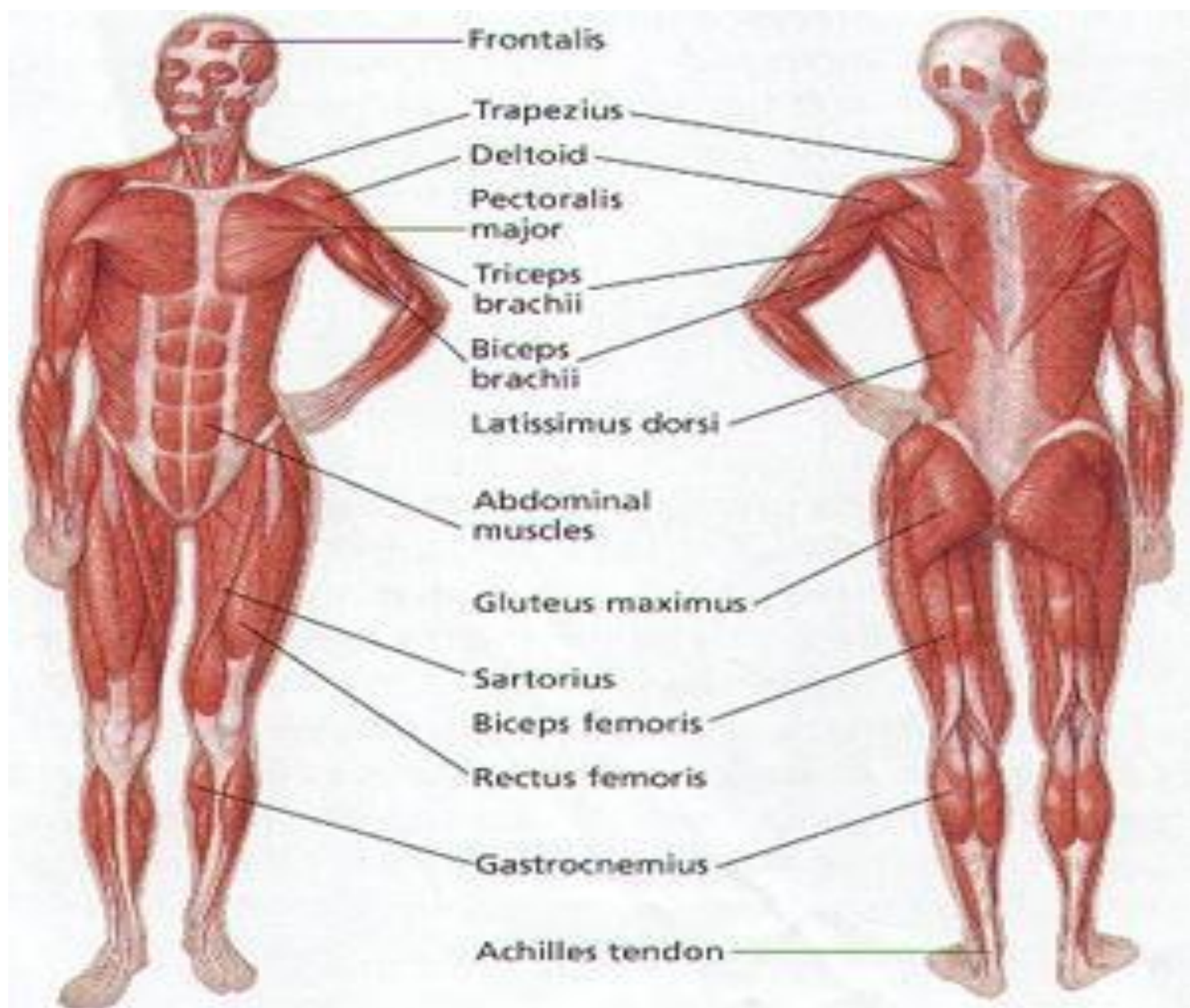


# **The Muscular System**

## **ANATOMY AND PHYSIOLOGY OF MUSCULAR SYSTEM**

**Dr.Ibtisam Khalaf Abd Ali**



Frontalis

Trapezius

Deltoid

Pectoralis major

Triceps brachii

Biceps brachii

Latissimus dorsi

Abdominal muscles

Gluteus maximus

Sartorius

Biceps femoris

Rectus femoris

Gastrocnemius

Achilles tendon

# MUSCULAR SYSTEM

- **Muscle is “a machine of converting chemical**
- **energy into mechanical work” “energy transfer”.**

# MUSCLE TISSUE

- All muscle tissue is composed of muscle cell “muscle fibers”, and exhibits specific characteristics including the following:
- **1. Excitability:** response to stimuli by initiating electrical signal (action potential) that spread across plasma membrane and spark internal events leading to muscle contraction.
- **2. Contractility:** cell shortening.
- **3. Extensibility:** extending in length in response to contraction of opposing muscle cells.
- **4. Elasticity:** ability to return to its original length when tension is released •

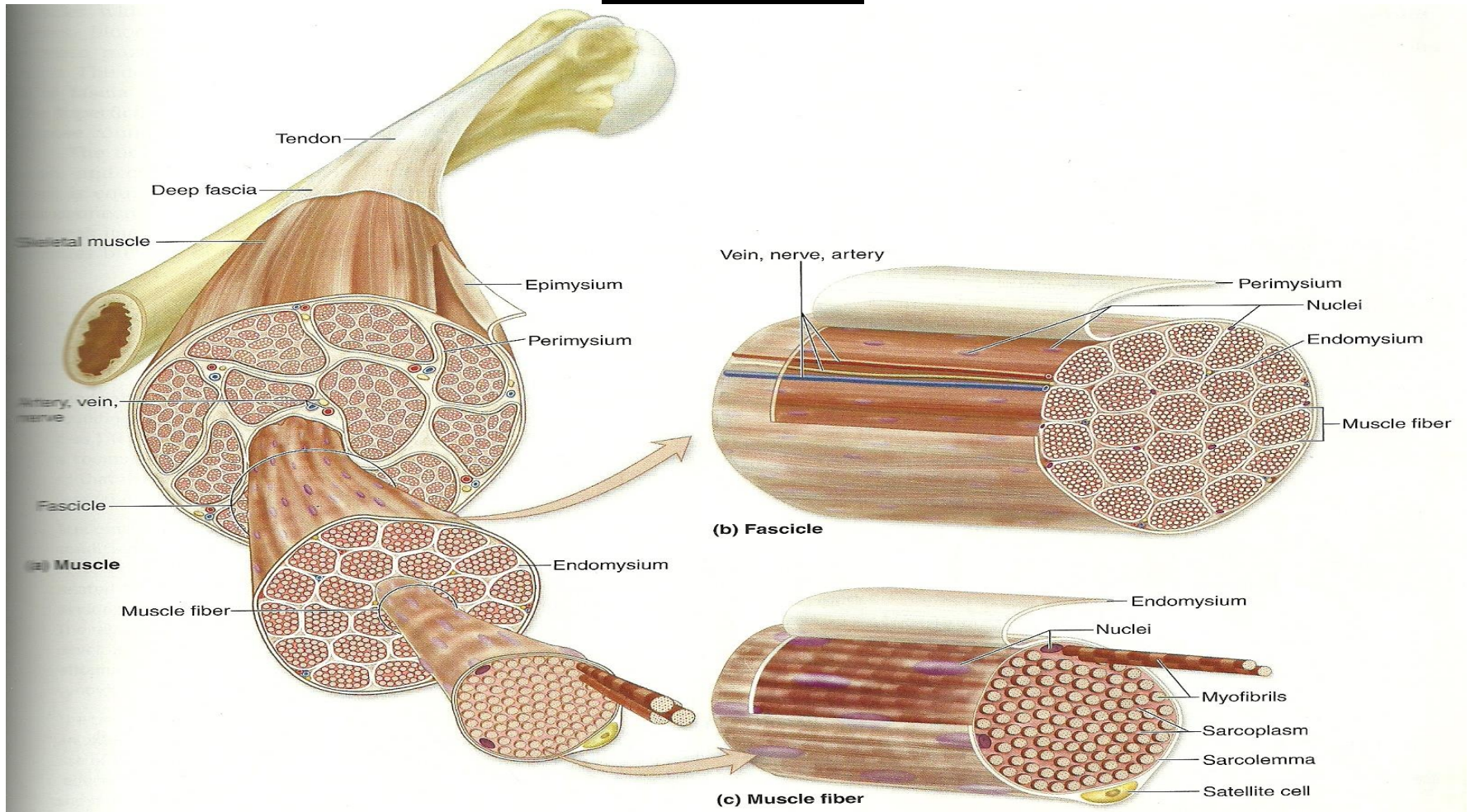
# TYPES OF MUSCLE OR MUSCLE TISSUE

- 1. Skeletal muscle.
- 2. Cardiac muscle .
- 3. Smooth muscle.

# SKELETAL MUSCLE

- **I. Structural Organization of Skeletal Muscle**
- **1. Structures of muscle.**
- a. Epimysium                      b. Fascicle                      c. Perimysium
- d. Muscle fiber                      e. Endomysium                      f. Myofibrils
- g. Deep fascia                      h. Tendon                      i. Sattellite cel

# Structural Organization of Skeletal Muscle



**Figure 10.1**

**Structural Organization of Skeletal Muscle.** (a) A skeletal muscle is ensheathed within a connective tissue layer called the epimysium. (b) Each fascicle (bundle of muscle fibers) is wrapped within a connective tissue layer called the perimysium. (c) Each muscle fiber is surrounded by a delicate connective tissue layer termed the endomysium.

## 2. Structures of fascicle.

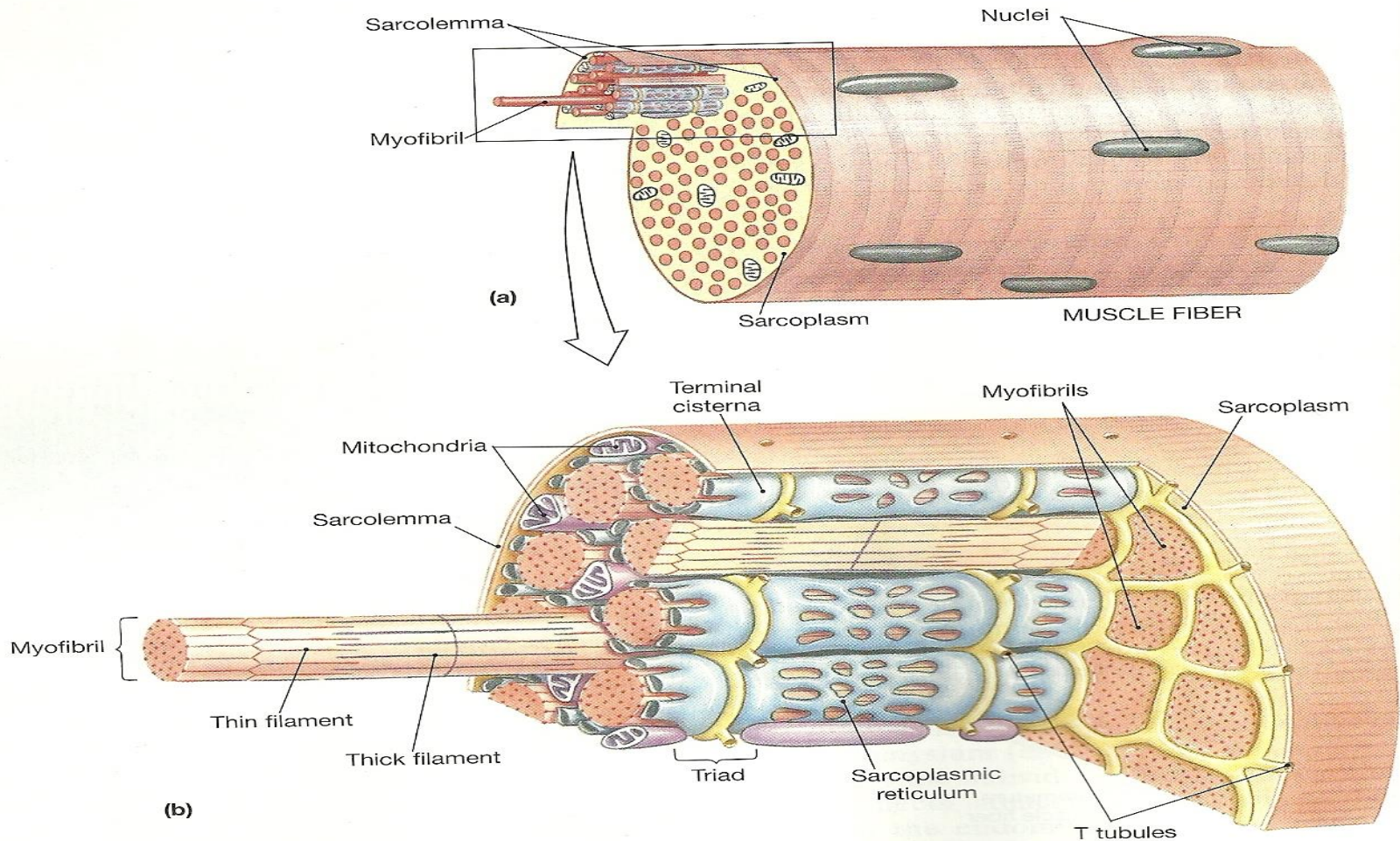
- a. Perimysium
- b. Muscle fiber
- c. Endomysium
- d. Nerve



