Section 2.1 Plant Cells, Tissues, and Organs

(Student textbook page 57)

In this section, students will investigate plant systems biology by starting with cell differentiation and specialization. Students will understand the function of meristematic cells, plant stem cells, for growth and repair. A plant's organization of tissues into three main organs of root, stem, and leaf (and sometimes the reproductive flower) will be presented to students so that they may learn their functions and inter-connectedness. Students will perform inquiry investigations into the structure and cellular components of a leaf and the rate of transpiration in different plant species.

Common Misconceptions

- Students may not be aware of the purpose of flowers. When asked, they may present ideas such as: food for insects, aesthetics, to spread seeds. When students arrive at this narrative in the section, begin with a short dialogue about what students think is the purpose of flowers and how they serve the plant, how the plant structures itself to engage other organisms in helping it grow and reproduce. Have a classroom dialogue at the end of the section to check for new understanding and conceptualization.
- Students may not be aware of what seeds are, and their function to the plant. Bring in lots of example of seeds (peas, corn, beans, apple seeds, cherry pits, etc.). Provide an analogy to animal embryonic development (how yolks, embryonic sacs, and placenta are food sources for animal embryos) to help explain the parts of a seed (embryo and food source).

Background Knowledge

Due to the immense biodiversity of the plant kingdom, teachers often worry that their breadth of knowledge is not extensive enough to investigate plants in a serviceable manner to students. The solution to this is to explore with the students; become a facilitator of their hands-on investigation into plant structure and function.

Grade 10 is an appropriate grade to revisit the age-old question, "Why are plants green?" but in a more sophisticated, knowledgeable manner. Inform students that, in the case of green-coloured plants, green light is absorbed and not 100% reflected as they may have learned previously. It is the visible light wavelength that is absorbed least by photosynthetic cells. Leaves often absorb more than 50% of the green light and effectively use it like other wavelengths to drive the chemical reactions in photosynthesis. The chlorophyll absorption spectrum is a graph of light absorption versus light colour. It shows that chlorophyll absorbs much red and blue light but little green light. However, accessory pigments absorb green light and pass that energy on to chlorophyll. Students are not often exposed to accessory pigments in previous grades, when their introduction is not required in discussions about plant photosynthesis.

Chlorophyll is just one of many pigments found in a photosystem. In fact, there are many varieties of chlorophyll, including chlorophyll a, b, c1, c2, and d. Chlorophyll a and b are found in plants, while the other three are not. Chlorophyll is found in every plant.

It may be helpful to know that phloem does transport more than sugars. It usually contains high concentrations of potassium, phosphate, and magnesium to redistribute nutrients where they are needed. The key here is to emphasize that phloem transports substances from the leaves and shoots down to the roots or lower structures. Xylem transports the water and other minerals from the roots up. In the spring it also transports a sugar sap from the roots to the leaves to sustain bud growth. The emphasis should be on direction, not content. Xylem flows upward.

Specific Expectations

- **B1.1** analyse, on the basis of research, ethical issues related to a technological development in the field of systems biology, and communicate their findings
- **B2.1** use appropriate terminology related to cells, tissues, organs, and systems of living things, including, but not limited to: *absorption, anaphase, capillaries, concentration, differentiation, diffusion, meristematic, mesophyll, phloem, prophase, red blood cells, regeneration, stomate,* and *xylem*
- **B2.4** investigate, using a microscope or similar instrument, specialized cells in the human body or in plants, focusing on different types of cell, and draw labelled biological diagrams to show the cells' structural differences
- **B2.7** use a research process to investigate a disease or abnormality related to tissues, organs, or systems of humans or plants
- **B3.2** explain the importance of cell division and cell specialization in generating new tissues and organs
- **B3.3** explain the links between specialized cells, tissues, organs, and systems in plants and animals

Mineral requirements by the plant are often not discussed as much as water and carbon dioxide (sources of C, H, and O). Students will tell you that soil is needed as a source of minerals and nutrients. In fact, plants require and absorb, through their roots, 13 minerals. Many soils are lacking in some of these, inhibiting growth. Farmers test and correct the soil with fertilizers as much as possible to ensure a quality crop year to year. Large amounts of nitrogen, phosphorus, and potassium. Lower amounts of calcium, magnesium, and sulphur. Trace amounts of boron, copper, iron, chloride, manganese, molybdenum, and zinc.

