series which we have followed beyond the lying-in period have shown it is not difficult for between 70 and 80 % to continue to breast feed for 6 months and longer.

EXPLANATION OF PLATE

Pl. 1. Breast shield to be worn during pregnancy for correcting defective nipples.

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Composition of Human Milk and Factors Affecting It

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The composition of breast milk is of interest primarily because it is the recipe of the most satisfactory food for a baby. It is also to some extent a measure of the mother's nutrition and an indication of the mother's food requirements. Its variation may help to reveal how milk is formed.

The secretion of the mammary gland varies during the course of lactation, starting during pregnancy and the first days after delivery as colostrum, changing to milk which again alters in composition with the passage of days and weeks. Eventually the secretion of full milk is succeeded by a secretion resembling colostrum. This has been called regression milk. After the first acceleration on the 3rd or 4th day the rate of secretion of milk is almost constant from hour to hour and day to day with a slow increase of about 1–1½ oz. on the day's total in the course of a week to meet the baby's growing needs. The removal of milk, partly brought about by the mechanism of the baby's mouth, is aided by an expulsive mechanism within the breast. This, the draught reflex, may be impaired by emotion. The degree of emptying depends not only on the activity of the baby but on the vigour and timing of the draught and there is no clear end-point. The milk that is not removed at one feed is believed to be added to the subsequent secretion. As the fat globules of milk tend to remain in the gland, the fore-milk contains little fat, the hind-milk much more and the milk obtained at a feed or at a sampling may vary much in fat content.

Nitrogenous substances. The protein of breast secretion normally decreases rapidly in the first days and then more slowly throughout lactation; the first viscous material may contain as much as 10 % or more protein; towards the end of the 1st week the percentage has usually fallen to less than 2, and after months of lactation may be less than 1. The content of protein is affected very little, if at all, by diet, as is shown by the agreement between the figures relating to peacetime United States (Bell, 1928) and wartime Britain (Kon & Mawson, 1950). In the very first days the fall is more rapid where the output is greater. In the cow, the protein content of colostrum is reduced when milking is begun before calving, and a similar effect of antenatal expression may explain the low values found in some estimations of protein in colostrum after delivery. The protein content of the first secretion removed may be above that of the serum, and similarly the globulin concentration, judged by the titre of the antibodies, may be above that of the serum. Despite extensive investigation there is no evidence that these antibodies are absorbed unaltered by healthy babies (Boorman, Dodd & Gunther, unpublished).

The protein of mature milk contains 0·7–0·8 g lactalbumin and lactoglobulin in 100 ml., rather more than cow's milk (0·5 g/100 ml.), but the casein (0·4–0·5 g/100 ml.) is much less than that of cow's milk (3·0 g/100 ml.) (Nelson, 1950). The non-protein nitrogen is slightly less in human than in cow's milk, but the free amino-acids are about the same in amounts and proportions in both.

Much emphasis has been laid in the past on the amino-acid composition of the protein of breast milk, probably because it was thought that protein is absorbed from the gut only after being broken down to amino-acids. Williamson (1944) and Block & Bolling (1950) have shown that the proportions of the acids in human and in cow's milk are almost alike although, as is well known, the total protein content is higher in cow's milk. Even the subdivisions, casein, lactalbumin and lactoglobulin in both kinds of milk all resemble one another in their amino-acid proportions. There is, however, some doubt about the sulphur-containing amino-acids. It has been maintained, on the basis of some estimations of cystine, that there is more of it in human than in cow's milk, and this has been advanced as an advantage of human over cow's milk. The reported values for the cystine content of human milk differ, ranging from 1·8 to 4·0 g/16 g nitrogen. The methionine ranges from 2·2 to 2·5 g/16 g nitrogen, and the corresponding values for cystine and methionine in cow's milk are, respectively, 0·8 and 3·4 g/16 g nitrogen (Block & Bolling, 1950). Cystine is said to be difficult to estimate, and the recent analyses imply that the similarities between human and cow's milk extend to include the proportions of sulphur-containing amino-acids. Block & Bolling (1950) conclude that 'the often expressed opinion that breast milk is superior for the *protein* nutrition of the human infant must be based either on differences in the non-protein amino-acid fraction or on teleological reasoning'. The evidence of a large survey (Douglas, 1950) shows, on the other hand, that in England the breast-fed child has specific advantages. When allowance had even been made for birth weight and body-weight, the breast-fed baby was shown to walk on average some 10 days earlier than the bottle-fed and to have received an immunity to measles. It is tempting to conclude from the protection against measles that breast milk gives babies a greater store of γ-globulin; possibly the globulins of milk are broken down by digestion sufficiently to lose their antibody pattern and yet retain some linkages that assist the baby to reconstruct human γ-globulin. A similar suggestion has been put forward by Mellander (1945) who has shown that the products of tryptic digestion of human and cow's milk differ; the human milk retains a phospho-peptone of glutamic acid, isoleucine and serine containing organically bound phosphorus. Mellander suggests that this complex, if absorbed intact, might explain in part the breast-fed child's freedom from rickets. If the structure of a protein leaves its mark on the nitrogenous substances absorbed from the gut, the amino-acid composition of milk proteins represents only part of the proteins' nutritive value, and the debate on the relative merits of breast and cow's milk enters a new phase.

