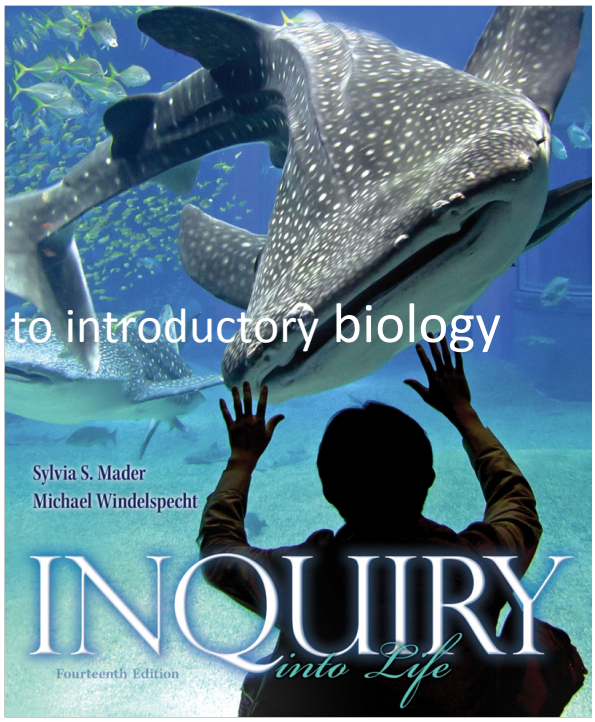
Fundamental Biology
BI 1101

an interdisciplinary approach to introductory biology



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Five Levels of Organization

Molecular

Cellular

Organismal

Population

Ecological System

Learning outcomes

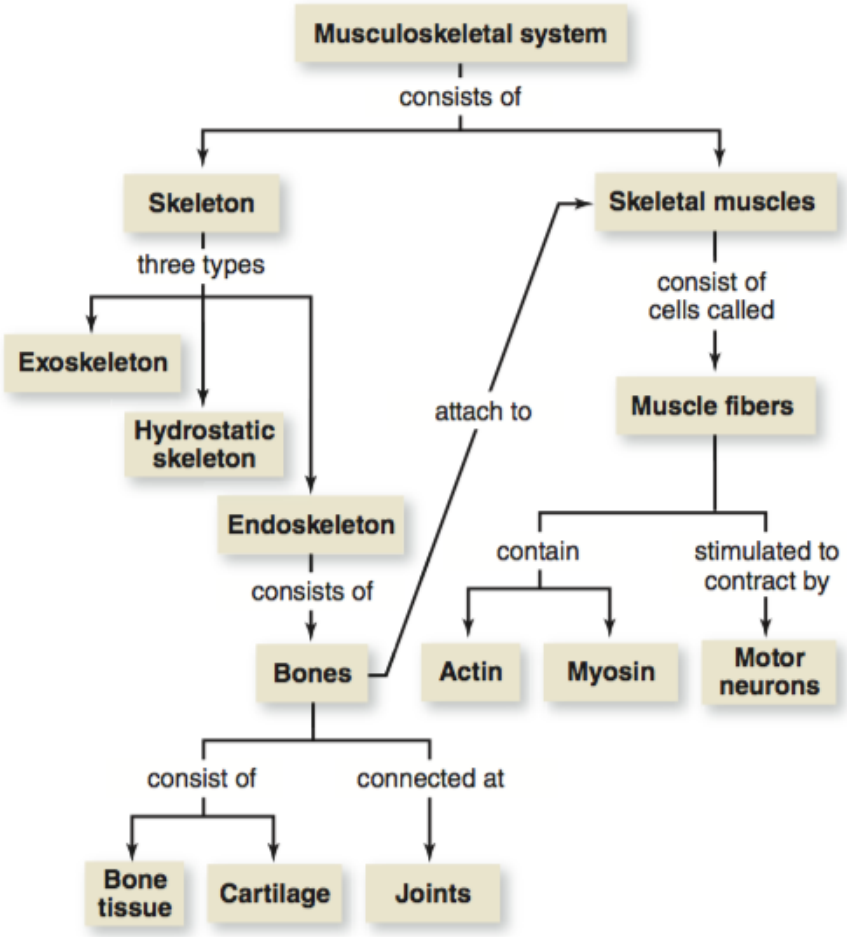
After this lecture, you should be able to:

1. Describe the diverse methods of locomotion found among animals and the forces each method must overcome.
2. Describe the three main types of skeletons, their advantages and disadvantages, and provide examples of each.
3. Describe the common features of terrestrial vertebrate skeletons, distinguishing between the axial and appendicular skeletons.
4. Describe the complex structure of bone, noting the major tissues and their relationship to blood-forming tissues.
5. Explain why bones break and how we can help them heal.
6. Describe three types of joints and provide examples of each.

You should now be able to

6. Explain how muscles and the skeleton interact to produce movement.
8. Explain at the cellular level how a muscle cell contracts.
9. Explain how a motor neuron signals a muscle fiber to contract.
10. Describe the role of calcium in a muscle contraction.
11. Explain how motor units control muscle contraction.
12. Explain what causes muscle fatigue.
13. Distinguish between aerobic and anaerobic exercise, noting the advantages of each.
14. Compare the structure and functions of slow, intermediate, and fast muscle fibers.

MUSCULOSKELETAL SYSTEM



Locomotion requires energy to overcome friction and gravity

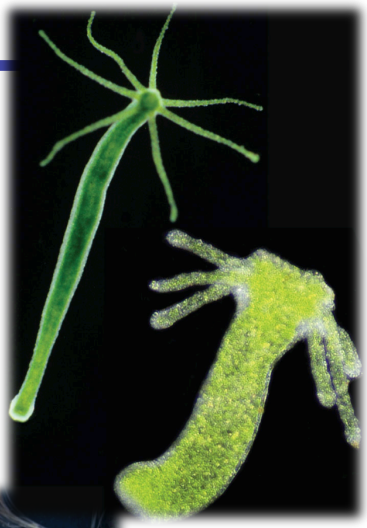
- Animal movement results from a collaboration between muscles and a skeletal system to overcome
  - friction and
  - gravity.

Skeletons function in support, movement, and protection

- Skeletons provide
  - body support,
  - movement by working with muscles, and
  - protection of internal organs.
- There are three main types of animal skeletons:
  - hydrostatic skeletons,
  - exoskeletons, and
  - endoskeletons.

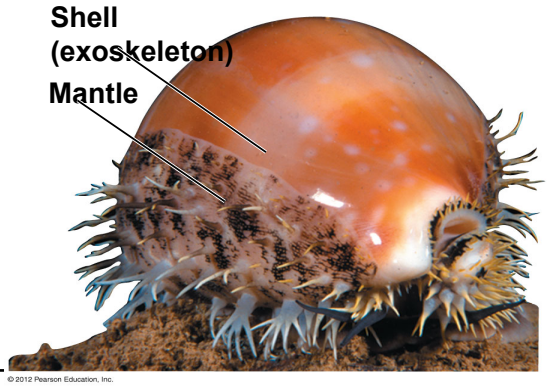
Skeletons function in support, movement, and protection

1. **Hydrostatic skeletons**
   - fluid held under pressure in a closed body compartment and
   - found in worms and cnidarians.
   - Hydrostatic skeletons
     - help protect other body parts by cushioning them from shocks,
     - give the body shape, and
     - provide support for muscle action.



