12.2 Leaves

Perhaps the most popular leaf in the world comes from the plant *Camellia sinensis*. The Chinese were the first to use the leaves of the *Camellia* to make tea, about 5000 years ago. From there, tea-drinking spread through Southeast Asia and Japan. Europeans were introduced to tea when they arrived in China in the seventeenth century, and today tea is consumed around the world.

Tea has had a profound effect on many cultures. Japan and China have elaborate ceremonies developed around the drinking of tea (**Figure 1**). The popularity and relative scarcity of tea made it a very valuable commodity, so at first drinking tea was an upper-class privilege. Trading in tea then became big business. China was the main producer, and trade routes were established to western Europe and Russia. These trade routes also allowed cultural exchange between Europe and Asia. Tea was thought to have medicinal properties and so became more popular among Europeans. By the late 1600s, tea drinking was common worldwide.

Figure 1 A Japanese tea ceremony.

UNIT TASK BOOKMARK

As you work on your Unit Task, consider how the demand for particular plant products, such as tea leaves, by wealthier nations can affect human life and the environment in less wealthy areas.

Research This

Sustainable Tea Production

Skills: Researching, Analyzing, Identifying Alternatives, Defending a Decision

SKILLS HANDBOOK A5.1

Tea is usually produced in large plantations, where it is the only plant grown (**Figure 2**). It is often grown in less-developed nations and harvested by workers who receive low pay and few benefits. This situation is beginning to change, however. Tea growers are developing new ways of growing and harvesting tea leaves that provide the workers with larger incomes and have fewer negative effects on the environment.

1. Use the Internet and other sources to research sustainable tea production.

A. Why are traditional ways of growing and harvesting tea not sustainable? T/I A

B. What changes are taking place in the tea industry to make it more sustainable? T/I A

C. Is there a link between improved living and working conditions for workers and sustainable production of tea? Explain. T/I A

Figure 2 Many different varieties of tea made from *Camellia* are now produced in China, India, Sri Lanka, Taiwan, Sumatra, Indonesia, and parts of Africa including Kenya.

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Functions of Leaves

Tea plants contain many chemical compounds, including pigments, tannins, and caffeine. These compounds help the leaves function. For example, both tannins and caffeine are noxious defence chemicals that protect the leaves from herbivores. Leaves may play various roles in the plant, including photosynthesis, gas exchange, storage, and protection from predators.

Leaves are the primary site of photosynthesis in most plant species. Recall that during photosynthesis, plant cells use solar energy to convert carbon dioxide and water to glucose and oxygen. The plant uses the glucose as a building material. Plants also use glucose as an energy source for cellular processes. Humans and many other organisms rely on the oxygen released by photosynthesis to breathe. Recall that carbon dioxide is a greenhouse gas that contributes to climate change. On a global scale, therefore, photosynthesis has an important influence on the climate, since it removes carbon dioxide from the atmosphere.

Leaf cells absorb energy from sunlight in an organelle called a **chloroplast** (**Figure 3**). Certain cells in leaves each contain many chloroplasts. Each chloroplast contains various **photopigments**, which are chemicals that absorb particular wavelengths of light. The most common photopigments are the chlorophylls, which absorb light at the red and blue ends of the visible light spectrum and reflect green light. This gives leaves their characteristic green colour. Chloroplasts also contain accessory pigments, which are pigments that absorb light wavelengths not absorbed by chlorophyll.

chloroplast an organelle found in large numbers in many plant cells; the site of photosynthesis within a plant cell

photopigment a pigment that undergoes a physical or chemical change in the presence of light

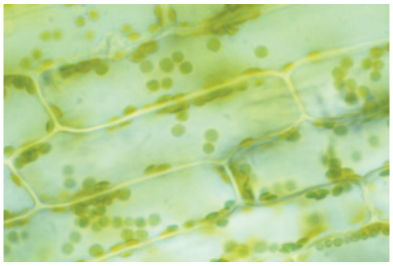

Figure 3 The small green dots in these *Elodea* (pondweed) cells are the chloroplasts.

Another function of leaves for most species is gas exchange between the interior of the plant and its environment. The surface (epidermis) of most plants' leaves contains many pores through which gases pass in and out. Two important cellular processes require gas exchange: photosynthesis and cellular respiration. Photosynthesis uses carbon dioxide gas and releases oxygen gas and water vapour; cellular respiration uses oxygen and produces carbon dioxide.

