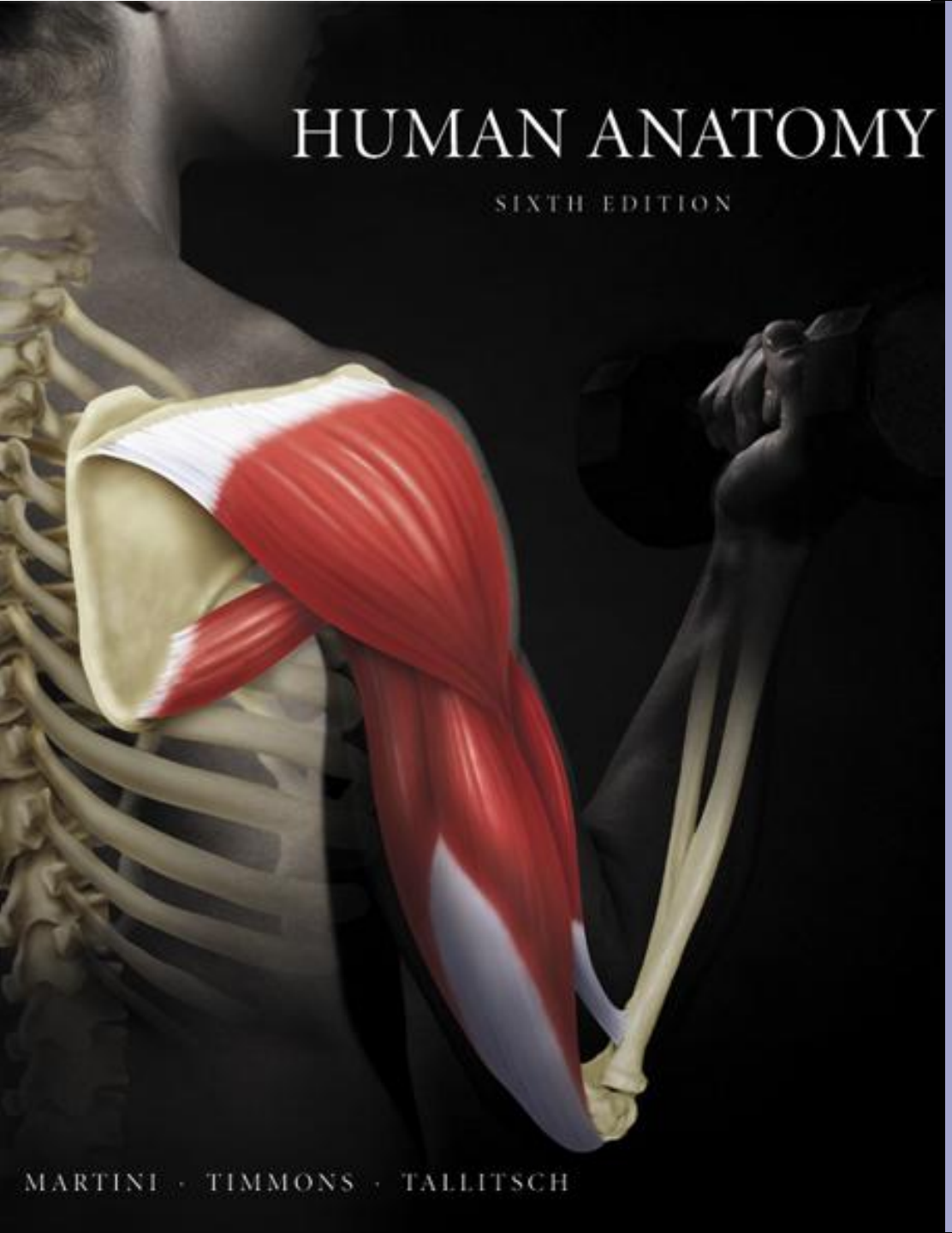


Chapter

9

The Muscular System—Skeletal Muscle Tissue and Organization

PowerPoint® Lecture Slides
prepared by Jason LaPres
North Harris College
Houston, Texas

Introduction

- Humans rely on muscles for many of our physiological processes, and virtually all our dynamic interactions with the environment involve muscle tissue.

Muscles and Life

Introduction

- There are three types of muscle tissue:
  - ***Skeletal muscle***—Skeletal muscle tissue moves the body by pulling on bones of the skeleton.
  - ***Cardiac muscle***—Cardiac muscle tissue pushes blood through the arteries and veins of the circulatory system.
  - ***Smooth muscle***—Smooth muscle tissues push fluids and solids along the digestive tract and perform varied functions in other systems.

Introduction

- Muscle tissues share four basic properties:
  - **Excitability**: the ability to respond to stimulation
    - Skeletal muscles normally respond to stimulation by the nervous system.
    - Cardiac and smooth muscles respond to the nervous system and circulating hormones.
  - **Contractility**: the ability to shorten actively and exert a pull or tension that can be harnessed by connective tissues
  - **Extensibility**: the ability to continue to contract over a range of resting lengths
  - **Elasticity**: the ability of a muscle to rebound toward its original length after a contraction

Functions of Skeletal Muscle

- Skeletal muscles are contractile organs directly or indirectly attached to bones of the skeleton.
- Skeletal muscles perform the following functions:
  - Produce skeletal movement
  - Maintain posture and body position
  - Support soft tissues
  - Regulate entering and exiting of material
  - Maintain body temperature