Skeletons function in support, movement, and protection

2. **Exoskeletons** are rigid external skeletons that consist of
   - chitin and protein in arthropods and
   - calcium carbonate shells in molluscs.
   - Exoskeletons must be shed to permit growth.



Skeletons function in support, movement, and protection

3. **Endoskeletons** consist of hard or leathery supporting elements situated among the soft tissues of an animal. They may be made of
   - cartilage or cartilage and bone (vertebrates),
   - spicules (sponges), or
   - hard plates (echinoderms).

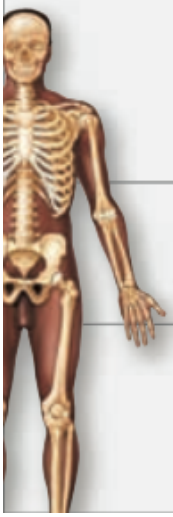
Figure 30.2E

Function	Explanation
Support	The skeleton is a framework that supports an animal's body against gravity. It largely determines the body's shape.
Movement	The vertebrate skeleton is a system of muscle-operated levers. Typically, the two ends of a skeletal (voluntary) muscle attach to different bones that connect in a structure called a joint. When the muscle contracts, one bone is pulled toward the other.
Protection of internal structures	The backbone surrounds and shields the spinal cord, the skull protects the brain, and ribs protect the heart and lungs.
Production of blood cells	Many bones, such as the long bones of the human arm and leg, contain and protect red marrow, a tissue that produces red blood cells, white blood cells, and platelets.
Mineral storage	The skeleton stores calcium and phosphorus.

Functions of the Vertebrate Endoskeleton

THE VERTEBRATE SKELETON

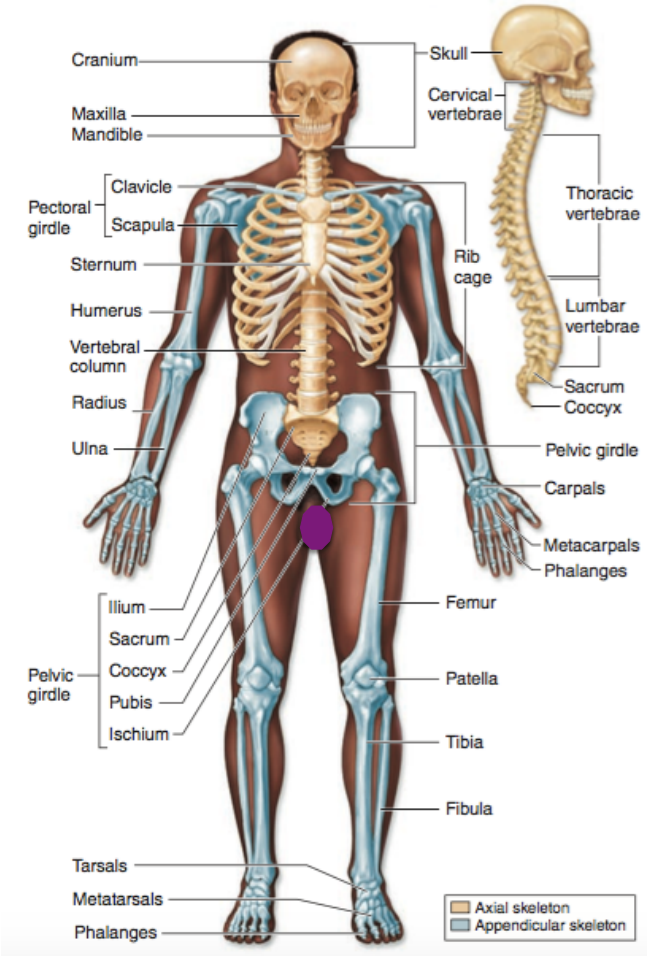
Skeletal system

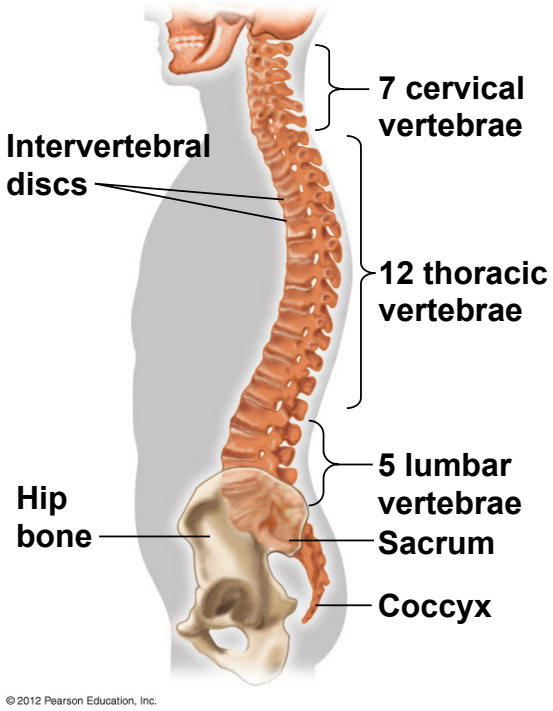


Skeletal System	
Main Tissue Types*	**Examples of Locations/Functions**
Connective	Makes up bone, cartilage, tendons, ligaments, marrow of vertebrate skeleton
Muscle	Skeletal muscle connects to movable bones, enabling voluntary movements
Nervous	Senses body position and controls muscles

EVOLUTION CONNECTION: Vertebrate skeletons are variations on an ancient theme

- The vertebrate skeletal system provided
  - the structural support and
  - means of location
  - that enabled tetrapods to colonize land.
- The human skeleton consists of an
  - **axial skeleton**
    - that supports the axis or trunk of the body and
    - consists of the skull, vertebrae, and ribs and
  - **appendicular skeleton**
    - that includes the appendages and the bones that anchor the appendage and
    - consists of the arms, legs, shoulders, and pelvic girdles.





