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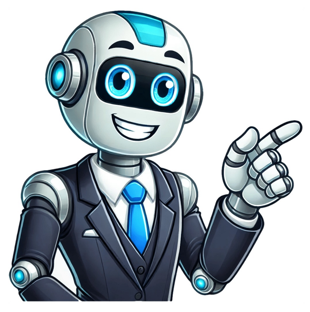

 Phloem is the complex tissue, which acts as a transport system for soluble organic compounds within vascular plants. The phloem is made up of living tissue, which uses turgor pressure and energy in the form of ATP to actively transport sugars to the plant organs such as the fruits, flowers, buds and roots; the other material that makes up the vascular plant transport system, the xylem, moves water and minerals from the root and is formed of non-living material. Through the system of translocation, the phloem moves photoassimilates, mainly in the form of sucrose sugars and proteins, from the leaves where they are produced by photosynthesis to the rest of the plant. The sugars are moved from the source, usually the leaves, to the phloem through active transport. The next step, translocation of the photoassimilates, is explained by the pressure flow hypothesis. When there is a high concentration of organic substance (in this case sugar) within the cells, an osmotic gradient is created. Water is drawn passively from the adjacent xylem over the gradient to create a sugar solution and a high turgor pressure within the phloem. The high turgor pressure causes the water and sugars to move through the tubes of the phloem, in to the 'sink tissues' (e.g. the roots, growing tips of stems and leaves, flowers and fruits). When the sink receives the sugar solution, the sugars are used for growth and other processes. As the concentration of sugars reduces in the solution, the amount of water influx from the xylem also drops; this results in low pressure in the phloem at the sink. Where there are areas of high and low pressure, the photoassimilates and water are consistently moved around the plant in both directions. The structure of the phloem is made up of several components. Each of the components work together to facilitate the conduction of sugars and amino acids, from a source, to sink tissues where they are consumed or stored. Phloem cells The sieve elements are elongated, narrow cells, which are connected together to form the sieve tube structure of the phloem. The sieve element cells are the most highly specialized cell type found in plants. They are unique in that they do not contain a nucleus at maturity and are also lacking in organelles such as ribosomes, cytosol and Golgi apparatus, maximizing available space for the translocation of materials. There are two main types of sieve element: the 'sieve member', which is found in angiosperms, and the more primitive 'sieve cells', which are associated with gymnosperms; both are derived from a common 'mother cell' form. At the connections between sieve member cells are sieve plates, which are modified plasmodesmata. Sieve plates are relatively large, thin areas of pores that facilitate the exchange of materials between the element cells. The sieve plates also act as a barrier to prevent the loss of sap when the phloem is cut or damaged, often by an insect or herbivorous animal. After injury, a unique protein called "P-protein" (Phloem-protein), which is formed within the sieve element, is released from its anchor site and accumulates to form a 'clot' on the pores of the sieve plate and prevent loss of sap at the damage site. In gymnosperms, the sieve elements display more primitive features than in angiosperms, and instead of sieve plates, have numerous pores at the tapered end of the cell walls for material to pass through directly. Each sieve element cell is usually closely associated with a 'companion cell' in angiosperms and an albuminous cell or 'Strasburger cell' in gymnosperms. Companion cells have a nucleus, are packed with dense cytoplasm contain many ribosomes and many mitochondria. This means that the companion cells are able to undertake the metabolic reactions and other cellular functions, which the sieve element cannot perform as it lacks the appropriate organelles. The sieve elements are therefore dependent upon the companion cells for their functioning and survival. The sieve tube and companion cells are connected via a plasmodesmata, a microscopic channel connecting the cytoplasm of the cells, which allows the transfer of the sucrose, proteins and other molecules to the sieve elements. The companion cells are thus responsible for fuelling the transport of materials around the plant and to the sink tissues, as well as facilitating the loading of sieve tubes with the products of photosynthesis, and unloading at the sink tissues. Additionally, the companion cells generate and transmit signals, such as defense signals and phytohormones, which are transported through the phloem to the sink organs. The parenchyma is a collection of cells, which makes up the 'filler' of plant tissues. They have thin but flexible walls made of cellulose. Within the phloem, the parenchyma's main function is the storage of starch, fats and proteins as well tannins and resins in certain plants. The sclerenchyma is the main support tissue of the phloem, which provides stiffness and strength to the plant. Sclerenchyma comes in two forms: fibers and sclereids; both are characterized by a thick secondary cell wall and are usually dead upon reaching maturity. The bast fibers, which support the tension strength while allowing flexibility of the phloem, are narrow, elongated cells with walls of thick cellulose, hemicellulose and lignin and a narrow lumen (inner cavity). Sclereids are slightly shorter, irregularly shapes cells, which add compression strength to the phloem, although somewhat restrict flexibility. Sclereids act somewhat as a protective measure from herbivory by generating a gritty texture when chewed. Xylem – One of two types of transport tissue within vascular plants, xylem is responsible for the transport of water from the roots to the leaves and shoots. Photosynthesis – The process which most plants use to convert energy from the sunlight, water and carbon dioxide into oxygen and carbohydrates. Photoassimilates – The biological compounds (usually energy-storing monosaccharaides) which are produced by photosynthesis. ATP – Adenosine triphosphate is the high-energy molecule that transports energy for metabolism within cells. 1. What is the main function of the phloem? A. Transporting nutrients from a source to a sink B. Transporting nutrients from a sink to a source C. Transporting water from a sink to a source D. Transporting water from a source to a sink A is correct. The main function of the phloem is to transport nutrients from the source where they are produced (e.g. the leaves through photosynthesis) to the sink (e.g. flowers and fruits) where they are used. 2. What service does the companion cell not provide to the sieve element? A. Providing energy B. Communication between cells C. Physical rigidity D. Unloading photoassimilates to sink tissues C is correct. The companion cell is important for providing energy, transferring materials and transmitting signals. The parenchyma and sclerenchyma provide strength and rigidity to a plant. 