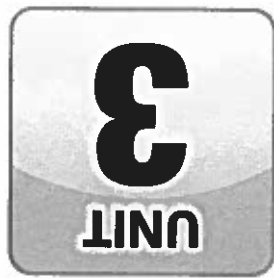


Biology: Tissues, Organs,
and Systems



SNC2D-B

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Introduction

All organisms are made up of systems of interacting parts, even single cells. More complex organisms, like mammals, are made up of big systems and small parts operating together, just like a complex machine. This “machinery” is made up of cells, tissues, organs, and organ systems that work together. This unit will feature the hierarchical organization of organisms, from cells to tissues to organs to systems. You will look at this organization in both plants and animals, including humans.

The unit will cover cell specialization, cell division, and the organization of tissues and organ systems. You will explore the impact of technologies and diseases on an organ system or on the entire organism. You will learn to gather qualitative data from viewing and drawing cells under a microscope, and from viewing cells that are undergoing mitosis.

Overall Expectations

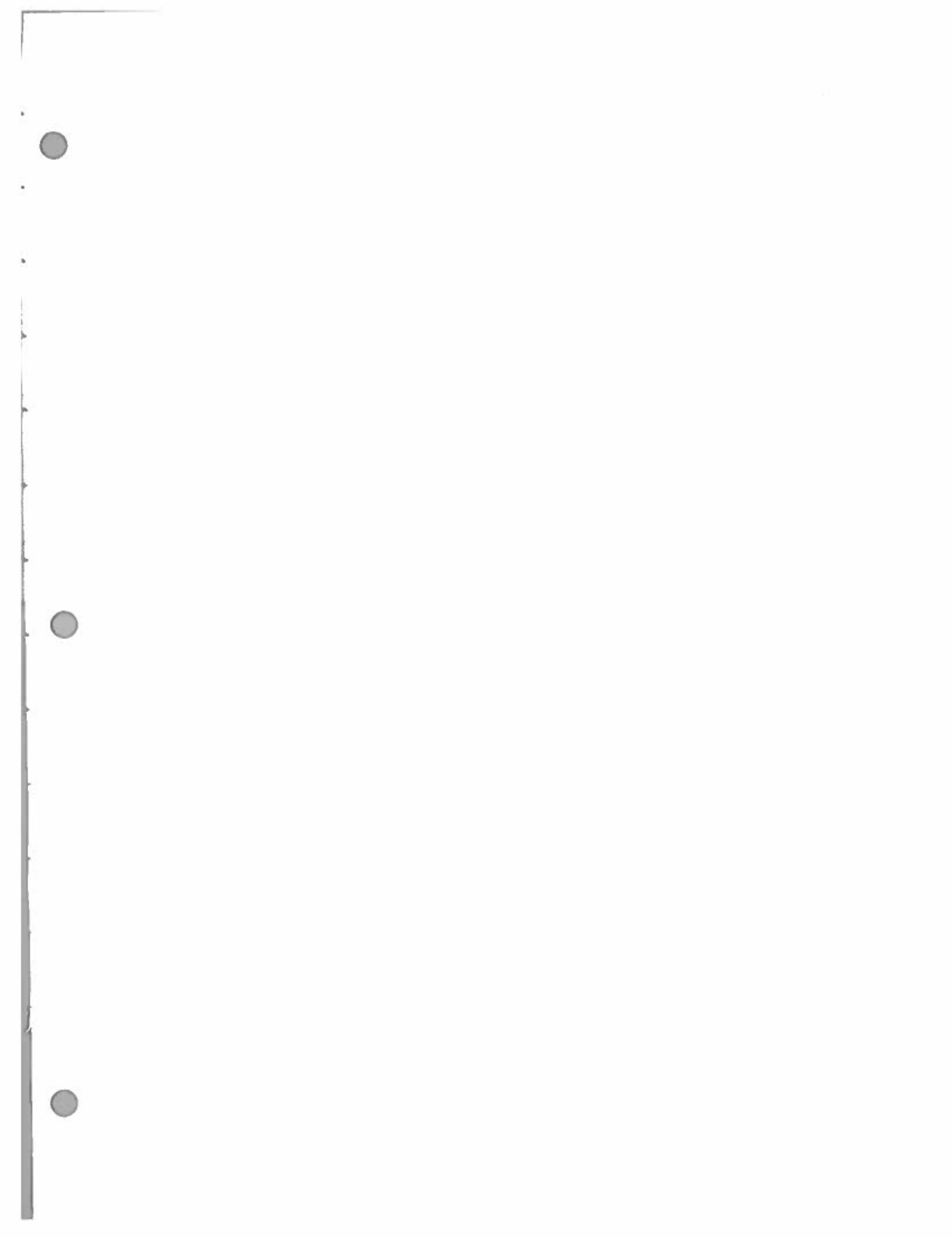
After completing this unit, you will be able to

- analyze some current technologies or substances that have an impact on human tissues, organs, or systems, and evaluate their effects on human health
- use various laboratory techniques to investigate cell division, cell specialization, and the organization of systems in animals, including humans
- demonstrate an understanding of the hierarchical organization of cells—from tissues to organs to systems in animals, including humans

SNC2D-B



From Cell to Clone



Introduction

Discoveries in biology and medicine seem to happen daily. New ways of treating ailments like cancer and heart disease are just around the corner, as are revolutions in cloning. These discoveries owe their existence to a basic understanding of the structure and function of cells. Having unlocked many of the cell's secrets, biologists can now begin to manipulate cells, producing the medical miracles we take for granted.

Cells are the building blocks of life. All life began as single cells. Many life forms today still exist as single-celled organisms. In other organisms, cells combined and specialized to form the complex systems that make up bodies like yours. But even *you* started out life as a single cell. Understanding how cells function, grow, reproduce, and specialize is the secret to many medical mysteries.

In this lesson, you will explore the basic structures of plant and animal cells, and learn how to use one of the most basic tools in cell biology, the microscope.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Animal Cells: Structures and Functions	½
Plant Cells: Structures and Functions	½
Microscopes	1
Activity: Virtual Microscope	¾
Regeneration	¼
Cloning	¾
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- distinguish between plant and animal cells
- use a microscope to view cells
- describe cell organelles by both structure and function
- identify key differences in organelle function between plant and animal cells
- describe the processes of regeneration and cloning, as well as related ethical issues

What Is a Cell?

A **cell** is the basic unit of life. All living organisms—animals, plants, fungi, bacteria—are made up of cells. **Unicellular organisms** like the amoeba consist of only one cell. Forms of life made up of more than one cell are called **multicellular organisms**. Some organisms are made up of thousands, millions, and even trillions of cells. Over 100 trillion cells make up the human body.

Not discovered until after the invention of the microscope, cells were first seen in 1665 by an English scientist named Robert Hooke. While examining a thin slice of cork under a microscope, Hooke noticed many repeating honeycomb-shaped structures that he called “cells.” As microscopes improved and research continued, a greater understanding of cells developed. In the mid-1800s, two scientists, Theodor Schwann and Matthias Schleiden, concluded that plant and animal tissues were composed of cells. Their discoveries led to the formation of modern **cell theory**. Modern cell theory has three main principles:

1. All living things are composed of one or more cells.
2. The cell is the basic structural and functional unit of life.
3. All cells arise from pre-existing cells by the process of cell division.

Animal Cells: Structures and Functions

The basic structure of all animal cells is the same, but their appearance differs depending on the cell's type and function. Cells are complicated structures that must carry out many processes in order to keep the overall organism functioning. Just as you use different organs in your body to do different things, the cell uses specialized structures to handle different processes. In cells, these specialized structures are called **organelles**.

The following 11 organelles are found in all animal cells:

- nucleus
- nucleolus
- chromosome
- ribosome
- endoplasmic reticulum
- Golgi apparatus
- mitochondrion
- cytoplasm
- cell membrane
- lysosome
- centriole

Figure 11.1 below depicts the general structure of all animal cells. It shows the appearance, structure, and general location of the 11 organelles listed.

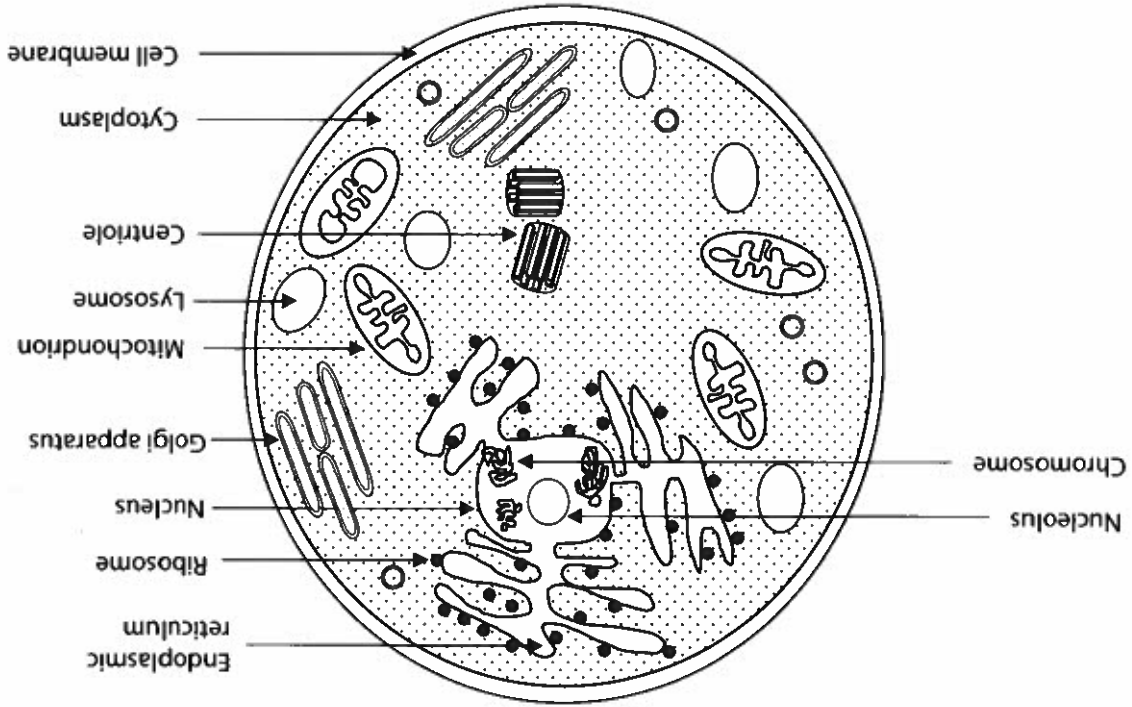


Figure 11.1 Animal cell with organelles

Organelle Functions

The organelles found in all animal cells are described below.

Table 11.1 Functions of Animal Cell Organelles

Organelle	Function
Nucleus	The nucleus acts as the cell's control centre, directing all cellular activity. It contains the nucleolus and the genetic material, and is surrounded by a nuclear membrane.
Nucleolus	Found within the nucleus, the nucleolus is responsible for ribosome production.
Chromosomes	These thread-like structures contain the genetic material for living organisms. This genetic material is called deoxyribonucleic acid (DNA).
Ribosomes	These important structures are involved in producing protein through a process known as protein synthesis. Protein is important for forming the overall structure of an organism.
Endoplasmic reticulum	This series of canals carries materials (for example, ribosomes) throughout the cell.
Golgi apparatus	This structure stores and packages material produced within the cell (for example, protein) until it is needed for use inside or outside the cell.
Mitochondria	Often referred to as the "powerhouse" of the cell, mitochondria (singular: mitochondrion) are oval-shaped organelles that convert sugar into useable energy through the process of cellular respiration.
Cytoplasm	This fluid fills the entire cell, surrounding the other organelles. In addition to holding the organelles in place, the cytoplasm is the area where most cellular work is done (absorption of nutrients, transport of material, and so on).
Cell membrane	The cell membrane surrounds the entire cell. It acts as a gatekeeper, controlling the movement of materials into and out of the cell.
Lysosomes	These sac-like structures formed in the Golgi apparatus are used for digesting (breaking down) large molecules.
Centrioles	Unique to animal cells, these small protein-based structures play a critical role in cell division.

All animal cells have the organelles listed above. In addition, certain cells contain others organelles whose purpose is movement. A flagellum is a whip-like tail that can propel the cell. Sperm cells spin their flagella in order to swim. Other cells use cilia, tiny hairs that vibrate like oars, to move the cell or to move material around outside the cell. The cells that line your lungs use their constantly waving cilia to remove debris, such as dust, that has landed in the mucus of your respiratory tract. (As you'll see in Lesson 15, smoking damages the cilia, making it hard for them to get rid of irritants. In response the body produces extra mucus, leading to "smoker's cough.")

You may find it easier to understand the function of each organelle if you relate it to something you already know. A cell can be compared to a factory: both contain various components that carry out specific tasks.

Table 11.2 Comparing animal cell organelles to factory components

Cell Organelle	Factory Equivalent	Explanation
Nucleus	Head Office	Both are control centres
Nucleolus	Employee Services	Production/Hiring (ribosomes correspond to workers)
Chromosomes	Planning Department	Both store information that indicates how the factory is to work
Ribosomes	Workers	Both do work (building protein/building parts)
Endoplasmic reticulum	Assembly Line	Both transport material
Golgi apparatus	Packaging Department	Both store finished products
Mitochondrion	Powerplant	Both provide useable energy
Lysosome	Maintenance Crew	Both remove broken equipment to keep processes running smoothly
Centriole	Internal Walls	Division (of cell/sections of factory)
Cytoplasm	Factory Floor	Space where all the work is done
Cell membrane	Outside walls with lockable doorways and restricted access	Both provide support/structure and restrict who can enter or leave the building

Plant Cells: Structures and Functions

Plant cells share the same basic structure. Like animal cells, plant cells differ in appearance according to the cell's type and function. Plant cells contain organelles very similar to those of animal cells. In addition, because plants have the ability to generate their own food from sunlight, they contain a few more specialized cells. The following 12 organelles are found in all plant cells. The first nine are the same as in animal cells, but the last three are unique to plants:

- nucleus
- nucleolus
- chromosome
- ribosome
- endoplasmic reticulum
- Golgi apparatus
- mitochondrion
- cytoplasm
- cell membrane
- vacuole
- chloroplast
- cell wall

What are the main differences between animal and plant cells? Plant cells are surrounded by a stiff cell wall, and contain vacuoles to store water and chloroplasts to help them convert sunlight into food. Plants need vacuoles because they require a lot of water to help them convert sunlight into food.

Organelle	Function
Vacuole	A large fluid-filled space containing water and dissolved minerals, the vacuole helps maintain water pressure inside the cell.
Chloroplast	This organelle contains a pigment molecule known as chlorophyll that is used by plants for the life-sustaining processes of photosynthesis. A by-product of this process is oxygen, which animals use to breathe.
Cell wall	Surrounding the entire cell, this organelle is composed of a rigid material called cellulose. The cell wall protects and supports plant cells.

Table 11.3 Functions of Plant Cell Organelles

The three additional organelles found only in plant cells are described below.

Plant Organelle Functions

Figure 11.2 Plant cell with organelles

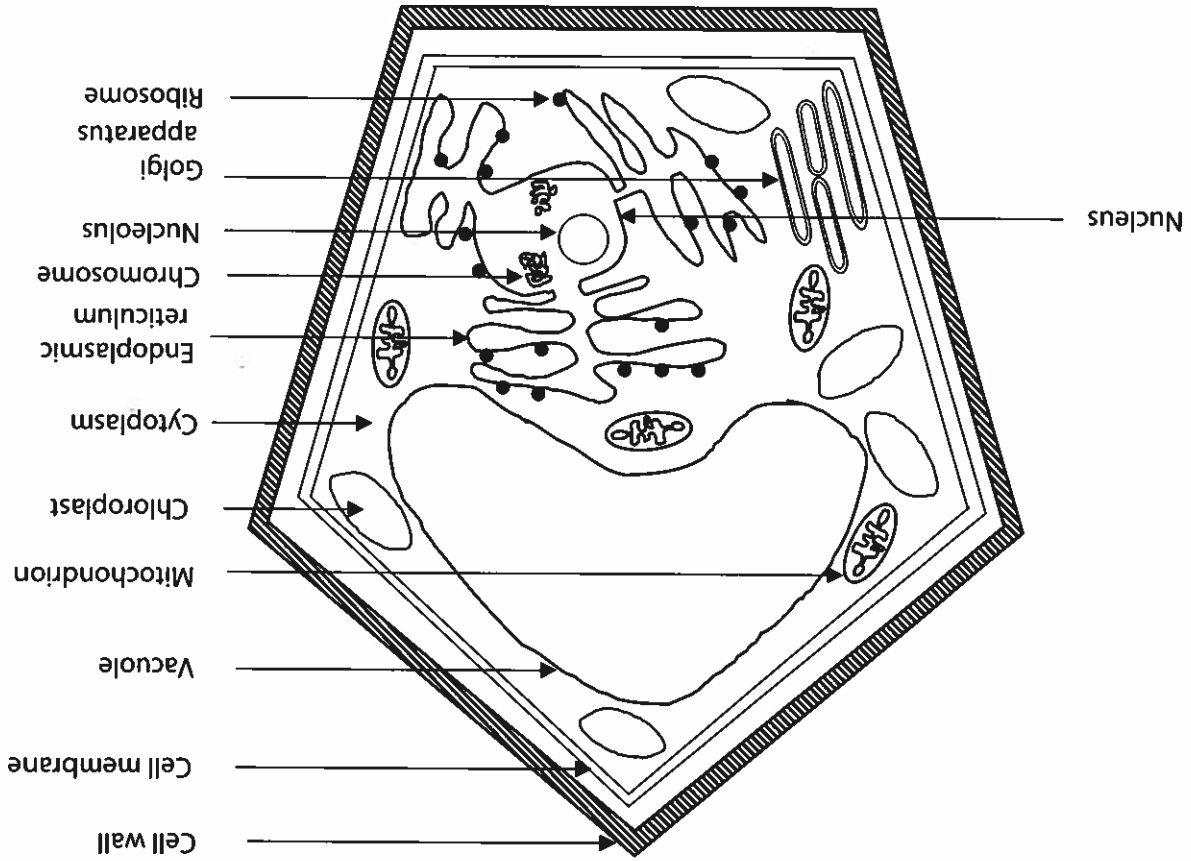


Figure 11.2 below depicts the general structure of all plant cells. It shows the appearance, structure, and general location of each of the 12 organelles listed.

The three additional plant cell organelles can also be compared to components of a factory.

Table 11.4 Comparing plant cell organelles to components of a factory

Cell Organelle	Factory Equivalent	Explanation
Vacuole	Water Tanks	Both allow for the storage of water
Chloroplast	Windows	Both allow for the capture of sunlight
Cell wall	Exterior Walls	Both provide support to the overall structure

Support Questions

1. What are the three principles of the cell theory?
Do not send your answers in for evaluation.

2. Indicate the function of the following:
a) cell membrane
b) mitochondrion
c) ribosome

3. Where is a cell's genetic information found?

Microscopes

Scientists use microscopes to study material and organisms too small to see with the naked eye. The first microscope was built by Anton van Leeuwenhoek in the 17th century. Containing only one lens, it was called the Simple Light Microscope. In order to illuminate the object under study, it required a mirror to reflect visible light from the sun or a candle flame.

In recent years, new microscope technology has used non-visible light sources to see things at the very small scale. Both the Transmission Electron Microscope and the Scanning Electron Microscope can significantly increase the magnification of a specimen, up to two million times. The Transmission Electron Microscope uses an invisible beam of electrons to illuminate the specimen. However, only thin sections of a specimen can be used, and they must be encased in plastic, which makes it difficult to examine living cells. The Scanning Electron Microscope uses electrons to produce a three-dimensional image on a television monitor.

The type of microscope used today in most secondary schools, the **Compound Light Microscope**, uses visible light to illuminate the specimen. It contains both an ocular lens and multiple objective lenses, allowing for a significant increase in the magnification of a specimen (up to a maximum of 2000 times). A built-in electric lamp is used to illuminate the specimen from below, permitting viewing in all light conditions. Figure 11.3 shows the parts of the Compound Light Microscope.

There are Suggested Answers to Support Questions at the end of this unit.

4. What can a plant cell do that an animal cell cannot? What structure enables it to carry out this function?

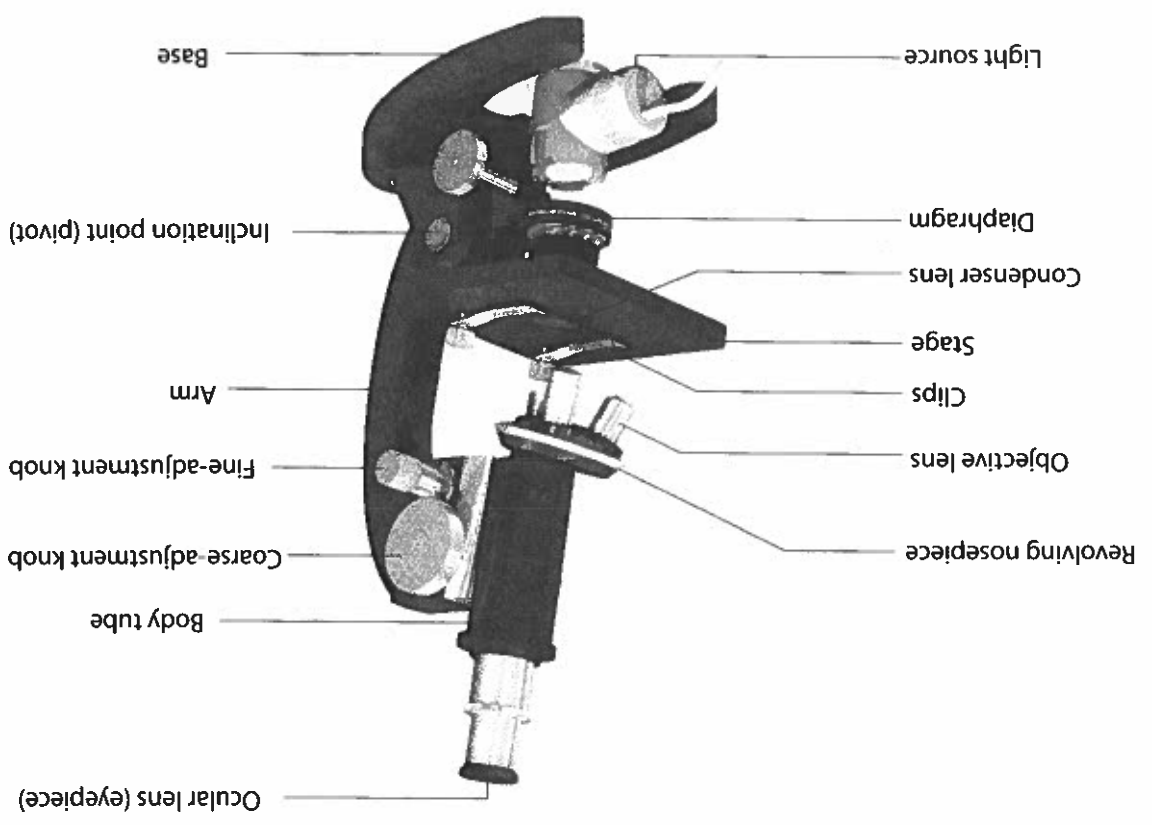


Figure 11.3 Parts of the compound light microscope

Source: Nelson Education Ltd.

Parts of a Compound Light Microscope

Each part of the microscope has a specific function described below.

Table 11.5 Function of Microscope Parts

Part	Function
Revolving nosepiece	Used to change objective lens power for different magnifications by revolving (spinning) each lens into place
Objective lens	A lens that can further magnify the specimen. Most microscopes have low-, medium-, and high-power objective lenses
Stage and clips	Hold the microscope slide in place
Condenser lens	Condenses the light towards the stage opening
Diaphragm	Controls the amount of light passing through the stage opening
Eyepiece	Component through which the specimen is observed. It contains an ocular lens that magnifies the specimen.
Body tube	Holds the ocular lens the correct distance from the eyepiece
Coarse-adjustment knob	Rough focus for low-power objective lens only
Fine-adjustment knob	More delicate focus for medium- and high-power objective lenses
Arm	Used to carry the microscope
Base	Supports the microscope
Light source (lamp)	Lights the specimen from underneath

In this course, you will have an opportunity to use a virtual microscope that functions just like the compound light microscopes commonly used in schools. Before using the virtual microscope to study the structure of cells, you need to learn about magnification and biological drawings.