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Scoliosis → the vertebral column curves to the side, ione of disorder of the axial skeleton

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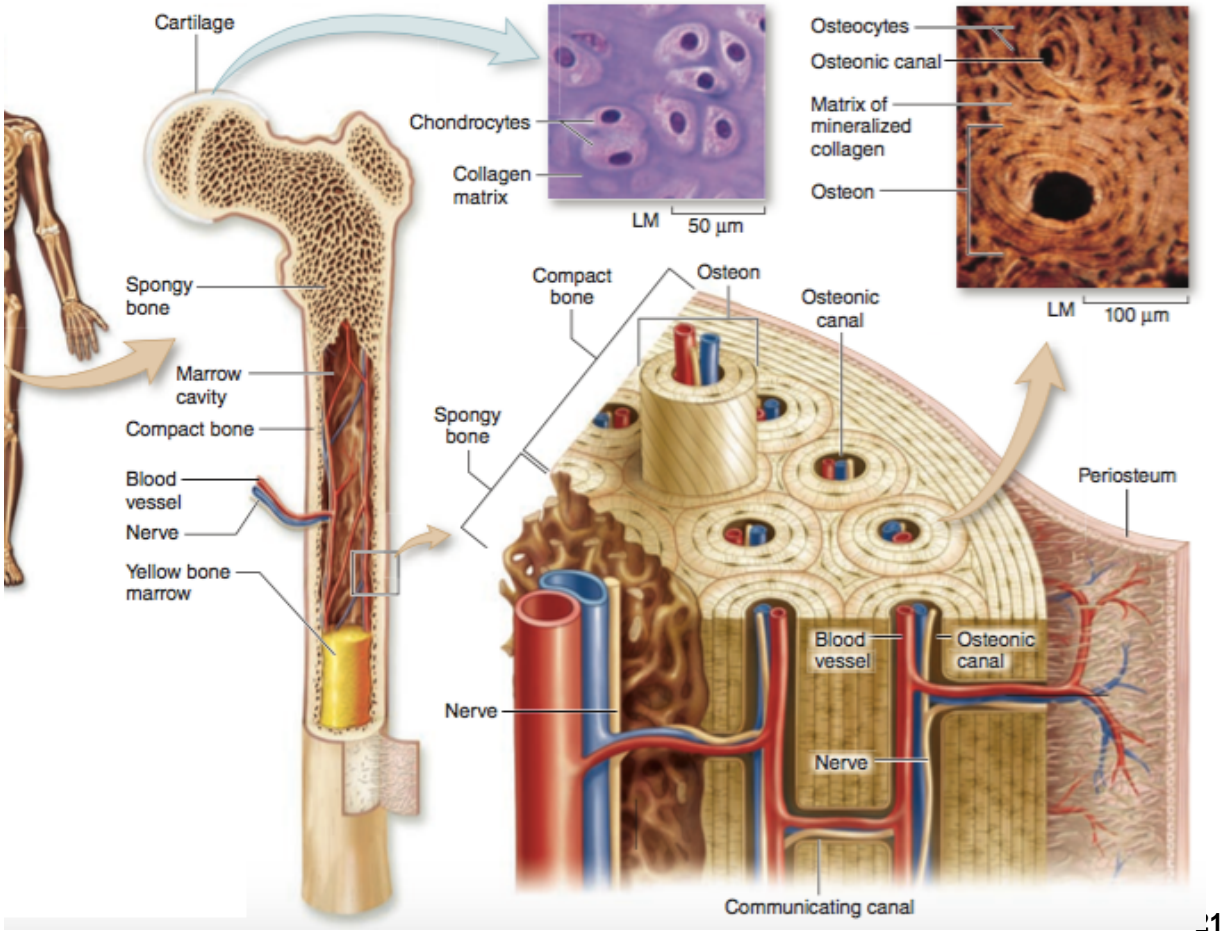
Bones are complex living organs

- Cartilage at the ends of bones
  - cushions joints and
  - reduces friction of movements.
- Fibrous connective tissue covering most of the outer surface of bone forms new bone in the event of a fracture.
- Bone cells
  - live in a matrix of flexible protein fibers and hard calcium salts and
  - are kept alive by blood vessels, hormones, and nerves.

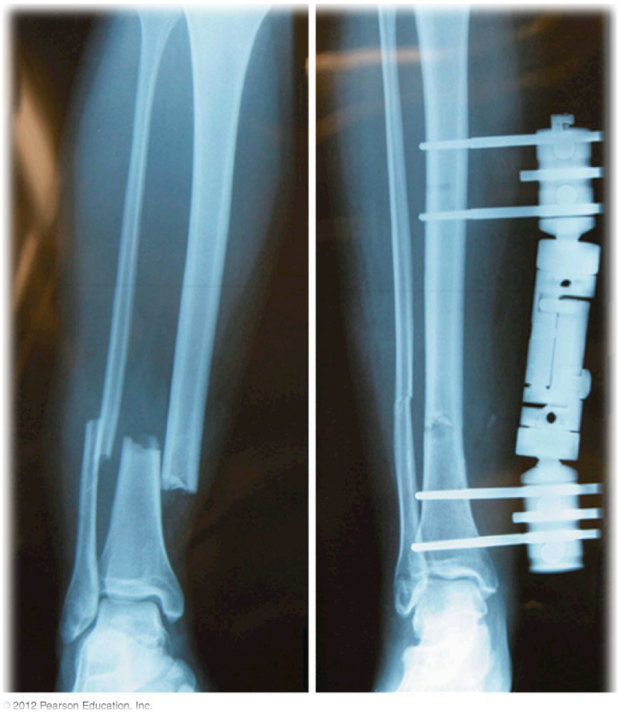
Bones are complex living organs

- Long bones have
  - a central cavity storing fatty **yellow bone marrow** and
  - spongy bone located at the ends of bones containing **red bone marrow**, a specialized tissue that produces blood cells.



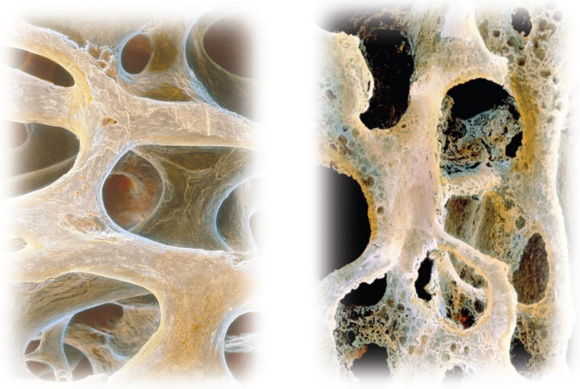
CONNECTION: Healthy bones resist stress and heal from injuries

