How Animals Move 30

Look at the palm of your hand. Primates are the only mammals that can turn their arms palm up. Our lower arm bones are able to pivot at the elbow and cross, so we are able to rotate our hands through almost a full circle. The arrangement of bones and muscles that allows us to do this is a heritage passed down from our tree-living ancestors. Although other mammals cannot do the palm-up trick, their skeletons and muscles show equally remarkable adaptations to other methods of movement. A horse runs on very long middle toes. A sea lion's legs have become flattened paddles, and its muscles can store extra oxygen for extended dives. Every hop of a kangaroo stores energy in elastic leg tendons; rebound of the tendons helps power the next hop. Running, swimming, and hopping are all movements produced by muscles pulling on bones. Skeletons, muscles, and movement are the subjects of this chapter.

Organizing Your Knowledge

Exercise 1 (Module 30.1)

This module introduces various forms of animal locomotion. Test your knowledge of locomotion by filling in the blanks.

Mammals range in size from tiny shrews to great whales. They have become adapted to a variety of lifestyles on land, in the water, and in the air.

Most mammals, from mice to musk oxen, walk or run on land. The surrounding air offers little resistance to movement, so [1]_____ is not much of a problem, even for the fastest runners. But a mammal that walks or runs must expend considerable effort supporting itself against the force of [2]_____. To maintain balance and stability when it walks, an animal employs the principle of the [3]_____, keeping three feet on the ground most of the time. The fastest land animal, the cheetah, is of course a mammal. When it runs, all of its feet may leave the ground at once, but its [4]_____ stabilizes its position.

Some mammals crawl or burrow—moles and gophers, for example. Unlike the earthworm, which moves by waves of muscular contractions called [5]_____, burrowing mammals use their legs for digging. The mole's coat is velvety smooth, reducing [6]_____ as it tunnels underground.

Millions of years ago, a group of shore-dwelling mammals took up life in the sea. Their descendants are the whales and dolphins. Because of their buoyancy, [7]_____ is no problem for these aquatic animals, and some have grown to enormous size. Water is much more dense than air, but a whale's tapered, [8]_____ shape enables it to slip through the water with little effort. The whale's tail forms a pair of broad, flat flukes, and the whale bends its body [9]_____ to push it through the water.

Bats are the only flying mammals. A bat's wings are modified arms, with skin stretched between elongated fingers. The bat's wings, like those of airplanes and birds, are [10]_____. As a bat beats its wings, air travels farther over the top surface than the bottom surface, making the pressure underneath the wings [11]_____ than the pressure on top. This generates [12]_____ and allows the bat to overcome the pull of [13]_____.

Exercise 2 (Module 30.2)

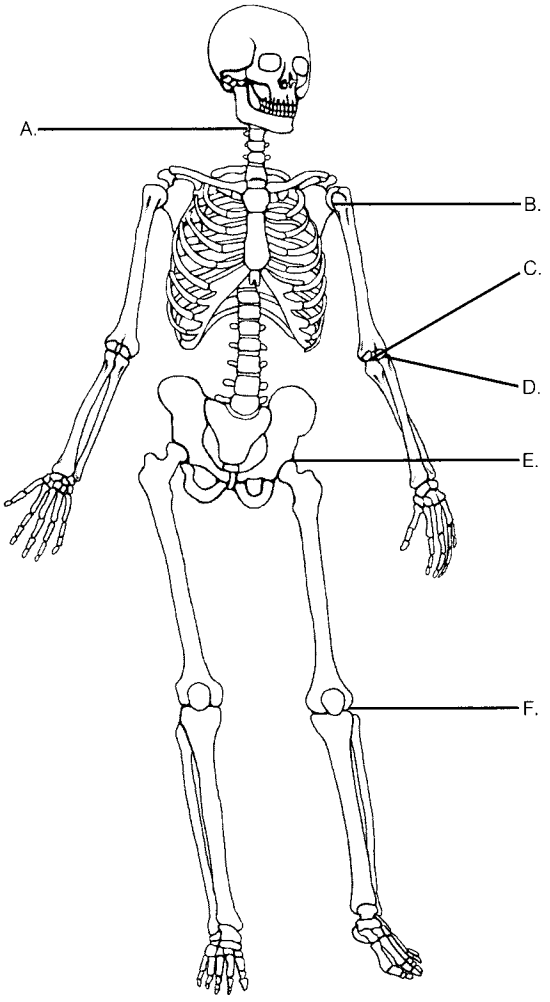
There are three main kinds of skeletons. Summarize your knowledge of skeletons by completing this chart.