Fats. Since the breast cannot be emptied in the first days of lactation, the fat content of early milk is hard to determine. At the end of the 1st week the percentage in milk collected over 24 h is about 3, and it tends to increase slightly in the next days. The fat content during the rest of lactation appears to run no consistent course (Nims, Macy, Hunscher & Brown, 1932), and the factors controlling it are little understood. The percentage of fat in 24 h samples is little affected by the fat in the diet in normal circumstances, but there is some evidence that starvation or a diet containing very large amounts of fat may cause a big reduction in the output of milk and an increase in the percentage of fat (Ružičić, 1934). Moderate supplements of fat given to women on a low-fat diet had no significant effect on the percentage of fat in the day's secretion of milk in one investigation, although there was some slight rise in fat content some 6–12 h after the fat had been eaten (Gunther & Stanier, 1951). There is a diurnal variation in the fat content for which there is at present no explanation (Planchu & Rendu, 1911; Gunther & Stanier, 1949); it is unaffected by the mother's intake of calories or fat. The variation may be as much as from 2 to 4 % fat, the highest content occurring about noon. This variation is so great that the mechanism controlling it must be the principal one determining the content of fat in milk. Although the percentage of fat is apparently independent of the fat intake, some of the fat is believed to be derived from ingested fat (Bendix, 1898); it is also believed that ingested fat may alter the action of enzymes concerned with fat synthesis (Hilditch, 1947).

The composition of the fats of breast milk is remarkable for the absence, or very low content, of the short-chain saturated fatty acids. The C_{18} acids constitute about 57 % of the total, about one-half being unsaturated (Hilditch & Meara, 1944; Brown & Orians, 1946). The proportion of unsaturated acids of the diethenoid series and the amounts of C_{20-22} acids are characteristic of breast-milk fat; in this it resembles human depot fat and is more like vegetable-oil fat than butter.

Sugar. Lactose, the sugar characteristic of breast activity, is present in slightly lower amounts in colostrum (about 5 %) than in milk (about 6·5 %), the value remaining almost constant after the 10th day. Lactose is not better than sucrose or glucose in the artificial feeding of infants and we are still without an explanation of why this particular sugar is present in milk. One can only speculate that the formation of lactose is in some way involved in the processes of secretion of the fat and protein.

Vitamins. The very numerous estimations of vitamins made by Kon & Mawson (1950) have provided a fairly clear picture of the variations in their secretion. The amounts of vitamin A and of carotenoids are directly related to the fat content of milk, although there is also an inverse relation, the concentration being less in the fat where the fat content of the milk is high. Kon, Mawson & Thompson (1944) have shown that the carotenoid content of cow's milk is related to the size of the fat globules, and it appears that the carotenoids are associated with the membrane of the globules in both human and cow's milk. According to Kon & Mawson (1950), the vitamin A content is high at the beginning of lactation (100 i.u./g fat or more on the 3rd and 4th days). It falls rapidly to mean values of 46 i.u. in the 3rd week and 30 i.u. at the 20th, after which it may rise slightly. The carotenoids also decrease during the first 3 weeks, falling from about 20 μg/g fat at the outset to 4·3 in the 3rd week, but from the 4th week the value, around 3·6 μg/g fat, shows no definite trend. By means of a mathematical formula Kon & Mawson (1950) were able to correct the values of vitamin A of different samples to make them comparable despite the stage of lactation. In this way vitamin A and carotene content are found to increase with the age of the mother; this age effect is unrelated to parity and is so far unexplained. Consumption of the vitamin by the mother increases the content in the milk fat, but only for a few days. Carotenoids when eaten have little effect on the carotenoids and none on the vitamin A in the milk fat. β-Carotene constitutes only about one-fifth of the total carotenoids in milk and supplies some 3–4 % of the child's vitamin A intake. Kon & Mawson found that among the carotenoids, lycopene was more abundant than β-carotene, but it is not known to have any physiological significance.

Vitamin D is present in very small quantities in breast milk. Kon & Mawson (1950) found only 0·13–0·41 i.u./g fat, rather less than that reported by Drummond, Gray and Richardson (1939) and roughly the same as the amounts found by American workers (Harris & Bunker, 1939; Polskin, Kramer & Sobel, 1945). Assuming a fat content of 4 %, the daily intake of a 12 lb. baby taking 1 l. milk would be about 16 units. Supplements of vitamin D do not appear to alter the content of calcium or of phosphorus in breast milk (Macy, Hunscher, McCosh & Nims, 1930), or the content of the vitamin except in massive doses, but the mother needs adequate vitamin D for her own safeguard. When mother and child are unclothed the baby may receive direct irradiation and possibly he gets significant amounts of irradiated fats from the mother's areola and his own hand.

