Key Terms
stem cell
embryonic stem cell

3.1 Cells and Tissues

In a single-celled organism, such as the amoeba shown in **Figure 3.1**, the cell has to be able to do everything that is needed for the organism to survive. For example, the cell has to find food, break it down to release energy, respond to its environment, and eliminate wastes. Organelles in the amoeba, such as digestive vacuoles, perform these jobs. In more complex organisms, such as the whale in **Figure 3.1**, humans, and the plants you investigated in Chapter 2, these tasks are handled by *groups* of specialized cells.

What Factors Influence Cell Specialization in Animals?

Scientists estimate that there are between 75 and 100 trillion cells in the body of an adult human. Most of those cells are specialized to do certain tasks. Three main factors influence differentiation in animal cells:

- the contents of the cell's cytoplasm
- environmental conditions, such as temperature
- the influence of neighbouring cells

The Effect of Cytoplasm on Cell Specialization

Mitosis ensures that daughter cells receive identical sets of chromosomes. However, the contents of the cytoplasm may differ in each daughter cell. For example, one daughter cell may have more storage vacuoles than the other. Having more of these vacuoles will allow the cell to use more energy as it grows. Even when a human embryo is only a few hours old, the future of many of its cells—how they will specialize—has already been determined. This early specialization is partly because of differences in each cell's cytoplasm.

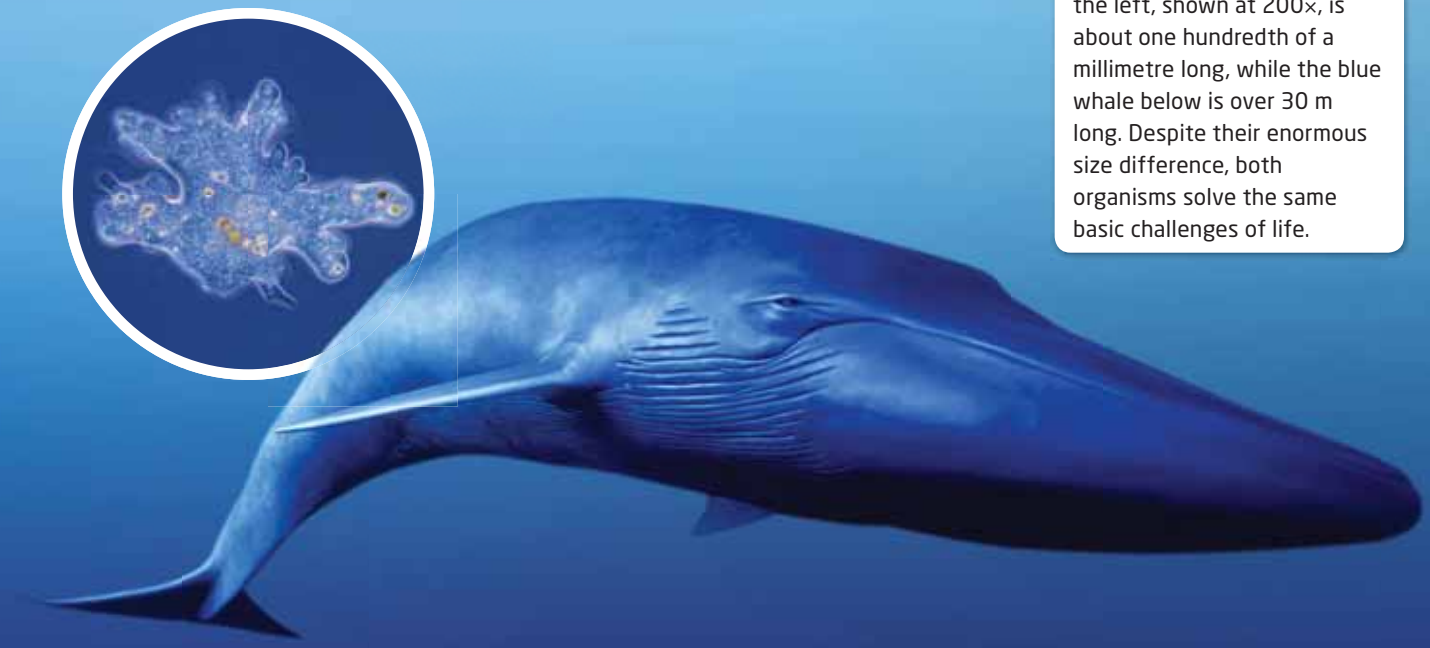


Figure 3.1 The amoeba on the left, shown at 200×, is about one hundredth of a millimetre long, while the blue whale below is over 30 m long. Despite their enormous size difference, both organisms solve the same basic challenges of life.

