Fisiologi Otot

DR. HANNA CAKRAWATI
LABORATORIUM FISIOLOGI FK
UMM

Jaringan Otot

Jenis jaringan otot:

- Otot rangka→ melekat pada tulang→ gerakan tubuh
-
- Otot jantung→ pada jantung→ pompa jantung
- Otot polos→ otot organ dalam

Otot lurik

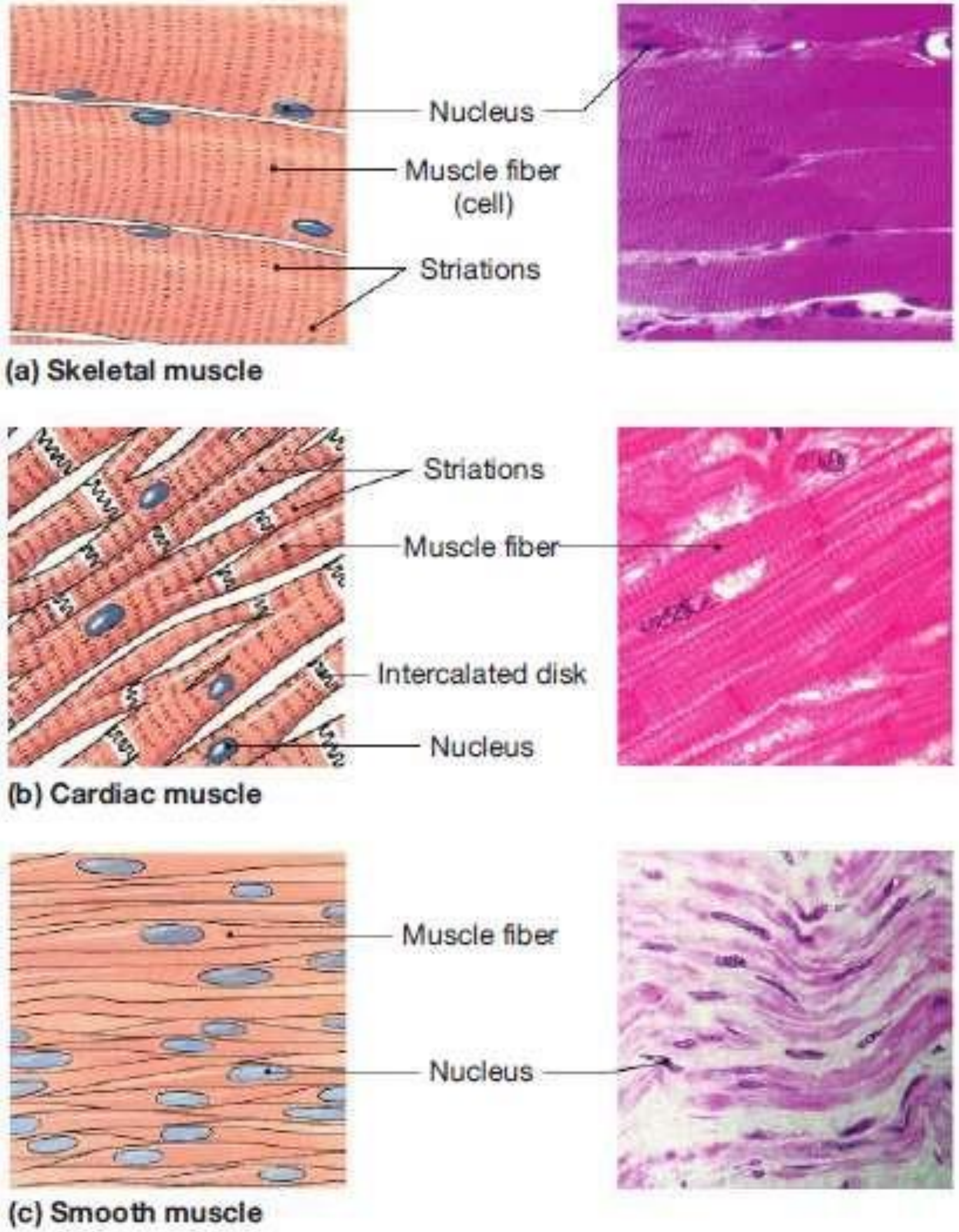


FIGURE 12-1 *The three types of muscles*

- Serat otot rangka merupakan sel besar dan berinti banyak, memperlihatkan gambaran lurik.

- Serat otot jantung juga bergaris namun lebih kecil, bercabang dan berinti tunggal. Sel tersusun secara seri melalui taut (diskus interkalaris)

- Serat otot polos berujuran kecil dan tidak bergaris (kurang terorganisasinya penataan serat kontraktil)

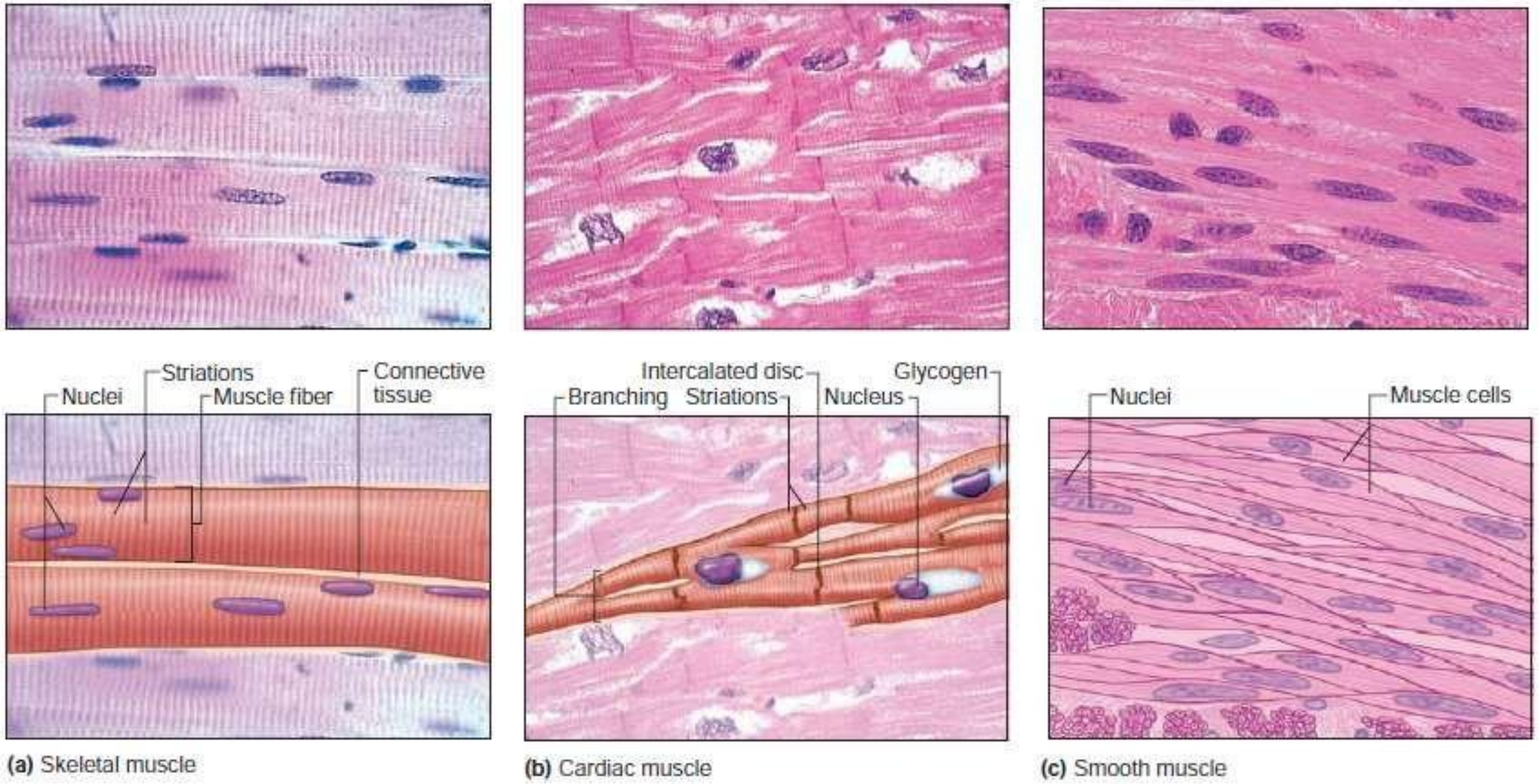


Figure 9–1

Comparison of skeletal muscle (a) to cardiac (b) and smooth (c) muscle. Both skeletal and cardiac muscle have a striated appearance. Cardiac and smooth muscle cells tend to have a single nucleus, while skeletal muscle fibers are multinucleated.

Fungsi Jaringan Otot

- Menghasilkan gerak tubuh→Membangkitkan gerakan serta menghasilkan gaya/kekuatan (kontraksi otot). Ex. Berjalan, berlari
- Menstabilkan posisi tubuh→kontraksi otot rangka menstabilkan sendi, otot postural berkontraksi secara kontinu ketika sadar. Ex otot leher
- Menghasilkan panas. Otot rangka juga menghasilkan panas dan berperan penting dalam menjaga keseimbangan suhu tubuh. (dingin→ menggigil)
- Menyimpan dan menggerakkan substansi dalam tubuh.
  - Menyimpan→kontraksi sfingter
  - Menggerakkan→ kontraksi otot jantung

Sifat Jaringan Otot secara Umum

- Eksitabilitas listrik, kemampuan memberikan respon terhadap stimulus tertentu dengan menghasilkan sinyal listrik yang disebut potensial aksi. Ex stimulus utama: pacemaker dan stimulus kimiawi (neurotransmitter, hormone, pH)
- Kontraktilitas, kemampuan jaringan otot untuk berkontraksi dgn kuat ketika dirangsang oleh potensial aksi.
- Ekstensibilitas, kemampuan jaringan otot untuk merenggang dalam batas-batas, tanpa menjadi rusak.ex: otot lambung saat terisi makanan
- Elastisitas, kemampuan jaringan otot untuk kembali ke panjang dan bentuk asalnya setelah kontraksi atau ekstensi.

Jaringan Otot Rangka

- Otot membentuk 40% berat badan total.
- Menggerakkan tubuh.
  - Otot rangka berkontraksi sebagai respon terhadap sinyal yg berasal dari neuron motoric somatic.
  - Kontraksi tidak di pengaruhi oleh hormone.

Istilah-istilah

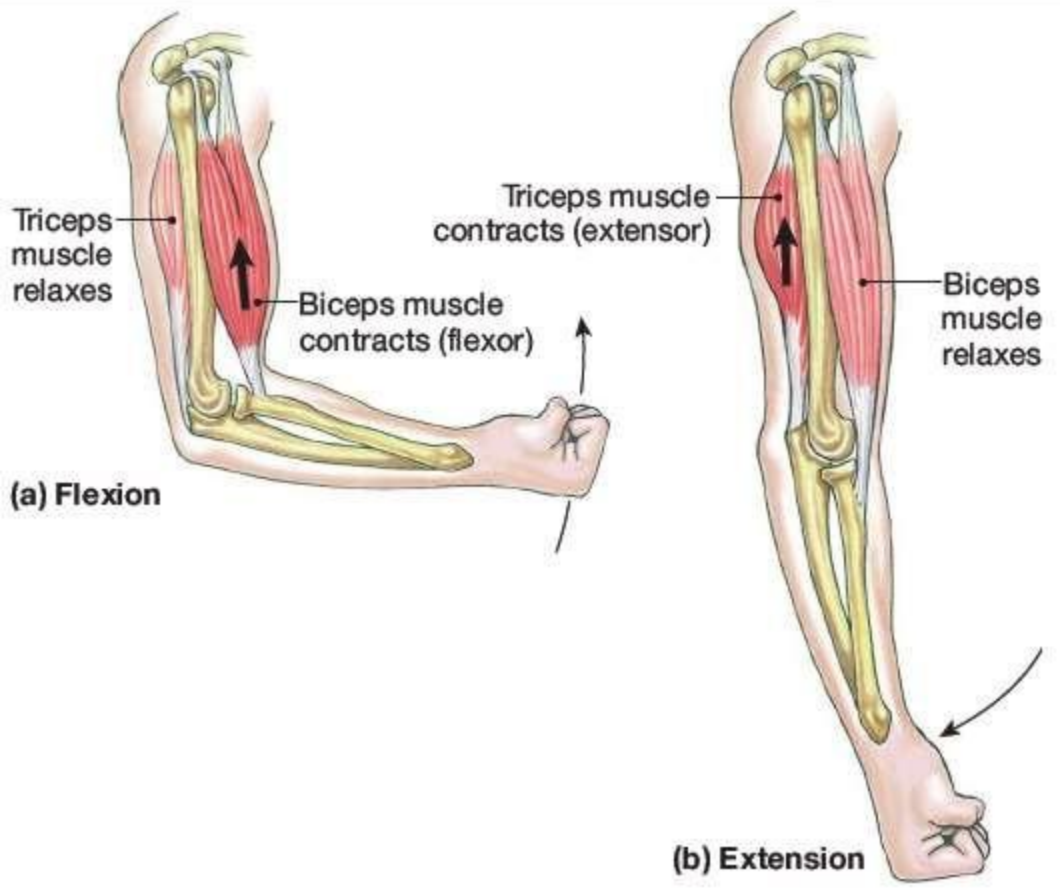
Tendon→ otot dilekatkan ke tulang melalui berupa serat kolagen.

Origo→ ujung otot melekat lebih dekat dgn batang tubuh (tulang yg tidak bergerak)

Insersio → ujung otot melekat lbh jauh dgn batang tubuh (tulang yg bergerak)

Otot fleksor (fleksi)

Otot ekstensor (ekstensi)



● **FIGURE 12-2** ***Antagonistic muscle groups move bones in opposite directions.*** Muscle contraction can pull on a bone but cannot push a bone away.

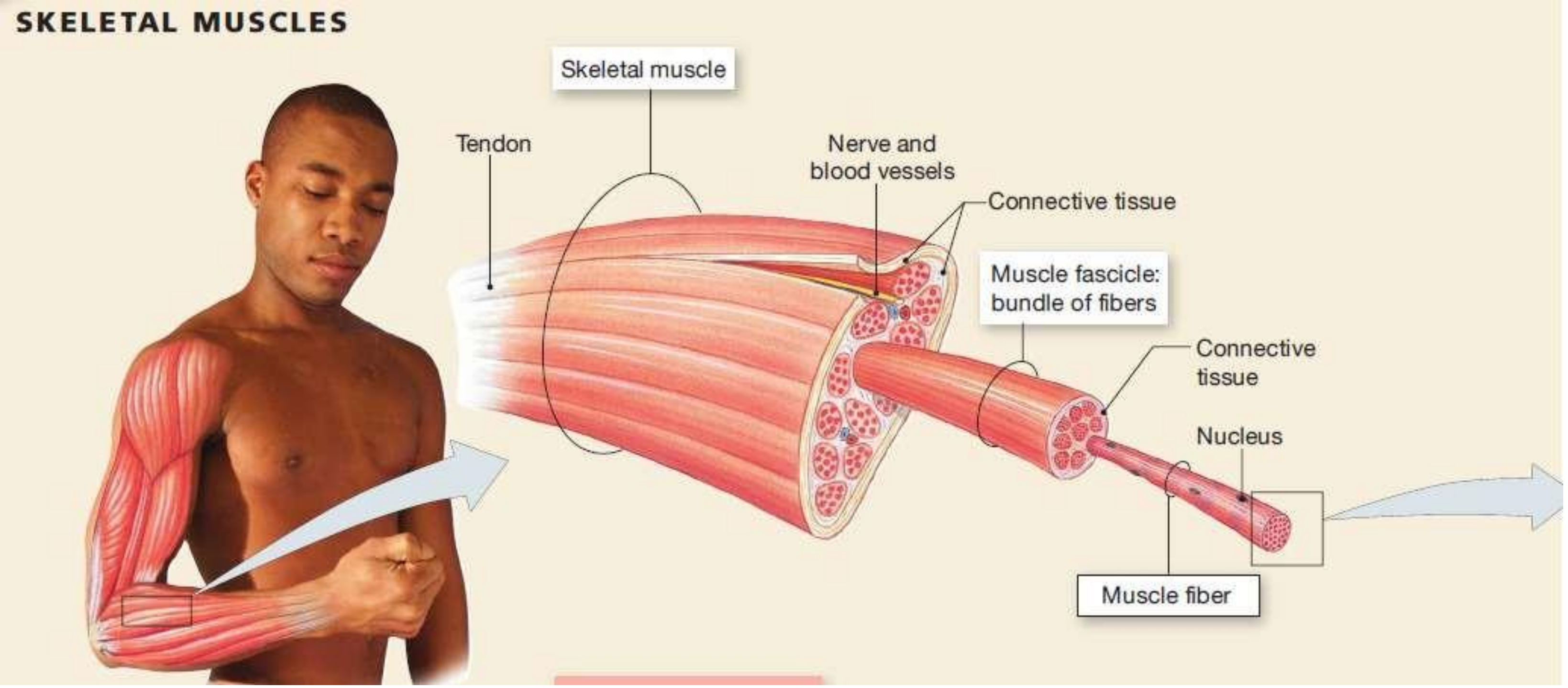
Otot fleksor (fleksi)→ gbr.A

Otot ekstensor (ekstensi)→gbr.B

Pasangan otot fleksor-ekstensor (**kelompok otot antagonis**):

Kontraksi dan pemendekan otot yg satu harus disertai relaksasi dan pemanjangan otot antagonisnya

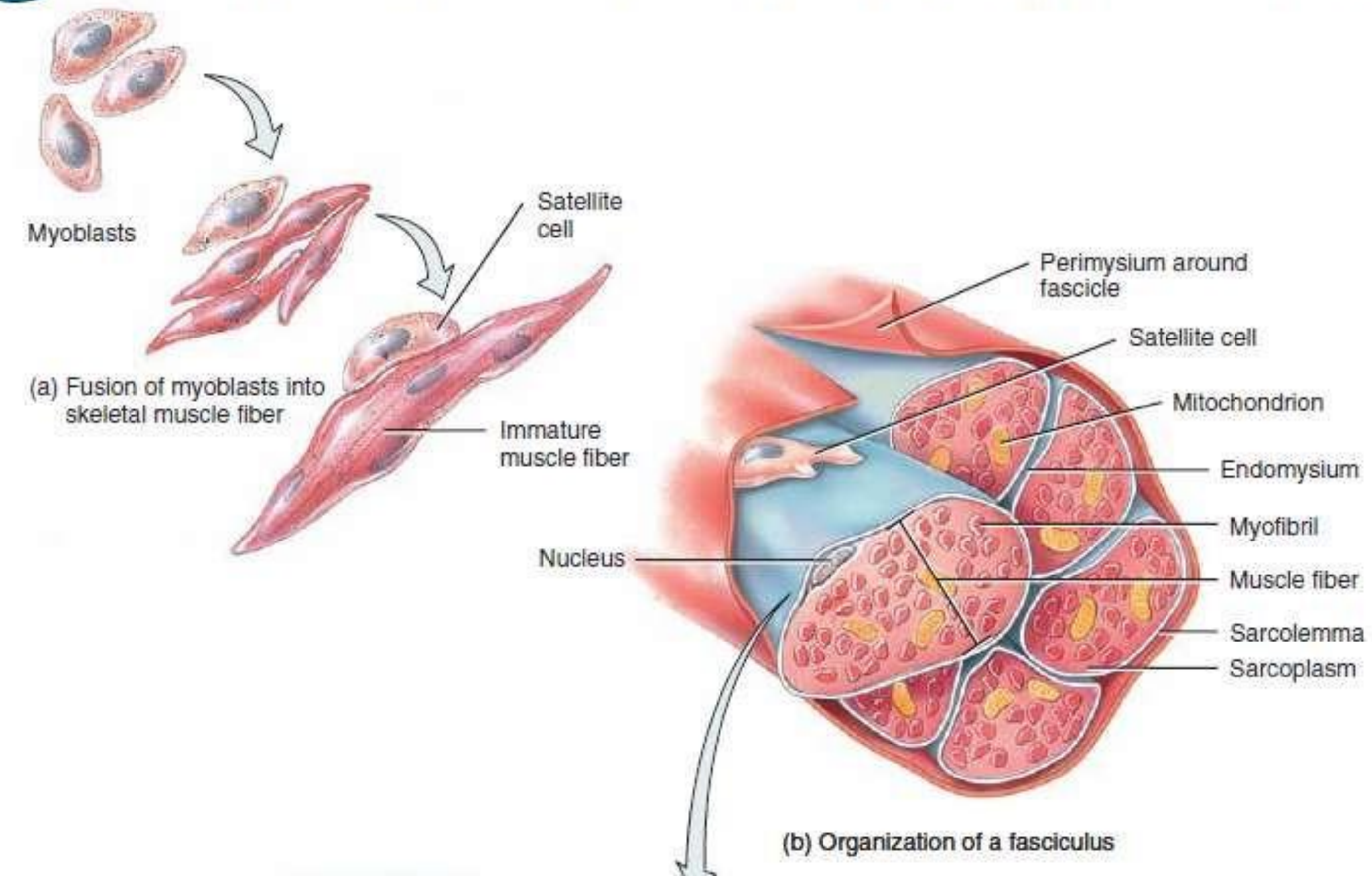
Otot Rangka Tersusun dari Serat-serat Otot



- Sel otot = serabut otot
- Satu berkas otot rangka→ sekumpulan serat otot (fasikulus otot)→ serat otot, sel berbentuk silinder yg panjang dan memiliki beratus inti di dekat permukaan sel.

Figure 10.2 Microscopic organization of skeletal muscle. (a) During embryonic development, many myoblasts fuse to form one skeletal muscle fiber. Once fusion has occurred, a skeletal muscle fiber loses the ability to undergo cell division, but satellite cells retain this ability. (b–d) The sarcolemma of the fiber encloses sarcoplasm and myofibrils, which are striated. Sarcoplasmic reticulum wraps around each myofibril. Thousands of transverse tubules, filled with interstitial fluid, invaginate from the sarcolemma toward the center of the muscle fiber. A triad is a transverse tubule and the two terminal cisterns of the sarcoplasmic reticulum on either side of it. A photomicrograph of skeletal muscle tissue is shown in Table 4.9.