Literacy Support

Using the Text

- The material in this section will be easier to understand and retain if it is supported by illustrations or even rough sketches. Ensure that students accompany their notes with some type of diagram.

Before Reading

- Have students prepare for reading by prompting them to look for opportunities where two concepts or structures can be compared.
- Have students prepare for reading by reviewing how to construct a Venn diagram and use it together with the preparation noted above. You may wish to have students use **BLM G-47 Venn Diagram** for this activity.
- Have students prepare a table to enter about 10 words (perhaps as an informal contest) that have a common and scientific meaning.
- Have students take inventory of their understanding of the classification of plants that they have seen in their lives. Then, ask students to consider their classification.
- Ask students to consider all the ways that animals (or humans) interact/rely on plants. Have students share answers with each other and the class using a cooperative learning structure.
- Ask students to consider what it would be like to plant new trees for an entire summer somewhere in Canada. How many trees would that be? Would they enjoy the work? Why do people choose to plant trees for a summer job? Have students share answers with each other and the class using a cooperative learning structure.

During Reading

- Students can go to **www.scienceontario.ca** to find out more about plants and their associated diseases, and pollination.
- Have students create a graphic organizer to organize the information on the four plant organs: roots, stems, leaves, and flowers (in some plants). The graphic organizer may be in the form of a fishbone, mind map with drawings, or spider map (see Science Toolkit for additional options).
- Have students create a graphic organizer to organize the information on the diseases discussed in the section (table, chart, interesting shape such as drawing a generic plant and pointing to the specific areas where the disease attacks, or use different colours to represent different disease attack areas). Diseases encountered in the section include: Tobacco Mosaic Virus (and other viruses), rusts, insects, fungi, bacteria, and viral attack causing galls. Students may want to add to this graphic organizer with the information found at **www.scienceontario.ca**.
- Use Venn diagrams to compare and contrast any of the following for further support: auxin and ethylene, upper and lower leaf structures, tree circles for dermal, ground and vascular tissue.

- Have students add new words to a word wall or word page in their notes as they read. Consider having students represent definitions pictorially instead of with words.
- Continue to have students monitor and record growth changes in their bean plants. Have students make connections between reading and experience.

After Reading

- Have students reflect on the following Big Idea: *Plants and animals, including humans, are made of specialized cells, tissues, and organs that are organized into systems.* Have students perform a didactic example review to help them recall specific examples of plant specialized cells (photosynthetic chlorophyll containing, pericycle, etc.), tissues (mesophyll, xylem, phloem, etc.), and organs (roots, stems, leaves, etc.).
- Perform a formative assessment of learning by having students answer the Learning Check and Section Review questions.
- Perform a simple dissection of a flower to show the basic male and female reproductive parts—see instructional strategies for additional support.
- Have students connect new learning to previous learning and what they know by asking them, "How does this new information add to or alter what you already knew about the topic?"

