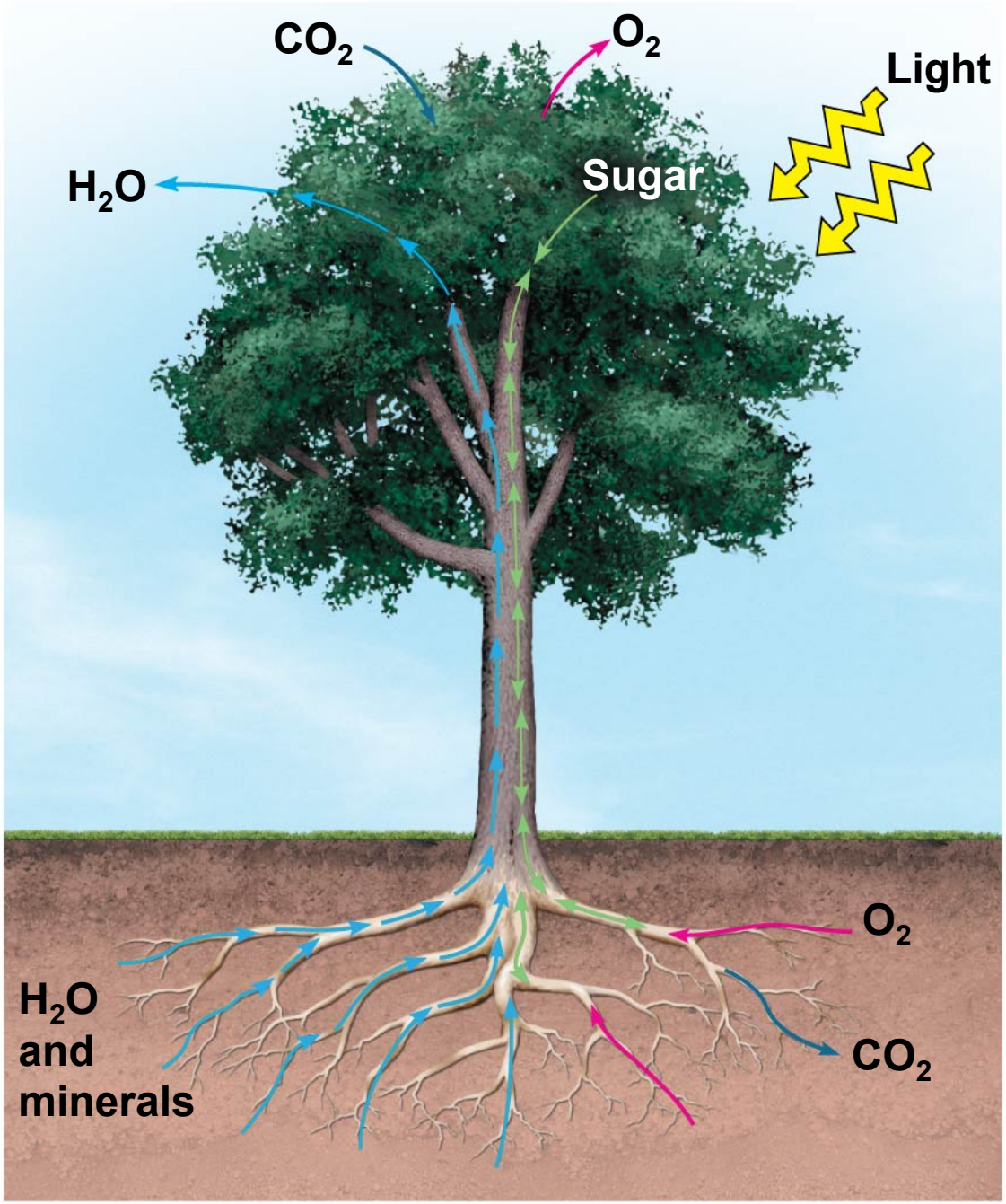
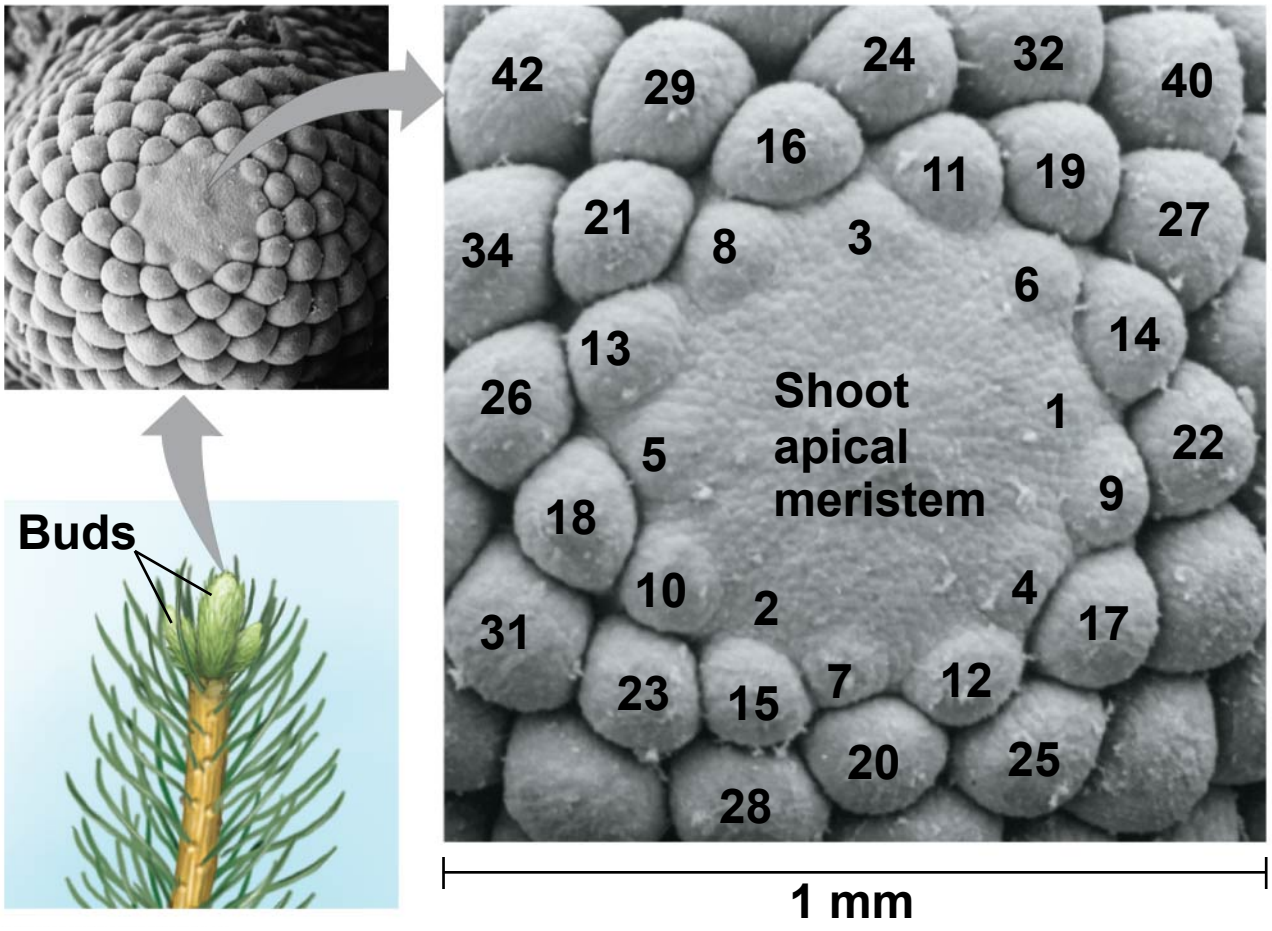
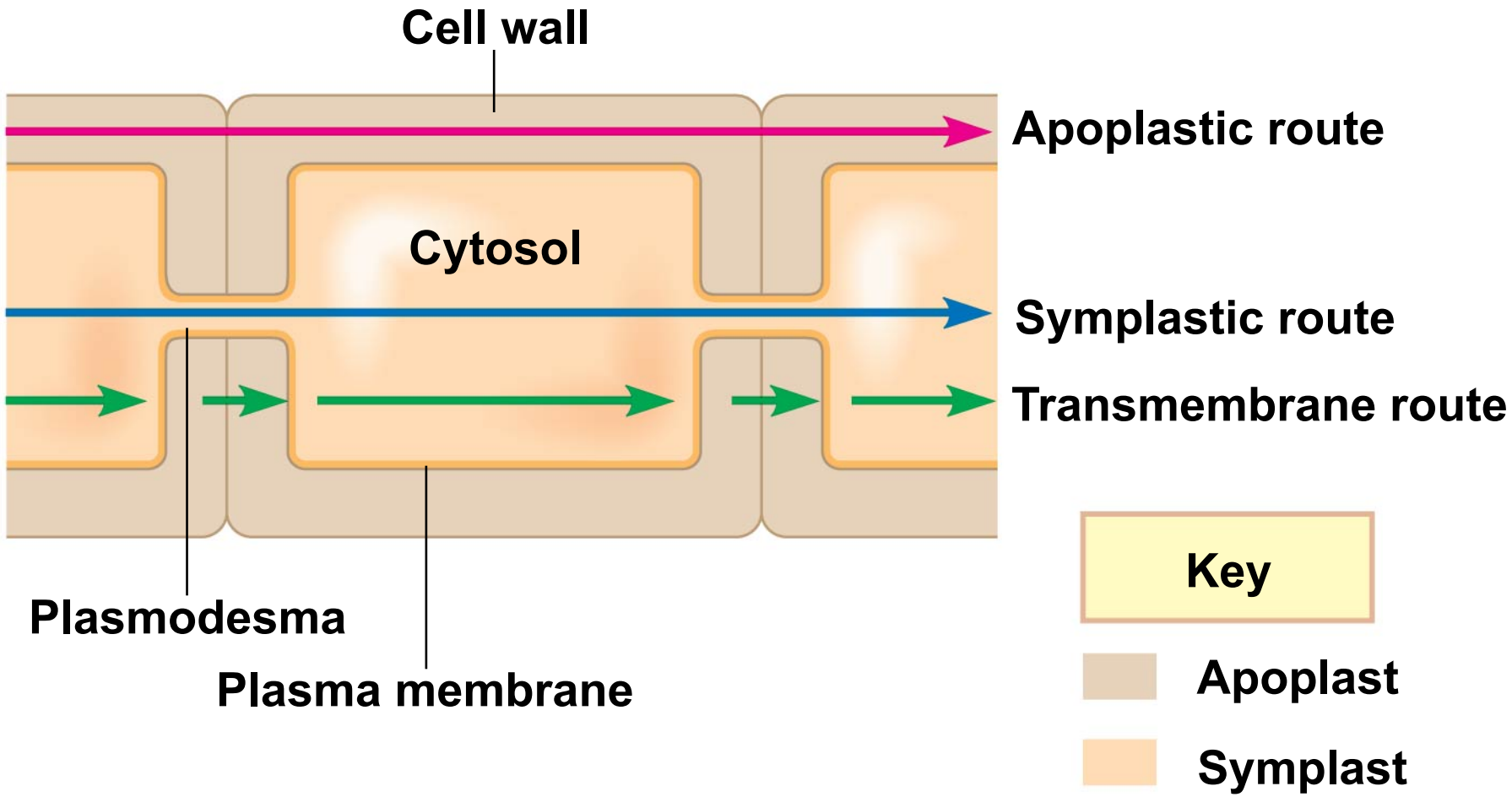
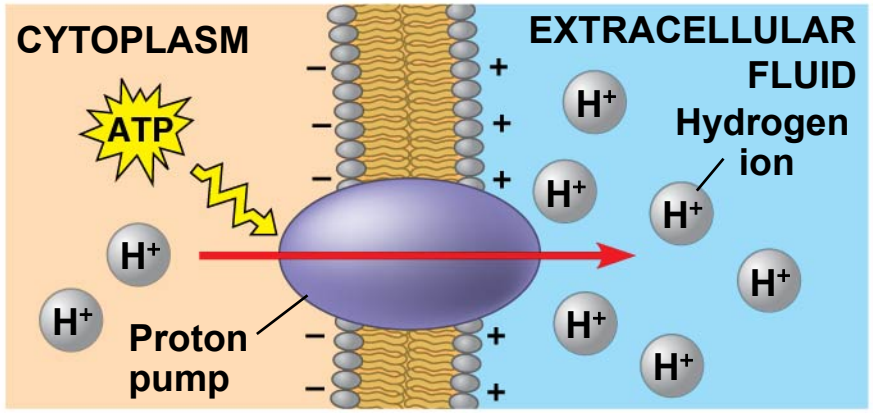
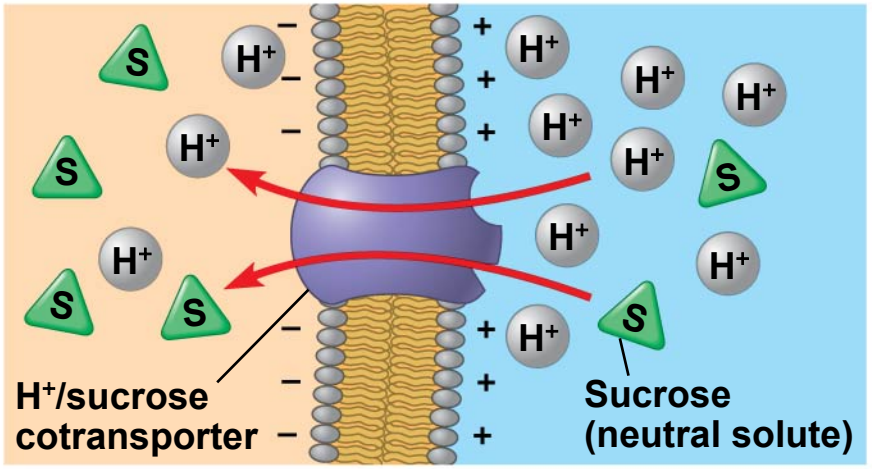