3. What does the P-protein do? A. Increases the rate of metabolism within the companion cell B. Builds the sieve plates C. Forms a clot over a sieve plate when the phloem is damaged D. Works within the phloem to transport sap C is correct. When the phloem is damaged, the P-protein, which is produced in the sieve element lumen, accumulates on the sieve plate to prevent loss of nutrient rich sap. By the end of this reading you should be able to: Describe the structure of phloem Differentiate between source and sink tissues in plants Explain the pressure-flow mechanism of sugar transport in phloem Compare and contrast xylem and phloem structures and functions Describe the link between phloem sugars and the rhizosphere Much of the body of a vascular plant is devoted to the uptake and transport of the water required by leaves rather than to photosynthesis. In contrast, all cells of the algal ancestors of plants would have been capable of photosynthesis. Roots and stems contribute indirectly to photosynthesis but produce little or no carbohydrate themselves. Thus, although vascular plants are photosynthetic, a large part of their body must be supplied internally with food. Phloem transport takes place through multicellular sieve tubes, which are composed of highly modified cells called sieve elements that are connected end to end. During development, sieve elements lose much of their intracellular structure, including the nucleus and the vacuole. At maturity, sieve elements retain an intact plasma membrane that encloses a modified cytoplasm containing only smooth endoplasmic reticulum and a small number of organelles, including mitochondria. Cellular functions such as protein synthesis are carried out by an adjacent companion cell, to which the sieve element is connected by numerous plasmodesmata. Sieve elements are linked by sieve plates, which are modified end walls with large (1 to 1.5 µ,m diameter) pores. The plasma membrane of adjacent sieve elements is continuous through each of these pores, so each multicellular sieve tube can be considered a single cytoplasm-filled compartment. Phloem sap is the sugar-rich solution that flows through both the lumen of the sieve tubes and the sieve plate pores. Multiple answers:Multiple answers are accepted for this question A large numbers of plasmodesmata with companion cells B a nucleus and internal organelles D cytoplasmic connections with other sieve elements Phloem transports carbohydrates as sucrose (glucose plus fructose) or larger sugars, assembled from monosaccharides in the cytoplasm. Phloem also transports amino acids, inorganic forms of nitrogen, and ions including K^+, which are present in much lower concentrations. Finally, phloem transports informational molecules such as hormones, protein signals, and even RNA. Thus, phloem forms a multicellular highway for the movement of raw materials and signaling molecules across the entire length of the plant. Phloem transports its molecular cargo from source to sink. In plants, sources are the regions that produce or store carbohydrates. For example, leaves are sources because they produce carbohydrates by photosynthesis, and potato tubers after they have been formed are sources because they can supply stored carbohydrates to the rest of the plant body. Sinks are any portion of the plant that needs carbohydrates to fuel growth and respiration-examples are roots, young leaves, and developing fruits. Whereas the direction of xylem transport is always up toward the leaves, the direction of phloem transport can be either up or down, depending on where the source and sink are relative to each other. are plant tissues that are capable of providing to tissues which require them for growth. How does phloem transport sugars from source to sink? In some plants, active transporters powered by ATP move sucrose into the phloem. The buildup of sugar concentration causes water to be drawn into the phloem by osmosis. Because the cell walls of the sieve tube resist being stretched outward to accommodate the influx of water, they press back (inward) against the cytoplasm. Their resistance to stretching increases the turgor pressure at the source end of a sieve tube. At sinks, sugars are transported out of the phloem into surrounding cells. This withdrawal of sugars causes water to leave the sieve tube, again by osmosis, reducing turgor pressure at the sink end. It is the difference in turgor pressure that drives the movement of phloem sap from source to sink. This video demonstrates how pressure-flow results in the movement of sugars and how this transport is linked to the movement of water. The water that exits the phloem can be used locally to support the enlargement of sink cells or it can be carried back to the leaves in the xylem. Thus, some of the water in the phloem sap is recirculated in the xylem. The volume of water that moves through the phloem, however, is tiny compared to the amount that must be transported through the xylem to replace water lost by transpiration. Therefore, the number and size of xylem conduits greatly exceed the number and size of sieve tubes. Phloem transport is sometimes referred to as "translocation," a term that pairs well with "transpiration." Yet in almost every way, phloem and xylem are a study in contrasts. In phloem, the plant generates the gradient that drives transport, whereas water moving through xylem is driven by the difference in hydration between soil and air. Furthermore, water is pulled upward through xylem conduits, while transport through phloem is more of a push. These fundamental differences in function explain the cytological differences between xylem and phloem: Phloem conduits retain an intact plasma membrane and modified cytoplasm, whereas xylem conduits retain only their cell walls. What xylem and phloem have in common is that both are essential in enabling vascular plants to carry out photosynthesis on land. Moreover, like xylem, phloem is subject to risks that arise from the way flow through sieve tubes is generated. Damaged sieve tubes are at risk of having their contents leak out, pushed out by high turgor pressures in the phloem. Damage is an ever-present danger because the sugar content of phloem makes it an attractive target for insects. Cell damage activates sealing mechanisms that repair breaks in sieve tubes. In some respects, these mechanisms are comparable to the formation of blood clots in humans, except that phloem can seal itself much more rapidly, typically