Leaves may also offer protection from herbivores. In some species such as cacti, leaves are reduced to sharp spines that help protect the thick, green photosynthetic stem. Other leaves protect themselves with surface hairs, which make the leaves unpalatable, and may contain irritating compounds. Other species produce toxins or bad-tasting chemicals within their leaves to deter herbivores.

Structure of Leaves

The general structure of a leaf helps it carry out its roles in photosynthesis and gas exchange. As shown in **Figure 4**, most leaves have a flattened area, known as a **blade**. The blade is attached to the stem by a stalk-like structure called a **petiole**. Leaves can be simple, with just one blade, or compound, with several leaflets attached to the petiole.

blade the flat part of a leaf

petiole the stalk that attaches the leaf blade to the plant stem

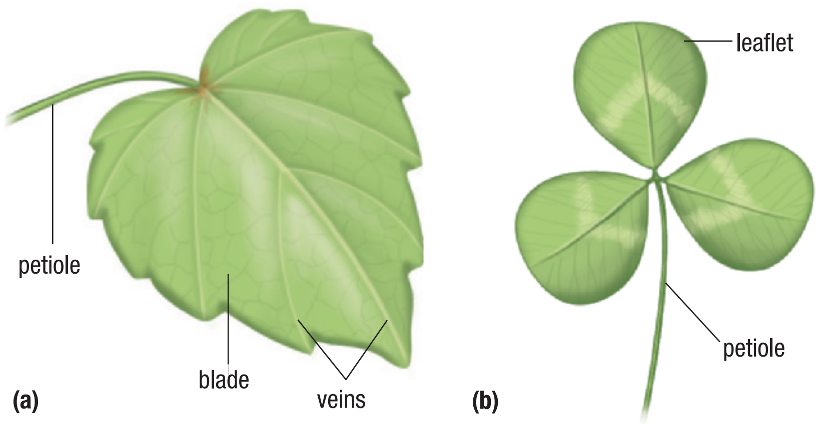

Figure 4 (a) A simple leaf and (b) a compound leaf

venation the arrangement of veins within a leaf

LEARNING TIP

Leaf Shape
Most familiar leaves are flat and very thin with a distinct upper and lower surface. This shape maximizes the efficiency of the leaves in capturing sunlight and ensures that they are very lightweight and easy to support. Other factors, such as environmental conditions and the need to conserve and/or store water, have resulted in some plants evolving other specialized leaf shapes.

The veins of leaves contain the vascular tissue. The arrangement of the veins within a leaf is called its **venation**. Monocots and eudicots have distinct venation. Monocots have parallel venation; the veins are parallel to one another (**Figure 5(a)**). Eudicots have branching venation: the veins form a branching network (**Figure 5(b)**).

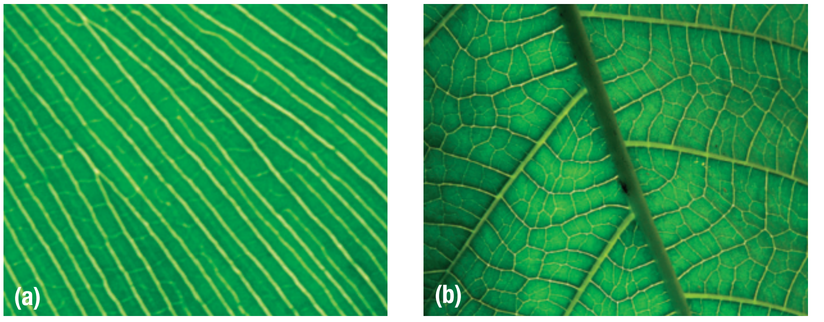

Figure 5 (a) This monocot leaf has veins running parallel to each other. (b) This eudicot leaf has a network of veins.

Internal Leaf Structure

The cells in a leaf are arranged to support photosynthesis and gas exchange. **Figure 6** shows the internal structure of a leaf in a typical vascular plant.

