Energy for Muscle Contraction

- Initially, muscles use stored ATP for energy
  - ATP bonds are broken to release energy
  - Only 4–6 seconds worth of ATP is stored by muscles
- After this initial time, other pathways must be utilized to produce ATP

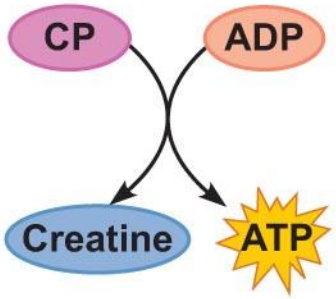
Energy for Muscle Contraction

- **Direct phosphorylation of ADP by creatine phosphate (CP)**
  - Muscle cells store CP
    - CP is a high-energy molecule
  - After ATP is depleted, ADP is left
  - CP transfers a phosphate group to ADP, to regenerate ATP
  - CP supplies are exhausted in less than 15 seconds
  - About 1 ATP is created per CP molecule

(a) Direct phosphorylation

Coupled reaction of creatine phosphate (CP) and ADP

Energy source: CP



Oxygen use: None
Products: 1 ATP per CP, creatine
Duration of energy provision: 15 seconds

Figure 6.10a

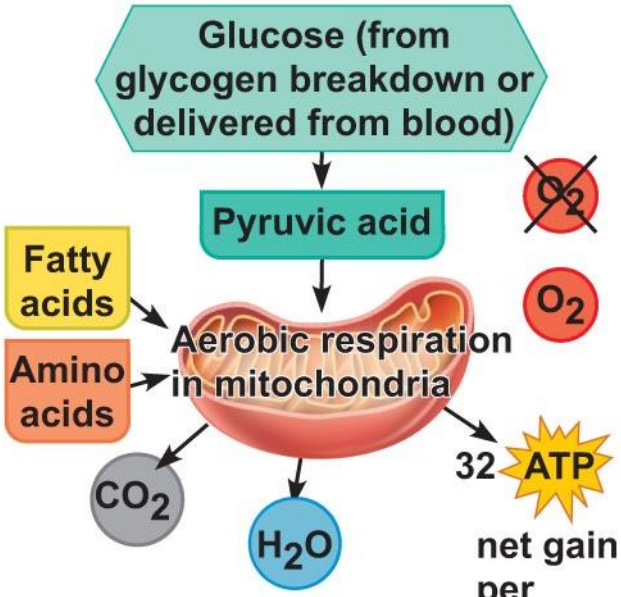
Energy for Muscle Contraction

- **Aerobic respiration**
  - Glucose is broken down to carbon dioxide and water, releasing energy (about 32 ATP)
  - A series of metabolic pathways occur in the mitochondria
  - This is a slower reaction that requires continuous oxygen
  - Carbon dioxide and water are produced

(c) Aerobic pathway

Aerobic cellular respiration

Energy source: glucose; pyruvic acid; free fatty acids from adipose tissue; amino acids from protein catabolism



Oxygen use: Required
Products: 32 ATP per glucose, CO_2, H_2O
Duration of energy provision: Hours

Figure 6.10b

Energy for Muscle Contraction

- **Anaerobic glycolysis and lactic acid formation**
  - Reaction that breaks down glucose *without* oxygen
  - Glucose is broken down to pyruvic acid to produce about 2 ATP
  - Pyruvic acid is converted to lactic acid

- This reaction is not as efficient, but is fast
  - Huge amounts of glucose are needed
  - Lactic acid produces muscle fatigue

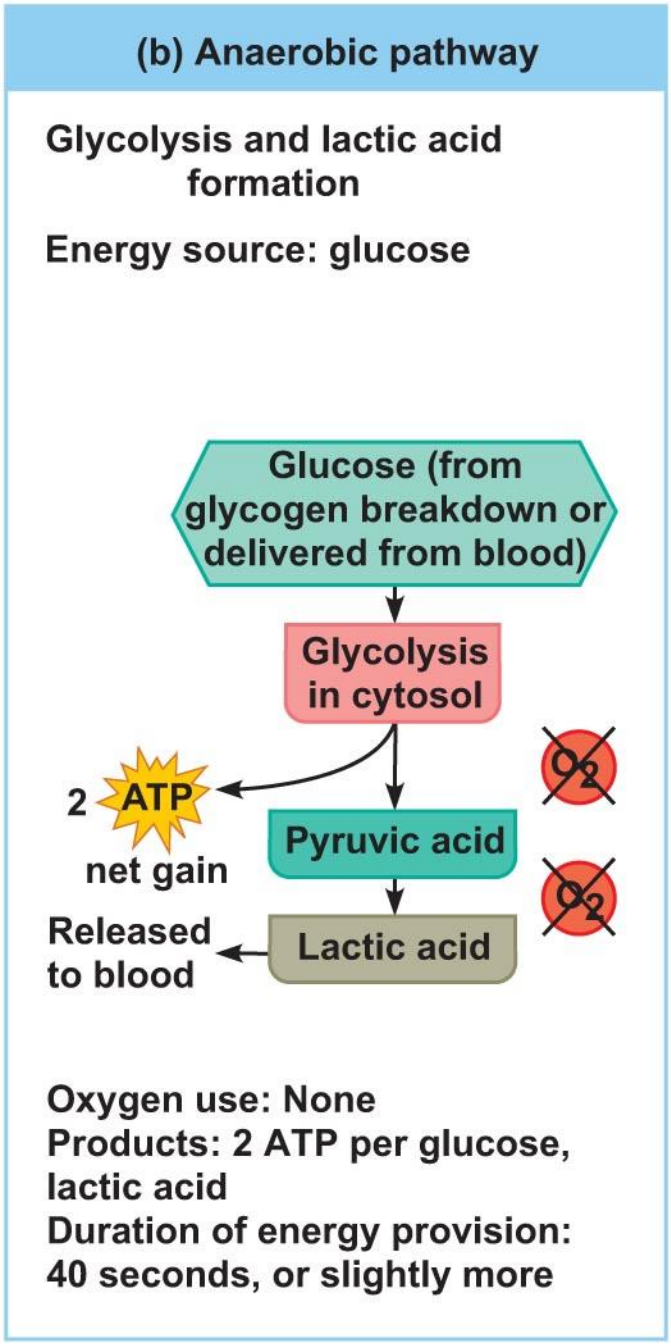


Figure 6.10c

Muscle Fatigue and Oxygen Deficit

- When a muscle is fatigued, it is unable to contract even with a stimulus
- Common cause for muscle fatigue is oxygen debt
  - Oxygen must be “repaid” to tissue to remove oxygen deficit
  - Oxygen is required to get rid of accumulated lactic acid
- Increasing acidity (from lactic acid) and lack of ATP causes the muscle to contract less

