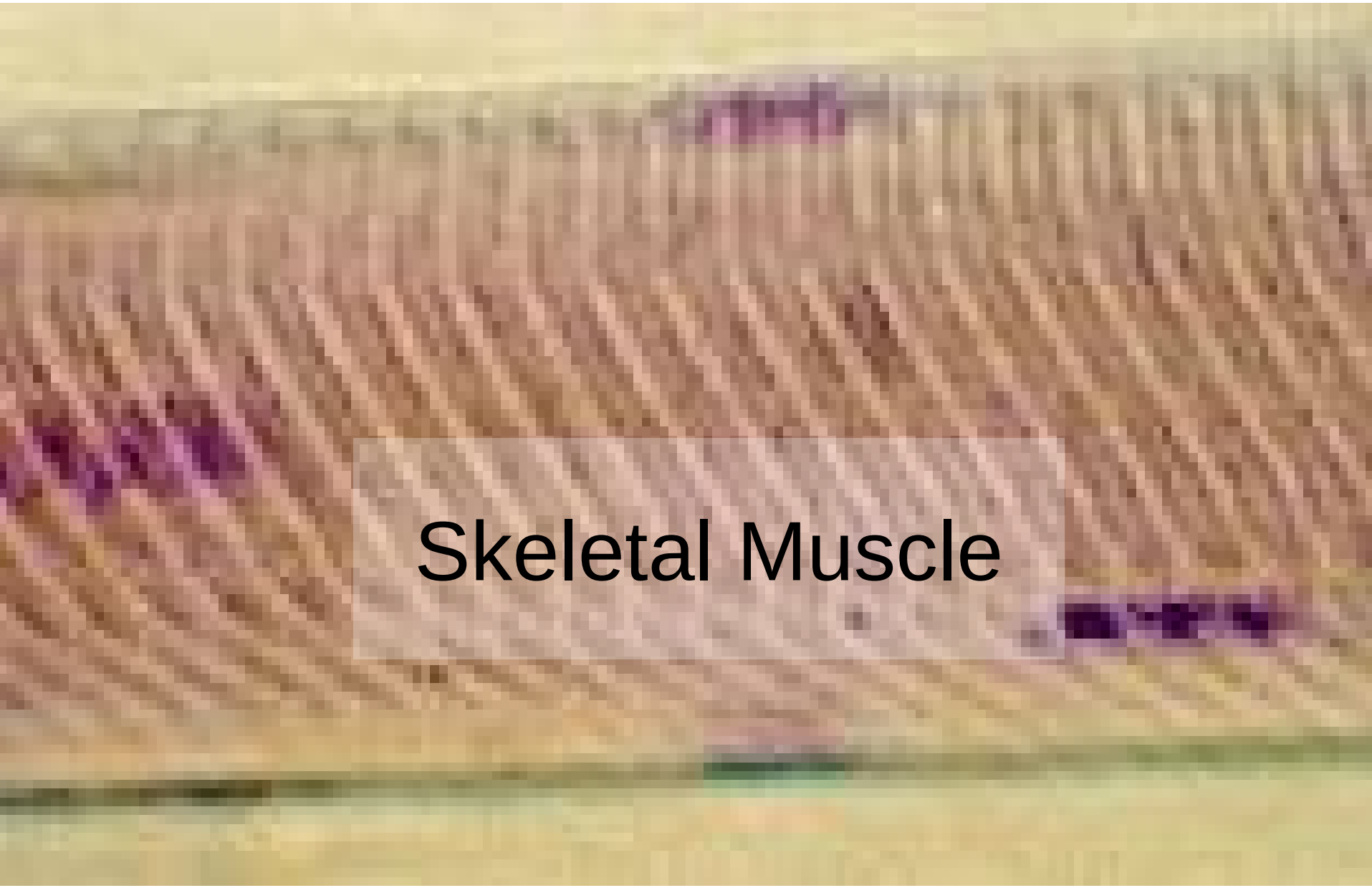
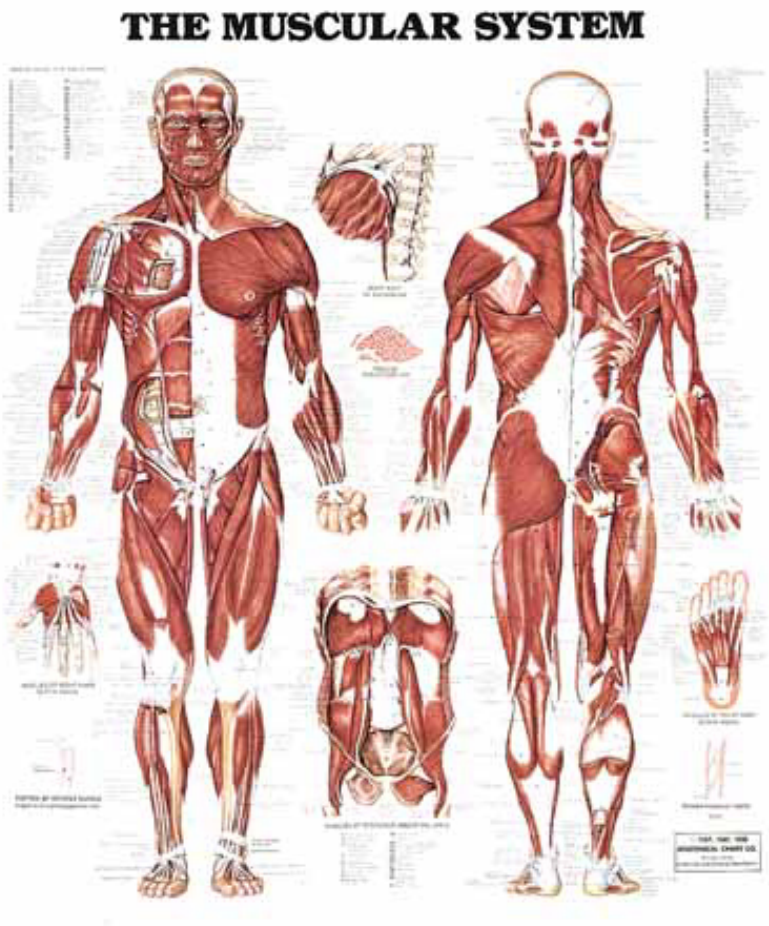
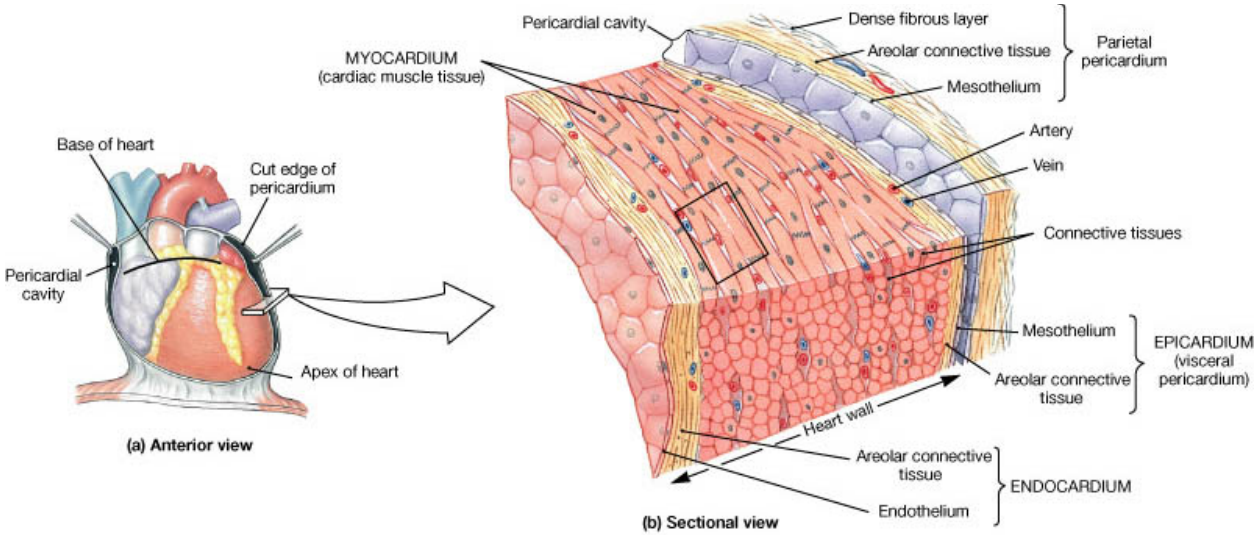

Skeletal Muscle

Types of muscle

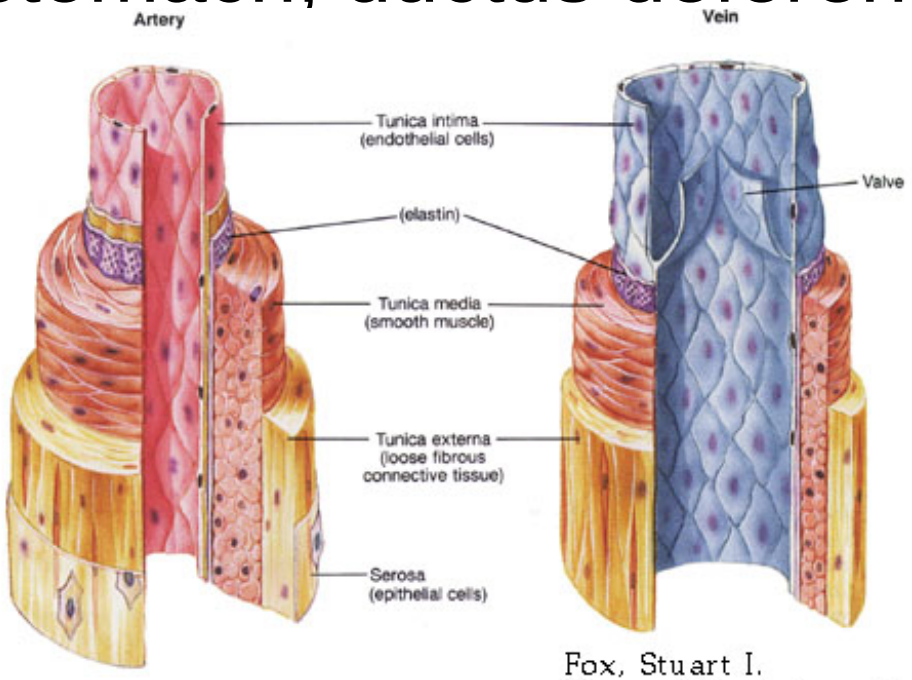
- Skeletal muscle-moves the skeleton by pulling on the tendons that are connected to the bones



- Cardiac muscle-pumps blood through the heart and blood vessels



- Smooth muscle-various functions in many diverse organs (arrector pilli muscle, iris, uterus, stomach, ductus deferens)



Fox, Stuart I.
Human Physiology 4th
Brown Publishers

Function of skeletal muscle

- Locomotion
- Maintain posture
- Support of soft tissues
- Regulation of orifices
- Maintain body temperature

Muscle fiber microanatomy

- Sarcolemma-plasma membrane of muscle cells
- Sarcoplasm-cytoplasm of muscle fibers
- Skeletal muscle fibers have multiple nuclei
  - fusion of multiple myoblasts

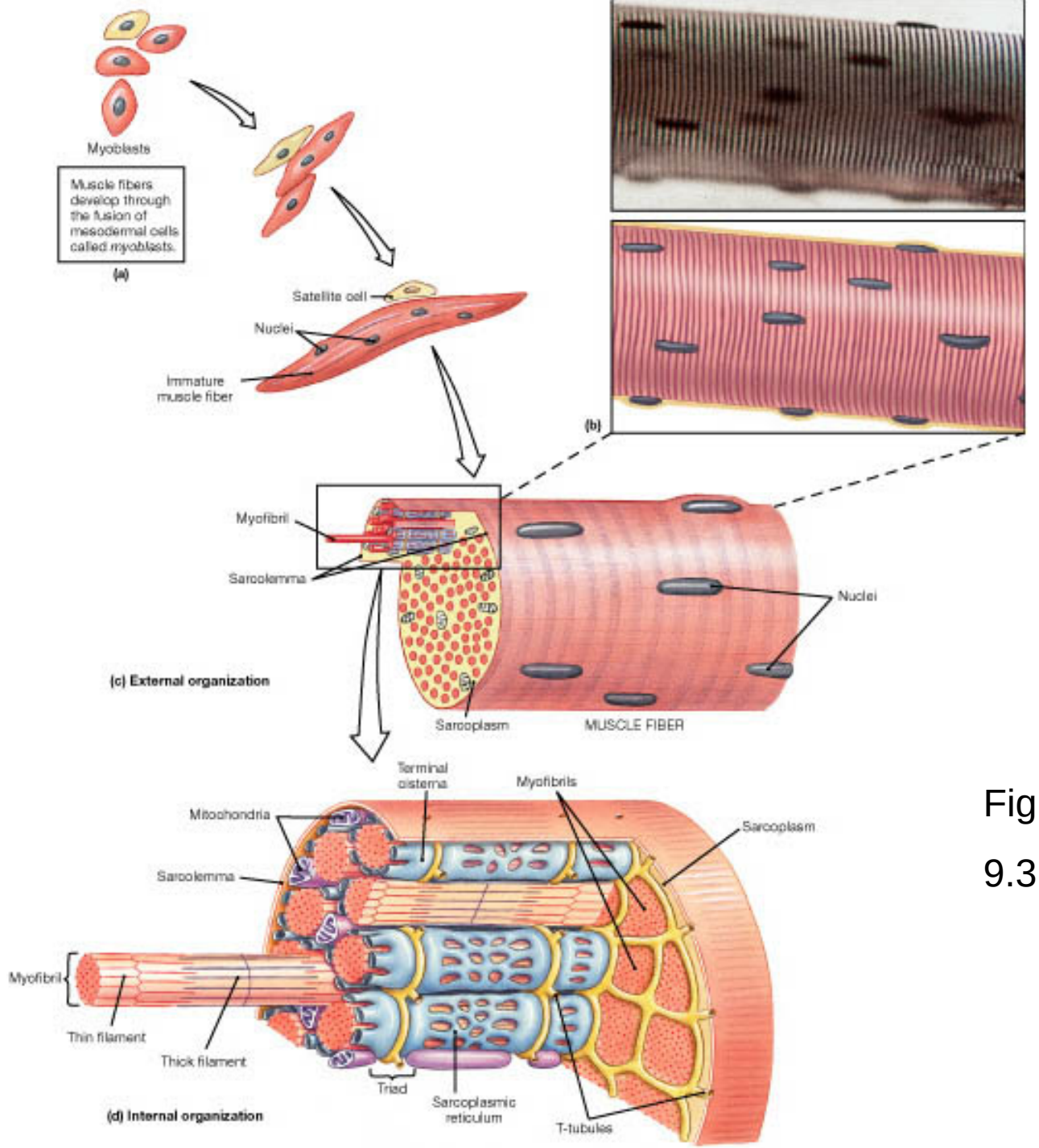

Myoblasts
Muscle fibers develop through the fusion of mesodermal cells called myoblasts.
(a)
Satellite cell
Nuclei
Immature muscle fiber
(b)
Myofibril
Sarcolemma
Nuclei
(c) External organization
Sarcoplasm
MUSCLE FIBER
Terminal cisterna
Myofibrils
Mitochondria
Sarcolemma
Sarcoplasm
Myofibril
Thin filament
Thick filament
Triad
Sarcoplasmic reticulum
T-tubules
(d) Internal organization

Fig 9.3

- Myofibrils-bundles of myofilaments
- Myofilaments-two types:
  - Actin-thin filaments
  - Myosin-thick filaments