	Hydrostatic Skeleton	*Exoskeleton*	*Endoskeleton*
Example animals	1.	2.	3.
Description of skeleton	4.	5.	6.
Materials skeleton is made of	7.	8.	9.
Functions of skeleton	10.	11.	12.
Drawbacks of skeleton	13.	14.	15.

Exercise 3 (Module 30.3)

Web/CD Activity 30A *The Human Skeleton*

The human skeleton is unique in several ways, but it has the same overall pattern as the skeleton of a mouse or a duck. You may find it useful to know the names of some of the major bones of the skeleton. Label these bones on the diagram below: **humerus, sternum, femur, tarsals, tibia, carpals, radius, phalanges, ulna, vertebrae, skull, clavicle, metacarpals, ribs, scapula, fibula, pelvic girdle, metatarsals, shoulder girdle,** and **patella.** (Note: The letters relate to Exercise 4, below.) Before you leave this exercise, color the bones of the axial skeleton green and the appendicular skeleton yellow.



Exercise 4 (Module 30.3)

Web/CD Activity 30A *The Human Skeleton*

Which of the letters in Exercise 3 identifies each of the following types of joints? (Three are from the module; you will have to figure out the other three yourself.)

1. Ball-and-socket joints: _____
2. Hinge joints: _____
3. Pivot joints: _____

Exercise 5 (Modules 30.4 - 30.6)

Review bone structure, growth, disease, and injury by matching each phrase on the right with a word or phrase from the left. Some answers are used more than once.

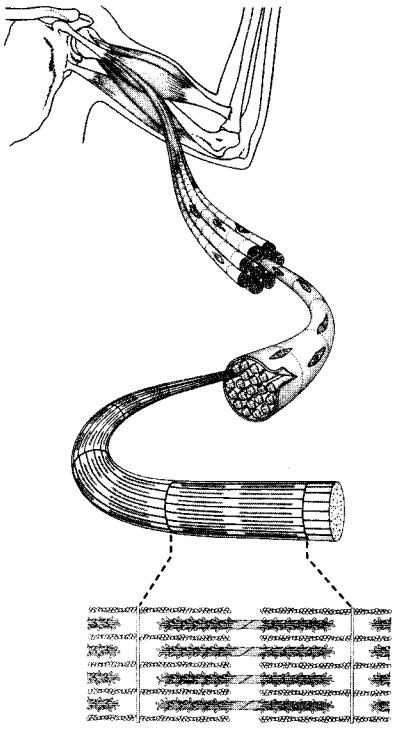
A. Spongy bone
B. Cartilage
C. Estrogen
D. Red bone marrow
E. Blood vessel
F. Fibrous connective tissue
G. Yellow bone marrow
H. Compact bone
I. Osteoporosis
J. Tendon
K. Stress fracture
L. Matrix
M. Arthritis

____ 1. Fat stored in central cavity
____ 2. Protein fibers and hard calcium salts
____ 3. Outer hard layer of bone
____ 4. Cushions ends of bone at joints
____ 5. Decrease after menopause may cause osteoporosis
____ 6. Bone break that occurs from long-term repeated forces
____ 7. Shafts of long bones made of this at first
____ 8. Delivers food and hormones to bone
____ 9. Produces blood cells
____ 10. Site of red marrow
____ 11. Bone grows until plates of this material are replaced by bone
____ 12. Makes up the shaft of a long bone like the tibia
____ 13. Connects a muscle to a bone
____ 14. Covers outside of bone
____ 15. Joint inflammation
____ 16. Weakening of bones that often occurs in older women

Exercise 6 (Modules 30.7 - 30.9)

Web/CD Activity 30B *Skeletal Muscle Structure*

Many muscles work in opposing pairs to move the skeleton. Each muscle is composed of many muscle fibers. Each fiber contains smaller parts, which are responsible for muscle contraction. Review the contractile machinery of muscle by labeling these parts in the diagram below: **biceps muscle, triceps muscle, thin filament, muscle fiber, myofibril, tendon, thick filament, sarcomere,** and **Z line.**



Exercise 7 (Modules 30.8 – 30.10)

Web/CD Activity 30B *Skeletal Muscle Structure*
Web/CD Activity 30C *Muscle Contraction*

Try to visualize the inner workings of a muscle by filling in the blanks below.

