Knowledge of the conversion of dietary carbohydrate into fat is part of the history of nutrition and this knowledge is widely applied in food production from animals. There is no doubt that man converts dietary carbohydrate into depot fat but until recently it was thought that the type of carbohydrate consumed was immaterial as far as the lipid response of the body was concerned. Evidence is accumulating, however, to suggest that this view may be wrong, and, furthermore, implications have been laid at the door of certain carbohydrates (R. E. Hodges and M. A. Ohlson, Fed. Proc. 22, 209 (1963)), suggesting that in man they may have a sinister influence in the etiology of some of the diseases of civilization.

Early accounts stated that starch and sucrose have different effects on water retention by the body and that lactose has effects in experimental animals not seen with comparable consumption of other carbohydrates (D. L. Duncan, Nutrition Abst. Rev. 25, 309 (1955); W. W. Wells and S. C. Anderson, J. Nutrition 68, 541 (1959)). Experimental work in animals has shown that starch is associated with a lower serum cholesterol than is sucrose (O. W. Portman, E. Y. Lawry, and D. Bruno, Proc. Soc. Exp. Biol. Med. 91, 321 (1956); D. Kritchevsky, R. R. Kolman, R. M. Guttmacher, and M. Forbes, Arch. Biochem. Biophys. 85, 444 (1959)). In guinea pigs it has been found that gallstones form more easily when sucrose is included in the diet instead of starch (H. Dam, Sixth International Congress of Nutrition, p. 9. Edinburgh, 1963).

In rabbits the amount of lipid in the liver is greater when sucrose is given than when starch is fed, with liquid glucose occupying an intermediate place. The fatty acid composition of the liver lipid and of the depot fat in rabbits again depends on the type as well as the amount of dietary carbohydrate consumed (I. Macdonald, J. Physiol. 162, 334 (1962)). There is thus ample evidence that under experimental conditions the lipid metabolism of the animal is affected by the type of carbohydrate fed.

Protein metabolism as judged by changes in serum proteins seems to be uninfluenced by the type of dietary carbohydrate, though a high carbohydrate intake, even with an adequate protein intake, does cause characteristic changes to occur in the serum protein pattern both in animals and in man.

Perhaps of wider interest is the influence of dietary carbohydrate on the lipid metabolism of man. In reviewing this, two aspects must be considered: firstly the amount of carbohydrate consumed and secondly the type of dietary carbohydrate. These aspects assume clinical importance when one considers that in some parts of the world the diet of large numbers of people contains mainly carbohydrate and that other groups of people exist, whose carbohydrate consumption, although not high, consists of increasing quantities of refined carbohydrate as sucrose. Can it be that some of the malnutrition of the former is aggravated by the relative excess of carbohydrate and that some of the diseases of the latter are aggravated by the increasing consumption of refined carbohydrates (A. M. Cohen, Am. Heart J. 65, 291 (1963))?*

In consideration of the amount of carbohydrate consumed the most important aspect is obviously in relation to calories and the contribution it makes to the calorie balance. Excess calories, whether from carbohydrate or other sources, will be deposited as fat.
In one situation, however, there exists a relative, though probably not an absolute, excess of dietary carbohydrate, and this is kwashiorkor. In this condition the relative excess of dietary carbohydrate and the inadequate protein intake contribute to the characteristic picture of a very fatty liver, and the presence of depot fat in reasonable quantities, in a child who is obviously malnourished. The excess lipid in the liver can only come from the dietary carbohydrate, as the diet leading to this condition is low in fat as well as protein.

The serum protein level is very low in kwashiorkor, largely because of a marked fall in the albumin concentration. This fall in albumin is due to the low protein intake, but it has been shown in adults with an adequate protein intake that the serum albumin falls when large quantities of carbohydrate, starch or sucrose, are consumed. It could be, therefore, that with a low protein intake the fall in serum albumin is exaggerated by a relative excess of dietary carbohydrate.

Thus, there are some facts to suggest that the amount of dietary carbohydrate may have effects which go beyond the simple concept of storage or removal of calories, though whether these effects are due to the carbohydrates per se or to their caloric content is not, at the moment, clear. It seems likely that the serum albumin lowering effect is carbohydrate, and not caloric, induced.

The second, and perhaps even less understood aspect of the role of dietary carbohydrates, is the varying metabolic response to different types of carbohydrates. The work in this sphere, in its infancy, has shown that lipid metabolism can be considerably influenced by the type of dietary carbohydrate consumed. There has been recent speculation as to the part played by the refined carbohydrates in the etiology of such diseases as atherosclerosis, ischemic heart disease, and diabetes mellitus, since the consumption of sucrose seems to increase with the prosperity of a community.