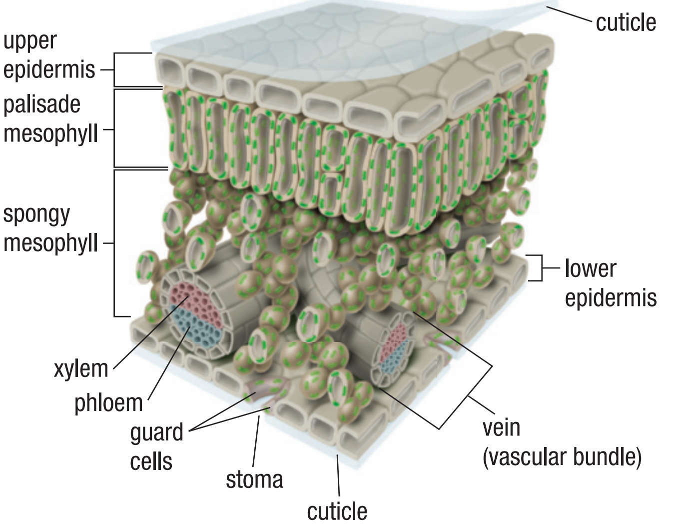

Figure 6 General internal leaf structure of vascular plants

mesophyll the photosynthetic middle layer of cells in the leaf of a terrestrial plant

palisade mesophyll the layer of elongated photosynthetic cells arranged in columns under the upper surface of a leaf on a terrestrial plant; part of the mesophyll

spongy mesophyll the layer of loosely packed photosynthetic cells with large air spaces between them under the lower surface of a leaf on a terrestrial plant; part of the mesophyll

stoma a small opening in the epidermis of a plant that allows gas exchange

guard cell one of two kidney-shaped cells that control the opening and closing of a stoma

aerenchyma tissue composed of loosely

Investigation 12.2.1

Leaf Structure in Vascular Plants (page 575)
Now that you have read about the structure of leaves, you can complete Investigation 12.2.1.

In this observational study you will observe prepared slides of cross-sections of leaves from different vascular plants.

The epidermal cells are tightly packed in a single layer and covered by a waxy coating called the cuticle. The cuticle prevents water loss and provides a physical barrier against bacteria, moulds, and insects. Epidermal cells do not contain chloroplasts, so they do not perform photosynthesis. Epidermal cells are transparent, so light can pass through them to the cells within the leaf.

Chloroplasts are found mainly in the cells of the **mesophyll**, which means "middle leaf." This ground tissue is specialized for photosynthesis. In most terrestrial plants there are two parts to the mesophyll. The region directly under the upper epidermis is the **palisade mesophyll**. Cells in the palisade layer are elongated and closely packed, and contain many chloroplasts. This arrangement maximizes the amount of light the plant can collect and use for photosynthesis. Directly beneath the palisade is the **spongy mesophyll**, a layer in which mesophyll cells are loosely packed. This layer has large air spaces, which allow for gas exchange between the mesophyll cells and the atmosphere through stomata. A **stoma** (plural: stomata) is an opening in the epidermis of a leaf, through which gases pass in and out. Two kidney-shaped cells, called **guard cells**, control the opening and closing of a stoma. In terrestrial plants, most of the stomata are in the lower epidermal layer, below the spongy mesophyll. The vascular tissues (xylem and phloem) are arranged into veins that run through the spongy mesophyll.

In aquatic vascular plants, such as water lilies (**Figure 7**), the spongy mesophyll is replaced with aerenchyma. **Aerenchyma** is a type of tissue found in aquatic plants that is composed of loosely packed parenchyma cells with large pores between them. Aerenchyma helps leaves to float on the surface of the water. The leaves of many floating aquatic plants have most of their stomata on the upper epidermis, so they are exposed to the air. Other aquatic leaves do not float and have no stomata.

Figure 7 Aquatic plants, such as water lilies, have stomata on the upper surface of the leaf to allow for gas exchange with the atmosphere.

aerenchyma tissue composed of loosely packed parenchyma cells with large pores; found in aquatic plants

Leaf Specializations

The primary role of some leaves is to carry out photosynthesis and gas exchange. However, some leaves also have an important role in protecting the plant, while still others are responsible for storing carbohydrates and/or water. The leaf structure of some species is significantly adapted to performing these functions. **Figure 8** shows some examples of leaves that are specialized for storage.

Figure 8 (a) An onion bulb is made up of leaves modified to store water and carbohydrates. (b) *Aloe vera* leaves store water and contain chemicals that have medicinal properties. (c) The jade plant is adapted to very dry climates with fleshy leaves that store water.