### **3. Structures of muscle fiber (muscle cell).**

- a. Endomysium
- b. Myofibril
- c. Neuromuscular junction
- d. Nuclei

# The Structure of Skeletal Muscle fiber

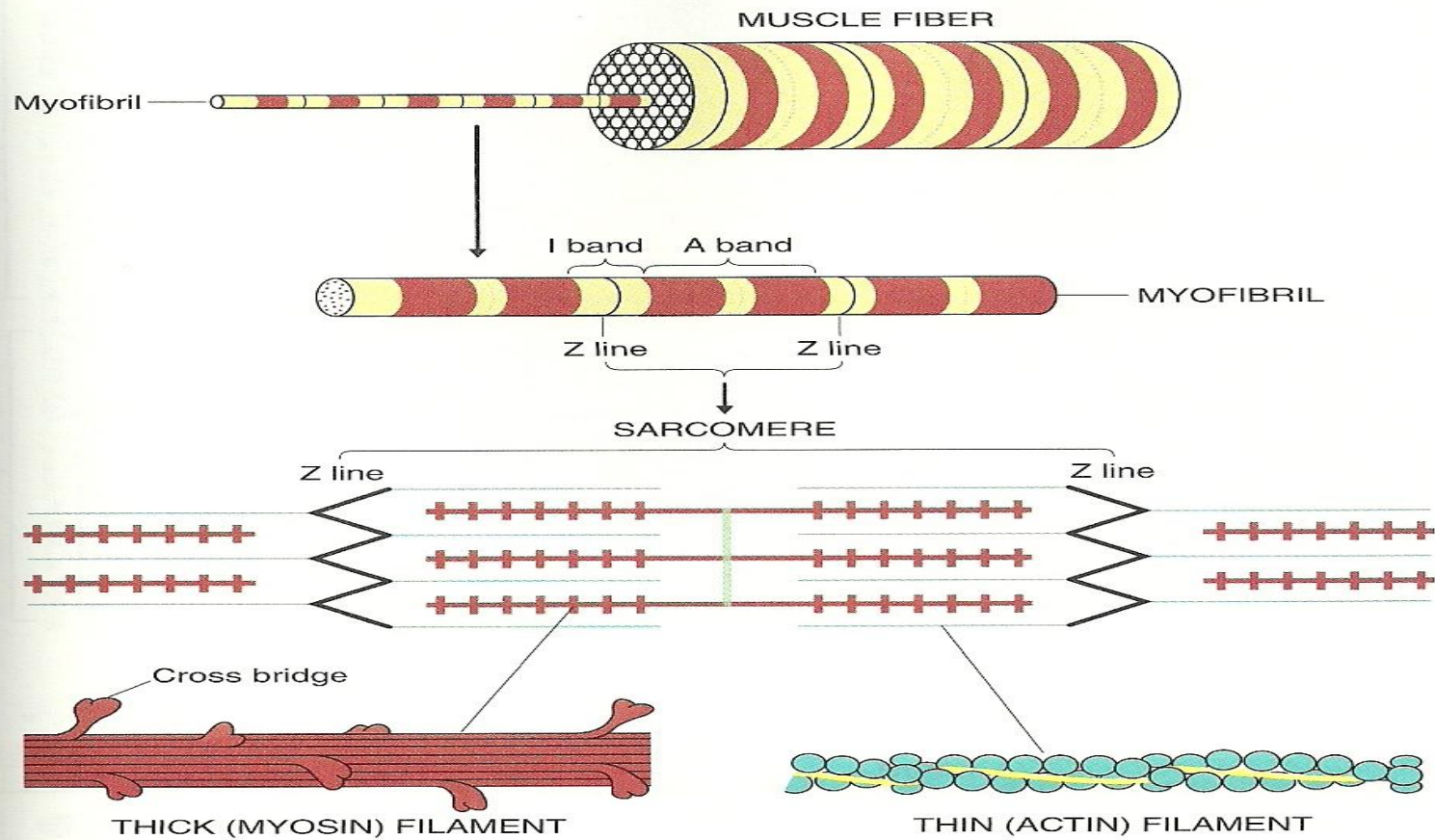


• **FIGURE 10-3 The Structure of a Skeletal Muscle Fiber.** (a) The superficial structure of a muscle fiber. (b) The internal organization of a muscle fiber.


# II. Structural Organization of Myofibrils and Myofilaments

- **. Structures of myofibrils:** compose from many sarcomeres
- **Sarcomere:** the smallest contractile unit in myofibril of striated muscle fiber. Each sarcomere composed from:
  - **a. Myofilament – Actin- (Thin filament)**
  - **b. Myofilament-Myosin (Thick filament)**
  -

# Arrangement of filaments in skeletal muscle fiber

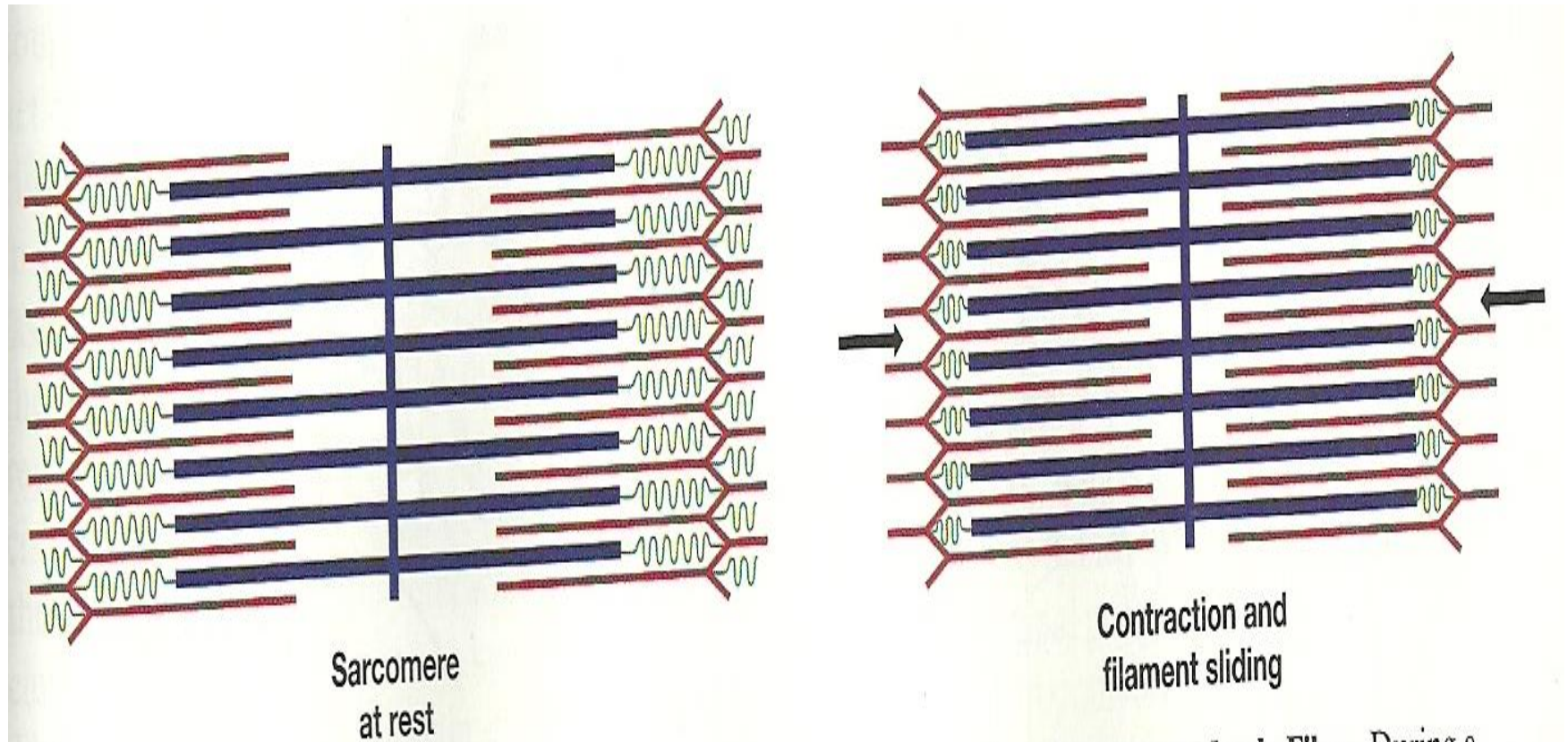


**FIGURE 11-4**

Arrangement of filaments in a skeletal-muscle fiber that produces the striated banding pattern. 



# Changes in the appearance of a Sarcomere during the Contraction of Skeletal Muscle Fiber

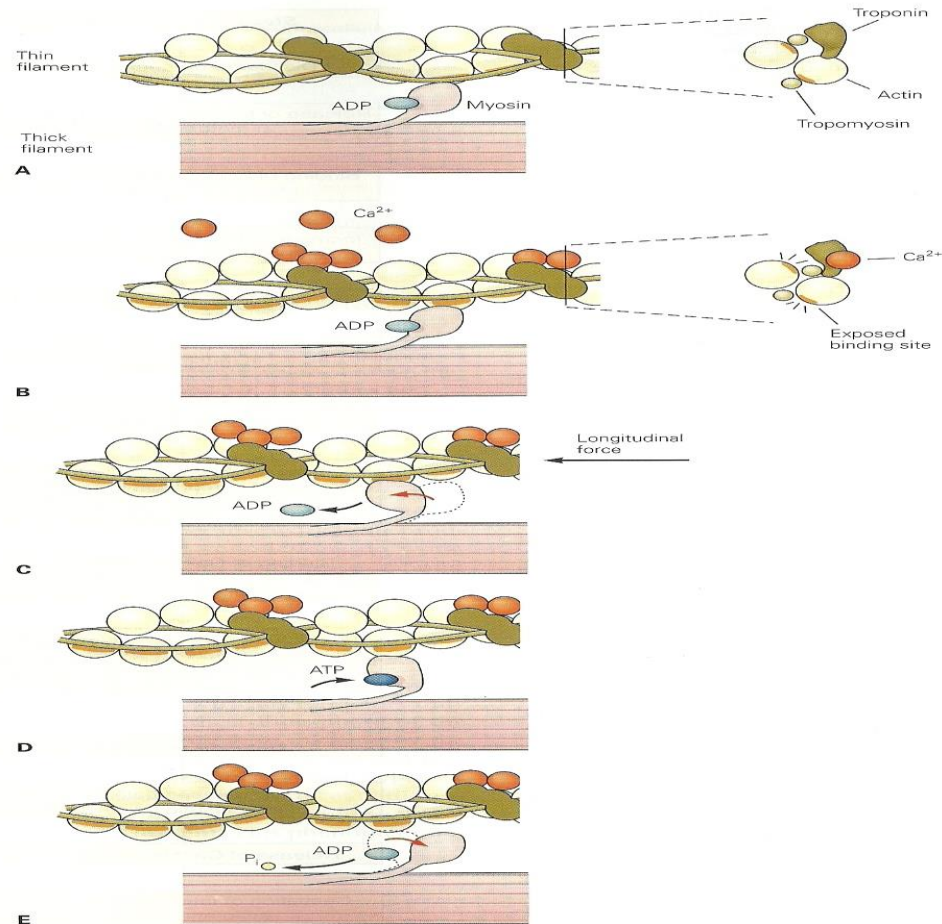


• **FIGURE 10-8** Changes in the Appearance of a Sarcomere during the Contraction of a Skeletal Muscle Fiber. During a contraction, the A band stays the same width, but the Z lines move closer together and the I band gets smaller.