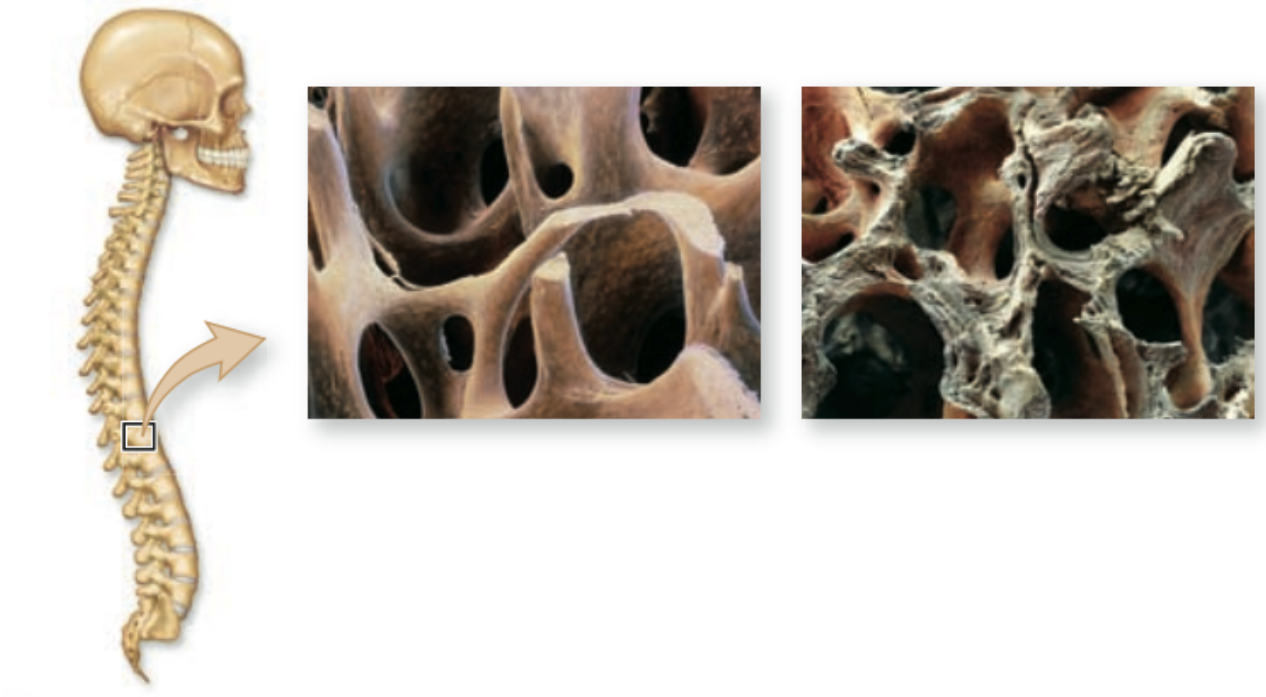
- Bone cells
  - repair bones and
  - reshape bones throughout life.
- Broken bones
  - are realigned and immobilized and
  - bone cells build new bone, healing the break.



CONNECTION: Healthy bones resist stress and heal from injuries

- **Osteoporosis** is
  - a bone disease,
  - characterized by low bone mass and structural deterioration, and
  - less likely if a person
    - has high levels of calcium in the diet,
    - exercises regularly, and
    - does not smoke.





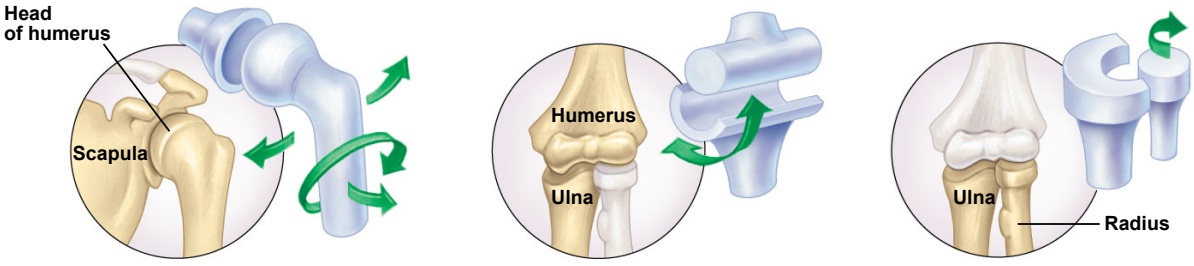
Fibrodysplasia Ossificans Progressiva

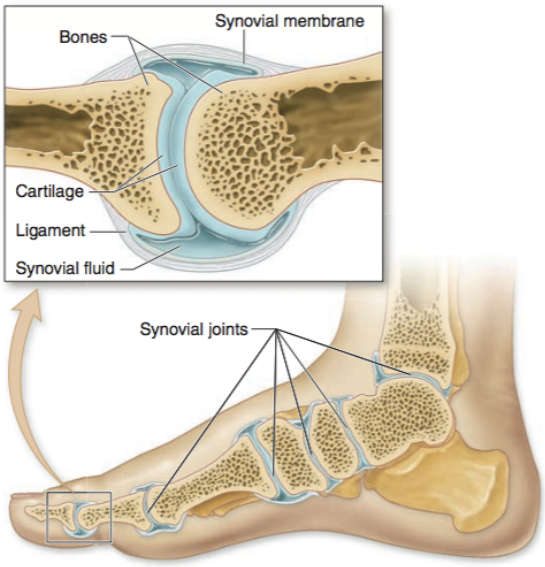
Fibrodysplasia Ossificans Progressiva is also known as Stone Man Syndrome, and it lives up to its name as its victims produce bone matter where no bone matter is needed. Muscles, tendons and ligaments begin to turn to bone as the body's repair mechanism turns on itself. Worse, surgical removal of the excess bone tissue causes your body to amp up its own repair system and produces even more bone making the condition worse.

Joints permit different types of movement

- Joints allow limited movement of bones.
- **Ligaments** connect bone to bone.
- Different joints permit various movements.
  - **Ball-and-socket joints** enable rotation in the arms and legs.
  - **Hinge joints** in the elbows and knees permit movement in a single plane.
  - **Pivot joints** enable the rotation of the forearm at the elbow.

Figure 30.6



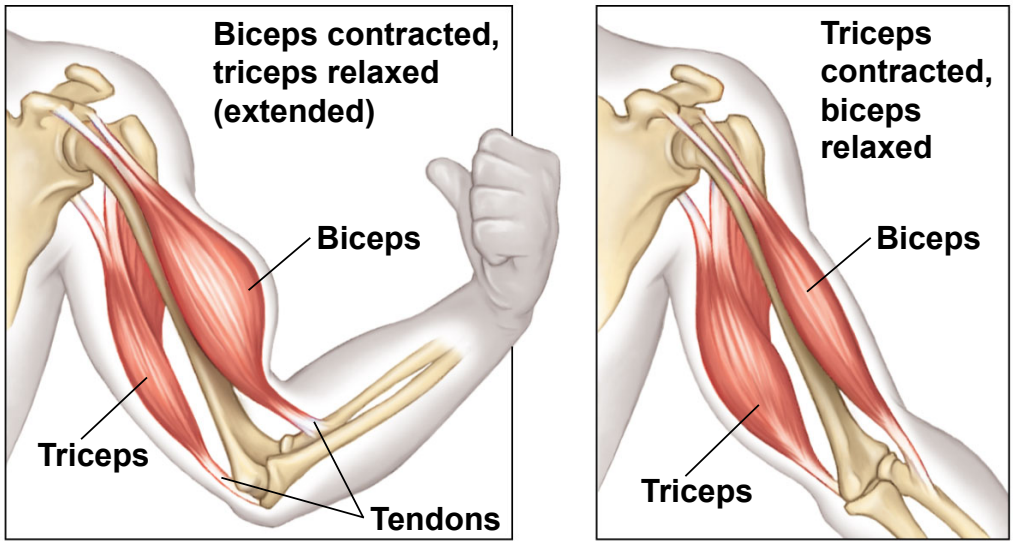


MUSCLE CONTRACTION AND MOVEMENT

The skeleton and muscles interact in movement

- Muscles and bones interact to produce movement.
- Muscles
  - are connected to bones by **tendons** and
  - can only contract, requiring an antagonistic muscle to
    - reverse the action and
    - relengthen muscles.