Plant leaves often have specializations that help protect the plant. Most species produce chemicals in their leaves to repel herbivores. For example, the chemical nicotine, produced by the leaves of tobacco plants, deters herbivores **(Figure 9(a))**. Other species deter herbivores through the structural specializations of the leaves. Cactus spines are modified leaves that no longer perform photosynthesis—instead, their sole function is to protect the stem from being eaten.

Leaf cells contain water, and if the water freezes into ice crystals, the leaf cells can be damaged or killed. In regions that experience below-freezing temperatures, such as Canada, large, thin leaves are easily frozen and killed. Plants with leaves like these lose their leaves in the fall in order to help the plant conserve water and nutrients during the winter (**Figure 9(b)**). In contrast, most gymnosperms do not lose their leaves. To prevent water loss, their leaves are small and have a thick cuticle and epidermis, and the stomata are recessed below the epidermis. Many gymnosperm leaves also produce chemicals that prevent their cells from freezing. Conifer species, such as spruce and pine, have needle-shaped leaves that allow them to shed snow more readily (**Figure 9(c)**).

Figure 9 Leaf specializations that protect the plant include (a) deterrant chemicals, (b) the ability to drop leaves, and (c) needle-like leaves with thick cuticles and “antifreeze” chemicals.

Human Uses of Leaves

Leaves provide important nutrients and food energy in the diets of humans and our livestock. Most cultures use fragrant leaves to add flavour to other food. These are known as herbs and include parsley, basil, sage, oregano, and cilantro. Teas can be made from the leaves of many plant species, such as peppermint and even catnip. Leaves are used in the traditional foods of many cultures (**Figure 10**).

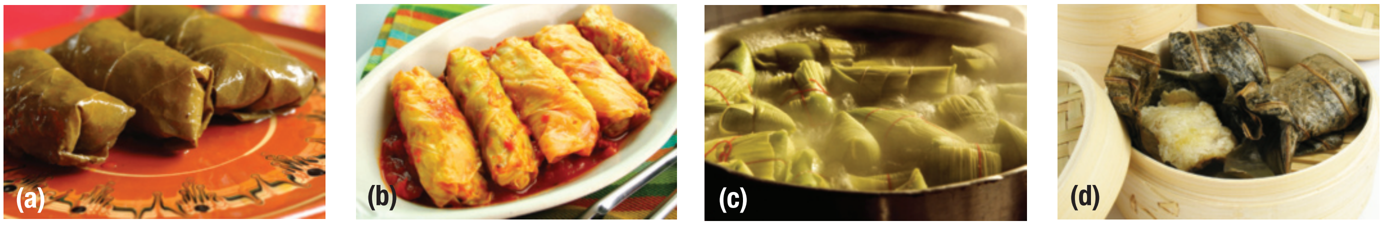

Figure 10 (a) A traditional Greek food called dolmades is made from grape leaves stuffed with rice or meat. (b) Cabbage rolls are cabbage leaves stuffed with meat or rice. (c) Tamales, a traditional South American food, are sometimes cooked in banana leaves. (d) Asian sticky rice is cooked in bamboo leaves.

Dark green leafy vegetables, such as spinach, are especially nutritious. They contain important minerals, such as calcium, potassium, iron, and magnesium, as well as vitamins B, C, E, and K. They also provide nutrients that protect our cells from damage, such as beta-carotene, lutein, and zeaxanthin. Dark green leaves also contain small amounts of omega-3 fats, which are essential for brain and heart function.

Humans have found many uses for the waxy cuticle of leaves. For example, the wax produced by carnauba palm leaves is used to make car and furniture polishes. It is also used in surfboard waxes. It is sometimes an added ingredient in chocolate and is also used as a coating for candies. Candelilla wax, produced by a Mexican desert plant, *Euphorbia cerifera*, is a soft wax used to make lipstick.

CAREER **LINK**

Cosmetic Chemist

Cosmetic chemists use many substances produced by plants in their products. To learn more about becoming a cosmetic chemist,

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Leaves are also used in religious ceremonies. The leaves of the sweet grass plant (also called buffalo grass) are widely used in North American Aboriginal peoples' religious ceremonies. For example, the Cree and Anishinaabe Algonquian peoples burn braided sweet grass at the start of all ceremonies, to purify the spirit. Christians use palm leaves in Easter ceremonies.

Leaves are even used as construction materials. In tropical countries, thatched roofs are made from the leaves of palm trees.