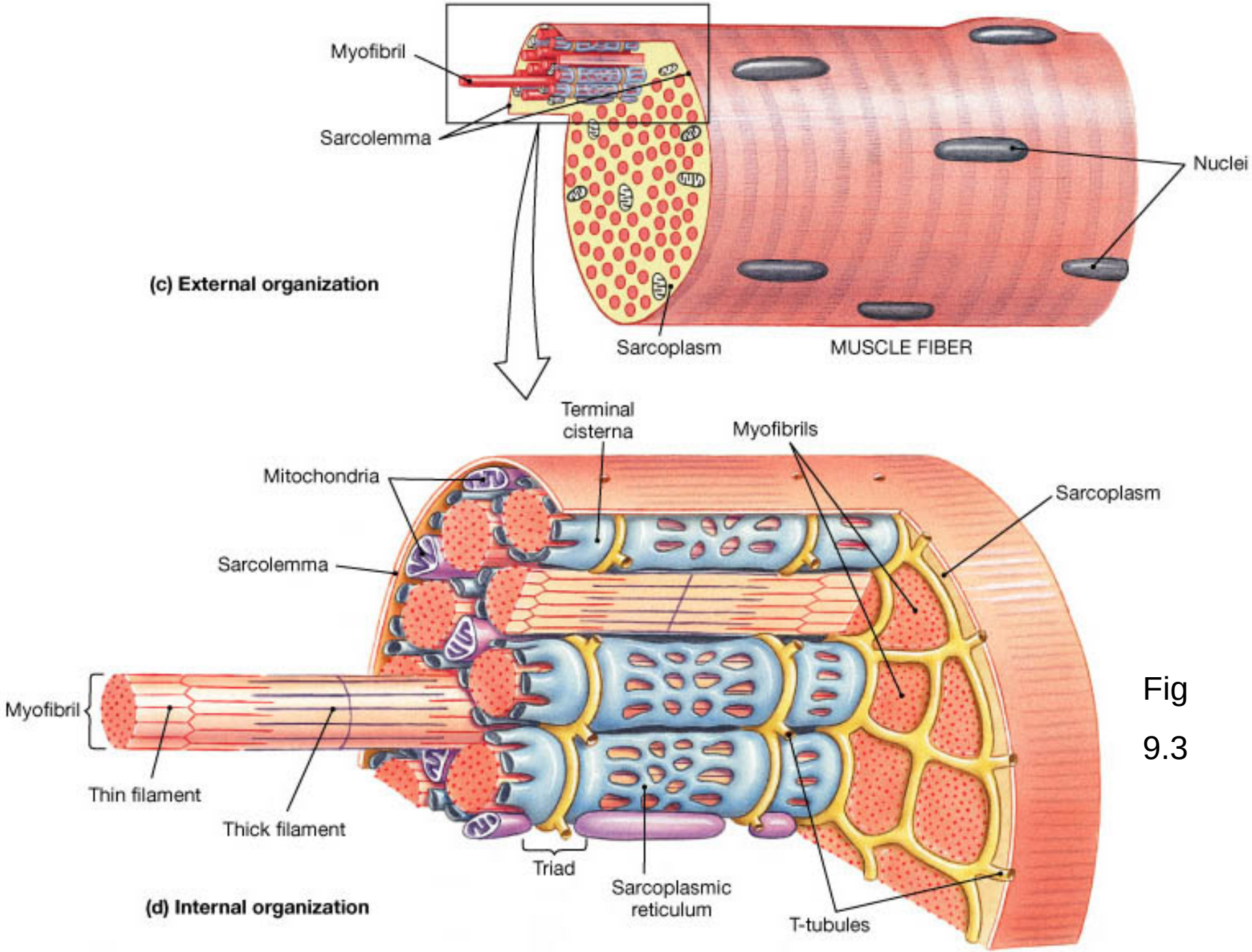

Myofibril
Sarcolemma
Nuclei
(c) External organization
Sarcoplasm
MUSCLE FIBER
Terminal cisterna
Myofibrils
Mitochondria
Sarcoplasm
Sarcolemma
Myofibril
Thin filament
Thick filament
Triad
Sarcoplasmic reticulum
T-tubules
(d) Internal organization

Fig 9.3

- Sarcoplasmic reticulum- SR-ER in muscle fibers (release Ca for muscle contraction)
- Terminal cisternae-widened ends of the SR
- Transverse tubules (T-tubules)
- Triad-two terminal cisternae and the t-tubule between them

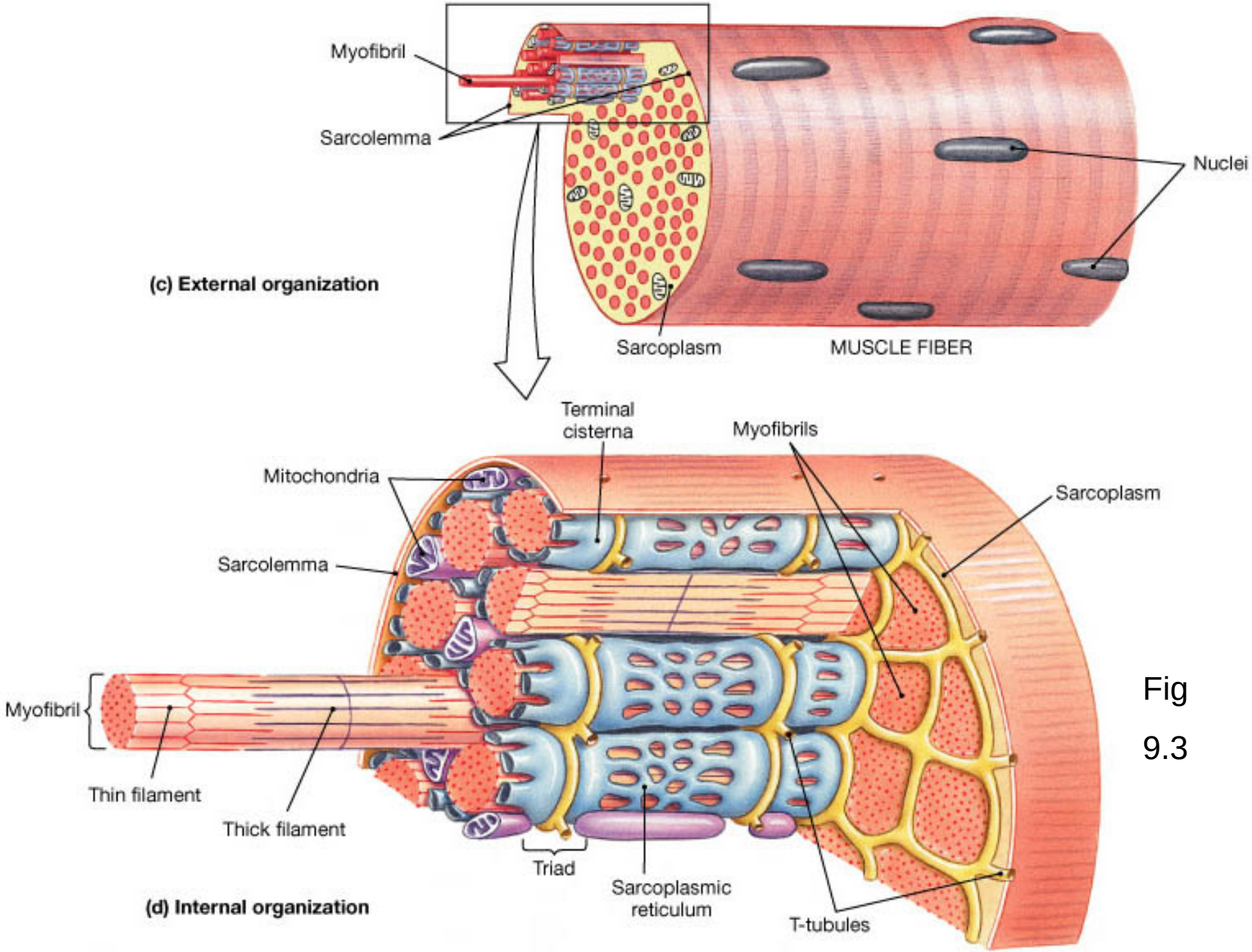

Myofibril
Sarcolemma
Nuclei
(c) External organization
Sarcoplasm
MUSCLE FIBER
Terminal cisterna
Myofibrils
Mitochondria
Sarcoplasm
Sarcolemma
Myofibril
Thin filament
Thick filament
Triad
Sarcoplasmic reticulum
T-tubules
(d) Internal organization

Fig 9.3

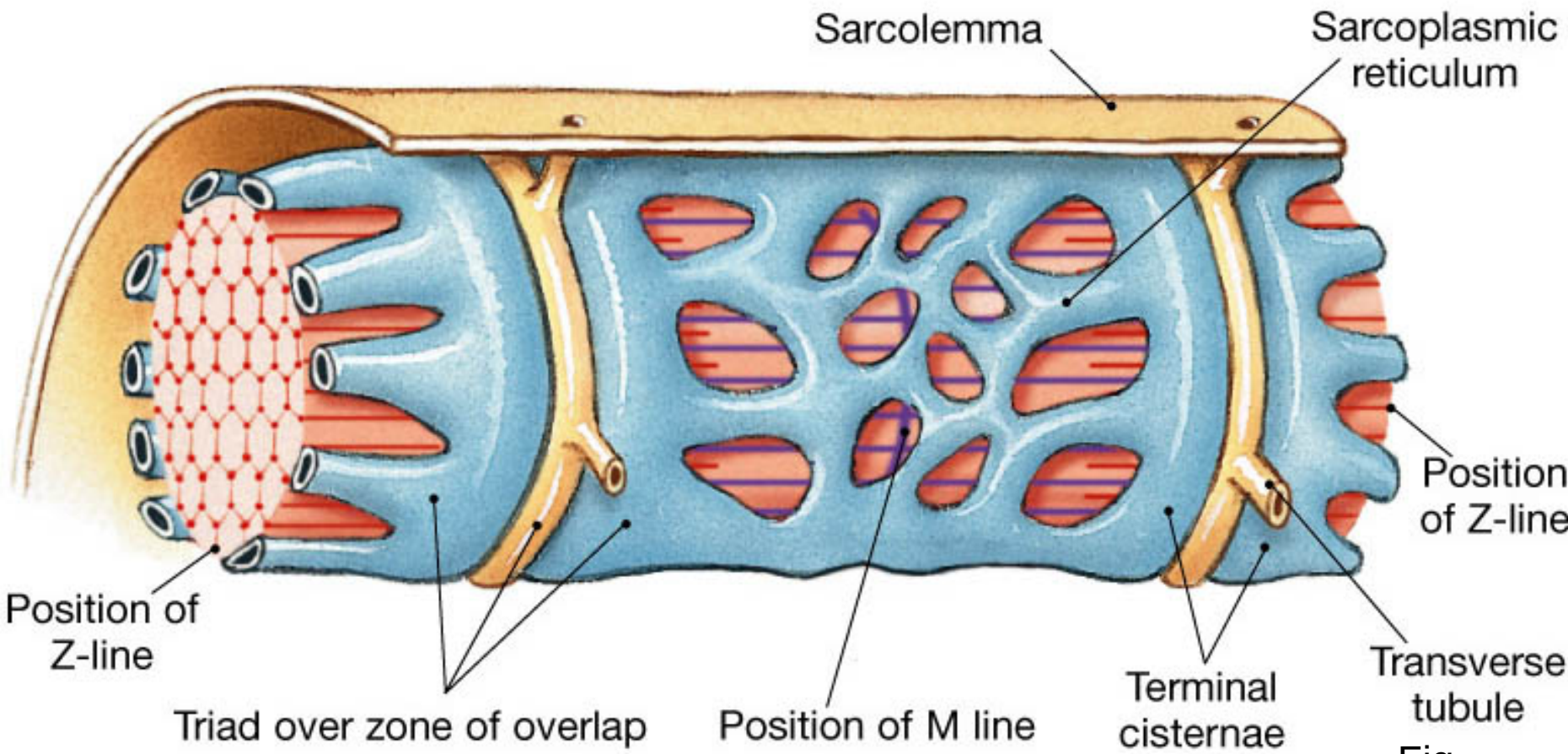
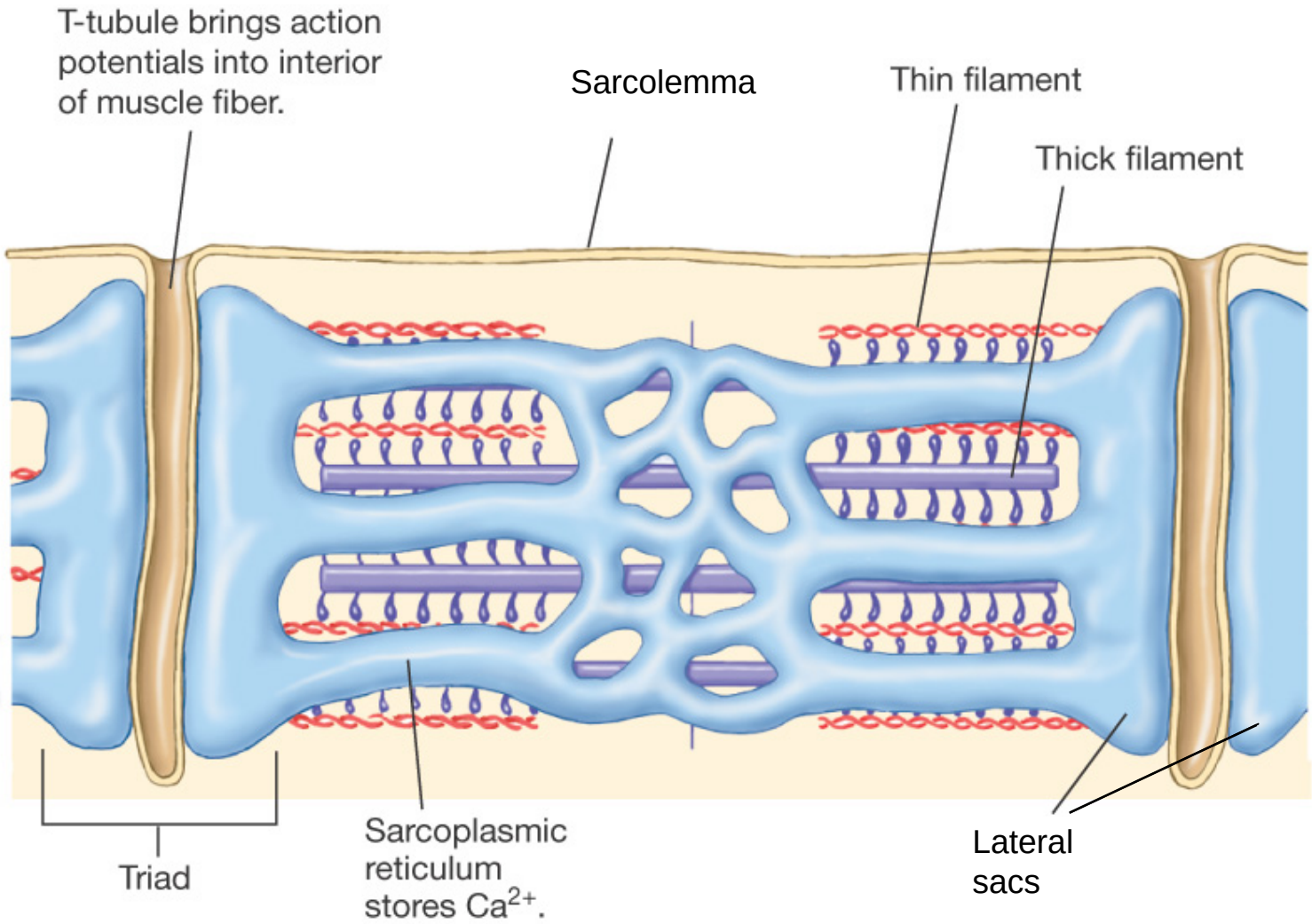

Sarcolemma
Sarcoplasmic reticulum
Position of Z-line
Position of Z-line
Triad over zone of overlap
Position of M line
Terminal cisternae
Transverse tubule

Fig 9.9


T-tubule brings action potentials into interior of muscle fiber.
Sarcolemma
Thin filament
Thick filament
Triad
Sarcoplasmic reticulum stores Ca^{2+}.
Lateral sacs

Sarcomere

- The functional unit of skeletal muscle
- Sarcomeres are connected in series to make myofibrils
- ~10,000 of sarcomeres make a myofibril
- Each sarcomere contracts shortening the length of the entire myofibril

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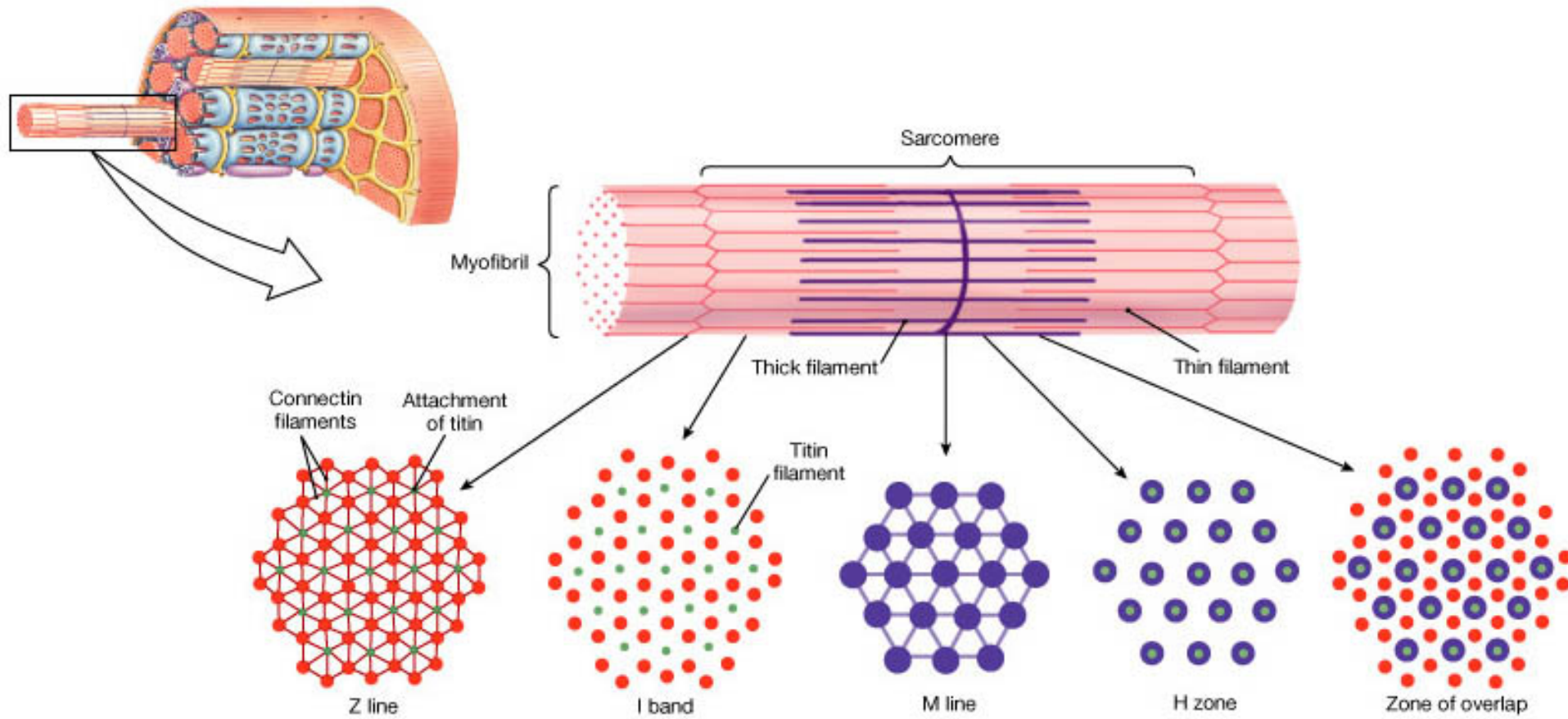
Stockholm 1998