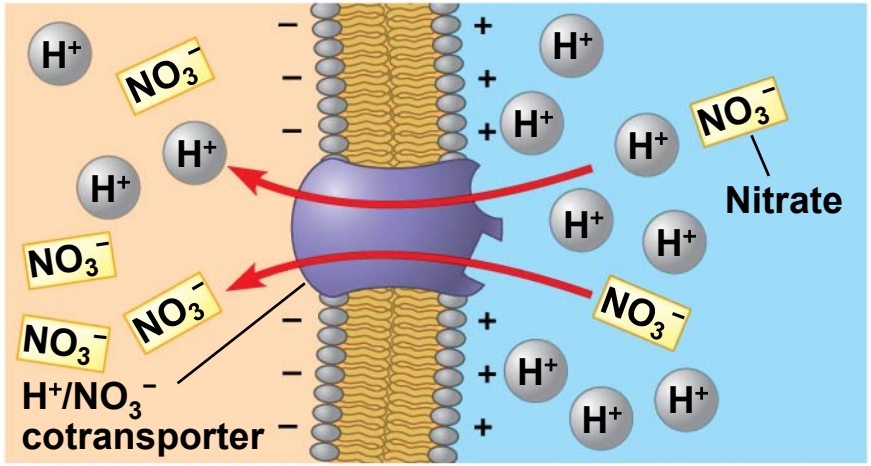




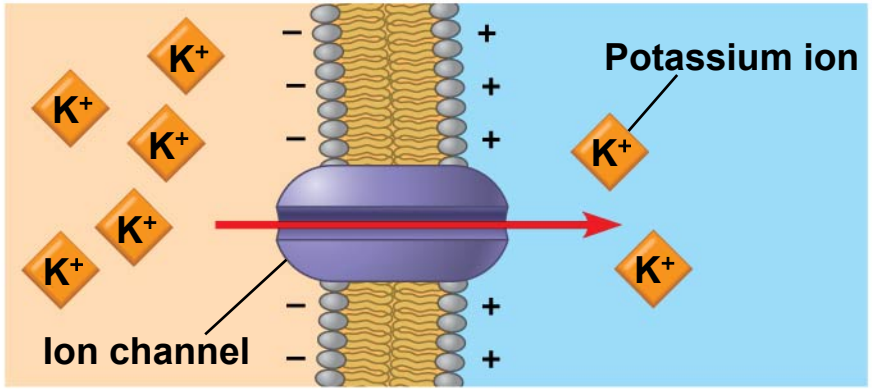
(a) H^+ and membrane potential



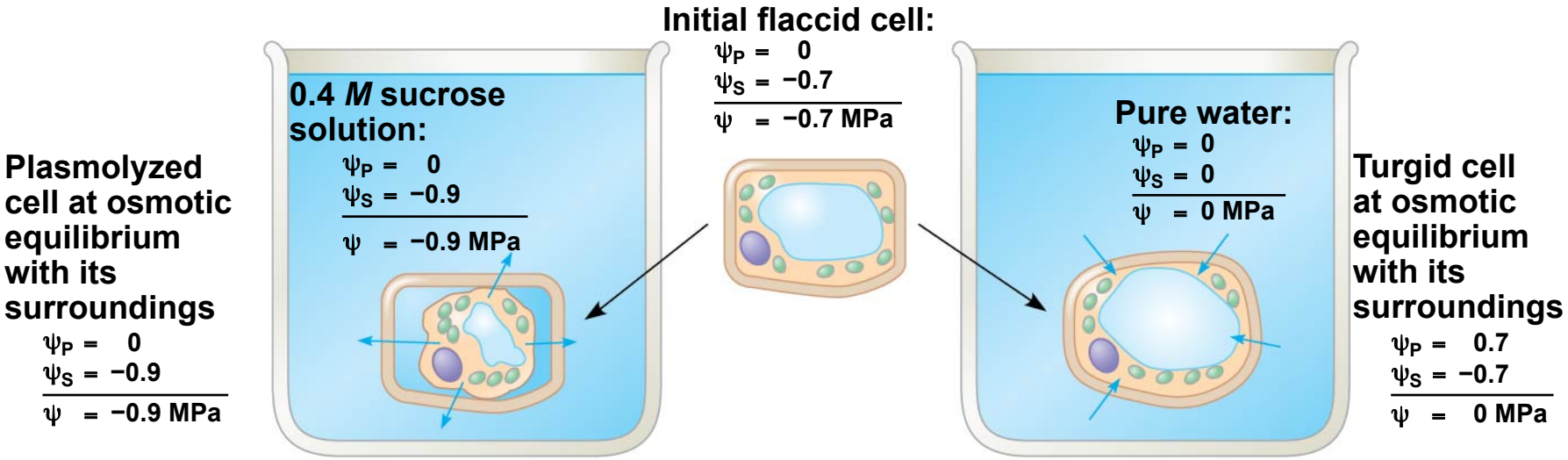
(b) H^+ and cotransport of neutral solutes