6 The contractile elements of muscle fibers, the myofibrils, contain overlapping thick and thin filaments.



(a) Fusion of myoblasts into skeletal muscle fiber

(b) Organization of a fasciculus

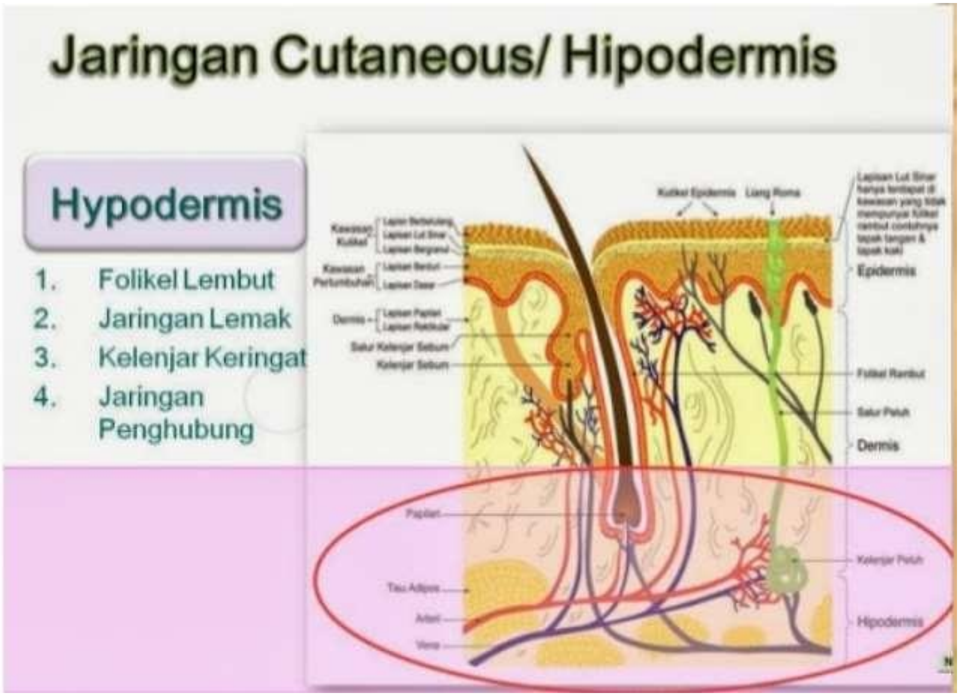
Kulit tersusun atas tiga lapisan, yaitu :

1. Epidermis
2. Dermis
3. Subkutan atau Hipodermis

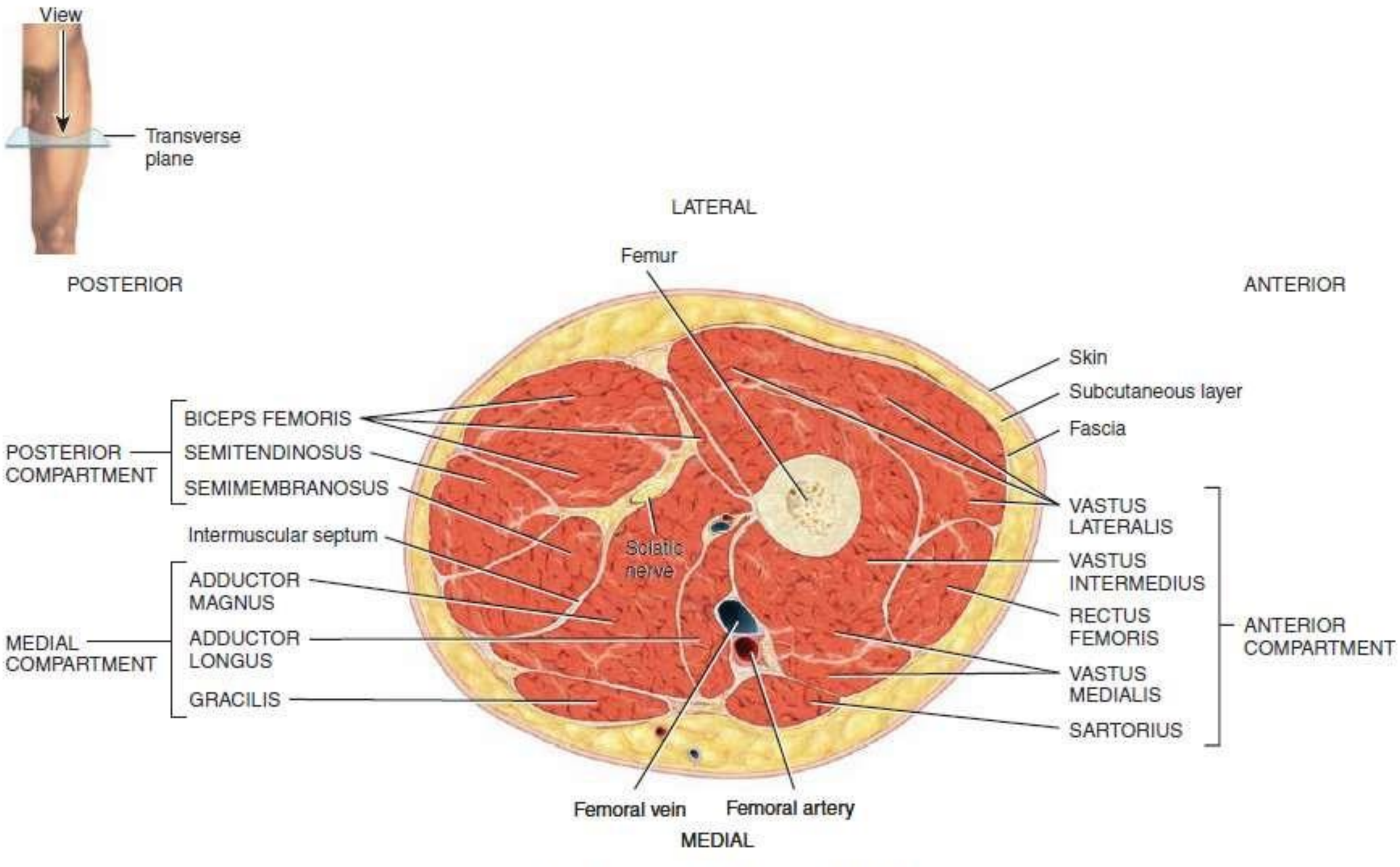
Memisahkan otot dari kulit, tersusun dari jar ikat alveolar dan jar adiposa

Pada bagian subdermis ini terdiri atas jaringan ikat longgar berisi sel-sel lemak di dalamnya.

Pada lapisan ini terdapat ujung-ujung saraf tepi, pembuluh darah dan getah bening.

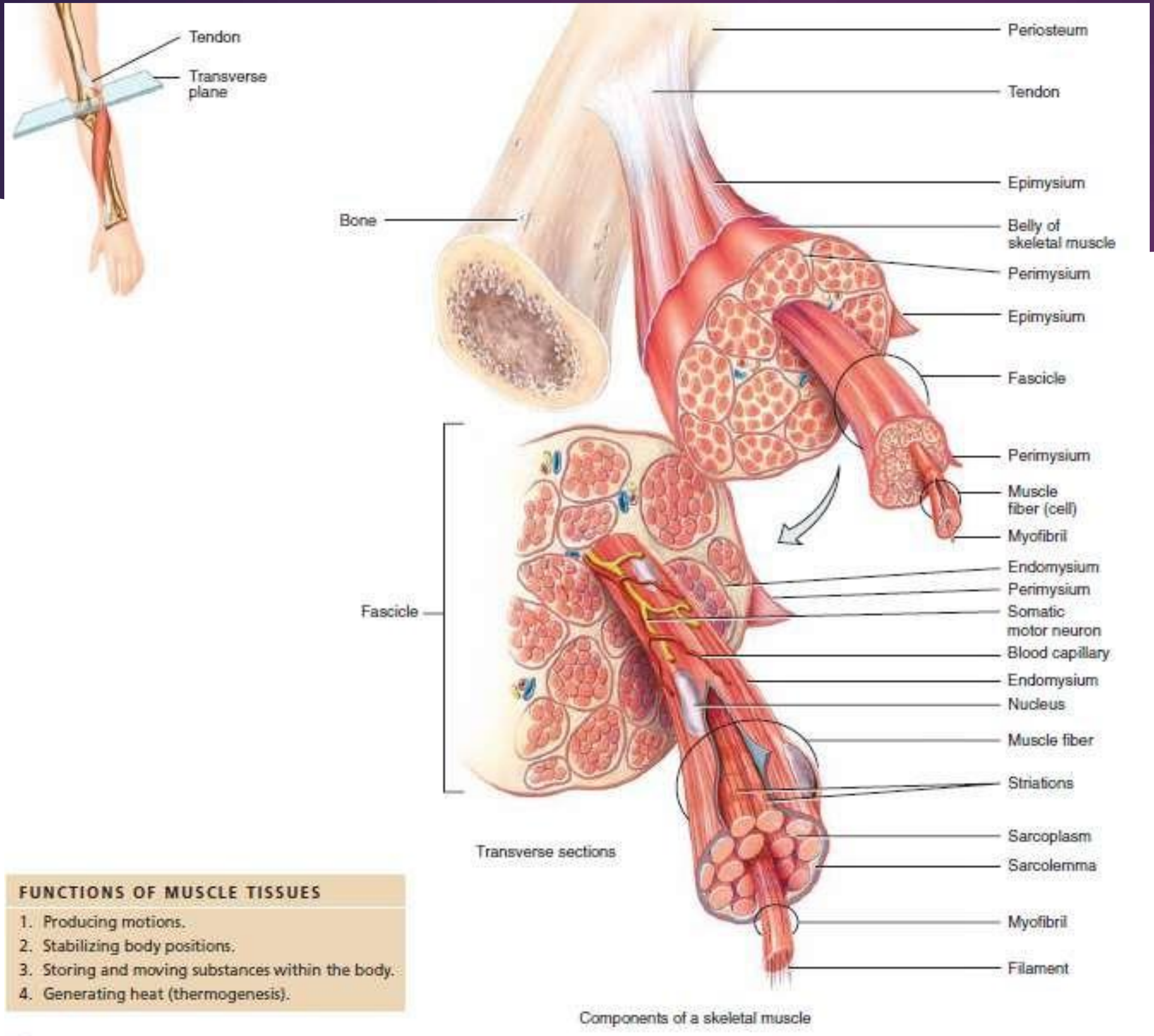


Jar. Adiposa pada lap subkutan menyimpan TG→ lap penyekat mengurangi hilangnya panas dan Melindungi dari trauma fisik



(a) Superior view of transverse section of thigh

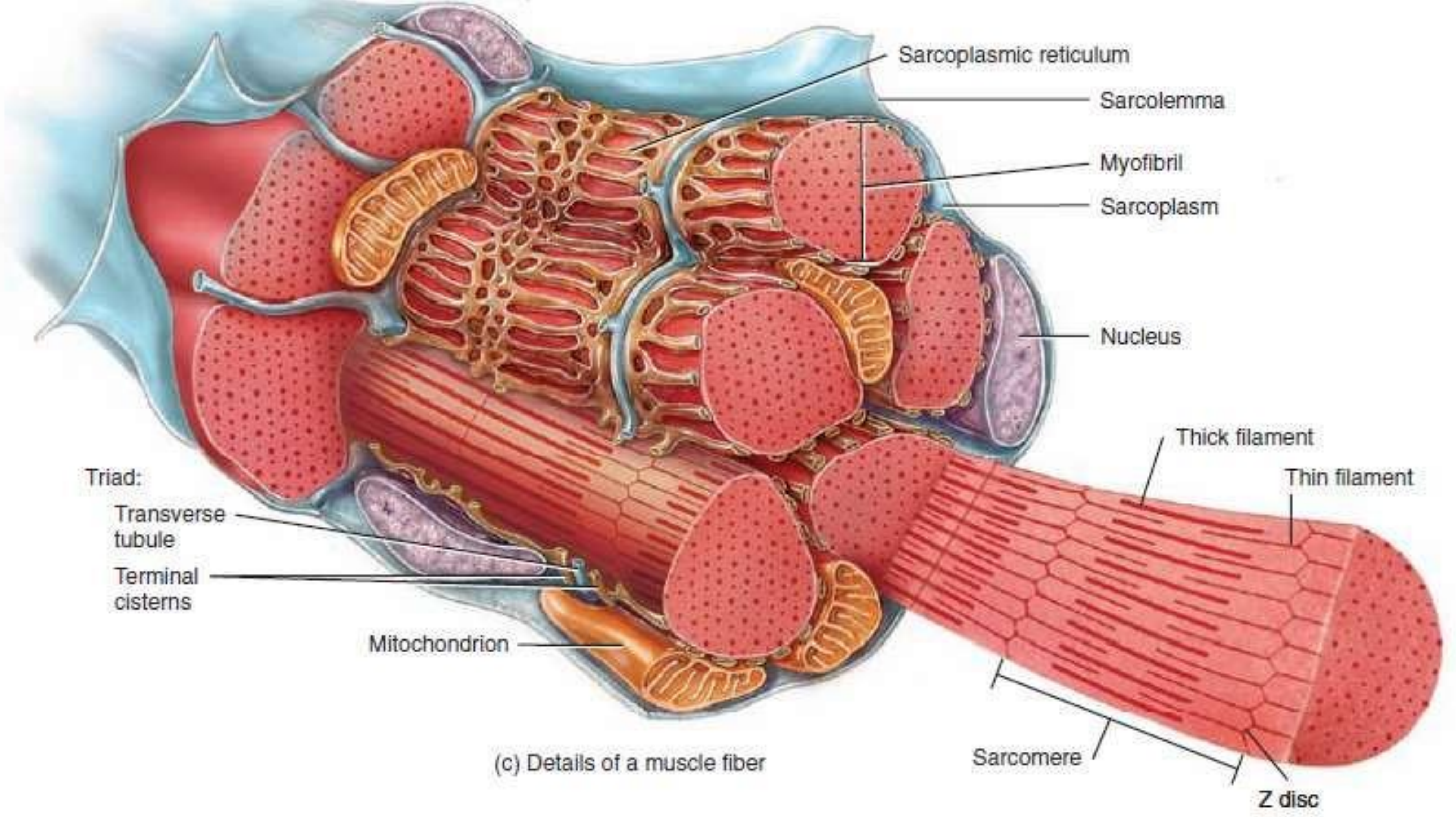
- Fasia→ lapisan padat atau pita lebar jar ikat tak teratur yg melapisi dinding tubuh dan ekstermitas serta menopang danmengelilingi otot dan organ-organ lain pada tubuh.
- 3 lapis jar ikat meluas dari fasia u melindungi dan memperkuat otot rangka
  - Epimisium
  - Perimisium
  - Endomisium



Components of a skeletal muscle

FUNCTIONS OF MUSCLE TISSUES

1. Producing motions.
2. Stabilizing body positions.
3. Storing and moving substances within the body.
4. Generating heat (thermogenesis).

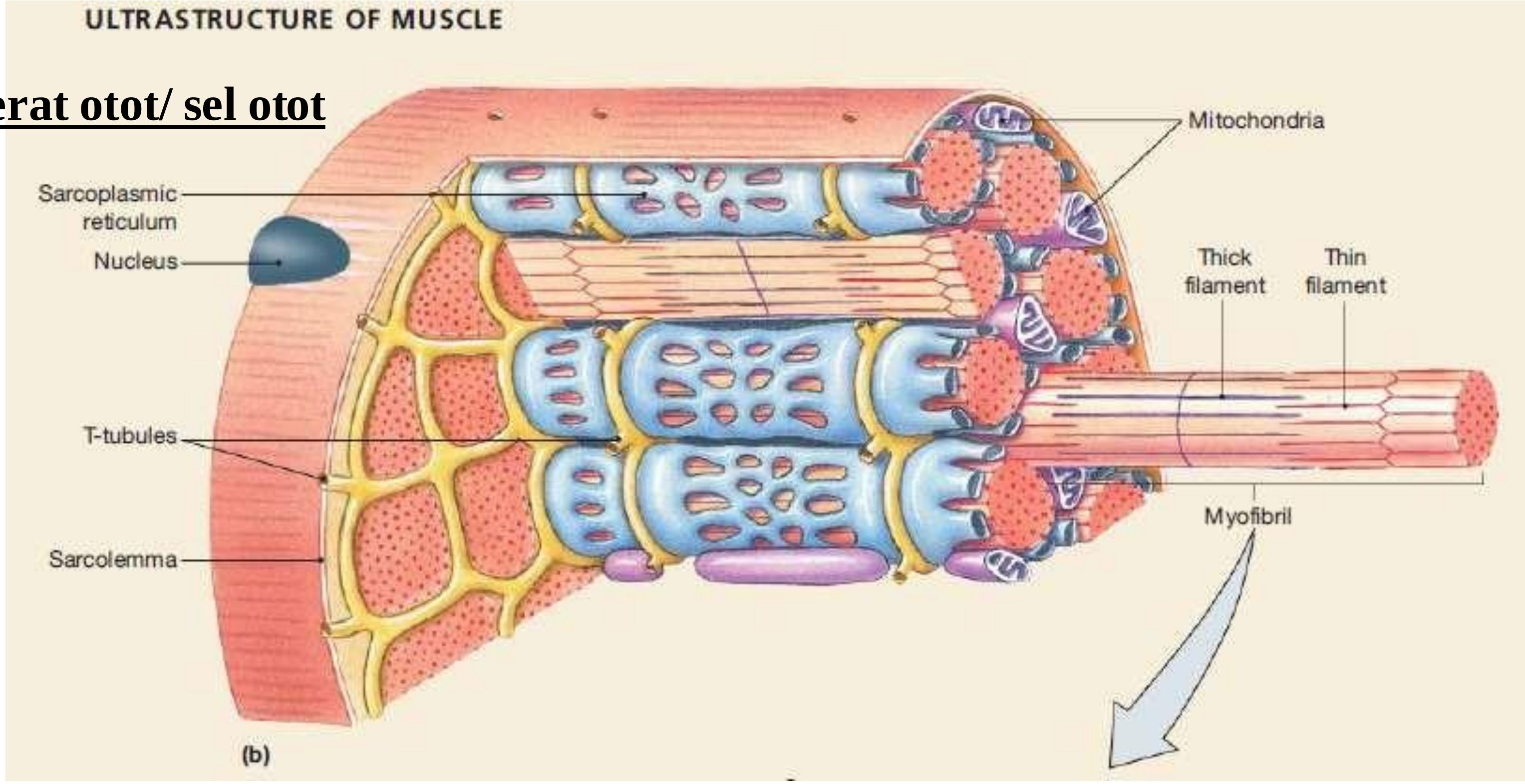


(c) Details of a muscle fiber

Terminologi Otot

TABLE 12-1 Muscle Terminology	
GENERAL TERM	MUSCLE EQUIVALENT
Muscle cell	Muscle fiber
Cell membrane	Sarcolemma
Cytoplasm	Sarcoplasm
Modified endoplasmic reticulum	Sarcoplasmic reticulum

Serat otot/ sel otot



- Sarkolema
  - Membran sel otot
- Tubulus Transversus (T)
  - Invaginasi kecil sarkolema, berisi cairan intrerstitial
  - Potensial aksi menjalar melalui sarkolema dan melalui tubulus T secara cepat menyebar ke seluruh serat otot.

- Sarkoplasma
- Sitoplasma sel otot

Ditemukan :

  - Glikogen
  - Protein myoglobin (fungsi sprt Hb)
- Miofibril→ kumpulan protein kontraktil dan elastis yang tersusun rapi yg menyelenggarakan kerja kontraksi.
- Retikulum sarkoplasma berfungsi untuk menghimpun dan menampung Ca (dgn bantuan Ca-ATPase di dlm membrane RS)

Tubulus T (Tubulus Transversal)

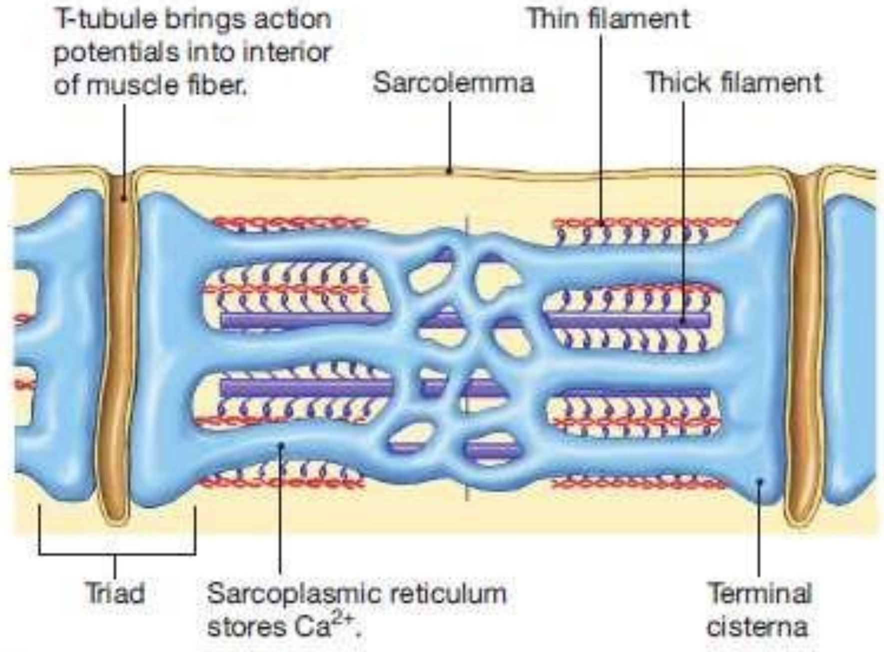
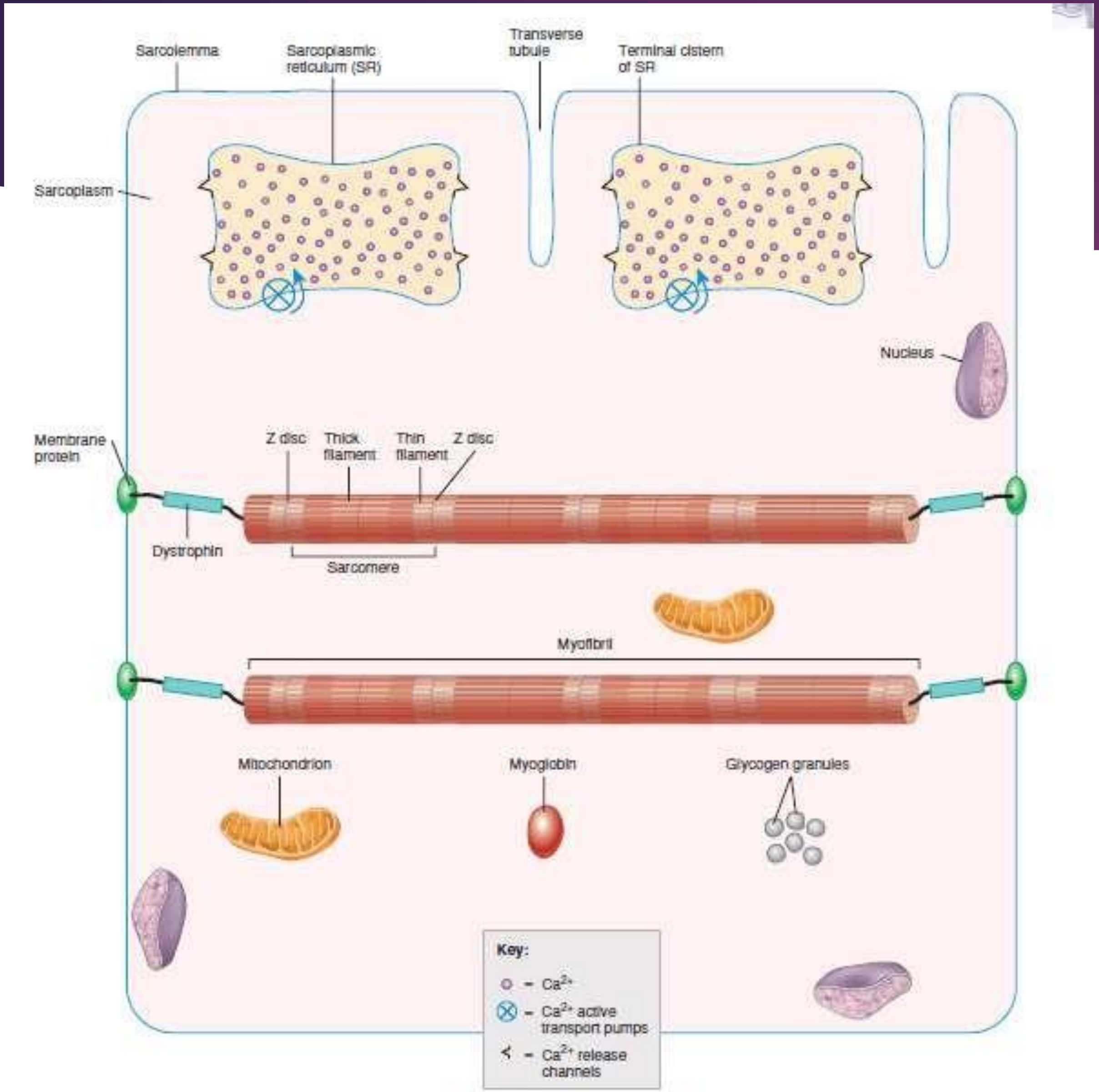


FIGURE 12-4 *T-tubules are linked to the terminal cisternae of the sarcoplasmic reticulum.*

- Tubulus T berhubungan langsung dgn cairan ekstrasel
- Memungkinkan potensial aksi bergerak cepat dari permukaan sel ke bagian dalam serat dan mencapai sisterna terminal.
- Tanpa adanya tubulus T, penjalaran potensial aksi hanya dapat dicapai bagian tengah serat otot
- Trias→ tubulus transversus dan 2 cisterna terminalis pada kedua sisinya.