Figure 30.7A

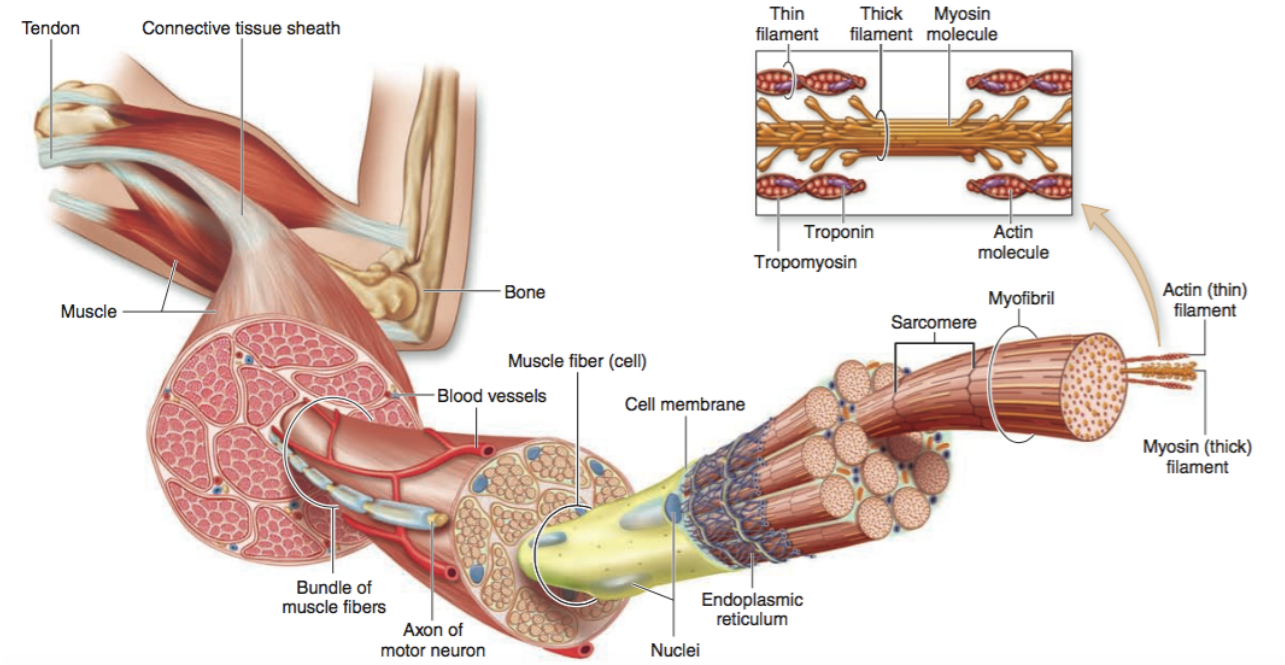


Each muscle cell has its own contractile apparatus

- **Muscle fibers** are cells that consist of bundles of myofibrils. Skeletal muscle cells
  - are cylindrical,
  - have many nuclei, and
  - are oriented parallel to each other.
- **Myofibrils** contain overlapping
  - **thick filaments** composed primarily of the protein **myosin** and
  - **thin filaments** composed primarily of the protein **actin**.

Each muscle cell has its own contractile apparatus

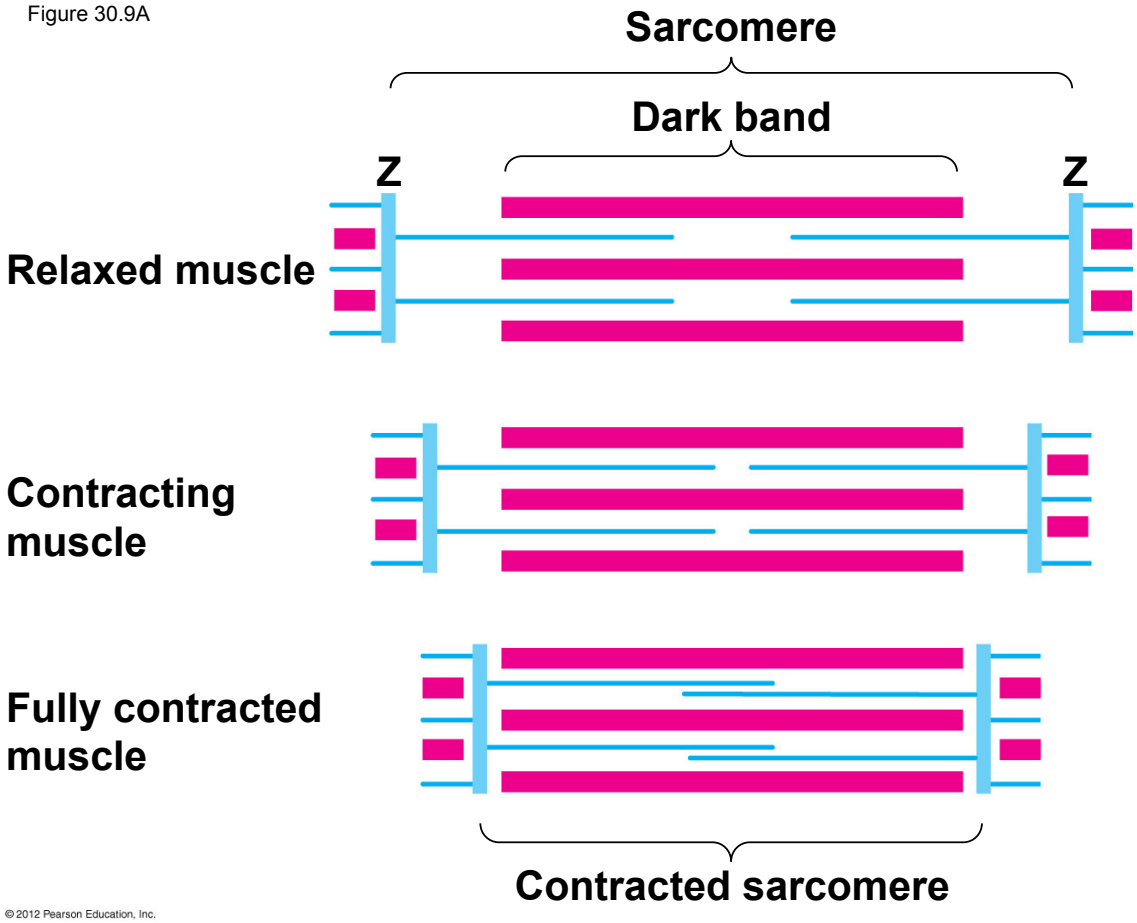
- **Sarcomeres** are
  - repeating groups of overlapping thick and thin filaments and
  - the contractile unit—the fundamental unit of muscle action.