(c) H^+ and cotransport of ions



(d) Ion channels



Wilted

Turgid

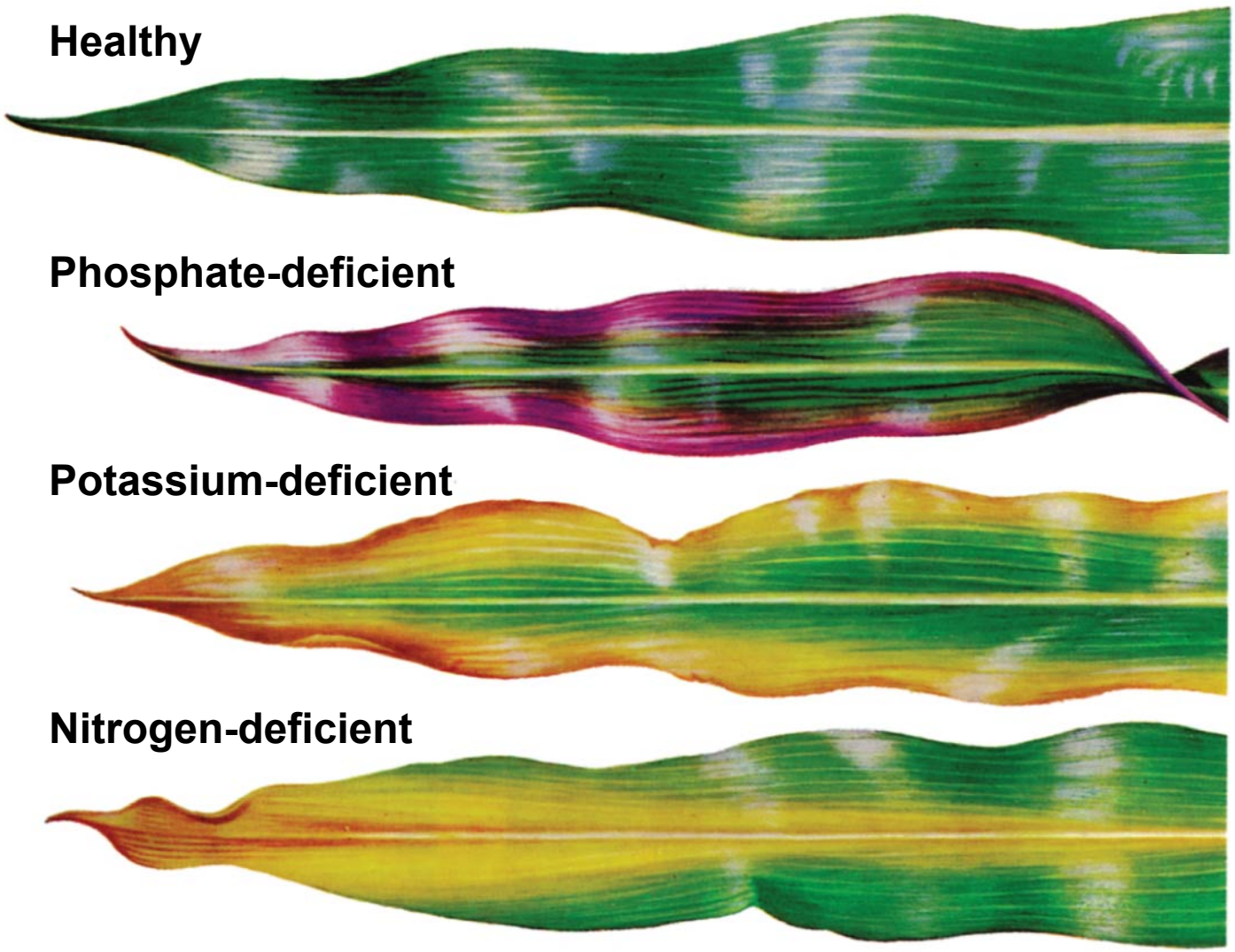
Technique

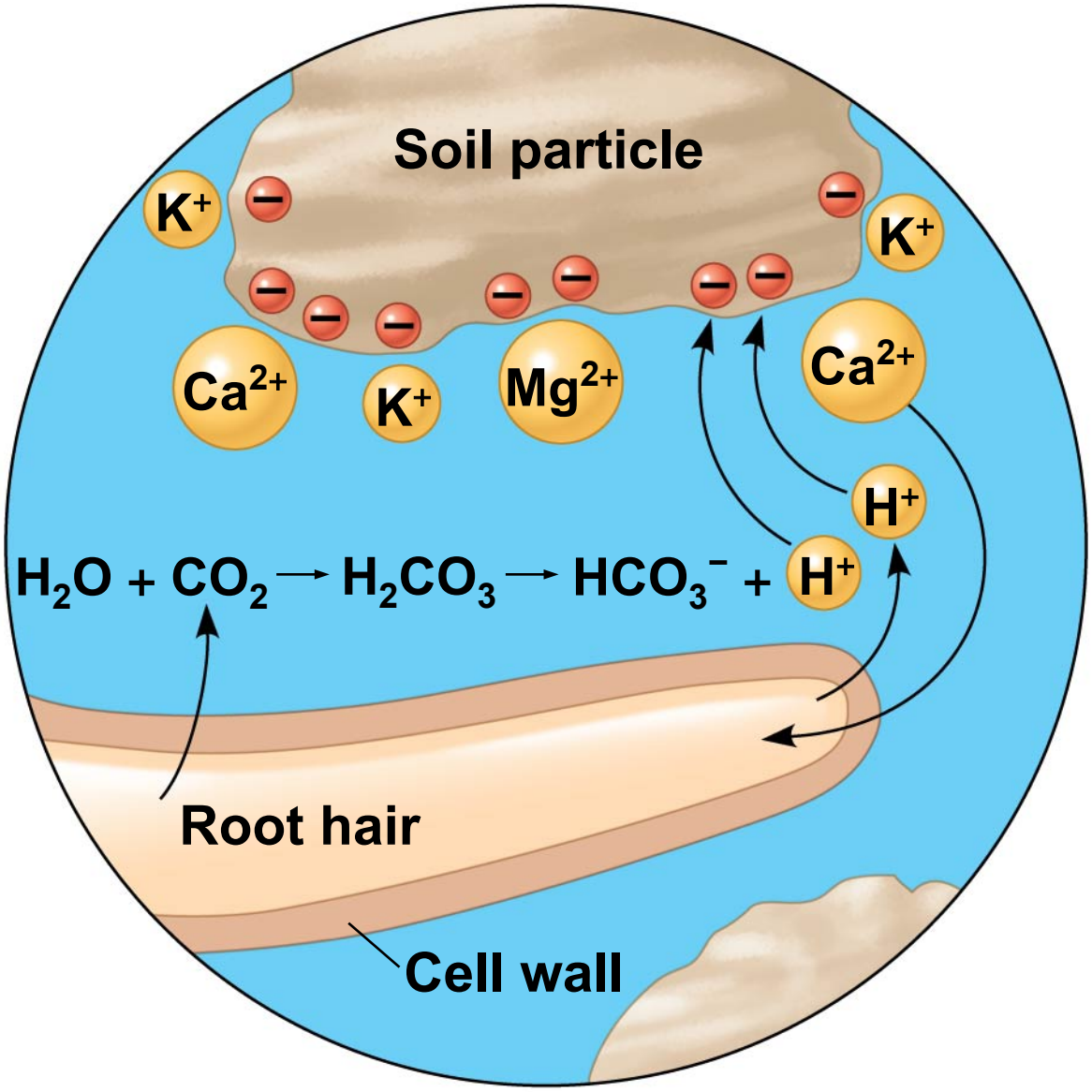
Control: Solution containing all minerals