Gambaran Sederhana Sel otot

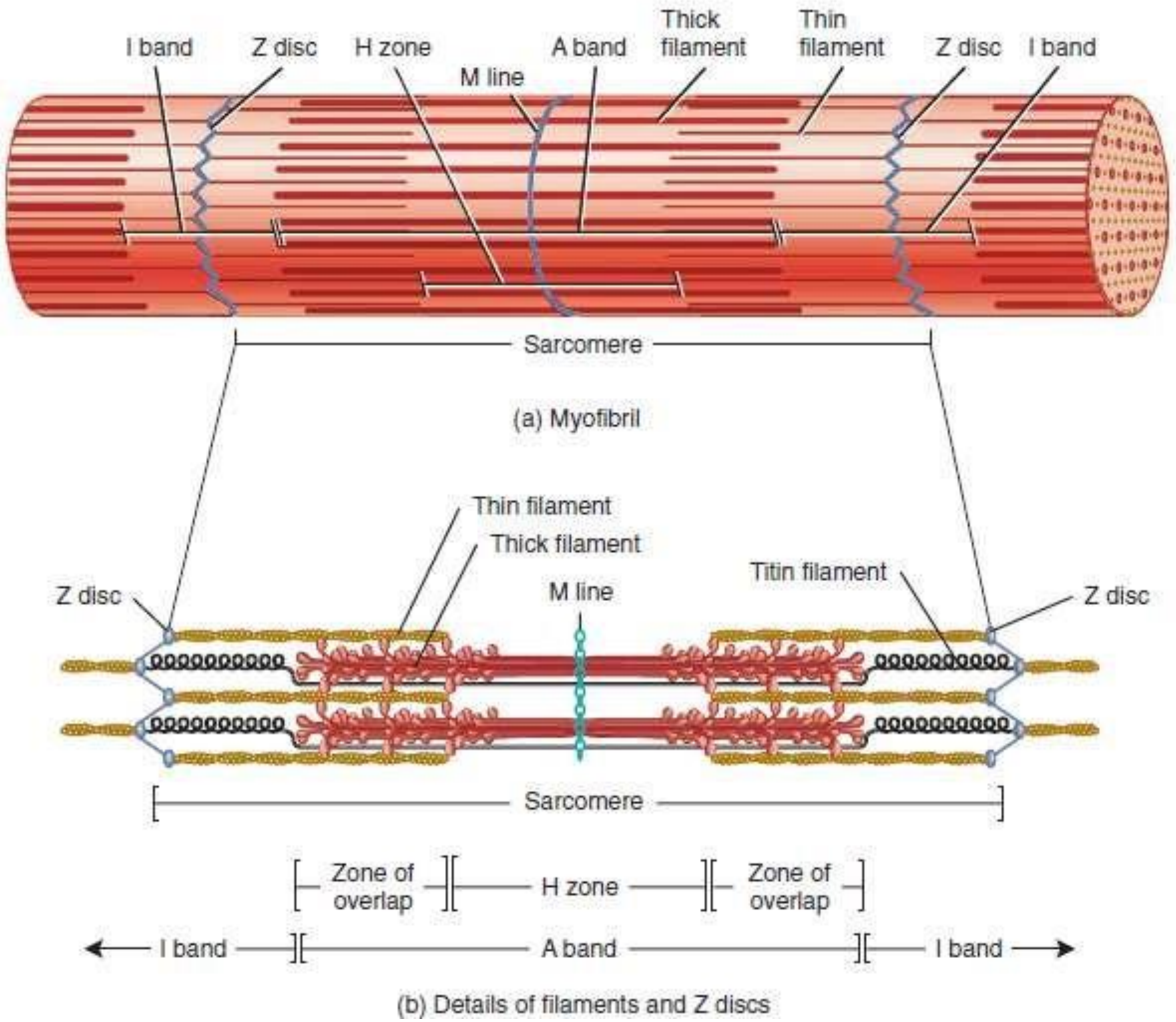


(d) Simplistic representation of a muscle fiber

Filamen dan Sarkomer

Figure 10.3 The arrangement of filaments within a sarcomere. A sarcomere extends from one Z disc to the next.

Myofibrils contain two types of filaments: thick filaments and thin filaments.



Didalam myofibril terdapat struktur protein lbh kecil, yaitu: Filamen (miofilamen)

- **Filamen tipis**→ tersusun protein aktin. Aktin (aktin-G) memiliki satu situs pengikat myosin
- **Filamen tebal**→ tersusun protein myosin→protein penggerak yg memiliki kemampuan untuk mewujudkan gerakan. Kepala myosin memiliki satu situs pengikat aktin dan satu situs pengikat ATP

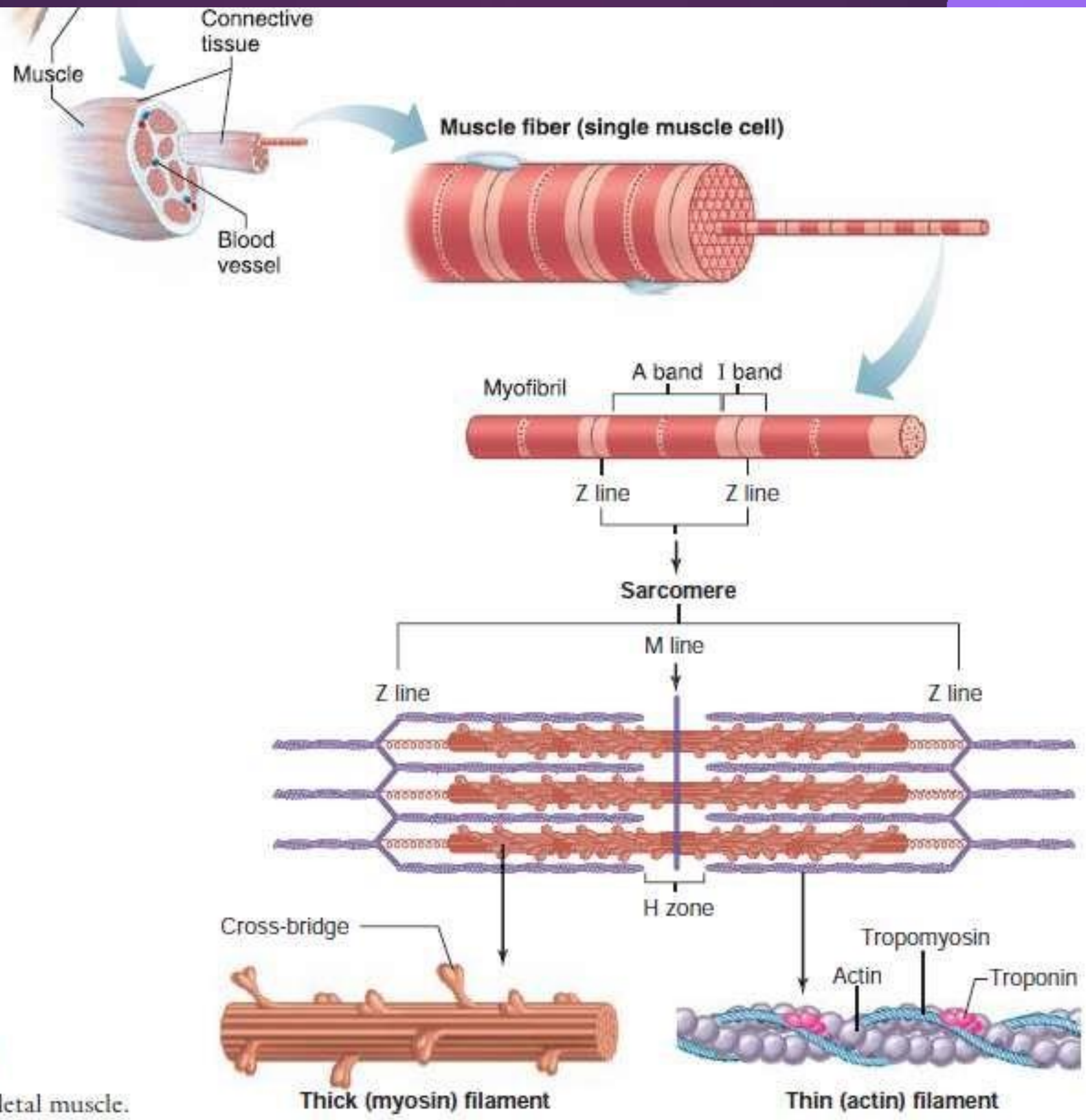


Figure 9–2

Structure of skeletal muscle.

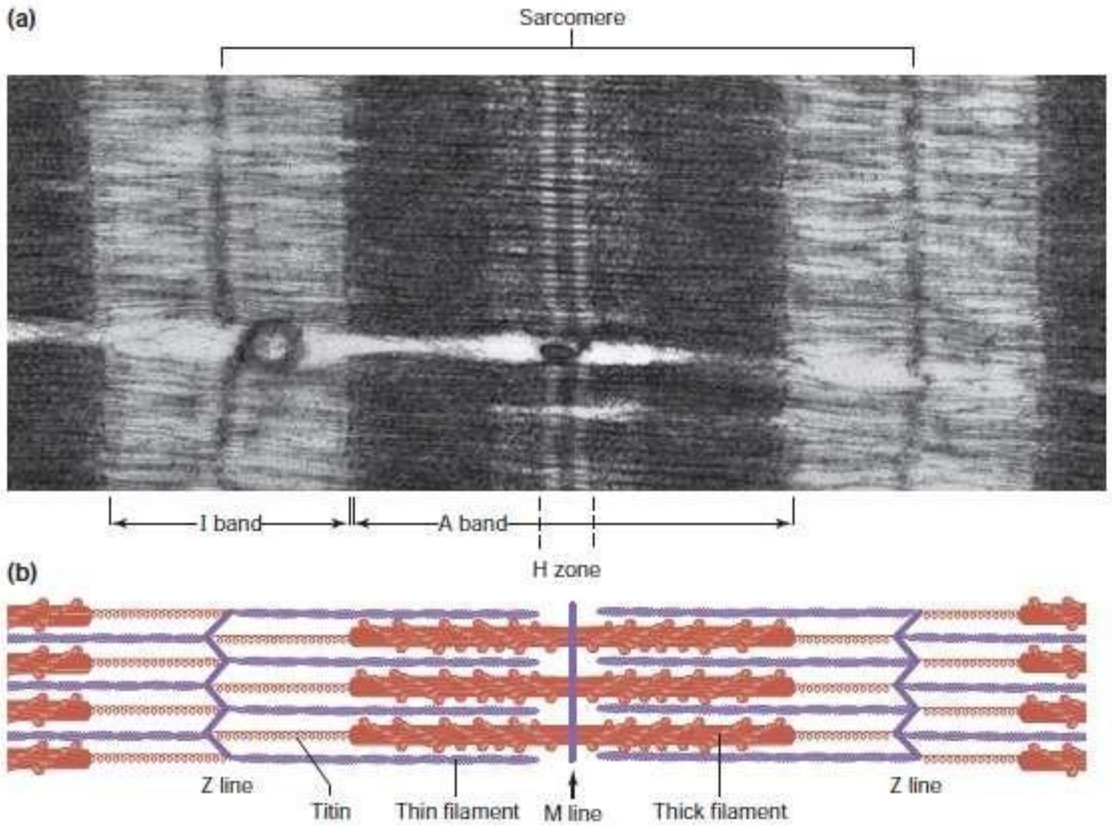


Figure 9–3
(a) High magnification of a sarcomere within myofibrils. (b) Arrangement of the thick and thin filaments in the sarcomere shown in (a).

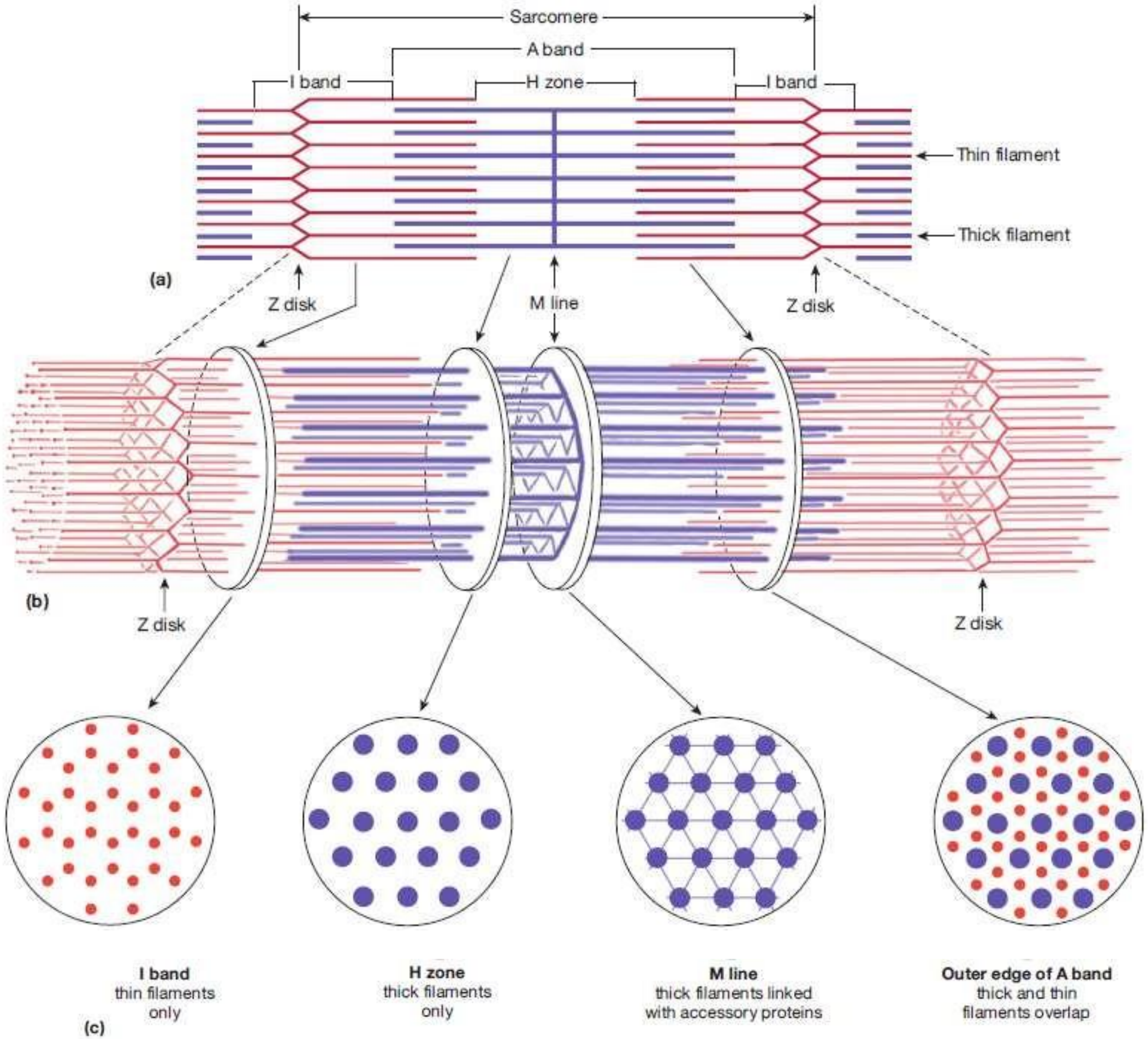
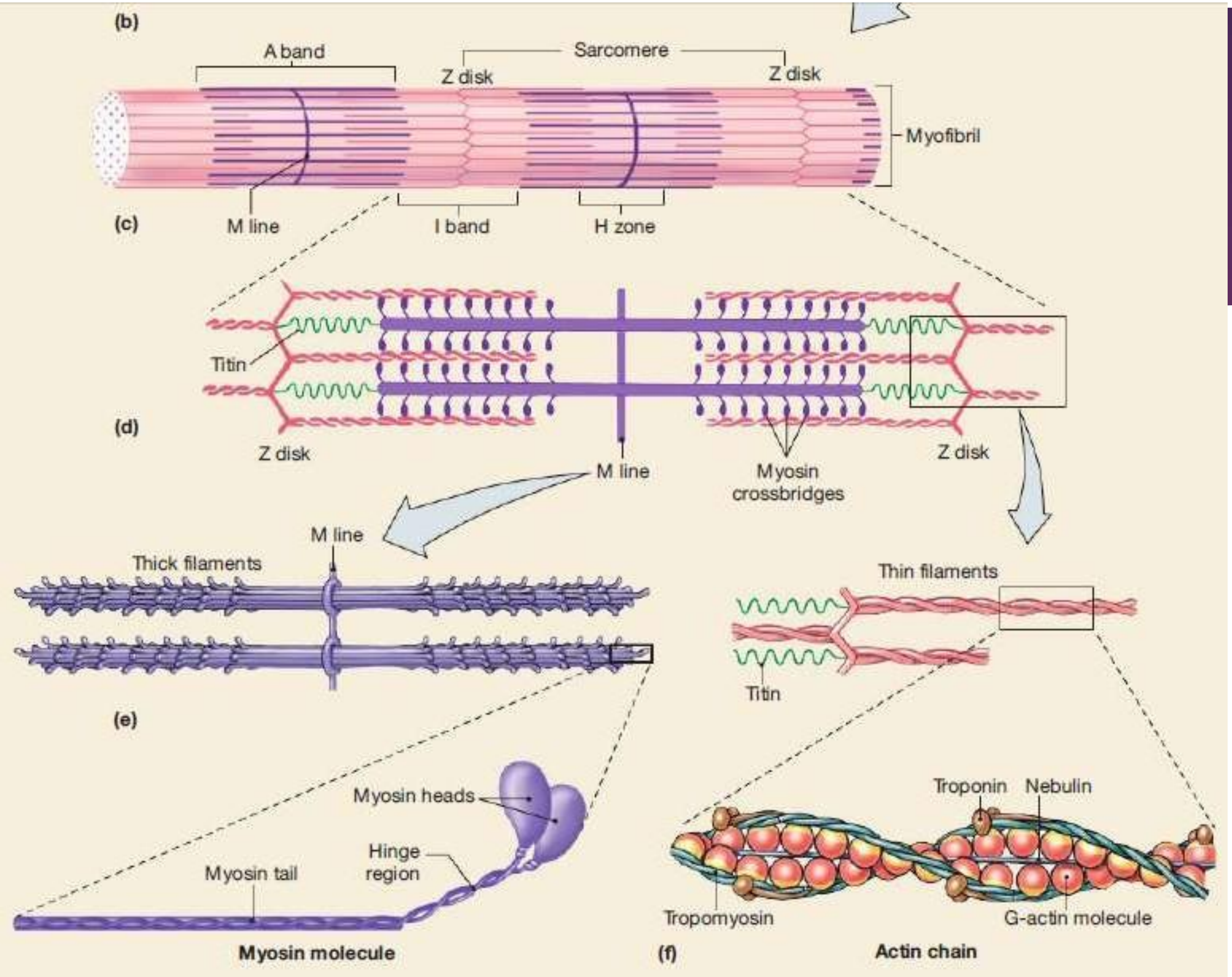


FIGURE 12-5 *The two- and three-dimensional organization of a sarcomere.* The Z disk (not shown in part c) has accessory proteins that link the thin filaments together, similar to the accessory proteins shown for the M line.

Komponen Sarkomer:

- Lempeng Z (discus z),Unit fungsional dasar myofibril, memisahkan satu sarkomer dgn sarkomer lain
- Pita I (tipis)
- Pita A, bag tengah sarkomer terdapat zona tumpang tindih
- Zona H (tebal)
- Garis M, protein penunjang yg menahan filament tebal bersama-sama pada bag tengah zona H



- Miofibril terbentuk dari 3 jenis protein:
  - Protein kontraktil (aktin dan myosin)→ menghasilkan kekuatan selama kontraksi
  - Protein pengatur (troponin dan tropomiosin)→ membantu menyalakan dan mematikan proses kontraksi
  - Protein structural (Titin, α-aktinin, miomesin, nebulin, dan distrofin)→ berperan pada kesegarisan, stabilitas, elastisitas, dan ekstensibilitas myofibril.