Using the Images

- ELL Use Figure 2.1 as a way to engage students on a cultural level. Ask students if they have ever seen tree planting in other countries, and why or why not it is practised there. Have students use the information in the image as clues about what province or time of year it represents, the time of the year it is best to plant young trees, what type of tree is being planted and why. Visual cues and hints will help all learners, and especially ELLs, to engage in new learning.
- DI Using Figure 2.3, students can connect visual learning to previous linguistic learning when you ask them to use this diagram to explain the terms *differentiation* and *specialization.*
- DI Students may need additional support in understanding the structures identified in Figure 2.9, including video clips, additional images, classroom models, and scale drawings. This is a good time to activate visual/spatial strengths. You may wish to have students draw chloroplasts or make 3-D models of the contents.
- Some students may think that the explanation for Figure 2.8 is the opposite of what should happen. They may reason that when cells fill with water they swell in all directions, forcing a closure of the stomata. Have students try to think in different ways to come up with this correct process. Guide them to consider "black box" possibilities—things they cannot see but can determine exist from a number of different angles.
- Use Figure 2.11 to connect to students' prior knowledge, and senses of touch and taste, by asking them what parts of a plant they have eaten. Ask them how the different parts taste, and the purpose (reason) for eating each part. Have a conversation about the different types of storage modifications a plant may have.
- Use Figure 2.14 to get students thinking about how they think viruses attack and affect the colours of the flower. Have them write down their ideas. It does not necessarily matter if they know how viruses infect, only that they show understanding of the cellular level of the process. Alternatively, ask students to make a quick concept map of all the different symptoms a viral infection may cause in a plant.
- An opportunity to discuss mutualism and symbiotic relationships arises when discussing pollination in Figure 2.17. Ask students what the benefit is to the pollinator.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Activity 2-1 Observing Plant Growth, page 55	Students connect their observations to knowledge and terminology they learned including: meristem, vascular bundles, xylem, phloem, seed, germination, photosynthesis, chloroplast, epidermis, stoma, transpiration, cell respiration, etc. Students should show skill in forming a logical hypothesis and recording observations accurately.	Demonstrate to students what a growth log/journal might look like in terms of the quantity and quality of entry information. Help students connect watering the plant, soil conditions, and light with the needs of the plant's cells, and the transport of water, nutrients and photosynthetically produced sugar. Provide students with examples of hypotheses for consideration before they formulate their own. Have students watch a video or animation on plant growth before answering the last question.
Activity 2-2 Inside a Leaf, page 62	Students accurately identify plant leaf structures. Students relate cell and tissue function to structure. Students relate photosynthesis to the location of photosynthetic cells in the leaf (which occurs mostly in the palisade cells under the epidermis).	Provide multiple visual examples on the chalkboard, digitally, or using models to prompt and cue students. Provide examples of other tissues where form fits function to guide students in this example of leaf tissue.

Instructional Strategies

- Build an attitude of quest for information, appreciation, and a willingness to work with plants and cultivate them for experiential knowledge. Start slow, plant a plant, then present information about human reliance on plants. Visit a greenhouse or nursery, and have students perform microscopical investigations on plant organs and tissues. Take a walk through a meadow or forest, identify and classify plants, and practise using a dichotomous key.
- To begin the section, the students can bring a variety of plants from home as examples for investigations of leaves, stems, flowers, and roots (e.g., carrots, alfalfa sprouts, celery, beets, any flower or cultivar) to activate visual and spatial learning.
- At the beginning of the chapter, have the students play a game. The game may be called The Hunt for Misinformation. To play, each student is required to find one piece of information about plants that is a common misconception or myth. Students have one week to find it, write it down on a piece of paper with their name, and place the paper in a box. Compile the common misconceptions on a chart, without student names, and then post them for a class vote on the most interesting one. For example, the poinsettia is not poisonous, as is often stated. Its poisonous reputation was due to an erroneous report in the early 1900s that a child died after eating poinsettia leaves.
- Once students have learned the different organs of a plant, ask them to think about a celery stalk and ask what plant organ it is. Students often think it is a stem, but in fact it is a leaf base, due to its crescent shape (stems have circular arrangements). This can help students use their logical and deductive skills, basing their responses on patterns just previously learned.
- When considering having students plant their own seeds and grow plants, consider using crucifers, a large group of plants that includes mustard, radish, cabbage, etc., specifically those that have been bred and selected to have a uniform, short flowering time (around 14 days) and grow well in small indoor spaces. Consider using a plant stand with artificial light to promote growth. Cultivated crucifer seeds can be purchased from most science supply companies.

- Remind students that plants perform photosynthesis (or carbon fixation) when sunlight is available, but perform cellular respiration (carbon-molecule combustion) at all times of the day to support the energy requirements of all the cells.
- Be aware that most cross-sectional diagrams of roots do not show mycorryzal fungi, which resides on about 90% of plant species' roots.
- Consider creating stations for each plant organ and have students visit each station to investigate each of the different plant organs. At each station, set up multiple activities for students to perform. For example, a station on roots might have: a few microscopes set up to view root microslides; a carrot, dandelion, or alfalfa sprouts for root type exemplars. After the two days of station exploration, follow up with a formative assessment with open-ended comparative questions such as, "In what ways are stems, roots, leaves and flowers alike?", "In what ways are they different?" Have students consider structure and function when responding.
- Plant applications, agriculture, and farming are excellent avenues to explore with a field trip. Consider a local greenhouse, farm, or seed production company.
- For enrichment and further interest, you may wish to have students perform a flower dissection. Lilies, daffodils, and tulips work well, but consider what is local, available, and cost-effective.