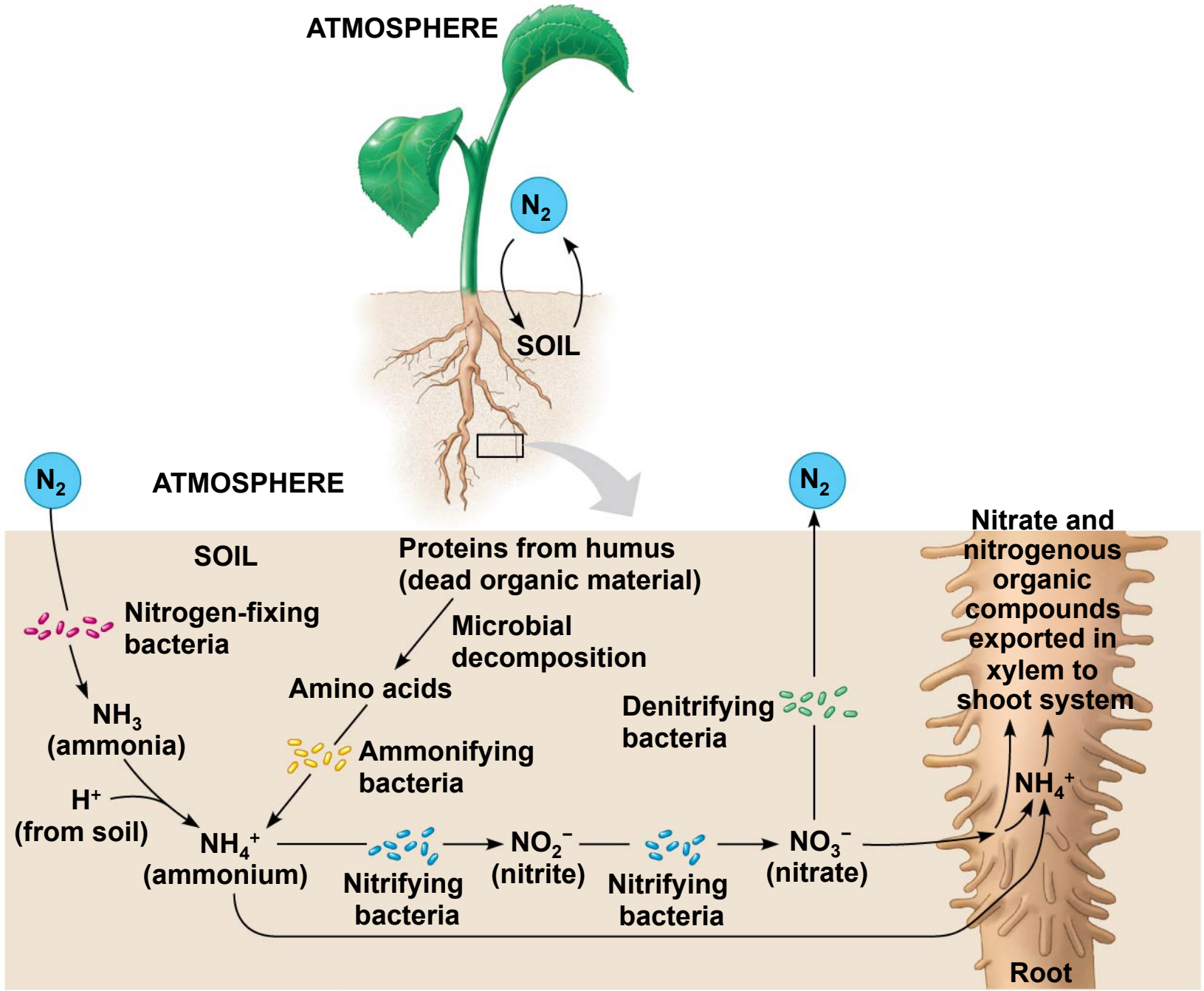
Experimental: Solution without potassium