# CONTRACTION OF SKELETAL MUSCLE

**Contraction:** is the sliding of actin over myosin •  
in the presence of  $\text{Ca}^{++}$  (calcium ion). “Skeletal  
muscle are attached to bones by tendons, and  
contraction of skeletal muscle exerts a pull on  
bone and movement”, most skeleton muscles  
extend between bones. The less movable  
point of attachment of the muscle called  
“Origin”, and the more movable called  
“Insertion”.

# I. Steps Involved in the Mechanisms of Sliding Theory



**FIGURE 5-6 Power stroke of myosin in skeletal muscle. A)** At rest, myosin heads are bound to adenosine diphosphate and are said to be in a "cocked" position in relation to the thin filament, which does not have  $\text{Ca}^{2+}$  bound to the troponin-tropomyosin complex. **B)**  $\text{Ca}^{2+}$  bound to the troponin-tropomyosin complex induced a conformational change in the thin filament that allows for myosin heads to cross-bridge with thin filament actin. **C)** Myosin heads rotate, move the attached actin and shorten the muscle fiber, forming the power stroke. **D)** At the end of the power stroke, ATP binds to a now exposed site, and causes a detachment from the actin filament. **E)** ATP is hydrolyzed into ADP and inorganic phosphate ( $\text{P}_i$ ) and this chemical energy is used to "re-cock" the myosin head. (Modified with permission from Kandel ER, Schwartz JH, Jessell TM [editors]: *Principles of Neural Science*, 4th ed. McGraw-Hill, 2000.)

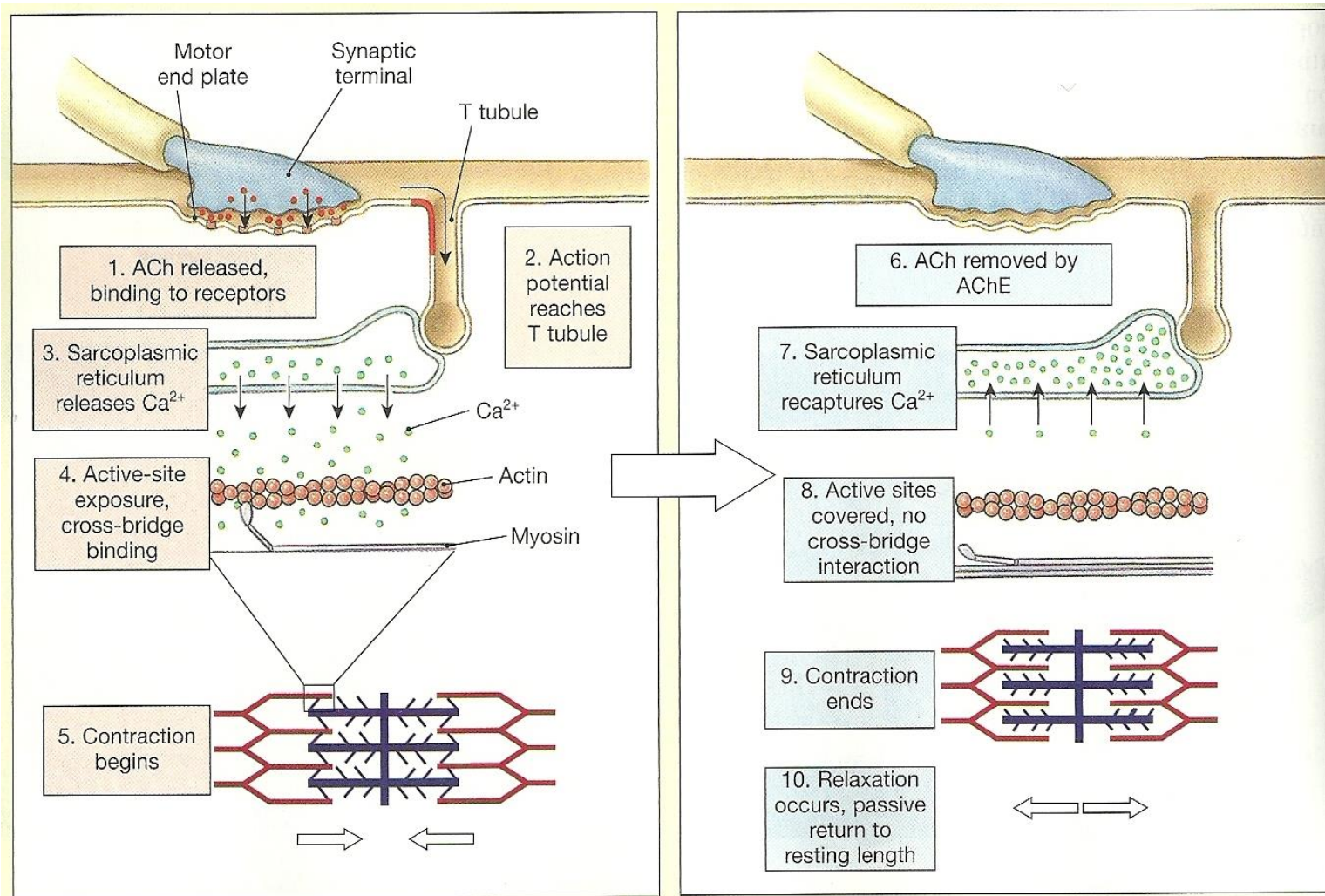
# I. Steps Involved in the Mechanisms of Sliding Theory:

- 1. Excitable tissues: nerve and muscle (nerve impulse in axons cause muscle impulses in sarcolemma).
- 2. Excitable cell: cell that is capable to create and conduct action potential
- 3. Action potential: Changes in membrane potential of excitable cells .also defined as electrical activity or electrical signal.
- 4. Motor end plate produces neurotransmitter at the neuromuscular junction, to stimulate the cell membrane (sarcolemma) to produce Action potential (electrical signal).



- 5. Action potential (electrical signal) spread through cell membrane to “T –tube” and then to sarcoplasmic reticulum to release calcium ion.
- 6. Calcium ion triggers the process of sliding.
- 7. Relaxation: the period after a contraction when the tension in the muscle fiber return to resting levels, and this done by:
  - a. Active cytosolic calcium ( $\text{Ca}^{++}$ ) transported across the cell membrane into the extracellular fluid.
  - b. Active cytosolic calcium ( $\text{Ca}^{++}$ ) transported into the sarcoplasmic reticulum.

# Steps in the initiation and the end of contraction




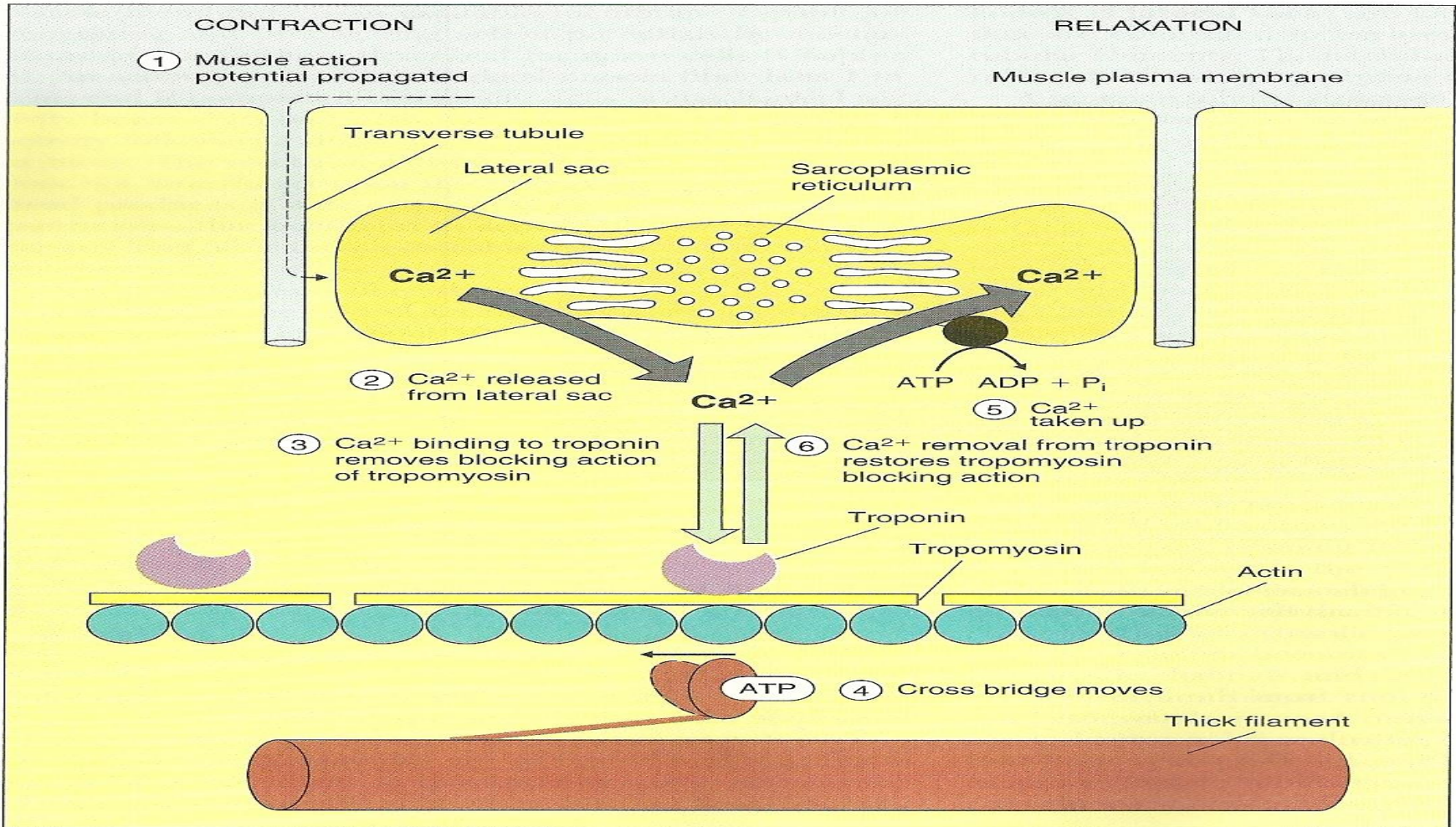
Steps in the initiation of a contraction

