

Lesson 4

Contraction of Skeletal Muscle

Graded responses

Energy sources

Effect of Exercise on Muscles



<https://www.biointeractive.org/classroom-resources/electrical-measurement-muscle-activity>

Contraction of Skeletal Muscle

- Muscle fiber contraction is “all or none”
- Within a skeletal muscle, not all fibers may be **stimulated** during the same interval
- Different **combinations** of muscle fiber contractions may give differing responses
- **Graded responses**—different degrees of skeletal muscle shortening

Contraction of Skeletal Muscle

- Graded responses can be produced by changing:
 - The *frequency* of muscle stimulation
 - The *number* of muscle cells being stimulated at one time

Types of Graded Responses

- **Twitch**
 - **Single, brief contraction**
 - **Not a normal muscle function**

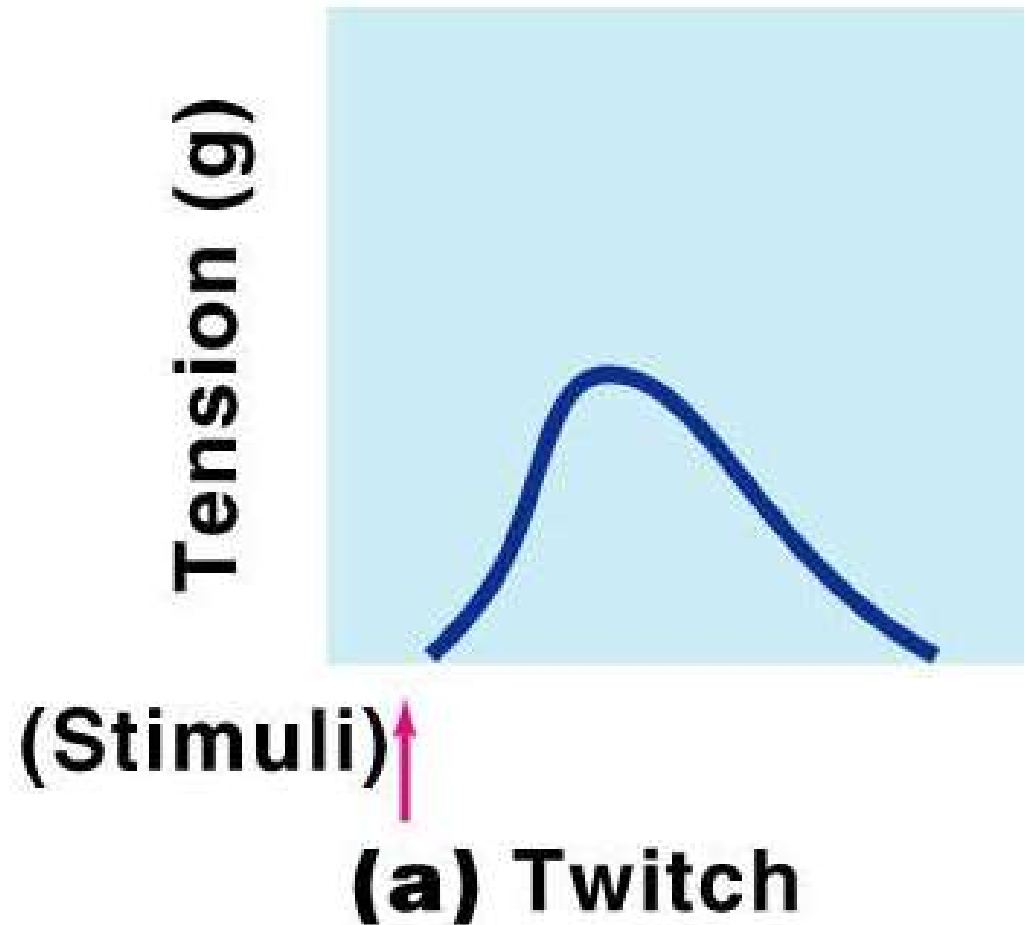


Figure 6.9a

Types of Graded Responses

- Tetanus (summing of contractions)
 - One contraction is immediately **followed** by another
 - The muscle does not completely return to a **resting** state
 - The effects are added