(a) Organization of thick and thin filaments

Fig 9.4

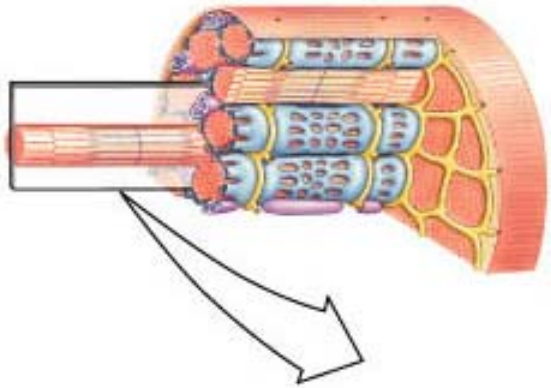
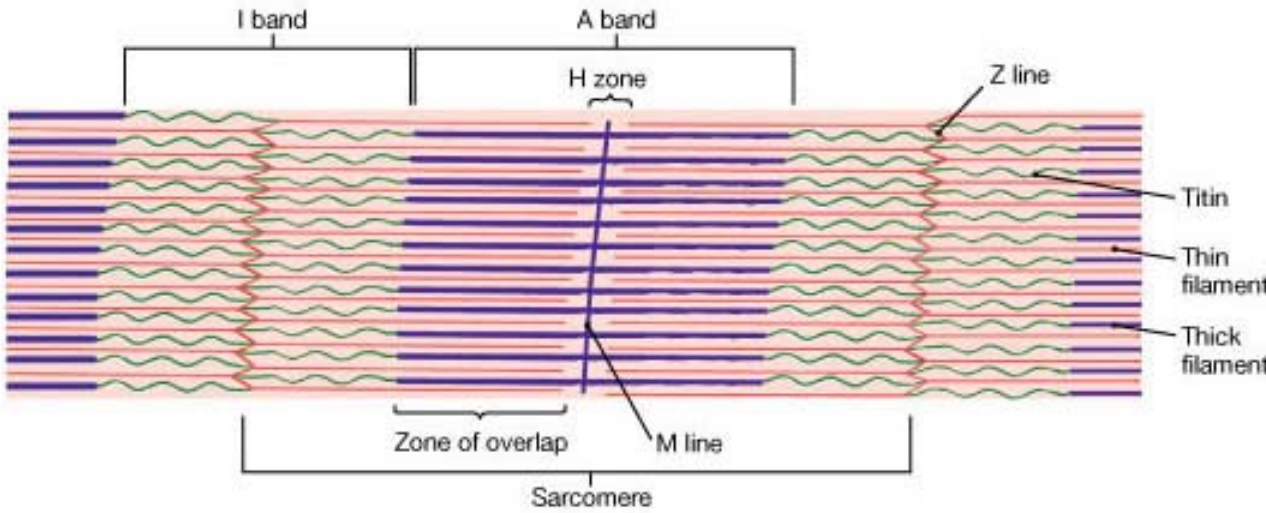


Fig 9.4



(b) Sarcomere in longitudinal section

I-band= light band-contains actin=thin filament

A-band=dark band-contains myosin=thick filament

Z-line/disc-the ends of the sarcomere-actin connects to the z-bands

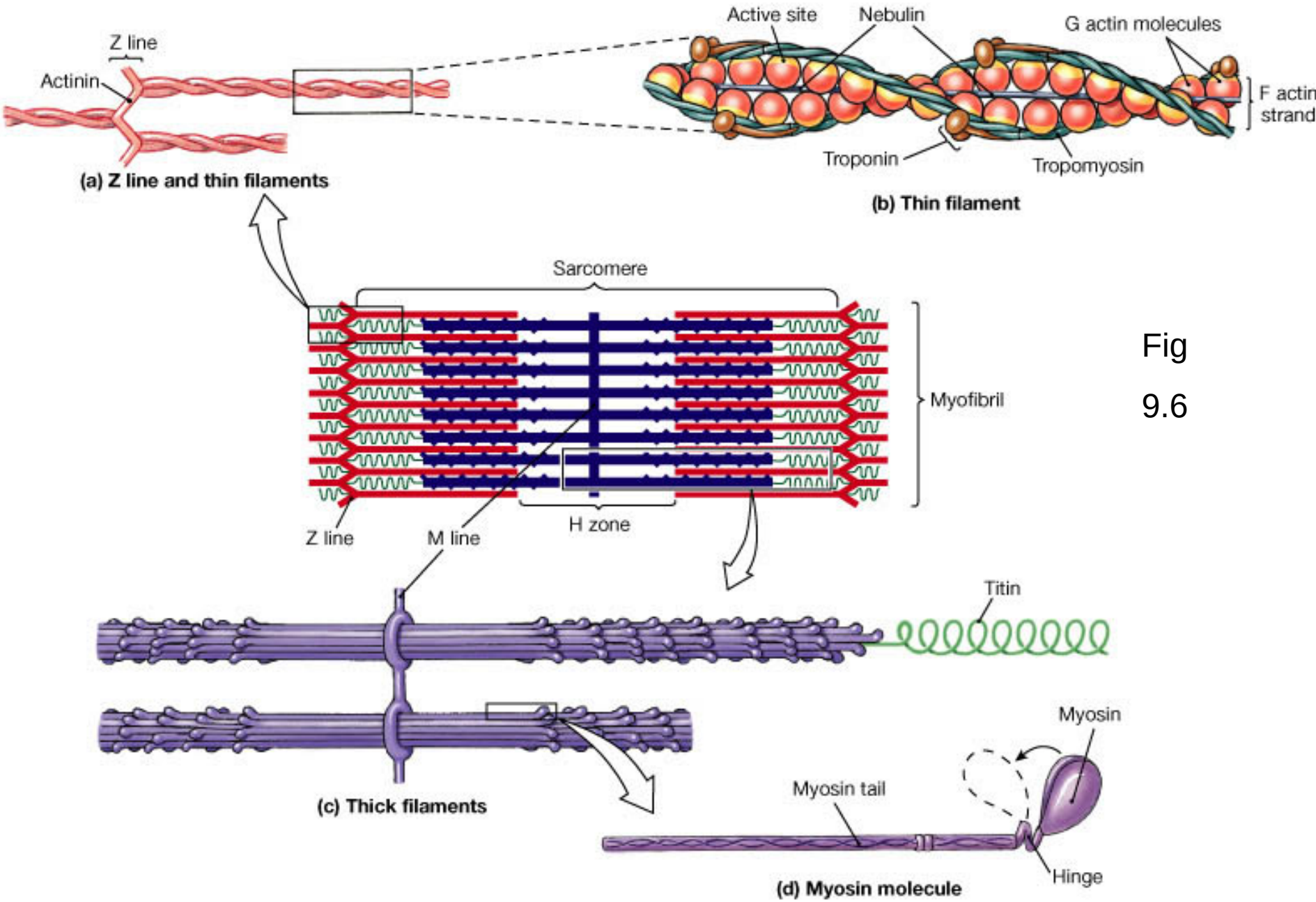

Z line
Actinin
(a) Z line and thin filaments
Active site
Nebulin
G actin molecules
F actin strand
Troponin
Tropomyosin
(b) Thin filament
Sarcomere
Myofibril
H zone
Z line
M line
Titin
(c) Thick filaments
Myosin
Myosin tail
Hinge
(d) Myosin molecule

Fig 9.6

Structures of the Sarcomere

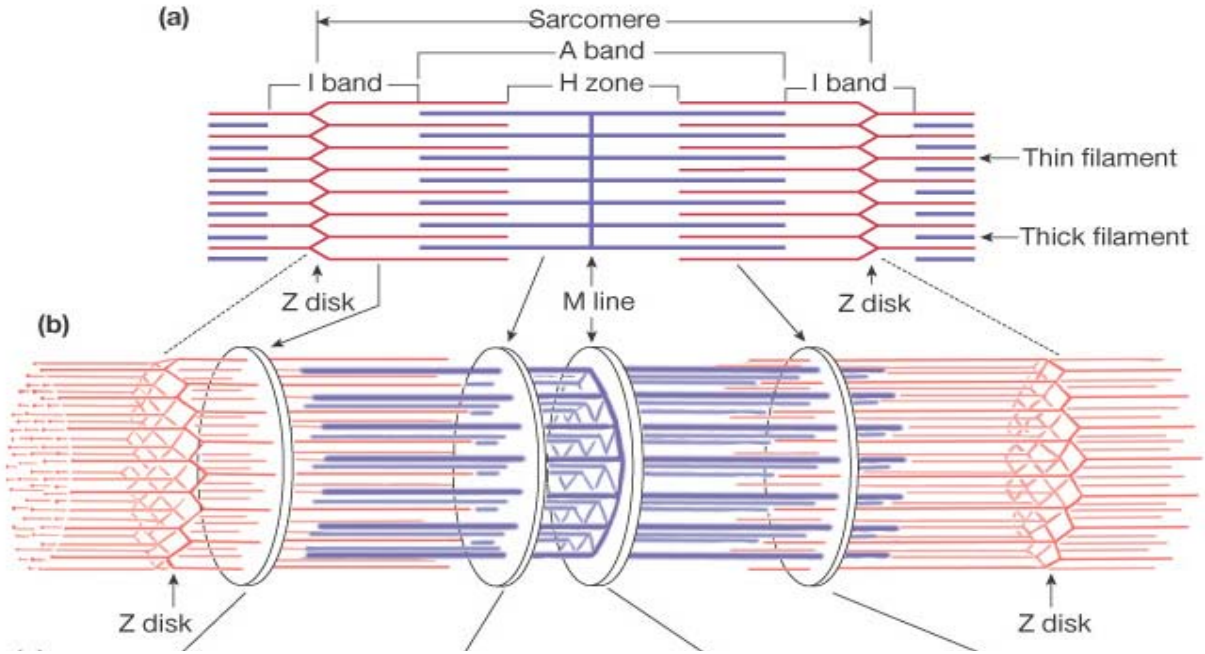
Z disks

H-band

I-band

A-band

M line



H-band = myosin only

I-band = actin only

A-band = all of the myosin

Thin filaments

- Contains actin, tropomyosin, and troponin
- Tropomyosin blocks the active site on actin
- Troponin holds tropomyosin in place
- Calcium binds to troponin causing dissociation of the troponin-tropomyosin complex

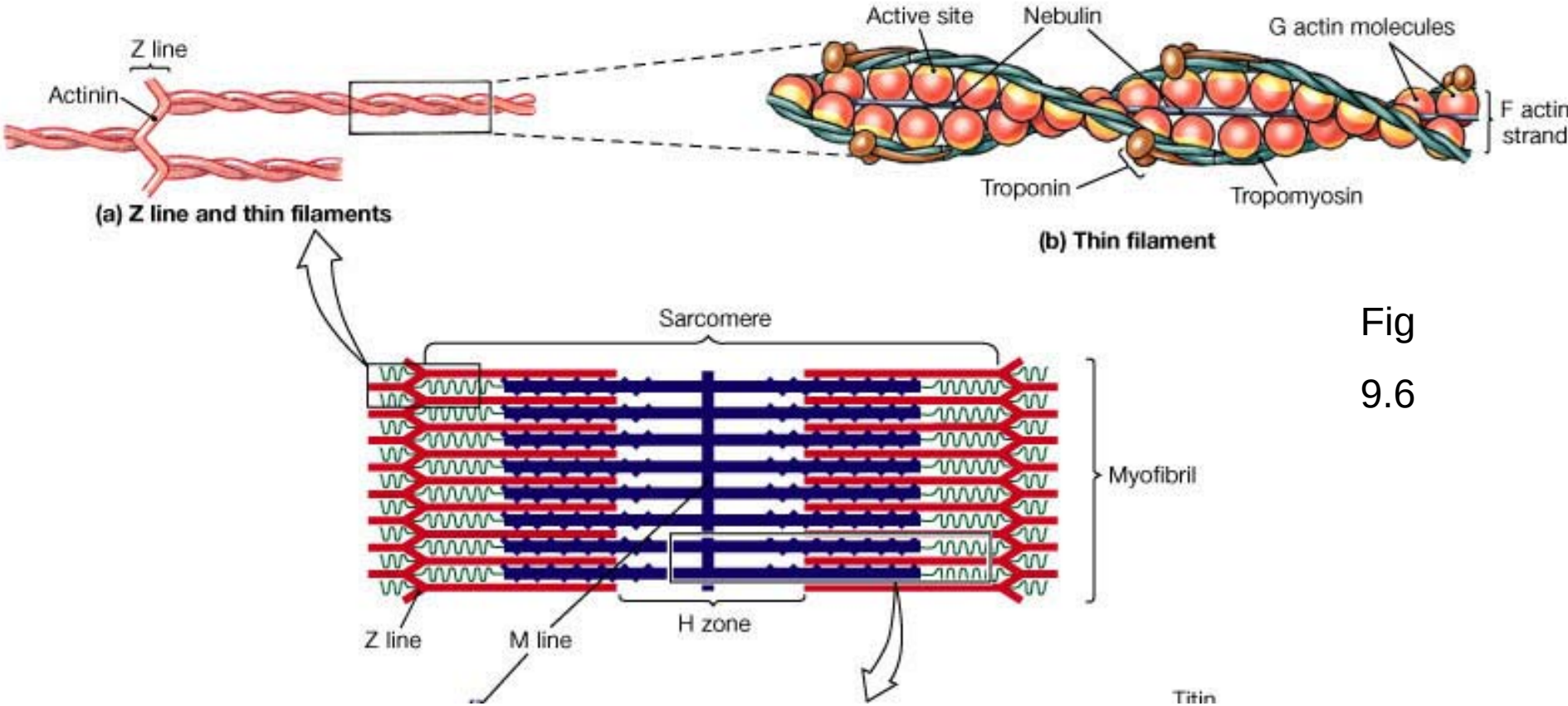

Z line
Actinin
(a) Z line and thin filaments
Active site
Nebulin
G actin molecules
F actin strand
Troponin
Tropomyosin
(b) Thin filament
Sarcomere
Myofibril
Z line
M line
H zone
Titin

Fig 9.6

Thick filament

- Contain bundles of myosin molecules
- The tail of myosin is attached to the center of the sarcomere, M-line
- The head of myosin attaches to actin if Ca is present in the sarcoplasm