Steps that end the contraction

# Release and uptake of calcium by the Sarcoplasmic Reticulum during Contraction and Relaxation of Skeletal Muscle

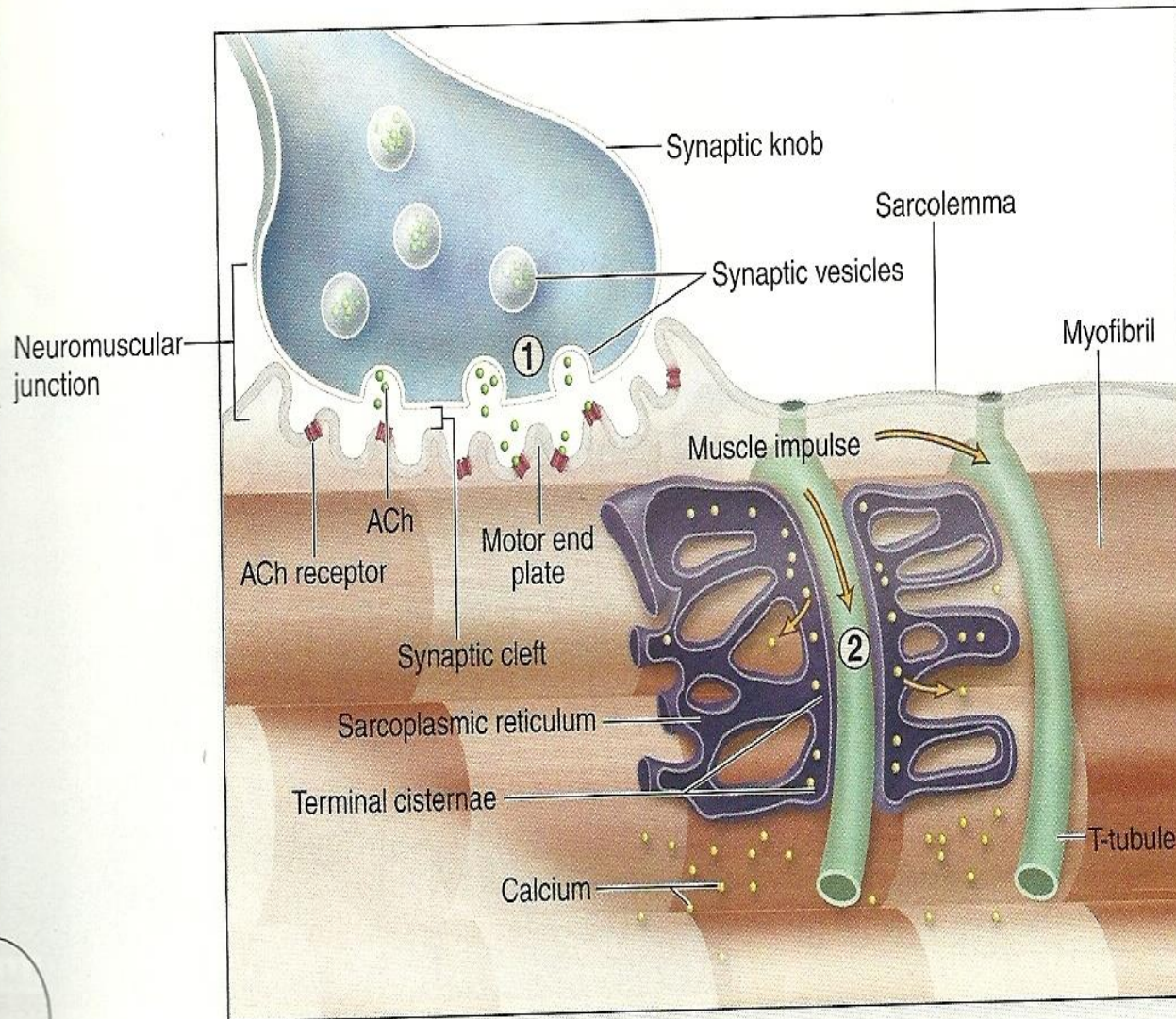
**FIGURE 11-16**

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





# Neuromuscular Junction



① A nerve impulse triggers release of ACh at the neuromuscular junction. ACh binds to motor end plate receptors initiating a muscle impulse in the sarcolemma of the muscle fiber.

② The muscle impulse spreads quickly from the sarcolemma along T-tubules, causing release of calcium ( $\text{Ca}^{2+}$ ) ions from terminal cisternae into the sarcoplasm.

# CONTROL OF SKELETAL MUSCLE CONTRACTION

Skeletal muscle fibers contract only under the •  
control of the **nervous system**.

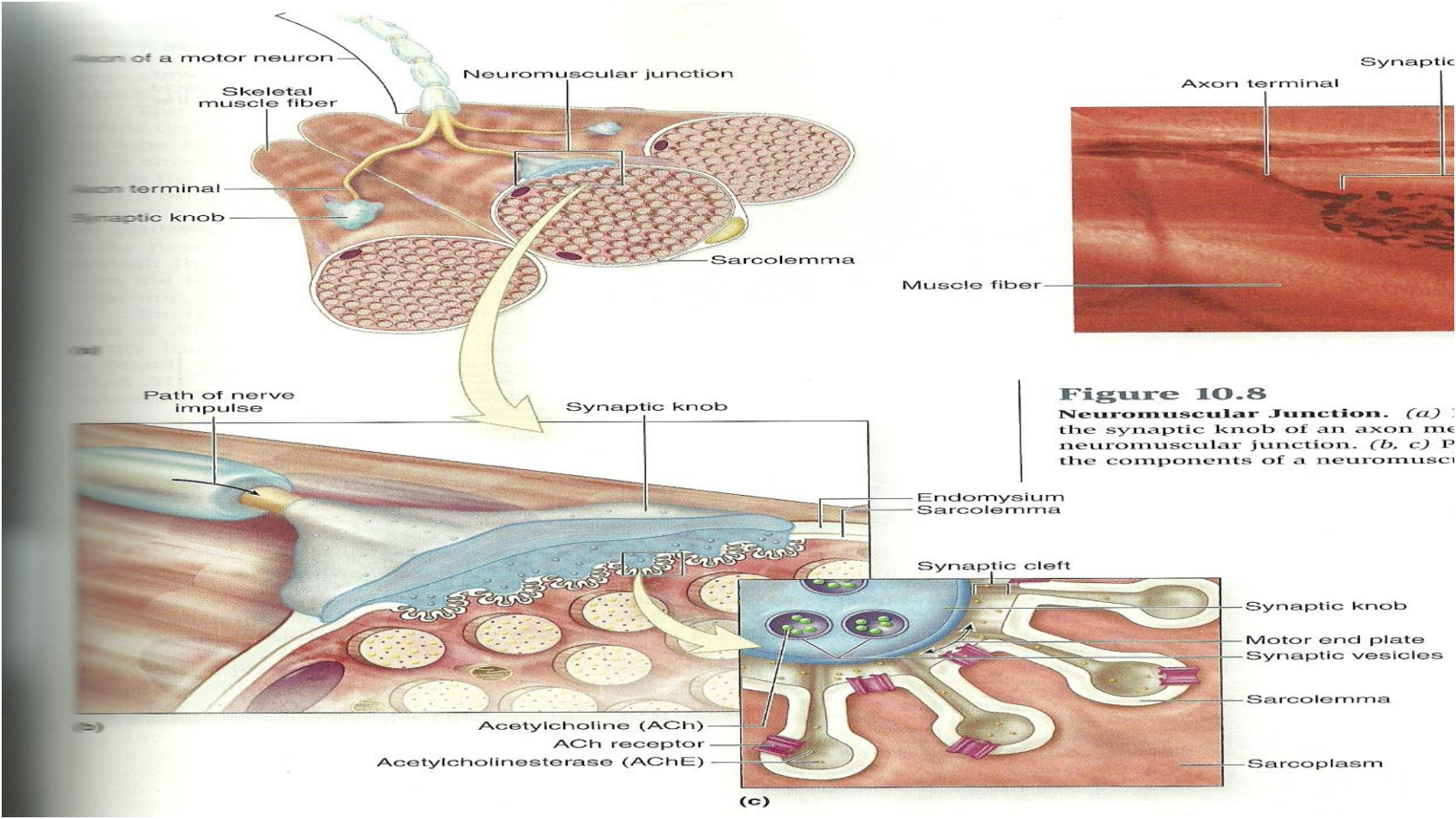
Communication between the nervous system  
and the skeletal muscle fiber occurs at a  
specialized intercellular connection known as  
**neuromuscular junction**

# I. Structures of Neuromuscular Junction (Chemical Synapse and Motor End Plate)

- (Structure where axons transmit nerve impulse to muscle fiber)
- 1. Synaptic knob (terminal)
- 2. Acetylcholine (ACh) (Synaptic Vesicles)
- 3. Synaptic cleft
- 4. Motor end plate
- 5. Sarcolemma
- 6. Acetylcholine receptor
- 7. Acetylcholinestrerase  
(AChE)



# Neuro Muscular Junction



**Figure 10.8**  
**Neuromuscular Junction.** (a) shows the synaptic knob of an axon terminal at a neuromuscular junction. (b, c) show the components of a neuromuscular junction.

## II. Ions Fluxes in Action Potential

- 1. Sodium
- 2. Potassium
- 3. Calcium



**TABLE 5–1** Steady-state distribution of ions in the intracellular and extracellular compartments of mammalian skeletal muscle, and the equilibrium potentials for these ions.

Ion <sup>a</sup>	Concentration (mmol/L)		Equilibrium Potential (mV)
	Intracellular Fluid	Extracellular Fluid	
Na <sup>+</sup>	12	145	+65
K <sup>+</sup>	155	4	–95
H <sup>+</sup>	$13 \times 10^{-5}$	$3.8 \times 10^{-5}$	–32
Cl <sup>–</sup>	3.8	120	–90
HCO <sub>3</sub> <sup>–</sup>	8	27	–32
A <sup>–</sup>	155	0	...
Membrane potential = –90 mV			

# MUSCLE PERFORMANCE

- **Muscle performance:** mean power and endurance.
- **Power:** the ability to act (capability).
- **Endurance:** the ability to sustain an activity over a period of time.

# **I. Factors Determine the Performance Capabilities of any Skeletal Muscle**

- **1. Types of muscle fibers in the muscle.**
  - a. Fast fibers.
  - b. Slow fibers.
  - c. Intermediate fiber.
- **2. Physical Conditioning**
  - a. Aerobic endurance.
  - b. Anaerobic endurance.

# MUSCLE TONE AND CONTRACTION

**I. Muscle Tone:** normal tension, in muscle the resistance to passive elongation or stretch; or partial contraction of the muscle; or residual muscle tension

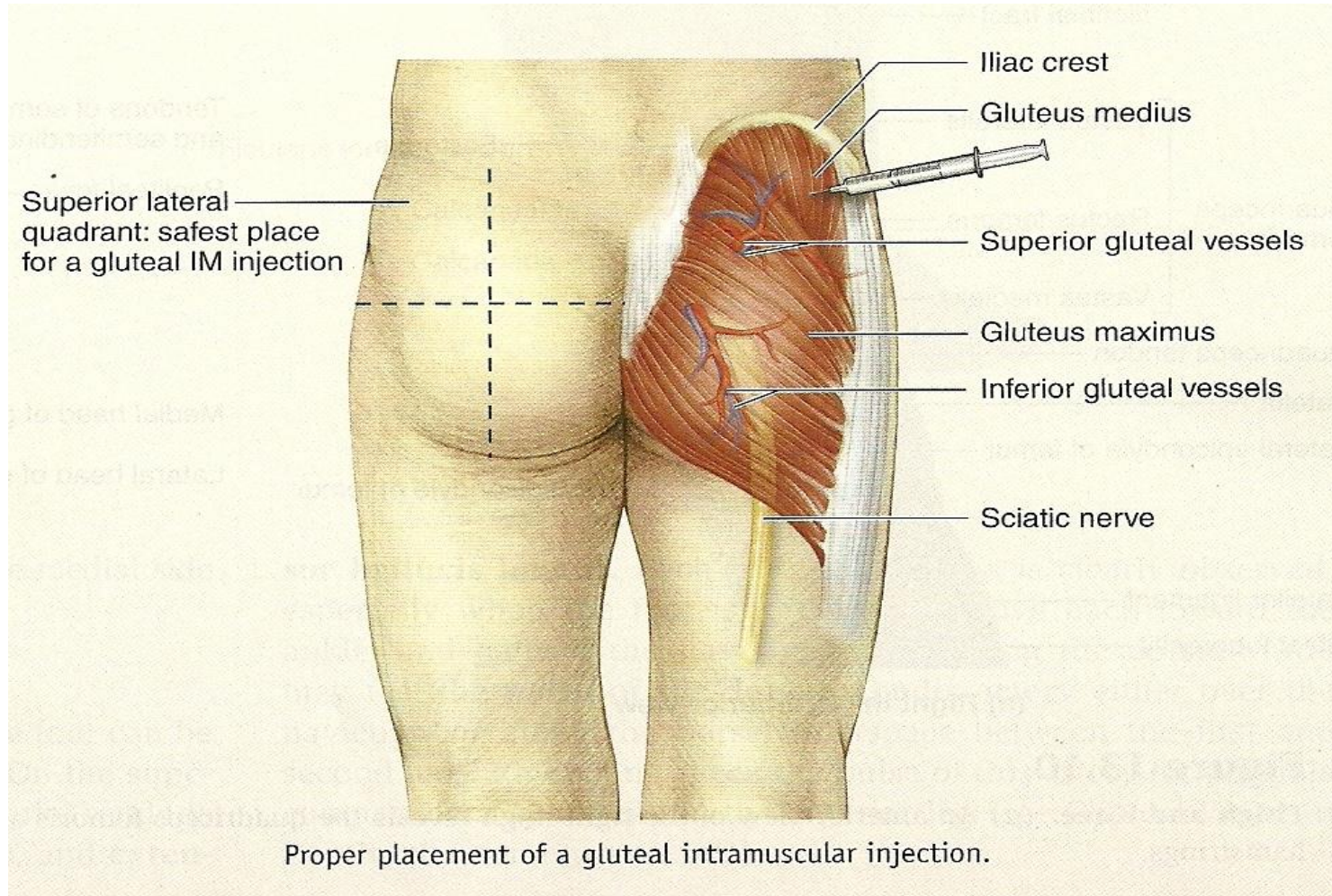
**II. Muscle Contraction:** shortening of the muscle

## **Types of Muscle Contraction**

1. Isometric contraction.
2. Isotonic contraction



# III. Gluteal Intramuscular Injection



# ENERGETIC OF MUSCULAR ACTIVITY

A single muscle fiber may contain 15 billion thick filaments, during muscle fiber contraction, each thick filament break down roughly 2500 ATP molecule per second. Small skeletal muscle contains thousands of muscle fibers.

