AN INQUIRY INTO

SUGARS AND SUGARY FOODS

WITH AN

ANALYSIS OF THE CARBOHYDRATE CONSTITUENTS OF "INFANTS' FOODS"

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Preface.

The following Thesis is devoted to a consideration of Sugars and Sugary Foods as articles of diet. It has special reference however to the effects which these produce on the health of infants when employed as their food.

In order to define their value as food Elements at different periods of the child's life or in varying conditions of health, I have gone somewhat fully into the physiological processes of digestion and absorption of sugars and starches, and have made many experiments to Elucidate these.

I have also made an analysis of the Carbohydrate constituents of the more important preparations which are sold as infants' foods and also of the more commonly used saccharine foods.

It is from these data that my conclusions have been drawn.

April 28th. 1892. W.G.A.R.

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Introduction.

In recent years much greater attention has been given to foods and feeding as predisposing or as actual causes of disease than was formerly devoted to them. One would think that this was a subject which would have received attention at an early period, and the only wonder is that it has been neglected for so long a time

We may, in a measure, counteract bad sanitary arrangements and unhealthy dwellings by living much out-of-doors, as most of our poorer classes do; but we cannot thus escape from the effects of bad or improper feeding. By such food we may satisfy sensible hunger, while at the same time doing, it may be, irreparable damage to the organism, which has its needs still

unsatisfied. Such feeding of course tells most disastrously amongst our infantile population, each member of which is rapidly growing and so requires a diet perfect in its chemical composition and adapted for easy assimilation by the delicate and, as yet, imperfectly developed alimentary canal.

It is ~~to this~~ portion of our community that I dedicate these pages, in the hope that however feeble the attempt may be, it may yet help in some small way to increase the sum of human happiness or lessen the amount of human woe by diminishing the amount of infantile suffering and resulting mortality.

Infant Mortality

The question of infant mortality demands the attention of every intelligent person; but to the sanitarian and to the Medical Officer of Health it is one of the most important, if not indeed the most important of the subjects which demands their attention

We are all aware in a general way of the rate of mortality at early periods of human life. We know that by far the greatest number of children die during their first year; a much smaller number in their second, and still fewer during the third year.

If however we look into this subject more carefully we find that the mortality amongst infants is at its maximum during the first month of life. After the first few weeks of extra-uterine life have been passed, the rate of mortality undergoes a marked decrease and continues to fall gradually during the succeeding months.

The following table[1] shows this very clearly.

(1). Thirty-eighth Annual Report of the Registrar General, 1875.

I. Annual Death Rate per 1000 at each month of age.

Age in months	In healthy districts	By English Life Table	In Liverpool district
0	447·51	571·32	672·19
1	145·49	218·37	316·72
2	102·05	157·10	226·78
3	84·16	131·87	209·37
4	81·09	126·04	205·25
5	75·54	120·50	203·65
6	70·54	115·09	204·89
7	65·97	109·92	209·17
8	61·85	105·01	216·42
9	58·32	100·33	227·30
10	55·28	95·84	241·80
11	52·86	91·61	260·23

The death rates which this table exhibit are enormous. In a large town, as Liverpool, nearly $\frac{7}{10}$ths of all children born die during their first month, while during the second month nearly $\frac{1}{3}$ die.

What are the chief causes of such high rates of mortality? To answer this we must again consult the mortality statistics together with the causes of death, as is shown in the following table :—

II. Infantile and Total Deaths in 1887.

Causes of Death	Under One Year		At all ages	
	Males	Females	Males	Females
From all causes	71463	56 814	272 137	258 621
Measles	1902	1485	8657	8108
Scarlet Fever	239	205	3899	3960
Diphtheria	134	91	2116	2327
Pertussis	2195	2555	4928	6623
Diarrhoea	7750	6351	10725	9517
Parasitic Diseases	362	278	445	379
Dietetic Diseases	145	124	1099	666
Constitutional "	4713	3537	44181	45223
Developmental "	9479	7355	21219	22714
Local Diseases	30611	23241	140761	133776

Looking over this table we see at a glance that of the acquired diseases, diarrhoea causes the greatest death rate both in children under one year and also at all ages. The other zymotic diseases, taken together, fall a long way below this.

In England and Wales during 1886 there died from diarrhoea and diseases of the digestive system 57 014 persons of all ages or 10·67 % of the total deaths. From diarrhoea alone there were

25284 deaths or 4·76 %; while from diseases of the digestive system 31733 persons died or equal to 5·91 %. During this year the total deaths from the other zymotic diseases taken together amounted to 41219 or 7·64 % of the total deaths.

Of the infantile deaths in 1884 we see from the table that there were 14101 deaths (male and female) from diarrhoea amongst children under one year; whilst the total deaths of infants under one year from all causes were 128277; this is equal to 10·9 % of the total deaths due to diarrhoea alone. From the other zymotic diseases together the deaths of infants amounted to 8806 or 6·8 %

The mortality due to diarrhoea during the last decennium is shown in this table (1):—

III. Annual death rate per 1000 living from diarrhoea in the third or summer quarters of the years 1880-90 in 28 great English towns.

England & Wales.	1·8	Leicester	6·1
28 Great towns	2·8	Preston	6·6
50 other towns	1·9	Salford	4·4
England & Wales exclusive of 78 towns	1·1	Leeds	3·9
		Hull	3·8

(1) Registrar Generals Reports for 1890. Table IX.

It is clear therefore that though the disease or diseases which are grouped under the general term of "diarrhoea" causes a high death rate amongst people of all ages, yet its greatest ravages are confined to children under twelve months.

If then diarrhoea causes such an enormous loss to our population by removing so many infants, what must be the amount of sickness and ill-health which it produces? Of this we can have no idea. The term diarrhoea being a vague one, we cannot, by knowing the number of deaths from it, calculate how many may have suffered from it, as we can roughly tell in the case of some fevers as typhus and smallpox where the rate of mortality in each epidemic is known. It must however be enormous and its effects incalculable: and this too amongst an utterly helpless part of the community.

It behoves us all therefore to bestir ourselves and try if, by any means in our power, we cannot remove the cause or causes of this great infantile mortality.

Diarrhoea is of course, as we all know, merely a symptom; but all authorities agree however in stating that its most fertile cause is due to improper feeding or unsuitable food. The continual irritation of the delicate gastro-intestinal mucous membrane by such food may cause so active an intestinal peristalsis that the food is hurried along the whole length of the alimentary canal and ejected before it has been digested (the so-called lientary). On the other hand the irritation may set up a catarrhal condition of the intestinal mucous membrane and thus diarrhoea results. Moreover the child is frequently so debilitated, owing to the improper food, that he is unable to resist any slight aggravating cause, such as chilling of the body (as happens so often after the child is put into "short-clothes") and in this way he may succumb to the diarrhoea which has been set up.

The rickety condition is usually caused by improper feeding alone or associated with bad hygienic conditions. In children so affected the mucous lining of the alimentary tract is very irritable, and severe and

frequently fatal attacks of diarrhoea are very liable to occur.

I have used the terms "injudicious" or "improper food" several times. What do they mean?

Very often an infant suffers from diarrhoea even when nursed by his mother, and this may even have continued from birth. The child is shrivelled and puny. In such cases we may find that the child is being starved and that the milk which his mother secretes is of so poor a quality that it does not constitute a sufficient food. If such a child be put to wet-nurse or on a properly prepared artificial diet, he rapidly improves and puts on flesh. Were we to allow him to be nursed by his mother he would be having an "improper food." Again, pure cow's milk may be given to an infant. Soon afterwards diarrhoea commences and continues while such milk is given. If however it be diluted with lime-water, the diarrhoea soon ceases. Pure cow's milk would be an injudicious diet for such a child.

Bread and milk, corn flour, arrowroot and other farinaceous foods are certainly improper foods for young children; but of this we shall speak later on.

In the majority of cases the mother nurses her child for five or six months and then it is weaned. Amongst the poorer classes however the child is nursed a much longer time - nine to twelve months. This transition period between mother's milk and artificial food is a trying time for the child, and if a suitable food is not selected for him, diarrhoea is very apt to follow and thus "wasting" often commences at this time; so much so is this the case that the name of "atrophia lactantium" is given to the Emaciation so often seen in the recently weaned.

We find frequently that amongst the poor the period of lactation is most unduly prolonged for twelve to fifteen months. A child above twelve months old so fed, has, most undoubtedly, "injudicious food," and it is amongst such children that we meet with rickets, simple atrophy (marasmus) and diarrhoea. Corbeau records the case of a woman who had been

nursing for twelve months and whose milk, when analyzed, was found to contain only a trace of casein. The child who had been wasting on this milk, soon improved when put on suitable diet (1)

In 1880 there died in England and Wales from diarrhoea 29 519 persons; of these 18 440 or 62·5 % were infants under one year, and 25 998 or 88·1 % children under five years. Of the 18 440 infants who died from diarrhoea 29·5 % were under three months; 31·5 % were over three but under six months; while 39 % were above this. "As there are more infants living under three months than over three and under six months, it appears that diarrhoea is not so destructive of infants in the first as in the second three months of life, which may with probability be ascribed to the greater prevalence of "feeding by hand" after this period of life" (2)

Without any doubt whatever, the chief cause of infant mortality is mismanaged hand-feeding. It is a well-known fact that the mortality of infants is greatest amongst the

(1). Corbeau - Archives of Pediatrics, Philadelphia. Feb. 1890.
(2.) Newsholme. "Elements of Vital Statistics" 1889 p. 189.

poorer classes, and is certainly due to the inexperience or neglect of the mothers as regards the proper feeding of their infants. In many cases the mother is too poor to devote the whole of her time to the nursing of her child; so, after having suckled it for one or two weeks, she weans it partly or entirely, and it is then given in charge to some female to be hand-fed while the mother goes to work. The children, and many are treated thus, during the day are fed on badly prepared cow's milk, and which is often in a state of incipient decomposition owing, most frequently, to imperfect cleansing of the feeding bottle and this is specially true in the summer time. Many again are fed partly or entirely on one or other of the many preparations called "infants' food." A great many of these consist entirely (as I shall show further on) of farinaceous materials and form a most injudicious diet; others, though undoubtedly good, are improperly prepared, or are used at so early a period of the infant's life that its digestive powers are unable to put such food to proper use. Instead of therefore affording a nourishing article of diet, such foods only act as irrit-

ants and produce gastro-intestinal disturbance, vomiting and diarrhoea and only too frequently have a fatal termination.

The number of children under one year who die in country districts is very much less than the number of those who die in the larger towns This is exhibited in the following table:—

IV. Death Rate per 1000 from Diarrhoea in different Populations.

	1885	1886	1887
Rural districts	0·34	0·63	0·50
England & Wales	0·49	0·88	0·69
50 towns	0·47	0·98	0·74
28 Great towns	0·69	1·16	0·97
London.	0·66	0·95	0·90

The same is also seen in Tables I and III. These tables show how unhealthy life must be in a large manufacturing city like Liverpool to infants under one year. After the end of the first month the mortality of the urban district (I Table) is more than twice that of the rural and this ratio goes on increasing till, at the eleventh month, it reaches so high as to be five times as great.

In the town, we may note, that the mortality decreased gradually from the first month to the fifth, but after this it increased. This is caused no doubt by the gastric and intestinal troubles ensuing on the eruption of the teeth and the want of proper care and feeding at this time. The health of the country districts on the contrary, must depend on the good hygienic conditions, the healthiness of the mothers and their ability to nurse their children.

Another fact must not be lost sight of, which is, that the rate of mortality from diarrhoea amongst infants during the warm months of the summer and autumn (July, August & September) is very much greater than what it is during the remainder of the year. This is often termed "Epidemic diarrhoea" or Cholera infantum. Apart from the question of there being a specific materies which causes this Epidemic (and of its reality there is abundance of proof), there is the much greater risk of chills at this time of year, and the more rapid decomposition of organic matter and specially of milk.(1)

(1.) Dr. Ballard remarks on the great mortality of hand-fed children from diarrhoea during the summer months. See Supplement to Report of Medical Officer of the Local Government Board for 1874

The fermentation begun in the milk is increased in the alimentary tract of the infant. During summer also the child's thirst is greater and is assuaged, not by water, but by milk. The stomach consequently is apt to get overloaded, and fermentation is still more prone to occur. If this is sufficient to set up gastro-intestinal catarrh in a healthy child, it will be much more liable to do so in a delicate child or one enfeebled from receiving improper food.

It may be thought that I am giving too much prominence to this one symptomatic disease; my object however is to draw special attention to the great fact, that improper food is the chief cause of this most fatal disease in children - viz. diarrhoea. We have only to think of the enormous number of children's deaths which are registered under the general terms of "Convulsions," "Marasmus", "atrophy", "gastric catarrh", "Constitutional diseases" &c., to have forcibly brought to our minds the fact that an overwhelming proportion of these diseases are brought on and kept up by injudicious feeding. It is to this lamentable (may we not even call it criminal?) cause that our enormous infantile mortality is chiefly due, and one which, it might be thought,

would be easily remedied. The food which the infant ought to have is withheld in ignorance or apathy and that which is given, instead of affording nourishment, becomes the most powerful agent in the destruction of the child. If it be not itself the direct cause of death, it causes such weakness and consequent loss of resisting power, that the child falls a prey to any constitutional or hereditary disease which may be latent in it, and is also much more liable to be attacked by any of the infectious diseases than would a healthy child of the same age.

My attention was first drawn to this subject by noticing the very large number of infants whom I saw in dispensary and private practice suffering from gastro-intestinal catarrh and general wasting (marasmus, arthrepsia, infantile atrophy). I found that the vast majority of these cases occurred in hand-fed children. The uniformity of the answer to my question regarding the manner of feeding the child struck me forcibly, "On the bottle", being the almost invariable answer.

I find from my own experience, that, when

cow's milk is given, as a general rule for infants under four months, it is prepared by diluting the milk one half. Enough to fill a feeding-bottle is prepared at once and to each bottle about a teaspoonful of cane sugar is added or sufficient to give it a distinctly sweet taste. Very frequently a tablespoonful of lime water is added to each bottle of milk. From the fourth to the eighth month the amount of water is reduced to one-third, till, at about the ninth month, pure cow's milk is given either alone or, more generally, with some farinaceous material added. In a large proportion of the hand-fed however artificial feeding stuffs are used at an early period.

A small proportion of the cases of diarrhoea, wasting &c. occurred in the breast-fed. Many of these children however would evidently have thriven had they been fed by a wet-nurse or given a properly selected artificial food. It was evident that in many of these cases the mother was in such a delicate state of health or so overworked that her lacteal secretion could have had only a small nutritive value for her rapidly growing and actively assimilat-

ing infant. The milk of unhealthy women varies much from the normal standard, as in those suffering from phthisis, syphilis or albuminuria. It has been found that the milk of women suffering from Bright's disease contains a far larger proportion of albuminoid matters than normal milk does, while at the same time the fats and carbohydrates are diminished.

Where the food has been unsuitable the following is a general description of what the mother gives:— At birth the child was healthy and well. He soon began to fall off till he became wasted to a shadow and is even smaller than he was at birth. In spite of the emaciation his appetite is voracious and he always empties his bottle. Soon after being fed he begins to cry, for more food as his mother thinks. She gives him more and then, very soon afterwards, his bowels move. They are far too loose and the diarrhoea in some cases is very severe. He is always moaning, even during his sleep, and his mother is sure he takes "inward fits", which she describes as showing themselves by squinting or turning in of the thumbs and toes. These may be true convulsions or may be only the outward manifestations of intestinal colic which is

common is such cases. This condition gets worse and worse. till you may see the child in an almost moribund condition, lying quite still or feebly moaning. Its complexion shows a dark livid colour and its eyelids are kept half-open. Such is the usual history of a case of chronic wasting and diarrhea in infants due to starvation and irritation of the gastro-intestinal mucous membrane by unsuitable food.

Amongst what are called the "better" (wealthier only?) classes, we know that the mothers are frequently unable to nurse their children owing to deficiency or entire absence of the lacteal secretion. In a much larger number however it is the desire which is absent and not the milk. Again, amongst the "lower" or working classes, though the amount of milk secreted is usually ample, yet in very many cases it is not used as the food for the infant or, if so, only partially. This secretory function is put in abeyance by the mother who, either by necessity is compelled to go out and work for her own and her childrens' living or, as is often the case in large manufacturing towns, she returns to

work through greed of gain having nursed her child for only one or two weeks after its birth. In these cases the woman's wage is often nearly as high as that of her husband and this forms the great inducement to her to cease nursing her child. She often however partially nurses it during the night or when at home during the day in the intervals of work.

Of necessity therefore all these children must be hand fed, for it is only a very small number of infants, and these amongst the wealthier classes, who are put to wetnurse. The great majority of these children are fed on cow's milk or on the various baby-foods.

From data which I collected myself I calculated that one child in every four was brought up on artificial food. I made inquiry however of several gentlemen who have very large obstetric experience as to what proportion of children they thought were hand-fed. One said that in his practice hardly a single woman nursed her child, and if they did it was only for a fortnight. Another said that he was sure the proportion was one to two. None however said that it exceeded one in three. Still that I may not overstate the number thus fed, I will take

it at my own calculation - which is that one child out of every four is brought up artificially.

It is therefore evident that there must be some radical and outstanding defect in such artificial foods, else why should such an enormous mortality follow their use, and of necessity an infinitely greater amount of sickness during their employment? What is it in the artificial food which causes such gastro-intestinal irritation or is so indigestible as to cause starvation of the infant? If cow's milk is the artificial food used, it may be given in too great amount and what is unabsorbed undergoes fermentative changes and so causes irritation. This may also be the reason why infants' foods are harmful. It is however generally said to be due to the starch which they contain. As some of these foods are somewhat troublesome to prepare, it is a common custom to make sufficient in the morning to last the child during the day. Now, if these are made with milk and contain much saccharine material, they are very liable to undergo fermentation in warm weather. When food in such a state is ingested by the infant, these fermentative changes go on with much greater

rapidity in the alimentary canal and give rise to great irritation. It is to the subject of the relative assimilability of the various carbohydrates and their employment as foods for infants that I would direct attention in this paper.

Of course many children may be brought up on almost any kind of food. I have seen many healthy children who, from their birth almost, had been fed on pure cow's milk; others on milk and gruel or bread and milk or with such feeding from the table as they were able to take, as tea, soup, egg &c. Such children had healthy and vigorous digestion; "a healthy child can extract what its system needs from very unpromising materials; but not the child which comes into the world with an impaired physique."(1) It is not for such healthy children that we require to make rules. As in the social world, laws are not made for the law-abiding, but for the lawless; so in Medicine or rather Preventive Medicine, we lay down rules to enable the healthy to continue so and to render the weak strong. All children therefore who are not fed by healthy mothers, who alone can give them their only perfect food, are on treacherous ground; a

(1.) Manual of Dietetics. J. M. Fothergill M.D. 1887.

false step may cause serious or even fatal illness. As I once heard an esteemed teacher of mine say regarding another subject, "pathology is on their tract."

In this paper, the preparation of which has cost me many months' labour, I wish to devote attention particularly to the nature and composition of the carbohydrate constituents of what are known as "Infants" or "Babies' Foods", many of which are patent or proprietary articles of universal repute. Before doing so however it is absolutely necessary that we should investigate the digestion of the carbohydrate elements of our food so that we may be able to lay down rules for infant feeding.

It seems to me that there is a very great deal of loose writing and still looser ideas are prevalent regarding the use of such artificial foods. This is in all probability due to the fact that the constitution of many of these is unknown and of those that are, many practitioners are entirely ignorant. It is therefore a frequent occurrence to find that the child not having thriven on cow's milk, the mother is advised to try a certain baby-food which is specified by name. No improvement resulting from the use of this food another

one is recommended and so on. In many cases a kind of blind experimenting is being tried at the expense of the infant and yielding in the long-run but little information to the practitioner. (1.)

(1). "The proper one (infants' food) for a particular case must always be somewhat a matter of experiment" Dr. J. T. Goodhart. "Diseases of Children" p. 21. 1865.

Dr. Andrew Combe's remarks are well worthy of attention:—

"In a general way we all acknowledge that diet is a "powerful agent in modifying the animal economy; yet from "our conduct it might justly be inferred that we either "regarded it as totally devoid of influence, or remained "in utter ignorance of its mode of operation, being left to the "guidance of chance alone or of notions picked up at "random, often at variance with reason and, it may be, "in contradiction even with our own daily experience." p 10.

..... "When we consider the defective education "and entire ignorance of the human economy, not only of the "nurses and servants to whose care the young are entrusted, "but of the parents themselves our wonder ought to become "greater that so many survive than that so many die" p 220

..... "through pure ignorance and mistaken Kindness "many nurses .... conceiving that the newly-born infant must "of necessity be starving after ... its nine-months' fast, hasten "to fill its stomach with gruel or some other food.

Surely this ought not to be so! Were the question of infant feeding to be looked at from a scientific point of view this might be changed and instead of empiricism we might have proper knowledge and rules to guide us in the management of infant dietary. — a question as I have already shown of infinite importance to the community at large and one which surely, now that we have skilled and scientific practitioners and Medical Officers of Health, we may expect more light to be soon thrown upon.

Apart from the mortality of infants and children from intestinal disorders consequent on injudicious feeding, there is the immense importance of dietetics as regards the many forms of indigestion and diseases of the alimentary tract in adults. Statistics of hospitals and dispensaries prove that affections of the digestive organs form by far the largest proportion of all diseases occurring during adult life. As is well known the cause of these is in most cases unsuitability

"Not unfrequently severe indigestion is thus induced at the "very outset, which in a delicate child may be sufficient to "lay the foundation of much suffering and bad health" p 224. — The "Physiology of Digestion" Edinburgh. 1836.

of food or irregularity in meals; but the former has by far the preponderating influence.

Very many dyspeptics have at an early period of their trouble to give up the use of saccharine foods, as these soon after ingestion cause much acidity, heartburn, nausea &c. In a numerous class of dyspeptics also starchy matters (especially if taken in slight excess) form a source of much uneasiness and cause flatulence and acidity. In the treatment of such affections the management of diet is the chief factor, medicines are only of secondary importance. By proper management of diet and improved hygienic conditions we may therefore hope in the future to extend the scope of Preventive Medicine so as to lessen to a great extent the number of martyrs to gastric and intestinal disorders.

In questions of this kind we must have no preconceived ideas as regards the ease or difficulty of digestion of the foods we are investigating. I therefore made experiments for myself as to the physiological digestion of sugars and starches both by observations on patients and laboratory experiments. Having thus laid a physiological basis, it is easy to lay down rules regarding the nature in which such foods ought to be given so as to be easily assimilated by the infant or invalid.

I will in the first place briefly consider the chemical constitution and changes which the carbohydrates undergo and will then pass on to their physiological digestion.

I have paid special attention to the saccharine elements of the food and so will commence with a consideration of them.

Cane Sugar.

It is only within the last century that the consumption of Cane Sugar has become so general. Till a comparatively recent period its expense limited its use except to the wealthy. With the poor it was formerly almost unknown. When a sweetening agent was desired, honey was the one commonly employed, and thus nearly every cottager kept his beehive, a custom which has now unfortunately fallen into desuetude. The various articles of food used by us every day now, prepared and preserved by the aid of sugar, were to them unknown. Our forefathers had certainly this advantage that they were spared the risks of eating an article which in its natural state is not easy of digestion and prone to undergo fermentation in the stomach. The universal and large use of saccharine matters in these days is no doubt a very powerful factor in inducing many of the forms of dyspepsia with which we are so well acquainted. Our great-grandfathers were undoubtedly much less troubled with indigestion than the present

generation. The increase of gastric disorders is popularly said to be due to an increased civilization (?) and more sedentary occupations. Perhaps the latter is to a certain extent true, but I have not found that these affections are more common amongst our hard brain-workers than amongst manual labourers. In my opinion the prevalence of indigestion amongst us is due to the great complexity of diet which we now make use of. Formerly very plain and natural food was used. Now the gastronomic art has reached a high degree of perfection (indicating increased civilization?) and our food is very complex, and includes a large amount of sugary materials.

As the price of Cane Sugar has decreased so has its consumption greatly increased. According to McCulloch, the amount consumed in Great Britain in 1700 was 10,000 tons. In 1790 it reached 81,000 tons. In 1808, though the duty had risen to 24/- per cwt., 142,000 tons were used; while in 1864 there were imported 551,105 tons or 30 lbs. per head. In 1880 the import had reached the enormous amount of above one million tons. Great

Britain and America are the largest consumers of sugar. In other countries, as France, where the import duty is high, the consumption is proportionately less. In 1890 the sugar imported into Great Britain was 1,225,000 tons, which is equal to a consumption of 47¾ lbs per head.

An article of such universal use as this merits as great attention from the physiologist and sanitarian as it has already received from the chemist.

Chemistry of the Inversion of Cane Sugar.

A solution of Cane sugar (Saccharose - $C_{12}H_{22}O_{11}$) when heated by itself for long or more quickly on the addition of dilute mineral acids becomes, what is termed, "inverted". The solution of Cane sugar originally has the property of retarding one of the two circularly polarised rays of light of which a plane polarised ray is believed to be composed. At any rate it retards one of these rays more than the other, and so the plane of polarization of their resultant as they leave

the solution is not the same as the incident ray, but is deflected to the right. The solution of cane sugar is therefore said to be dextro-rotatory. The degree of this rotation varies with the strength of the solution, being greater the stronger the solution is. When however the solution of cane sugar has been heated with dilute acids instead of turning the polarised ray to the right, it turns it to the left and hence the term "inverted sugar" or as it is sometimes termed "fruit sugar". The degree of this left rotation varies ~~also~~ with the strength of the solution and also with the nature and proportion of the acid used in causing inversion (1.) Cane sugar is inverted still more quickly when it is boiled with dilute acids or even when yeast is added to a warm solution. Yeast before it can produce the alcoholic fermentation of sugar first must invert the cane sugar and this it does by the action of a ferment which it possesses and which can be isolated ("invertin")

Cane sugar during the process of inversion takes up a molecule of water and becomes

(1.) Dubrunfaut "Sur quelques phénomènes rotatoires et sur quelques propriétés des Sucres" Comptes Rendus II p. 38. 1846

changed into a mixture of Equal parts of dextrose and levulose.(1) Some chemists think however that these are not the proportions in which dextrose and levulose occur in invert sugar(2), and it is even said that in addition to these, other optically neutral bodies arise during inversion(3), and that the products of inversion are much more numerous than is generally supposed. To obtain an invert sugar solution with constant properties great care is necessary as regards using a constant temperature, constant dilution and amount of acid added. I have already said that when yeast or malt is added to a warm solution of Cane sugar, the latter becomes hydrated and then split up into dextrose and levulose. If the yeast be allowed to act longer, these two sugars in their turn are split up into alcohol and Carbonic acid.

(1). Bourquelot "Sur la fermentation et la composition du sucre interverti" Comptes Rendus, ⅱ p. 68. (1885)

(2). Petit, A. "Quelques faits observés sur le sucre interverti" Ibid ⅱ p 1008. (1869)

3. Maumené, E. "Faits observés sur le sucre interverti," Ibid ⅱ p 1242. (1869) "Etudes sure le sucre interverti" Ibid ⅰ p 1139 (1875) "Les éléments du sucre interverti" ⅰ p 336. (1876)

Guiard et Laborde "Sur l'inactivité optique du sucre reducteur" Ibid ⅰ pp 214 + 417. (1876)

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6 \quad (1)$$

Cane Sugar — Dextrose — Levulose

$$C_6H_{12}O_6 + 2H_2O = 2C_2H_6O + 2CO_2 + 2H_2O$$

Dextrose — Alcohol.

A solution of cane sugar if left exposed to the air or to sunlight for some days undergoes partial inversion. The longer it is so exposed the more sugar becomes inverted.(2) Some think that it is the water itself which induces the inversion, others that it is due to the influence of moulds growing in the solution.(3) Béchamp finds that if moulds already well-developed are introduced into the solution inversion takes place much more rapidly. If antiseptics are added however, the growth of the mould is stopped and then no inversion occurs.