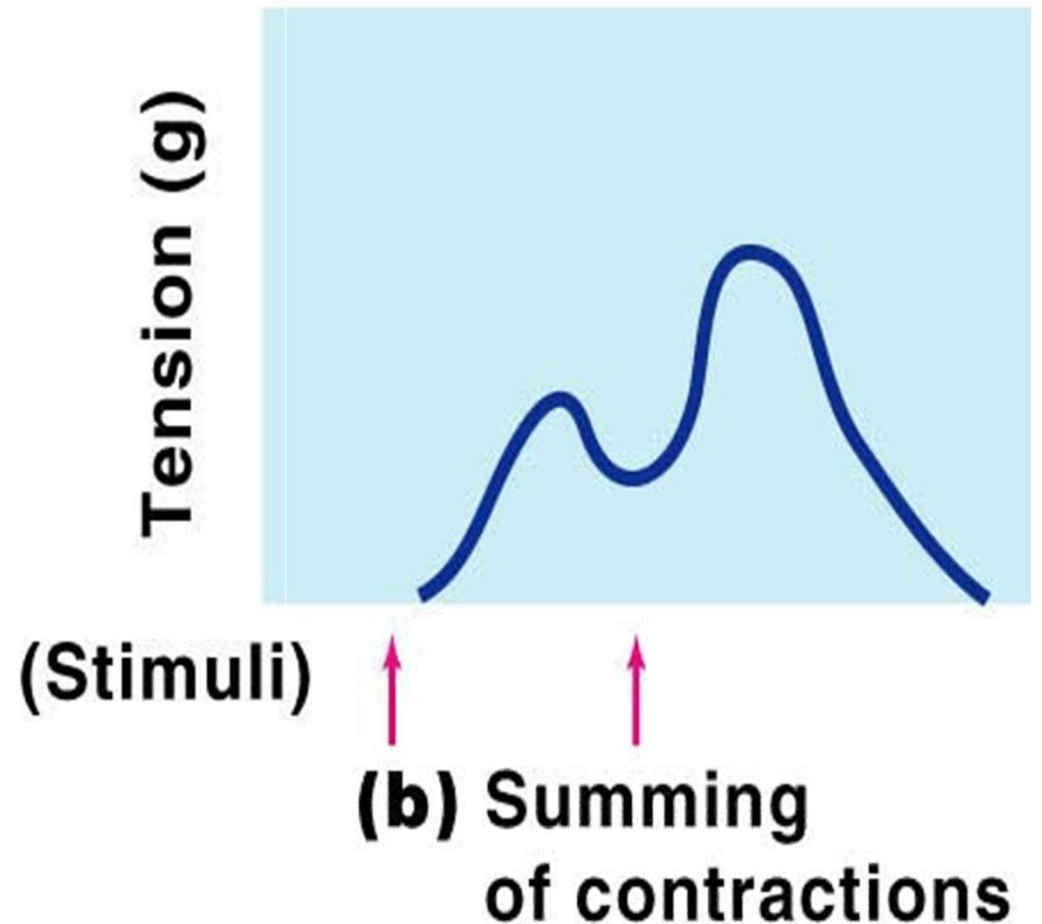


Figure 6.9b

Types of Graded Responses

- Unfused (incomplete) tetanus
 - **Some** relaxation occurs **between** contractions
 - The results are summed

