The student should note that for the shortening of an acyl CoA by two carbon atoms, acetyl CoA, the net $\Delta G'$ is -8.45 kcal per mole. Therefore thermodynamically the cleavage of a C_2 unit (acetyl CoA) is highly favored. The β-oxidative system is found in all organisms. However, in bacteria grown in the absence of fatty acids, the β-oxidative system is practically absent but is readily induced by the presence of fatty acids in the growth medium. The bacterial β-oxidation system is completely soluble and hence is not membrane-bound. Curiously, in germinating seeds possessing a high lipid content, the β-oxidation system is exclusively located in microbodies called glyoxysomes (see Chapter 9), but in seeds with a low lipid content, the enzymes are associated with mitochondria. The important function of the glyoxysomes is considered in more detail in Chapter 9.

The universality of the β-oxidative system implies the prime importance of this sequence as a means of degrading fatty acids.

13.6.2 Energetics of β-Oxidation. In the total combustion of palmitic acid, considerable energy is released:

$$C_{16}H_{32}O_2 + 23\ O_2 \longrightarrow 16\ CO_2 + 16\ H_2O$$
$$\Delta G' = -2340\ \text{kcal/mole}$$

Palmitic acid

$$C_{15}H_{31}COOH + 8\ CoASH + ATP + 7\ FAD + 7\ NAD^+ + 7\ H_2O \longrightarrow$$
$$8\ \underset{\textit{Acetyl CoA}}{CH_3CO \sim SCoA} + AMP + PPi + 7\ FADH_2 + 7\ NADH + H^+$$

$$8\ CH_3CO \sim SCoA + 16\ O_2 \xrightarrow{\text{TCA cycle}} 16\ CO_2 + 16\ H_2O + 8\ CoASH$$

How much of this potential energy is actually made available to the cell? When palmitic acid is degraded enzymically, one ATP is required for the primary activation, and eight energy-rich acetyl–CoA thioesters are formed. Each time the helical cycle (Figure 13-5) is traversed, 1 mole of $FAD–H_2$ and 1 mole of NADH are formed; they may be reoxidized by the electron-transport chain. Since, in the final turn of the helix, 2 moles of acetyl–CoA are produced, the helical scheme must be traversed only 7 times to degrade palmitic acid completely. In this process 7 moles each of reduced flavin and pyridine nucleotide are formed. The sequence can be divided into two steps:

Step 1:

$$\text{Palmitic acid} \longrightarrow 8\ \text{Acetyl–S–CoA} + 14\ \text{Electron pairs}$$

7 electron pairs via Flavin system at 2 $\sim$ P/one electron pair = 14 $\sim$ P
7 electron pairs via NAD^+ system at 3 $\sim$ P/one electron pair = 21 $\sim$ P
Total = 35 $\sim$ P
Net = 35 $\sim$ P − 1 $\sim$ P
= 34 $\sim$ P

Step 2:

$$8\ \text{Acetyl–CoA} + 16\ O_2 \xrightarrow{\text{TCA cycle}} 16\ CO_2 + 16\ H_2O + 8\ \text{CoA–SH}$$

If we assume that for each oxygen atom consumed 3 $\sim$ P are formed during oxidative phosphorylation, then