in less than a second. How is phloem able to transport carbohydrates from the shoot to the roots, as well as from the roots to the shoot (although not at the same time)? Ordered by Phloem also supplies carbohydrates to organisms outside the plant. A fraction of the carbohydrates transported to the roots spills out into the rhizosphere, the soil layer that surrounds actively growing roots. This supply of carbohydrates stimulates the growth of soil microbes. As a result, the densities of microbial organisms near roots are much greater than in the rest of the soil. The interactions between soil microbes and plants can vary greatly. Those soil bacteria that are decomposers of soil organic matter, can make nutrients such as nitrogen and phosphorus more accessible to the plant. Other soil microbes can release hormones that stimulate plant growth, aid in atmospheric nitrogen fixation, and some even provide protection against soil plant pathogens. Thus, the release of carbohydrates by roots into the soil is beneficial to the overall growth and survival of the plants. All the cells in a plant's body contain mitochondria since all cells need a constant supply of ATP. Typically, about 50% of the carbohydrates produced by photosynthesis in one day are converted back to CO_2 by respiration within 24 hours. Carbohydrates that are not immediately consumed in respiration can be used as raw materials for growth, or they can be stored for later use. Carbohydrates stored within roots and stems, or in tubers (specialized storage organs such as potatoes), can support new growth in the spring or following a period of drought. Stored reserves can also be used to repair mechanical damage or replace leaves consumed by insects or grazing mammals. Like their green algal ancestors, vascular plants store carbohydrates primarily as starch, a large molecule that is not soluble and so does not affect the osmotic balance of cells. What determines how carbohydrates become distributed within the plant? Where phloem sap ends up is determined by the sinks. Phloem transport to reproductive organs appears to have priority over the movement to stems and leaves, and these have priority over movement to roots. Hormones play a key role in controlling the growth and development of plants and these hormones may influence the ability of different sinks to compete successfully for resources delivered by the phloem. Indicate where these are characteristics of xylem, phloem or both. Cells are dead at maturity Generation of a pressure gradient Mature cells do not have nuclei Molecules move due to hydration differences Are linked to companion cells Multiple answers:Multiple answers are accepted for this question B mature storage organs (like tubers) Multiple answers:Multiple answers are accepted for this question A attraction of microbes that can protect against pathogen B attraction of microbes that can fix nitrogen C attraction of microbes that enhance access to nutrients D enhances uptake of water from the soil environment Sugar is an essential component of plant nutrition and is transported throughout the plant by the vascular system. The vascular tissue responsible for this transportation is called phloem. Phloem is made up of modified cells called sieve elements, which are connected end to end and have a high sugar concentration at the source, creating a low solute potential that draws water into the phloem from the adjacent xylem. This movement of water creates turgor pressure in the phloem, which forces the phloem sap from the source to the sink through a process called bulk flow. The sugar is then removed from the phloem at the sink, increasing the solute potential, which causes water to leave the phloem and return to the xylem, decreasing the turgor pressure at the sink. This process is known as the pressure-flow model and explains the movement of sugar in phloem.Sugar sources and sinks A source is any structure in a plant that either produces (like a leaf) or releases (like a storage bulb) sugars for the growing plant. A sink is any location where sugar is delivered for use in a growing tissue or storage for later use.The role of phloem The phloem is a living tissue that transports glucose and other soluble compounds to parts of the plant where they are needed. This process is called translocation. The phloem is composed of living tissue called sieve tube members, which are joined end-to-end to form a tube that conducts food materials throughout the plant. The phloem transports sugars from sites where they are produced or stored to sites where they are needed for growth or storage.Sources of sugar include leaves, stems, and storage bulbs, while sinks include areas of active growth like new leaves, flowers, seeds, and fruits, as well as storage locations like roots, tubers, and bulbs. The phloem is supported by companion cells, which carry out metabolic functions and provide energy.The movement of sugars in the phloem is best explained by the pressure-flow model. According to this model, a high concentration of sugar at the source creates a low solute potential, which draws water into the phloem from the adjacent xylem. This movement of water creates high turgor pressure, which forces the phloem sap from the source to the sink through bulk flow. The sugar is then removed from the phloem at the sink, causing water to leave the phloem and return to the xylem, thus maintaining the direction of bulk flow from source to sink.The pressure-flow model also accounts for the bidirectional movement of translocation, which can proceed in both directions simultaneously (but not within the same tube). The movement of sugars into the phloem requires energy and is facilitated by proton pumps and co-transporters. The active transport of sucrose into the phloem is particularly important, as sucrose is the most prevalent solute in phloem sap.The pressure-flow model The model describes the movement of fluid in the phloem, a process called translocation, which can occur in any direction—up or down the plant. However, the fluid typically flows from source cells to sink cells. Source cells produce sugars and pump them into the phloem, while sink cells do not make enough sugars for their own growth and metabolism and must import them from the phloem.In the first step of the pressure-flow model, sugar (mainly sucrose) is actively transported from source cells into the sieve tubes of the phloem. The addition of sucrose into the sieve tubes increases the concentration of this solute, causing water to flow into the sieve tubes by osmosis. With the entry of water, the sieve tube pressure near the source cells increases, and the solution is forced to move to regions of lower pressure.At the regions of lower pressure, sink cells remove the sucrose by