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A CRITICAL DISCUSSION OF SUGAR IN ITS RELATION TO INFANT FEEDING.

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Up to a few years ago the sugar in milk modifications attracted comparatively little attention. It was known that it was a necessary part of the diet, that it furnished calories for the fuel needs of the baby's body, and that, under certain conditions it might cause disturbances of digestion; but in comparison with the other food elements, protein and fat, it was looked upon as relatively harmless. At that time the protein was considered the harmful element, and most of the efforts in modifying milk were concerned with making it easy of digestion. It is natural that this should have been so, inasmuch as perhaps the most striking difference between human and cows' milk is the relatively large amount of protein in the latter. In the last few years the pendulum has swung the other way, largely owing to the influence of Finkelstein and his pupils, who go so far as to teach that sugar is the cause of practically all the digestive and nutritional disturbances of infancy, that fat may cause trouble secondarily, and that protein practically never does any harm. It is unquestionably true that most of Finkelstein's conceptions have been of

great value, and that his work has made an epoch in the science of infant feeding. It is also true that many experienced pediatricians, in the Eastern part of this country, particularly, do not entirely accept his ideas, nor attach so much importance to sugar as a cause of nutritional disorders as he does. It is the purpose of this paper to consider sugar in its relation to the physiology, pathology, and therapeutics of infant feeding, and to attempt to offer a conception of sugar which may, perhaps, help to harmonize certain of the differences between the various methods of infant feeding.

I. PHYSIOLOGY.

Necessity of Sugar. Sugar is necessary to life. A baby may be fed for a long time on a fat-free diet, provided the caloric value of its food and its nitrogen requirement is maintained by adding suitable amounts of the other food elements; but if he is put upon a sugar-free diet, and kept on it for any length of time, he dies from the development of acidosis. Acidosis is produced in this manner in infants much more readily than it is in adults. Therefore, at the outset, let us say that a baby must have in its diet a reasonable amount of sugar (or carbohydrate in some form) if it is to thrive. The exact minimum of sugar necessary for babies of different weights and ages is not known. Sugar is also of great importance as a nitrogen sparer, and seems to have more power in this regard than does an isodynamic amount of fat. When carbohydrate (sugar) is given in the diet it is possible to establish nitrogen equilibrium at a much lower level than when protein alone or when protein and fat alone are ingested. Thomas¹ showed that a diet containing the large amount of 18.4 gm. nitrogen did not suffice to keep the adult body in nitrogen equilibrium when no carbohydrate was given. The reason for this is that the protein food is drawn upon so heavily for fuel in the body that not enough is left for the needs of growth and repair. This holds even more for infants than it does for adults, as the nitrogen needs of infants per kilogram of body weight are considerably greater than those of older persons. The importance of sugar for fuel is shown in breast milk, of which 48.7% of the calories are furnished by the sugar.

Relation of Sugar to Weight and to the Retention of Nitrogen and Salts. The feeding of

large amounts of sugar may cause a rapid increase in weight, provided the sugar is well digested. This is partly due to water retention, and high sugar feeding is particularly likely to bring this about because the deposition of glycogen in the body cells, which may be considerable after high sugar feeding, is possible only when accompanied by a retention of two or three times the amount of water. The considerable salt retention with high sugar feeding may also account for a part of the water retention. Thus we see many babies who have been fed on a one-sided high sugar diet, who appear fat, and are perhaps above normal weight. The apparent robust health and weight in these cases is deceptive, because it does not consist of healthy fat and muscle, but of water which has been retained in the body cells. Condensed milk babies are likely to be of this type.

Sugar is not without a good deal of influence upon the retention of the other food elements; up to a certain point, the more sugar that is fed, the greater is the retention of nitrogen and salts, particularly of nitrogen. If the tolerance for sugar is overstepped, and fermentation results, the retention of nitrogen, and especially of salts, may be greatly diminished.

Digestion and Absorption. The sugars used in infant feeding—lactose, sucrose, and dextrin-maltose preparations,—are polysaccharides of complex formula, and must undergo splitting in the intestinal tract before being absorbed. It is probable that sugar is normally acted upon very little in the stomach. It is broken down in the small intestine by the intestinal ferments into two molecules of a monosaccharide, or simpler sugar, and is absorbed as such. The absorption of sugar in health is excellent, and most investigators have been unable to find sugar in the stools of normal babies. Those who have found it have found only very small amounts. In cases where the baby is not absorbing sugar well, it is broken down into acid end-products, by bacterial action, and thus, even in sugar indigestion, it is not usual to find sugar in the stools.

Normal Action of Sugar in the Intestine. The stools of a breast-fed baby are normally quite strongly acid in reaction, due to the large amount of sugar and fat in breast milk. There is always normally a certain amount of sugar fermentation going on in the intestine of a breast-fed baby, caused by the normal

bifidus and acidophilus acid-producing flora, which does not appear without sugar. Normally, in the breast-fed baby's intestine there is fermentation going on; normally, in the bottle-fed baby's intestine, putrefaction is likely to exist, on account of the relatively large amount of protein in most cows' milk modifications. This calls forth a different sort of intestinal flora from that of the breast-fed baby, and we do not see the pure acidophilus and bifidus flora that we do in the former. In the bottle-fed baby there is hardly any normal standard of stool acidity or of intestinal flora to go by, as the intestinal processes depend so much upon variations in the food supply, but stools of the same acidity as those normal for the breast baby would be quite abnormal for the bottle baby, and would be due to pathological, and not physiological, fermentative processes. The reason that a breast baby can stand such high acidity of the stools is that the fermentation is going on in the large intestine, and the peristalsis and digestive functions of the small intestine are, therefore, not interfered with. In the bottle-fed baby with very acid stools, or in the breast baby with excessive sugar fermentation, there is an increased bacterial content of the small intestine from various causes, favoring abnormal fermentation there. An important point to remember is that there are always two antagonistic processes going on in the bottle-fed baby's intestine: breaking down of protein, which tends to cause an alkaline reaction in the intestine, partly from the alkaline end-products that are formed, partly from the large amount of alkaline pancreatic juice which is thrown into the intestine in order to digest the protein. The opposite process consists in a breaking down of sugar and, secondarily, of fat, with acid end-products. In a normal bottle baby, whose food is agreeing with him, these two processes just about balance one another; if one greatly predominates, trouble results, due to a too acid or too alkaline reaction in the intestine. The processes of digestion and of absorption are very delicately adjusted with regard to the intestinal reaction, and must have a certain optimum reaction in order to proceed efficiently; comparatively slight changes in acidity or alkalinity may serve to upset these carefully adjusted processes. The breaking down of protein is caused by one group of bacteria, that of

sugar by another group, and the bacteriology of the intestine, and thus the reaction, can be very largely controlled by the type of food offered. A food high in protein will call forth groups of bacteria that live upon protein, and hence an alkaline intestine; a food high in sugar will call forth bacteria that live upon sugar, hence an acid intestine. We cannot separate bacteriology and problems of digestion and absorption: bacteria *always* play an important rôle in the interaction between the various food elements in the intestine. The pediatrician can control the type of stools, and make the intestine acid or alkaline at will, according to the type of food he offers to the baby, according to the amounts of the food elements in his mixture, and most particularly according to the *relation* between these food elements. It is vital for the baby to have a well-balanced food, and no one element can be considered apart from its relation to the other food elements.

These principles are, I believe, of great importance in practical feeding.