Leaves and Chemicals

Many species protect themselves by synthesizing toxic chemicals in their leaves. Many leaf chemicals are poisonous to humans. For example, the leaves of many house plants and even some vegetables contain toxins that can be harmful to humans if eaten. Consuming hydrangea leaves can cause vomiting, diarrhea, and even coma. Interestingly, we can eat the leaf stalks of the rhubarb plant, but eating the leaf blades could cause vomiting, nausea, and, in some cases, kidney damage.

However, humans have discovered how to use some plant toxins in beneficial ways. Digitalis is a drug used to treat heart disease. It can be deadly, but it is beneficial when used in very small amounts. Digitalis was first isolated from the leaves of the foxglove, an ornamental garden plant.

Some plant poisons can be beneficial in cancer treatment. This is because the toxins produced by some plant leaves can be used to kill the rapidly dividing cancer cells. For example, vincristine and vinblastine are poisonous chemicals produced by the leaves of the rosy periwinkle (**Figure 11**). Vincristine is used to treat childhood leukemia, and vinblastine is used to treat Hodgkin's disease.

Figure 11 The rosy periwinkle is a source of two cancer-fighting drugs.

PSYCHOTROPIC DRUGS

Some plants produce deterrent chemicals that affect the nervous systems of some species. Research suggests that these chemicals could protect the plant by partially debilitating the herbivores that ate them. These chemicals are **psychotropic**, meaning they alter perception, emotion, or behaviour. For example, one species of the cannabis plant (marijuana) produces the psychotropic compound tetrahydrocannabinol (THC). THC has medical uses. It can increase appetite and reduce nausea, and may reduce muscle spasms. These properties make it useful for lessening symptoms of various diseases. It also reduces internal pressure in the eye, which makes it useful in treating glaucoma. However, since it is psychotropic, THC causes distorted perceptions, impaired coordination, difficulty in thinking and problem solving, and problems with learning and memory, which can have serious consequences.

psychotropic mind-altering

WEB LINK

Canadian doctors can prescribe marijuana to treat a number of conditions. To learn more about the use of medical marijuana in Canada,

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The leaves of the coca plant also produce a psychotropic substance. The coca plant is native to the slopes of the Andes in South America, and the local indigenous peoples chew the leaves because it suppresses hunger, pain, and fatigue and helps lessen the symptoms of altitude sickness. Coca leaves, when chewed or made into a tea, are only mildly stimulating. In the nineteenth century, German chemists isolated the active substance in the coca leaf, cocaine. Cocaine was used medicinally as an anesthetic and a stimulant. It was also widely available to the public in the form of pills and cigarettes. Cocaine can produce euphoria, talkativeness, and alertness. It can also produce paranoia, irritability, and nervousness. By the turn of the twentieth century, it became evident that cocaine is highly addictive to humans, and it was banned in many countries. Cocaine addiction continues to be a huge social problem.

12.2 Summary

- The leaf is the primary site of photosynthesis and gas exchange.
- Leaves have adaptations for protecting the plant from herbivores.
- Some leaves have specializations for storage or protection against the cold.
- Monocots and eudicots have different venation patterns in their leaves.
- Humans use plant leaves for food, medicine, and waxes, and in religious ceremonies.

12.2 Questions

1. What functions do leaves serve to the plant? K/U
2. How do monocot and eudicot leaves differ? K/U
3. Describe the function of the following: epidermis, cuticle, mesophyll, guard cells. K/U
4. Explain how the organization of cells in the palisade mesophyll and spongy mesophyll in a typical vascular plant help fulfill the leaf's roles. K/U
5. (a) Describe why sub-zero temperatures can damage some types of leaves. K/U
   (b) Describe the adaptation that angiosperm trees have to cope wth below-freezing temperatures, and explain how this adaptation helps the plants. K/U
6. Health experts constantly remind us to eat leafy vegetables. Explain why. K/U
7. You are given the leaves of one plant from a desert environment and one from a rainforest. Predict the differences you would see in each of the leaves that would make it more adapted to its environment. T/I A
8. Identify at least one food you enjoy that uses leaves as an ingredient in its preparation. Identify the leaf or leaves that are used in the recipe. A
9. There are many sources of food, fibres, medicines, and waxes other than leaves. If leaves did not exist, would human life suffer? Why or why not? C A
10. Most plant leaves contain toxic or foul-tasting compounds. How do they benefit the plant? In what ways have these compounds been beneficial and harmful to humans? K/U A