Your new mission is to view contracting muscle cells close up. You step into the Microtron, and a moment later, you are working your way against the current in a small arm vein. Ahead are smaller, thin-walled [1]_____ that exit from the muscle and join to form the vein. You stay close to the wall and enter the smallest vessel.

Through the translucent wall of the capillary, you can make out a nearby surface that seems to be made of shiny white ropes. This is the [2]_____ that connects the end of the biceps to the lower arm bones. Also visible is a smoother, shinier cylindrical structure—one of the [3]_____ that controls contraction of the muscle. Ahead, you see the wrinkled blob of a white blood cell slipping through a gap in the vessel wall, and you follow it into the intercellular fluid. Close up, the nerve you saw a moment ago appears frayed—its neurons branch and rebranch to control every muscle cell. You follow one of the neurons; it branches to about 50 cells. The neuron and the cells it controls make up a [4]_____—a group of muscle fibers that work together.

Following one of the axons to its end, you finally arrive at a [5]_____, where the axon synapses with a muscle cell—called a muscle [6]_____. You are deep inside the muscle now, so you radio for more light and ask for the subject to tense her arm.

Suddenly a cloud of particles sprays from the end of the axon, the membrane of the muscle fiber seems to shimmer, and you are tossed by a surge of pressure into a nearby tangle of connective tissue fibers. She's moving the arm just a little bit, but to you it feels like an earthquake! You contact your colleagues: "Hey, take it easy! Try it again, but gently!" This time you hang on tightly. Again there is a spray of particles—the release of [7]_____ from the end of the axon, signaling the muscle fiber to contract. When the neurotransmitter molecules contact the muscle fiber membrane, the shimmer you saw before is repeated—an [8]_____ spreading across the cell. Another earthquake, but this time you are ready.

You grip the membrane of the muscle fiber. It is pocked with numerous openings, where infoldings of the membrane form [9]_____ that carry action potentials deep into the cell. You swim inward, following the action potentials, as the cell continues to receive impulses and contract. You can press your powerful spotlight against the tubule wall and illuminate the inside of the fiber. Inside are numerous [10]_____, large bundles of parallel protein filaments. Transverse [11]_____ lines, made of protein, separate repeating [12]_____, the basic contractile units of the muscle fiber. The filaments themselves are of two types: The [13]_____ filaments look like twisted strings of beads, the beads themselves being globular [14]_____ molecules. The [15]_____ filaments are made of elongated [16]_____ molecules, each with a head that can reach out and pull against the thin filaments.

You watch the thick and thin filaments [17]_____ along each other with each volley of nerve impulses. As each action potential travels into the cell via the tubules, you see a cloud of [18]_____ ions released from storage in the endoplasmic reticulum. These ions quickly attach to the thin filaments, freeing up binding sites for the myosin [19]_____ on the adjacent thick filaments. Meanwhile, the myosin molecules of the thick filaments are writhing like a bundle of worms. Their heads use energy from [20]_____ molecules to detach from the thin filaments, straighten, attach, and bend, several times per second. The hundreds of myosin heads in one thick filament pull on all the surrounding thin filaments. This creates the pull that causes the thick and thin filaments to slide together, [21]_____ the sarcomere, and on a larger scale, the muscle fiber.

The nerve impulses cease. You can see [22]_____ ions being pumped out of the cytoplasm and back into the [23]_____. As the binding sites on the thin filaments close up, the myosin heads let go, and the muscle stops contracting.

Exercise 8 (Modules 30.11 - 30.12)

Muscles illustrate the relationship between structure and function. Aerobic and anaerobic exercise change the function of a muscle, and as a result they actually alter its structure. State whether each of the changes below relates primarily to aerobic or anaerobic exercise.