Magnification of a Compound Light Microscope

Magnification is the ability of a lens to enlarge an image of a specimen. An image magnified 100× will appear 100 times larger than the specimen looks to the unaided eye. To calculate the total magnification of an object, multiply the ocular lens (eyepiece) magnification by the objective lens magnification.

Example

You are looking at an animal cell under the microscope. If the ocular lens is 10× (sometimes also called “10 times” or “10 power”) and the objective lens is 40× (“40 times” or “40 power”), then the total magnification = $10 \times 40 = 400\times$.

Most light microscopes have several objective lenses ranging in power from 4× to 100×, which gives them a range of magnifications from 40× to 1000× (assuming the power of the ocular lens is 10×). However, the highest magnification (starting around 1000×), requires the use of special preparations for the slide (called “oil immersion”), so it is not used as often in classrooms. Your virtual microscope will only go up to a maximum of 400× magnification.

You usually start looking at a slide image under the lowest magnification on a microscope because this helps you locate the slide image and begin focussing. Then you gradually switch to higher magnifications to view more details.

Field Diameter

The field diameter is the diameter of the field of view when you are looking through the ocular lens. This value is useful for estimating cell size. To determine the field diameter under low power, a millimetre ruler is placed on the microscope stage and examined through the eyepiece at the lowest magnification. The field diameter is equivalent to the number of millimetres visible on the ruler. For the microscope described above, the field diameter at 40× is 2 mm. To calculate the field diameter under a higher magnification, use this simple calculation:

$$\text{Field diameter (higher power)} = \frac{\text{field diameter (low power)}}{\text{total magnification (higher power)}} \times \text{total magnification (low power)}$$

Example

If the magnification of the ocular lens is 10× and the objective lens is 25×, and the field diameter using a 4× objective lens is 2 mm, what is the field diameter when using a 25× objective lens?

Solution

Step 1: Calculate the total magnifications for each objective lens:

Total magnification using the 4× objective lens

$$= \text{ocular power} \times \text{objective power} = 10 \times 4 = 40\times$$

Total magnification using the 25× objective lens

$$= \text{ocular power} \times \text{objective power} = 10 \times 25 = 250\times$$

Step 2: Calculate field diameter using the 25× objective lens:

$$\text{Field diameter (at 25×)} = \frac{2 \text{ mm (at 4×)}}{250 \text{ (at 25×)}} \times 40 \text{ (at 4×)} = 0.32 \text{ mm}$$

Therefore, the field diameter using a 25× objective lens is 0.32 mm. This makes sense: you have zoomed in on the slide by looking through a higher power objective lens, so the field diameter ought to be smaller.

Cell Size

It is often helpful to estimate the size of the cell you are viewing through the microscope. This gives you a better understanding of the specimen you are working with and can help classify specimens.

A fast way to estimate cell size is to divide the field diameter by the number of times you think the cell would fit across the field of view.

Cell size estimate = Field diameter ÷ Number of cells that fit

This makes intuitive sense: if the field diameter were 0.20 mm and you think 10 cells could fit across the field of view, then each cell would have to be about 0.020 mm in width.

Support Questions

5. What are two advantages of the Compound Light Microscope over the Simple Light Microscope?

6. Describe the function of the
- ocular lens
 - fine-adjustment knob
 - condenser

7. If the ocular lens has a magnification of 10× and the objective lens has a magnification of 60×, what is the total magnification?

8. Given the following information:

low power magnification = 50×

field diameter at 50× = 4 mm

high power magnification = 400×

Calculate the field diameter under high power magnification (400×)

Making Biological Drawings

When viewing objects under the microscope, you often need to hand draw a biological drawing to make proper observations of the specimen. Here are some tips for drawing biological drawings by hand.

Tips: Biological Drawings

1. Use pencil for drawings, including labels, name, and other information.
2. The title of the drawing is simply the name of the object you are looking at—for example, “Human Bone Cell.”
3. Use unlined white paper.
4. Make the drawing as large as possible. It should occupy at least a third of the page, and should be kept to the left of the centre of the page.
5. Print all labels, and line them up on the right-hand side of the drawing where possible. Use a ruler for label lines.
6. Each cell is different. The drawing should be an outline of what you see. Do not include additional structures just because you think you should see them.
7. Do not shade or fill in areas with colour. All lines should be solid and complete.

Here's an example of a good biological drawing. It is of a one-celled animal called a paramecium. Note the arrangement of the labels and the lack of shading.

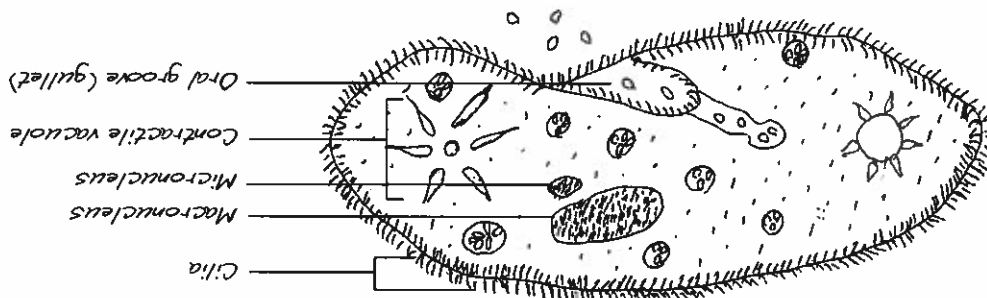


Figure 11.4 Biological drawing of a paramecium

Activity: Virtual Microscope



Go to your course page on the ILC website and click on "Learning to Use a Microscope" under Lesson 11.

In this activity, you will observe animal and plant cells using a virtual microscope. This activity will familiarize you with the operation of a Compound Light Microscope as well as with the structure of a typical animal and plant cell.

Procedure

1. Turn the light on under your microscope.
2. Select the human red blood cell slide. This is an example of an animal cell.
3. Use the coarse-adjustment knob to focus the slide as best you can. Then use the fine-adjustment knob to bring the image into sharp focus. You are actually viewing many red blood cells.
4. Select the highest magnification (400x).
5. Use the fine-adjustment knob to refocus the slide under the higher magnification.
6. Turn on the scale and determine the field diameter at 400x. For this microscope, the field diameter at 40x is 2 mm. To simplify your calculation, assume that the ocular scale occupies the whole field diameter so that the 10 ocular scale divisions equal 2 mm under 40x.
7. Make a biological drawing of a red blood cell as seen through the microscope under 400x magnification. Because red blood cells are so small, you will not be able to see many internal cell details at this magnification, so just draw what you can see. Estimate the size of the cell.

8. Go to the second screen "Viewing Plant Cells."
9. View examples of plant cells. Images of onion cells are provided already in position and in focus under low (40 $\times$), medium (100 $\times$) and high (400 $\times$) magnification.
10. Draw one of the onion cell samples under 400 $\times$ magnification. You will only be able to see certain large structures at this magnification (cell wall, membrane, nucleus, vacuole, and so on) so draw what you can see. Estimate the approximate size of the cell by how large it seems in relation to the field diameter.

Support Questions

9. Would you describe the shape of red blood cells as structured or irregular?
10. Do you find a cell membrane or a cell wall at the outer edge of the animal cell?
11. Would you describe the shape of onion cells as structured or irregular?
12. Do you find a cell membrane or a cell wall at the outer edge of the plant cell?

Regeneration

You cut your finger and it heals. You cut your hair and it grows back. You mow the grass and a week later it needs mowing again. Every organism can repair itself in some way. New cells grow to replace damaged or lost cells. The ability of living things to repair themselves is called regeneration. **Regeneration** is defined as the ability to re-grow a tissue, an organ, or a part of the body. Plants generally have greater powers of regeneration than animals do. Regeneration in animals varies greatly, with simple animals able to regenerate much more than complicated ones. For example, the starfish is a simple animal. It usually has five arms. If one arm is cut off, the tissue will be able to regenerate and a new arm will form. Starfish are made of only a few kinds of cells, so if a few cells are left alive, they can regenerate the missing ones. Other groups of animals are a bit more complicated. They are made of many kinds of cells and can regenerate only certain body parts. For example, a lobster or crab can grow a new claw. Salamanders can regenerate limbs, and lizards can regenerate severed tails—but they can't grow new heads or stomachs.

As animals become more complex, greater cell specialization is needed, so regeneration in complicated animals is very limited. Mammals (including humans) can only regenerate skin, nails, hair, and a few other tissues. Mammals cannot regenerate whole parts due to the complexity and specialization of their cells. You will learn more about cell specialization in Lesson 13.

Support Questions

13. Define regeneration.
14. Why can a starfish regenerate almost their entire body, while salamanders and lizards can only re-grow certain body parts?
15. What tissues can humans regenerate?

Cloning

Through modern medical science, scientists are now able to perform a type of regeneration called **cloning**. Although cloning is a natural process that allows simple organisms to reproduce, researchers have developed techniques to clone complicated animals. You may have heard of Dolly, a sheep in Scotland who was the first animal cloned from an adult organism. Recently some research companies have been offering to produce clones of dead family pets.

Cloning is the process of forming identical genetic offspring from a single cell. This occurs daily in nature. All somatic (body) cells can undergo the process of cell division, in which a copy of the genetic material is made; the cell then divides the genetic material and splits into two genetically identical cells.

The cells of your body do this every day to grow new tissue, repair damaged tissue, or replace lost tissue. Every cell of the human body is an identical copy (or clone) of another cell, with the exception of reproductive cells, which undergo a different process in order to make sperm or egg cells. The process of cell division is the focus of Lesson 12.

Types of Cloning

In addition to natural cell cloning, many organisms have the ability to produce offspring without a mate. Organisms that create offspring on their own demonstrate a form of cloning known as **asexual reproduction**. There are five main types of asexual reproduction:

1. **Binary fission**, carried out by bacteria, involves a cell splitting into two identical genetic copies.
2. **Budding** involves forming a small genetic copy of the organism that breaks off and develops into a full-grown genetic duplicate of the parent.
3. **Fragmentation** is demonstrated by many organisms, including starfish. Part of the parent organism (for example, a limb) breaks off, then grows into a new organism genetically identical to the parent.
4. **Spore formation**, often demonstrated by fungi, involves the formation of genetically identical cells encapsulated in a protective coating. Fungi usually release spores in the fall. These stay in the ground until favourable conditions for germination return in the spring, when a new mushroom will grow that is genetically identical to one that died the previous fall.
5. **Vegetative reproduction** involves a plant sending out runners (often underground) and having a genetically identical organism grow from the end of the runner.

Each of these forms of asexual reproduction produces a genetic duplicate, thus asexual reproduction is a form of cloning.

Cloning Technology

As scientific technology rapidly improves, concepts once thought possible only in Hollywood movies have become real. Artificial cloning is one of these. The process of organism cloning is not new, but improved technology has dramatically increased the success rate. Many plants can be easily cloned, including carrots, ferns, tobacco, petunias, and lettuce. Many animals have also been cloned successfully, including mice, frogs, cats, sheep, goats, pigs, and cows.

The initial process of cloning involves the use of a **stem cell**: an undifferentiated (unspecialized) cell that has not yet taken on a specific role within the organism. This means that all its genetic material is active and available. Once a cell begins to specialize, the genes unrelated to the cell's function are turned off or deactivated.

One type of stem cell often used in cloning comes from embryos in the very early stages of development. At this stage, every cell in the developing embryo is unspecialized and all its genetic material is available. The cloning process usually involves **embryonic nuclear transfer**. A nucleus is removed from a cell in the embryo and then inserted into an unfertilized egg cell, taken from another individual, which has been "enucleated" (had its nucleus removed). The result is an egg cell from one individual containing an exact duplicate of the genetic material of another individual.

This egg can be implanted into the uterus of a surrogate mother, where it will undergo division. It will eventually develop into an adult organism that is a clone of the parent who donated the nucleus.

First Successful Clone of a Mammal

Prior to 1996, scientists believed that only unspecialized cells, like those found in embryos, could be used to obtain a nucleus for cloning. However, this was disproven with the birth of Dolly. In 1996, a group of scientists in Scotland announced the birth of the first cloned mammal—a sheep named Dolly. This historic event was covered extensively by the media, mainly due to the ethical controversy surrounding the process. Many people feel that cloning is unethical and could lead to abuse of the technology, such as the cloning of humans.

Dolly was created through the process of **somatic nuclear transfer**: instead of using an embryonic cell, scientists used genetic material from an adult somatic cell (body cell) from the udder of a female sheep. This was revolutionary because it had been assumed that since the somatic cell had already undergone specialization, it would be impossible to get its genetic material to trigger the development of a complete organism. The Scottish scientists found a way to unlock the DNA from the somatic cell nucleus so that it would act like the unspecialized DNA in

an embryo and permit the full development of the embryo into a healthy lamb. This new technology opens the door to cloning all kinds of organisms, including humans, using any cell in the body.

Figure 11.5 shows the process that was used to create Dolly.

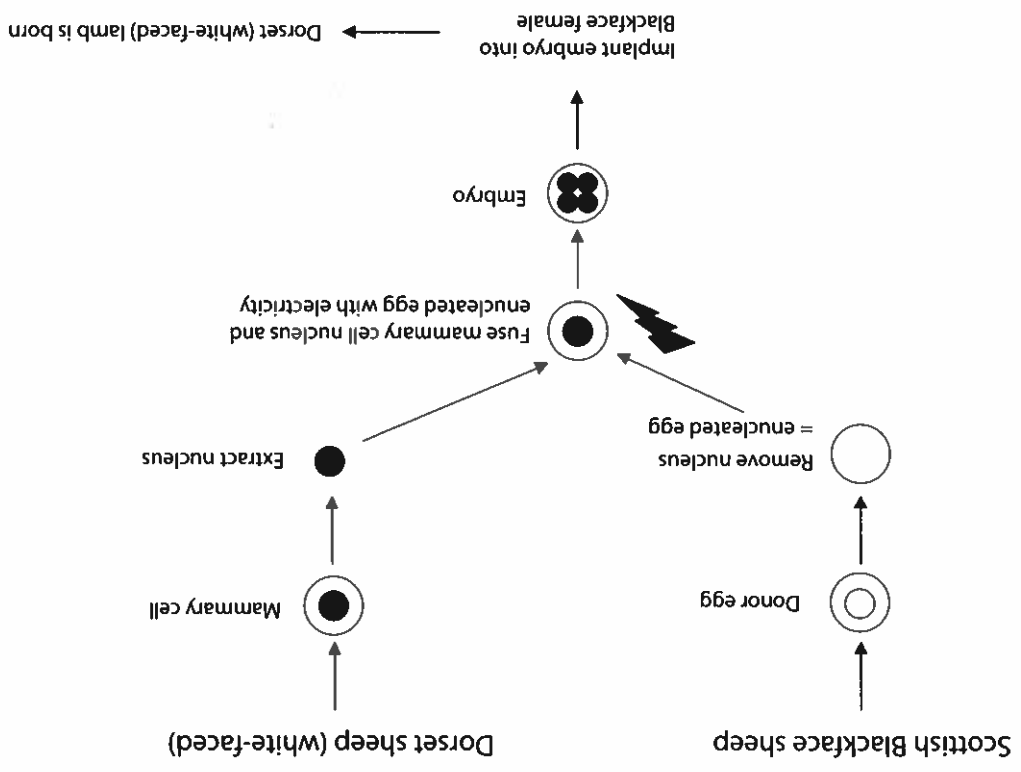


Figure 11.5 Process of creating Dolly, a sheep clone

An egg was removed from a Scottish Blackface, a sheep that, as its name suggests, has a black face. A mammary cell was removed from a Dorset sheep, which has a white face. After the nucleus was removed from the egg cell, the enucleated egg was fused with the nucleus from the mammary cell using electricity. This cell was then allowed to develop into an early embryo and implanted into a Scottish Blackface sheep. The offspring that was born did not look like its birth mother, but rather was a genetically identical copy of the Dorset sheep that had donated the mammary cell. It is currently illegal in most countries to attempt human cloning. Canada passed a bill in 1997 to outlaw human cloning; anyone who breaks the law faces a prison term. Nonetheless, human cloning may one day be a reality. It is important for scientists and other members of society to have informed discussions about the possibilities and ethical issues surrounding this topic.

Support Questions

16. Identify the five types of asexual reproduction.

17. Starfish feed on oysters. Oyster fishermen have been known to try to kill the starfish by scooping the starfish up from their oyster beds, chopping them up, and then dumping the pieces back into the water. Describe what you think probably happens to the number of starfish and oysters.

18. What is an enucleated egg?

19. What is the difference between embryonic and somatic nuclear transfer?

Conclusion

In this lesson, you learned about the basic structure of cells and the differences between plant and animal cells. You also learned how to use a microscope to draw and measure the size of cells. You learned that cell specialization determines how easily an animal's body parts can be regenerated. Finally, you learned the basics of somatic nuclear transfer cloning and how this process has opened the doors to cloning on a wide scale, if society is willing to accept it. In the next lesson you will learn more about cell replication by focussing on the process of cell division.

Key Concepts

Cell: the basic structural and functional unit of life

Unicellular organism: organism consisting of only one cell (for example, an amoeba)

Multicellular organism: organism made up of more than one cell. Humans are made of 100 trillion cells.

Cell theory: the three principles that form the basis of our knowledge about cells

Organelle: a specialized structure found within a cell

Compound light microscope: a type of microscope that uses visible light and two lenses to magnify images of cell-sized objects

Regeneration: the ability to re-grow a tissue, an organ, or a part of the body

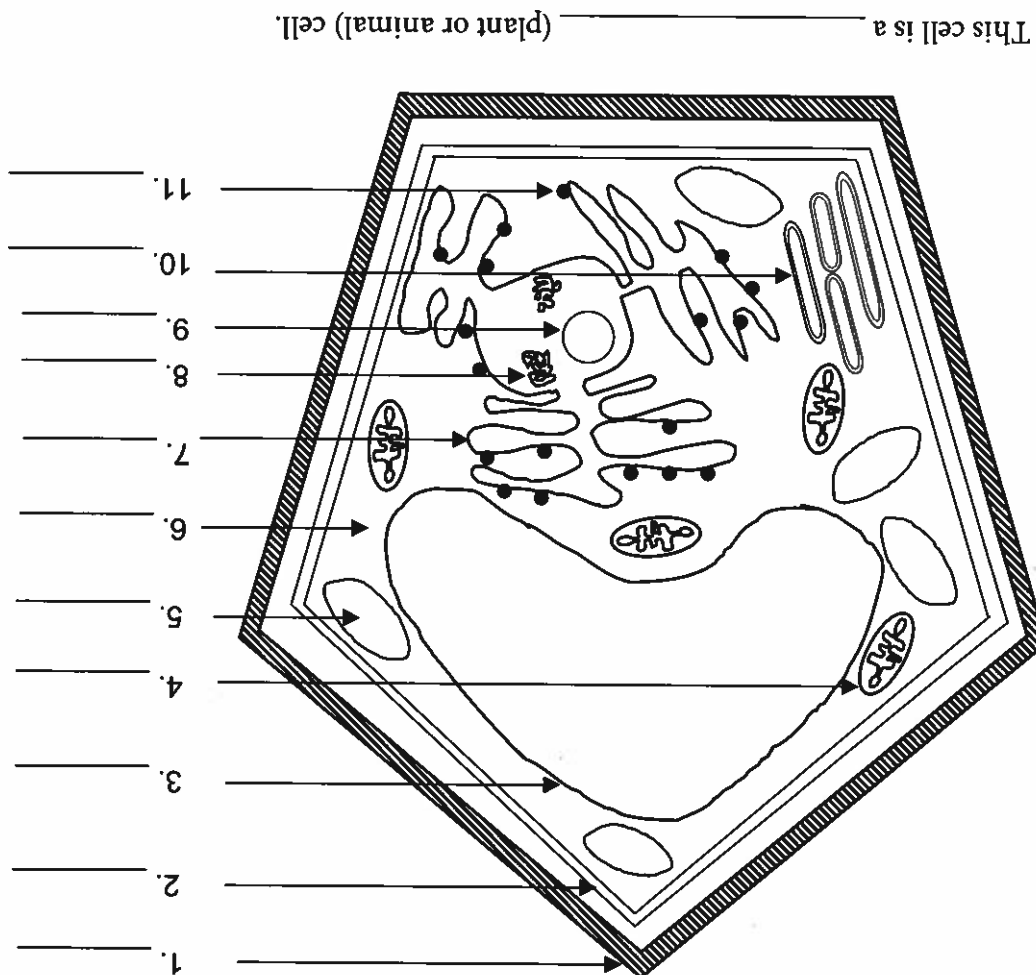
Cloning: the process of forming an exact genetic copy of a single cell

Asexual reproduction: reproduction without a mate. It produces a clone of the parent.

Stem cell: a type of undifferentiated (unspecialized) cell that has not yet taken on a specific role within the organism. A stem cell can develop into any kind of specialized cell.

Embryonic nuclear transfer: the process of making a clone by transferring nuclear DNA from an embryonic cell into an enucleated egg cell from another individual

Somatic nuclear transfer: the process of making a clone by transferring nuclear DNA from a somatic (body) cell into an enucleated egg cell from another individual



45. Label 8 of the 11 arrows in the following diagram of a cell. Identify the cell as either an animal or plant cell. (9 marks: 1 for each label and 1 for the identification of the cell)

Total: 20 marks

Save your answers to the Key Questions in your Course Journal or e-Journal.

Key Questions

46. Match each of the following organelles with its function. (4 marks)

Organelle	Function
1. Golgi apparatus	A. Contains the genetic material
2. Endoplasmic reticulum	B. Breaks down large molecules
3. Vacuole	C. Transport network
4. Nucleus	D. Absorbs sunlight for photosynthesis
	E. Produces ribosomes
	F. Stores and packages material
	G. Stores water and minerals
	H. Produces protein
	I. Regulates what enters and exits a cell

47. Describe three differences between animal and plant cells. (3 marks: 1 mark for each description)

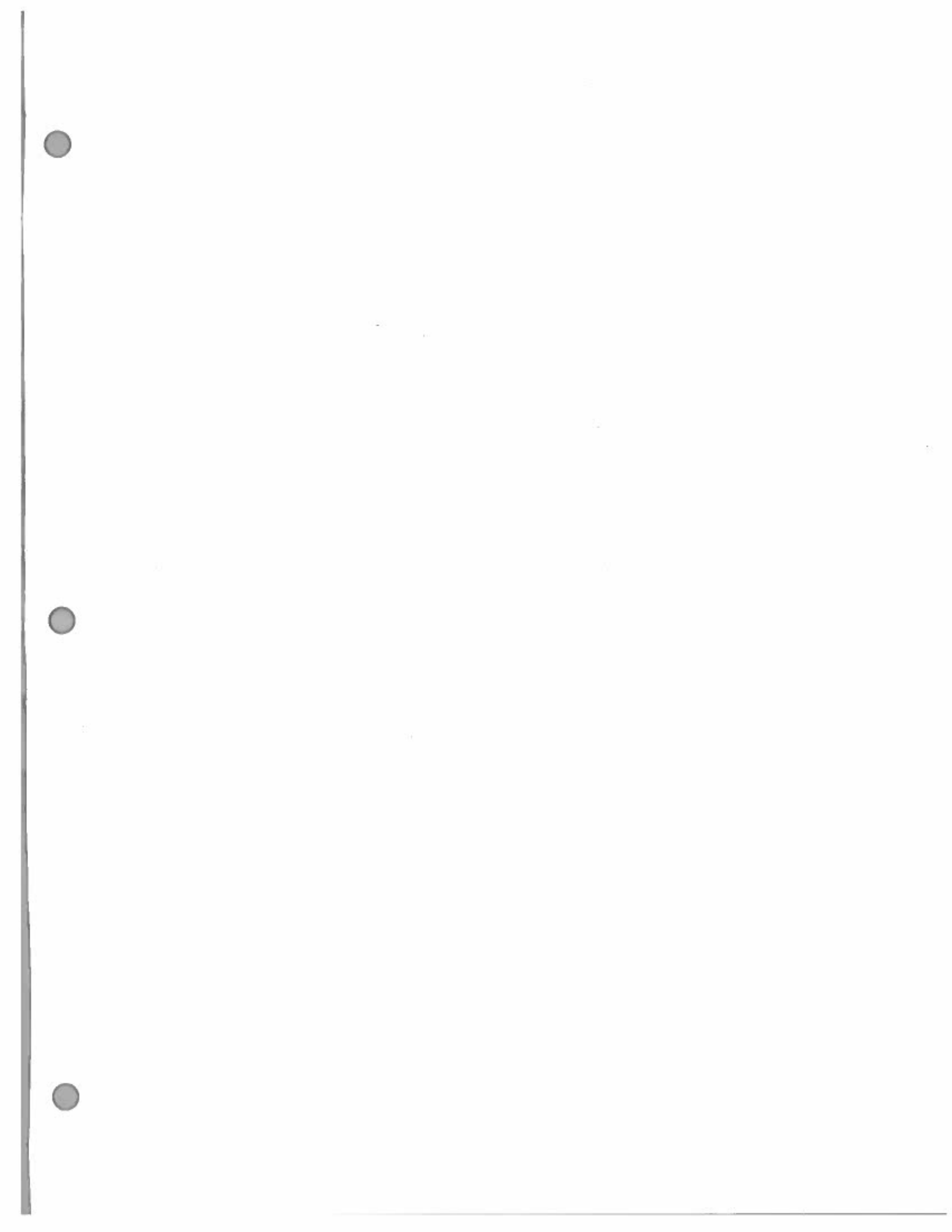
48. Describe the process of cloning. Your answer should include a description of somatic nuclear transfer, what is done to initially stimulate cell division, and how the offspring's genetic material compares to the donor of the somatic cell used for cloning. (4 marks)

Now go on to Lesson 12. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 3 (Lessons 11 to 15).