# I. Sources of Energy Stored in Muscle Fiber

1. ATP “Adenosine triphosphate”

2. CP “Creatine phosphate”

3. Glycogen

**ATP + Creatine**      Creatine Phosphokinase      **ADP+ Creatine phosphate**

**ADP + Creatine phosphate**      Creatine Phosphokinase      **ATP + Creatine**

## II.ATP Generation

1. Aerobic metabolism “Oxidative phosphorelation”.
2. Anaerobic metabolism “glycolysis”.

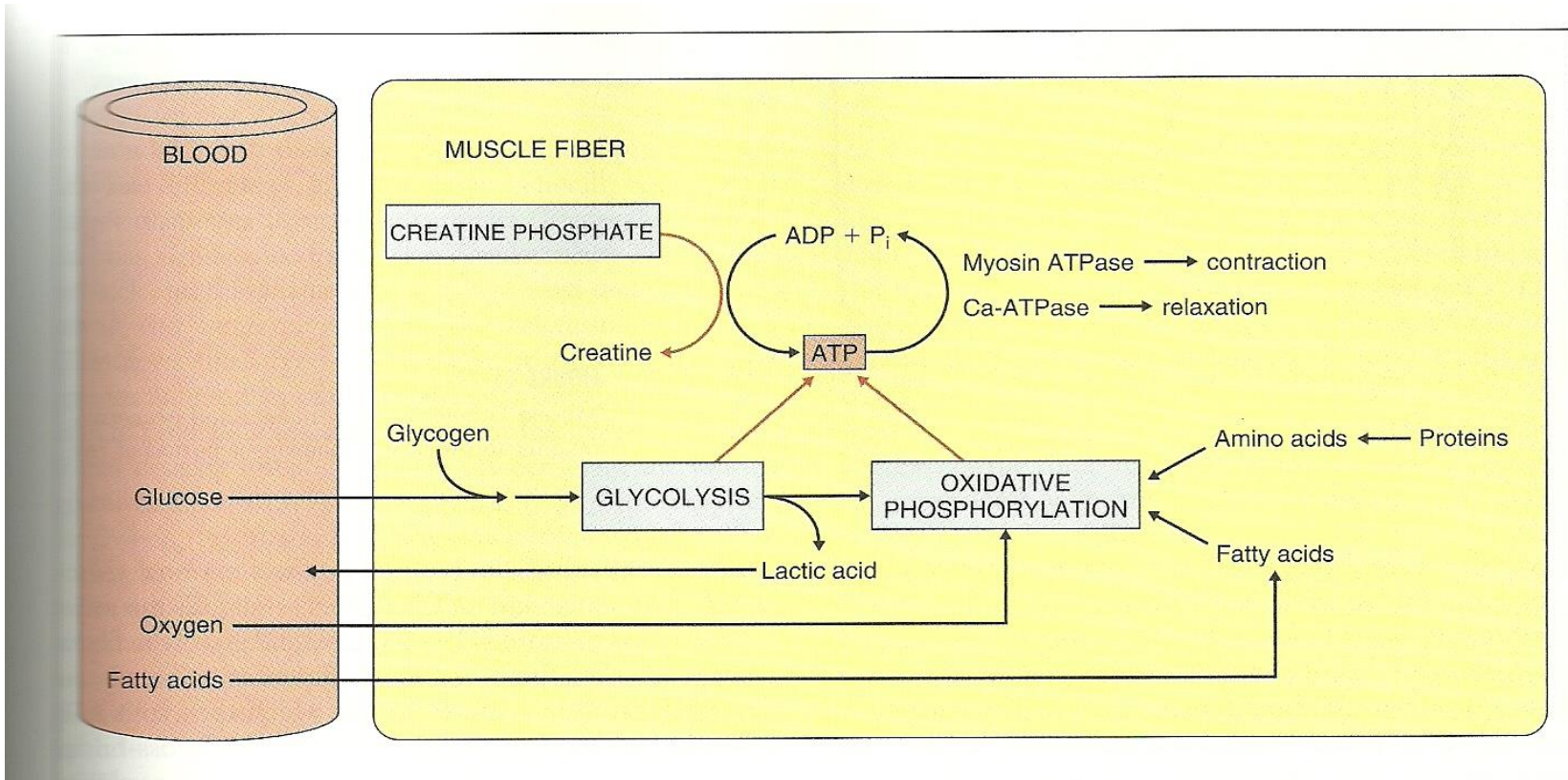


# III. Hormones and Muscle Metabolism


1. Growth hormone.

2. Testosterone.

# The three sources of ATP production during Muscle contraction



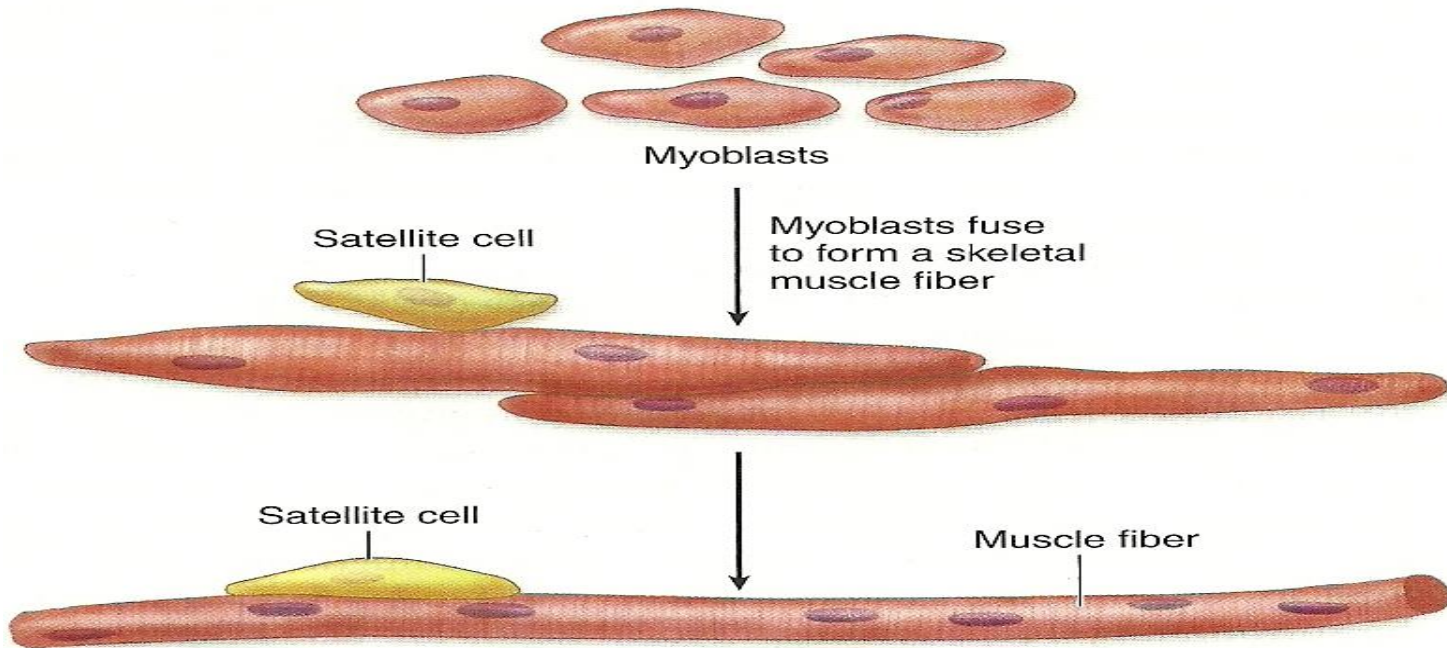
**FIGURE 11-26**

The three sources of ATP production during muscle contraction: (1) creatine phosphate, (2) oxidative phosphorylation, and (3) glycolysis. 

# **FUNCTIONS OF SKELETAL MUSCLE**

1. Producing skeletal movement.
2. Maintaining posture and body position.
3. Supporting soft tissues.
4. Guarding entrance and exits.
5. Maintaining body temperature.

# DEVELOPMENT OF SKELETAL MUSCLE



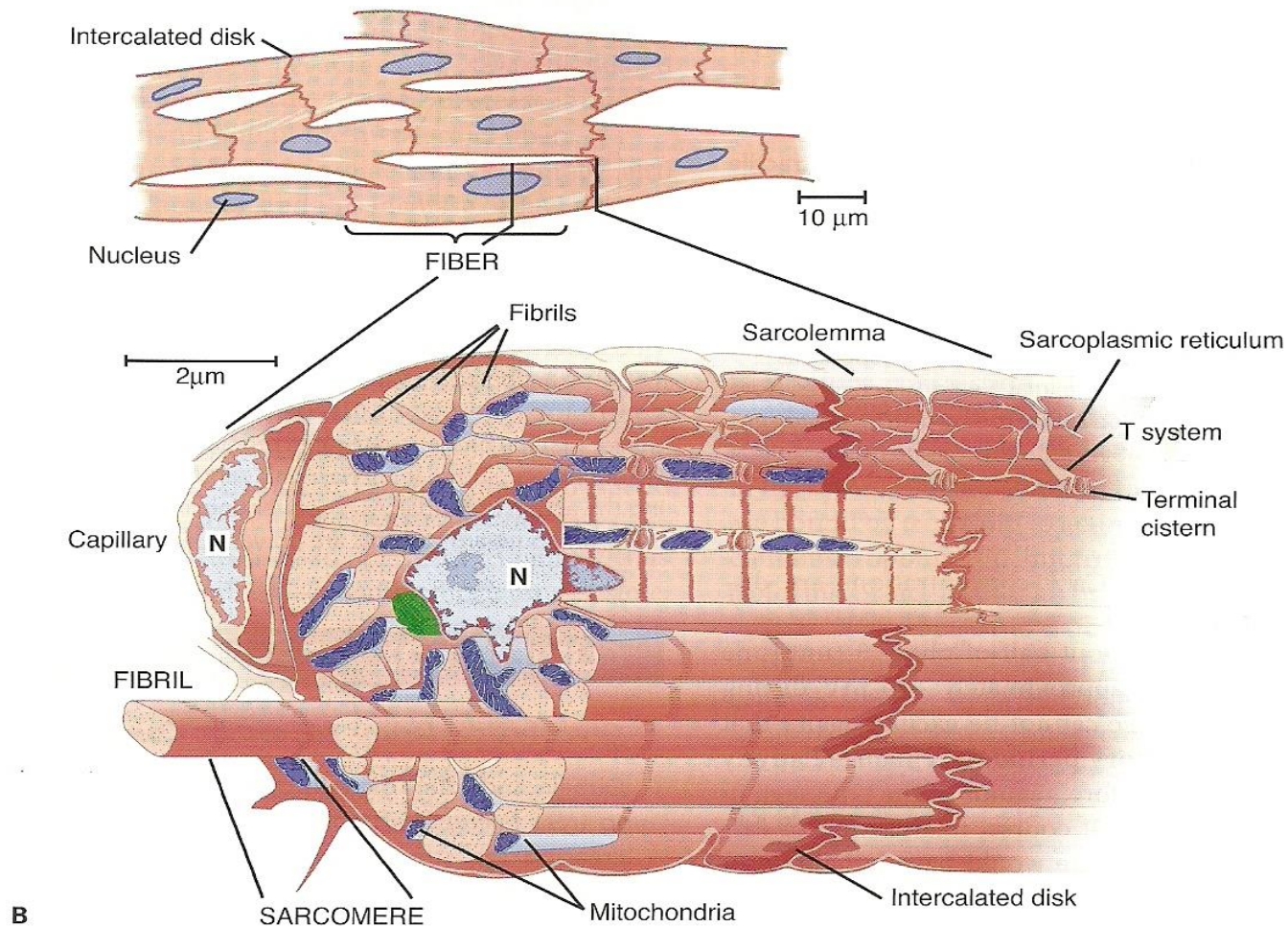
**Figure 10.4**

**Development of Skeletal Muscle.** Embryonic muscle cells called myoblasts fuse to form a single skeletal muscle fiber. Satellite cells are myoblasts that do not go on to form the skeletal muscle fiber. Instead, satellite cells remain with postnatal skeletal muscle tissue and assist in repair of muscles.

