A CONTRIBUTION TO THE STUDY OF DIETETICS.
CARBOHYDRATES:
THEIR DIGESTION AND ASSIMILATION IN HEALTH AND DISEASE.

BY

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NOTE.

This paper is offered in competition for the Miller Tootegill Prize (Gold Medal) to be awarded this year for an essay and description of an original research on a Pharmaceutical or Therapeutic subject, though preferably to a subject relating to Dietetics.
"The Day of Dietetics has arrived."

J. Weilner Fothergill.
The following paper is devoted to a consideration of sugars and sugary foods as articles of diet with special reference however to their ease of digestion and to their effects on health when employed as foods for invalids and infants.

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

Then follows an analysis of the carbohydrate constituents of the more important preparations sold as invalids’ and infants’ foods, as they occur in the foods when prepared and ready for eating.

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

I have to express my warm thanks to Professor Rutherford, who kindly granted me the free use of his well equipped laboratory for the carrying out of this investigation.
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In recent years much greater attention has been given to foods and feeding as predisposing or as actual causes of disease than was formerly the case. One would think that this question was one which would have appealed to reason at once and the only wonder is that attention was not much longer ago drawn to it.

The cannot escape from the effects of bad or improper food; the only way is to avoid such food altogether. Inexitable food may satisfy sensible hunger, while at the same time doing it may be, irreparable damage to the organism, which has its cravings for the elements of food which are wanting still unsatisfied.

This of course tells chiefly and most directionally 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 not fully-developed alimentary canal. In a not-unimportant extent, it also applies to the proper dieting of the general population, and specially to the weakly or dyspeptic members of it.
If we examine the death rate amongst children who die during their first year of life, we find that it is highest during the first month of life. After the first few weeks of extrauterine life have been passed, the death rate undergoes a marked decrease and continues to fall gradually in the succeeding months. The following table, taken from the Registrar General’s 38th Annual Report for 1875, shows this very clearly:

<table>
<thead>
<tr>
<th>Age in months</th>
<th>In healthy districts</th>
<th>By English Life Table</th>
<th>In Liverpool district</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>447.51</td>
<td>671.32</td>
<td>672.19</td>
</tr>
<tr>
<td>1</td>
<td>145.49</td>
<td>218.37</td>
<td>316.72</td>
</tr>
<tr>
<td>2</td>
<td>102.05</td>
<td>157.10</td>
<td>226.75</td>
</tr>
<tr>
<td>3</td>
<td>87.16</td>
<td>131.87</td>
<td>209.37</td>
</tr>
<tr>
<td>4</td>
<td>61.09</td>
<td>126.07</td>
<td>205.25</td>
</tr>
<tr>
<td>5</td>
<td>75.54</td>
<td>120.80</td>
<td>203.65</td>
</tr>
<tr>
<td>6</td>
<td>70.57</td>
<td>115.09</td>
<td>204.89</td>
</tr>
<tr>
<td>7</td>
<td>65.97</td>
<td>109.92</td>
<td>209.17</td>
</tr>
<tr>
<td>8</td>
<td>61.85</td>
<td>105.01</td>
<td>216.42</td>
</tr>
<tr>
<td>9</td>
<td>58.32</td>
<td>100.33</td>
<td>227.91</td>
</tr>
<tr>
<td>10</td>
<td>55.29</td>
<td>95.84</td>
<td>241.80</td>
</tr>
<tr>
<td>11</td>
<td>52.86</td>
<td>91.61</td>
<td>260.23</td>
</tr>
</tbody>
</table>
The death rates shown here are enormous. In a large town such as Liverpool nearly seven-tenths of all children born die during their first month. What then are the chief causes of such a high mortality? Let us again consult the mortality statistics along with the causes of death:

## Infantile and Total Deaths in 1884

<table>
<thead>
<tr>
<th>Causes of Death</th>
<th>Under One Year</th>
<th>At all ages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>From all causes</td>
<td>71463</td>
<td>55874</td>
</tr>
<tr>
<td>Measles</td>
<td>1902</td>
<td>1485</td>
</tr>
<tr>
<td>Scarlet Fever</td>
<td>239</td>
<td>205</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>134</td>
<td>91</td>
</tr>
<tr>
<td>Whooping Cough</td>
<td>2195</td>
<td>2555</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>7750</td>
<td>6351</td>
</tr>
<tr>
<td>Parasitic Diseases</td>
<td>362</td>
<td>278</td>
</tr>
<tr>
<td>Dietetic Diseases</td>
<td>145</td>
<td>124</td>
</tr>
<tr>
<td>Constitutional</td>
<td>4713</td>
<td>3637</td>
</tr>
<tr>
<td>Developmental</td>
<td>9479</td>
<td>7355</td>
</tr>
<tr>
<td>Local</td>
<td>30611</td>
<td>23241</td>
</tr>
</tbody>
</table>

Scanning over this table we see that of the acquired diseases, diarrhoea causes the greatest death rate both in children under one year and also at all ages. The other specific diseases together fall a long way behind it.
In England and Wales during the year 1856 there died from diarrhoea and from diseases of the digestive system 57,019 persons of all ages or 10.67 per cent of the total deaths. (From diarrhoea alone there were 25,284 deaths or 4.76 per cent; while from digestive diseases 31,735 persons died or 5.91 per cent.) From the other zymotic diseases together there were 41,219 deaths which is equal to 7.64 per cent of the total deaths.

Of the infantile deaths in 1857 the table shows no that there were 14,101 deaths (male and female) from diarrhoea amongst children under one year; whilst the total deaths of children under one year from all causes amounted to 128,277. This is equal to 10.89 per cent of the total deaths due to diarrhoea alone: while from the other zymotic diseases together the deaths amounted to 8806 children under one year, which is equal to 6.8 per cent.

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

If then diarrhoea causes such an enormous loss to our population, what must be the amount
any object apprehended sense, such as listening
your fingers feel that it is made of material
the skin is fragrant and, as demonstrated, since I
the universe, movement as to cause change.

Then, hand, not as a substantial condition
the current, of which the ear, without apparent
of the anatomy cause, and the speeded hunger is
that the press is listened through the vicinity.

Here we act on to cause an understanding of the
without mere surmise, movement by indifference. I
the essential, it is important to finding or important.

difference is important, finding in important.
that the more fragile some of the important
the chair and, it is the understanding, agree in poetry

can be a change of the community.

Effect manifest and the truth to study somewhere.

Exams. It must remain the starting and in the
when the most important in each situation to
the seat of some fact, to hypothesizes some situation

your effect from, calculations from money may possibly
a change on me, means, by counting the minute of
but can be found no other. At this conclusion, long
of security and it - rather vital, if possible; of the

10
of the body (as happens so often after the child is
put into "short clothes") and so succumbs to the
diarrhoea set up.

The rickety condition is usually caused by im-
proper feeding alone or associated with bad hygien-
ic conditions. In children so affected the mucus-
lining of the alimentary tract is very irritable, thus
severe and often fatal attacks of diarrhoea are very
liable to occur in children so affected.

I have used the term "injudicious diet" several
times already. What is meant by it?

Very often an infant suffers from diarrhoea even
when nursed by his mother and this may have
continued from birth. The child is shrivelled and
puny. In such cases one may find that the
child is being starved and that the milk
which his mother secretes is of so poor a
quality that it is unsuitable as his food. If
such a child be put to wet nurse or on a
properly prepared artificial diet be rapidly im-
proves and puts on flesh. Here one to allow
him to be nursed by his mother he would be
getting an "injudicious diet."

Again, pure cows' milk may be given to an
infant. Soon afterwards diarrhoea supervenes and
continues while such milk is given. If however it be
diluted with lime water, one half or one third, the diar-
rhoea soon ceases. Pure cows' milk is injudicious food
for such a child.

Corn-flour, arrowroot and other farinaceous foods are
most certainly injudicious food for very young
children as we shall more particularly see later on.

In the majority of cases the mother nurses her child for
at least nine or six months but then it is weaned.
Amongst the poorer classes however, the child is nurse
a much longer time, as nine, ten or even twelve months or
longer before it is weaned. This transition from mother's
milk to artificial food is a trying time for the child
and if a suitable food be not selected for him
diarrhea is set up with its serious consequences or
emaciation and wasting commence at this time. This
is often called atrophy lactantium owing to the emaci-
ation so often observed in those recently weaned.

We frequently find that amongst the poor the period
of lactation is most unduly prolonged as up to fifteen
months. A child above a year old so fed has, most
undoubtedly, injudicious food. It is amongst such children
that we meet with rickets, simple atrophy (maraconus)
and diarrhea. In one case the milk from a woman
who had been nursing for twelve months was
analyzed and found to contain only a trace of casein.
The child who had been wasting on this milk soon
improved when put on a suitable diet. (316)

In 1880 there were in England and Wales 29,519
deaths from diarrhea; of these 18,440 or 62.5 per cent
were infants under one year, and 25,998 or 88.1 per
cent children under five years. Of the 18,440 infants
who died from diarrhea 29.5 per cent were under
three months; 31.5 per cent were three and under six
months, while 37 per cent were above this. "As there are
more infants living under three months than over three
and under six months, it appears that diarrhea is
not so destructive of infants in the first as in the
second three months of life, which may with proba-

ility be ascribed to the greater prevalence of "feed-
ing by hand" after this period of life." (5a)

Without any doubt whatever the chief cause of
infant mortality amongst the industriously poor is
mismanaged hand-feeding. Everyone of experience
acknowledges this to be true. The infantile mortality
is greatest amongst the poorer classes and is certainly
due to the inexperienced 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 means it partly or entirely and it is then given in charge of 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 cows' milk which is often in an incipient state of decomposition owing usually to the imperfect cleansing of the feeding bottle, and especially in this true in summer weather.