Types of Muscle Contractions

- **Isotonic contractions**
  - Myofilaments are able to slide past each other during contractions
  - The muscle shortens and movement occurs
  - **Example:** bending the knee; rotating the arm

Types of Muscle Contractions

- **Isometric contractions**
  - Tension in the muscles increases
  - The muscle is unable to shorten or produce movement
  - **Example:** push against a wall with bent elbows

Muscle Tone

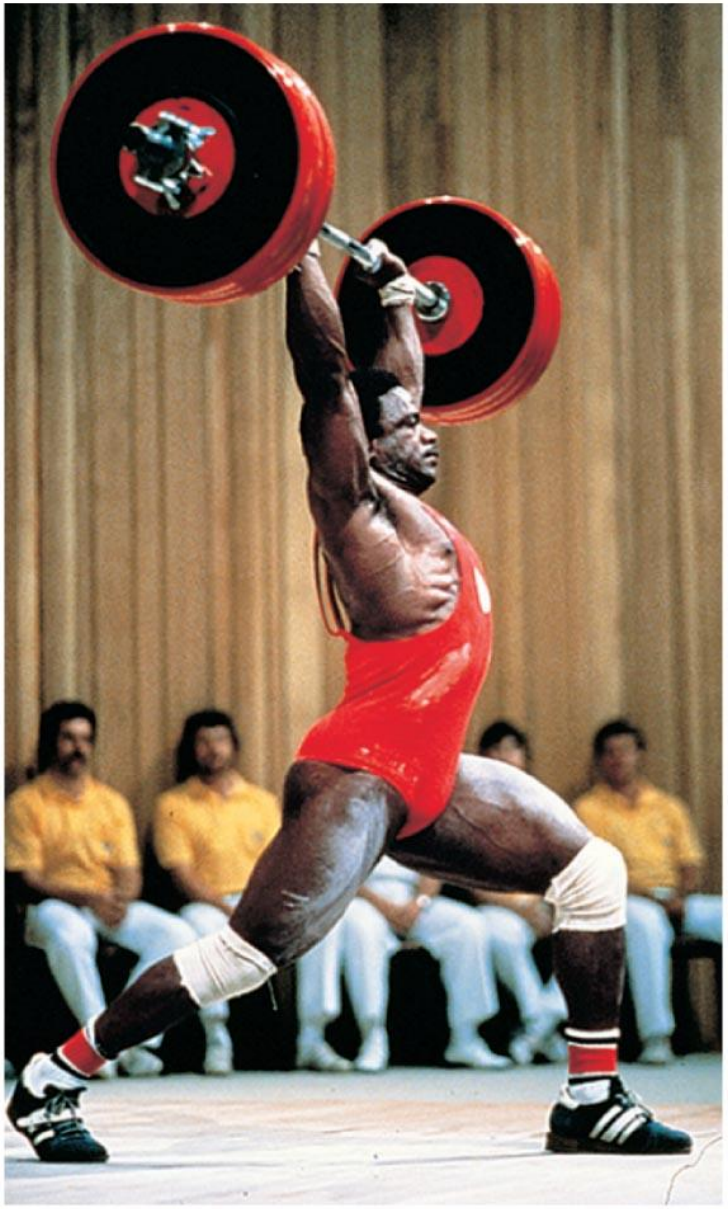
- Some fibers are contracted even in a relaxed muscle

- Different fibers contract at different times to provide muscle tone and to be constantly ready

Effect of Exercise on Muscles

- Exercise increases muscle size, strength, and endurance
  - Aerobic (endurance) exercise (biking, jogging) results in stronger, more flexible muscles with greater resistance to fatigue
    - Makes body metabolism more efficient
    - Improves digestion, coordination
  - Resistance (isometric) exercise (weight lifting) increases muscle size and strength

(a)



(b)

Figure 6.11a-b

Five Golden Rules of Skeletal Muscle Activity

1. With a few exceptions, all skeletal muscles **cross at least one joint**.

2. Typically, the **bulk of a skeletal muscle lies proximal to the joint crossed.**

3. All skeletal muscles have **at least two attachments: the origin and the insertion.**

4. Skeletal muscles **can only pull**; they never push.

5. **During contraction, a skeletal muscle insertion moves toward the origin.**

Muscles and Body Movements

- Movement is attained due to a muscle moving an attached bone

- Muscles are attached to at least two points
  - **Origin**
    - Attachment to a immoveable bone
  - **Insertion**
    - Attachment to an movable bone