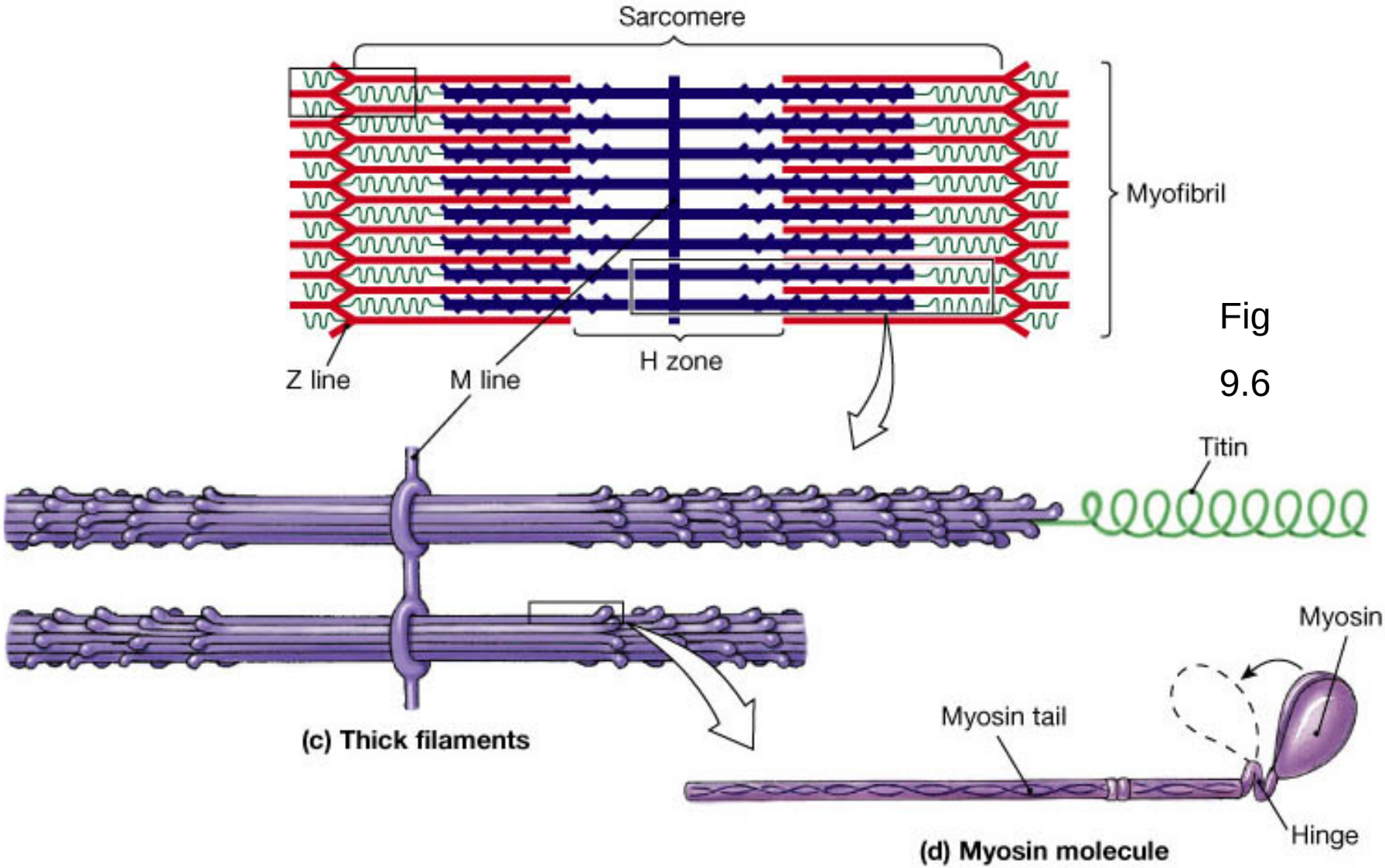

Sarcomere
Myofibril
Z line
M line
H zone
Titin
Myosin
Myosin tail
Hinge
(c) Thick filaments
(d) Myosin molecule

Fig 9.6

Sliding filament theory

- When a skeletal muscle contacts:
  - The I-bands get shorter
  - The z-lines move closer together
  - The myofilaments (actin & myosin) stay the same length
  - The two myofilaments move along side of each other

- Myosin attaches to actin
- Actin is pulled closer to the center of the muscle cell
- Actin is connected to the z lines
- The z lines are pulled closer together

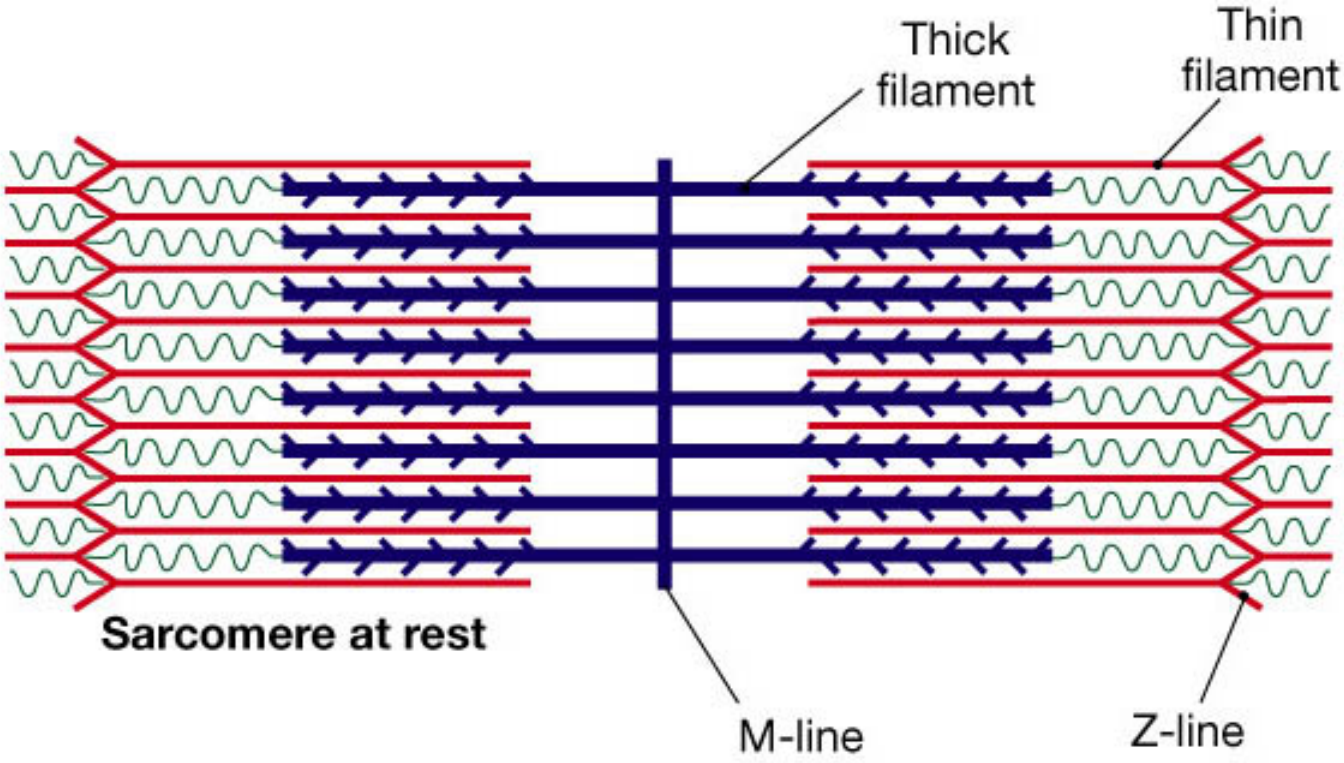
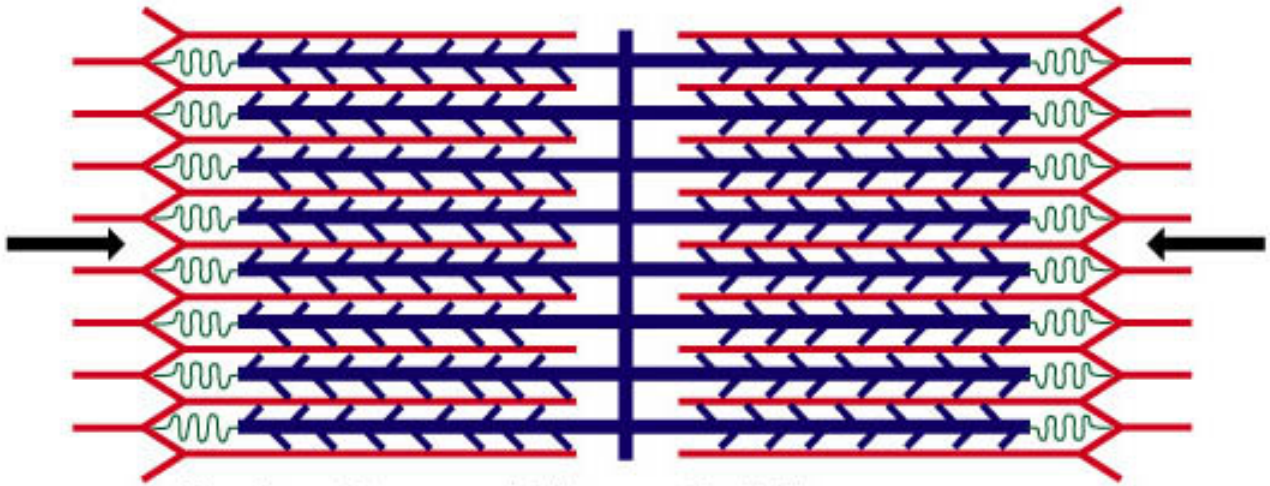

Thick filament
Thin filament
Sarcomere at rest
M-line
Z-line

Fig 9.7


Contraction and filament sliding

Motor neuron release neurotransmitter Ach

Changes in sarcolemma permeability to ions

Generation of electrical impulse called and action potential

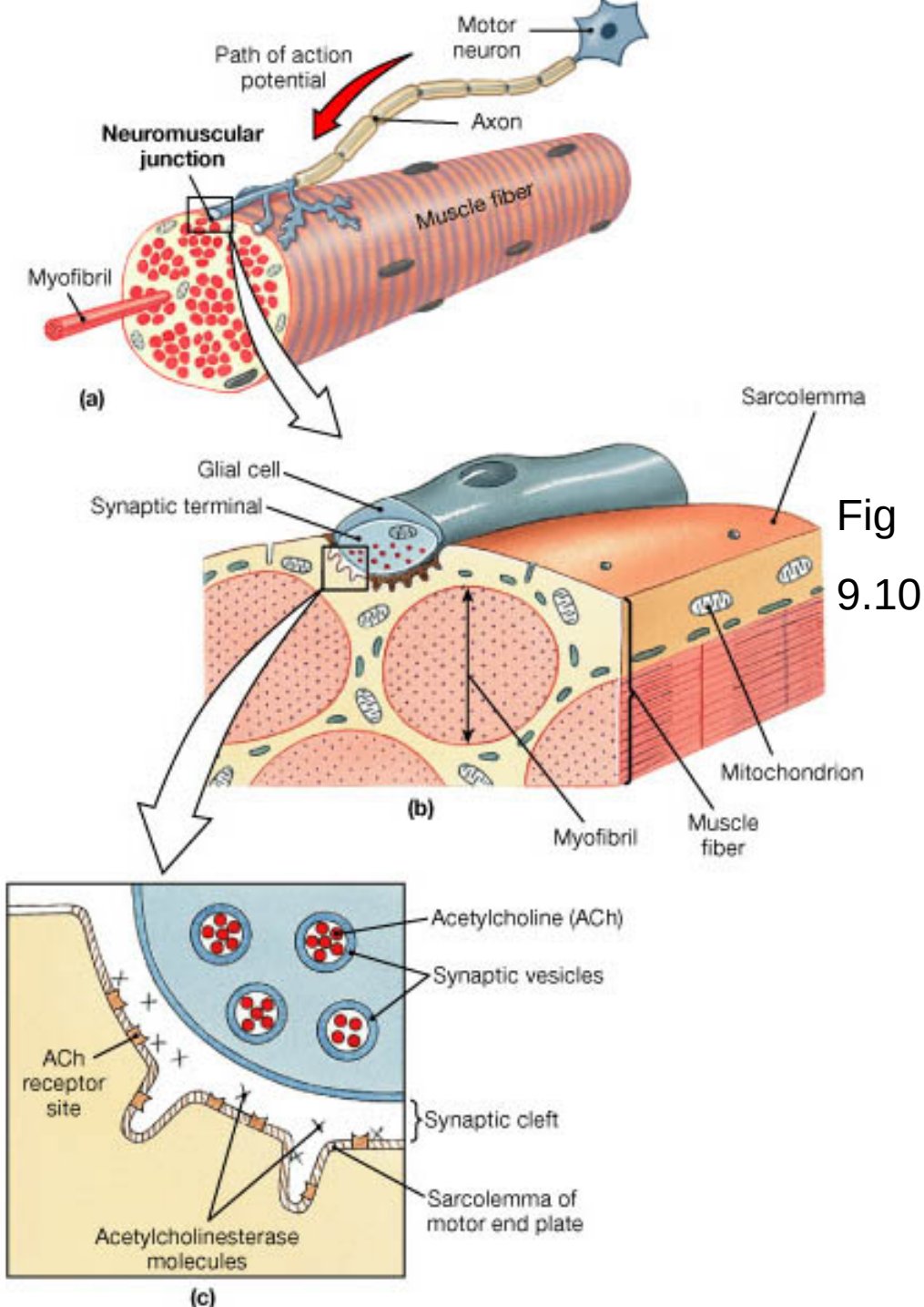
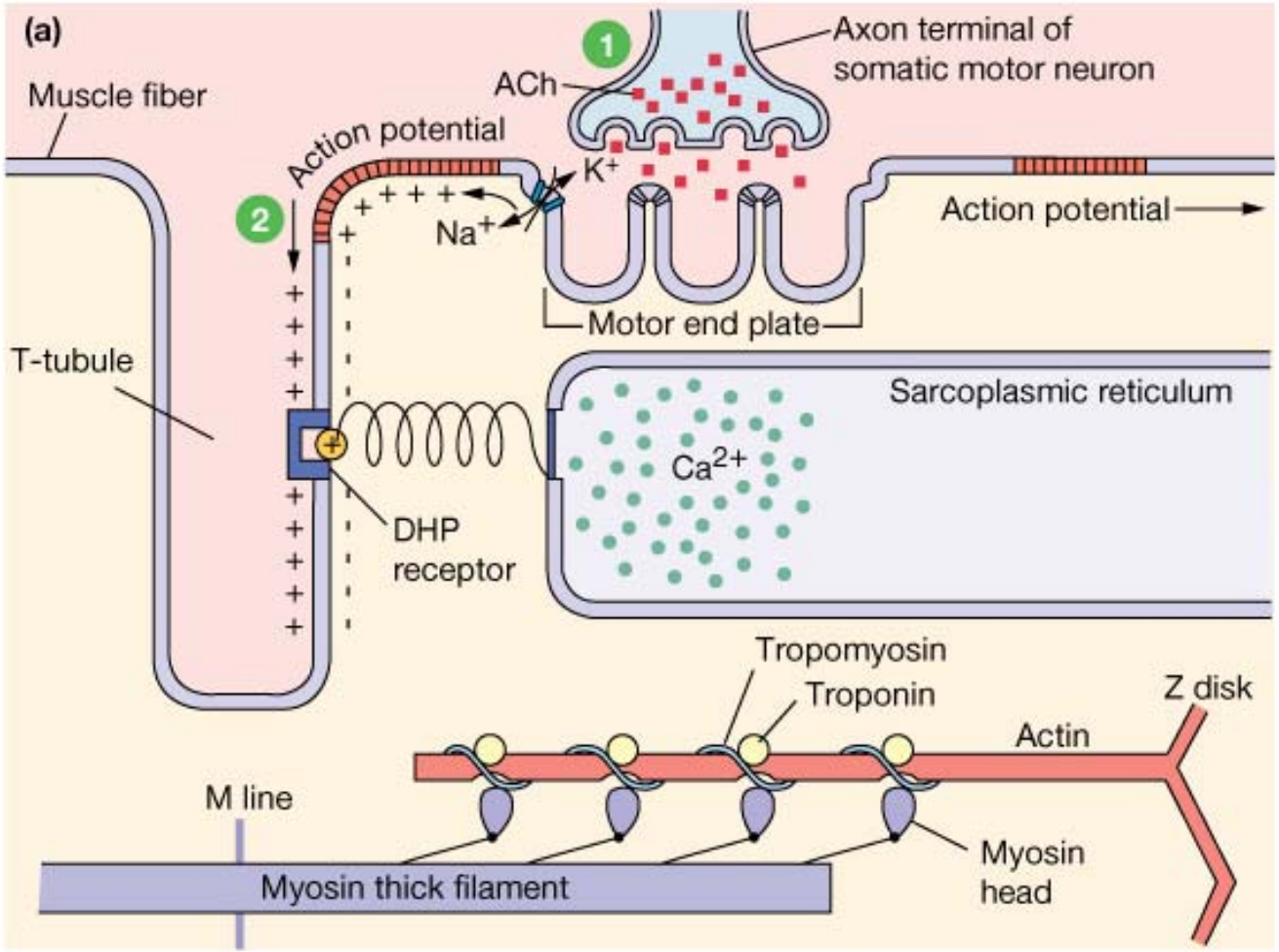