# CARDIAC MUSCLE

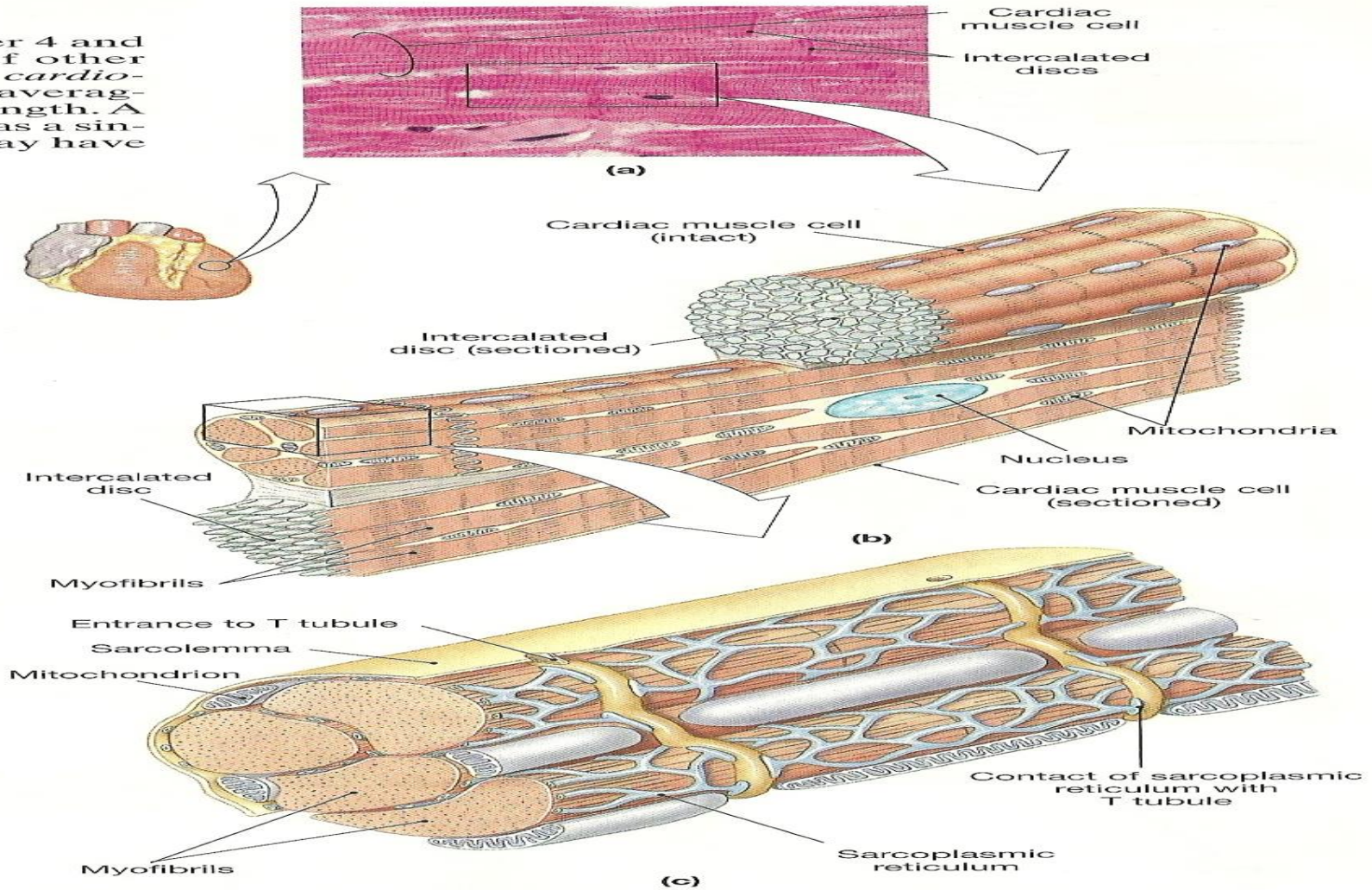
**I. Cardiac Muscle Fibers** are individual muscle fibers arranged in thick bundles like skeletal muscle fiber, but shorter and thicker, and have one or two nuclei. Cardiac muscle fiber forms Y-shaped branches; it is attached to adjacent muscle fibers by junctions termed intercalated discs





**FIGURE 5-15 Cardiac muscle.** **A)** Electron photomicrograph of cardiac muscle. Note the similarity of the A-I regions seen in the skeletal muscle EM of Figure 3-2. The fuzzy thick lines are intercalated disks and function similarly to the Z-lines but occur at cell membranes ( $\times 12,000$ ). (Reproduced with permission from Bloom W, Fawcett DW: *A Textbook of Histology*, 10th ed. Saunders, 1975.) **B)** Artist interpretation of cardiac muscle as seen under the light microscope (**top**) and the electron microscope (**bottom**). Again, note the similarity to skeletal muscle structure. N, nucleus. (Reproduced with permission from Braunwald E, Ross J, Sonnenblick EH: *Mechanisms of contraction of the normal and failing heart*. *N Engl J Med* 1967;277:794. Courtesy of Little, Brown.)

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**FIGURE 10-21 Cardiac Muscle Tissue.** (a) A light micrograph of a cardiac muscle tissue. Notice the striations and the intercalated discs. (b,c) The structure of a cardiac muscle cell; compare with Figure 10-3.



# Specific structure of cardiac muscle fiber

1. Intercalated disc.
2. Generally centrally located single nucleus.
3. Cardiac muscle fibers are: thinner and shorter than skeletal muscle fiber.
4. Contractions of cardiac muscle fiber depend on  $\text{Ca}^{++}$  in ECF and sarcoplasmic reticulum.
5. CMF are slower onset in contraction and resistant to fatigue.
6. CMFs control by pacemaker cells (Automaticity).
7. CMFs depend on aerobic metabolism (fat and carbohydrate) to maintain energy.



# **II. Control of Cardiac Muscle Contraction**

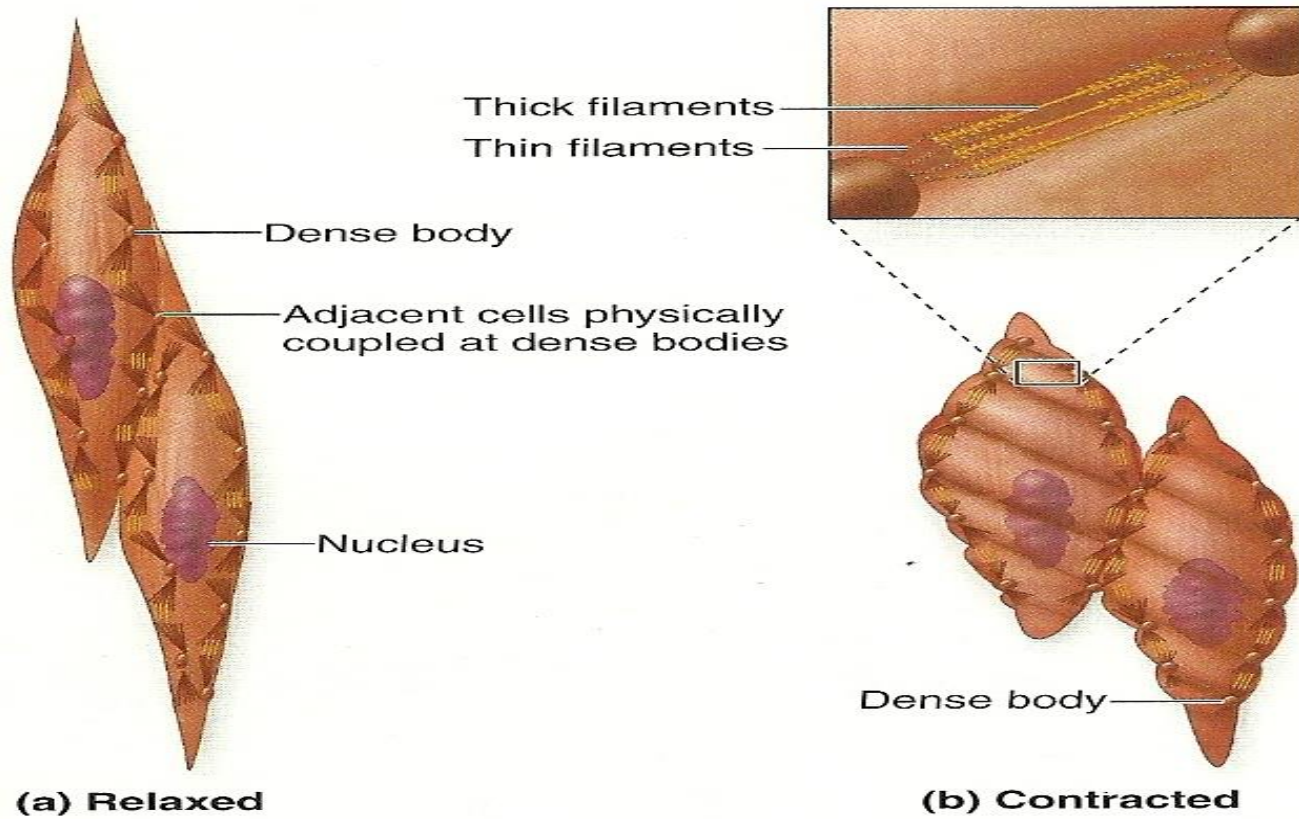
**1. Automaticity.**

**2. Autonomic innervations.**

**3. Blood born chemicals .**

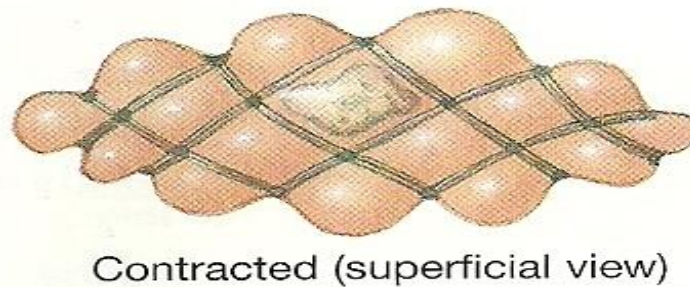
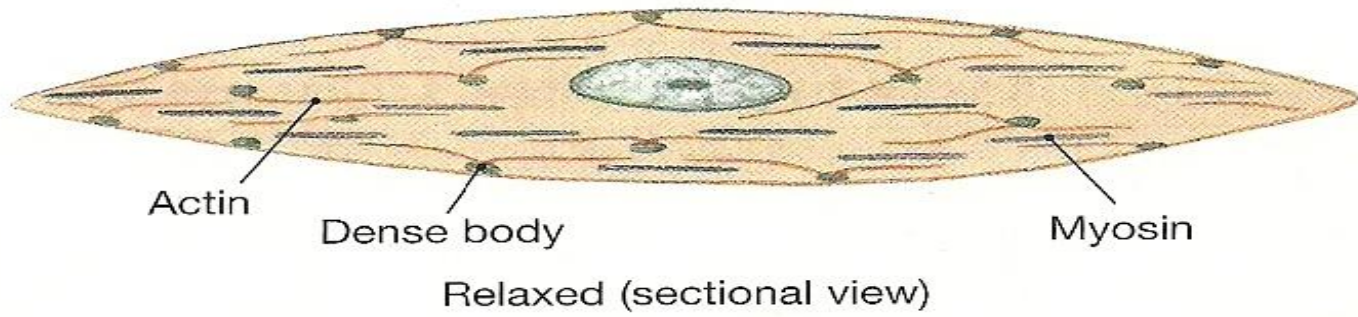
# SMOOTH MUSCLEI. Smooth Muscle Fiber Characteristic

1. Small cell.
2. Have one nucleus.
3. Capacity to divide.
4. Composed from thick and thin filaments and dense body.
5. Thick and thin filaments don't organize into myofibrils.
6. Slow onset contraction, and may be tetanized and resistant to fatigue.
7. Primarily aerobic metabolism.
8. Depend on ECF  $\text{Ca}^{++}$  to maintain contraction.
9. No T-tube and dispersed sarcoplasmic reticular throughout sarcoplasm.