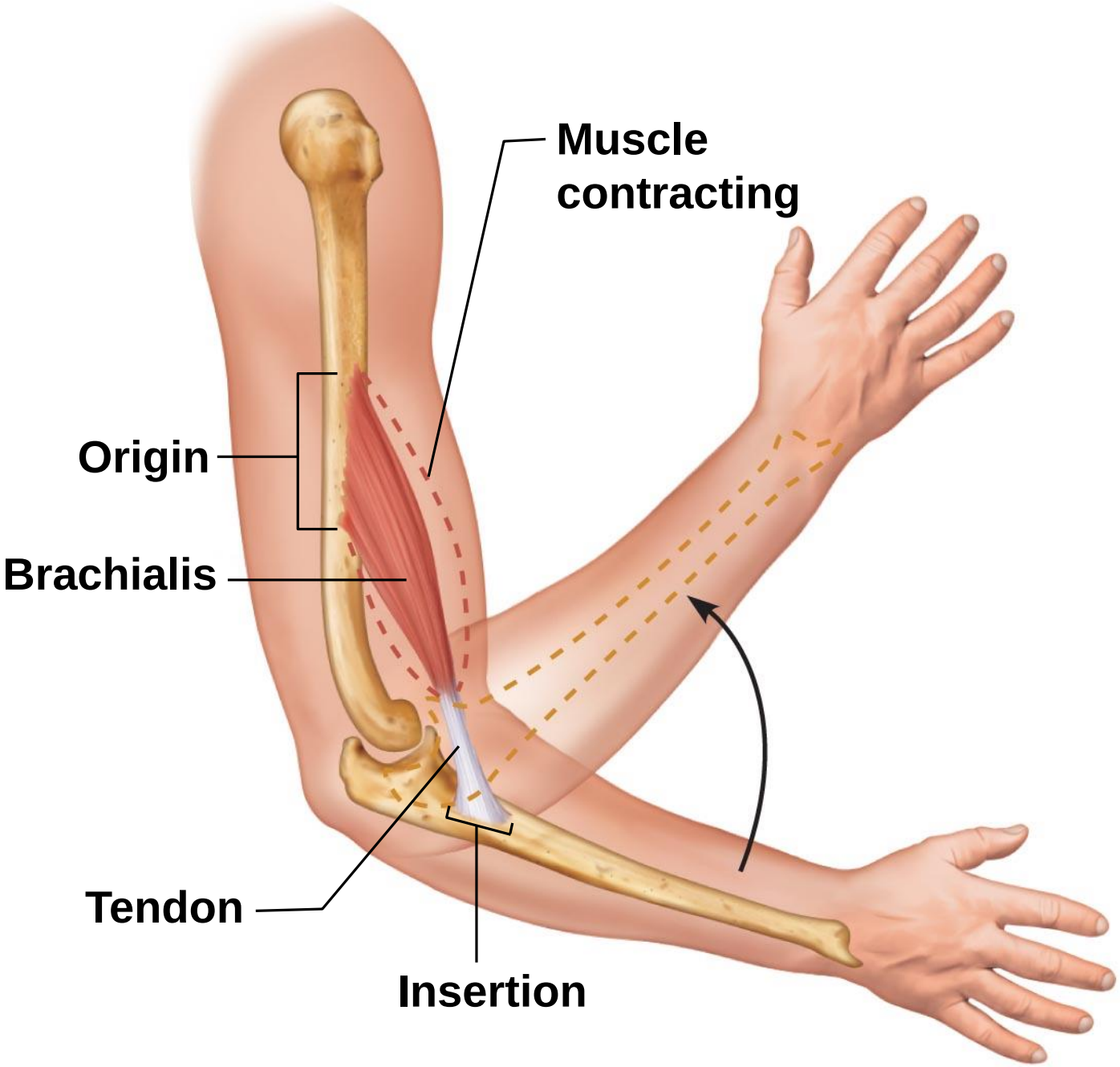
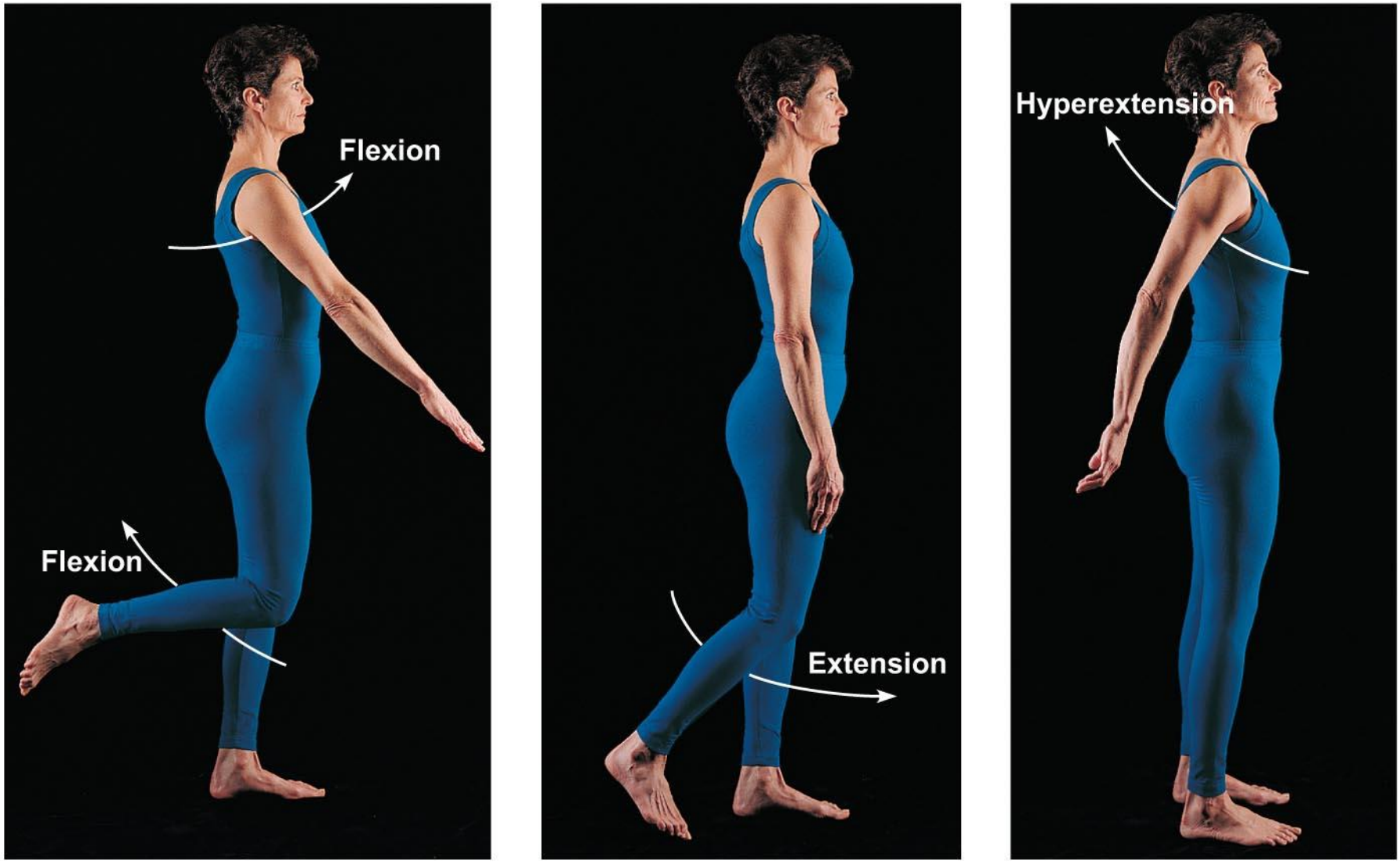