Fig 9.10

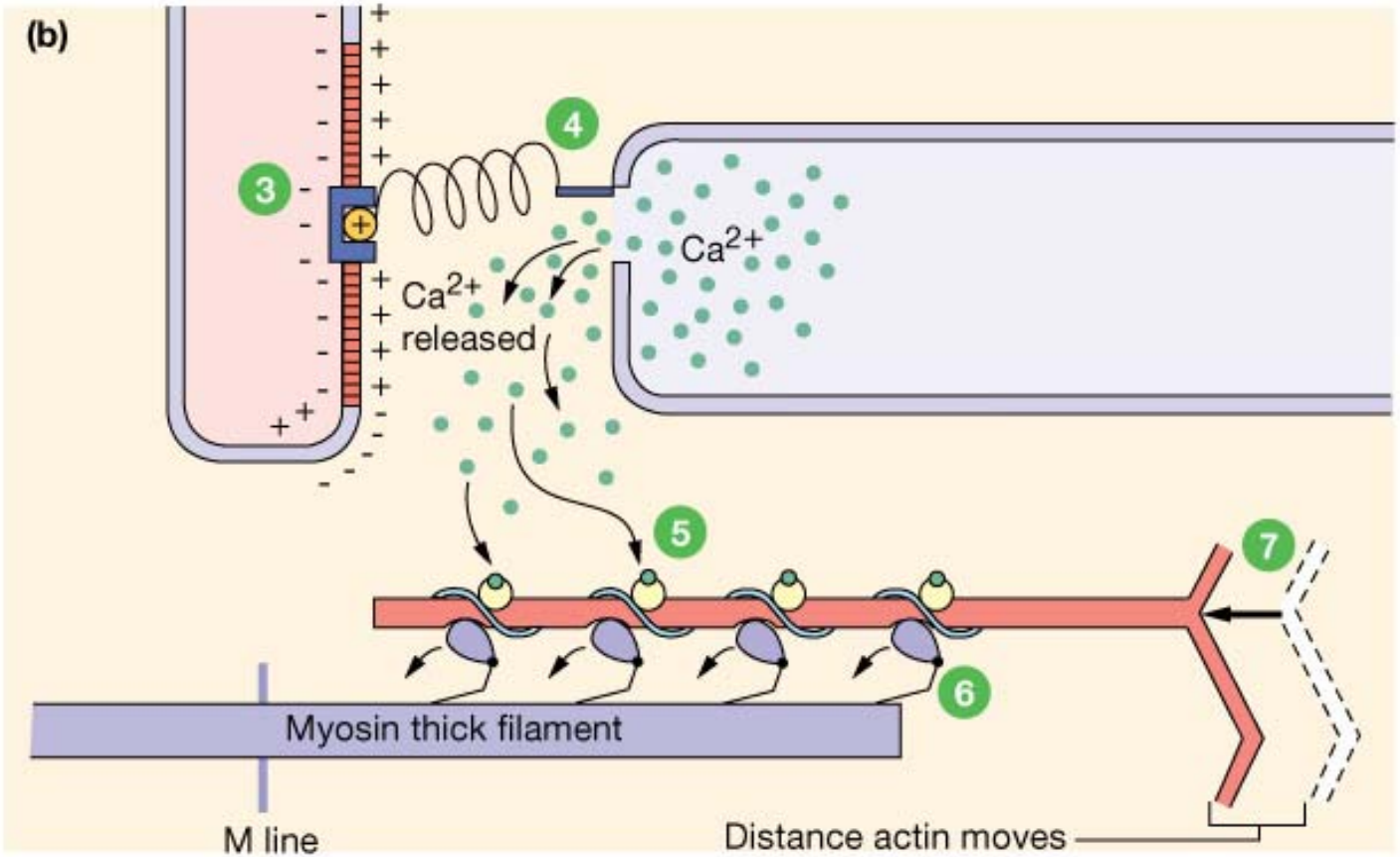
Excitation - Contraction in Skeletal Muscle



1 Somatic motor neuron releases ACh at neuro-muscular junction.

2 Net entry of Na^+ through ACh receptor-channel initiates a muscle action potential.

Intracellular Ca^{2+} triggers contraction



3. Action potential in t-tubule alters conformation of DHP receptor.

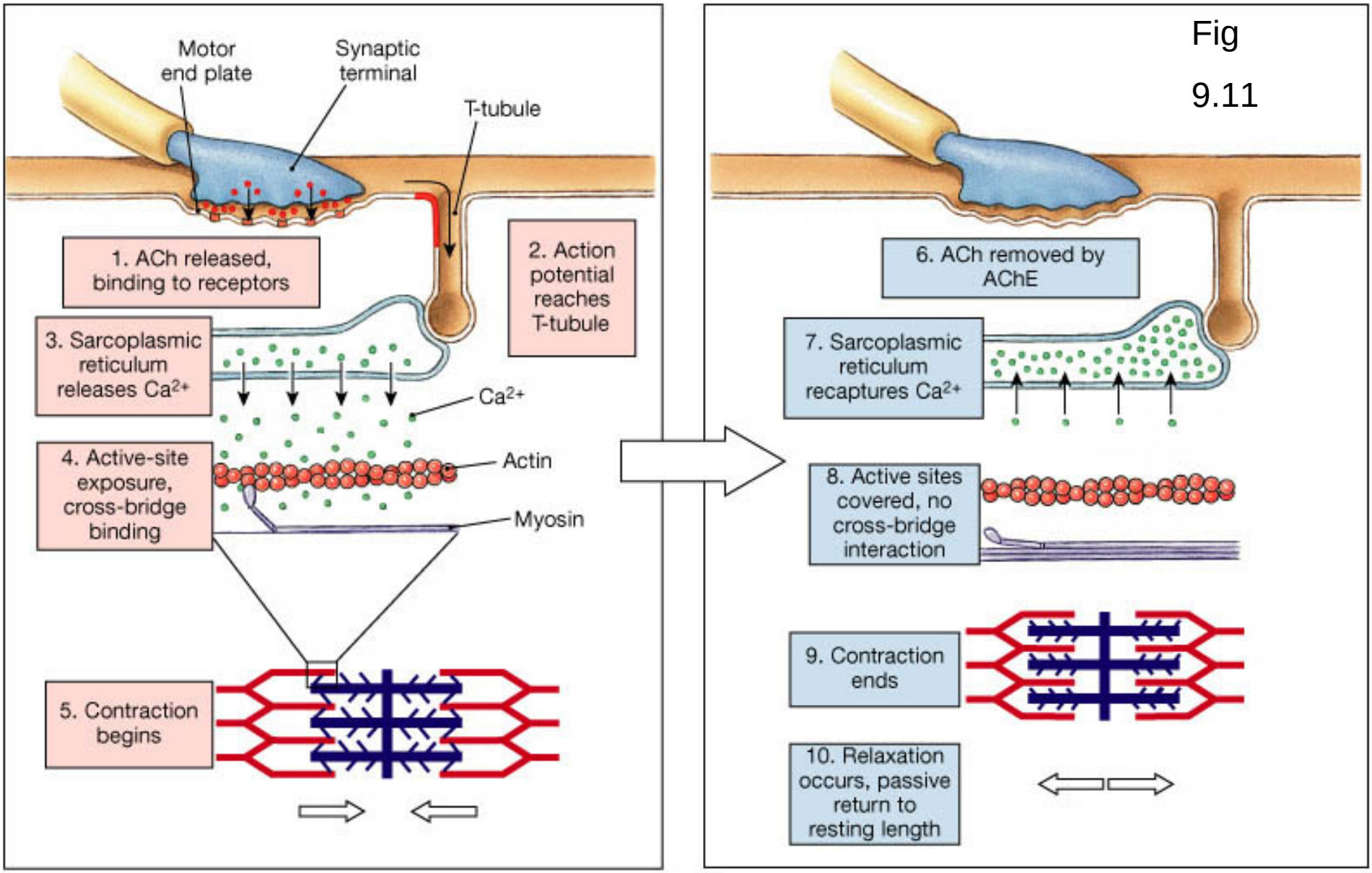
4. DHP receptor opens Ca^{2+} release channels in sarcoplasmic reticulum and Ca^{2+} enters cytoplasm.

5. Ca^{2+} binds to troponin, allowing strong actin-myosin binding.

6. Myosin heads execute power stroke.

7. Actin filament slides toward center of sarcomere.

Fig 9.11

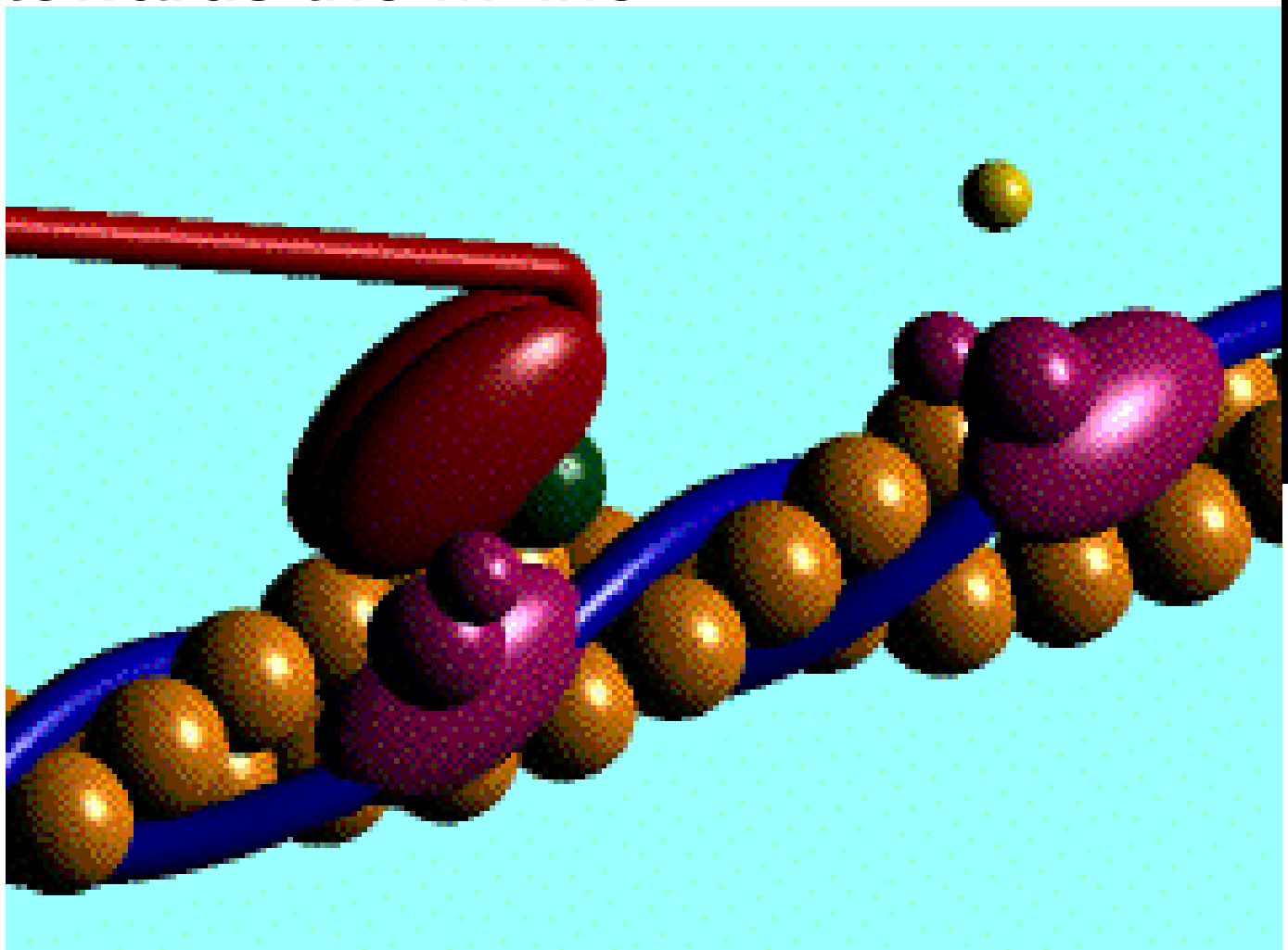


Steps in the initiation of a contraction

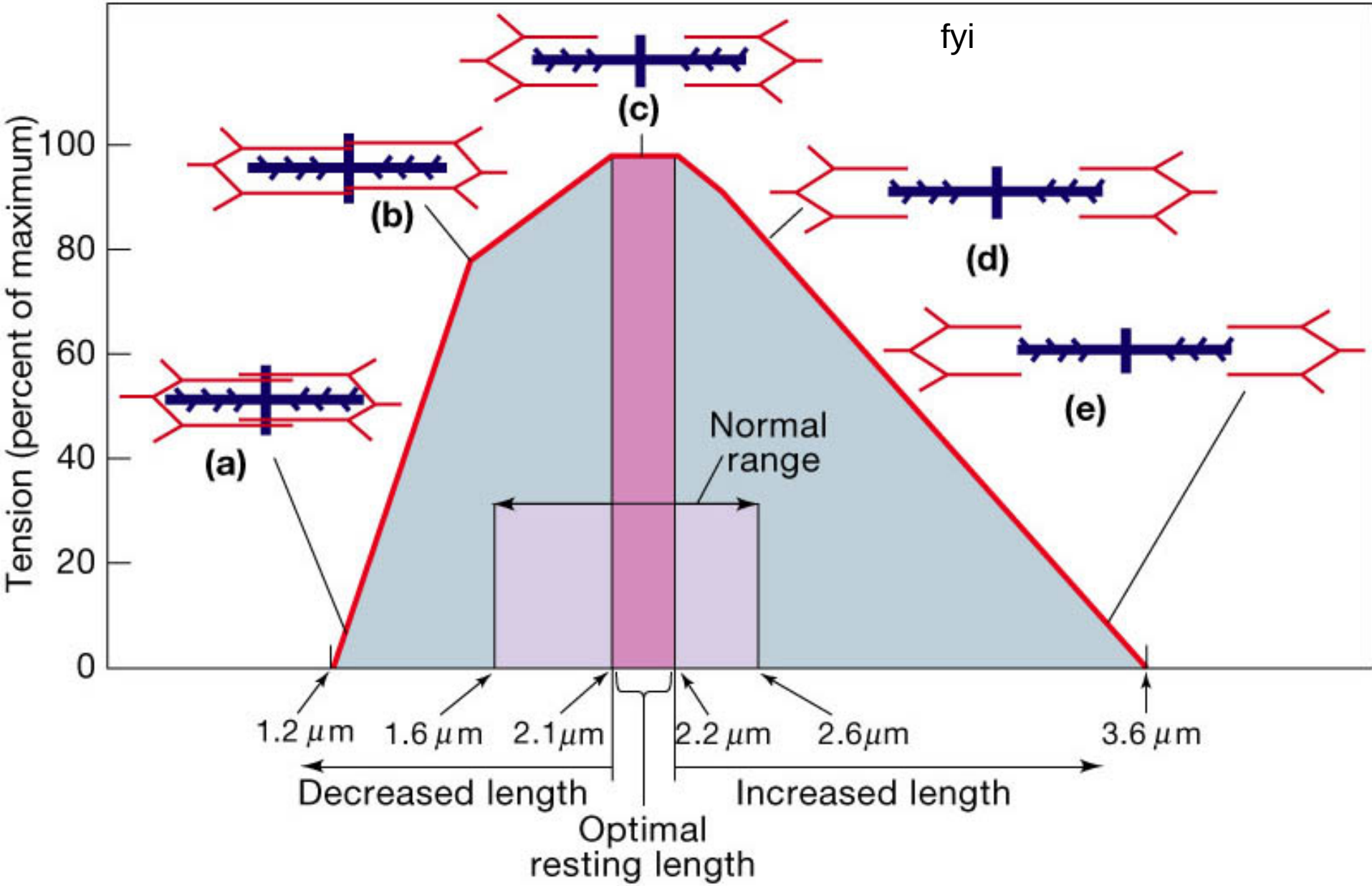
Steps that end the contraction

Sliding filament theory

- Contraction-myosin binds to actin pulling it towards the M line



fyi


Tension (percent of maximum)
100
80
60
40
20
0
(a)
(b)
(c)
(d)
(e)
Normal range
1.2 μm
1.6 μm
2.1μm
2.2 μm
2.6μm
3.6 μm
Decreased length
Increased length
Optimal resting length

Connective tissue of muscle

- Epimysium-surrounds the entire muscle
- Perimysium-surrounds fascicles
- Fasicle-a bundle of muscle cells
- Endomysium-surrounds individual muscle cells
- Epimmysium & perimysium are attachment sites for nerves & blood vessels