Anatomy of Skeletal Muscles

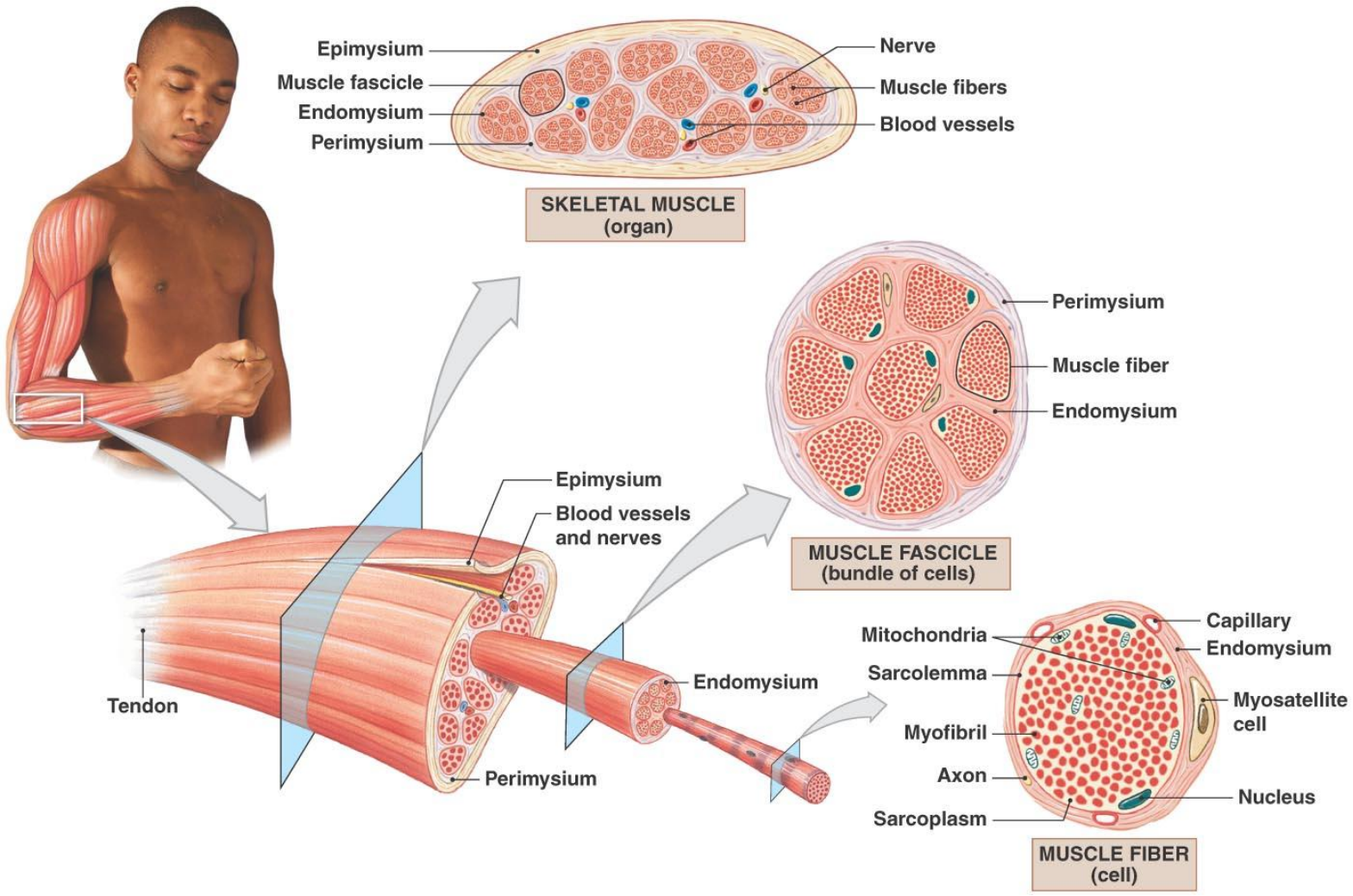


Figure 9.1 Structural Organization of Skeletal Muscle

Anatomy of Skeletal Muscles

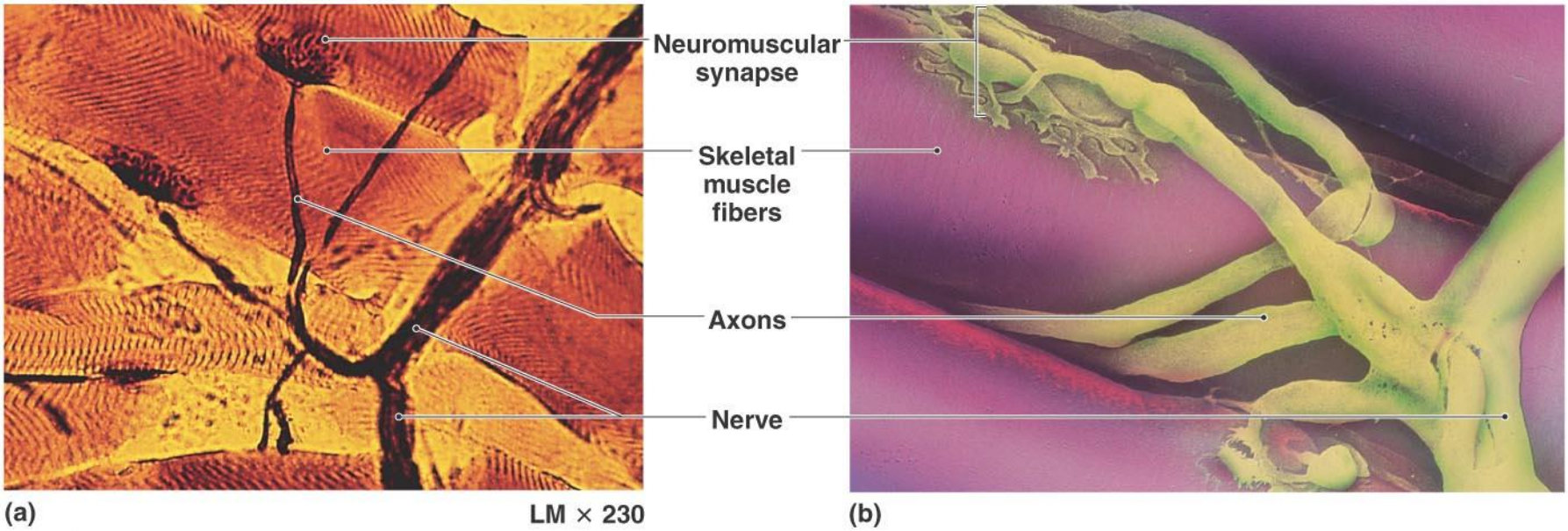


Figure 9.2 Skeletal Muscle Innervation

Anatomy of Skeletal Muscles

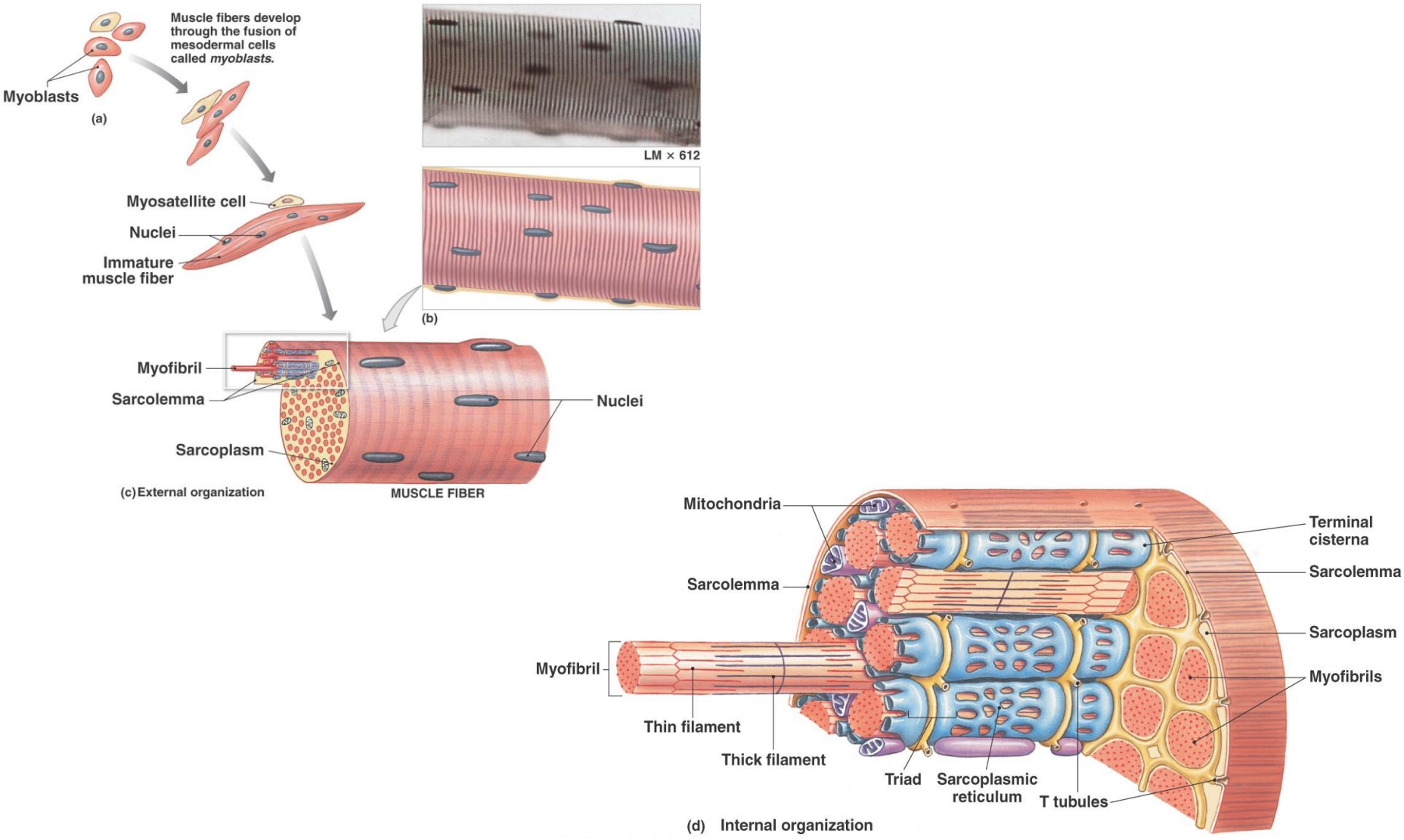


Figure 9.3 The Formation and Structure of a Skeletal Muscle Fiber

Anatomy of Skeletal Muscles

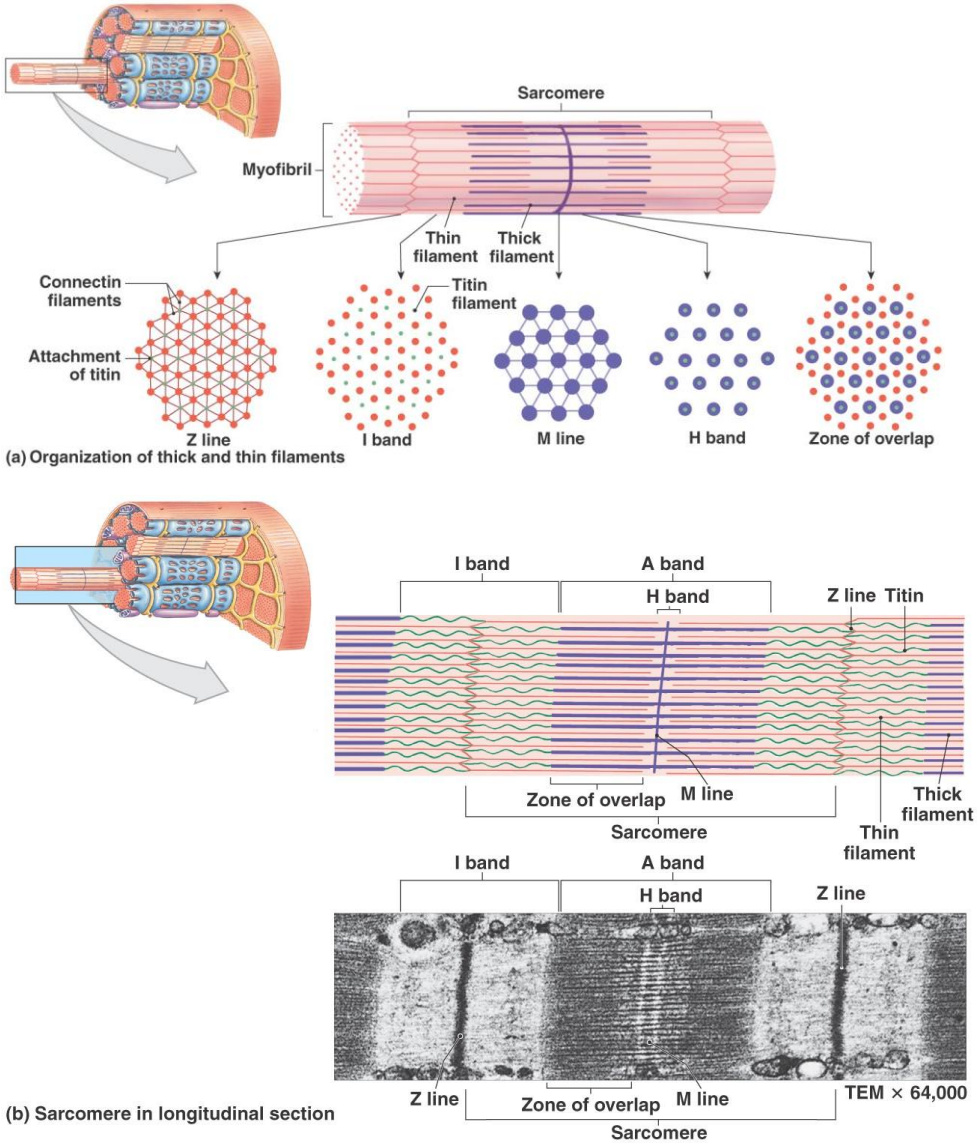


Figure 9.4 Sarcomere Structure

Anatomy of Skeletal Muscles

- Sarcomere Organization
  - **Thick** and **thin filaments** within a **myofibril** are organized in the sarcomeres.
  - All of the myofibrils are arranged parallel to the long axis of the cell, with their sarcomeres lying side by side.

Sarcomere Structure

Anatomy of Skeletal Muscles

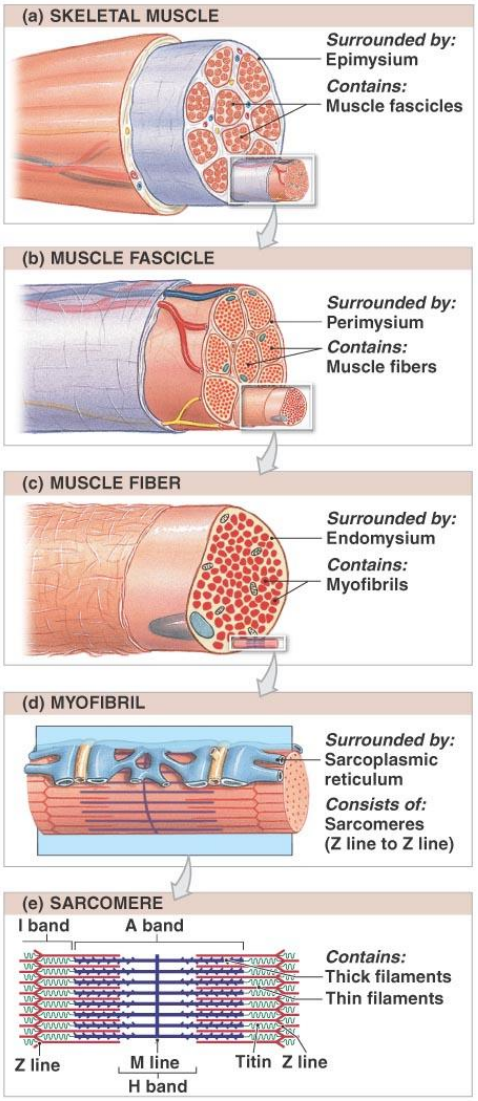


Figure 9.5 Levels of Functional Organization in a Skeletal Muscle Fiber

Anatomy of Skeletal Muscles

- Layers of a Muscle
  - Breakdown skeletal muscle from large to small

Anatomy of Muscle Review

Anatomy of Skeletal Muscles

- Thin and Thick Filaments
  - Each thin filament consists of a twisted strand of several interacting proteins 5–6 nm in diameter and 1 μm in length.
    - ***Troponin*** holds the ***tropomyosin*** strand in place.
  - Thick filaments are 10–12 nm in diameter and 1.6 μm in length, making them much larger than thin filaments.

