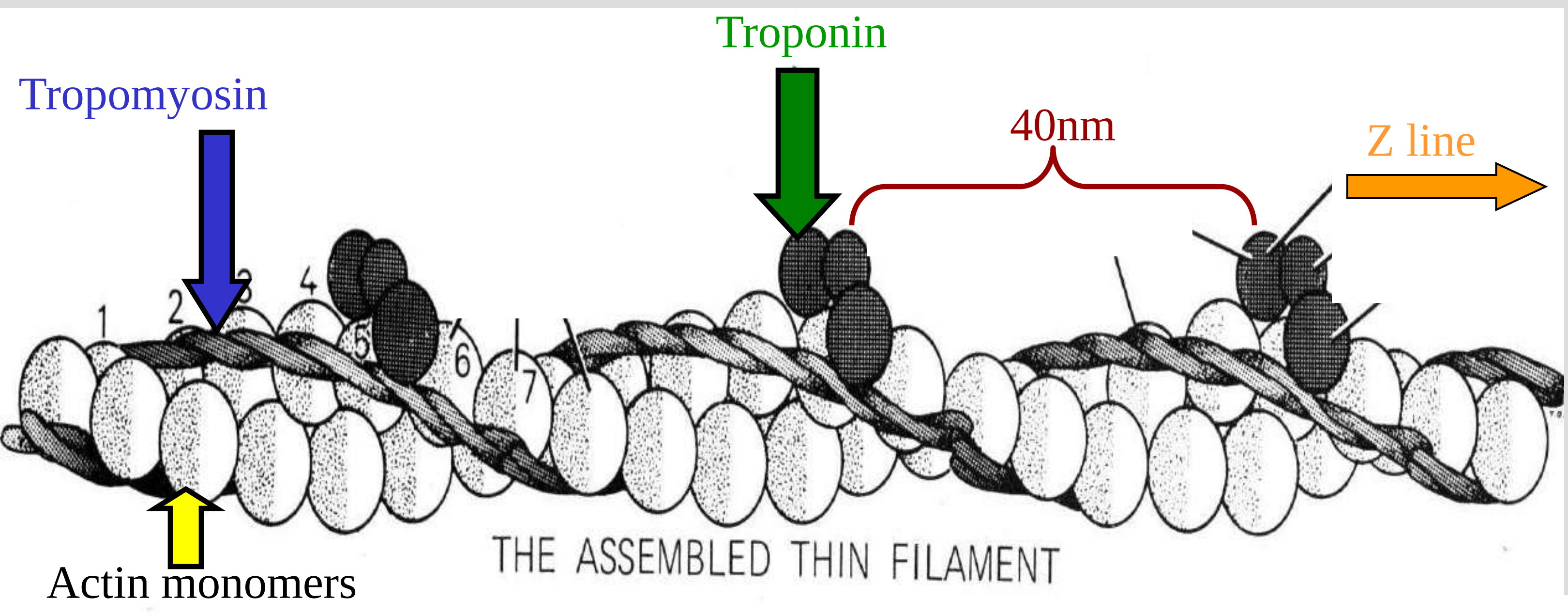
Electron Microscopy
Two types of myofilaments
Actin

- 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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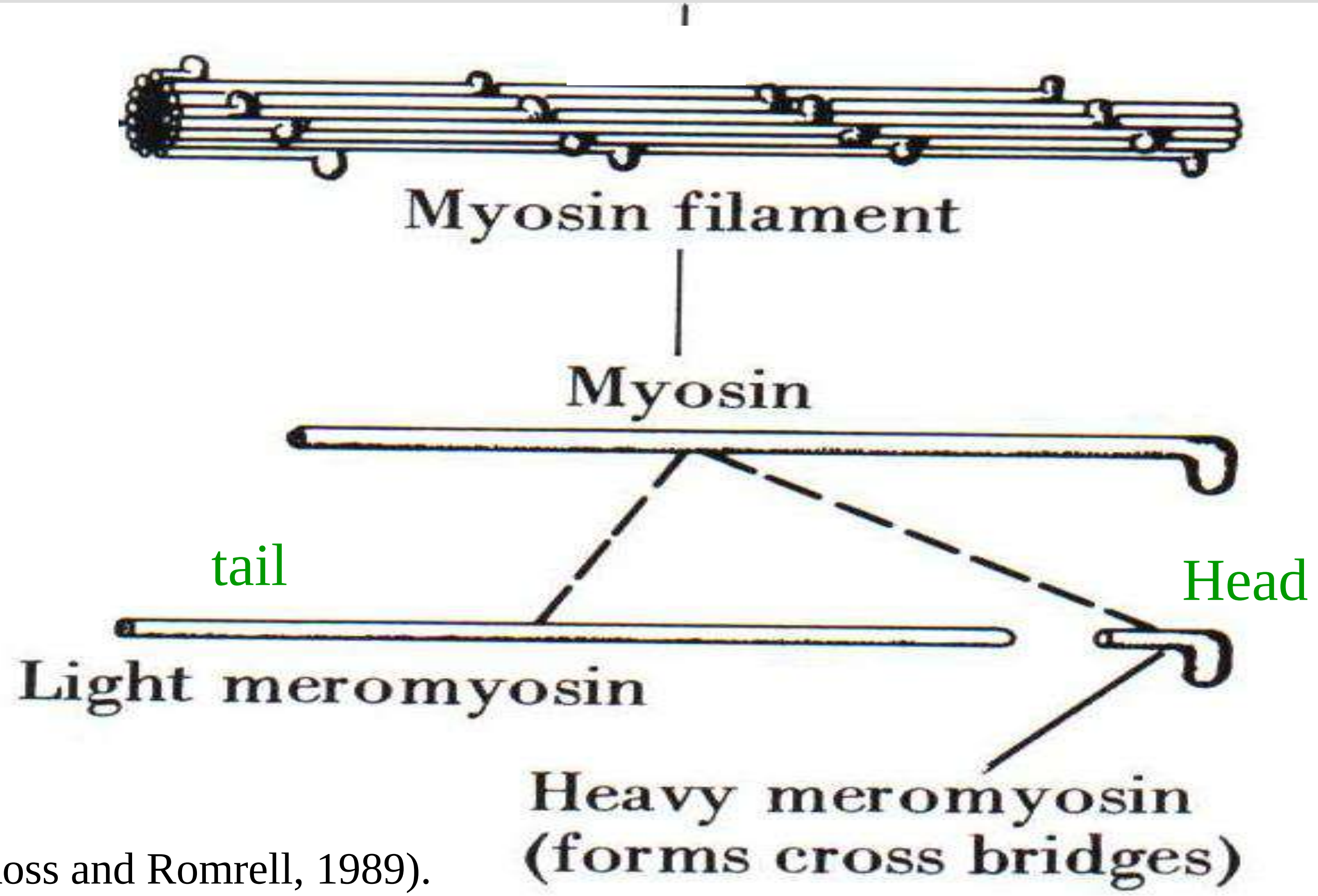
Myosin:

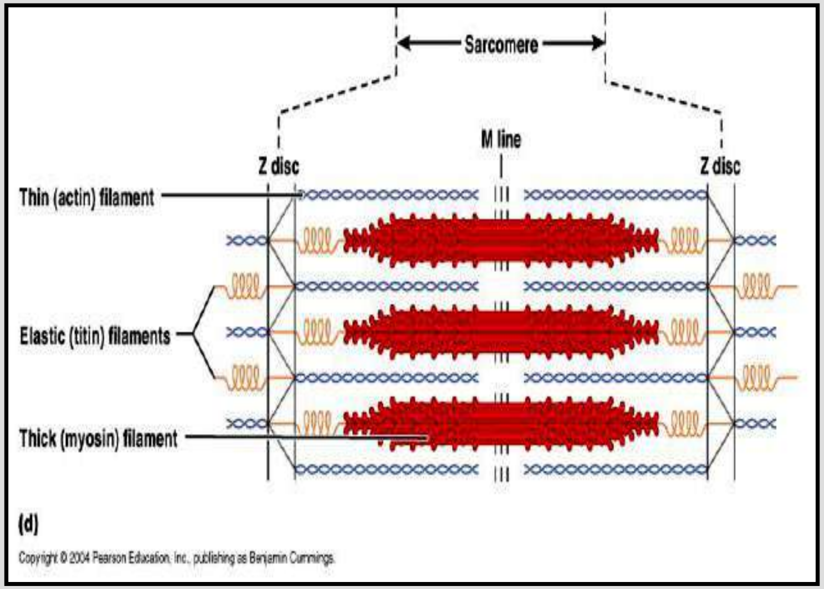
- 15 nm ϕ
- 1,6 μm long
- The molecule has a head and a tail
- tails are parallel
- heads project in a spiral
- in the middle is a thickening

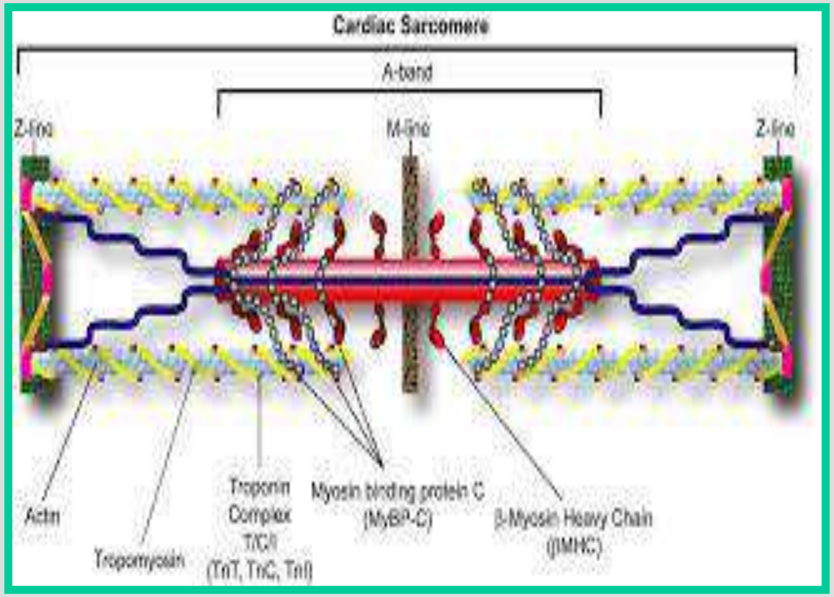


(Ross and Romrell, 1989).

Titin (Connectin)

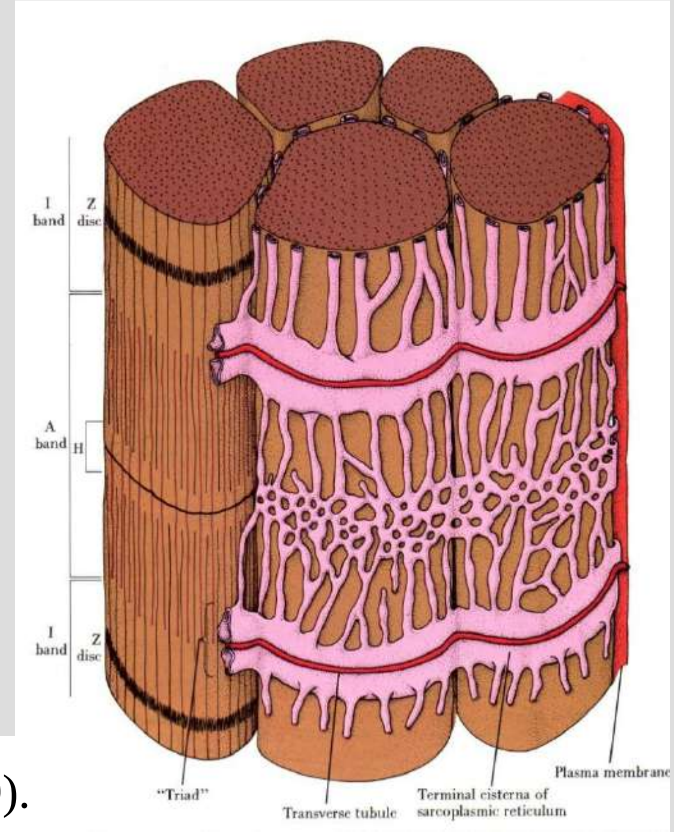
• titin is the **third** most abundant protein in muscle after myosin and actin
•titin is the **largest** known protein in mammals (greater than 1 μm in length)
• located between the **myosin thick** filament and the **Z line**
•**extends** from the **Z-line** to the **M-line**.
•**Two** titin molecules extends from each half of thick filaments to Z line== **four** titin molecules for each thick filaments and Z line
•important in the **contraction,** functions as a molecular **spring** / **elastic** properties,
• (1) to **stabilize** the thick filament, (2) **center** it between the thin filaments, (3) prevent **overstretching** of the sarcomere, and (4) to **recoil** the sarcomere like a spring after it is stretched
• *i.e.* keep the filaments of the contractile apparatus in **alignment** and to the **passive stretch** resistance of muscle fibres.