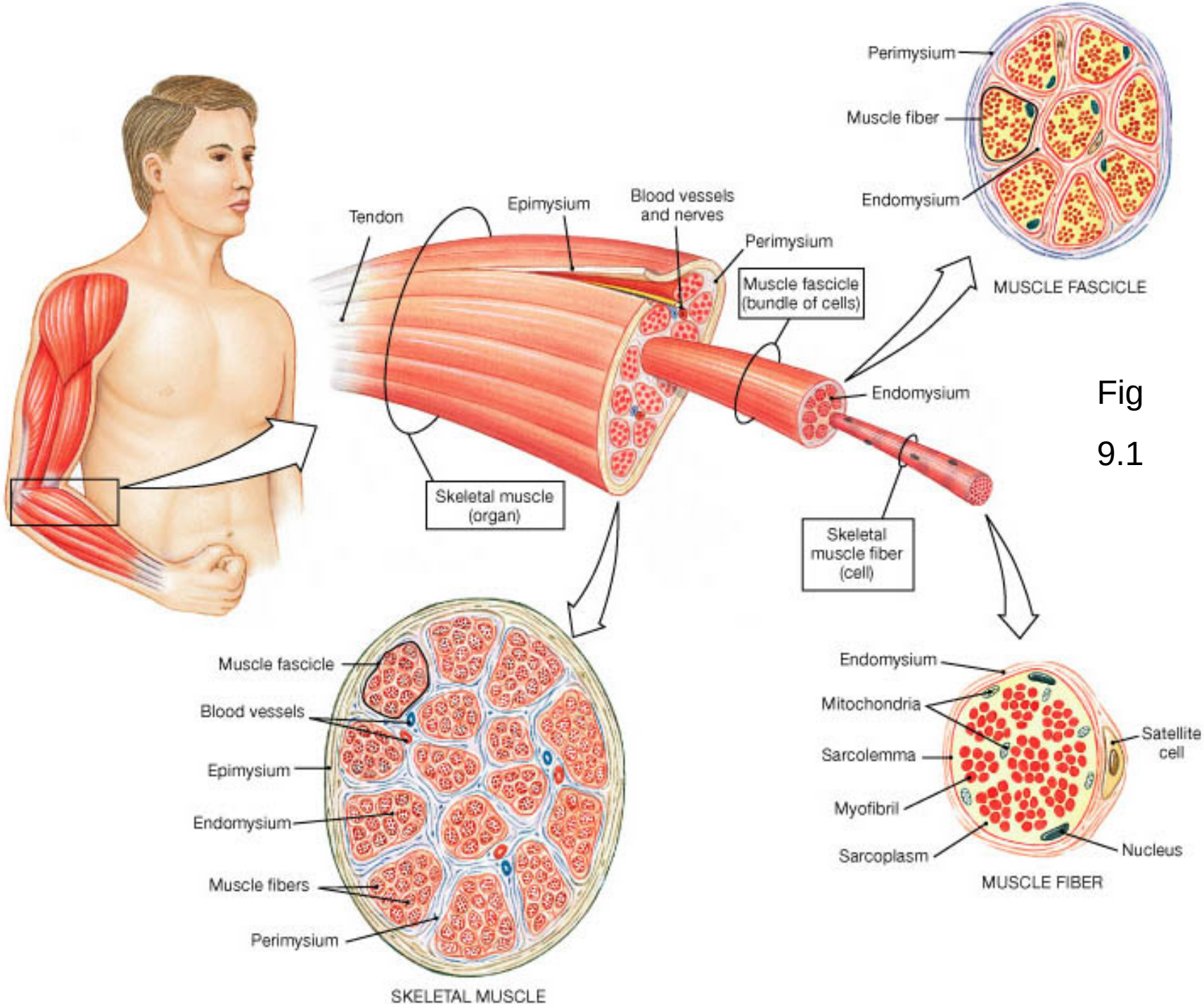

Perimysium
Muscle fiber
Endomysium
MUSCLE FASCICLE
Tendon
Epimysium
Blood vessels and nerves
Perimysium
Muscle fascicle (bundle of cells)
Endomysium
Skeletal muscle (organ)
Skeletal muscle fiber (cell)
Muscle fascicle
Blood vessels
Epimysium
Endomysium
Muscle fibers
Perimysium
SKELETAL MUSCLE
Endomysium
Mitochondria
Sarcolemma
Myofibril
Sarcoplasm
Satellite cell
Nucleus
MUSCLE FIBER

Fig 9.1

Fig 9.5

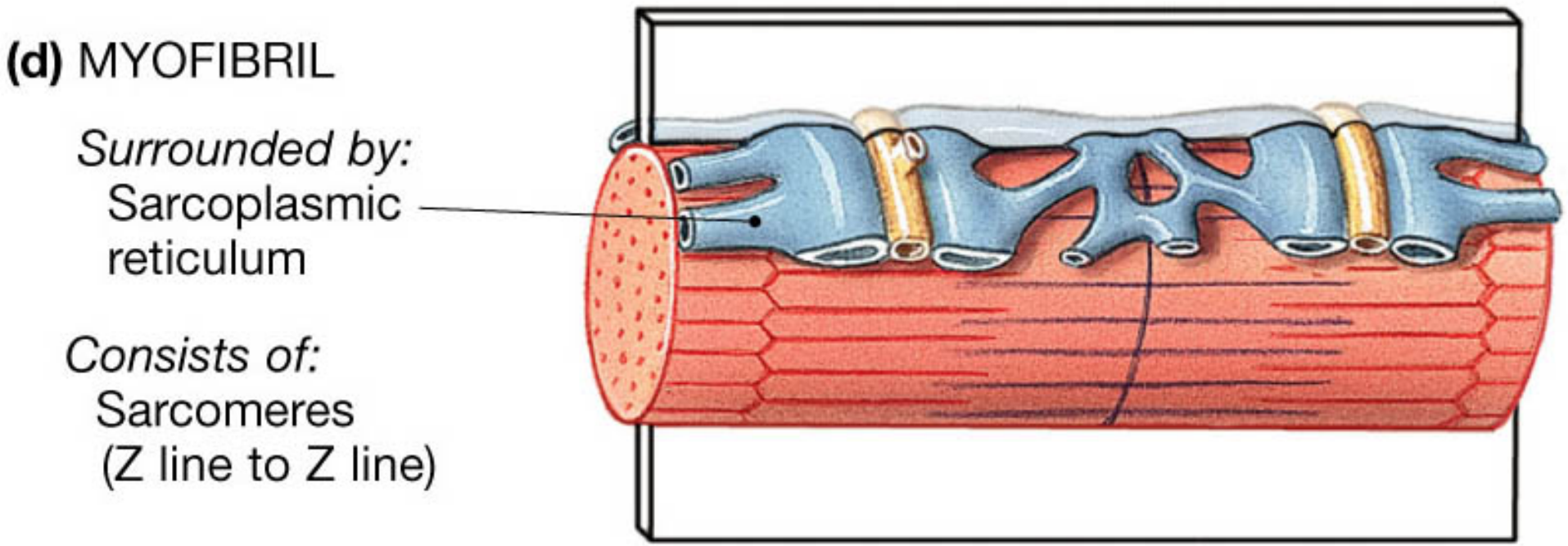

(d) MYOFIBRIL
Surrounded by:
Sarcoplasmic reticulum
Consists of:
Sarcomeres
(Z line to Z line)

Fig 9.5

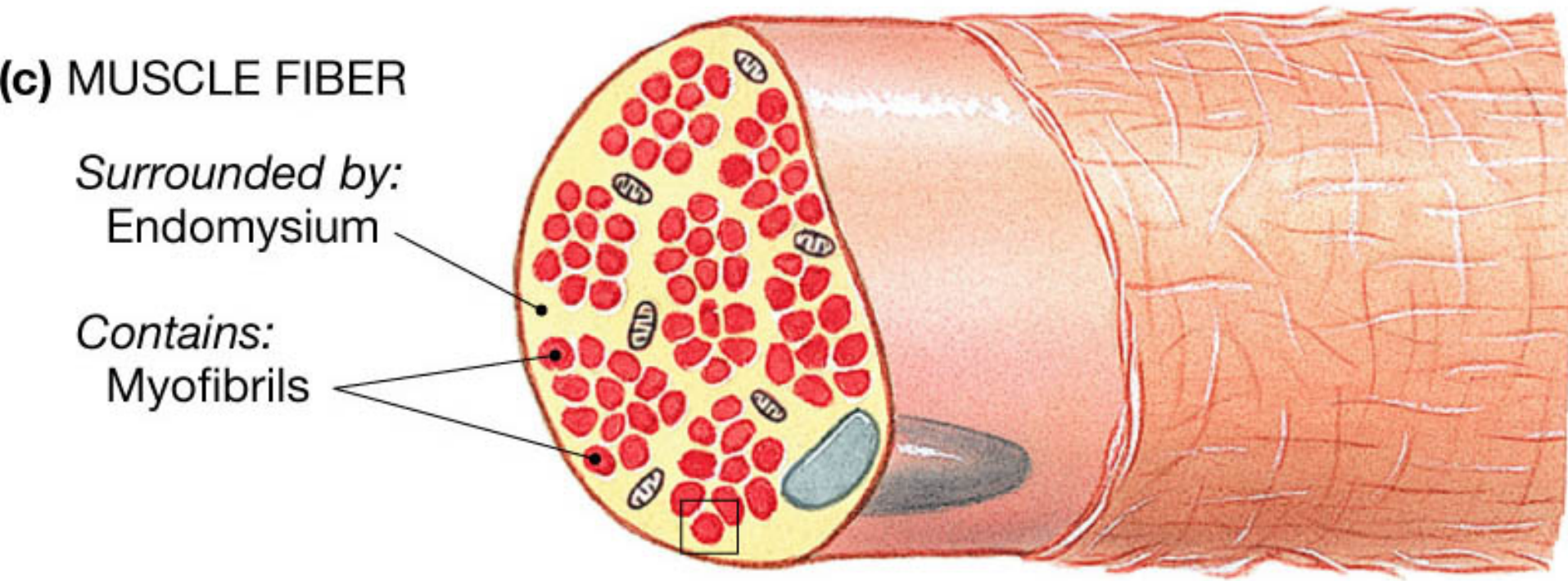

(c) MUSCLE FIBER
Surrounded by:
Endomysium
Contains:
Myofibrils

Fig 9.5

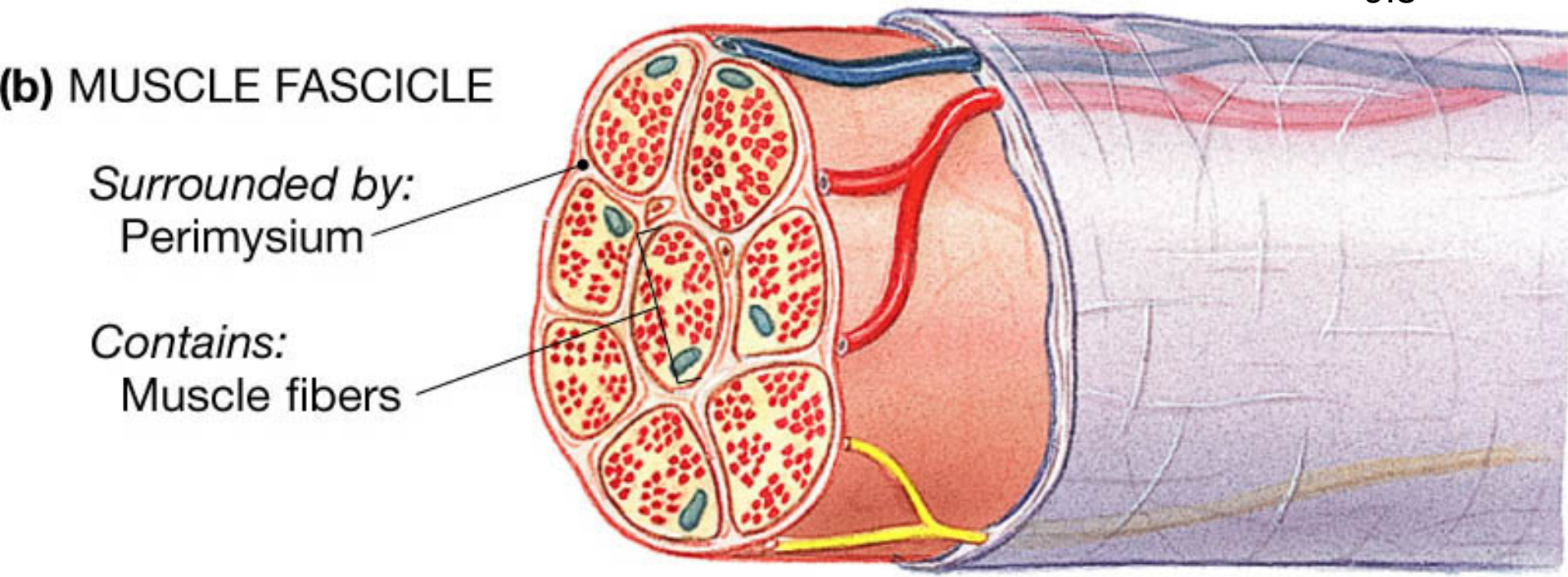
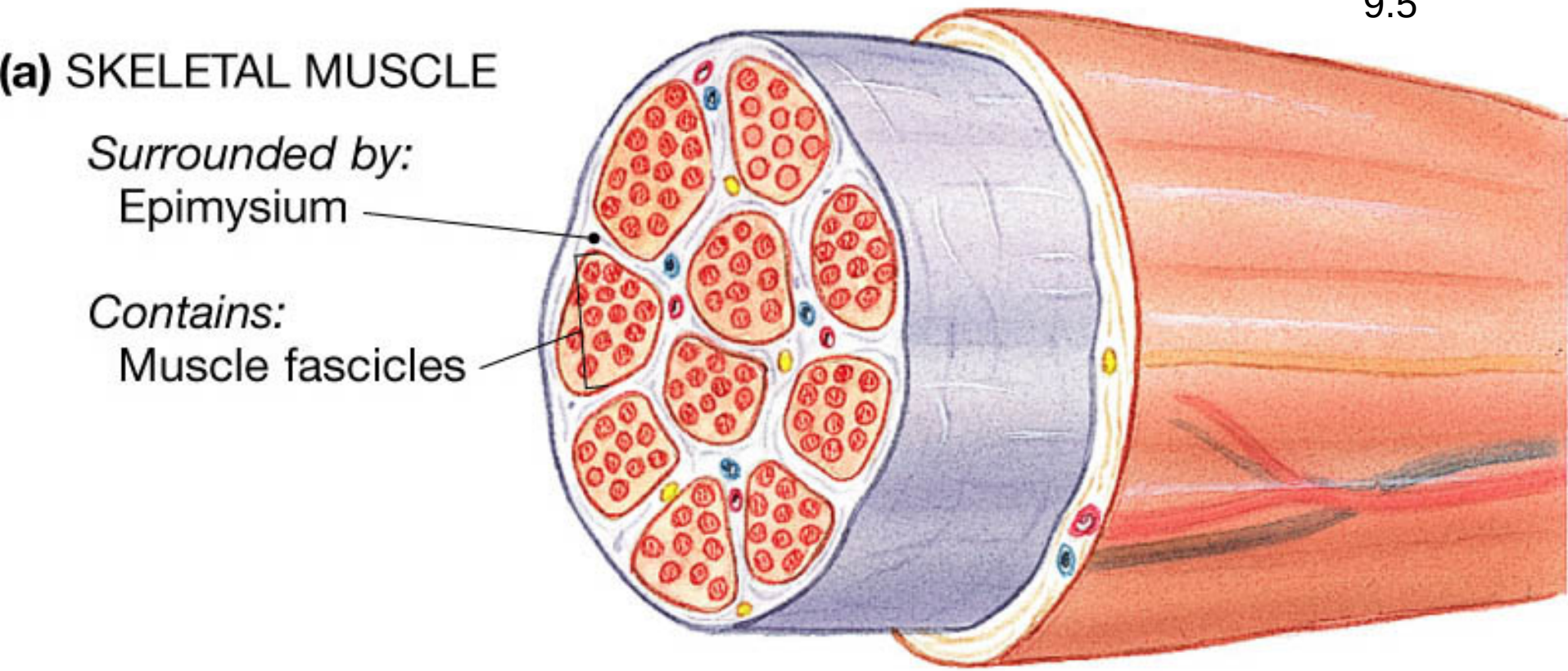