Many again are fed partly or entirely on one or other of the many preparations known as infants' food. Many of these, as we shall see later, consist entirely of farinaceous materials and form a most injurious diet; others again are undoubtedly good, but 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 a proper use. Instead of therefore affording a nourishing alimentary substance, these foods only act as irritants and produce gastrointestinal disturbance with vomiting and diarrhea, 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 num-
her of those who die in the larger towns. This is clearly shown in the following table:—

<table>
<thead>
<tr>
<th></th>
<th>1855</th>
<th>1886</th>
<th>1887</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Districts</td>
<td>0.34</td>
<td>0.63</td>
<td>0.50</td>
</tr>
<tr>
<td>England &amp; Wales</td>
<td>0.49</td>
<td>0.88</td>
<td>0.69</td>
</tr>
<tr>
<td>50 towns</td>
<td>0.47</td>
<td>0.98</td>
<td>0.74</td>
</tr>
<tr>
<td>25 Great towns</td>
<td>0.69</td>
<td>1.16</td>
<td>0.97</td>
</tr>
<tr>
<td>London</td>
<td>0.66</td>
<td>0.95</td>
<td>0.90</td>
</tr>
</tbody>
</table>

This shows how unhealthy the town life of a large manufacturing city, like Liverpool, must be to infants under one year. After the end of the first month the mortality of the urban district is more than twice what it is in 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 (see Table I.) we note that the mortality decreased gradually from the first month to the fifth but after this it increased.

This as doubt is caused by the many gastric and intestinal troubles ensuing on the eruption of teeth and the want of proper care and feeding at this time. The health of country districts must depend on the good hygienic conditions existing there, on the
Health of the mothers and their ability to nurse their children.

Another fact must not be lost sight of and that is that the rate of mortality from diarrhoea amongst infants is, during the warm months of the summer and autumn (July, August and September), 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 manner causing this diarrhoea, there is the much greater risk of sickness at this time of year and the more rapid decomposition of organic matter but especially of milk. (1) The fermentation begun in the milk is increased in the alimentary tract of the infant. During summer, the child's thirst is greater also and this is aggravated by giving it milk and not water. The stomach consequently is apt to become overloaded and fermentation are still more liable to occur in it. If this is sufficient to set up gastrointestinal cataract, in a healthy child, it will be much more liable to do so in a delicate child or one infected from being fed on improper food.

It may be thought that I am going 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. diarrhea.

We have only to think of the enormous number of deaths in children which are registered under the general terms of "convulsions," "malaria," "atrophy," "gastric catarh," "constitutional disease," &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 it not even be called 'criminal'? ) cause that our excessive 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 merely in ignorance or apathy, and 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 or is much more liable to be attacked by any of the infectious diseases than 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 general practice suffering from gastro-intestinal catarrh and general wasting (marasmus, atrophy, infantile atrophy). I found that the vast majority of such cases occurred amongst hand-fed children. The uniformity of the answer to my question regarding the manner of feeding the child struck me forcibly, "in the bottle" being the almost invariable answer.

From my own experience I found that when cow's milk was given, for infants under four months it was prepared as a general rule by diluting it one-half. Enough to fill a feeding bottle was prepared at once and to each bottle a teaspoonful of cane sugar was added and in many cases a tablespoonful of lizzy water was also added. From the fourth to the eighth month the amount of water was usually reduced to one third and prepared in the same way. In a very large proportion of the hand-fed however artificial feeding stuffs were used in the various forms of infant's and breast milk foods.

A smaller proportion of these diseases occurred in the breast-fed. Many of these children however would have thriven had they been fed by a wet-nurse or given a properly selected artificial food, for it was evident in many cases that the mother
was in such a delicate state of health or so over-worked that her lacteal secretion could have had only a small nutritive value for her rapidly growing and actively assimilating infant. The milk of unhealthy women deviates 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 matter than normal milk does, whereas the fats and carbohydrates are diminished. Even in health the quality of the milk varies much according to the condition of the mother and her nervous state.

Amongst what are called the "upper" or "better" classes we know that the mothers are frequently unable to nurse their children owing to deficiency or entire absence of lacteal secretion; in a much larger proportion 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 it is not used in very many cases as 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 children's living, or, as is specially the case in large manufacturing towns, she returns to work through desire for gain having only nursed her child for a week or two after its birth. In these cases the woman's wage is often almost as high as that of her husband and this is the great inducement to her to cease nursing her child. She may however partially nurse it during the night or when at home during the day in the intervals of work.

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

From my own observation and data I considered that one child in every four was brought up artificially. I made inquiries 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 began it, they almost invariably gave it up in a fortnight. Another was sure the proportion was one in two. One however said that it
preceeded one in three; still that I may not overstate the number thus fed, I will take it as that one in every four children are artificially fed.

What is it in the artificial food which causes such gastric and intestinal irritation or is it as indigestible as to cause the semi-starvation of the infant?

If cow's milk be the artificial food used, it may be given in too great amount and so what is unabsorbed undergoes fermentation with its resulting irritation. This may be also the cause with the "infants' foods" but more often is it due to the starchy materials 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 fermentation is very liable to occur, especially in warm weather. When such food is given to the infant these fermentations go on with much greater rapidity in the alimentary canal and so great irritation follows. It is evident that there must be some radical and outstanding defect in such artificial foods, else why show such an enormous mortality follow their use and of necessity an infinitely greater
amount of sickness during their employment.

Of course many children may be brought up on almost any kind of food. I have seen many healthy children who from their birth had been fed on pure undiluted cows' milk,Intro 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. These however were healthy children with healthy and vigorous digestion.

It is not for such as these that we require to lay down rules. As in the social world, laws are not made for the law-abiding, but for the lawless; so in medicine, we lay down rules so that the healthy may continue healthy and that the weak may be rendered 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 false step may cause serious or even fatal illness, or as I once heard an esteemed teacher of mine say regarding another subject,

“Pathology is on their track.”

* 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.

In the following paper, the preparation of which has cost me many months of 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. In the first place however, I have gone fully into the digestive processes which such elements of the food undergo.

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 published, 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 in the condition of the child resulting from this change of diet, another kind of baby food is recommended and so on. In many cases a kind of blind experimenting is being tried at the expense of the child and yielding in the long run but little information.
to the practitioner.* Surely this ought not to be so!

The words of Andrew Combe (157) are well worth attention:

"In a general way we see 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 chancer
alone or if notions picked up at random often
at variance with reason and, it may be, in contra-
diction even with our daily experience ...... In
many of our best works, the relation subsisting
between the human body on the one hand and
the qualities of the alimentary substances on the other,
are the only solid principles on which their proper
adaptation to each other can be based is altogether
lost sight of; so that, whilst the attention is
carefully directed to the consideration of the
abstract qualities of the different kinds of aliment,
little or no regard is paid to the relation in
which they stand to the individual constituents
as modified by age, sex, season and circumstances,
or to the observance of the fundamental laws of
"digestion" (Preface. p. X. X)

"There is no period of life during which it
is of greater import to follow the intentions of nature in
the regulation of diet, both as to quantity and quality,
than during the earliest part of childhood; for at
no period is the neglect of them more fatal. Surprised
is sometimes expressed at the number of children
who are carried off before completing their first or
second year; but when we consider the defective
education and entire ignorance of the human econ-
omy, 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. There is
perhaps not one mother in ten thousand who before
becoming such, has ever inquired into the nature and
wants of the newly-born infant or knows on what
principles its treatment ought to be directed.

Nearly one-half of the deaths occurring during the
first two years of existence are accountable to mis-
management and to errors in diet. (page 220)

Through pure ignorance and mistaken kindness
many nurses, imagining themselves wiser than Nature,
and conceiving that the newly-born infant must
of necessity be starving after what they consider a
"milk mortis facta," hasten to fill its stomach with
gruel or some bitter food. Not unfrequently severe
Physiological induction at the very outset, which in a delicate child may be sufficient to lay the foundation of much suffering and bad health (p. 222).

Here the question of infant feeding is 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 at work, we may expect more light to be thrown upon soon.

Apart from the mortality of infants and children from intestinal disorders due to mismanaged feeding, there is the immense importance of dietetics as regards the many forms of indigestion and diseases of the alimentary organs in adults.

Statistics of hospitals and dispensaries prove that affections of the alimentary tract form by far the largest proportion of all diseases occurring during adult life. The cause in most cases as is well known is unsuitability of food or irregularity in
meals but the former has by far the largest share in causation.

Very many dyspepsies have at an early period of their trouble to give up the use of acidulating foods as these soon after ingestion cause much acidity, nausea, heartburn &c., & a numerous class of dyspeptic also starchy matters (especially if taken in slight excess) form a source of much uneasiness, flatulence and acidity.

In the treatment of such affections management of diet is the chief factor, medicines are only of secondary importance. By proper regulation of diet and improved hygiene we may therefore hope in the future to extend the scope of Preventive Medicine so as to greatly lessen the number of martyrs to gastric and intestinal disorders.

So as to begin with no preconceived ideas as regards the ease or difficulty of digestion of such foods, I have worked at the physiological digestion of sugars and starches both by observations on patients and by experiments in the laboratory. Having thus laid a physiological basis on which to work, one is then able to lay down rules as to the nature in which such foods ought to be given
so as to be easily assimilated by the infant or the dyspeptic.

Before commencing, let me briefly consider the chemical nature of the saccharine elements of food and then we will investigate the changes which they undergo during digestion.

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. Amongst the poor it was almost unknown. When a sweetening agent was desired honey was the one commonly employed; this almost every cottage kept his beehive, a custom which has now unfortunately fallen into desuetude. The various articles of food prepared and preserved by the aid of sugar and used by us every day, were to them unknown. They certainly had one advantage in being spared the risk of eating an article which is not easy of digestion in its natural state and which is prone to undergo per-
mention. 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 forefathers were undoubtedly much less troubled with indigestion than the present population. The increase of gastric disorders is popularly said to be due to an increased civilisation (?) and more sedentary occupations. Perhaps this 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. I believe that 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 complexity and includes a large amount of sugary material.

As the price of 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 twenty-seven shillings 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 reached the enormous amount of above a million tons and in 1891 this had increased to 1,382,676 cwt (raw and refined sugar) which is equal to a consumption per head of above 50 lbs.
Great Britain and America are the largest consumers of sugar. In other countries as France, where the duty is higher the consumption is proportionally less.

An article of such universal use as a food, merits as great attention from the physiologist as it has already received from the chemist.
Chemistry of the Inversion of Sugars.

It will be useful to summarise shortly some facts which will be of use later on regarding the chemistry of sugars.

A solution of Cane sugar or sucrose \((C_12H_{22}O_{11})\) when heated by itself for long or more quickly on the addition of dilute mineral acids becomes "inverted." This happens still more quickly if the sugar is boiled with dilute acids. The yeast ferment has also the property of inverting Cane sugar, and this change must occur before it can produce the alcoholic fermentation. This special ferment can be separated from yeast and has been termed "invertin."