(1.) Hoppe-Seyler "Ueber Gährungsprocesse" Zeitschrift für Physiologische Chemie Bd II. p 1.
Lesplay H. "La fermentation alcoolique élective du sucre interverti" Comptes Rendus ii p 479 (1885)

(2.) Marmené, E. "De la transformation que le sucre de cannes éprouve par l'action de l'eau pure, et de ses conséquences dans l'analyse des sirops" Ibid ii p 914 (1854).

(3). Béchamp "Du rôle des moisissures et de l'action personelle de quelques sels dans la transformation de ce composé" Ibid i p 321 (1864)

Raoult[1] has found on the contrary that inversion takes place without the aid of ferments. Having boiled a solution of cane sugar he hermetically sealed it in glass tubes. Those tubes exposed to the light in five months became half-inverted; while others kept in the dark for a like period showed no inversion. If the solution of pure cane sugar is kept at a warm temperature however the rapidity of inversion is much increased.[2] When heated with acids the inversion is very rapid. The mineral are much more powerful and rapid in their action in this respect than the organic acids; and of the inorganic, sulphuric acid is the most potent of all. The various acids differ much in the rapidity with which they cause inversion; thus for sulphuric acid a proportion of $\frac{2}{1000}$ suffices for the complete inversion of a solution of equal parts of cane sugar and water, after 45 minutes' boiling; while it requires for tartaric acid a proportion of $\frac{1}{100}$ and one

(1). Raoult, F. M. "Transformation du sucre de canne dissous en glucose, sous l'influence de la lumière" Comptes Rendus T p 1049 (1871)

(2). Durin "Sur quelques causes d'inversion du sucre de canne et sur les alterations consécutives des glucoses formés". Ibid T" p 754 (1878)

hours boiling.[1] The organic acids are not nearly so powerful and take a much longer time to cause complete inversion.[2] In all cases however the higher the temperature to which these acid solutions are raised so is the rapidity of inversion increased. Neutral salts, even with an acid reaction, have little or no action in hastening inversion[3]

In the sugar cane, beetroot, and other plants where Cane sugar occurs, inversion takes place through the aid of a ferment, before the plant can make use of the sugar.

(1.) Klein & Fréchon "Le sucrage des moûts" Comp. Rend ṫ p 511 (1887)

(2). Berthelot "De l'action exercée par les acides, par la chaleur, et par les chlorures alcalins de terreux ..... sur le sucre" Comp. Rend. ṫ p 799 (1852)

" "Recherches sur les sucres" Ibid ẗ p 533 (1886)

Maumené " Ibid.

(3). Béchamp "De l'influence que l'eau pure et certaines dissolutions salines exercent sur le sucre de canne". Comp. Rend. ṫ p 435 (1855)

" " De l'influence que l'eau pure ou chargée de divers sels exerce à froid sur le sucre de canne" Ibid ṫ p. 44. (1858)

(4) Fleury. G. "Recherches sur l'inversion du sucre de canne par les acides et les sels." Ibid ẗ p. 823 (1875)

Dextrose, glucose or grape sugar (because it occurs largely in the grape) is a crystallisable sugar. It rotates the plane of polarised light to the right and the degree of this rotation does not vary with the temperature of the solution nor with the acid used.(1) It is not so sweet as cane sugar and is much less soluble in water.(2)

Levulose or fructose on the other hand is a colourless uncrystallisable syrup as sweet as or even sweeter than cane sugar. It has the property of turning the plane of polarization to the left. Its specific rotatory power is far greater than that of glucose and consequently even though these two sugars exist in equal amounts in invert sugar, the plane of polarization lies to the left. The rotation due to levulose varies with the temperature. If high, the degree of rotation is much diminished. There is a definite degree of rotation for each acid as

(1). Jodin "Recherches sur les modifications du pouvoir rotatoire des sucres." Comptes Rend. I p. 613 (1864)

2. Franchimont "Sur le glucose" Ibid II p. 713. (1879)
Peligot, E. "Sur quelques propriétés des glucoses" Ibid II p 918. (1879)

Biot[1] has shown as well as for each temperature.[2] Jungfleisch, Lefranc and Grimbert[3] have obtained levulose in a crystalline form as colourless, very hygroscopic needles. They say that the rotatory power of pure levulose is much modified by the action of mineral acids as hydrochloric, or sulphuric acids; while organic acids have no effect in modifying its rotation. Pure glucose treated thus has its rotatory power unchanged. Thus in inverting a solution of Cane sugar by the mineral acids, the levulose produced becomes acted on and its rotatory power changed by the acid. If however we cause inversion by the

(1). Biot. "Sur le degré de précision des caractères optiques dans leur application à l'analyse des matières sucrées" Comptes Rendus. p. 693 (1842)
" "L'application des propriétés optiques à l'analyse quantitative des mélanges liquides ou solides --- ou le sucre de canne est associé à des sucres uncristal." Ibid p. 619 (1843)

(2). Clerget. "Les moyens de simplifier l'analyse des sucres et liqueurs sucrées, par la lumière polarisée" Ibid p 1138 (1846)

(3). Jungfleisch et Lefranc "Sur le lévulose" Ibid T II p. 547 (1881)
" Et Grimbert "Sur le sucre interverti" Ibid T I p. 144 (1889)
" " " "Quelques faits relatifs à l'analyse des sucres" Ibid T II p. 867 (1889)

organic acids (as acetic) the resulting liquid has constant rotatory powers even on heating. It is said that levulose got by the ordinary processes from cane sugar is not identical with crystallised levulose.(1) This sugar ferments less easily than glucose, but it is very difficult to get levulose unmixed with glucose. Dubrunfaut has shown however that levulose forms with lime an insoluble crystalline compound and can in this way be separated from invert sugar.(2) The suboxide of copper is not precipitated from an alkaline solution of tartrate of copper by boiling with a solution of pure cane sugar, unless the ebullition is carried on for a long time. With invert sugar however the copper oxide is at once reduced from its alkaline solution and this forms one of the best tests for glucose or levulose.

(1). Jungfleisch et Grimbert - see preceding page.
(2). Dubrunfaut "Méthode de séparation du lévulose et du sucre interverti" Comp. Rend. 11 p.1366 (1869)

Chemistry of Starches.

Starch or Fecula. The composition of this may be represented in its simplest form by $C_6H_{10}O_5$. Actually, it is thought however to be a multiple of this, and $n(C_{12}H_{20}O_{18})$ represents it better, where n is unknown, though probably never less than five or six.

When starch is heated by itself or, as mucilage, if boiled with dilute acids (1) or when acted on by diastase, it becomes changed into an isomeric body, dextrin. There are many varieties of dextrin. The one which is first formed is termed soluble starch or amylodextrin. As dextrination proceeds, erythrodextrin is formed, and still later the achroodextrins appear. If ebullition with acids be continued for long or if diastase be allowed to act long enough on the dextrine it becomes hydrated and changed into maltose;

(1). Bondonneau "De la saccharification des matières amylacées" Comp. Rendus ii p. 972 (1875)
" et Foret " De la saccharification directe par les acides de l'amidon" Ibid ii p. 617 (1887.)

which lastly becomes converted into glucose[1] ($C_6H_{12}O_6$) by the continued action of diastase (though this is denied by some) or dilute acids on Maltose[2]

When a solution of iodine is added to starch a deep blue colour is produced.[3] Soluble starch however gives a violet colour with iodine when in solution; if dry however a yellow, violet or brown colour results. Soluble starch is only soluble in warm water but not in cold, and the starch granules still preserve their shape.[4] As the process of destination proceeds this violet colour becomes purplish-red and then red, showing the presence of erythrodestrin. Even when dry erythrodestrin.

(1). Flourens "Sur les produits de la saccharification des matières amylacées par les acides" Comp. Rend 7 p 1204 (1890)

(2). Musculus & Gruber "Ein Beitrag zur Chemie der Stärke" Zeitschrift für Physiol. Chemie Bd II p. 177 (1878)
Mering, von. "Ueber den Einfluss diastatischer Fermente auf Stärke, Dextrin, und Maltose" Ibid. Bd V. p 122 (1881)

(3) Mylius. F. "Ueber die blaue Jodstärke und die blaue Jodcholsäure". Ibid Bd XI. p 306 (1887)

(4). Musculus "Sur la constitution chimique de la matière amylacée" Comp. Rendus T. 68. p 1267 1869

still strikes a red colour with iodine. It is also soluble in cold water.

This red colour gradually becomes lighter till at length we get no colour on adding a solution of iodine. This shows that we have reached the stage of achroodextrines. There are many varieties of achroodextrine which differ from one another in their different rotatory and reducing powers.(1) The first formed (achroodextrin α) gives of course no colouration with iodine but can still by the action of diastase be changed into glucose as also happens with erythrodextrin and soluble starch. On the other hand, achroodextrin β and γ and maltose remain unchanged by diastase (This also is denied)

The formation of the dextrines may be explained thus:- The constitution of Soluble starch is more probably represented by the formula $C_{120}H_{200}O_{100}$. Under the influence of the diastase of malt, it assimilates a molecule of water and so forms a molecule of maltose, the rest going to form

(1). Musculus & Gruber - Ibid.

Grimaux et Lefèvre "Transformation des glucoses en dextrines" Comp. Rendus. ii p 146 (1886)

Petit, P "Sur la formation des dextrines" Comptes Rendus i p. 76 (1892)

Erythrodextrin α [1].

$$C_{120}H_{200}O_{100} + H_2O = C_{12}H_{22}O_{11} + C_{108}H_{180}O_{90}$$

(Soluble starch) (Maltose) (Erythrodextrin α)

On further hydration another molecule of maltose is formed and erythrodextrin β which has a less molecular weight than α

$$C_{108}H_{180}O_{90} + H_2O = C_{12}H_{22}O_{11} + C_{96}H_{160}O_{80}$$

(Erythrodextrin α) (maltose) (Erythrodextrin β)

Similar actions occurring we get achroodextrin.

$$C_{96}H_{160}O_{80} + H_2O = C_{12}H_{22}O_{11} + C_{84}H_{140}O_{70}$$

(erythrodextrin β) (Maltose) (achroodextrin)

There seems to be a difference of opinion amongst chemists as to the further changes which occur. Some say that the higher achroodextrines and maltose are unaffected by the continued action of diastase [2]; while others say that the hydration process goes on till only maltose is left, and that each of its molecules in turn becomes hydrated through the continued action of diastase or dilute acids, thus giving two molecules of Grape sugar [3]

$$C_{12}H_{22}O_{11}\text{(Maltose)} + H_2O = 2\,C_6H_{12}O_6\text{ (dextrose)}$$

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(1). Brown & Heron - Journal of the Chemical Society. Vol 35 pp 620.654.

(2). " " " " " " " " p 648 (1879)

Proceedings of the Royal Society p. 373 (1880)

(3). Musculus & Gruber. Ibid.

Lindet (1) agrees with Payen in stating that the conversion of starch into maltose by diastase is never complete, the maltose itself stopping the action when it has accumulated to a certain extent. There is consequently always dextrin present, he says, unless the maltose is removed as it is formed.

The rapidity of the conversion of starch by acids depends on their strength. Many hours elapse before complete conversion if the acid be very dilute. As the strength of the acid is increased so is the time diminished. Diastase however acts very quickly and converts the starch mucilage in a few minutes and this at a low temperature. (7½°). In plants, starch forms a store of reserved material. Thus, in the seed it forms the supply of nourishment till the young plant can support itself as germination proceeds, the starch is gradually used up as, under the influence of the diastase, it is converted into dextrin and glucose, soluble substances which are conveyed through the plant and help to build up its structure.

(1) Lindet. "Observations sur la saccharification par la diastase" Comptes Rendus. T p. 453. (1889)

Digestion of Cane Sugar.

In what form is sugar absorbed into the body of the animal? Is it as Cane sugar ($C_{12}H_{22}O_{11}$) or is it as glucose, levulose ($C_6H_{12}O_6$) or maltose? What is the action of digestion on Cane sugar?

In order to answer these questions we must first find what actions the various digestive secretions have on Cane sugar.

Action of Saliva on Cane Sugar.

Beginning with the first digestive fluid which we meet with, the inquiry is, if the salivary secretion has any inversive action on cane sugar, for almost all physiologists agree that cane sugar before it can be absorbed must first undergo inversion. Some writers consider that the saliva has an inverting action (1), while others deny that it has any (2).

I have already shown that when a solution of Cane sugar is heated by itself it undergoes a slow conversion. To estimate the amount of this inversion I placed a vessel containing a 20 % solution of pure Cane sugar in a water bath at a constant

(1). Richet. Ch. "Du suc gastrique chez l'homme et les Animaux" p. 116 (1878)

(2). Hoppe-Seyler. "Physiologische Chemie" p 188. Berlin (1881)

temperature of 38° C (body heat). The sugar solution was made by dissolving 200 grms. of pure dry cane sugar in distilled water and diluting to a litre. Such a solution produces no precipitation of suboxide of copper on boiling it with Fehling's solution and with the polariscope of Zeiss it gives a rotation of +27.2°.

After being heated thus for <u>one</u> hour it gave (after being cooled) a rotation of +26.65° and the amount of invert sugar estimated by Fehling's solution was 0.19 %. After being heated for <u>two</u> hours, the invert sugar amounted to 0.252 % and the rotation +25.7°. These observations were repeated several times and gave corresponding results.

1. 20 % Solution of Cane Sugar at 38° C.

	Rotation	Per cent. invert sugar.
One hour.	+26.65°	0.19
Two hours.	+25.7°	0.252.

This forms the <u>control experiment</u> and shows the amount of inversion which a 20 % solution of Cane sugar undergoes after one and two hours exposure to the normal body heat.

To try if the Saliva had any inversive action on Cane sugar, I performed the following experiment.

Equal volumes of human salvia (mixed) and 40% cane sugar solution were mixed together, thus giving a 20% solution of cane sugar, and placed in several beakers in the water bath at 38° C.. In 30 minutes there was no perceptible inversion. In 45 minutes a trace of invert sugar was manifest by the reduction of copper and in one hour the amount of invert sugar was 0·2 %, while after two hours it reached 0·27 %. The amounts in this case are so nearly similar to those obtained by heating the sugar solution alone that I think it clearly demonstrates the fact that normal human salvia has practically no influence whatever in hastening or retarding the inversion of cane sugar. It seems to be perfectly passive as regards inversion. In other experiments conducted on similar lines, almost identical results were obtained.

2.

Equal vols. of Cane Sugar (40 %) and Human Salvia at 38° C (= 20 % Cane Sugar.)	
Time	Per cent invert sugar.
One hour	0·2
Two hours	0·27

Gastric Digestion of Cane Sugar.

The next digestive fluid which we have to investigate is the gastric secretion. Cane sugar reaches the stomach unchanged. Does it undergo any change here?

Some think that cane sugar is absorbed unchanged and that after its entrance into the portal vessels it is transformed into glucose through the agency of a ferment existing in the blood.(1) From its solubility and diffusibility Pavy(2) thinks that it does not need any digestion to aid its absorption, but merely requires solution so as to pass into the bloodvessels. He is inclined to believe however that, though it requires no digestion, yet it is converted into grape sugar, if not wholly, certainly in part, before leaving the alimentary canal. Bouchardat and Sandras(3) say that under the influence of the gastric

(1). Drosdoff, Dr. W. "Ueber die Resorption der Peptone, des Rohrzuckers, ---- und ihren Nachweis im Blute der Vena Portae" Zeitschrift f. Physiol. Chemie Bd I p. 216 (1877)
" "Vergleichende Chemische Analyse des Blutes der Vena portae und der Venae hepaticae" Ibid p 233.

(2) Pavy, Dr. F.W "A Treatise on Food & Dietetics" 1874

(3) Bouchardat et Sandras "De la digestion des matières féculentes et sucrées, et du rôle que ces substances jouent dans la nutrition" Comp. Rendus T p 143 (1845)

juice and of the living membranes cane sugar is changed into inverted sugar and lactic acid and so absorbed and that it must be inverted before it can be absorbed and used up in the blood.

The great action of gastric juice is on proteids which it converts into diffusible peptones through the agency of the ferment pepsin acting in an acid medium. Besides this it contains also a milk-curdling ferment and, according to Hammersten,(1) there is also a lactic acid ferment, which acts on milk sugar. In opposition to this latter opinion is the fact that a pure solution of lactose does not undergo fermentation under the influence of the gastric juice.(2) On fats the gastric juice has little action. It dissolves the envelopes of the fat cells and thus allows the particles of fat to run together into masses.

Acidity of the Gastric Juice.

The acidity of the gastric secretion is now universally believed to be due to free hydrochloric acid. This was first conclusively proved by Bidder and Schmidt,(3) who, in a measured quantity of gastric juice, estimated the entire chlorine and the entire bases, reckoning them

(1). Hammerston - Jahresbericht f. Thierchemie 1872.
(2). Richet. "Du suc gastrique" p 107.
(3). Bidder und Schmidt "Die Verdauungssäfte und der Stoffwechsel". Leipzig (1852)

all as chlorides, and found that there was more chlorine than would be required to convert the bases into chlorides. The excess of chlorine could only exist as free hydrochloric acid and this usually amounts to two or three per mille. Richet (1) thinks that hydrochloric acid is the only mineral acid present and that it forms on an average 1.7 grms. per mille. This acid is perhaps best estimated quantitatively by Sjögvists' (2) method. It is said that in the first stage of digestion, even though the contents are strongly acid, no free hydrochloric acid can be found. The period when free hydrochloric acid appears varies in different

(1). Richet. "Sur l'acidité du suc gastrique de l'homme" Comptes Rendus. T p. 450 T. 84. (1877)
"De la recherche des acides libres du suc gastrique" Ibid p. 1514.
"De la nature des acides du suc gastrique" Ibid II p 155
"Sur l'acide du suc gastrique" T. 86. T p. 676. (1878) &c.
Bernard. Cl "L'acidité du suc gastrique" Comptes Rendus de Biologie T. IV. 6me série p. 244. (1877)
Reoch. J. M. B. "The acidity of Gastric Juice," Journal of Anatomy and Physiology p 274. (1873)

(2). Sjögvist. J. "Eine neue Methode, freie Salzsäure im Magensaft quantitativ zu bestimmen." Zeitschrift für Physiologische Chemie. Bd 13. p. 1. (1889)

persons and with the diet. After breakfast it does not occur till three-quarters to one hour afterwards; while after a full dinner it does not appear for two hours.(1)

Lactic acid is also said by some to exist normally(2) in gastric juice and to be fairly constant in amount; and though it may increase towards the end of digestion it never reaches one per mille(3). Laborde(4) even asserts that lactic acid is the only acid which the gastric juice contains and that hydrochloric acid does not exist in it.; while Blondlot(5) states that the acidity results from the presence of acid phosphate of lime.

(1). Velden. Dr. R. von den "Zur Lehre von der Wirkung des Mundspeichels im Magen" Zeitsch. für Physiol. Chemie Bd. 3. p 205 (1879)
" "Ueber vorkommen und mangel der freien Salzsäure im Magensaft." Deutsch. Archiv. f. Klinis. Med. Vol 23. p. 369. (1879)

(2). Szabó, D. "Beiträge zur Kenntniss der freien Säure des menschlichen Magensaftes" Zeitsch. f. Physiol. Chem. Bd. I p. 140 (1877)
Catrin. "Les acides de l'estomac" Arch. Génér. de Méd. T. I. pp. 455. 584 (1887)

(3). Rosenheim. "Ueber die Säuren des gesunden und Kranken Magens bei Einführung von Kohlehydraten" Virchows. Arch. Bd III. p. 414. (1888)

(4) Laborde "Reaction montrant qu'il n'y a pas d'acide chlorhydrique dans le suc gastrique." Comp. Rendus de Biol T. 4 p. 285. 1877.

(5) Blondlot "Traité analytique de la digestion" Paris (1843)

Free hydrochloric or lactic acids can very seldom be detected in the stomach of infants. Volatile organic acids are also said by some to be constantly present in small amount.(1) Of the total acidity which one estimates in the gastric juice during digestion, only a very small amount may be due to free hydrochloric acid, the greater part being due perhaps to acetic, butyric or lactic acids.(2) It is even said that hippuric acid is the chief acid during full digestion (2)

Dalton,(3) Leube (4) and others state that outside of the body Cane sugar is slowly inverted into grape sugar by the gastric juice. It is affirmed however

(1) Cahn & von Mering "Die Säuren des gesunden und kranken Magens" Deutsches Archiv f. Klinische Medicin Bd 39. Hefl. 3+4.

(2) Poulet V. "Nouvelles recherches expérimentales sur les principes acides du suc gastrique et sur celui du suc intestinal". Archives de Physiologie Normale et Pathol. Vol II. 4me serie p. 201 (1888)

(3). Dalton, J. C. "On the gastric Juice and its office in Digestion." American Journal of the Medical Sciences. p 318 (1854)

(4) Leube, Prof. W. "Ueber die Veränderungen des Rohrzuckers im Magen des Menschen." Archiv. fur. Pathol. Anatomie and Physiologie, von Dr. Virchow Vol 88 p. 222 (1882)

by Laborde[1] that Cane sugar is not inverted by gastric juice to the same amount as by a solution of hydrochloric acid of the same strength. If a trace of this acid however be added to the gastric juice it becomes more ready to cause inversion than the dilute hydrochloric acid solution alone Leube states exactly the reverse. Brown-Sequard,[2] Schiff[3] and Smith[4] agree in stating that Cane sugar is inverted in the stomach; and Bourquelot[5] thinks that it is partly inverted in the stomach, but that part passes directly into the blood and is there inverted by the carbonic acid.

On the other side, we have Matthew Hay stating that he could find no inversive ferment in the gastric

(1) Laborde. "Nouvelles recherches sur l'acide libre du suc gastrique" Mémoires lus à la Soc. de Biolog pend. 1874. p. 63 (1875) or in Gazette Méd. de Paris, p. 399 (1874)

(2) Brown-Séquard & Smith "Expériences sur la transformation de l'amidon en glucose dans l'estomac" Journal de la Physiologie. Vol I. p 158 (1858)

(3) Schiff "Leçons sur la physiologie de la digestion. Vol II. (1867)

(4) Smith, Dr. T. G "Expériences sur la digestion" Jour. de la Physiologie Vol I p 144 (1858)

(5) Bourquelot "Recherches sur les propriétés physiologiques du maltose" Comptes Rendus T. 94 II pp. 1000 & 1322 (1883)

mucous membrane, and Frerichs[1] that cane sugar is not inverted even if left in the gastric juice for from twelve to thirty-six hours; while Blondlot[2] believes that it undergoes no change during its stay in the stomach. Richet[3] agrees with Laborde in stating that unless he added hydrochloric acid to gastric juice he got no inversion of Cane Sugar. He believes that there is really no free hydrochloric acid in the gastric juice but that it is always combined with Leucine or some other organic body in the mucous membrane. It is on account of this that in normal conditions, the gastric juice does not act on sugars. He even states that the ingestion of Cane sugar diminishes the acidity.[4] Dalton[5] affirms that it cannot be shown that Cane sugar undergoes any inversion during

(1) Frerichs "Die Verdauung" in Wagners Handwörterbuch der Physiologie. Dritter Band, Erste Abtheil. (1846)

(2) Blondlot. "Traité Analytique de la Digestion

(3) Richet "Du suc gastrique

Salkowski "Ueber den Begriff der freien und gebundenen Salzsäure im Magensaft" Virchows Arch. Bd 122. p. 235 (1890)

(4) Richet "Sur l'acidité du suc gastrique de l'homme." Comptes Rendus T. 84. p 450 (1877)

(5) Dalton - Ibid.

Finkler & Rühle "Ueber Verdauungsprodukte des menschlichen Magens" Berlin. Klin. Wochensch. p 365 (1884)

ordinary digestion, and that if taken along with other food there is probably none of it changed into glucose in the stomach. Kühne (1) and Hermann (2) make similar statements, and Leube (3) comes to a similar conclusion. In the healthy stomach, he says, no inversion of Cane sugar occurs; but if dilated a considerable inversion takes place.

Weak acids as I have already shown, added to a warm solution of Cane sugar hasten inversion.

To estimate the amount of inversion which a dilute acid would cause I performed the following experiments.

To 100 c.c. of a 20 % solution of Cane sugar I added 0·2 c.c of hydrochloric acid (pure) and placed the vessel in a water bath at 38° C. In this and every other experiment I estimated the acidity by neutralising the acid fluid with a <u>centinormal</u> solution of caustic soda, using an alcoholic solution of phenolphthallein as the indicator of neutrality. This 0·2 % solution of hydrochloric acid is neutralised by a solution of caustic soda equal to $\frac{N}{62.5}$ - a fraction of

(1) Kühne, Dr W. "Lehrbuch der physiologischen Chemie" Leipsig (1868.)

(2) Hermann L. "Handbuch der Physiologie der Absonderung und Aufsaugung" Bd 5. 2ᵗ part. (1883)

(3). Leube - ut supra.

the normal solution of soda. After one hour when cooled and examined it gave a rotation of +25.2° and contained 0.37 % of invert sugar; while after two hours the rotation was + 23.5° and invert sugar 0.45 %. If we subtract from these the amount of sugar which is inverted when the 20 % solution is heated alone, we find that, after one hour the hydrochloric acid has caused an increase of inversion 0.18 % and after two hours 0.198 % or nearly one-fifth more.

3.

Amount of Cane Sugar inverted after simple (38°) heating and with 0.2 % Hydrochloric acid

	Polariscope		Per Cent Invert Sugar.	
	1 hour	2 hours	1 hour	2 hours
Heat alone	+ 26.65	+ 25.7	0.19	0.252
Heat + 0.2 HCl	+ 25.2	+ 23.5	0.37	0.45
Difference due to the acid	1.45	2.2	0.18	0.198

This experiment shows that in a 20 % solution of Cane sugar about $\frac{1}{45}$ of the sugar is inverted after being heated for two hours at 38° C. and with an acidity corresponding to the normal acidity of the gastric juice.

Behaviour of healthy Gastric secretion to Cane Sugar.

I then experimented with the gastric secretion from a patient with perfectly normal digestion. The mode of obtaining the gastric fluid was as follows. At 8 a.m. the patient had breakfast of porridge and milk. At 10 a.m. I washed out the stomach thoroughly and then injected three ounces of dilute liquor Carnis (Caffyn). Introducing the stomach tube an hour later, I drew off the gastric contents and used this, after filtration, as I had done with the 0.2% solution of hydrochloric acid. The liquor carnis contains no substance which has any reducing effect on alkaline solutions of copper.

The initial acidity of this gastric fluid was Equal to $\frac{N}{24}$ (N = normal solution of caustic soda) Into a vessel I placed 10 c.c. of each of the following:- the gastric fluid, water and 20% solution of Cane sugar. The acidity of this mixture was $= \frac{N}{71}$. after being kept for one hour at 38° C. there was a tolerably large amount of invert sugar present, which amounted to 0.83% after two hours.

4.

10 c c healthy gastric fluid
10 c c water
10 cc 20% Cane S. Sol
} $= \frac{N}{71}$ { Invert sugar 2 hrs = 0.83 %

To see if the gastric juice had a greater or less effect in inverting cane sugar than a pure solution of hydrochloric acid of similar strength, I made a solution of hydrochloric acid of an acidity equal to that of the gastric fluid which I had just used. Equal volumes of this acid solution, water and 20 % Cane Sugar solution were kept at 38° C. In two hours the invert sugar amounted to 0.66 %

5. 10 cc Solution of HCl = $\frac{N}{24}$
10 cc Water
10 cc 20 % Sugar Solution
} = $\frac{N}{71}$ { Invert Sugar 2 hrs = 0.66 %

This experiment shows that the healthy gastric fluid has a greater inverting power than a solution of hydrochloric acid of similar strength. This is in accordance with the statement of Leube, that inversion is less quick and energetic with acid solutions than with gastric juice; but is opposed to that of Laborde, that the inverting power of gastric juice is less than that of hydrochloric acid diluted to the same degree of acidity.

If we compare this last experiment (5) with that of the Cane Sugar solution with 0.2 % of hydrochloric acid added (3) we see, that, as we dilute the solution of Cane sugar the inversion is greater,

the acidity also being less in the last case. A weaker acid is Equal to a stronger one if the solution of sugar be at the same time diluted.