Assimilation Limit of Different Sugars. A baby takes relatively much more sugar than does an adult, and the assimilation limit is much higher in infancy than it is in later life. A breast-fed baby of 4 kgm.² would take, perhaps, 120 gm. of milk at a feeding, containing, roughly, 8.4 gm. of lactose, or 2.1 gm. per kgm. body weight. An adult usually shows sugar in the urine after taking about 1 gm. sugar per kgm. body weight. Practically speaking, it is difficult to exceed the assimilation limit of a baby before sugar fermentation and diarrhea occur. The assimilation limits of the different sugars vary somewhat, that of lactose and sucrose being about the same, from 3.1 to 3.6 gm. per kgm. body weight, that of maltose considerably higher, about 7 gm.

II. PATHOLOGY.

Chemistry of Sugar Fermentation. It is now generally granted that bacterial fermentation of sugar in the intestine plays a very important part in digestive and nutritional disturbances. A number of different agencies may bring this about, but the end-result is the same: excess of acid from the breaking down of the sugar, with consequent irritation of the intestinal mucous membrane. The production of acid is the first step in the chain of proc-

esses which may occur, and which may produce mild or severe conditions in the baby, depending upon how far they are allowed to go. I believe it is fair to say that the unchanged sugar molecule is without influence, and that it must be broken down into volatile acids before harmful results are brought about. This breaking down is done by the action of bacteria upon sugar, and the probability is that it cannot be done in any other way.

Let us consider for a moment the chemistry of sugar fermentation, and the products that are formed. Lactose is a polysaccharide, a rather complex chemical substance, with the formula $C_{12}H_{22}O_{11}$, containing many carboxyl and some aldehyde groups which may be very readily changed over into acid radicals. It will be seen from this that there is possibility for the formation of a considerable number of end-products when the molecule is torn apart, and that from the chemical constitution of sugar acids are the substances which are most likely to be formed. Two different groups of acids may result from the breaking down of sugar: the so-called volatile "fatty" acids and the non-volatile acids. The non-volatile acids are lactic and succinic acids and probably do no harm. It is the volatile fatty acids with which we are concerned. There are thirteen members in this acid series, as follows:

NAME*	FORMULA
Formic acid	$H\ COO\ H$
Acetic	$CH_3COO\ H$
Propionic	$C_3H_7O_2$
Butyric	$C_4H_9O_2$
Valeric	$C_5H_{11}O_2$
Caproic	$C_6H_{13}O_2$
Heptylic	$C_7H_{15}O_2$
Caprylic	$C_8H_{17}O_2$
Nonylic	$C_9H_{19}O_2$
Capric	$C_{10}H_{21}O_2$
Palmitic	$C_{16}H_{33}O_2$
Margaric	$C_{17}H_{35}O_2$
Stearic	$C_{18}H_{37}O_2$

* Text-book of Organic Chemistry, Holleman.

The lower members are liquids; the higher ones, beginning with C_{10} , are solids at ordinary temperature. It is the lower members of the group which are most important, and it is unlikely that the higher ones are formed by the breaking down of sugar. The higher acids are formed by the breaking down of fat, and it is also theoretically possible that the lower acids (formic, acetic) may be likewise formed from fat destruction. Probably always when there is a fermentation of sugar going on in

the intestine, there is also a secondary fermentation of fat, and it is quite impossible to tell how much of the acid formed comes from the one, how much from the other. The modern German school is inclined to attach very little importance to fat fermentation: they believe that it is practically always secondary to sugar fermentation, and does little harm. Salge, in his important monograph in 1906, believed, however, that *all* the trouble came from the fat, and none from the sugar. Chemically, both substances can form acids very easily, and it is probable that in many cases the sugar and the fat *both* play an important part.

Bokai³ found that the acids were irritating to the intestine in the following order: caprylic, capronic, acetic, propionic, formic, butyric, valeric. Bahrdrdt and Bamberg⁴ believe that acetic is the most irritating. Increased amounts of volatile fatty acids in the intestine may bring about the following harmful changes:

1. Increase peristalsis by irritating the intestine, with diarrheal stools as a result; these loose stools may carry out a good deal of undigested fat and protein which have not had time for absorption.

2. Injure the mucous membrane of the small intestine in such a way that it is unable to exert its normal anti-bacterial powers. Also, the functionally injured mucous membrane may allow the passage of harmful substances (lactose?, salts, acids, or bacterial endotoxins) into the system, which would not be able to pass the healthy intestine. This may lead to severe intoxication.

3. Draw upon the alkali reserve of the body in an attempt to neutralize the excessive acidity. This may help to cause an acidosis.

4. Upset the normal chemical processes of digestion, most of which cannot go on satisfactorily in an excessively acid intestine.

CONDITIONS WHICH MAY BRING ABOUT SUGAR FERMENTATION.

Two things are necessary for sugar fermentation: undigested sugar free in the intestine, and bacteria in sufficient quantity to attack it. It must be remembered that there is no specific bacterium which accomplishes this: it may be done by a number of different organisms, either the normal inhabitants of the intestine, or harmful organisms introduced from without. The place of fermentation is of a good

deal of importance. The small intestine is relatively sterile, partly from the antiseptic action of the hydrochloric acid of the stomach (upper portion), partly from the antibacterial action of the intestinal juices, and partly from the antibacterial action of the intestinal epithelial cells. The large intestine, on the other hand, is swarming with bacteria, and any conditions which allow these to migrate to the small intestine and flourish there favor sugar fermentation. In the breast-fed baby, sugar fermentation usually means simply that a certain portion of the large amount of sugar in breast milk has passed on undigested to the large intestine, and the acid reaction which is caused there by its fermentation is a physiological condition, which promotes proper peristalsis and evacuation of the bowel. In many bottle-fed babies with moderately acid stools such is also likely to be the case, but in the majority of bottle babies with loose acid stools the fermentation is proceeding in the small intestine, and is abnormal. A difficult problem in artificial feeding is to keep down excessive intestinal putrefaction with the formation of constipated alkaline calcium soap stools, without going to the extreme of excessive acid sugar fermentation. These two conditions are largely controlled by the relation between the different food elements in the mixture offered to the baby.

A. BACTERIA INTRODUCED FROM WITHOUT IN BAD MILK.

It is a well-known clinical fact that most cases of fermentative diarrhea are seen in the summer months, when milk has a greater chance to spoil than in the cold weather, and in babies who do not receive the best milk supply. I believe that more cases of fermentative diarrhea are caused in this way than in any other. The German school, however, considers this cause relatively unimportant, which is, perhaps, explained by the fact that they always feed their babies on a practically sterile, boiled milk. One of the greatest problems before pediatricians always has been to strive for the production of clean milk, and the causal relationship between so-called "summer diarrhea" and bacterial infection of milk was recognized long before any such thing as sugar fermentation was heard of. Different authors have described different specific bacteria which cause

the trouble, but I believe it probable that almost any bacterium when present in sufficient quantity in the milk may bring it about. It is probable that spoiled milk plus heat is more likely to cause trouble for the baby than is spoiled milk alone. Bahrdt⁵ and his co-workers investigated the following question: "Is the number and kind of bacteria in the stomach and intestine, as well as the number and kinds of fatty acids formed, dependent upon the bacterial infection of milk before ingestion"? They fed dogs on milk infected with many different sorts of bacteria, killed the dogs two hours after feeding, examined the stomach and intestinal contents, and found, that in spite of the large intake of bacteria, there was not a large bacterial increase in the stomach and intestinal contents, due, they believed, to the strong anti-bacterial powers of the normal stomach and small intestine. They conclude that milk infection is not a very great factor in the common (non-epidemic) diarrheas of children, and believe that the influence of food infection, plus heat and over-feeding is necessary to cause trouble in most cases. Such investigations as these are, of course, very artificial, and, while valuable, are by no means conclusive.