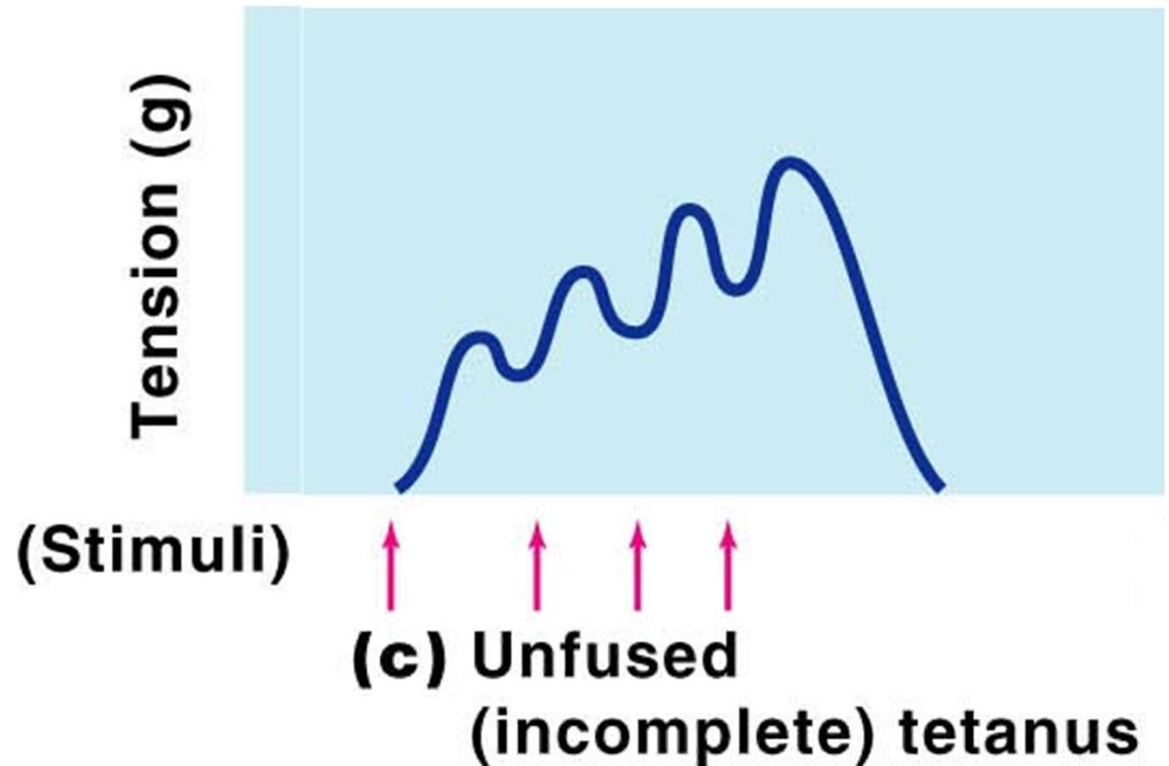


Figure 6.9c

Types of Graded Responses

- Fused (complete) tetanus
 - **No** relaxation before the following contractions
 - The result is a **sustained** muscle contraction

