Discuss the usefulness and limitations of anatomical studies when attempting to understand transport systems in plants.

The study of plant anatomy is the study of the plant cells, tissues and the structure of the plant as a whole. This is crucial in understanding how transport in plants works because without the knowledge of how the plant is built and what constitutes the different parts of the plant, scientists would not be able to visualize the organization within the plant and come up with viable deductions about the mechanisms of plant transport. However, anatomical studies alone would not be able to provide enough information about the mechanisms of plant anatomy. Processes involving the selective transport of materials and the chemical changes that take place within plant cells require studies in the chemistry of the plant as well as its anatomy.

Before we understand how water and minerals can be absorbed by the plant and transported to the leaves and everywhere else, we must first be equipped with the knowledge of plant anatomy. With the knowledge that the root is covered with tiny root hairs, we can deduce that this is for increasing the surface area of absorption for efficiency. We must also know the location of different types of cells in the roots, before we can deduce that the water passes from the soil solution into the epidermis(an outgrowth in an epidermal cell makes this cell a root hair cell), from which it may flow via the apoplastic (by cell wall), symplastic (by cytoplasm and adjoining plasmodesmata) or vacuolar (through cell membrane) pathways through the cortex cells, then endodermis and finally into the stele where it enters the xylem vessels. By knowing that there is the Casparian strip (a belt of suberin that blocks the passage of water and minerals) running across the cell wall of the endodermis, we can infer that this is to redirect the water and minerals into the symplast or vacuolar pathways via the crossing of the cell membrane.

However, to understand why this happens, pure anatomical studies will never provide a complete answer. At most, with this anatomical knowledge, we can deduce that the Casparian strip serves to prevent the backflow of water and minerals from the stele into the cortex. To understand the function of redirecting the water and minerals into the symplast and vacuolar pathways, we must first study the interactions between transport proteins present on the surface of the cell membranes and tonoplasts, and the ions transported. By studying this chemistry, the function of redirecting the apoplast pathways into the symplast and vacuolar pathways can be inferred as selectively transporting minerals into the stele via selective transport proteins of the plasma membrane and tonoplast. Also, the most basic fact that a cell membrane is selectively permeable cannot be deduced by anatomical studies---we may know a structure is there but what it does we may not understand by merely acknowledging its existence. The cell membrane not only selects mineral ions but also screens out undesirable pathogens.

Furthermore, it is difficult to understand just by looking at plant anatomy how minerals can diffuse into the cells from a lower concentration in the soil solution. In actual fact, scientists have deduced that ATP activated pumps on the cell membranes use energy to pump in ions and prevent the outward diffusion of ions and other valuable metabolites.

By anatomically studying the xylem vessel, we would know that it lacks protoplasm and forms a long continuous hollow tube from the roots to the leaves of a plant. Thus the water and minerals may flow easily through (apoplastic pathway). Since the xylem is long and continuous, we find it easier to understand how water may be pulled up the vessel in a long continuous stream by the adhesion-cohesion theory and transpirational pull.

To understand the mechanism of the transpirational pull, we must look at the anatomy of the leaf. The mesophyll cells in the spongy mesophyll layer contain many intercellular spaces between them through which water vapour/moisture can readily diffuse through to reach the guard cell. Guard cells dot the underside of the leaf and when the guard cells open, moisture lining the mesophyll cells evaporates into the drier atmosphere outside. This creates surface tension at the mesophyll surface, so water from inside the cell diffuses out to take the place of the moisture that left. Water is then drawn from the next mesophyll cell and the next as water potential drops in the previous one, until this reaches the xylem vessel from which water will be drawn in the same manner. This makes up the transpirational pull, and the path in which water travels from root to xylem to atmosphere can only be understood by the study of the structure of the leaf.

To understand how guard cells open to allow moisture to diffuse out of the leaf, we have to study in depth the structure of the guard cells. Guard cells occur in pairs and each pair is firmly joined at their ends. The cellulose thickening at the outer part of the cells causes turgid guard cells to buckle outwards pushing against the subsidiary cells. Microfibrils of cellulose in the cell walls are also laid down in directions that prevent the guard cells from expanding sideways but instead lengthwise, causing them the buckle outwards too.

However, using only anatomical studies, we cannot ascertain how the guard cells become turgid. This is because the explanations are mostly based on chemistry knowledge. An early hypothesis was that sugar made in the guard cells during photosynthesis lowered their water potential and caused water from subsidiary cells to diffuse in by osmosis. However, scientists later questioned this hypothesis, as the response of stomata is too fast to be caused by slow accumulation of sugar, and in some plants the stomata open before daybreak and photosynthesis. Also, scientists discovered a significant accumulation of potassium ions and malate in guard cells before the opening of stomata, and that a plant growth regulator, abscisic acid, causes stomatal closure (by suppressing the ability of guard cells to retain potassium ions). Thus they came up with another hypothesis, one that says the accumulation of postassium and malate ions in the guard cell lowers its water potential and causes water to enter and make the cell turgid. All of the above deductions have little to do with plant anatomy as the structure of the plant tells one little about the reactions or processes occurring within a cell itself.

Thus, based on the information provided above, I think that while plant anatomy is essential in mainly identifying pathways of plant transport and perhaps helping in the understanding of the plant transport systems in this way, it cannot be used alone to help us truly see what goes on within the plant and why. Studies of the interactions between cells and ions, and of the chemical processes that occur within cells, will probably fill us in on much more information pertaining to transport in plants, and allow us to have a fuller understanding of it.

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