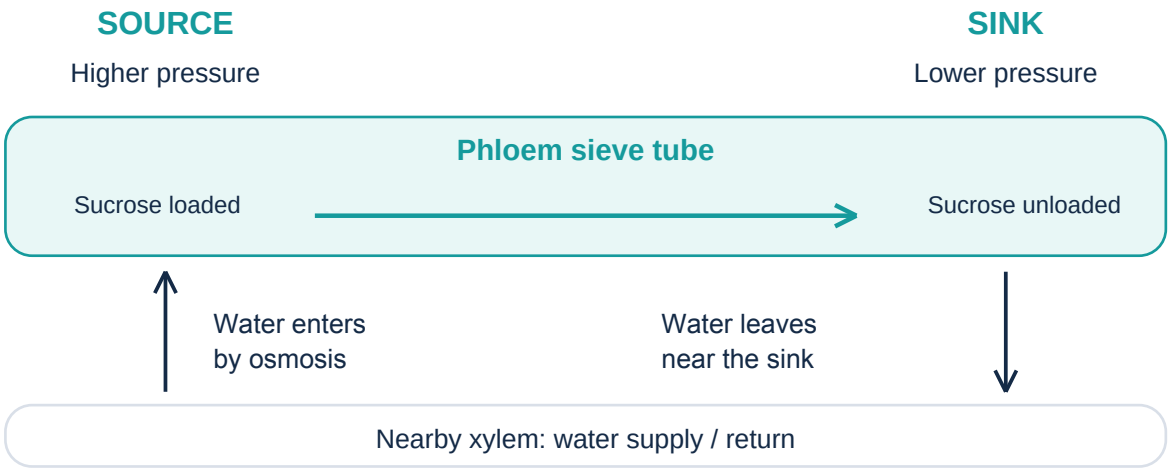
Pressure moves the phloem sap

Mass flow is the bulk movement of a solution. In phloem, water and dissolved assimilates move together from higher to lower hydrostatic pressure, from source to sink.

1. THE PRESSURE-FLOW MODEL



Schematic, not to scale. Water exchange is shown locally; the xylem is not a sealed return loop. Loading and unloading are explained on page 2.

2. THE DRIVING GRADIENT IS HYDROSTATIC PRESSURE

Higher pressure at the source pushes sap along the sieve tube towards lower pressure at the sink. Sap passes through pores in sieve plates between successive sieve tube elements. The diagram omits these plates.

3. SOURCE TO SINK DOES NOT MEAN ALWAYS DOWN

A source can supply a sink above or below it. Different sieve tubes can carry sap in opposite directions at the same time. Do not draw simultaneous opposing bulk flows in the same sieve-tube segment.

Use the full explanation: loading and unloading help maintain the pressure difference. A sucrose concentration gradient alone is not the direct cause of long-distance mass flow.

Pressure-flow evidence: Knoblauch et al. (2016), eLife 5:e15341.

Scope: Cambridge Biology 9700 syllabus, section 7.2, outcome 8, p. 26.

Build and maintain the gradient

Follow the changes in order. Solute loading changes water potential; osmotic water movement changes pressure. Pressure then drives the bulk movement along the tube.

1. LOAD AT THE SOURCE

Sucrose enters the source-end phloem. Increasing its concentration lowers solute potential and initially lowers water potential in the sieve tube.

2. DRAW WATER INTO THE PHLOEM

Water moves from nearby xylem into the sieve tube by osmosis, down a water-potential gradient across partially permeable membranes.

3. RAISE SOURCE PRESSURE

Water entry raises hydrostatic pressure. The pressure difference between source and sink drives bulk flow of sap through sieve tubes.

4. UNLOAD AT THE SINK

Sucrose leaves the phloem and is used in respiration or synthesis, or converted to storage compounds. Its removal makes solute potential less negative and tends to raise water potential.

5. ALLOW WATER TO LEAVE

Water leaves the phloem near the sink, often returning to xylem. In the simple model, this helps keep sink-end pressure below source-end pressure.

Loading, unloading and water exchange continue during transport. Real tissues regulate these processes; the five stages describe a causal model, not isolated one-off events.

Pressure-flow evidence: Knoblauch et al. (2016), eLife 5:e15341.

Scope: Cambridge Biology 9700 syllabus, section 7.2, outcome 8, p. 26.

Keep the transport processes distinct

Loading across a membrane, water exchange and movement along a sieve tube are different processes. Explain each using the appropriate driving force.

1. PROCESS, LOCATION AND DRIVER

PROCESS	WHAT MOVES / WHERE	DIRECT DRIVER
Active loading	Sucrose enters the loading cells	Proton gradient, maintained by ATP
Osmosis	Water crosses a partially permeable membrane	Water-potential gradient
Mass flow	Sap moves along phloem sieve tubes	Hydrostatic pressure gradient

2. WHERE ATP IS NEEDED

In the active loading model, ATP powers proton pumps that establish the gradient used for sucrose cotransport. Bulk sap flow itself is driven by pressure, not by an ATP-powered pump at each sieve plate.

3. CHECK A PRESSURE PREDICTION

If the pressure difference falls while resistance stays the same, bulk flow slows. If pressures become equal, the simple model predicts no net pressure-driven flow. This does not mean molecular motion or all diffusion stops.

Final distinction: high hydrostatic pressure is not the same as high water potential. Solute potential and pressure both contribute to water potential. Do not use these terms interchangeably.

Pressure-flow evidence: Knoblauch et al. (2016), eLife 5:e15341.

Scope: Cambridge Biology 9700 syllabus, section 7.2, outcome 8, p. 26.