Chapter 13

Control and Movement

Photo Credit: Anne-Marie Keppel

13.5 Muscles

You have more than 600 muscles in your body, including 30 in your face alone. You use these muscles for everything from smiling to making sandwiches. In fact, almost any time you say that you are "doing" something, you are doing it with your muscles.

Muscles work by contracting, or shortening. Many of your muscles are connected to bones via *tendons*. When these muscles contract, they pull at your bones, moving you. Because muscles can only pull, not push, you have many pairs of muscles with opposing effects. For example, your biceps muscle pulls on the inner part of your forearm, bending your forearm up toward your shoulder (Figure 13.11). Your triceps muscle pulls on the back end of your forearm (it attaches to the "funny bone" at the end of your elbow) and straightens the arm.

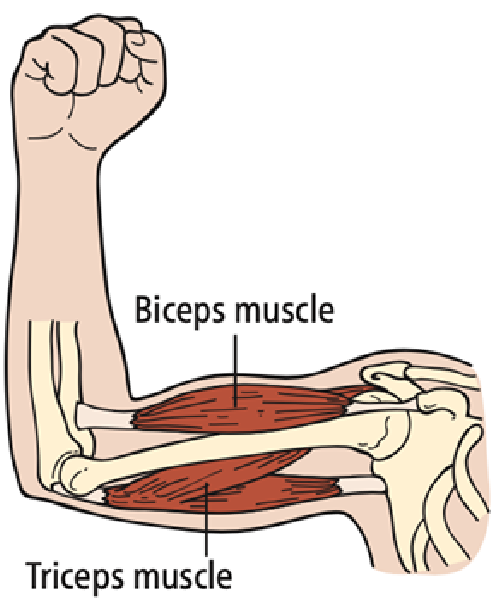
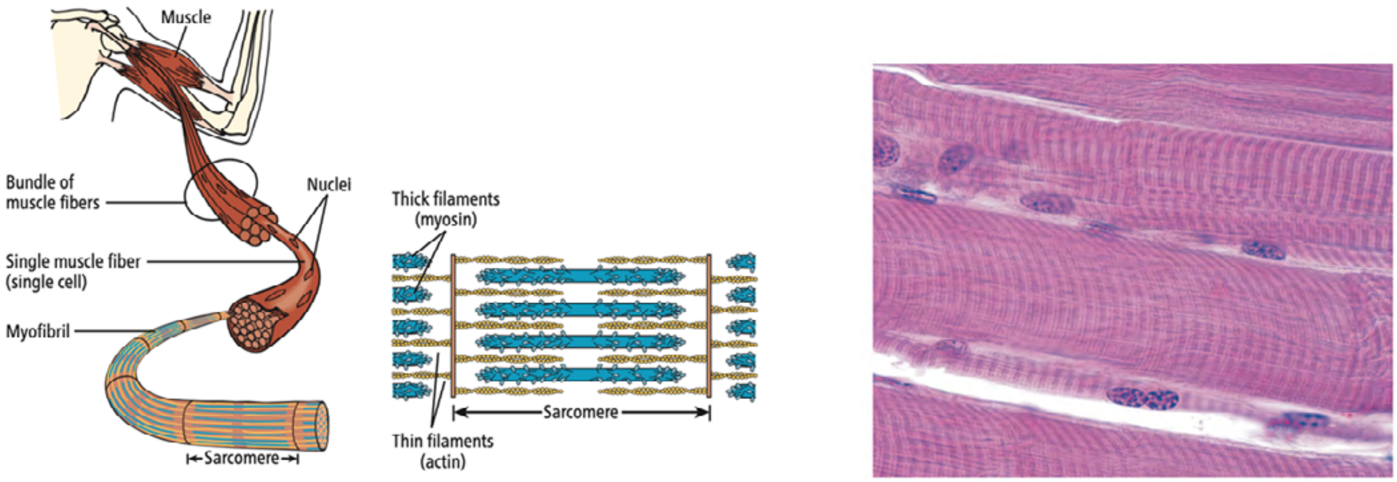


FIGURE 13.11
The biceps and triceps muscles move the forearm in opposite directions. The biceps bends the forearm, and the triceps straightens it.

How does a muscle contract? Let's start by looking at its structure. A muscle (Figure 13.12) consists of bundles of long muscle fibers. Each muscle fiber is actually a single cell with multiple nuclei. When you lift weights, you don't increase the number of muscle fibers in your muscles. That number stays the same. Instead, your muscles get bigger because the muscle fibers become thicker.



