Fat Absorption

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THE STUDY of absorption includes the reactions following digestion in the intestinal lumen and prior to appearance of the products in the blood or lymph. Since, in general, these reactions have not been well studied, the actual processes occurring during absorption are largely a matter of conjecture.

In the case of triglyceride absorption, some knowledge can be gleaned from the state of the triglycerides in the intestinal lumen and in the lymph or blood. Bollman, Cain and Grindlay[1] and others, using their technic for thoracic duct cannulation, demonstrated that most of the products of fat digestion appear in the lymph. Chaikoff and his collaborators,[2,3,4] however, found that in whatever form fed, the longer chain fatty acids appeared almost exclusively in the lymph, while those with less than 12 carbon atoms appeared to a greater extent in the portal vein.[5] The transition point appeared to be in the fatty acids with chain lengths of about 8–12 carbons, having a partition coefficient between water and fat of about unity (Table I).

Since most of the fatty acids of the diet are of the 16 to 18-carbon chain variety, it can be expected that the products of fat digestion will appear largely in the lymph. The exact form in which triglycerides are absorbed is in some doubt because of the possibility that following hydrolysis to the monoglyceride state, some resynthesis occurs.[6] At present it appears that glycerides of all sorts and fatty acids are probably absorbed as finely emulsified droplets of less than 0.5 μ in diameter.[7]

The reactions occurring in the intestinal cells lead to the formation of triglycerides and small amounts of phospholipids. The mechanisms of such reactions have been elucidated, largely by the work of Kennedy and his collaborators, and it seems logical to suppose that the same mechanisms occur in the intestinal cells as in cells of other types. It should be mentioned here that the starting materials in this case are probably the absorbed mono- or diglycerides and that the proportion of these two partial glycerides absorbed may determine the proportion of triglyceride and phospholipid formed in the intestinal cells. Triglyceride could be formed from diglyceride by reaction with acyl coenzyme A while monoglyceride could give rise to glycerophospholipid by reaction with ATP to form acyl glycerophosphate followed by reaction with unsaturated acyl coenzyme A to get the unsaturated acid in the α position. The resulting phosphatidic acid could then be transformed into phospholipids by the usual reactions. Triglycerides, which are also absorbed, could pass unchanged into the lymph.

The exact mechanism by which absorption occurs is not known. Frazer's hypothesis that small canals of about 0.5 μ diameter in the intestinal cells furnished the passage way[8] has been largely disproven.[9] At present it appears that finely divided lipid particles, emulsified with the aid of bile and hydrolysis products, may pass through the cell wall fairly readily in either direction, as will be seen later in discussions of fat transport.

TABLE I
Fatty Acids Transported by Thoracic Duct

Chain length	Per cent
18	95
16	97
14	70
12	35
10	10

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Little is known about the absorption of phospholipids. Although Artom and Swanson[10] demonstrated that some portion of the molecule could be absorbed unhydrolyzed, Bloom and co-workers[11] found that only about 17 per cent appears in the lymph as phospholipid. The remainder is apparently hydrolyzed to such an extent that the products are indistinguishable from those of triglyceride hydrolysis. It can be assumed that once both fatty acid residues are removed, the remainder of the glycerophosphatides will be absorbed into the portal system.

Since there is good evidence that the sterol esters are largely hydrolyzed in the small intestine[12] only the absorption of the sterols themselves need be considered.

Cholesterol absorption is strongly influenced by the presence of other substances in the small intestine. It has been reported many times that cholesterol fed in the absence of fat is not too well absorbed. Different types of fat, however, appear to have quite different actions. The greatest absorption, as measured by fecal cholesterol, occurs with concomitant feeding of oleic acid,[13] followed by the more unsaturated fats, as corn oil. Saturated triglycerides actually decreased cholesterol absorption. It has also been reported, however, that even with a cholesterol-free diet, the serum cholesterol levels of rats are higher with the more highly unsaturated fats.[14] Thus, fat is thought to have several effects on cholesterol absorption—stimulation of bile flow,[14] provision of fatty acid (especially polyunsaturated) for esterification, and some additional unknown influence. Mineral oil, as would be expected, decreases cholesterol absorption.[15]

Bile salts have been shown to be obligatory for cholesterol absorption, since when bile was prevented from entering the intestinal tract of rats, no cholesterol could be recovered from their lymph although palmitic acid could be absorbed at a reduced rate.[16]

The absorption of other sterols and their effect on cholesterol absorption is a complex and interesting subject. Although Schoenheimer[17] originally reported that plant sterols are not absorbed, evidence has recently accumulated indicating that this is not strictly true. Thus Gould[18] has shown that limited absorption of β-sitosterol can occur amounting to about 10 per cent of cholesterol absorption in rats and human beings. Other investigators have also shown that sterols other than cholesterol are absorbed to a greater or lesser degree.[19–23] It is generally agreed, however, that the saturated sterols and plant sterols are not nearly so well absorbed as is cholesterol. Moreover, inclusion of these sterols in the diet with cholesterol appears to result in a decreased absorption of the latter.[21,24] However, several difficulties are immediately apparent in attempts to control cholesterol absorption and serum cholesterol levels in human patients by this means. First, when substantial amounts of these sterols are fed, they are absorbed to some extent and contribute to serum sterol and to production of atheroma.[19,22] Second, very large amounts of these sterols must be included in the diet before a noticeable effect on absorption is seen. Finally, it has not been proven that regulation of dietary cholesterol or cholesterol absorption has any effect on serum cholesterol in man.

The mechanism of cholesterol absorption has not been thoroughly elucidated. Most of the absorbed cholesterol appears in the lymph, about 70 per cent in the esterified form.[25] Although the poorly absorbed sterols are also not esterified in the intestinal cells,[23] it does not appear that esterification is obligatory in sterol absorption, since even when cholesterol absorption is partially blocked, the proportion esterified remains the same.[26]

The absorption of hydrocarbons such as mineral oil (only if highly emulsified) and the carotenes has been studied to some extent and has again been found to depend on simultaneous absorption of fat, the presence of bile and other factors important in the absorption of fat and cholesterol. However, a complete discussion of this subject is beyond the scope of this review.

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