Thin Filament

Troponin

Thick Filament

Anatomy of Skeletal Muscles

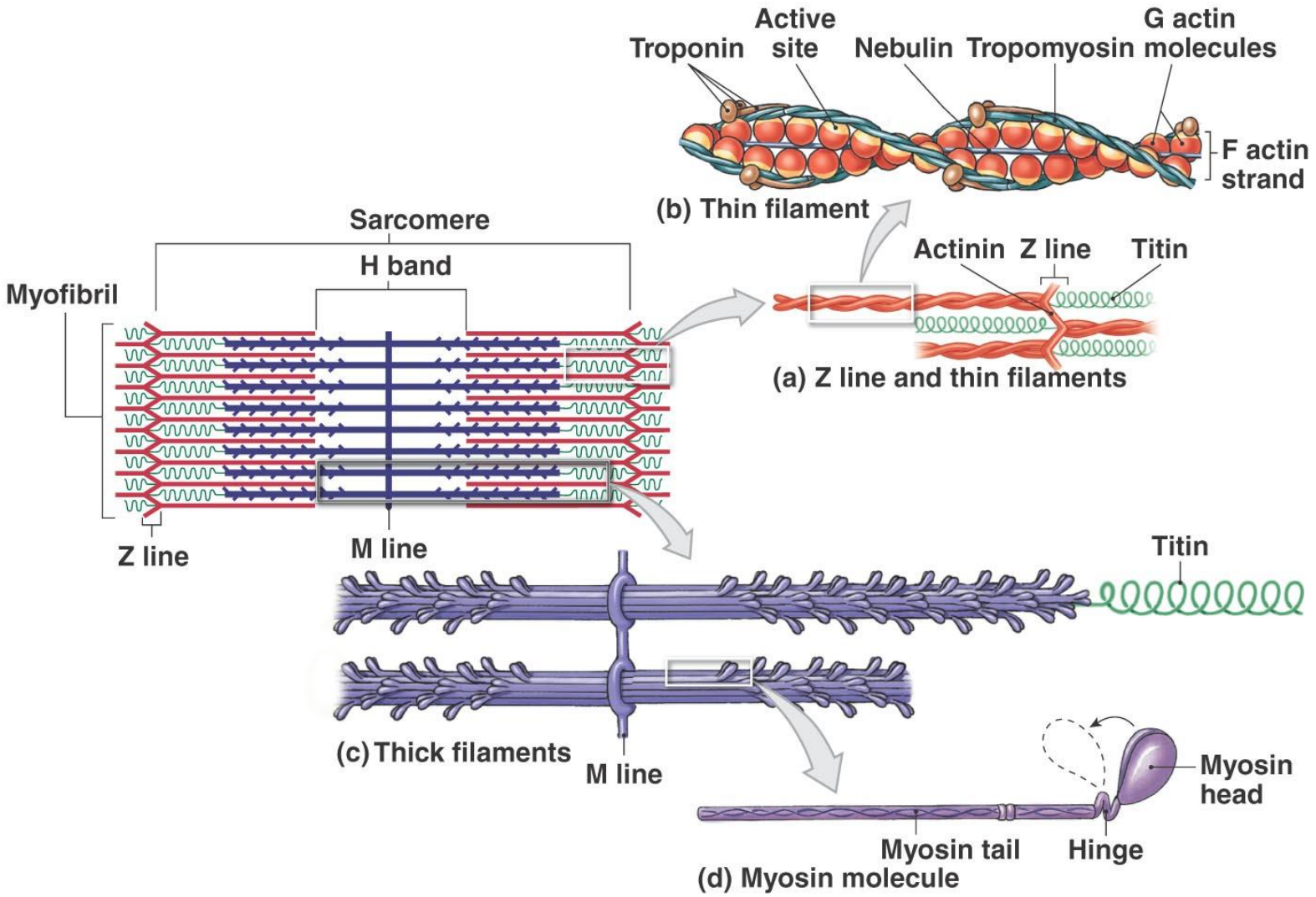


Figure 9.6 Thin and Thick Filaments

Muscle Contraction

- Contracting muscle fibers exert a pull, or tension, and shorten in length.
- Caused by interactions between thick and thin filaments in each sarcomere
- Triggered by presence of calcium ions
- Contraction itself requires the presence of ATP.

Muscle Contraction

Muscle Contraction

- The Sliding Filament Theory
  - Explains the following changes that occur between thick and thin filaments during contraction:
    - The H band and I band get smaller.
    - The zone of overlap gets larger.
    - The Z lines move closer together.
    - The width of the A band remains constant throughout the contraction.

Muscle Contraction

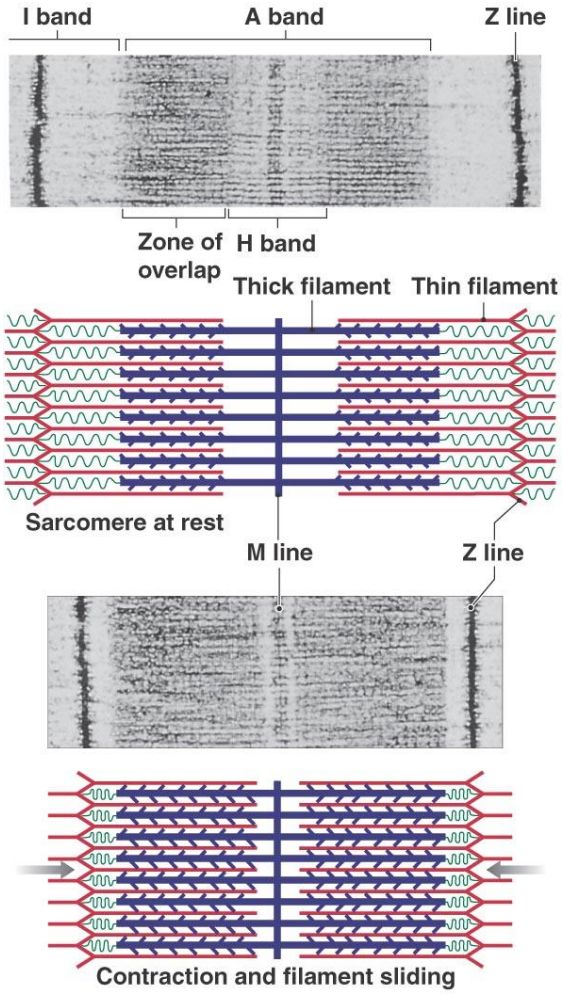


Figure 9.7 Changes in the Appearance of a Sarcomere during Contraction of a Skeletal Muscle Fiber

Muscle Contraction

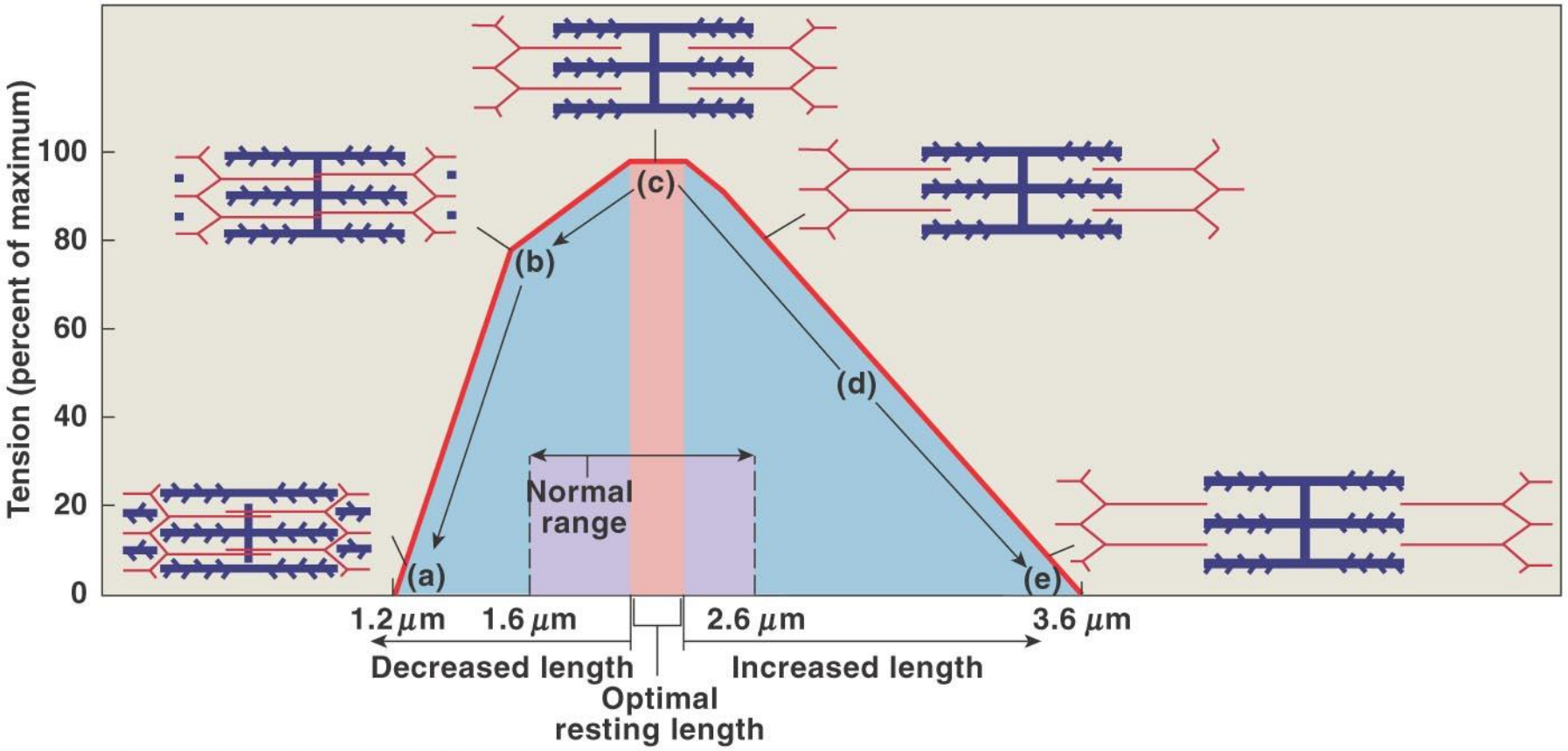


Figure 9.8 The Effect of Sarcomere Length on Tension

Muscle Contraction

- The Start of a Contraction
  - Triggered by calcium ions in the sarcoplasm
  - Electrical events at the sarcolemmal surface
    - Trigger the release of calcium ions from the terminal cisternae
    - The calcium ions diffuse into the zone of overlap and bind to troponin.
    - Troponin changes shape, alters the position of the tropomyosin strand, and exposes the active sites on the actin molecules.

Calcium and Troponin Interaction

Muscle Contraction

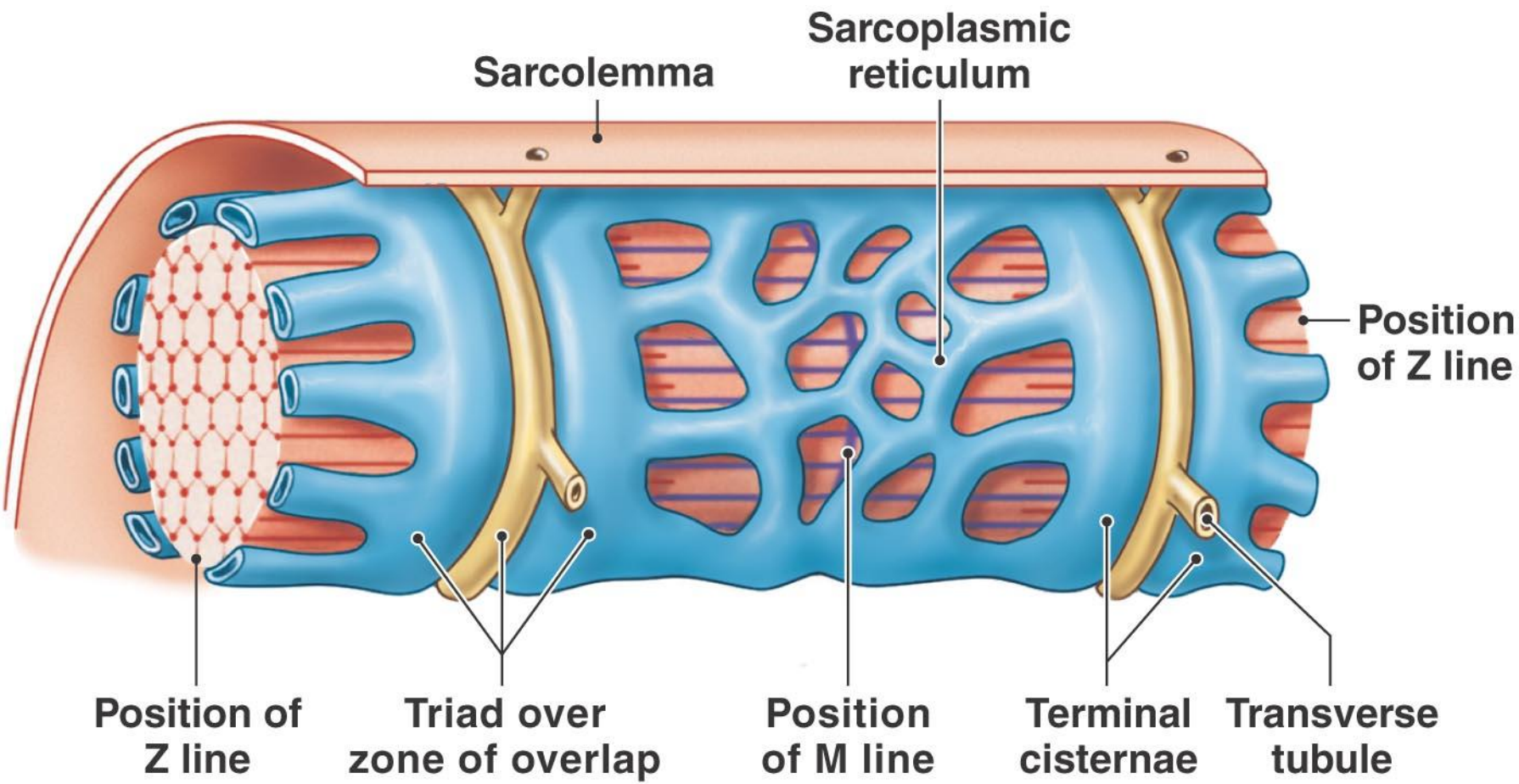


Figure 9.9 The Orientation of the Sarcoplasmic Reticulum, T Tubules, and Individual Sarcomeres

Muscle Contraction

- The End of a Contraction
  - When electrical stimulation ends:
    - The SR will recapture the Ca^{2+} ions.
    - The troponin–tropomyosin complex will cover the active sites.
    - And, the contraction will end.