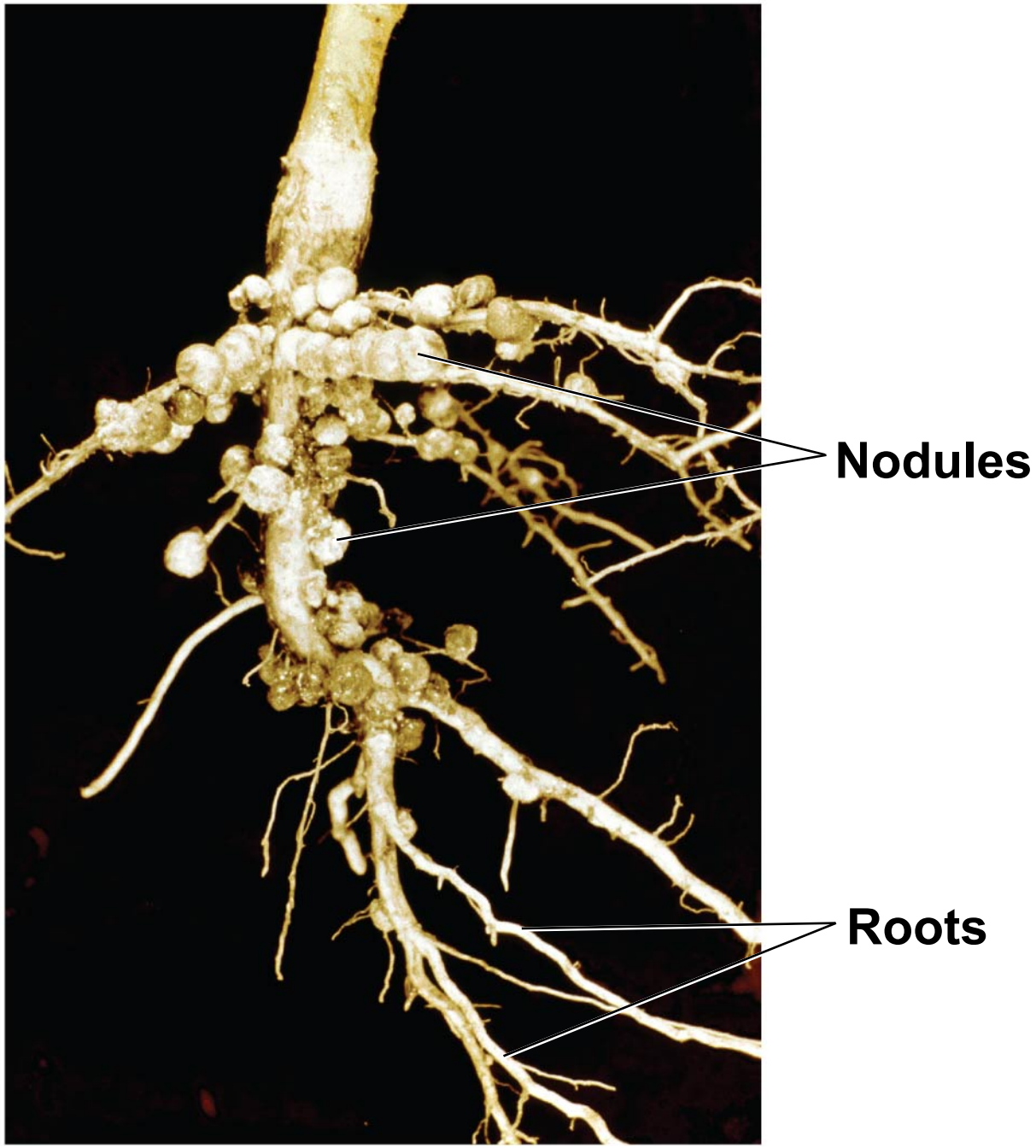
Table 29.1 Essential Elements in Plants

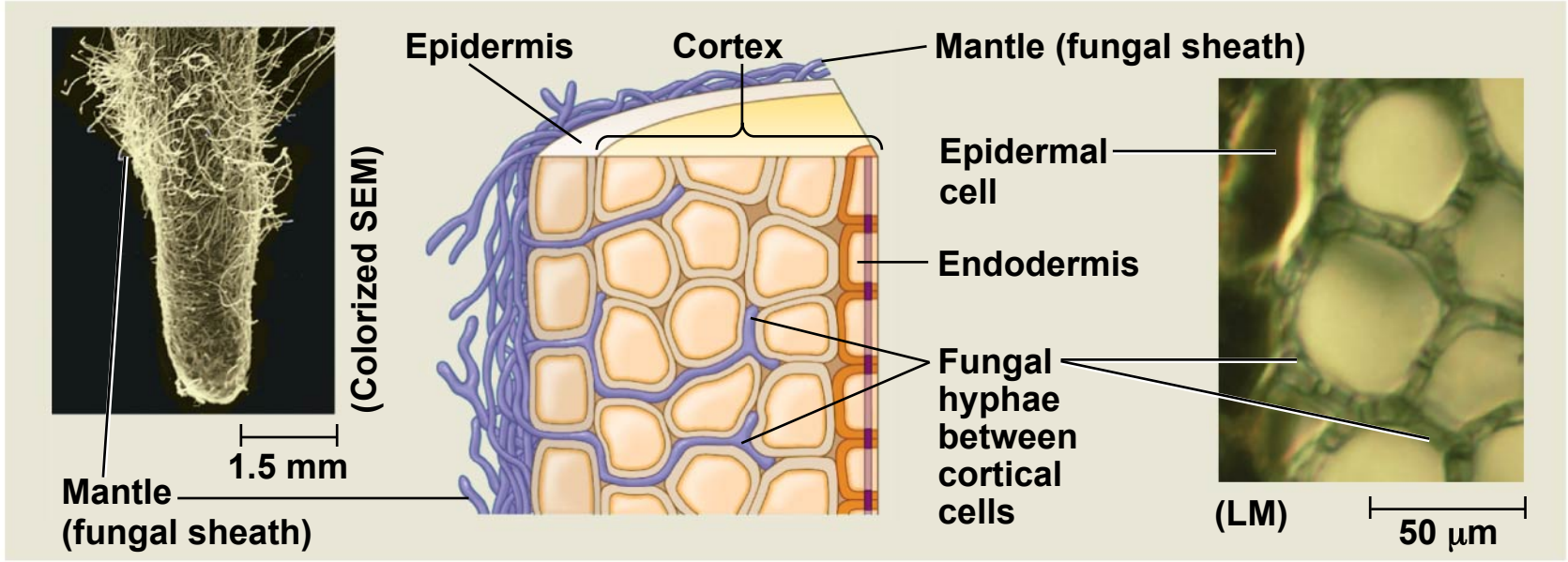
Element	Form Primarily Absorbed by Plants	% Mass in Dry Tissue	Major Functions
Macronutrients			
Carbon	CO_2	45%	Major component of plant's organic compounds
Oxygen	CO_2	45%	Major component of plant's organic compounds
Hydrogen	H_2O	6%	Major component of plant's organic compounds
Nitrogen	NO_3^-, NH_4^+	1.5%	Component of nucleic acids, proteins, hormones, chlorophyll, coenzymes
Potassium	K^+	1.0%	Major solute functioning in water balance; operation of stomata
Calcium	Ca^{2+}	0.5%	Important in formation and stability of cell walls and in maintenance of membrane structure and permeability; activates some enzymes; regulates many responses of cells to stimuli
Magnesium	Mg^{2+}	0.2%	Component of chlorophyll; cofactor and activator of many enzymes
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	0.2%	Component of nucleic acids, phospholipids, ATP, several coenzymes
Sulfur	SO_4^{2-}	0.1%	Component of proteins, coenzymes
Micronutrients			
Chlorine	Cl^-	0.01%	Required for water-splitting step of photosynthesis; functions in water balance
Iron	Fe^{3+}, Fe^{2+}	0.01%	Component of cytochromes; cofactor of some enzymes; needed for photosynthesis
Manganese	Mn^{2+}	0.005%	Active in formation of amino acids; activates some enzymes; required for water-splitting step of photosynthesis
Boron	$H_2BO_3^-$	0.002%	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall function
Zinc	Zn^{2+}	0.002%	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
Copper	Cu^+, Cu^{2+}	0.001%	Component of many redox and lignin-biosynthetic enzymes
Nickel	Ni^{2+}	0.001%	Cofactor for an enzyme functioning in nitrogen metabolism
Molybdenum	MoO_4^{2-}	0.0001%	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction