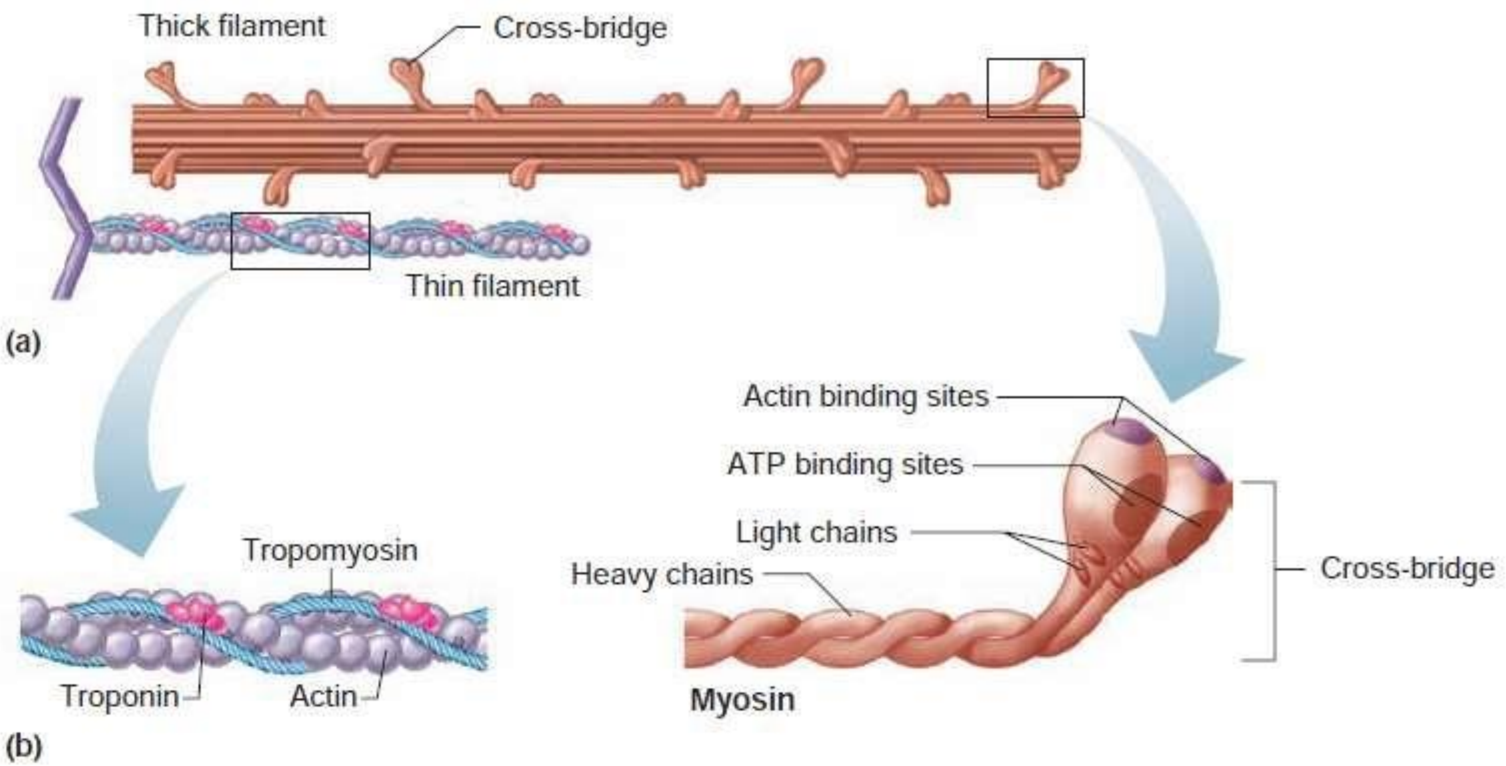
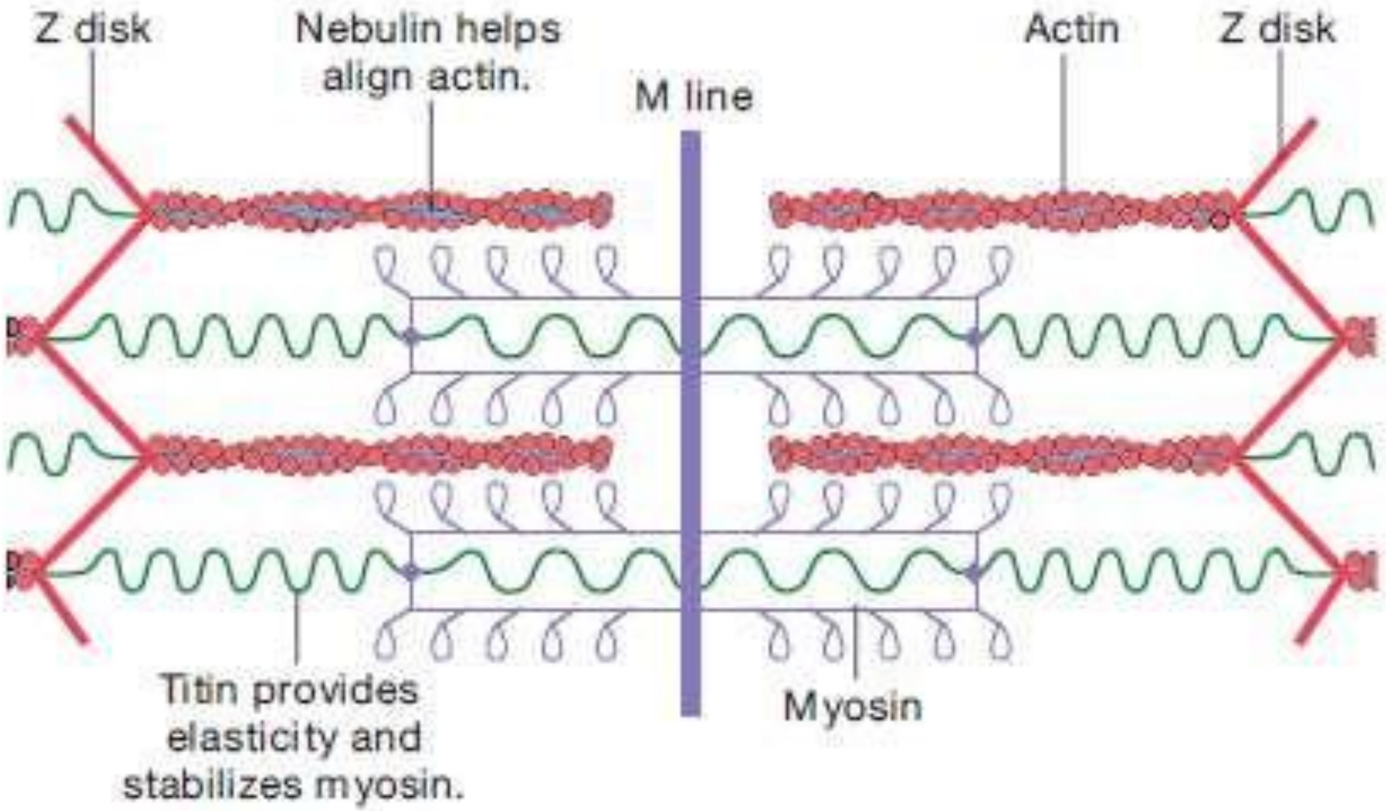


Figure 9–7

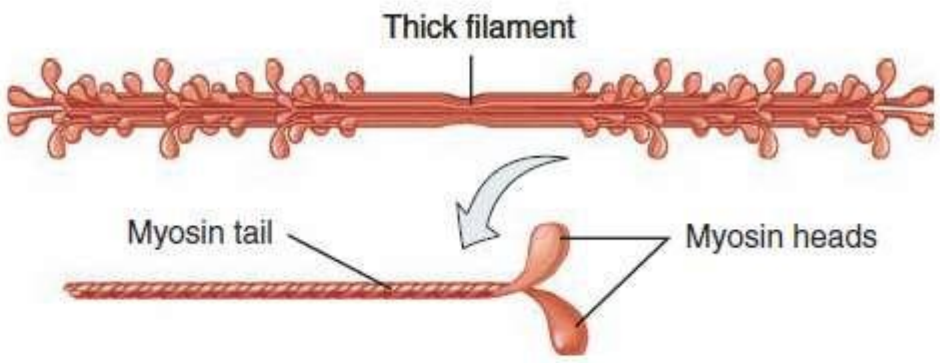
(a) The heavy chains of myosin molecules form the core of a thick filament. The myosin molecules are oriented in opposite directions in either half of a thick filament. (b) Structure of thin filament and myosin molecule. Cross-bridge binding sites on actin are covered by tropomyosin. The two globular heads of each myosin molecule extend from the sides of a thick filament, forming a cross-bridge.



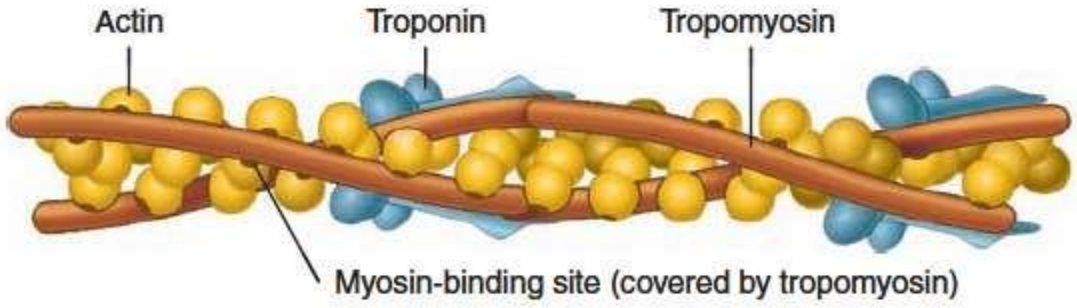
● **FIGURE 12-6** *Titin and nebulin are giant accessory proteins.* Titin spans the distance from one Z disk to the neighboring M line. Nebulin, lying along the thin filaments, attaches to a Z disk but does not extend to the M line.

Figure 10.4 **Structure of thick and thin filaments.** (a) A thick filament contains about 300 myosin molecules, one of which is shown enlarged. The myosin tails form the shaft of the thick filament, and the myosin heads project outward toward the surrounding thin filaments. (b) Thin filaments contain actin, troponin, and tropomyosin.

Contractile proteins (myosin and actin) generate force during contraction; regulatory proteins (troponin and tropomyosin) help switch contraction on and off.



(a) A thick filament and a myosin molecule



(b) Portion of a thin filament

Jembatan silang→ myosin dan aktin berikatan

Which proteins connect into the Z disc? Which proteins are present in the A band? In the I band?

Miofibril adalah Struktur Kontraktil Serat Otot

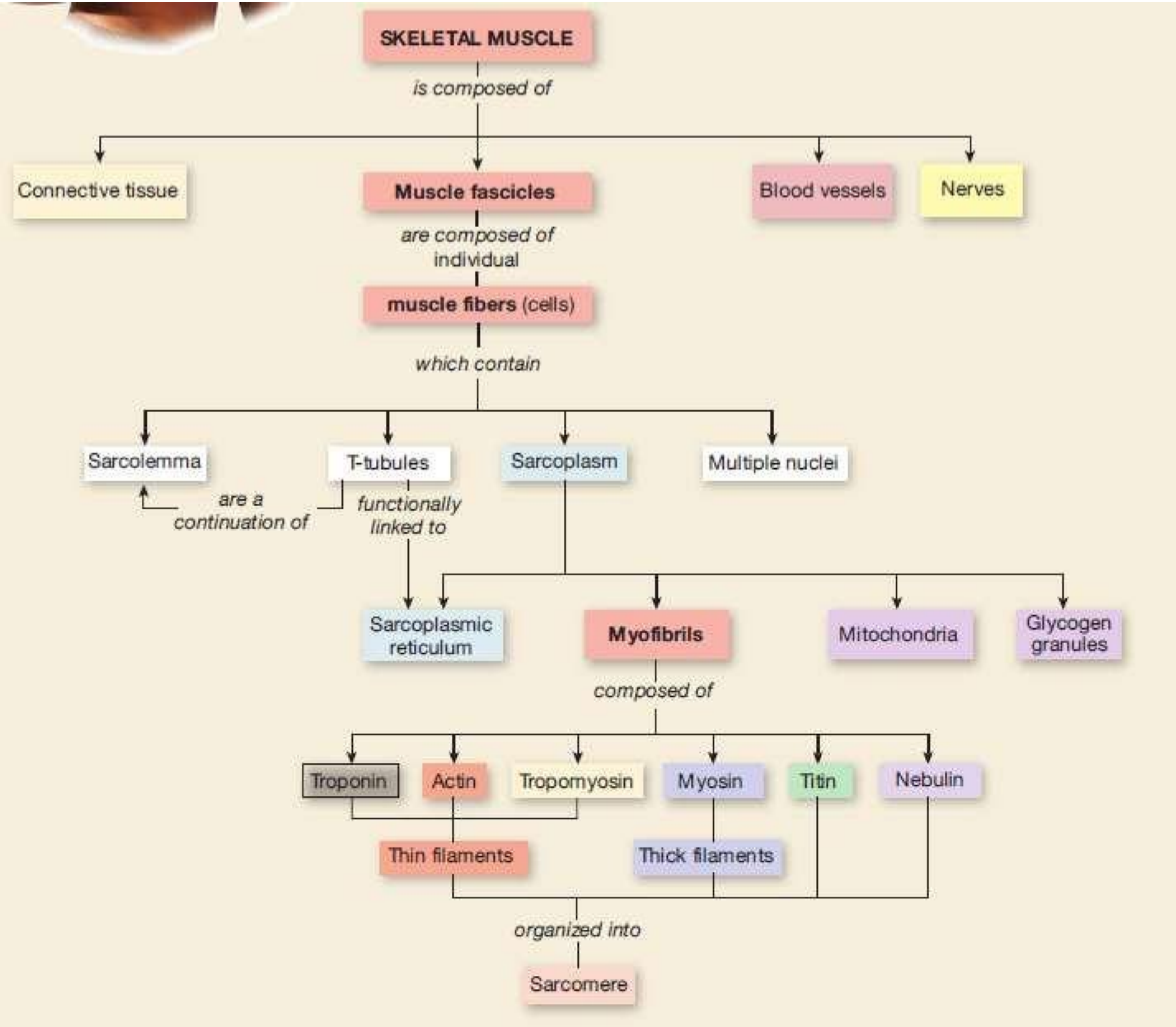
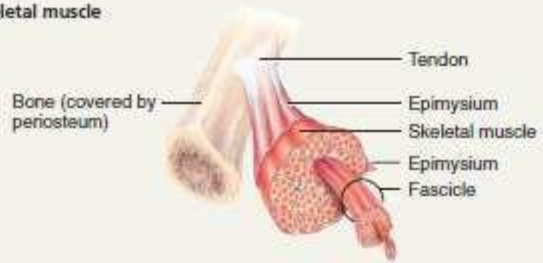
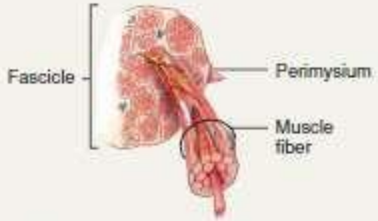
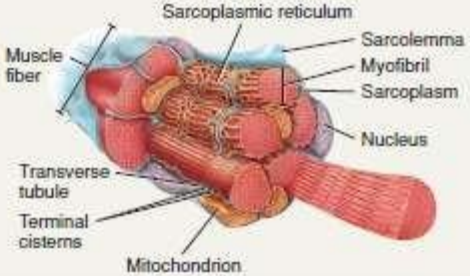
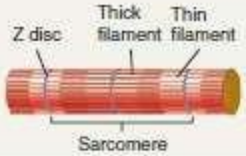
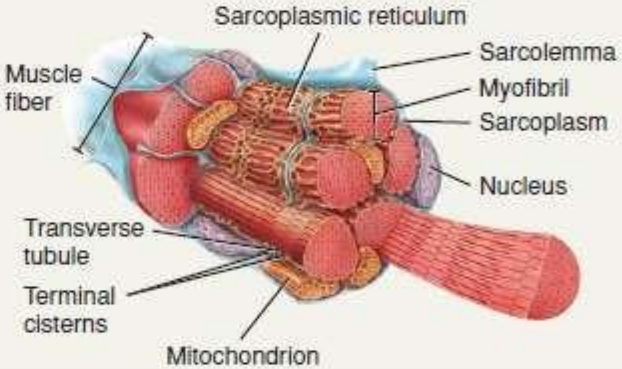


TABLE 10.3

Levels of Organization within a Skeletal Muscle

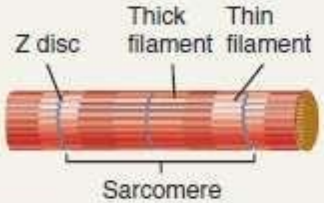
LEVEL	DESCRIPTION
Skeletal muscle 	Organ made up of fascicles that contain muscle fibers (cells), blood vessels, and nerves; wrapped in epimysium.
Fascicle 	Bundle of muscle fibers wrapped in perimysium.
Muscle fiber (cell) 	Long cylindric sarcoplasm, m transverse tubu has a striated a
Myofibril 	Threadlike con extend entire l

Muscle fiber (cell)



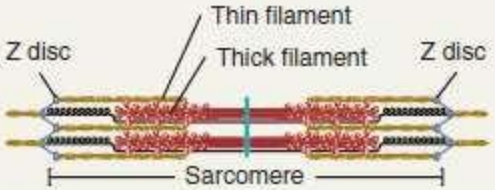
Long cylindrical cell covered by endomysium and sarcolemma; contains sarcoplasm, myofibrils, many peripherally located nuclei, mitochondria, transverse tubules, sarcoplasmic reticulum, and terminal cisterns. The fiber has a striated appearance.

Myofibril



Threadlike contractile elements within sarcoplasm of muscle fiber that extend entire length of fiber; composed of filaments.

Filaments (myofilaments)



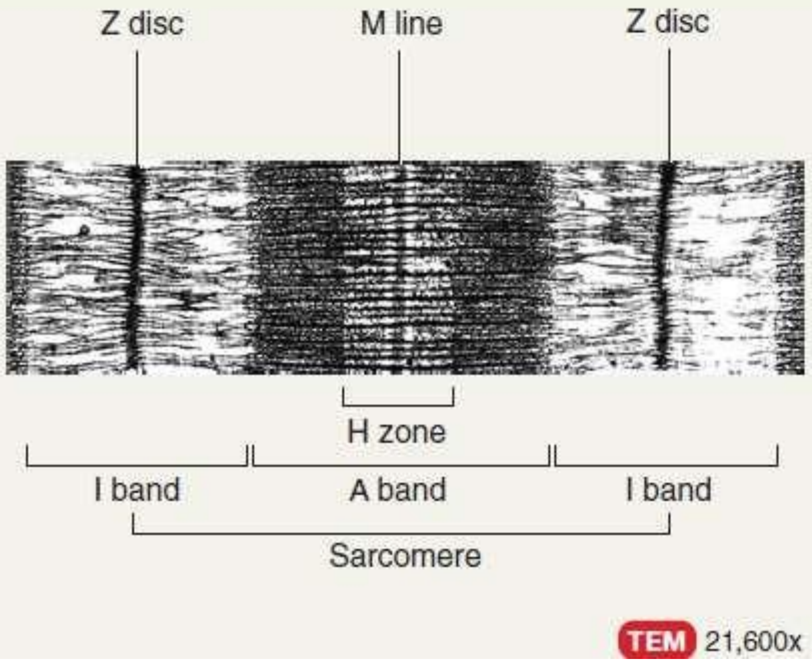
Contractile proteins within myofibrils that are of two types: thick filaments composed of myosin and thin filaments composed of actin, tropomyosin, and troponin; sliding of thin filaments past thick filaments produces muscle shortening.

Ringkasan komponen Sarkomer

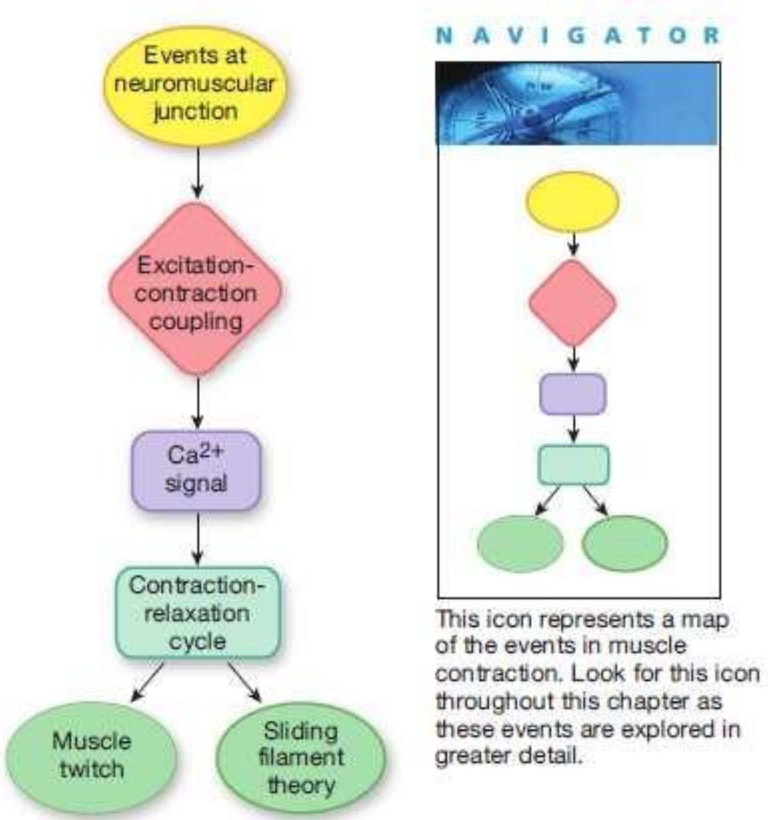
TABLE 10.1

Components of a Sarcomere

COMPONENT	DESCRIPTION
Z discs	Narrow, plate-shaped regions of dense material that separate one sarcomere from the next.
A band	Dark, middle part of sarcomere that extends entire length of thick filaments and includes those parts of thin filaments that overlap thick filaments.
I band	Lighter, less dense area of sarcomere that contains remainder of thin filaments but no thick filaments. A Z disc passes through center of each I band.
H zone	Narrow region in center of each A band that contains thick filaments but no thin filaments.
M line	Region in center of H zone that contains proteins that hold thick filaments together at center of sarcomere.