Figure 3.2 Siamese cats get their distinctive coat colour because only skin cells that experience cool temperatures during cell differentiation produce dark fur.

The Effect of Environmental Conditions on Cell Specialization

Cell specialization can also be affected by the environmental conditions a cell experiences as it develops. Such conditions include temperature and the presence or absence of certain nutrients. Differences in environmental conditions can also explain why cells with identical genes will develop differently. For example, in Siamese cats, only cells that develop at cool temperatures produce dark hair colours. Because the tips of the cat's feet, tail, ears, and nose are usually cooler than the rest of the body, the cat develops its distinctive dark "points," which can be seen in **Figure 3.2**.

The Effect of Neighbouring Cells on Cell Specialization

Nearby cells in the organism's body have one of the biggest influences on what a cell will become. When cells are close to one another, the substances produced by one cell can sometimes diffuse through a neighbouring cell's membrane. These substances can then change how the information in the DNA of the second cell gets expressed. For example, **Figure 3.3** shows where, in the developing embryo of a chick, neighbouring cells influence eye development in a specific location on the embryo.

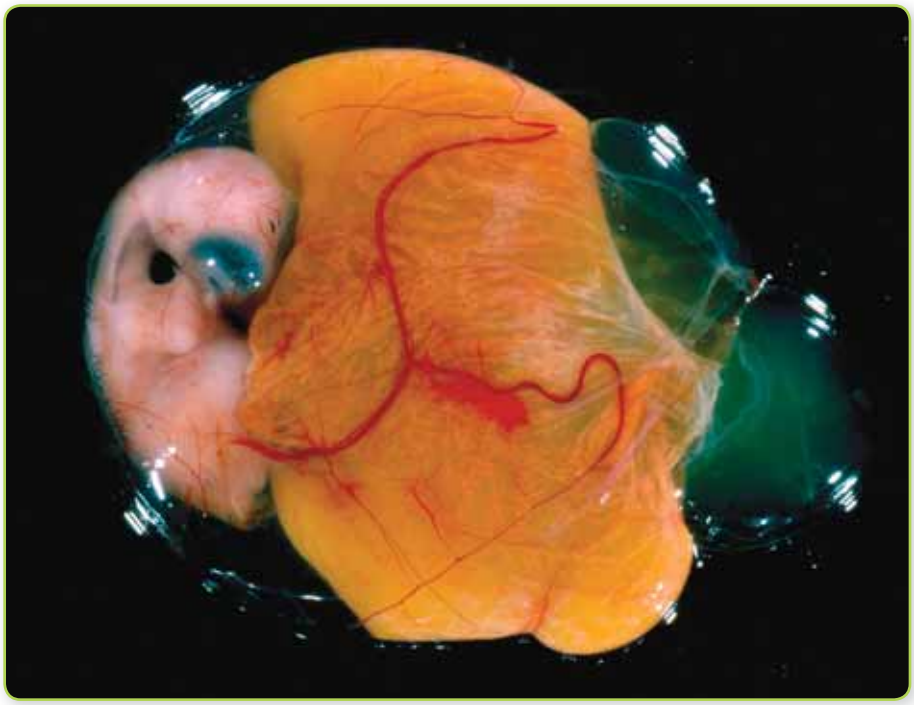


Figure 3.3 The bluish area on this 12-day-old chick embryo shows where cells have already begun to differentiate into what will become an eye. This differentiation occurs, in part, through the influence of neighbouring cells.

Why Abnormal Development Sometimes Occurs

Signals from the environment play an important role in normal development, and environmental factors are also often responsible when things go wrong, as shown in **Figure 3.4**.

Chemical contaminants in the environment have also been shown to trigger abnormal development. In humans, about 90 percent of problems in developing embryos can be traced to environmental factors, including a mother's exposure to harmful substances, such as heavy metals.