It has been supposed that there is an inverting ferment in the stomach which changes Cane sugar. Is this so, or is the inversion of Cane sugar in the stomach simply due to the acidity of the gastric juice? I made the following experiment in order to see if an inversive ferment exists in healthy gastric juice.

Into a vessel I placed Equal volumes of healthy gastric fluid, water, and 20 % solution of Cane sugar, and then carefully neutralised the mixture by adding a solution of caustic potash. I used specially prepared and very sensitive litmus paper to test the neutrality. Having done so, the mixture was kept at 38° C. If an inversive ferment existed in the gastric secretion it would then be free to act on the Cane sugar. After being heated for an hour there was no trace of invert sugar and Even after two hours the amount of invert sugar was far too small to allow its quantitative estimation.

6. 10 c.c. healthy gastric fluid
10 cc water
10 cc 20 % Sugar Sol
} Carefully neutralised } Invert Sugar. — Faint trace in 2 hrs.

This shows therefore that when the acidity of the gastric juice is neutralised, no inversion of Cane sugar takes place. There cannot therefore be an inverting ferment in the gastric juice, else we should have had a measurable amount of invert sugar produced.

We may therefore state ~~that~~ - the amount of invert sugar formed is proportional to the degree of acidity and to the dilution of the solution of Cane sugar.

Unhealthy Gastric Secretion

It is said that in unhealthy stomachs containing much mucus the gastric juice is very active in converting cane sugar into dextrose, and that this power seems to be due to the special ferment existing in the mucus (1)

To see if this were so, I performed a similar set of experiments with the gastric fluid of a patient suffering from chronic gastric catarrh with secretion of much mucus. I obtained his gastric fluid in the same manner as before. Its acidity was equal to $\frac{N}{54}$. Equal volumes of this fluid, water and

(1). Schiff "Leons sur la physiologie de la digestion" Vol II (1867) p. 129.

cane sugar solution were kept at 38° C. Invert sugar was present in one hour and amounted to 0.35 % after two hours heating.

%. 10 c.c. catarrhal fluid
10 c.c. water
10 c.c. 20% Cane S. Sol } = N/160 { Invert Sugar 2 hrs = 0.35 %.

As before, I made a solution of hydrochloric acid of a strength equal to that of this gastric fluid (N/54) and placed equal volumes of it, water and sugar solution on the water bath at 38° C. In one hour after there was a good reduction of copper, which in two hours amounted to 0.434 %.

8. 10 c.c. Sol. of HCl = N/54
10 c.c. water
10 c.c. 20 % Cane Sol. } = N/161 { Invert Sugar. 2 hrs = 0.434 %.

This last experiment shows that with the gastric fluid from a case of Chronic gastric catarrh there is less inversion than with a solution of hydrochloric acid of the same degree of acidity. This would agree with Laborde and Foster's (1) statement, but then this is abnormal gastric juice and not normal as they imply. Still less does it show that in cases

(1). Foster "Text Book of Physiology." p. 240.

of gastric catarrh there is increased inversion as Schiff states. If we compare Experiments 4 and 4 we find that the amount of inversion in the latter is less than half what it is in the former, but then the acidity of the first is more than twice that of the second. Yet, caeteris paribus, the acidity of the second ($\frac{N}{160}$) ought to have given an inversion of 0.368 %, while it is only 0.35 %, and according to Foster ought to have been much more.

From these experiments therefore I cannot say that in such dyspepsias there is increased inversion of Cane Sugar.

As regards the question of the presence of an inversive ferment in the gastric mucus, I modified the preceding experiment as follows.

In order to kill any ferment which might be present in the gastric fluid, I boiled it for a few minutes. I then took as before equal volumes of this, water and Cane sugar solution. and placed them at 38° C. After 2 hours the invert sugar amounted to 0.35 %, and this is exactly the same as when unboiled gastric fluid was used (cf. 7)

9. 10 c.c. boiled catarrhal fluid
10 c.c. water
10 cc 20 % Sugar Solution
$= \frac{N}{160}$ Invert sugar 2 hrs = 0.35 %

This proves undoubtedly, I think, that the inversion of Cane Sugar which takes place outside of the body is not due to the presence of any ferments, for the amount of invert sugar produced is the same before and after boiling the gastric fluid. There is no more inversion than can be accounted for by the acidity.

I also carefully neutralised the mixture of Equal volumes of catarrhal gastric fluid, water and 20 % Cane Sugar solution and then placed all on the water bath. There was no reduction of copper in one hour. After two hours there was a slight amount of invert sugar but not enough for one to estimate it quantitatively. This again is similar to what we got with the healthy gastric juice. (compare 6)

10. 10 c.c. catarrhal gastric fluid
10 c.c. water
10 c.c. 20 % Cane Sugar sol
} Carefully neutralised
} Invert Sugar. 2 hrs - faint trace

I varied these experiments in another manner also, by taking Equal volumes of gastric juice and 20 % of Cane Sugar solution only and keeping at 38°. C. for a period of one and two hours

Unhealthy Gastric Fluid - Catarrhal dyspepsia

The initial acidity was = $\frac{N}{35.7}$. After heating for one hour, the invert sugar formed 0.344 %; while after two hours it was 0.714 %

11. 20 cc

	One hour	Two hours
20 cc Gastric fluid = $\frac{N}{35.7}$ } = $\frac{N}{71}$ 20 cc 20 % Cane Sugar Sol } Rotation +13.3°	0.344 %	0.714 %

If we compare this with our first experiment (4) we see that the acidity is the same in both cases, yet the amount of inversion is greater in the first than in this last; but then the sugar solution in the first case is diluted to three, while in this last it is only diluted to two. Therefore dilute solutions of cane sugar undergo more inversion than do stronger ones.

I then made a dilute solution of hydrochloric acid of strength similar to this gastric fluid and having added an equal volume of sugar solution heated it on the bath. The invert sugar amounted to 0.44 % in one hour, and to 0.90 % in two hours.

12.

	One hour	Two hours
20 c.c. Sol. of HCl = $\frac{N}{35.7}$ } = $\frac{N}{71}$ 20 cc 20 % Cane S. Sol	0.44 %	0.90 %

Comparing this with 8, we see that relatively

the amount of inversion is greater in 8 than in 12, which ought to have given an inversion of 0.984 %; but in the last case the sugar solution was only diluted one half, whereas in 8 it was diluted two-thirds. Thus again it is proved that dilute solutions of cane sugar undergo a greater inversion with the same strength of acids than do more concentrated solutions.

Conclusions

It is manifest from a perusal of these experiments, that the acidity is the only factor in the inversion of cane sugar. As the acidity is diminished, caeteris paribus, so does the amount of inversion diminish. In neutral media, as when the gastric juice is neutralised, the amount of inversion is infinitesimal and would be quite as great if the sugar solution were alone heated.

The preceding experiments were all performed in the laboratory with fresh human gastric secretion.

I desired however to investigate what changes, if any, occur in cane sugar in the stomach, and for this purpose I performed a large series of experiments.

Digestion of Cane Sugar in the Stomach.

The method I pursued was as follows:
At 8 o'clock the patient had breakfast of porridge and milk. At 10 a.m. the stomach was thoroughly washed out by means of the syphon elastic tube in the manner first practised by Professor Kussmaul. I used a very dilute solution of permanganate of potash as the rinsing fluid, the colour of which is of use as telling us when the stomach is empty, as it then returns in its natural colour. Much time is required to entirely empty the stomach of its contents, and it cannot be properly done under half-an-hour, during which time the rinsing fluid is constantly poured in and syphoned off. Having washed it out thoroughly, I then poured into the stomach through the tube a warm 20 % solution of pure cane sugar. By introducing the fluid thus, the patient was quite unaware of the nature of the fluid and there was no admixture of saliva. I invariably introduced in this way 250 c.c. of the sugar solution ($= \bar{c}\ \overline{3v\text{iii}}$). At intervals varying from half to two hours afterwards (though generally at end of first and second hours) the stomach tube was again introduced and

portions of the gastric contents drawn off.

Each sample thus obtained was measured, filtered, examined by the saccharimeter and the amount of reducing sugar present estimated by the standard Fehling's solution (of which 10 c.c. were entirely reduced by 0·05 grm. glucose). The total Acidity was estimated by titrating with a centi-normal solution of caustic soda and expressed as being equal to a fraction of the normal solution of soda. I did not estimate the amount of hydrochloric acid quantitatively as that would have been too tedious, but I always tested qualitatively for the presence of inorganic (of which hydrochloric is the chief) and organic acids.

Free hydrochloric Acid. The presence of this acid is well shown by von den Velden's[1] test of methyl-aniline violet. a watery solution of this is placed on a porcelain slab and mixed with a few drops of the gastric fluid. If free hydrochloric acid is present a blue colour is produced, which becomes

(1). Velden, Dr. R. von den "Ueber vorkommen und mangel der freien Salzsäure im Magensaft" Deutsche Archiv. f. Klin. Medicin. Vol 23. p. 369. (1879

" "Ueber die Wirksamkeit des Mundspeichels im Magen" Ibid Vol 25 p 105 (1880) also see Zeitsch. f. Physiol Chemie Bd 3. p. 205. (1879)

greenish as the quantity of acid increases and is finally bleached if there is much free hydrochloric acid.

Clinically, a watery solution of tropaeolin is used to determine the presence of free acids in the gastric juice.

The anilin dye Congo Red forms perhaps the most convenient test for the presence of inorganic and organic acids. Filter papers dipped in a solution of this dye (0·1 grm. in 100 c.c. distilled water) and dried, form the best method of employing it. Strips of such paper are dipped in the gastric fluid, washed for a few seconds in cold water and then are dropped into a test tube containing sulphuric ether. If free acid is present the red colour is changed to a blue, violet or black according to the strength of the acid. If the ether restores the red colour, then the acid is organic (organic acids being soluble in ether); but if unchanged by ether the acidity must be due to free mineral acids which are insoluble in ether.

Besides these there are other tests for free hydrochloric acid as Mohr's, Uffelmann's (1) and Jolles'

(1). Uffelmann "Ueber die Methode der Untersuchung des Mageninhalts auf freie Säuren" Deutsch. Archiv. f. Klin. Med Vol 26. p. 431 (1880) "Ueber die Methoden des Nachweises freier Säuren in Mageninhalt" Zeitsch. f. Klin. Med. Vol 8. p 392 (1884)

but the preceding are the most satisfactory and were those which I employed.(1)

The presence of lactic acid is best indicated by Riegel's test. On the addition of a few drops of the gastric fluid to a dilute solution of perchloride of iron (m x Liq. Ferri Perch. Fort. to 100 c.c. water), if lactic acid is present the yellow colour becomes much darker. This is best seen by performing the trial with two test tubes each half-filled with the iron solution and adding the gastric fluid to one of them and using the other for comparison

Having estimated the acidity and the amount of invert sugar present in the gastric fluid, I then inverted the remaining cane sugar in a definite quantity of the fluid. This I did by placing 25 c.c. of the gastric fluid in a small flask and adding to it five drops of a dilute solution of sulphuric acid, made by adding one c.c. pure sulphuric acid to 9 c.c of water. I have already stated that this is the most powerful acid in causing inversion. I added this acid in case

(1). Jolles' test is very pretty and depends on the fluorescence of eosine in alkaline or in organic acid solutions, and its absence with mineral acids "Une nouvelle méthode de dosage de l'acide du suc gastrique" Jour. de Pharmacie et de Chemie. Vol 24. p 167 (1891)

there might be no free mineral acid already present. The flask with its contents was then placed in a water bath at a temperature of 170-180° F and heated for two hours. By the end of this time any cane sugar which was originally in the fluid had undergone complete inversion. After cooling, it was then made up to its former volume, neutralised, and the amount of invert sugar now present estimated by Fehling's solution and by the polariscope. The difference between this and the former amount represented the amount of Cane sugar present in the fluid.

Normal Healthy Digestion of Cane Sugar.

Patient was a man, age 43, with healthy digestion.

In the first place it was necessary to see what the normal character of his gastric juice was; so after washing out the stomach I allowed him to eat 250 c.c. of cooked minced beefsteak.

13. Normal digestion of Proteids.

(a) One hour afterwards I drew off 60 c.c of muddy dark brownish-red fluid containing much swollen and softened muscular tissue. The fat was in small globules.

Acidity = $\frac{N}{17.2}$ Inorganic acids were present

and organic acids in large amount; but no lactic acid.

Peptones were present and gave a good reaction

Fibrin soon dissolved in it on acidifying with hydrochloric acid.

(b) 2 hours afterwards 35 c.c. of turbid brown fluid were drawn off. The muscular tissue was more broken down and the fat was in larger globules.

Acidity = $\frac{N}{19.6}$. The inorganic acid was in greater amount than in 1st hour, and though the organic acids were also in large amount lactic acid was not present.

Peptones present as before

Fibrin soon dissolved after acidification

Polariscope showed rotation of − 2°.

14. Normal Gastric Secretion

As another control experiment, I injected into this healthy stomach, after washing it out thoroughly 250 c.c. of a normal saline solution (= 0.7 % chloride of sodium)

(a) One hour after I drew off 140 c.c. of clear fluid

Acidity = $\frac{N}{48}$. Inorganic acids were alone present

Polariscope − 1.2°

No substance was present which had any reducing

effect on Fehling's solution.

(b) 2 hours after 60 c.c. were drawn off

Acidity = $\frac{N}{20}$ - inorganic acids alone present

Polariscope — 0.7°

No reducing substance -

After being heated for two hours on the water bath, the results were similar.

We notice that the polariscope shows a rotation of the polarised ray to the left in the above cases and yet there is no sugar present. The reason of this is that all the proteids are laevorotatory and in both of the above cases peptones are present. Corvisart (1) found that the gastric juice of the first ten minutes after ingestion had a powerful laevogyre action. Isolated pepsin and indeed all peptones cause left sided rotation. The different peptones differ also in their rotatory powers. This rotatory power of the proteids interferes somewhat with the value of the saccharimetric readings. but this is of less account as I have in every case estimated also the amount of reducing sugar by means of Fehling's solution, and in any case the amount

(1). Corvisart, L. " Quelques observations sur le suc gastrique, les peptones et leur action sur la lumière polarisée " Comptes Rendues ⅼⅼ p. 62. (1862)

of peptones present was very small.

This then is the character of the gastric juice with which we have to deal in the digestion of Cane sugar in the healthy individual.

Gastric Digestion of Cane Sugar.

15. In this and the succeeding experiments the healthy stomach was first washed out and then 250 c.c of 20 % Cane Sugar solution introduced.

30 minutes later 160 c.c. turbid fluid drawn off.

Acidity = $\frac{N}{40}$. Inorganic and organic acids present but no lactic acid.

Polariscope + 2·2°

Invert Sugar 0·25 %.

Part of this fluid was then heated on the water bath for 2 hrs after being acidified. (In future I shall term this "after inversion".)

after inversion - Polariscope −1·1°

Invert sugar 2·44 %.

16. Same patient - 250 c.c. 20 % Cane Sugar injected

One hour afterwards 36·5 c.c. fluid extracted.

Acidity $\frac{N}{29}$ Both inorganic and organic acids present. and a trace of lactic acid.

Polariscope + 1.5°.
Invert Sugar 0.81 %.
After inversion
Polariscope − 1.3°
Invert sugar 1.28 %.

17. Same patient. 250 c.c. Cane Sugar Sol. 20 %.
One hour later 90 c.c. fluid obtained
Acidity $\frac{N}{31}$ Inorganic & organic acids and trace of lactic acid present.
Polariscope + 1.7°
Invert Sugar 0.42 %
After inversion
Polariscope − 0.6°
Invert Sugar 1.4 %

18. Same patient - 250 c.c. 20 % Cane Sugar Solution.
One and a half hours after 40 c.c. fluid withdrawn.
Acidity $\frac{N}{28.5}$ Both inorganic and organic.
Polariscope - 0
Invert Sugar 0.13 %.
After inversion
Polariscope − 0.8
Invert Sugar 0.495 %.

19. Same patient, 250 c.c. 20 % Cane Sugar Solution
Two hours after I drew off 41 c.c fluid
Acidity = $\frac{N}{25}$ - made up of inorganic and organic with a trace of lactic acid
Polariscope + 0.6°
Invert Sugar 0.68 %.
After inversion
Polariscope −1°
Invert Sugar 0.934 %

20 Same patient. 250 c.c. 20 % Sol. of Cane Sugar.
Two hours later drew off 85 c.c. fluid
Acidity = $\frac{N}{19.6}$ Inorganic acids are in greater amount than at end of the first hour.
Organic acids are also present and there is no lactic acid.
Polariscope + 0.6°
Invert Sugar 0.41 %.
after inversion
Polariscope −0.5°
Invert Sugar 0.65 %.

The results of these experiments may be tabulated as follows:—

V. Table showing amount of Inversion of Cane Sugar in healthy Stomach

No.	Length of time in Stomach	Number of c.c's withdrawn	Acidity	Inorganic Acids	Organic acids	Initial Rotation	Rotation after inversion	% sugar inverted in Stomach	% sugar after inversion outside	Amount of Cane Sugar in stomach	Remarks.
1	½ hr	160	$\frac{N}{40}$	+	+	+2.2	−1.1	0.25	2.44	2.19	
2	1 hr.	36.5	$\frac{N}{29}$	+	+	+1.5	−1.3	0.81	1.28	0.47	Slight dyspepsia
3	1 "	90	$\frac{N}{31}$	+	+	+1.7	−0.6	0.42	1.7	1.28	
4	1½ "	40	$\frac{N}{28.5}$	+	+	0	−0.8	0.13	0.495	.365	
5	2 "	41	$\frac{N}{25}$	++	+	+0.6	−1.	0.68	0.934	0.254	
6	2 "	85	$\frac{N}{19.6}$	++	+	+0.6	−0.5	0.41	0.65	0.24	

From this table we learn that —

1. Inversion of Cane sugar does take place in the healthy stomach.
2. The total amount of sugar diminishes as digestion proceeds.
3. As digestion goes on, the proportion of invert sugar to the whole sugar increases.
4. The amount of inversion is proportional to the acidity of the gastric juice.
5. The inverted sugar is apparently not more rapidly absorbed or passed on through the pylorus than is the cane sugar itself.

These are the chief points that we may draw attention to in the healthy digestion of Cane sugar.

The question which next arises is, "What happens to a solution of invert sugar in the healthy stomach?" To elucidate this I kept the same patient under observation and gave him now instead of the 20 % solution of Cane sugar, a solution of invert sugar.

Normal Gastric Digestion of Invert Sugar.

I prepared the solution of inverted sugar in this way. One litre of the 20 % solution of pure dry cane sugar was placed in a flask with one cubic centimetre of dilute sulphuric acid (1 c.c. acid to 9 c.c. water) The flask was then placed in a water bath and heated for two hours at 170-180° F. After cooling, the loss from evaporation was made up by adding water. This 20 % solution of invert sugar gives a rotation of −10° by Zeiss's saccharimeter.

21. The patient's stomach having first been thoroughly washed out, 250 c.c. of this invert sugar solution were injected

(a) <u>One hour later</u> 100 c.c. fluid were withdrawn.

Acidity = $\frac{N}{20.6}$

Polariscope −1.4°

Invert Sugar 1.8 %.

Of course there was no use in heating this outside, for the sugar being inverted to begin with, no increase could result from heating. Actually, there was none.

(b) <u>Two hours after injection</u> of the invert sugar (same day) I drew off 24 c.c. with difficulty.

Acidity. $\frac{N}{28}$

Invert Sugar 1.25 %.

22. Same patient, 250 c.c. invert Sugar sol (20%)

(a) One hour after 100 c.c. fluid were drawn off.

Acidity = $\frac{N}{21}$

Polariscope − 1.2°

Invert Sugar 2.77 %

(b) 2 hours after injection, the stomach was perfectly empty.

23. Same patient. 250 c.c. invert sugar solution

(a) One hour after 100 c.c. withdrawn.

Acidity = $\frac{N}{15.8}$ due to organic and inorganic acids - no lactic acid

Polariscope − 1.5°

Invert Sugar 2.27 %

(b) 2 hours after injection 66 c.c. fluid withdrawn

Acidity = $\frac{N}{22}$. Inorganic and organic acids - no lactic acid.

Polariscope − 0.8°

Invert Sugar 0.44 %.

24. Same patient. 250 c.c. 20 % invert sugar sol.

(a) One hour after 120 c.c. fluid drawn off

Acidity = $\frac{N}{20}$ due to inorganic and organic acids - no lactic acid.

Polariscope - 2.1°

Invert Sugar 3.3 %.

(b) 2 hours after injection, only 11 c.c. could be obtained.

Acidity = $\frac{N}{20.8}$ due chiefly to inorganic.

Invert Sugar - only a trace - not enough to be estimated.

25. Same patient, 250 c.c. 20 % invert sugar solution

(a) One hour after 75 c.c. drawn off.

Acidity = $\frac{N}{23.2}$ Chiefly due to inorganic acids

Polariscope - 2.2°

Invert Sugar 4.5 %.

(b) 2 hours after injection there was no fluid in the stomach 50 c.c. water were injected and then syphoned off. This rinsing fluid was neutral in reaction, polariscope gave - 0.4° and there was no sugar present.

VI. Normal Gastric Digestion of Invert Sugar.

No	Hour 1	Hour 2	No. of C.C.	Acidity	Inorgan. Acid	Organ. Acid	Polariscope	% Invert Sugar	Remarks.
1	1		100	$\frac{N}{20.6}$	+	+	-1.4°	1.8	
2		2	24	$\frac{N}{28}$	+	?	-	1.25	
3	1		100	$\frac{N}{21}$	+	+	-1.2°	2.77	
4		2	0	0			-	0	Stomach empty
5	1		100	$\frac{N}{15.8}$	+	+	-1.5°	2.27	
6		2	66	$\frac{N}{22}$	+	+	-0.8	0.44	
7	1		120	$\frac{N}{20}$	+	+	-2.1	3.3	
8		2	11	$\frac{N}{20.8}$	+	?	-	0	
9	1		45	$\frac{N}{23.2}$	+	?	-2.2°	4.5	
10		2	0	0	0	0	-	0	Stomach empty.

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If we compare these two tables of the digestion of Cane and Invert sugar, we see that there is a very great difference as regards the behaviour of these two sugars in the stomach

1. First, as regards the quantity of fluid in the stomach. In the Case of Cane sugar, there was always much fluid in the stomach, even after an interval of two hours after its ingestion. In no case was there less than 36 c.c. in the stomach and often I only withdrew a small part of the contents, leaving much still in the stomach.
With invert sugar however it is very different. There was plenty of fluid in the stomach after one hour, but after an interval of two hours it was entirely or almost entirely empty. Only once or twice and that with difficulty could a few cubic centimetres be extracted.
The stomach therefore becomes quickly empty after the reception of invert sugar.

2. If we compare the column after one hour with that after two hours in the case of the Invert sugar we see what a reduction has taken place in the amount of sugar. What has become of this invert sugar? It must either have been rapidly absorbed through the gastric walls

or probably has been passed on through the pylorus into the duodenum and small intestine. In all probability both of these processes go on in the healthy stomach.

We may note that this healthy patient made no complaint as to the fluids which were injected into his stomach giving him any uneasiness, except once when he complained of slight heart-burn after an injection of cane sugar solution.

Pathological Digestion

Having investigated in this way the changes which occur in Cane and Invert sugar during their stay in the healthy stomach, it was desirable to see in what way these differed in diseased conditions of the gastric mucous membrane. For this purpose I made a series of experiments in patients with digestive diseases.

I. Chronic Gastric Catarrh.

This was a male patient, a blacksmith, aged 47. who had suffered from this complaint for 2 years. There was no dilatation of the stomach.

To see what the usual character of his gastric secretion was, I first began with

26. Digestion of Proteids in Chronic Gastric Catarrh.

Having washed out his stomach thoroughly I allowed him to eat 250 c.c. of cooked minced steak.

(a) One hour afterwards I drew off 54 c.c. of turbid brownish-red fluid.

Acidity = $\frac{N}{11.7}$ due to the presence of inorganic and organic acids; the former form the largest part and there is no lactic acid

Peptones are present in large amount

Fibrin is digested in 45 min. without the addition of any acid.

(b) Two hours after ingestion of this 84 c.c. of fluid similar in character to the last were withdrawn.

Acidity = $\frac{N}{11.3}$ - Inorganic and organic acids

Polariscope $-2.6°$.

Peptones - present - reaction not so marked.

Fibrin digested in 65 min. without addition of acid.

Digestion of Cane Sugar in Chronic Catarrh.

I would desire to draw attention to the remarks which this and other patients made as regards pain, comfort or discomfort, after the injection of the sugary solutions. It must also be borne in mind that the

nature of the fluid was quite unknown to them and untasted, since it was introduced through the stomach tube. In all cases the statements were made quite voluntarily, as I carefully guarded myself from making any such inquiries.

2/. 250 c.c. 20 % Solution of Cane Sugar injected into Empty stomach.

(a) <u>One hour after</u> 70 c.c. of thick whitish fluid were obtained, which filtered with difficulty being much mixed with mucus.

Acidity = $\frac{N}{17.5}$. Inorganic and organic acids were present, with a trace of lactic acid.

Polariscope + 3.25°.

Invert sugar. 0.98 %.

After inverting.

Polariscope − 0.6

Invert Sugar 2. %

Soon after receiving this injection the patient felt very sick and vomited several times during the day. The vomit was very acid, putting his teeth "on edge" and rendering his tongue and gums tender. The pain over the gastric region was severe and the heartburn and flatulence much worse than usual.

28. Same patient.. At 10 a.m. I washed out his stomach; the patient having had no food since 5.a.m., at which hour he took some milk, and yet much white curdy material came away during the stomach washing. This shows how slow the digestion was in this patient and how long a time food remained in his stomach

250 c.c. 20 % Cane Sugar Solution injected.

(a) One hour afterwards 83 c.c. of viscid, whitish fluid with shreds of mucus were drawn off.

acidity $\frac{N}{27.4}$ due to inorganic acids chiefly

The fluid gave the lactic acid reaction.

Polariscope + 7.4°

Invert Sugar 1.47 %

after inversion

Polariscope - 3.7°

Invert sugar 5.9 %.

(b) Two hours after injection 130 c.c. of whitish fluid were withdrawn - It is not so viscid as after one hour.

acidity $\frac{N}{20.8}$ - much more inorganic acid than after the first hour. Lactic acid present.

Polariscope + 3.3°

Invert Sugar 1.7 %.

After inversion

Polariscope $-3°$

Invert Sugar 4.3 %.

Patient states that he suffered much after injection into stomach from pain, heartburn and flatulence and was not relieved till he produced emesis by thrusting his finger down his throat.

29. Same patient - 250 c.c. 20 % Cane Sugar Sol.

(a) One hour after I drew off 65 c.c. of turbid white fluid. A much greater quantity than this came through the tube but lest I should have emptied the stomach I returned much of it to the stomach.

Acidity = $\frac{N}{50}$ chiefly inorganic acid - No lactic acid.

Polariscope + 8.2

Invert Sugar 1.04 %.

After inversion

Polariscope $-4.4°$

Invert Sugar 6.6 %.

(b) Two hours after injection 125 c.c. of similar fluid were drawn off.

Acidity = $\frac{N}{28}$ - almost wholly due to inorganic acid - No lactic acid

Polariscope + 4°
Invert Sugar 0.9 %
after inversion
Polariscope − 3°
Invert Sugar 4.3 %.

30. Same patient - 250 c.c. 20 % Cane Sugar Sol.
(a) One hour after ½ c.c. of turbid white fluid were drawn off.
Acidity = $\frac{N}{38.4}$ Chiefly inorganic - No lactic acid
Polariscope + 5°
Invert Sugar 0.56 %.
after inversion
Polariscope − 1.4°
Invert Sugar 3.54 %.