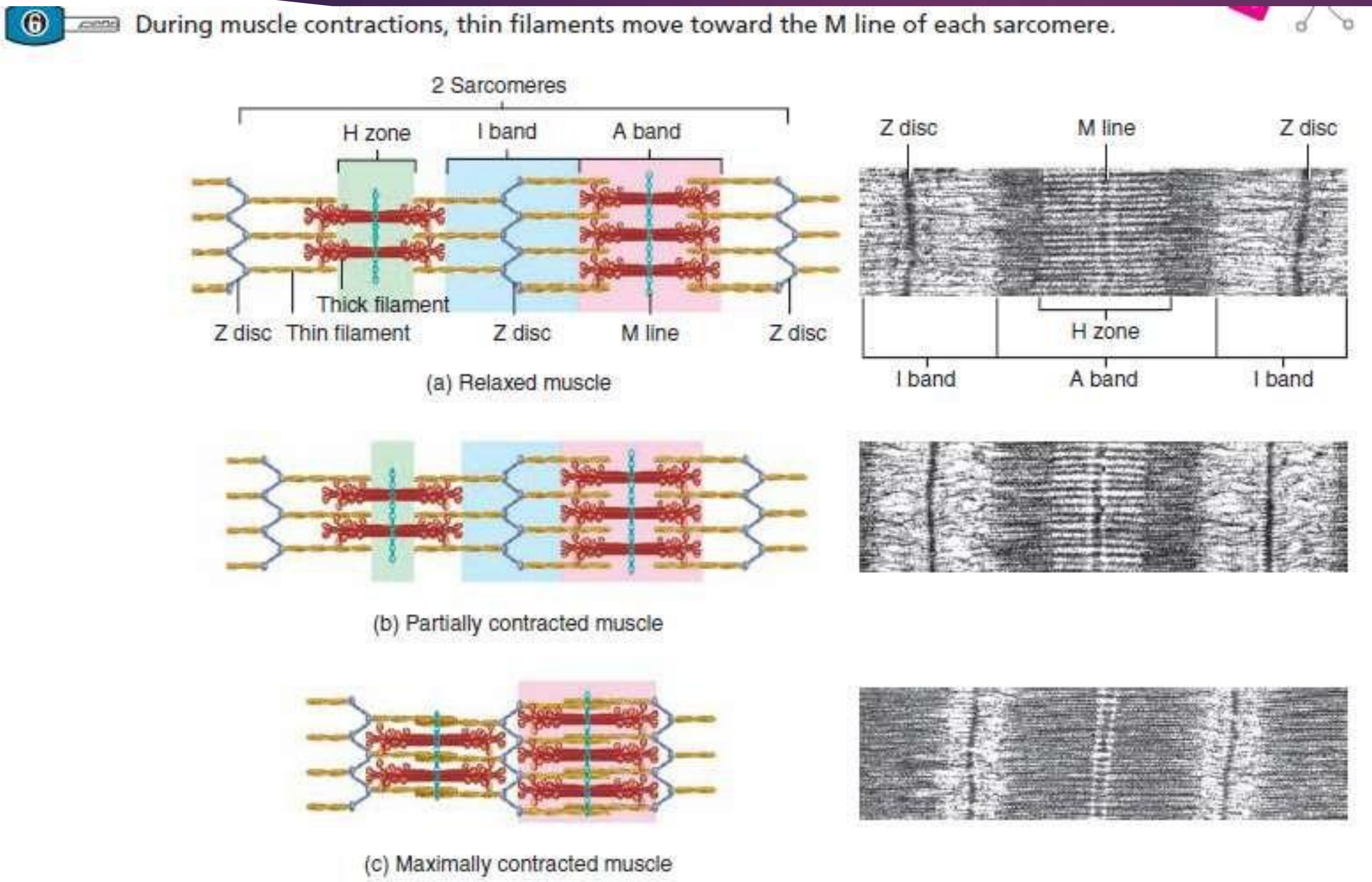


Kontraksi Otot



● **FIGURE 12-7** *Summary map of muscle contraction*

Kontraksi dan Relaksasi Serat Otot Rangka



(a) Relaxed muscle

(b) Partially contracted muscle

(c) Maximally contracted muscle

- Para peneliti menemukan otot rangka memendek selama kontraksi karena filament tebal dan tipis meluncur melewati satu sama lain→ mekanisme filament meluncur

- Mekanisme filament meluncur pada kontraksi otot, saat terjadi pada dua sarkomer yang berdekatan.

Sarkomer memendek selama kontraksi berlangsung

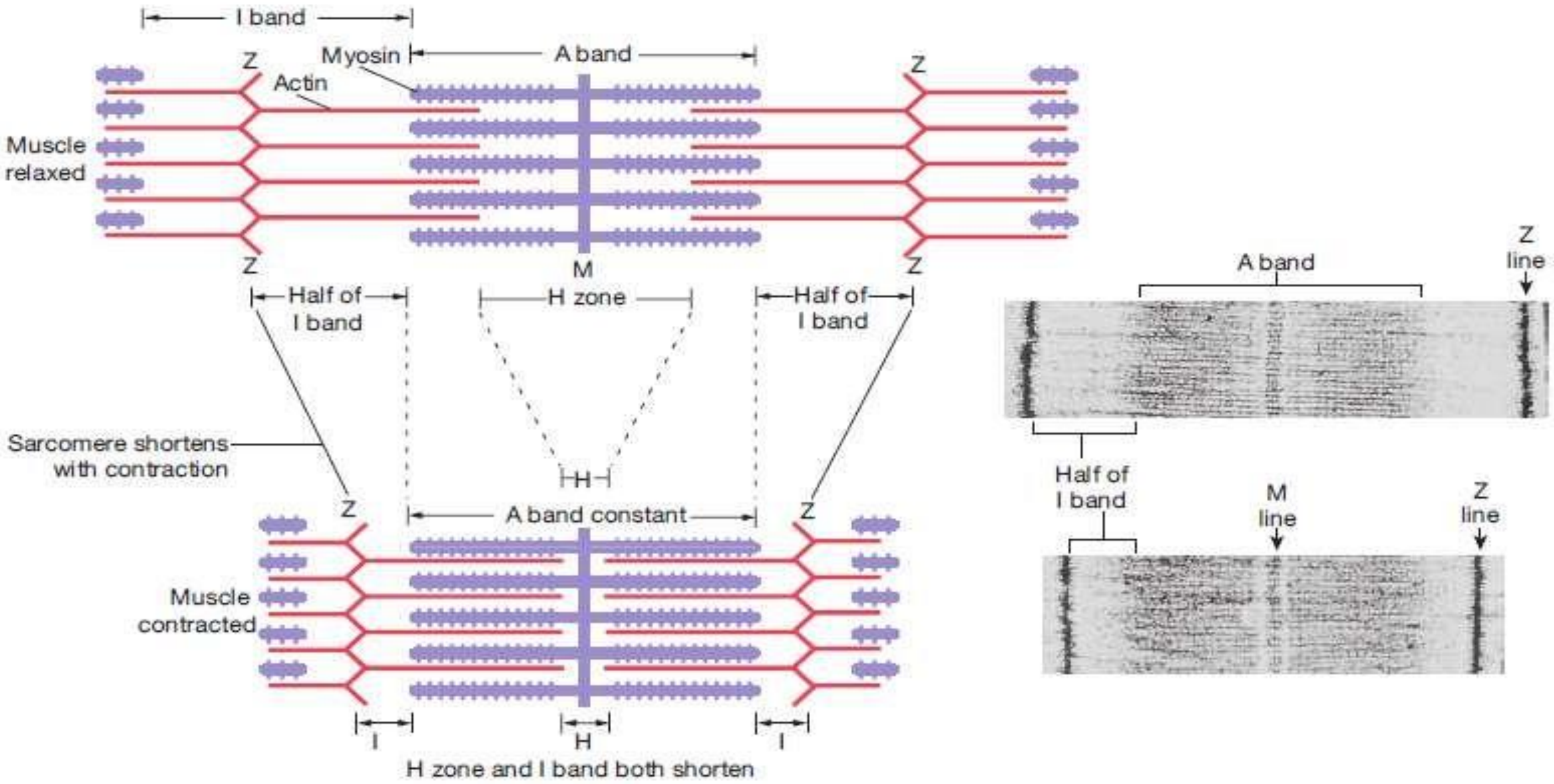


FIGURE 12-8 *The sarcomere shortens during contraction.* As contraction takes place, the thick and thin filaments do not change length but instead slide past one another.

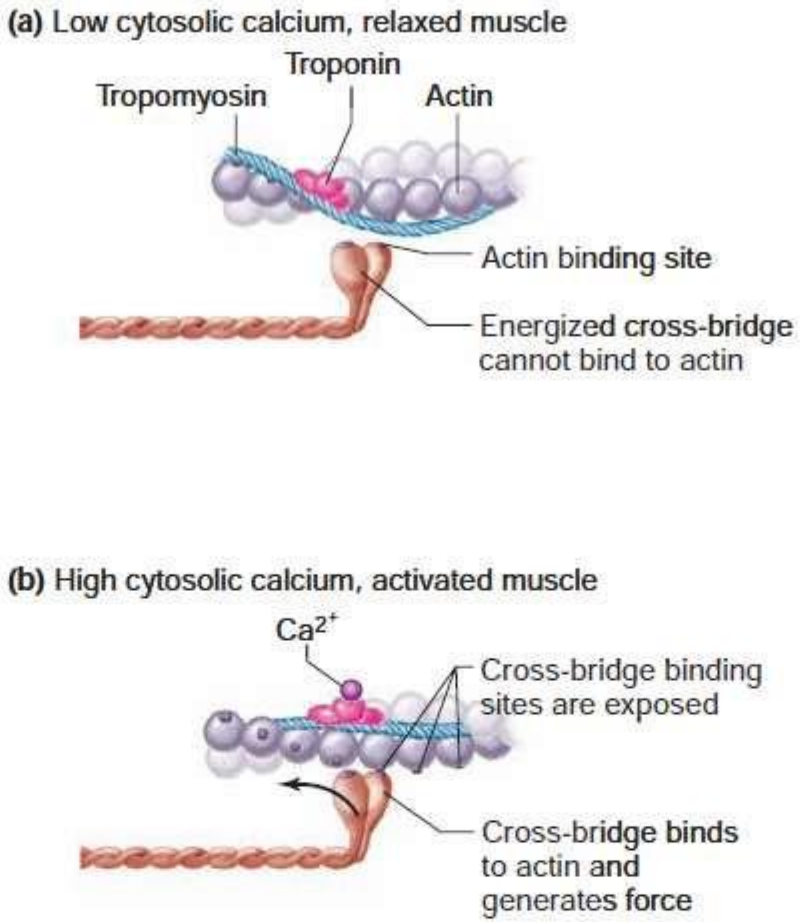


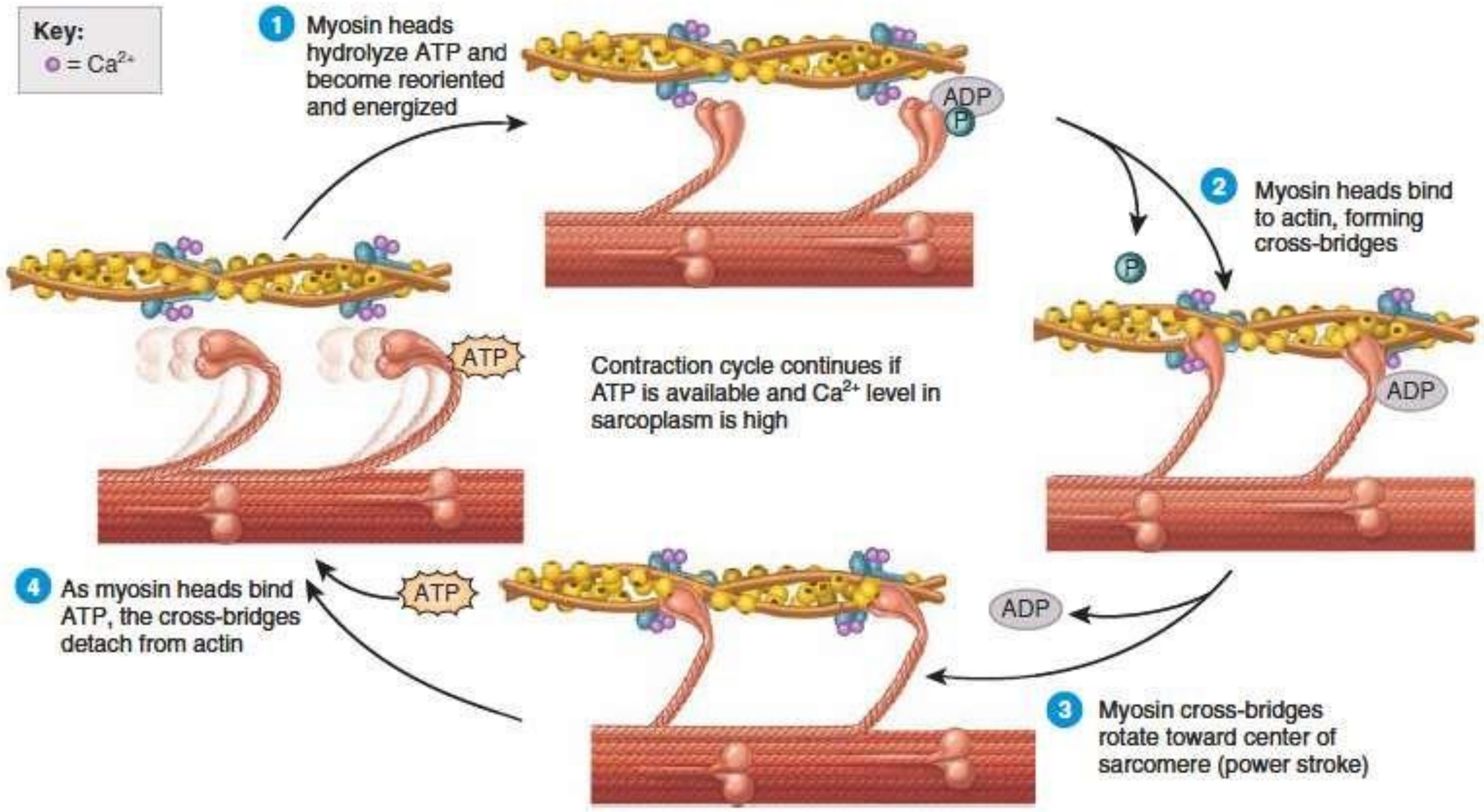
Figure 9–9

Activation of cross-bridge cycling by calcium. (a) Without calcium ions bound, troponin holds tropomyosin over cross-bridge binding sites on actin. (b) When calcium binds to troponin, tropomyosin is allowed to move away from cross-bridge binding sites on actin, and cross-bridges can bind to actin.

Siklus Kontraksi

Figure 10.6 **The contraction cycle.** Sarcomeres exert force and shorten through repeated cycles during which the myosin heads attach to actin (cross-bridges), rotate, and detach.

During the power stroke of contraction, cross-bridges rotate and move the thin filaments past the thick filaments towa the center of the sarcomere.



? What would happen if ATP suddenly were not available after the sarcomere had started to shorten?

Siklus kontraksi terdiri dari empat langkah:

- Hidrolisis ATP
- Pelekatan myosin pada aktin untuk membentuk cross-bridge
- Pelepasan myosin dari aktin

Kalsium berikatan pada Toponin untuk menginisiasi kontraksi otot

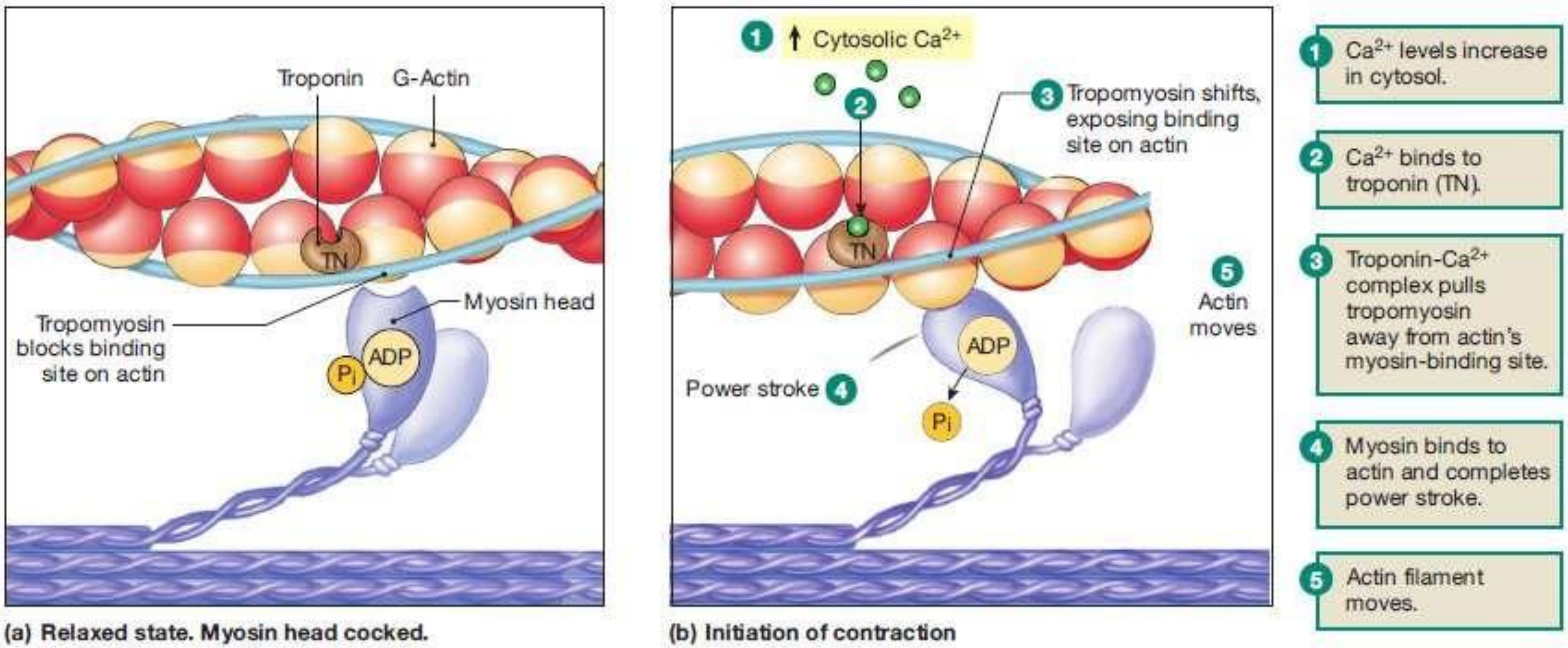
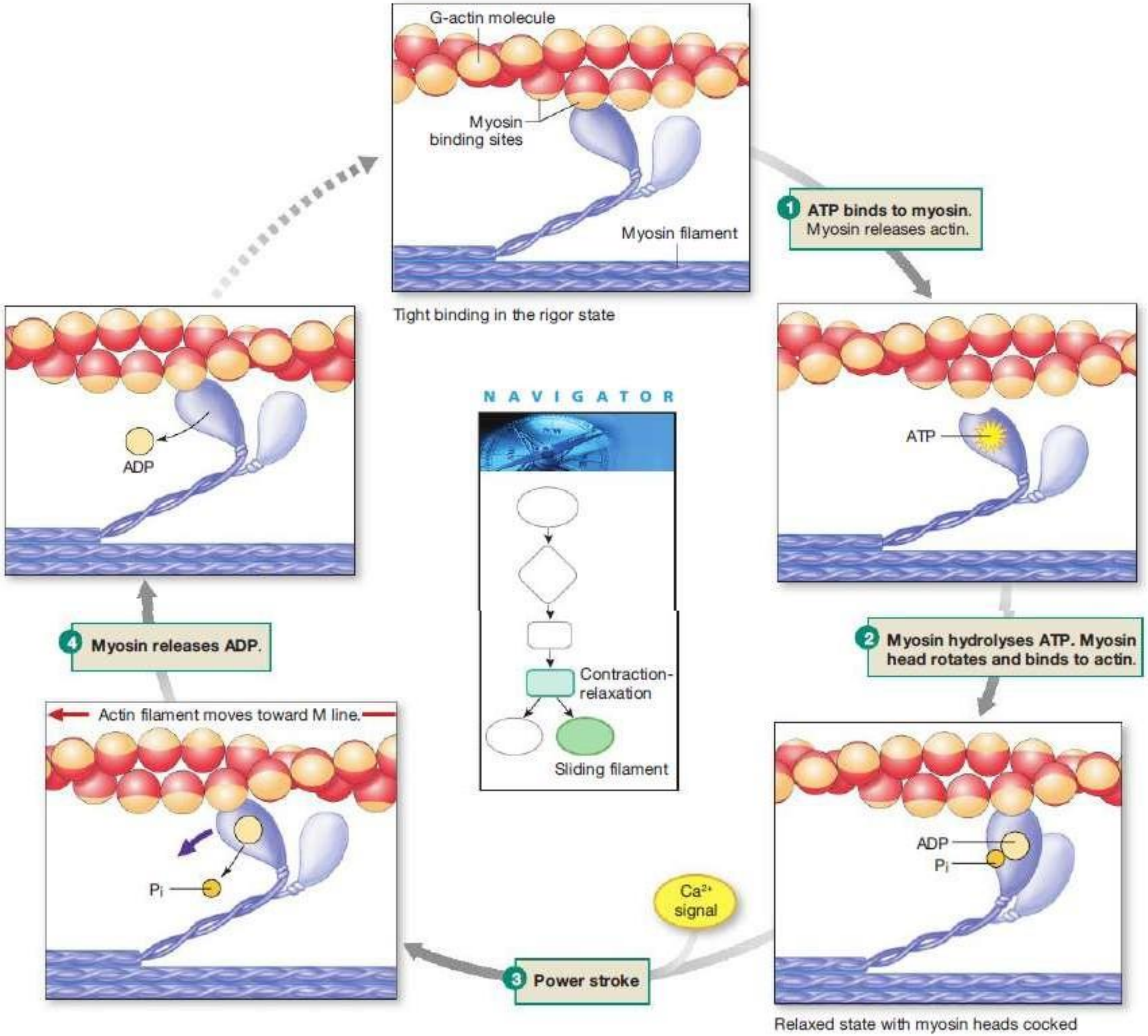


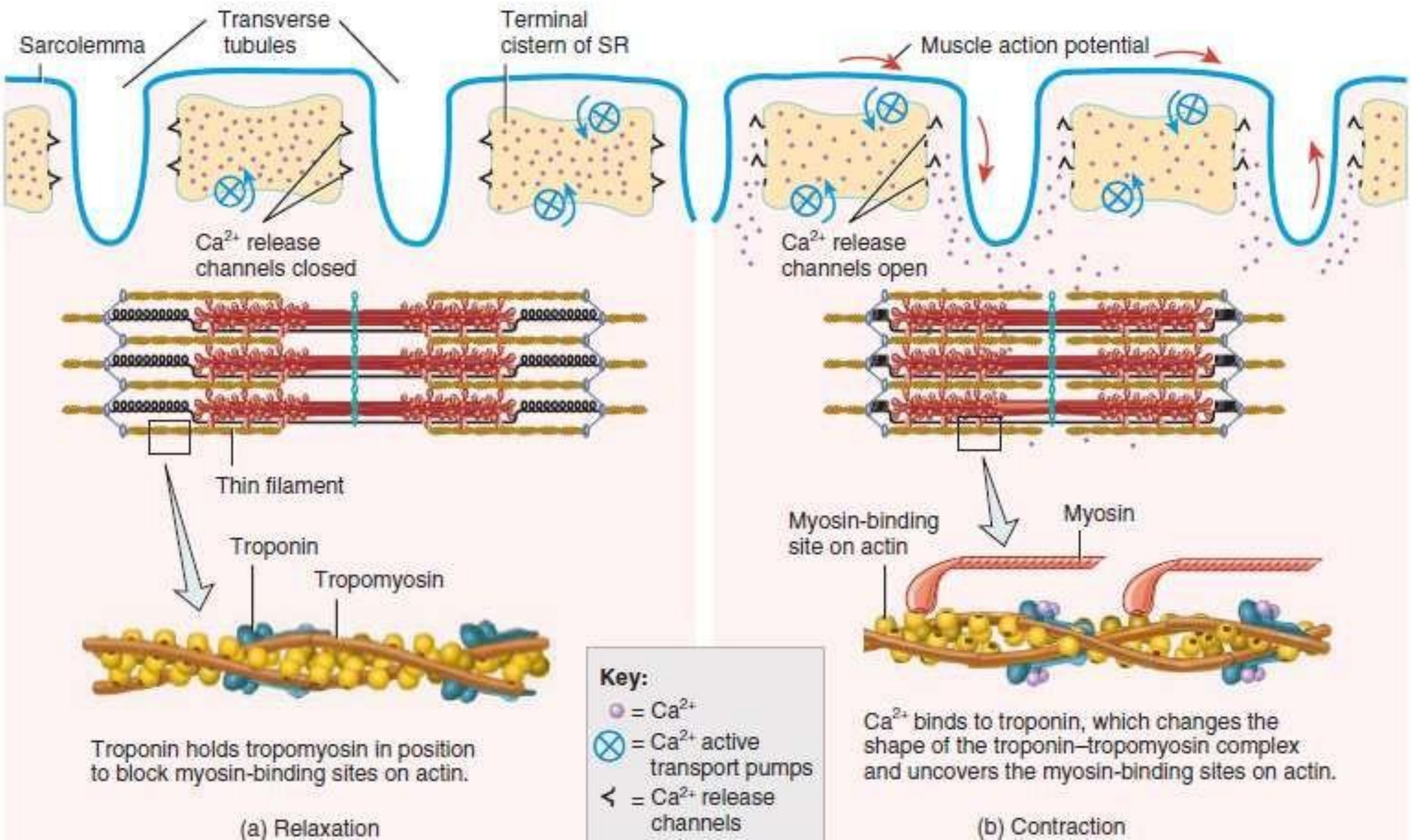
FIGURE 12-9 *Calcium binds to troponin to initiate muscle contraction.*


G-actin molecule
Myosin binding sites
Myosin filament
Tight binding in the rigor state
1 ATP binds to myosin. Myosin releases actin.
ATP
2 Myosin hydrolyses ATP. Myosin head rotates and binds to actin.
ADP
Pi
Relaxed state with myosin heads cocked
Ca2+ signal
3 Power stroke
Actin filament moves toward M line.
Pi
4 Myosin releases ADP.
ADP
NAVIGATOR
Contraction-relaxation
Sliding filament

Rangkaian Eksitasi-Kontraksi

Figure 10.7 **The role of Ca^{2+} in the regulation of contraction by troponin and tropomyosin.** (a) During relaxation, the level of Ca^{2+} in the sarcoplasm is low, only 0.1 μM (0.0001 mM), because calcium ions are pumped into the sarcoplasmic reticulum by Ca^{2+} active transport pumps. (b) A muscle action potential propagating along a transverse tubule opens Ca^{2+} release channels in the sarcoplasmic reticulum, calcium ions flow into the cytosol, and contraction begins.

