Subject Code	BIO 1	Biology 1
Lesson Guide Code	3.0	Transport and Circulation of Nutrients
Lesson Code	3.2	Transport Mechanisms in Plants
Time Frame		30 minutes

TARGET

After completing this learning guide, you are expected to:

1. compare and contrast xylem and phloem tissues; and
2. summarize the mechanism of water and food transport in plants.

HOOK

Have you ever wondered how water from the roots gets to the top of plants, especially those tall plants such as the coconut tree or the Philippine rosewood tree which can reach a height of 54 meters (see Figure1)?

Figure 1. A 300-year old rosewood tree (locally known as "toog") that stands 54 meters high; found in Agusan del Sur; by Panganiban (2020), from https://www.mindanews.com/top-stories/2020/08/300-year-old-giant-toog-tree-saved-anew-from-cutting/.

How could the plant transport water up to the leaves against the force of gravity? One could say, nature works in mysterious ways. However, if you look at the plant at the tissue level, you will find that there are different mechanisms within the plant that enable the plant to deliver water and nutrients to its different parts over short or long distances.

IGNITE

The tissues that work to transport water and nutrients in the plant are the **xylem** and **phloem**. These tissues are built in such a way that they are able to perform their specific functions. Xylem transports water and minerals from the roots to the leaves while phloem transports sugar and other nutrients to all parts of the plant.

Xylem tissue is composed of four different cell types: **tracheids, vessel elements, xylem fibers and xylem parenchyma**. **Phloem tissue** also has four different cell types: sieve cells, **companion cells, phloem parenchyma and phloem fibers**. Table 1 shows a comparison of the structure and functions of the different cells.

Table 1. Structure and Function of the Vascular Tissue of Plants

Tissue	Type	Structure	Function
Xylem	tracheids	dead thin walled, long cells hardened with lignin; with pits and tapered ends	conduct water and minerals
	vessel elements	dead thin-walled cells hardened with lignin; shorter, wider and less tapered; interconnected	conduct water; give mechanical strength
	xylem fibers	dead cells with thick lignified walls	conduct water; provide mechanical support
	xylem parenchyma	living cells with thin walls made of cellulose	store fat and starch; assist in the short distance transport of water
Phloem	sieve-tube elements	living cells but lacking a nucleus and ribosomes; end walls (called sieve plates) have pores	conduct sugars and other organic nutrients
	companion cells	living cells found alongside sieve-tube elements connected by channels (plasmodesmata)	the nucleus and ribosomes serve the adjacent sieve-tube element
	phloem parenchyma	living cells with thin walls made of cellulose	store food
	phloem fibers	dead narrow long cells with thick lignified walls	provide tension strength

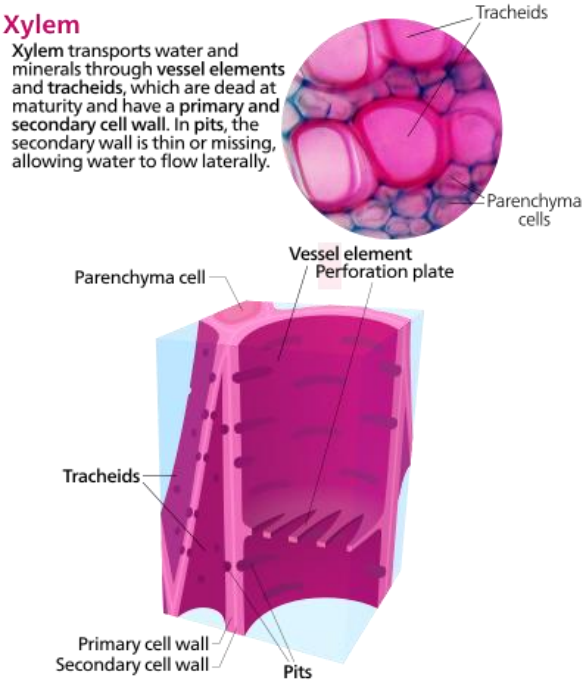

Figure 2. Cross section of some xylem cells by Kelvinsong (a) (2013, April 21), from https://en.wikipedia.org/wiki/Xylem#/media/File:Xylem_cells.svg. License: CC BY-SA 3.0