B. CONDITIONS UNDER WHICH THE NORMAL BACTERIA OF THE INTESTINE MAY CAUSE SUGAR FERMENTATION.

1. *Overfeeding.* Overfeeding with sugar, either given as too much food as a whole or as a too high sugar percentage, may cause fermentation. The excess of sugar cannot be absorbed before the intestinal bacteria attack it. Part of the sugar is probably fermented in the small intestine; part in the large, and oftentimes such a condition may be quickly relieved by simply cutting down the amount of sugar in the diet. This is the simplest condition of sugar fermentation and depends alone upon the excess sugar that is present and the bacteria, without the salts, spoiled milk, or heat, entering into the question at all. The next five types of sugar fermentation depend fundamentally upon changed processes in the small intestine; either a diminished anti-bacterial power, or a diminished secretion of digestive juices, from several causes.

2. *High Sugar in Combination with High Salts.* The German school has contended that perhaps the most important cause of sugar

fermentation is a depression of the anti-bacterial powers of the epithelial cells of the small intestine by the salts of the cow's milk—particularly those salts which are left behind in the whey after the curd has formed. This lowering of resistance allows bacteria to flourish in the small intestine, where they would not normally. We know that the small intestine does have considerable anti-bacterial power; whether this is dependent upon some peculiar property of the epithelial cells, or whether it depends upon the intestinal juices, is not certain. The importance that the German school ascribes to the whey salts is based largely upon Meyer's classical investigation, in which he separated breast milk and cows' milk each into curds and whey, and then added the whey of breast milk to the curds of cows' milk, and vice versa. He found that the mixture containing the cows' whey caused diarrhea when fed in conjunction with a high sugar; those containing the whey of breast milk did not.

There is no question but that cows' whey is rich in salts. It contains about .80 to .90% salts, in the form of the chlorides, citrates and phosphates of sodium, potassium and calcium. About half of the calcium of the original milk is present in the whey, probably nearly all of the sodium and potassium.⁶ There is a certain amount of evidence to show that strong solutions of salts may depress the functions of living cells, but the salt concentration of cow's whey, although higher than that of human whey, corresponds to a physiological saline solution only. It is hard to see how a concentration of salts which is thus practically isotonic with the body fluids, can act in an injurious manner to the intestinal cells. Again, we know that plain whey, undiluted, is usually borne very well by even the smallest babies, and often is fed to them with great success during gastro-intestinal disturbances of various sorts, when the casein and fat of cow's milk, perhaps, cannot be borne at all. Also when we add sodium citrate in the strength of one or two grains to the ounce of milk and cream in the mixture, to modifications to favor the digestion of the protein, we are adding a large amount of sodium and of citrate ions, which does not seem to upset the baby. Again, when we add calcium chloride to a baby's milk in order to lessen nervous irritability in spasmodia, we add much more than is ever present

in whey. Neither does this ordinarily upset the baby.

One of the chief purposes of the famous "eiweiss milk" was to dilute the whey salts, but in eiweiss milk we have all the salts of the buttermilk used in its preparation, which, in the finished eiweiss milk would correspond approximately to a salt concentration obtained by dilution of cow's milk one-half with water. "Eiweiss" milk works; there is no question of that; but may not its beneficial effect be due rather to a very low sugar content (1.5%) than to a low salt content, which it does not contain? Let us suppose a baby was having dyspepsia on a dilution of one-half milk with added sugar; we would feed him eiweiss milk, and it would probably arrest the sugar fermentation, but we would not have decreased the salt content of his food at all.

The work of Courtney and Fales,⁷ under the direction of Dr. Holt, is interesting in this connection.

"Protein milk contains a higher ash, and higher amount of all the different salts than are ordinarily given to infants artificially fed. As compared with woman's milk, not only are the total salts of the ash in great excess, but the amount of calcium is nearly five times and the phosphorus nearly seven times as great. The soluble salts, also, are nearly twice as abundant in protein milk as in human milk. As used at the Babies' Hospital extensively for three years with most satisfactory results, eiweiss milk has contained, owing to the addition of sodium chloride to the buttermilk used, an amount of Na and Cl nearly as great as in undiluted cow's milk, and much greater than in woman's milk. The following table shows the salt content in percentages of protein, cow, and human milk."

	TOTAL ASH	Ca O	Mg O	P ₂ O ₅	K ₂ O	Na ₂ O	Cl
Protein	.648	.201	.021	.222	.109	.032	.061
Cow	.743	.176	.020	.206	.189	.050	.111
Human	.206	.047	.008	.034	.057	.014	.035

It can be seen from these few suggestions, that the question of the harmfulness of the whey salts is not at all a clear one, and that Meyer's original suppositions can be by no means unconditionally accepted. There is no question but that breast milk, even with its high sugar content, can often be fed with beneficial results to babies who are suffering from sugar fermentation. Sugar fermentation must, therefore, be due in these cases to

sugar plus some indeterminate factor, present in cow's milk, and not present in breast milk. There is evidently some property of breast milk which allows its high sugar content to be handled by the baby without undue fermentation; whether this is due to the relatively low salt content of breast milk, or to other factors, is not certain.

3. *Overheating of the Baby's Body.* Overheating is of great importance in bringing about sugar fermentation. It is generally recognized that in adults not so much food can be tolerated in very hot as in colder weather, and the same applies to babies. Meadowikow's^s researches are of interest in this connection. He found that with dogs kept in a hot room there was a very greatly increased bacterial growth in the small intestine, and actually found bacteria in various organs at autopsy, where they were not found in control dogs. Besides diminishing the anti-bacterial powers of the intestine, he believes that heat may so depress the vitality of the intestinal epithelial cells that bacteria may actually pass through them into the tissues. It is also likely that the digestive juices of the intestine under the influence of heat are decreased in amount and in functional powers, so that not as large quantities of sugar can be digested as under normal conditions. What is undigested ferments readily.

It is hard to separate the influence of heat from other influences, but all clinical writers are agreed that excessive heat, particularly caused by overclothing in the hot weather, is a very important cause of sugar fermentation.

4. *"Parenteral" Infections.* Infections of various sorts in other parts of the body than the digestive tract are important as a cause of sugar fermentation. This has been noticed by American pediatricians for years, but has received much more attention from German writers than it has from those in this country, and it is my belief that followers of the German school are, perhaps, too prone to ascribe sugar fermentation to "parenteral" infection, as it is called. There is no question, however, but that many babies with otitis media, nasopharyngitis, etc., will show evidences of sugar indigestion by loose, green, acid movements, when their movements previous to the onset of infection may have been quite normal. This is an important group of cases, and I believe

that many of us in this country have gone to the other extreme, and have not realized how important and how frequent this cause of sugar fermentation is. Clinically, the diarrhea is usually not severe, and the baby is likely to have merely six or seven loose, greenish, acid stools a day, without evidences of prostration or toxemia. The explanation is probably that in any infection the digestive juices are partly suppressed, so that undigested sugar can proceed lower than is normal down the digestive tract, where the ever ready bacteria there attack it; or again, that suppression of the anti-bacterial powers of the small intestine from the general lowering of vitality may allow these same bacteria to flourish higher in the gut than they normally would.

5. *Nervous Influences.* Nervous exhaustion and excitement may also bring about sugar fermentation by suppressing the secretion of the intestinal juices, and possibly by increasing intestinal peristalsis, in which case time is not given for the proper digestion of the sugar in the small intestine, and it proceeds to the large intestine, where it ferments. This is a relatively mild and unimportant form of sugar fermentation.