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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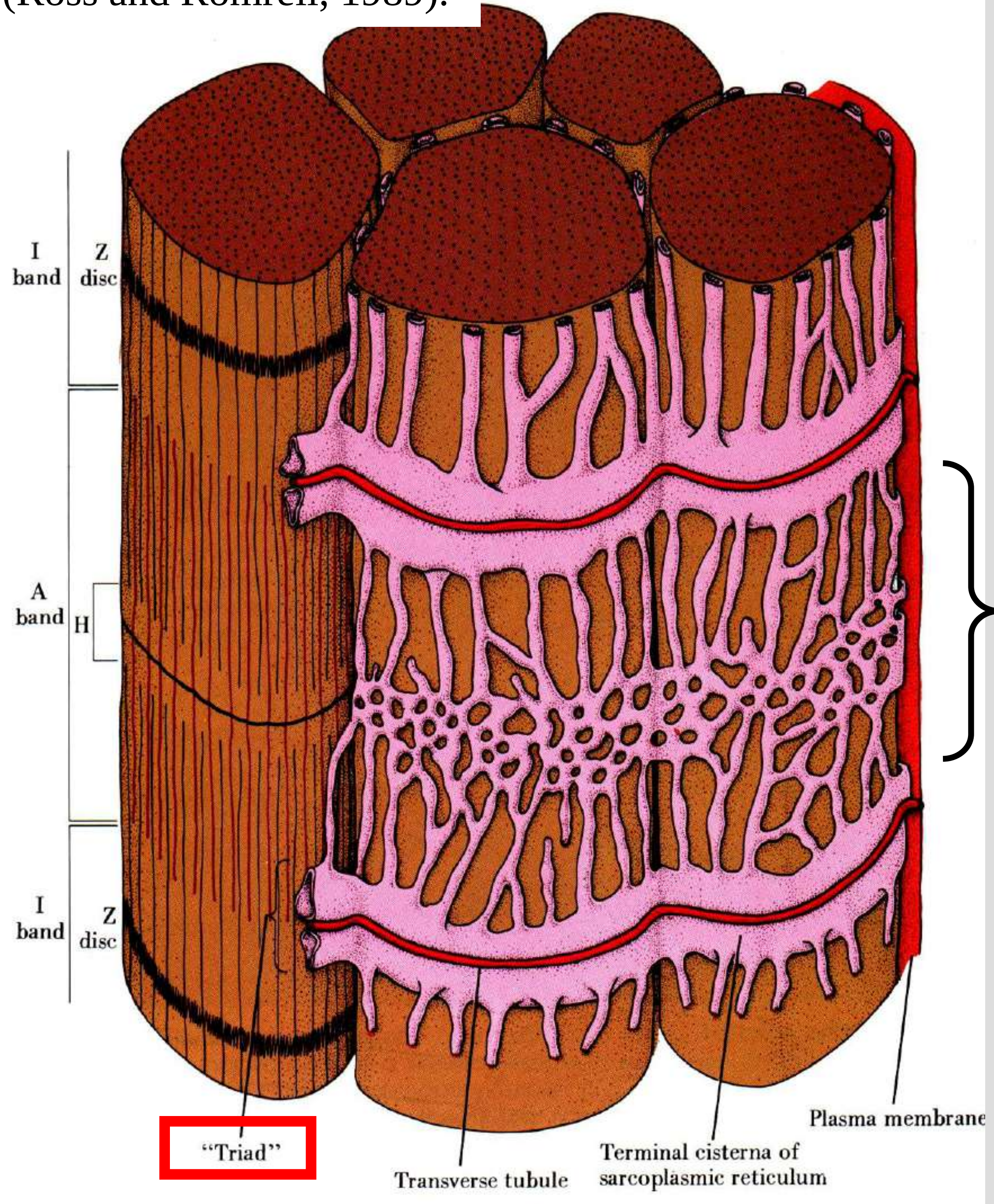
(Ross and Romrell, 1989).



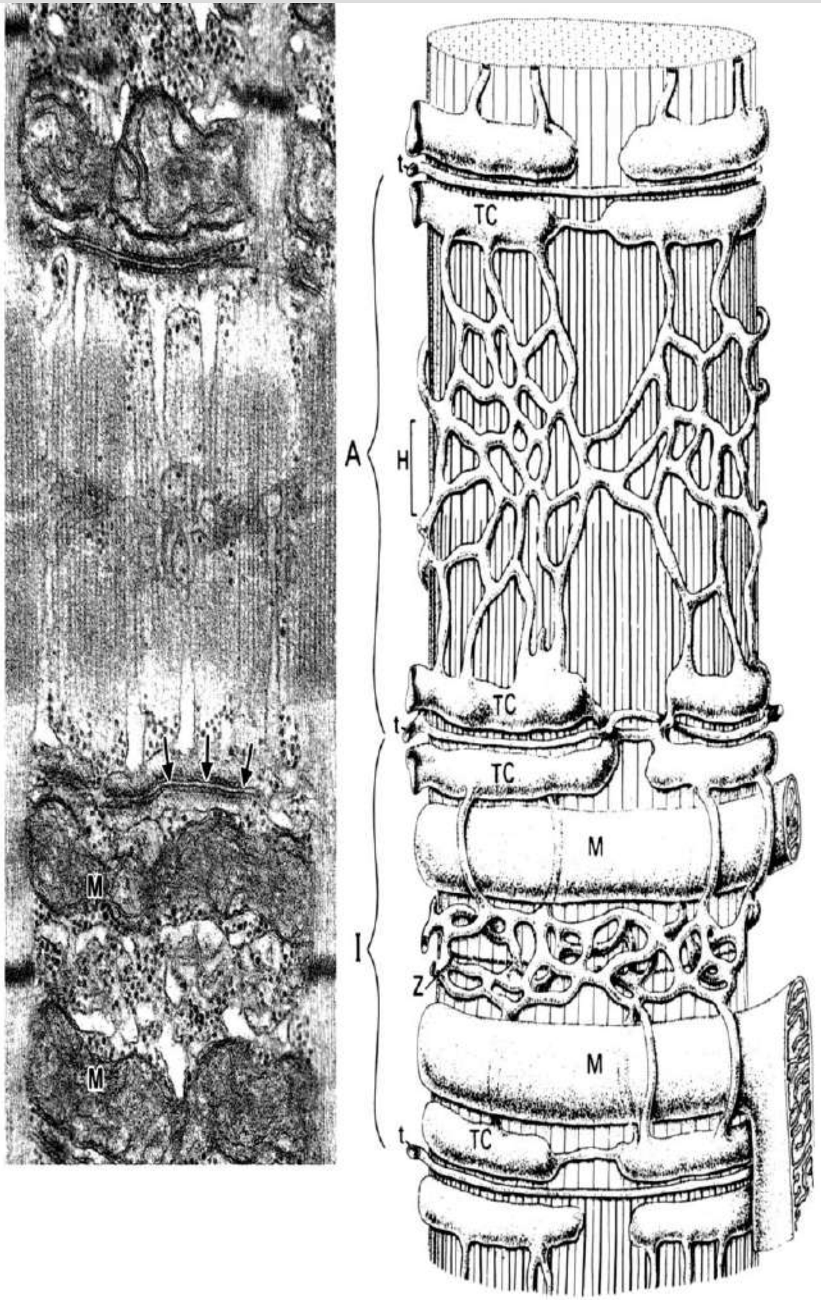
Identify:

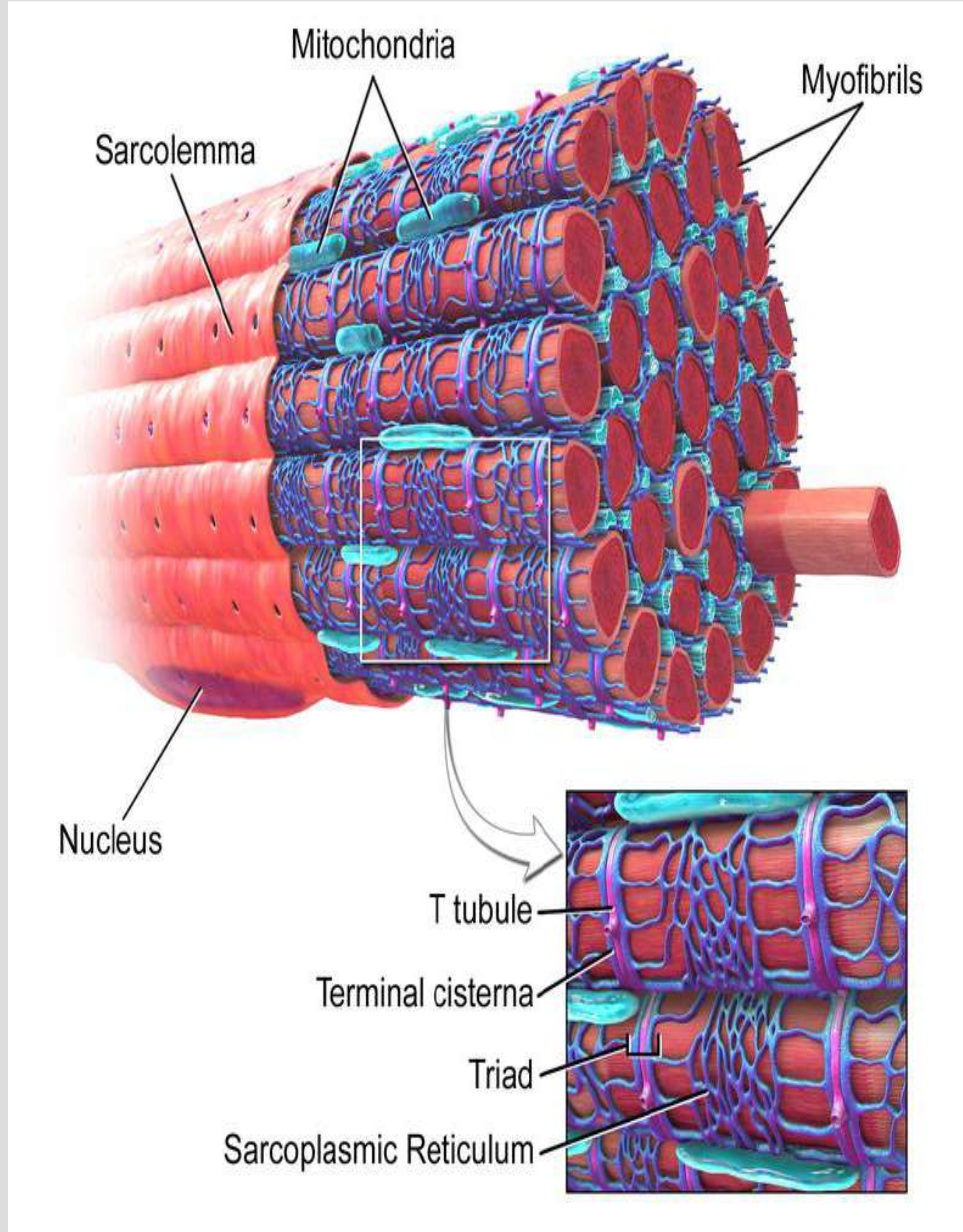
T tubule,

Terminal cisternae and

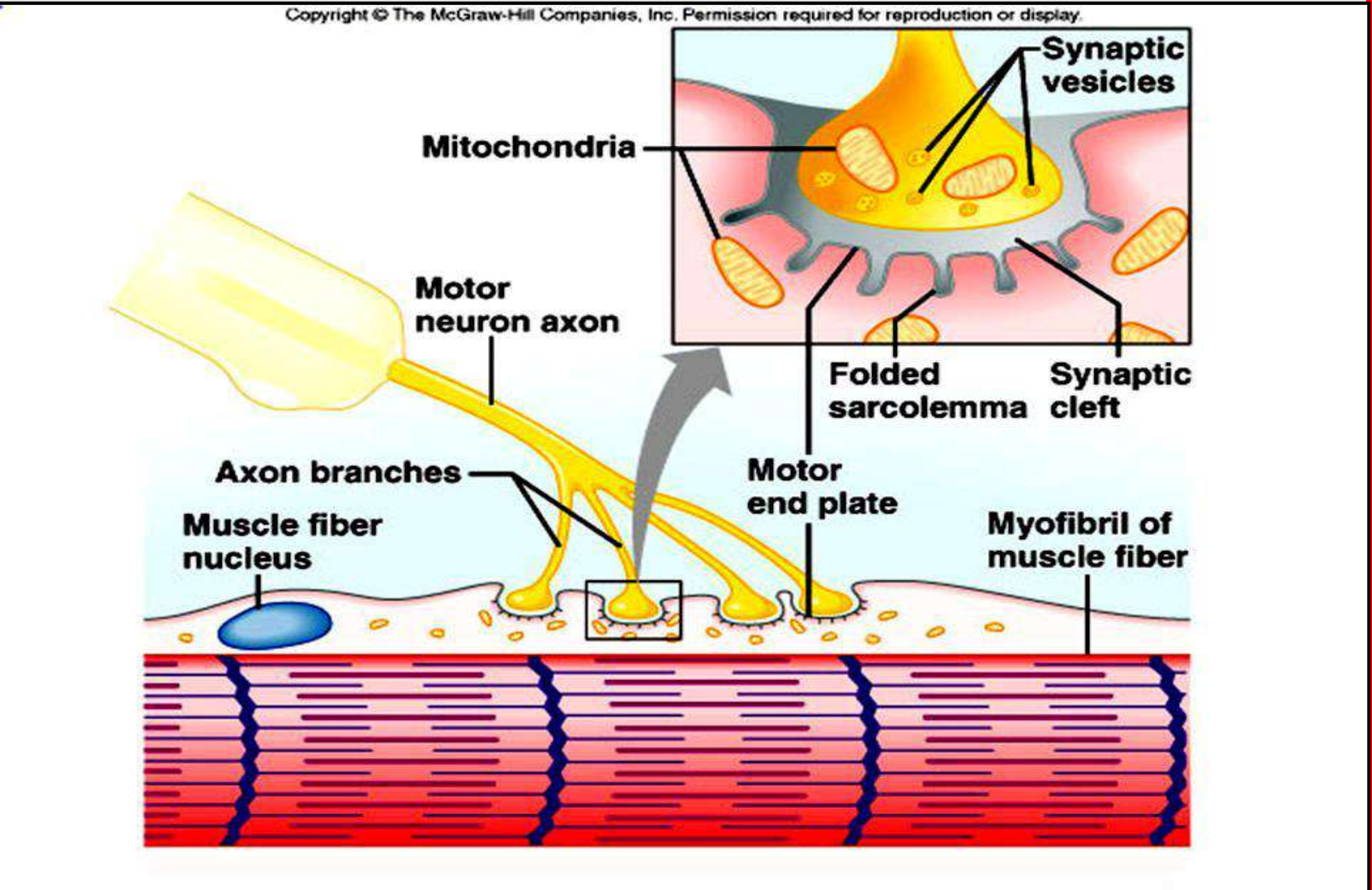
Sarcotubules

The level at which the T tubule lies


M
M
t
TC
A
H
TC
t
TC
I
M
Z
M
t
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**