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 polarisation of their resultant as they leave the solution is not the same as the incident ray but is deflected to the right. The cane sugar solution is therefore said to be dextrorotatory. The degree of this rotation varies with the strength of the solution, being greater the stronger the solution is in sugar and also with the nature and proportion of the acid used in inversion. (27-30) When however the solution of Cane sugar has been heated with dilute acids instead of turning the polarised ray of light to the
right, it turns it to the left and hence the term "inverted sugar," or as it is sometimes called "fruit sugar."

Cane sugar during inversion takes up a molecule of water and becomes changed into a mixture of equal parts of dextrose and levulose. (24) Petit (69) however thinks that there are not the proportions in which these two sugars exist in invert sugar. Lavoniere (56) believes that in addition to these the process of inversion gives rise to other optically neutral bodies and that its products are much more numerous than is generally supposed.

To obtain an invert sugar solution with constant properties great care is necessary as regards using constant temperature and a definite amount of acid and water. Yeast or malt cause the cane sugar to become hydrated in the manner and then split up into dextrose and levulose, thus:—

\[ C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6 \]

(Cane sugar) (Dextrose) (Levulose)

The greater action of the yeast ferment causes the formation of alcohol, carboxylic acid and water with probably other products:

\[ C_6H_{12}O_6 + 2H_2O = 2C_2H_50 + 2CO_2 + 2H_2O. \]

(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. (56) Some think that it is the water itself which induces the inversion of the sugar; others again think that the inversion is due
to the influence of moulds growing in the solution. (12) Béchamp finds that if moulds already well developed are introduced into the cane sugar solution inversion is much more rapid. If anti-septics are added however the growth of the mould is stopped and then no inversion takes place.

Ravet (12) on the contrary has found that inversion takes place without the aid of ferments. Having boiled a solution of cane sugar he hermetically sealed it in glass tubes. Some which were exposed to the light became half-inverted after five months; while others which had been kept in the dark showed no inversion. When a pure solution of cane sugar is kept at a warm temperature however the rapidity of inversion is much increased. (34) Rapid inversion takes place however if a solution of cane sugar be heated with the addition of an acid. The mineral acids are much more powerful and rapid in their action in this respect than the organic, 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 1/20 the 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 1/20 and requires one hours boiling. (49) 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 the inversion of a solution of Cane Sugar. (35.)

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 (43) nor with the acid used. It is not so sweet as Cane sugar and is much less soluble in water. (37, 65)

Fruuctose or fructose, on the other hand, is a colourless, uncrystallisable syrup as sweet as 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 is one even though these two sugars melt in equal amounts in invert sugar the plane of polarization lies to the left. Temperature has a marked effect on the rotation caused by fructose; if high, the degree of rotation is much lessened.

There is a definite degree of rotation for each acid at 20° C (51-2) has shown as well as for each
Temperature \((83.9^\circ)\) Jungfleisch, Lefranc and Timbert \((102)\) who have also succeeded in obtaining cellulose in colourless acicular crystals, say that pure cellulose has its rotatory power much modified by the action of mineral acids as hydrochloric and sulphuric; organic acids, as acetic and formic, have no effect on its rotation. If pure glucose be treated thus with acids its rotatory power remains unchanged. Thus, on inverting a solution of cane sugar by the mineral acids, the cellulose produced becomes acted on and its rotatory power is changed. If however we cause inversion by the organic acids, it is said, the resulting liquid has constant rotatory powers even on heating. Cellulose got by the ordinary processes from cane sugar is not identical with crystallised cellulose, as Jungfleisch affirms. \((45)\)

Cellulose ferments less easily than glucose. It is very difficult however to get pure cellulose unmixed with glucose. Dubrunfaut \((31)\) has shown however that cellulose forms an insoluble crystalline compound with lime and can in this way be separated from the invert sugar.

The solution of toffee is not precipitated from its alkaline solution by boiling with a solution of pure cane sugar unless the solution be carried on for long. Invert sugar at once reduces it however and this forms one of the best tests for glucose and cellulose.
Chemistry of Starches.

Starch or Zeelular. The composition of this may be represented in its simplest form by C₆H₁₀O₅. It is really supposed however to be a multiple of this and n(C₆H₁₀O₅) represents its composition better, n being an unknown quantity, though probably never less than five or six.

When starch is heated by itself or, as mucilage, if boiled with dilute acids, or when acted on by diastase, it becomes changed into an isomeric body, dextrine. There are many varieties of dextrine, that just formed is termed soluble starch or amylo-dextrin. As destituation proceeds crystallodextrin is formed and still later the achroodextrins. If the crystallization with acids be continued or if diastase be allowed to act long enough on the dextrine, it becomes hydrated and changed into maltose, which itself lastly becomes converted into glucose (C₆H₁₂O₆) through the continued action of the diastase or of the dilute acids on maltose.

When a solution of iodine is added to starch it produces a deep blue colour. Soluble starch however gives a violet colour with iodine when in solution, but if dry the colour produced is yellow.
violet or brown. This variety of starch is insoluble in cold water but dissolves in warm water and the starch granules still preserve their shape. As the starch becomes further dehydrated the violet coloured reaction with iodine gives place to a purplish-red and then a red colour showing the presence of erythrodestrin. Even when dry, erythrodestrin still strikes a red colour with iodine and is soluble in cold water. This red colour reaction with iodine gradually becomes lighter till at length we get no colour on adding a solution of iodine. This shows that we have now reached the stage of aehrodestrin.

There are many varieties of aehrodestrin which differ from one another in their different rotatory and reducing powers. The first formed is aehrodestrin &i, quite of course no colouration with iodine but can still by the action of diastase be changed into glucose as happens with erythrodestrin and soluble starch. On the other hand aehrodestrin β and γ and maltose remain unchanged by diastase.

The formation of the destrines may be explained in the following manner:

The constitution of soluble starch is most probably represented by the formula C_{12}H_{20}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 erythrodextrin. (150)

\[ C_{20} H_{100} O_{10} + H_2 O = C_2 H_22 O_{11} + C_{10} H_{150} O_90 \]

(soluble starch) (maltose) (erythrodextrin 

On further hydration another molecule of maltose is formed and erythrodextrin \( \beta \) which has a lower molecular weight -

\[ C_{10} H_{150} O_{90} + H_2 O = C_2 H_22 O_{11} + C_9 H_{160} O_80 \]

(erythrodextrin \( \alpha \)) (maltose) (erythrodextrin \( \beta \))

Similar further hydration occurring we get now adrodextrin -

\[ C_9 H_{160} O_80 + H_2 O = C_2 H_22 O_{11} + C_8 H_{140} O_{90} \]

(erythrodextrin \( \beta \)) (maltose) (adrodextrin)

There seems to be a difference of opinion amongst chemists as to the further changes which occur. Some say that the higher adrodextrins and maltose are unaffected by the continued action of diastase; (150) while others say that the hydration process goes on till only maltose is left and that each of its molecules in turn undergoes
hydration through the continued action of diastase or dilute acids giving rise to two molecules of grape sugar (63)

$$C_{2}H_{12}O_{11} + H_{2}O \rightarrow 2 C_{6}H_{12}O_{6}$$

(Diastase) (Grape sugar)

Lindley (51) agrees with Payen in stating that the conversion of starch into maltose by the ferment diastase is never complete, the maltose itself stopping the action when it has accumulated to a certain extent. There is consequently diastre always present unless the maltose be removed as it is formed.

The rapidity of the conversion of starch by acids depends on their strength. Many hours elapse before complete conversion is effected if the acid be very dilute. As the strength of acid is increased so is the time diminished.

Diastase however acts very quickly and converts the starch mucilage in a very few minutes and this takes place at a comparatively low temperature (71°).

In plants starch is stored up for future use. Thus, in the seed it forms the supply of food for the young plant till it can support itself. As germination proceeds the starch is gradually used
up, as, under the influence of the diastase in the plant, it is converted into dextrose and glucose which are soluble substances and which are conveyed through the plant and built up to its structure.

In the first place, we shall look at the digestion of carbohydrate matters and after that take up the consideration of the digestion of starchy foods.

Is what form is sugar absorbed into the body of the animal? Do it as Cane Sugar ($\text{C}_12\text{H}_{22}\text{O}_11$) or is it as glucose, fructose, or maltose? What is the change, if any, which Cane Sugar under goes during digestion and in what form or forms is it absorbed?
Digestion of Cane Sugar.

Action of Saliva on Cane Sugar.

It having been affirmed by some writers (29) that saliva has an inverse action on Cane Sugar, while this is denied by others (20), I have endeavored to determine this point.

I have already stated that when a solution of Cane Sugar is heated alone it undergoes a slow inversion. 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 temperature of 38°C. This solution of sugar was made by dissolving 200 grammes of pure dried Cane Sugar in distilled water and diluting to one litre. This solution caused no precipitation of the suboxide of copper when boiled with Fehling's Solution and gave with the Polariscoppe of Zies a rotation of + 27.2°.

After having been kept for one hour at 38°C, it showed, (after cooling) a rotation of + 26.65° and the amount of invert sugar estimated by Fehling's Solution was 0.19%.

After having been kept at 38°C for 2 hours, the invert sugar amounted to 0.252% and the rotation was +25.7°.
These observations were repeated several times and gave almost exactly similar results.

<table>
<thead>
<tr>
<th></th>
<th>1 hour</th>
<th>2 hours</th>
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<tbody>
<tr>
<td>Polariscopes</td>
<td>+26.65°</td>
<td>+25.7°</td>
</tr>
<tr>
<td>Invert sugar per cent</td>
<td>0.19</td>
<td>0.252</td>
</tr>
</tbody>
</table>

This constitutes the control experiment and shows the amount of inversion which a 20% solution of cane sugar undergoes after one and two hours exposure to the normal temperature of the body.

To determine whether the saliva had a greater inverting action on cane sugar than distilled water I performed the following experiment:

Equal volumes of human saliva and cane sugar solution (of strength equal to 40%) were mixed together to give a 20% solution of sugar. Several beakers containing this solution were placed in the water bath at 38° C. After 30 minutes there was no recognisable inversion. In 45 minutes traces of invert sugar appeared as shown by the reduction of copper acide, and in one hour the invert sugar amounted to 0.2%, while in two hours it reached 0.27%.