Figure 6.12

Types of Body Movements

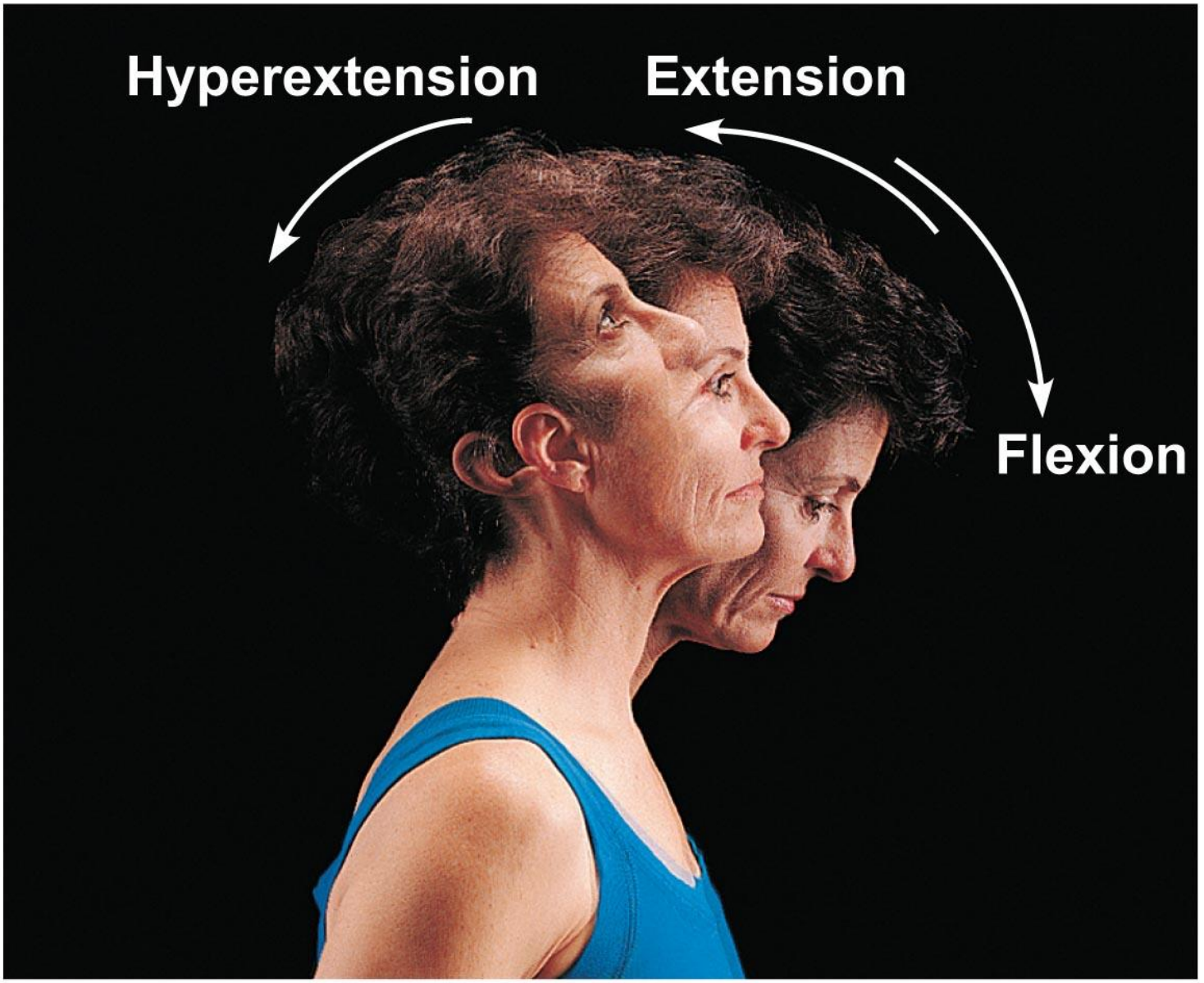
- **Flexion**
  - Decreases the angle of the joint
  - Brings two bones closer together
  - Typical of bending hinge joints like knee and elbow or ball-and-socket joints like the hip

- **Extension**
  - Opposite of flexion
  - Increases angle between two bones
  - Typical of straightening the elbow or knee
  - Extension beyond 180° is hypertension