The vitamin B_1 in breast milk increases slowly in the first days of lactation, from 3 μg/110 ml. on the 3rd day to 9 on the 10th (Kon & Mawson, 1950). After the 5th week there is no consistent trend. The content responds slowly to the amount of the vitamin eaten but does not rise above 20–35 μg/100 ml. The riboflavin content, on the other hand, is altered in a matter of hours by the mother's food and has no maximum level. It increases during the first days of lactation, and Kon & Mawson (1950) found that riboflavin was present on average in a concentration of 26 μg/100 ml. in the milk of English women.

The concentration of vitamin C is probably higher in colostrum than in milk; otherwise it varies with the mother's intake, changing markedly in a matter of days. Commonly there are about 4 mg ascorbic acid in 100 ml. milk. The concentration cannot be raised above about 10 mg/100 ml., a value reached when the mother is taking 300 mg daily. The concentration falls slowly when the mother's intake is reduced and there is then a danger of the mother's being depleted, especially when she is feeding twins. The concentration in milk is above that of the serum; this difference may be due partly to the booster effect which the mammary gland is able to produce, just as free amino-acids are in higher concentration in milk than in serum. One may conjecture, however, that the effect may in part be produced by the ascorbic acid of colostrum bodies that may be seen in milk, for it is known that white corpuscles hold a much higher concentration than blood plasma and continue to do so when the plasma is depleted.

Minerals. Estimations or qualitative analyses have been made of many elements in breast milk. Of principal interest are calcium, phosphorus, sodium, potassium, chlorine and iron. The calcium and phosphorus of milk vary greatly in concentration in different women, although the level of secretion by one woman is relatively constant. Many workers have reported a range of calcium content between 19 and 40 mg/100 ml. This is in contrast to the constancy of plasma calcium, which ranges at most from 8·2 to 11·6 mg/100 ml. The phosphorus content of milk ranges between 10 and 20 mg/100 ml. (Kon & Mawson, 1950) giving a Ca : P ratio of 2·2 after the first weeks.

There is less sodium and potassium in human than in cow's milk, the range being from 11 to 19 mg/100 ml. for sodium and from 48 to 65 mg/100 ml. for potassium, approximately one-third of the concentration in cow's milk (Macy, 1949). The iron ranges from 0·09 to 0·2 mg/100 ml. (McCance & Widdowson, 1951) and the copper from 0·5 to 0·6 μg/ml. (see Kon & Mawson, 1950), the values in both instances being greater than for cow's milk. The many estimations of chloride made by Miller and his co-workers (Kermack & Miller, 1951) suggest that chlorides increase in concentration when the breast is lax; early in the day the concentration is less than later, and it is also less when the milk flow is abundant than when it is scanty. The range is from 30 to 150 mg/100 ml.

SUMMARY

The composition of breast milk depends primarily on the phase of lactation. Whereas the contents of protein, fat and sugar are virtually uninfluenced by diet, the concentration of the vitamins depends partly on what the mother eats.

Recent analyses of the amino-acids suggest that they are not present in significantly different proportions in human and cow's milk and that the reasons for the advantages of breast milk for a baby must be sought elsewhere.

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Artificial Infant Feeding

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It can be accepted as axiomatic at the present time that the basic food substance for the artificial feeding of healthy infants is cow's milk. In the first place, therefore, attention must be directed towards a comparison between human breast milk and cow's milk. Ideally, the substitute food should approximate to nature's food as closely and as exactly as possible. Towards the end of the last century this seemed to be a simple and relatively easy procedure and was the basis of what was called the percentage method of infant feeding. The protein, fat and carbohydrate content of the two milks was known and a little juggling with cow's milk, sugar and water provided the satisfactory modification. The advances of science and chemical analysis soon revealed differences, particularly in the proteins and fats of the two milks, and then the different amino-acid composition and the varying amounts and proportions of the many mineral substances began to render the problem increasingly difficult and complex. To-day, a perusal of current paediatric text-books and handbooks on the artificial feeding of healthy infants and a cursory glance at the spate of pamphlets, booklets and advertisements of the manufacturers of infant feeds leaves one disconcerted, overawed and aghast. Not unnaturally, the impression is being created, particularly in the minds of the uninitiated, that the whole subject is confused and chaotic. Indeed, the position might almost appear to be that, before any intelligent advice can be given on substitute or bottle-feeding, technical knowledge of the chemical composition of the innumerable constituents of breast and cow's milk must be profound, precise and exact. Surely this pseudo-scientific approach has been overdone, and has not the time come when we should return to a more simple, commonsense and realistic attitude?

It is submitted that fundamental principles seem to have been buried beneath a welter of secondary, minute or perhaps even unessential details. To-day in the streets of our cities and towns we can see countless happy, healthy and contented babies reared on artificial feeds by parents with a very wide range of intelligence, and it is difficult to feel that all have followed current professional advice, assuming that this has been sought. Let me reiterate that I am only concerned with the feeding of healthy infants; the problems in connexion with sick or premature infants will be dealt with by other speakers.