Hydrogen atoms released in biological oxidation–reduction reactions are carried by nucleotide derivatives, especially by nicotinamide adenine dinucleotide ($NAD^+$) and nicotinamide adenine dinucleotide phosphate ($NADP^+$) (see Fig. 5.3). The oxidation–reduction reaction described is readily reversible. NADH can donate electrons to certain compounds and accept from others, depending on the oxidation–reduction potential of the compounds. NADH has two major functions in biological systems:

1. *Reducing power:* NADH and NADPH supply hydrogen in biosynthetic reactions, such as $CO_2$ fixation by autotrophic organisms.

$$CO_2 + 4\,H \longrightarrow CH_2O + H_2O \tag{5.3}$$

2. *ATP formation in respiratory metabolism:* The electrons (or H atoms) carried by NADH are transferred to oxygen via a series of intermediate compounds (respiratory chain). The energy released from this electron transport results in the information of up to three ATP molecules.[†] ATP can be formed from the reducing power in NADH in the absence of oxygen if an alternative electron acceptor is available (e.g., $NO_3^-$).

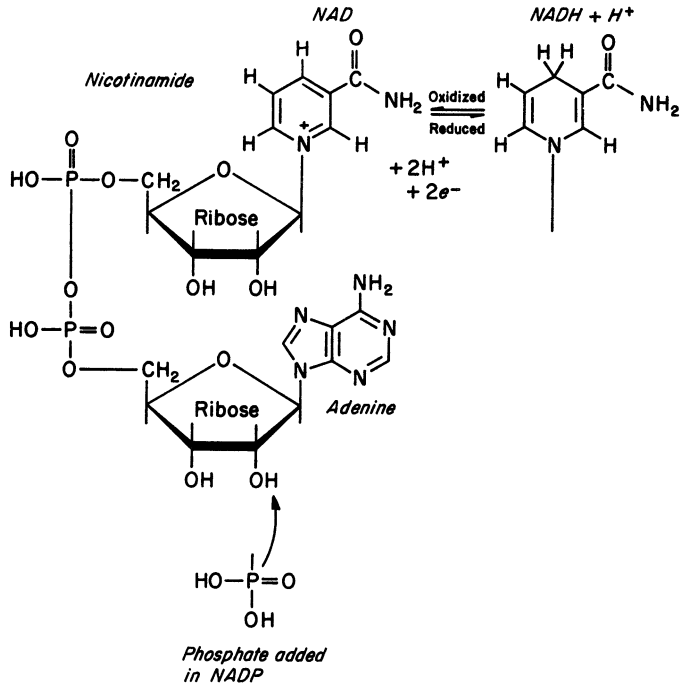


**Figure 5.3.** Structure of the oxidation–reduction coenzyme nicotinamide adenine dinucleotide (NAD). In NADP, a phosphate group is present, as indicated. Both NAD and NADP undergo oxidation–reduction as shown. (With permission, from T. D. Brock, D. W. Smith, and M. T. Madigan, *Biology of Microorganisms*, 4th ed., Pearson Education, Upper Saddle River, NJ, 1984, p. 104.)

[†]Some research suggests that the theoretical limit may be 2.5 ATP for each NADH, rather than 3.