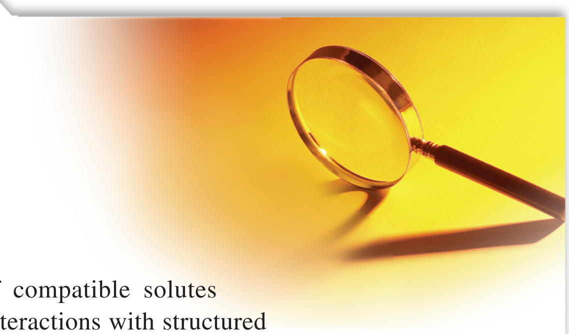
BIOCHEMISTRY IN PERSPECTIVE

Water, Abiotic Stress, and Compatible Solutes



If water is so important for sustaining life, how can certain organisms survive catastrophic dehydration conditions? Abiotic stresses are environmental conditions that can potentially threaten the survival of living organisms. Examples include drought, temperature extremes, and excessive salinity. The adverse effects of these conditions are caused by alterations in the amounts and/or physical properties of water in affected organisms. Desiccation due to drought and high temperature results when environmental vapor pressure is low. Cell dehydration occurs in low temperatures as water moves down its concentration gradient and ice crystals form outside cells. (Since ice is a poor solvent, extracellular fluid becomes hyperosmotic.) The formation of intracellular ice crystals causes membrane rupture and disruption of osmotic gradients. Dehydration also occurs when cells are exposed to high salt concentrations.

Organisms vary widely in their capacity to adapt to environmental stresses. For those that can adapt, protection is afforded by stress-triggered signal transduction mechanisms that result in the accumulation of specialized molecules. Many organisms are protected by *compatible solutes* and/or the synthesis of protective proteins. Compatible solutes are a diverse group of water-soluble organic molecules that are generally considered to be nontoxic even at high concentrations. Commonly observed examples include sugars (e.g., trehalose and sucrose), alcohols (e.g., sorbitol, see p. 235), amino acids such as proline, or amino acid derivatives such as taurine (see p. 455). The protective effects of compatible solutes include interactions with structured water that prevent protein and membrane destabilization, as well as freezing-point depression, and osmoprotection. Some organisms also produce protective proteins. Antifreeze proteins (p. 252) are used by some cold-water fish and freeze-resistant plants and insects. Plants such as cotton and rice use LEA (late embryogenesis abundant) proteins to protect seeds from dehydration damage during the desiccation phase of seed development.

The stress adaptations of some organisms are astonishing. Anhydrobiotes, which can tolerate an almost complete loss of water, are such a group. Nematodes, brine shrimp, yeast, and other such organisms survive desiccation by producing certain compatible solutes that can function as water substitutes. The most common of these is trehalose, which is believed to stabilize cells by transforming cytoplasm into a glassy matrix. (All glasses are viscous liquids that have the mechanical properties of a solid.) As desiccation proceeds, newly synthesized trehalose molecules replace water throughout the cell. In the absence of water, the hydroxyl groups of trehalose form hydrogen bonds with the ionic and polar groups of cellular macromolecules. All metabolic and potentially damaging processes are considerably slowed because all the cell's molecules become immobilized within a sugar glass.

SUMMARY: Organisms that can adapt to severe water loss utilize specialized protective molecules, such as compatible solutes, that replace water by forming hydrogen bonds with proteins and other macromolecules and membranes.