The amount of inversion in presence of saliva is so
nearly the same as in its absence that we may safely conclude that normal human saliva has practically no influence in hastening or retarding the inversion of Cane Sugar. It seems to be perfectly passive as regards inversion. The results given in this experiment were almost identical with those obtained in other experiments conducted on similar lines.

Gastric Digestion of Cane Sugar.

The next fluid which we meet with is the gastric secretion. Cane sugar reaches the stomach unchanged. Does it undergo any change in this organ or does it require any?

It is thought by some that Cane sugar is absorbed unaltered and that after its entrance into the portal vessels it is transformed into glucose through the agency of a ferment in the blood (186) from its solubility and diffusibility Pavl (241) is of opinion that it does not require to be changed by digestion to aid its absorption but merely requires solution to enable it to pass into the bloodvessels. He is inclined to believe however that, as a matter of fact, it is at all events partially converted into grape sugar before its absorption from the alimentary canal.
Bouchardat and Sandras (142) state that, under the influence of the gastric juice and of the living membranes, cane sugar is changed into invert sugar and lactic acid and absorbed as such, and that it must undergo inversion before it can be absorbed and used up in the blood.

The gastric juice contains besides pepsin, a milk-coagulating ferment and, according to Hammerstorph (136), there is also a lactic acid ferment that acts on milk sugar. But in opposition to this last statement, it is the fact that a pure solution of lactose does not undergo fermentation when acted on by gastric juice (136).

The acidity of the gastric secretion is now universally believed to be due to free hydrochloric acid as was first conclusively proved by Ritter and Schmidt (138). In a measured quantity of the juice they estimated the entire chlorine and the entire bases reckoning them all as chlorides, and found more chlorine than was required to convert the bases into chlorides. The excess of chlorine could only exist as free hydrochloric acid and this usually amounts to 0.2 - 0.3 per cent. Richet (142) states that this is the only mineral acid present and that its average amount is 0.14 per cent.

During the first stage of digestion, even though the contents of the stomach are acid, no free hydrochloric acid
is found. The period when it appears varies in different individuals and also varies with the diet. After breakfast it is said not to occur until 45-60 minutes have elapsed, while after a full dinner it is not rare until after the lapse of about two hours (277c).

Lactic acid is said by some to exist normally in gastric juice (272g) and to be constant in amount, and, though it may increase towards the end of digestion, never reaches one per mille (262). It is even said that lactic acid is the only acid which the secretion contains and that there is no free hydrochloric acid.

(Blondlot affirms that the acidity of the gastric secretion is due to the presence of acid phosphate of lime.) Others say that volatile organic acids are always present in small amount in the gastric juice.

Free hydrochloric or lactic acid can seldom be detected in the stomach of infants.

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 caused by the presence of acetic, butyric or lactic acid derived from the fermentation of injected materials. (Poulet (246) states that the chief acid during full digestion is lactic acid.)
Action of the Gastric secretion on Cane Sugar.

Dalton (161) Leube (172) and others state that outside of the body the gastric juice slowly inverts cane sugar. Laborde (210) however affirms that the inverting power of the gastric juice is less than that of a solution of hydrochloric acid of the same strength; but if a trace of hydrochloric acid be added to the gastric juice its inverting power becomes greater than that of the dilute solution of hydrochloric acid alone.

Leube makes an exactly contrary statement. Brown-Séquard (159), Schiff and Smith (270) say that cane sugar is inverted in the stomach; while Baur-quelot (145) 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.

Ray could find no inverting ferment in the gastric mucous membrane. Fresnel (185) states that cane sugar is not inverted even if left in the gastric juice for twelve to thirty-six hours; and Blondlot (140) believes that this sugar undergoes no change while in the stomach. Richet (157) found that unless he added hydrochloric acid to gastric juice there was no inversion of cane sugar and asserts in explanation of this that there is really no free hydrochloric
acid in the gastric juice but that it is always combined
with glycine or some other body-organic in nature. He
states that in the stomach, under normal conditions, the
gastric juice does not act on sugars and that the in-
jection of cane sugar diminishes the acidity. According
to Dalton (184) it cannot be shown that cane sugar under-
goes any inversion during ordinary digestion and that if
taken along with other food there is probably no conversion
of it into luctose in the stomach. Kühne and Herrmann
make similar statements. Leube (212) comes to the same
conclusion. In the healthy stomach, he says, no inversion
of cane sugar occurs; but if the stomach be dilitated there
is a considerable amount of inversion.

Inversion of Cane sugar by dilute Hydrochloric acid.

To estimate the amount of inversion caused by dilute acid
in a solution of Cane sugar 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 and placed it in a water-

bath at 38° C. After the lapse of one hour it was
removed and, when cold, its rotatory power was +25.2°
and on estimation by Zehling's solution, it was found to
contain 0.37% of inweet sugar. After being heated
for two hours the rotation was +23.5° and the
amount of reducing sugar estimated by Fehling's solution
was 0.45%. Subtracting the amount of sugar
which is inverted when the 20% solution of Cane
sugar is heated alone, we find, that after one hour
the hydrochloric acid has caused an increased in-
version of 0.15%, and after two hours 0.198%,
or nearly one-fifth per cent more.

Inversion of 20% Solution of Cane Sugar
at 38° C. alone, and with 0.2% HCl added.

<table>
<thead>
<tr>
<th>Cane Sugar</th>
<th>Polarimeter</th>
<th>Invert Sugar</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1 hour</td>
<td>2 hours</td>
</tr>
<tr>
<td>Alone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+26.65</td>
<td>25.7</td>
</tr>
<tr>
<td>With HCl</td>
<td>+25.2</td>
<td>23.5</td>
</tr>
<tr>
<td>Difference due to HCl</td>
<td>1.45</td>
<td>2.2</td>
</tr>
<tr>
<td>1 hour</td>
<td>0.19</td>
<td>0.252</td>
</tr>
<tr>
<td>2 hours</td>
<td>0.37</td>
<td>0.45</td>
</tr>
</tbody>
</table>

This experiment shows that in a 20% solution of Cane
Sugar about 45% of the sugar undergoes inversion in the
course of two hours with temperature of 38° C. and with
an acidity corresponding to the normal acidity of
the gastric juice.
Inversion of Cane Sugar by Gastric secretion.

I then continued the experiments with gastric secretion from a man with a 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 (Caffein). This fluid contains no substance which has any effect in causing the reduction of copper from its alkaline solution. Introducing the stomach tube an hour later, I drew off the gastric contents and used it in the same way (after filtration) as I had formerly used the 0.2% solution of hydrochloric acid. The initial acidity of this healthy gastric secretion was equal to \( \frac{\sqrt{2}}{24} \) (the fraction of the normal soda solution) or, if estimated as free hydrochloric acid, it contained 0.15%.

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 estimated as hydrochloric acid was 0.05%.

It was kept at a temperature of 38°C. On testing it after two hours the invert sugar present amounted to 0.83%.

\[
\begin{align*}
10 \text{ c.c. healthy gastric fluid} & \quad \text{at 38°C} & \quad \text{Invert Sugar in 2 hrs} \\
10 \text{ c.c. 20% Cane Sugar Sol.} & = 0.05\% & = 0.83\% \\
10 \text{ c.c. Water} & & \text{h.c.}
\end{align*}
\]
To determine whether the gastric juice had a greater or less effect in inverting Cane sugar than a pure acid solution of similar strength, I made a solution of hydrochloric acid of strength equal to that of the gastric fluid I had just employed. I placed equal volumes of this dilute acid, water, and 20% solution of Cane sugar in the water-bath at 38° C. At the end of one hour it reduced cupric oxide; while at the end of two hours estimation by Fehling's solution showed the presence of 0.66% of invert sugar.

\[
\begin{align*}
& \text{10 c.c. solution of HCl} \\
& \text{at 38° C} \\
& \text{10 c.c. 20% Cane Sugar Sol.} \\
& \text{10 c.c. Water} \\
& = 0.66\% \\
& = 0.66\% \\
& \text{invert sugar after 2 hrs} \\
& \text{HCl}
\end{align*}
\]

This experiment demonstrates that healthy gastric juice has a greater inverting power than a solution of hydrochloric acid of similar strength. This is in accordance with what Leube (272) states, that murrain is less rapid and energetic with acid solutions than with gastric juice, but is opposed to the statement of Laborde (210) 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 (VII) with the first (VI), it shows that, as we dilute the solution of Cane sugar, the
Inversion is greater, the acidity also being less. A weaker acid is equal to a stronger one, if the Sacialaric solution be at the same time diluted.

It has been supposed that there is an inverting ferment in the stomach which changes cane sugar. To determine whether the inversion is due to this or to the acidity of the secretion, I proceeded as follows:

I mixed equal volumes of healthy gastric fluid, 20% solution of cane sugar and water and then carefully neutralised the mixture with caustic potash, using specially prepared and very sensitive litmus paper to test the reaction. It was then kept in a water bath at 38° C. After one hour there was no trace of invert sugar, and after two hours there was a faint trace of invert sugar, too small for quantitative estimation.

10 c.c. healthy gastric fluid
10 c.c. 20% Cane Sugar Sol.
10 c.c. water

\[ \begin{align*}
\text{neutralised} \quad 38^\circ \text{C} \quad \text{In 2 hours} \\
\text{no trace of invert sugar.}
\end{align*} \]

This shows that when the acidity of the gastric juice is neutralised no inversion of cane sugar occurs. There is therefore no inverting ferment in the gastric juice, otherwise an appreciable amount of invert sugar would have been formed. (See on page 54.)

The amount of invert sugar produced is proportional to the
degree of acidity and to the dilution.

It is evident from these experiments that the acidity of the gastric juice is the only factor in causing the inversion of Cane Sugar. As the acidity diminishes, ceteris paribus, so does the amount of inversion. In neutral media (as when the gastric secretion is neutralised) the amount of inversion is infinitesimal and would be quite as great if the dilute solution of sugar were treated alone.

It is said that in unhealthy stomachs containing much mucus the gastric juice is very active in changing cane sugar into glucose and that this power seems to be due to a special ferment existing in the mucus. (245)

In order to see if this were so, I performed a set of experiments on a patient suffering from chronic gastric catarrh similar to those I had carried out with the patient with healthy digestion. As before the gastric contents were drawn off one hour after three ounces of dilute ringer's solution had been injected. This was filtered and the total acidity then estimated as hydrochloric acid was 0.06%.