Activity 2-2 Inside a Leaf (Student textbook page 62)

Pedagogical Purpose

Biologists classify organs differently in plants than in animals. In the case of plants, there are three organ systems: roots, stems, and leaves. In order to investigate the organization of the leaf as an organ, students shall observe the structures and relationships at the cellular level. In this way, they can visualize the different types of cells and tissues found in leaves, and how structure (form) fits function.

It is important to continue to develop student skill in microscopy. In this case, by viewing images of micrographs, and then correlating and identifying the same structures and cell types in prepared micrographs using a microscope or microviewer. In the case of the microviewer, there are usually multiple micrograph images to observe and draw connections. In this way, students are given the opportunity to think a little more about cells and tissues found in leaves, and their roles with respect to the entire plant. Lastly, students will be able to ask further questions about structure and function as the section continues.

Planning	
Materials	Microscopes/microviewers Micrographs Stains Microslides Biological drawings **BLM 2-3 Inside a Leaf** (optional) Week before–Ensure microscopes/microviewers are working and micrographs can be easily obtained. Day before–Collect prepared microslides and microscopes and microviewer.
Time	45 min
Safety	Handle microscope and slides carefully.

Background

Leaf morphology varies greatly among plant species. A leaf is considered a plant organ and typically consists of the following tissues:

1. an epidermis that covers the upper and lower surfaces
2. an interior chlorenchyma called the mesophyll
3. an arrangement of veins (the vascular tissue)

Many tree and flowering plant species are excellent specimens for leaf cross section micrograph preparation. For example, a poplar leaf is typical and easy to study. Corn (Zea mays), lilies, broad bean, and pea plants are all easy to obtain and will produce cross sections of instructional value.

Multiple stains are required to view cells and their internal structures. Some used are Safranin-O (stains red) stain for xylem, fast green (stains green) stain for phloem, and toluidine blue (stains blue) for epidermis. All should be handled with care. Each leaf's profile is different, although there are more similarities than differences if both plants have photosynthetic, flat, broad leaves. Be cognizant of this if students are looking at microslides that are different from the picture in the student text.

Activity Notes and Troubleshooting

- If possible, maximize student observation time by having one microscope/microviewer per student, practice on focussing.
- Explain to students that a microviewer is just as good a tool as a microscope. The photographs are made from true micrographs, and multiple images are provided on the slide strips.
- Students will ask for help in order to identify cells and structures. Teach students how to use the pointer found in the ocular lens to target areas in the field of view of interest to better communicate their questions.
- Consider setting up a microscope camera and guiding students to find specific structures.
- Have students either work with a partner or practise using Science Skills Toolkit 8, page 546, to focus the microscope.
- As a class, read Science Skills Toolkit 6, on page 543 of the student textbook.
- Use **BLM A-48 Using Tools, Equipment, and Materials Rubric** to assess use of microscopes.

Additional Support

- DI This activity does not require students to draw their field of view. However, for spatial learners, consider having them draw an alternative answer form for question 2.
- DI For logical-mathematical learners, consider having them count the number of open and closed stoma, and calculate a ratio.
- DI For any learner who enjoys it, or for spatial learners, consider having them draw a mind map for an alternative response for question #3, where they compare structure and function of various leaf tissues using pictures and minimal words. You may wish to have students use **BLM G-42 Concept Map** for this activity.
- ELL For ELL students, consider exploring the word origins of new words, and create a word wall *(epidermal, palisade, spongy, stoma, vascular, guard).*
- ELL Consider pairing students to help ELL students in the most appropriate way.
- To help students with terminology or names of structures, have them employ one or more the Study Toolkit tools, such as recognizing word origins (e.g., epidermal, palisade, mesophyll).
- Consider showing students some sample labelled micrograph images to guide their investigation of the microslides.
- Consider setting up a microscope camera to demonstrate focussing and leaf structure identification.
- Consider exploring what stains were used to fix and visualize all the different cell types.

- Consider providing a different plant micrograph set for leaf structure comparisons.
- Hand out **BLM 2-3 Inside a Leaf** which scaffolds this investigation.