active transport. As the sink cells pull the solute out of the phloem, water leaves the phloem by osmosis, passing to neighbouring tissues that have higher solute concentrations. The retreating water reduces the pressure in this region of the sieve tubes and encourages fluid to continue to flow from regions of higher pressure.At different times of the year, a tissue may act as either a source or a sink. For example, during the growing season, mature leaves and stems are sources, while areas of active growth, such as new leaves, flowers, and seeds, are sinks. At the end of the growing season, the plant will drop its leaves and will not have any actively photosynthesizing tissues. At the start of the next growing season, the plant will resume growth, and the sugar stored in roots, tubers, or bulbs from the previous growing season will become the source of sugar for the developing leaves, which act as sinks.Sugar movement in two directions The pressure flow model for phloem transport explains how sugars can move in two directions in plants. This model accounts for the observation that translocation (the movement of sugar through the plant phloem) can proceed in both directions simultaneously, but not within the same tube.The direction of phloem transport can be either up or down, depending on the relative positions of the source and sink. A source is any structure in a plant that either produces (like a leaf) or releases (like a storage bulb) sugars for the growing plant. A sink is any location where sugar is delivered for use in a growing tissue or storage for later use.The pressure flow model works as follows: a high concentration of sugar at the source creates a low solute potential, which draws water into the phloem from the adjacent xylem. The movement of water into the phloem creates high turgor pressure, which forces the movement of phloem sap from the source to the sink through bulk flow. The sugars are then removed from the phloem at the sink, increasing the solute potential, which causes water to leave the phloem and return to the xylem, reducing the turgor pressure at the sink.The movement of sugars in phloem relies on the movement of water in phloem, which is driven by the active transport of sucrose from source cells into phloem sieve tube elements. This is in contrast to the movement of fluid in xylem, which is driven by transpiration (evaporation) from leaves.The role of roots In the context of sugar flow, roots serve as both a source and a sink. As a source, roots store excess sugar produced during the growing season, which can then be utilised during the dormant season when there are no actively photosynthesising leaves. This stored sugar is released to support the growth of new leaves and other developing tissues.Additionally, the formation of new lateral roots is influenced by the availability of sugar resources. The target of rapamycin (TOR) protein plays a crucial role in this process. TOR acts as a gatekeeper, ensuring that there are sufficient sugar resources available for root formation by controlling the expression of specific genes involved in root development. When TOR activity is suppressed, lateral root formation is hindered, indicating the significance of sugar availability in this process.Furthermore, the presence of sugar in the roots influences the formation of adventitious roots, which are roots that develop from plant tissues other than the main root. This discovery highlights the intricate connection between sugar availability and root development in plants.Understanding the role of roots in sugar flow and plant growth has important agricultural implications. By manipulating the processes that regulate root branching and sugar allocation, scientists can potentially develop new strategies for optimising plant growth in various environmental conditions, ultimately leading to improved crop yields.Frequently asked questions Sugar is transported through the phloem, the vascular tissue responsible for carrying nutrients around the plant body. The phloem is made up of cells called sieve-tube elements, which are supported by companion cells. Sugar is produced in the leaves of the plant through photosynthesis. It is then loaded into the phloem in preparation for transport to other areas of the plant. Sugar in the phloem is transported to areas of the plant that need nutrients, such as growing tissues and storage locations. These areas are called sinks, and can include the roots, stems, seeds, flowers, and fruits. The movement of sugar from the phloem to the sinks is called translocation. This process is driven by a difference in water pressure between the phloem and the xylem, the neighbouring tissue. The high concentration of sugar in the phloem draws water from the xylem, increasing the pressure in the phloem and forcing the sugar-water mixture towards the sinks. We know all living organisms need food and water for their growth and survival. Have you ever thought about how these nutrients are transported within the body of plants and animals? In animals, this function is performed by the circulatory system. Plants perform a similar function of transporting these nutrients — what we know as sap, by using complex tissues called xylem and phloem. Xylem is the dead, permanent tissue that carries water and minerals from roots to all other parts of the plant. The term 'xylem' is derived from the Greek word 'xylon', meaning wood. Phloem, on the other hand, is the living, permanent tissue that carries food and other organic nutrients from leaves to all other parts of the plant. The word 'phloem' is obtained from the Greek word 'phloios', meaning 'bark'. Xylem and Phloem Together, these two make up the vascular tissues in plants, forming the vascular bundle. Most plants have multiple vascular bundles that form a connection between its different parts, including leaves, stems, and roots. BasisXylemPhloemOccurrencePresent in roots, stems, and leaves.Initially present in stems and leaves that later grow in roots, fruits, and seedsStructureTubular-shaped with absence of cross wallsElongated, tubular-shaped with thin-walled sieve tubes connected end to endLocationFound in the center of the vascular bundleFound in the outer side of the vascular bundle.Composed ofConsists mainly of tracheid and vessel elementsConsists mainly of sieve tubes, sieve cells, phloem parenchyma, fibers, and sclereidsQuantityConstitute the bulk of the vascular bundleConstitute a small portion of the vascular bundleNature of Cells– Made up of dead cells that are hollow from within with no cytoplasm and cell content. Parenchyma is the only living cell– Cell wall is thick and made of lignin– Cells are impermeable to water – Made up of living cells with little cytoplasm and no nucleus.