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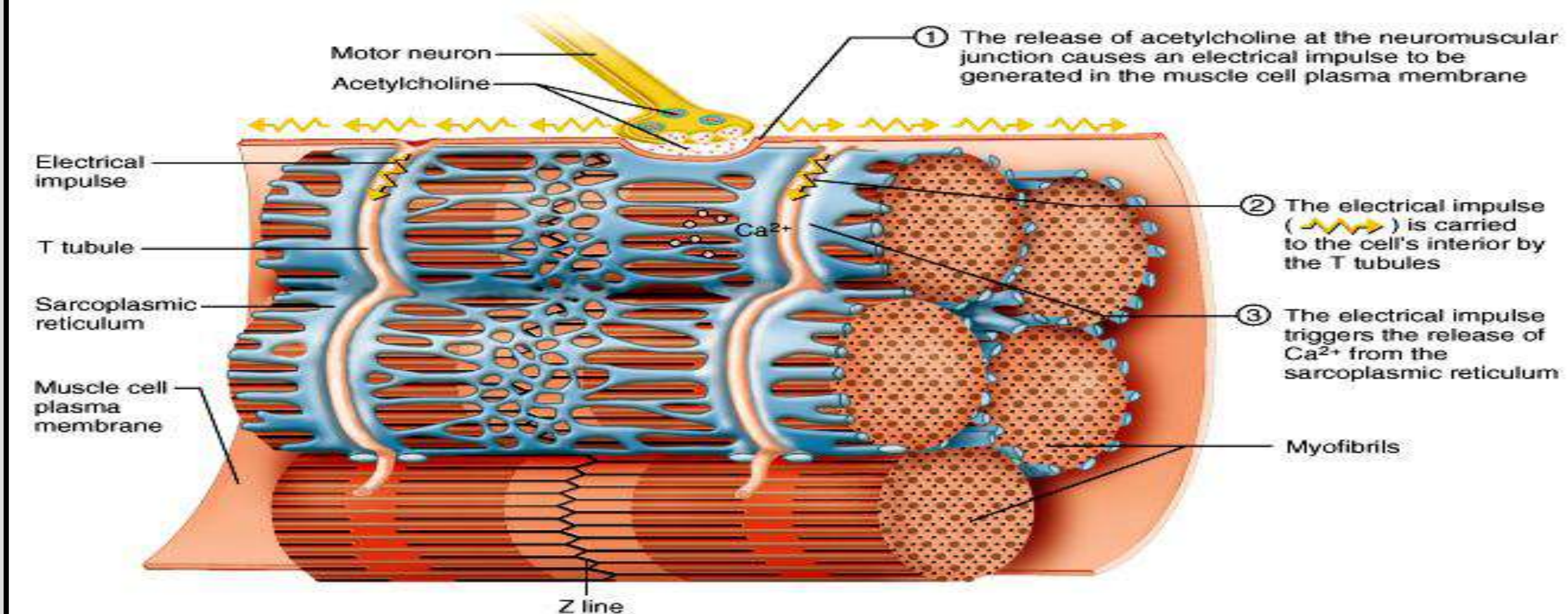
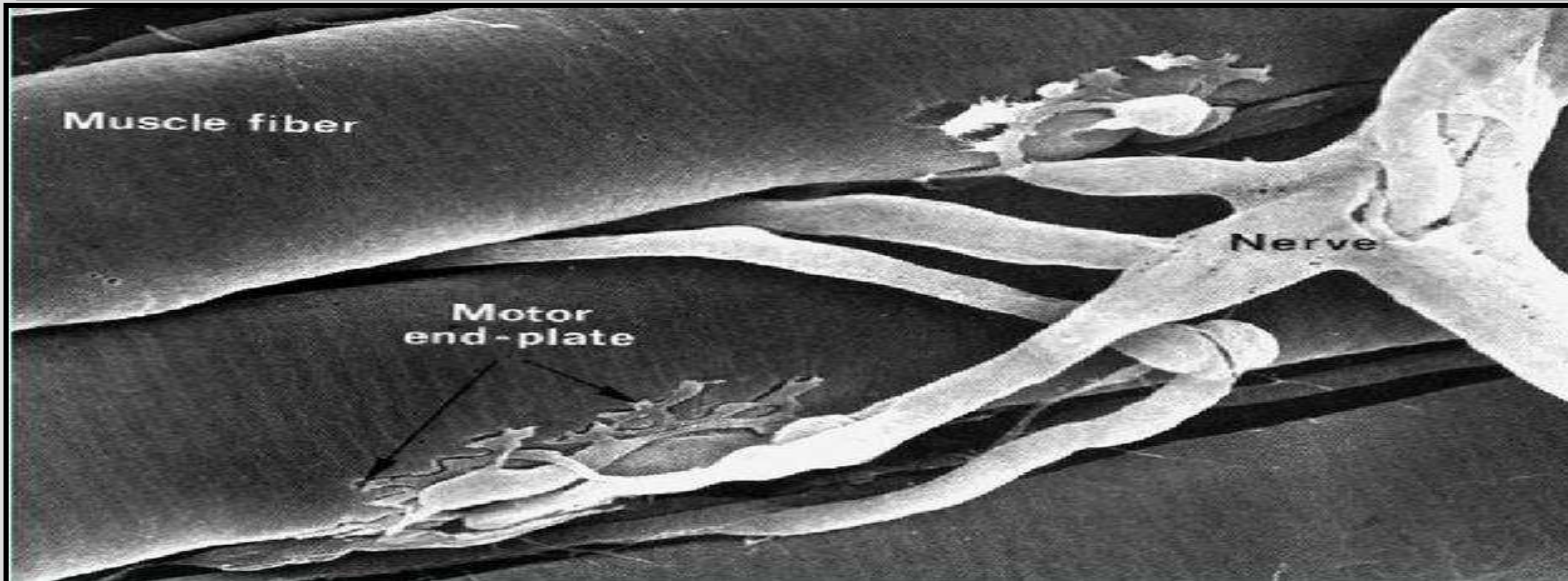
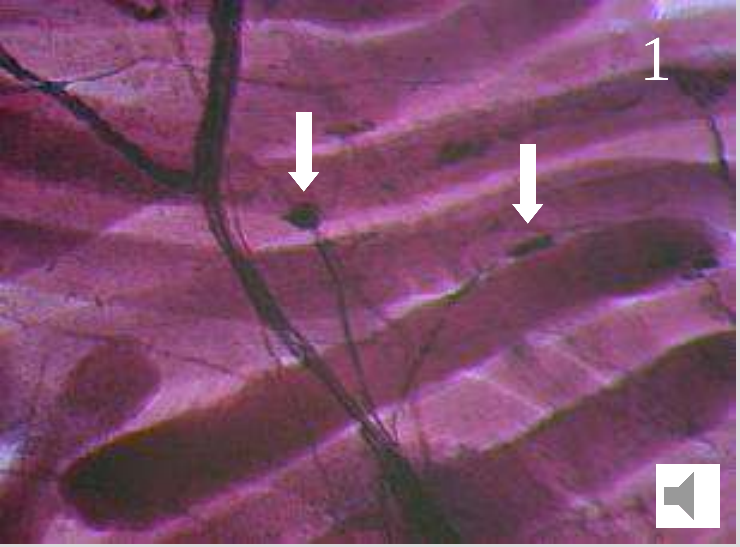
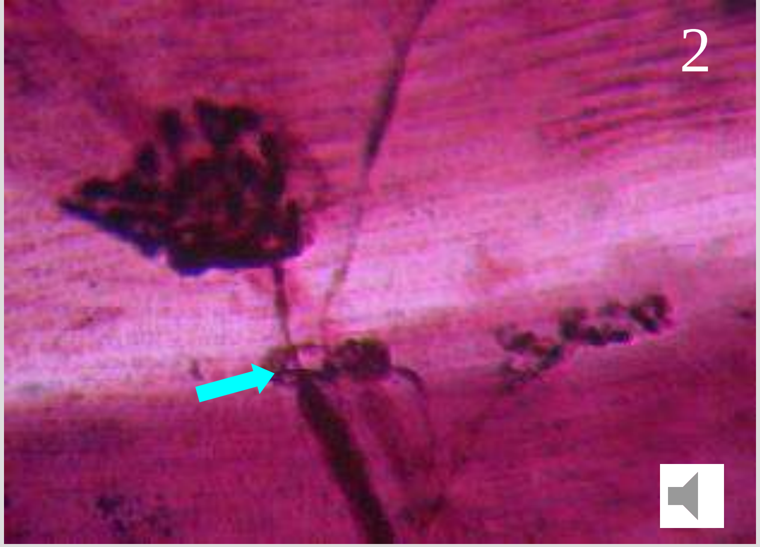
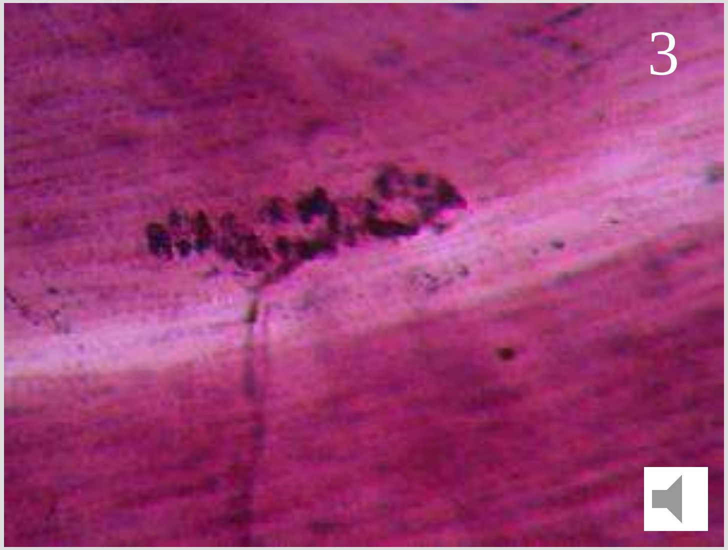