I then placed in a water bath at 38° C equal volumes of this fluid, 20% solution of Cane Sugar and
water. An hour later invert sugar was present and at the end of two hours it amounted to 0.35%.

\[
\begin{align*}
10 \text{ c.c. gastric fluid} & \quad \text{at } 38^\circ \text{C} \\
10 \text{ c.c. 20% sol of sugar} & \\
10 \text{ c.c. water} & \quad \text{Invert sugar in 2 hrs} \\
& = 0.35\%.
\end{align*}
\]

I next made a solution of hydrochloric acid of strength equal to that of the gastric fluid. I had just employed viz. 0.06%. Equal volumes of this sugar solution and water were kept at 38°C. After the lapse of two hours there was 0.434% of reducing sugar present.

\[
\begin{align*}
10 \text{ c.c. solution of } HCl = 0.05 & \quad \text{at } 38^\circ \text{C} \\
10 \text{ c.c. 20% sugar sol.} & \\
10 \text{ c.c. water} & \quad \text{Invert sugar in 2 hrs} \\
& = 0.434\%.
\end{align*}
\]

This last experiment shows that with the fluid from a case of chronic gastric catarrh there is less inversion of Cane Sugar than with a solution of hydrochloric acid of the same degree of acidity. This would agree with Foster’s statement, but then it has happened with abnormal gastric juice and not with normal as he implies. Still less does it show that in cases of chronic catarrh of the stomach there is an increased inversion as Schilling states. If we
compare Experiment V with IX we find that the amount of inversion in the latter is less than half what it is in the former. The acidity of the first however is more than twice that of the second. The acidity of the second (0.06%) bacteria fabrius ought to have given an inversion of 0.368 %, while we find it is only 0.35 % and according to Foster ought to have been much more. From these experiments we cannot say that there is increased inversion in such cases.

As regards the question of the presence of an inverting ferment in the gastric mucus, I modified the preceding experiment as follows. In order to kill any inverting 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, cane sugar solution and water and kept the mixture at 38° C. There was a reduction of sugar in an hour and the invert sugar amounted to 0.35 % in two hours.

10 c.c. boiled gastric fluid - 0.06% \( \text{at } 38^\circ C \)
10 c.c. 20% Cane Sugar Solution \( = 0.02 \% \)
10 c.c. water

\[
\text{invert sugar } = 0.35 \%
\]

This is exactly the same as when unboiled gastric
fluid was used (IX).

This and the following experiment prove undoubtedly what I think that the inversion of Cane Sugar which takes place outside of the body is not due to the presence of 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 then neutralised carefully the mixture of Catarrhial gastric fluid, cane sugar solution and water and kept all at 38° C. There was no reduction of sugar produced by heating after one hour at 38°; while after two hours there was a small amount of reducing sugar but too faint for quantitative estimation.

\[
\begin{align*}
10 \text{ c.c.} & \text{ Catarrhial gastric fluid} \\
10 \text{ c.c.} & \text{ 20\% Cane Sugar sol.} \\
10 \text{ c.c.} & \text{ Water} \\
\end{align*}
\]

\[
\begin{align*}
\text{Carefully neutralised} & \quad \text{Invert sugar in 2 hrs.} \\
\text{at 38° C} & \quad \text{only faint trace.} \\
\end{align*}
\]

This result agrees with that given with the healthy gastric fluid. (VIII.)

I repeated these experiments in a slightly different manner by taking equal volumes of the gastric fluid and 20\% solution of Cane Sugar and keeping at 38° C. This time the initial acidity of the gastric juice was equal to 0.1\% hydrochloric acid. After
being kept at 38° C. for one hour it contained 0.344% of invert sugar and this had increased to 0.714% after the lapse of two hours.

\[
\begin{align*}
20 \text{ c.c. } & \text{ Bacterial gastric fluid } = 0.17 \% \text{ HCl} \quad \text{ at } 38\text{°C} \\
20 \text{ c.c. } & \text{ 20% Cane Sugar Solution } = 0.05\% \\
& + \text{ 2 c.c. } \text{ Invert Sugar in 2 hr. } = 0.714\%
\end{align*}
\]

If we compare this with Experiment VII we see that the acidity is the same in both cases and yet the amount of inversion is greater in VII than in XIII. In VII however the sugar solution is diluted three times, while in this last experiment it is only diluted three times. This allows therefore that dilute solutions of Cane Sugar undergo a greater inversion than stronger solutions.

The foregoing experiments were all performed in the laboratory with fresh human gastric juice. I desired now to investigate the changes, if any, which Cane Sugar undergoes in the Stomach, and to this end I performed the following series of experiments.

My method of procedure was as follows:—

At 8 a.m. the man had breakfast of porridge and milk. At 10 a.m. the stomach was thoroughly washed out with a syphon elastic tube and a warm 20% solution of pure Cane Sugar was then forced into the stomach through the tube, the patient being thus quite
Ignorant of the nature of the fluid which was introduced, I invariably injected 250 c.c. of the saccharin solution at intervals of one-half to two hours after the injection the stomach tube was again passed and some of the gastric content aspirated off.

Each sample of the gastric fluid was then measured, filtered, examined by the saccharimeter and the reducing sugar estimated by titration with Fehling's solution. The total acidity was estimated by titration with a centi-normal solution of caustic soda and expressed in terms of anhydrous hydrochloric acid. I did not estimate the amount of free hydrochloric acid as it is too troublesome a process, but I always tested for the presence of inorganic (of which hydrochloric is the chief) and organic acids qualitatively.

The presence of free hydrochloric acid is well shown by its reactions on many of the aniline dyes; thus, with methylanilinio violet (176) in water solution the free acid gives a sky-blue colour which becomes greenish as the amount of acid is increased and finally bleached. The chloroglucin-vanillin test is the most delicate of all, according to Tawal, and may be used as a rough quantitative test. Filter paper dipped in a solution of the dye "Congo-red" (0.1 grm. in 100 c.c. distilled water) and dried forms a most convenient test both for
free morganic and organic acids. Strips of such prepared paper dipped in the gastric fluid and washed for a few seconds in water, then dropped into a test-tube containing some eucaphorin ether become changed in colour to a lilac, blue, violet or black according to the strength of free acid present. If the ether restores the red colour to the paper 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 as they are insoluble in ether.

Besides these there are many other tests for free hydrochloric acid, as Mohr's, Duflembert's and Jollès' but the preceding are very satisfactory and were those commonly employed.

Lactic Acid. The presence of this acid is most easily indicated by the darkening which it causes when added to a dilute solution of neutral perchloride of iron (-). On the addition of a few drops of the gastric fluid to a test-tube filled with the dilute iron solution the light yellow colour becomes much darkened and can easily be seen by comparing the tube with one to which no gastric fluid has been added.

Having estimated the acidity and the amount of inexcet sugar present, I then inverted the remain-
ing Cane Sugar in a definite amount of the gastric fluid. This I did by placing 25 c.c. of the gastric fluid in a small flask and adding to it 5 drops of a solution of sulphuric acid (made by adding 2 c.c. of ordinary sulphuric acid to 9 c.c. of water). This acid, I have already stated, is the most powerful acid in causing inversion. The flask with its contents was then placed on a water bath and kept at 170-180° F. for two hours, when any Cane Sugar present in the fluid had undergone complete inversion. After cooling it was made up to its former volume and the invert sugar again estimated.

Normal Healthy Gastric Digestion.

Male - age 43 - perfectly healthy.

In the first place it was necessary to see what was the general character of the gastric juice; so after washing out his stomach, he was allowed to eat quickly 250 c.c. of cooked minced beef steak with a little water added.

(a) After one hour 60 c.c. of dark brownish-red muddy fluid were drawn off containing much bovine and softened muscular tissue; fat in very small masses.

Acidity = 0.211 % hydrochloric acid; organic acids were present and a large quantity of organic
acid. Peptones were present and fibrin soon dissolved in it on the addition of a trace of hydrochloric acid.

(b) After two hours 35 c.c. of turbid brunt fluid were drawn off. The muscular tissue was further broken down and the fat occurred in larger globules. Acidity = 0.165% hydrochloric acid. The inorganic acid was in greater amount than before, while the organic acid still remained in large quantity. Peptones were present, though the reaction was hardly so marked as after the first hour. Fibrin soon dissolved on acidifying the solution and the polariscope showed $-2^\circ$.

As another control experiment, I washed out this healthy man's stomach and then injected 250 c.c. of normal saline solution (0.9% sodium chloride).

(a) After one hour I drew off 140 c.c. slightly turbid fluid; Acidity = 0.075% hydrochloric acid; inorganic acid alone present; polariscope $-1.2^\circ$. It contained no substance that had any reducing effect on Fehling's solution. After acidifying this fluid and heating it in a water bath (as if it had been a solution of Caro Rege) there was no chemical change and the polariscope showed $-1.1^\circ$. 
After two hours 60 c.c. were drawn off: Acidity = 0.1786 % hydrochloric acid; inorganic acid alone present; polariscope = 0.7°; no reducing substance present. After heating as before for two hours some coagulation of albumen occurred and after filtration the polariscope showed - 0.5°.

The polariscope shows a rotation of the polarised ray to the left in this case although no sugar was present. All proteids are dextrorotatory and there are peptones in the gastric fluid after injecting saline solution. Corvisart (60) found that the gastric juice of the first ten minutes after ingestion had a powerful dextrorotatory action. Isolated pepsin and indeed all peptones are dextrorotatory and the different peptones differ in their rotatory power. This dextrorotatory property of the proteids interferes with the value of the nebulometric readings and so I have discarded them. I have in every case however estimated the amount of inert sugar by Yelling's solution.

This then is the character of the gastric fluid with which we have to deal in the case of the healthy digestion.
Normal Gastric Digestion of Cane Sugar

XVI. Cane Sugar Solution (20%) 250 c.c. injected into the perfectly empty stomach.
(a) 30 minutes later 160 c.c. of turbid fluid expelled off. Acidity = 0.09% hydrochloric acid; inorganic and organic acids present but no lactic acid. Invert sugar 0.25%.
(b) After inversion - Invert sugar 2.44%.

XVII. Same patient. 250 c.c. 20% Solution of Cane Sugar introduced into empty stomach.
(a) After one hour 36.5 c.c. fluid withdrawn. Acidity = 0.124%: inorganic and organic acids present with a trace of lactic acid. Invert sugar 0.81%.
(b) After inversion - Invert sugar 1.28%.