Figure 3.4 Development went off course in these leopard frogs. Biologists are unsure whether pollution, parasites, disease, or some other condition caused the deformities.

Similar Cell Conditions Form Similar Cells

As a cell matures, more of its genes get turned off or on by the effects of other cells or environmental conditions. One combination of active and inactive genes will produce a skeletal muscle cell. A different combination will produce a nerve cell. At some point, cells have had so many of their genes turned off that they stop dividing and live out their lives as mature, specialized cells. A muscle cell, for example, remains a muscle cell as long as it lives. It has left the cell cycle and no longer undergoes mitosis. It does not normally change to become a different type of cell.

Furthermore, cells that experience similar conditions—whether from the effects of other cells or environmental conditions such as temperature—become specialized to do similar jobs. Groups of similarly specialized cells form tissues.

Study Toolkit

Word Origins The word *striation* comes from a Modern Latin word meaning *strip* or *streak*. Look at the photograph of striated skeletal muscle on this page. How could word origin help you remember a feature of this muscle type?

Types of Tissues

It may surprise you to learn that although there are millions of different kinds of organisms on Earth, there are only a few different kinds of tissues. Animals—from worms to walruses—have four main tissues: *epithelial*, *muscle*, *nervous*, and *connective*. **Table 3.1** shows these major tissues, types of each, and how cross sections of them appear under a light microscope, each magnified about 250 or 300 times.

Table 3.1 Tissues in the Human Body

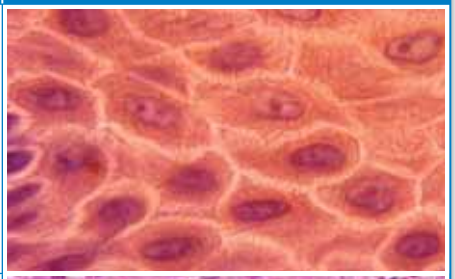
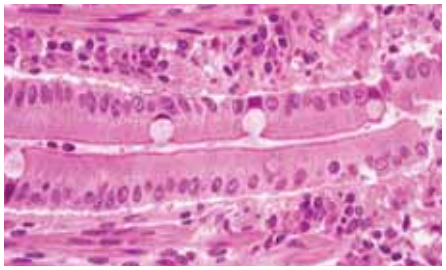
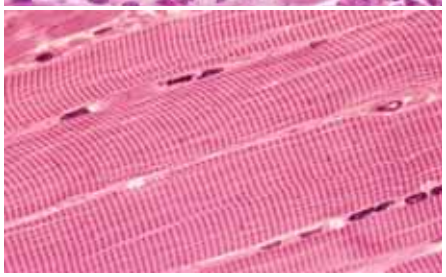
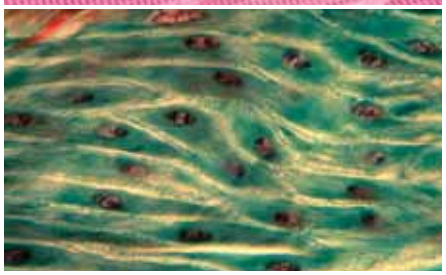
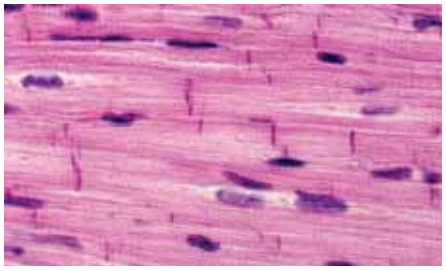
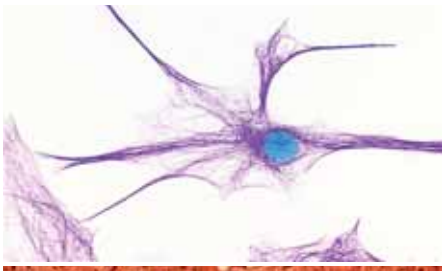
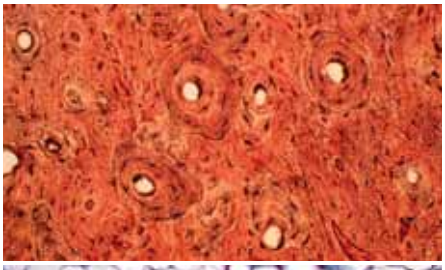
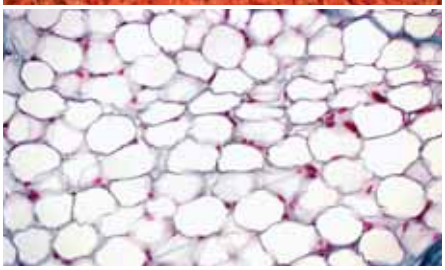
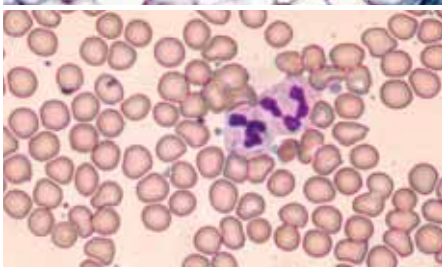
Tissue	Some Types	Appearance
Epithelial • line the surfaces of the body, both as a body covering and between internal organs • made of cells with strong connections between adjoining cell membranes, so they form a barrier	**Skin epithelia** • made of thin, flat cells that form sheets and act as a semi-permeable barrier between the inside and outside of a body	
	Columnar epithelia • made of columns of cells that line the small intestine (shown here), the stomach, and glands • may secrete mucus, have finger-like projections called cilia, and or absorb materials	
Muscle • designed to change their shape • act by shortening or lengthening	**Skeletal muscle** • made of cells that line up in the same direction, making the tissue look striped, or striated • attaches to bone, making it possible for the body to move • is found in limbs, like arms and legs, and places where the body needs support, such as around the lower abdomen and back	
	Smooth muscle • made of cells that are tapered at both ends and do not have a striated appearance • is found in blood vessels and the walls of internal organs like the esophagus and stomach • contracts more slowly than skeletal muscle, but its action can be sustained for a long time	
	Cardiac muscle • made of cells whose nuclei sometimes appear to be between cells • are branched and unevenly striated • contracts as a unit • found only in the heart	