In one study it was found that the incidence of ischemic heart disease and diabetes was higher in Yemenite Jews in Israel than it had been when these people were living in Yemen (Cohen, loc. cit.). Investigation into the dietary history of these people showed little alteration in the amount or type of fat consumed; in fact the major dietary difference between the domicile in Yemen and in Israel was an increase in the sucrose intake in Israel. These findings to some extent implicate sucrose, yet it should be pointed out that with this increased sucrose intake went an increase in weight. In another study volunteers on the diet consumed in Yemen showed a decrease in serum cholesterol level.

A study has been made of the different effects of corn starch and of sucrose on lipid metabolism in which healthy male volunteers consumed, for 25 days, a low fat, adequate protein diet together with 500 g of starch or sucrose daily. Serum lipid and depot fat studies made weekly revealed marked differences between the starch and sucrose regimens. The starch diet caused the serum cholesterol and phospholipids to fall significantly. These changes were not seen during the sucrose diet, but the serum triglycerides were significantly raised. The total serum lipid level fell during the starch diet and increased with the sucrose diet.

Differences were also found between the fatty acid compositions of the serum during the two carbohydrate regimens. The high carbohydrate intake also produced change in the composition of the depot fat. Again the differences were not of the same order for the starch as for the sucrose diet. A significant increase in serum transaminases from the starch but not on the sucrose diet, together with no change in the serum creatine phosphokinase, hinted that the high starch intake may cause liver damage (Maedon and Braithwaite, Clin. Sci. 27, 23 (1964)).

Thus there seems little doubt that in certain circumstances the lipid metabolism reacts in a different manner to dietary starch.
to dietary sucrose and the serum lipid reaction to sucrose is in the direction towards that found in ischemic heart disease. Though efforts are being made to discover the mechanism of these different responses to various dietary carbohydrates no hints as to the site of differentiation have been forthcoming. Possibilities to be considered are that the microflora of the gut, which are known to be disturbed by various carbohydrates, may in some way influence the lipid metabolism. Can it be that the fructose present in sucrose but absent in the breakdown of starch is responsible? These, and other possibilities, are hypotheses which need to be put to the test.

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DETERMINATION OF CIRCULATING LIPIDS BY VARIOUS METHODS

The various blood lipids and their components have been studied in a clinical investigation using a number of methods. In the coronary patients included in this group a relationship between the triglyceride and the presence of the disease was apparent.

Studies relating various serum lipids to atherosclerosis are numerous. Attempts to connect one or another of the circulating lipids or lipoproteins with the presence of coronary disease in groups of individuals have produced considerable confusion. This confusion in part may be the result of failure to appreciate the very close relationship between the various lipid components of the blood.

The selection of the serum cholesterol as a blood component best suited for correlating with the incidence of atherosclerosis in coronary disease has been the subject of many articles (see Nutrition Reviews 16, 68 (1958); 17, 10 (1959); 18, 21 (1960)). In addition, other workers have stressed triglycerides as a more useful measure of abnormal lipid metabolism, and groups studying the problem suggest that a relationship between this lipid fraction and the incidence of ischemic heart disease does exist (M. J. Albrink and R. S. Neuwirth, J. Clin. Invest. 39, 441 (1960); Albrink, J. W. Meigs, and E. B. Man, Am. J. Med. 31, 4 (1961)).

However, the triglycerides or cholesterol, either free or as esters, should not be considered as totally separated from lipoproteins. Changes in the lipoprotein fraction bring about measurable changes in these other components. As R. E. Olson and J. W. Vester (Physiol. Rev. 40, 677 (1960)) have pointed out, the beta lipoprotein molecules serve as a transport system for triglycerides and contain significant amounts of cholesterol. Increases in these low density lipoproteins bring about increases in the cholesterol or triglyceride concentration in the blood.

Changes can also occur in the alpha lipoproteins, and these will influence, to some extent, the concentration of lipids in the serum.

Specific changes in various fractions of the beta lipoproteins cause changes in the serum triglyceride or cholesterol content. The less dense beta lipoproteins are rich in triglycerides, while the more dense contain larger amounts of cholesterol esters. Unfortunately, the tremendous number of reports on blood lipids have served to confuse physicians.

In an attempt more clearly to establish the relationships of the various circulating lipids, E. V. Feldman (Am. J. Cardiol. 13, 632 (1964)) has reported on circulating lipids in 247 subjects: healthy men and women, and patients suffering from a large number of diseases. Included in these latter subjects were those with hyper- or hypothyroidism, essential hyperlipidemia, gout,