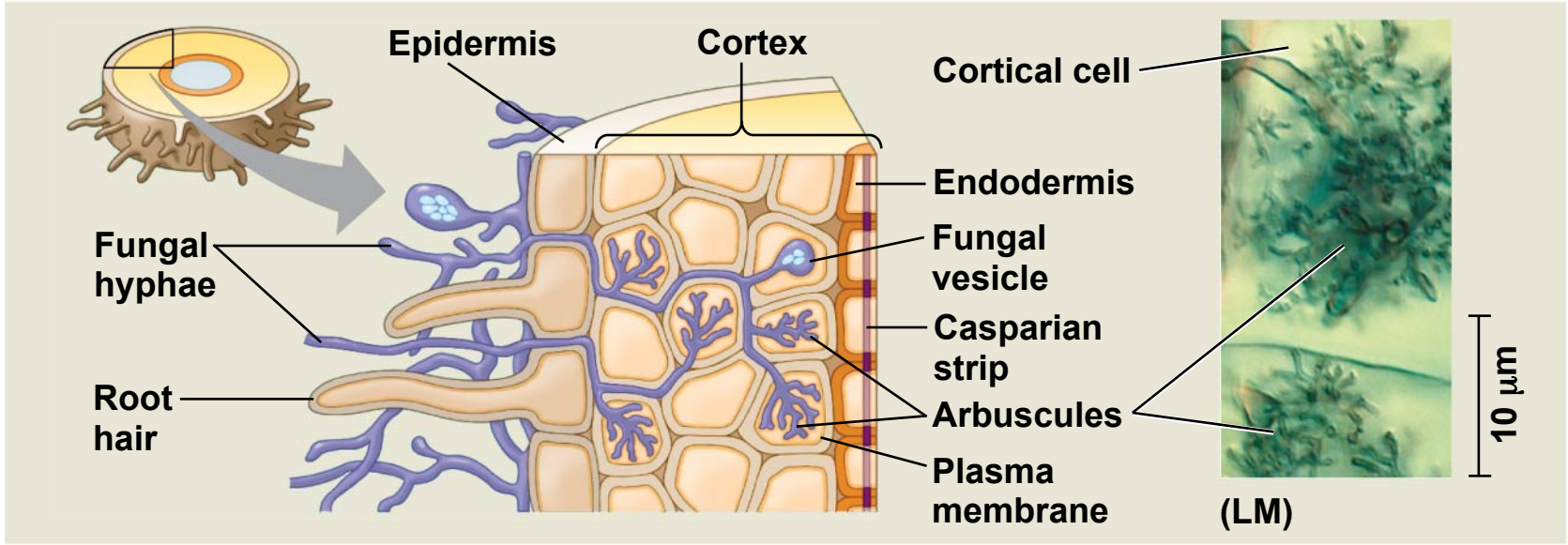






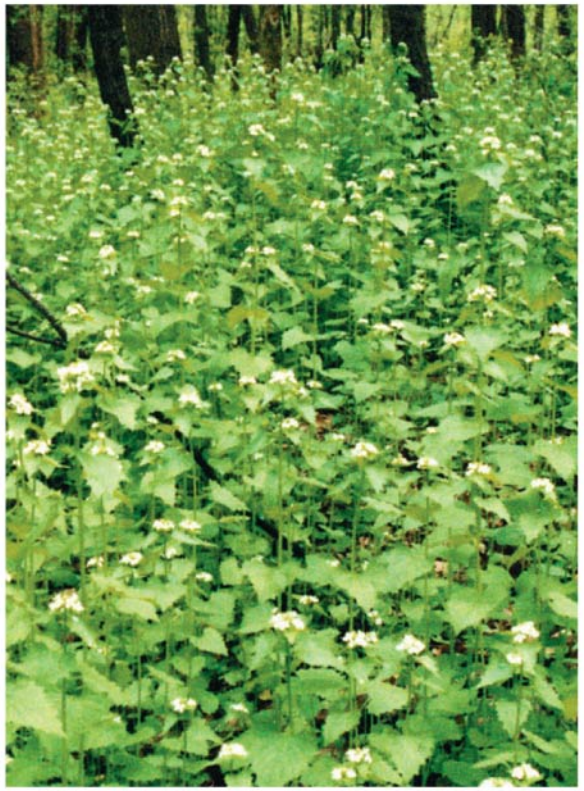


(a) Ectomycorrhizae

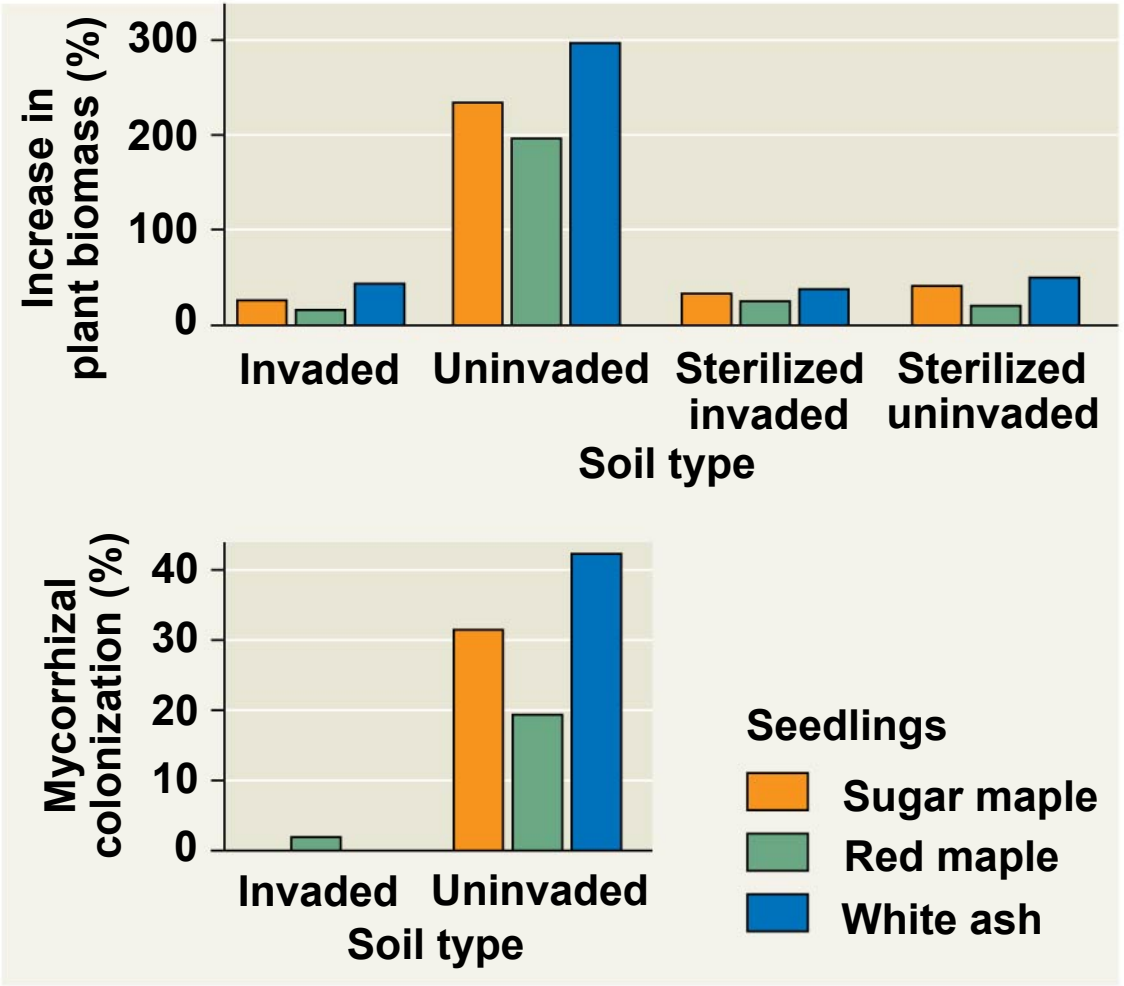


(b) Arbuscular mycorrhizae (endomycorrhizae)

Experiment



Results



Staghorn fern, an epiphyte

Parasitic plants

Mistletoe, a photosynthetic parasite

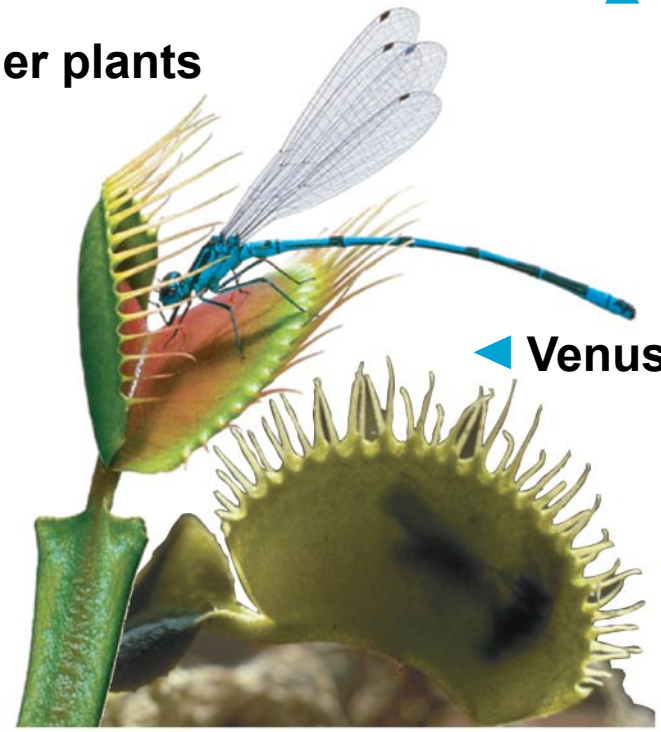
Dodder, a nonphoto-synthetic parasite (orange)