6. *Constitutional Weakness.* As a last and important cause of sugar fermentation, constitutional weakness of the baby is to be considered. In these cases the tolerance is likely to be weak for every food element. The anti-bacterial forces of the small intestine are not powerful enough to keep down bacterial growth the way they should, and bacteria flourish where they normally should not. The functions of the intestinal epithelium are easily disturbed by forces which would have no influence upon a more vigorous child. The sugar-digesting juices are also deficient, and with the abnormal bacterial growth and poor digestive power of the intestine, ideal conditions for sugar fermentation are at hand. This group of cases comprises those babies whom we are accustomed to class under the head of chronic sugar indigestion rather than as acute. Any overstepping of their rather meager tolerance is practically sure to result in a sugar diarrhea.

CLINICAL APPEARANCES OF MILD AND OF SEVERE CASES OF SUGAR FERMENTATION.

The mild and the severe cases of sugar fermentation we are accustomed to call "mild"

or "severe" cases of fermental diarrhea, or of indigestion with fermentation. The Germans call the mild cases "dyspepsia," the severe ones "intoxication."

The clinical appearance of the mild and of the severe cases is considerably different.

Mild Cases. The baby has usually from four to ten loose, green, acid stools a day. His appetite is impaired, he is fussy and restless, and is obviously moderately but not severely sick. The temperature is slightly elevated, usually 99° to 100.5°. The respiration is of normal character, the tissues are still firm and hard, and there is either stationary weight, or perhaps a slight loss. The outlook is good, and the baby will in most cases respond readily in a few days to proper treatment.

Severe Cases. The severe cases present a quite different picture, which has been very well described by Dr. Gerstley of Chicago.

"The child is very feverish and lies in semistupor. The sunken cheeks, the sharp nose, the ashen, mud-colored, wrinkled skin, the cold extremities—all show great loss of weight and prostration. Intense watery diarrhea drains the body of its food, pulls out the very building-blocks of the tissues. The pulse is rapid and weak. Lying apathetically, the baby takes not a particle of interest in his surroundings. The unclosed lids show the glassy eyes fixed unintelligently upon a corner of the room. Occasionally he wakes for a moment, looks at us, cries fretfully, and wanders off into apathy. The breathing is characteristic; deep and sighing, like the air hunger of diabetic coma. Occasionally one of the limp extremities moves slightly; sometimes it takes a cataleptic attitude. The urine may show sugar, albumin and casts."

Metabolism. The metabolism in the two groups of cases is quite different. In the mild cases the disturbance is a local intestinal affair and, practically speaking, its influences do not extend beyond the digestive tract. The sugar in the intestine is fermented by bacteria, and the resulting acid end-products irritate the intestinal mucous membrane and cause a diarrhea. The chemical processes in the intestine are considerably changed, but there is no profound and far-reaching change in the chemistry of the whole body, as there is in the more severe cases. There is a moderately diminished absorption of all the food

elements, partly due to increased peristalsis, partly to the altered chemistry of the intestine. The absorption of ash is particularly poor, although the diminished absorption of nitrogen and of some of the ash constituents seems to be partly compensated for by a somewhat increased retention."

There is probably very little absorption of injurious products into the general circulation, and the metabolism of the baby as a whole is not seriously affected. The intestinal mucous membrane is irritated, but is still functionally efficient enough to prevent toxic substances from being absorbed through it. The stools are so acid that considerably more of the alkali excreted from the body goes out in the stool than normally, but not enough alkali is withdrawn to cause severe acidosis. In the severe cases (intoxication) the situation is quite different. The process which has started locally in the intestine, has spread its effects all through the body, so that the chemistry of the baby's body cells is completely upset. In the beginning, the sugar is fermented, and acids are formed as in the mild cases, but the process continues so long or with such a degree of intensity that the intestinal mucous membrane is severely injured, not anatomically, but functionally, and allows substances to pass through into the general circulation, which it would never allow under normal conditions.

All investigators are agreed up to this point: that the acids formed depress the function of the intestinal epithelial cells in such a way that toxic substances are allowed to pass into the circulation. But there has been considerable disagreement as to what the nature of these substances or substance is.

Five things may be considered:

1. Lactose.
2. Salts.
3. Food decomposition products.
4. Bacteria.
5. Bacterial decomposition products (endotoxins).

1. Lactose.

Finkelstein originally believed that lactose unchanged was the toxic agent. This view originated because it was noted that in nearly all cases of "intoxication," sugar was found in the urine.

Meyer¹⁰ found sugar in the urine in every urine of 150 cases of intoxication, and regarded

it as one of the earliest symptoms of the toxic state. The sugar was lactose, and was usually in a concentration of about 1%. The specific toxic effect of lactose is denied now by Finkelstein himself, as well as by other observers (see Allen: "Glycosuria," etc.), and the lactosuria is looked upon as a symptom of the toxic state rather than the cause of it.

2. Salts. The next substance that attracted attention as a cause of fever were the salts, and Finkelstein, as well as many of his followers, adheres to this view. Much has been written about "salt fever," and many authors claim to have produced fever by injecting subcutaneously sterile solutions of various salts, particularly sodium chloride. Other investigators believe, however, that the fever is caused by the bodies or endotoxins of dead bacteria in the water, and that if sterile distilled water be used, no fever results. There are a number of objections to the theory of salt fever, not the least of which is that subcutaneous injections of normal saline are one of the most efficient means of combating some of the most severe cases of "intoxication." And indeed, Langstein and Meyer, in their book on infant nutrition, advocate this as a method of treatment, also sodium chloride solutions by rectum, despite the fact that they assert that the salts, particularly sodium chloride, are important in depressing the anti-bacterial function of the intestinal epithelium, and that, when they are absorbed, they are extremely toxic and pyrogenetic. Without further discussion, I believe it is fair to say that it has never been shown conclusively that the salts are to be regarded as the cause of the toxic state, and that at the present time the theory of "salt fever" has few adherents.

3. Products of Food Decomposition.

The acids that are formed from sugar fermentation have also been taken into consideration as the toxic agents. It is true that these acids are to a certain extent absorbed, but they are almost completely burned in the body, and in the urine rarely occur, or if they do, only in the smallest traces. It is probable that they have little to do with causing fever, but may play a small part in causing the acidosis, which is a part of the symptom complex.

4. Bacteria.

It is conceivable that the intestinal mucous membrane may allow bacteria to pass through

it into the circulation, and that these bacteria are the cause of the fever. This possibility is not at all likely, although there is some evidence to show that it may occur. Blood cultures from cases of "intoxication" have not shown that there is any demonstrable growth in the blood, and the bacteria which inhabit the intestine and cause fermentation are mainly saprophytes, and have little tendency to invade the body tissues. In true infectious diarrhea, caused by the dysentery bacillus we know, on the other hand, that infection of the blood is not at all an uncommon occurrence.

5. Tobler¹¹ believes that absorption of bacterial endotoxins is the most important cause of the fever, and of most of the toxic symptoms. This seems the most reasonable explanation. In the intestinal tract, during processes of sugar fermentation, there is an enormous increase in the number of bacteria present. Millions of bacteria are being destroyed every moment, and countless new ones are appearing. Why is it not reasonable to suppose that the soluble toxins from the disintegrated bodies of dead bacteria are the substances that cause fever? We can thus liken the fever to other familiar fevers which are caused by absorption of bacterial toxins from other parts of the body. Why should we look to salts and lactose, when there is present a much more reasonable and probable source of fever?