Muscle Contraction

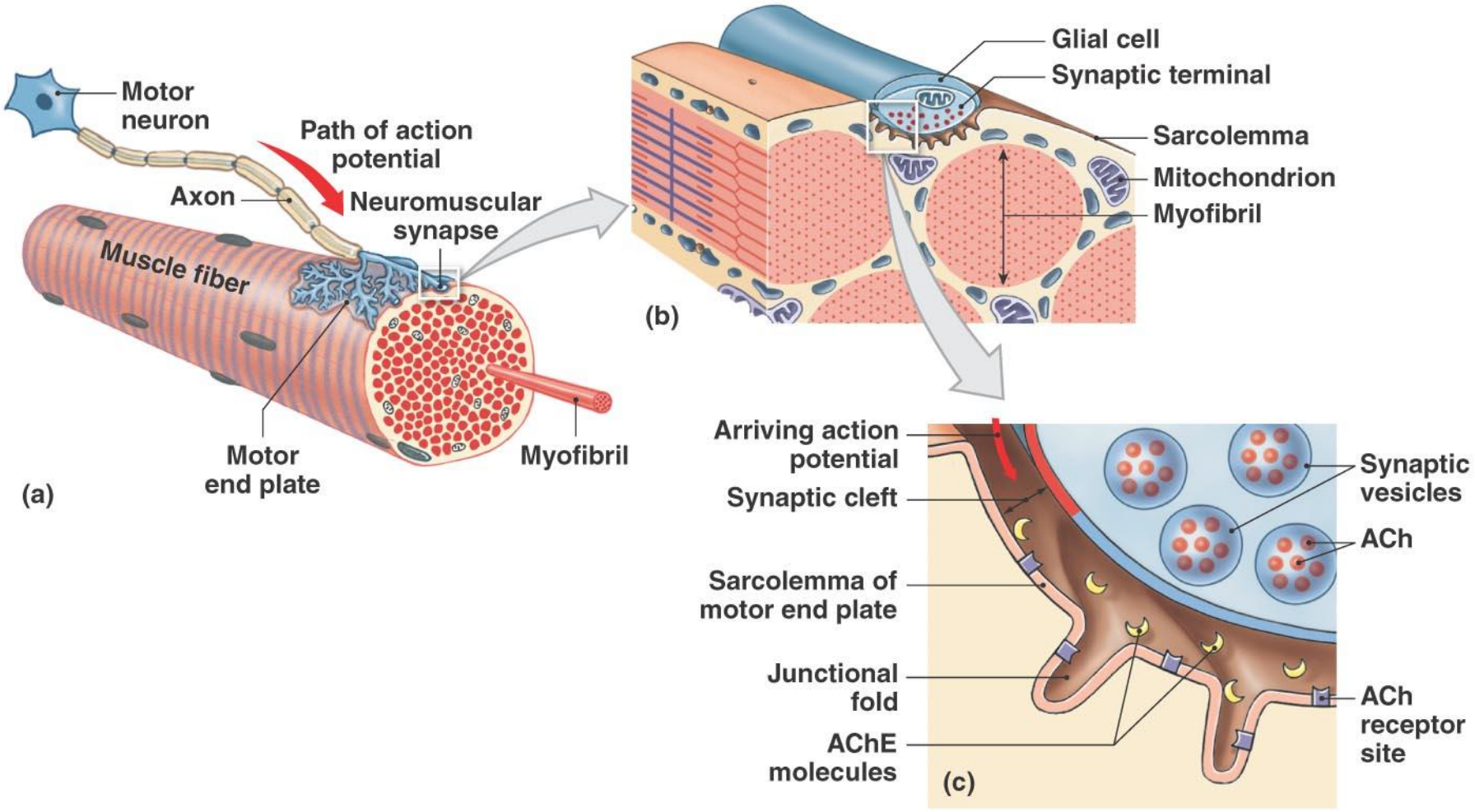


Figure 9.10 The Neuromuscular Synapse

Muscle Contraction

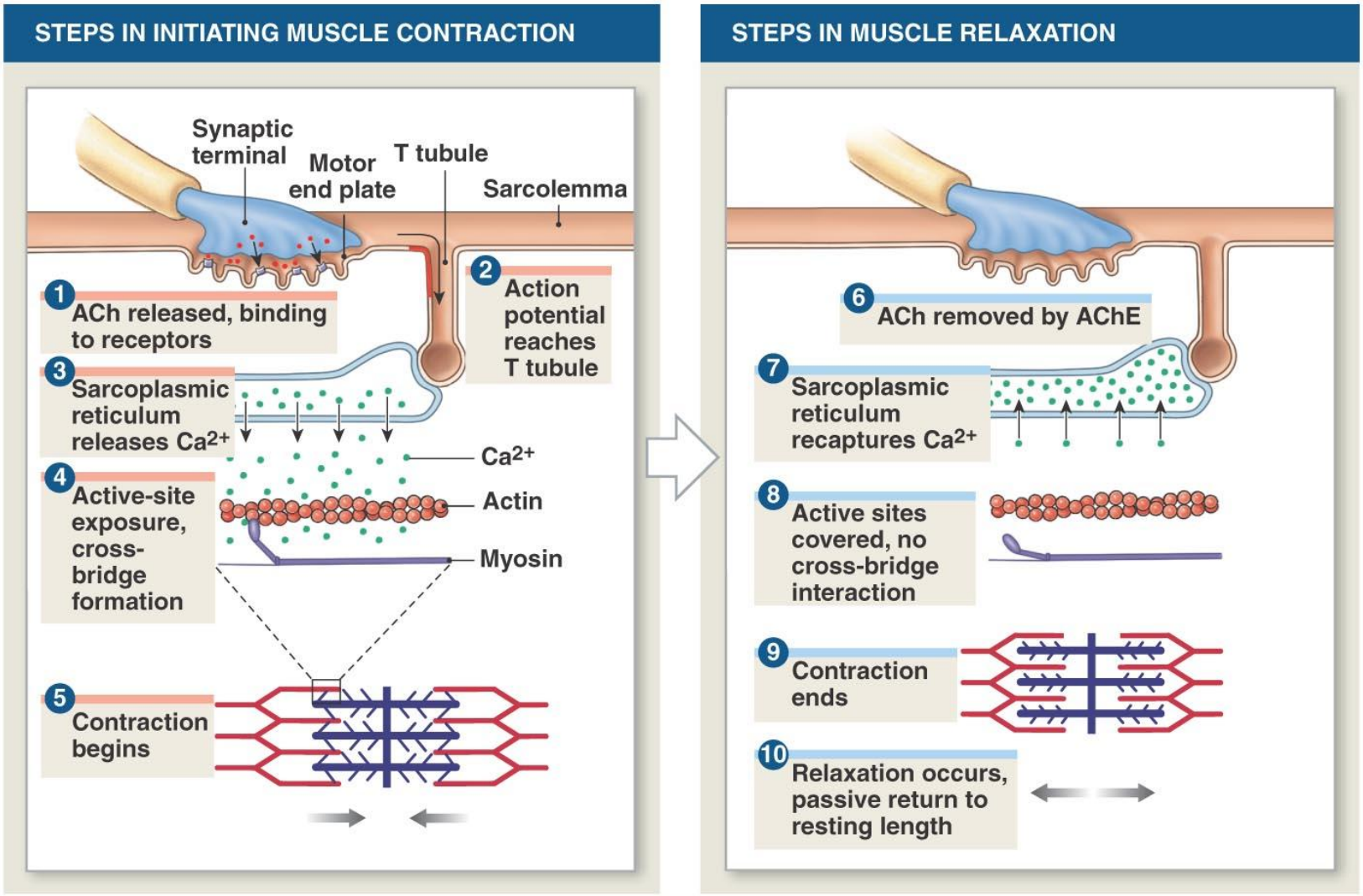


Figure 9.11 The Events in Muscle Contraction

Motor Units and Muscle Control

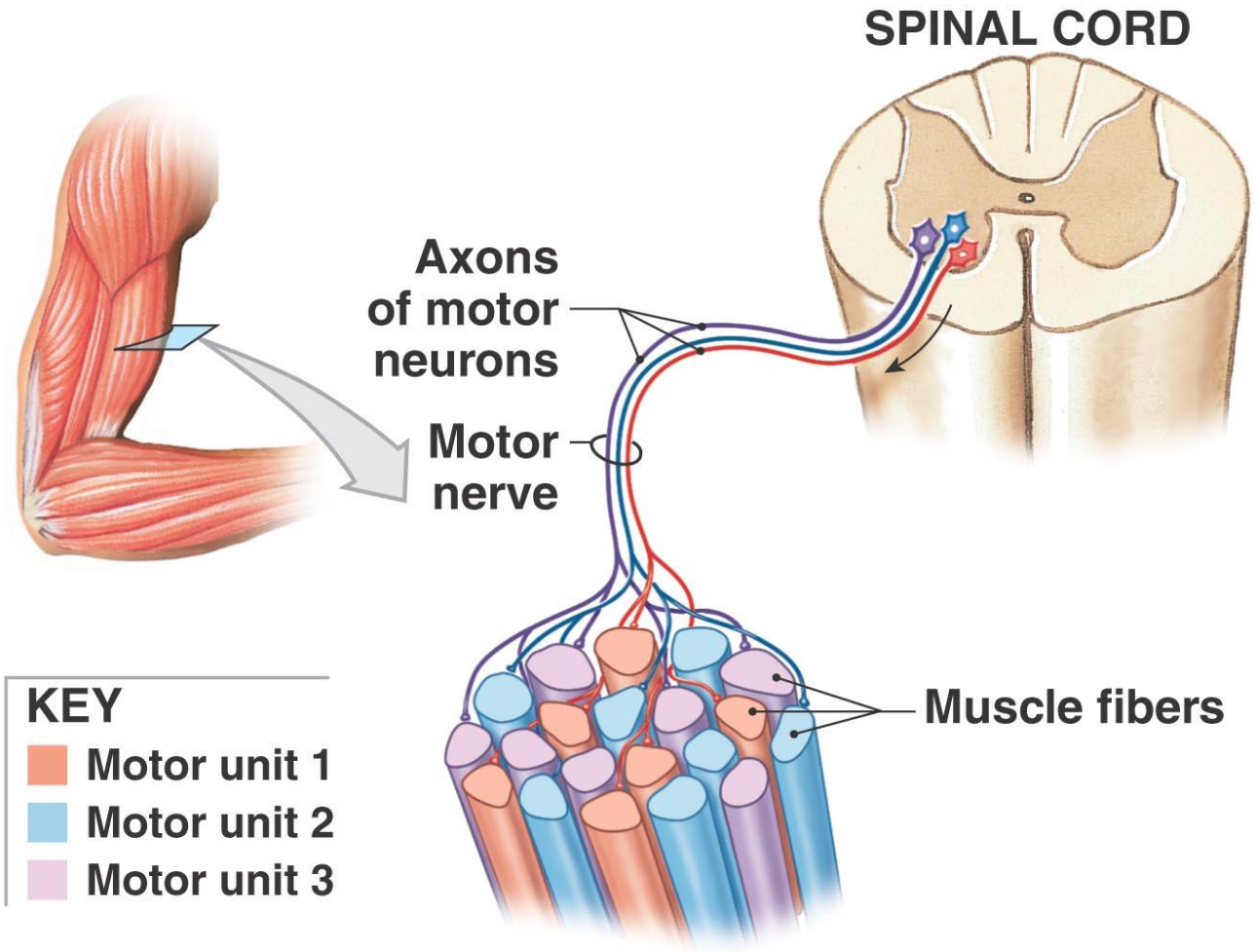


Figure 9.12 The Arrangement of Motor Units in a Skeletal Muscle

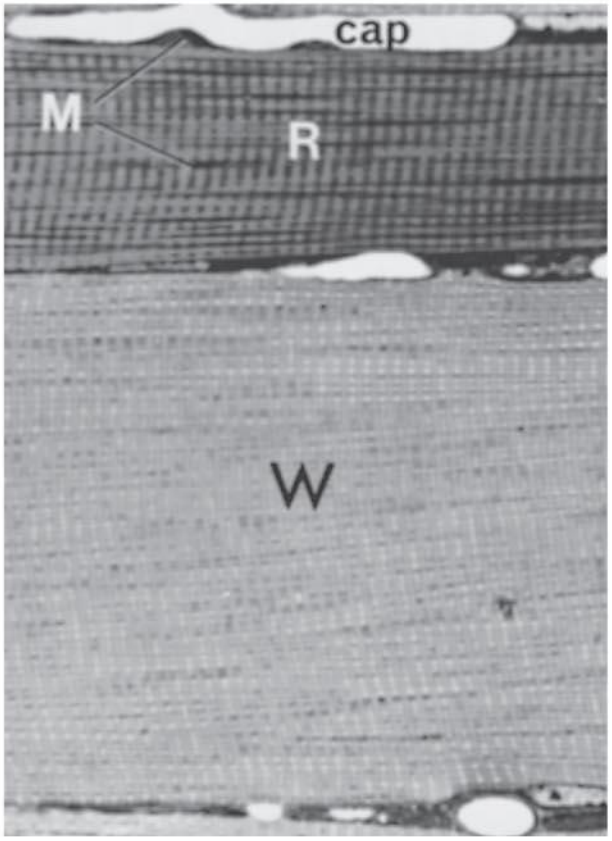
Motor Units and Muscle Control

- Muscle Tone
  - Some of the motor units of muscles are always contracting, producing a resting tension in a skeletal muscle that is called muscle tone.
  - Resting muscle tone stabilizes the position of bones and joints.

Motor Units and Muscle Control

- Muscle Hypertrophy and Atrophy
  - Exercise causes increases in
    - Number of mitochondria
    - Concentration of glycolytic enzymes
    - Glycogen reserves
    - Myofibrils
      - Each myofibril contains a larger number of thick and thin filaments.
    - The net effect is an enlargement, or ***hypertrophy***, of the stimulated muscle.
  - Disuse of a muscle results in the opposite, called ***atrophy***.

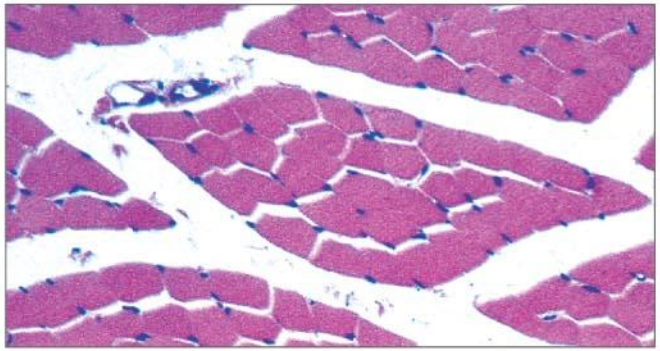
Types of Skeletal Muscle Fibers



(a) LM × 783

Slow fibers

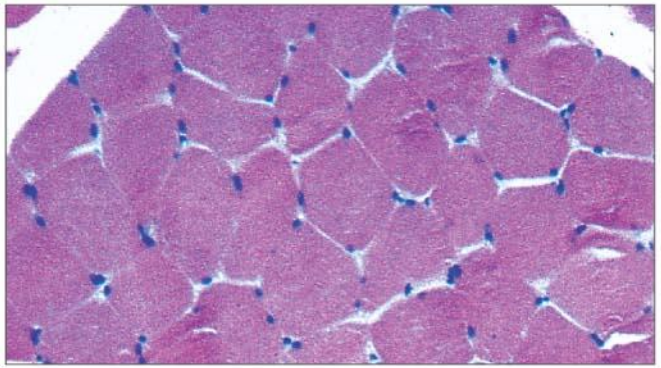
Smaller diameter, darker color due to myoglobin; fatigue resistant



Slow LM × 171

Fast fibers

Larger diameter, paler color; easily fatigued