Answers

1. The stomata can be observed on the bottom, or lower side, of a leaf.
2. (Answers are for ideal cross-sectional view; stomata will be difficult to discern if they are open or closed). For open stoma, the guard cells are expanded, and, as a cross section, appear larger in diameter. The space between the guard cells is larger. In the closed stoma, the guard cells appear smaller in diameter, and the space between the guard cells is small or there is no space at all.
3. The shape and arrangement of each group of cells relates to their function as follows:
   Epidermal cells—flat with random membranes to allow cell-cell continuous surface coverage, contain chloroplasts to capture "first round" of electromagnetic solar energy
   Palisade cells—aligned vertically to "slow down" and capture a significant amount of electromagnetic solar energy
   Spongy mesophyll cells—spread out "spherical" cells to support leaf structure while allowing for gas exchange and transport (including water vapour) to occur, contain chloroplasts to capture any leftover electromagnetic energy penetrating the leaf
   Stoma and guard cells—two modified epidermal cells, elongated and larger, in a shape of "bananas," with tips attached, able to expand outward with increased turgor pressure to open space in between, allowing gas exchange to occur, as well as transpiration to support xylem water transport upwards
   Vascular cells (xylem and phloem)—arrangement in a bundle groups tissues responsible for substance transport, as well as providing structural support for the plant's leaves (plus other organs); bundles are positioned in the middle of the leaf for overall best access to all leaf cells; numerous bundles are seen, again, to ensure access to all cells
4. Example: The leaf itself maximizes the process by having a broad and flat surface; from there, cells are arranged in both horizontal and vertical orientations to ensure any penetrating energy is absorbed. To maximize surface area and number of cells, palisade cells are thin and long while mesophyll cells are small in diameter. The leaf is just thick enough to also prevent any radiation from transmitting right through the leaf. The cells are packed with chloroplasts that also increase surface area for photosynthesis.

Learning Check Answers (Student textbook page 62)

1. In the process of differentiation, cells become specialized for certain functions. This occurs as a result of specific genes being activated, which produces certain proteins that carry out those functions.
2. Diagrams should indicate dermal tissue (outer covering of a plant), ground tissue (support to the plant and photosynthesis), and vascular tissue (support to the plant)
3. Diagrams should indicate leaf, stem, root, and flower.
4. Removing the terminal bud could produce a bushier plant.

Learning Check Answers (Student textbook page 64)

5. Chloroplasts contain grana, which are stacks of thylakoids.
6. The two functions of stems are to provide physical support and in transportation of sap. Xylem tissue forms tubes to allow transportation and provide support through lignin. Phloem tissue is also formed like tubes and is involved in transport through its porous cell walls. Xylem and phloem vessels are grouped to provide even more strength for support.

7. Flowcharts should indicate input of sunlight, water, and carbon dioxide. Outputs are glucose and oxygen.
8. Diagrams should indicate a stomata that is closed.

Section 2.1 Review Answers (Student textbook page 69)

Please also see **BLM 2-5 Section 2.1 Review (Alternative Review).**

1. No; a plant could not live without meristem. Meristem constantly produces new specialized cells that are essential for plant growth.
2. Graphic organizers should summarize the three major types of plant tissue (ground, vascular, and dermal) that derive from meristem
3. **a.** A is phloem and B is xylem.
   b. When grouped together, xylem and phloem form vascular bundles.
   c. Xylem and phloem make up the vascular tissue of plants.
4. Diagrams should indicate each of the following:
   leaf: where photosynthesis takes place
   stem: needed for physical support and sap transportation
   root: needed for anchoring to the ground and uptake of water and nutrients from the soil
5. Cuticle on a leaf helps to limit the amount of water that is lost through evaporation. Since roots are needed to take up water, they are not covered in cuticle.
6. Sunlight must pass through the epidermal cells to reach cells that carry out photosynthesis. If they are transparent, more sunlight can pass through them and the plant will be more efficient at trapping sunlight.
7. Example: I would suggest using plants with fibrous roots, such as yarrow.
8. Example: The fact that tobacco mosaic virus was the first virus to be studied is likely because it causes severe reductions to crops that people rely on a great deal, such as potatoes and tomatoes.