Cell Division



SNC2D-B



- describe the process of cell division
- identify the different stages of mitosis
- identify key differences between animal and plant cell division
- describe how abnormalities occur during cell division

After completing this lesson, you will be able to

What You Will Learn

Suggested Timing for This Lesson (hours)	
Cell Division	½
Cell Cycle	¾
Activity: Mitosis	1
Cancer	¼
Meiosis	1
Key Questions	1

You may find this time grid helpful in planning when and how you will work through this lesson.

Planning Your Study

Every human starts out as one tiny cell and eventually becomes an organism made up of over 100 trillion cells. When you cut your hair, more grows back. When you cut your finger, the wound repairs itself. When your sunburnt skin peels, it is eventually replaced by new skin. How does all this happen? How do you get so many cells and why do you never seem to run out? To answer these questions, you need to understand the process of cell division.

In this lesson you will learn about the cell cycle and the two forms of cell division. Cell division is a continuous process that occurs throughout your life. Generally it is a well-controlled process that keeps you healthy. But you will also explore some of the consequences of errors in cell division, including cancer, and see how cell division relates to aging.

Introduction

Cell Division

Cell division is responsible for growth. The human body starts out as one cell when a sperm cell fertilizes an egg cell. Cells divide at a rapid rate during pregnancy, and continue dividing quickly after birth as you grow. The rate of cell division is most rapid during the childhood and adolescent years, and then slows down during adulthood.

When you are born, you are made up of trillions of cells. Yet you started as just one cell. How can cell division reach that number in such a short time? The answer lies in exponential growth. With every cell division, the number of cells doubles. Using the table provided, determine how many cells there would be after 5 divisions and then after 10 divisions.

Table 12.1 Exponential growth by cell division

Number of Divisions	Number of Cells
0	1
1	2
2	4
3	8
4	
5	?
6	
7	
8	
9	
10	?

After 5 divisions, the number of cells would be 32. Because $2 \times 2 \times 2 \times 2 \times 2 = 32$, this can also be expressed as 2^5 .

After 10 divisions, the number of cells would be 1024, or 2^{10} .

Now, how many divisions do you think it would take to make a trillion cells? (A trillion is a thousand billion, or 1 with 12 zeros after it, or 1×10^{12} .) The answer is only about 40! That's the power of exponential growth.

Cell Division: Basic Terminology

To understand the concept of cell division you need to be familiar with some key terminology. Most of the following terms relate to the genetic material in the cell, particularly to its packaging and distribution.

Chromosomes are the structures in the nucleus that contain the DNA (deoxyribonucleic acid). They are composed of two halves, the *chromatids*. Each chromatid is made of *chromatin*, which is composed of highly condensed strands of DNA. Chromosomes are a way to arrange large amounts of DNA into a relatively small and easily manipulated package, just as rolling long strands of yarn into a ball makes it easier to handle.

Near the centre of the chromosome is an area called the *centromere*. This is the region where microtubules attach during mitosis and meiosis in order to pull the chromosome around. You can think of it as a handle. A chromosome typically looks like a flattened “X”; each arm of the “X” is a chromatid with a centromere in the middle, as shown in the diagram below.

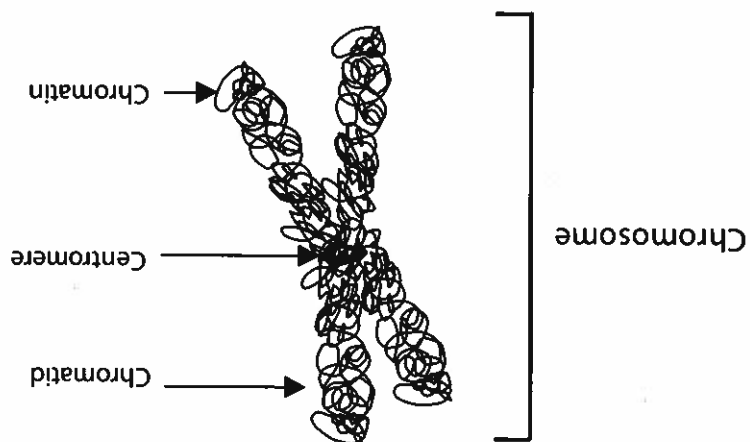


Figure 12.1 Structure of a chromosome

During cell division, chromosomes have to be doubled, then split apart so that each of the daughter cells gets one copy. When chromosomes are doubled, they form a pair of *homologous chromosomes*. These are two chromosomes of the same size, appearance, and gene arrangement.

When a cell has finished dividing, it has as many chromosomes as its parent cell. That means it contains two copies of every chromosome, one from the father and one from the mother. When a cell has the full complement of chromosomes, it is called **diploid** and it is said to contain **2n** chromosomes (where **n** represents the number of chromosomes for that species). During cell division for reproduction (meiosis), the sperm and egg cells contain only half the number of chromosomes; they are called **haploid** and are said to contain **n** chromosomes.

Different organisms have different numbers of chromosomes. You might assume that the more complicated or seemingly advanced the organism, the more chromosomes it needs in order to store more genetic information—but this is not the case. While humans have 46 chromosomes, chimpanzees have 48, ducks have 80, and ferns have 1262; clearly chromosome number alone does not determine complexity.

Cell Cycle

The approximately 100 trillion cells in your body began as a single fertilized egg cell. This cell divides into two cells, then each of these divides into two cells, and so on. The sequence of events from one division to another is called the **cell cycle**. Cells are always in some phase of this cycle. The cell cycle can be divided into three phases: **interphase**, **mitosis**, and **cytokinesis**. Each of these phases will be explained in more detail in sections below.

A pie chart is a useful way to represent the cell cycle. The following pie chart depicts the sequence of the five activities that occur in an animal cell cycle. Ninety percent of the cell cycle consists of a period of growth called interphase (including the G_1 , S, and G_2 phases), and 10 percent is a period of division, including the two phases of mitosis and cytokinesis.

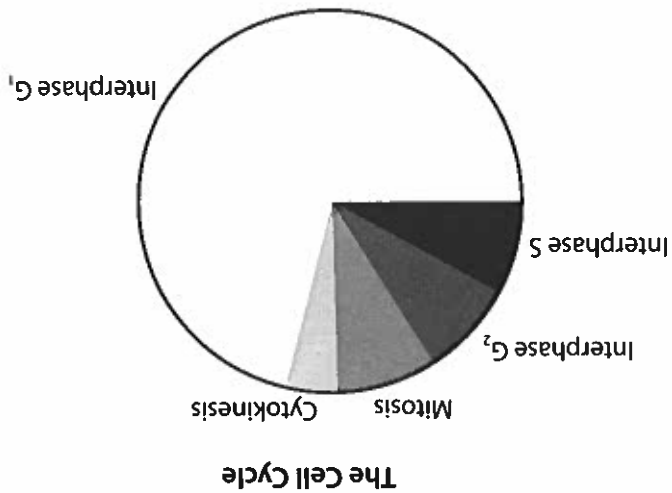


Figure 12.2 The cell cycle in an animal cell

The amount of time it takes to complete one full cell cycle depends on a number of things. For instance, some types of bacteria can rapidly divide, performing the entire cycle every 20 minutes. Human cell cycles can take 8 to 24 hours. The cell cycle varies not only from species to species, but also from cell type to cell type. The cells in your body do not all divide at the same rate. The lifespan of a cell depends upon the “wear and tear” on that cell. A cell’s location determines

how much abuse it will get, just like a tire's location on a car determines how much wear it will get—a tire receives a lot more wear when it is being used on the car than it would get stored as a spare in the trunk.

One question that has yet to be answered completely is *why do people get older?* If our body is continuously replacing cells, why don't we simply look and feel the same way all the time? It may be because of changes to the cell cycle. Research indicates that there is a limit to the number of times a cell can divide, and different cells seem capable of different numbers of divisions. If cells die and are not replaced because the cycle has stopped, damage will build up and inhibit the function of associated organs. Eventually, the damage becomes so serious that an organ or organ system can no longer function and the person dies. Scientists are researching the cell cycle in an attempt to understand degenerative conditions like aging.

Interphase

Interphase is the stage where a cell prepares to undergo cell division. It is the longest stage of the cell cycle. During this time the cell grows and accumulates nutrients needed for division. It also involves periods of rest. It is made up of two resting periods known as Gap 1 (G_1) and Gap 2 (G_2), and an active phase known as the Synthesis phase or S phase. The S phase is the most important: during this stage the genetic material (DNA) is replicated. Each of these stages is described in more detail below.

Three Stages of Interphase

1. **First growth (G_1) phase.** The cell grows and carries out most of its normal life functions such as metabolism and building proteins. If it is a specialized cell in a human body, it will also perform its primary job during this phase. Muscle cells will contract. Blood cells will deliver oxygen. Some cells never divide after they have specialized. For example, nerve cells in the brain and muscle cells will remain in this growth phase of cell division for their entire life.
2. **Synthesis (S) phase.** The cell's genetic material is duplicated. This material consists mostly of very long molecules called DNA (deoxyribonucleic acid), which are copied so that when the cell divides, both of the new cells produced (called daughter cells) will have the genetic instructions needed to carry out normal cell processes. DNA is often called the "software of the cell" as it contains most of the templates and information needed to create proteins and to direct the activities of the cell.

Mitosis

3. Second growth (G_2) phase. Protein components that help with cell division are copied. The cell's nucleus is very well defined (becoming large and easily visible) during this phase.

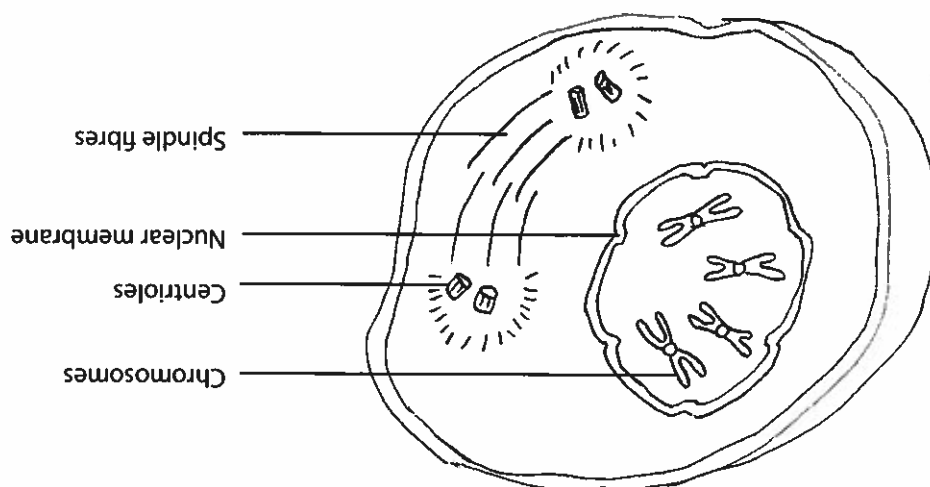
At the end of interphase, the cell is ready for division. The process of division—one cell dividing into two exact copies of itself—is called mitosis.

Mitosis is the process of dividing genetic material during cell division. Every somatic cell (every cell of the body) undergoes the process of mitosis. The only exception is reproductive cells found within the testes or ovaries. These cells undergo a process known as meiosis, described later in this lesson.

Mitosis has three purposes. First, somatic cells undergo the process of mitosis in order to make more cells, which allows for overall growth of the organism. Cells cannot simply grow in size; the distance of the nucleus from all parts of the cytoplasm must be kept small for efficient communication. Second, mitosis occurs in order to repair any damaged tissue. If an organism receives a cut or scrape, cellular division will occur to heal the wound. Third, mitosis is necessary to replace any tissue that is lost, for example through sunburn.

The end result of the mitotic process is two identical daughter cells that have the exact same number and type of chromosomes as the original parent cell. Each stage in the process of mitosis is explained in the following sections.

Figure 12.3 Prophase



- sister chromatids join together to form chromosomes
- the point of connection is called the centromere
- chromosomes condense and become visible
- nuclear membrane begins to dissolve
- centrioles, used to move the chromosomes, migrate towards opposite ends of the cell ("the poles")

Prophase

Metaphase

- chromosomes line up in the middle (equator) of the cell
- spindle fibres (like cellular "tow ropes") shoot out from the centrioles and connect to the centromeres of chromosomes

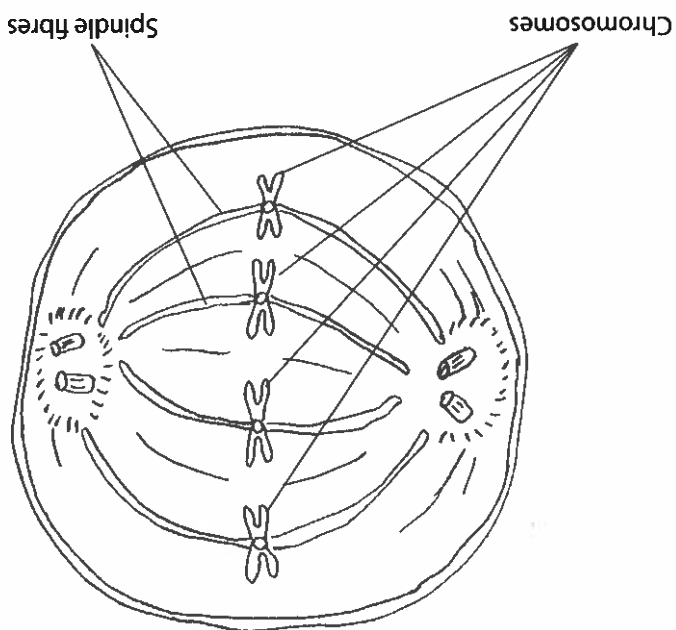
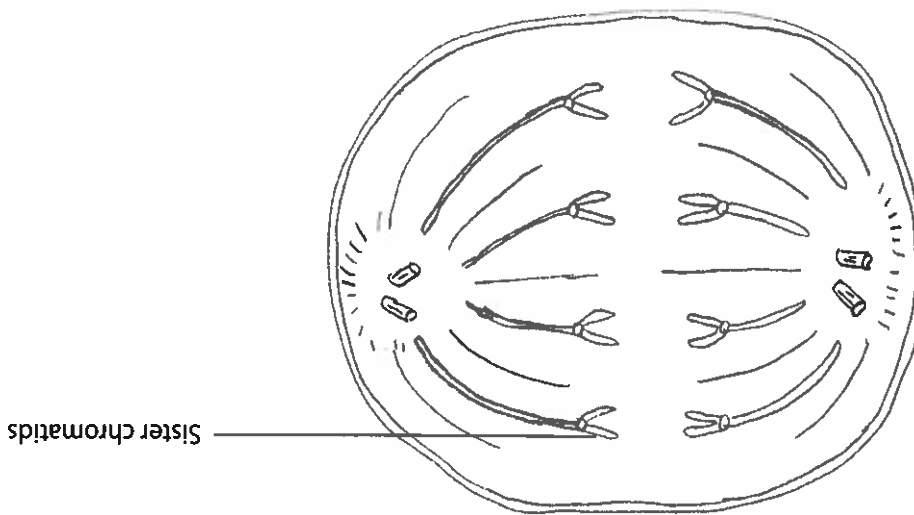


Figure 12.4 Metaphase

Figure 12.5 Anaphase



- spindle fibres begin to retract (like pulling on the "tow ropes")
- this exerts a force on the sister chromatids that pulls them apart
- the two halves move to opposite poles of the cell

Anaphase

Telophase

- chromatids reach the opposite pole
- genetic material begins to recondense
- a nuclear membrane begins to form around each set of chromatids
- cell membrane begins to pinch and form two cells
- the process of cytokinesis begins

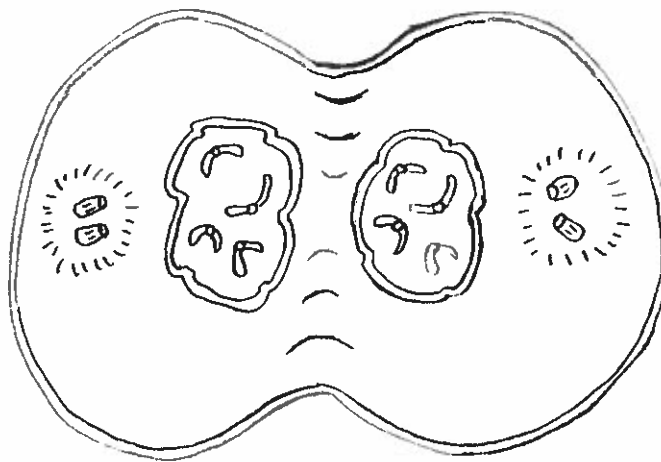


Figure 12.6 Telophase

Many people find that a mnemonic sentence helps them remember the sequence of stages in mitosis. An example is given below. Try to develop your own sentence to remember the stages in order.

Interphase Prophase Metaphase Anaphase Telophase
I Picked Many Apples Today

After the genetic material of the cell has successfully been copied in mitosis, it is time for the last phase of the cell cycle, cytokinesis.

Cytokinesis

In **cytokinesis**, the final phase of the cell cycle, the cytoplasm divides in half, producing two fully independent, separate cells. In Lesson 11, you learned that the layer that surrounds an animal cell is called the cell membrane. This membrane plays a major role in cytokinesis. During cytokinesis in animal cells, the membrane pinches inward, forming a wall between the two halves. Eventually this wall closes up, dividing the cell into two equal parts. Plants undergo a slightly different process, building up a new cell wall between the two halves of the nearly divided cell.

The end result of cell division (mitosis and cytokinesis) is two smaller cells that contain identical genetic information. These are called daughter cells. For example, if the starting cell is a skin cell, then the result will be two identical skin cells.

Support Questions

Do not send your answers in for evaluation.

20. List the three parts of the cell cycle.
21. Which part of the cell cycle takes longest?
22. What happens during the S phase of interphase?
23. What are the four stages of mitosis?
24. What types of cells undergo mitosis?
25. What is the purpose of mitosis?



Activity: Mitosis

Objective

To determine the time required for the various stages of the cell cycle of a fish and calculate the dividing time, both in normal cells and ones with cancer.

Go to your course page on the ILC website and click on "Viewing and Classifying Cells in Various Stages of Mitosis" under Lesson 12.

In this activity, you see pictures of cells from an animal called a whitefish, whose cells closely resemble your body cells when dividing. Using the virtual microscope, you will examine two sets of cells. The first set will be from normal tissue and the second set will be from cells that have cancer. (You will learn more about cancer later in this lesson.)

Begin the activity by counting and classifying the phase each cell is in as it appears on your screen. The phase choices are interphase, prophase, metaphase, anaphase, and telophase. Then you will total up the cells found in each phase and use those numbers to predict how much time a dividing whitefish cell spends in each phase. You will base your calculation on a total cell cycle time of 24 hours. You will do this for both the normal and cancer cells (40 of each). Use the following tables to keep a tally of the different cells you will view. After counting the cells, you will write the percentage in the "percent of cells" row.

There are Suggested Answers to Support Questions at the end of this unit.

26. What is the end result of mitosis?

27. During which stage of mitosis do chromosomes line up at the equator of the cell?

28. During which stage of mitosis does the nuclear membrane dissolve?

29. What happens during cytokinesis?



Part 1: Normal Cells

Table 12.2 A blank table in which to keep your tally of normal cell mitosis

	Interphase	Prophase	Metaphase	Anaphase	Telophase	Total
Number of cells						
Percent of cells						100%
Time spent (hours)						24 hours

Part 2: Cancer Cells

Table 12.3 A blank table in which to keep your tally of cancer cell mitosis

	Interphase	Prophase	Metaphase	Anaphase	Telophase	Total
Number of cells						
Percent of cells						100%
Time spent (hours)						24 hours

Analysis

Calculate the time spent in each phase.
Example:

Number of cells in prophase = 16

Total number of cells observed = 40

Percentage of cells in prophase = 40%

Time spent in prophase = 40% × 24 hours = 9.6 hours

Support Question

30. After completing the cell cycle activity ("Viewing and Classifying Cells in Various Stages of Mitosis") you will be able to answer the following questions.

a) Complete the following table.

Stage	# Cells viewed in stage	Percent of cells in this stage	Time spent in stage
Interphase			
Prophase			
Metaphase			
Anaphase			
Telophase			
Total		100%	24 hours

b) In which stage do normal cells spend most of their time? How are cancer cells different in this respect?

Cancer

Sometimes our DNA can mutate, leading to uncontrolled cell growth known as cancer. This mutation is usually the result of external factors such as radiation from the sun, viruses, cigarettes, alcohol, and other toxic chemicals.

Most cells divide through communication with similar cells, but cancer cells divide on their own, regardless of what other cells are doing around them. As you saw in the mitosis activity, cancer cells divide at a faster rate than normal cells. In fact, they divide so rapidly that they don't get a chance to develop a specialized function like other cells.

In Lesson 11, you learned that cells can become specialized to form specific cells such as nerve cells and muscle cells. Your body has specialized cells called immune cells that detect and destroy bacteria and some kinds of cancer cells. Unfortunately, sometimes your immune cells are unable to detect and destroy cancer cells because they are "camouflaged" as normal cells.

Cause	Percentage
Smoking	32
Diet	30
Viruses	10
Environment	10
Sexually transmitted diseases	7
Alcohol	3
Food additives	2
Excessive sunlight	1

Table 12.4 Some common causes of cancer

These cancer cells will continue to grow and divide until they form a mass of cells called a **tumour**. Some tumours are diagnosed as benign (non-harmful). For instance, if the mass of mutated cells remains where the mutation started, does not grow in an unlimited manner nor invade surrounding tissues, it is referred to as a **benign tumour**. If a doctor suspects that a benign tumour is becoming cancerous, she often removes it by surgery, assuming it is in an operable location.

A benign tumour that becomes cancerous can begin to flake off tumour cells. If the cancer cells dislodge from the original site, cancer can spread throughout the body (a process called **metastasis**). In this case the tumour is a harmful or **malignant tumour**. Metastasis of cancer cells results in new cancer colonies. These cells travel to other tissues in the body through the circulatory or lymphatic system. A person with a malignant tumour is considered to have been infected with cancer. A person with a benign tumour will be monitored and tested periodically, but is not considered infected with cancer.

Cancer cells are unwanted mutations from inside your own body. Cancer is not contagious, but the risk (predisposition) for cancer can be passed down from grandparents to parents to children. Just like normal cells, cancer cells require nutrients, oxygen, and living space—hence cancer cells can often starve normal body cells.

The causes of cancer are complex. However, research has shown that various factors can play a role. The following table shows the major causes of cancer based on external factors.

Support Questions

- 31.** Which of the causes of cancer listed on page 15 could be reduced by changes in lifestyle?

- 32.** Explain the difference between a benign and malignant tumour.

Meiosis

As you have seen, the process of mitosis produces identical copies of the parent cell. But sometimes an identical copy is not desirable. Organisms that reproduce sexually, like humans, combine the genetic material of two parents to produce an offspring. If each parent were to give a diploid cell (containing $2n$ chromosomes) to the offspring, then the offspring would start out with $4n$ ($2n + 2n$) chromosomes. When that generation grew up and reproduced, their offspring would have $8n$. In only a few generations, the number of chromosomes in the cells would be in the trillions, and the cell would have to be as big as a house just to hold it all.