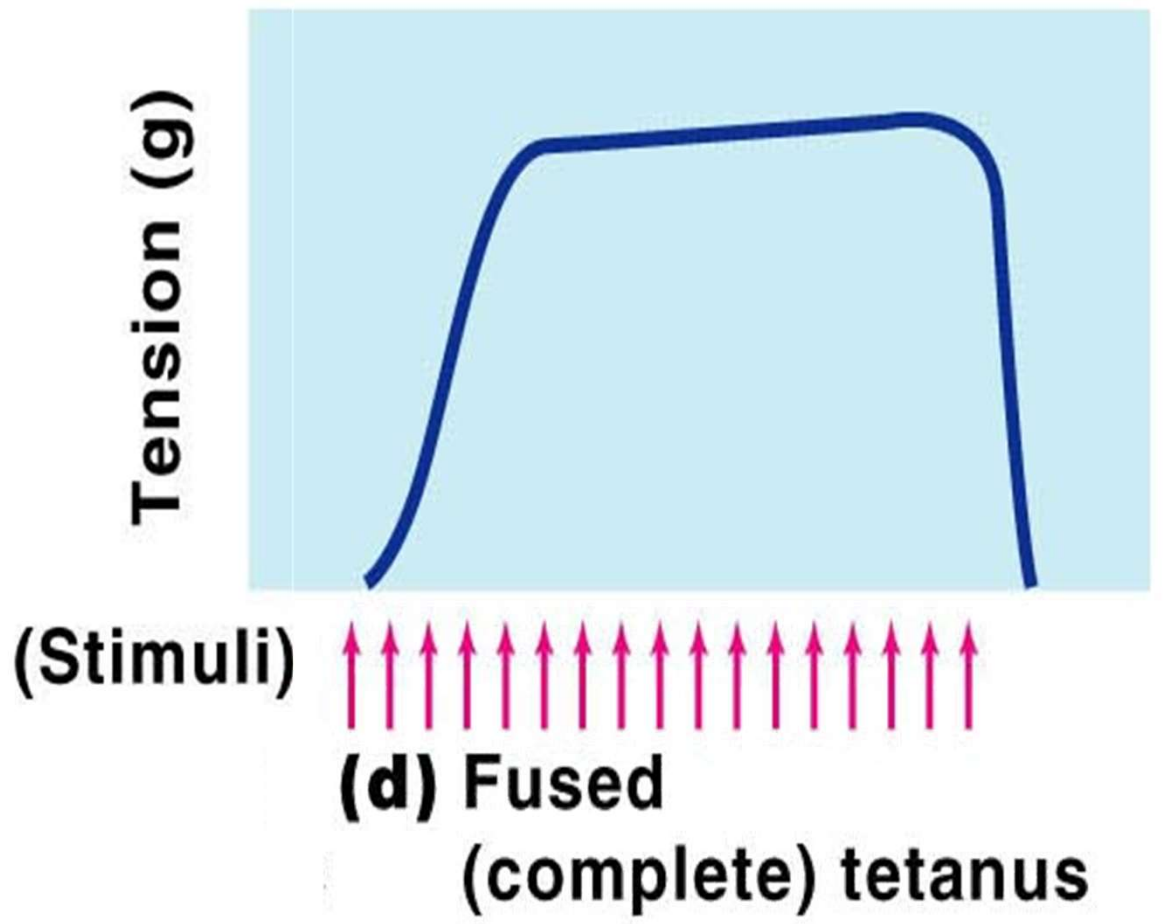


Figure 6.9d

Muscle Response to Strong Stimuli

- Muscle force depends upon the **number** of fibers stimulated
- **More** fibers **contracting** results in **greater** muscle tension
- Muscles can continue to contract unless they run out of **energy**

