water-soluble, single-membrane-bounded inclusions of various shapes and dimensions outside of the chloroplast (Fig. 6.2). Paramylon consists solely of β-1,3 linked glucose residues, and the molecule is about as large as that of chrysolaminarin.

3 **Fructosans:** *Acetabularia* (Chlorophyta) has an inulin-like storage product consisting of a series of 1,2 linked fructose units terminated by a glucose end group (Fig. 1.28).

Low-molecular-weight compounds

1 **Sugars:** Chlorophyta and Euglenophyta form sucrose as a reserve product; trehalose is found in the Cyanophyta and at low levels in the Rhodophyta.
2 **Glycosides:** The glycerol glycosides, floridoside (Fig. 1.28) and isofloridoside, are widely distributed in the Rhodophyta.
3 **Polyols:** Mannitol (Figs. 1.28, 4.4) occurs in Rhodophyta and Phaeophyceae. It is also present in lower green algae, where it replaces sucrose as a photosynthetic product. Free glycerol occurs widely in the algae and is an important photosynthetic product in several zooxanthellae (endosymbiotic algae in animals) and in some marine Volvocales, especially *Dunaliella*.

Contractile vacuoles

The ability of algal cells to adjust to changes in the salinity of the medium is an important aspect of the physiology of these cells. In cells with walls, this osmoregulation is accomplished with the aid of turgor pressure, whereas in naked cells it is accomplished by means of contractile vacuoles and/or regulation of the solutes present in the cells. In the latter case, cells increase the internal concentration of osmotically active molecules and ions when the concentration of dissolved solutes increases in the external medium. Likewise, the internal concentration of such molecules decreases when the concentration of dissolved salts in the external medium decreases.

Most algal flagellates have two contractile vacuoles in the anterior end of a cell (Fig. 1.1). A contractile vacuole will fill with an aqueous solution (**diastole**) and then expel the solution outside of the cell and contract (**systole**). The contractile vacuole rhythmically repeats this procedure. If there are two contractile vacuoles, they usually fill and empty alternately. Contractile vacuoles occur more frequently in freshwater than marine algae, a phenomenon that gives credence to the theory that the contractile vacuoles maintain a water balance in the cells. The algal cells in freshwater have a higher concentration of dissolved substances in their protoplasm than in the surrounding medium so that there is a net increase of water in the cells. The contractile vacuoles act to expel this excess water. An alternate theory on the function of the contractile vacuoles is that they remove waste products from the cells. The Dinophyta have a structure similar to a contractile vacuole, called a pusule, which may have a similar function but is more complex.

The contractile vacuoles of the Cryptophyta are characteristic of the algae (Fig. 1.29). In the Cryptophyta, the contractile vacuole occurs in a fixed anterior position next to the flagellar depression (Patterson and Hausmann, 1981). At the beginning of the filling phase (**diastole**), there is no distinct contractile vacuole, only a region filled with small (*ca.* 0.5-μm diameter) contributory vacuoles. These vacuoles fuse to form a large irregular vacuole which subsequently rounds up. The contributory vacuoles destined to form the next contractile vacuole now appear around the rounded contractile vacuole. The contractile vacuole fuses with the plasma membrane of the flagellar pocket and discharges its contents outside the cell. The area of the plasma membrane that fuses with the contractile vacuole does not have a periplast (specialized plates within the plasma membrane). This area is, instead, bounded by microtubules. The membrane of the contractile vacuole is recovered by the cell as small vesicles with an electron-dense coat, and the membrane components are reutilized by the cell. These vesicles plus the contractile vacuole occur in the **spongiome** or area around the contractile vacuole. In freshwater algae the contractile vacuole cycle lasts for 4 to 16 seconds, whereas in marine species the cycle can last for up to 40 seconds.

Algal flagellates use a combination of contractile vacuoles and osmoregulation to control the water content of their cells. In the chrysophyte