Clearly this is not desirable, so reproductive cells undergo a process of division that does not duplicate the genetic material. This process is called **meiosis**.

Organisms that reproduce sexually contain two types of cells with the following characteristics:

1. Somatic cells
 - divide by mitosis
 - each daughter cell contains the full number (diploid) of chromosomes as the parent cell

2. Reproductive cells

- divide by meiosis
- each daughter cell contains half the number (haploid) of chromosomes as the parent cell

Meiosis is a special type of cell division occurring in organisms that reproduce sexually. It is a process very similar to mitosis. The purpose of meiosis is to create **gametic cells** (sperm and egg cells) to allow for sexual reproduction of the organism. In males the process is referred to as **spermatogenesis** (the formation of sperm cells); in females the process is referred to as **oogenesis** (the formation of egg cells).

Gametic cells must be haploid; that's to say, they must have half the number of chromosomes as somatic cells. In humans this means that one sperm cell contains 23 chromosomes and one egg cell contains 23 chromosomes. These can fuse together to make a zygote containing 46 chromosomes. This is the first cell that eventually leads to the adult organism.

In order to create a haploid cell, the process of meiosis involves two divisions rather than just one. As in mitosis, there is an interphase phase prior to meiosis in which the genetic information duplicates. The eight stages of meiosis of a human reproductive cell are outlined below.

Prophase I

- The chromosomes condense and become visible.
- The centrioles move towards the poles.
- The nuclear membrane begins to dissolve.
- Homologous chromosomes pair to form a "tetrad."
- Each tetrad is composed of four chromatids.

Homologous chromosomes will swap genetic material in a process known as *crossing over*, which serves to increase genetic diversity.

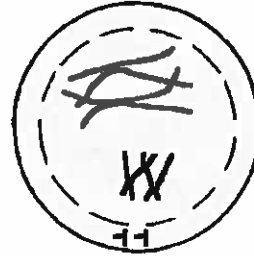


Figure 12.7 Prophase I

Metaphase I

- Tetrads align at the equator.
- Spindle fibres shoot out from the centrioles and attach to the centromeres of chromosomes.

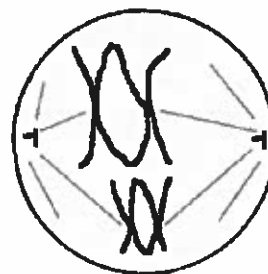


Figure 12.8 Metaphase I

Anaphase I

- Homologous chromosomes are pulled apart.

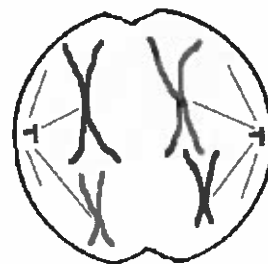


Figure 12.9 Anaphase I

Telophase I

- Two cells are formed, each containing one homologous pair.

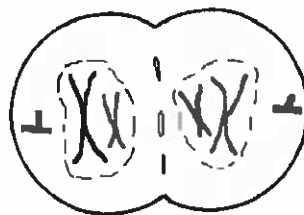


Figure 12.10 Telophase I

NOTE: There is no second interphase in meiosis because this would reduplicate the genetic material, preventing the creation of haploid cells.

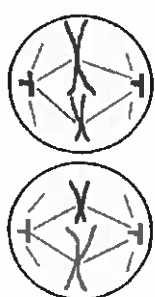
Figure 12.13 Anaphase II



- Sister chromatids are pulled apart as spindle fibres retract.

Anaphase II

Figure 12.12 Metaphase II



- Chromosomes align at equator.
- Spindle fibres attach to centromeres.

Metaphase II

Figure 12.11 Prophase II



- Centrioles move to the poles.
- The nuclear membrane dissolves.

Prophase II

Telophase II

- Four haploid cells are formed, with only 23 chromatids in each cell.

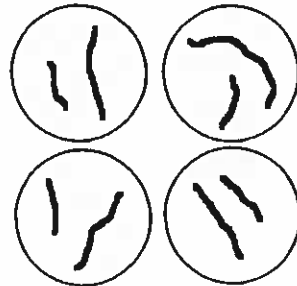


Figure 12.14 Telophase II

Problems During Meiosis

If errors occur during division of a somatic cell, such as a skin cell or a liver cell, it may not cause much harm because there are many other cells of the same type to keep the organism functioning properly. However, if something goes wrong in a reproductive cell during meiosis, the resulting fertilized egg will contain an improper amount of genetic material. Since every subsequent somatic cell is a descendent of that original fertilized egg, each will contain the same mistake. This could inhibit the organism from functioning properly.

The failure of chromosomes to divide correctly during meiosis is called **nondisjunction**. Cells that lack genetic information or have too much information will not function properly. The following are examples of nondisjunction disorders:

- Down Syndrome—extra chromosome 21
- Edwards Syndrome—extra chromosome 18
- Patau Syndrome—extra chromosome 13
- Turner Syndrome—missing chromosome 23
- Klinefelter Syndrome—extra chromosome 23

Support Questions

33. How is meiosis different from mitosis?

34. Why is there only one interphase associated with meiosis?

35. What types of cells undergo meiosis?

36. What is the purpose of meiosis?

37. What is the end result of meiosis?

38. During which stage of meiosis do homologous chromosomes find each other and pair up?

39. During which stage of meiosis do sister chromatids get pulled to opposite sides of the cell?

40. Define nondisjunction.

41. What type of nondisjunction results in Down Syndrome?

Conclusion

In this lesson, you learned that cells have a lifespan that revolves around their cell cycle. During brief periods in their life, cells may duplicate and divide by the process of mitosis. This results in identical daughter cells. Reproductive cells undergo a slightly different process called meiosis, where the cell is reproduced with only half its original number of chromosomes.

The cell cycle and cell division are central to the process of life. Problems can arise during the cell cycle leading to medical conditions, such as genetic diseases and cancer. Aging may also be caused by changes in the cell cycle.

In the next lesson, you will learn how cells can specialize to carry out all the functions necessary to create complex organisms.

Key Concepts

Chromosomes: structures in the nucleus that contain the DNA (deoxyribonucleic acid)

Diploid: a cell that has the full complement of chromosomes (2n)

Haploid: a cell that has half the complement of chromosomes (n)

Cell cycle: the sequence of events in the life of a cell from one division to another

Interphase: the stage in the cell life cycle where a cell prepares to undergo cell division. The genetic material is duplicated at this stage.

Mitosis: the stage in the cell life cycle where a cell undergoes cell division to produce two identical daughter cells that contain the full number of chromosomes (diploid)

Prophase: the stage in cell division where the cell's internal structure is getting ready to divide

Metaphase: the stage in cell division where the chromosomes line up in the middle of the cell

Anaphase: the stage in cell division where the chromosomes are being pulled to opposite poles

Telophase: the stage in cell division where chromosomes are at the poles and the cell begins to physically divide, with the membrane pinching down in the middle

Cytokinesis: the stage in the cell life cycle where the duplicated cell divides into two halves

Cancer: a disease caused by flaws in the cell cycle; cells divide very rapidly beyond the control of the rest of the body

Tumour: a group of cancer cells that form a mass

Benign tumour: a non-harmful tumour that remains where the mutation started, without growing in an unlimited manner or invading surrounding tissues

Metastasis: the spreading of cancer cells from their original site

Malignant tumour: a harmful tumour that spreads throughout the body

Meiosis: a stage in the life cycle of reproductive cells that results in duplicated cells containing only half the original number of chromosomes (haploid)

Gametic cells: reproductive cells like sperm or eggs

Nondisjunction: a flaw during meiosis whereby the number of chromosomes in the gametic cells is wrong because of problems in the way the chromosomes divide

Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 21 marks

49. Use your knowledge of cell division to complete the table below for four stages of mitosis. (12 marks: 1 mark for the location of the chromosomes and 2 marks for the description of the stage)

Phase	Where are the chromosomes?	What is happening?
Prophase		
Metaphase		
Anaphase		
Telophase		

Now go on to Lesson 13. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 3 (Lessons 11 to 15).

51. Why is it worse for nondisjunction to occur during meiosis than mitosis? (2 marks)

Factor	Mitosis	Meiosis
Type of cell involved		
Number of divisions		
Number of genetic duplications		
Number of resulting cells		
Chromosome # of parent cell		
Chromosome # of resulting cells		
Function of process		

50. Complete the table below to compare the division processes of mitosis and meiosis. (7 marks)



SNC2D-B



Cells That Specialize

Introduction

Look at yourself in the mirror. What do you see? You have eyes, lips, skin, and hair. If you open your mouth, you see your tongue and gums. If you could see inside yourself, you'd see your heart, lungs, stomach, muscles, bones ... too many parts to name here.

Each of these parts has a job to do—its function. Thus each part needs to be built using special cells designed to do that job. Just as you can't use a hammer to do the job of a screwdriver, your lungs can't do the job of your eyes. Your body is full of many different types of cells, yet you were created from just two cells: a sperm and an egg. So how do all these other cells get made?

Mitosis can explain how you get more cells in your body, but mitosis produces exact copies of the original cell. In order to create all the different structures in your body, some cells have to change from the original and become specialized to do a certain job. In this lesson, you will learn about the different kinds of specialized cells that are needed and how they are created.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Cell Specialization	$\frac{1}{2}$
Animal Cell Types	1
Activity: Microscopic Examination of Animal Cells	$\frac{3}{4}$
Plant Cell Types	$\frac{1}{2}$
How Cells Become Specialized	$\frac{1}{2}$
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- explain why cells specialize
- explain what a stem cell is and what role it plays in cell specialization
- compare embryonic and adult stem cells
- describe the structures and functions of different types of animal and plant cells

Cell Specialization

Unicellular organisms are living creatures made up of only one cell. All the functions required by that organism are carried out within that cell. Multicellular organisms, on the other hand, are much more complex and require many different types of specialized cells to carry out various functions. Examples of specialized cells include the muscle cells that help the organism move and the blood cells that carry nutrients and help remove waste.

In multicellular organisms, there is a hierarchy of cellular organization. A **cell** is always considered to be the basic functional unit of life. If multiple cells with the same functions are joined together, the structure is called a **tissue**. If multiple tissues work together to perform a specific task, they are referred to as an **organ**. If multiple organs work together to perform a specific task (respiration, digestion, reproduction), they are referred to as an **organ system**. Multiple organ systems are integrated into the overall function of an **organism**, or complete life form.

To help you remember this organization, think of an organism as a book. An organ system would be like a chapter within the book, while an organ would be like a page within the chapter. Finally, a tissue would be like a word on the page and a cell would be like a letter within the word.

Cell specialization is also referred to as cell differentiation.

Example of an Organ System: The Circulatory System

A human being is an organism made up of multiple organ systems, including the circulatory system. The function of the circulatory system is to transport oxygen and carbon dioxide. It also plays important roles in transporting nutrients and hormones, excreting waste, and regulating temperature.

The circulatory system is an example of an organ system organized in a hierarchy. The main organ of the circulatory system is the heart, which pumps blood throughout the body. The heart is made up of several different types of tissue, including muscle tissue, nervous tissue, and dermal (skin) tissue. These tissues are made up of different kinds of cells, including cardiac muscle cells, smooth muscle cells, neuron cells, and dermal cells.

Types of Specialized Cells

All organ systems are made up of many kinds of specialized cells. To understand how they are created. You will start by learning about the different kinds of animal and plant cells.

Plants and animals have their own unique types of specialized cells. For example, animals have cells that are specialized for contracting (heart and muscle cells), digesting (mucosal and gland cells), structure (bone cells), communication (brain cells), transport (blood cells), and many more. Having different structures than animals, plants have cells specialized for their needs. For example, plants have cells responsible for growth called meristematic cells, as well as cells responsible for transporting water and sugars. Plants also need cells to protect the surface of stems and leaves, as well as cells within their leaves (mesophyll cells) that are responsible for turning light into food in the process called photosynthesis.

Because different types of cells have different functions, they contain different types of organelles. For example, cells in your pancreas are responsible for producing digestive enzymes. Because enzymes are made from protein, pancreatic cells contain large numbers of the organelles needed for protein production like ribosomes, endoplasmic reticulum, and Golgi apparatus. Similarly, heart and muscle cells require large numbers of mitochondria to make the energy needed to keep the heart beating and move the animal around.

The shape of a cell is dictated by its function and the conditions under which it works. In order for a cell to specialize, it may have to change shape, lose organelles (including the nucleus), or even shed little pieces of itself. These different cellular shapes will be discussed in the next section.

Support Questions

Do not send your answers in for evaluation.

- 42.** Put the following terms in order from smallest to biggest:

organ, cell, organism, tissue, organ system

- 43.** What is cell specialization (also known as cell differentiation)?

- 44.** List three different functions that animal cells must carry out.

- 45.** Why do different types of cells have different types of organelles?

There are Suggested Answers to Support Questions at the end of this unit.

Animal Cell Types

Animals, including humans, have a wide range of cell types that carry out a variety of different functions. The following sections will describe the structure and function of some common cell types.

Blood Cells

Blood cells play important roles in both the immune system and the circulatory system. Even though blood travels in a liquid form through veins, arteries, and capillaries, it is classified as a tissue because it is a collection of different cells that performs a set of particular tasks.

Source: iStockphoto.com

Figure 13.1 Red blood cells



Red blood cells, shown below, specialize in transporting oxygen throughout the body. They have a flattened, disk-shaped appearance. This shape increases their surface area and allows them to travel within tiny vessels. To maximize their effectiveness, red blood cells are missing most organelles, including a nucleus. Instead, they are packed full of oxygen-binding proteins known as hemoglobin.

Red Blood Cells

Function	Size	Origin
To carry oxygen and carbon dioxide	Small (8 micrometres in diameter)	Bone marrow
To fight off infection	Large (10–25 micrometres in diameter)	Bone marrow, spleen, and lymph nodes
To aid in blood clotting	Tiny (2 micrometres in diameter)	Bone marrow

Table 13.1 Summary of the features of the three blood cell types

The following table summarizes the features of each type.

- red blood cells (erythrocytes)
- white blood cells (leucocytes and lymphocytes)
- platelets

Blood is composed of two components: plasma and cells. Making up the bulk of blood, plasma is a solution of water, dissolved gases, proteins, sugars, vitamins, minerals, and waste products. There are three main types of blood cells:

White Blood Cells

White blood cells are involved in the immune system. All white blood cells contain nuclei, which makes them easy to distinguish from red blood cells. The presence of a nucleus allows white blood cells to alter their function as needed to protect the body from different types of foreign invaders.

There are two types of white blood cells: *leucocytes* and *lymphocytes*. Leucocytes are large opaque blood cells that can either engulf (swallow) invading microorganisms or produce antibodies to fight off infection. Lymphocytes are white blood cells that are released in response to foreign invasion. They are designed to identify and mark as “non-self” any foreign cell in the blood, and release antibodies or other forms of defence to destroy the invader.

Platelets

The final type of blood cell, the megakaryocyte, stays in the bone marrow. Megakaryocytes manufacture and shed millions of little pieces of themselves into the blood. These pieces of cell, called platelets, help the blood clot to seal up cuts and wounds.

Nerve Cells

The nervous system is the most important system in the entire human body. It is responsible for responding to changes in the internal and external environment. The entire nervous system is an integrated network of nerves. A nerve is a tissue made up of a bundle of specialized cells called *neurons*. There are three types of neurons found within the human body: *sensory neurons*, *motor neurons*, and *interneurons*. Sensory neurons receive the stimulus and send impulses to the brain. Motor neurons carry impulses from the brain to muscles or glands. Interneurons, found only within the brain and spinal cord, help coordinate the appropriate response. They typically link the sensory and motor neurons. The general appearance of a neuron is shown in Figure 13.2. The long, thin part is called the *axon*. The signal generated in the main body of the neuron travels down the axon where it gets picked up by another neuron. The smaller branching extensions are called *dendrites*, and this is where the neuron receives signals. Most neurons have a similar structure; however, interneurons typically do not have dendrites.

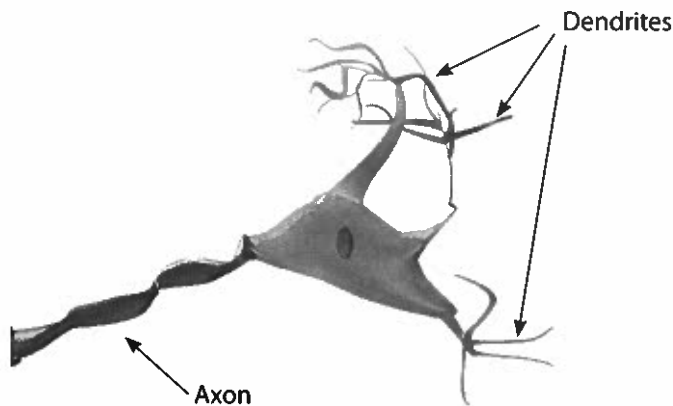


Figure 13.2 Structure of a neuron

Source: iStockphoto.com with added labels

A neuron uses electrochemical messages to communicate with other neurons. These messages are transmitted by both electrical and chemical processes. Dendrites receive the signals at connections called *synapses*. If the cell decides to respond, it sends an electrochemical impulse along its axon to the next neuron. This electrochemical message is passed from neuron to neuron at lightning speed.

Muscle Cells

Muscle cells are another type of specialized cell that play an important role in the overall function of animals. Used to move the body, muscle cells are often required to generate large amounts of force. They contain many mitochondria to provide the necessary energy. There are three different types of muscle cells: *cardiac muscle cells*, *skeletal muscle cells*, and *smooth muscle cells*.

Found only in the heart, cardiac muscle is specialized for continuous contractions. Cardiac muscle cells have to contract regularly every few seconds for your entire life, without ever taking break!

Skeletal muscles are what most people think of when they think of muscles. For example, your biceps or leg muscles are skeletal muscles because they are connected to bones in your skeleton.

Smooth muscles are found in your digestive system. They cause involuntary movements that help to move food through your gut.

Muscle cells are usually long, thin, and tapered on either end. They work by contracting so that the cell changes shape from long and thin to short and thick. A photograph of skeletal muscle cells is shown in Figure 13.3.



Figure 13.3 Skeletal muscle cells arranged in layers in muscle tissue. Note their long, thin shape.

Skin Cells

Skin is the largest organ of the human body, covering its entire surface. It is called an organ because it is composed of multiple types of tissues, including dermal tissue (epidermis, dermis, hypodermis), glandular tissue (sweat glands, sebaceous glands), and nervous tissue.

The main function of skin is protection. Skin cells are typically flat and thin with a brick or honeycomb shape that allows them to fit closely together to form a continuous protective layer.

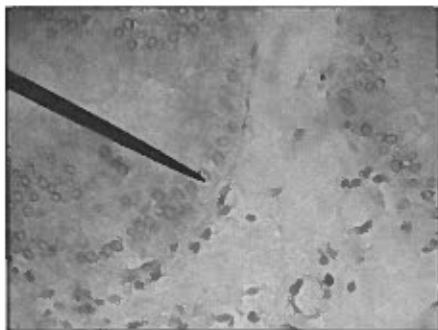


Figure 13.4 Skin cells arranged in layers

Bone Cells

Bone cells are specialized to give the organism structure and support. They combine in tissue layers to form bones. Without bones, you would resemble a limp bag of jelly. Bone cells are typically thick. They surround themselves with a thick mineral and protein coating that gives them their strength.

There are three different types of bone cells: *osteoclasts*, *osteoblasts*, and *osteocytes*.

Osteoclasts, large cells that contain more than one nucleus, are responsible for dissolving bone, which is important to bone growth, healing, and remodelling. Osteoblasts contain only one nucleus and are found on the surface of bone. They are responsible for forming new bone and often work in teams. Osteocytes are cells inside the bone that sense pressures or cracks in the bone, directing osteoclasts and osteoblasts to where they need to dissolve or repair bone.

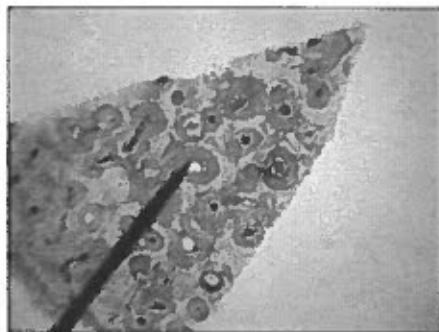


Figure 13.5 Bone cells. Note the thick layer of mineral and protein around each cell.

Reproductive Cells

Reproductive cells are unique cells found in the testicles of males and the ovaries of females. These cells undergo the specialized division process known as meiosis (see Lesson 12). In both males and females, meiosis results in four cells being produced from one. In males, all four of these cells develop into functioning sperm cells. In females, only one of the cells goes on to become an egg. A human egg cell (called an **ovum**) is a large circular structure that contains a haploid nucleus with only 23 chromosomes (half the normal number in a human cell). One of the largest cells in the human body, the ovum is typically visible to the naked eye. A human ovum measures between 100 and 200 μm in diameter. The sperm cell is also a haploid cell. It is approximately 100 000 times smaller than an egg and consists of a head, body, and tail. The head is made up primarily of the nucleus. This cell contains very little cytoplasm, which is shed during sperm maturation in order to decrease the weight and increase the speed of the sperm cell. The body of the sperm contains many mitochondria used to provide fuel for the long journey in search of an egg. Sperm cells are designed to do one thing—deliver genetic material to an egg as fast as they can.

Support Questions

46. Name six different types of animal cells.

47. What are the three main types of blood cells?

48. Describe the structure and function of a red blood cell.

49. What is the function of the cells of the nervous system?

50. What are the three types of muscle tissue and what are their functions?

51. What are the three types of bone cells and what are their functions?

52. Why do sperm cells have smaller amounts of cytoplasm than most cells?

Activity: Microscopic Examination of Animal Cells



In this activity, you will develop a better understanding of structural differences between various types of animal cells by examining different animal tissues under a virtual microscope.

Go to your course page on the ILC website and click on “Viewing Specialized Animal Cells” under Lesson 13.



You will observe specialized cells under low, medium, and high power.

1. Select the human skin slide under 40× magnification. All images are pre-focused for you. You are actually viewing many skin cells.

2. View the cells at higher powers (100× and 400×).

3. Observe the cell structure and try to recognize its main features.

4. Repeat steps 1–3 for the bone, nerve, and muscles cells.

5. Make a labelled biological drawing of the *nerve* cell under 400×. Be sure to include magnification and cell size. Recall that the field diameter under 40× magnification is 2 mm. (See Lesson 11 if you need to review the guidelines for biological drawings.)

Plant Cell Types

Like animals, plants have a variety of different types of cells. These carry out specialized functions that allow the organism to grow and carry out its day-to-day activities. There are many different kinds of specialized cells in plants. They can be grouped into the four most common types of tissues:

- Meristematic tissue
- Vascular tissue
- Dermal tissue
- Ground tissue

The following sections explain each of these different tissue types, along with the cell types it contains.

Meristematic Tissue

Meristematic tissue contains cells that undergo division, aiding in plant growth. This tissue is located in the roots of plants. When a plant starts to grow from a seed, the root emerges from the seed first. Within the root is a meristematic region called the *apical meristem*, where rapid mitosis of undifferentiated cells (stem cells) takes place. This important region is protected by dermal tissue known as the root cap. As the cells divide, the root tip gets longer, forcing the root deeper into the soil (to access water and stabilize the plant) and the rest of the plant up through the soil.

Vascular Tissue

Plants do not have blood or hearts like animals, but many do have vascular systems that transport water and essential nutrients (mainly sugar). Vascular tissue is organized into vascular bundles. A vascular bundle contains two types of vascular tissue: *xylem* and *phloem*. Xylem transports water from the roots of the plant up the stem and to the leaves. Phloem transports food (sugar) throughout the plant. Xylem tissue is made up of two types of specialized cells: tracheids and vessels. Composed of dead cells, both tracheids and vessels are hollow tubes that move water against gravity by a process known as the transpiration-cohesion theory. Phloem is also made up of two types of specialized cells: sieve tubes and companion cells. These cells work together to move sugar and other nutrients throughout the plant.

Dermal Tissue

Dermal tissue contains cells that specialize in covering and protecting the outer surfaces of leaves, stems, and roots. This tissue protects the plant body from cuts, invasion by microorganisms, and water loss. For example, the surface layer of leaves and needles is made up of epidermal cells; these secrete a waxy substance that forms the cuticle. The cuticle helps prevent water loss.