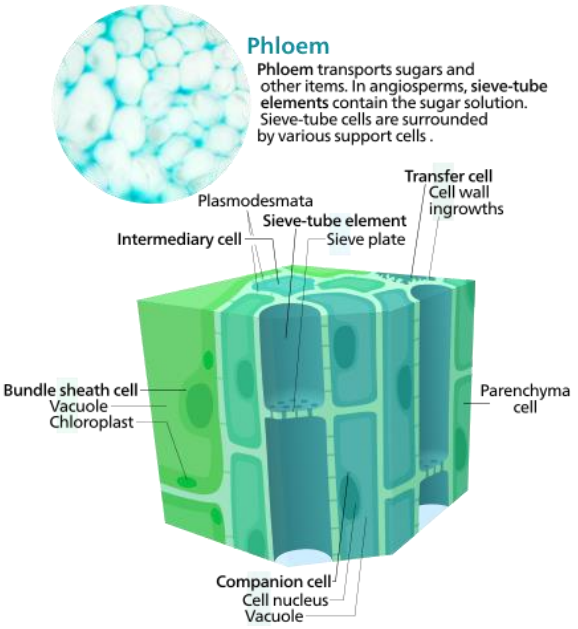

Figure 3. Cross section of some phloem cells; by Kelvinsong (b) (2013, April 21), from https://en.wikipedia.org/wiki/Phloem#/media/File:Phloem_cells.svg. License: CC BY-SA 3.0

Based on their functions, they work in tandem to provide the plant the nutrients and water that it needs. But how is water carried up to the top of the plant? Sugar nutrients are made by the leaves through photosynthesis thus, the transport of these molecules does not work against gravity because the direction is mostly from the top (leaves) to the bottom (roots) (see Figure 4). Water, on the other hand, can only go through the roots, up the stem or trunk and to the leaves.

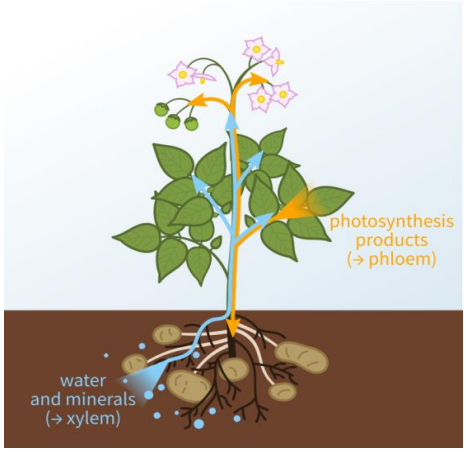

Figure 4. Transport of nutrients in plant: phloem (orange) and xylem (blue); by Nefronus (2019), from https://en.wikipedia.org/wiki/Phloem#/media/File:Xylem_and_phloem_diagram.svg. License: CC BY-SA 4.0

There are different mechanisms or processes that help in the transport of water and minerals. At the cellular level, water and minerals move in and out of the cell by diffusion, and move from a region of higher concentration to a region of lower concentration.

Plants employ three major pathways of transport: **the apoplast, transmembrane and the symplast**. The **apoplast** refers to everything outside the plasma membrane of living cells and in this pathway; water and dissolved minerals move through porous cell walls but do not go through or into the cell (see Figure 5). The **symplast** refers to the entire mass of cytosol of living cells and in this

pathway; movement is from the cytoplasm of one cell to the next via open channels between cells. In the transmembrane pathway, movement occurs through the plasma membrane from one cell to another.

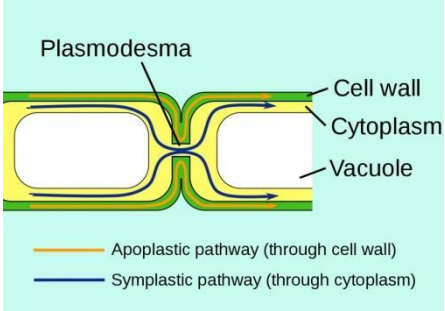

Figure 5. Apoplast and symplast pathways, from http://organismalbio.biosci.gatech.edu/nutrition-transport-and-homeostasis/plant-transport-processes-i/. Public domain

Water and minerals are absorbed from the soil by the roots hairs and moves to the ground tissue through one of the possible pathways. The root hairs increase the surface area of the roots thus, more water and minerals are absorbed by the plant. Within the root, the water and dissolved minerals will reach the endodermis, a structure exclusive to roots that separate the ground tissue from the vascular tissue (see Figure 6). It contains a waxy region, known as the **Casparian strip**, which forces the water and minerals to go through the plasma membrane of the endodermal cells instead of traveling via the apoplast pathway (see Figure 7). The water and minerals then travel up through the xylem tissue.