XVIII. Same patient. 250 c.c. Cane Sugar solution injected.
(a) One hour later 90 c.c. fluid drawn off. Acidity = 0.115%: inorganic and organic acids present with trace of lactic acid. Invert sugar 0.42%.
(b) After inversion - Invert sugar 1.7%.

XIX. Same patient. 250 c.c. Cane Sugar solution injected
(a) One and a half hours later 40 c.c. fluid drawn off.
Acidity = 0.125%: both inorganic and organic acids present. Invert sugar 0.13%.
(a) After inversion - invert sugar 0.495%.

XX
Same patient - 250 c.c. Cane Sugar Solution injected.
(a) Two hours later 41 c.c. fluid drawn off.
Acidity = 0.1428%: inorganic and organic acids present with trace of lactic acid. Invert sugar 0.65%.
(b) After inversion - invert sugar 0.934%.

XXI
Same patient - 250 c.c. Cane Sugar Solution.
(a) Two hours later 85 c.c. fluid drawn off.
Acidity = 0.185%: inorganic acids are greater in amount than after one hour; organic acids also present but no lactic acid. Invert sugar 0.41%.
(b) After inversion - invert sugar 0.65%.

These results may be tabulated as follows:-
<table>
<thead>
<tr>
<th>Series</th>
<th>Time in Stomach</th>
<th>Number of c. e. drawn 90</th>
<th>Acidity as % HCl</th>
<th>Inorganic acids</th>
<th>Organic acids</th>
<th>Per cent sugar inverted in stomach</th>
<th>Per cent sugar inverted outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>½ hr</td>
<td>160</td>
<td>0.09</td>
<td>+</td>
<td>+</td>
<td>0.25</td>
<td>2.44</td>
</tr>
<tr>
<td>2</td>
<td>1 &quot;</td>
<td>36.5</td>
<td>0.124</td>
<td>+</td>
<td>+</td>
<td>0.81</td>
<td>1.28</td>
</tr>
<tr>
<td>3</td>
<td>1 &quot;</td>
<td>90</td>
<td>0.115</td>
<td>+</td>
<td>+</td>
<td>0.42</td>
<td>1.7</td>
</tr>
<tr>
<td>4</td>
<td>1½ &quot;</td>
<td>40</td>
<td>0.125</td>
<td>+</td>
<td>+</td>
<td>0.13</td>
<td>0.495</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>41</td>
<td>0.142</td>
<td>++</td>
<td>+</td>
<td>0.68</td>
<td>0.934</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>85</td>
<td>0.185</td>
<td>++</td>
<td>+</td>
<td>0.41</td>
<td>0.65</td>
</tr>
</tbody>
</table>
This shows that:

1. Inversion of Cane Sugar does not 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 Cane Sugar itself.

Normal Gastric Digestion of Invert Sugar.

I prepared the invert sugar in the following manner:—

One litre of a 20% solution of pure dry Cane Sugar was placed in a flask with 1 c.c. of dilute acetic acid (1 c.c. ordinary commercial acid to 9 c.c. water). The flask was then placed in a water bath and heated for two hours at a temperature of 140-180° F. After cooling, it was made up to its original volume with water. This 20% solution of invert sugar gave a rotation of -10° by the polariscope of Zéise.
As before, I thoroughly washed out the healthy man's stomach and then injected 250 c.c. of the solution of invert sugar.

XXII

Healthy Digestion. 250 c.c. 20% invert sugar introduced into stomach.

(a) One hour later 100 c.c. were drawn off. The acidity was equal to 0.176% hydrochloric acid. The invert sugar amounted to 1.8%. (50 c.c. of the fluid after having been acidified and heated for two hours gave exactly similar results)

(b) Two hours after the injection 14 c.c. were drawn off. The acidity = 0.127% and invert sugar 1.25%.

XXIII

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

(a) After one hour 100 c.c. drawn off, acidity = 0.172% invert sugar 2.77%.

(b) Two hours after injection the stomach was perfectly empty and when washed out, the washings had no effect in reducing Helings' solution.

XXIV

Same patient - 250 c.c. invert sugar introduced.

(a) One hour after 100 c.c. drawn off. Acidity = 0.229%: inorganic and organic acids present but no lactic acid: invert sugar 2.77%
(b) After two hours 66 c.c. drawn off. Acidity = 0.164 %; organic and inorganic acids present but no lactic acid. Invert sugar 0.44 %.

**XXVI**

**Same patient - 250 c.c. invert sugar solution.**

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

Acidity = 0.182 %; inorganic and organic acids present but no lactic acid; invert sugar 3.5 %.

(b) After two hours only 11 c.c. could be drawn off.

Acidity = 0.175 %; chiefly inorganic. Invert sugar was found only as a trace - not in sufficient quantity for quantitative estimation.

**XXVII**

**Same patient - 250 c.c. invert sugar solution.**

(a) After one hour 75 c.c. drawn off.

Acidity = 0.156 %; chiefly due to inorganic acids. No lactic acid; invert sugar 4.5 %.

(b) After two hours there was no fluid in the stomach. When washed out, the rinsings were neutral in reaction and there was no invert sugar present.

We may tabulate these results in the following manner:
## Digestion of Invert Sugar in the Healthy Stomach.

<table>
<thead>
<tr>
<th>Series</th>
<th>Number of c.c.</th>
<th>Acidity = % #cc</th>
<th>Invert Sugar per cent</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st hour</td>
<td>2nd hour</td>
<td>1st hour</td>
<td>2nd hour</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>24</td>
<td>0.176</td>
<td>0.127</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>0</td>
<td>0.172</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>66</td>
<td>0.229</td>
<td>0.164</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
<td>11</td>
<td>0.182</td>
<td>0.175</td>
</tr>
<tr>
<td>5-</td>
<td>75</td>
<td>0</td>
<td>0.156</td>
<td>0</td>
</tr>
</tbody>
</table>
If we compare this table with that of the digestion of Cane Sugar we see that there is a very great difference as regards the behaviour of these two sugars in the stomach. In the case of the Cane Sugar there was always much fluid in the stomach even after the lapse of two hours after its reception, in no case was it less than 76 c.c. With the Invert Sugar however the case is different. Much fluid could be withdrawn one hour afterward, but after two hours the stomach was entirely or almost empty. Only in one or two cases and in these with difficulty, could a few entire centimeters be extracted. The stomach therefore becomes quickly empty after the injection of Invert Sugar.

In the case of Invert Sugar if we compare the column after one hour with that after two hours 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 walls of the stomach or, more probably, has been passed through the pylorus into the duodenum. Both of these processes in all likelihood go on at the same time.

We may note that this healthy man made no complaint as to the fluids which were introduced into his stomach.
giving him any uneasiness, except once, when he suffered from slight heartburn after 250 c.c. of cane sugar solution had been injected.

**Digestion of Sugars in Pathological Conditions.**

Having seen what changes occur in cane and invert sugar during their stay in the healthy stomach, I now carried out a series of experiments regarding their digestion in diseased conditions.

**Chronic Gastric Catarh.**

The patient was a blacksmith, aged 44. He had suffered much for two years from heaviness, flatulence and drowsiness after taking food. There was no dilatation of the stomach.

I examined first the normal condition of his gastric secretion by giving him 250 c.c. of cooked minced steak after having washed out the stomach (a) One hour later 57 c.c. were drawn off. This was a turbid brownish-red fluid; acidity = 0.30% hydrochloric acid, due to inorganic and organic acids but the former in larger amount, no lactic acid; peptones present in large amount; fibrin digested in
three-quarters of an hour without the addition of any acid.

(b) After two hours 87 c.c. of fluid similar in character to the last were drawn off.

Patient felt great relief after his stomach was washed out and experienced but little discomfort from the meat which was injected.

Acidity = 0.32%: inorganic and organic acids in large amount; peptones present but reaction not so marked as after the first hour; gelatin was digested in 65 minutes without the addition of any acid.

Digestion of Cane Sugar in Chronic Gastric Cataract.

In the first place I would remark that the nature of the fluid introduced into the patient's stomach was quite unknown to me and therefore it is the more necessary to pay attention to the statements regarding pain or discomfort or the reverse after the reception of the sugary solutions.

XXVIII 250 c.c. Cane Sugar Solution introduced into empty stomach

(a) After one hour 70 c.c. of thick whitish fluid were drawn off. This filtered with difficulty as it was
mixed with much mucus. Acidity = 0.2% hydrochloric acid, organic and inorganic acids were present including lactic acid; invert sugar amounted to 0.98%.

(b) After inverting the fluid artificially the invert sugar amounted to 2.0%.

Soon after receiving the sugary solution into his stomach 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; pain over the region of the stomach was severe while the heartburn and flatulence were more severe than was usual.

Same patient. At 10 a.m. I washed out the stomach. He had partaken of no food since 5 a.m. when he had taken some milk; yet much white curdly material came through the tube on washing out the stomach. This shows how slow the processes of digestion are in such cases and for how long a time food remains in the stomach.

XXIX 250 c.c. Cane Sugar Solution injected into stomach
(a) After one hour 83 c.c. viscid white fluid containing shreds of mucus were drawn off.
Acidity = 0.133% due chiefly to inorganic acids; organic acids also present including lactic acid. Invert sugar present to 1.47%.

(b) After inversion much of the organic acid had been driven off by the heat. Invert sugar forms 5.9%.

(2) XXX Two hours after receiving the Cane Sugar solution 130 c.c. of which fluid were drawn off. This was not so viscous as after the first hour.

(a) Acidity = 0.175% . There is much more inorganic acid present than after the first hour and lactic acid is also present. Sugar inverted in the stomach formed 1.7%.

(b) After inversion, the invert sugar formed 4.3%.

The patient suffered much after this fluid was injected from pain in the stomach and heartburn with much flatulence. He was not relieved till he produced emesis by thrusting his finger down his throat.

XXXI Same patient. 250 c.c. Cane Sugar solution.

(a) After one hour 65 c.c. turbid white fluid were drawn off. A much greater quantity came through the tube but much of it was at once returned to the stomach.
Acidity = 0.04 % chiefly inorganic; no lactic acid; sugar inverted in stomach 1.04 %.
2. After inversion, the invert sugar formed 6.6 %.