Acidosis. It had been noticed for some years that the severe cases of sugar fermentation had the hyperpneic type of breathing: deep, sighing, tireless respiration—and that the worse the case, the more marked was the hyperpnea. Howland and Marriott¹² have investigated this extensively, and have shown that many of the severe cases have a considerable amount of acidosis, and that acidosis accounts for the hyperpnea, and probably also, in combination with the other factors already discussed, for the toxic condition. It is likely that a good many babies who die from "alimentary intoxication" really die from acidosis. The acidosis may be produced by a number of factors. Acidosis, in general, may be produced in three ways:

1. Increased acid production within the body, by the breaking down of body fat.
2. Increased alkali loss.
3. Decreased acid elimination.

In severe conditions of sugar fermentation

the acidosis is probably produced by a combination of all three factors. The baby is taking little food, hence his body fat is broken down. Also, as mentioned before, there is in "intoxication" a negative alkali balance, caused largely by a considerable withdrawal of the alkali reserve of the body in an attempt to neutralize the acid condition in the intestine. Lastly, the kidneys are as a rule very inactive in intoxication, and it has been recently demonstrated by Schloss¹³ that there may be a considerable impairment of kidney function, as shown by various functional tests. This leads to a retention of acid sodium phosphate, which may be considerable, and which Howland and Marriott believe to be probably the most important factor in producing acidosis.

SUMMARY.

In the severe cases of sugar fermentation there is a fairly distinct clinical picture present which has been called alimentary intoxication. It is a condition arising primarily from the digestive tract, but in its fully developed state it is no longer confined to the intestine, and the entire chemistry of the body is upset. Several views have been advanced to explain the fever, the most reasonable of which is that it is due to the absorption of bacterial toxins. The fever, however, is only a part of the picture; acidosis, a diminished fluidity of the tissues, retention of toxic waste products, and a negative salt and nitrogen balance play important rôles. It is thus impossible to ascribe the toxic state to the influence of one factor alone; several are involved, and each plays its part.

III. THERAPY.

What Sugar to Feed to Normal and Abnormal Babies. Inasmuch as lactose is the natural sugar which a baby gets in breast milk, it seems only reasonable to use this in feeding normal babies. There is no good reason for feeding normal babies on any other sort of sugar. If the baby has a tendency to sugar fermentation, with rather frequent and loose stools, it is better to use one of the maltose-dextrins preparations, as these ferment less easily than does lactose. On the other hand, if the baby is having hard, soapy, alkaline stools, lactose is to be preferred, as it promotes normal fermentative processes in the intestine, and does away with

the constipation. In this type of case large amounts of lactose can sometimes be fed without harm. The constipated, soapy type of stools is especially likely to be seen, I believe, in babies who are fed on dextri-maltose in combination with rather a high protein percentage. There is not enough fermentation of the sugar to promote the normal peristaltic processes, and to make an acid intestine. An alkaline intestine favors calcium soap formation and constipation. Often the addition of one of the liquid malt extract preparations will correct this type of constipation, or lactose may be added to the dextri-maltose already in the mixture, and increased until looser movements result. If, for one reason or another it becomes necessary to feed an unusually large amount of sugar, it is best not to use lactose, as there is less risk of upsetting a baby with large amounts of a maltose-dextrins preparation than with equal amounts of lactose. It must be remembered, however, that maltose is not a specific for all sugar troubles, and that certain babies do not do at all well on it. Sucrose has as its only advantage that it is cheaper than any of the other sugars, and it is well not to use it unless for financial reasons, as it is not a good plan to have a baby develop a sweet taste. Sucrose seems to ferment with about the same readiness that lactose does.

Amount of Sugar to be Fed. Practically speaking, it is very difficult to exceed the sugar assimilation limits of a baby, because almost always vomiting or diarrhea result before this stage is reached. Babies vary immensely in the amount of sugar that they can take. The usual rule is not to exceed 7.00% of sugar in the formula, and in general this is a good rule to follow, but may often be broken with advantage. There are many babies who cannot digest fat well, some who cannot digest protein well, and in these cases the sugar digestion is often very good, and a large amount of sugar may be fed without causing any disturbance. This is a truth that we often do not realize in difficult feeding cases. In babies with loose bowels the sugar cannot usually be much increased, but in a certain type of baby who does not gain, who does not digest fat, and who has constipated stools, a large amount of sugar can be fed with perfect safety. I have in mind a baby six months old who cannot take over 1.25% of protein without diarrhea and vomiting, and who never could be made to gain until she was

put upon 10% of sugar, partly as maltose, partly as lactose. There are a good many babies of this type, I believe, and high sugar feeding seems to send them ahead faster than anything else. The nitrogen needs must be covered, of course, and the minimum of protein necessary for this should be given. Ordinarily in these cases one of the maltose-dextrins preparations is the best sort of sugar to use.

The relation between the sugar and the other food elements, particularly the fat, is important. A very high sugar should never be offered in conjunction with a high fat. It is possible many times to feed a high sugar with a high protein, but in general, if the sugar is to be varied it is best to keep the other food elements low. In certain difficult feeding cases I am in the habit of having the baby's formula made up with perhaps 6 or 7% of sugar and then instructing the mother to add one, or later, perhaps two teaspoonfuls of sugar to each feeding. In this way the baby's sugar tolerance may be tested, and the sugar can be pushed to just under the limit. It is quite surprising to see how well some babies will do on this high sugar feeding, and how rapidly they will gain. They must be kept under close observation, however, for sugar diarrhea may occur at any time. The work of Dunn and Porter¹⁴ is interesting in this connection. They fed a number of babies on high sugar percentages, in many cases as high as 15 or 18%, and as a result of these studies arrived at the following conclusions: "It seems to us that the idea of sugar injuries and sugar intoxication has possibly kept us from the use of large amounts of soluble carbohydrate in certain cases, particularly those unable to take a quantity of fat sufficient to meet their nutritive requirements. That many such babies have intolerance for sugar, is undoubtedly true. But the danger of pushing the sugar to the limit of tolerance we believe to have been exaggerated. The signs of sugar indigestion are distinct and easily recognized, and do not appear to be in any way serious. In many cases great benefit appears to be obtained by greatly increasing the carbohydrate content of the food, and this proceeding may prove a valuable addition to our stock of resources in dealing with difficult feeding cases."

Calculation of Sugar. In calculating the required amount of sugar to add to a mixture to secure a given sugar percentage, one of two

methods may be used. The weight of the sugar may be calculated in relation to the amount of the total mixture, remembering that two rounded tablespoonfuls of lactose weigh about an ounce. Then, if we wanted to add, let us say 3.00% of lactose to a thirty-two ounce mixture,

$3/100$ of 32 oz. = 1.00 (approx.) = 1 oz., or 2 rounded tablespoons.

The next method consists in the use of a table.

One level tablespoon of sugar raises the sugar percentage

2.40%	in a 16 ounce mixture
2.00%	in a 20 ounce mixture
1.60%	in a 24 ounce mixture
1.20%	in a 32 ounce mixture
1.00%	in a 40 ounce mixture
.95%	in a 42 ounce mixture
.80%	in a 48 ounce mixture

WEIGHTS AND MEASURES.

3 level teaspoons = 1 level tablespoon

2 level tablespoons = 1 large kitchen spoon

Cane sugar is considerably heavier than lactose or the dextri-maltose preparations, and this should be taken into consideration in using it.

	CANE SUGAR	LACTOSE	DEXTRI-MALTOSE
1 level tablespoon	= 15 gm.	—10 gm.	—9 gm.
1 rounded tablespoon	= 25 gm.	15 gm.	14 gm.