Indian pipe, a nonphoto-synthetic parasite of mycorrhizae

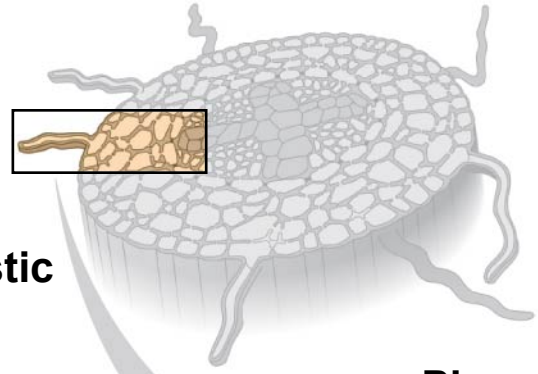
Carnivorous plants

◀ Pitcher plants

▲ Sundew



◀ Venus flytraps

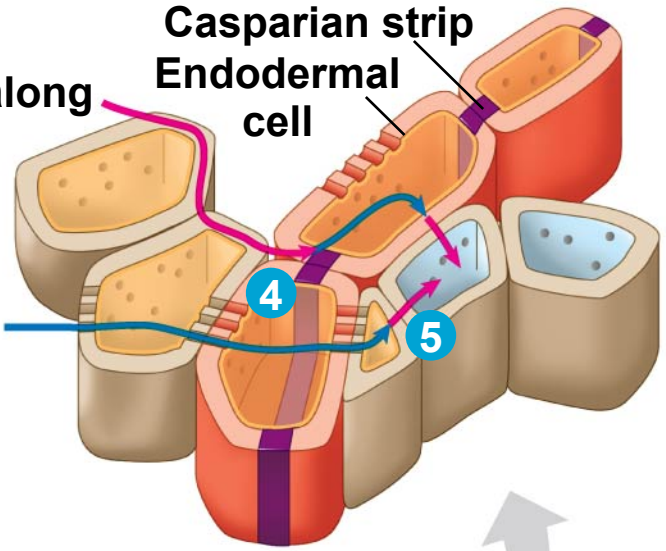


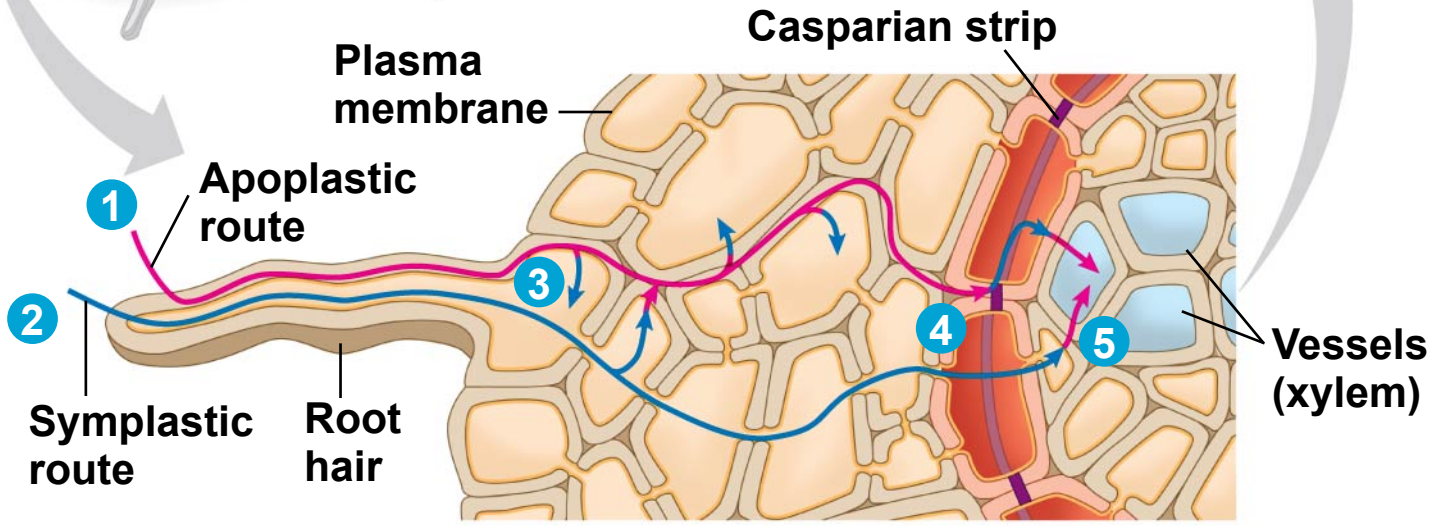
1 Apoplastic route

2 Symplastic route

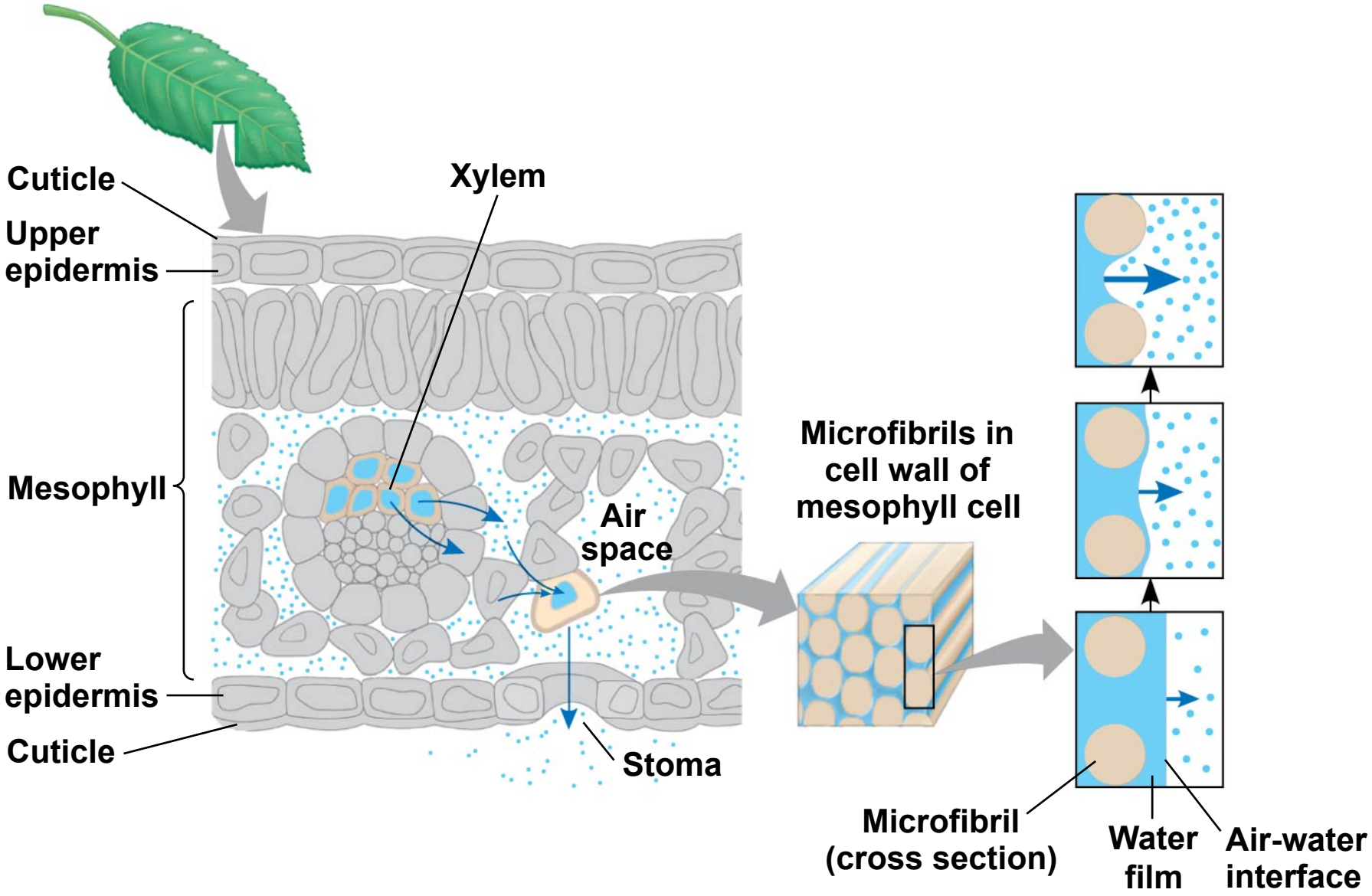
3 Transmembrane route

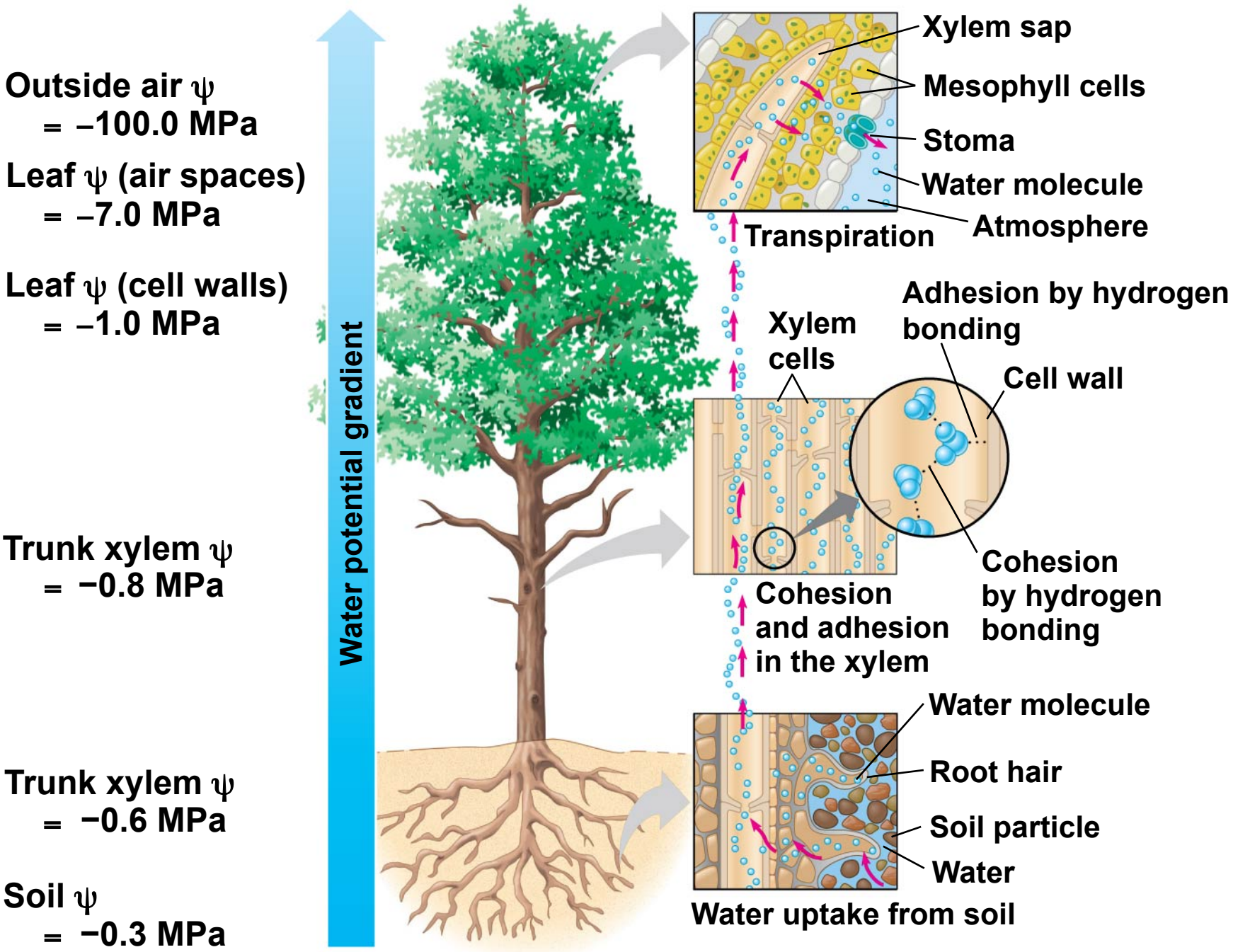
4 The endodermis: controlled entry to the vascular cylinder (stele)