_____ 1. Increases muscle endurance

_____ 2. Pushes muscle fibers to the point where they are not getting enough oxygen

_____ 3. Increases the size of muscle fibers and muscle "bulk"

_____ 4. Causes muscle to become more efficient

_____ 5. Increases muscle strength

_____ 6. Chosen by sprinters, weightlifters, and other "power" athletes

_____ 7. Increases resistance to muscle fatigue

_____ 8. Chosen by distance runners and cross-country skiers

_____ 9. Improves circulation and gas exchange

_____ 10. Increases size and number of mitochondria in muscle cells

Testing Your Knowledge

Multiple Choice

1. ____ connects a muscle to a bone.
   a. Cartilage
   b. A neuromuscular junction
   c. A tendon
   d. A myofibril
   e. A motor unit

2. Inside a muscle fiber, _____ trigger(s) contraction and _____ provide(s) the energy.
   a. myosin . . . actin
   b. calcium ions . . . ATP
   c. actin . . . myosin
   d. calcium ions . . . myosin
   e. ATP . . . calcium ions

3. Rheumatoid arthritis
   a. is a disease in which joints are attacked by the immune system.
   b. results from the wear and tear of old age.
   c. is deterioration of joints that results from a hormone imbalance.
   d. occurs most frequently in women after menopause.
   e. can be prevented by adequate calcium in the diet.

4. Muscles are arranged in pairs,
   a. so if one is injured, the other can take over.
   b. doubling their strength.
   c. because one pulls while the other pushes.
   d. enabling them to perform opposing movements.
   e. so they can take turns contracting and resting.

5. Which of the following is the last part of a long bone to harden?
   a. the central shaft
   b. the heads
   c. cartilage between the heads and the shaft
   d. the central cavity
   e. cartilage at the very ends

6. Which of the following correctly pairs an example of a joint with its general type?
   a. ball and socket—elbow
   b. pivot—shoulder
   c. hinge—hip
   d. hinge—elbow
   e. ball and socket—knee

7. Which of the following skeletons works poorly on land?
   a. endoskeleton
   b. hydrostatic skeleton
   c. exoskeleton
   d. a and b
   e. b and c

8. A stronger muscle contraction occurs when the brain
   a. activates muscle cells more quickly.
   b. sends stronger nerve impulses to the muscle.
   c. activates the motor units of the muscle one at a time.
   d. signals a larger number of motor units to contract.
   e. sends nerve impulses to the muscle one at a time instead of in bursts.

9. Which of the following animals has an endoskeleton?
   a. clam
   b. sea star
   c. sponge
   d. a and b
   e. b and c

10. Which of the following is part of the human appendicular skeleton?
    a. vertebral column
    b. scapula
    c. rib
    d. sternum
    e. skull

Essay

1. How do the shape of its wings and their movement through the air lift a bird off the ground?

2. What are the three major functions of a skeleton? Describe each, using parts of your own skeleton as illustrations.

3. What kinds of animals have jointed exoskeletons? What are the major advantages and disadvantages of exoskeletons, compared with endoskeletons?

4. What two forces must be overcome by a moving animal? Which is more of a problem on land? In the water?

5. Without looking it up, make a sketch showing the arrangement of thick and thin filaments in a muscle cell when the cell is relaxed and when the cell is contracting.