(b) MUSCLE FASCICLE
Surrounded by:
Perimysium
Contains:
Muscle fibers

Fig 9.5


(a) SKELETAL MUSCLE
Surrounded by:
Epimysium
Contains:
Muscle fascicles

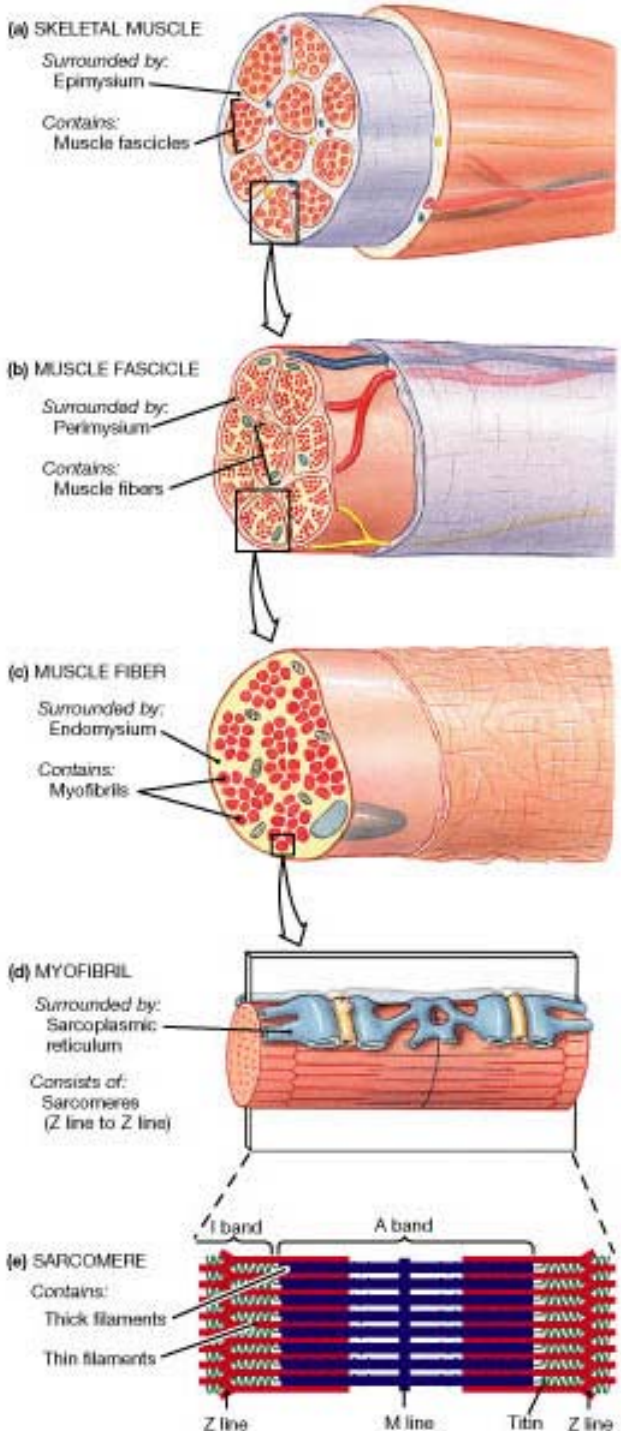
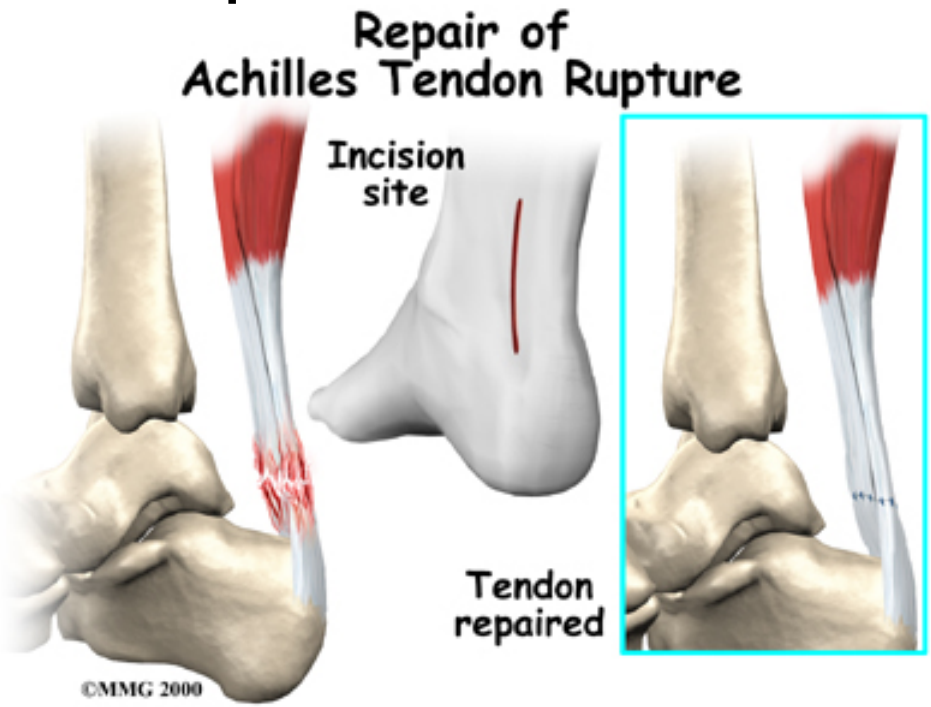
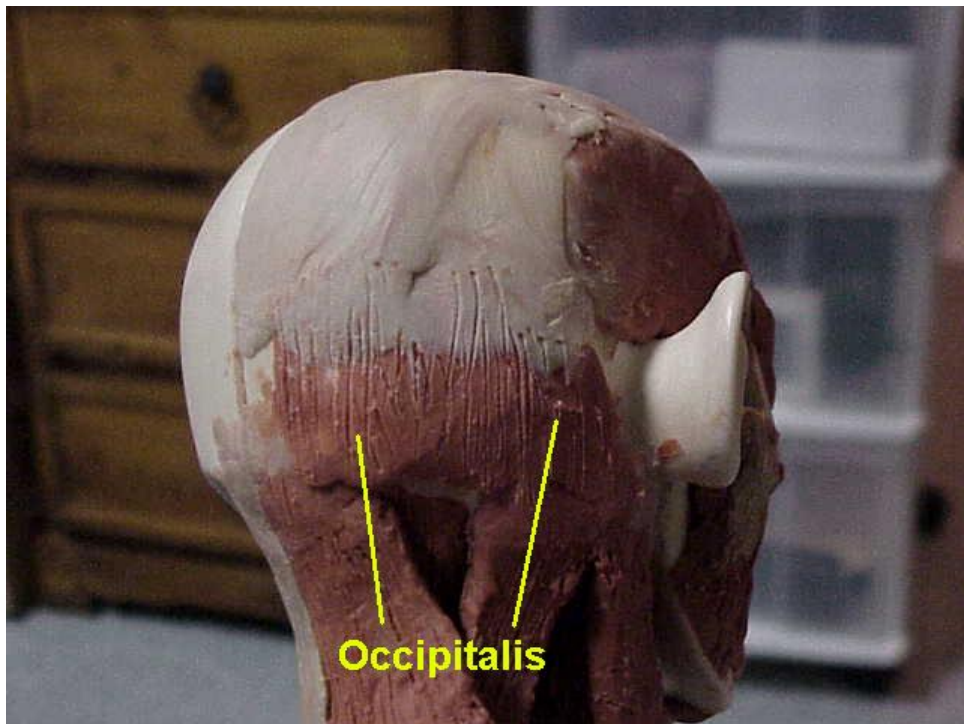

(a) SKELETAL MUSCLE
Surrounded by:
Epimysium
Contains:
Muscle fascicles
(b) MUSCLE FASCICLE
Surrounded by:
Perimysium
Contains:
Muscle fibers
(c) MUSCLE FIBER
Surrounded by:
Endomysium
Contains:
Myofibrils
(d) MYOFIBRIL
Surrounded by:
Sarcoplasmic reticulum
Consists of:
Sarcomeres
(Z line to Z line)
I band
A band
(e) SARCOMERE
Contains:
Thick filaments
Thin filaments
Z line
M line
Titin
Z line

Fig 9.5

Tendons & aponeuroses

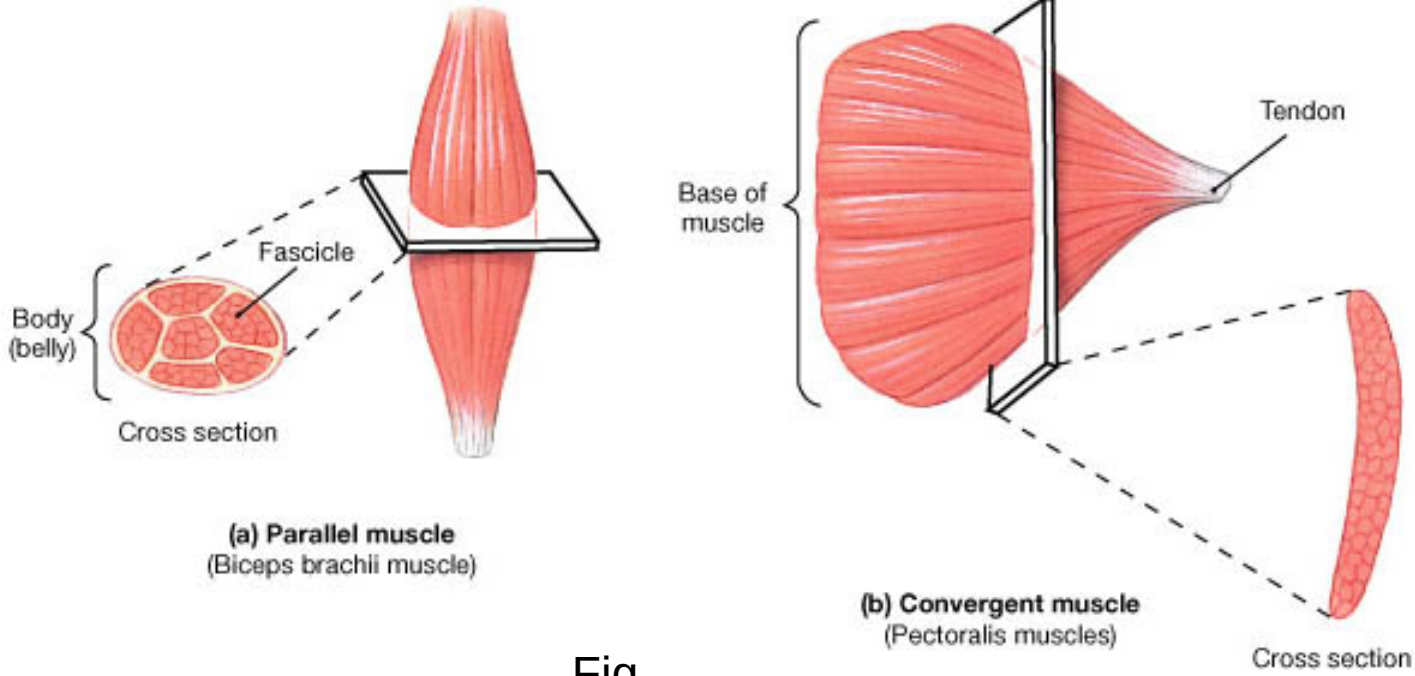
- Tendons attach skeletal muscle to bone, skin, or another muscle
- Aponeuroses-a wide flat tendon





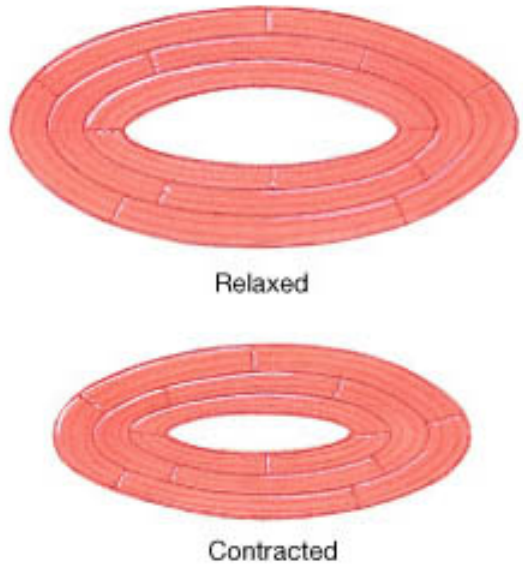
Organization of muscle fibers

- Muscle fascicles are organized six different ways:
- Parallel-parallel to the long axis of the muscle
- Convergent-converge from a wide area to a small area
- Circular-concentrically arranged around a opening


Fascicle
Body
(belly)
Cross section
(a) Parallel muscle
(Biceps brachii muscle)
Base of
muscle
Tendon
(b) Convergent muscle
(Pectoralis muscles)
Cross section

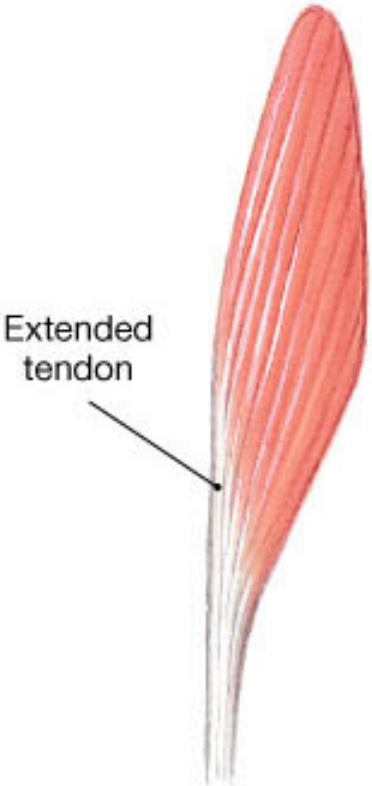
Fig

9.14


Relaxed
Contracted
(f) Circular muscle
(Orbicularis oris muscle)

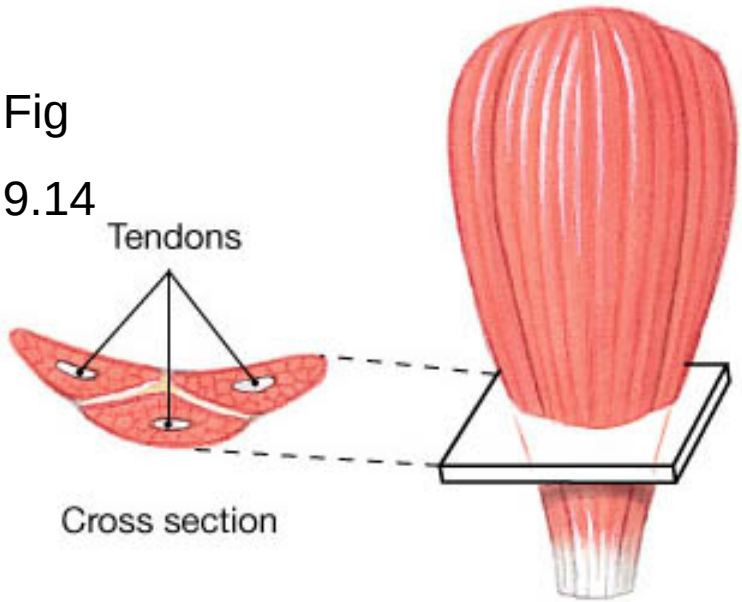
- Unipennate-at an angle on one side of the tendon
- Bipennate- at an angle on both sides of the tendon
- Multipennate-converge from a wide area to a small area. The tendon branches within the muscle

Fig 9.14



(c) Unipennate muscle
(Extensor digitorum muscle)

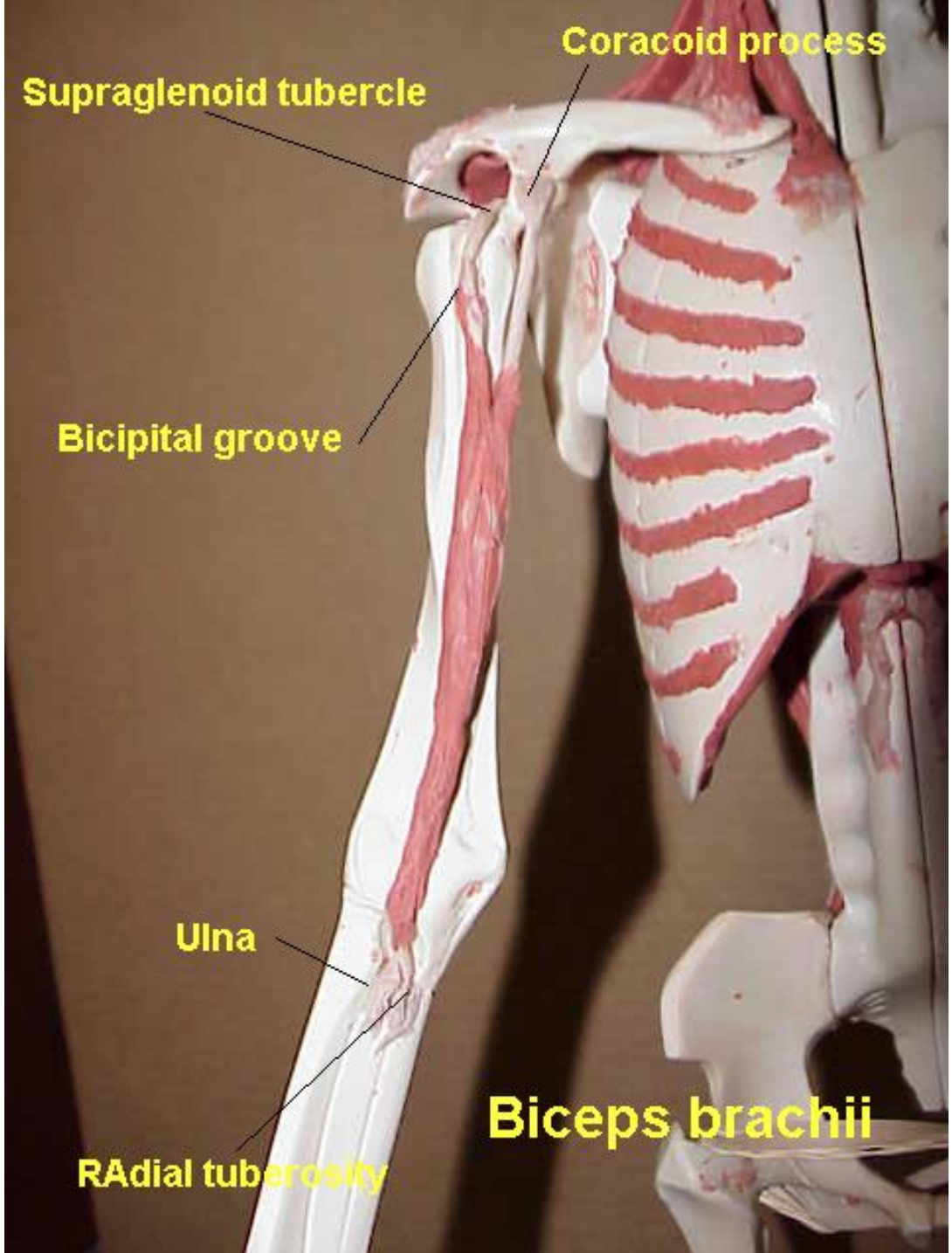
(d) Bipennate muscle
(Rectus femoris muscle)