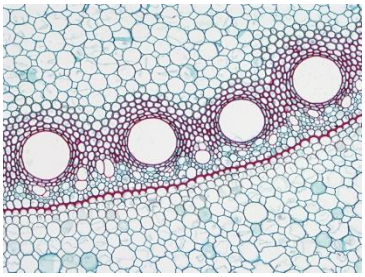

Figure 6. The endodermis denoted by the band of the red stained casparian band in *Zea mays* (corn), from *Plant anatomy and physiology* by Bellairs (n.d.). https://cduebooks.pressbooks.pub/plantanatomy/chapter/3-2-roots/. License: CC BY-NC-SA 4.0

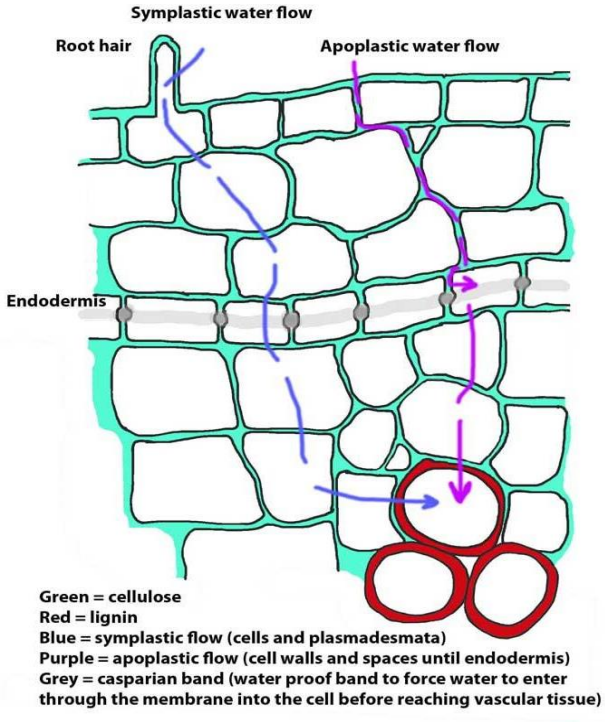

Figure 7. Effect of the casparian band on water flow between cortex (ground tissue) and xylem, from *Plant anatomy and physiology* by Bellairs (n.d.). https://cduebooks.pressbooks.pub/plantanatomy/chapter/3-2-roots/. License: CC BY-NC-SA 4.0

Once inside the xylem tissues, long distance transport occurs through bulk flow. **Bulk flow** is the movement of liquid (xylem sap and phloem sap) in response to a pressure gradient and is much faster than diffusion. The perforation plates in vessel elements and the porous sieve plates connecting sieve-tube elements enhance bulk flow ensuring the transport of water and nutrients in the plant.

Transpiration drives the movement of water in the xylem. It is the loss of water from the plant through evaporation of water through the leaf stomata. The opening and closing of the stomata thus regulates transpiration. When water is constantly lost from the leaves, a negative pressure occurs. This negative pressure acts like a suction force that pulls water up the stem (see Figure 8).