(a) Flexion and extension of the shoulder and knee

Figure 6.13a

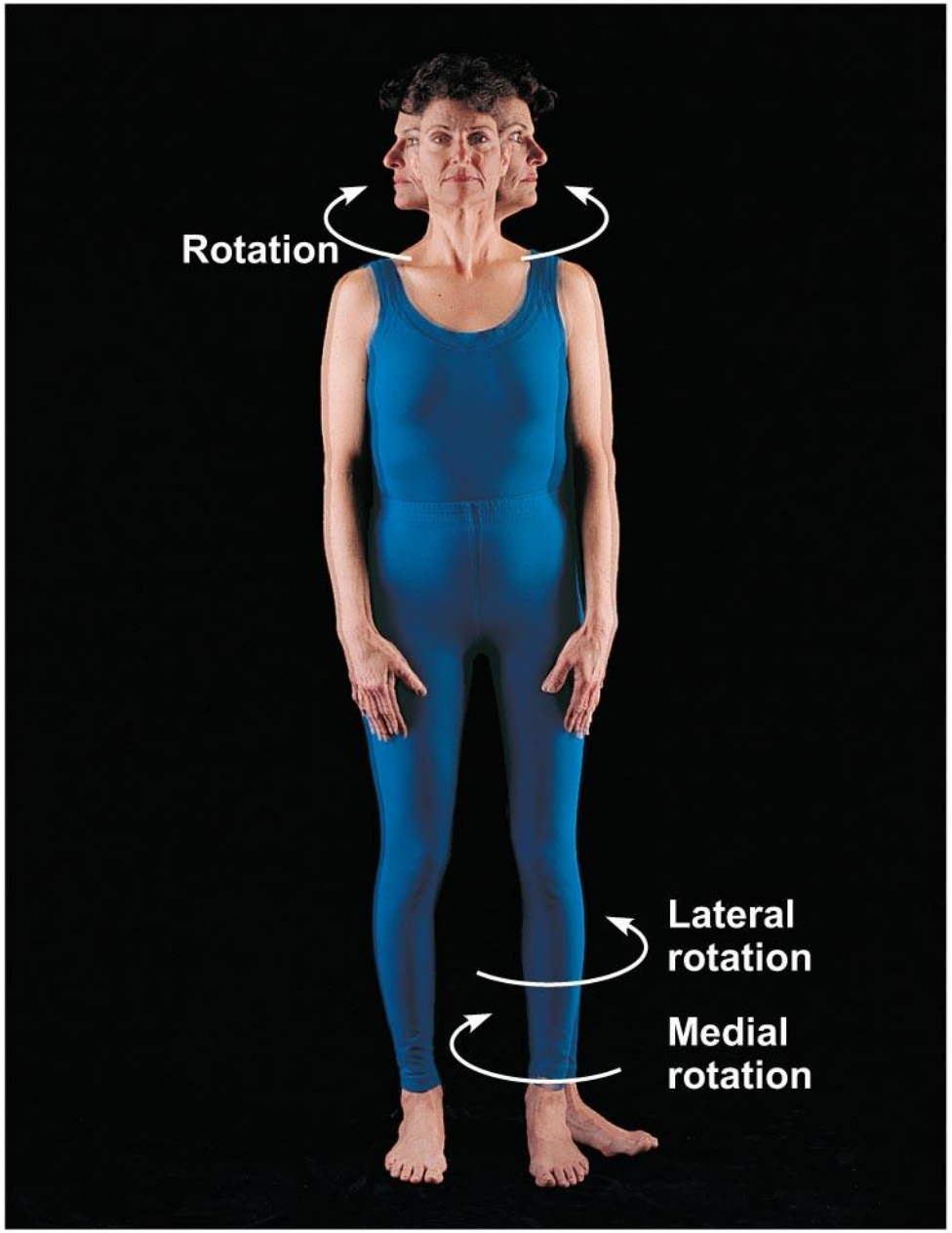


(b) Flexion, extension, and hyperextension

Figure 6.13b

Types of Body Movements

- **Rotation**
  - Movement of a bone around its longitudinal axis
  - Common in ball-and-socket joints
  - Example is when you move atlas around the dens of axis (shake your head “no”)



(c) Rotation

Figure 6.13c

Types of Body Movements

- **Abduction**
  - Movement of a limb away from the midline

- **Adduction**
  - Opposite of abduction
  - Movement of a limb toward the midline

(d) Abduction, adduction, and circumduction

Figure 6.13d

Types of Body Movements

- **Circumduction**
  - Combination of flexion, extension, abduction, and adduction
  - Common in ball-and-socket joints

(d) Abduction, adduction, and circumduction

Figure 6.13d

Special Movements

- **Dorsiflexion**
  - Lifting the foot so that the superior surface approaches the shin (toward the dorsum)

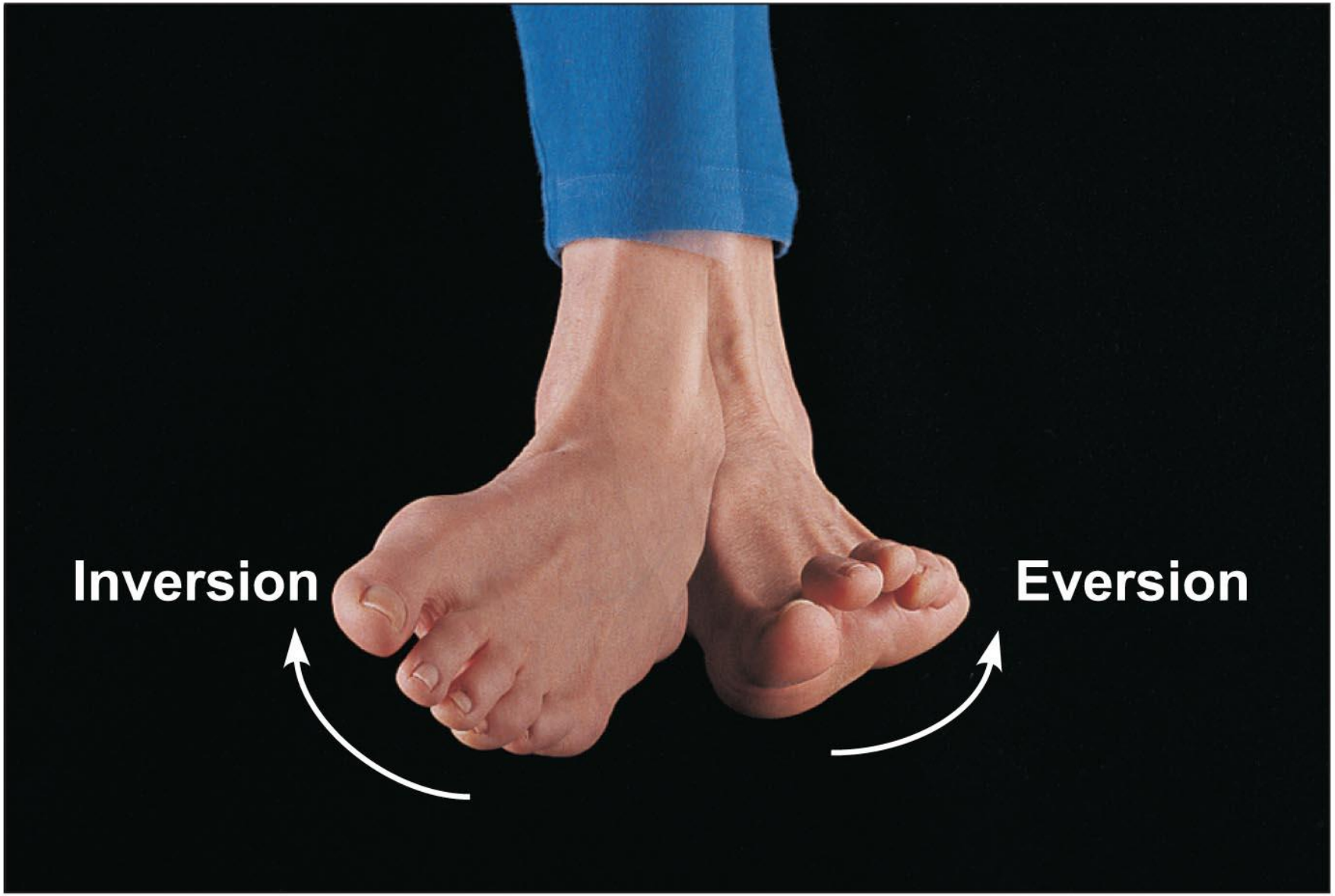
- **Plantar flexion**
  - Depressing the foot (pointing the toes)
  - “Planting” the foot toward the sole