(b) Fast LM × 171

Types of Skeletal Muscle Fibers

- The features of ***fast fibers***, or white fibers, are:
  - Large in diameter—due to many densely packed myofibrils
  - Large glycogen reserves
  - Relatively few mitochondria
    - Their mitochondria are unable to meet the demand.
  - Fatigue easily
  - Can contract in 0.01 seconds or less following stimulation

Types of Skeletal Muscle Fibers

- ***Slow fibers***, or red fibers, features are
  - Only about half the diameter of fast fibers
  - Take three times as long to contract after stimulation
  - Contain abundant mitochondria
  - Use aerobic metabolism
  - Have a more extensive network of capillaries than do muscles dominated by fast muscle fibers.
  - Red color because they contain the red pigment **myoglobin**

Types of Skeletal Muscle Fibers

- ***Intermediate fibers*** have properties intermediate between those of fast fibers and slow fibers.
  - Intermediate fibers contract faster than slow fibers but slower than fast fibers.
  - Intermediate fibers are similar to fast fibers ***except***
    - They have more mitochondria.
    - They have a slightly increased capillary supply.
    - They have a greater resistance to fatigue.

Types of Skeletal Muscle Fibers

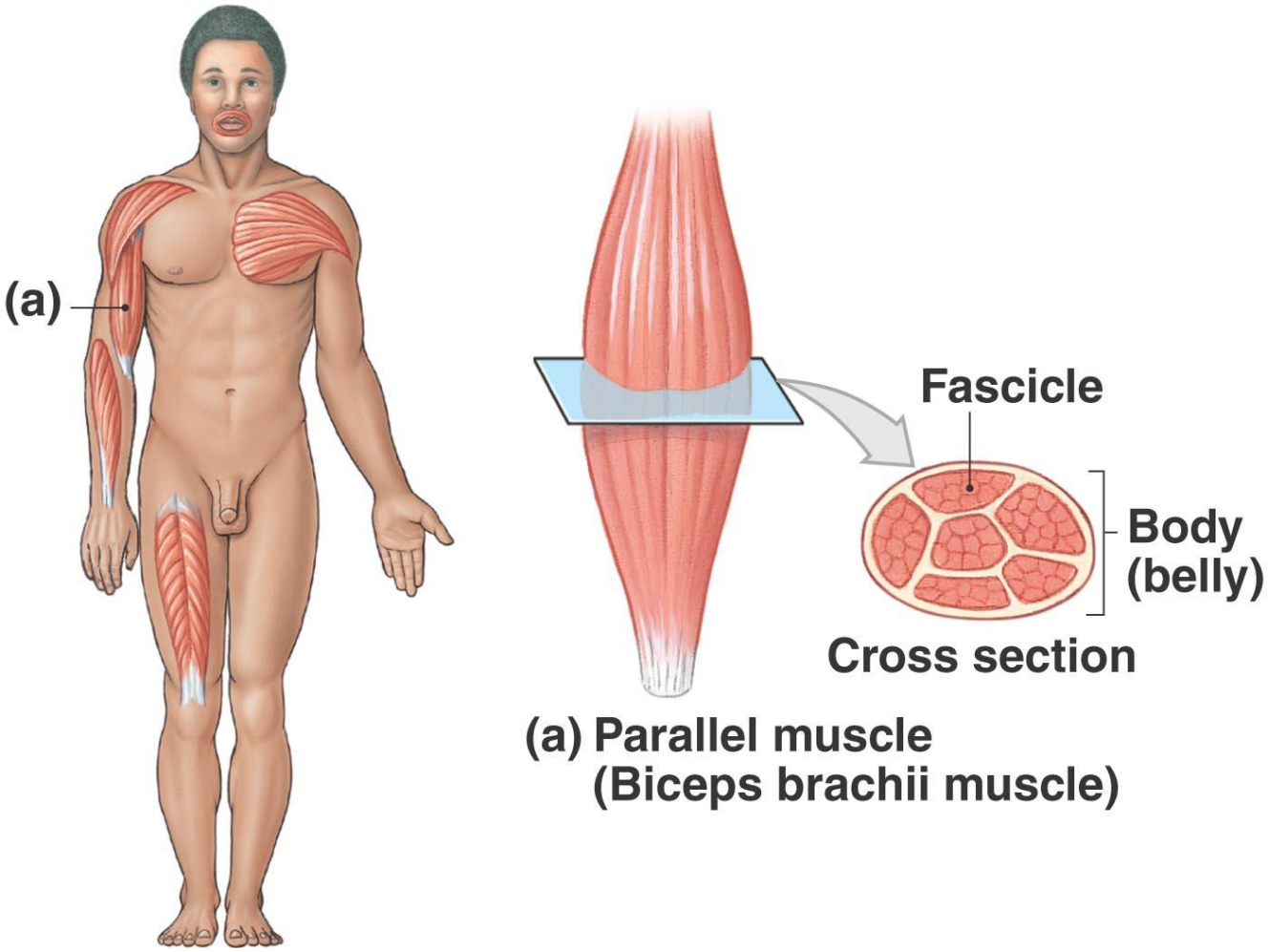


Figure 9.14 Skeletal Muscle Fiber Organization (Parallel Muscle)

