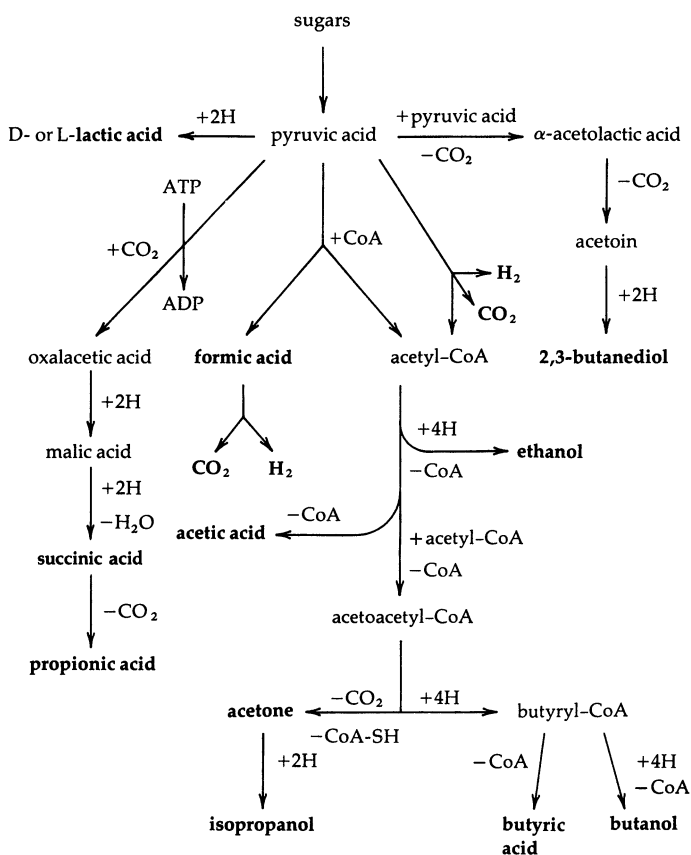


commercial products from bioprocesses. Other partially oxidized by-products from fermentation are or have been commercially important [acetone–butanol fermentation, propionic acid, acetic acid (for vinegar), 2,3-butanediol, isopropanol, and glycerol].

Figure 5.10 summarizes common routes to some of these fermentation end products. Pyruvate is a key metabolite in these pathways. In most cases, pyruvate is formed through glycolysis. However, alternative pathways to form pyruvate exist. The most common of these is the *Entner–Doudoroff pathway* (see Fig. 5.11). This pathway is important in the fermentation of glucose by the bacterium *Zymomonas*. The use of *Zymomonas* to convert glucose into ethanol is of potential commercial interest, because the use of the Entner–Doudoroff pathway produces only 1 mol of ATP per mole of glucose. This low energy yield forces more glucose into ethanol and less into cell mass than for yeast, which uses glycolysis to produce pyruvate, which yields 2 mol ATP per mole of glucose.

No one organism makes all the products indicated in Fig. 5.10. Different organisms will contain different combinations of pathways. Thus, it is important to screen a wide va-



**Figure 5.10.** Derivations of some major end products of the bacterial fermentations of sugars from pyruvic acid. The end products are shown in boldface type. (With permission, from R. Y. Stanier and others, *The Microbial World*, 5th ed., Pearson Education, Upper Saddle River, NJ, 1986, p. 95.)