Ground Tissue

Ground tissue is a plant's internal nonvascular tissue, and contains a variety of cell types. Some of these cells specialize in storage and support. Others specialize in the more complicated task of photosynthesis.

Ground tissue is found in all parts of the plant. It is used to store starch in the roots, and is a structural element in the stem. In the leaves, ground tissue performs the critical process of photosynthesis. The palisade mesophyll cells containing chloroplasts are arranged in a tightly packed orientation. However, the spongy mesophyll cells have air spaces between them to allow for gas exchange. Embedded within the ground tissue are vascular bundles (veins) that bring water to the leaves and distribute the glucose made during photosynthesis to the rest of the plant. Within the lower epidermal layer are guard cells that regulate gas exchange by controlling openings known as stomata.

Leaves are made up of a variety of different tissues, including vascular, dermal, and ground, as shown below.

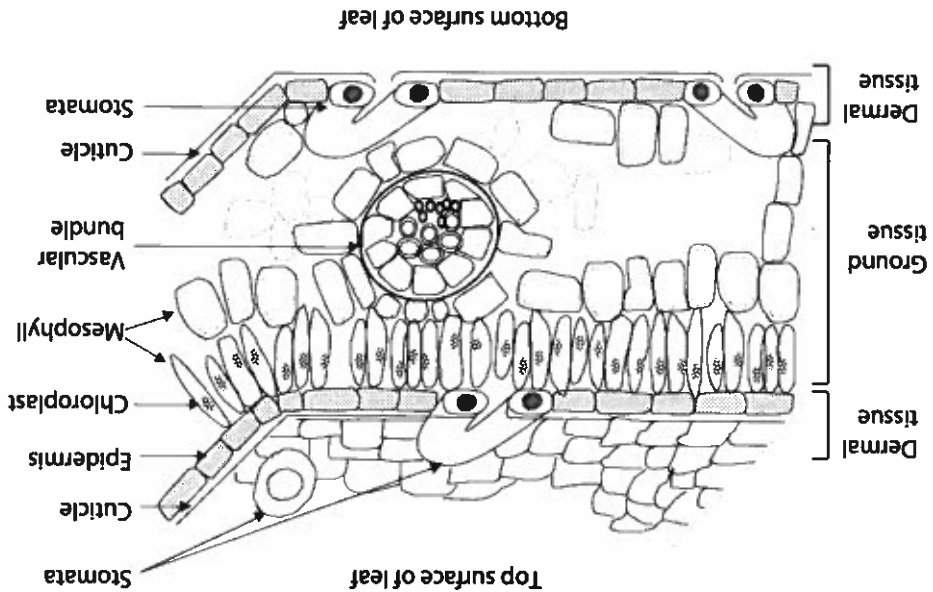


Figure 13.6 Cross-section of a typical plant leaf showing tissue layers

Support Questions

53. What are the four most common types of plant tissue?

54. What happens in the region known as the apical meristem? Why are the roots a good location for this grouping of cells?

55. What are the two types of vascular tissue found in plants and what do they transport?

56. What is the purpose of dermal tissue?

57. What is the function of epidermal cells in plants?

How Cells Become Specialized

You've seen examples of specialized cells in animals and plants. But where do they come from? In order to develop cells with different functions, an organism must start with one cell that is unspecialized (has no function). This initial unspecialized cell can then go through a process known as **differentiation** in order to become a specialized cell.

Though they may not look the same, all cells within an organism contain the exact same genetic complement. In many cases, cells arise from a zygote (fertilized egg). This cell differentiates into different cell types that all have the same genetic information. However, during the differentiation process, only portions of the total genetic information contained within the nucleus are expressed within each cell type. For example, even though all cells contain the DNA sequence coding for

insulin, only cells within the pancreas activate this sequence to manufacture and secrete insulin.

The initial unspecialized cell of an organism is referred to as a **totipotent** cell. This is a cell capable of expressing all the genes of the genome and can become any cell in the body, including other embryonic cells. In humans, the fertilized egg is totipotent until the eight-cell stage, at which point the cells begin to specialize. Most plant cells retain totipotency even after becoming specialized. This initial unspecialized cell is commonly referred to as a **stem cell**.

Stem Cells

Stem cells are unspecialized cells that can continuously undergo the process of cell division without differentiating. Though they cannot perform any specialized functions, stem cells give rise to cells that develop specialized functions. In 1998, it was discovered that stem cells could be isolated from human embryos and grown in the laboratory. This process had already been done with mouse stem cells, but it took about 20 years to learn how to grow human stem cells. Dividing stem cells are grown in a culture plate, with cells continuously removed and placed in other plates to start multiple cell cultures. Cells that grow and differentiate for at least six months are called a *stem-cell line*. (Because of governmental regulation, a limited number of stem-cell lines are available for use; we will discuss this later.) Stem-cell cultures grown in the laboratory can be induced to generate specialized, differentiated cells, such as the beating cells of the heart muscle or the insulin-producing cells of the pancreas. There are two different types of stem cells: embryonic stem cells and adult stem cells.

Embryonic Stem Cells

Embryonic stem cells are derived from the inner mass of the blastocyst stage of embryonic development. A blastocyst is a 3–5-day-old embryo composed of two distinct cell types: cells that become the placenta and an inner mass of stem cells. Embryonic stem cells are **pluripotent**, which means they can become all cell types of the body except other embryonic cells; adult stem cells are generally limited to differentiating into different cell types of their tissue of origin. For example, an adult stem cell in the blood-producing bone marrow will only give rise to the various types of blood cells.

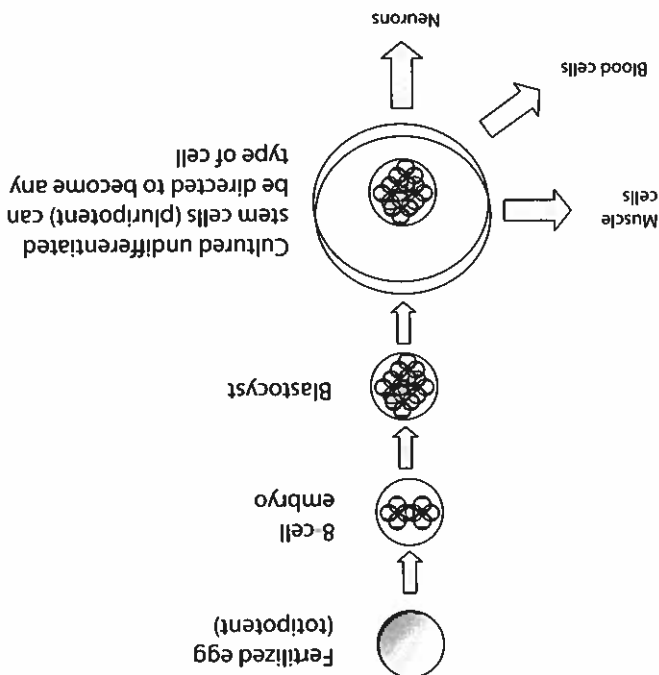
Adult stem cell type	Cell types they can produce
Hematopoietic Stem Cells	All blood cells
Bone Marrow Stem Cells	Bone, cartilage, fat
Neural Stem Cells	Neurons
Epithelial Stem Cells (lining of the digestive tract)	Cells that absorb materials on the inside of the intestines
Follicular Stem Cells	Hair follicles, epidermal (skin)

Table 13.2 Types of cells produced by adult stem cells

Adult stem cells are rare and do not appear to have the same capacity or potential to differentiate as embryonic stem cells. This would mean that adult stem cells are **unipotent** (can develop into only one cell type) rather than pluripotent. Though rare, adult stem cells have been found in many different tissues such as brain, bone marrow, skin, liver, skeletal muscle, and peripheral blood vessels. The following is a list of different adult stem cells and the type of cells that they can produce.

Adult Stem Cells

Figure 13.7 The formation and differentiation of pluripotent stem cells



Medical Research Using Adult Stem Cells

The purpose of adult stem cells is to repair or replace tissue that has been damaged or lost through accident or disease. If the differentiation of adult stem cells can be controlled in the laboratory, it may become the basis for treatment of many common diseases. The main advantage of using adult stem cells rather than embryonic stem cells is that the patient's own cells could be grown in culture and then reintroduced into the patient. This would prevent the rejection that can happen with the embryonic stem cells.

Finding adult stems within the human body is a difficult task. Identifying what types of cells they can differentiate into is even more difficult. Three methods can help solve this problem:

1. Cells within living tissue can be labelled with molecular markers, and then any specialized cell types that form within this tissue can be identified.
2. Cells can be removed from a living animal, labelled in a cell culture, and transplanted back into another animal to determine whether the cells develop into their tissue of origin.
3. Cells can be isolated, grown in a cell culture, and genetically manipulated to determine what differentiated cell types they can become.

Stem-cell research holds significant promise for the medical treatment of numerous diseases and injuries. For example, stem cells could be used to

- generate insulin-producing cells that could be transplanted into diabetics
- generate neuron cells that improve the lives of those people with Parkinson's disease or paralysis
- generate liver cells, kidney cells, and heart cells to repair damage caused by disease

The challenge is to direct the development of stem cells into a purified specialized-cell population.

Ethical Issues and Concerns

Stem cells and stem-cell research have been a hot topic in the news for the last decade or so for two main reasons. First, stem cells have a great potential to help scientists cure many medical problems, from heart disease to Parkinson's. Many studies have been done on stem cells, and success has been seen in laboratory animals such as mice. Second, there are moral and ethical issues surrounding the retrieval and use of stem cells from embryos. From a moral standpoint, many people are against the use of human embryos for any form of medical research—hence the strong interest in developing techniques to use adult stem cells, which could provide the medical benefit without the ethical challenges.

The resistance to the use of human embryos for scientific research has resulted in governmental laws banning the creation of embryonic stem-cell lines in many countries. Until recently this was the case in the United States. However, in 2009, President Barack Obama reversed a previous ruling, opening the door for the development of new stem-cell lines. Canada has had less resistance to stem-cell research, and so has become a leader in the field.

New Directions in Stem-Cell Research

- Many questions remain regarding stem cells and their use in curing medical conditions:
- How do stem cells remain unspecialized and self-renewing for many years?
 - What are the signals that cause stem cells to become specialized cells?
 - Why can embryonic stem cells proliferate for a year or more in the laboratory without differentiating, but most adult stem cells cannot?
 - What are the factors in living organisms that normally regulate stem-cell proliferation and self-renewal?
 - How many kinds of adult stem cells exist, and in which tissues?
 - What are the sources of adult stem cells in the body?

Support Questions

58. What is a stem cell?
59. What are the two categories of stem cells?
60. What is the difference between unipotent and pluripotent?
61. Identify two different adult stem cells and list the types of cells that they can differentiate into.

Conclusion

Multicellular organisms are made up of many different kinds of specialized cells, each performing a different function. These cells are organized in a hierarchical structure with groups of cells forming tissues, tissues forming organs, and organs working together to form organ systems.

In this lesson, you learned about the different types of specialized animal and plant cells and how to recognize them under a microscope. You also learned that specialized cells arise by differentiation from stem cells. Modern medicine is using features of stem cells to develop treatments for a wide variety of illness, but this process is not without controversy.

In the next lesson, you will see how the organ systems built upon these specialized cells work together to create a functioning organism.

62. Why might governments want to ban the development of embryonic stem-cell lines?

Key Concepts

Cell: basic unit of life

Tissue: combination of multiple cells with similar function

Organ: multiple tissues working together to perform a function

Organ system: multiple organs working together to perform a specific task
(for example, respiration, digestion)

Organism: multiple organ systems working together to produce an integrated, complete life form

Ovum: a human egg cell (plural: ova)

Differentiation: process whereby a cell's structure and function become specialized

Totipotent: a feature of the initial cell of an organism that is capable of expressing any gene and so can become any type of cell

Stem cell: an undifferentiated cell that can divide without differentiating. It has the potential to become a specialized cell.

Embryonic stem cell: stem cell that comes from an early embryo, usually at the blastocyst stage

Pluripotent: a feature of an embryonic stem cell that allows it to become any cell in the body

Adult stem cell: a stem cell that comes from an adult

Unipotent: a feature of an adult stem cell that allows it to develop into only one cell type

Description	Cell Type
Possess dendrites, axons	A. Red blood cells
Flattened, disk-like appearance with no nucleus	B. Nerve cells
Thick cells with a high mineral content	C. Muscle cells
Possess little cytoplasm and are haploid	D. Skin cells
Flat and thin with a brick or honeycomb shape	E. Bone cells
Elongated and tapered on either end	F. Sperm cells

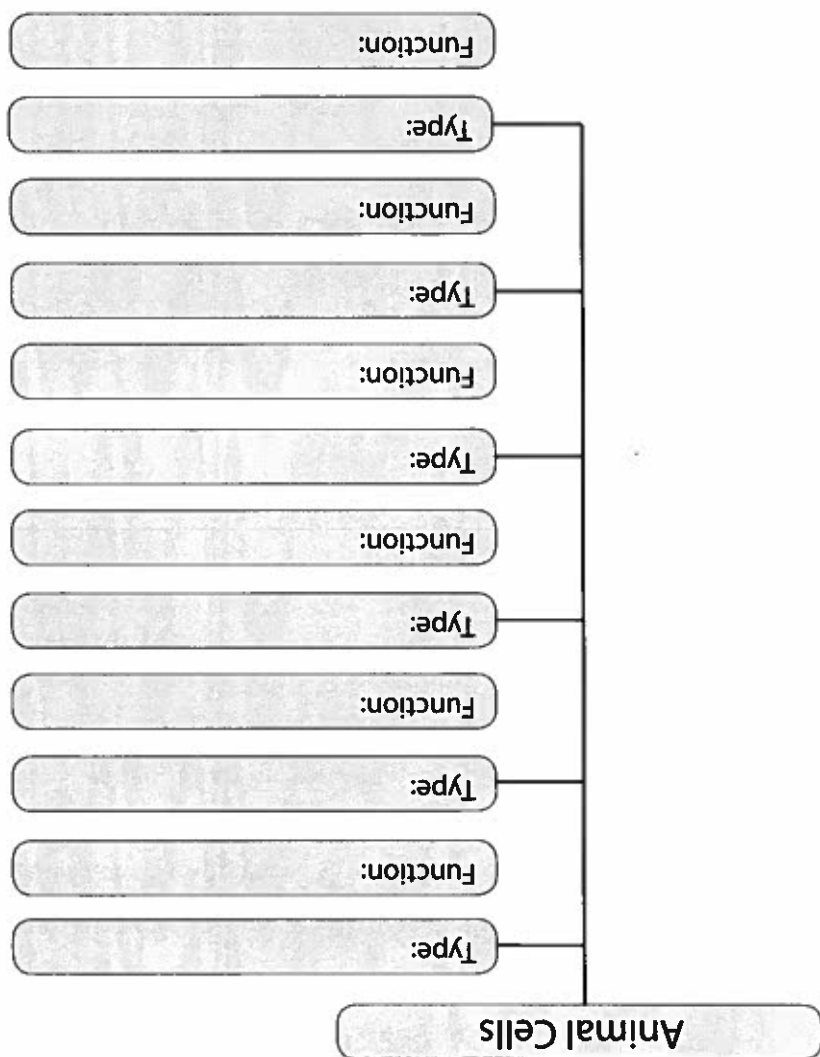
52. Why is differentiation necessary for plant and animal growth? (1 mark)
53. Identify three ways that embryonic stem cells and adult stem cells are different. (3 marks)
54. Should the development of embryonic stem-cell lines be allowed or not? Give two reasons to support your opinion. (2 marks)
55. Match the type of animal cell to the corresponding description. (6 marks: 1 mark for each)

Total: 18 marks

Save your answers to the Key Questions in your Course Journal or e-Journal.

Key Questions

- 56.** Complete the concept map summarizing the six different types of animal cells and their key functions. (6 marks: 1 mark for each, made up of ½ mark for the type and ½ mark for the function)



Now go on to Lesson 14. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 3 (Lessons 11 to 15).

Organ Systems



SNC2D-B

- explain the primary functions and structures of the major organ systems in the human body
 - assess the importance of medical-imaging technologies (MRI, CT scans, X-rays) used for diagnosing problems in organs and organ systems
- After completing this lesson, you will be able to

What You Will Learn

Suggested Timing for This Lesson (hours)	
Digestive System	½
Activity: Enzyme Action	1
Circulatory System	½
Activity: Heart Performance Score	½
Respiratory System	½
Medical-Imaging Technology	½
Key Questions	1

You may find this time grid helpful in planning when and how you will work through this lesson.

Planning Your Study

Have you ever wondered what happens to your food after you swallow it? Or why your heart beats faster when you exercise? Or what allows you to breathe? The human body is an amazing machine that can do a lot of different things: eat, breathe, think, move. All of the many things that your body can do require specific organs. For example, you need a heart to pump blood, lungs to breathe, and a stomach to digest food. However, most of the tasks the body undertakes require the involvement and coordination of multiple organs. An organ system is a combination of organs that work together to perform a certain task. This lesson will examine three essential organ systems—the digestive, circulatory, and respiratory systems.

Sometimes our organ systems break down and fail. With advances in technology, we are now able to study the various organ systems of the human body in great detail to solve problems with various organs. Some of these forms of technology are Magnetic Resonance Imaging (MRI), CT scans, X-rays, and ultrasounds. This lesson will give you a brief introduction to these tools.

Introduction

Organ Systems in the Human Body

For most of history, the inner workings of the human body were a complete mystery. Diseases were thought to be caused by bad spirits. The heart was considered the centre of love, rather than the incredibly efficient pump it is. Mind you, a Valentine's Day card would not be quite as romantic if it only celebrated a mechanical pump!

After 500 years of careful observation and gradual scientific developments, medicine now understands organisms as amazingly coordinated systems of cells, tissues, organs, and organ systems. This lesson will explore in detail three of the main organ systems of the human body: the digestive system, circulatory system, and respiratory system.

Digestive System

The human **digestive system** is a complicated but coordinated pathway that retrieves nutrients from various food sources. The four stages of the digestive process take place in this sequence:

1. Ingestion—the intake of nutrient material
 2. Digestion—the breakdown of molecules
 3. Absorption—the intake of nutrients into cells
 4. Excretion—the removal of waste
- The human digestive system contains the following organs:
- mouth (including the tongue, teeth, and salivary glands)
 - pharynx
 - esophagus
 - stomach
 - pancreas
 - liver and gall bladder
 - small intestine
 - large intestine

The mouth contains teeth, which are used for mechanical digestion (chewing, crunching, grinding), and salivary glands, which are used for chemical digestion. When food first enters the mouth, the tongue directs it to the teeth for the process known as mastication (chewing). The human mouth has four different types of teeth that classify us as omnivores (organisms that digest both plant and animal material). The four different types of teeth are

- incisors—used to cut food into smaller pieces
- canines—used to pierce and tear food
- bicuspsids—used to pierce and tear food
- molars—used to crush and grind food

Mouth

Each organ has a critical role to play in the digestive process. These functions are described below.

Figure 14.1 Components of the human digestive system

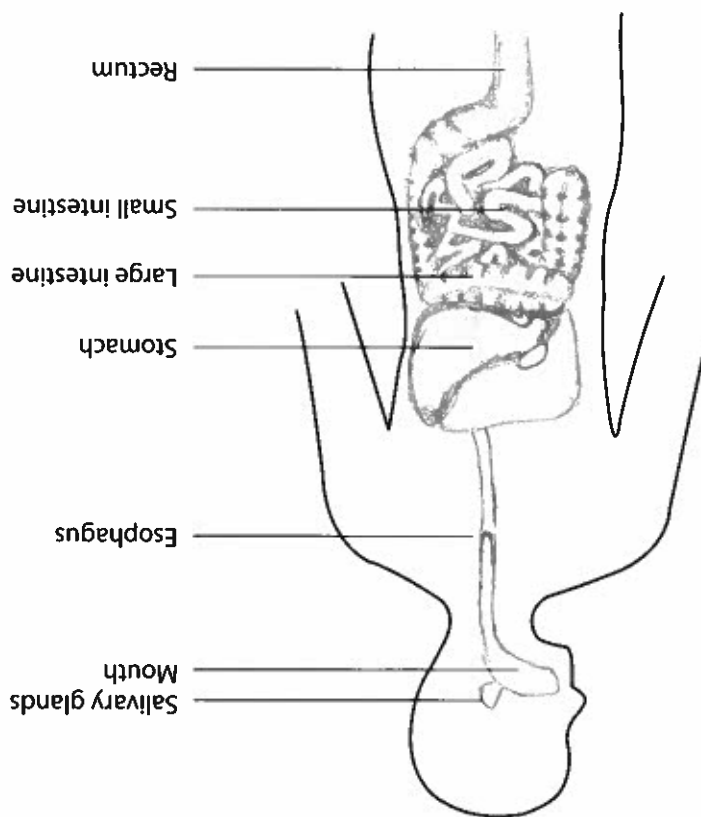


Figure 14.1 shows the structure and location of each of these digestive organs.

Because they digest only plant material, herbivorous organisms lack bicuspid and canines. They typically have very long incisors (think of beavers) and huge molars (think of cows). Carnivores have all four types of teeth, but their canines and bicuspid are much larger and sharper because they are needed to capture and kill prey.

As the teeth grind and crush the food, the salivary glands secrete saliva into the mouth. Saliva serves two purposes. First, saliva contains **amylase**, an enzyme that helps digest starch, a key component of plant material. A complex sugar, starch is broken down by amylase into simpler sugars such as glucose. Second, saliva helps lubricate the esophagus so that food can be delivered to the stomach more easily. For this reason, saliva is often produced before food enters the mouth; smells stimulate the senses, resulting in saliva production as the brain anticipates the arrival of food.

Pharynx

The pharynx is the empty cavity at the back of the throat. It serves as the gateway to the esophagus. Food that has been broken down by the teeth and lubricated is rolled into a bolus (ball) by the tongue. The tongue then pushes the mass of food to be swallowed into the pharynx.

Below the pharynx are two separate tubes: the esophagus and the trachea. The esophagus brings food to the stomach, while the trachea brings air to the lungs. To prevent food from going down the wrong tube and ending up in the lungs, a small flap of tissue known as the epiglottis closes the trachea when food is being swallowed in order to direct the bolus down the correct pathway. This is all done automatically—you only notice this process when it goes wrong. For example, when you drink something too fast and it starts to go down the trachea, you cough and gag.

Esophagus

The esophagus is a tube of smooth muscle that connects the pharynx with the stomach. Food is pushed through this organ by smooth muscle contractions called **peristalsis**. As food moves down the esophagus, the muscle relaxes ahead of the food and contracts behind it, forcing it down towards the stomach. Unlike humans, birds do not have the ability to move food by peristalsis, and must rely solely on gravity to swallow food. Birds cannot swallow while standing on their heads, but humans can!

Stomach

The entrance to the stomach is controlled by the cardiac sphincter. This ring of muscle is opened when sensory receptors detect the sensation/pressure of food. The cardiac sphincter is also responsible for preventing acid splashback. If an individual has a defective cardiac sphincter, hydrochloric acid from the stomach can splash up into the esophagus, causing a burning sensation known as acid reflux or heartburn.

After passing through the cardiac sphincter, food enters the J-shaped organ known as the stomach. The stomach is located primarily on the left side of the abdomen because the liver takes up a lot of room on the right. Food that enters the stomach undergoes further mechanical and chemical digestion. Smooth muscle contractions allow for further mechanical digestion. Chemical digestion occurs because the stomach lining contains two different types of cells that secrete gastric juice, acid, and digestive enzymes.

One type of cell produces hydrochloric acid to help digest food. Because this acid has a pH of 2 that could damage the stomach lining, the other type of cell that lines the stomach secretes a protective mucous layer. This layer of mucus is replaced every two weeks. Once food is thoroughly digested in the stomach, it exits through another sphincter muscle known as the pyloric sphincter. This sphincter leads to the small intestine.

Small Intestine

The small intestine is a highly folded tube structure, approximately 7 m in length and 2.5 cm in diameter. It is divided into three sections along its length—the duodenum, the jejunum, and the ileum. The main function of the small intestine is to finish the digestive process and absorb essential nutrients. It does this using digestive enzymes and finger-like projections called villi, which line the inside wall of the small intestine and increase absorptive surface area.

Large Intestine

The small intestine is connected to the large intestine, which is also divided into three sections—the cecum, the colon, and the rectum. The large intestine is 1.5 m in length and 5 cm in diameter. The main function of the large intestine is to absorb water.