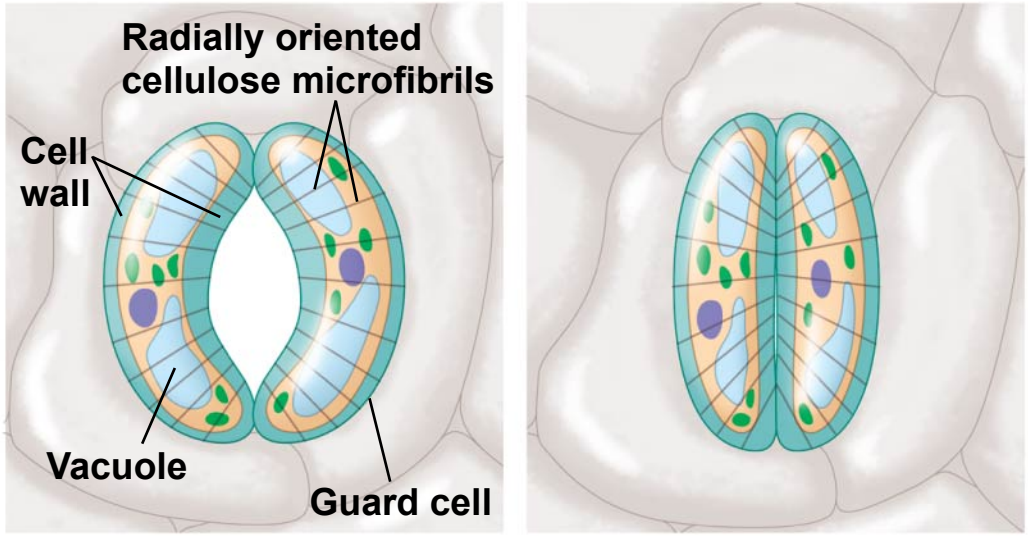




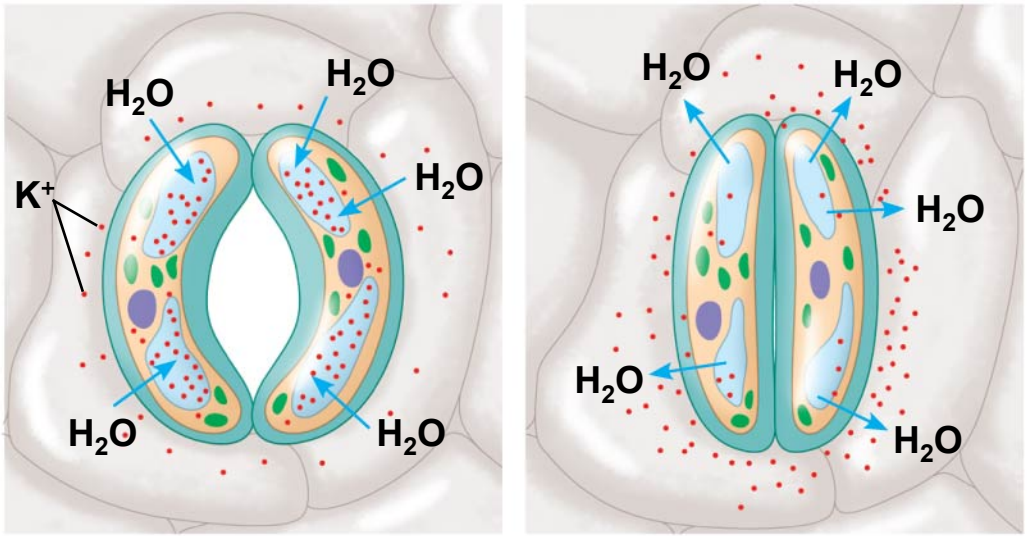
5 Transport in the xylem







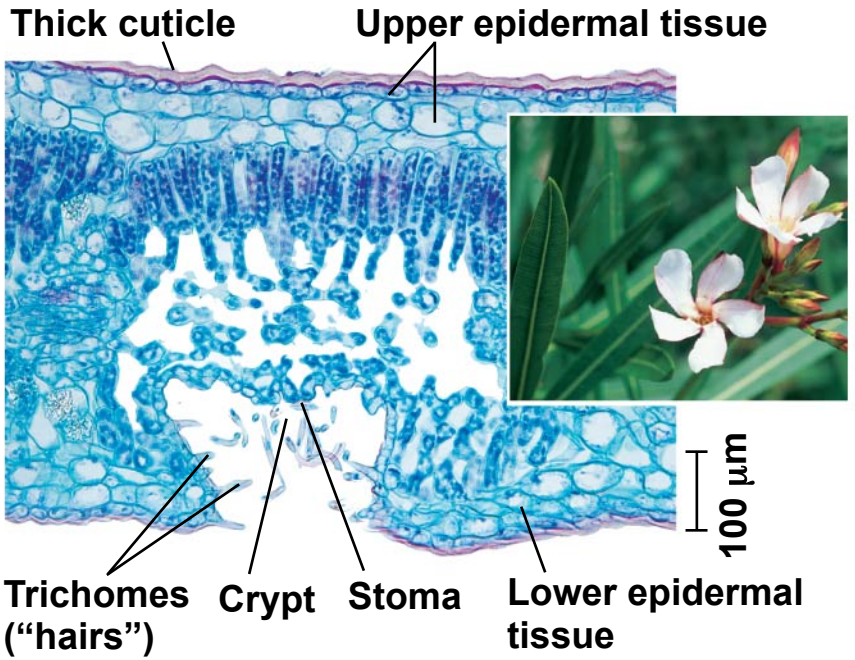
(a) Changes in guard cell shape and stomatal opening and closing (surface view)



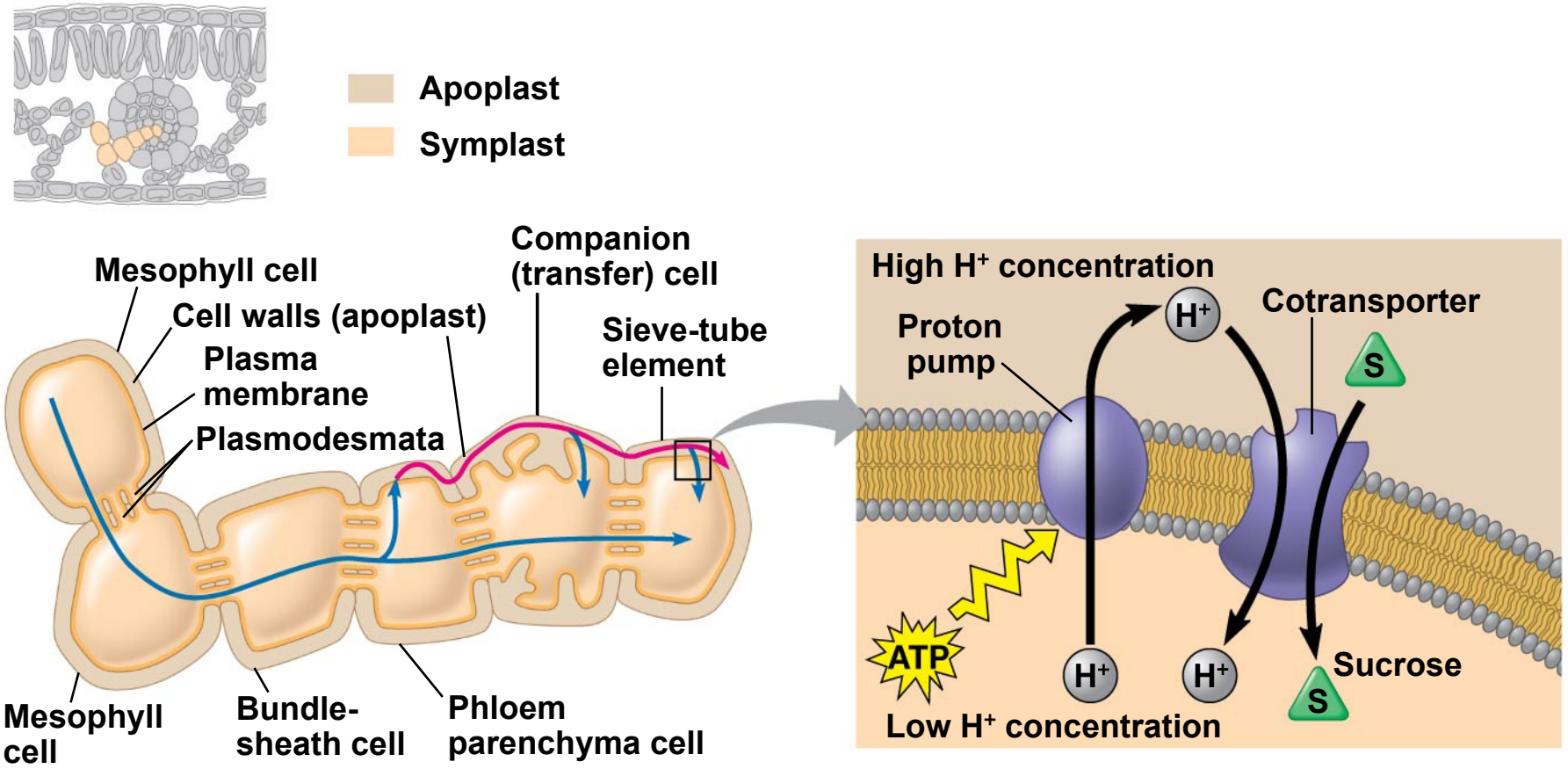
(b) Role of potassium ions (K^+) in stomatal opening and closing

► Ocotillo (*Fouquieria splendens*)

▼ Oleander (*Nerium oleander*)



► Old man cactus (*Cephalocereus senilis*)



(a) Sucrose manufactured in mesophyll cells can travel via the symplast (blue arrows) to sieve-tube elements.

(b) A chemiosmotic mechanism is responsible for the active transport of sucrose.