An increase in the Ca^{2+} level in the sarcoplasm starts the sliding of thin filaments. When the level of Ca^{2+} in the sarcoplasm declines, sliding stops.

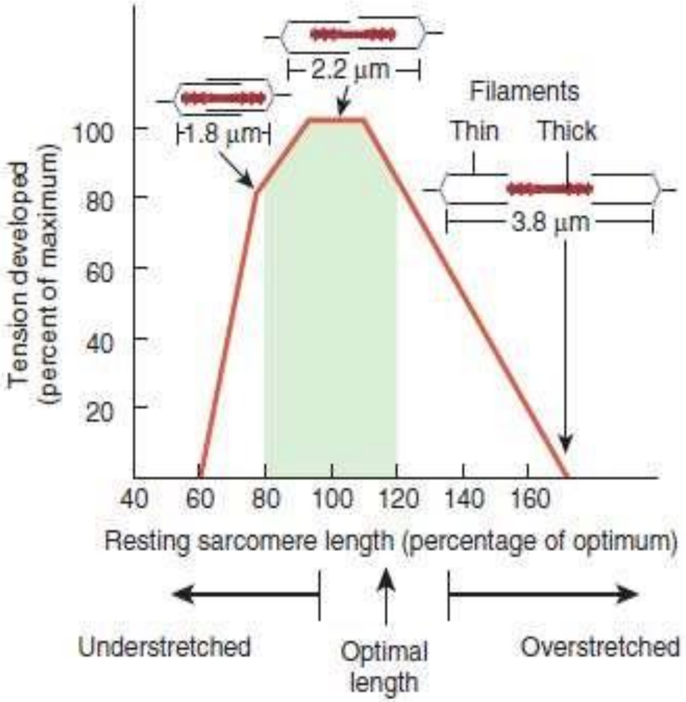


- Peningkatan [Ca] dlm sarkoplasma memulai kontraksi otot dan penurunan konsentrasi menghentikannya.
- Pompa transport aktif Ca menggunakan ATP untuk menggerakan CA dari sarkoplasma ke SR

Hubungan Panjang-Tegangan

Figure 10.8 **Length–tension relationship in a skeletal muscle fiber.** Maximum tension during contraction occurs when the resting sarcomere length is 2.0–2.4 μm.

A muscle fiber develops its greatest tension when there is an optimal zone of overlap between thick and thin filaments.



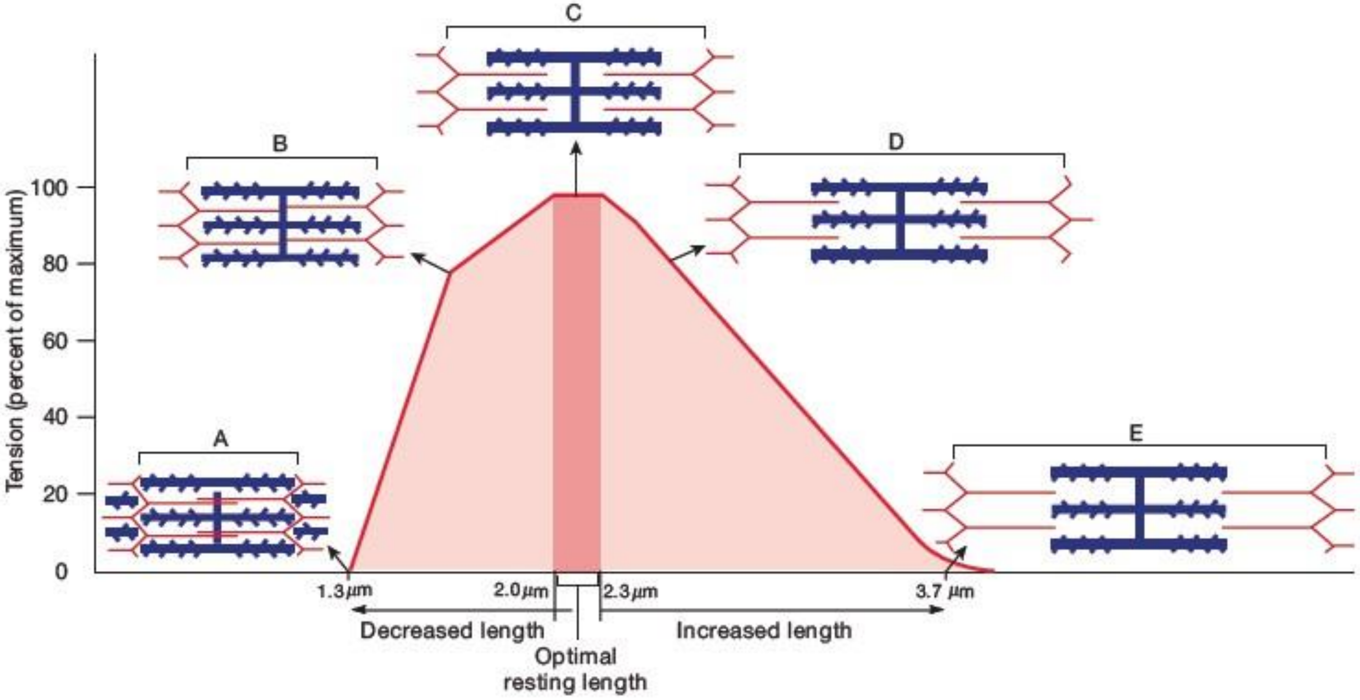
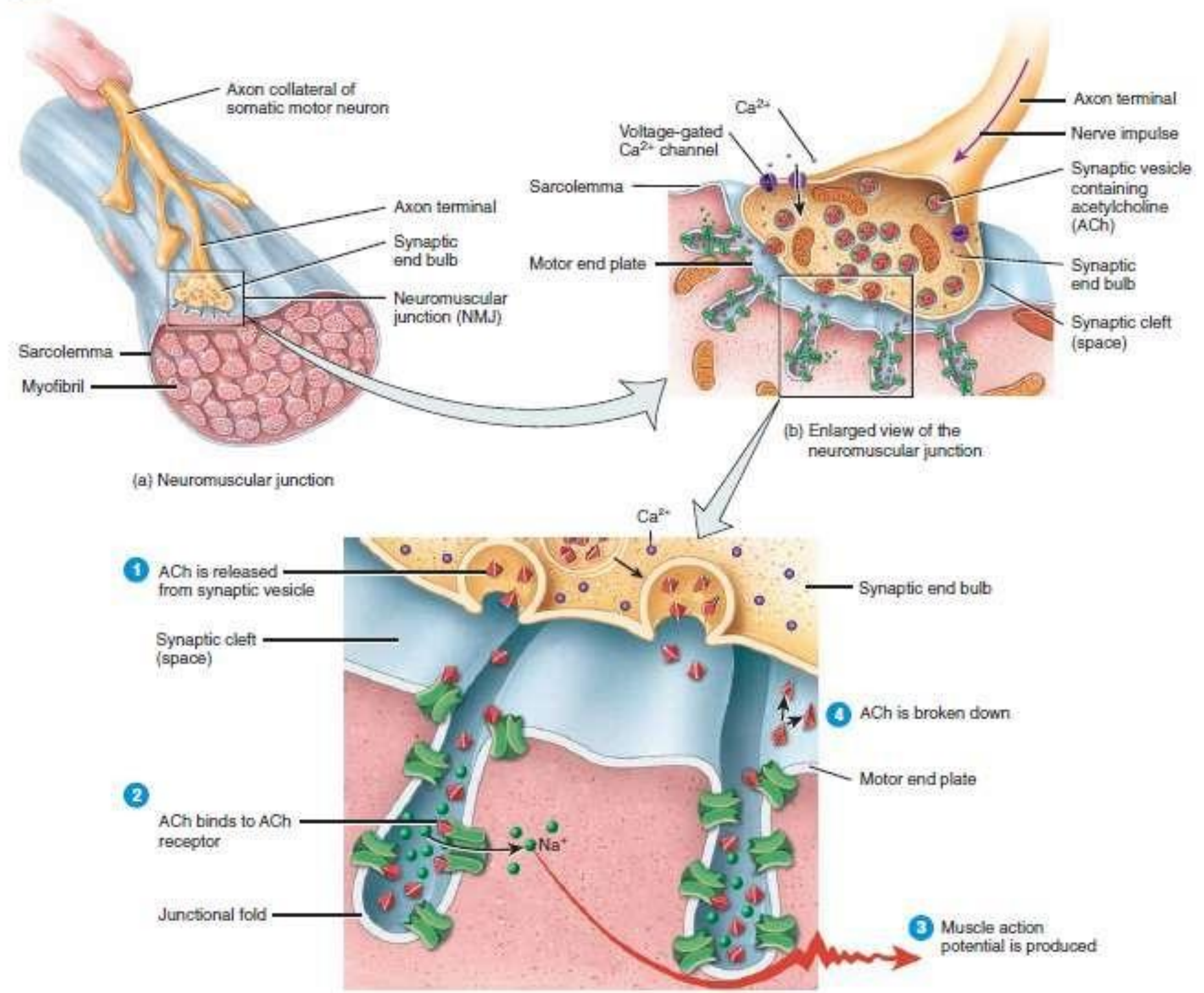


FIGURE 12-16 ***Too much or too little overlap of thick and thin filaments in resting muscle results in decreased tension.*** Adapted from A.M. Gordon *et al.*, *J Physiol* 184: 170–192, 1966.

Taut Neuromuskular

Figure 10.9 Structure of the neuromuscular junction (NMJ), the synapse between a somatic motor neuron and a skeletal muscle fiber.

Synaptic end bulbs at the tips of axon terminals contain synaptic vesicles filled with acetylcholine (ACh).



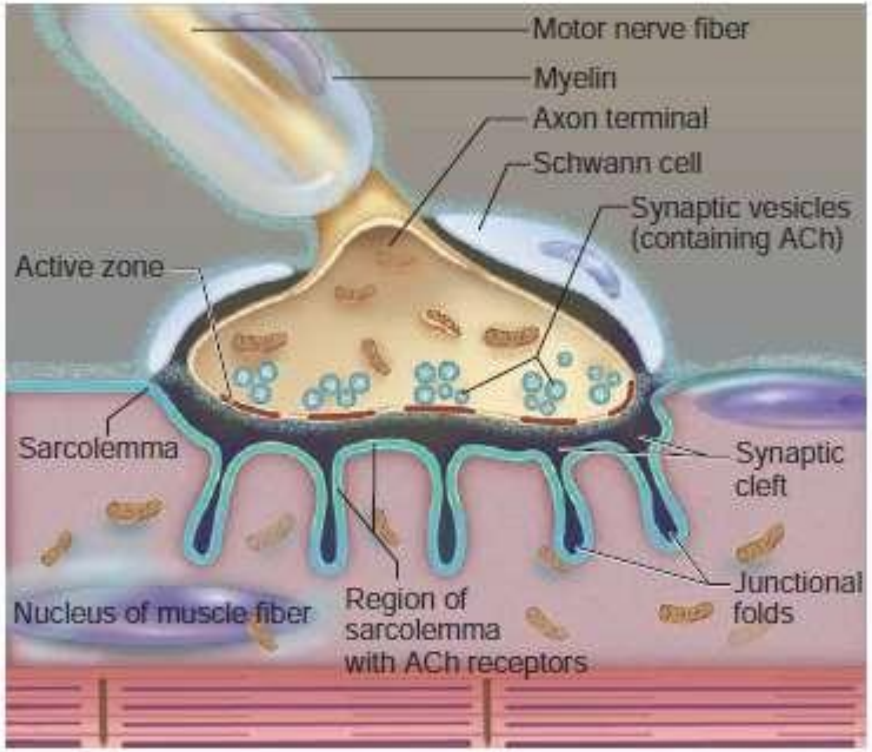
Impuls saraf (potensial aksi saraf) mencetuskan potensial aksi otot dengan cara berikut:

- Pelepasan astilkolin
- Aktivasi reseptor Ach
- Pembentukan potensial aksi otot
- Terminasi aktivasi Ach→ asetilkolinesterase (AChE) memecah ACh menjadi asetil dan kolin sehingga tdk dpt mengaktivasi reseptor ACh

Neuromuscular Junction

(d) Neuromuscular junction

(a)



(b)

Figure 9–14

The neuromuscular junction. (a) Scanning electron micrograph showing branching of motor axons, with terminals embedded in grooves in the muscle fiber's surface. (b) Structure of a neuromuscular junction.

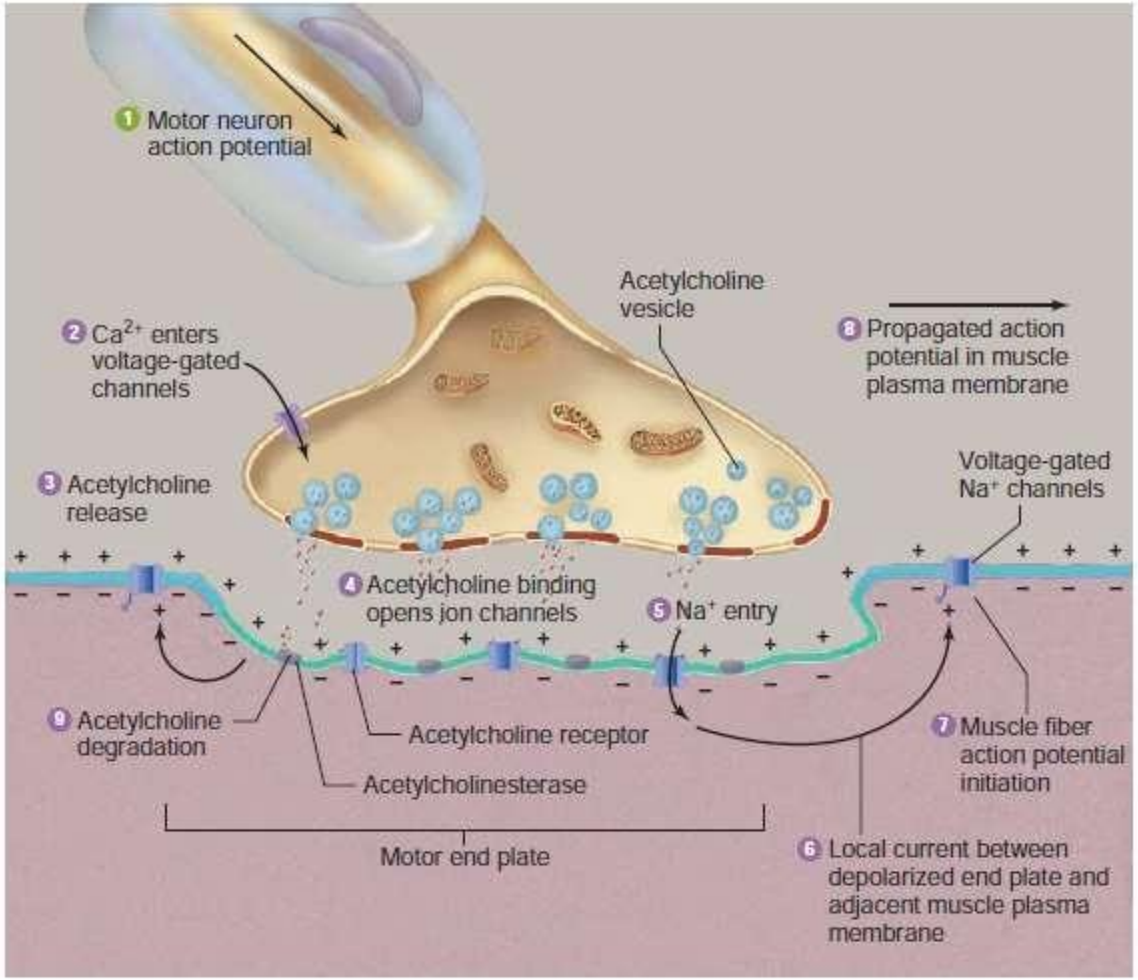


Figure 9–15

Events at the neuromuscular junction that lead to an action potential in the muscle fiber plasma membrane. Although potassium also exits the muscle cell when ACh receptors are open, sodium entry and depolarization dominates, as shown here.

