Introduction: *Man Versus Horse*

- Horses are well adapted for long-distance running
  - Longer legs
  - Lighter legs
  - Increased oxygen-carrying capacity
Humans have a more versatile body

- Humans run, crawl, swim, tumble, and throw
- Flexibility generally reduces efficiency
MOVEMENT AND LOCOMOTION
Animal movement is very diverse

Locomotion

- Active travel from place to place
- Requires energy to overcome friction and gravity
30.1 Animals have evolved diverse means of locomotion

- Swimming
  - Supported by water
  - But slowed by friction
30.1 Animals have evolved diverse means of locomotion

- Walking, hopping, or running
  - Less affected by friction
  - But must resist gravity
30.1 Animals have evolved diverse means of locomotion

- Burrowing or crawling
  - Must overcome great friction
  - May move by side-to-side undulations
  - Or may move by a form of peristalsis
Longitudinal muscle relaxed (extended)
Circular muscle contracted
Circular muscle relaxed
Longitudinal muscle contracted

1

Bristles

2

Head

3
30.1 Animals have evolved diverse means of locomotion

- **Flying**
  - Wings are airfoils that generate lift
  - Flying is seen in birds, bats, and most insects
SKELETAL SUPPORT
30.2 Skeletons function in support, movement, and protection

- Skeletons provide
  - Body support
  - Movement by working with muscles
  - Protection of internal organs
30.2 Skeletons function in support, movement, and protection

- Hydrostatic skeletons
  - Fluid held under pressure in a closed body compartment
  - Found in worms and cnidarians
30.2 Skeletons function in support, movement, and protection

- **Exoskeletons**
  - Hard external cases
  - Chitinous, jointed skeletons of arthropods
  - Calcium carbonate shells of molluscs
Shell (exoskeleton)

Mantle
30.2 Skeletons function in support, movement, and protection

- **Endoskeletons**
  - Internal skeleton
  - May be made of
    - Cartilage or bone—vertebrates
    - Spicules—sponges
    - Hard plates—echinoderms
30.3 EVOLUTION CONNECTION: Vertebrate skeletons are variations on an ancient theme

- Human skeleton
  - Axial skeleton
    - Skull
    - Vertebrae
    - Ribs
  - Appendicular skeleton
    - Shoulder and pelvic girdles
    - Arms and legs
Metacarpals
Phalanges
Carpals
Pelvic girdle
Ulna
Radius
Vertebra
Humerus
Ribs
Sternum
Clavicle
Scapula
Shoulder girdle
Skull
Pelvic girdle
Carpals
Phalanges
Metacarpals
Intervertebral discs

7 cervical vertebrae

12 thoracic vertebrae

5 lumbar vertebrae

Hip bone

Sacrum

Coccyx
Vertebrate bodies reveal variations of this basic skeletal arrangement

Master control (homeotic) genes

- Are active during early development
- Direct the arrangement of the skeleton

Vertebrates have evolved by changes in these master control genes
Gene expression during development

- **Hoxc6**
- **Hoxc8**
- **Hoxc6 and Hoxc8**
30.4 Bones are complex living organs

- Cartilage at the ends of bones
  - Cushions joints
  - Reduces friction of movements
Bone cells

- Live in a matrix of
  - Flexible protein fibers
  - Hard calcium salts
- Are kept alive by
  - Blood vessels
  - Hormones
  - Nerves
30.4 Bones are complex living organs

- Long bones have
  - A fat-storing central cavity
  - Spongy bone
    - Located at the ends of bones
    - Contains bone marrow, the site of blood cell production
Cartilage

Spongy bone
(contains red bone marrow)

Compact bone

Central cavity

Yellow bone marrow

Blood vessels

Fibrous connective tissue
30.5 CONNECTION: Healthy bones resist stress and heal from injuries

- Bone cells
  - Repair bones
  - Reshape bones throughout life

- Broken bones
  - Are realigned and immobilized
  - Bone cells build new bone, healing the break
30.5 CONNECTION: Healthy bones resist stress and heal from injuries

- Osteoporosis is a bone disease characterized by
  - Weak, porous bones
  - Less likely if
    - High levels of calcium in diet
    - Regular exercise
    - No smoking
30.6 Joints permit different types of movement

- Joints allow limited movement of bones
- Different joints permit various movements
Head of humerus

Scapula

Ball-and-socket joint
Humerus

Ulna

Hinge joint
Pivot joint

Ulna

Radius
MUSCLE CONTRACTION
AND MOVEMENT
Muscles and bones interact to produce movement

Muscles can only contract
30.7 The skeleton and muscles interact in movement

- Antagonistic pairs of muscles
  - Reverse actions
  - Relengthen muscles
Biceps contracted, triceps relaxed (extended)

Triceps contracted, biceps relaxed
30.8 Each muscle cell has its own contractile apparatus

- **Muscle fibers**
  - Are cells
  - Consist of bundles of myofibrils

- **Myofibrils** contain overlapping
  - Thick (myosin) filaments
  - Thin (actin) filaments
30.8 Each muscle cell has its own contractile apparatus

- **Sarcomeres** are
  - Repeating groups of thick and thin filaments
  - The contractile unit—the fundamental unit of muscle action
Muscle fibers

Several muscle fibers

Single muscle fiber (cell)