XXXII
2. (a) After two hours 125 c.c. of fluid similar to the last were drawn off.
Acidity = 0.131 % almost wholly due to inorganic acids; no lactic acid present. Sugar inverted in stomach 0.9 %.
(b) After inversion, the invert sugar formed 4.3 %

XXXIII
Same patient - 250 c.c. Cane Sugar solution.
(a) After one hour 72 c.c. turbid white fluid drawn off; Acidity = 0.09 %, chiefly inorganic; small amount of organic acids but no lactic acid present.
Sugar inverted in stomach was 0.56 %
(b) After inversion, the invert sugar formed 3.54 %

XXXIV
2. (a) After two hours 83 c.c. of fluid similar in character were drawn off.
Acidity = 0.134 %; inorganic and organic acids present in nearly equal proportions; no lactic acid.
Sugar inverted in stomach 0.56 %
(b) After inversion, invert sugar formed 3.44 %

Same patient - He has felt very ill for the past three days, & since this treatment was commenced.
(i.e., washing out stomach and injecting cane sugar solution).

He had only milk and bread for breakfast, yet on washing out the stomach there was much evolution of sulphured hydrogen.

XXXV

250 c.c. 20% Cane sugar solution injected.

1. (a) After one hour 75 c.c. turbid white fluid withdrawn; Acidity = 0.109 %; large amount of mineral acids; organic acids in small amount; no reaction for lactic acid. Sugar inverted in stomach 0.392 %

(b) After inversion, invert sugar forms 5.26 %

2. (a) Two hours after injection 100 c.c. of thick fluid drawn off; Acidity = 0.095 % due chiefly to inorganic acids; no lactic acid. Sugar inverted in stomach 0.9 %

(b) After inversion, invert sugar 5 %.

Patient suffered much pain till he induced emesis.

XXXVI

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

1. (a) After one hour 100 c.c. thick white fluid drawn off; Acidity = 0.105 %; principally mineral; no lactic acid; sugar inverted in stomach 1 %

(b) After inversion, invert sugar 5.5 %

XXXVII

(b) Two hours after 75 c.c. of fluid similar in
<table>
<thead>
<tr>
<th>Remarks</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<td>2.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Series:**

- **1:** 0.2
- **2:** 0.15
- **3:** 0.15
- **4:** 0.15
- **5:** 0.15
- **6:** 0.15

**Acidity:**

- **1:** 7.0
- **2:** 8.3
- **3:** 6.5
- **4:** 7.2
- **5:** 7.5
- **6:** 7.5

**Organic acids:**

- **1:** 130
- **2:** 125
- **3:** 83
- **4:** 83
- **5:** 83
- **6:** 83

**Sequence of Cane Sugar in Chronic Pts. Gastrointestinal:**

- **1:** 1
- **2:** 2
- **3:** 3
- **4:** 4
- **5:** 5
- **6:** 6
character drawn off. Acidity was equal to 0.115% hydrochloric acid; trace of organic but no lactic acid present: Sugar inverted in Stomacl 0.6%.
(b) After inversion. Invert Sugar = 2.3%.

If we compare this table with that of the healthy digestion of Cane Sugar VII we see that the acidity is very much alike in both. 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 as in the healthy individual. This case shows the tardy nature of the digestive processes in catarrhal conditions of the gastric mucous membrane.

This patient made constant complaint of pain, heartburn and flatulence after the ingestion of the cane sugar solution into his stomach; while the healthy man only once mentioned that he had very slight pyrosis.

Digestion of Invert Sugar in Chronic Gastric Catarrh.

The next set of experiments deals with the gastric digestion of invert sugar in the same patient.
XXXIX. Chronic Gastric Cataract. 250 c.c. of a 20% solution of invert sugar injected into stomach.

(a) One hour later 80 c.c. thick viscous fluid resembling saliva drawn off by aspiron tube.

Acidity = 0.153% ; inorganic acids form the greater part of the acidity, though organic acids are also present but no lactic acid. Invert sugar forms 5.26%.

(b) After the lapse of two hours 120 c.c. drawn off. The fluid is not so viscous as after the first hour.

Acidity = 0.094% ; principally inorganic; no lactic acid.

Invert sugar 1.54%.

The patient complained of no pain, nor suffered from heartburn or flatulence after receiving the injection till about 4 p.m. or nine hours after the invert sugar solution had been introduced.

XL. Same patient. 250 c.c. invert sugar solution given.

(a) One hour afterwards 65 c.c. thick whiteish fluid were drawn off; Acidity = 0.091% ; Small amount of organic acid present (no lactic acid) but much mineral.

Invert sugar 5.5%.

(b) Two hours after injection 62 c.c. drawn off.

Acidity = 0.138% - similar in character to the preceding.

Invert sugar 2.6%

Patient felt no discomfort whatever after the injection.
XLI. Some patient - 250 c.c. invert sugar solution.
(a). After one hour 52 c.c. turbid thick fluid syphoned off.
Acidity = 0.122 % due chiefly to inorganic acid.
Invert sugar 5.5 %.
(b). After two hours 42 c.c. of fluid similar in character
to the preceding were drawn off.
Acidity = 0.113 % chiefly inorganic; no lactic acid.
Invert sugar 1.2 %.
Patient made no complaint whatever.

XLII. Some patient - 250 c.c. invert sugar solution.
(a). One hour later drew off 68 % turbid white fluid.
Acidity = 0.116 %; small amount of organic acid
present; no lactic acid.
Invert sugar 4.76 %.
(b). After two hours 100 c.c. of fluid resembling preceding
drawn off.
Acidity = 0.102 %; chiefly mineral acid; no lactic.
Invert sugar 3.7 %.
Patient felt no discomfort.

XLIII. Some patient - 250 c.c. invert sugar solution.
(a). After one hour 75 c.c. turbid fluid drawn off.
Acidity = 0.109 %; chiefly due to inorganic acids;
no lactic acid; invert sugar 4.35 %.
(b) Two hours after injection 30 c.c. were drawn off with difficulty,
the stomach being almost empty.

Acidity = 0.07 % - chiefly inorganic in nature.
Invert sugar = 0.8 %.

Patient made no complaint whatever.

These results are tabulated on the following page.

This table shows that a great reduction has taken place in the percentage of invert sugar after the second hour as compared with the first. If we compare this table with that of 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 two hours, while in this dyspeptic there is still a large proportionate amount. The absorption from the stomach or the emptying of it is much less rapid in this catarrhal condition than in health.

The great and important point to notice however is that with invert sugar there is no pain or discomfort while with cane sugar on nearly every occasion the patient suffered much from heartburn, flatulence or actual pain over the stomach.
<table>
<thead>
<tr>
<th>Series</th>
<th>Time</th>
<th>No. of C.C.</th>
<th>Acidity</th>
<th>Inorganic Acid</th>
<th>Organic Acid</th>
<th>Invert Sugar %</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>80</td>
<td>0.153</td>
<td>+++</td>
<td>+</td>
<td>5.26</td>
<td>No discomfort</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>120</td>
<td>0.094</td>
<td>+++</td>
<td>+</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>65</td>
<td>0.091</td>
<td>+++</td>
<td>+</td>
<td>5.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>62</td>
<td>0.138</td>
<td>+++</td>
<td>+</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>52</td>
<td>0.122</td>
<td>+++</td>
<td>+</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>42</td>
<td>0.113</td>
<td>+++</td>
<td>+</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>68</td>
<td>0.116</td>
<td>+++</td>
<td>+</td>
<td>4.76</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>100</td>
<td>0.102</td>
<td>+++</td>
<td>+</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>75</td>
<td>0.109</td>
<td>+++</td>
<td>+</td>
<td>4.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>30</td>
<td>0.07</td>
<td>+++</td>
<td>+</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>
Digestion of Cane Sugar in Pernicious Anaemia.

The next patient on whom I carried out a similar set of experiments was a labourer, aged 45, suffering from pernicious anaemia. Six months previously he began to have a heavy, dull weight over the stomach after eating food. This increased in severity, till, at the time when I had him under observation, he suffered severe headache soon after taking food with water, and even vomiting.

What was the nature of the gastric juice in such a case and how would it behave towards sugar?

To investigate the first of these questions, I gave him 250 c.c. of cooked minced steak (with some water added) to eat after being first washed out his stomach thoroughly.

XLIV

(a) One hour later I drew off 76 c.c. of muddy light yellow fluid containing very small fragments of muscular tissue forming an almost amorphous deposit. Fat was floating on the surface in tolerably large round masses. The acidity was equal to 0.0164 per cent., estimated as hydrochloric acid. There was no tannate acid. The acidity was so feeble that one might almost have said that it was neutral in reaction. There was no peptone reaction. Albumin was detected by it after the
addition of dilute hydrochloric acid.

(F.) Two hours after eating the minced meat 30 c.c. of pale yellow fluid were drawn off. It also contained a fine deposit of muscular fibre. On the surface the fat floated in one single large mass.

Acidity = 0.006 per cent; faint trace of lactic acid.

No peptone reaction. Fibres depigmented after the fluid was acidified with hydrochloric acid.

The gastric secretion of this individual has therefore hardly any acidity. Resin is present and is shown by the ready digestion of fibrin after the fluid has been acidified.

Gastric Digestion of Cane Sugar in Pernicious Anaemia.

1. (a.) 250 c.c. 20% solution of Cane Sugar injected into stomach.

XLY. One hour later, 25 c.c. yellow coloured fluid drawn off.

Acidity = 0.0018 per cent; no lactic acid.

Sugar invessted in stomach - none.

(b). After inversion outside - Invert Sugar = 0.43%.

2. (a) After two hours 30 c.c. of fluid paler in colour than the preceding drawn off.

Acidity = 0.0007 per cent - No reducing sugar present.

(b). After inversion outside - Invert Sugar - none.

This patient had been accustomed to have his stomach washed out. He stated that little to after such
treatment—he had felt "light" and comfortable, but
this time (after the introduction of Cane Sugar into the
stomach) he had felt very heavy and had a "pore feeling"
over the region of the stomach.

XLVII

Same patient—250 c.c. Cane Sugar solution introduced.
1. (a) After one hour I drew off 50 c.c. of yellow fluid
with many mucous flocculi in it.
Acidity = 0.021 per cent.
Sugar inverted in stomach—none—
(b) After inversion outside—invert sugar 4.17%.
Patient stated that he felt "very bad indeed;"
headache was very severe.