Maltose-Dextrins Preparations. In the last few years, numerous maltose-dextrins preparations have been put upon the market. Most of the proprietary foods contain large amounts of dextrins and maltose, but the preparations referred to below should hardly be classed as proprietary foods, as no extravagant claims are made for them, and it is recognized that none of them are complete *foods*, and should be used simply as sugars, when the addition of a maltose-dextrins preparation to the mixture is indicated for any reason. The maltose-dextrins preparations are made from potato, barley or wheat starch by the action of the diastatic malt ferment. The starch is first broken down into a mixture of various dextrins, and as the process continues some of these dextrins are further broken down into maltose. Pure maltose is never used in infant feeding; it is a chemical curiosity, very expensive and difficult to prepare, and is said also to cause a severe diarrhea, not from its fermentation, but from its own irritating action. So when we ordinarily speak of feeding a baby on maltose, we mean a mixture of maltose and dextrins. The

maltose-dextrins preparations on the market vary considerably in their composition: some contain a larger amount of maltose than of dextrins; some the reverse.

It is important to bear in mind that they cannot be used interchangeably, as some of them act much differently from others. In general, the preparations that contain large amounts of dextrins are rather constipating in their action, on account of the fact that dextrins are broken down and absorbed so slowly. These preparations may often be advantageously combined with lactose in the formula, and if constipation exists, 2 or 3% of added lactose will usually correct it. The preparations that contain a large amount of maltose are, on the other hand, quite laxative in action, and sometimes a most excellent method of treating constipation in babies is to add one or two teaspoonfuls of one of the liquid malt extracts to each feeding. The important thing in dealing with most cases of constipation is to have a proper understanding of the use of the various sugars. A list of some of the maltose-dextrins preparations follows, with their percentage compositions.

MEADE'S DEXTRI-MALTOSE No. 1.	D.-M. No. 2.	D.-M. No. 3.
Maltose 52%	Maltose. 53%	Maltose 52%
Dextrins ... 41%	Dextrins 42%	Dextrins ... 41%
Sodium chlor- ide 2%		Potassium carbonate. 2%
 HORLICK'S FOOD	 HORLICK'S "DIASTOID"	
Maltose 64%	Maltose 73%	
Dextrins 17%	Dextrins 11%	
Protein 12%		
Fat 1.4%		
 BORCHERT'S MALT SOUP EXTRACT*	 BORCHERT'S DRI- MALT SOUP EXTRACT	
Maltose 57%	Maltose 71%	
Dextrins 12%	Dextrins 13%	
Protein 6%	Protein 9%	
Potassium car- bonate 1.1%		
 "MALTINE"	 MELLIN'S FOOD	
MALT SOUP EXTRACT*		
Maltose 62%	Maltose 58%	
Dextrins 3%	Dextrins ... 20%	
	Protein ... 10%	
	Fat16%	
	Potassium bi- carbonate. 2.5%	

* A liquid of the consistency of very thick molasses.

The liquid maltose preparations are very laxative in action, and not more than 2% should ever be added to a mixture. Also, it must be remembered, in using the liquid

preparations, that they contain a good deal of water, and allowances must be made accordingly in calculation.

TREATMENT OF MILD AND OF SEVERE CASES OF SUGAR FERMENTATION.

The treatment of these conditions is of very great importance, as often by proper treatment life may be saved, and with improper treatment the case may be changed from a mild to a severe one, and death may result. Many cases of mild sugar fermentation may be controlled by simply diluting the food for a few days or by omitting all added sugar. If the case is a mild one it may not be necessary to go further than this. The more severe cases will require further treatment, which may be discussed under the following heads:

1. Purgation.
2. Food.
3. Water.
4. Alkali.
5. Intestinal irrigations.
6. Drugs.

1. It is a routine with many practitioners to give castor oil or calomel to any baby with diarrhea the first time they see him. This is often a grave error. It is true that it is desirable to empty the intestine, but if the baby is having ten or fifteen loose stools a day he is emptying himself as fast as he possibly can, and to give a purge to such a baby is simply to irritate and to make functionally weaker an already irritated and weakened intestinal mucous membrane. If the baby is having fewer stools, and particularly if he is seen at the very onset of his illness, a purge is by all means desirable. Personally, I prefer castor oil, and this is the purge used almost universally in this part of the country. In the South, however, where there is an enormous amount of infantile diarrhea of various sorts, I have rarely seen castor oil used. Calomel takes its place, and it is often true that a baby who has an irritable stomach will keep down calomel better than he will oil. Calomel also is of service occasionally in controlling vomiting when it is due to reversed peristalsis. As an intestinal antiseptic it should not be used, and there is a certain amount of evidence to show that there may actually be a greater bacterial growth in the intestine when calomel is given than when

it is not. The initial purge should not be repeated, and I believe it a great mistake to give a daily purge, a practice which is not at all uncommon. In the mild cases it is not necessary to starve, and many times the mildest ones will respond to a simple dilution of the food for a day or two. Cases slightly more severe may be put on special food (see below) without a preliminary starvation, but the really severe cases with toxic symptoms must have the intestine thoroughly emptied by starvation for about twenty-four hours. During the period of starvation nothing should be given but water or weak tea, and this should be forced in order to supply the child with fluid.

2. Food.

Principles of Feeding. Inasmuch as the condition that we are dealing with is a fermentation of sugar, the chief principle to bear in mind is to feed a low percentage of sugar. Since there is often a secondary fermentation of fat, it is usually desirable to reduce somewhat the fat in the food offered. A high protein in an easily assimilable form in combination with a low sugar and a fairly low fat gives us a food which will stop excessive fermentation by withdrawing the fermentable substance, and also by tending to produce an alkaline intestine instead of an acid one. An alkaline intestine containing little sugar also favors the formation of solid soapy stools, a condition which is desirable, as in this way the diarrhea is controlled. Small amounts of food should be offered at first as the food tolerance for every element is much lowered.

Details of Feeding. Any milk modification which is put together on these principles is a suitable food upon which to feed cases of sugar fermentation. The exact method to be used will vary somewhat according to whether the baby is to be fed on a home modification or from a milk laboratory.

HOME MODIFICATION.

1. Skim Milk Mixtures.

In much of our out-patient work it is impossible to prescribe complicated formulae, for home modification, as the intelligence of the patients and the conditions of the home are incompatible with any procedure which is not very easily explained and understood. For these cases simple dilutions of skim milk with water answer fairly well, although not nearly

so well as some of the more complicated mixtures, as it is impossible with simple skim milk dilutions to secure a high protein in combination with a low sugar. We can, however, secure a fairly low sugar, and after the preliminary purge or starvation, may begin with skimmed milk or water equal parts (boiled five minutes), giving a percentage composition of fat .00, sugar 2.25, protein 1.60. Small amounts should be used at first; a baby who would ordinarily take perhaps six ounces at a feeding, would be given three or four ounces of this mixture. Such a procedure does not apply at all well to the very severe cases, however, and these cases should have hospital treatment if conditions are such that one of the more complicated mixtures cannot be prepared at home. As the baby improves, the amount of the feeding may be gradually increased, and soon a little fat may be added. Lastly, sugar is to be added, in the form of one of the maltose-dextrins preparations. A more satisfactory method of feeding is with skim milk dilutions to which powdered casein has been added. In 1915 I fed a series of cases on this method with very good results. Unfortunately, since the war, the only preparation of powdered casein (Laroson) that was on the market, is not available. A commercial powdered casein preparation is very much needed at the present time, and it would be a great benefit to many babies if one were put upon the market.

2. "Eiweiss" Milk.