Types of Skeletal Muscle Fibers

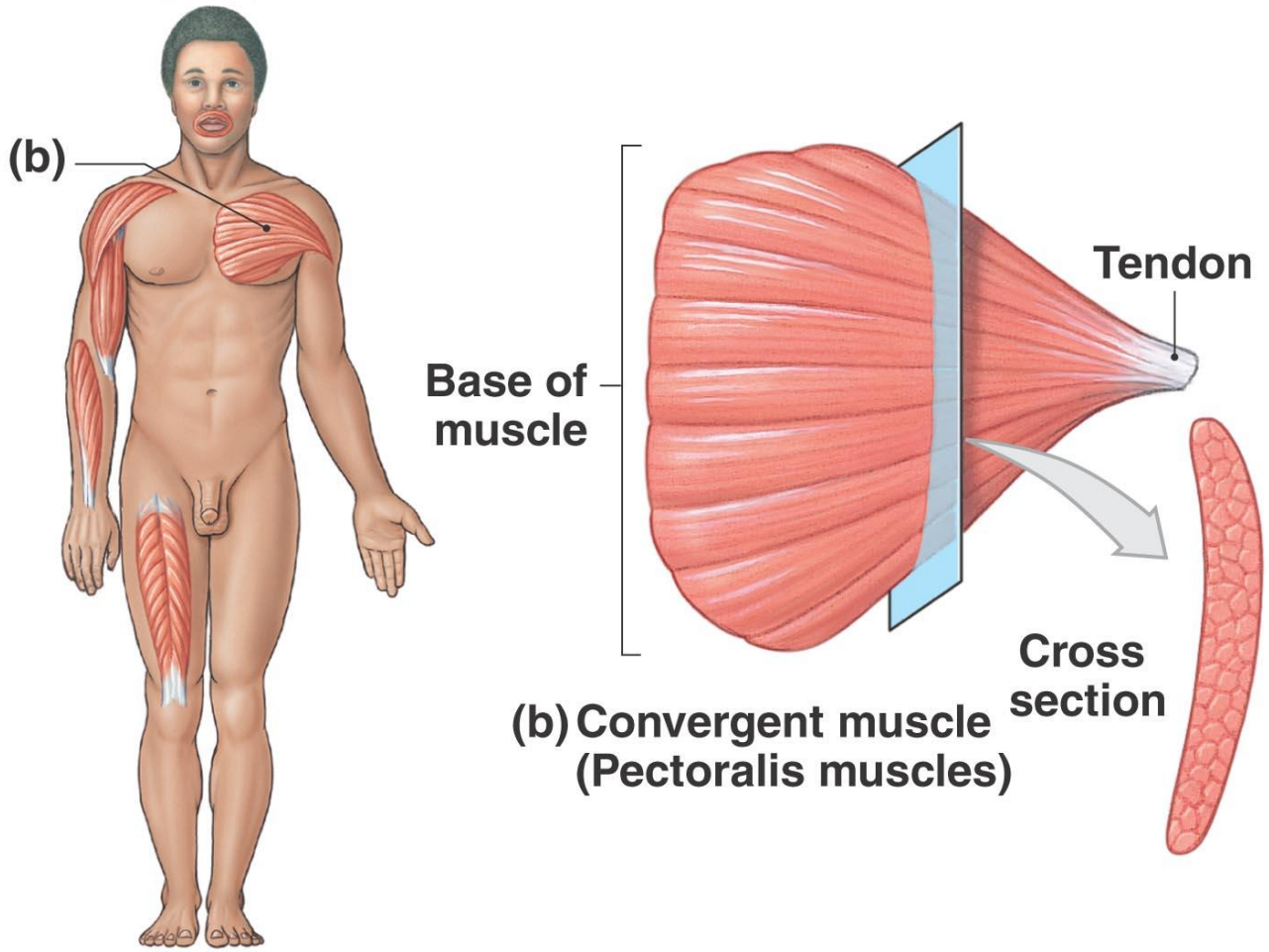


Figure 9.14 Skeletal Muscle Fiber Organization (Convergent Muscle)

Types of Skeletal Muscle Fibers

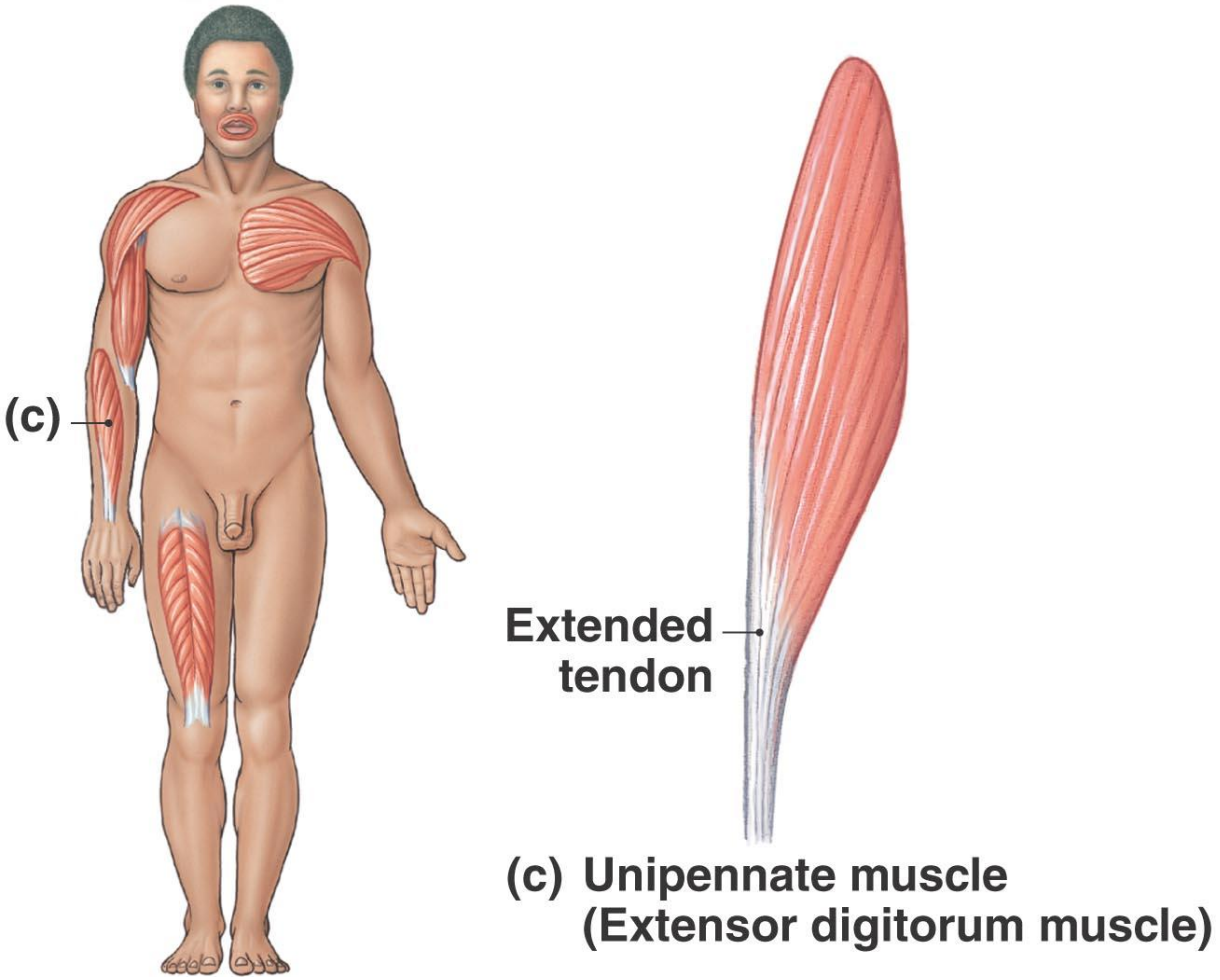


Figure 9.14 Skeletal Muscle Fiber Organization (Unipennate Muscle)

Types of Skeletal Muscle Fibers

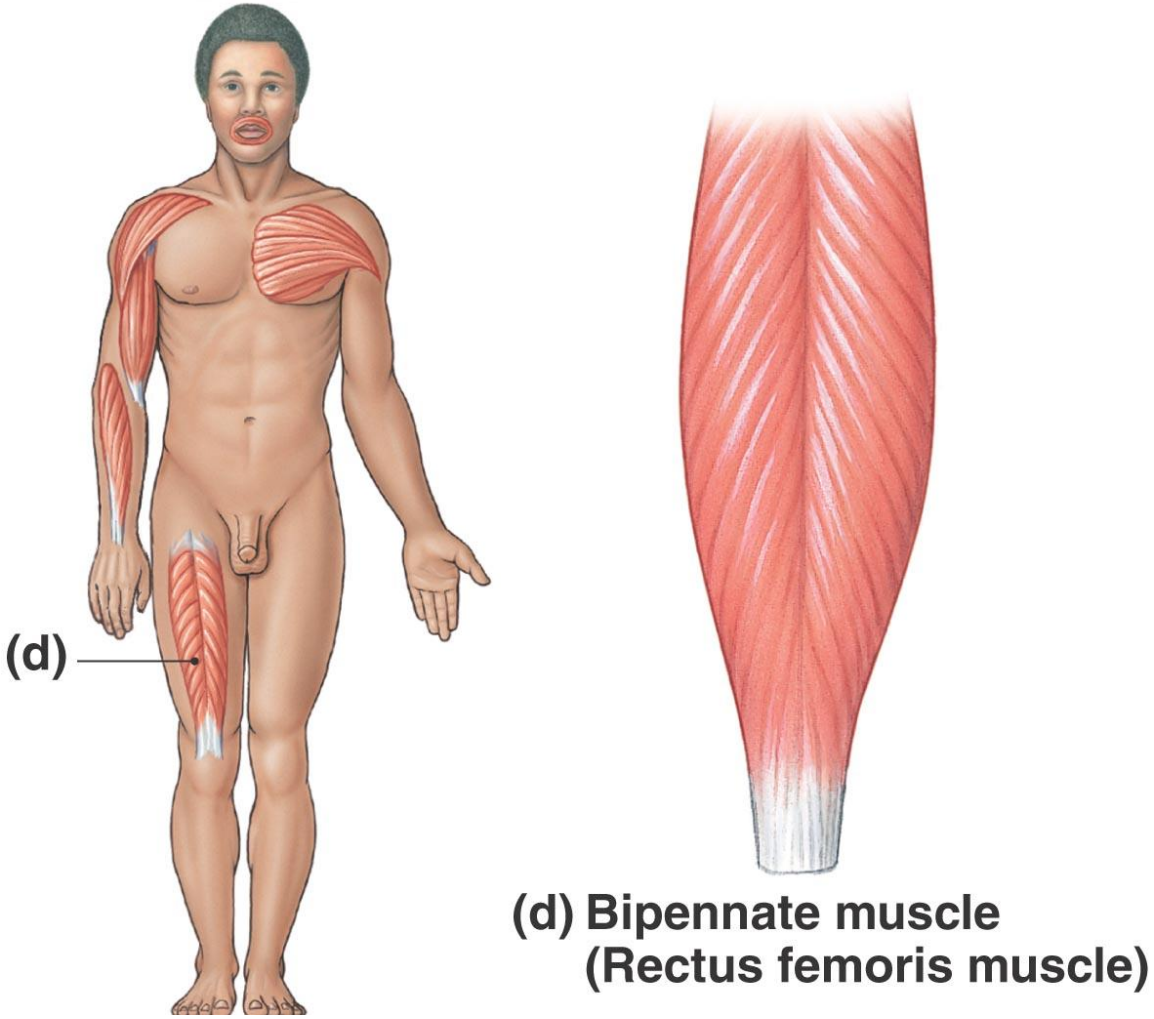


Figure 9.14 Skeletal Muscle Fiber Organization (Bipennate Muscle)

Types of Skeletal Muscle Fibers

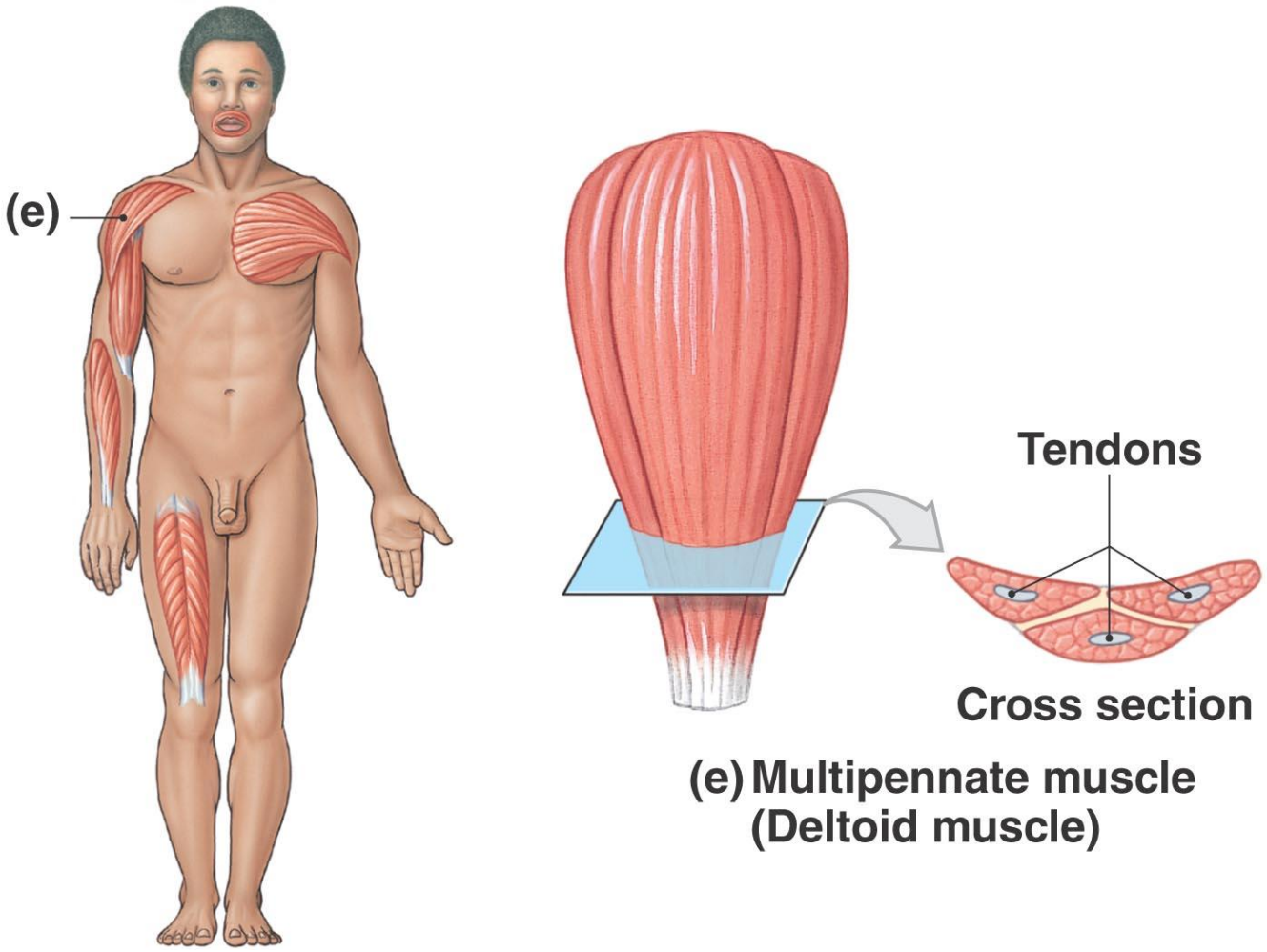


Figure 9.14 Skeletal Muscle Fiber Organization (Multipennate Muscle)