Liver

One the largest organs in the body, the liver produces a substance called bile. Bile is responsible for the breakdown of lipids (fat) into glycerol and fatty acids. A yellowish-green fluid produced in the liver, bile is stored in the gall bladder until needed. The gall bladder is a small sac located under the liver. When needed in the digestive process, bile is secreted from the gall bladder through the bile duct and into the small intestine.

Pancreas

The pancreas is best known for the secretion of insulin, a hormone that regulates blood sugar. However, the pancreas also helps digestion by secreting digestive enzymes to break down carbohydrates, lipids, protein, and nucleic acids. In addition, it secretes sodium bicarbonate into the small intestine to help neutralize the acidic pH of the digested food coming out of the stomach.

Support Questions

Do not send your answers in for evaluation.

63. What are the four stages of digestion?

64. How does food move down the esophagus?

65. What is acid reflux and how is it prevented?

66. What is the main function of the small intestine? Of the large intestine?

67. Name two substances released by the pancreas that aid digestion.

There are Suggested Answers to Support Questions at the end of this unit.

Enzymes

Enzymes are chemicals produced by the body that take part in chemical reactions. The enzymes used in digestion allow us to digest and absorb most food. One particularly important food type is starch. A type of carbohydrate, starches contain sugar molecules. Your body needs sugar for energy to fuel the cellular processes. It is important that the starch molecules in your food get broken down quickly into sugars for quick absorption into the blood. This happens at several points along the digestive system pathway from the mouth to the stomach to the intestines.

As you've seen, one important digestive enzyme is amylase. Amylase breaks down only starch. Amylase is released in your mouth and in your stomach. When you chew your food, saliva containing amylase is released in your mouth, and gets mixed in with the food as you chew.

An easy way to find out if something contains starch is to add iodine solution. Commonly used to disinfect scrapes and minor cuts, iodine can be obtained from any drugstore or store selling first-aid supplies. Usually red-brown in colour, iodine turns dark purple when it comes into contact with starch. To examine how effective amylase is at breaking down starch into sugars, you will do an experiment using iodine as an indicator.

Activity: Enzyme Action



Purpose

To study the effect of salivary amylase on starch.

Materials

- unsalted crackers
- iodine (available at drugstores or in the first-aid section of supermarkets)
- saliva (which naturally contains the enzyme amylase)
- water
- 3 small glasses

Procedure

1. Arrange three small glasses in a row and number them 1–3.
2. In the first glass, add approximately 5 mL of saliva (which contains amylase)
3. In the second glass, place one quarter of a finely crushed unsalted cracker.
4. In the third glass, place one quarter of a finely crushed cracker and approximately 5 mL of saliva.
5. Add 5 mL of water to each of the three glasses.
6. Add 10 drops of iodine into each glass and swirl the mixture around.
7. After 10 minutes, record your observations.

Observations

Note:

- If adding iodine turns the test solution purple, then starch is present.
- If adding iodine turns the test solution brown, then starch is not present.

Table 14.1 Observations of colour changes in the glasses

Solution	Indicator	Colour	Starch Present?
1. amylase (in saliva) + water	Iodine		
2. cracker + water	Iodine		
3. amylase + cracker + water	Iodine		

Analysis

Answer Support Questions 68–69.

Circulatory System

- The circulatory system is one of the most critical systems in the entire human body. Connected to every other system, it keeps all 100 trillion cells supplied with oxygen. The circulatory system has four main functions:
1. Transportation of oxygen and carbon dioxide: Oxygen is obtained from the lungs and carbon dioxide is delivered to the lungs.
 2. Transportation of nutrients and waste: Nutrients are delivered to all cells and waste is delivered to the kidneys.
 3. Maintenance of body temperature: Blood vessels in the skin dilate (expand) to dissipate heat when the organism is overheated, and constrict to reduce heat loss when the organism is cold.
 4. Circulation of hormones: Hormones are delivered from glands to organs through the bloodstream.
- While the digestive system has many parts working together for a common purpose, the circulatory system only has three main components:
- a fluid in which material is transported (blood)
 - a system of vessels to carry the fluid (arteries, veins, capillaries)
 - a pump that pushes the fluid through the vessels (heart)

Support Questions

68. a) Which glass(es) indicated the presence of starch?
- b) Explain this result.
69. Why was Glass #1, containing just saliva and water, included in this experiment?

Each of these three components is described in more detail below.

Blood

As discussed in the previous lesson, blood is composed of plasma and cells. The transportation of oxygen and carbon dioxide is carried out by red blood cells. These cells are packed full of oxygen-binding proteins known as **hemoglobin**.

Arteries, veins, and capillaries

Arteries, veins, and capillaries are different types of vessels that carry blood throughout the body. The largest vessels in the body, **arteries** carry oxygenated (oxygen-rich) blood from the heart to the rest of the body. The dorsal aorta, which exits the heart and runs the length of the spine, is the largest artery in the body. Other important arteries include the femoral arteries in the legs and the carotid arteries in the neck; the latter deliver blood to the head.

Smaller in diameter than arteries, **veins** are responsible for delivering deoxygenated (oxygen-deficient) blood back to the heart so that it can be reoxygenated and recirculated. **Capillaries** are the smallest of the three types of vessels. They are found within organs and connect arteries with veins. There are approximately 96 000 km of blood vessels in your body to sustain your 100 trillion cells.

Blood vessels play a key role in regulating body temperature. When the body is overheated, for example during heavy exercise, the capillaries near the skin will dilate, or increase in diameter. This brings them closer to the surface of the skin, allowing for the dissipation (loss) of heat. Arteries and veins also need to dilate to accommodate the increased blood flow generated by the increase in heart rate. Conversely, when the body temperature is low, the vessels constrict to reduce the loss of heat. You notice this on cold winter days when your fingers, lips, and toes start feeling cold and stiff: your body is restricting the amount of blood flow to those areas in order to conserve heat.

With a poor diet and lack of exercise, blood vessels can easily get blocked by the build-up of a sticky substance called **plaque**. Plaque is a by-product of a diet high in cholesterol. It gets into the bloodstream and as it travels around the body, it gradually sticks to the inside walls of the blood vessels, eventually forming a thick coating. If the coating gets too thick, it can block the vessel. In a major artery, this blockage could have devastating consequences such as a heart attack or stroke.

The Heart

The heart is an organ found slightly left of centre in the chest. No larger than your fist, it has a mass of about 300 grams. The structure of the heart can be seen in the figure below.

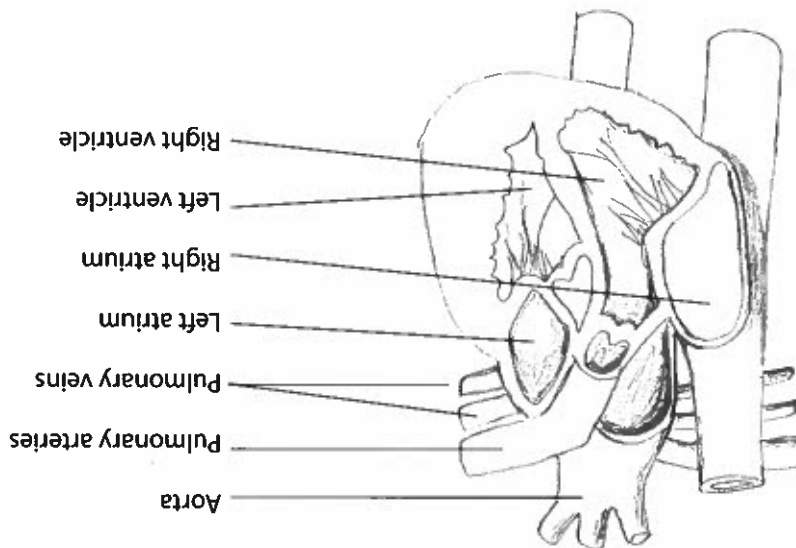


Figure 14.2 The human heart as seen from the front

The heart is an organ made up of muscle tissue arranged into four chambers that are connected by valves. Two different forms of blood enter the lungs. Blood that returns to the heart from the rest of body through veins lacks oxygen, and is called deoxygenated blood. This blood enters the right side of the heart and goes through a process known as pulmonary circulation to the lungs to pick up oxygen. The oxygen-rich blood that enters the heart from the lungs is called oxygenated blood. It is ready to be sent to all the organs and tissues of the body through a process known as systemic circulation. Each of these circulation patterns is described in more detail below.

Pulmonary Circulation

Deoxygenated blood returns to the heart and enters the right atrium. It then passes through a valve into the right ventricle. A contraction of the heart muscle causes the blood to be forced up through the pulmonary valve and into the pulmonary artery. This artery splits into two, each branch directed toward one lung. The blood within the pulmonary arteries enters the respiratory system into the lungs with the aid of small capillaries. The blood exchanges oxygen and carbon dioxide gas with the air in the lungs in small sacs called alveoli. This allows oxygen to diffuse from the alveoli into the capillaries, and carbon dioxide to diffuse from the capillaries into the alveoli. The blood is now rich in oxygen and has expelled its load of carbon dioxide.

Systemic Circulation

The oxygenated blood returns to the heart and enters the left atrium. The blood then passes through a valve and enters the left ventricle. A contraction of the heart muscle forces the oxygenated blood out of the left ventricle up through a valve into the aorta. The aorta is a very large blood vessel that sends the oxygenated blood throughout the body through various arteries.

It is important to take good care of your heart. You literally can't live without it, even for a few minutes. Your heart has to work every second of your life. For the average person, the heart beats about 72 times a minute, or 37 843 200 times a year. Every minute, five litres of blood cycles from the heart to the lungs, picks up oxygen, and returns to the heart. During an average lifetime, the heart pumps enough blood to fill two large ocean tankers.

Support Questions

70. What are the four functions of the circulatory system?

71. What protein allows red blood cells to transport oxygen?

72. Explain the difference between veins and arteries.

73. Explain the difference between pulmonary and systemic circulation.

Activity: Heart Performance Score



Purpose

To determine your heart fitness level using the heart performance score (HPS).

Materials

- timing device (a watch or clock that can show seconds)
- a set of steps

Procedure

You are going to measure your pulse rate after each of four different activities: sitting, standing, exercise, and recovery. You will then combine these pulse rates to determine your heart fitness level.

Activity 1: Sitting

- Sit still (no talking or moving) for 2–3 minutes. After this time interval, take your pulse for 20 seconds. Record this value in Table 14.2 and multiply it by three to get the rate in minutes. You can use your fingers to feel your pulse. Place two fingers on your neck just below the corner of your jaw or feel your pulse on the inside of your wrist.

Activity 2: Standing

- Stand up, wait 10 seconds, then take your pulse for 20 seconds again. Record this value in Table 14.2 and multiply the pulse count by three.
- Calculate the difference between your pulse rate while sitting and standing by subtracting your sitting value from your standing value. Record this value in Table 14.2.

If you exercise vigorously, your heart rate increases. The amount that it increases depends on how fit you are. A strong heart can pump blood more efficiently than a weak one. Therefore, the pulse rate of a physically fit person will not increase as much with exercise as it will in a physically unfit person. You can test your heart fitness level using the activity below.

Important Note: If you have a medical condition that makes it inadvisable for you to exercise, please skip this activity—or preferably, determine the heart fitness level of a friend.

Activity 3: Exercise

- Stand at the bottom of a stairway, facing the steps.
- Raise your left leg and move it up one step. Bring your right leg up and stand on the same step with both feet.
- Then move back down to the base of the steps, reversing the procedure (left leg off followed by the right leg).
- Repeat this motion of stepping up and stepping down one step for 60 seconds, making sure to maintain a rate of at least one step per second.
- Immediately following the 60 seconds of exercise, take your pulse for 20 seconds. Record the value and multiply this number by three to get your pulse rate in beats per minute.

Activity 4: Rest

- After 60 seconds of rest, take your pulse again. Record this value in Table 14.2 and multiply by three.
- Calculate your HPS by adding together the four pulse rates (in beats/minute) that you measured, as well as adding the difference that was calculated in Activity #2.
- Determine your general fitness level by comparing your HPS score to the ones given in Table 14.3

Table 14.2 Record of pulse rates during four activities to produce your HPS score

Your own results		Example	
Activity	Pulse count in 20 seconds	Pulse rate per minute	Pulse count in 20 seconds
Sitting			21
Standing			23
Standing – sitting			23 – 21 = 2
Exercise			44
Recovery			32
Heart Performance Score (= total of above counts)			366

Support Questions

74. What is the effect of exercise on the heart?
75. Why does the heart react in this way?
76. Suggest some reasons why everyone does not have the same pulse rate at rest.
77. Each ventricle pumps out approximately 70 mL of blood with every beat. How many beats are necessary to pump all five litres of blood?

Table 14.3 Heart performance score (HPS) and general fitness level

HPS	General Fitness Level
200-250	Endurance Athlete
250-300	Athletic
300-325	Very Good
325-350	Good
350-375	Fairly Good
375-400	Fair
400-450	Poor
450-500	Very Poor

Respiratory System

The **respiratory system** is located in the chest cavity. Its purpose is to transport oxygen from the air you breathe into the blood and to excrete carbon dioxide out of the blood.

The human respiratory system contains the following organs:

- nasal cavity
- pharynx
- trachea
- bronchi
- lungs
- bronchioles
- alveoli
- diaphragm

The general structure of the respiratory system is shown in the figure below.

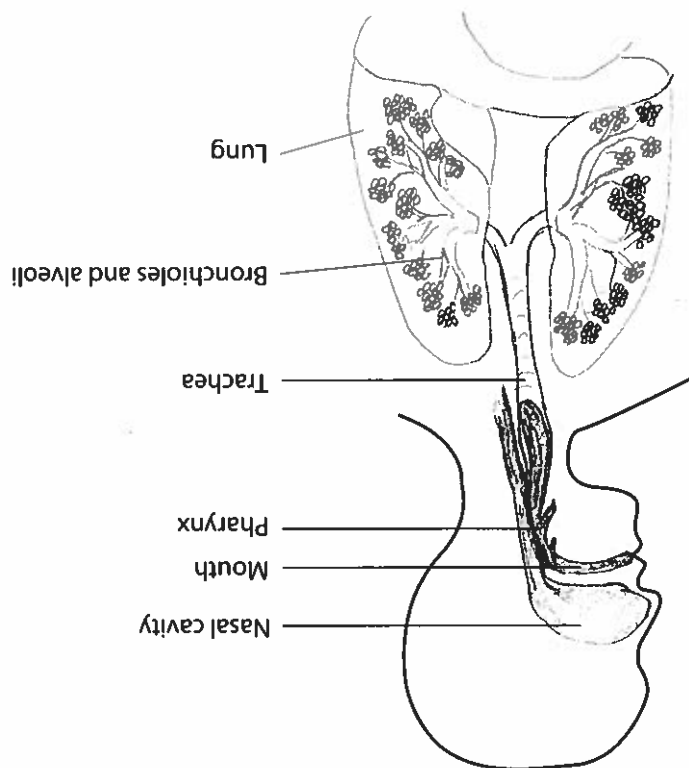


Figure 14.3 The human respiratory system

Within each lung, the bronchi divide into numerous small tubes called bronchioles. There are approximately 30 000 bronchioles in each lung, each one about the diameter of a hair. At the end of each bronchiole is an alveolar sac (air sac). The alveolar sac contains a cluster of alveoli tightly wrapped in capillaries (Figure 14.4). Alveoli are like clusters of tiny hollow grapes at the end of the bronchioles.

Bronchioles and Alveoli

The trachea branches into the left and right bronchi (singular: bronchus), which direct air into the left and right lung. The two lungs are not the same size. While the right lung is divided into three lobes, the smaller left lung is divided into two. This is to make room for the heart, also located on the left side of the chest cavity. The lungs are covered by a pleural membrane to protect them and prevent infection.

Lungs and Bronchi

Below the pharynx is the trachea, which extends down through the neck beside the esophagus. The trachea is larger in diameter than the esophagus, being approximately 2–2.5 cm in diameter and 10–16 cm in length. A delicate organ, the trachea is held open by cartilaginous rings that prevent collapse of the windpipe.

Trachea

The nasal cavity is found within the nose. Air entering the body is first brought here. The nasal cavity cleans, humidifies, and warms the air that enters the body. It is lined with mucus and hair to trap unwanted bacteria or other irritants. The nasal cavity draws in air and passes it into the pharynx (the same area where the tongue pushes the bolus). Air is directed into the trachea (windpipe) via a small flap of tissue called the epiglottis. The epiglottis closes over the trachea when food is being swallowed so that it does not enter the lungs. This is critical in order to prevent choking. Because talking requires you to breathe, you shouldn't talk while eating as this could cause food to enter the trachea.

Nasal Cavity and Pharynx

Each of these organs plays a critical role in the process of respiration, as outlined below.

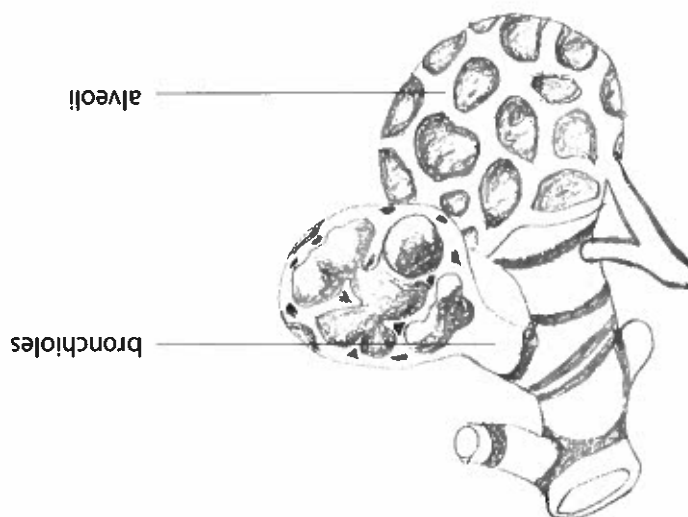


Figure 14.4 Alveoli in the lungs are attached to tubes called bronchioles

There are approximately 600 million alveoli in your lungs. The alveoli are lined with capillaries. The capillaries are the sites of gas exchange. Oxygen diffuses from the alveoli into the capillaries containing the red blood cells, and carbon dioxide diffuses from the red blood cells in the capillaries into the alveoli. The circulatory system can then transport the oxygen to all cells in your body.

Diaphragm

The lungs operate by air-pressure changes within the bronchi and bronchioles. The pressure changes are caused by the expansion and contraction of a muscle called the diaphragm. The diaphragm is a dome-shaped muscle that extends across the bottom of the rib cage. It separates the thoracic (chest) cavity from the abdominal cavity. When it expands, the diaphragm moves downward, allowing the tubes to dilate and bring in fresh outside air containing oxygen. When the diaphragm contracts, it moves up, causing the tubes to constrict and forcing out the waste air containing carbon dioxide. The entire thoracic cavity—including the lungs and heart—is covered by the rib cage, which provides support and protection.

Lung Capacity

The average breathing rate while at rest is 15–25 breaths per minute. A much higher resting heart rate could indicate a respiratory ailment such as the common cold, asthma, or bronchitis. Symptoms of these include an inflammation or

swelling of the bronchi and bronchioles, which results in excess mucus and narrowing of passageways. That makes it harder to get air into your lungs with each breath, so you have to take more breaths.

Under normal conditions, your regular breathing does not use the full capacity of your lungs. The volume of air inhaled and exhaled in a normal breathing movement—called your tidal volume—is about 500 mL. However, as your need for oxygen increases during exercise, the volume of air drawn in can also increase. Beyond a regular inhalation, an additional volume of air called the inspiratory reserve volume can be taken in. This volume is around 3100 mL. Similarly, an additional volume of air can be forced out of the lungs, beyond a regular exhalation. Called the expiratory reserve volume, this volume is around 1200 mL. The total volume of gas that can be moved in or out of the lungs (tidal + inspiratory + expiratory) is approximately 4800 mL and is called the vital lung capacity. The air within the lungs can never be completely removed as this would make the tubes collapse. Therefore, a small amount of gas (1200 mL), called the residual volume, remains in the lungs and the passageways. If the residual volume gets close to zero, the lung will collapse and the wet internal surfaces will stick together, making it very hard to inflate the lung again.

Support Questions

78. What is the function of the respiratory system?

79. Why is it a bad idea to talk while eating?

80. What prevents the trachea from collapsing?

81. Explain the role of alveoli in gas exchange.

82. Describe the movement of the diaphragm when you inhale and exhale.

Medical-Imaging Technology

Organ systems are complex and can occasionally run into problems. One of the main problems shared by the digestive, circulatory, and respiratory systems is blockage. Blockages in vessels and tubes can be caused by obstacles (for example, plaque or tumours), scarring, swelling, or sharp twists and bends. All of these are usually treatable, but first you have to find where they are—and that is hard because the human body is not transparent.

Fortunately, the past 100 years have seen the development of different forms of medical-imaging technology that allow us to see inside the human body. We are thus better able to understand our internal systems and to diagnose and treat problems like blockages and cancers. This revolution in medicine has significantly increased treatment rates and made surgeries much less dangerous. Before these imaging technologies were developed, doctors had to operate on a patient just to explore what might be wrong. This led to a lot of surgical stress and potential infection.

Some examples of these imaging technologies—ultrasounds, X-rays, CT scans, and MRIs—are discussed below.

Ultrasound

An **ultrasound** is a procedure that involves exposing part of the body to high-frequency sound waves to produce pictures of the inside of the body. Ultrasound scanners consist of a computer, a video-display screen, and a transducer used to scan the body. The transducer sends out high-frequency sound waves into the body and then listens for the returning echoes from the tissues in the body. These returning waves are measured and analyzed by a computer to create a picture of the object on the display screen.

For this procedure, a patient must lie down on an examination table. A clear gel is applied to the area being studied to help the transducer make secure contact with the body. The ultrasound technician then presses the transducer firmly against the skin and sweeps it over the area.

This non-invasive medical test is most commonly used to view a developing baby within the uterus (Figure 14.5). However, it can also help doctors diagnose and treat a wide variety of medical conditions. Many different organs can be examined using ultrasound techniques, including heart, liver, gall bladder, spleen, pancreas, kidneys, bladder, thyroid, uterus, and testicles. Ultrasounds can also be used to help with surgeries. Doppler ultrasound is a special technique used to study blood flow. Doppler ultrasound images can help doctors see and evaluate the following:

- blockages to blood flow (such as clots)
- narrowing of vessels (which may be caused by plaque)
- tumours and congenital malformation



Figure 14.5 Ultrasound image of a baby

Source: iStockphoto.com

Ultrasound provides great benefits to society since it is relatively easy and inexpensive to perform, poses little risk to the patient, and provides a way to directly observe a developing baby without having to enter the uterus.

X-Ray

X-rays are a form of electromagnetic radiation. They were discovered in 1895 by Wilhelm Conrad Röntgen. He observed that these wavelengths can pass through some forms of material but not others. For example, in the human body, X-rays can pass through soft tissue but not bone. This permits the projection of a black and white image.

Doctors discovered early in the 1900s that X-rays can be used effectively to examine the inner organs and bones of the human body. They have been doing this successfully now for over 100 years. Figure 14.6 shows doctors examining X-rays of a patient's rib cage and spine. This technology is particularly useful for examining broken bones and teeth below the gumline, identifying tumours, and locating foreign objects (such as bullets) within tissue.

While very beneficial, X-rays do have some drawbacks. X-rays are a form of radiation that can damage tissue and even cause cancer in high doses. It is wise to limit exposure to X-rays unless they are absolutely necessary. They are also not very good at identifying structures in soft tissue like inside the brain or heart. Newer technologies, such as the MRI described below, are much better in those situations and do not pose the same radiation risk. X-rays are also used in many industries, such as air travel. Luggage is scanned using X-ray machines to see inside people's bags to make sure nothing dangerous is being brought aboard the airplane.



Figure 14.6 A doctor examines an X-ray image of a rib cage to determine if any bones are damaged or broken

Source: iStockphoto.com

CT Scan

A computed tomography scan or **CT scan** is a non-invasive test that helps doctors diagnose and treat medical conditions. It is sometimes known as a CAT scan. The scan combines X-ray equipment with computers to create images of the inside of the body. Scans can be done of internal organs, bone, soft tissue, and blood vessels. Typically CT scans can provide more detail with greater clarity than an X-ray. CT scans can be used to examine organs in the chest, abdomen, and pelvis. They can be used to diagnose problems such as cancer, heart disease, and musculoskeletal disorders. They can also be used during surgery to guide the surgeons.