(a) (b)

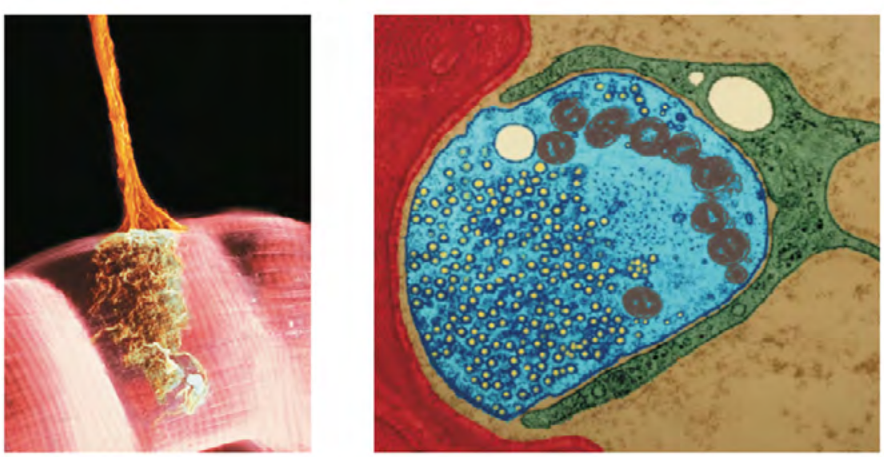
FIGURE 13.12

(a) A muscle is made up of bundles of muscle fibers. A muscle fiber contains smaller fibers called myofibrils. A myofibril consists of sarcomeres arranged end to end. Two proteins in the sarcomere, actin and myosin, allow sarcomeres—and consequently muscles—to contract. (b) This photo shows the "striated" or striped appearance of skeletal muscle due to the appearance of the sarcomeres. The darker oval shapes are cell nuclei.

A muscle fiber contains bundles of smaller elements called *myofibrils*. Each myofibril is made up of a series of contractile units called **sarcomeres**. Sarcomeres are made up of carefully arranged fibers of two proteins: thin filaments of **actin** and thick filaments of **myosin**. When a muscle contracts, the actin and myosin filaments slide past each other, shortening the length of each sarcomere. Let's look at how this happens.

Muscle Contraction

A muscle contracts when it receives a signal from a motor neuron. An action potential in the motor neuron arrives at a chemical synapse connecting the neuron to a muscle cell. The action potential triggers the release of the neurotransmitter **acetylcholine** at the synapse (Figure 13.13). Acetylcholine then binds to receptors on the muscle cell's membrane, starting an action potential in the muscle cell.



(a) (b)

FIGURE 13.13

(a) This photo shows a motor neuron (orange) and its synapse with muscle cells (red). (b) This is a closeup view of a synapse between a motor neuron and muscle cell. The motor neuron is shown in blue, and the muscle cell is shown in red. Small vesicles containing the neurotransmitter acetylcholine are clustered near the muscle cell. (The larger brown structures in the neuron are mitochondria. The green cell surrounding the neuron is a glial cell)

An action potential in a muscle cell causes calcium ions to be released from the muscle cell's endoplasmic reticulum (a cell organelle). Calcium ions enable a series of "heads" on the myosin fibers to attach to actin (Figure 13.14). Specifically, calcium ions bind to proteins that normally block the myosin-binding spots on actin and essentially move them out of the way, so that myosin is able to bind to actin. The myosin heads attach and pivot due to intermolecular forces, such as dipole-dipole attractions. This results in a pulling on the actin filaments. Each pull shortens the length of the sarcomere a tiny bit—about 10 nanometers—and, consequently, the length of the muscle as a whole. After pulling, the myosin heads release, extend, attach, and pull again. This cycle repeats until the signal to contract ends or until the muscle has fully contracted.