– Fibers are the only dead cells Cell wall is thin and made of cellulose– Cells are permeable to foodDirection of WorkUnidirectional – from roots to the apical parts of the plant through the stemBidirectional – both up and down the stemMain Functions– Transporting water and mineral from the roots to all parts of the plant– Passive transport; does not require energy– Replacing water lost through transpiration and photosynthesis– Providing mechanical strength– Transporting food from leaves to different parts of the plant– Active transport; requires energy – Transporting proteins and mRNAs throughout the plant– Does not provide mechanical strength Both xylem and phloem are complex conducting tissues composed of more than one type of cell.Both are components of vascular tissues in plants that serve the purpose of transporting materials throughout the plant.Living parenchymatous cells are found in both.Dead cells called bast fibers surrounds both tissues.Both primary and secondary growth periods are found in xylem and phloem.Both develope from procambium that has not been wholly differentiated during primary xylem and primary phloem formation. Combining the differences and similarities, we can conclude that both xylem and phloem have key features that help to maintain the transport of water, food, and minerals throughout the plant body. Article was last reviewed on Friday, February 3, 2023 Identify examples of and differentiate between sugar sources and sugar sinks in plant tissues Explain the roles of solute potential, pressure potential, and movement of water in the Pressure Flow Model for sugar translocation in phloem tissue Describe the roles of proton pumps, co-transporters, and facilitated diffusion in the Pressure Flow Model Recognize that the transport pathway used to load sugars at sources or unload sugars at sinks will depend on whether sugar is moving down or against its concentration gradient Compare and contrast the mechanisms and requirements of fluid transport in xylem and phloem The information below was adapted from OpenStax Biology 30.5 Plants need an energy source to grow. In growing plants, sugars move from sites where they are produced (or stored) to sites where they are needed for growth (or storage) via a process called translocation, or movement of sugar through the plant phloem: A source is any structure in a plant that either produces (like a leaf) or releases (like a storage bulb) sugars for the growing plant. A sink is any location where sugar is delivered for use in a growing tissue or storage for later use. Growing tissues might include apical and lateral meristems or developing leaves, flowers, seeds, and fruits; storage locations might include roots, tubers, and bulbs. Notice that a storage location might be either a source or a sink, depending on the plant's stage of development and the season: In the middle of the growing season, the sources include mature leaves and stems which are actively photosynthesizing and producing excess sugars. Sinks during the growing season include areas of active growth meristems, new leaves, and reproductive structures like flowers and seeds. Sinks also include sugar storage locations, such as roots, tubers, or bulbs. At the end of the growing season, the plant will drop leaves and no longer have actively photosynthesizing tissues. Depending on the local climate, the growing season may end either due to onset of winter or onset of the dry season. Early at the start of the next growing season, a plant must resume growth after dormancy. Because the plant has no existing leaves, its only source of sugar for growth is the sugar stored in roots, tubers, or bulbs from the last growing season. These storage sites now serve as sources, while actively developing leaves are sinks. Once the leaves mature, they will become sources of sugar during the growing season. The information below was adapted from OpenStax Biology 30.5 The best-supported hypothesis to explain the movement of sugars in phloem is the pressure flow model for phloem transport. This hypothesis accounts for several observations: The fluid in phloem is under high positive pressure Translocation stops if the phloem tissue is killed Translocation can proceed in both directions simultaneously (but not within the same tube) Translocation is inhibited by compounds that stop ATP production in the sugar source In very general terms, the pressure flow model works like this: A high concentration of sugar at the source creates a low solute potential (Ψs) The low solute potential draws water into the phloem from the adjacent xylem. Movement of water into the phloem creates a high pressure potential (Ψp), aka high turgor pressure, in the phloem. The high turgor pressure forces movement of phloem sap from source to sink through a process called "bulk flow." The sugars moved via bulk flow are then rapidly removed from the phloem at the sink. Removal of the sugars at the sink then increases the Ψs, which causes water to leave the phloem and return to the xylem, which then decreases Ψp at the sink. The video below provides a concise overview of sugar sources, sinks, and the pressure flow hypothesis: Before we discuss more details of the pressure flow model, let's first review some of the transport pathways we've previously discussed and add some new information to some of these transport pathways: Diffusion occurs when molecules move from an area of high concentration to an area of low concentration. Diffusion does not require energy because the molecules move down their concentration gradient (from areas of high to low concentration). Proton pumps use energy from ATP to create electrochemical gradients, with a high concentration of protons on one side of a plasma membrane. This electrochemical gradient can then be used as a source of energy to move other molecules against their concentration gradients via co-transporters. Co-transporters are channels that perform a type of secondary active (energy-requiring) transport. Co-transporters move two molecules at the same time: one molecule is transported along ("down") its concentration gradient, which releases energy that is used to transport the other molecule against its concentration gradient. Symporters are a type of co-transporter that transports two molecules in the same direction: both into the cell, or both out of the cell. Antiporters are a type of co-transporter that transports two molecules in opposite directions: one into the cell, and the other out of the cell. Symporters move two molecules in the same direction; Antiporters move two molecules in opposite directions. Image credit: Khan Academy, modified from OpenStax Biology. Original image by Lupask/Wikimedia Commons. The information below was adapted from OpenStax Biology 30.5 Photosynthates such as