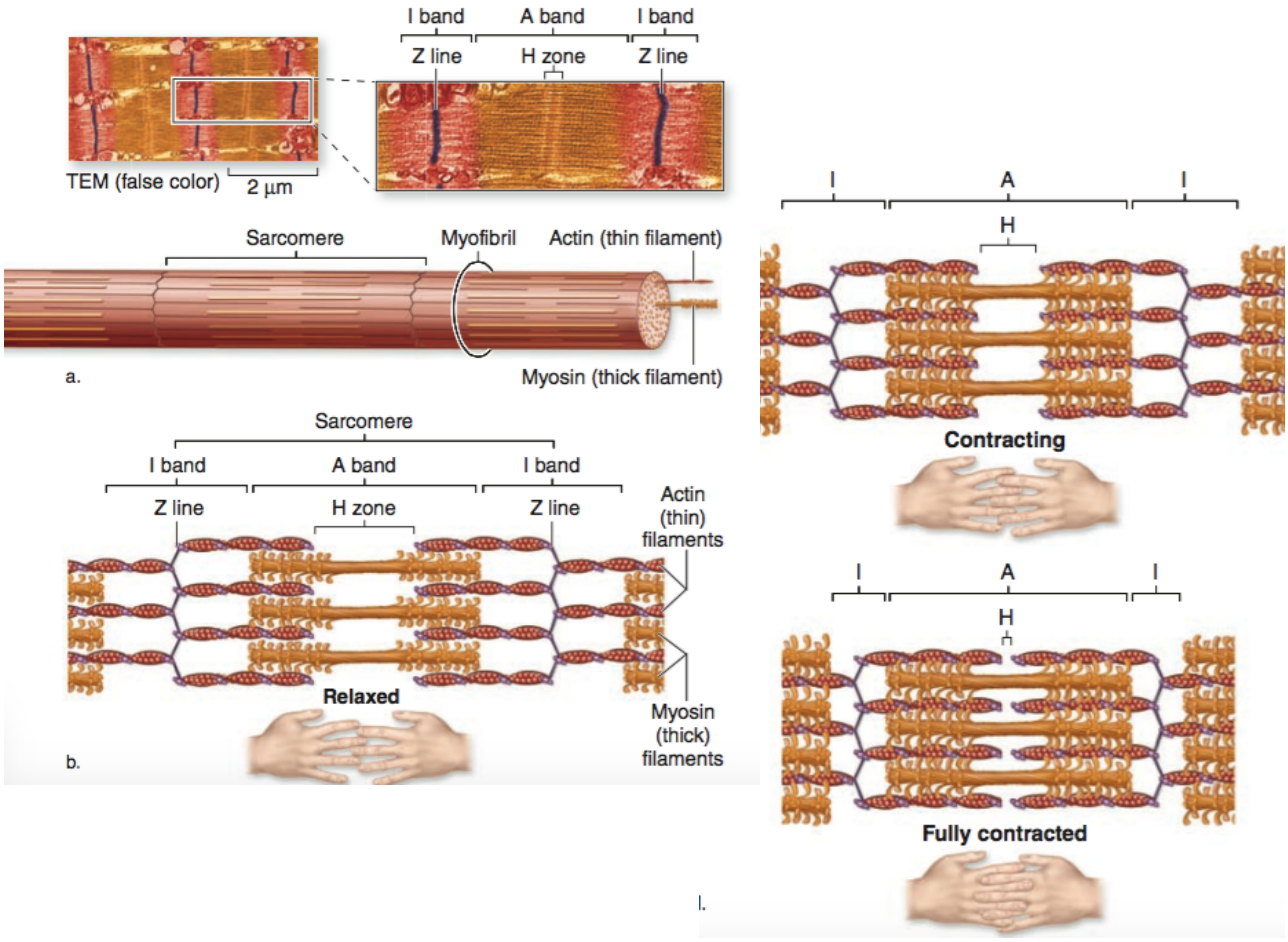


A muscle contracts when thin filaments slide along thick filaments

- According to the sliding-filament model of muscle contraction, a sarcomere contracts (shortens) when its thin filaments slide across its thick filaments.
  - Contraction shortens the sarcomere without changing the lengths of the thick and thin filaments.
  - When the muscle is fully contracted, the thin filaments overlap in the middle of the sarcomere.

Figure 30.9A





A muscle contracts when thin filaments slide along 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.

Figure 30.9B_s3

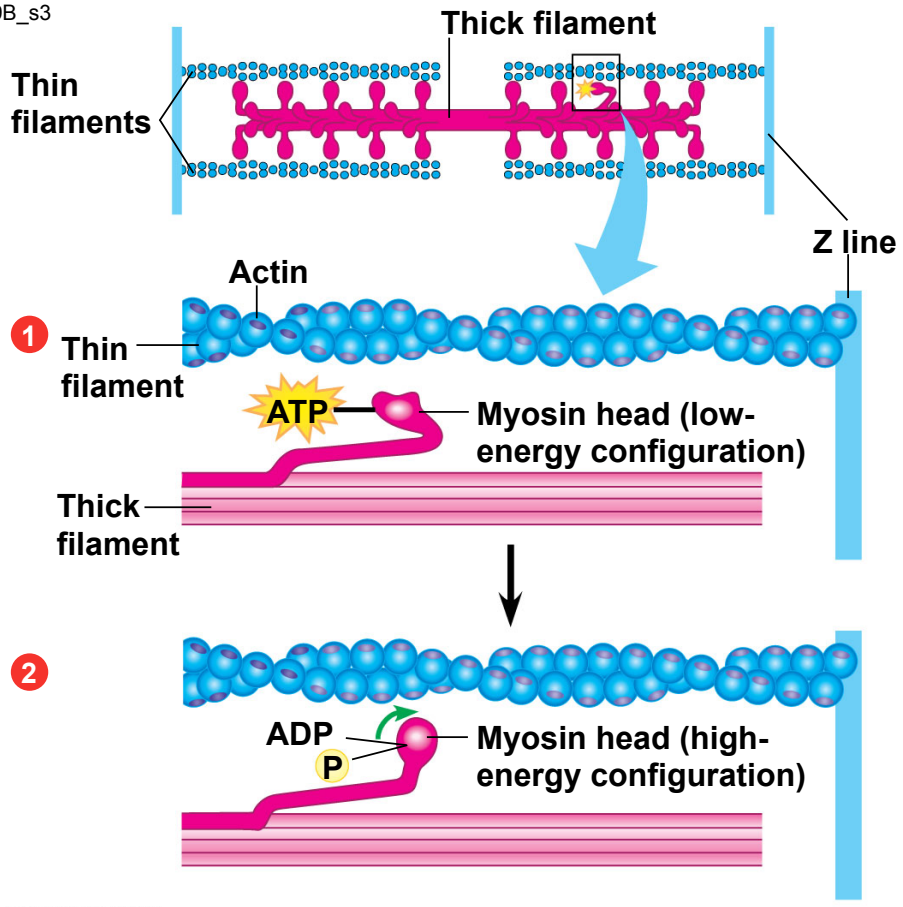
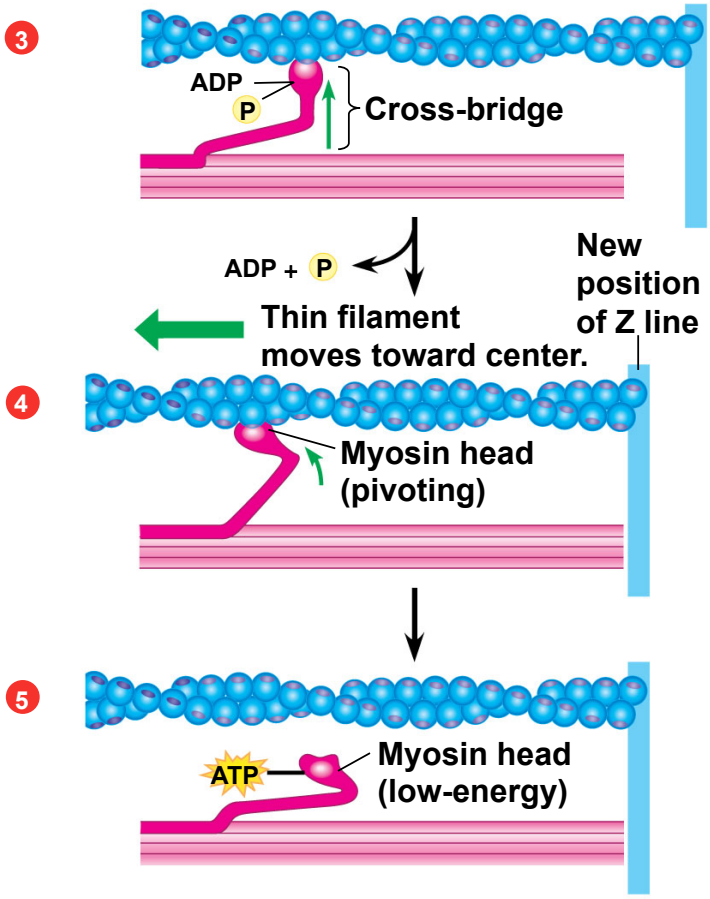