$$32 \times 3 = 96 \sim P$$

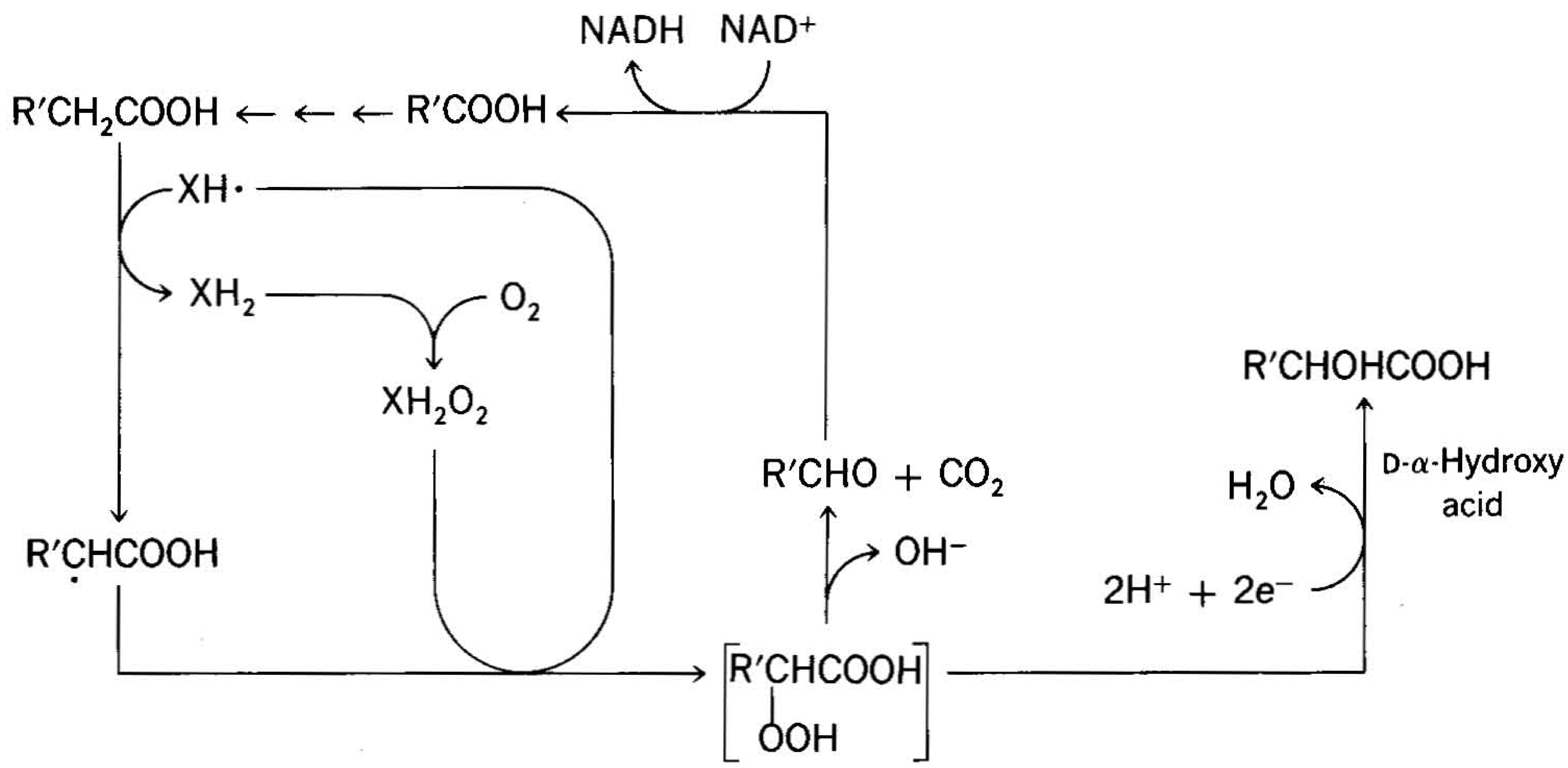
Thus, step 1 ($34 \sim P$) and step 2 ($96 \sim P$) = $130 \sim P$; and

$$\frac{130 \times 8000 \times 100}{2{,}340{,}000} = 48\%$$

In the complete oxidation of palmitic acid to CO_2 and H_2O, 48% of the available energy can theoretically be conserved in a form (ATP) that is utilized by the cell for work. The remaining energy is lost, probably as heat. It hence becomes clear why, as a food, fat is an effective source of available energy. In this calculation we neglect the combustion of glycerol, the other component of a triacylglycerol.

While the β-oxidative system undoubtedly is the primary mechanism for degrading fatty acids, the student should be aware of a number of other systems that attack the hydrocarbon chain oxidatively. A brief survey of these mechanisms and possible functions will now be given.

13.6.3 α-Oxidation. This system, first observed in seed and leaf tissues of plants, is also found in brain and liver cells. The mechanism for this reaction in plants is depicted as:



D-α-Hydroperoxyl fatty acid

Note that in this system only free fatty acids serve as substrates and molecular oxygen is indirectly involved. The products may be either a D-α-hydroxyl fatty acid or a fatty acid containing one less carbon atom. This mechanism explains the occurence of α-hydroxy fatty acids and of odd numbered fatty acids. The latter may, in nature, also be synthesized *de novo* from propionate. The α-oxidation system has been shown to play a key role in the capacity of mammalian tissues to oxidize phytanic acid, the oxidation product of phytol, to CO_2 and water. Normally, phytanic acid is rarely found in serum lipids because of the ability of normal tissue to degrade the acid very rapidly. It has now been observed that patients with Refsum's disease, a rare