The CT scanner is a large box-like machine with a tunnel through the centre. The patient lies on an examination table that can move in and out of the tunnel. An X-ray tube rotates around the patient and delivers information to a computer for processing.

A CT scan is very similar to an X-ray. However, instead of one beam of radiation focused on a body part, multiple X-ray beams rotate around the whole body to develop two-dimensional, cross-sectional images. Figure 14.7 shows the results of a CT scan on a patient's head.

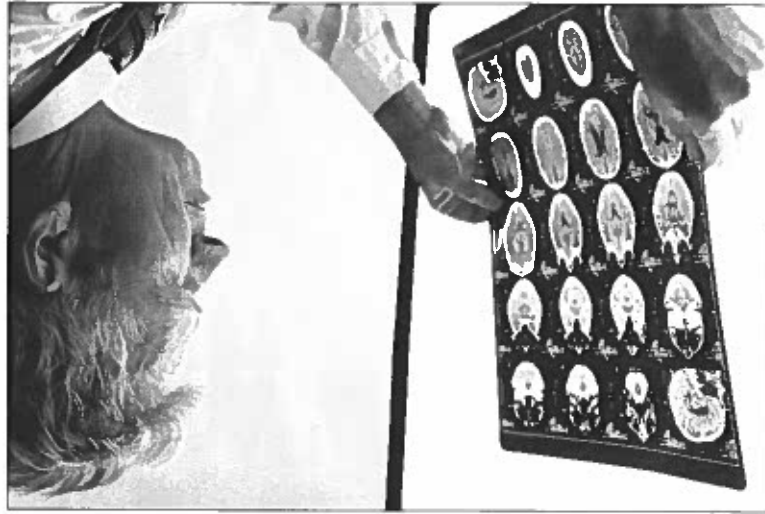


Figure 14.7 Doctor examining a patient's CT scan results

Source: iStockphoto.com

Magnetic Resonance Imaging (MRI)

An MRI is an imaging technique used to visualize the internal structure of the body. It provides contrast between the different soft tissues of the body, making it very useful for studying the brain. The procedure uses a powerful magnetic field, radio frequency pulses, and a computer to produce detailed pictures of body structures.

MRIs can be used to evaluate organs of the chest, abdomen, pelvis, and brain. Doctors use the MRI examinations to help diagnose many different conditions such as cancer, coronary artery disease, cirrhosis of the liver, endometrios, and heart anomalies. When the first MRI was performed in 1977, it took many hours to generate one image. With improved technology, multiple images can now be generated in a matter of seconds.

An MRI unit is a large cylinder-shaped tube surrounded by a circular magnet. The patient lies on a moveable examination table that slides into the centre of the magnet. Unlike CT scans, MRI does not depend upon radiation. Instead, radio waves reorganize hydrogen atoms in a strong magnetic field. A signal is generated and is processed by a computer into a series of images. MRIs are extremely beneficial because they do not expose a patient to radiation, and can deliver much more detail than the other methods.

Figure 14.8 shows one image from an MRI performed on a patient's head. Note the incredible amount of detail that this technology can provide. Because MRIs provide multiple images through sections of tissue, doctors can zoom through the images to see different layers, giving them a three-dimensional view of the area.



Figure 14.8 MRI image reveals the inside of a man's head

Source: iStockphoto.com

Conclusion

Organs work together in organ systems in the human body to carry out complex, specialized tasks. You have examined three of these organ systems in detail: the digestive, circulatory, and respiratory systems. You also learned how new medical imaging devices are changing the way medicine deals with diseases in these systems, leading to faster and better treatments.

In the next lesson, you will learn how these organ systems work together to produce the function and behaviour of a whole person.

85. Which form of technology provides the most detailed images?

84. Which forms of technology use radiation?

83. Which form of technology uses sound waves?

Support Questions

Key Concepts

Digestive system: organ system that takes in and digests food, and then excretes the waste

Amylase: an enzyme found in saliva that helps digest starch

Peristalsis: organized contractions by smooth muscle to move material along the esophagus and intestines

Villi: finger-like projections on the inside of the small intestine used to absorb nutrients

Enzymes: chemicals produced by the body that take part in chemical reactions

Circulatory system: organ system that moves blood around the body where it can absorb or give up oxygen, deliver nutrients and hormones, and help regulate body temperature

Hemoglobin: oxygen-binding protein carried by red blood cells; used to transport oxygen

Arteries: these large vessels carry oxygenated (oxygen-rich) blood from the heart to the rest of the body

Veins: smaller vessels that deliver deoxygenated (oxygen-deficient) blood back to the heart so that it can be reoxygenated and recirculated

Capillaries: small vessels found within organs; they connect arteries with veins, and are the site of gas exchange

Plaque: a by-product of a diet high in cholesterol, this sticky substance can build up in blood vessels and cause blockages

Respiratory system: organ system brings in outside air and then allows an exchange of gases with the blood, bringing oxygen in and expelling carbon dioxide

Ultrasound: a medical-imaging technique that uses high-frequency sound to create a picture of tissues inside the body

X-rays: a form of electromagnetic radiation that can pass through soft tissue but not bone

CT scan: a computed tomography scan is a non-invasive test that combines X-ray equipment with computers to create images of the inside of the body

MRI: a medical-imaging technique used to visualize the internal structure of the body. It provides contrast between the different soft tissues of the body.

Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 18 marks

- 57.** Explain why the human circulatory system requires both the pulmonary and systemic circulation patterns. (6 marks)

- 58.** Place the letter "T" beside each true statement, and the letter "F" beside any false statement. (10 marks)

Statement	True (T) or False (F)?
The epiglottis closes over the esophagus to prevent air from entering the stomach.	
The left lung is bigger than the right lung.	
The bronchioles are the site of gas exchange.	
The vital capacity is the total amount of air that can be moved in and out of the lungs.	
A specific amount of air must stay in the lungs at all times to prevent collapse.	
Test tube containing salivary amylase + cracker + Benedict's solution turns orange, indicating that simple sugars were produced.	
The pyloric sphincter prevents food from entering the trachea.	
The pancreas releases enzymes and sodium bicarbonate.	
The gall bladder stores bile from the liver.	
The small intestine primarily absorbs water.	

- 59.** If someone you knew had to have images taken of their brain, would you recommend that they go for an X-ray, a CT scan, or an MRI? Explain why. (2 marks)

Now go on to Lesson 15. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 3 (Lessons 11 to 15).



SNC2D-B



**Your Functioning Body:
Organ Systems Working Together**



Suggested Timing for This Lesson (hours)	
Organ Systems	½
Systems Working Together	½
Examples of Systems Working Together	½
Activity: The Frog: A Virtual Dissection	1½
Medical Conditions and Treatments	¾
Key Questions	1

You may find this time grid helpful in planning when and how you will work through this lesson.

Planning Your Study

It might seem like an easy task to jump in the air or even just stand up, but it actually requires a lot of coordination among many organ systems in your body. For example, your muscles need to be told when to contract and your blood has to send them the necessary oxygen and fuel. Luckily, you don't actually have to think about all these things since your systems are designed to work with each other automatically. In this lesson, you will learn about the main organ systems of the body and how they interconnect. You will also explore these systems by performing a virtual dissection.

In a healthy person, all the organ systems work well together. However, sometimes problems can arise leading to medical disorders that range from minor to critical. Some of these problems are the result of unhealthy choices. For example, smoking can have adverse effects on many organ systems. You will examine how smoking is a source of health-related issues in society, and look at the strategies to reduce it. Fortunately, modern technology can be used to examine many health problems related to the organ systems and to help diagnose and treat disease. You will learn about some of the common diseases associated with each of the main organ systems and their medical treatments.

Introduction

What You Will Learn

After completing this lesson, you will be able to

- explain how organ systems are interconnected, and why this is necessary for an organism's survival
- determine the interconnectedness of organs by dissecting an organism
- describe disorders affecting the respiratory and circulatory systems, as well as technologies used to treat them
- describe a public-health strategy used to combat diseases of major systems

When they work together, organ systems can create conditions that affect the whole body. One very important function of coordinated organ systems is to maintain the steady internal environment needed by the chemical processes in the body. Most organisms, including you, can only function within a limited range of internal temperatures and chemical conditions. The maintenance of these conditions is a process called **homeostasis**. This process is described below using the human body as an example.

Organ System	Major Organs	Major Function
Nervous	Brain, spinal cord, eyes, ears	Response to environment
Circulatory	Heart, arteries, veins, capillaries	Transport of nutrients, gases and waste
Respiratory	Lungs, trachea, diaphragm	Gas exchange
Digestive	Esophagus, stomach, intestines, liver, gall bladder, pancreas	Physical and chemical breakdown of food
Excretory	Kidneys, bladder	Removal of wastes
Reproductive	Male: testes, vas deferens, penis Female: ovaries, fallopian tubes, vagina	Sexual reproduction
Locomotive	Muscles, bones	Movement
Endocrine	Glands (for example, pituitary, thyroid, parathyroid, adrenal), pancreas	Chemical regulation
Immune	Thymus, lymph nodes, spleen, bone marrow	Protection from foreign invaders (for example, parasites, bacteria, viruses)

Table 15.1 Human Organ Systems

An **organ system** is a group of organs that work together to perform a specialized task. The human body contains multiple organ systems. These systems work together to keep the whole organism functioning. For example, since all parts of the body need oxygen, all systems must connect with the respiratory system. Also, since all cells in the body need nutrients, the digestive system must connect to the other systems.

Table 15.1 lists the major organ systems of the human body, the major organs each contains, and the main function of each system. This lesson will focus on the first five of these systems: the nervous, circulatory, respiratory, digestive, and excretory systems.

Organ Systems

Homeostasis

In humans, homeostasis is the process of maintaining a steady-state environment inside the body to create optimal conditions for all its chemical reactions. When a change in the internal or external environment upsets this balance, the body senses the change and responds by trying to re-establish the balance. This often requires multiple organ systems to work together toward a common goal.

When restoring conditions to normal, organ systems use a process of **negative feedback**. In this process, a system is kept within certain bounds by feedback from its actions that prevents it from getting out of control. The home thermostat provides a familiar example of negative feedback. In a typical home, a thermostat regulates the temperature. When the house is too cold, the thermostat senses the decrease in temperature and activates the furnace to heat it up. When the house reaches the desired temperature, the thermostat deactivates the furnace so the house doesn't get too hot. The organ systems of the human body work in a similar fashion to regulate all internal processes.

Three of the main goals of homeostasis in the human body are to maintain body temperature, breathing rate, and heart rate.

Body Temperature

The average human body temperature is between 36.2 degrees Celsius and 37.2 degrees Celsius. A higher temperature could indicate a fever and a lower temperature could lead to hypothermia, where the body temperature gets too cold to support normal metabolism and bodily functions. How does your body stay within this narrow temperature range when it can be much colder or warmer than that outside?

Several organ systems work together to warm you up or cool you down as needed. Most of the time, your body temperature is being regulated without you being aware of it. The regulation of body temperature involves four systems:

- the nervous system
- the circulatory system
- the respiratory system
- the locomotive system

The nervous system tells your brain when you are too hot or too cold. When your body starts getting cold, you respond by decreasing blood flow to your skin, twitching your muscles (shivering), and making "goose bumps." The decrease in blood flow to the skin decreases heat loss, while shivering causes heat-generating muscle contractions. The goose bumps result from hair follicles on your skin

standing up, causing the skin around them to pull up also. This causes the fine hairs on your skin to rise up and trap an insulating layer of warm air against you. You also instinctively avoid taking deep breaths of cold air that could further chill you down.

When your body starts getting too hot, the opposite happens. You respond by increasing blood flow to your body surface, relaxing your muscles, and increasing perspiration. The increase in blood flow to the surface allows for greater heat dissipation. Relaxed muscles do not generate heat, and increasing perspiration will cause a cooling sensation when the moisture is evaporated from the skin surface. You also try to get rid of excess heat by filling your lungs with as much cooler air as possible. You may have noticed that if you get really hot, you start to breathe faster.

Resting Heart Rate

The average resting heart rate of a person is between 50 and 100 beats a minute. Of course, not everyone has the same resting heart rate. As you learned in Lesson 14, people have different resting heart rates due to gender, age, weight, diet, and smoking. The typical resting heart rate is approximately 70 beats a minute for an adult male and 73 for an adult female, with a range of about ± 5 beats a minute.

A resting heart rate faster than 100 beats a minute is called tachycardia and could lead to a heart attack. A resting heart rate that is slower than 50 beats a minute is called bradycardia and could lead to a stroke. You do not consciously think about making your heart beat, so how does your body keep the heart beating at the proper rate?

The regulation of heart rate involves three systems:

- the nervous system
- the circulatory system
- the respiratory system

When a person exercises, his or her heart rate can reach well above 100 beats a minute. During exercise, the muscles consume more oxygen and release more carbon dioxide. The increase in heart rate is caused by the brain sensing that more oxygen is needed by the muscles; the heart pumps oxygenated blood to the muscles to provide this. The nervous system transmits a signal from the brain to the heart muscles, telling them to contract faster. Since extra oxygen is also needed, the breathing rate increases. When the exercise ends, the organ systems involved will restore the resting heart rate to normal.

Resting Breathing Rate

The average resting breathing rate of a person is 16 to 20 breaths a minute. If the resting breathing rate drops below 16 breaths a minute, this could lead to hyperventilation, a condition that occurs when there is not enough air in the lungs for gas exchange. If the rate is higher than 20 breaths a minute, this could lead to hyperventilation, a condition caused by too much breathing, resulting in too low carbon dioxide levels in the blood and feelings of light-headedness.

Too much oxygen or not enough oxygen could cause you to lose consciousness, so it is important for your body to maintain just the right breathing rate for your needs. For example, during exercise, your breathing rate will go up, but this is only temporary in order to supply your muscles with the required amounts of oxygen. Once your oxygen needs are reduced, your breathing rate will be automatically reduced too.

The regulation of breathing rate involves three systems:

- the nervous system
- the circulatory system
- the respiratory system

When muscles are asked to work harder and begin to require more oxygen than the blood is delivering, a chemical signal is transmitted to the brain, telling it to increase breathing and heart rate. The brain sends signals along the nervous system, telling the heart to beat faster and the diaphragm to breathe deeper and faster. As a result, more blood will be pumped to the lungs where it picks up oxygen and then is circulated through the body.

Systems Working Together

As the above examples have shown, the respiratory and circulatory systems regularly cooperate. Together they are responsible for the intake and delivery of oxygen to cells so that the cells can undergo the process of cellular respiration and generate useable energy. Because the cooperation of these two systems is essential to your overall health, the next sections explore their structure in more detail. Examples will illustrate how they interconnect with each other and with other major organ systems in the body.

There are Suggested Answers to Support Questions at the end of this unit.

systems.

87. Explain how heart rate is regulated by the respiratory and circulatory

86. Explain the process of homeostasis using breathing rate as an example.

Do not send your answers in for evaluation.

Support Questions

Respiratory System

In Lesson 14 you learned about the organs that make up the respiratory system. The general structure of the respiratory system is shown for review in Figure 15.1.

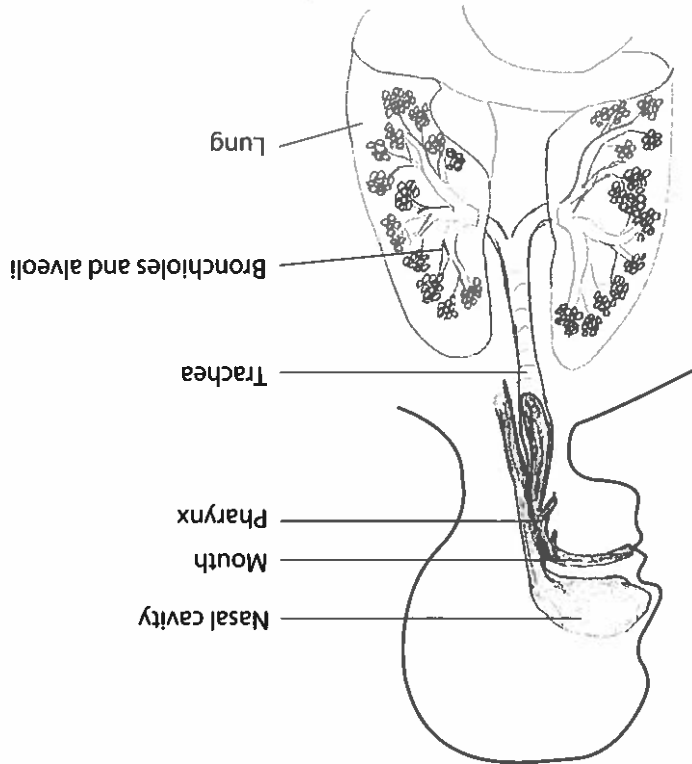


Figure 15.1 Main components of the human respiratory system

One of the key components to the respiratory system is the alveolar sac. As you learned in the previous lesson, these air sacs contain a cluster of alveoli tightly wrapped in capillaries. The alveoli are arranged in grape-like clusters that greatly increase their surface area, which is four times the surface area of your skin. The approximately 600 million alveoli in your lungs facilitate the diffusion of oxygen into the bloodstream and carbon dioxide out of it. **Diffusion** is the movement of materials from an area of high concentration to an area of low concentration that occurs without the use of energy. You have seen diffusion in action when you add sugar to coffee or watch a tea bag slowly steep in a pot. The material eventually spreads evenly everywhere.

Alveoli have thin walls made of epithelial cells. Being very thin, this layer of cells increases the rate of diffusion. The walls of the alveoli are moist, which also helps to speed up diffusion and hence the exchange of gases. Oxygen diffuses from an area of high concentration inside the alveoli to an area of low concentration inside the blood. At the same time, carbon dioxide moves from an area of high concentration inside the blood to an area of low concentration inside the alveoli.

The circulatory system is located throughout the body. In addition to regulating temperature, it transports oxygen, carbon dioxide, nutrients, wastes, and hormones. The general structure of the circulatory system is shown in Figure 15.2.

Circulatory System

89. Identify three physical characteristics of alveoli that make them effective in regulating gas exchange.

88. Describe the process of gas exchange in the lung.

Support Questions

The alveoli are densely covered with capillaries. These numerous capillaries provide a large contact area between the alveoli and blood. Because they have these two features of high surface area and large areas of blood contact, alveoli are highly effective at exchanging gases between the air and blood. The alveoli also contain stretch receptors that prevent over-filling with air and causing damage to thin walls.

An *optional* interactive animated tutorial on the ILC website demonstrates the process of gas exchange in the lung. If you want to view this tutorial, go to your course page on the ILC website and click on "Gas Exchange in Lungs, Alveoli, and Human Cells" under Lesson 15.



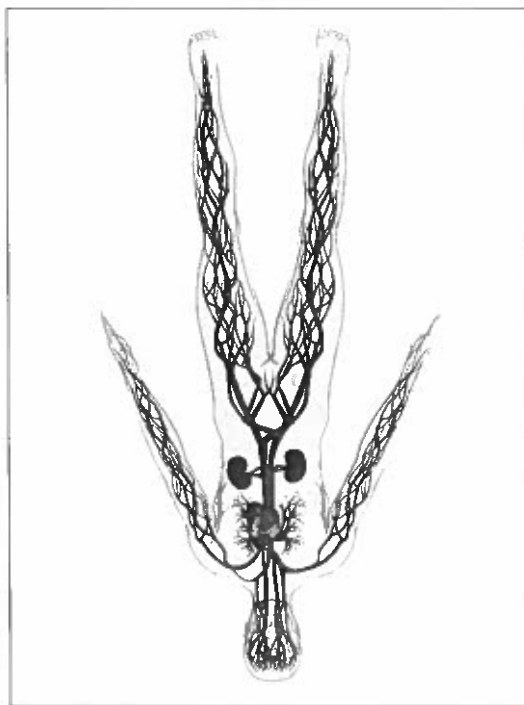


Figure 15.2 Human circulatory system.

Source: iStockphoto.com

Connected to every other system in the body, the circulatory system keeps all 100 trillion cells supplied with oxygen. The oxygen that is transported through the circulatory system is obtained from the lungs via pulmonary circulation, and dispersed throughout the body via systemic circulation. Every minute, five litres of blood cycles from the heart to the lungs, picks up oxygen, and then returns to the heart.

As discussed in the previous lesson, oxygen is carried by an iron-rich protein molecule called **hemoglobin** that is found within red blood cells. Hemoglobin makes up about 97% of the mass of a red blood cell. In fact, each red blood cell contains around 250 million molecules of hemoglobin, giving it the capacity to carry 1000 million molecules of oxygen. The hemoglobin molecule is actually made up of four connected protein chains, each containing a *heme* group (molecules containing iron).

Hemoglobin is not the only oxygen-binding protein in the human body. Found in muscle tissue, myoglobin gives muscle tissue a distinct red or dark gray color. Very similar to hemoglobin in structure and sequence, it is used to store oxygen rather than transport it.

The circulatory and respiratory systems work together to deliver oxygenated blood to the body's cells.

The process starts with deoxygenated blood returning to the heart from the body after it has delivered oxygen to all the tissues, glands, and organs that needed it. The deoxygenated blood enters the heart, passes through the right atrium and ends up in the right ventricle. A contraction of the heart muscle forces this blood up through the pulmonary valve of the heart and into the **pulmonary artery**. This artery splits into two, each directed toward one lung.

Example 1. Respiratory and Circulatory Systems

The next sections will describe three examples of multiple organ systems working together to produce beneficial effects for the whole body.

Examples of Systems Working Together

91. Besides hemoglobin, name an oxygen-binding protein in humans. Why is this protein important?

90. Why is hemoglobin important?

Support Questions

As you saw in Lesson 14, the heart has the following structure:

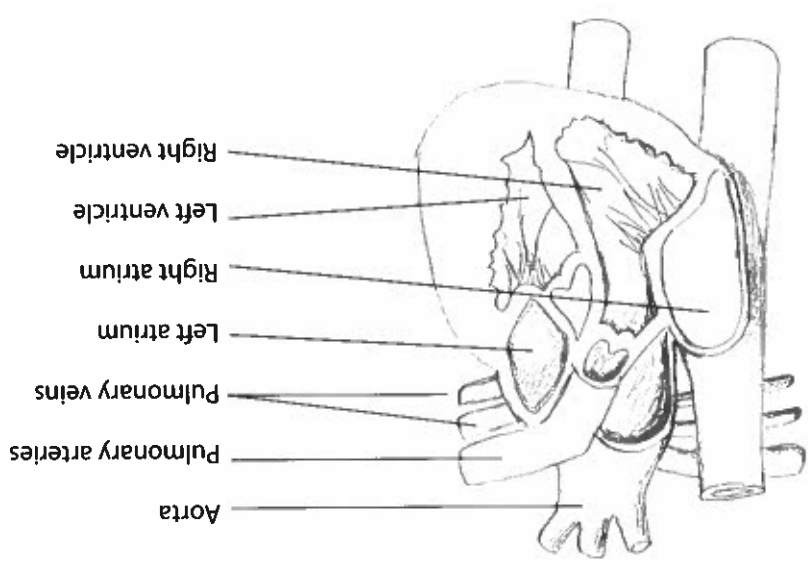


Figure 15.3 The human heart as seen from the front

The blood within the pulmonary arteries enters the lungs and branches down into small capillaries in the alveoli. It is within the alveoli of the respiratory system that the exchange of oxygen and carbon dioxide occurs. Oxygen diffuses from the alveoli into the capillaries, and carbon dioxide diffuses from the capillaries into the alveoli.

The blood in the capillaries is now oxygenated. This oxygenated blood returns to the heart via the **pulmonary vein**, enters the left atrium, and passes into the left ventricle. The contraction of the heart muscle forces the oxygenated blood up through the aortic valve and into the aorta. The aorta is responsible for sending the oxygenated blood throughout the body through various arteries.

By combining the blood circulation system with the gas exchange system in the lungs, your body can efficiently deliver oxygen to all its cells.

In this example, three systems—the respiratory, circulatory, and digestive—work together to deliver nutrients to all cells in the body.

The digestive system involves the multiple organs discussed in the previous lesson. One organ in particular, the small intestine, is directly associated with the circulatory system. The small intestine is the main area of nutrient absorption. Digested material entering the small intestine comes in contact with the small-intestine surface, which is covered in villi (see Figure 15.4 below). Villi are tiny, finger-like folds in the inner wall of the small intestine. They increase the surface area of the small intestine, allowing it to absorb much more material.