(b) Two hours after injection 83 c.c. fluid obtained
acidity = $\frac{N}{24}$ Inorganic and organic acids in nearly equal amount.
No lactic acid.
Polariscope + 2.1°
Invert Sugar 0.56 %.
after inversion
Polariscope − 1.9°
Invert Sugar 3.44 %

31. Same patient. He states that for the last three days or since this treatment (stomach washing) was begun, he has felt very ill.
He had only milk and bread for breakfast and yet there was eructation of much sulphuretted hydrogen gas while washing out the stomach.

Injected 250 c.c. 20 % Cane Sugar Solution.

(a) One hour after 75 c.c. of turbid white fluid were obtained.

Acidity = $\frac{N}{33.3}$ Inorganic acids in large amount
Organic acids present - Is lactic acid

Polariscope + 8.7°
Invert Sugar 0.392 %.
After inversion
Polariscope − 3.6°
Invert Sugar 5.26 %.

(b) Two hours after 100 c.c. thick fluid drawn off.

Acidity = $\frac{N}{38.4}$ chiefly inorganic.
Polariscope + 7.4°
Invert sugar 0.9 %
After inversion
Polariscope − 3°
Invert Sugar 5 %

Patient had much pain till he induced emesis

32 Same patient. Injected 250 c.c. 20% Cane Sugar Sol.

(a) One hour after 100 cc thick white fluid obtained

Acidity $\frac{N}{34.4}$ - Inorganic chiefly - No lactic acid

Polariscope + 6.1°

Invert sugar 1.0%

after inversion

Polariscope − 3.6

Invert Sugar 5.5%.

(b) 2 hours after injection 75 c.c. of similar fluid drawn off.

Acidity = $\frac{N}{31.2}$ Inorganic chiefly

Polariscope + 0.6°

Invert sugar 0.6%

after inversion

Polariscope − 2.1°

Invert Sugar 2.3%.

I have tabulated these in the following table —

VII. Amount of Inversion of Cane Sugar in Chronic Gastric Catarrh.

Nos.	Hours in Stomach 1h	2h	No. of C.C.	Acidity	Inorganic Acids	Organic Acids	Initial Rotation	Rotation after inversion	% Sugar inverted in Stomach	% Sugar after outside inversion	Amount of Cane Sugar in Stomach	Remarks.
1	1		70	$\frac{N}{17.5}$	+	+	+3.25	-0.6	0.98	2.	1.02	Much pain - acid vomit, Flatulence &c
2	1		83	$\frac{N}{27.4}$	++	+	+7.4	-3.7	1.47	5.9	4.43	Pain, Heartburn Flatulence severe. Relieved by Emesis
		2	130	$\frac{N}{20.8}$	+++	+	+3.3	-3	1.7	4.3	2.6	
3	1		65	$\frac{N}{50}$	++	+	+8.2	-4.4	1.04	6.6	5.56	Pain severe
		2	125	$\frac{N}{28}$	+++	+	+4	-3	0.9	4.3	3.4	
4	1		72	$\frac{N}{38.4}$	++	+	+5	-1.4	0.56	3.57	3.01	Pain severe
		2	83	$\frac{N}{27}$	++	++	+2.1	-1.9	0.56	3.44	2.88	
5	1		75	$\frac{N}{33.3}$	++	+	+8.7	-3.6	0.392	5.26	4.868	Much pain till he vomited.
		2	100	$\frac{N}{38.4}$	+++	+	+7.4	-3.	0.9	5.	4.1	
6	1		100	$\frac{N}{34.4}$	++	+	+6.1	-3.6	1.	5.5	4.5	
		2	75	$\frac{N}{31.2}$	++	+	+0.6	-2.1	0.6	2.3	1.7	

If we compare this table with that of the healthy digestion of Cane Sugar we see that the acidity has been very much alike in both cases. There has been a tolerably large amount of inversion in the case of this dyspeptic but the sugar has been retained in the stomach along with a large amount of fluid and has not been absorbed or passed on out of the stomach as in the healthy individual. It shows also the tardy nature of digestive processes in catarrhal conditions of the stomach. When this dyspeptic made constant complaint of gastric pain, heartburn, flatulence &c. after the reception of the cane sugar solution in his stomach; while the healthy man digested it without any discomfort (except once when he complained of very slight hyposis).

My next set of experiments deals with the gastric digestion of inverted sugar in this case of Chronic gastric catarrh: —

Digestion of Invert Sugar in Chronic Gastric Catarrh.

33. Same patient as before. Stomach washed out; then 250 c.c. 20 % invert sugar injected.

(a) One hour after I drew off 80 c.c. of thick viscid fluid resembling saliva.

Acidity = $\frac{N}{23.8}$ Inorganic acids form the largest part of the acidity. Organic acids are also present, but no lactic acid.

Polariscope − 3.5°

Invert sugar 5.26 %

(b) Two hours after injection 120 c.c. of fluid were drawn off. It was not as thick as after one hour

Acidity = $\frac{N}{39.6}$ chiefly inorganic. No lactic acid.

Polariscope − 1.7°

Invert sugar 1.54 %

He suffered no pain, nor complained of heartburn or flatulence after receiving this invert sugar, till about 4 p.m. or 6 hours after its introduction, and so the sugar solution cannot be responsible for this, specially as he had had dinner at 2 p.m.

34. Same patient. 250 c.c. 20% Invert sugar introduced

(a) <u>One hour after</u> 65 c.c. of thick whitish fluid were drawn off.

Acidity = $\frac{N}{40}$ Much inorganic and small amount of organic acids - No lactic acid.

Polariscope – 3.9°

Invert sugar 5 %.

(b) <u>Two hours after</u> injection 62 c.c. fluid drawn off

Acidity = $\frac{N}{26}$ Chiefly inorganic. No lactic acid

Polariscope – 1.2°

Invert sugar 2.6 %.

Patient felt no discomfort of any kind.

35. Same patient; 250 c.c. 20% Invert sugar injected

(a) <u>One hour after</u> 52 c.c. of thick turbid fluid obtained

Acidity = $\frac{N}{29.7}$ chiefly inorganic acids. No lactic acid.

Polariscope – 3.6°

Invert Sugar 5.5 %.

(b) <u>Two hours after</u> injection 42 c.c. of fluid similar in character to the last were syphoned off

Acidity = $\frac{N}{32.2}$ Chiefly inorganic - No lactic acid

Polariscope — 2·8

Invert sugar 1·2 %.

Patient passed a very comfortable day.

36. Same patient. 250 c.c. 20 % invert sugar introduced

(a) <u>One hour later</u> 68 c.c. of turbid bluish fluid got.

Acidity = $\frac{N}{31.2}$ chiefly inorganic but small amount of organic acids present.

No lactic acid.

Polariscope — 3·5 °

Invert sugar 4·76 %

(b) <u>Two hours after</u> 100 c.c. of similar fluid obtained

Acidity = $\frac{N}{35.7}$ chiefly inorganic acids.

No lactic acid present.

Polariscope — 3·2 °

Invert sugar 3·7 %

Patient made no complaint as to pain &c.

37.

Same patient; 250 c.c. 20 % Invert Solution introduced

(a) <u>One hour after</u> I drew off 78 c.c. of turbid fluid

Acidity = $\frac{N}{33.3}$ chiefly due to inorganic acids

No lactic acid

Polariscope – 3°
Invert Sugar 4.35 %

(b) Two hours afterwards I drew off 30 c.c. of fluid with difficulty, the stomach being almost empty.
Acidity = $\frac{N}{50}$ chiefly inorganic acids.
Polariscope – 0.3°
Invert sugar 0.8 %.

The following table, giving the results of these experiments, shows how great a reduction has taken place in the per centage of invert sugar after two hours sojourn in the stomach as compared with one hour. If we compare this with the digestion of the same sugar in the healthy stomach we are struck by the fact that in the healthy stomach there is very little invert sugar left after an interval of two hours; while in the dyspeptic there is still a large proportional amount. The absorption from, or emptying of the stomach is much less rapid in the catarrhal condition than in health. The great and important point to note however is, that with the invert sugar there is no pain or discomfort, while with the cane sugar on almost every occasion this dyspeptic suffered much from heartburn, flatulence or actual gastric pain.

VIII. Gastric Digestion of Invert Sugar in Chronic Gastric Catarrh.

No.	Hour 1	Hour 2	No. of C.C.	Acidity	Inorgan. Acid	Organic acid	Polariscope	% Invert Sugar	Remarks.
1	1		80	$\frac{N}{23.8}$	++	+	-3.5	5.26	No discomfort
2		2	120	$\frac{N}{39.6}$	++	+	-1.7	1.54	
3	1		65	$\frac{N}{40}$	++	+	-3.9	5.	
4		2	62	$\frac{N}{26}$	++	+	-1.2	2.6	" "
5	1		52	$\frac{N}{29.7}$	++	+	-3.6	5.5	
6		2	42	$\frac{N}{32.2}$	++	+	-2.8	1.2	" "
7	1		68	$\frac{N}{31.2}$	++	+	-3.5	4.76	
8		2	100	$\frac{N}{35.7}$	++	+	-3.2	3.7	" "
9	1		78	$\frac{N}{33.3}$	++	+	-3.	4.35	
10		2	30	$\frac{N}{50}$	++	+	-0.3	0.8	" "

I now made a similar series of observations in a case of Anaemic dyspepsia.

II. Dyspepsia in Pernicious Anaemia

Patient was a labouring man, aged 45 years. Six months previously he began to have a dull heavy pain or weight over the region of the stomach after taking food. This increased in severity and now he has headache soon after taking food, along with waterbrash and then vomiting. He suffers from well-marked pernicious anaemia.

To try what the usual characteristics of his gastric juice were, I, as before, began with

38. Digestion of Proteids in Anaemic Dyspepsia.

Having washed out his stomach thoroughly I let him eat 250 c.c. of cooked minced steak.

One hour after I drew off 76 c.c. of muddy, light yellow fluid containing exceedingly small fragments of muscular tissue which formed an almost amorphous deposit. The fat was floating on the surface in tolerably large round masses. Acidity = $\frac{N}{222}$ - No lactic acid. In fact the acidity was so feeble that it might

almost be said to be neutral.

No peptone reaction.

Fibrin digested after the fluid was acidified with hydrochloric acid

Two hours after ingestion of the meat. I drew off 30 c.c. of pale yellow fluid containing a fine powder of muscular fibres.

Fat floats on the surface in one large mass.

Acidity = $\frac{N}{568}$. Faint trace of lactic acid

Polariscope $-1.1°$.

No peptone reaction

Fibrin digested after acidification.

This gastric juice has hardly any acidity: the pepsin is present as is shown by the ready digestion of fibrin after the secretion is artificially acidified. It seems as if almost all the proteid matter had been passed on out of the stomach, so little of the muscular tissue came away in the fluid. The stomach not being able to digest proteids, through want of acidity probably passes them on to the small intestine to be there dealt with. The presence of the fat in large amount however in the stomach explains why we are so apt to have the butyric acid fermentation in cases of dyspepsia.

Digestion of Cane Sugar in Anaemic Dyspepsia.

39. Same patient - 250 c.c. 20% Cane sugar solution injected after washing out stomach.

(a) One hour later 25 c.c. of yellow coloured fluid was withdrawn.

Acidity = $\frac{N}{2000}$ - No lactic acid

Polariscope - 0.5°

Invert Sugar - 0

After inversion outside

Polariscope - 1.3°

Invert Sugar 0.43 %

(b) Two hours after injection 38 c.c. of pale yellow fluid drawn off.

Acidity = $\frac{N}{5000}$

Polariscope - 1°

Invert Sugar 0

After inversion outside

Polariscope - 1.1°

Invert Sugar - 0

This patient had been accustomed to have his stomach washed out previously in order to relieve his symptoms. He told me however on my visit to him an hour after receiving the cane sugar

solution, that hitherto after having his stomach washed he felt "light and comfortable" but this time he felt very heavy and had a "gone-feeling" over region of stomach.

40. Same patient. 250 c.c. 20% Cane Sugar solution.

(a) <u>One hour after</u> I drew off 50 c.c. of yellow fluid with mucus flocculi in it.

Acidity = $\frac{N}{166}$

Polariscope + 6°

Invert Sugar 0

after inversion

Polariscope − 2·6°

Invert Sugar 4·17%.

He stated that he "felt very bad indeed" with severe headache; but after I drew off these 50 c.c. he expressed himself as being decidedly relieved.

(b) <u>Two hours after</u> injection there was no fluid in his stomach and when rinsed out with water, the rinsings contained no sugar of any kind even after prolonged heating after acidifying.

IX. Amount of Inversion of Cane Sugar in Anaemic Dyspepsia.

No.	Hours in stomach 1	2	No of c.c.		Acidity		Rotation before inversion		Rotation after inversion		% Sugar inverted in stomach		% Sugar after outside inversion		amount of Cane Sugar in stomach	Remarks.
1	1		25		N/2000		-0.5		-1.3		0		0.43		0.43	much pain & discomfort
2		2		38		N/5000		-1°		-1.1		0		0		
3	1		50		N/166		+6°		-2.6		0		4.17		4.17	Patient very ill
4		2		0		0		0		0		0		0		

Practically the gastric juice of this patient had no acidity and thus we account for the absence of inversion of the Cane sugar. The probability is that the Cane sugar after staying in the stomach for some time unchanged, and with no possibility of being digested by this vesicus, was then passed on through the pyloric orifice into the duodenum.

Digestion of Invert Sugar in Anaemia Dyspepsia.

41. Same patient. 250 c.c. 20 % invert sugar injected into empty stomach.

15 min. later 150 c.c. were obtained from stomach

Acidity = $\frac{N}{1000}$
Polariscope − 4°
Invert sugar 18.2 %

42. Same patient. 250 c.c. 20% Invert solution
(a) <u>One hour later</u> 52 c.c. of greenish yellow fluid were drawn off.
Acidity = $\frac{N}{250}$ - No lactic acid
Polariscope − 2°
Invert sugar 0.7 %

(b) <u>2 hours after injection</u> 54 c.c. colourless fluid obtained
Acidity = neutral
Polariscope − 1.1°
Invert sugar - none.
He stated that he had felt no discomfort that day; that he had the "light feeling" that he used to have after getting his stomach washed. He had no flatulence or waterbrash.

43. Same patient; 250 c.c. 20% invert sugar solution.
(a) <u>One hour after</u> 23 c.c. were drawn off
Acidity = $\frac{N}{333}$
Polariscope − 1.6°
Invert sugar 3.7 %

Two hours after there was no fluid in the stomach and when rinsed out the rinsings contained no sugar.

X. Gastric Digestion of Invert Sugar in Anaemic Dyspepsia.

No	Hour	No of C.C.	Acidity	Polariscope	% Invert Sugar	Remarks.
1	¼	150	$\frac{N}{1000}$	-4	18.2	
2	1	52	$\frac{N}{250}$	-2	8.7	Felt very well
3	2	54	0	-1.1	0	
4	1	23	$\frac{N}{333}$	-1.6	3.7	" " "
5	2	0	0	0	0	

The stomach has behaved in a similar way with this invert sugar as it did with the cane sugar in this patient. It has simply emptied itself very quickly and most probably has passed all or nearly all the invert sugar into the duodenum.

III. Alcoholic Dyspepsia.

Patient, a mariner, aged 54. addicted to much "tippling." Troubled with morning vomiting, weight and uneasiness over stomach after

partaking of any food; flatulence very troublesome; no appetite.

Digestion of Cane Sugar in Alcoholic Dyspepsia.

44. Injected 250 c.c. 20 % Cane sugar solution into the empty stomach.

(a) One hour after 45 c.c. of turbid ropy fluid with much mucus were drawn off. Much flatus escaped on passage of stomach tube.

Acidity = $\frac{N}{250}$ – Trace of lactic acid.

Polariscope + 3.5

Invert sugar 0.208 %.

after inversion

Polariscope – 2.6°

Invert sugar 5 %.

Patient stated that he had been more troubled with flatulence after getting his stomach washed than he ever was before.

(b) Two hours after injection 30 c.c. of thick viscid fluid drawn off: much flatus also.

Acidity $\frac{N}{1000}$

Polariscope – 1.2°

Invert sugar 0.089 %.

after inversion

Polariscope 0

Invert Sugar 0.213 %.

45. Same patient. 250 c.c. Cane sugar solution.

One hour after 50 c.c. thick oxeid blood-stained fluid were drawn off.

Acidity = $\frac{N}{333}$. No lactic acid.

Polariscope + 2°.

Invert sugar. 0

After inversion

Polariscope −1.8°

Invert Sugar 1.56 %.

XI. Digestion of Cane Sugar in Alcoholic Gastric Catarrh.

No	Hour	No. of c.c.	Acidity	Rotation before inversion	Rotation after inversion	% Sugar inverted in stomach	% Sugar inverted outside	Amount of Cane Sugar in stomach	Remarks.
1	1	45	$\frac{N}{250}$	+3.5	-2.6	.208	5.	.792	Flatulence severe.
2	2	30	$\frac{N}{1000}$	-1.2	-	.084	.213	.124	
3	1	50	$\frac{N}{333}$	+2	-1.8	0	1.56	1.56	

In this case the acidity is very slight and the amount of inversion proportionately small. This is quite opposed to the usual statement, that in diseased conditions

of the gastric mucous membrane with secretion of much mucus, there is a great inversion of cane sugar, due to a special ferment which is said to exist in the mucus and is allied to ptyalin.(1) In my case the secretion of mucus was very great and yet hardly any cane sugar has been inverted.

The preceding experiments show that invert sugar is very quickly passed on out of the stomach and that the absorption of this sugar through the walls of the stomach seems to be very slight. That this is so, is I think, shown by what takes place when cane sugar is introduced into the stomach (Compare Tables V & VII.) We see that the amount of invert to Cane sugar remains very much the same at the first and second hours. Had there been much absorption through the gastric walls of invert sugar this relation would have undergone a change.

The changes therefore which cane sugar undergoes in the stomach are simply that a certain

(1) Schiff, Maurice "Leçons sur la Physiologie de la digestion" (1867) Vol II p 129

Leube. Dr. W "Ueber die Veränderungen des Rohrzuckers im Magen des Menschen" Virchow's Arch. Vol 28 p. 222 (1882)

amount of inversion takes place depending on the degree of acidity of the gastric juice; neither cane nor invert sugar are absorbed (the latter may however in a slight degree) through the walls of the stomach, but that after a variable time both cane and invert sugar are passed on into the duodenum. There can be no doubt also but that cane sugar is much less easily borne by the stomach than is invert sugar.

Intestinal Digestion of Cane Sugar.

Neither the biliary nor the pancreatic secretions seem to have any inversive action on cane sugar.(1) The mucous membrane of the small intestine however secretes a ferment which has been named "invertin." and which causes the cane sugar to becomes hydrated and then splits it up into glucose and levulose. This fermentative

(1.) Ewald Lectures on Digestion "Sydenham Soc. (1891) p. 147.
Hoppe Seyler. "Physiologische Chemie" (1881) p. 263.
Brown & Heron "Some Observations upon the Hydrolytic ferments of the Pancreas and Small Intestine" Proceedings of the Royal Society p. 393 (1880)

action of the succus entericus was first described by Claud Bernard (1), who showed that before its absorption cane sugar must be inverted. This ferment can be isolated, and when so, it inverts cane sugar but much more slowly than when the sugar solution is placed in contact with the mucous membrane. Bernard found this ferment in every part of the small intestine but not in the large intestine. Sir William Roberts has obtained this ferment from the small intestine of the pig, fowl and hare. He states that the ferment will not pass through a filter and its inversive action is very slow, usually requiring two hours at a temperature of 38° F. before any reduction of copper can be obtained (2)

Hoppe Seyler does not think that this is a true ferment of the intestinal mucous membrane but believes that it is one introduced from without. Busch (3) could not find that Cane sugar underwent

(1) Bernard "Phénomènes de la Vie" T. II. pp. 320 & 434 (1878)
(2) Roberts. Sir W. "Digestion & Diet" p 38 (1891)
(1) Bernard - Bulletin de la Société de Biologie 1877.
(3) Busch. Prof. W. "Beitrag zur Physiologie der Verdauungsorgane" Virchow's Archiv. Bd 14 p. 140 (1858) p 162

any change during its stay in the intestines.

Matthew Hay found it constantly present in every part of the small intestine of the foetus and in such a case it could not have been introduced from without. He could not find this ferment in any other part of the body. Demant[1] has also described this "invertin" ferment, as also a diastatic one in the small intestine. These require, he says, to act on the sugar or starch for from four to five hours before any sugar appears. Brown and Heron[2] have also studied this question. They found that a watery infusion of the small intestine possessed no inversive action on Cane sugar, but when they used the dried and powdered mucous membrane of the small intestine, they found a marked inversion. This property lies chiefly in the agminated glands of the small intestine.

Béchamp[3] thought that the pancreas had a slight inversive action, but the change in the sugar

(1) Demant B. "Ueber die Wirkungen des menschlichen Darmsafts" Virchow's Arch. Bd. 75 p. 419

(2) Brown & Heron - Ibid

(3) Béchamp. A "Sur les microzymas gastriques" Comptes Rendus de Biologie T. IV. 7me Serie p. 68. (1882)

was in all probability due to the presence of bacteria causing a fermentative decomposition and not from any pancreatic inversive ferment.

I desired to try for myself what the nature of this ferment was, its activity and in what localities it existed.

46 Inversive Ferment.

A healthy young rabbit was starved for thirty-six hours. It then received a full meal and was killed two hours subsequently. The various digestive processes would therefore be in full activity I had previously prepared a 5 % solution of pure cane sugar, and into 18 flasks I had placed 50 c.c. of this sugary solution and heated all to 38° C. Having carefully and gently washed the contents from the alimentary canal of the animal with a stream of normal salt solution, I then placed 5 grms of each of the different parts of the intestinal tract and other organs into each of the flasks and kept them all at 38° C for 2 hrs.

The flasks were then cooled, filtered and then the filtrate was examined by the polariscope and the reducing sugar estimated by Fehling's solution.

The results may be tabulated as follows:—

XII

No	Tissue.	Polariscope	% Invert Sugar
1	Salivary glands	+ 5.	0.068
2	Oesophagus	+ 5.	0.061
3	Cardiac End of Stomach	+ 5.	0.144
4	Stomach - middle part	+ 4.7	0.233
5	Pyloric end of Stomach	+ 5.	0.143
6	Small intestine - Upper part	+ 2.5	0.961
7	Small intestine - Lower part	+ 2	1.14
8	Vermiform Appendix - Lower part	+ 3.5	0.362
9	" " Upper part.	+ 4.8	0.233
10	Large intestine	+ 4.5	0.148
11	Liver	+ 4.2	0.297
12	Pancreas	+ 3.7	0.217
13	Spleen	+ 4.8	0.133
14	Thyroid (piece of)	+ 6.1	0.084
15	Kidney	+ 6.5	0.062
16	Bile	+ 6.5	0
17	Muscle	+ 5.5	0.065
18	5% Sugar at 38° for 2 hrs	+ 6.5	

This certainly shows that the small intestine has a very much greater inversive action than other parts

4% of the intestinal tract

Baby. I then performed exactly the same experiment with the digestive tract of a baby (one of twins) which had lived three days and had been fed on the breast during its life. The salivary glands were too feebly developed to be worth while removing.

XIII.

	Tissue.	Polariscope.	% Invert Sugar.
1	Oesophagus	+ 5.	.012
2	Stomach - Cardiac end	+ 5.2	.0
3	" middle of	+ 4.6	.032
4	" pyloric end	+ 4.5	.0
5	Small intestine	+ 3.4	.543
6	Large intestine	+ 3.8	.384
7	Liver	+ 5	.0
8	Pancreas	+ 5.4	.0
9	Spleen	+ 0	.0
10	Thyroid	+ 5	.0
11	Kidney	+ 5	.0
12	Bile	+ 0	.0
13	Thymus gland.	+ 0	.0
14	5% Cane Sugar at 38°.	+ 6.4	
15.	" " " + N 5 dil H_2SO_4	+ 4.3	1.08

XIV.

Comparison of Inverting Power of Digestive Tract in Rabbit and Infant.

	Tissue.	Polariscope		% Invert Sugar.	
		Rabbit.	Baby	Rabbit.	Baby.
1	Small intestine - lower part	+ 2	3.4	1.14	.543
2	" " upper "	2.5		.961	-
3	Vermiform appendix - lower	3.5		.362	-
4	Liver	4.2	5.	.297	0
5	Vermiform append: upper	4.8		.233	-
6	Stomach - middle of	4.7	4.6	.233	.032
7	Pancreas.	3.7	5.4	.217	0
8	Large intestine	4.5	3.8	.148	.384
9	Stomach - Cardiac end	5.	5.2	.144	0
10	" pyloric end.	5.	4.5	.143	0
11	Spleen	4.8		.133	0
12	Thyroid	6.1	5.	.084	0
13	Salivary glands	5.		.068	0
14	Muscle	5.5		0.065	0
15	Kidney	6.5	5.	.062	0
16	oesophagus	5.	5.	.061	.012
17	Bile	6.5		0	0
18	5% Cane Sugar	6.5		0	0

From this table we see that the chief inversive action is in the small intestine both in the rabbit and in the infant. In the rabbit it suffices to invert more than one-fifth of the cane sugar; while in the infant it inverts more than one-tenth. In both cases it has required prolonged action - that is to say two hours, to produce this amount of inversion. It is therefore not a powerful ferment, but may exist in large amount, seeing that it occurs in the whole length of the small intestine. It may therefore be sufficient to invert all the assimilable cane sugar which is introduced into the digestive tract.

Before speaking of the absorption of sugars after the changes which, as we have seen, they undergo in the alimentary canal, I will first describe the work I have done regarding the digestion of starch in the stomach.

Digestion of Starch.

Firstly - What rôle does salwia play in the digestion of starch?

In virtue of the ferment ptyalin which it contains, the granulose of starch is changed into dextrines, maltose and glucose.(1) Through the continued action of the ptyalin, maltose is believed to be slowly split up into glucose.(2) This amylolytic action of salwia is destroyed by high temperatures, as by boiling.

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(1) Bourquelot "Sur quelques points rélatifs à l'action de la salwie sur le grain d'amidon" Comptes Rendues T. p 71 (1867)

Mialhe "De la digestion et de l'assimilation des matières sucrées et amilöides" Comp. Rend. T p. 954 (1845)

Musculus + v. Mering "Ueber die Umwandlung von Stärke und Glycogen durch Diastas, Speichel, Pancreas- und Leberferment" Zeitsch. f. Physiol. Chemie Bd II p 403 (1878)

Nasse. O. "Untersuchungen über die ungeformten Fermente" Pflugers' Archiv Bd 11. p. 138 (1875)

Gamgee. A. "Lectures, on Digestion -" Lancet. Vol I + II (1882)

(2) Von Mering "Ueber den Einfluss diastatischer Fermente auf Stärke, Dextrin und Maltose" Zeitsch. für Physiol. Chemie. Bd 5. p. 122. (1881)

at low temperatures conversion is slow and ceases entirely at 0°. The conversion of starch by ptyalin takes place very rapidly at the normal blood heat (38° C) in an alkaline solution. It is said that small quantities of hydrochloric acid suspend and rapidly kill the ferment (1); others again say that it acts in neutral as well as in slightly acid solutions, (2) and in fact Richet (3) thinks that it acts best in a slightly acid fluid, while Langley and Eves (4) say that this is incorrect and that ptyalin acts to most advantage in a perfectly neutral medium. Strong alkalies or acids soon kill the ferment

(1) Foster. "Text Book of Physiology"

(2) Ewald. "Diseases of the Digest. Organs." p 47 (1891)
Roberts. Sir Wm. Ibid p. 28.
Bendersky, Dr. J. "Ueber die Ausscheidungsfermente (Pepsin, Trypsin, Ptyalin) aus dem Organismus bei gesunden und kranken Menschen"
Virchows' Arch. Bd 121 p. 554 (1890)
Schiff "Leçons sur la Physiologie de la Digestion. Vol II p. 129. (1867)

(3) Richet - Ibid

(4). Langley & Eves "On certain conditions which influence the amylolytic action of Saliva"
Journal of Physiology Vol 4. p. 18 (1881)

The amylolytic action of salwa in acid solutions is of great importance as regards digestion of starchy matters in the stomach. Food taken into the stomach leads to secretion of gastric juice. If hydrochloric acid is secreted and formed at early in digestion, it will soon neutralise the alkalinity of the salwa swallowed. It is therefore of great consequence to know if the salwa continues to act for any time in the stomach or whether its action at once ceases or if the ptyalin is killed by the acidity of the gastric juice. Have the free acids of the gastric secretion any effect on the diastatic action of the salwa? If ptyalin only acts in alkaline or neutral solutions then its action in the stomach will be limited to the time during which the food is being masticated and swallowed, and in the stomach only till the alkalinity of the salwa is fully neutralised.