sucrose (a type of sugar) are produced in parenchyma cells of photosynthesizing leaves. Sugars are actively transported (requires ATP) from source cells into the sieve-tube companion cells, which are associated with the sieve-tube elements in the vascular bundles. This active transport of sugar into the companion cells allows the companion cells to accumulate a higher concentration of sugar than is present in the photosynthesizing leaves. To make this process work, the companion cells use an ATP-powered proton pump to create an electrochemical gradient outside of the cell; then a proton-sucrose cotransporter couples the movement of a proton down its concentration gradient with sucrose against its concentration gradient and into the companion cells. Once inside the companion cells, the sugar diffuses down its concentration gradient from the companion cell and into the phloem sieve-tube elements through the plasmodesmata that link the companion cell to the sieve tube elements. Recall that phloem sieve-tube elements have reduced cytoplasmic contents and are connected by pores that allow for pressure-driven bulk flow, or translocation, of phloem sap. Phloem is comprised of cells called sieve-tube elements. Phloem sap travels through perforations called sieve tube plates. Neighboring companion cells carry out metabolic functions for the sieve-tube elements and provide them with energy. Lateral sieve areas connect the sieve-tube elements to the companion cells. Image credit: OpenStax Biology. As noted in the previous section, the presence of high concentrations of sugar in the sieve tube elements drastically reduces Ψs; as a result, water then moves by osmosis from xylem into the phloem cells. This movement of water into the sieve tube cells then causes Ψp to increase, which increases both the turgor pressure in the phloem and the total water potential in the phloem at the source. This increase in water potential then drives the bulk flow of phloem from source to sink. Unloading at the sink end of the phloem tube can occur either by diffusion, if the concentration of sucrose is lower at the sink than in the phloem, or by active transport, if the concentration of sucrose is higher at the sink than in the phloem: If the sink is an area of active growth, such as a new leaf or a reproductive structure, then the sucrose concentration in the sink cells is usually lower than in the phloem sieve-tube elements because the sink sucrose is rapidly metabolized for growth. If the sink is an area of storage where sugar is converted to starch, such as a root or bulb, then the sugar concentration in the sink is usually lower than in the phloem sieve-tube elements because the sink sucrose is rapidly converted to starch for storage. If the sink is an area of storage where the sugar is stored as sucrose, such as a sugar beet or sugar cane, then the sink may have a higher concentration of sugar than the phloem sieve-tube cells. In this situation, active transport by a proton-sucrose cotransporter (which relies on an ATP-powered proton pump) is typically used to transport sugar from the companion cells into storage vacuoles in the storage cells. Once sugar is unloaded at the sink cells, the Ψs increases, causing water to diffuse by osmosis from the phloem back into the xylem. This movement of water out of the phloem causes Ψp to decrease, reducing the turgor pressure in the phloem at the sink and maintaining the direction of bulk flow from source to sink. Sucrose is actively transported from source cells into companion cells and then into the sieve-tube elements. This reduces the water potential, which causes water to enter the phloem from the xylem. The resulting positive pressure forces the sucrose-water mixture down toward the roots, where sucrose is unloaded. Transpiration causes water to return to the leaves through the xylem vessels. Image credit: OpenStax Biology This video (beginning at 5:03) provides a more detailed discussion of the pressure flow hypothesis: It should be clear that movement of sugars in phloem relies on the movement of water in phloem. But there are some important differences in the mechanisms of fluid movement in these two different vascular tissues: The "driving force" for fluid movement: Xylem: transpiration (evaporation) from leaves, combined with cohesion and tension of water in the vessel elements and tracheids (passive; no energy required) Phloem: Active transport of sucrose from source cells into phloem sieve tube elements (energy required) The cells facilitating fluid movement: Xylem: Non-living vessel elements and tracheids Phloem: Living sieve tube elements (supported by companion cells) Type of pressure potential Xylem: Negative due to pull from the top (Ψp decreases due to combined effects of transpiration combined with cohesion and tension of water) Phloem: Positive due to push from source (Ψp increases due to influx of water which increases turgor pressure at source) The Role of Phloem in Transporting Sugars In plants plants are remarkable organisms that play a crucial role in the ecosystem. Central to their survival and growth is a system of vascular tissues. These tissues facilitate the movement of water, minerals, and nutrients throughout the plant. Among the various components of this system, one notable structure is Phloem. This tissue is specifically responsible for sugar transport and plays a vital role in the overall health of the plant. During the process of photosynthesis, plants convert sunlight into energy, producing sugars as a byproduct. These sugars are essential for powering growth and development. However, simply generating sugars is not enough; they must be transported efficiently to all areas of the plant. This necessity gives rise to specific transport mechanisms that ensure nutrients reach every cell. Sieve tubes and companion cells work together in transporting sugars. Sieve tubes are like the highway of the plant, allowing for quick movement of substances. Companion cells assist by maintaining and supporting sieve tubes, ensuring smooth operation. By coordinating these functions, the plant can sustain its metabolic activities and growth processes. Understanding how sugar transport operates enhances knowledge of plant physiology. Without a doubt, this process is fundamental for the overall vitality of any plant. It allows nutrients produced in the leaves to be distributed effectively to other parts, such as roots, stems, and flowers. Consequently, grasping this concept helps in appreciating the complexity of plant biology. In summary, the role of phloem in transporting sugars is essential for life in plants. Without it, growth would be stunted, and development would falter. Thus, the significance of this process cannot be overlooked in studies of