Table 3.1 continued

Tissue	Some Types	Appearance
Nervous • made of cells called *neurons*, which have finger-like projections to receive and transfer signals • coordinates body actions	• are varied in their actions: – some relay signals from the brain or spinal cord to muscles and glands – others detect information from their environment (like the heat of a hot stove) and trigger the body's responses	
Connective • strengthens, supports, protects, binds, or connects cells and tissues • consists of cells in an extracellular matrix that can range from a liquid (in blood), to elastic materials that can stretch (in ligaments), to mineral deposits (in bone)	**Bone** • made of cells surrounded by calcium-hardened tissue through which blood vessels run • needed for movement, support, protection	
	Fat (adipose tissue) • made of large, tightly packed cells • found under the skin and around organs • needed for energy storage, padding and insulation	
	Blood • includes red blood cells, white blood cells, and platelets within a straw-coloured liquid matrix called plasma • transports nutrients and oxygen • clots when the skin is cut • attacks invaders such as bacteria and viruses	

Activity 3-2

Tissue Sleuth

In **Table 3.1**, you can see many examples of cells from different tissues in the human body. What characteristics differentiate each type of tissue?

Materials

- microviewer or compound microscope
- unidentified, prepared slides of various tissues from the human body

Procedure

1. Using a microviewer or a microscope, examine the tissue specimens provided.
2. Make a labelled biological drawing of a cell for each specimen. If you can, identify and label the cell membrane, cytoplasm, and nucleus, as well as any other structures you can see.
3. Use **Table 3.1** to Identify the type of tissue shown in each specimen.

Questions

1. Briefly explain how the appearance of tissue, when magnified, gives you clues about the tissue's function and identity.
2. Write a short description below each of your drawings that states the function of that tissue in your body.

Sense of scale

No one has figured out precisely how many cells there are in a typical human body. Estimates range from 10 trillion to 100 trillion cells.

Learning Check

1. What is cell differentiation?
2. Create a web showing factors that affect cell specialization.
3. Name the four main types of animal tissues, and give examples of where they are found in the human body.
4. Skeletal muscle is also known as "voluntary" muscle, and smooth muscle as "involuntary" muscle. Explain why.