Defresne[1] and Richet[2] maintain that salwa continues to act on starch in the stomach. Von den Velden[3] states that so long as the acidity of the

(1) Defresne - Proceedings of the academy of Med Nov. 4 (1879)
(2) Richet "Du sue gastrique" p 118.
(3) Velden. "Zur Lehre von der Wirkung des Mundspeichels im Magen" Zeitsch. f. Physiol. Chem. Bd 3. p 205 (1879)

gastric juice is not due to free hydrochloric acid (which acid he says does not appear for some time $\frac{3}{4}$ – 2 hours after ingestion of food) conversion of starch by the saliva goes on. As soon as hydrochloric acid appears however conversion ceases. Consequently, he says, there are two periods in digestion, (1) when saliva still acts, (2) & when pepsin only acts. Falk[1] states that when peptones are present they combine with the acid and thus the saliva continues to act on starch. He adds that this happens only if the acid is very weak however. Sir W. Roberts[2] and Langley[3] both state that the salivary and pancreatic ferments are destroyed by the acids of the gastric juice when in full digestion.

To try which of these opinions were tenable I performed the following experiments.

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(1) Falk. F. "Ueber die Einwirkung von Verdauungssäften auf Fermente" Archiv. für Physiologie. (J. Anat und Physiol) p. 187 (1882)

Roberts - Ibid p 47.

Langley, J. N. "On the destruction of ferments in the alimentary Canal." Journal of Physiology." Vol 3. p 246 (1880)

48. Behaviour of Saliva in Acid Fluids.

I placed Equal volumes of human saliva, 1% starch solution and 2 per mille solution of hydrochloric acid in a flask and kept it at 38°C.

Within 5 minutes the starch was wholly converted and gave no reaction with iodine but strongly reduced Fehling's solution. On testing the reaction of this mixture, I found that it was neutral, the alkalinity of the saliva having been greater than the acid solution was able to neutralise.

10 c.c. saliva
10 c.c. 1% Starch sol.
10 cc 0·2% HCl. $= \frac{N}{62.5}$

} = neutral in reaction at 38°C } Starch wholly converted in 5 min.

This experiment shows therefore that the normal acidity of the gastric juice would not hinder the conversion of starch. In reality however the amount of hydrochloric acid in the stomach is always increasing and in this way the alkalinity of the saliva will very soon be overcome.

It was necessary therefore to observe how the gastric secretion itself behaved towards the digestion of starch.

The succeeding experiments were therefore carried

on with healthy human gastric secretion. I have already explained how I got this fluid (p. 473) several ounces of dilute liquor carnis were injected into the empty stomach and after the lapse of an hour the gastric contents were drawn off. This was then filtered and used to mix with the saliva and starch solution.

49. This healthy gastric fluid contained chiefly mineral acid and its total acidity was = $\frac{N}{24}$

Equal volumes of this, starch solution and saliva were mixed and heated on the water bath. Even after two hours exposure at 38° C the starch was quite unchanged - There was no trace of conversion.

10 c.c. gastric fluid
10 c.c. 1% Starch sol
10 c.c. saliva.
} at 38° C { No change in 2 hours.

This shows that the normal acidity of the gastric contents while in process of digesting proteids quite restrains the action of ptyalin on starch.

50. I then took Equal volumes of this gastric fluid, starch solution and saliva and carefully neutralised the mixture with a solution of

caustic potash, using very delicate test papers to show neutrality. This was then kept at 38° C. On examining it ten minutes afterwards, the whole of the starch was found to be converted and gave no reaction with a solution of iodine. It showed the presence of 0·22 % of reducing substances.

10 c.c. gastric fluid
10 c.c. 1% starch sol
10 c.c. saliva
} neutralised carefully } Completely converted in 10 min 0·22 % "sugar."

This experiment shows that it is the acidity of the mixture which prevents the conversion of starch; for when neutralised, the action goes on rapidly

51. Behaviour of Gastric secretion from case of Chronic Gastric Catarrh.

I performed exactly similar experiments with the gastric fluid from a case of Chronic Gastric catarrh. Acidity of this fluid was = $\frac{N}{54}$. I placed Equal volumes of this, starch solution and saliva on the water bath at 38° C. When examined after being heated thus for two hours, the starch was found to be unchanged - This is exactly analogous to what we found to be the case with the healthy gastric juice -

10 c.c. Catarrhal secretion
10 c.c. Starch 1% sol
10 c.c. saliva
} = N/160 { No change in 2 hours.

52. I made a similar mixture but before heating it I carefully neutralised it with caustic potash. I found that the starch was completely converted within ten minutes and the mixture showed the presence of 0.23 % reducing material

10 c.c. Catarrhal fluid
10 c.c 1% starch sol.
10 c.c. saliva
} neutralised carefully { Completely converted within 10 minutes.

In this case also the acidity was clearly the restraining agent.

Does the acid merely restrain or does it actually kill the ptyalin? By some, as by Schiff[1], it is said merely to restrain the ferment from converting starch, but that the ptyalin again becomes active on the gastric contents becoming alkaline after passing into the duodenum and small intestine. Others[2] affirm that it is actually killed in the stomach

(1). Schiff "Leçons sur la Physiologie de la Digestion" T. I. p 158.
(2). Langley. "On the destruction of ferments in the alimentary canal" Jour. of Physiol. Vol 3. p 246. (1880)

53 To see if the ptyalin is really killed by the gastric secretion while in full digestion of proteids, I placed in a vessel Equal volumes of gastric fluid ($= \frac{N}{35.7}$) starch solution and saliva and kept it at 38° C for an hour. At the End of this time the starch had undergone no conversion. I then neutralised the mixture carefully and returned it to the water bath for 30 minutes. When examined after this time, it was found to contain much erythrodextrin, some starch, and reducing matters formed 0·19 %.

10 cc gastric fluid
10 cc 1% starch sol
10 cc saliva
} at 38° for 1 hr. → Then neutralised and heated for 30 min → much erythrodextrin, Starch, 0·19 % "Sugar".

54. I did the above experiment again with a slight modification. After keeping the mixture at 38° C for one hour, I did not at once neutralise it, but left it till next day before doing so. In this way the ptyalin was under the influence of the acid during this time. After neutralising it after this long interval, it was placed in the water bath at 38° C for 30 minutes. It then showed some erythrodextrin, a good deal of starch and

contained 0·09 % of reducing matter. After being kept two hours at 38° C after neutralization it gave no reaction with iodine and the reducing matters had increased to 0·138 %.

We gather from these, that with the acidity of the gastric contents while digesting proteids, the ptyalin is not killed, but its conversive action is prevented. It is probably also much weakened by the acid, for in the second case where the ptyalin was left in the acid fluid for twenty-four hours, its diastatic action was feeble and very slow compared to the first where it had only been exposed to the acid secretion for an hour. It is in all probability killed by the prolonged action of the gastric juice.

Action of Gastric Juice on Starch.

Has the gastric juice any digestive action on starch as saliva has?

If to a solution of starch we add dilute acids and keep the mixture at a high temperature, the starch becomes changed into dextrine and glucose. Does the acidity of the gastric juice play a similar part with regard to starch?

A priori one would not expect any conversion of starch in the stomach as the acidity is so comparatively feeble and the temperature comparatively low. Smith [1] however from his experiments on Alexis St. Martin concluded that starchy food was digested in the stomach independently of saliva. Brown-Séquard [2] from his own experience comes to a similar conclusion. Munk [3] and Hayecraft [4] have even described a ferment which is sometimes found in the gastric mucous membrane of the pig, and which changes starch into sugar. It is also said that soluble starch is formed in large amount in the stomach and its formation is due

(1) Smith. F. G. "Expériences sur la digestion." Journal de la Physiologie Vol I p 144. (1858)

(2) Brown-Séquard "La transformation de l'amidon en glucose dans l'estomac". Ibid Vol I p. 158

(3) Munk. I. "Ueber die Verbreitung der ungeformten Fermente im Thierkörper." in Verhandlungen der Physiologischen Gesellschaft. zu Berlin. Deutsche Medicin Wochenschrift. No. 48. p 575. (1876)

(4). Haycraft & Southall "Note on an amylolytic ferment found in the gastric mucous membrane of the Pig." Jour. of Anat. & Physiol. Vol 23. p 452 (1889)

to the acidity and that erythroelextrin is formed from starch by the lactic acid fermentation.[1] Ellenberger and Hofmeister state that when dogs are fed on starchy dextrin and sugar are found in the stomach along with free hydrochloric acid, and yet in these animals the saliva has only a very slight diastatic action.[2] On the opposite side are Dalton,[3] Külme,[4] Duelaux[5] and Schiff[6] who deny that starchy matters are digested. Blondlot[7] declares that the gastric juice having other functions to perform, has consequently no action on it, besides its acidity is too feeble, the temperature not high enough and the stay of the food in the stomach

(1) Brücke E. "Studien über die Kohlehydrate". Sc. Sitzungsber. der. Wien. Akad. Vol 65. (1872)

(2) Ellenberger + Hofmeister "Ueber die Verdauung der Stärke bei Hunden" Arch. f. Anat. und Physiol p. 212 (1891)

(3) Dalton "On the Gastric juice and its office in digestion". American Jour. of Med. Science p. 318. (1854)

(4) Külme "Lehrbuch der Physiologischen Chemie." Leipsig (1868) p. 51.

(5) Duelaux "De la digestion gastrique" Comptes Rendus T. 94. p 736 (1882)

(6) Schiff "Leçons sur la physiologie de la digestion" Vol II. p 141. (1867)

(7) Blondlot "Traité Analytique de la digestion" p. 300. (1843

too brief. Foster[1] says that the gastric juice per se has no effect on starch whatever. Bouchardat and Sandras[2] found that in the stomach of rodents starch was unchanged. It is only in the small intestine of these animals that dextrine and glucose are formed from starch, and absorbed as such. They also state that lactic acid is formed from starch. In birds starch is much more completely digested, and so it is that we find dextrine and glucose in the gizzard. Bouchardat and Sandras think however that in man cooked starch begins to be dissolved in the stomach. Laborde[3] finds that gastric juice has not the same power of converting starch as a solution of hydrochloric acid of the same degree of acidity. He thinks that this is another proof that the free acid of the gastric juice is not hydrochloric but lactic acid. If the reaction of the gastric contents be neutral or alkaline, achroodextrin may be formed

(1) Foster "Text Book of Physiology" p. 240.

(2) Bouchardat et Sandras "De la digestion des matières féculentes et sucrées, et du rôle que ces substances jouent dans la nutrition" Comptes Rendus. T p. 143. (1845)

(3) Laborde "Nouvelles recherches sur l'acide libre du suc gastrique" Mémoire lu à la Société de Biologie pendant 1874. p. 63 (1875)

through the continued action of the saliva; if acid however, erythrodextrin is alone formed, grape sugar not being so formed or only to a very slight extent in the human stomach.(1) Von den Velden(2) states that ptyalin acts in the stomach only in presence of weak organic acids but not if free hydrochloric acid is present also; In connection with this however it has been found that when starchy food is taken into the stomach the secretion of hydrochloric acid takes place very early and in not an inconsiderable amount and remains as till the food passes out of the stomach.(3) In starch removed from the stomach Zechnissen(4) found erythrodextrin, achroodextrin and reducing matters.

(1) Ewald und Boas "Beiträge zur Physiologie und Pathologie der Verdauung" II. Virchow's arch. Bd 104. p 290. (1886)

(2) Velden. von den "Ueber die Wirksamkeit des Mundspeichels im Magen." Deutsch. arch. für Klinische Medicin. Vol 25. p. 105. (1880)

(3) Rosenheim "Ueber die säuren des gesunden und Kranken Magens bei Einführung von Kohlehydraten" Virchow's arch. Vol 111. p 421. (1888)

(4) Zechnissen "Die Umwandlung der Kartoffelstärke im menschlichen Magen." Centralblatt für die medicinischen Wissenschaften Vol 26. No. 31 (1888)

Ewald and Boas find that the maximum amount of reducing substance is reached in the first two minutes after the ingestion of starch. After this it decreases. They never find lactic acid after a starchy diet had been taken; this acid never arise from the fermentation of maltose got from the starch and the rapid secretion of hydrochloric acid would soon stop the conversion. (1)

Has the gastric secretion <u>per se</u> any effect on starch?

55. To determine this I placed 30 c.c. of a 1% solution of starch in a vessel with 10 c.c. of healthy gastric secretion obtained as I have already described; kept on the water bath for two hours at 38°C. At the end of this time when examined the starch had undergone no change whatever. There was absolutely no conversion

30 c.c. 1% starch solution
10 cc healthy gastric fluid - Acidity = $\frac{N}{17.2}$
} at 38°C { In 2 hours. no change.

(1) Compare Ellenberger & Hofmeister "Der Zuckergehalt des Magen-Darminhaltes bei Ernährung mit stärkemehlhaltigen Nahrungmitteln." Pflugers' Archiv Bd 41. p 484 (1887)

56. I did the same with the gastric fluid from the case of chronic gastric catarrh and got a negative result likewise.

30 c.c. 1% Starch Sol.
10 c.c Catarrhal fluid } at 38°C { after 2 hours.
Acidity = $\frac{N}{11.3}$ { No change.

57. I now took the fluid got from the stomach of the patient with pernicious anaemia. We have already seen that this secretion was almost totally devoid of acids. After being kept at 38°C for one hour there was 0.6% of reducing substances present. After two hours the amount was similar, thus showing that the whole of the starch had been converted at a very early period. The conversion was due in all probability to swallowed saliva.

30 c.c. 1% starch sol.
10 c.c. gastric fluid of } at 38°C { In one hour
Acidity = $\frac{N}{222}$ { Starch wholly converted
0.6% "sugar".

Having performed these experiments in the laboratory I now continued these observations as shown by the action of the living stomach on starch mucilage.

58. Healthy Gastric Digestion of Starch.

after washing out the stomach of the healthy patient I injected 250 c.c of a 5% solution of boiled starch (mucilage)

(a) One hour afterwards I drew off 72 c.c. of a muddy fluid.

acidity = $\frac{N}{15.8}$ due almost entirely to inorganic acid.

Polariscope − 0.3°.

(Reducing substances - these for brevity I will call

Sugar - trace of - too small to estimate.

Erythrodextrin - plenty.

Unchanged starch - plenty.

(b) Two hours afterwards I drew off 56 c.c. of clear yeast fluid.

acidity = $\frac{N}{21.2}$ - Inorganic acids only

Polariscope − 1.1°

Sugar - none

Erythrodextrin - none.

Unchanged starch - very little.

at the end of the first hour we find erythrodextrin and sugar in the stomach, while these are absent at the end of the second hour. They have probably either been absorbed through the walls of the stomach or passed on into the duodenum as has happened with the starch itself.

59. Unhealthy Digestion.

Digestion of Starch in Chronic Gastric Catarrh.

250 c.c. of the 5% starch mucilage were injected into the patient's empty stomach.

(a) One hour after 96 c.c. of whitish fluid were drawn off.

Acidity = $\frac{N}{28.5}$ chiefly inorganic

Sugar - mere trace.

Erythrodextrin - small amount.

Stasch - great amount.

(b) Two hours afterwards 100 c.c. of thick faintly yellow fluid were drawn off.

Acidity = $\frac{N}{16.1}$ both mineral & organic acids.

Sugar - trace of.

Erythrodextrin - small amount.

Starch - plenty.

Patient has felt no discomfort

The condition of the gastric contents is very similar both after the first and second hour. The starch seems to have remained unchanged in the stomach.

60. Unhealthy Digestion

Digestion of Starch in Pernicious Anaemia.

250 c.c 5% starch solution introduced into empty stomach.

(a) One hour after 41 c.c. clear thin fluid obtained

acidity = $\frac{N}{333}$

Polariscope + 3.2°

Sugar 1 %

Erythrodextrine - trace

Starch - small amount

(b) Two hours after injection of starch

67 c.c. of thin yellowish fluid drawn off.

acidity = $\frac{N}{1000}$

Polariscope - 0.5°

Sugar - none

Erythrodextrin - none.

Starch (on filter paper) trace.

Patient had no discomfort after injection

I have tabulated these experiments thus :—

XV. Gastric Digestion of Starch Mucilage

(a) = healthy. (b) = Chronic Gastric Catarrh (c) = Pernicious Anaemia.

	Hour 1 2	No. of C.C.	Acidity	% Reducing substances	Erythrodextrin	Starch	Remarks
a	1	-	$\frac{N}{17.2}$	0	0	+	Viscid fluid
	2		$\frac{N}{17.2}$	0	0	+	
a	1	72	$\frac{N}{15.8}$	trace	++	++	viscid
	2	56	$\frac{N}{21.2}$	0	0	+	
b	1	-	$\frac{N}{11.3}$	0	0	+	viscid
	2	-	$\frac{N}{11.3}$	0	0	+	
b.	1	96	$\frac{N}{28.5}$	trace	+	++	viscid
	2	100	$\frac{N}{16.1}$	trace	+	+	
c	1	-	$\frac{N}{222}$	0.6	0	?	thin fluid
	2	-	$\frac{N}{222}$	0.6	0	?	
c	1	41	$\frac{N}{333}$	1.0	?	+	thin fluid.
	2	67	$\frac{N}{1000}$	0	0	?	

These cases show clearly that with the normal acidity of the healthy stomach or in diseased conditions where the acidity is not diminished, the conversion of starch is soon ended in the stomach; whereas in other conditions where the gastric juice has only a feeble degree of acidity the conversion of starch is carried on to a very considerable degree in the stomach. This latter is exemplified in the case of pernicious Anaemia, where probably the whole of the starch was converted in the stomach and the products either at once absorbed or else passed on out of the stomach.

The gastric juice has in itself therefore no converting action on starch, but is in fact inimical to it, as from its acidity it soon causes the Saliva to cease its amylolytic action.

In the above related experiments, the starch solution was introduced directly into the stomach by means of the stomach tube. Thus the starch was in the stomach without admixture of saliva except what was swallowed afterwards. When starchy food is taken into the stomach the secretion of acid takes place very rapidly, so

the saliva which was swallowed afterwards would almost at once have its converting action restrained by the acid fluid in which it fell. The table shows this fact also - that in the cases where the normal acidity was not lessened, the swallowed saliva had little or no effect on the starch.

This however is not the usual condition in which starchy food is received into the stomach. It is always mixed and accompanied by more or less saliva.

In order to see what changes occur in starch solutions received into the stomach under such circumstances, I performed the following experiments.

Combined Effect of Salivary and Gastric digestion on Starch.

Having thoroughly washed out the stomachs of my patients, I allowed them to sip slowly a fluid mucilage of boiled starch

61. Healthy digestion

He supped slowly 250 c.c. of the starch sol. 15 minutes later I drew off 40 c.c. fluid

Acidity = $\frac{N}{58.8}$

Sugar 0.16 %.

Erythrodesetrin - much.

Starch - much.

62. I then carefully neutralised this fluid and placed it at a temperature of 38°C to see if any further conversion would occur or if the acid fluid had killed the ptyalin. after being kept for 45 minutes at this temperature there was no further change in the starch. the reducing matters were similar in amount. We may therefore believe that in this case the ptyalin had been killed by the acidity of the gastric secretion.

63. One hour after eating the starch solution I drew off other 45 c.c.

Acidity = $\frac{N}{35.7}$

Sugar — traces

Erythrodextrin - traces.
Starch - much.

64. I also neutralised this fluid and kept it at 38° C for 45 min. but as before, no further conversion took place -

The normal acidity of healthy gastric juice very soon kills the ferment ptyalin

65. Chronic Gastric Catarrh.

He ate 250 c.c. starch solution after having his stomach thoroughly emptied. 15 minutes later I drew off 45 c.c. fluid

acidity = $\frac{N}{26.3}$
Sugar - faint trace
Erythrodextrin - much
Starch - much.

66. This fluid was also neutralised and kept for 45 minutes at 38° C., but the starch underwent no further conversion

67. One hour after ingestion of starch 38 c.c. were drawn off.

Acidity = $\frac{N}{18.5}$

Sugar - none

Erythrodextrin - none

Starch - very small amount.

68. This was neutralised and kept at 38°. C for 45 min. but no further change occurred.

69. I repeated these observations again on the same patient. - allowing him again to sup 250 c.c. starch solution.

10 minutes after I drew off 80 c.c. of thin white fluid.

Acidity = $\frac{N}{35.7}$

Sugar 0.4 %

Erythrodextrin - present.

Starch - much.

70. This fluid was neutralised and kept at 38°. C. for 45 minutes. The reducing matters then amounted to 0.63 %. This is a gain of 0.23 % and shows that the ptyalin had not been killed, as after the acidity of the fluid in which it was, was neutralised, further conversion of starch

occurred.

1/1. One hour after ingestion of starch
100 c.c. of muddy fluid were drawn off
acidity = $\frac{N}{20.8}$
Sugar - 0.153 %.
Erythrodextrin present.
Starch - much.

1/2. This was neutralised and kept at 38°. for 45 min. The reducing matters were similar in amount as before.

From an examination of these (see table on next page) we see that the acidity of healthy gastric juice soon kills ptyalin. In 15 minutes it has been quite killed; but it must have been rendered inert, or its power wonderfully diminished at a much earlier period, for there is always much unchanged starch in the gastric contents got in these cases. Now I have shown that the saliva is very rapid in its conversive action on starch outside of the body - a few minutes (certainly five) suffice to completely change starch. Now we do not find this to be the case in the stomach, the starch is never completely converted and therefore the ptyalin must have been almost if not altogether

XVI. Combined Digestion of Starch by Saliva & Gastric Juice.

Cases	Time	No. of c.c.	Acidity	Erythrodextrin	Starch.	% "Sugar"	% "Sugar" after neutralization & heating	Remarks.
Health. (1)	15 min	40	$\frac{N}{58.8}$	++	++	0.16	0.16	Ptyalin killed
Health (2)	60 min	45	$\frac{N}{35.7}$	+	++	trace	trace	"
Gastritis Catarrhalis (1)	10 min	80	$\frac{N}{35.7}$	+	++	0.4	0.63	Ptyalin active.
Gastritis catarrh. (2)	15 min	45	$\frac{N}{26.3}$	++	++	trace	trace.	Ptyalin killed
" (3)	60 min	38	$\frac{N}{18.5}$	0	+	0	0	Ptyalin killed
" (4)	60 min	100	$\frac{N}{20.8}$	+	++	0.153	0.153	Ptyalin killed

powerless from the moment of its entering the stomach. In the case of catarrhal dyspepsia we see that the ptyalin has not been totally killed after a stay of ten minutes in the stomach, for when the fluid is neutralised further conversion of starch occurs. In this case however probably the digestive processes are not so rapid as in health, but even here though the ptyalin was not killed it must have been powerless in the stomach, for there was still much unchanged starch present. In quarter of an hour in this dyspeptic also, the ptyalin had been destroyed by the increasing acidity of the gastric secretion. In some cases of dyspepsia (e.g. anaemic dyspepsias) where the secretion of acid is defective, the amylolytic action of the saliva will continue in the stomach for a variable period; whereas in health it is almost at once brought to a cessation. My experiments refute the statement of Falk (1) that saliva continues to act on starch in the stomach when proteids are present, for these combine with

(1) Falk "Ueber die Einwirkung von Verdauungsäften auf Fermente". Arch. f. Physiologie p 187 (1882)

the acid (compare experiments 49-57)
In nearly all cases however ptyalin must be entirely destroyed before the contents of the stomach escape into the duodenum. Only in those cases where the acid has been so deficient that conversion of starch has gone on uninterruptedly in the stomach, can ptyalin escape destruction. Nor indeed, is it necessary to be preserved, for, soon after the gastric contents escape into the duodenum their acidity is neutralised, and then they encounter the pancreatic secretion which is very much more powerful than the saliva in its diastatic action on starch, transforming it almost immediately into maltose and glucose. The diastatic action of the pancreatic secretion is due to the ferment amylopsin which it contains and which can act even on raw starch at the temperature of the body.(1) The products of the pancreatic digestion of starch are maltose, dextrines which have a reducing action on Fehling's solution and glucose.(2) The early effects

(1) Liversidge A. "The amylolytic ferment of the Pancreas" Jour. of Anat & Physiol. p. 23. (1873.

(2) Musculus & Von Mering "De l'action de la diastase, de la salive, et du suc pancréatique sur l'amidon" Comptes Rendus. T. 88 i p. 87. (1879)

of this digestion may be shown thus :-

$$10(C_{12}H_{20}O_{10}) + 8H_2O = 8(C_{12}H_{22}O_{11}) + C_{24}H_{40}O_{20}$$

soluble starch — maltose — achroodextrin γ

The maltose and dextrines are however changed into dextrose under the influence of the pancreatic ferment.(1) This is a slow process however and would in itself be insufficient, were it not greatly assisted by the succus entericus as I shall immediately show. Bourquelot(2) denies that the pancreas or any of the digestive fluids, have any effect on maltose which he thinks is directly assimilable. Besides the other recognised ferments of the pancreas, Lépine(3) believes

(1) Brown & Heron " Some observations upon the hydrolytic ferments of the Pancreas & small intestine" Proceedings of the Royal Society, p. 393 (1880)

(2) Bourquelot. " Recherches relatives à la digestion chez les mollusques céphalopodes " comptes Rendus T. 95 ii p 1174 (1882)

" "Recherches sur les propriétés physiologiques du maltose" Ibid. T. 97 ii p 1000 (1883)

" " p. 1322 "

" et Dastre " De l'assimilation du maltose" Ibid. T. 98. p. 1604 (1884)

(3) Lépine "Sur la présence normale, dans le chyle, d'un ferment destructeur du sucre" Ibid i p 742 (1890)

that he has found one which destroys grape sugar. He thinks that the diabetes which can be produced in dogs by removal of the pancreas is due to the absence from the blood of a sufficient quantity of this sugar-destroying ferment. He has also shown that this ferment is normally present in blood and chyle.(1) The normal living tissues can however destroy much glucose in the circulating blood, and Magendie(2) long ago showed that blood serum has the power of converting starch into glucose and dextrine.

The <u>secretion of the intestinal mucous membrane</u> has only a very slight action on starch (some even deny that it has any). It takes many hours digestion with it, even to produce a small amount of erythrodextrin and soluble starch.(3) Brown and Heron(4) have found

(1). Lépine et Barral "Sur le pouvoir glycolytique du sang et du chyle" Comp. Rendus T p 1314 (1890)
(2). Magendie "La présence normale du sucre dans le sang" Ibid. p. 149. (1846)
(3). Busch. "Beitrag zur Physiologie der Verdauungs-organe" Virchow's Arch. Bd 14 p. 140 (1858)
(4). Brown & Heron - Ibid.

however that the small intestine has a powerful hydrolytic action on maltose, much more so than on soluble starch, dextrines or even on Cane sugar. They believe that the molecule of maltose is too large and complex to be directly absorbed and so it is changed into the less complex form of glucose. This hydration and splitting up of maltose takes place very quickly under the influence of the succus entericus which owes this property chiefly to the secretion from Peyer's glands. The physiological actions of the pancreas and secretion of the small intestine are therefore mutually dependent. Starch under the influence of the pancreatic ferment becomes changed for the greater part into maltose and glucose. The former then encounters the ferment secreted by the intestinal glands and undergoes hydration and splitting up, to form glucose. The last product of the digestion of starch is therefore glucose.

To summarise the facts regarding the digestion of Carbohydrates, we have seen that –

I. Cane sugar is

(a) Unchanged by saliva

(b) In the stomach it undergoes a certain amount of inversion, depending entirely on the degree of acidity of the gastric juice

(c) In the small intestine it undergoes a relatively great amount of inversion.