(e) Dorsiflexion and plantar flexion

Figure 6.13e

Special Movements

- **Inversion**
  - Turn sole of foot medially
- **Eversion**
  - Turn sole of foot laterally

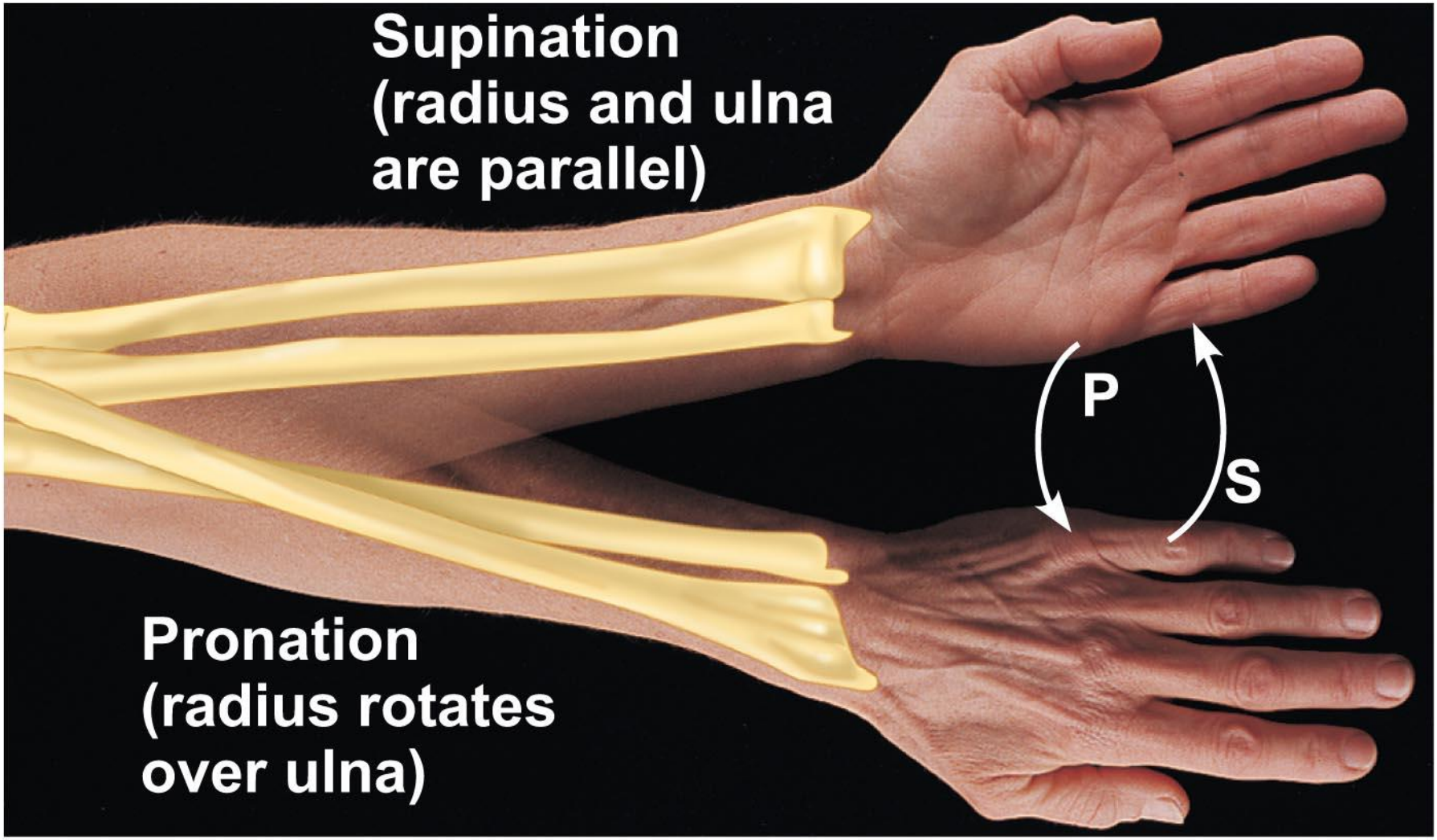


(f) Inversion and eversion

Figure 6.13f

Special Movements

- **Supination**
  - Forearm rotates laterally so palm faces anteriorly
  - Radius and ulna are parallel
- **Pronation**
  - Forearm rotates medially so palm faces posteriorly
  - Radius and ulna cross each other like an X