Stem Cells

stem cell an unspecialized cell that can produce various specialized cells

As you learned in Chapter 2, plants have meristematic cells that remain unspecialized and continue dividing. Animals have similar cells, called **stem cells**. While an animal grows to adulthood, these stem cells perform a function similar to that of meristem cells—they produce more cells so the animal grows larger.

While animals like starfish and salamanders can regenerate some body parts, mammals can replace only small amounts of tissue, such as that needed for bone or skin repair. Human organs are formed in the embryo and the body cannot produce new ones.

As you can see in **Figure 3.5**, early in their development, human embryos have *totipotent* stem cells, which can become any kind of cell in the body. As the embryo develops, its stem cells become *pluripotent*. These stem cells are less versatile. They are capable of producing many, but not all types of cells. Late in development and after birth, people have only adult stem cells, which can produce only specific kinds of cells. For example, only skin stem cells can produce cells to repair skin, and only bone stem cells can repair bone.

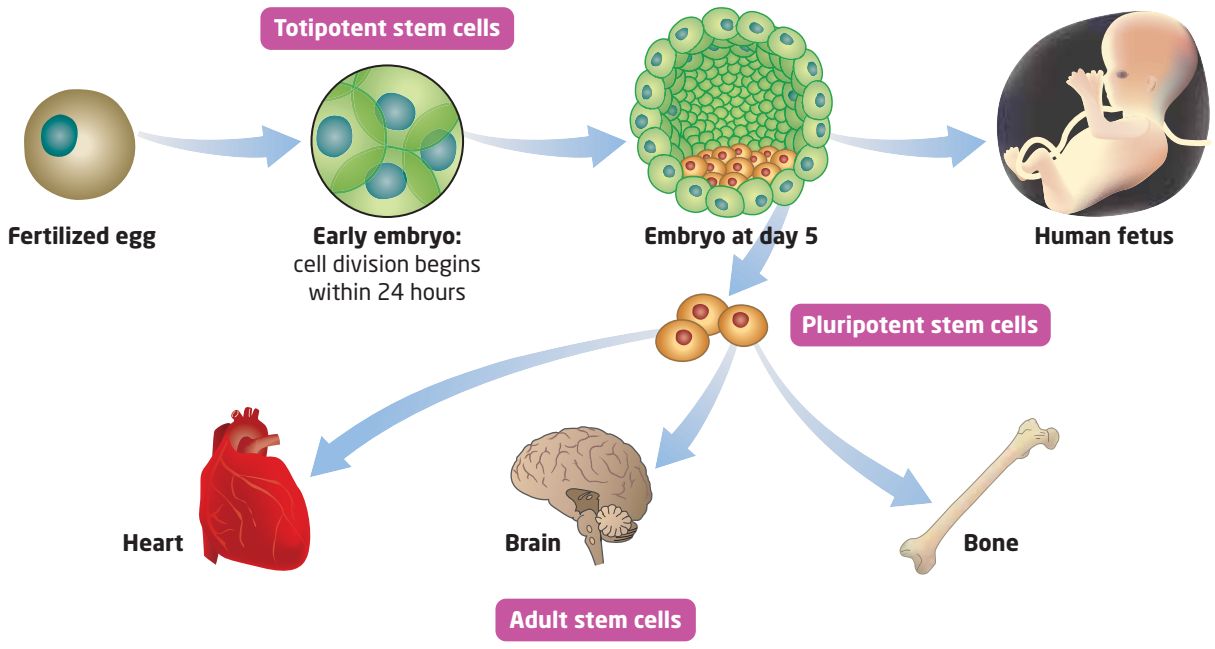


Figure 3.5 Human stem cells become less versatile as they become more specialized.

The Medical Potential of Stem Cells

In 1968, two Canadian researchers, Dr. Ernest McCulloch and Dr. James Till, made an important discovery about the medical use of stem cells. The researchers showed that marrow transplanted from a healthy animal could restore blood cells in an animal that had undergone radiation therapy. Radiation, which can destroy rapidly dividing cells, is commonly used as a cancer treatment. Sometimes, radiation also destroys the patient's normal bone marrow cells. Then a bone marrow transplant is needed, as shown in **Figure 3.6**.

Figure 3.6 Traditional techniques used to harvest bone marrow for transplant (shown here) involve surgery. New techniques can harvest stem cells from a blood sample.