Motor neuron
Acetylcholine
① The release of acetylcholine at the neuromuscular junction causes an electrical impulse to be generated in the muscle cell plasma membrane
Electrical impulse
T tubule
Sarcoplasmic reticulum
Muscle cell plasma membrane
Ca^{2+}
② The electrical impulse ( ) is carried to the cell's interior by the T tubules
③ The electrical impulse triggers the release of Ca^{2+} from the sarcoplasmic reticulum
Myofibrils
Z line


Muscle fiber
Nerve
Motor end-plate







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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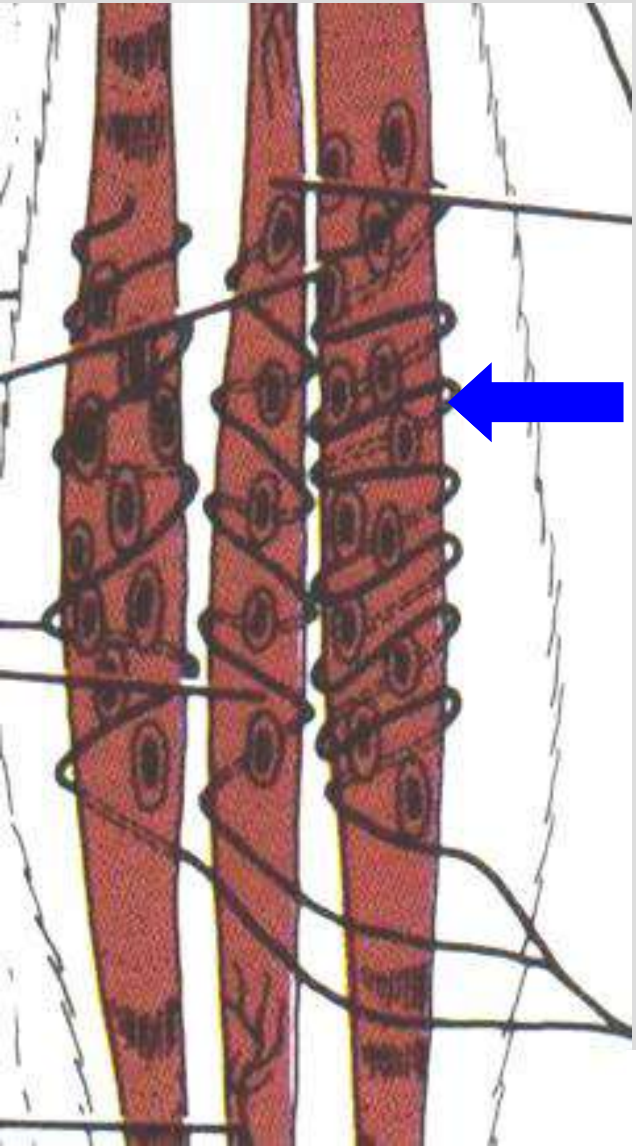
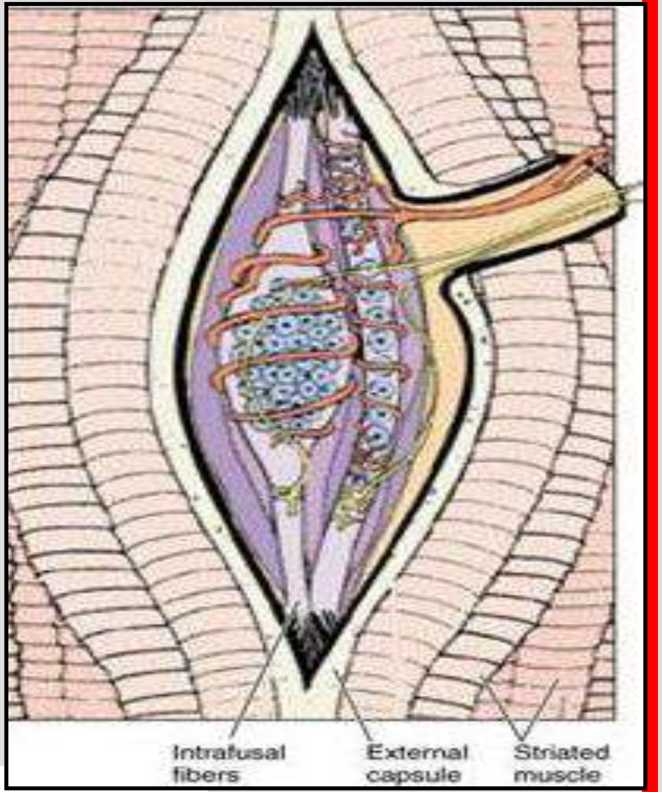
Nerves: sensory

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



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

Stretch receptor



(Ross and Romrell, 1989).