plant health and function. Understanding Phloem Artists impression of – The Role Of Phloem In Transporting Sugars In Plants The phloem is an essential part of vascular tissue in plants. This type of tissue plays a critical role in the transport of sugars produced during photosynthesis. Its primary function is to move these sugars, along with other nutrients, throughout the plant. To grasp how this transport works, we must explore both its structure and function. Within the phloem, special structures called sieve tubes are present. These tubes facilitate the movement of sugars in a solution. Companion cells are closely associated with sieve tubes. They support the metabolism of sieve elements and help manage the transport process. This interaction is crucial for efficient translocation, ensuring sugars reach all parts of the plant. When comparing phloem to xylem, distinct differences emerge. While xylem is responsible for transporting water and minerals from the roots to the leaves, phloem operates in the opposite direction. Xylem contributes to maintaining a plant's structural integrity by providing support through its thick-walled cells. In contrast, phloem focuses primarily on supplying the energy and nutrients needed for growth and development. Both systems are vital to plant physiology. They work together to sustain life in the plant. Without a functioning transport mechanism, the plant would struggle to acquire the nutrients necessary for survival. Understanding this offers a glimpse into the complexity of plant biology and how different parts cooperate in harmony. The Process of Photosynthesis Artists impression of – The Role Of Phloem In Transporting Sugars In Plants Photosynthesis is a vital process that allows plants to produce their own sugars. During this process, plants use sunlight to convert carbon dioxide and water into glucose. This glucose serves as an essential energy source for growth and development. Chlorophyll, found in the leaves, captures sunlight. This green pigment plays a crucial role in absorbing light energy. In this chemical reaction, oxygen is released as a by-product, which is important for many living organisms. Leaves are the primary sites for photosynthesis. Their broad surfaces allow for maximum light absorption. With numerous tiny pores known as stomata, leaves can take in carbon dioxide from the air. Water, absorbed through the roots, travels through specialized vascular tissue. This transport mechanism brings water up to the leaves where it is needed for photosynthesis. Oxygen released from the leaves escapes through the same stomata. During photosynthesis, the produced glucose must be transported to different parts of the plant for use or storage. This is where translocation comes into play. Sieve tubes and companion cells work together in this transport process. Sieve tubes are responsible for moving the sugars away from the leaves. Companion cells support the sieve tubes by providing them with the necessary nutrients and energy they need to function. Together, they form an efficient system for distributing sugars throughout the plant. In plant biology, this transport mechanism is crucial. Plants rely on sugars not only for energy but also for growth and reproduction. Without effective transport of glucose, plants would struggle to thrive. The relationship between photosynthesis and the vascular system is significant. Understanding this connection helps explain how plants maintain their health and vitality. Structure of Phloem Artists impression of – The Role Of Phloem In Transporting Sugars In Plants The phloem is made up of several key components that work together to transport sugars and nutrients throughout plants. Sieve tubes stand out as one of the most important structures. These tubes are long, cylindrical cells that connect end to end to form pathways for the movement of sap. They lack a nucleus and are less complex than other plant cells. This specialization allows them to efficiently transport sugars produced during photosynthesis from the leaves to all parts of the plant. Their walls, made of cellulose, are perforated with sieve plates, which facilitate the flow of sap between cells. Companion cells play a vital supporting role for sieve tubes. They are found adjacent to sieve tube elements and are crucial for their function. These specialized cells have a full set of organelles, including a nucleus, which the sieve tubes lack. This arrangement is essential, as companion cells help load sugars into the sieve tubes. Through active transport mechanisms, they manage the flow of nutrients, ensuring that sieve tubes maintain the proper concentration of sugars. In this way, companion cells are indispensable for the translocation of vital resources throughout the plant. Each component of the phloem showcases the complexities of plant biology. Together, sieve tubes and companion cells illustrate the intricate systems that enable plants to thrive. Understanding this cooperation is key to grasping various concepts within plant physiology. Transport needs in plants are often high due to active growth and development. Thanks to sieve tubes, sugars can reach all tissues, which is crucial for energy needs and overall health. Mechanism of Translocation Artists impression of – The Role Of Phloem In Transporting Sugars In Plants Translocation is the process through which plants transport sugars and nutrients from one part of the plant to another. This essential function occurs primarily in the vascular tissue. During photosynthesis, leaves create sugars which need to travel to various parts of the organism. To move effectively, the sugars utilize specialized structures. Sieve tubes play a critical role in this movement. These long, tube-like cells form a system that runs throughout the plant. When sugars are produced in the leaves, they enter these tubes. The movement relies heavily on the pressure created within these tubes. This pressure allows the contents to flow from areas of high concentration to areas of low concentration. Companion cells accompany sieve tubes, aiding in the process. The relationship between these two types of cells is vital for healthy plant biology. Companion cells help load sugars into the sieve tubes. They also take care of transporting other nutrients necessary for the plant's growth and development. A complex series of transport mechanisms facilitates the flow of sugars. One mechanism involves active transport, which requires energy to move sugars against their concentration gradient. This energy comes primarily from ATP produced in the plant cells. By using active transport, plants ensure a steady supply of energy-rich compounds to growing tissues. Another mechanism is passive transport, which occurs when sugars flow naturally