Types of Skeletal Muscle Fibers

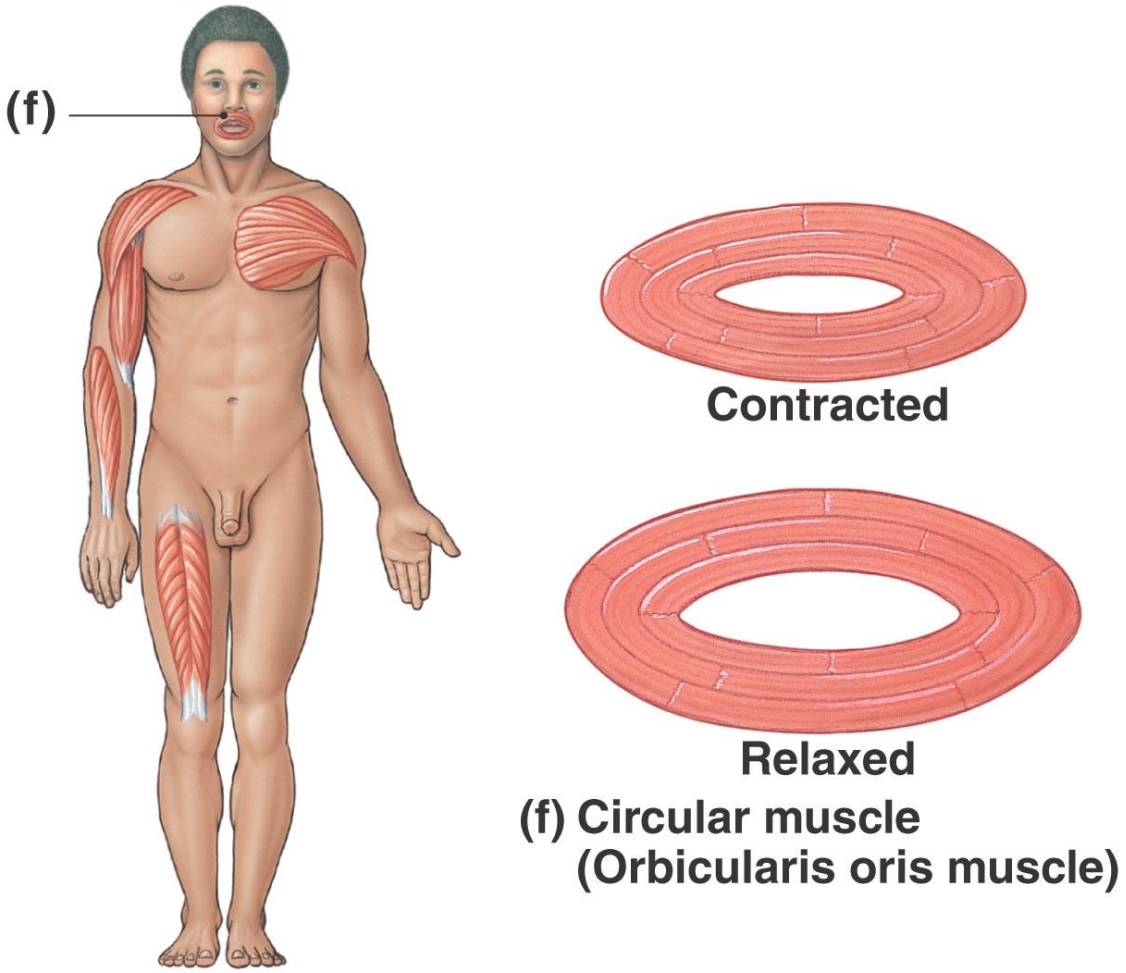


Figure 9.14 Skeletal Muscle Fiber Organization (Circular Muscle)

Muscle Terminology

- ***Origin*** remains stationary
- ***Insertion*** moves
  - Commonly the origin is proximal to the insertion.
- If the muscle extends from a broad **aponeurosis** to a narrow **tendon:**
  - Aponeurosis = origin
  - Tendon = insertion
- If there are several tendons at one end and just one at the other:
  - Multiple = origins
  - Single = insertion

Muscle Terminology

- Muscle Actions
  - There are two methods of describing actions.
    - The first references the bone region affected.
      - For example, the biceps brachii muscle is said to perform "flexion of the forearm."
    - The second method specifies the joint involved.
      - For example, the action of the biceps brachii muscle is described as "flexion of the elbow."

Muscle Terminology

- Muscles can be grouped according to their primary actions into three types:
  - ***Prime movers*** (agonists*):* are muscles chiefly responsible for producing a particular movement
  - ***Synergists****:* assist the prime mover in performing that action
    - If a synergist stabilizes the origin of the agonist, it is called a fixator.
  - ***Antagonists****:* are muscles whose actions oppose that of the agonist
    - If the agonist produces flexion, the antagonist will produce extension.

Muscle Terminology

- Muscles are named for:
  - Specific body regions
    - Brachialis
  - Shape of the muscle
    - Trapezius
  - Orientation of muscle fibers
    - Rectus, transverse, oblique
  - Specific or unusual features
    - Biceps (two origins)
  - Identification of origin and insertion
    - Sternocleidomastoid
  - Primary functions
    - Flexor carpi radialis
  - References to actions
    - Buccinator

Levers and Pulleys: A Systems Design for Movement

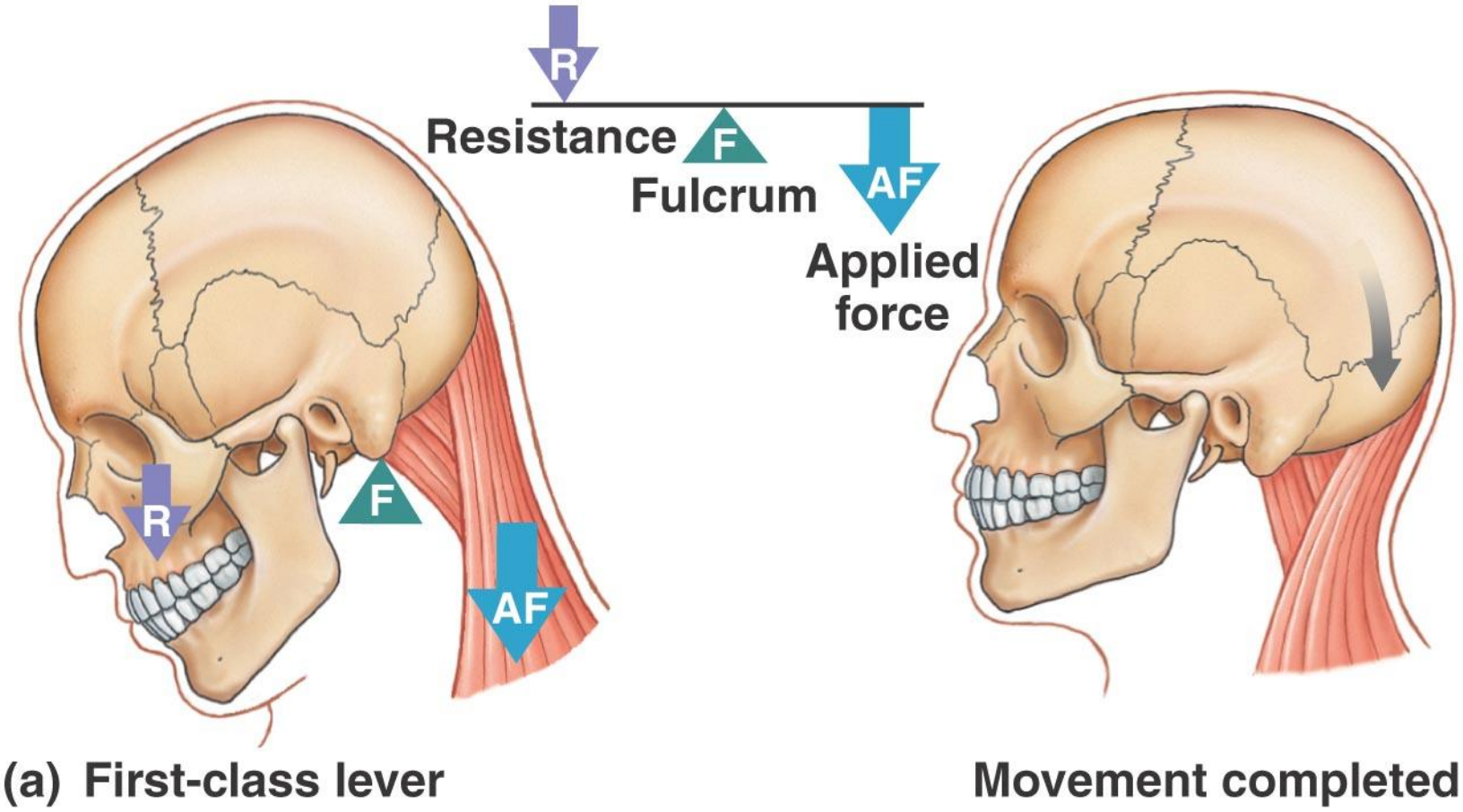
- **First-class levers**
- **Second-class levers**
  - Characteristics of second-class levers are:
    - The force is magnified.
    - The resistance moves more slowly and covers a shorter distance.
- **Third-class levers**
  - The characteristics of the third-class lever are:
    - Speed and distance traveled are increased.
    - The force produced must be great.

Levers and Pulleys: A Systems Design for Movement

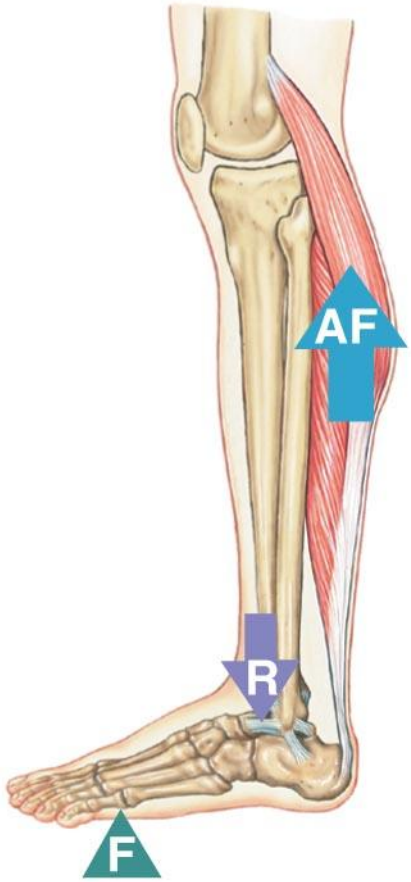
- Although every muscle does not operate as part of a lever system, the presence of levers provides speed and versatility far in excess of what we would predict on the basis of muscle physiology alone.