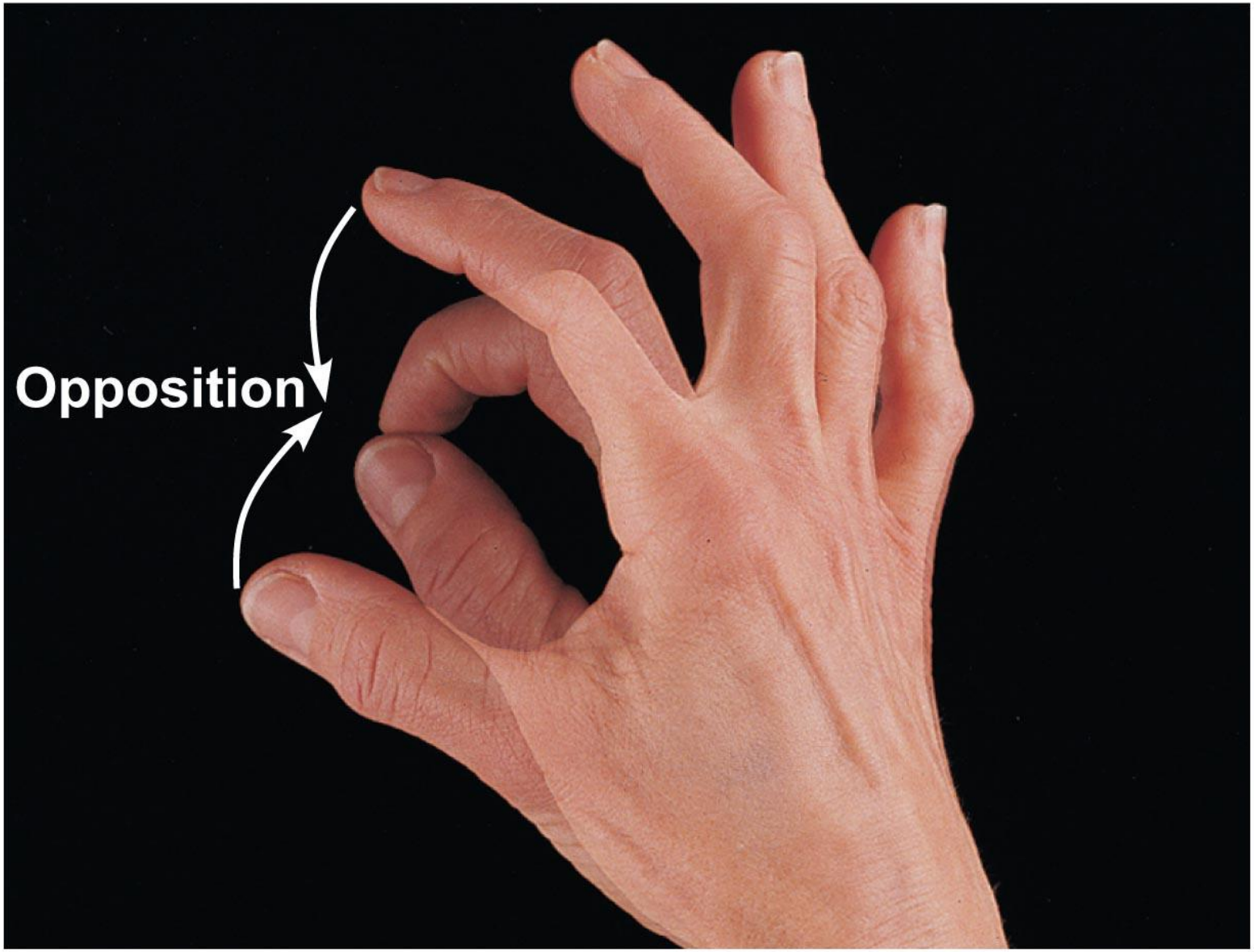


(g) Supination (S) and pronation (P)

Figure 6.13g

Special Movements

- **Opposition**
  - Move thumb to touch the tips of other fingers on the same hand



(h) Opposition

Figure 6.13h

Types of Muscles

- **Prime mover**—muscle with the major responsibility for a certain movement
- **Antagonist**—muscle that opposes or reverses a prime mover
- **Synergist**—muscle that aids a prime mover in a movement and helps prevent rotation
- **Fixator**—stabilizes the origin of a prime mover