The Ethics of Using Embryonic Stem Cells

Embryonic stem cells are found in embryos that are very young—less than a week old. Under laboratory conditions, these totipotent stem cells are able to keep dividing for a year or even longer without ever differentiating. Embryonic stem cells are sometimes called "source" or "starter" cells because they can become any of the roughly 300 different types of human body tissue, making them valuable for research and medical treatments.

Despite the potential applications of embryonic stem cells, their use is not without problems. Scientists obtain these cells from eggs fertilized in vitro (outside the womb). Sources are usually unused embryos from fertility clinics. However, obtaining stem cells destroys the embryo. Some people consider this use to be taking a human life.

How might researchers avoid this problem? Recent studies have shown that some adult stem cells, such as those from the skin, can be transformed, or induced, into becoming pluripotent stem cells. However, most *induced pluripotent stem cells* are created using viruses, which could potentially damage the stem cells' DNA. As **Figure 3.7** shows, however, new research may soon offer a solution to this problem.

embryonic stem cell an unspecialized cell that can become any one of an organism's body cells

Go to **scienceontario** to find out more

Figure 3.7 In 2009, Andras Nagy (pictured here) and fellow researchers at Mount Sinai Hospital in Toronto successfully used DNA from a cabbage looper moth to induce pluripotent stem cells from adult skin cells. Unlike techniques that use viruses, this technique avoids the risk of damaging the stem cells' DNA.

Section 3.1 Review

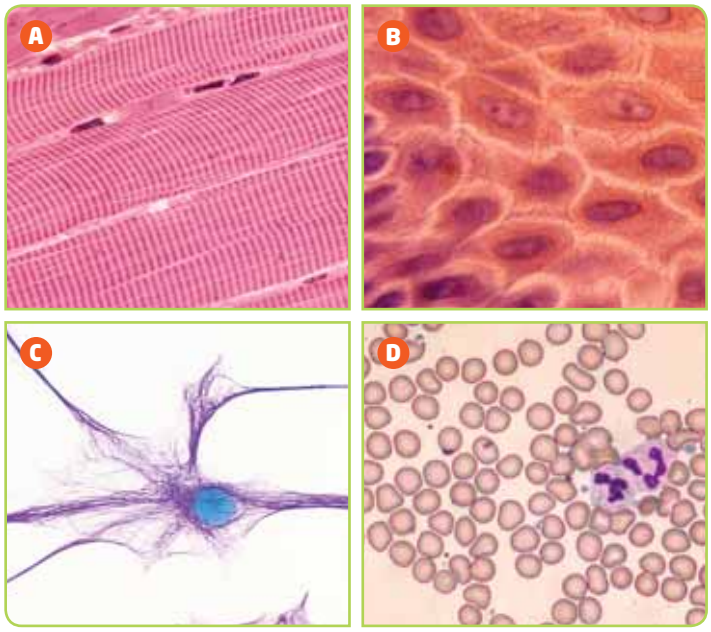
Section Summary

- Cell specialization is influenced by the contents of an individual cell's cytoplasm, environmental factors such as temperature, and secretions from neighbouring cells.
- Animals have four main types of tissues: muscle, epithelial, connective, and nervous.
- Because stem cells have the potential to repair and replace damaged cells, they offer opportunities to develop new medical treatments. However, their use also raises some ethical questions.

Review Questions

C **1.** Draw three types of specialized cells and state how their appearance relates to their function.

K/U **2.** Match the images of tissues shown on the right to the correct function below.



a. transports nutrients and oxygen

b. transmits electrical signals

c. covers the surface of the body

d. assists in body movement

T/I **3.** A toxic chemical was accidentally spilled by an industry into a river in early spring. A few months later, researchers retrieved fish and frogs with 20 times more abnormal growths than would normally be found. The next year, the growths were only 5 times greater than normal, and the third year after the spill, the number of abnormal growths had returned to normal levels. Provide a possible explanation for these changes.

A **4.** What would happen if cells of a chick embryo did not specialize?

K/U **5.** What features distinguish stem cells from other cells?

K/U **6.** Create a table or Venn diagram to compare adult stem cells and embryonic stem cells.

C **7.** Explain to a partner how embryonic stem cells differ from adult stem cells.

K/U **8.** Why are researchers so interested in trying to induce adult stem cells to become pluripotent or even totipotent?