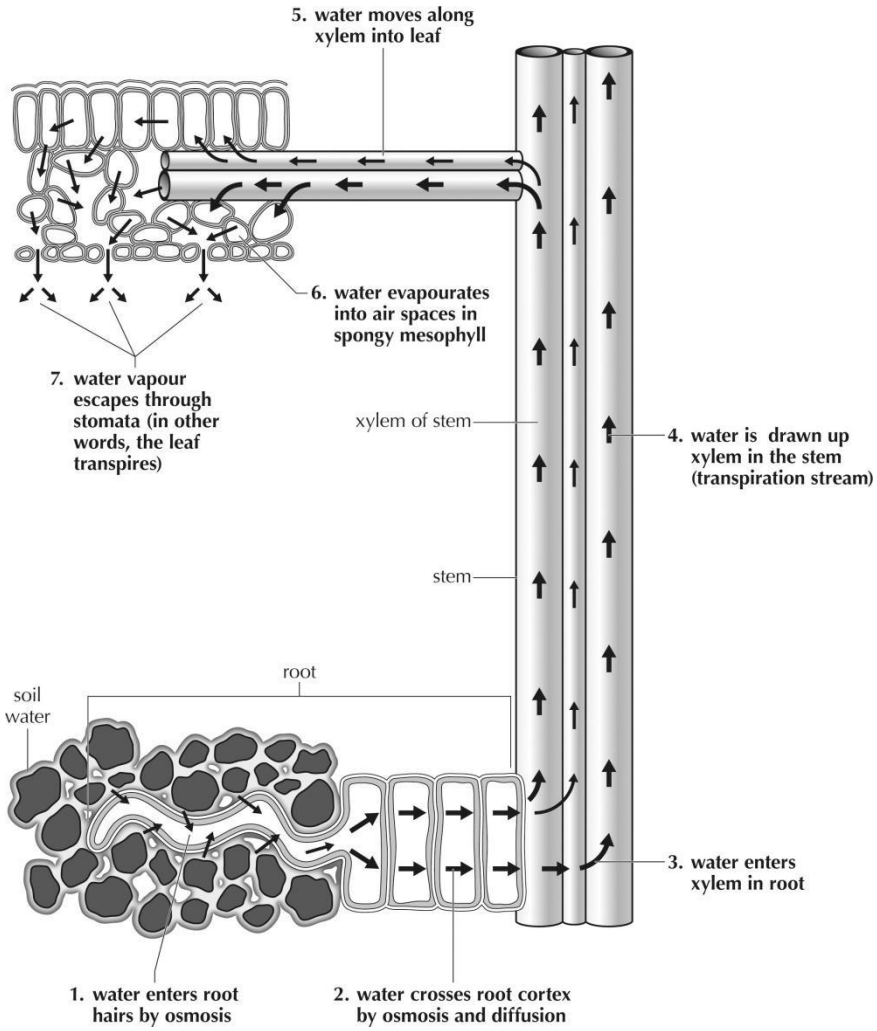

Figure 8. Step-by-step transport of water in plants, from roots to the xylem; from https://intl.siyavula.com/read/science/grade-10-lifesciences/support-and-transport-systems-in-plants/05-support-and-transport-systems-in-plants-05. License: Creative Commons Attribution

Water can also be moved up the plant via root pressure. This pressure is created by the roots constantly absorbing water from the soil. The constant movement of water into the roots results in a force that pushes the water into the xylem and up the plant. However, this force is not enough to drive the movement of water up the plant.

One hypothesis that explains the movement of water in plants is the **cohesion-tension hypothesis**. It is the most accepted model for the transport of water. According to this hypothesis, transpiration pulls the water up the plant, and adhesion of the water to the cell walls and the cohesion of water molecules to each other ensure the transmission of this pull in the xylem tissue from shoots to roots (see Figure 9). Thus, water continuously flows up the xylem tissue to the leaves.