(a) A muscle that crosses on the anterior side of a joint produces flexion*

Figure 6.14a

(b) A muscle that crosses on the posterior side of a joint produces extension*

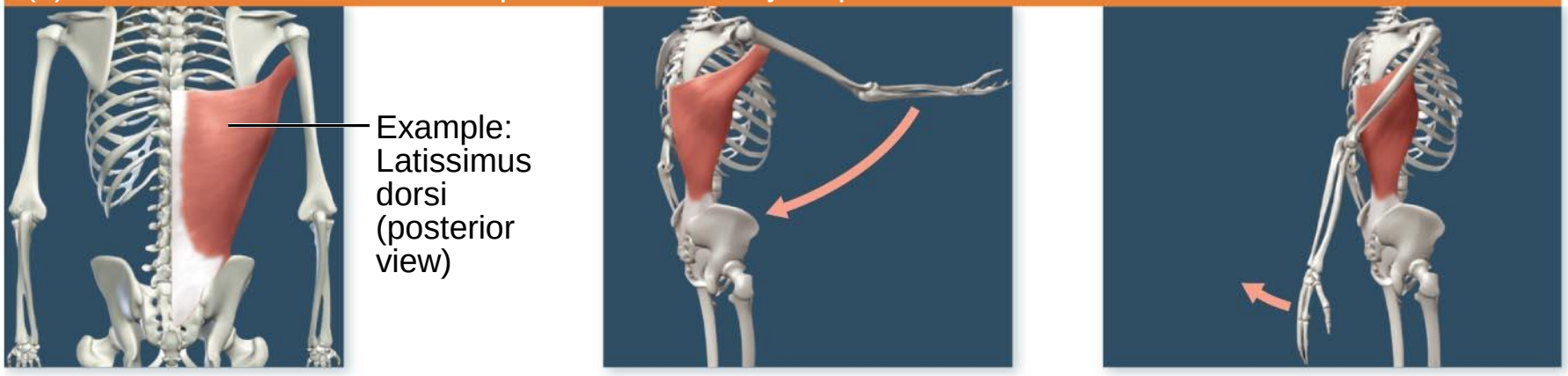


Figure 6.14b

(c) A muscle that crosses on the lateral side of a joint produces abduction

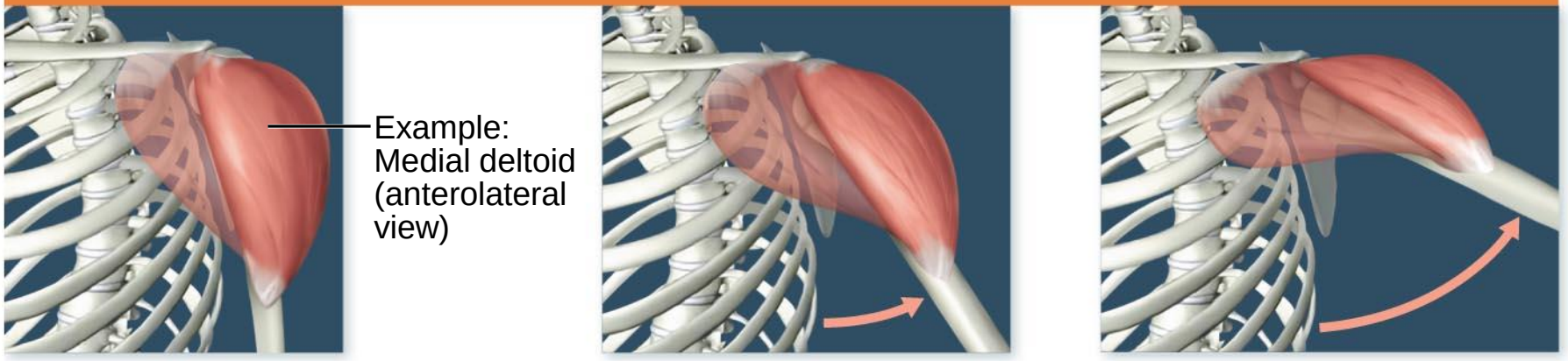


Figure 6.14c

(d) A muscle that crosses on the medial side of a joint produces adduction

Figure 6.14d

Naming Skeletal Muscles

- By **direction** of muscle fibers
  - **Example:** *Rectus* (straight)

- By relative **size** of the muscle
  - **Example:** *Maximus* (largest)

Naming Skeletal Muscles

- By **location** of the muscle
  - **Example:** *Temporalis* (temporal bone)

- By **number of origins**
  - **Example:** *Triceps* (three heads)

Naming Skeletal Muscles

- By **location of the muscle's origin and insertion**
  - **Example:** *Sterno* (on the sternum)
- By **shape** of the muscle
  - **Example:** *Deltoid* (triangular)
- By **action** of the muscle
  - **Example:** *Flexor* and *extensor* (flexes or extends a bone)

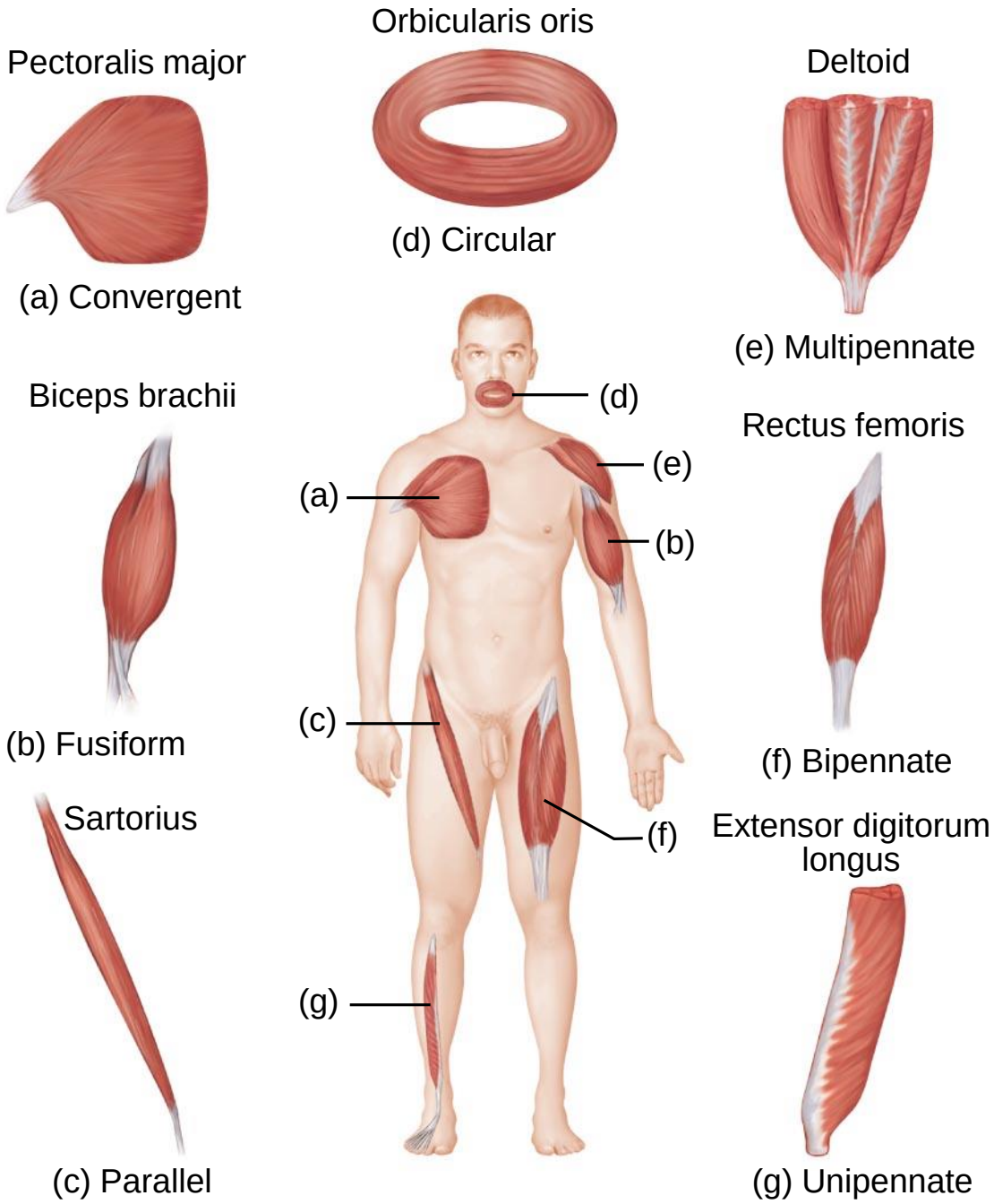


Figure 6.15