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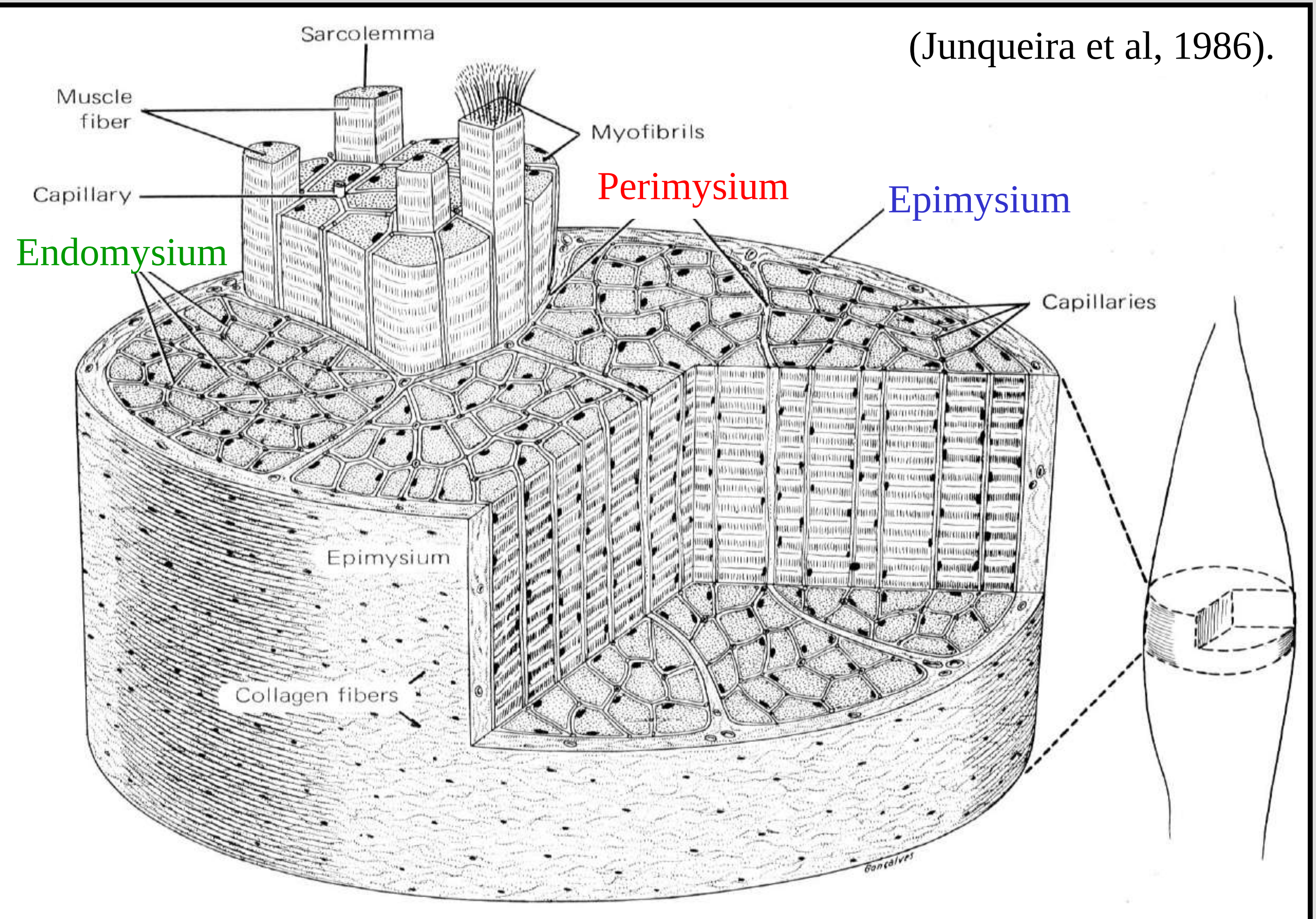
Connective tissue coverings of the muscle

- 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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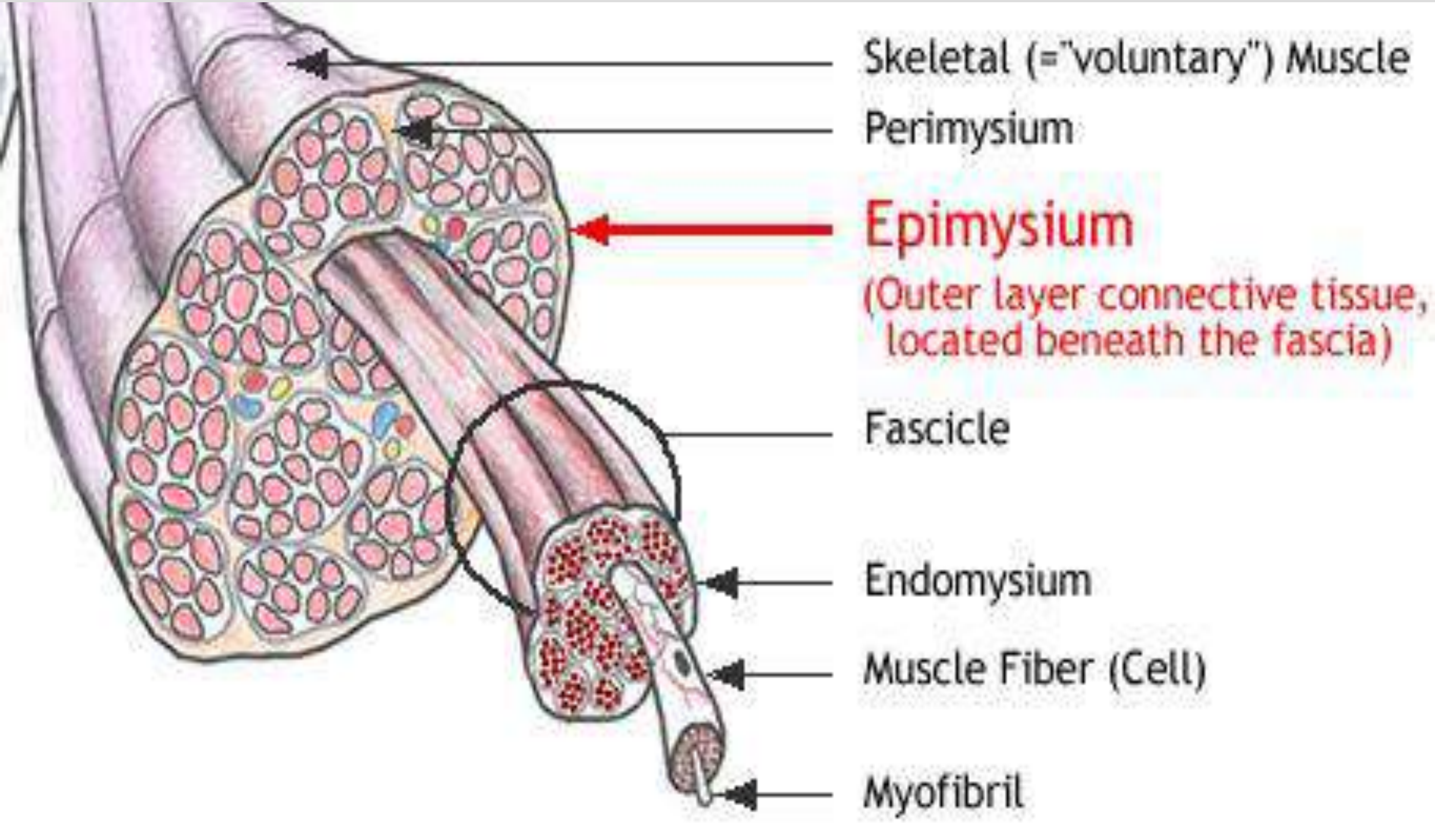

Skeletal (="voluntary") Muscle
Perimysium
Epimysium
(Outer layer connective tissue, located beneath the fascia)
Fascicle
Endomysium
Muscle Fiber (Cell)
Myofibril