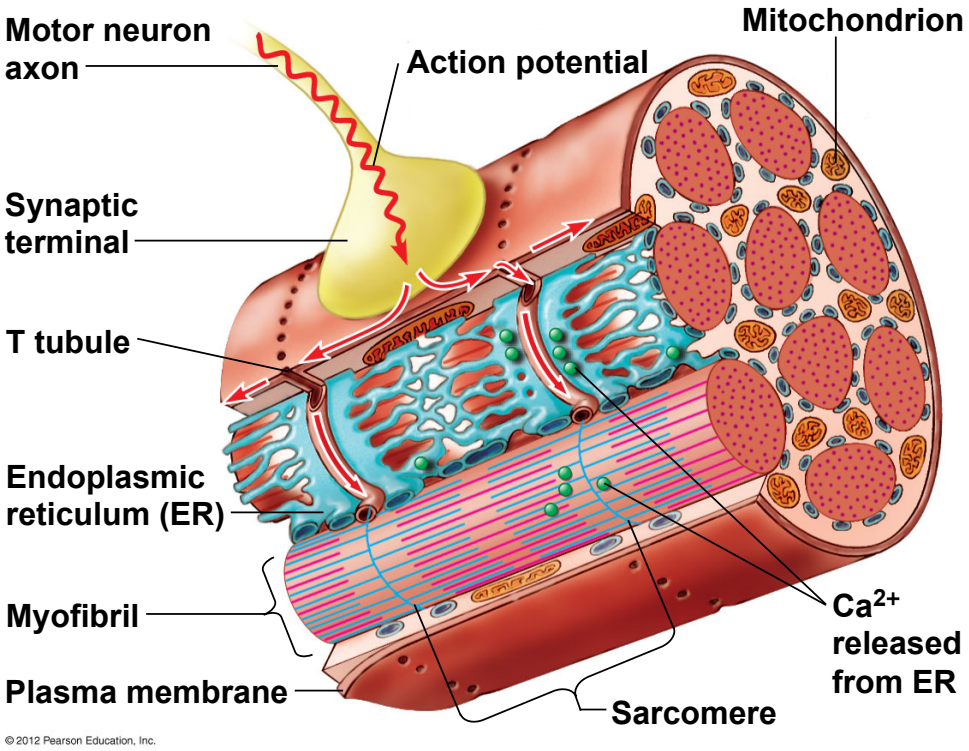
Figure 30.9B_s6



Motor neurons stimulate muscle contraction

- A motor neuron
  - carries an action potential to a muscle cell,
  - releases the neurotransmitter acetylcholine from its synaptic terminal, and
  - initiates a muscle contraction.