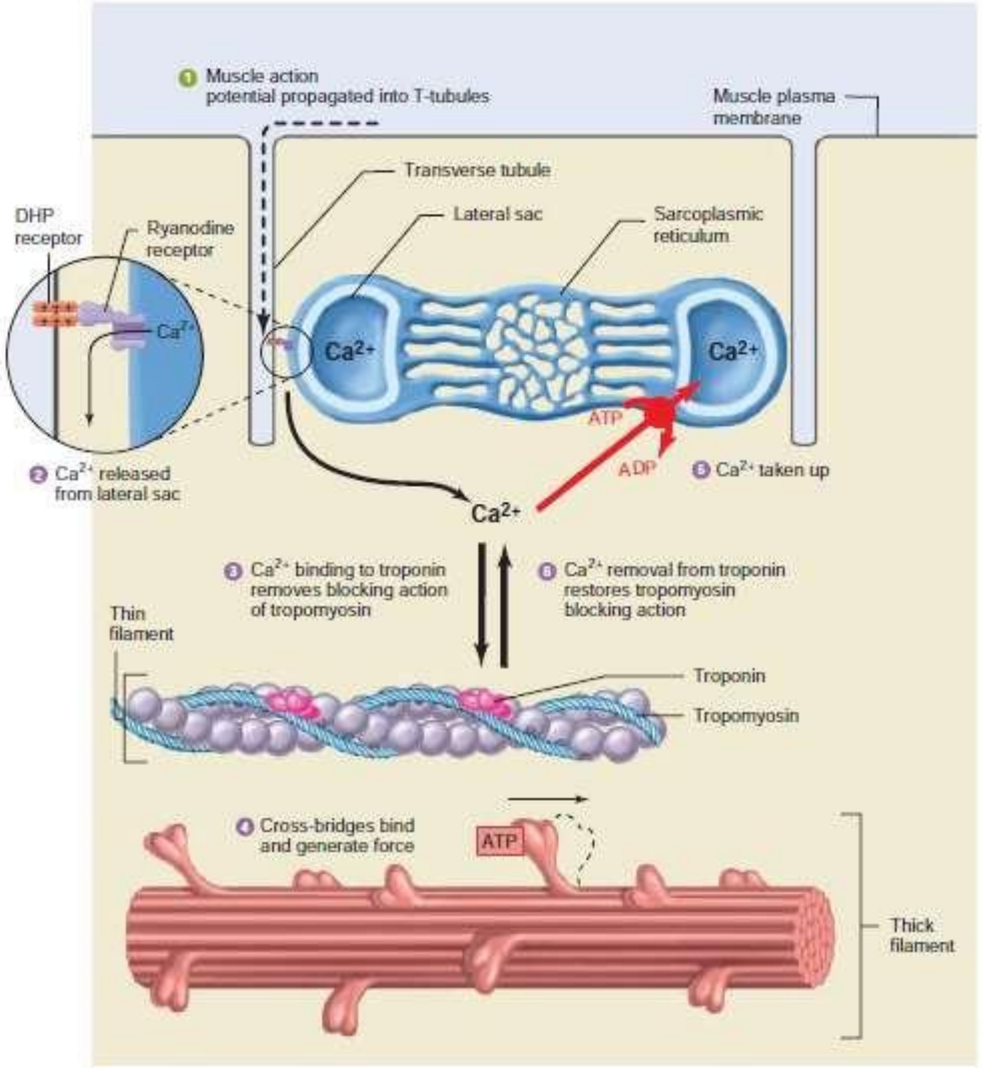
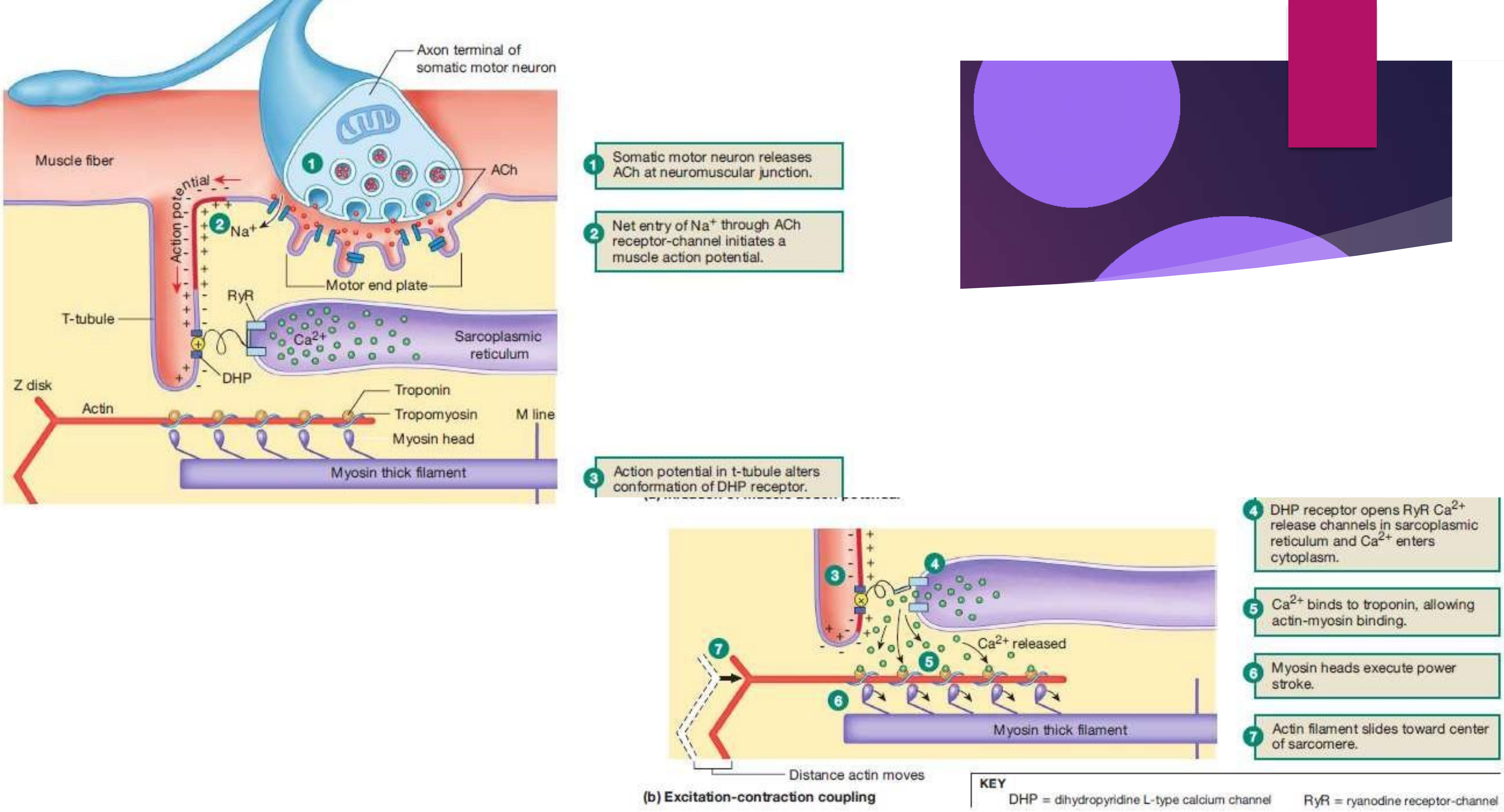
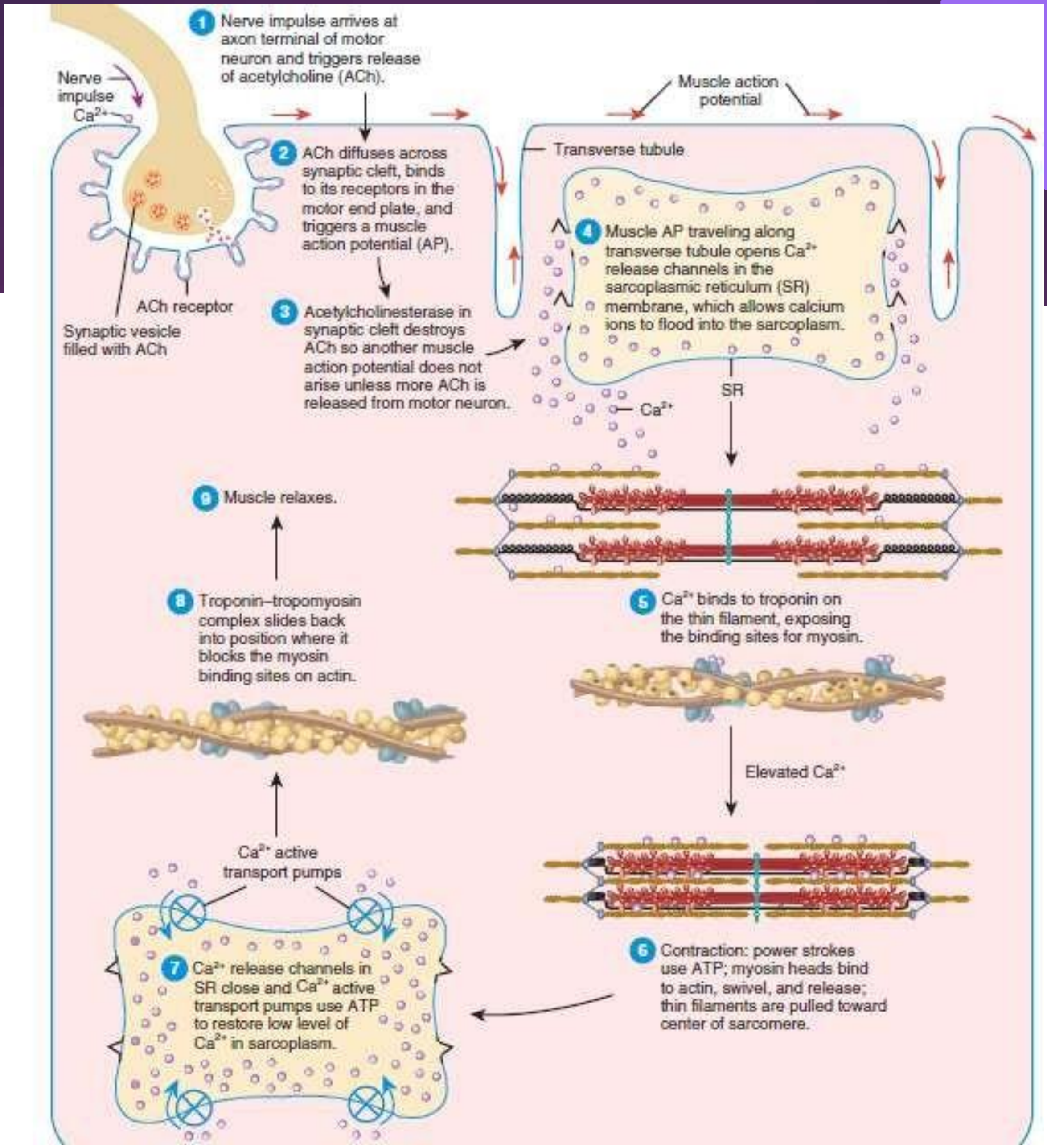


Figure 9–12

Release and uptake of calcium by the sarcoplasmic reticulum during contraction and relaxation of a skeletal muscle fiber.



● **FIGURE 12-11** *Excitation-contraction coupling converts an electrical signal into a calcium signal.*



1 Nerve impulse arrives at axon terminal of motor neuron and triggers release of acetylcholine (ACh).
Nerve impulse
Ca^{2+}
Muscle action potential
Transverse tubule
2 ACh diffuses across synaptic cleft, binds to its receptors in the motor end plate, and triggers a muscle action potential (AP).
3 Acetylcholinesterase in synaptic cleft destroys ACh so another muscle action potential does not arise unless more ACh is released from motor neuron.
ACh receptor
Synaptic vesicle filled with ACh
4 Muscle AP traveling along transverse tubule opens Ca^{2+} release channels in the sarcoplasmic reticulum (SR) membrane, which allows calcium ions to flood into the sarcoplasm.
SR
Ca^{2+}
9 Muscle relaxes.
5 Ca^{2+} binds to troponin on the thin filament, exposing the binding sites for myosin.
8 Troponin–tropomyosin complex slides back into position where it blocks the myosin binding sites on actin.
Elevated Ca^{2+}
Ca^{2+} active transport pumps
7 Ca^{2+} release channels in SR close and Ca^{2+} active transport pumps use ATP to restore low level of Ca^{2+} in sarcoplasm.
6 Contraction: power strokes use ATP; myosin heads bind to actin, swivel, and release; thin filaments are pulled toward center of sarcomere.

Table 9–2	Sequence of Events Between a Motor Neuron Action Potential and Skeletal Muscle Fiber Contraction
1.	Action potential is initiated and propagates to motor neuron axon terminals.
2.	Calcium enters axon terminals through voltage-gated calcium channels.
3.	Calcium entry triggers release of ACh from axon terminals.
4.	ACh diffuses from axon terminals to motor end plate in muscle fiber.
5.	ACh binds to nicotinic receptors on motor end plate, increasing their permeability to Na^+ and K^+.
6.	More Na^+ moves into the fiber at the motor end plate than K^+ moves out, depolarizing the membrane and producing the end plate potential (EPP).
7.	Local currents depolarize the adjacent muscle cell plasma membrane to its threshold potential, generating an action potential that propagates over the muscle fiber surface and into the fiber along the T-tubules.
8.	Action potential in T-tubules induces DHP receptors to pull open ryanodine receptor channels, allowing release of Ca^{2+} from lateral sacs of sarcoplasmic reticulum.
9.	Ca^{2+} binds to troponin on the thin filaments, causing tropomyosin to move away from its blocking position, thereby uncovering cross-bridge binding sites on actin.
10.	Energized myosin cross-bridges on the thick filaments bind to actin: $A + M \cdot ADP \cdot P_i \rightarrow A \cdot M \cdot ADP \cdot P_i$
11.	Cross-bridge binding triggers release of ATP hydrolysis products from myosin, producing an angular movement of each cross-bridge: $A \cdot M \cdot ADP \cdot P_i \rightarrow A \cdot M + ADP + P_i$
12.	ATP binds to myosin, breaking linkage between actin and myosin and thereby allowing cross-bridges to dissociate from actin: $A \cdot M + ATP \rightarrow A + M \cdot ATP$
13.	ATP bound to myosin is split, energizing the myosin cross-bridge: $M \cdot ATP \rightarrow M \cdot ADP \cdot P_i$
14.	Cross-bridges repeat steps 10 to 13, producing movement (sliding) of thin filaments past thick filaments. Cycles of cross-bridge movement continue as long as Ca^{2+} remains bound to troponin.
15.	Cytosolic Ca^{2+} concentration decreases as Ca^{2+}-ATPase actively transports Ca^{2+} into sarcoplasmic reticulum.
16.	Removal of Ca^{2+} from troponin restores blocking action of tropomyosin, the cross-bridge cycle ceases, and the muscle fiber relaxes.

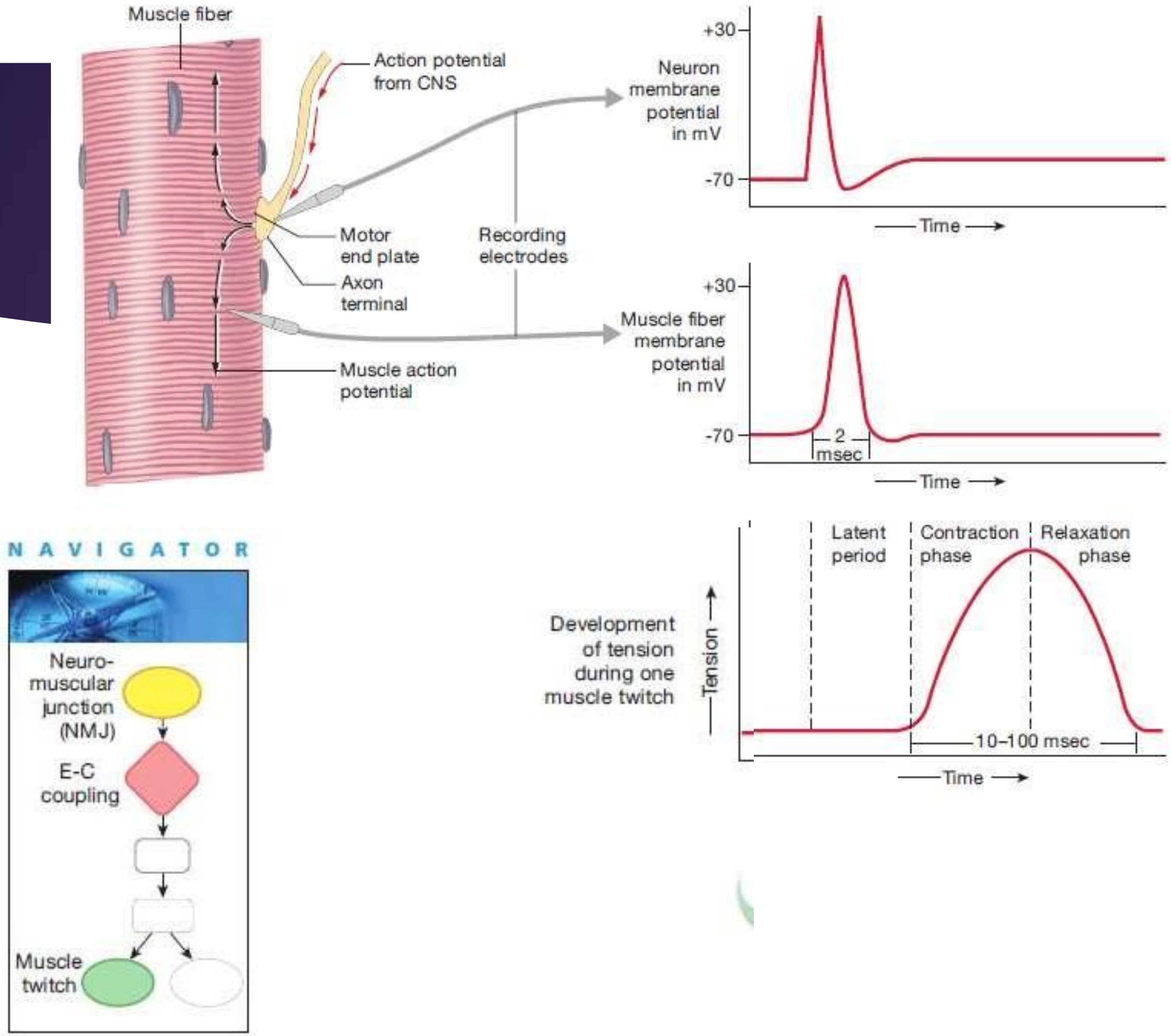
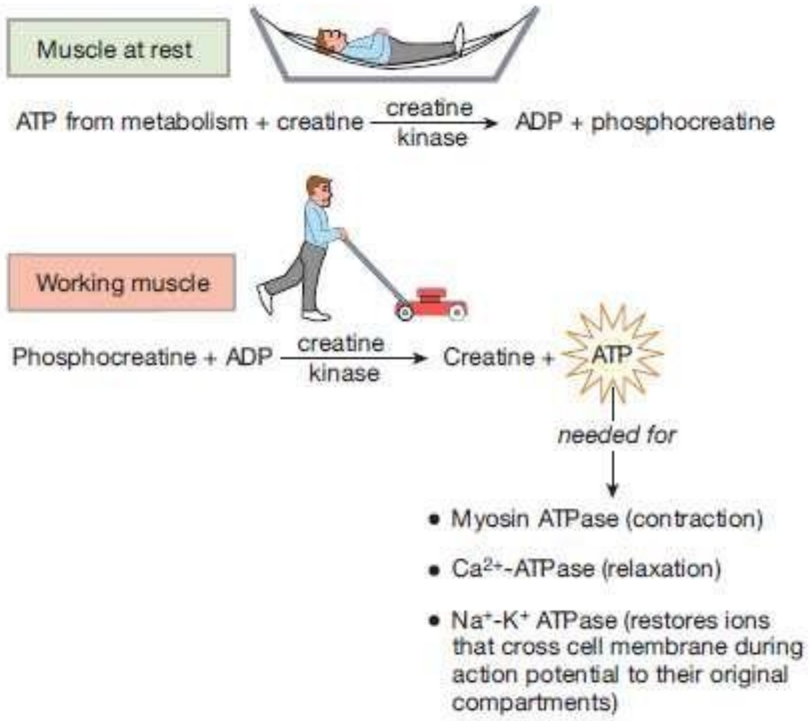


FIGURE 12-12 *Electrical and mechanical events in muscle contraction.* Action potentials in the axon terminal (top graph) and in the muscle fiber (middle graph) are followed by a muscle twitch (bottom graph).



● **FIGURE 12-13** *Phosphocreatine.* Resting muscle stores energy from ATP in the high-energy phosphate bonds of phosphocreatine. Working muscle then uses that stored energy.

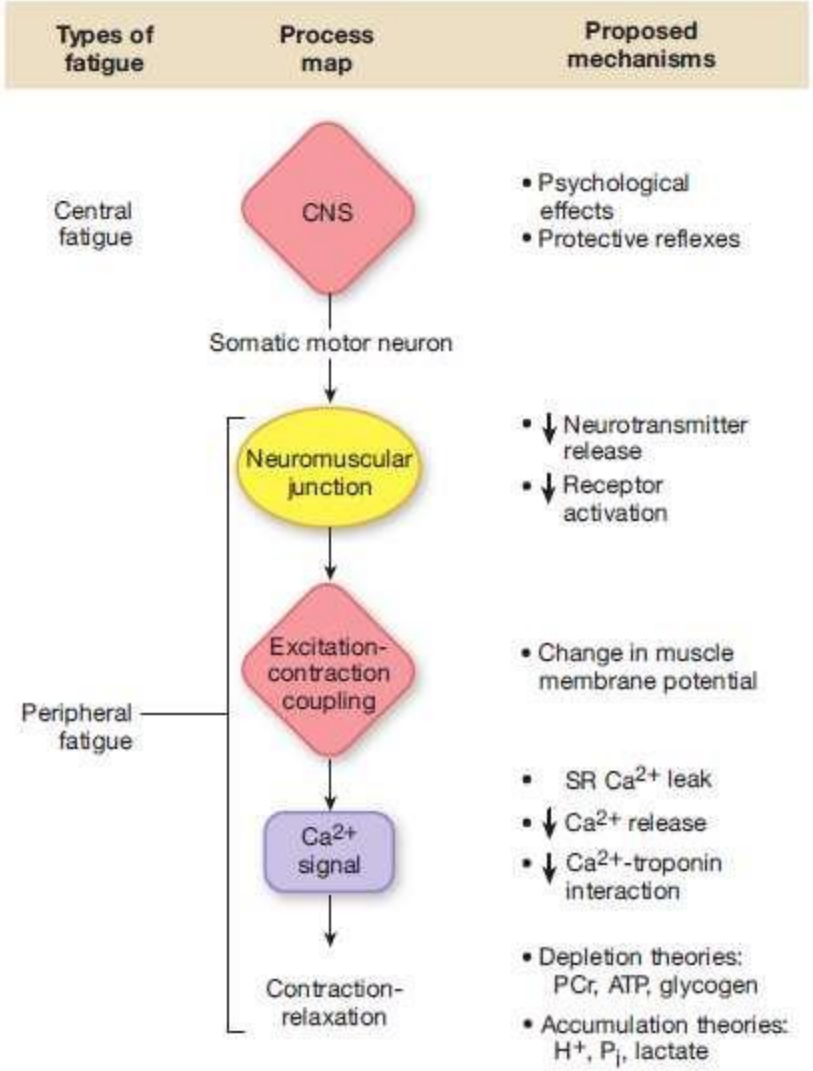
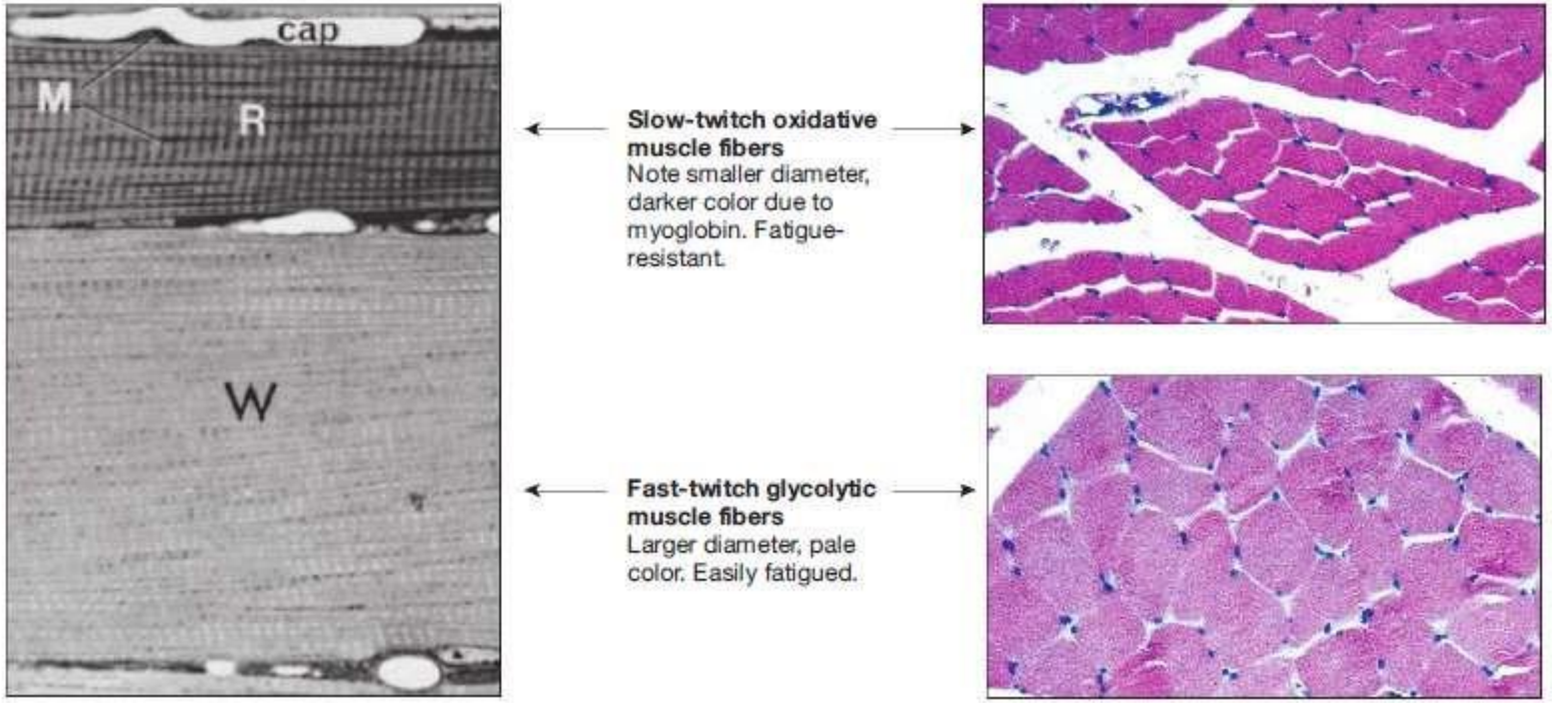


FIGURE 12-14 *Locations and possible causes of muscle fatigue.* In recent years, research indicated that lactate accumulation is no longer a likely cause of fatigue. A new theory that sarcoplasmic Ca^{2+} leaks cause fatigue has emerged.