Applying Your Knowledge

Multiple Choice

1. Which of the following shortens when a muscle fiber contracts?
   a. thin filament
   b. myosin molecule
   c. sarcomere
   d. actin molecule
   e. thick filament
2. Which of the following ranks the parts in order, from largest to smallest?
   a. muscle, myofibril, filament, fiber
   b. fiber, muscle, myofibril, filament
   c. muscle, fiber, filament, myofibril
   d. myofibril, muscle, fiber, filament
   e. muscle, fiber, myofibril, filament
3. His doctor suspects that Jon might be suffering from leukemia. The doctor orders a sternal puncture, a test that samples red marrow. This test is performed to determine
   a. whether the marrow holds sufficient fat reserves.
   b. how fast Jon is growing.
   c. the rate of blood flow through the bone tissues.
   d. whether blood cell production is occurring normally.
   e. how fast cartilage is forming in the bones.
4. For every bone in the arm and hand, there is a corresponding bone in the leg and foot. Which of the following matches corresponding bones?
   a. humerus—femur
   b. metacarpals—tarsals
   c. radius—femur
   d. carpal—patella
   e. humerus—tibia
5. An animal that crawls or burrows faces problems similar to those faced by an animal that
   a. swims.
   b. runs.
   c. flies.
   d. walks.
   e. hops.
6. A scallop escapes from danger by clapping its shells together, which shoots out a stream of water and causes the scallop to hop backward. This is most like the movement of
   a. an earthworm.
   b. a water beetle.
   c. a squid.
   d. a bird (but under water instead of in the air).
   e. a whale.
7. Smooth muscle is a type of muscle found in the internal organs—the walls of blood vessels and the intestine, for example. It is called "smooth" because the cells of smooth muscle lack the alternating light and dark bands seen in the muscle fibers that move the skeleton. Which of the following do you think might best explain this difference? Smooth muscle
   a. does not require nervous stimulation to contract.
   b. does not contain the regular, repeating filaments of skeletal muscle.
   c. cells are much larger than the cells of skeletal muscle.
   d. motor units are much smaller than those of skeletal muscle.
   e. requires much less blood flow than skeletal muscle.
8. Which of the following drugs would cause muscle spasms or cramps (uncontrolled contractions)? A drug that
   a. blocks the release of calcium ions from endoplasmic reticulum.
   b. prevents the release of acetylcholine from motor neurons.
   c. blocks neurotransmitter receptors on muscle fiber membranes.
   d. blocks the enzyme that breaks down acetylcholine after contraction.
   e. prevents attachment of myosin heads to thin filaments.
9. If you were to cut through a muscle fiber and look at the cut end under a powerful microscope, what would the contractile parts of the cell look like?
   a. many crisscrossing lines
   b. thousands of tiny dots
   c. thousands of overlapping circles
   d. numerous irregular splotches
   e. many overlapping, parallel lines

10. A wildlife biologist came across the carcass of a deer. He suspected that the deer had died of starvation. To check this guess, he could
    a. examine the cartilage at the ends of the bones for signs of wear.
    b. crack open a bone and check the yellow bone marrow.
    c. have the deer's tissues tested for signs of rheumatoid arthritis.
    d. look for signs of spongy bone in the ends of long bones.
    e. evaluate the amount of fat stored in the red bone marrow.

Essay

1. Look at the skeleton of the frog in Module 30.2. In what ways is the frog's skeleton modified for its way of life?
2. Both roundworms and earthworms possess hydrostatic skeletons. The body of a roundworm is a single elongated sac, filled with fluid. The roundworm is able to move only by thrashing from side to side. Compare this with the structure and movement of an earthworm, and explain the difference.
3. The wings of birds come in several different shapes. Many small songbirds have short, stout wings. The wings of an eagle are long and broad, while those of a gull are long and narrow. How are these different wing shapes (structures) well suited to the activities and environments (functions) of these different birds?
4. A map of the human cerebral cortex shows that the area of the brain that controls muscle activity of the hands is equal in size to the area that controls all the muscles below the neck. The total size of the muscles moving the hands is much smaller than all the muscles of the trunk, legs, and so on. Explain in terms of the motor units that make up the muscles why so much nerve tissue is required to control the hands.
5. Early reconstructions of dinosaur skeletons showed them with their legs splayed out to the sides, like present-day alligators and lizards. Most dinosaur experts now think that the legs of dinosaurs were directly under the torso, like those of a dog or elephant. Why do you think they consider this important?

Extending Your Knowledge

1. There are actually two main kinds of muscle tissue: slow (red) muscle and fast (white) muscle. Slow muscle contracts slowly in response to nerve impulses. It is able to store oxygen and keep working with more endurance for extended periods. White muscle contracts quickly but has much less endurance. Most muscles contain a mixture of both types, in different proportions in different muscles. With this information in mind, speculate about the following: Which muscle type would you expect to predominate in the muscles that are moving your eyes as you read this? In your thigh muscles? Why is the breast muscle of a duck dark (red) meat but a chicken breast white meat? Which type do you think has been found in higher-than-average proportions in the leg muscles of world-class marathoners?
2. Millions of Americans regularly engage in bodybuilding exercise at health clubs, weight rooms, and gyms. Millions of others engage in aerobic activities like swimming, running, cycling, and dance aerobics. How does bodybuilding differ from aerobic exercise? Do you participate in any of these activities? What is their value, in your opinion? What effects does each have on muscle tissue, respiration, and the cardiovascular system? The experts say that 20 minutes of aerobic exercise at least three times a week is important for overall cardiovascular fitness, weight control, and stress reduction. How much exercise do you get each week? Is it enough? If you would like to get more exercise, how could you make it a higher priority?