nucleases hydrolyzing RNA and DNA. Nucleases with different specificities hydrolyze different bonds in nucleic acid structure, producing ribose/deoxyribose, phosphoric acid, and purines/pyrimidines. Sugar molecules are metabolized by glycolysis and the TCA cycle, producing CO_2 and H_2O under aerobic conditions. Phosphoric acids are used in ATP, phospholipid, and nucleic acid synthesis.

Purines/pyrimidines are degraded into urea and acetic acid and then to ammonia and CO_2. For example, the hydrolysis of adenine and uracil can be represented as follows:

$$\text{adenine} \longrightarrow CO_2 + NH_3 + \text{acetic acid} + \text{urea} \longrightarrow 5\ NH_3 + 5\ CO_2 \quad (5.12)$$

$$\text{uracil} \longrightarrow \text{alanine} + NH_3 + CO_2 \longrightarrow 2\ NH_3 + 4\ CO_2 \quad (5.13)$$

5.7. NITROGEN FIXATION

Certain microrganisms fix atmospheric nitrogen to form ammonia under reductive or microaerophilic conditions. Organisms capable of fixing nitrogen under aerobic conditions include *Azotobacter, Azotomonas, Azotococcus,* and *Biejerinckia*. Nitrogen fixation is catalyzed by the enzyme "nitrogenase," which is inhibited by oxygen. Typically these aerobic organisms sequester nitrogenase in compartments that are protected from oxygen.

$$N_2 + 6\ H^+ + 6\ e \longrightarrow 2\ NH_3 \quad (5.14)$$

Azotobacter species present in soil provide ammonium for plants by fixing atmospheric nitrogen, and some form associations with plant roots. Some facultative anaerobes such as *Bacillus, Klebsiella, Rhodopseudomonas,* and *Rhodospirillum* fix nitrogen under strict anaerobic conditions as well as strict anaerobes such as *Clostridia* can also fix nitrogen under anaerobic conditions. Certain cyanobacteria, such as *Anabaena sp.,* fix nitrogen under aerobic conditions. The lichens are *associations* of cyanobacteria and fungi. *Cyanobacteria* provide nitrogen to fungi by fixing atmospheric nitrogen. *Rhizobium* species are heterotrophic organisms growing in the roots of leguminous plants. *Rhizobium* fix atmospheric nitrogen under low oxygen pressure and provide ammonium to plants. *Rhizobium* and *Azospirillum* are widely used for agricultural purposes and are bioprocess products.

5.8. METABOLISM OF HYDROCARBONS

The metabolism of aliphatic hydrocarbons is important in some bioprocesses and often critical in applications such as bioremediation. Such metabolism requires oxygen, and only few organisms (e.g., *Pseudomonas*, *Mycobacteria*, certain yeasts and molds) can metabolize hydrocarbons. The low solubility of hydrocarbons in water is a barrier to rapid metabolism.

The first step in metabolism of aliphatic hydrocarbons is oxygenation by oxygenases. Hydrocarbon molecules are converted to an alcohol by incorporation of oxygen into the end of the carbon skeleton. The alcohol molecule is further oxidized to aldehyde