through the sieve tubes without the need for additional energy. This happens due to the differences in pressure along the tubes. Active and passive transport work together to make translocation efficient. Understanding how this system operates enhances our knowledge of plant physiology. Without these functioning mechanisms, plants would struggle to distribute the energy necessary for their survival. Translocation is indeed a fundamental process for sustaining plant life. Sources and Sinks in Sugar Transport In plant biology, understanding the dynamics of sources and sinks is essential for grasping how sugars are transported. Sources are areas where sugars are produced, while sinks are places where these sugars are utilized or stored. This process plays a critical role in the overall growth and health of plants. Vascular tissue, which includes both xylem and phloem, functions in the transport mechanisms of these essential nutrients. Photosynthesis happens mainly in leaves, making them primary sources of sugars. During sunlight hours, chloroplasts in leaf cells convert carbon dioxide and water into glucose. Glucose is then loaded into the sieve tubes, where it travels through the phloem to various parts of the plant. This journey, known as translocation, involves companion cells that support the sieve tubes and help manage the flow of this sugar-rich solution. Roots and developing flowers are common examples of sinks. Roots store sugars to ensure energy is available during periods when photosynthesis cannot occur, like winter. Similarly, flowers use sugars to support development and attract pollinators. During the growing season, newly developing fruits also act as sinks, requiring high amounts of sugars to mature properly. Different plants exhibit varied patterns of sources and sinks. For instance, a tomato plant has leaves as sources, while its fruit acts as a prime sink. This relationship helps manage energy efficiently within the plant. Understanding how these relationships function allows for deeper insight into plant physiology and growth. Understanding these dynamics can reveal much about how plants adapt to their environment. Environmental factors like sunlight and water availability can shift the balance between sources and sinks. For example, during drought conditions, roots may become more active sinks as plants shift focus to survival rather than growth. Nutrient Transport Alongside Sugars The transport of sugars in plants is well-studied, yet the movement of other nutrients is equally vital. Vascular tissue plays a key role in this process, as it helps distribute essential compounds throughout the plant. The transport mechanisms involved are intricate. Sieve tubes are the main pathways for transporting sugars, but they also carry various nutrients. Alongside sugars, plants require minerals and other vital nutrients for successful growth and development. For instance, nitrogen, phosphorus, and potassium are critical for different physiological processes. Companion cells support sieve tubes, ensuring that these nutrients reach their destinations efficiently. This partnership is essential for maintaining plant health. Translocation is not just about moving sugars; it also includes these other nutrients. In fact, the balance of nutrients can affect a plant's ability to perform photosynthesis. When plants have access to adequate nutrients, they grow stronger and more resilient. This strength is necessary to fend off diseases and adapt to changing environments. Understanding nutrient transport enhances our knowledge of plant biology. It sheds light on how plants thrive in their ecosystems. Without effective transport systems, plants could struggle to survive. Consequently, nutrient transport is a cornerstone of plant physiology, impacting everything from overall health to yield in agricultural settings. Impact of Environmental Factors on Phloem Function Environmental factors significantly affect how plants transport sugars and nutrients. Temperature plays a crucial role in regulating plant physiology. High temperatures can increase the rate of photosynthesis up to a point, but excessive heat can damage the vascular tissue responsible for translocation. If it gets too warm, the sieve tubes may become less efficient, affecting overall transport. Drought conditions pose a serious challenge. When water is scarce, plants often close their stomata to prevent further loss, reducing carbon dioxide intake. This leads to less sugar production during photosynthesis. As a result, already stressed plants struggle even more to maintain healthy sugar transport through their tissues. Moreover, nutrient availability directly impacts sugar transport mechanisms. Nutrients are vital for healthy growth and functioning of companion cells. These cells support sieve tubes in transporting essential substances. When nutrients are lacking, the plant's ability to transport sugars efficiently declines, which may lead to stunted growth or poor fruit development. Understanding these factors helps explain how plants adapt to their surroundings. Some species develop stronger roots or thicker leaves to cope with limited water. Others may adjust their internal processes to use available resources more efficiently. These adaptations are essential for survival, especially in changing environments. In conclusion, the relationship between environmental conditions and phloem function is complex. Each factor can influence the transport of sugars in different ways. By studying these interactions, we gain insights into plant biology and how various species thrive despite adverse conditions. Final Thoughts on Sugar Transport in Plants In summary, the role of the vascular tissue system in transporting sugars is fundamental to plant health. It works by moving essential nutrients from leaves, where they are produced, to other parts of the plant that need them. This transport process supports growth and energy needs across various plant systems. Transporting sugars is not just about nourishment; it also plays a critical part in plant development and reproduction. Understanding how this transport process works can have significant implications for advancing plant science. Researchers can discover ways to improve crop yields and enhance resilience against diseases. Insights gained can lead to more efficient farming practices as well. Knowledge about this aspect of plant biology acts as a foundation for innovation in agriculture. Ultimately, a deeper understanding fosters appreciation for the complex systems at work in plants. This knowledge influences how humans manage and cultivate these life forms. By comprehending these mechanisms, we take a step closer to optimizing food production and ensuring food security for everyone.