Plasma membrane

Nuclei

Myofibril

Light band

Dark band

Light band

Z line

Sarcomere
Plasma membrane

Myofibril

Light band

Dark band

Light band

Z line

Sarcomere

Thick filaments (myosin)

Thin filaments (actin)

Z line

Sarcomere

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30.9 A muscle contracts when thin filaments slide across thick filaments

- The sliding-filament model explains muscle contraction
Sarcomere

Dark band

Relaxed muscle

Contracting muscle

Fully contracted muscle

Contracted sarcomere
30.9 A muscle contracts when thin filaments slide across thick filaments

- Myosin heads of the thick filaments
  - Bind ATP and
  - Extend to high-energy states

- Myosin heads then
  - Attach to binding sites on the actin molecules and
  - Pull the thin filaments toward the center of the sarcomere
1. Thick filament
   
   Thin filament
   ATP
   Myosin head (low-energy configuration)

2. Actin
   ADP
   Myosin head (high-energy configuration)

3. ADP
   Cross-bridge
   ADP + P

4. Thin filament moves toward center of sarcomere.
   New position of Z line

   Myosin head (low-energy configuration)
Thick filament

Thin filament

ATP

Myosin head (low-energy)

Z line
1. **Thin filament**
   - ATP
   - Myosin head (low-energy)

2. **Thick filament**
   - Actin
   - ADP
   - Myosin head (high-energy)
1. Thin filament
   - ATP
   - Z line
   - Myosin head (low-energy)

2. Thick filament
   - ADP
   - P
   - Myosin head (high-energy)

3. Actin
   - ADP
   - P
   - Cross-bridge
1. Thin filament 
   ATP 
   Myosin head (low-energy) 

2. Thick filament 
   Actin 
   Myosin head (high-energy) 

3. ADP 
   Cross-bridge 
   P 

4. New position of Z line 
   Myosin head (low-energy) 

ADP + P
30.10 Motor neurons stimulate muscle contraction

- Motor neurons
  - Carry action potentials
  - That initiate muscle contractions
30.10 Motor neurons stimulate muscle contraction

- The axon of a motor neuron
  - Forms synapses with a muscle
  - At a neuromuscular junction
30.10 Motor neurons stimulate muscle contraction

- **Acetylcholine**
  - Is released from the synaptic terminal of a motor neuron
  - Diffuses to the plasma membrane of the muscle fiber
30.10 Motor neurons stimulate muscle contraction

- An action potential in a muscle fiber
  - Passes along T tubules
  - Into the center of muscle fiber

- Calcium ions
  - Are released from the endoplasmic reticulum
  - Initiate muscle contraction by moving regulatory proteins away from the actin binding sites
Ca^{2+}\text{-binding sites} \\
Myosin-binding sites blocked \\
Tropomyosin \quad \text{Ca}^{2+}\text{-binding sites} \\
Troponin complex \\
Myosin-binding site \\
Ca^{2+} \\
Myosin-binding sites exposed
A motor unit consists of

- A neuron
- The set of muscle fibers it controls
30.11 CONNECTION: Aerobic respiration supplies most of the energy for exercise

- Aerobic exercise provides most of the ATP used to power muscle movement during exercise

- Aerobic exercise requires a steady supply of
  - Glucose
  - Oxygen
30.12 CONNECTION: Muscle fiber characteristics affect athletic performance

- Anaerobic exercise
  - Generates ATP faster
  - Is much less efficient at producing ATP
Muscle fibers can be classified as
- Slow fibers
- Intermediate fibers
- Fast fibers

Most muscles have a combination of fiber types

The proportion of fiber types can be affected by exercise
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Slow Fibers</th>
<th>Intermediate Fibers</th>
<th>Fast Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of contraction</td>
<td>Slow</td>
<td>Fast</td>
<td>Fast</td>
</tr>
<tr>
<td>Rate of fatigue</td>
<td>Slow to fatigue</td>
<td>Intermediate</td>
<td>Fatigue rapidly</td>
</tr>
<tr>
<td>Primary pathway for making ATP</td>
<td>Aerobic respiration</td>
<td>Aerobic (some fermentation)</td>
<td>Anaerobic (fermentation)</td>
</tr>
<tr>
<td>Myoglobin content</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Mitochondria and capillaries</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
</tbody>
</table>
Muscles adapt to exercise by increasing
- Levels of myoglobin
- Number of mitochondria
- Number of capillaries going to muscles
World-Class Sprinter
Average Couch Potato
Average Active Person
Middle-Distance Runner
World-Class Marathon Runner
Extreme Endurance Athlete

Percent of total muscle

Slow
Intermediate
Fast

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Animal movement requires both forces of gravity and friction. Types are hydrostatic skeleton and antagonistic pairs. Moving parts of the body are usually in units of contraction. Contraction shortens as myosin pulls actin filaments, which is called the sliding-filament model. The endoskeleton is made of...
You should now be able to

1. Compare the adaptations of humans and horses that increase speed
2. Describe the diverse methods of animal locomotion and the forces they must overcome
3. Describe the three main types of skeletons
4. Describe the complex structure of bone
5. Describe the causes of osteoporosis
6. Describe three types of joints
You should now be able to

7. Describe the structure and arrangement of the filaments found in a muscle cell

8. Explain how a muscle cell contracts

9. Describe the role of calcium in a muscle contraction

10. Distinguish between aerobic and anaerobic exercise

11. Compare the structure and functions of different muscle fiber types