II Starch.

(a) During the brief period in which saliva acts on it, a large amount of starch is changed into dextrine, and maltose, with a little glucose.

(b) In the stomach this continues for a very brief period, the acidity causing it to have a very feeble converting power and at length killing the ptyalin

(c) On escaping from the stomach the unchanged starch and lower dextrines are converted by the amylopsin into reducing dextrines and maltose with a little glucose.

(d) Each molecule of maltose thus formed takes up a molecule of water under the influence of the intestinal ferment and then splits up to form two molecules of glucose.

Absorption of Digested Carbohydrates.

Many opinions have been put forward regarding the absorption and assimilation of Cane Sugar since the time when Bernard(1) first injected a solution of cane sugar into the veins and found it excreted unchanged in the urine. This classic experiment showed that cane sugar was treated as a foreign body by the blood and quickly eliminated.

There can be no doubt whatever but that glucose is the ultimate form in which cane sugar is absorbed, as well as its isomere levulose. It is as these two sugars, glucose and levulose, that cane sugar passes into the blood and not as maltose as used to be affirmed and still is, by some.(2) I have shown that glucose and levulose are formed from cane sugar both during its stay in the stomach and later in the small intestine, where, under the influence of the "invertin" ferment, the cane sugar is inverted.

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(1) Bernard. Cl "Intravenous injection of cane sugar". Comptes Rendus (1844) p. 1125) or in Leçons sur les Phénom. de la Vie".

(2). Salkowski. Prof. E. "Zur Kenntnis pathologischen Speichels" Virchow's Arch. Bd 109. p 360.

The products of Starch conversion are various dextrines but chiefly glucose. A large part of these dextrines must, from their high diffusibility, pass at once by osmosis, through the gastric walls and so find their way into the gastric capillaries of the portal vein;[1] (but I cannot believe what one writer states that "much and sometimes all the sugar is absorbed in the mouth and gullet."[2]); along with these, peptones, diffusible salts, water, alcohol &c pass through the walls of the stomach. The same will take place in the small intestine - Unchanged cane sugar which passes into the small intestine will become inverted, and then the products of inversion pass through the intestinal walls owing to their relatively high endosmotic Equivalent and thus reach the rootlets of the portal vein. This will take place to a greater extent at the upper part of the small intestine where the absorptive power is also greater than it is lower down.[3]

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(1) Murray "The relation of Digestion --- to Osmosis". Jour. of Anat + Physiol.

(2) Chambers. King "Manual of Diet in Health and Disease" p. 272. (1868) (1875)

(3). Lannois et Lépine "Sur la manière différente dont se comportent les parties supérieure et inférieure de l'intestin grêle au point de vue de l'absorption et de la transsudation" Comp. Rend. de Biolog. T. IV. 7me série p. 99 (1882)

Sugar which reaches the stomach in the condition of invert sugar is either very quickly absorbed through the gastric walls or is passed on through the pylorus. The experiments which I made on the healthy digestion seem to bear out the idea that absorption through the gastric walls does take place but still not to any great extent. When invert sugar was given however, it soon became greatly reduced in amount and at the end of two hours hardly any was to be found in the stomach. It had been partly absorbed and partly passed on.

Leube [1] found that twenty minutes after the introduction of a half per cent. solution of Cane Sugar into the stomach, the amount of reduction was very small, while in thirty minutes the grape sugar had totally disappeared, having been absorbed through the stomach walls; while Lehmann [2] found that a solution of glucose tied up in a loop of the small intestine soon totally disappeared. We know however that the absorptive power of the small intestine

(1) Leube. Dr. W. "Ueber die Veränderungen des Rohrzuckers im Magen des. menschen" Virchow's Arch. Vol 88 p 222 (1882)

(2) Lehmann. "Physiological Chemistry" Translated by Dr. Day. (1851) Vol III p 283.

is much greater than that of the stomach.

The acidity of the gastric juice plays a most important part in the inversion of Cane sugar in the stomach. My experiments on the healthy man show, that the amount of inversion caused by the gastric juice was much greater than that caused by a solution of hydrochloric acid of equal acidity, and in this case the acidity of the gastric juice was chiefly due to mineral acids.

In the case of the dyspeptic on the other hand, the gastric juice had a less inverting power than a solution of hydrochloric acid of the same degree of acidity, but in this case organic acids formed the chief part of the total acidity and these, we know, have a far smaller inverting power than mineral acids.

As regards absorption, the observations on the healthy patient show, that in two hours the whole of the inverted sugar introduced into the stomach had disappeared; while, in the dyspeptic, the rate of absorption or passage or for invert sugar was very slow. It remained in such cases for a long time in the stomach in very slightly lessened amount.

There is therefore a very great difference in the relative absorptive powers of the gastric mucous

membrane in healthy or diseased conditions for the products of inversion of Cane Sugar.

Absorption of the Individual Sugars.

1. Cane Sugar. I need not again refer to this sugar. I have already shown that it is not absorbed as such but that it must be changed into glucose and levulose to enable it to be absorbed.

2 **Glucose**. This sugar is ready for immediate absorption. It is in effect a predigested food, and is, as I have shown in my experiments, very rapidly absorbed from the stomach and intestines in health. Injected into the blood it is not eliminated in the urine, unless given in excess.(1) As regards its absorption, there is of course a limit of assimilability with this as with any other sugar or food for that matter, but up to 50 grammes of Grape sugar may be taken at once by a healthy adult without producing any glycosuria. If much more than this be taken, small quantities

(1) Dastre "Pouvoir nutritif direct du sucre de lait". Archives de Physiologie normale et Pathologique "5me série T. I. p. 718 (1889)

are excreted in the urine for the next three or five hours. (1)

3. Levulose. This sugar is quite as rapidly absorbed as dextrose and it is even better borne than it. It may be taken in greater quantities than the preceding sugar without passing the limits of assimilability (2) and does not undergo fermentation so rapidly as glucose.

4 Maltose. I have shown that before this sugar is absorbed it must be changed into glucose, and this is brought about by the continued action of the diastatic ferments of the pancreas but chiefly by the intestinal secretion.

5. Lactose. Neither is this sugar absorbed as such. It also requires transformation to fit it for absorption, even though it does occur in human milk to about

(1) Worm-Müller "Die Ausscheidung des Zuckers im Harne des gesunden Menschen." Pflugers' Archiv. Bd 34. p 576 (1884)

(2) " "Die Ausscheidung des Zuckers im Harne nach genuss von Kohlenhydraten bei Diabetes Mellitus" Ibid Bd 36. p 172 (1885)

five per cent. When a solution of this sugar is injected into the veins, it is excreted unchanged in the urine in the same way as Cane sugar (1) neither is it changed in amount or in constitution by circulating artificially through the body. When sugar of milk is heated with dilute mineral acids it is split up into glucose and galactose. It is believed, and with great probability of truth, that, under the influence of the digestive secretions, a like splitting up takes place in the alimentary canal, but the ferments which cause this change have not yet been discovered. The glucose is directly absorbed and Dastre has also proved that galactose can be directly absorbed (2), for when a solution of galactose is injected into the veins none or only a trace can be recovered in the urine. If diabetic patients are fed on milk alone or with lactose added, glucose alone appears in the urine (3)

(1) Dastre "Pouvoir nutritif direct du sucre de lait," Ibid

(2) " "Rôle physiologique du sucre de lait"
Comp. Rend. de Biologie. Vol I. new ser. p 145 (1889)

(3) Bourquelot et Troisier "Recherches sur l'assimilation du sucre de lait." Journal de Pharmacie et de Chemie. Vol 19. p 277 or in Comptes Rendus de Biologie T. 142. (1889)

This also goes to prove that the lactose must have been absorbed as glucose.

Lactose is one of the least assimilable sugars. The sugars have been arranged by Bastre in the following order as regards their ease of absorption, the first being least directly useful.

(1). Cane sugar and Lactose
(2). Maltose.
(3). Glucose.

The limit of assimilability for lactose is low, and so it appears in the urine very much more easily than the other sugars, glucose and levulose.(1) Clinically, it has been found that milk sugar is in no way superior to cane sugar as part of the dietary of infants, but tends more easily to give rise to acid fermentation.(2)

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(1) Hofmeister. "Über die Assimilationsgrenze der Zuckerarten" Fünf. Pt. "Neben Resorption und assimilation der Nährstoffe" Arch. f. Experimentelle Pathologie und Pharmakologie. Vol 25. (1889)

(2) Ashby & Wright "Diseases of Children" p. 37-8. (1889)
Brush "Cow's milk for Infant Food." Archives of Pediatrics, Philadelphia. Vol 6. p 587 (1889)

Absorption of the Products of Starch Digestion

In the stomach we have found that there were small quantities of sugar and dextrines formed by the action of the diastatic ferment of the salvia on starch; and as these are highly diffusible, they may be directly absorbed through the walls of the stomach. There is much unchanged starch also and it remains in this condition till the contents of the stomach pass into the intestine, where, under the influence of the pancreatic ferment, it becomes wholly changed into maltose and dextrines. Through the continued action of this and the intestinal ferment, the maltose is at length totally changed into glucose. It is in these two forms, glucose and dextrines, that starch is ultimately absorbed. Indeed Lehmann (1) has shown that glucose and a dextrin-like body exist in the blood of the portal vein to a considerable amount. When blood from this vein is boiled with dilute sulphuric acid the amount of sugar is increased.

(1) Lehmann Prof. "Analyse comparée du sang de la veine porte et du sang des veines hépatiques" Comptes Rendus i p 589 (1855)
"Sur la recherche du sucre dans le sang et la veine porte" Ibid ii p 661 (1855)

thus showing that a process of conversion has occurred.(1)

Fermentative Changes in Carbohydrates in the Alimentary Canal.

It is a perfectly well known and appreciated fact that saccharine and starchy matters are exceedingly prone to undergo fermentative changes in the alimentary tract with the consequent formation of acids and gases. These fermentations are specially liable to occur if an excess of carbohydrate food be ingested or in weak and diseased conditions of the stomach and intestines. In health even, if an excess of such food be taken, though it may be in itself easy of digestion, the whole cannot be absorbed, and so that which is unabsorbed is extremely liable

(1) Drosdoff "Ueber die Resorption der Peptone, des Rohrzuckers und der Indigoschwefelsäure vom Darmkanal aus und ihren Nachweis im Blute der vena portae." Zeitsch. f. Physiol. Chemie Bd I p 216. (1877)
Musculus & v. Mering "De l'action de la diastase, de la salive et du suc pancréatique sur l'amidon et le glycogene" Comptes Rendus Hebdomadaires de l'académie des Sciences. Vol 88 I p 87 (1879)

to undergo various fermentative changes under the influence of the natural unorganised ferments, or of those having a bacterial origin and introduced from without, and which are always present in large amount in the stomach and intestines.(1)

Schiff(2) says that if Cane Sugar remains long in the stomach, lactic, butyric, mucic and valerianic acids result from its decomposition.

Lactic Acid Fermentation

I have already drawn attention to the supposed presence of the lactic acid ferment in the gastric juice. If then Lactose is introduced into the stomach in excess, or if it remains there long, under the influence of this ferment, hydration occurs with the formation of lactic acid. In its simplest form this may be expressed thus —

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(1) Cohn. "Ueber die Einwirkung des künstlichen Magensaftes auf Essigsäure und Milchsäure". Zeitsch f. Physiol. Chemie. Bd 14. p. 75. (1890)
Dr Barry "Beiträge zur Kenntniss der niederen Organismen im Mageninhalte" Arch. f. Experiment. Patholog. und Pharmakol. Bd XX. p 243.

(2) Schiff "Leçons sur la Physiol. de la Digest." Vol II p 130.

$$C_{12}H_{22}O_{11} + H_2O = 4(C_3H_6O_3)$$

Lactose — Lactic acid.

It is probable that there are also many other products besides lactic acid in this fermentation. Carbonic acid is always present in the lactic fermentation and it is likely that alcohol, butyric acid &c. are also formed (1)

So common is the lactic acid fermentation that it is by many supposed to be a normal process, and that the saccharine constituents of the food are absorbed as lactic and carbonic acids. In all probability however, it is an abnormal fermentation induced in carbohydrates by bacteria. This seems to be proved by the fact that the amount of lactic acid increases as the food descends the intestine, whereas it ought to diminish through the continued absorption of the lactic acid if it were a normal process. A pure solution of lactose does not ferment when exposed to the influence of the gastric juice. (2) No doubt, this fermentation once begun, is hastened by the gastric juice and not retarded as was formerly thought. Solution of starch under the action of the bacterium of lactic fermentation becomes changed in part into glucose.

(1) Flugge - "Micro-organisms" Transl. by W. Cheyne. New Sydenham Soc. (1890) p 596.

(2) Richet. "Du suc gastrique chez l'homme et les animaux" p 107 (1878)

Butyric Acid Fermentation

From lactic acid a step further in the downward progress brings us to butyric acid. The fermentation of lactic acid induced by the bacillus subtilis leads to the production of butyric and carbonic acids and free hydrogen - (1)

$$2(C_3H_6O_3) + 2H_2O = C_4H_8O_2 + 2CO_2 + 2H_2O + 2H_2$$

Lactic acid — Butyric acid.

The chyme has been found to evolve carbonic acid and hydrogen gases in equal volumes when removed from the alimentary canal and kept at the body temperature, thus showing that the butyric acid fermentation was proceeding.

Other fermentations may arise due to bacteria and so we may have the alcohol and acetic acid fermentation or the lactic and butyric fermentations Thus.

$C_6H_{12}O_6$ (Glucose)

$2C_2H_6O + 2CO_2$
alcohol
$C_2H_6O + O = C_2H_4O + H_2O$
aldehyde.
$C_2H_4O + O = C_2H_4O_2$
Acetic acid

$2(C_3H_6O_3)$
Lactic acid
$C_4H_8O_2 + 2CO_2 + 2H_2$
Butyric acid

(1) Velden. von den " Studien zur Chemie des Bacillus subtilis " Zeitsch. f. Physiol Chem. Bd 8. p 367 (1884)

These different fermentations may alternate in the same individual & give rise at one time to "a vinegar factory, and sometimes to a gas works" in his inside,[1] owing in the first case to the alcohol and acetic acid fermentation and in the second to the formation of butyric acid, hydrogen and carbonic acid.

These fermentations occur very rapidly and thus the acids rapidly appear. Glucose is much more rapidly fermented than Levulose.[2] The butyric fermentation of glucose is most apt to occur when albumen in a putrescent condition, as in tainted milk, is taken into the stomach along with it.[3]
It is said that Maltose tends rather to undergo the lactic acid fermentation; while Cane sugar inclines rather to the acetous fermentation and this acid is much more irritating to the gastric mucous membrane. than Lactic acid.[4]

(4) Fothergill - Milner - "Manual of Dietetics" p. 98 (1887)
(1) Ewald "Lectures on Diseases of the Digestive Organs" p 70.
(2) Bourquelot. "Sur la fermentation alcoolique "Elective" d'un mélange de levulose et de maltose" Comptes Rendus de Biologie p 191. Vol II 8e série (1885-)
" ..... "d'un mélange de glucose et de levulose" Ibid. p 221.
(3) Leube - in von Ziemssens Handbook. Vol 7. p 116.

In the alimentary tract of the foetus no bacteria can be found. This immunity however does not last long after birth, for in a very few days large numbers are found throughout the whole length of the digestive tract, having been carried there in the food: It is owing to the presence of these bacteria in the intestinal canal of infants that fermentative processes are so liable to occur. Many of these micro-organisms have been isolated and studied. There is one, a micrococcus, which induces the alcoholic and acetic fermentation in sugar; another (Brieger's bacillus (1)) is found in large numbers at the lower part of the intestine and causes the fermentation of grape but not of milk sugar. At the upper part of the small intestine a third bacillus is found, and it induces lactic and butyric acid fermentation in sugar of milk (2) There are many others also which have been described by Escherich,

(1) Brieger "Ueber Spaltungsprodukte der Bacterien" Zeitschrift f. Physiol. Chemie Bd. 8 p 306. Bd 9. p 1. (1884-5)

(2) Escherich. Dr. Theo. "Die Darmbacterien des Säuglings und ihre Beziehungen zur Physiologie der Verdauung" Stuttgart (1886).

Brueger and Vignal.(1)

The gases chiefly found in the intestines of children fed on milk alone are free from smell and consist of hydrogen and carbonic acid.(2) These probably arise from the lactic acid fermentation of milk sugar followed by the butyric fermentation. The former fermentation (lactic) may be innocuous and may even be partly (though unlikely) a normal physiological process; but the butyric fermentation is very hurtful, the acid produced having a toxic effect on the nerve centres.(3) All putrefactive fermentations which go on in the alimentary tract are most inimical to health, owing to the absorption of the decomposition products.

Milk is specially prone to undergo fermentative decomposition. If taken into the stomach when in an incipient state of fermentation, this is very likely to be hastened(4) and to set up a like fermentation in the saccharine elements of the food and specially in milk sugar. Cane sugar.

(1) Vignal "Arch. de Physiologie" p 492 (1884)
(2) Money, Angel "The Physiology of Infancy" in Keatings Cyclopaedia of Diseases of Children Vol I p 69.
(3) Weber. O. - quoted by W. Hadgen "Behaviour of Bacteria"
(4) Richet "De quelques conditions de la ferment. lactique" Comptes Rendus. T. 88 1 p. 750 (1879)

much less easily undergoes lactic acid fermentation but is prone rather to butyric fermentation.

Normal healthy gastric juice has a certain effect in restraining such fermentations. This property is due to the hydrochloric acid which it contains and which Bunge[1] says is destructive to bacteria. Cohn[2] states that the acetic acid fermentation is arrested by 0.05 parts hydrochloric acid per mille. The antiseptic power of the gastric juice is not nearly so powerful as was formerly believed. In those cases where the hydrochloric acid is absent, as in many forms of dyspepsia and infantile atrophy[3] or when an excess of carbohydrate has been ingested, the above described fermentations are most liable to occur.

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(1) Bunge "Lehrbuch der Physiologischen und pathologisch-en Chemie" Leipzig. p 143. (1889)

(2) Cohn. "Ueber die Einwirkung des künstlichen Magen-saftes auf Essigsäure und Milchsäure-Gährung" Zeitsch. f. Physiol. Chemie. Bd. 14. p 75 (1890)
Rosenheim "Ueber die säuren des gesunden und Krankens magens bei Einführung von Kohle-hydraten" Virchow's Arch. Bd 111 p 414 (1888)

(3) Cassel "Zur Kenntniss der Magenverdauung bei atrophia infantum". Archiv f. Kinder-heilkunde. Bd 12. p 175. Stuttgart (1891)

As a result of these fermentations taking place in the digestive tract, the mucous membrane of the stomach and intestines is irritated, and in infants where these organs are so delicate and irritable, vomiting and diarrhoea ensue. These symptoms are accompanied or succeeded in their turn by gastric and intestinal catarrh, and in this way very often a chronic diarrhoea is set up, leading to general wasting, and in too many cases ends ultimately in death. When once begun, these fermentations are very difficult to cure, for then the special bacteria have secured a lodgment in the alimentary canal, and as yet we know of no means of destroying them directly

Are the digestive processes of the young child sufficiently active to prepare sugars and starches for absorption? Do their digestive powers differ in any way from those of the adult?

Zweifel (1) and Korowin have carefully studied the nature of the digestive secretions in infants. They find that the salivary and pancreatic secretions of the young infant have only a slight diastatic action

(1) Zweifel. "Untersuchungen über den Verdauungsapparat der Neugeborenen" Berlin (1874.)

on starch, and indeed it is said that in the newly born these secretions have no action on starch. It has been found however that the parotid salvia has a converting action on starch from the first day of the child's life, but owing to the scantiness of its secretion the diastatic power is very limited and this is probably why it is said that in the newly born this secretion has no converting action. For the first two months of the child's life the amount of salvia which is secreted is very small, and we have all noticed how dry the month is in healthy infants. At about the third month of the child's life the salvia is found to have a distinct diastatic action on starch; but the ptyalin does not appear to any great extent till the sixth month or when eruption of the teeth begin. At this time also the salvia begins to be secreted in great abundance. It is not however till nearly the end of the first year that the salvary ferment has attained to its full amount and power..

Korowin found that during the first month of life the pancreatic secretion possessed no diastatic action. This power is developed during the second, and is well marked at the third month. As with the salvary glands so it is with this one,

the full development of its diastatic action is not reached till the end of the first year.

The gastric juice in adults, as my experiments show, has no converting action on starch, and this is true also for infants.(1) In young children the number of glands in the intestinal canal is relatively small. As the child grows older so does the number of the glands increase. The development of the glandular system advances pari passu as the lymph vascular system decreases in importance(2)

These are the essential points of difference between infantile and adult digestion.

Having entered thus fully into the processes of digestion and absorption of saccharine and farinaceous materials, we are now in a position to consider if such foods should be given to infants, and if so, what are the best forms in which to administer them, for I have shown that they require a special and elaborate digestion to render them fit for absorption.

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(1) Cassel - Ibid

(2) Baginsky "Untersuchungen über der Darmkanal des menschlichen Kindes" Virchow's Archiv. Bd. 89. p. 64. (1882)

What then is the most suitable food for the infant?

To this there is but one answer - the healthy mother's milk. Unfortunately however in too many cases she cannot or does not nurse her child. A suitable wet-nurse is rarely to be found. What then is the child to have as a food? (I have no intention, nor would it be within the scope of this paper, of laying down general rules for infant feeding, but only in so far as they have reference to the carbohydrate constituents of their dietary.

Cow's milk.

Next to human milk, cow's milk forms one of the best, and indeed the very best, and most convenient substitutes. The two milks are compared in this table

Average Composition of Human and Cow's milk.

	Human.	Human	Cows'
	Reaction	Slightly alkaline	alkaline at first soon becomes acid
	Specific Gravity	1030-5	1029
	Water	87-8	87.
	Total Solids	12-13	12-13
	Fat	3-4	3
	Albuminoids	1. 2	4·2
	Sugar	7	4.7
	Ash	0·2	0·73

It however requires some preparation in order to make it resemble ordinary human milk; thus, it requires dilution, as the casein is in much greater amount than in woman's milk. The dilution however lessens the amount of fat and sugar to too great an extent. Ordinarily, it is prepared by diluting with one-half or one-third of its volume with lime-water (to counteract the acidity of the cow's milk) or with ordinary water. Then cane or milk-sugar is added in sufficient quantity to give it a sweet taste. Now neither of these sugars are easily absorbed, even though one is the natural sugar of milk. In fact they are both of them the sugars which are most difficult of absorption, and yet most prone to undergo fermentative changes, giving rise as we have seen, to lactic or butyric acids. Of these two sugars, milk sugar is the most easily fermented. Given along with milk, these sugars are most liable to ferment, as this menstruum is so apt to decompose. In order to lessen the chance of the milk souring it should always be sterilized, or at least boiled as is advocated strongly by some[1], before it is given to the child; a little cream might also be added to make up

(1) Dronet, Dr. H. "De l'assimilation artificielle des jeunes enfants" Paris (1891)

for the low per centage of fat owing to the dilution of the milk.

Instead of adding either Cane or milk sugar, the only sugars which ought to be given to infants are those which are at once absorbed and do not remain in the alimentary canal for any time. By giving these the chances of fermentation are reduced to a minimum. The sugars which require no digestion, but are at once absorbed, are manifestly glucose and levulose. These are the sugars which we ought to use or rather, and perhaps better, the mixture of them as they occur in invert sugar, and I have already shown how easily this may be prepared and how advantageous is its use compared with that of Cane sugar. Maltose would even be preferable to use instead of Cane or milk sugar as an addition to milk, for, even if it did ferment, the lactic acid which is formed from it, is less harmful than acetic acid which the fermentation of Cane sugar gives rise to. Maltose is not at-once absorbed but requires digestion to change it into glucose and this only occurs in the small intestine. This sugar must, of necessity therefore remain in the alimentary canal for a considerable time and thus there is great risk of its fermentation.

What I have stated as regards the ordinary preparation of cows' milk and the addition of sugars to it, have a far greater importance in the next substitute for mothers' milk which is used - viz

Condensed Milk.

This preparation is undoubtedly by far the most universally-used form of infants' food, and naturally so, for owing to its small bulk, length of time which the sweetened variety keeps and the ease with which it can be made ready, make its general use of greatest value amongst the poor and also with many who could well nurse their children but prefer not to do so.

It is certainly for many children a good substitute for mothers' or even fresh cows' milk, and specially so for children during their first one or two months of life, with whom it nearly always seems to do well. Still this does not warrant us in recommending its general use; I would restate the fact, that some children assimilate with impunity food which is most deleterious to infants as a class.

This milk is prepared in two forms —

(1). Simply condensed - unsweetened.
(2) Condensed and with Cane sugar added to preserve the milk.

The first simply consists of cows milk evaporated to about one-third or one quarter of its orginal volume. It forms a thick, syrupy, pale yellow mixture, and merely requires the addition of water to restore it to its original condition. This variety is not so largely used as the second, as, on account of there being no preservative added, it does not keep sweet for more than two or three days after the tin is opened. If kept for a longer time than this, or earlier, in warm weather, when organic fluids decompose rapidly, there are all the risks of giving the infant a food which is beginning to undergo fermentative changes. In many samples of this milk also, the amount of fat is very small. This may be due either to original poorness of the milk in cream or to its abstraction before evaporation.

The sweetened variety of this milk is the one which is so universally used as a food for infants. This is simply cows' milk evaporated down and with Cane sugar added to an amount varing from 30 to 50 % of the milk.

It is a generally accepted fact that many infants fed on sweetened condensed milk rapidly put on fat. I, with many others, have noticed however that a very large number of children fed thus are pale and flabby and very many soon show signs of rickets. Gastric and intestinal catarrhs are frequently met with in them and they rarely have uninterrupted good health. My own experience agrees with the usual opinion, that such feeding makes the children less able to withstand the usual diseases of infancy, or renders their convalescence from them slow and unsatisfactory. I have no doubt whatever that of the large number of rickety children found in all large towns, a very great proportion occur in children who have been brought up on artificial food, such as condensed milk or some of the infants' foods.

Whilst in cows' milk the proportion of nitrogen to carbon is as one to twelve, in preserved milk it is only one to twenty.(1) The large amount of carbon given in such foods accounts for the rapid deposition of fat, but as muscle and

(1) Smith, Edward, "Foods" p 325 N. York. (1873)

bone form the strength-giving tissues we must give a food which contains the proportions of the food Elements as they occur naturally in milk. Cane sugar is not a natural food for an infant and yet by giving it condensed milk, it receives a large amount of an article which it can hardly, if at all, digest but which is prone to ferment.

The amount of Cane Sugar which is found in condensed milk varies greatly, as from 36 - 58 %(1). To see how much cane sugar was added to this milk in the usual kinds sold in the shops, I examined

43. Nestlés Swiss Milk.

I found that it contained naturally 13.135% of milk sugar.

I then estimated the amount of Cane sugar which it contained. I followed Pavy's method, which consists in adding pounded citric acid in the proportion of 2% to the milk and boiling for ten minutes. This inverts the Cane sugar but leaves the milk sugar untouched. Subtracting the amount of milk sugar normally

(1) Hehner. O. "The analyst". Vol 4. p. 44 (1879)

present we get the amount of added cane sugar. I also acidified another portion of a 2% solution with dilute sulphuric acid and heated it for two hours on the water bath and then estimated the total amount of reducing sugars. These two processes gave similar results and showed that the milk contained 41.6 % of cane sugar.

4. In another specimen of Condensed Milk (Tip Top Brand) I found that it contained 11.7 % lactose and that there was present 43 % of added cane sugar.

5 Loeflund & Company's Kindermilch.

This preparation is said to be partially peptonised, and condensed, and with dextrine and maltose added. It contains 12.63 % lactose; 33.84 % of substances which reduce Fehling's solution and reckoned as maltose. - Iodine solution shows the presence of Erythrodextrin but there is no unchanged starch in this preparation.