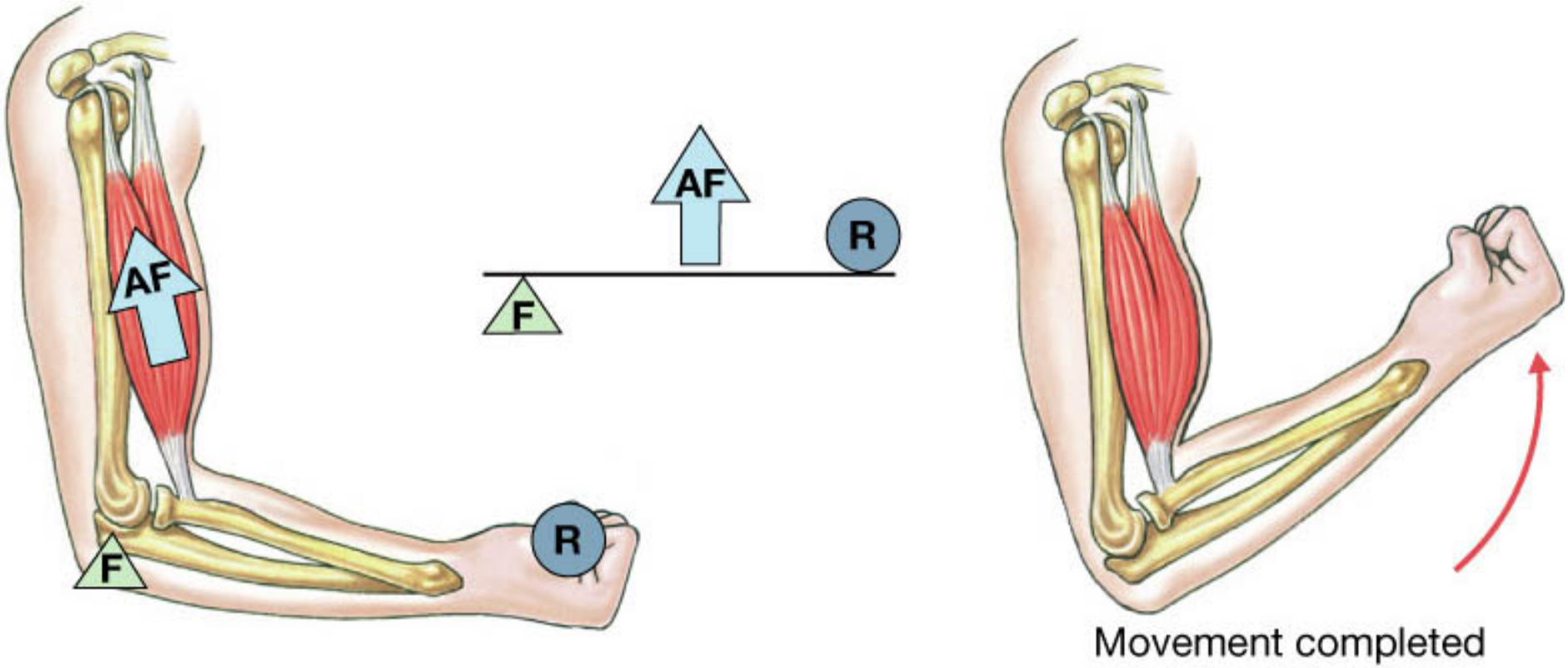


(e) Multipennate muscle
(Deltoid muscle)

Origins/Insertions/Actions of muscles

- Origins & insertions-the point on the skeleton where the tendon of a muscle attaches to the skeleton
- Origin-usually proximal to the insertion
- Actions-sarcomeres contract to pull the insertion closer to the origin
  - Move the skeleton (flexion, elevation, etc)

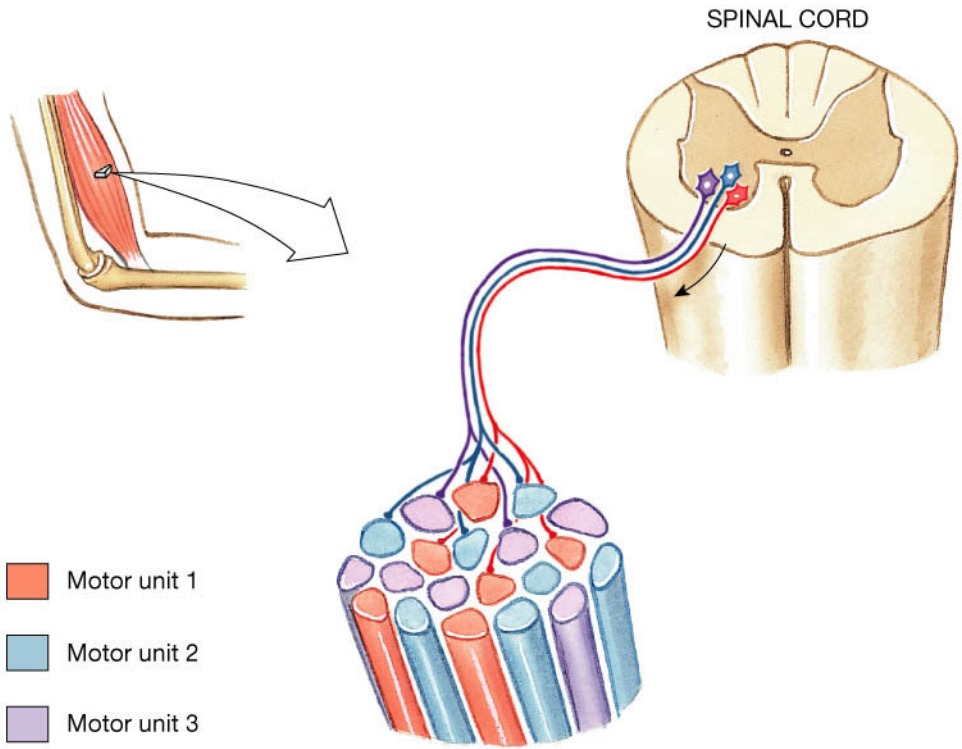

Coracoid process
Supraglenoid tubercle
Bicipital groove
Ulna
RAdial tuberosity
Biceps brachii



(c) Third-class lever

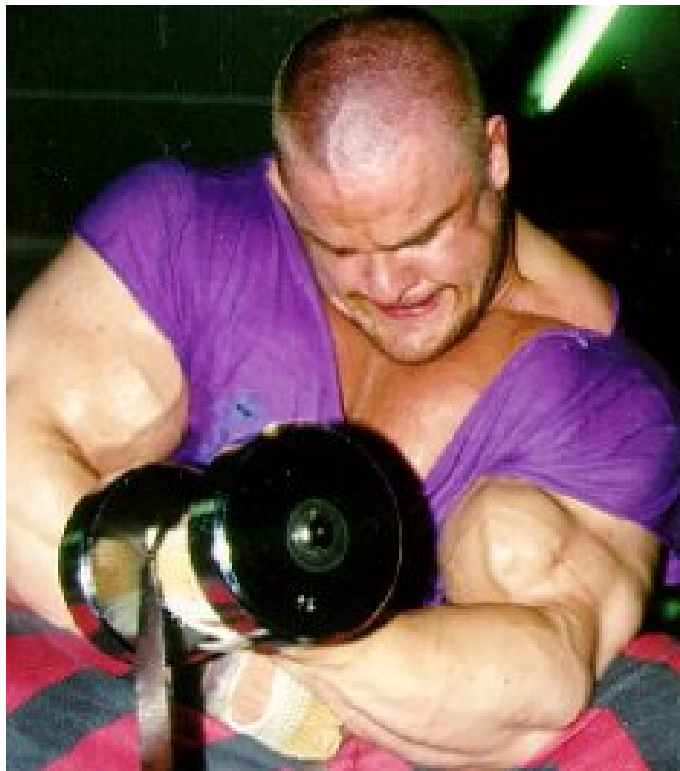
Motor unit

- All of the muscles fibers controlled by a single motor neuron
- Can range from 2 to 2,000 muscle fibers per motor unit



Exercise-muscle hypertrophy

- Exercise causes skeletal muscles to develop more myofibrils per sarcomere
- Hypertrophy of each muscle cell makes the entire muscle larger
- Increased concentrations of mitochondria & glycolytic enzymes



Sources of ATP in Muscle Tissue

FYI

1) Immediate – Creatine Phosphate

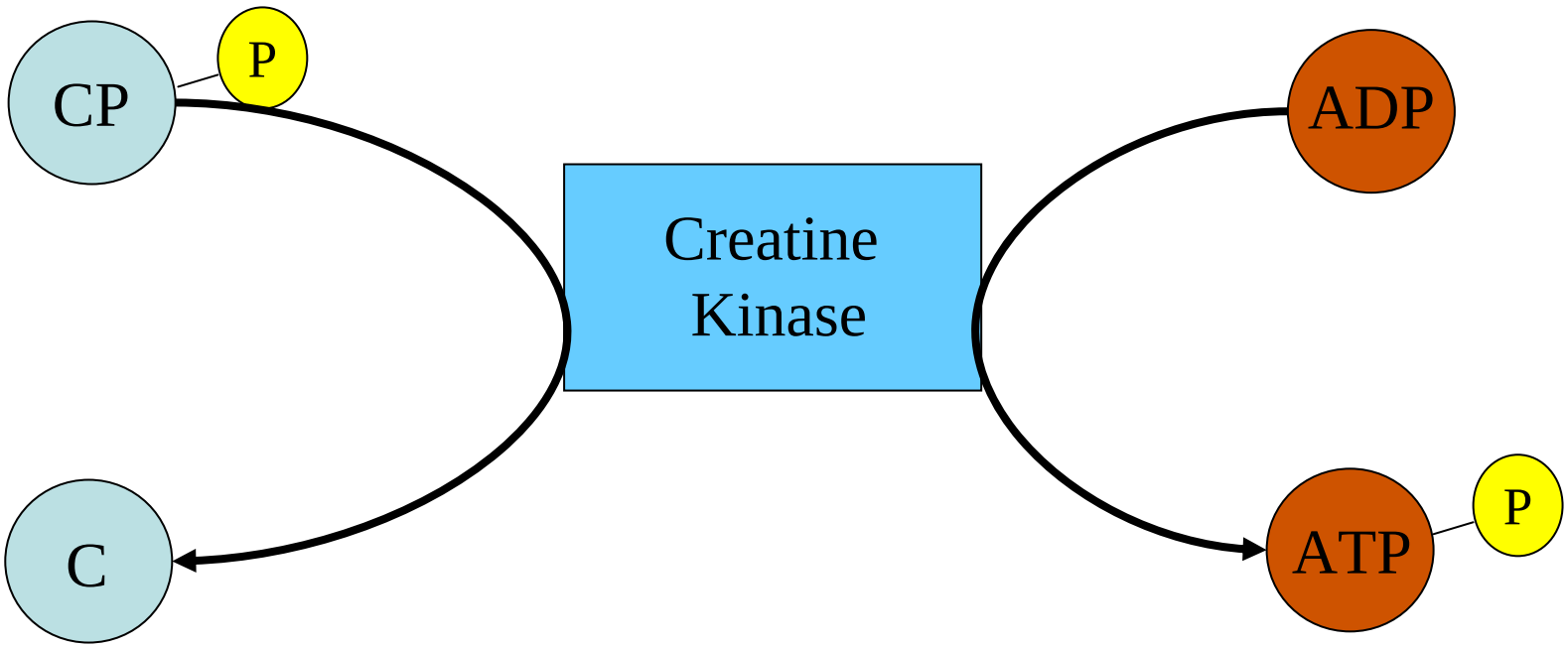
2) Short Term – Glycolysis (Lactic Acid)

3) Long Term – Oxidative Phosphorylation

1) Creatine Phosphate

FYI

- Takes P from creatine and sticks it on ADP



Muscle Fatigue

Depletion of O_2 - decrease in ATP available. FYI

Depletion of glucose or glycogen - decrease in ATP available.

Slows Na^+/K^+ pumps.

Lactic Acid Build-Up.

Motor neuron exhaust ACh: "junctional fatigue".

CNS (origin of signals) ”central fatigue”, mentally exhausted.

Types of skeletal muscle fibers

FYI

- FYI
- Slow red fibers
- Fast white fibers
- Intermediate fibers
- They vary in their blood supply, oxygen consumption, enzymes but that's physiology

1. Slow Twitch: Aerobic

- Slow onset of contraction
- Slower to fatigue
- More mitochondria
- More capillaries
- Myoglobin
- Smaller diameter
- Endurance activities
- Postural muscles

FYI

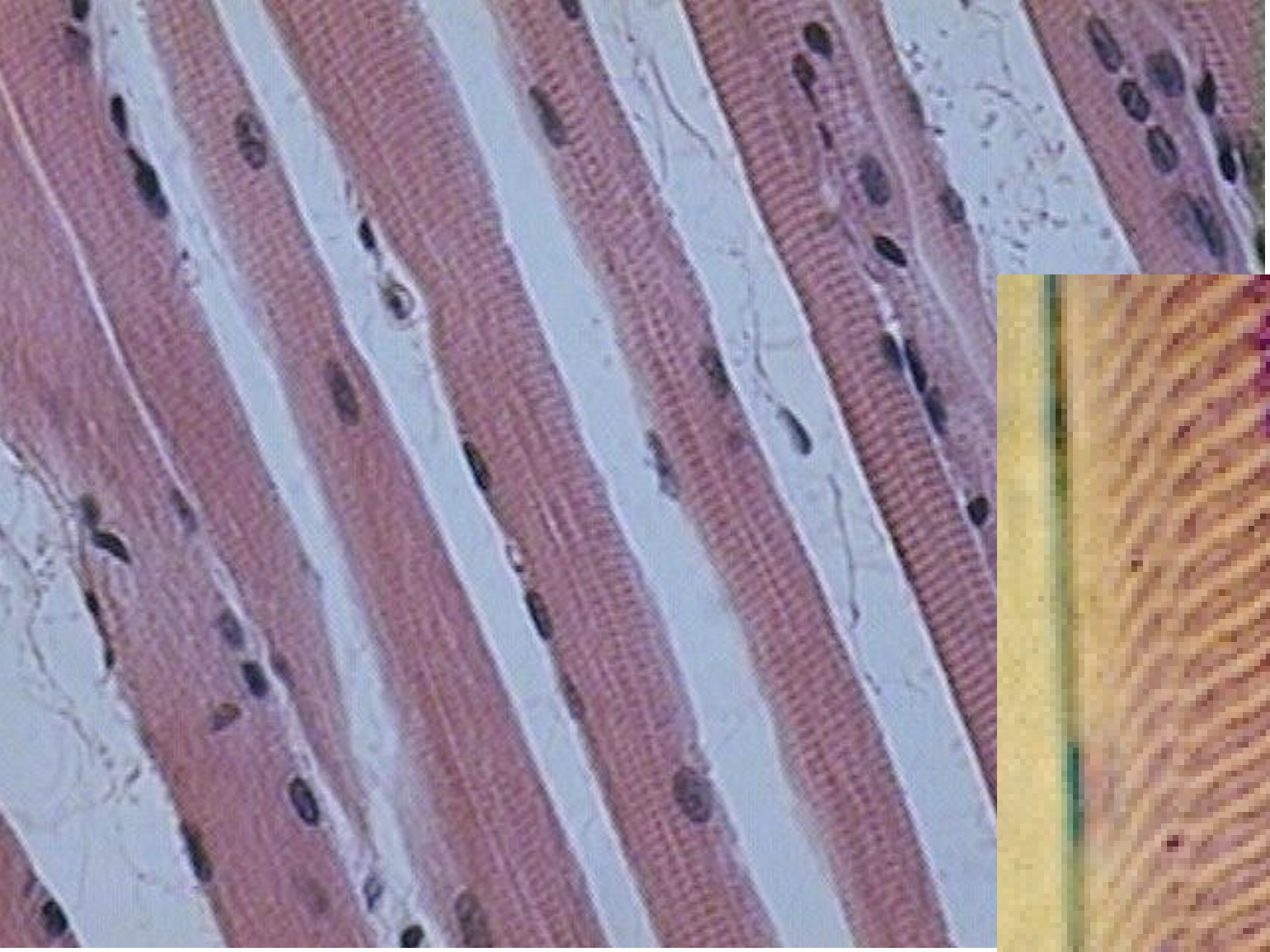
2. Fast Twitch:Anaerobic

- Fast onset of contraction
- Faster to fatigue
- Faster SR uptake of Ca^{2+}
- High glycogen stores
- Less mitochondria/blood
- Larger diameter
- Power lifting
- Sprint

break

Fascicle arrangements

- Models
- Cadaver



Muscle fibers, sarcolemma, nuclei,

a-band, I-band

Sliding filament theory

- Animations from CD