The famous "eiweiss" milk is probably the most satisfactory food upon which to feed cases of sugar fermentation. It was devised by Finkelstein and Meyer in 1910, and its usefulness, according to them, is based upon the following properties:

1. Low sugar.
2. Dilution of the whey.
3. High casein.
4. Combination of relatively high fat and high casein, thus favoring the production of formed stools.

Since Finkelstein's original contribution, eiweiss milk has been used extensively in all parts of the world, with a great deal of success. Their original directions for preparing it are as follows:

"To one liter of milk one teaspoon of rennet is added. This is then allowed to stand in a

water bath at 100° F. for one hour. It is then placed in a linen bag and the whey strained off by suspending this for one hour. The curd is rubbed once or twice through a fine sieve with the addition of one-half liter of water, and one-half liter of buttermilk." "Eiweiss" milk, then, consists of the curds from a quart of milk, plus a pint of buttermilk, and a pint of water. It has the following composition: fat, 2.5%; sugar, 1.5%; protein, 3.0%; salts, .50%.

Since Finkelstein published his original formula, several modifications have been proposed, all based upon the same principles, however. At first it was thought best to use as low a sugar percentage as possible in eiweiss milk, but it is recognized now that many babies with severe sugar fermentation will die if the sugar is entirely withdrawn, so it is usually best to add sugar up to about 3%. If it is desired to use a nearly fat-free eiweiss milk, fat-free milk may be used instead of whole milk in making the curd. Then the only fat in the mixture is the small amount contained in the buttermilk. The Germans use at the onset very small feedings of eiweiss milk, perhaps giving only one or one and a half ounces at a feeding for the first day or two. In this country the tendency is to use somewhat larger amounts, bearing constantly in mind, however, that the food tolerance of babies with severe sugar fermentation is very meager, and that fatal results may occur from over-feeding. As the baby grows better, and as the stools decrease in frequency the amounts of the feedings may be increased and more sugar may be added. Eiweiss milk is not a permanent food, and a baby should not be kept on it for longer than a few weeks. Eiweiss milk is a tried, proved, and satisfactory food for sugar fermentation, but the difficulties of its proper preparation are considerable, and if a milk laboratory is at hand it is usually better to order the same sort of preparation prepared at the laboratory.

3. *Lactic Acid Milks.*

Natural buttermilk or artificially prepared lactic acid milk are foods which may be used with considerable success. Buttermilk is a food very low in fat, lactic acid milk may or may not be, depending upon what fat percentage the original milk used in its preparation contains. Buttermilk and artificial lactic acid milk are both high protein foods, containing the protein in an easily digestible form (lac-

tate of casein). The sugar is somewhat lower than in ordinary milk, owing to the fact that some of it has been changed into lactic acid. The chief advantages of these preparations are their high protein content, and the fact that they contain living lactic acid bacilli. The intestine in babies with sugar fermentation is swarming with all sorts of harmful organisms, and if it can be flooded with lactic acid organisms in a viable state, the theory is that the growth of the other organisms will be suppressed, and that the harmless lactic acid organisms will supplant them as the intestinal flora. Metchnikoff was the most prominent advocate of these ideas, believing that old age was largely due to putrefaction in the large intestine, and that this could be overcome and the life of the individual prolonged and his general condition greatly improved by the drinking of large quantities of the lactic acid milk preparations. Owing to the prominence of Metchnikoff and the attractiveness of the theory, his views received wide attention, and the drinking of the various lactic acid milk preparations became the fad. This has spread to infant feeding, and it is my belief that the advantages of "buttermilk" feeding have been considerably exaggerated. There is no question but that many cases of sugar fermentation respond well to lactic acid milk, particularly those cases in which the gas bacillus is causing the fermentation, but I believe that the principle of a low sugar and a high protein is, in most cases, much more important than the principle of implanting the lactic acid bacillus in the intestine. If one of these preparations is to be used it is better to have the lactic acid milk prepared at home by means of one of the various liquid cultures on the market than to use ordinary buttermilk, as buttermilk is likely to be rather old when it reaches the consumer, and putrefactive as well as fermentative changes may have occurred in it. I have actually known a specimen of buttermilk in Carolina which was about to be fed to a baby, to be full of well-grown maggots!

Laboratory Feeding. In a large city where there is a milk laboratory, laboratory feeding is the most satisfactory way of feeding babies whose parents can afford it. This is particularly true in cases of sugar fermentation, where, in order to secure the best results, rather complicated mixtures may need to be used. The

milk laboratories have a stock preparation of precipitated casein, and this can be added in any desired amount to any formula, to secure a wide variety of relationships between the protein and the sugar in the mixture. In a severe case of sugar fermentation we might write such a prescription as this: fat 1.00%, sugar (dextri-maltose) up to 2.50%, protein 1.20%, plus precipitated casein up to 3.5%. If the baby has a low fat tolerance a low fat may be used; if it is advisable to use a high fat, as high a fat as desirable may be prescribed, relationships which are not nearly so feasible when the milk is prepared at home. Then again, in laboratory feeding the high protein milk may be run through the homogenizing machine, and a very smooth mixture obtained, a condition which is much desired on account of the ease with which it goes through the nipple, and which cannot be obtained in home modifications. Also, if lactic acid milk is desirable, the mixture (of any prescribed composition) may be treated with the lactic acid bacillus. In short, with laboratory feeding at our command we are much more likely to feed the individual baby according to his individual needs than if we use home-made *eiweiss* milk of stock composition; we save the family an immense amount of trouble, and we feed our baby with a product which we know is uniform in composition.

Water. Fully as important as the feeding is the administration of fluid. *Never let a baby with sugar fermentation get into a "dried out" condition.* In severe diarrhea there is a great loss of water from the body, also in these cases the child is usually taking but little milk, so that he may be putting out a great deal more fluid than he takes in. Again, if there are evidences of acidosis, and if the breathing is of the hyperpneic type, he is probably losing more water through the lungs than would be the case under normal conditions. Evidence is accumulating year by year to show that the toxic symptoms in severe cases of sugar fermentation are largely due to a lack of water. The kidneys are always very inactive in these cases, and it has been recently shown by Schloss that there is a considerable impairment of renal function, and that the blood nitrogen is considerably increased, due to deficient excretion of waste products by the kidney. There is much evidence, according to Schloss, to show that "in-

testinal intoxication" is very similar to uremia. Also Howland and Marriott have shown that the acidosis in this condition is largely due to defective elimination of acid sodium phosphate by the kidney. The faulty action of the kidney is caused by a dehydration of the tissues brought about by a loss of water in the stools (and possibly expired air) and by the fact that the baby takes little fluid by mouth and is very likely to vomit what he does take. It is, therefore, vital to supply fluid in some way. Water by mouth is the simplest method, and if the baby can retain it, it is best given in this way. A chart, showing the exact intake of fluid, should always be kept in dealing with a severe case of sugar fermentation. If the baby does not take fluid well by mouth it is best to resort to subcutaneous administration of normal saline, and this should be done *early*. It is surprising to see how much fluid a baby will take in this way, how quickly it is absorbed, and how great an improvement in the general condition often follows. If normal saline is given it is best given in the loose tissue of the abdomen or flank, and *not* subpectorally, for the reason that a baby with intoxication has very little strength to spare, and when perhaps 500 grams of water are put upon his chest, and he has to raise this weight with each respiratory movement, it uses up a part of his scanty store of strength. It has also been recommended to administer fluid intravenously through the longitudinal sinus, and intraperitoneally. The fluid is undoubtedly absorbed more quickly by these methods, and the technic is not difficult, but in my personal opinion such methods as these apply very poorly to private practice, and for practical purposes the method of subcutaneous administration is satisfactory. The administration of fluid by the rectum does not work well, as it is very difficult to keep a rectal tube in position, owing to the increased peristalsis and frequency of defecation.

