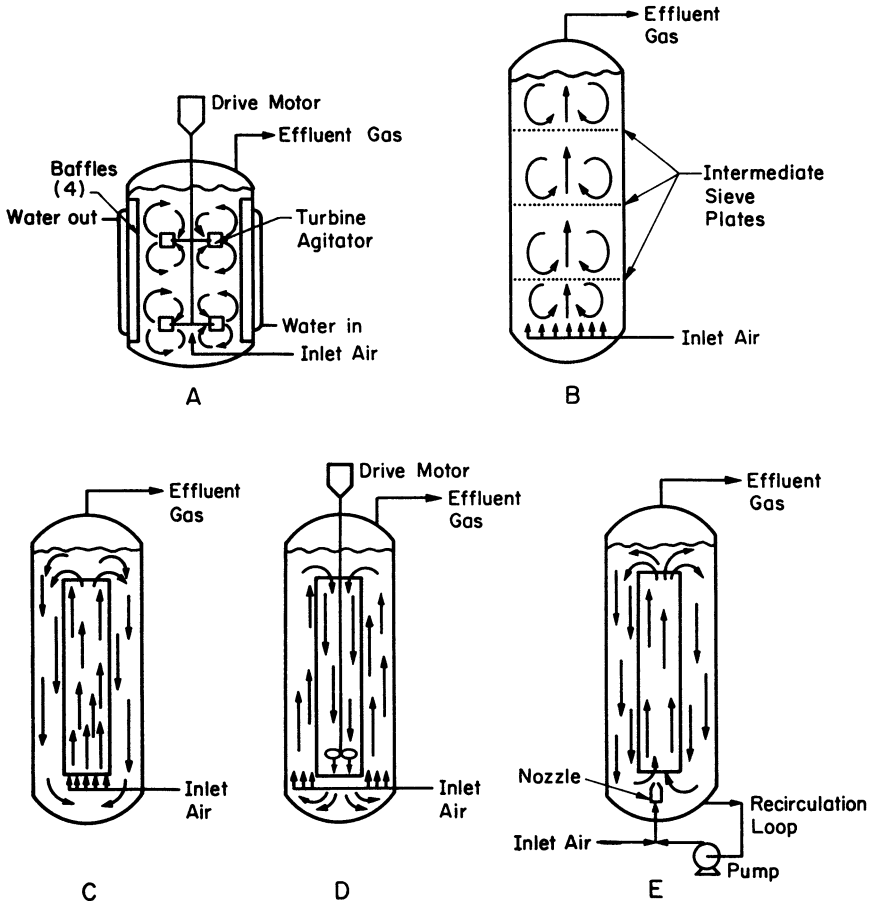

Figure 10.1. Bioreactor types. (a) Stirred-tank reactor, (b) bubble-column reactor, (c) airlift loop reactor with central draft tube, (d) propeller loop reactor, and (e) jet loop reactor. Arrows indicate fluid circulation patterns. (With permission, from D. N. Bull, R. W. Thoma, and T. E. Stinnett, *Adv. Biotechnol. Processes I*, 1, 1985, and Alan R. Liss, Inc., New York.)

with multiple-impeller systems. Although a wide variety of impeller designs have been proposed, the predominant choices are disc- and turbine-type impellers, while marine and paddle impellers are of particular interest for cellular systems with high levels of shear sensitivity.

The Rushton impeller (Fig. 10.3) is a disc with typically 6 to 8 blades designed to pump fluid in a radial direction. This was the predominant impeller design up to the mid-1980s and is commonly found on industrial and laboratory fermenters. The axial flow hydrofoil impellers (Fig. 10.3) have become increasingly popular. These axial flow systems can pump liquid either down or up. They have been shown to give superior performance (compared to Rushton radial flow impellers) with respect to lower energy demands for the same level of oxygen transfer. Further, they show reduced maximum shear rates,