**Figure 10.16**

**Smooth Muscle.** Smooth muscle is located in the walls of hollow organs and blood vessels. (a) Relaxed smooth muscle fibers appear more elongated than (b) contracted smooth muscle fibers.



**(b)**

## II. Types of Smooth Muscle\_

### 1. **Single unit smooth muscle (visceral smooth muscle).**

Found for example in the wall of gastrointestinal tract, gallbladder, urinary bladder and other internal organs.

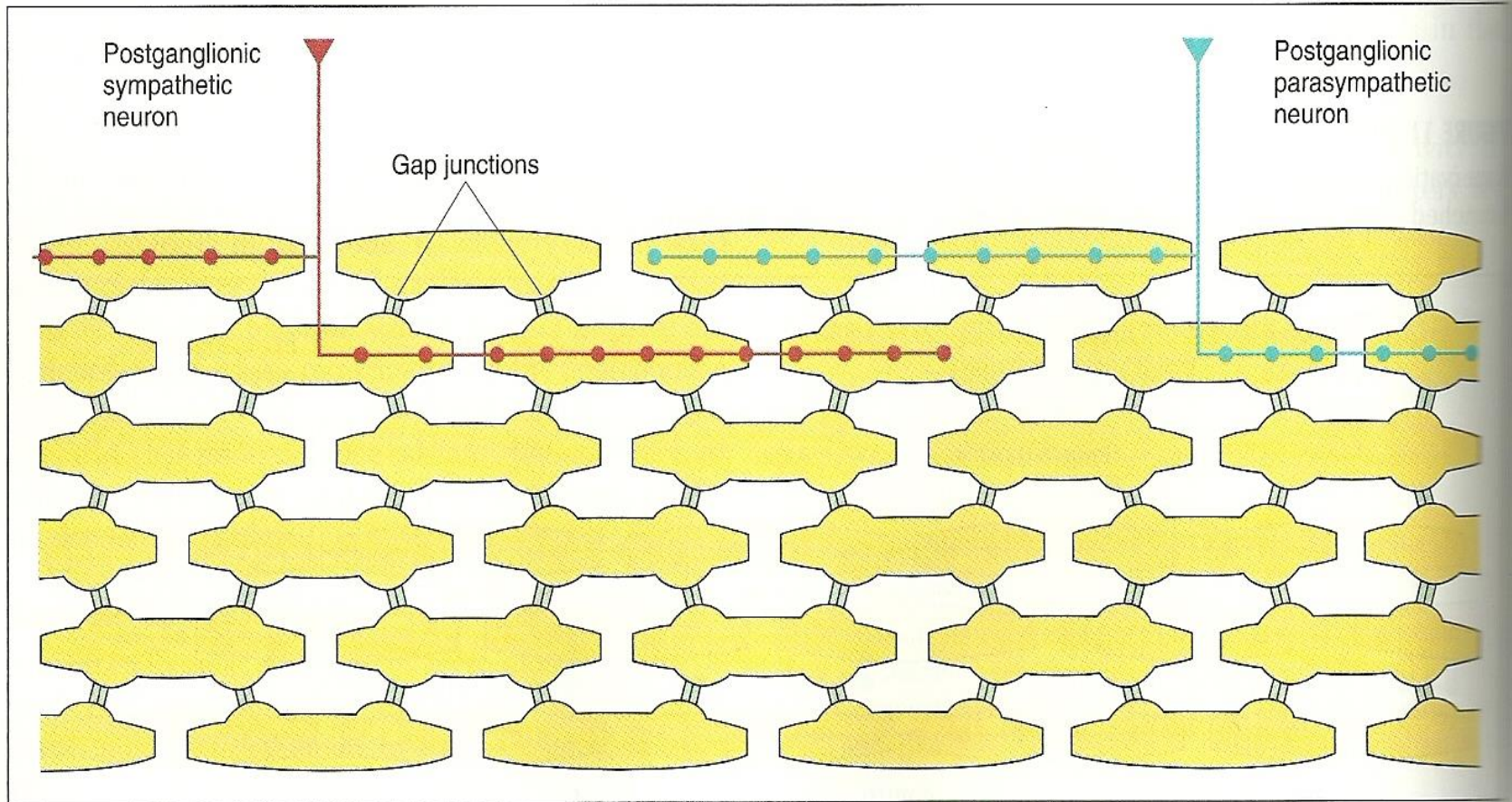
### 2. **Mutiunit smooth muscle** found for example in iris of the eye (to regulate the diameter of pupil), male reproductive gland and wall of large arteries.





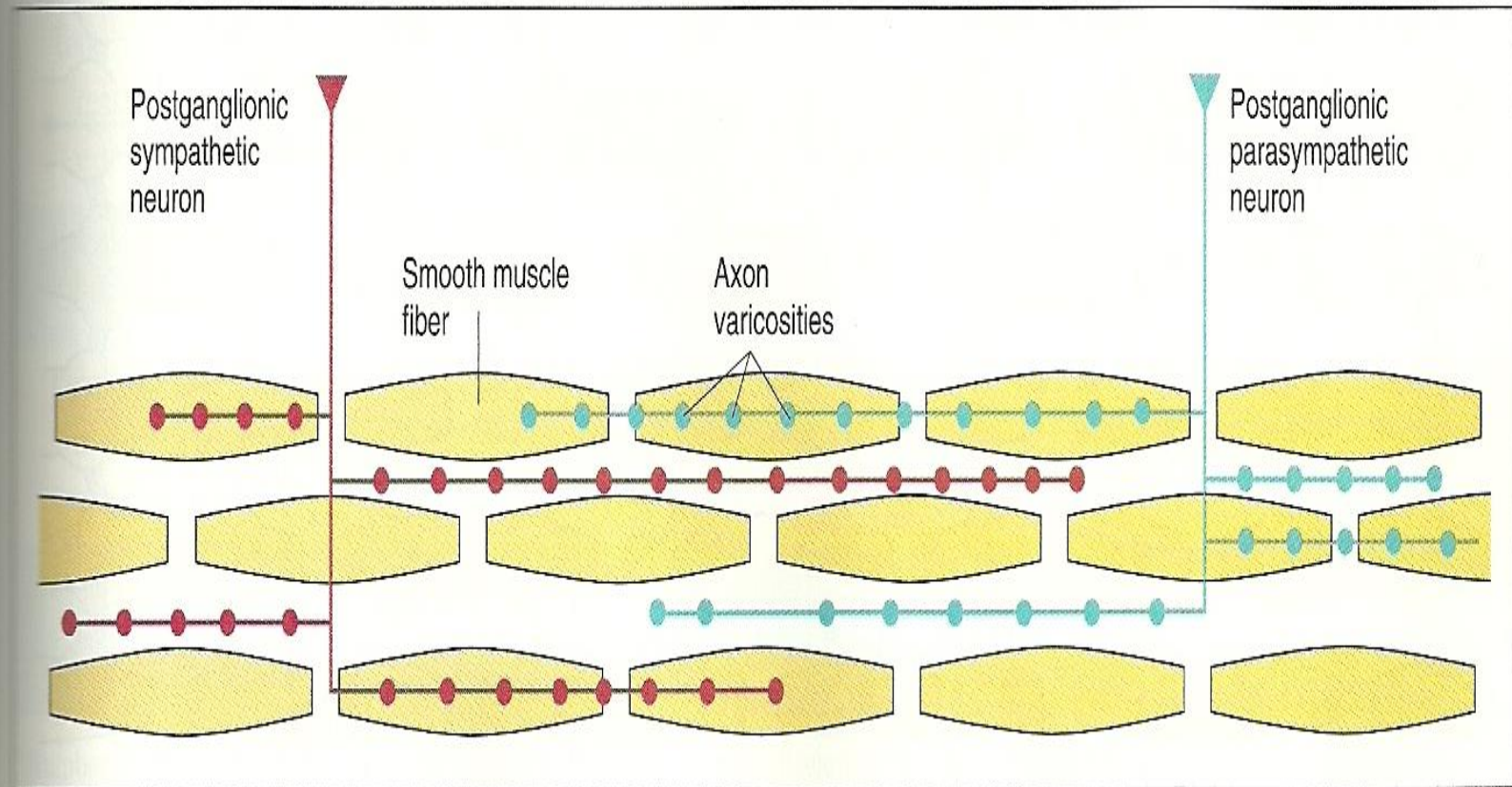
**FIGURE 11-40**

Innervation of a single-unit smooth muscle is often restricted to only a few fibers in the muscle. Electrical activity is conducted from fiber to fiber throughout the muscle by way of the gap junctions between the fibers.



**FIGURE 11-39**

Innervation of smooth muscle by postganglionic autonomic neurons. Neurotransmitter is released from the varicosities along the branched axons and diffuses to receptors on muscle-fiber plasma membranes.