● **FIGURE 12-15** ***Fast-twitch glycolytic and slow-twitch oxidative muscle fibers.*** Slow-twitch oxidative muscle (labeled R here for red muscle) has large amounts of red myoglobin, numerous mitochondria (M), and extensive capillary blood supply (cap), in contrast to fast-twitch glycolytic muscle (labeled W for white muscle).

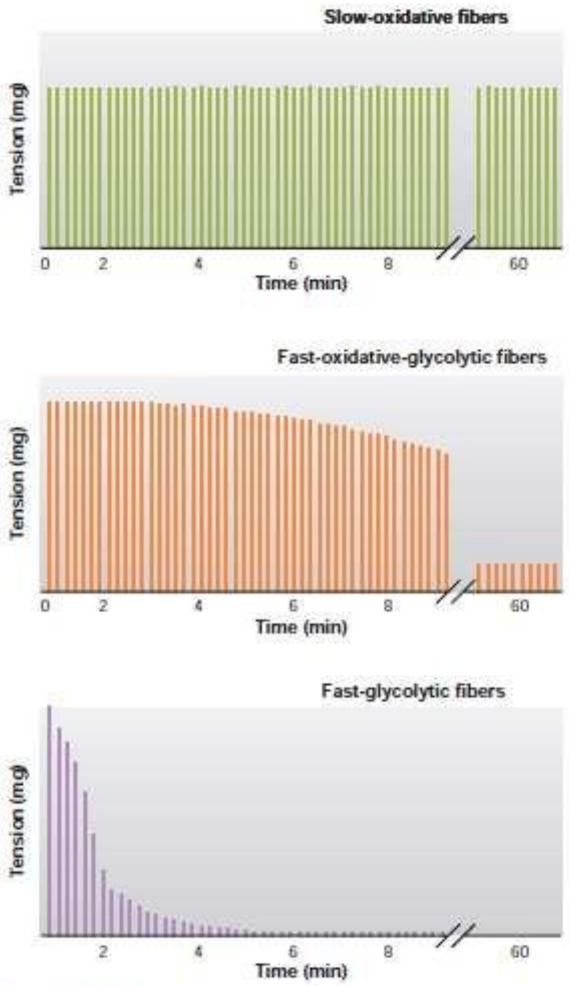


Figure 9–25

The rate of fatigue development in the three fiber types. Each vertical line is the contractile response to a brief tetanic stimulus and relaxation. The contractile responses occurring between about 9 min and 60 min are not shown on the figure.

Table 9–3 Characteristics of the Three Types of Skeletal Muscle Fibers

	Slow-Oxidative Fibers (Type I)	Fast-Oxidative-Glycolytic Fibers (Type IIa)	Fast-Glycolytic Fibers (Type IIb)*
Primary source of ATP production	Oxidative phosphorylation	Oxidative phosphorylation	Glycolysis
Mitochondria	Many	Many	Few
Capillaries	Many	Many	Few
Myoglobin content	High (red muscle)	High (red muscle)	Low (white muscle)
Glycolytic enzyme activity	Low	Intermediate	High
Glycogen content	Low	Intermediate	High
Rate of fatigue	Slow	Intermediate	Fast
Myosin-ATPase activity	Low	High	High
Contraction velocity	Slow	Fast	Fast
Fiber diameter	Small	Intermediate	Large
Motor unit size	Small	Intermediate	Large
Size of motor neuron innervating fiber	Small	Intermediate	Large

*Type IIb fibers are sometimes designated as type IIx in the human muscle physiology literature.

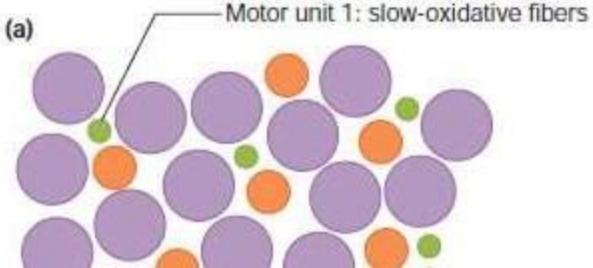


Table 9–4 Factors Determining Muscle Tension

1. Tension developed by each fiber
   a. Action potential frequency (frequency-tension relation)
   b. Fiber length (length-tension relation)
   c. Fiber diameter

TABLE 12-2 Characteristics of Muscle Fiber Types

	SLOW-TWITCH OXIDATIVE; RED MUSCLE	FAST-TWITCH OXIDATIVE-GLYCOLYTIC; RED MUSCLE	FAST-TWITCH GLYCOLYTIC; WHITE MUSCLE
Speed of development of maximum tension	Slowest	Intermediate	Fastest
Myosin ATPase activity	Slow	Fast	Fast
Diameter	Small	Medium	Large
Contraction duration	Longest	Short	Short
Ca^{2+}-ATPase activity in SR	Moderate	High	High
Endurance	Fatigue resistant	Fatigue resistant	Easily fatigued
Use	Most used: posture	Standing, walking	Least used: jumping; quick, fine movements
Metabolism	Oxidative; aerobic	Glycolytic but becomes more oxidative with endurance training	Glycolytic; more anaerobic than fast-twitch oxidative-glycolytic type
Capillary density	High	Medium	Low
Mitochondria	Numerous	Moderate	Few
Color	Dark red (myoglobin)	Red	Pale

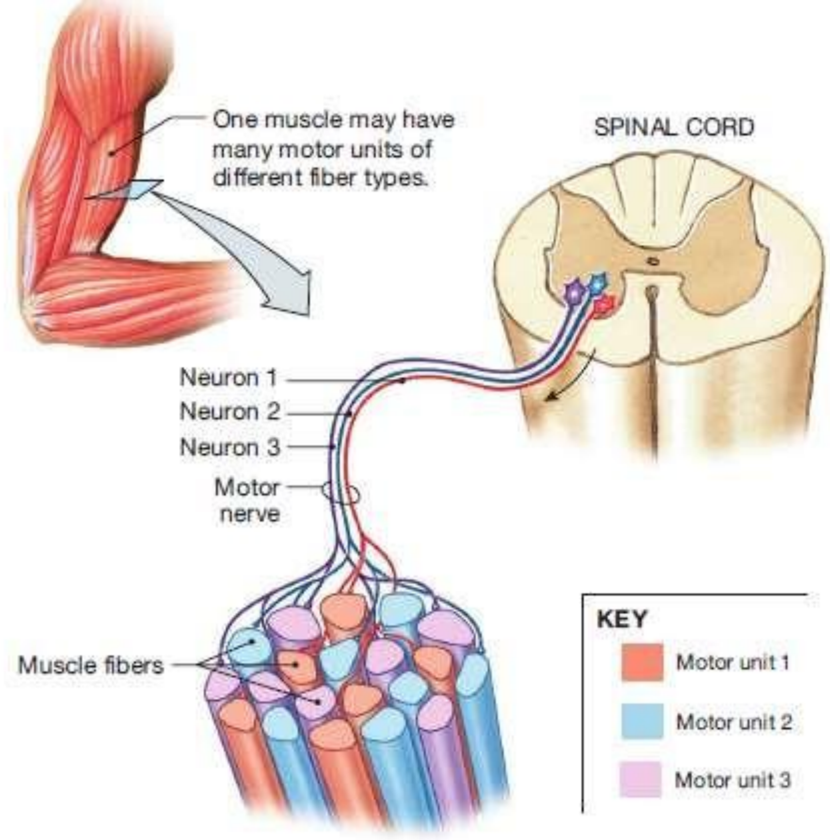
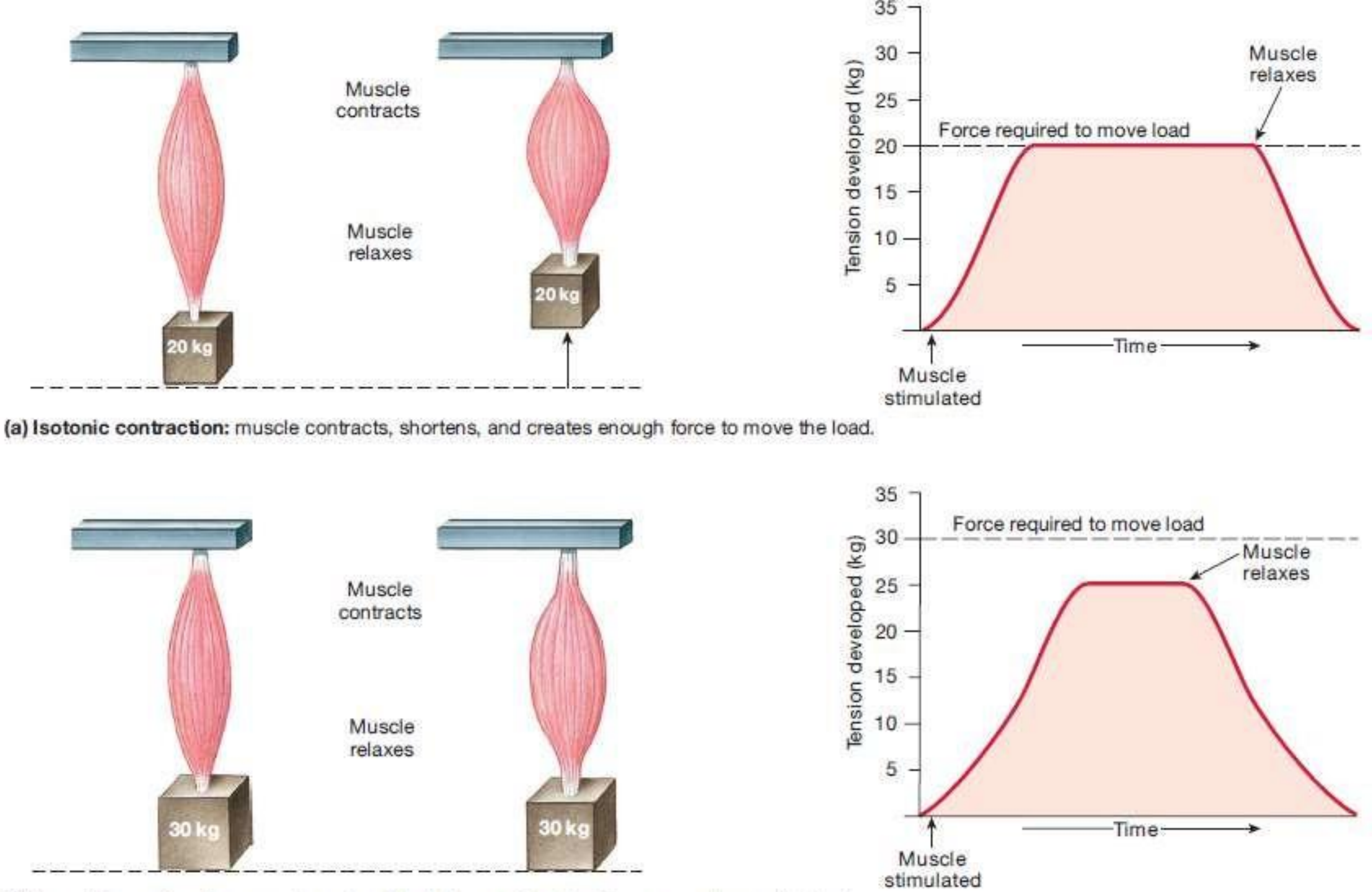


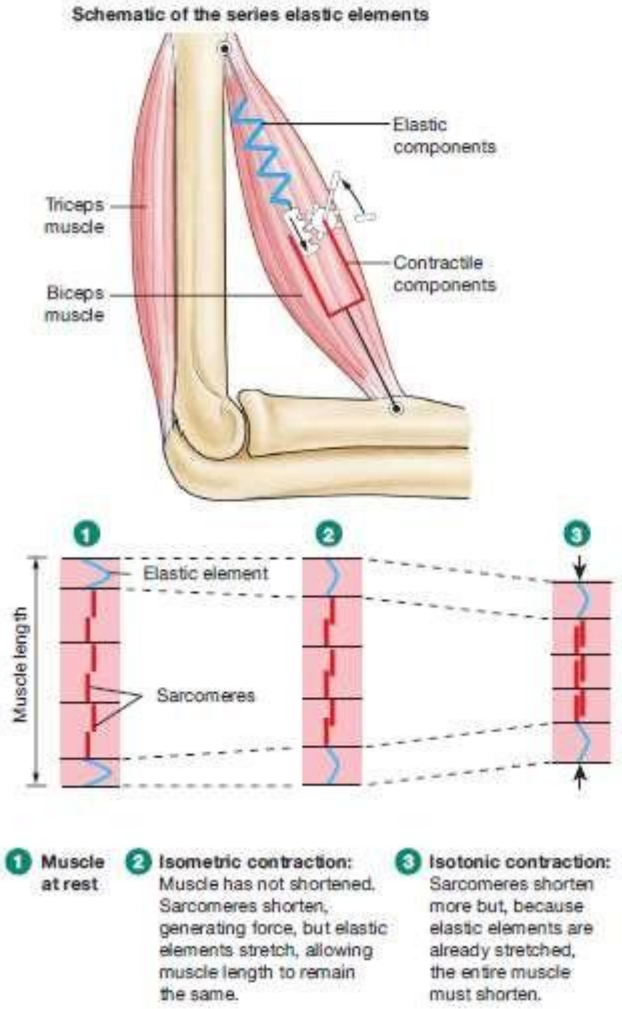
FIGURE 12-18 *A motor unit consists of one motor neuron and all the muscle fibers it innervates.*



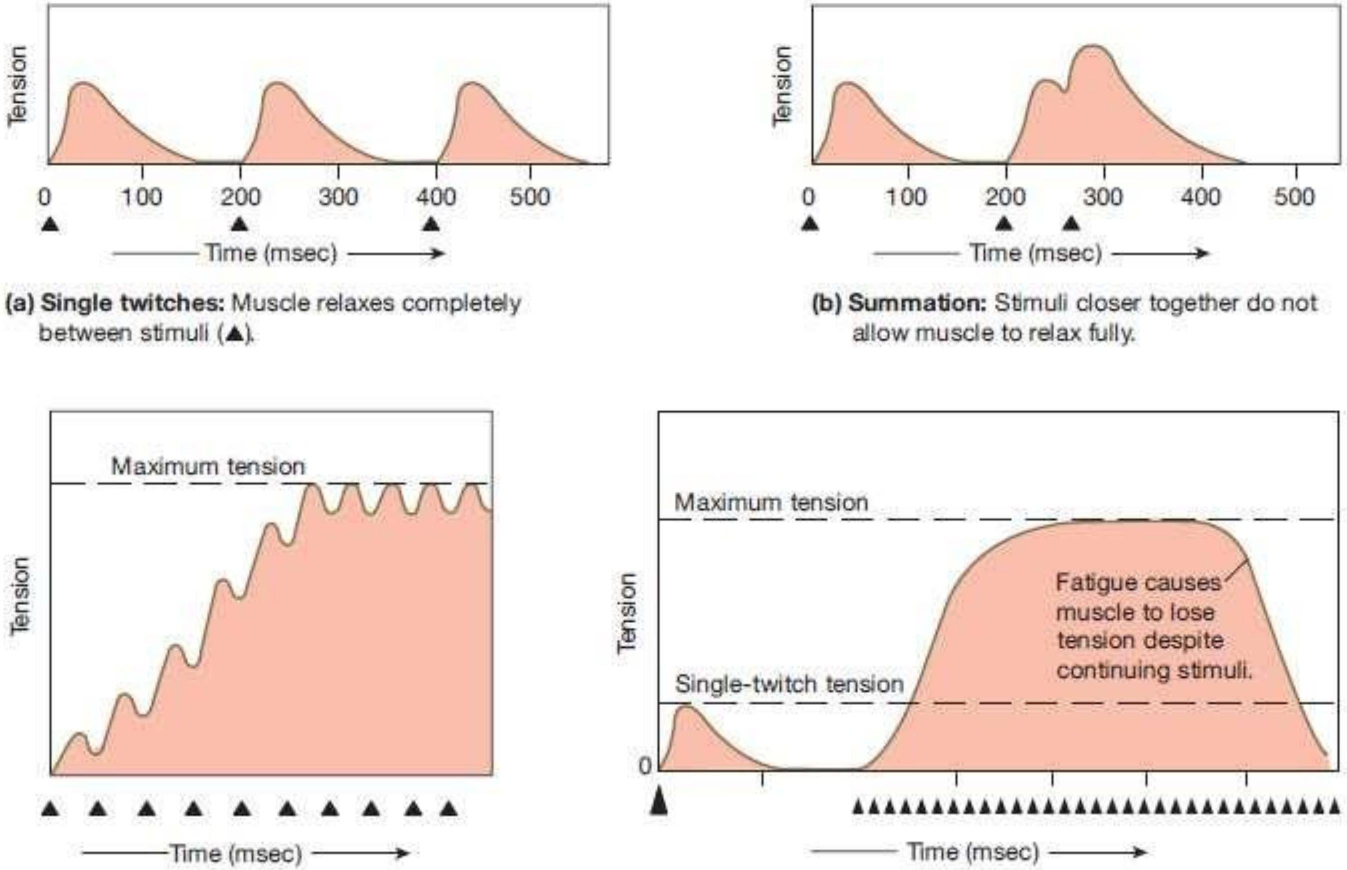
(a) **Isotonic contraction:** muscle contracts, shortens, and creates enough force to move the load.

(b) **Isometric contraction:** muscle contracts but does not shorten. Force cannot move the load.

FIGURE 12-19 *Isotonic and isometric contractions*



● **FIGURE 12-20** *Series elastic elements in muscle.* A muscle has both contractile components (sarcomeres, shown here as a gear and ratchet) and elastic components (shown here as a spring).



(a) Single twitches: Muscle relaxes completely between stimuli (▲).

(b) Summation: Stimuli closer together do not allow muscle to relax fully.

(c) Summation leading to unfused tetanus: Stimuli are far enough apart to allow muscle to relax slightly between stimuli.

(d) Summation leading to complete tetanus: Muscle reaches steady tension.

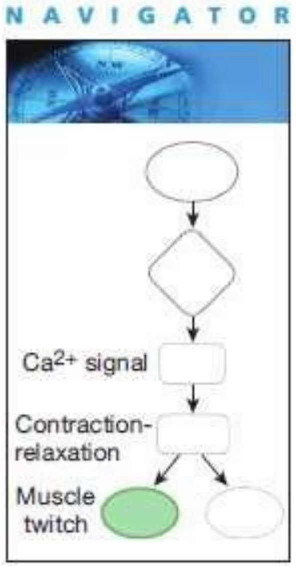


FIGURE 12-17 *Summation of contractions*

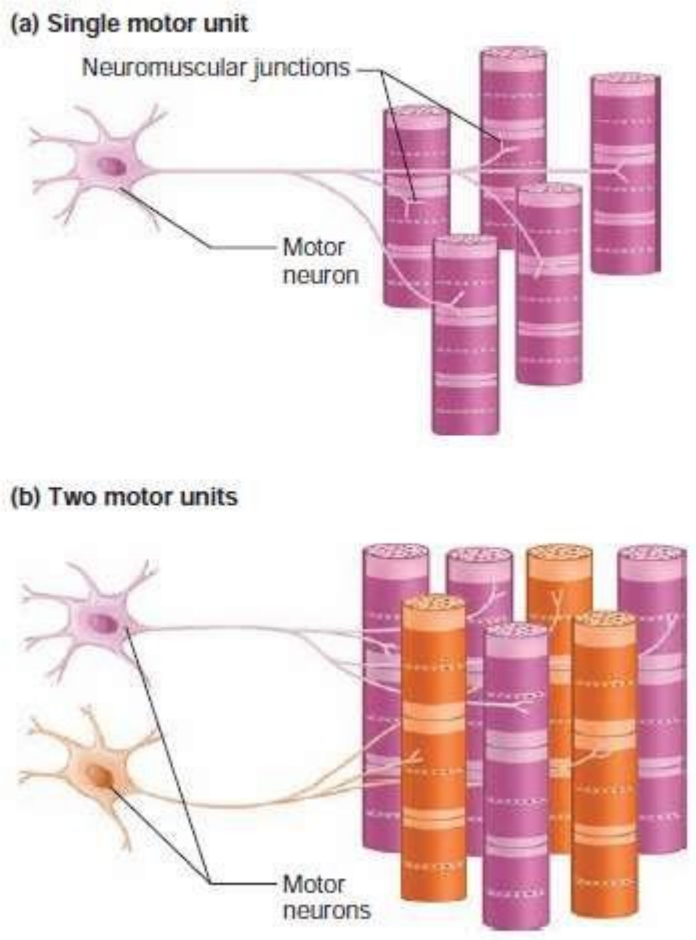


Figure 9–13

(a) Single motor unit consisting of one motor neuron and the muscle fibers it innervates. (b) Two motor units and their intermingled fibers in a muscle.

TAHUKAH KAMU

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YOGA FOR ADULT HEALTH

Henny Dwi Susanti[1*], Tri Lestari Handayani[2], Nurul Aini[3], Ika Rizky Anggraini[4] Yoyok Bekti Prasetyo[5], Rusnani Binti Ab Latif[6]

[1,2,3,4,5]Nursing Department, Faculty of Health Sciences, University of Muhammadiyah Malang
[6]Nursing Department, Faculty of Health Sciences, UITMCPP Kampus Bertam, Pulau Penang, Malaysia

Email Korespondensi: hennydwi@umm.ac.id

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ABSTRACT

Yoga is an exercise that combines mind, spirit and body. This yoga combines breathing techniques, physical postures, relaxation and meditation. The aim of this community service is to improve the health of teenagers. This community service activity starts from the preparation stage, distributing questionnaires for pre-tests, explaining the purpose, benefits of yoga, steps for yoga exercises, and doing yoga exercises. Next, participants were given a questionnaire to assess the post-test. This activity was carried out in collaboration between the University of Muhammadiyah Malang and UiTM Cawangan Pulau Pinang Bertam Campus at the Az Zahra orphanage in Bandar Laguna Merbok, Sungai Tani, Kedah, Malaysia. Showed significant resultsthat teenagers understood the importance of yoga for health and they carried out the steps of yoga exercises. Yoga is very beneficial for the health of teenagers. It is best to do yoga every day to maintain both physical and psychological health in teenagers, so that health is maintained well.

Keywords: *Yoga, Adult, Physic, Psychology*

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YOGA DAN FISIOLOGI OTOT RANGKA

Yoga memiliki banyak manfaat bagi fisiologi otot rangka, yang berperan penting dalam mendukung gerakan dan postur tubuh.

Berikut adalah hubungan yoga dengan fisiologi otot rangka:

1. Meningkatkan Kekuatan Otot

2. Meningkatkan Fleksibilitas

3. Meningkatkan Sirkulasi dan Penghantaran Oksigen

4. Meningkatkan Keseimbangan dan Koordinasi Otot

5. Mengurangi Tegangan dan Kekakuan Otot

6. Perbaikan Postur

Sharma, M., & Haider, T. (2022). "The Impact of Yoga-Based Interventions on Musculoskeletal Health: A Review of Systematic Reviews." *Complementary Therapies in Clinical Practice*, 47, 101521.