5. **Alkali.** In severe cases of sugar fermentation, when the breathing is of the hyperpneic type, alkali administration is advisable, as acidosis probably exists. Sodium bicarbonate is the best alkali to use, and should be given either by mouth or intravenously. Rectal administration* of soda to babies with diarrhea is not at all satisfactory, for reasons mentioned above. Neither is the subcutaneous use of soda

* In older children with acidosis without diarrhea, rectal administration is the method of choice.

advisable, and it is very irritating to the tissues, and is likely to cause necrosis. If carbon dioxide is bubbled through the solution of soda it is much less irritating (Howland and Marriott—*loc. cit.*) but this procedure is hardly practical for general clinical use.

If soda can be retained by mouth it is best given in this way in fairly large dose; 30 grains every two hours can be given to most babies. Soda should be pushed until the urine becomes alkaline as shown by the simple litmus paper test. If the baby is unable to retain soda by mouth, which is very likely, it must be given intravenously. A 4% solution may be used, and, depending upon the size of the baby, from 75 to 150 cc. of this may be given (Howland and Marriott). In this way a large amount of soda is immediately distributed through the system. In very few babies is it possible to give intravenous injections into an arm vein on account of the small size of the parts, and for this reason the jugular is the best vein to select. In most cases there will be little difficulty in getting into the jugular, but if this is unsuccessful the soda will have to be given through the anterior fontanelle into the superior longitudinal sinus.*

6. *Intestinal Irrigations.* Intestinal irrigations with normal saline *used at the beginning of the attack* may be of considerable value in emptying the colon of toxic products. They have, however, little place in the *later* treatment, and in most cases when used as a daily routine, I believe they do more harm than good, by irritating and disturbing the child. The baby's body is ridding itself of noxious material as fast as it can by watery diarrhea, and there is no point in attempting to wash out the intestine farther, particularly as most of the trouble is in the small intestine, and it is doubtful if this can be reached by intestinal irrigations. In infectious diarrhea (an entirely different condition), where there may be ulceration of the colon and of the ileum, intestinal irrigations with astringents sometimes probably do some good.

7. *Drugs.* In most cases of sugar fermentation drugs are of little value; in some cases they are needed. The drugs that have been used may be divided into two classes:

1. Those which are directed against the diarrheal process itself.

2. Those used as stimulants.

1. Often in private practice it is necessary to give some drug on account of the state of mind of the family. They feel that the baby is not being treated correctly if he gets no medicine. Under these conditions *chalk mixture* or *bismuth* may be given. The chalk mixture is mildly alkaline, and may do some good in helping to neutralize the acids which are present in the intestine, although this is accomplished much more efficiently by a suitable regulation of the food supply. Bismuth subcarbonate has been used for years in the treatment of diarrheas of all sorts; it is mildly astringent, and probably slows the intestinal peristalsis somewhat. Its chief disadvantage is that it turns the stools black, and thus makes it difficult to judge of their true character. These two drugs can do no harm, and *may* do some good.

Intestinal antiseptics, such as *salol*, *calomel*, etc., are of no value, and should not be given, as it is quite impossible to sterilize the intestine, or to influence its bacterial flora enough to amount to anything in this way. Here again, the character of the food supply is the most important factor to consider.

Opium in some form, usually as paregoric, has a definite place in the treatment of some cases of sugar fermentation. It should never be given as a routine, but only when the watery diarrhea and tenesmus is so excessive as to exhaust the child. Opium has its dangers, for if the diarrhea is stopped by it, the absorption of toxic material is favored, but in many cases where the child is worn out by excessive straining and tenesmus, its use seems to be the lesser of two evils.

2. Stimulants may be often needed, of which the most valuable are caffeine, camphor in oil, adrenalin and brandy. Personally, I prefer caffeine citrate, or caffeine sodium benzoate, subcutaneously, given in rather large doses. Camphor in oil is also valuable for a failing circulation, but as a general stimulant cannot be compared with caffeine. Brandy or whiskey, ten or fifteen drops subcutaneously, is a valuable stimulant for one or two doses, but should not be used continually, as each period of stimulation is followed by a period of depression. Caffeine or camphor is, I believe, in most cases superior to alcohol. The subcutaneous injection of one or two minims of a one to one thousand adren-

* For the technique see Dunn, *Am. Jour. Dis. Child.*, Vol. xiv, No. 1, 1917, p. 52.

alin chloride solution may be of service where there is circulatory collapse with very low blood pressure. Its action is, however, only fleeting.

As a brief summary let me say that the two most important things in the treatment of sugar fermentation are proper feeding, and plenty of water, and that most cases may be controlled by these alone, without the use of any other special methods of treatment.

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DENTAL DISEASES IN RELATION TO DISEASES OF THE NOSE AND THROAT.*

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ORAL diseases are quite frequently closely related to diseases of the nose and throat. They may be the direct cause of the disease (dental infection and maxillary sinusitis) or they may be only a debilitating influence (compressed maxillae and adenoids). Another type of condition presents a still different character. I have in mind referred pain of dental origin, simulating symptoms associated with diseases of the ears and sinuses.

The diagnosis of dental lesions very often calls for most careful and painstaking investigation, as many conditions are not evident in an ordinary dental examination. They are frequently of chronic character, giving no local symptoms, and are not noticed by the patient. As no special complaint is made, such diseases may develop under the very eyes of the dental practitioner, who, as a rule, spends little time in making a thorough examination of the mouth and adjacent parts, being too much taken up with routine work. In an examination of the patients at the Robert Brigham

Hospital I found that 72 out of 81 (90%) had dental abscesses,¹ and none was really aware of having trouble with the teeth, although it was necessary to extract 334 teeth from the 72 patients.

The development of the Roentgen diagnosis² has greatly facilitated examination of the oral tissues, but such a diagnosis should not be entirely relied upon. The application of temperature and electrical tests, as well as the diagnostic use of local anesthesia, are quite frequently necessary in order to ascertain the exact location and nature of the trouble.

The research work of the last few years has increased our knowledge a great deal, and I am taking the liberty of showing, with the Roentgen pictures accompanying the case reports, slides of microscopic specimens which illustrate typical lesions.

COMPRESSED MAXILLAE AND NASAL OBSTRUCTION.

The connection between malocclusion and nasal disorders has been observed by Hippocrates, who writes, "Those who suffer from headache and running ears have a high-arched palate and irregular teeth." Bottle-feeding and thumb-sucking are the primary causes of the compressed, V-shaped arch and protruding maxillary bones. The lack of lateral development prevents the expansion of the nasal passages and invites the formation of adenoids. This, in turn, causes mouth-breathing, which completes the vicious circle. When treating a case of malocclusion of this type it is important, first, to establish nasal respiration, as without the coöperation of the rhinologist, the dentist's treatment would be futile. On the other hand, it would be entirely useless to hope for permanent relief by removing the nasal obstruction if the jaws did not receive proper orthodontic treatment. It is important to undertake this at an early age, the principal aim being not only to straighten the teeth but to stimulate growth of the bones of the entire face. This can also be furthered by proper diet, which forces the child to masticate, and by special exercises of the muscles of the face.

MAXILLARY SINUSITIS.

Maxillary sinusitis in its various forms is, according to Brophy,³ in about 75% of the cases due to diseases of the teeth. Chronic abscesses on the upper teeth very frequently

* Paper read before the New England Otological and Laryngological Society.