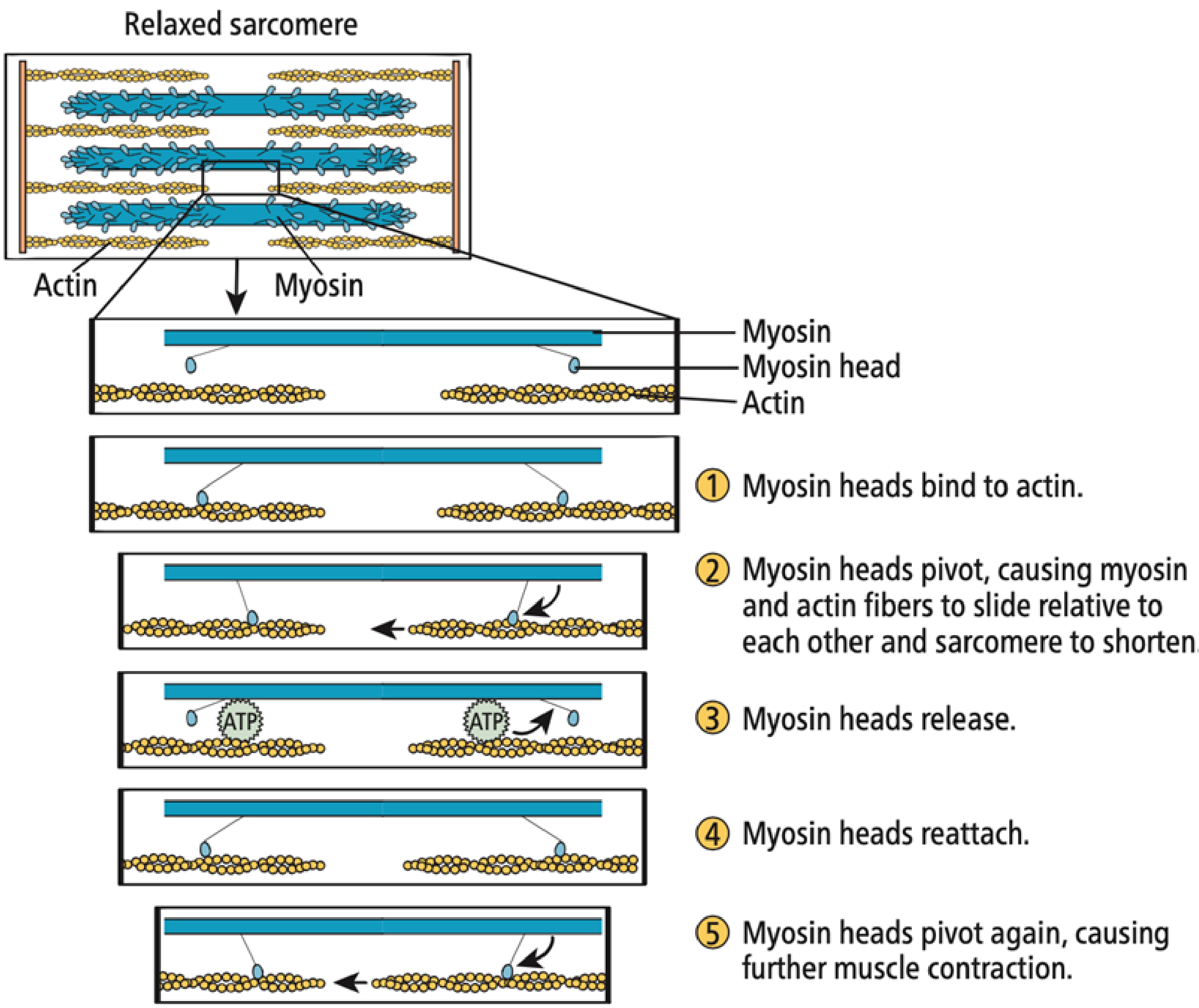


FIGURE 13.14

During contraction, the myosin heads bind to actin, pivot (pulling the actin), release, reattach, and pull again. (For simplicity, only one myosin head is shown on each side. In reality, many myosin heads pull on actin.) This process causes the sarcomere to shorten, resulting in muscle contraction.

Muscle contraction requires energy: ATP is needed for the myosin heads to release actin, an essential step in the contraction cycle. Once the motor neuron stops signaling, acetylcholine stops binding to the muscle cell, and the muscle cell's endoplasmic reticulum stops releasing calcium. Without calcium, the myosin heads are unable to bind to actin, and the muscle relaxes.

Several well-known toxins work by interfering with the connection between neurons and muscles. Curare, an arrow poison used in the South American tropics for hunting, binds to acetylcholine receptors on muscle cells, preventing acetylcholine itself from binding. Curare causes paralysis and then death as the respiratory muscles become paralyzed. The powerful nerve gas sarin prevents acetylcholine from being broken down after muscles contract. Muscles are stimulated continuously and soon become exhausted. Again, death occurs through asphyxiation as the respiratory muscles stop working.

Muscle contraction also explains rigor mortis, the stiffness of the body that sets in after death. After death, calcium ions leak from the endoplasmic reticulum of muscle cells. Myosin binds to actin, and muscles contract. Once the available ATP is used up, the myosin heads are unable to disengage, and the muscles remain contracted.

READING CHECK

1. **Why is calcium necessary for muscle contraction?**
2. **Why is ATP necessary for muscle contraction?**

CHECK YOUR ANSWERS

1. Calcium enables the myosin heads to attach to actin.
2. ATP is required for the myosin heads to release actin, an essential step in the contraction cycle.

You can read more about muscle contraction here:

https://www.visiblebody.com/learn/muscular/muscle-contractions