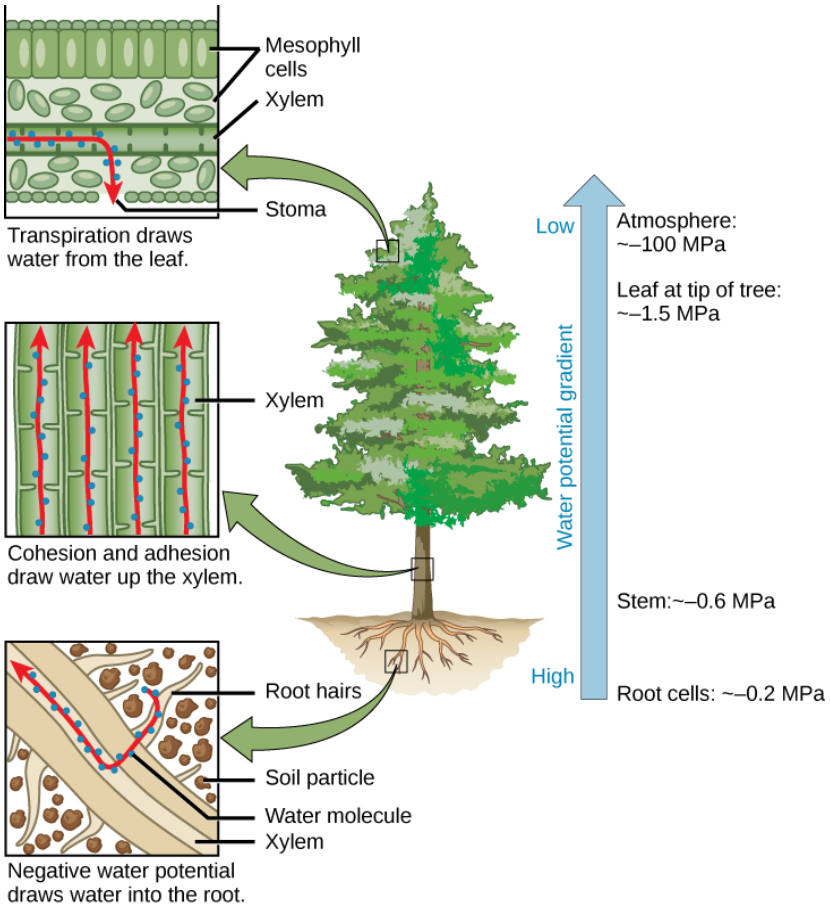

Figure 9. The cohesion-tension hypothesis of sap ascent, from https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_(OpenStax)/6%3A_Plant_Structure_and_Function/30%3A_Plant_Form_and_Physiology/30.5%3A_Transport_of_Water_and_Solutes_in_Plants. License: CC BY-NC-SA 3.0

The movement of xylem sap is unidirectional, from roots to leaves. The movement of phloem sap, on the other hand, is multidirectional. It is from sites of sugar production to sites of sugar use or storage. The transport of the products of photosynthesis is called translocation. Sugar molecules are actively transported from the source cells to the closest sink, or the points of delivery, through the phloem tissues.

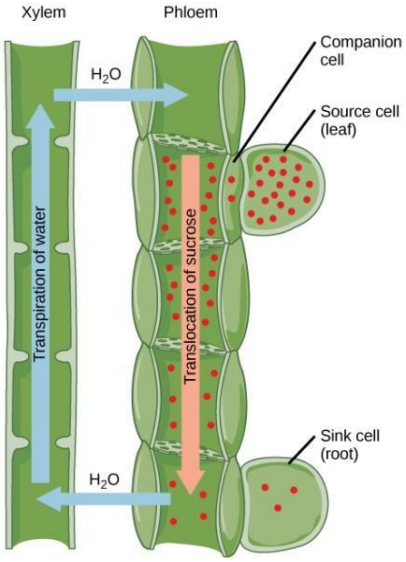

Figure 10. Active transport of sucrose from source cells into companion cells and then into sieve-tube elements, from https://cnx.org/contents/GFy_h8cu@10.61:5aq8b3HZ@5/Transport-of-Water-and-Solutes-in-Plants. License: Creative Commons Attribution License 4.0

NAVIGATE

Concept Check. (This is a non-graded assessment.)

1. Which of the following statements is FALSE?
   a. Negative water potential draws water into the root hairs. Cohesion and adhesion draw water up the xylem. Transpiration draws water from the leaf.
   b. Negative water potential draws water into the root hairs. Cohesion and adhesion draw water up the phloem. Transpiration draws water from the leaf.
   c. Water potential decreases from the roots to the top of the plant.
   d. Water enters the plants through root hairs and exits through stoma.

2. Which of the following is NOT part of the xylem tissue?
   a. vessel elements
   b. fibers
   c. parenchyma
   d. sieve-tube elements

3. Trace the flow of water from the root to the leaf by arranging the following terms.
   stem, cortex, root hairs, leaf xylem tissue, endodermis, stomata, root xylem

KNOT

Movement of water and nutrients in plants occurs in the xylem and phloem. Transport of water and dissolved minerals occurs in the xylem whereas, transport of sugar and organic compounds occur in the phloem. Different mechanisms drive the movement of water and nutrients in the plant; and these are enhanced by the different structures of the xylem and phloem tissues.

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