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 **creatine phosphate**
 - CP is a high-energy molecule
 - After ATP is depleted, ADP is left
 - CP **transfers** energy to ADP, to regenerate ATP
 - CP supplies are exhausted in less than **15 seconds**

Energy for Muscle Contraction

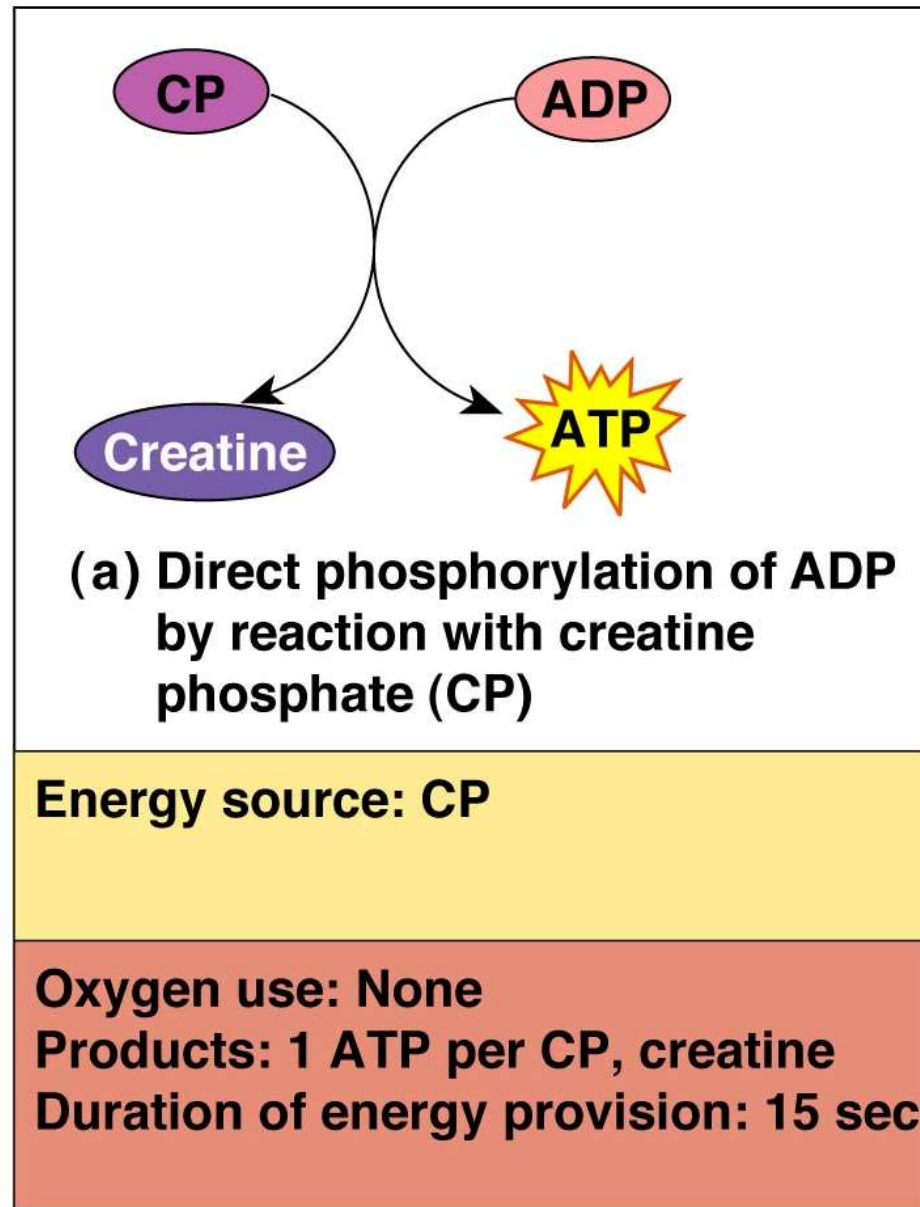
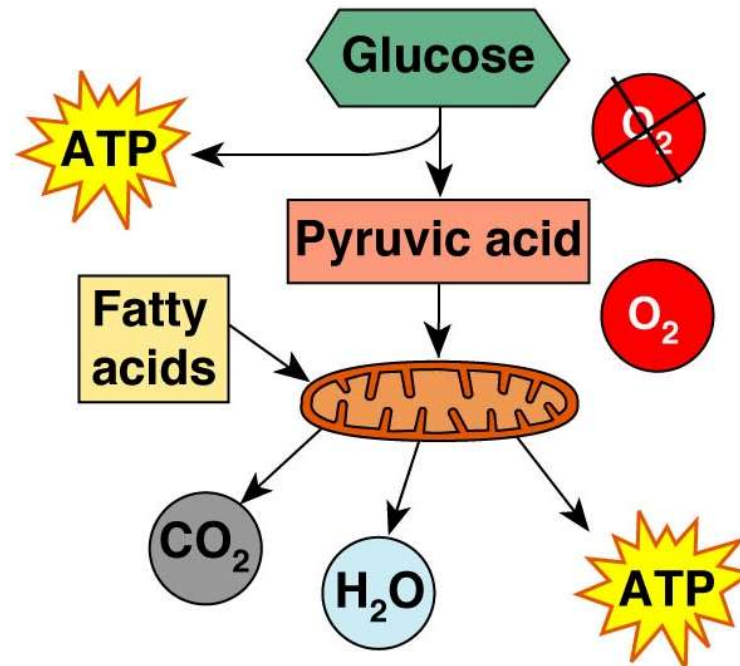