The first two of these preparations contain a very large amount, in fact nearly one half of the total constituents, of a substance so difficult of absorption as Cane sugar. As the child grows older so is the amount of this improper food increased for then the milk is not diluted so much. He therefore gets more of this sugary food and thus the risks increase *pari passu* with the age of the infant. In spite therefore of the general use of such sweetened and condensed milks, I have no hesitation in stating, that their use constitutes a form of injudicious feeding. The proportion of the food constituents is so altered that it has, Even when diluted, but small resemblance to ordinary breast milk. Simple unsweetened condensed milk is not in itself to be condemned as a food, though certainly far inferior to fresh cows' milk, for the relative proportions of the milk constituents remain pretty much as they were in the original milk when it is again diluted, or they can be altered, as is done to fresh cows milk; but the constant use of the sweetened condensed milk is certainly to be strongly deprecated.

Of Loeflund's Kindermilch I will speak later on.

It is a very common practice amongst the poor to add starchy materials, as cornflour, arrowroot, pounded biscuit &c. to the milk which is given to the child. This is done with the idea of thickening the milk and rendering it more nutritious, as it is a popular idea that cows' milk is in itself not a sufficient food for the infant. They forget meanwhile that if the child were fed from the breast, they would give it no other food.

The physiological processes of digestion in the infant show us that starchy matters must be very imperfectly digested at an early age, owing to the extreme feebleness of the diastatic ferments then. All authorities agree in stating that farinaceous materials are quite unadapted and hurtful to the young child. The greater part of such food simply passes through the alimentary canal unchanged.

The only carbohydrate which a naturally-fed child receives is sugar of milk. There is no substance in milk which in the least corresponds to starch. Then why should a food-substance

so unnatural and so indigestible be given to the infant? It is only at the sixth month that the diastatic ferments of the salvia and pancreas are secreted to any appreciable extent, and certainly no starchy food ought to be given before this age. The full action of the salivary and pancreatic secretions on starch is not attained till the end of the first year and it is only then that we ought to allow ordinary farinaceous food, as rice, cornflour, arrowroot, whole meal &c. to be given. If we permit its use before this period, then assuredly the starch must be predigested. By this I mean that unchanged starch must be rigidly excluded from the dietary up to the end of the first Year. When given earlier than this, it must be changed into the readily assimilable forms, as after partial or complete conversion into dextrines, maltose and glucose. I have demonstrated earlier that glucose and some dextrines are directly absorbed, while maltose is not so but requires to be changed into glucose first.

The starch should be wholly converted into dextrines and glucose when added to milk

for infants under six months of age, and even at an early age it is sometimes found to be necessary to add a carbohydrate to the milk when the child is not thriving on milk alone, or in some cases where the cows' milk sets in too firm a curd even though diluted. This firm curd is not well acted on by the gastric juice and is often rejected by vomiting. When a farinaceous material is added however, the density of the curd is lessened and so it is digested more readily. In such conditions only the easily assimilated carbohydrates ought to be employed and of these I would specify, dextrines and glucose, which from their rapidity of absorption, afford small opportunity for the occurrence of fermentative changes.

As the diastatic power of the saliva and pancreatic secretions increases so we ought gradually to lessen the degree of starch conversion so as to stimulate the secretion of these ferments. After the age of six months the starch is only to be partially converted and thus a mixture of dextrines, maltose and glucose is to be given. As the child grows older the degree of starch conversion ought to

be still further lessened, and so reducing the amount of glucose while increasing relatively the amounts of dextrin and maltose; till, at the end of the first year we may allow almost natural starchy foods to be given.

I am laying down general rules for the feeding of infants, but each individual case is to be judged of alone. One child may require to have starchy food predigested for a very much longer time than another, but still in the great majority of cases the above ought to be followed out.

It has been shown by analyses, that as lactation in the human female proceeds, the amount of albumen diminishes while the amount of carbohydrate increases, the fat remaining constant in quantity.(1)

These essentials of infant dietary lead us therefore to the consideration of the so-called "infants' foods." We require to vary the diet according to the age of the infant. The food which is suitable and sufficient for the young

(2) Pfeiffer. "Ueber die Verdauung im Säuglingsalter bei krankhaften Zuständen". Jahresb. für Kinderheilkunde: Leipsig. Vol 28. p 164 (1888)

child is unsuitable or insufficient for the same child when older. In order to direct the infants' dietary properly it is absolutely necessary to know the composition of these infant foods. By knowing them we are then able to select a suitable food for the different ages, or else we can give directions for the proper preparation of the food for the infant.

"Infants' Foods"

"Many different preparations are sold to the public under the name of "Babies' Foods" or "Infants' Foods." Some through their own merits, but many through judicious or persistent advertising have become widely known and therefore largely employed as additions to or substitutes for cow's milk.

The foods in themselves may be good enough, but may be unsuited to the ages or conditions of the children to whom they are given. An infant may thrive on a certain food for a time but afterwards begins to fall off, even

though he takes the same food readily. If so, there must be some error in the feeding and we will probably find it in the character of the artificial food, which, though it nourished the infant well enough at first, does not form a sufficiently nourishing food for the same child when older.

Again, if we continue to give predigested food for too long a time, the secretions of the alimentary canal lose their digestive properties to a large extent through disuse of the glands. Thus, on changing the food and not predigesting it, rapid Emaciation follows, as the secretory glands having [redacted] been badly developed through not being employed, take some time to attain their full functional power

In order therefore to prescribe a rational diet it becomes a question of the greatest importance to know the composition of these infants' foods. The constitution of some, we know; but in many the nature of the ingredients is kept secret. In Medicine, anything which savours of quackery is eschewed. Why should it not be so as regards the foods given to infants, the proper or improper constitution of which

may make or mar their whole after life?

In all foods designed for the use of infants we must have the four elementary principles — (1) proteids, (2) Fats, (3) Carbohydrates and (4) mineral matters. These must be combined in certain relative proportions so that the child may get a sufficiency of each of the alimentary principles and yet not an excess of individual ones. Too small or too great a relative amount of any leads ultimately to ill-health. In the first case, some of the tissues are starved; while, in the second, all that is ingested cannot be absorbed and so gastro-intestinal disorders and general ill-health follow.

It is to the carbohydrate constituents of these infants' foods that I wish now to devote attention, as these form by far their most important elements, and require, as I have already shown, the greatest care in their proper administration.

Examination of Infants' Foods as regards their Carbohydrate Constituents.

In preparing these foods for examination, I followed the printed directions given with each, only, instead of using milk as the menstruum as is often recommended, I used ordinary water.

I generally made a 5 % solution of the food; but when this gave too thick a mixture, I reduced it to a 2, or even a 1 % solution. Having cooled it, I then tested the mixture for the presence of unchanged starch, erythrodextrin or achroodextrin, with a solution of iodine. I then filtered and tested for soluble starch, dextrines, and estimated the amount of reducing matters which it contained by means of a standardised Fehling's solution. I have named these reducing matters "sugar" for brevity, but they may be glucose, levulose, maltose, lactose or reducing dextrines. In each case however I have estimated them as glucose.

A definite amount of the mixture was then heated on the water bath for two hours at 140° F., After having previously added a few

drops of dilute sulphuric acid (one in ten) any cane sugar present would be inverted by this prolonged heating. Having again cooled the mixture and made up any loss from evaporation, and filtered it, the condition of the starch was again examined and the reducing matters estimated.

In those cases where malt or extract of malt was supposed to be present, I also, instead of boiling, which would have destroyed the diastase, simply warmed the mixture and having kept it so for half-an hour, I examined the state of the starch and estimated the "sugar" quantitatively.

Analyses of the Carbohydrate Constituents of Infants' Foods.

16. Nestlé's Milk Food. (Lacteous Farina)

This is in the form of a yellow powder, extremely difficult to mix with cold water, and when so giving a brownish-yellow mixture which is faintly acid in reaction. It has a very sweet taste resembling that of ground biscuit

The directions bear that it should be mixed with cold water and then boiled for a few minutes with continuous stirring. I made in this way a 2% solution.

1. a cold retract of this food shows the presence of unchanged starch, some erythrodextrin and reducing matters ("sugar") form 4·35 %.

2. a solution made as directed by boiling showed unchanged starch and some erythrodextrin. Sugar was present to 4·5 %.

3. In case there might be malt or malt retract in this food and which the boiling would have destroyed I made a solution but did not raise the temperature above 100° F.

This showed presence of unchanged starch - trace of erythrodextrin and sugar formed 6.65 %.

4. This same solution when heated for half an hour, afterwards gave similar results.

5. Having acidified and heated it for two hours in the water bath, it showed much erythrodextrin as well as unchanged starch. The sugar now formed 38.5 % of the food.

This food therefore contains a large amount of Cane sugar (34 %) which must by the usual method of preparation be administered as such. In inverting the sugar there was hardly any possibility of there being any complete conversion of starch - the acidity being so very slight and the temperature not high enough - Some of the starch may have been dextrinised but that is the only change which would take place

As usually prepared this food consists of much unchanged starch, a small amount of dextrin and much Cane sugar. When heated for long (Specially when acidified) this food is greatly improved - a large amount of dextrines are formed and the Cane sugar undergoes inversion.

45. Loefund's Kindermilch (see page 183)

This preparation contains no unchanged starch, but there is plenty of erythrodextrin and a very large amount of "sugar" (33.84 %) which probably arises from the action of the pancreatic ferment on starch. The condensed milk with which it is mixed is also valuable, but unfortunately it also is peptonised and this is hardly necessary. In my opinion this food would be of great value in acute diseases in infancy or when the digestive processes are much impaired in function, but as a general food is cannot be recommended on account of all its elements being predigested.

46. Carnrick's Soluble Food for Infants (Milk-Wheat Food)

This is in the form of a very fine light yellow powder, freely soluble in water and having a neutral reaction. It is stated that this food is also partially predigested by pancreatinine.

Directions for Use - It is to be dissolved in a definite amount of cold water and then to be gradually added to an equal amount of boiling water, stirred till it boils, and boiled for two minutes.

1. A cold extract of this food shows the presence of starch, erythrodextrin and much sugar.

2. A solution made by boiling as directed shows unchanged starch only and "sugar" to 20 %.

3. I then prepared a solution but did not raise the temperature above 120° F, to see if the pancreatic ferment were active. This showed only unchanged starch and sugar to 18.5 %.

4. This same unboiled solution when heated for 30 minutes at 100° F showed starch, erythrodextrin in small amount and sugar formed 25.6 %.

5. Acidified and heated at 140° F. for two hours. the mixture showed the presence of a large amount of erythrodextrin and unchanged starch, also soluble starch. The sugar is now 23 % of the food.

This food contains therefore only a very small amount of invertible substance, but the pancreatic ferment seems to be still active, though its full advantage is not obtained by following the directions, for when the solution is merely heated for half-

an hour the sugar forms 25.6 %, whereas when boiled it forms only 20 % of the food. It would therefore afford a more assimilable product if it were simply heated and not boiled. The starch is either unchanged or is present only as soluble starch when prepared in the usual method, but by heating it for long a large amount becomes destrinised. Owing to the presence of the dried milk in it, this however cannot be done, for then the pancreatic ferment would act for too long a time on the milk and render it bitter. Thus owing to the milk in this food, we cannot get the full advantage of the amylopsin. Besides this the milk is also predigested and this is unnecessary and even hurtful, in a general food for infants. It like the preceding is a valuable food however in certain diseases of the digestive tract, in acute diseases or during convalescence.

178 Mellin's Food for Infants.

This is in the form of a yellow powder, having a sweet malt taste. It dissolves in water giving a muddy yellow mixture and has a neutral reaction.

It is directed to be prepared by dissolving the

food in cold water, then adding milk and water and heating gently.

1. Prepared as directed by dissolving in warm water it gives no colour on the addition of a solution of iodine. There is therefore no unchanged starch present, which must be in the form of achroodextrin, maltose or glucose. Sugar forms 29.8 % of the food.

2. This solution kept at 100° F. for 30 minutes gives similar results.

3. When acidified and heated for two hours, there is of course, no colouration with iodine and the sugar now forms 30.4 %. This is almost exactly the same as before. We may therefore conclude that there is no invertible substance present.

The slight increase in the amount of glucose is probably due to conversion of some of the non-reducing dextrines into ones capable of reducing copper from its solutions, owing to the prolonged heating in the faintly acid medium.

19. Mellin's Lacto-glycose.

This is in the form of a coarse brownish-yellow powder, having a sweetish taste of malt. It dissolves to a turbid fluid in cold water and has an alkaline reaction. It is prepared like the preceding, by dissolving in warm water.

1. The solution made as directed gives a very faint reddish tint on the addition of a solution of iodine, thus showing the presence of a small amount of erythrodextrin. Sugar forms 32.7 % of the food.

2. After being acidified and heated for two hours it gives no reaction with iodine and sugar is present to 33.6 %. This amount of sugar differs very little from that got before inversion.

In this food there is only a trace of invertible substance present, or rather and more probably, convertible substance, for it is only the erythro-dextrines which have become achro- and reducing dextrines and so have caused an increase of nearly 1% in the amount of sugar.

This food closely resembles the last in its

carbohydrate composition but it has dried milk in addition. The carbohydrates are all in a very easily assimilable condition and no cane sugar is present.

80. Benger's Food (Pancreatised)

This is a dry white powder resembling wheaten flour. In preparing it for infants' use we are directed to mix it into a paste with one-third cold milk, then to add two-thirds of boiling milk or milk and water. It is then to be set aside in a warm place. In 15 minutes it will have been sufficiently digested and is then to be slowly heated till it boils. It is then ready for use.

1. Mixed with cold water it has a slightly alkaline reaction. A solution of iodine shows the presence of much unchanged starch and a trace of erythrodextrin. It causes no reduction when boiled with Fehling's solution

2. When prepared according to the directions, the starch reaction is not so marked; erythrodextrin is present in large amount and sugar forms 1.2%.

3. A solution made with warm water and examined at once shows abundance of starch and a fair amount of erythrodextrin. Sugar is present to 4.8 % of the food.

4. A solution acidified and heated for 2 hours shows with solution of iodine that starch is not present to any great extent, for the colour produced is reddish - thus showing that much erythrodextrin is present. Sugar amounts to 13.9 %.

After this prolonged heating the amount of reducing material ("sugar") has diminished. I cannot account for this, unless the pancreatic ferment has split up the products of digestion owing to the prolonged time during which it has acted. This also goes to prove that Lépine's statement is correct and that there is a ferment in the pancreas which is destructive to grape sugar(1). I repeated this and similar experiments several times but always with a corresponding result.

This food therefore contains originally no substances which have a reducing action, that is to say it has not been previously malted. During

(1) Lépine "Sur la présence normale dans le chyle d'un ferment destructeur du sucre". Comptes Rendus 1 p 742 (1890)

the preparation however, the pancreatic ferment which it contains acts on the starch and in this way we have a large amount of dextrine and glucose along with maltose formed. Even when digested for 15 minutes however the whole of the starch is not converted - some still remains unchanged; but after being heated for two hours the whole of the starch is converted into dextrines and sugar.

This food therefore consists chiefly of flour with the pancreatic extract added.

The milk which is employed in making this food will be of course digested at the same time by the pancreatic ferments.

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81. Allen and Hanbury's Malted Infants' Food.

This appears as a cream coloured powder having a sweet taste of flour and malt.

In preparing it for use, boiling milk and water is added to the food, which has previously been mixed to a paste with cold water and to which cane sugar has been added.

1. Mixed with cold water it shows the presence of unchanged starch - There is no soluble starch

and sugar amounts to 10.85 %.

2. Made according to the printed directions and examined at once we find unchanged starch present, some erythrodextrin and sugar to 12.4 %.

3. This same solution when kept at 100° F for 30 min. shows only a trace of unchanged starch Erythrodextrin is in large amount and sugar amounts to 12.85 %.

4. Heated for two hours on the water bath after being acidified, we find much erythrodextrin and soluble starch with still a trace of unchanged starch and sugar has increased to 14 %

This food is therefore partly malted to begin with. The mode of preparation increases the action of the diastase on the flour and so we have in addition to starch, erythrodextrin and an increased amount of sugar. By continuing the heat for some time however this food would be rendered much more easily assimilated as almost all the starch becomes converted either into dextrines or sugar (compare 3 and 4)

82. "Savory and Moore's Food for Infants.
Malted and cooked upon Baron Liebig's principles."

This is a fine cream-colored powder, closely resembling and having the taste of heated flour.

Directions for use. The food is to be mixed with cold milk or milk and water into a thin paste. Then boiling milk or milk and water is to be added till the food thickens (at 140° F.) It then rapidly becomes fluid and is then ready for use.

1. When mixed with cold water, its reaction is faintly alkaline. It consists of starch simply and there is no sugar.

2. Prepared according to the directions but with water only we find that starch is present in very small amount, but erythrodextrin occurs in large amount and sugar forms 9.25 %.

3. Part of this solution kept at 100°. for 30 minutes resembles the preceding, but the amount of erythrodextrin is greater and sugar has in-

creased to 11.1 %.

5. A solution made by adding tepid water and keeping at 80° F. for 30 min. showed only little starch, but much erythrodextrin and sugar in 5.3 %.

6. When a solution, after being acidified, has been heated for 2 hours on the water bath, there is only a trace of unchanged starch found, but soluble starch occurs and very large quantities of erythrodextrin, while sugar forms 15.6 %.

This is also a malted food. It seems to consist of flour and malt. Under the influence of heat and solution the malt acts on the starch of the flour and converts it into dextrines, maltose and glucose. We see that the conversion is more complete the longer the mixture is kept warm and the higher the temperature (within certain limits). If however the temperature is never raised high (as in 5) the diastase of the malt converts the starch merely into dextrines and but little reaches the condition of sugar. If kept for long however even at this temperature all the

starch becomes ultimately changed into maltose and glucose. We can therefore vary the degree or amount of conversion in the starch of such foods by varying the degree of heat or the length of time that they are exposed to heats.

83. Savory and Moore's Self-digesting Whole Meal Food.

This is a fine yellowish powder, with brownish particles in it like scales of meal. It has a strong taste of malt. It is prepared in exactly the same way as the preceding food.

1. Mixed with cold water it gives a faintly alkaline solution and shows merely unchanged starch without (or with only the faintest trace of) sugar

2. Prepared as directed, it contains much erythrodextrin, soluble starch and starch. Sugar forms 4.35 %.

3. Part of this solution kept at 120°. for 30 minutes. The erythrodextrin has increased in amount and the sugar now amounts to 8.3 %.

(4) Acidified and heated for two hours - Much erythrodextrin and soluble starch present and sugar amounts to 11 %.

This food closely resembles the last - they are both malt foods - The latter however has the flour in a coarser form as the outer parts of the wheat grain are also ground up in the food.

84. Horlick's Malted Milk.

This is a granular gritty yellow powder with a sweet milky taste.

It is prepared simply by dissolving it in hot water. The amount used is regulated, it states, by the age and condition of the child.

1. A solution made with warm water is alkaline in reaction. There is no colouration produced on the addition of a solution of iodine - Sugar forms 23.25 % of the food. No precipitate falls on the addition of Acetic acid

2. Part of this solution kept at 100° F. for 30 min. shows the sugar increased to 25 %.

3. Acidified and heated for two hours - Sugar forms 31.25 % of the food.

This preparation is said to contain and to consist of desiccated cows' milk, malted flour and alkaline carbonates to neutralise the acidity of the milk.

It contains we see, no starch or early formed dextrines. Any starch which it contains has been completely converted already. The length of time it is heated alone increases but little the amount of sugar. The increase in amount of reducing substances by the prolonged heating, after acidifying, is not likely due to added cane sugar but is most probably due to the more complete conversion of some of the higher dextrines (achroodextrins) into reducing dextrines and sugar.

This preparation therefore contains dextrines, maltose, glucose, albuminous matters and mineral salts.

85. Ridge's Patent Cooked Food for Infants.

This is a cream coloured powder, looking and tasting like heated flour.

Directions - Mix the food with water or milk

to form a cream. Add hot water or milk "stirring briskly while boiling." It is then ready.

1. A solution made with cold water has a faint degree of acidity and contains only unchanged starch and no sugar.

2. Prepared as directed but not boiled, then kept at 120° F. for 30 minutes. This contains only unchanged starch along with the faintest trace of sugar.

3. Prepared as directed by boiling - starch alone and no sugar.

4. Part of this solution kept at 120° F. for 30 min. results similar.

5. Acidified and heated at 140° F. for two hours a large amount of erythrodextrin is present along with much starch. Sugar forms 5.4 % of the food.

This food therefore contains apparently only flour, and if prepared according to the directions, we

only get a paste, containing no dextrines or sugar. At best the starch is only in the form of soluble starch and no great amount of it either. Prolonged heating, after acidification, converts a good deal of the starch into dextrines along with a little sugar.

86. Neave's Farinaceous Food.

This appears in the form of a light cream-coloured powder, having the taste of heated flour.

Directions. Mix the food with cold water to form a paste. Add boiling water and boil gently for five to seven minutes. Then milk and sugar are to be added and it is then ready.

1. Mixed with cold water it has a neutral reaction. Consists of unchanged starch and no sugar.

2. a solution made as above but not raised above a temperature of 140°. F. and kept at 100°. F. for 30 minutes shows only the presence of unchanged starch. Sugar forms 1.65 %

3. Prepared as directed, by boiling, shows only unchanged starch - no dextrine or sugar.

4. Part of this solution kept at 120°F. for 30 min. shows a trace of sugar.

5. Acidified and heated for two hours. Nearly all the starch has been converted - There is only a trace of unchanged starch left. Erythrodextrin is present in large amount and sugar amounts to 6·88 %.

This food is very similar to the last. If prepared in the usual way the starch is left almost unchanged, whereas if heated for long, it undergoes a large amount of conversion. It is evident that the mode of preparing these foods is of the greatest importance as regards rendering them easy of assimilation.

87. <u>Hard's Farinaceous Food for Infants.</u>

This is a fine powder and closely resembles ordinary wheaten flour.

It is prepared by mixing it in a little cold

water, boiling water is then added and it is boiled for eight minutes. Milk and sugar are added and it is ready.

1. Mixed with cold water, it has a neutral reaction and contains no sugar or dextrines, but only unchanged starch.

2. A solution made with warm water and kept at 140° F. for 30 minutes, but never boiled, shows the presence of a small amount of dextrine and much starch. Sugar is present to 2.27 %.

3. Prepared as directed by boiling. There are no dextrines nor sugar but only starch.

4. Part of the last mixture heated for 30 minutes gives no difference in the results.

5. Acidified and heated for two hours — A great amount of conversion has taken place; there is very little unchanged starch left; Erythro-dextrin is present in large amount.

and sugar forms 6·25 % of the food.

It also closely resembles the two preceding foods. A floury paste is the only result from making it according to the directions; but a more easily digested mixture is obtained if one heats it for long.

88. Dr. Nicol's Food of Health.

This appears as a coarse white powder containing small hard brown scales like bran.

For infants' use it is prepared by pouring equal parts of boiling milk and water over the food which has previously been slightly moistened. It is then boiled for five minutes.

1. Mixed with cold water, it has a faintly acid reaction and shows only unchanged starch.

2. A solution made with hot water only and kept at 120° F. for 30 minutes, shows still much starch - dextrine in small amount and sugar to 5.2 %

3. Prepared by boiling as directed, it shows only unchanged starch - no sugar or dextrines.
4. Part of this mixture heated for 30 minutes shows a trace of sugar.
5. Acidified and heated for two hours. There is much starch present, small amount of erythrodextrin and sugar to 2.32 %.

It is evident that the boiling which the food is directed to have destroys the power of the converting ferment, which it seems to possess (probably malt extract). When made with warm water and kept warm it develops 5.2 % of sugar; while if boiled, no sugar is produced

XVII Carbohydrate Constituents of Infants' Foods.

Food & Condition.	Starch	Erythrod.	% Sugar.	Remarks.
1. Nestlé's Milk Food				
(a) Cold extract.	+++	+	4·35	Contains much Cane Sugar.
(b) Heated simply	++	+	6·65	
(c) as directed	+++	+	4·5	
(d) Heated + acid	++	++	38·5	
2. Carnrick's Sol. Food				
(a) Cold extract.	++	++	+	Pancreatised
(b) heated simply	++	++	25·6	
(c) as directed	++	-	20·	
(d) heated + acid	+	+++	23	
3. Mellin's Food				
(b) heated simply	0	0	29·8	Fully converted.
(c) as directed	0	0	29·8	
(d) heat + acid	0	0	30·4	
4. Mellin's Lacto glycose				
(c) as directed	0	+	32·7	Fully converted.
(d) heat + acid	0	0	33·6	

Food & Condition	Starch	Erythro dextrin	% Sugar	Remarks.
5. Bengers Food				
(a) cold extract	+++	+	0	Pancreatised.
(b) Simply heated	++-	++-	7.8	
(c) As directed	++	++	17.2	
(d) heat + acid	+	+++	13.9	
6. Allen & Hanbury's Food				
(a) cold extract	++	-	10.85	Malted Food
(b) Simply heated	+	+++	12.85	
(c) as directed	++	++	12.4	
(d) heat + acid	+	+++	14.	
7. Savory & Moores Food				
(a) cold extract	++	-	-	Malted Food
(b) Simply heated	-	+++	11.1	
(c) as directed	+	+++	9.25	
(d) heat + acid	+	++++	15.6	
8. Savory Moore's Wholemeal				
(a) cold extract	+	0	0	Malted.
(b) simply heated	+	+++	8.3	
(c) as directed	+	++	7.35	
(d) heat + acid	?	+++	11.	

Food & Condition	Starch	Erythro-dextrin	% Sugar	Remarks.
9. Horlick's Malted milk				
(b) Simply heated	0	0	25.	
(c) as directed	0	0	23·25	
(d) heat + acid	0	0	31·25	
10. Ridge's Food				
(a) cold extract	+	-	0	
(b) simply heated	+	-	?	
(c) as directed	+	-	0	
(d) heat + acid	++	++	5·4	
11. Neave's Food.				
(a) cold extract	+	-	0	
(b) Simply heated	+	-	1·65	
(c) as directed	+	-	0	
(d) heat + acid	?	+++	6·88	
12. Hard's Food				
(a) cold extract	+	-	0	
(b) simply heated	++	?	2·27	
(c) as directed	+	-	0	
(d) heat + acid	?	+++	6·25	

Food & Condition	Starch	Erythrodext	% Sugar	Remarks.
13. Nicols' Food				*
(a) Iced extract	+	−	0	
(b) simple heat.	+	?	5.2	
(c) as directed	+	−	0	
(d) heat + acid	++	+	2.32	

We gather from the preceding analyses of the carbohydrate constituents of the principal kinds of infants' food now in the market the following facts –

1. Most of these foods consist of wheaten flour mixed with malt or extract of malt. The diastase of the malt is supposed to act on the starch of the flour during the process of cooking and to convert it into maltose, dextrines and glucose.

I have shown however that in several of these foods, if prepared according to the directions accompanying each, only a very slight conversion of starch occurs. A temperature of 140 - 50° F is most suitable for the action of diastase, but if it be carried to 212° F. the ferment is killed or at least its action is arrested. Now several of these foods are prepared by adding boiling milk or water and then boiling for several minutes. Such treatment effectually prevents any conversion from occurring or soon stops any that is already going on. I have shown that in some of these foods, if prepared only with warm water and heated for half an hour (never allowing the temperature to rise above 150° F) part of the starch undergoes conversion and we

then fluid dextrin, maltose and glucose with or without unchanged starch depending on the time allowed and strength of ferment. Some of the foods composed of flour and malt are directed to be so prepared and with these no fault can be found. Those however which are ordered to be boiled, I have no hesitation in saying, are quite unsuitable as food for young infants. Not that the food is in itself bad or that it would not be a suitable food for an older child, but owing to the manner of preparation is is rendered unsuitable for infants, as it simply is made to consist of much starch, traces of dextrine and sugar.

Those containing ground malt should always be used in preference to those containing the extract of malt as the former is much more active in its converting action.