Levers

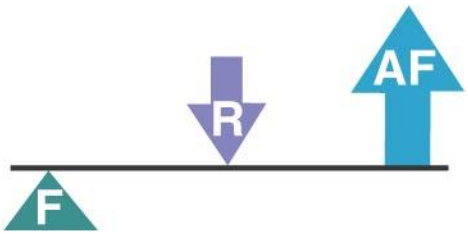
Levers and Pulleys: A Systems Design for Movement



Levers and Pulleys: A Systems Design for Movement

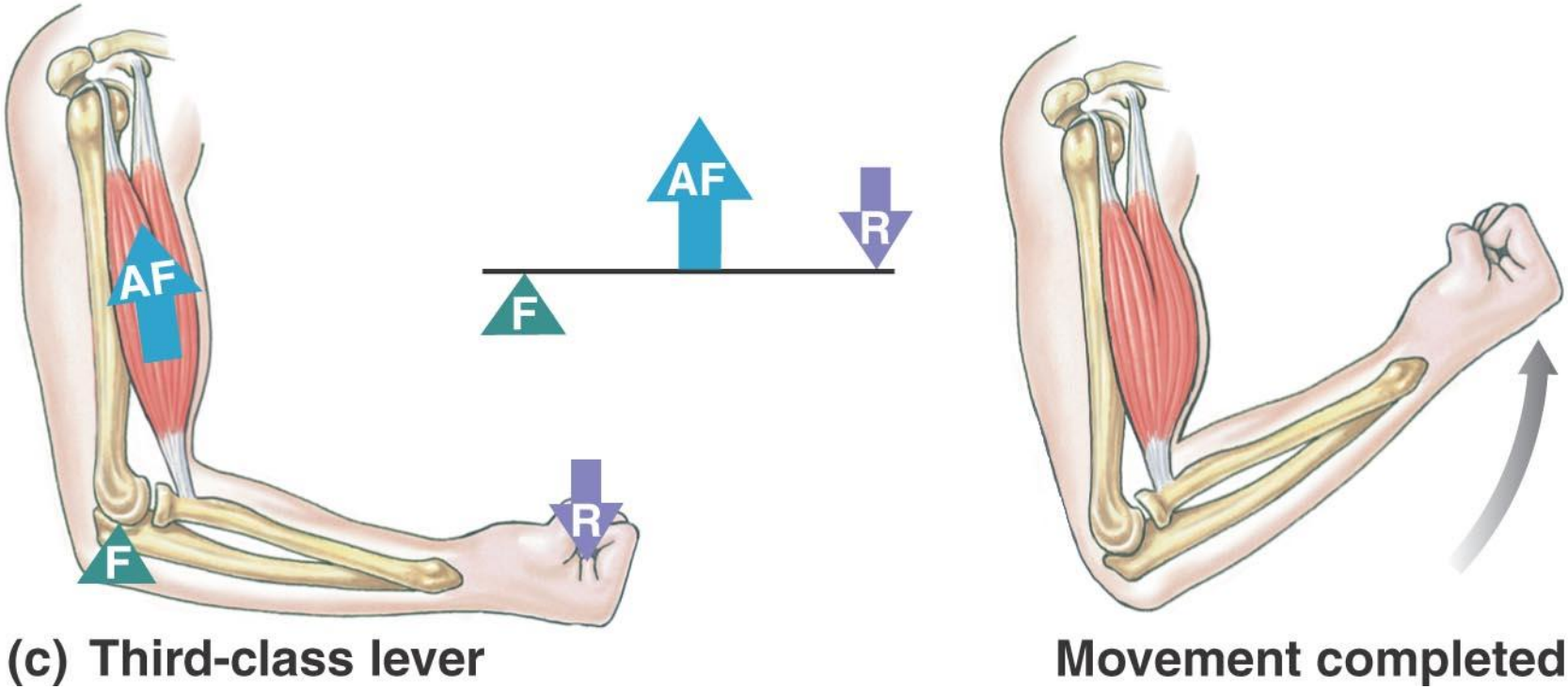


(b) Second-class lever



Movement completed

Levers and Pulleys: A Systems Design for Movement



Levers and Pulleys: A Systems Design for Movement

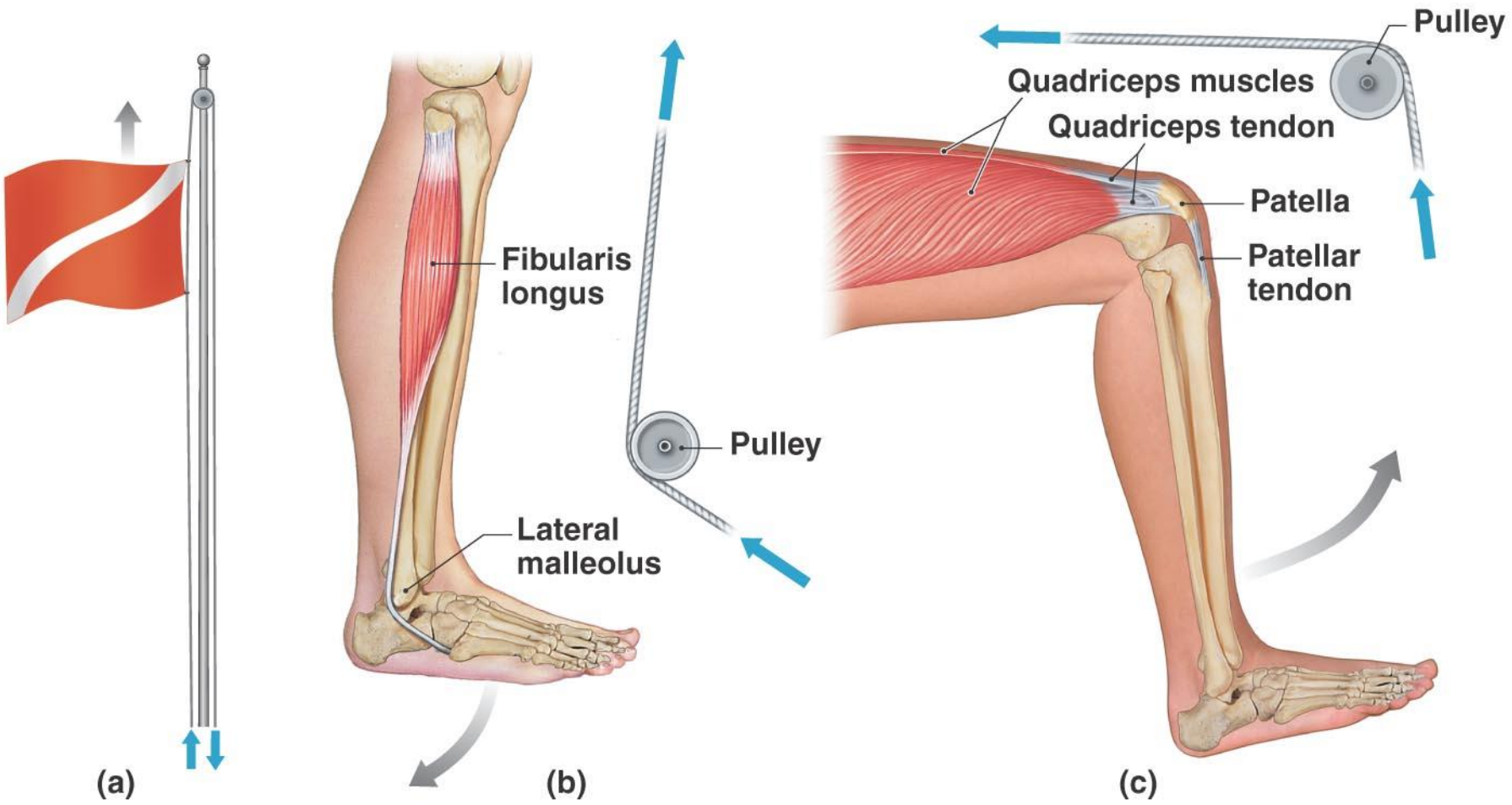


Figure 9.16 Anatomical Pulleys

Aging and the Muscular System

- Skeletal muscle fibers become smaller in diameter.
- Skeletal muscles become smaller in diameter and less elastic.
- Tolerance for exercise decreases.
- The ability to recover from muscular injuries decreases.

Aging and the Muscular System

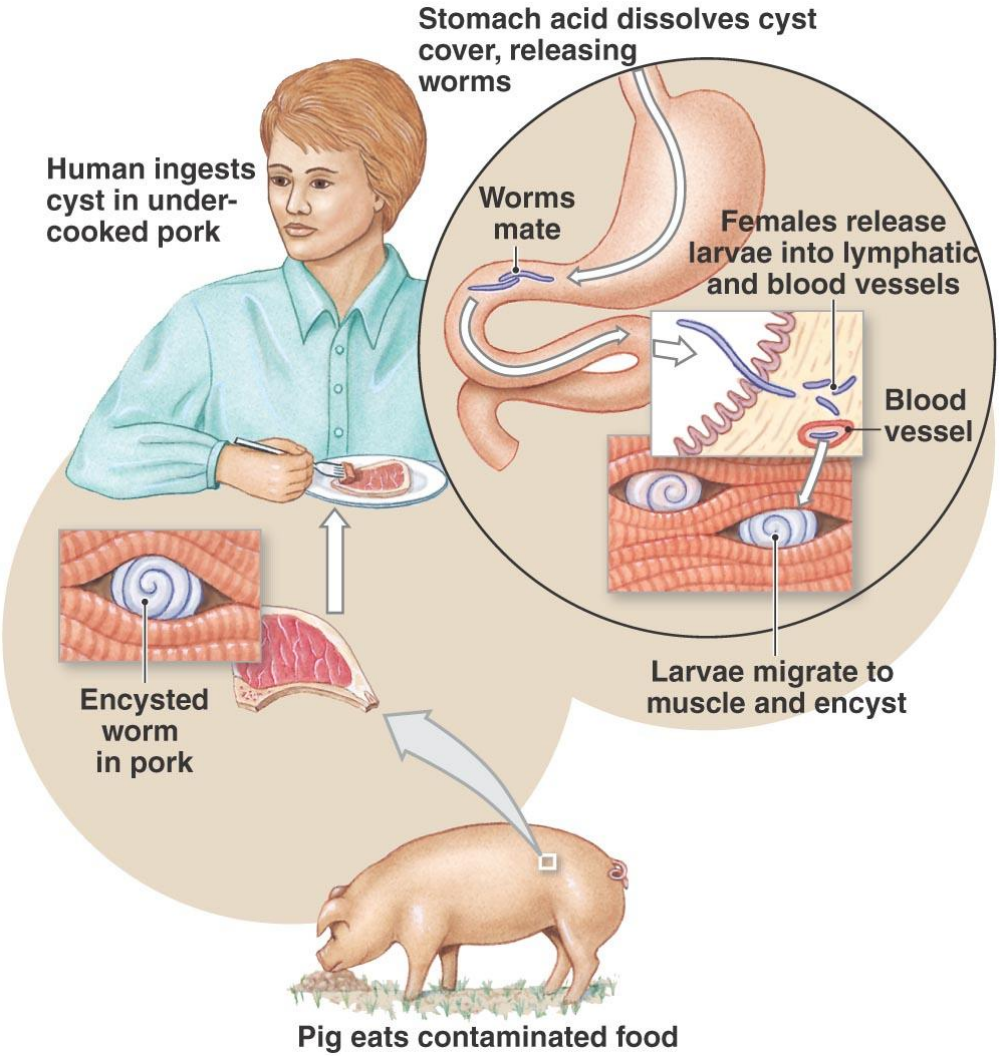


Figure 9.17 The Life Cycle of *Trichinella spiralis*