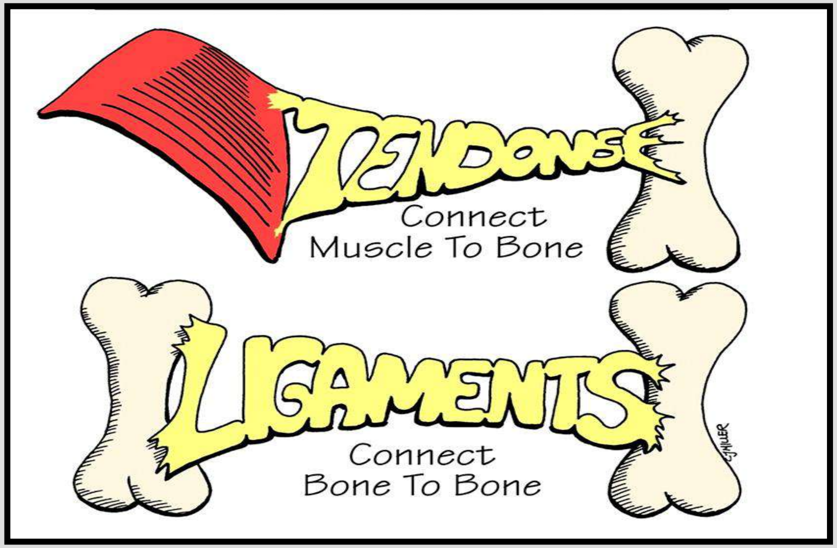
Tendon/ Ligament / Fasciae

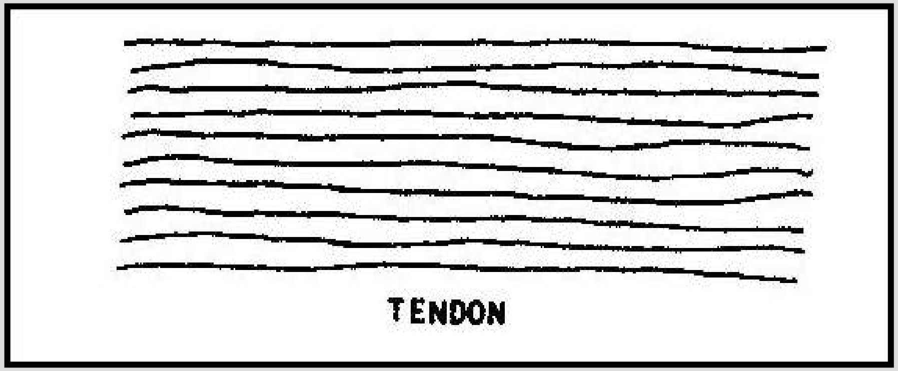
•Tendon connect muscle to bone

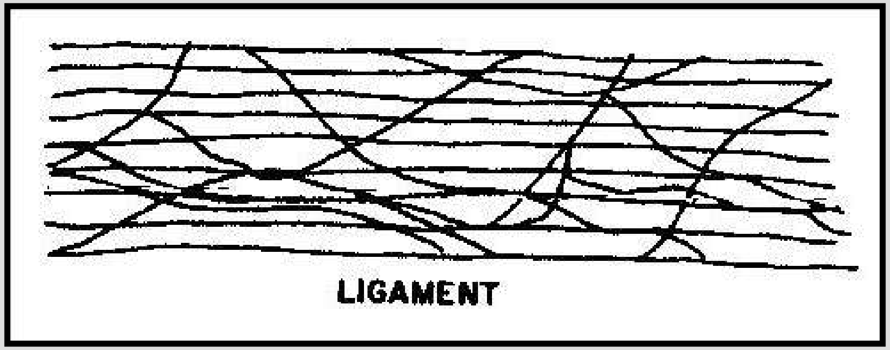
•Ligaments join bone to bone

•Fasciae connect muscles to muscles and soft tissues.

All made of collagen, present in different orientations







Tendon

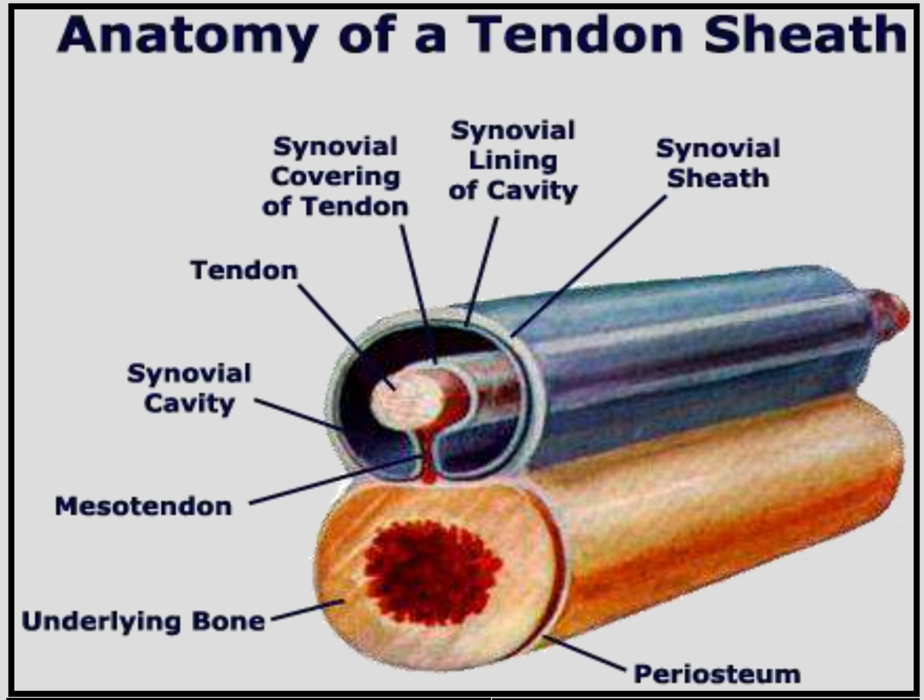
•**dense regular** connective tissue fascicles encased in **dense irregular** connective tissue **sheaths**.

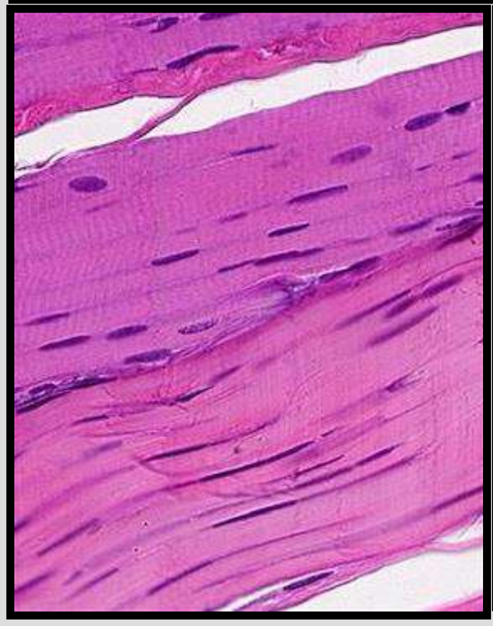
•Normal healthy tendons are composed mostly of **parallel** arrays of **collagen** fibers closely packed together// **fibroblasts** between fibers

•The dry mass = **86% collagen** (98% type I), 2% elastin, 1–5%proteoglycans, and 0.2% inorganic

• **Aponeurosis**, are layers of flat **broad tendons**. They have a shiny, whitish-silvery color, are histologically similar to tendons, with limited blood supply e.g.

- Anterior abdominal aponeuroses
- Posterior lumbar aponeuroses





Ligament

•band of **dense regular connective** tissue bundles made of collagenous fibers
•protected by **dense irregular connective** tissue sheaths.
•Ligaments connect bones to other bones to form joints // ligaments **limit** the mobility of articulations // or prevent certain movements
•Have **more** elastic fibres and more **ground** substances than tendon
•More **weaving** pattern and more **random** than tendon
•non-parallel collagen arrangement, aligned in direction of **imposed** stress