If properly cooked these mixtures of malt and flour make excellent foods for infants. It is to such mixtures that I look for the greatest improvement in the future in the feeding of infants

By varying the length of time during which such mixtures are heated, we may cause the starch to be converted to any degree which we desire and so make it a suitable addition

to the milk for the child at different ages or in varying conditions of health. We may either wholly convert the starch by prolonged heating and so make it suitable for infants of a few months or weeks old, or we may allow only a partial conversion into soluble starch, dextrines and maltose and so make it fit for an older child. As I have said before the degree of conversion ought to be lessened as the age of the child increases.

Cane sugar is also added to some of these foods and of course it is to be condemned.

2. Instead of Malt, some of the foods contain some of the various preparations of the pancreatic ferments. These ferments act both on the starch of the food and on the milk which the food already contains or to which it is added in the course of preparation. Thus both milk and starch are predigested in such foods.

This predigestion of proteids and carbohydrates must render such foods most valuable in cases of great debility, inanition or exhaustion in infants or in the course of acute illnesses; but in an ordinary food for infants we do not wish to predigest the milk which is the natural

food of the child and which he can usually digest well enough when it is properly prepared. Proteids are generally well digested by infants. We take advantage of this to feed them on meat infusions where there is great debility. We wish to avoid therefore the predigestion of the proteids of milk and only require that the carbohydrates, which the infant himself cannot properly digest or only partially, be rendered easily assimilable by conversion or inversion. Sir William Roberts (1) has shown that kittens fed on fully predigested milk did not, for a time, thrive so well when this was replaced by only partially predigested milk, as their brothers and sisters who had been fed all along on ordinary milk. The use of predigested foods lessens the activity of the glands, which ought to secrete the digestive fluid. We ought not therefore to give artificially digested food for a longer time than is absolutely necessary, and that is why I have so often insisted on lessening the amount of starch conversion as the child increases in age, or in debilitated conditions as his health improves.

(1) Roberts, Sir. W. "Digestion and Diet" p 211 (1890)

3. In some of these foods the starch has been previously converted through the action of the diastase of malt. In such foods we find none, or the merest traces of unchanged starch; erythrodextrins and achroodextrins are present in varying amounts, while maltose and glucose usually occur in large amount.

Nearly all of these are made from wheaten flour. Some contain alkaline carbonates to neutralise the acidity of the cow's milk to which they are added; in others again desiccated milk has already been added

Such foods are usually easily assimilated, for in some the starch has been entirely changed into dextrines and glucose and these are at once absorbed; while others consisting of dextrines and maltose still require some digestion.

These malted foods are of great value to the child in whom the power of digesting raw carbohydrate is at the minimum.

4. Combinations of dextrin and starch are often met with as infants' foods. Such consist simply of flour which has been subjected to a high

temperature and has in this way been baked. Under the influence of heat starch becomes changed into soluble dextrines. If the flour has been carefully heated and for a sufficiently long time, the starch becomes wholly dextrinised. In the foods usually met with however, such treatment has rarely been carried sufficiently far and thus only a part, and usually a small part, of the starch has been converted even into the early-formed or low dextrines. These foods usually contain much unchanged starch along with the albuminous constituents and salts of the grain. Domestically, this admixture is known as the "flour-ball", and is prepared by boiling flour in a cloth for from 12 to 24 hours. It then forms a hard ball, which, after the translucent outside skin has been pared off is seen to consist of a dense white substance which is dextrinised starch. This white inner part is ground down and mixed with milk for the infants' use. Used in this manner it forms an easily assimilated carbohydrate and, acting as a mechanical diluent, helps to prevent the milk from coagulating in too large or firm clots in the child's stomach.

If these dextrinised foods are thoroughly prepared they form valuable additions to the ordinary milk diet of the child, specially when a few months old. If however they are imperfectly dextrinised as is too often the case, the large amount of unchanged starch which is also given forms a great drawback to their use as safe articles of diet for infants.

5. Many preparations sold as food for infants consist simply of flour or unchanged starchy matter. Such foods ought never to be given to the child before the end of his first year, as earlier than this only a small part can be digested by him.

The fluid besides that many of these are very coarsely prepared and exhibit when examined by the microscope the presence of husks, spicules &c. which must form a source of great irritation to the delicate intestinal mucous membrane of the infant, and which form a sufficient cause in many cases for the diarrhoea which ensues after the commencement of such food.

Owing to the relatively small number of glands in the gastro-intestinal tract of the infant and to their immaturity, the young child is unable to assimilate carbohydrates which require extensive change. As the child grows older greater liberties may however be taken with his digestion; but at an early period of the childs' life it is culpable ignorance to tamper with his delicate digestion by giving him any or the first food which may present itself to the parent or to the seller.

Restrictions of the Sale of Food for Infants.

It seems to me that the general sale of such preparations as food for infants ought to be prohibited; or that, at least, they should only be sold by qualified chemists, who should first inquire as to the age and condition of the child, and who would then in a manner know whether such food were suitable for the child or not. A much better plan would however be, that none of these foods should be supplied to the purchaser, unless the latter at the same time presented a note from a medical practitioner

stating that such food would be suitable for the child. I would have them in fact, dispensed in the usual manner by chemists as drugs are sold.

It is the wholesale vending, or rather the intrusion of such foods on people, that makes their use so general. It is a fact that so soon as a birth is advertised in the newspapers, many of the manufacturers of these foods send samples of their preparations to the parents. Of course each is accompanied by its own laudatory literature. The parents knowing little regarding the proper feeding of their child and thinking it proper that it should have "a food" as well as milk, select that one which they think is best and so, unguided by experience and ignorant of physiological processes, they usually select that one which is most highly vaunted or is accompanied by portraits of the fattest babies reared on this particular food.

It is on account of the incalculable harm that is thus done, unwittingly in most cases, to the infantile population that I would put the sale of such foods under a restriction. For this purpose a special clause might be introduced into the "Sale of Foods and

Drugs Act" so as to make the indiscriminate sale of infants' foods penal.

Almost all the varieties of infants' foods are directed to be prepared with milk or a mixture of milk and water, except those which already contain desiccated milk.

In those which contain malt, the starch becomes converted to a varying degree depending on the manner in which the food is prepared as I have already described. Now, it has been shown that if malt be added to milk and if this mixture be kept at 100° F. for some time, the casein of the milk undergoes such a change that it becomes uncoagulable by acids. I have verified this, and found that when acetic acid is added to milk which has been previously heated with infusion or extract of malt, no curdling takes place. This must be of great importance as regards the digestion of milk, for one fertile cause of infantile indigestion is the too dense curdling of milk in the stomach. During the preparation of those infants' foods which contain malt, the milk is also acted on during the process of cooking and so changed

that it does not coagulate on encountering the acid secretion of the stomach, or at any rate does not form nearly so dense a coagulum. This property which malt possesses might be put to great service in the treatment of those forms of indigestion following the use of cow's milk. Instead of adding any of the farinaceous matters to the milk, it might be preferable in some cases to keep the milk in contact with malt for some time so as to prevent its coagulation taking place so readily in the stomach.

Such foods containing malt, when properly prepared so as to cause complete or almost complete conversion of the starch, or those which are already entirely converted, form, when added to dilute cows' milk, in my opinion the most suitable food for infants with whom ordinary cows' milk does not agree or who are not thriving on it. In nearly all cases it is also better to add a little cream to the food so prepared, as almost all the infants' foods are somewhat poor in fat, and the dilution of the milk reduces the fat in it too much: Amongst the poor or with careless nurses those foods which are wholly converted are preferable to those which undergo conversion

during preparation, especially for young infants. By giving these we know that the child is receiving an easily assimilated diet, whereas with the others care is required in their preparation.

Not only are these foods good as adjuvants to milk, but they are sometimes the only food which the child can digest. After once that fermentative changes have taken place in the gastric and intestinal contents giving rise to vomiting and diarrhoea, the bacteria which have caused these decompositions remain and cause milk which is ingested to become acid as soon almost as it is taken. Under these circumstances the use of milk must be entirely stopped and we then have recourse to such foods as the above along with infusions of meat, as veal or chicken broth.

At a later date also these foods are of great value when we are beginning to add other food materials to the purely milk diet, and what better can be begin with than some of the easily assimilated carbohydrates?

It would be improper for me to specify by name the particular foods which I would recommend and which I employ in the feeding of infants of different ages, but after what I have said regarding the condition in which the carbohydrates ought to be given at different periods of the infants life and from the analyses of the foods, there can be no difficulty in choosing the particular food for the particular age and condition of the child, so as to form a desirable addition to or substitute for a purely milk diet.

To make this investigation more complete, I wish now, and very briefly, to direct attention to the nature of the sugars in the usual saccharine Elements of our food stuffs.

Saccharine Foods.

The condition of the saccharine constituents of food is, apart from the question for the present of infant feeding, of great importance as regards the diet of children, invalids and dyspeptics.

All who suffer from weak or disordered digestion know that if they partake of much sugary food they will suffer in regard to subsequent gastric pain, flatulence, headache, nausea &c. My own experiments on dyspeptic patients show this clearly. When cane sugar was given them in large amount, in nearly every case were some of these symptoms complained of.

Sugar forms however such a large and important part in dietary that the dyspeptic finds he cannot avoid consuming some, and besides it is almost a necessity in order to render other articles of diet pleasant (The use of "saccharin" has not yet become so general that it has at all displaced sugar for ordinary culinary purposes)

Some sugary foods are, as is well known, much more easily borne by the stomach than others. or more of one kind may be taken with impunity than

another. Why is this? I have already shown what forms of sugar are most easily assimilated. Does the ease or difficulty of digestion of certain sugary foods depend on the nature of the sugars which they contain?

In order to answer this we require to know the nature of the sugars as they occur in some of the commoner articles of diet.

Nature of Sugars in Saccharine Foods.

Preserved Fruits.

Jams. Two per cent. solutions of these were made and the sugar estimated by the saccharimeter of Zeiss and also by Fehling's solution. These solutions were then heated for two hours at 180°. F. after being acidified so as to invert any cane sugar which they contained

73. 1. Strawberry Jam.

Its acidity was equal to = $\frac{N}{72}$

The invert sugar which naturally was present amounted to 18 %

While after inversion it formed 41.6 %

thus showing that cane sugar was present to 23·6 % in the jam.

It is evident that a very large proportion of the cane sugar has undergone inversion during the process of manufacturing the jam.

74. 2. Marmalade

Acidity = $\frac{N}{50}$

Invert sugar naturally present	5/ %
Invert sugar after inversion	61 %

In this case almost all the cane sugar $(\frac{5}{6})$ has been inverted during the preparation.

75. 3. Bramble Jam.

Acidity = $\frac{N}{64}$.

Invert sugar naturally present	47·6 %.
Invert sugar after inversion	59·4.

76. 4. Raspberry Jam.

Acidity = $\frac{N}{70}$

Invert sugar naturally present.	26·12 %
Invert sugar after inversion	42·68 %

47.5 Plum Jam.

Acidity = $\frac{N}{30}$

Invert Sugar naturally present 50 %

Invert Sugar after inversion 58 %

XVIII Sugars in Jams.

Jam.	Acidity	Natural Invert Sugar.	Invert S. after inversion.	Cane Sugar.	Proportion of Cane Sugar inverted
Strawberry	$\frac{N}{72}$	18	41.6	23.6	3.4
Marmalade	$\frac{N}{50}$	51	61	10.	5.6
Bramble	$\frac{N}{64}$	47.6	59.4	11.8	4.5
Raspberry	$\frac{N}{70}$	26.12	42.68	16.56	2.3
Plum.	$\frac{N}{30}$	50.	58.	8.	5.6

In these different jams the acidity is distinct and the amount of inversion of Cane sugar has been in a manner proportional to the acidity, the greater the acidity the greater the inversion.

Jams are considered to be very wholesome and form a pleasant manner of taking a large amount of concentrated carbohydrate food along with the valuable organic acids which the fruits contain.

Marmalade is a very common adelition to our dietary and one half of it consists of invert sugar.

I am convinced that the large amount of invert sugar which these preserves contain is the cause of their easy digestibility. Many chronic dyspeptics are found who still eat jam along with their bread and suffer no discomfort from doing so.

Crystallised Fruit (Fruits glacés)

78. An infusion of several different kinds gave a total acidity of = $\frac{N}{66.6}$

Naturally present invert sugar forms 29.5%
Invert sugar after inversion 50. %
Cane sugar therefore is present in 20.5 %.

There is consequently about three-fifths of the cane sugar inverted during the preparation. Such fruits however are hard and dense and difficult of disintegration. This form of preserved fruit is well known to be most indigestible.

Confections.

Very many sweetmeats consist of finely ground cane sugar made into a paste with gum, albumen or gelatine and with a flavouring agent added. This mixture is either rolled out and made into

lozenges or coloured and made into various shapes. These are then dried in a warm room and at no time are such sweets subjected to heat. The various lozenges, French crêmes, icing for cakes &c. consist of almost pure Cane sugar

Inverted sugar resulting from prolonged boiling alone or from the addition of organic acids is found in such sweets as toffy, various clear sweets which are technically known as "boilings" &c. Most of these are made by adding a little water to a quantity of sugar and heating till the sugar is dissolved. It is then boiled, after a quantity of cream of tartar, acetic acid or vinegar (1) has been added, and the boiling is continued till the candy is "high", that is till a quantity of it when dropped on to a cold surface becomes at once brittle. The addition of the acid and the prolonged boiling is simply to prevent the sugar from crystallising again on the candy cooling. By this treatment a tolerably large proportion of the cane sugar is inverted. When insufficiently inverted, the whole mass of candy recrystallises on cooling and the sweet is spoiled.

(1) Francatelli "The Royal Confectioner, a Practical Treatise" (1887)

It is well known in the nursery that clear sweets and toffy are much less harmful to children than white crystallised sweets. A mother will allow her child to eat much more of the former than of the latter as she thinks that "they do not harm the stomach so much." Is this not due to the fact that they contain a large amount of invert sugar which is easily assimilated.

To determine in what proportions cane and invert sugar existed in different sweets, I examined the following: —

French Crême Sweets.

49. Having made a 2 % solution of these, I determined both by the polariscope and by Fehling's solution the amount of invert sugar which they naturally contained. I then took a definite volume of this solution and having acidified it with very dilute sulphuric acid I heated it on the water bath at 180° F. for two hours so as to invert any cane sugar present in the sweet. These crêmes contained of

Invert sugar naturally present	7.7 %.
Invert sugar after inversion	79. %
Cane sugar was therefore present in	71.3 %

The greater part of the sweets consists of Cane Sugar.

(71.3 %) and the smaller part of invert sugar, water, gum and flavouring agent.

80 **Chocolate**

I found that ordinary chocolate contains no invert sugar. Cane sugar is alone present and amounts to 45 %. It does not therefore constitute half the sweetmeat, cocoa forming the larger part of the chocolate.

This is considered to be a very wholesome confection and naturally so, for even though all the sugar is present as Cane sugar it only forms the smaller half of the chocolate, the cocoa of which contains a large amount of fat and albuminous matter along with its active principle, theobromine. *A priori* one would not expect to find any invert sugar present in chocolate when we learn how it is prepared. Cane sugar is merely ground in with the warm cocoa paste and it is then turned into moulds.

81 **Chocolate Crème**

This sweet of which so much is consumed, contains of natural invert sugar 8.6 %

The invert sugar after inversion forms 62.5 %
Cane sugar is therefore present to 53.9 %

The invert sugar however which we find naturally in this sweet is confined to the white crême, for when this is isolated from the surrounding chocolate it gives the same per centage of reducing sugar. viz 8.6 %., while the chocolate which encloses it contains no invert sugar.

82 Acid drops.

The acidity of these sweets is equal to = $\frac{N}{7.1}$ (N = normal solution of caustic soda), but probably varies greatly in different samples.

Invert sugar naturally occurring forms 27.5 %
Invert sugar after inversion amounts to 83 %.
Cane sugar is therefore present to 55.5 %.

We might have expected to find a greater amount of invert sugar present in these sweets, specially as the acidity is relatively high The method of manufacture explains this however. The candy from which they are made, is prepared in the same way as for all clear boiled sweets, that is to say that acetic acid or tartrate of potash is added and it is boiled to "candy high". All

these sweets are prepared at first in exactly the same way, it is only the after treatment which differs and which gives rise to the varieties of clear sweets. In the case of acid drops, after being boiled "high" the candy is poured on to a slab and when sufficiently cool a definite quantity of the acid tartrate of potash is kneaded in so as to give the mass the desired degree of acidity. It is this added acid which causes the high degree of acidity.

83 Everton Toffy

Its acidity is = $\frac{N}{100}$

Invert sugar occurring naturally forms	27·7 %.
Invert sugar after inversion	62·5 %.
Cane sugar is therefore present in	34·8 %.

The invert sugar is present in almost the same amount as in the last case, showing that their preparation is similar. After being boiled to "Candy high" butter is added and the candy is then poured on to a slab. This sweet contains therefore much fat. Curiously enough this sweet is well known to be very wholesome. One often sees it

given to delicate children who are forbidden to eat other sweets. Dr. Milner Fothergill has even recommended it instead of cod liver oil for strumous children, and states that he has saved many children from death by its use.(1) This high recommendation is no doubt based on the fact that this sweet contains a large amount of fat, which is eagerly taken in this form by delicate children who would refuse to take fat in its natural condition or even as butter. But may not this be greatly helped by the large amount of easily digested carbohydrate which it contains as invert sugar? That this is so, is my firm conviction. Everton toffy is valuable therefore as containing a large amount of easily assimilated carbohydrate and hydrocarbons in a pleasant form.

84 Extract of Malt Lozenges.

Acidity = $\frac{N}{16.6}$

Invert sugar naturally present 14.7 %

Invert sugar after inversion 85 %.

This lozenge resembles closely in composition other lozenges. The higher per centage of

(1) Fothergill, "Manual of Dietetics" p 164.

naturally occurring invert sugar is probably due to the added extract of malt causing an excess of reduction in the copper solution.

85 Clear Transparent Sweets.

Naturally occurring invert sugar forms 13.8 %.
Invert sugar after inversion 85 %
Cane sugar is therefore present in 71.2 %.

XIX Sugars present in Confections.

Variety.	Acidity	Invert Sugar naturally present.	Invert Sugar after inversion outside.	% Cane Sugar.
French Crêmes		7.7	79.	71.3
Chocolate		0	45.	45.
Chocolate Crême		8.6	62.5	53.9
Acid Drops	$\frac{N}{7.1}$	27.5	83.	55.5
Toffy	$\frac{N}{100}$	27.7	62.5	34.8
Malt Lozenges	$\frac{N}{16.6}$	14.7	85.	70.3
Clear Sweets.		13.8	85	71.2

Honey

Before the sugar Cane was so largely cultivated as it now is, honey was employed as the sweetening

agent generally in this and in other countries, and up till a comparatively recent period honey was employed as we now use preserves. Since the great fall in the price of sugar, the industry of bee-keeping has diminished greatly.

The chief constituents of pure honey are dextrose and levulose with a certain amount of less well-known sugars (said by some to be Cane sugar) as mannite &c. Organic acids are also present, of which formic acid is the chief. The reducing sugars amount on an average to 67.85 %[1] and in one sample dextrose formed 37.58 % and levulose 36.22 %

Treacle - Golden Syrup -

Treacle is the refuse got in sugar refining and consists of Cane sugar in an uncrystallisable condition and invert sugar in nearly equal amounts. There is also about one-fifth water present.

Golden syrup is a purified form of treacle.

These syrups form a common addition to the food stuffs of the poorer classes.

(1) Hehner. "Analyst" April 1884.

Fruits.

These all contain a good deal of sugar when ripe and it is to this chiefly, along with the organic acids, that they owe their value as articles of diet. The sugar is chiefly in the uncrystallisable form of levulose with a small proportion of glucose and in some cases cane sugar is also present.

The acidity of the fruit is often so marked that sugar has to be added to counteract the sourness. It is however better to neutralise the acidity by adding an alkali, as bicarbonate of potash or soda, than to sweeten it by means of cane sugar.

When cane sugar is added to acid fruits, much becomes inverted during the process of cooking and as invert sugar is less sweet than cane sugar, the housewife is frequently at a loss to understand why the fruit is so sour in spite of her having added much cane sugar before cooking it.

Stewed or boiled fruits constitute a most valuable addition to our food, specially when no cane sugar has been added to them.

Summary and Conclusion

What I have stated regarding the kind of carbohydrate food which may be given to the infant applies, and in some cases with even greater force, to the dyspeptic and invalid or during senescence when the digestive organs grow feeble and assimilation is not so active as it formerly was. In acute illnesses or during convalescence the digestive powers are also weak and the secretion of saliva is small in amount. Such patients have to be treated, as regards their food, almost as infants. What better food or more easy of digestion can we give them than the easily assimilated carbohydrates along with milk?

In the gouty condition also which is due to excess of uric acid, the use of cane sugar has usually to be avoided. We might however in such cases with safety allow the patient to use invert sugar or fully converted starch, for these are absorbed so quickly that acid fermentations have not time to take place.

In such diseases as Chronic Gastric catarrh, dilatation of stomach with concomitant atrophy of the

gastric glands, acid dyspepsia, cancer of stomach, congestion of gastric and intestinal mucous membrane from heart or lung diseases even with edema or ascites. I would forbid the use of Cane sugar and ordinary farinaceous foods unless in small amount; while I would advocate the use of inverted sugar and converted starch. In ascites or dropsy such food would act most beneficially and even therapeutically, as it has been shown that glucose and even dextrine form powerful diuretics and act without raising the blood pressure (1)

Such easily assimilated carbohydrates used as articles of diet give rise to no inconvenience (unless when, like any other food, taken in excess) but are quickly absorbed and thus form most valuable additions to our fat producing and energy-saving foods.

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(1) Dastre - "Observations relativement à la diurèse produite par les sucres" Comptes Rendus de Biologie p 574. (1889) - Shows that lactose is not a more powerful diuretic than glucose.
Germain Sée "Sur la diurèse produite par la lactose". Ibid p 606.
Meilach, Dr Sophie "Les sucres comme diurétiques".
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Vol 118. p. 24 (1890)

My task is now Ended.

I have striven to show the unsuitability of Cane Sugar as an article of diet and specially so for children.. This led me on to speak of farinaceous foods and the absorption of the products of starch conversion.

I have demonstrated both physiologically and clinically that unchanged cane sugar and amylaceous foods are quite unassimilable as such. Before they can be absorbed they must undergo a special and complicated digestion by which they are converted into glucose and levulose. This digestion they cannot receive in the alimentary tract of the infant, for as yet it is not fully developed and does not possess the digestive powers which are necessary for this food. If however such foodstuffs are changed into less complex combinations then their absorption is rendered much more easy, and they then form very valuable additions to the infant dietary.

I began this thesis by stating that the chief cause of infant mortality was due

to errors in or mismanagement of infant feeding. I close it, reiterating the same words; but with the hope that this feeble effort of mine may not be entirely fruitless in directing greater attention to this most important subject and may thus help to ameliorate the condition of our helpless little ones.

It is by improvements such as I have indicated, regarding the dietary of infants along with improved hygienic conditions that we may in the future, with confidence, expect a greatly diminished rate of infant mortality and a much improved state of general health amongst the new members of our population.

I have to express my warmest thanks to Professor Rutherford, who courteously and most kindly granted me the free use of his well-equipped laboratory for the carrying on of my experiments.

APPENDIX.

Laboratory Experiments with digestive preparations.

Do any of the preparations of the digestive ferments which are commonly sold cause any inversion of Cane sugar?

1. Liquor Pepticus (Benger)

This has an initial acidity of = $\frac{N}{7.9}$. I added 8 c.c. of this preparation to 50 c.c. of a 20 % Solution of Cane Sugar and placed at 38° C.

One hour after the polarisope gave + 20°.

and the invert sugar by Fehling's solution 0.71 %

two hours after - Rotation +19.3°

Invert Sugar 1.04 %

This is a large amount of inversion but when we look to the acidity we find that it is high and so accounts for the inversion.

2. Tablet of pepsin - added to 50 c.c. 20 % Cane sugar solution - the solution is faintly acid.

One hour after Rotation +23.5

Invert Sugar 0.43 %

Two hours after Rotation +23.3

Invert Sugar 0.44 %.

This inversion is almost equal to that produced by the addition of 0.2 % of hydrochloric acid

3. Liquor Pancreaticus (Fairchild)

Initial acidity = $\frac{N}{22.7}$

To 50 c.c. Cane sugar solution (20 %) 5 grams of bicarbonate of soda were added and 8 c.c. liquor pancreaticus. At 38° C

One hour afterwards Rotation + 22.1°

Invert sugar 0.33 %.

Two hours afterwards Rotation + 22.1

Invert sugar. 0.34 %

4. Zymine Peptonising powder (Fairchild)

To 50 c c 20 % Cane sugar solution I added $\frac{1}{3}$ of a tube of this powder. At 38° C.

One hour after - Rotation + 21.2°

Invert sugar 0.26 %.

Two hours after.

Rotation +20.6°

Invert sugar 0.38 %.

The solution is strongly alkaline.

Nothing much can be said regarding the inversive power (if any is possessed by them) of these ferments. The inversion which takes place with the

latter is hardly greater than that produced by heating the sugar solution by itself

Volumetric Analysis of Sugar.

The solution which I employed in estimating the sugars was that known as Fehling's solution and standardised so that the copper of 20 c.c. was exactly precipitated (as suboxide) by 0·1 gramme of glucose.

It has been shown that the amount of cuprous oxide precipitated by reducing sugars is greater according as the degree of concentration of the Fehling's solution is greater and with the length of time the solution is boiled.(1) To obviate these errors as much as possible, I always used 20 c.c. of Fehling's solution when practicable, and diluted it with 50 c.c. water. The same degree of heat and approximately the same duration of boiling were applied in each test and so far as possible the conditions were kept similar.

(1) Bourquelot et Grimbert "Documents relatifs au dosage des matières sucrées". Journal de Pharmacie et de Chemie Vol 19. 5me Série. p 465 (1889)

Soxhlet (1) has also shown that the nature of the sugar as well as its concentration causes a variation in the quantity of copper reduced, as also, if the sugar solution is added slowly a greater amount of copper is reduced than if it is added rapidly. I made a trial experiment in every case to begin with, so as to roughly estimate the sugar. The succeeding tests were then applied with greater care.

I tried the modification of Fehling's colour test devised by Causse (2). It consists in boiling 20 c.c. of Fehling's solution, 40 c.c. of distilled water and 8 c.c. of a solution of ferrocyanide of potash (1 in 20) and while boiling the sugar solution is dropped in. The blue colour becomes less and less distinct as the sugar is added till at length the blue has entirely disappeared. When the solution is colourless then the whole of the copper has been reduced. I did not find that this possessed any material advantage however over ordinary Fehlings' solution, so I soon left it off.

(1) Soxhlet. "Journal de Pharmacie et de Chemie T. II p 67 (1880)

(2) Causse "Sur le dosage du sucre par la liqueur de Fehling". Jour. de Pharm. et de Chemie. T. 19. 5me Serie p 171 (1889)

Saccharimetry by the Polariscope.

I made use of the polariscope of Zeiss for the purpose of estimating the sugars. Each of the degrees on this instrument towards the right corresponds to 0.75 % or 1.33° is Equal to 1 % of Cane sugar; while 0.44° to the left is equal to 1% of sugar.

For further particulars regarding saccharimetry, both volumetric and polarimetric, I would refer to the literature of saccharimetry (page) The papers there referred to go fully into the fallacies, effects of acids on polariscopic readings, Effect of heat &c on the sugar solutions.

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5 NORTH CHARLOTTE STREET,
EDINBURGH 5th February 1892

I hereby certify that Mr W. G. Aitchison Robertson M.D. 26 Minto Street Edinburgh has studied practical sanitation under my direction, that he possesses a knowledge of the modern sanitary requirements of public and private buildings, & is familiar with the different tests applied and the manner of applying them as well as with the forms of reports usually issued.

James Thomson C.E.
(Assoc. M. Inst. C.E.)

28th April 1892.

I desire to present this Thesis for the degree of Doctor of Science in the Department of Public Health, and I certify that the whole of the work set forth in it, both theoretical and experimental, is the result of my own labours

I desire also to place it in the competition for the Cunning Victoria Jubilee Prize in Public Health which is to be awarded this year.

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