Figure 6.10a

Energy for Muscle Contraction

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

Energy for Muscle Contraction



(b) Aerobic respiration (oxidative phosphorylation)

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

Oxygen use: Required

Products: 36 ATP per glucose, CO₂, H₂O

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 a small amount of 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**

Energy for Muscle Contraction

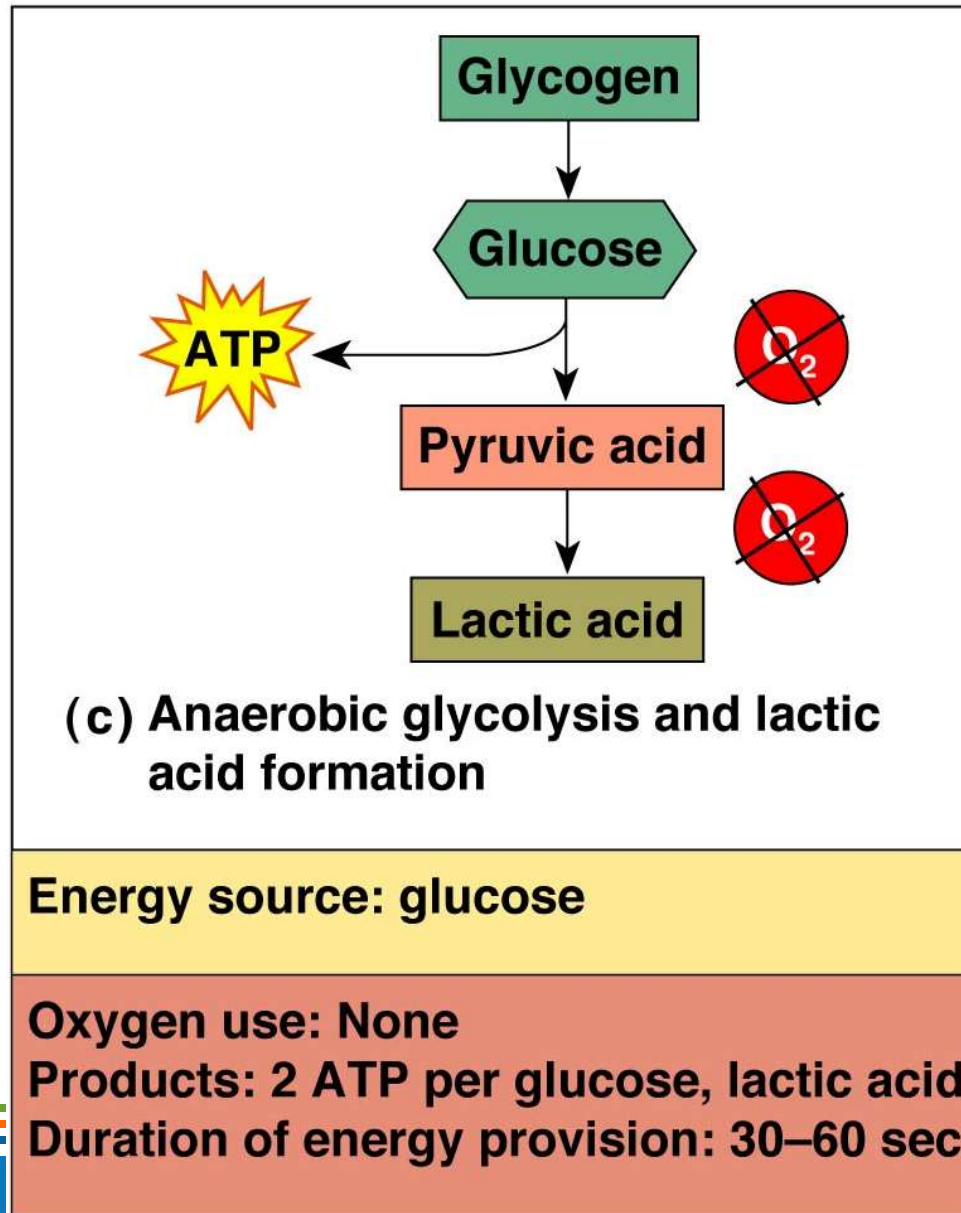


Figure 6.10c

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 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
- **Isometric** contractions
 - Tension in the muscles increases
 - The muscle is unable to shorten or produce movement

Muscle Tone

- Some fibers are contracted even in a **relaxed** muscle
- Different fibers **contract** at different **times** to provide muscle tone
- The process of stimulating various fibers is under **involuntary** control

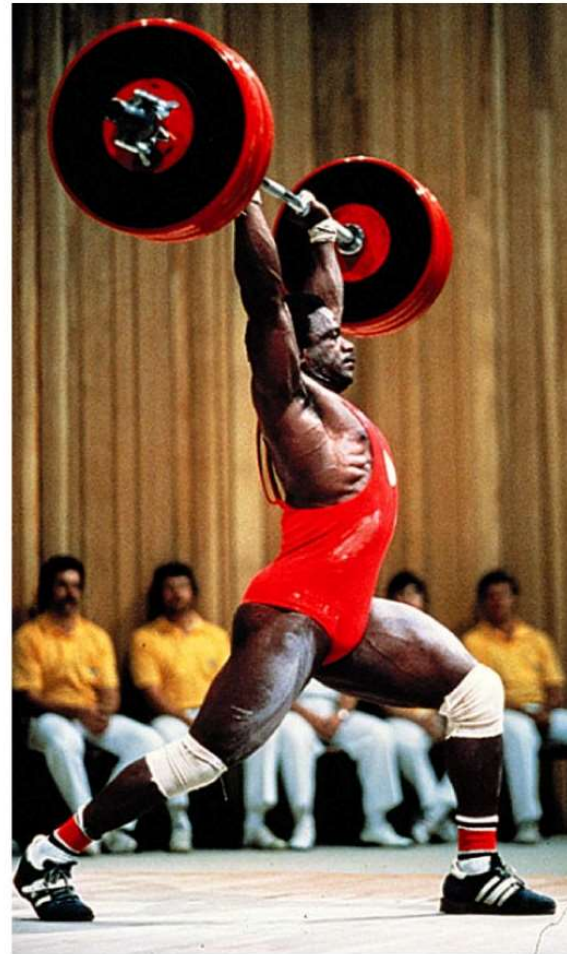
Effect of Exercise on Muscles

- 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 and coordination
 - **Resistance (isometric)** exercise (weight lifting) increases muscle size and strength

Effect of Exercise on Muscles



(a)



(b)

Figure 6.11