Figure 30.10A



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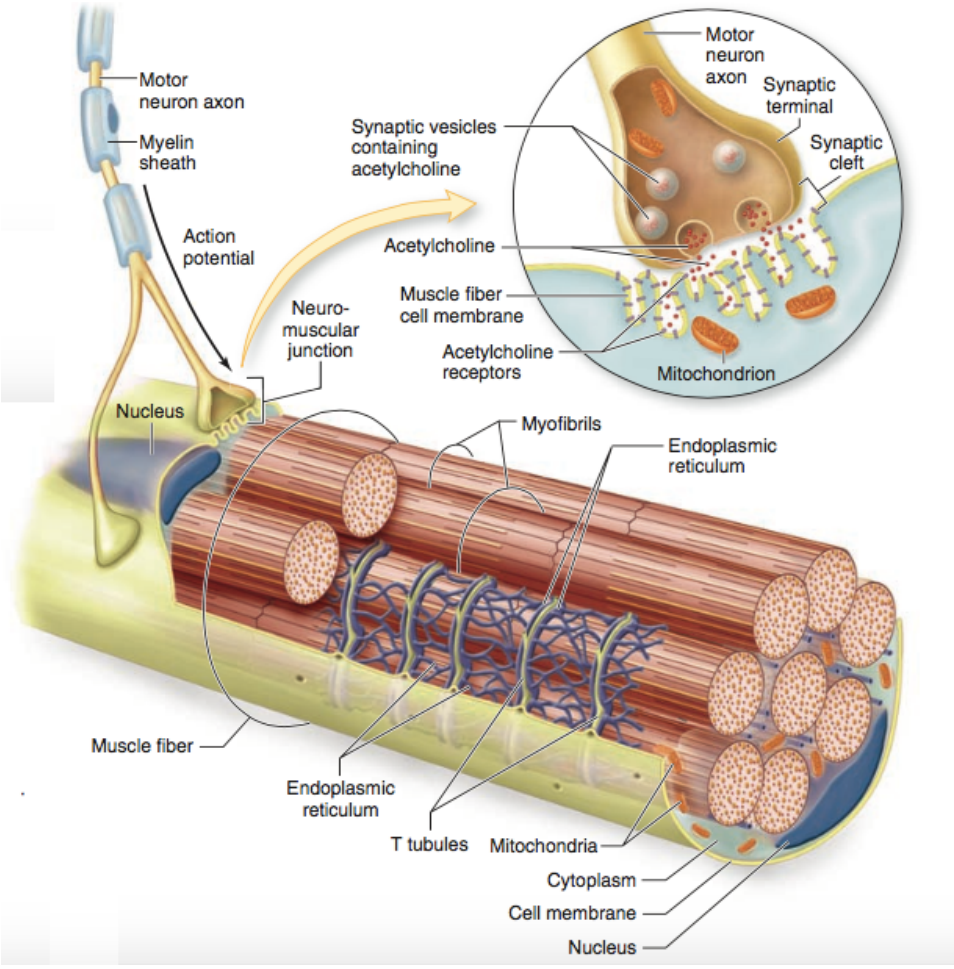
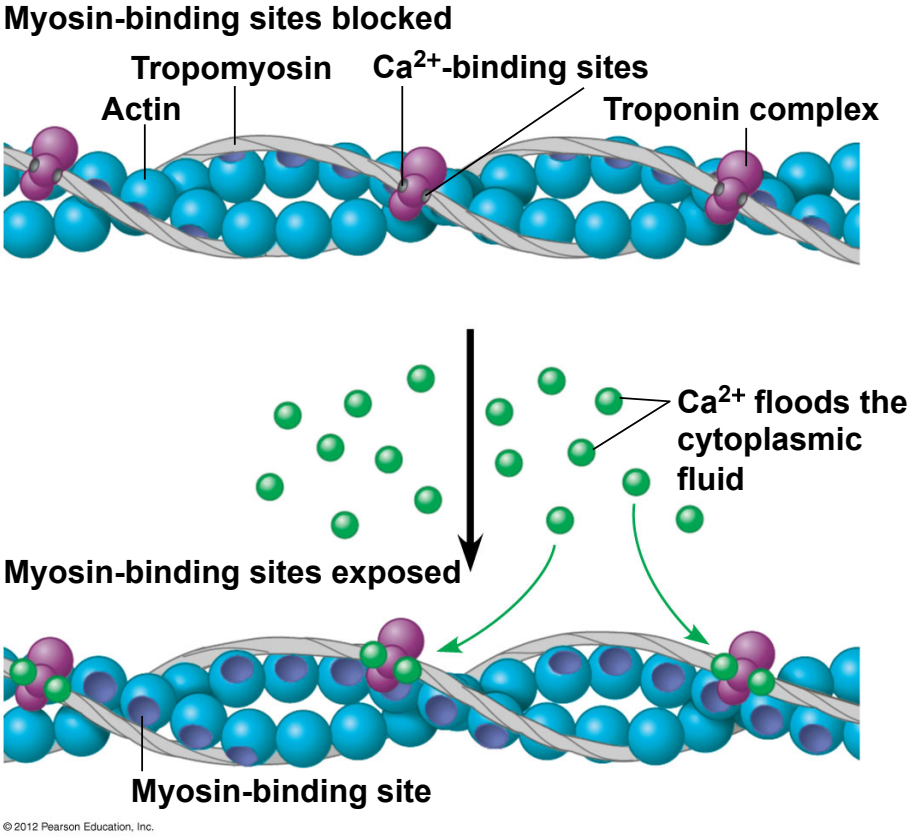
Motor neurons stimulate muscle contraction

- An action potential in a muscle cell
  - passes along T tubules and
  - into the center of the muscle fiber.
- Calcium ions
  - are released from the endoplasmic reticulum and
  - initiate muscle contraction by moving the regulatory protein tropomyosin away from the myosin-binding sites on actin.

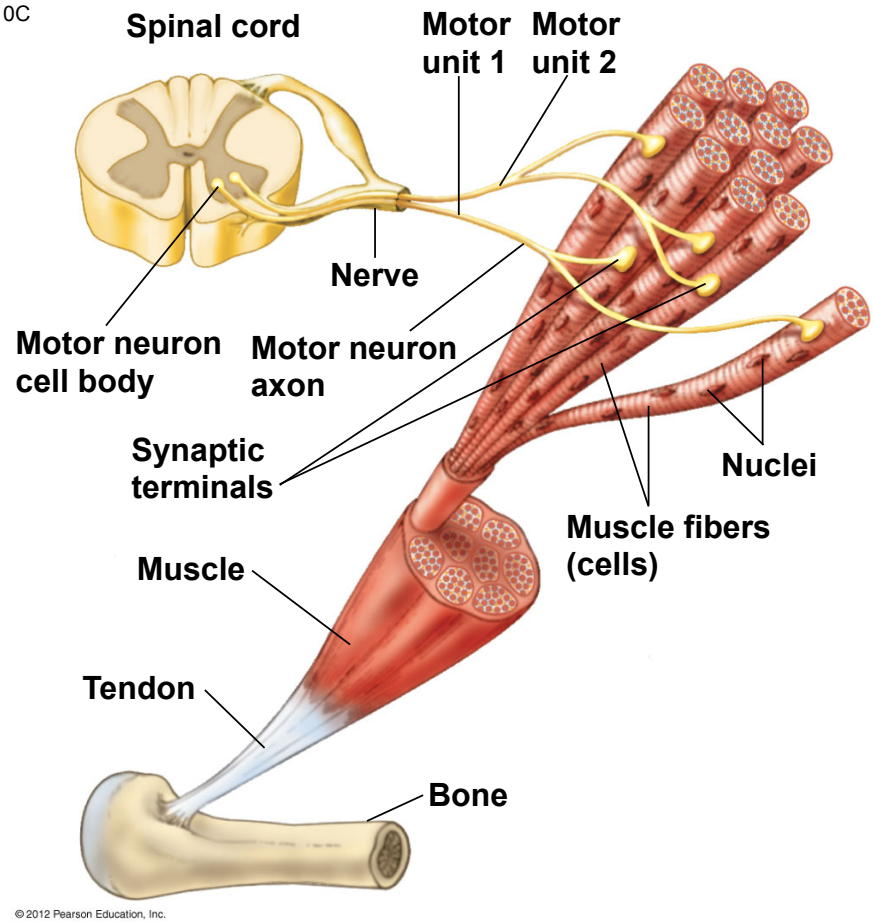




Motor neurons stimulate muscle contraction

- A **motor unit** consists of
  - a neuron and
  - the set of muscle fibers it controls.
- More forceful muscle contractions result when additional motor units are activated.

Figure 30.10C



CONNECTION: Aerobic respiration supplies most of the energy for exercise

- Aerobic respiration
  - requires a constant supply of glucose and oxygen and
  - provides most of the ATP used to power muscle movement during exercise.
- The anaerobic process of lactic acid fermentation
  - can provide ATP faster than aerobic respiration but
  - is less efficient.

Figure 30.11

Table 30.11

TABLE 30.11 SOURCES OF ATP FOR ATHLETIC ACTIVITIES

Athletic Activity	Energy Use	Main Source of ATP
100-m sprint; power lifting	10- to 15-second burst of activity	Stored ATP and PCr
200-m or 400-m race	Intense effort sustained over a short period of time	Stored ATP and PCr plus lactic acid fermentation
Jogging; long-distance running	Prolonged, low-level activity	Aerobic respiration
Tennis; squash; soccer	Prolonged, low-level activity with intermittent surges of intense effort	Aerobic respiration and lactic acid fermentation