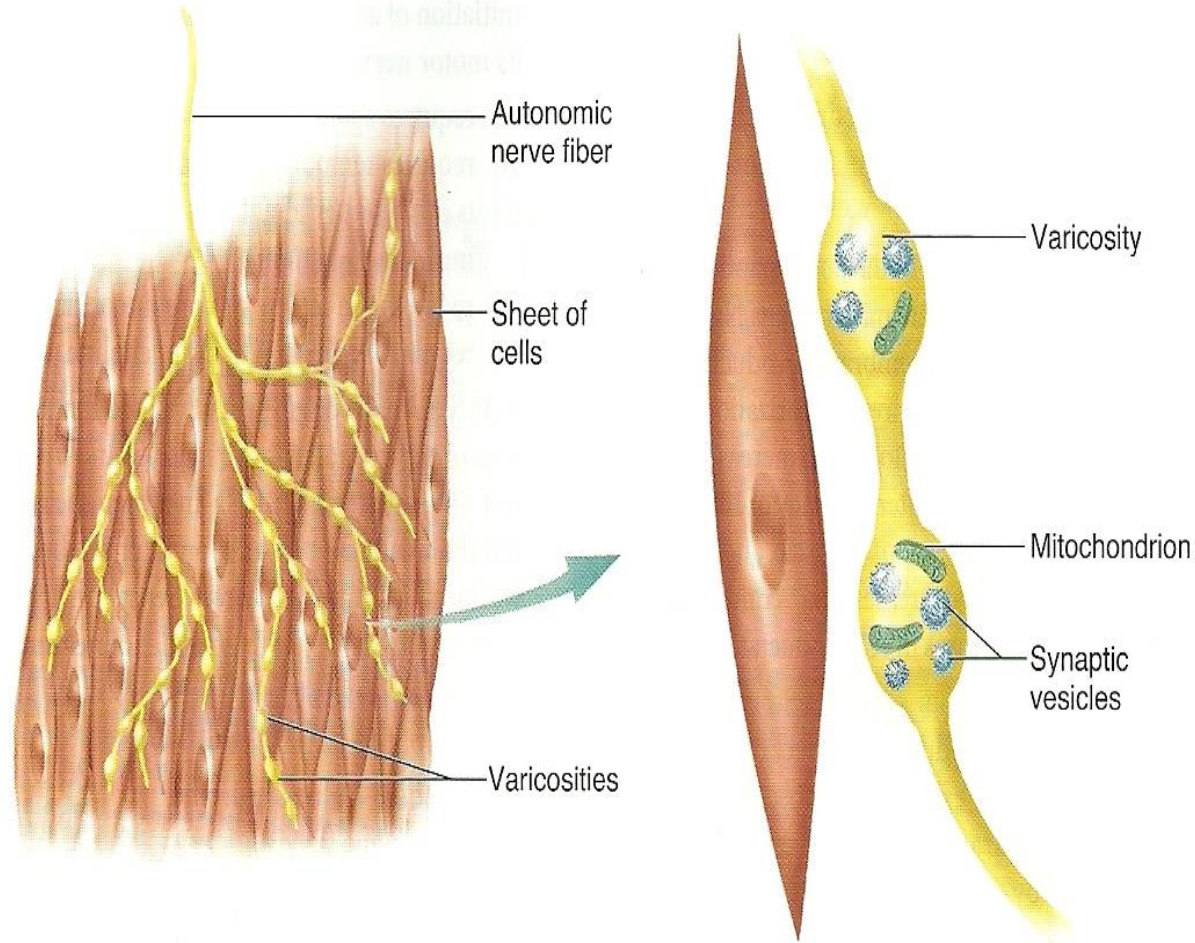




# III. Control of Smooth Muscle Contraction

## TABLE 11-5 INPUTS INFLUENCING SMOOTH-MUSCLE CONTRACTILE ACTIVITY

1. Spontaneous electrical activity in the fiber plasma membrane
2. Neurotransmitters released by autonomic neurons
3. Hormones
4. Locally induced changes in the chemical composition (paracrine agents, acidity, oxygen, osmolarity, and ion concentrations) of the extracellular fluid surrounding the fiber
5. Stretch

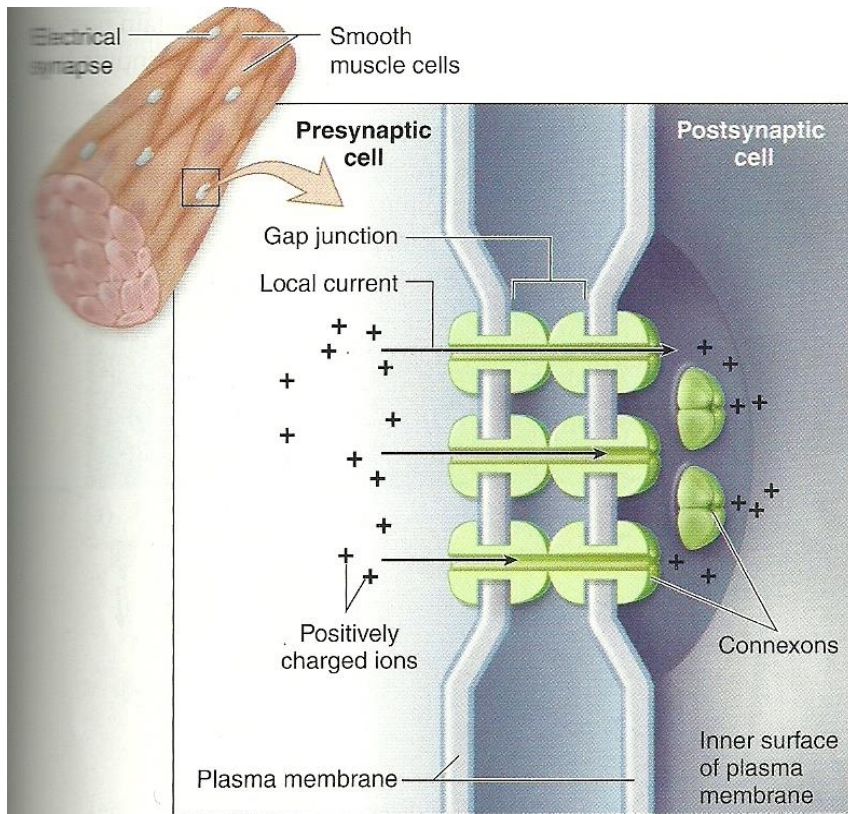


**FIGURE 6-15** Endings of postganglionic autonomic neurons on smooth muscle. Neurotransmitter, released from varicosities along the branched axon, diffuses to receptors on smooth muscle cell plasma membranes. (From Widmaier EP, Raff H, Strang KT: *Vanders Human Physiology*. McGraw-Hill, 2008.)

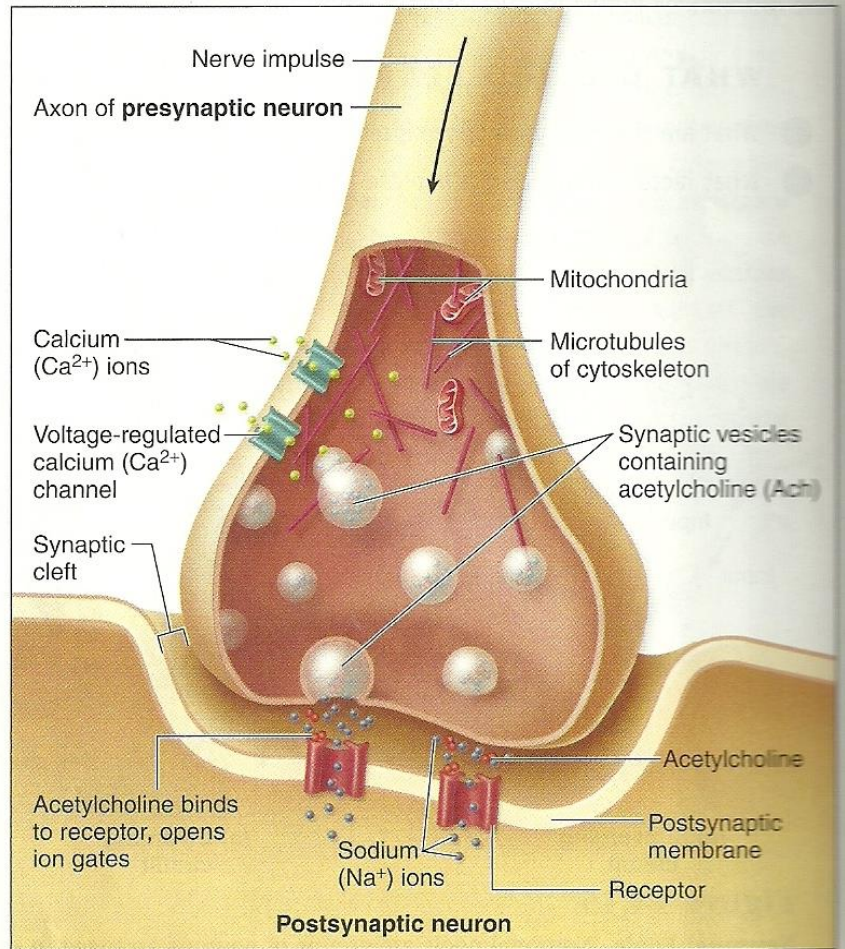
# **IV. Types of Synaptic Communication**

- 1. Chemical synapse.
- 2. Electrical synapse.





(a) Electrical synapse



(b) Chemical synapse

### Figure 14.14

**Electrical and Chemical Synapses.** In an electrical synapse, (a) ions pass through gap junctions between presynaptic and postsynaptic neurons. (b) In a chemical synapse, a neurotransmitter is released from the presynaptic neuron to receptors on the membrane of the postsynaptic neuron.

## DIFFERENCES BETWEEN SKELETAL MUSCLE, CARDIAC MUSCLE AND SMOOTH MUSCLE TISSUES

Striated Muscle Cells	Smooth Muscle Cells	Cardiac Muscle Cells
<p><b>Voluntary</b></p> <p>Attached to bones or skin</p> <p>Very long, cylindrical, multinucleate, cells</p> <p>Striated: packed with orderly arrangement of myofibrils</p> <p>Not self stimulating: each fiber innervated by branch of somatic motor neuron as part of <i>motor unit</i></p> <p>Under control of nervous system</p> <p>High energy requirement: lots of mitochondria, creatine phosphate, myoglobin</p> <p>Fast Contracting</p> <p>No rhythmic contractions</p> <p>Strength increases with stretching</p> <p>Fatigues Easily</p>	<p><b>Involuntary</b></p> <p>Line walls of most internal organs</p> <p>Single, tapering, cells with a single nucleus</p> <p>Not Striated: Fewer myofibrils of varying lengths</p> <p>Self stimulating: not individually innervated, impulse spreads from cell to cell</p> <p>Under control of nervous and endocrine systems and various chemicals and stretching</p> <p>Lower energy requirement: fewer mitochondria, etc.</p> <p>Slower contracting and rhythmic in some organs producing peristaltic waves along organ</p> <p>Rhythmic contractions</p> <p>Stress - Relaxation Response</p> <p>Doesn't fatigue</p>	<p><b>Involuntary</b></p> <p>Found only in the Heart</p> <p>Branching chains of cells connected by porous intercalated discs, with single nucleus and striations</p> <p>Striated: many myofibrils in orderly arrangement</p> <p>Self stimulating: impulse spreads from cell to cell</p> <p>Under control of nervous and endocrine systems and various chemicals</p> <p>Intermediate energy requirement</p> <p>Intermediate speed of contraction yet contraction spreads quickly through tissue due to intercalated discs</p> <p>Rhythmic contractions</p> <p>Strength increases with stretching</p> <p>Doesn't fatigue</p>

# CLINICAL TERMINOLOGY OF MUSCULAR SYSTEM

**Convulsion:** a series of involuntary contraction of the voluntary muscles produced hypoglycemia, hypocalcemia, metabolic disturbances, hormonal imbalances, brain cell injury, stroke, anoxia, hemorrhage, high fever and epilepsy.

**Cramp:** painful spasmodic muscular contraction.

**Creatine:** nonprotein substance synthesized in the body from three amino acids: arginine, glycine and methionine .present in the muscle to store high energy phosphate necessary for muscle contraction.

**Dystrophy :** imperfect nutrition.

**Endurance:** the ability to sustain an activity over a period of time.

**Fibromyalgia syndrome :** An inflammatory disorder characterized by a distinctive pattern of symptoms including tender points of body surface.



**Fibrosis** : process in which muscle tissue is replaced by fibrous connective tissue ,making muscle weaker and less flexible.

**Hypertonia** : abnormally increased tonicity or strength .

**Muscle atrophy:** skeletal muscle that is not regularly stimulated by a motor neuron loses muscle tone and mass. The reduction in muscle size, tone and power is called atrophy.

**Muscle fatigue:** muscle can no longer contract ,because of change in pH ,due to building of lactic acid, a lack of energy or other problem.

**Muscle Contraction:** shortening of the muscle.

**Muscular dystrophy** : degenerative myopathies that produce muscle weakness and atrophy.

**Power:** the ability to act (capability).

**Spasm:** sudden involuntary contraction of muscle or group of muscle accompanied by pain

**Synapse:** the junction between the processes of two neurons or between a neuron and effector organ (muscle, gland or GI neurons)

**Tendonitis: inflammation** of tendons and of tendon-muscle attachments, one of the most common causes of acute pain in the shoulder. It is frequently associated with calcium deposit (calcium tendinitis) which may involve the bursa around the tendon or near the joint, causing bursitis .

**Tetany** : continuous tonic spasm of a muscle, it is due to abnormal calcium metabolism ,vitamin D deficiency and alkalosis.

**Tone** :normal tension, in muscle the resistance to passive elongation or stretch.

**Twitch** : mechanical response of skeletal muscle to single volley action potential