Example 2. Respiratory, Circulatory, and Digestive Systems

System Component	Oxygenated or Deoxygenated Blood
Pulmonary veins	
Pulmonary arteries	
Right ventricle	
Left atrium	
Aorta	

93. Indicate whether the components of the circulatory system listed in the table below carry oxygenated or deoxygenated blood.

92. List three ways in which the circulatory and respiratory systems work together.

Support Questions

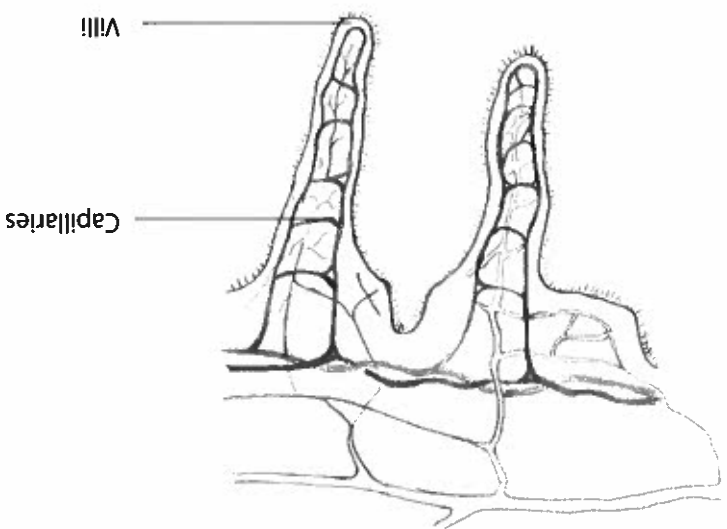


Figure 15.4 Villi protruding from the surface of the small intestine

Inside the villi are capillaries, which are connected to major veins or arteries travelling to and from the heart. Essential nutrients such as carbohydrates, lipids, and amino acids are absorbed into the capillaries through the villi. These nutrients can then be transported via the blood to any cell within the body. At the same time, the circulatory system supplies all of the digestive organs with the oxygen, obtained from the respiratory system, that these organs need to function. That is why during heavy exercise, your body does not digest food very well. The oxygenated blood needed by the digestive organs is instead directed towards the muscles because their need is more urgent.

Support Question

94. List one way in which the circulatory and digestive systems work together.

Example 3. Respiratory, Circulatory, Digestive, and Excretory Systems

In this example, four systems—the respiratory, circulatory, digestive, and excretory—work together to eliminate unwanted materials from the body. Many individuals digest more food products than are required by the cells of the body for growth and/or function. These materials are still absorbed through the villi of the small intestine and end up the circulatory system. These extra materials, plus additional waste products generated by the cells, must be removed from the body. For example, the digestion of protein often results in the formation of ammonia, which is toxic to the human body. Ammonia can be combined with carbon dioxide in the bloodstream to form urea, a harmless chemical. Urea is one of the main components of urine.

Waste products from digestion and cell activities are continually being added to the blood. The carbon dioxide produced as a result of cellular metabolism of the ingested food is carried by the blood to the lungs, where it is expelled. The blood needs to be cleaned of the other waste products, and that is the main purpose of the kidneys. Unfiltered blood is transported via the circulatory system to the kidneys, the main organs of the excretory system. Inside the kidney are millions of small structures called nephrons, which are the functional units of the kidneys. This is where the waste products and urea are removed from the blood. Blood entering the kidney is directed into small capillaries and then into the nephrons where the capillaries eventually become highly folded and twisted, like balls of wool. Surrounding them is a cup-like sac in the nephron called Bowman's capsule. Any waste material and excess water diffuses out of the blood through the capillary membrane and into Bowman's capsule. The waste material in Bowman's capsule is collected as urine and eventually makes its way to the bladder for excretion. The clean blood flows out of the nephrons and moves through other parts of the kidney where it can absorb some water and salt if needed.

Support Question

95. List ways in which the circulatory and excretory systems work together.

So far, in Lesson 14 and in the first half of this lesson, you have been learning about organs and organ systems individually. But of course they are all connected and are all part of the same body. To really understand how organs relate, you need to study a whole organism. A dissection is the best way to study the internal organ systems of any organism. You will conduct a virtual dissection of a frog using the virtual dissection tool available through your course web page.



Activity: The Frog: A Virtual Dissection

You will use the virtual dissection software tool available on the course website to conduct a dissection of a frog. This will help you develop a better understanding of the main organ systems of vertebrates. As you work through this online activity, keep your lesson book beside you and take notes to help you answer the Support Questions included throughout the activity.



Go to your course page on the ILC website and click on “The Frog: A Virtual Dissection” under Lesson 15.

Purpose

To develop a better understanding of the internal anatomy of a vertebrate.

Procedure

This activity is divided into three sections. In the first section, you will learn how to dissect a frog using the online virtual dissection. In the second, you will explore the organ systems revealed by your dissection and answer some Support Questions related to organ-system function. In the third section, you will learn how the internal anatomy of mammals differs from frogs and how this relates to differences in their lifestyle. Your study specimen for mammals will be a fetal pig. Because pigs and humans have very similar internal anatomies, this will also give you insight into how your own internal anatomy looks and functions.

Section 1: Abdominal Dissection of Frog

- When you start the virtual dissection activity, an introductory screen appears that explains the purpose of dissection and shows three examples. Proceed to the second screen, "Dissecting the Chest/Abdominal Area," to begin the virtual dissection.
- This screen shows the equipment you will use in the dissection, including a scalpel (for precise cutting), scissors (for general cutting), forceps (for grasping and pulling), a blunt probe (for pointing and exploring), and pins (to pin back flaps of skin and muscle). As you roll over each instrument, you will see its name and a brief description of its function in the dissection.
- To begin the dissection, click on button 1, "Opening the Skin," and follow the instructions for making incisions and pulling back the skin.
- Use the pins to hold down the specimen.
 - Use the scalpel to make the first incision (in other words, cut) down the middle of the abdomen.
 - Use the scalpel to make lateral (side-to-side) cuts at the top and bottom of first incision.
 - Use the forceps to pull the skin back and use the pins to hold it in place.
- At this point you can examine a photograph of a real specimen prepared in the same way.
- Click on "2" to view "Opening the cavity" and follow the instructions for opening the abdominal cavity. Use the scissors, scalpel, and forceps to cut through the muscle layers and pin back the flaps.
 - Remove the fat bodies to reveal the internal organs. At this point you can view a photograph of an actual dissection at this stage.
 - Click on "3" to view "Removing the organs."
 - Follow the instructions to select, view, and remove each of the main organs in the abdominal cavity.
 - Do not close the virtual dissection window. You will review the organs in more detail in the next section.

Section 2: Exploring Internal Organs

Now that the frog's internal organs are exposed, you can explore each one in more detail. You will focus on four main organ systems: circulatory, respiratory, digestive, and excretory. It is easiest if you explore each organ system separately and answer the Support Questions as you go.

1. Circulatory System

Click on the heart to bring up a photograph of the frog's heart. Locate the heart and the two red arteries taking blood away from the heart. Try to follow some of the major arteries and veins connected to the heart. Note that in this prepared specimen, the arteries are dyed red and the veins blue to make them easier to follow.

Examine the structure of the heart. The frog heart has three chambers: two atria (on top) and a single ventricle (on the bottom). Try to identify each one. This is how the three-chambered frog heart works:

- The right atrium receives deoxygenated blood from the blood vessels (veins) that drain the various organs of the body.
- The left atrium receives oxygenated blood from the lungs and skin (which also serves as a gas-exchange organ in most amphibians).
- Both atria empty into the single ventricle, which is divided by a spiral valve to help keep the blood from each atrium somewhat separate.
- When the ventricle contracts, oxygenated blood from the left atrium is sent through the two arteries leading to the head. Deoxygenated blood from the right atrium is sent to the arteries, taking blood to the skin and lungs where fresh oxygen can be picked up.

Support Question

96. In the frog heart, how is oxygenated blood kept separate from deoxygenated blood?

2. Respiratory System

Click on the lungs to bring up a photograph of the frog's lungs. The two lungs are located at the anterior end (head end) of the body cavity on either side of the heart. The lungs are often difficult to locate in a preserved frog because they deflate and shrink.

Adult frogs use their lungs to breathe on land. Frogs have no ribs or diaphragm, and they do not use chest muscles to help them pump air in and out of their lungs like you do. Instead, frogs gulp air into their mouth and then use the floor of their mouth to force the air into their lungs.

The frog's skin serves as a supplementary organ of gas exchange. However, it must remain moist to perform this function, which is one reason that frogs, like other amphibians, live in moist places. To enable skin breathing, the skin of a frog is permeable to oxygen and carbon dioxide, as well as to water.

Close the image of the lungs and take a look at the skin you pinned back earlier. You will notice that there are a number of blood vessels near the surface of the skin. When a frog is underwater, oxygen is transmitted through the skin directly into the bloodstream through these blood vessels.

Support Question

97. Explain how an adult frog can breathe both on land and under water.

3. Digestive System

Click on the stomach to bring up a photograph of the frog's upper digestive system. Locate the stomach. Notice how large it is in this specimen; this indicates that it is still full of undigested food.

Click on the liver to bring up a photograph of the frog's liver. Notice how large it is and that it is divided into three lobes.

Next, click on the gall bladder to bring up a photograph of the frog's gall bladder. Notice how it is hidden below the liver (now cut away to reveal the gall bladder) and how it attaches to the small intestine.

Click on the intestines to bring up a photograph of the frog's lower digestive system. The small intestine is in the upper part of the picture (near the stomach). The large intestine is partially hidden in the lower part of the picture, and ends in the colon.

The frog uses its sticky tongue to catch food, such as insects, which then moves through the esophagus into the stomach. The stomach partially digests the food, which then proceeds to the small intestine where most digestion occurs. Secretions from the pancreas and gallbladder flow into the small intestine where they help digest the food and extract the nutrients. When the food passes into the large intestine, the water is reabsorbed. Finally, the waste is excreted out the cloaca (similar to the anus in mammals).

Support Question

98. Why is the stomach relatively large in this frog?

4. Excretory System

Click on the kidneys to bring up a photograph of the frog's excretory system. Locate the kidneys and the severed cloacal canal. Frogs excrete all waste out through their cloaca, so do not need a bladder. However, they still need to clean their blood using the kidneys.

Support Question

99. What kinds of waste flow out of a frog's cloaca?

Section 3: Fetal Pig Anatomy

The internal anatomy of all vertebrates is similar because of their shared evolutionary history. However, there are differences between frogs and mammals that relate to their different diets and ways of life. In this section you will explore mammalian anatomy, using a fetal pig as your study specimen.

Fetal pigs are commonly dissected because they are very similar in anatomical structure to humans. Humans and pigs are both omnivorous mammals, which mean they eat both vegetation and meat. As a result, they have similar digestive systems. They also have similar circulatory and endocrine systems. In fact, pigs are so similar to humans that pig organs are sometimes transplanted into humans as a temporary measure until human donor organs can be found.

You will notice that pigs are still different from humans in several ways. For example, they lack an appendix and are quadrupeds (walk on four legs) rather than bipeds (walk on two legs) like us.

Just like you did with the frog, explore each of the four organ systems separately and answer the Support Questions as you go.

Because you have already dissected the frog, you don't need to repeat the dissection process in this lesson to examine the anatomy of the pig. The process is identical. Instead, you will examine photographs taken from actual dissections of a fetal pig and concentrate on recognizing important features of each organ system. There is one thing to note about the image descriptions. Because you will often be examining images of organs removed from the body, sometimes it is hard to know which end is up, front, or back. That is why many images will tell you their orientation using these terms:

1. ventral—which means front, or chest view
2. dorsal—which means back view
3. anterior—which means toward the head end
4. posterior—which means towards the tail end

So, for example, a ventral view of the heart means the image shows the heart as it would look if you cut open the chest to examine it when the pig is lying on its back. A dorsal view in this dissection means it is showing the underside of the organ.



To start exploring the anatomy of the pig, go to your course page on the ILC website and click on "Fetal Pig Anatomy" under Lesson 15.

The image gallery is organized into four rows. Each row shows images related to one of the four major organ systems in the pig: circulatory, respiratory, digestive, and excretory.

Click on the thumbnail images to view the larger image. Use the following instructions and Support Questions to guide your exploration of the anatomy of the fetal pig.

1. Circulatory System

Locate the heart within the chest cavity. Notice its position tucked inside the lobes of the lungs.

Identify the right and left atria, the right and left ventricles, the aorta, and the superior and inferior vena cava.

Just like in the frog, the arteries have been dyed red and the veins blue to make it easier to follow them.

Notice that the pig has a four-chambered heart, unlike the frog, which has a three-chambered heart.

Support Questions

- 100.** For each chamber of the heart, state whether the type of blood it contains is oxygenated or deoxygenated.
- a) right atrium
 - b) left atrium
 - c) right ventricle
 - d) left ventricle
- 101.** In a fetus, only a small amount of blood travels from the heart to the lungs and back. Why is it not necessary to send all of the blood back to the lungs?

2. Respiratory System

Locate and identify the organs of the respiratory system, including the larynx, trachea, bronchi, and lungs.

Notice that the pig's lungs are relatively much larger than the frog's.

Support Question

102. At what point in time will the pig first begin to make full use of its lungs?

3. Digestive System

Examine the mouth. Locate the epiglottis and opening of the esophagus. You may not be able to see them, but there are small teeth present in the upper jaw. The roof of the mouth is divided into a front portion called the hard palate and a rear portion called the soft palate.

Locate the tongue, hard palate, soft palate, epiglottis, and opening to the esophagus.

Examine the digestive system in the abdominal cavity. Locate the stomach, liver, pancreas, and intestines.

Support Question

103. Why is the stomach relatively small in the fetal pig?

4. Excretory System

Find the two large, bean-shaped kidneys located along the dorsal surface of the abdominal cavity hidden beneath the liver and intestines. Notice the large veins that connect to them.

Identify the two ureters that exit from the kidneys. These tubes carry urine from each kidney to the urinary bladder.

Locate the rectum and urinary duct where waste is evacuated from the body. Note that the pig has two openings to evacuate waste while the frog uses just one opening (the cloaca).

Support Questions

104. When someone donates a kidney, the incision is usually made through the wall of the back rather than through the front of the abdomen. Why is this method preferred?

105. The thoracic cavity is surrounded by a stiff rib cage, while the abdominal cavity has a softer muscular wall. Explain how these structures are beneficial in each case.

106. Which system(s) are the most similar between humans and pigs. Why?

Medical Conditions and Treatments

The complexity of organs and organ systems allows your body to do amazing things. But sometimes the organ systems do not function as well as they should. The consequences can range from relatively minor to fatal. The last section of this lesson focuses on some of the more common disorders that occur in the respiratory and circulatory systems.

Respiratory Disorders

Three of the most common respiratory disorders—asthma, bronchitis, and smoking-related illness—are described in the following sections.

Asthma

Asthma is a common ailment that causes difficulty in breathing. It can even be severe enough to cause death. Asthma occurs when the cells of the respiratory system are irritated, causing an inflammation or swelling of the bronchi and bronchioles. This inflammation results in excess mucus production, which in turn leads to narrowing of the passageways.

An asthma attack is usually caused by some type of allergic reaction. The treatment for asthma typically involves some form of inhaler containing corticosteroids. These drugs stimulate the bronchi and bronchioles to increase in diameter. This eases the passage of air, making breathing significantly easier.

Bronchitis

Bronchitis is a severe, prolonged form of asthma. It also involves an inflammation or swelling of the bronchi and bronchioles that results in excess mucus and narrowing of passageways. Bronchitis is usually caused by some type of viral or bacterial infection rather than by an allergy. In addition to inhalers, treatment often involves some medication, such as antibiotics, to treat the infection.

Smoking-Related Illness

Smoking involves the inhalation of smoke, tobacco, nicotine, and approximately 4000 other chemicals. Once nicotine is inhaled, its effects reach the brain within six seconds, and it is very addictive. This makes it hard for people to quit smoking even when they understand its health consequences.

The term **smoking-related illness** refers to the many diseases of the circulatory and respiratory systems caused by smoking tobacco. Illness related to smoking has been linked to millions of deaths around the world. Globally, tobacco causes 10 000 deaths each day. It is one of the leading preventable causes of death in the world. Cigarette smoking is responsible for more deaths each year than AIDS, alcohol, car accidents, cocaine, heroin, fires, homicides, and suicides combined. In Canada alone, 22 billion dollars a year is spent on smoking-related illness.

Smoking can cause extreme damage to both the respiratory and circulatory systems. With regards to the respiratory system, smoking is related to 87% of all lung cancer cases, which is the leading cause of cancer deaths in Canada for both men and women. Even non-smokers can fall victim to it. Each year, 330 non-smoking Canadians die from lung cancer as a result of second-hand smoke. With regards to the circulatory system, smoking is the leading cause of heart attacks and causes 25% of all coronary artery disease.

How Does Smoking Cause Health Problems?

Respiratory

- Tobacco smoke enters the bronchi and bronchioles, and irritates the cells.
- The cells then produce excess mucus to trap foreign particles.
- The chemicals in the smoke stop the cilia from moving, which means foreign particles cannot be removed.
- Lungs become susceptible to infection from bacteria and/or viruses.
- The alveoli are damaged by gases in the smoke and lose their elasticity. They can't hold as much air, causing shortness of breath.

Circulatory

- Several ingredients in tobacco lead to the narrowing of blood vessels.
- This increases the chance of getting a blockage, and thus a heart attack or stroke.
- The heart has to beat harder and faster to send more blood around quickly to meet the needs of the cells since less oxygen is getting into the blood.

Cancer

- Tar and other toxins in tobacco smoke can trigger mutations in the cells.
 - Mutated cells begin uncontrolled growth, resulting in a cancerous tumour.
- With more research showing a strong link between smoking and cancer and heart disease, governments and health professionals have been working hard to make people aware of the dangers of smoking. Restrictions on tobacco advertising, packaging, and sales have all helped to reduce the rate of smoking in Ontario. Cigarette packages must contain warnings, and new laws require that stores hide tobacco products from the view of the customer. Many towns and cities have banned smoking from all public buildings. Some cities have even banned outdoor smoking in parks and playgrounds.

With all these changes, attitudes in society are changing so that fewer people now smoke. Smoking rates in North America and Europe have declined steadily since the 1960s. Unfortunately, the rate of smoking is actually increasing in other parts of the world.

Support Questions

107. What is the difference between asthma and bronchitis?

108. Make a list of ways that smoking damages your cardio-respiratory system.

Circulatory Disorders

Three of the most common circulatory disorders—**anemia**, **sickle cell anemia**, and **arteriosclerosis**—are described in the following sections.

Anemia

Anemia is a disorder that results from insufficient hemoglobin. This results in an insufficient quantity of oxygen being transported throughout the circulatory system. Many people with anemia don't know they have the problem because quite often there are no dramatic symptoms. Symptoms include paleness, tiredness, shortness of breath, and increased heart rate.

There are multiple causes of anemia, including the inability to make enough blood or the excessive loss of blood through bleeding. However, the most common cause is insufficient intake of iron in the diet. Iron is the structural building block of hemoglobin. Eating iron-rich foods or taking iron supplements can help control the problem.

Sickle Cell Anemia

Sickle cell anemia is an inherited genetic disorder caused by a mutation in the hemoglobin gene that creates irregularly shaped red blood cells. Normal red blood cells are circular in shape and move easily through the blood vessels. Sickle cells are curved like the letter "C" or a crescent moon. This abnormal shape can cause clumping within veins and arteries, which can inhibit blood flow. Also, normal red blood cells last only about 10 to 20 days. Therefore, a person with sickle cell anemia has a lower-than-normal red blood cell count. Symptoms of sickle cell anemia include tiredness, general weakness, pain, poor circulation, and problems fighting off infections. There is no cure for sickle cell anemia, but there are treatments for the symptoms, including taking in more folic acid to help produce new red blood cells. Sickle cell anemia is more common in certain ethnic groups, including those from Africa, Central and South America, and India. People with sickle cell anemia are less susceptible to malaria. This disorder is thus more prevalent in areas where malaria is common.

Arteriosclerosis

Arteriosclerosis is a condition that involves the hardening (loss of elasticity) of the arteries. This is caused by the build-up of plaque on the inside walls of the blood vessels. Plaque is a thick, sticky substance that can build up in the blood. The causes of plaque build-up typically include high levels of cholesterol in the diet and smoking. As the layers of plaque build up on the walls of the main blood vessels, there is less room for the blood to flow. In extreme cases the blood vessel gets blocked entirely. The restriction of blood flow could lead to heart attacks or strokes.

Many people don't know they have arteriosclerosis until they suffer a heart attack or stroke. One way to diagnose the problem early is to use a brachial ultrasound. This tests the elasticity of the brachial artery in the arm. The ultrasound can determine the diameter of that artery, and so will be able to tell if there is a blockage caused by the build-up of plaque. If there is plaque build-up in that artery, then the chances are pretty high that the problem exists in other important arteries too.

There are several ways to treat arteriosclerosis. In an angioplasty, a tube-like object called a stent is surgically inserted into the blood vessel. The stent keeps the artery wide open, allowing for increased blood flow. Another surgical method is called a bypass: blood vessels are cut and reconnected to go around the blockage completely. The best way to avoid this problem is to eat a balanced diet, maintain a healthy weight, avoid smoking, and exercise regularly.

Support Questions

109. What are some common symptoms of anemia?

110. What causes the formation of sickle cells and what problems can this lead to?

111. What causes arteriosclerosis and how can it be treated?

Conclusion

In this lesson you learned how the main organ systems work together to create a functioning organism. One of the most important functions is maintaining constant conditions within the body in a process called homeostasis. You also became more familiar with the different organs and their relationship to each other by performing a virtual dissection on a fetal pig, an omnivorous mammal very similar to a human.

Many diseases are caused by problems in organ systems, and you learned about a few of the major ones in the respiratory and circulatory systems. You also learned that smoking is a major cause of illness that impacts both these systems severely.

Key Concepts

Organ system: a group of organs that work together to perform a specialized task within a limited range

Negative feedback: a process whereby a system is kept within certain bounds by feedback from its actions

Nervous system: organ system that detects and responds to changes in the external environment, then sends signals to the organs to cause them to react. In humans it consists of the brain, nerves, and sensory organs like the eyes and ears.

Circulatory system: organ system that moves blood around the body where it can absorb or give up oxygen, deliver nutrients and hormones, and help regulate body temperature. In humans it consists of the heart, veins, arteries, and capillaries.

Digestive system: organ system that takes in and digests food, and then excretes the waste. In humans it consists of the mouth, esophagus, stomach, small intestine, large intestine, and pancreas.

Respiratory system: organ system that brings in outside air and then allows an exchange of gases with the blood, bringing oxygen in and expelling carbon dioxide. In humans it consists of the nose, trachea, lungs, bronchi, bronchioles, and alveoli.

Excretory system: organ system that filters out waste products from the blood. In humans it consists mainly of the kidneys and bladder.

Diffusion: the movement of materials from an area of high concentration to an area of low concentration that occurs without the use of energy

Hemoglobin: iron-rich protein molecule found within red blood cells; its function is transporting oxygen

Pulmonary artery: a major blood vessel that comes out of the right ventricle in the heart and connects to the lungs. It splits into two, each directed toward one lung. It carries deoxygenated blood to the lungs.

Pulmonary vein: a major blood vessel that connects the lungs to the heart and ends up in the left ventricle. It carries oxygenated blood away from the lungs.

Villi: folds in the surface of the small intestine inner wall that stick out and absorb nutrients from the digesting food

Smoking-related illness: the many diseases of the circulatory and respiratory systems caused by smoking tobacco

Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 18 marks

- 60.** Explain the process of homeostasis using body temperature regulation as an example. (4 marks)
- 61.** Explain why it is beneficial to have your organ systems interconnected and working together. (2 marks)
- 62.** Explain why strengthening your heart and lungs can improve locomotive muscle performance. (3 marks)
- 63.** Give three reasons why smoking is harmful to the respiratory and circulatory systems. (3 marks)
- 64.** Complete the following table for the three illnesses indicated.
(6 marks: 1 mark for each box in the table)

Illness/Disorder	Cause	Solution (treatment)
Asthma		
Bronchitis		
Arteriosclerosis		

This is the last lesson in Unit 3. When you are finished, do the Evaluation work in your Course Journal or e-Journal for Unit 3. Follow any other instructions you have received from ILC about submitting your journal, then send it to ILC. A teacher will mark your work, and ILC will send it back to you as soon as possible.