XLVIII

2. (a) Two hours after the injection there was no fluid
in stomach and when it was rinsed out with pure
water, the rinsings contained no sugar of any kind.

Practically, the gastric juice of this patient had no acidity.
This accounts for there being no inversion of the Cane
Sugar during its stay in the stomach. The probability is
that, after staying in the stomach unchanged for some
time, the Cane Sugar was then passed on through the
pylorie orifice into the duodenum.
### Gastric Digestion of Cane Sugar in Pernicious Anaemia.

<table>
<thead>
<tr>
<th>Series</th>
<th>Time</th>
<th>Volume of C.C.</th>
<th>Acidity</th>
<th>Invert Sugar formed in stomach per cent.</th>
<th>Invert Sugar formed outside</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>25</td>
<td>0.0018</td>
<td>0</td>
<td>0.43</td>
<td><a href="#">Reactivity and discomfort.</a></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>38</td>
<td>0.0007</td>
<td>0</td>
<td>0</td>
<td><a href="#">Reactivity and discomfort.</a></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>57</td>
<td>0.0210</td>
<td>0</td>
<td>4.17</td>
<td>Felt very ill</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

---

**Behaviour of Invert Sugar in the Stomach in the Case of Pernicious Anaemia.**

---

**XLVIII** Same patient - 250 c.c. of 20% solution of invert sugar introduced into stomach.

(a) After fifteen minutes 150 c.c. expelled off.
   - Acidity = 0.0036%.
   - Invert Sugar = 15.2%.

---

**XLIX** Same patient - 250 c.c. invert sugar solution

(a) After one hour 52 c.c. greenish-yellow fluid drawn off.
   - Acidity = 0.0145% - no gastric acid.
   - Invert Sugar = 8.7%. 

(b) Two hours after injection 54 c.c. pale fluid drawn off.
Neutral in reaction.
Invert sugar - none.

The patient stated that he felt no discomfort this day and that he experienced the same "light" feeling which he formerly had after having his stomach washed out. He had no flatulence or waterbrash.

1. Same patient - 250 c.c. invert sugar solution:
   (a) One hour later 33 c.c. drawn off.
   Acidity = 0.01%. Invert sugar 3.7%.
   (b) Two hours after introduction of the sugary solution there was no fluid in the stomach and when raised out the runnings contained no reducing sugar.

| XI. Behaviour of Invert Sugar in Pericardiac Anemia. |
|---------------------------|-------------|----------------|-----------------|-----------------|
| Series | Hour | No. of c.c. | Acidity | Invert Sugar per cent | Remarks |
| 1      | 1st  | 52          | 0.0145  | 8.7              | no discomfort  |
| 2      | 2nd  | 54          | .51     | 0.7              |    "           |
| 3      | 3rd  | 23          | 0.51    | 3.7              |    "           |
| 4      | 2nd  | 0           | 0       | 0                |    "           |

In this patient the stomach has behaved to this sugar in a similar way to what it did with cane sugar. It has simply emptied itself very quickly and most probably has passed all
the invert sugar on into the duodenum.

Digestion of Cane Sugar in Alcoholics Dyspepsia.

Patient was a seafaring man aged 54. His complaints were, morning vomiting, keel, fulness and uneasiness over the stomach, very troublesome flatulence and want of appetite.

I. 250 c.c. 20% solution of Cane Sugar were introduced into his empty stomach.

1(a) After one hour 45 c.c. of turbid rosy fluid containing much mucus were drawn off. Much flatue also escaped through the tube.
   Aecidity = 0.0145%. Traces of lactic acid.
   Sugar inverted in stomach 0.208%.

(b) After inversion outside - Invert sugar 5%.
   Patient stated that the flatulence became very severe after injection of the Cane Sugar.

2. (a) Two hours after injection 30 c.c. thick viscous fluid drawn off.
   Acidity = 0.0036%. Sugar inverted in stomach 0.069%.

(b) After inversion outside - Invert-sugar amounted to 0.213%.
LIII. Same patient. 250 c.c. Cane Sugar solution.

1(a) An hour later 50 c.c.: thick mastic blood-stained fluid expelled off.
Acidity = 0.01 % - no lactic acid.
Sugar inverted in stomach - none.

(b) After inversion in waterbath - 1.56 % invert sugar.

XII. Gastric Degestion of Cane Sugar in Alcoholische Gastrie Catarrh.

<table>
<thead>
<tr>
<th>Series</th>
<th>Hour.</th>
<th>No. of c.c.s</th>
<th>Acidity</th>
<th>Percent inverted in stomach</th>
<th>Percent inverted outside</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st</td>
<td>45</td>
<td>0.0145</td>
<td>0.01</td>
<td>0.208</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>2nd</td>
<td>30</td>
<td>0.0036</td>
<td>0.059</td>
<td>0.213</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>3rd</td>
<td>30</td>
<td>0.01</td>
<td>0</td>
<td>1.56</td>
<td></td>
</tr>
</tbody>
</table>

In this case the acidity is very slight and the amount of inversion in the stomach proportionally small. His experience is quite opposed to the usual statement, that in diseased conditions of the mucous membrane of the stomach with the 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 which is allied to pylalii (245).
The preceding experiments show that invert sugar is very quickly passed on into the duodenum and that the absorption of this sugar through the walls of the stomach seems to be very slight. That this is so, that this is so is shown by the table of events in the digestion of Cane Sugar in cases of Chronic Gastric Catarrh. This shows that the amount of invert to Cane Sugar remains very much the same at the end of the first or second hour. Had there been much absorption through the gastric walls the relative strength would have been changed.

The changes therefore which sugar undergoes in the stomach are simply that a certain degree of inversion of Cane Sugar takes place; the amount of this change depends on the degree of acidity of the gastric secretion. Neither Cane nor invert sugar are absorbed to any degree through the walls of the stomach but after a variable time, but Cane and invert sugar are passed on into the duodenum. The passage of Evert sugar, however, out of the stomach is very much more rapid than that of Cane Sugar.
Intestinal digestion of Cane Sugar.

Neither the bile nor the pancreatic secretions seem to have any mivasive action on cane sugar. Béchamp thought that the pancreas had a slight mivasive action, but the change was in all probability due to bacteria causing a decomposition and not from any pancreatic ferment (Cron and Kern).

The mucous membrane of the small intestine however secretes a ferment which has been named "invertin" and which causes Cane Sugar to become hydrated and split up into glucose and Saccharose. The fermentative action of the succus entericus was first described by Claude Bernard (139) who also showed that before its absorption Cane Sugar must be inverted. This ferment can be isolated and then acts on Cane Sugar but much more slowly than when in contact with the mucous membrane of the small intestine. Bernard found it in every part of the small intestine but not in the large intestine.

Sir William Roberts also describes this ferment and has extracted it from the small intestine of the pig, fowl and hare. It will not, he says, pass through a filter and its invertive action is very slow, usually requiring two hours at 38° C. before any reduction of colour takes place.
Hoffe-Seyler does not think that this is a true ferment of the intestinal mucous membrane but believes that it is one introduced from without and Busch (153) could not find that Cane sugar underwent any change during its stay in the bowels. Matthews Bay however found this ferment constantly present in every part of the small intestine of the fowls and in such a case it could not have been introduced from without. He could not discover it in any other part of the body.

Finsen (166) has also described this mastic ferment and also a diastatic one in the small intestine, but they require to act on the sugar or starch for four or five hours before any inversion of sugar or conversion of starch occurs. Brown and Horne (152) have also studied this question and found that a watery infusion of the small intestine possessed no mastic action on Cane Sugar but when they used the dried and powdered mucous membrane of the small intestine they got a marked inversion. They say that this property lies chiefly in the gminated glands of the small intestine.

To observe for myself whether this mastic ferment was active and in what localities it was to be found,
I performed the following experiments:

A healthy young rabbit was starved for thirty-six hours. It then received a full meal and was killed two hours subsequently, at which time the various digestive processes would be in full activity.

I had previously prepared a 5% solution of pure cane sugar and into eighteen flasks I placed 50 c.c. of this sugar solution and heated all to 38° C.

Having carefully and gently washed the contents from the alimentary canal of the animal by means of a stream of normal salt solution, I then placed 5 grammes of different parts of the intestinal tract and other organs of its body into each of the flasks and kept them at 38° C. for two hours. They were then allowed to cool and the sugar which was inverted estimated by Petkow's solution.

The following table shows the various tissues employed and is arranged in the order of the greatest inverting power of the different parts.

This table certainly shows that there is a very decided inverting action in the small intestine of the rabbit and also an inverting power to a very much smaller extent in the other parts of the digestive tract.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lower part of small intestine</td>
<td>1.14%</td>
</tr>
<tr>
<td>2</td>
<td>Upper part of small intestine</td>
<td>.96%</td>
</tr>
<tr>
<td>3</td>
<td>Vermiform appendix - lower part.</td>
<td>.32%</td>
</tr>
<tr>
<td>4</td>
<td>Liver</td>
<td>.29%</td>
</tr>
<tr>
<td>5</td>
<td>Vermiform appendix - upper part</td>
<td>.23%</td>
</tr>
<tr>
<td>6</td>
<td>Central part of stomach</td>
<td>.23%</td>
</tr>
<tr>
<td>7</td>
<td>Pancreas</td>
<td>.21%</td>
</tr>
<tr>
<td>8</td>
<td>Large intestine</td>
<td>.14%</td>
</tr>
<tr>
<td>9</td>
<td>Cardiac end of stomach</td>
<td>.14%</td>
</tr>
<tr>
<td>10</td>
<td>Pyloric end of stomach</td>
<td>.14%</td>
</tr>
<tr>
<td>11</td>
<td>Spleen</td>
<td>.13%</td>
</tr>
<tr>
<td>12</td>
<td>Thyroid gland (piece of)</td>
<td>.08%</td>
</tr>
<tr>
<td>13</td>
<td>Salivary Gland</td>
<td>.06%</td>
</tr>
<tr>
<td>14</td>
<td>Muscle</td>
<td>.06%</td>
</tr>
<tr>
<td>15</td>
<td>Kidney</td>
<td>.06%</td>
</tr>
<tr>
<td>16</td>
<td>Eustachian</td>
<td>.06%</td>
</tr>
<tr>
<td>17</td>
<td>Bile</td>
<td>0%</td>
</tr>
<tr>
<td>18</td>
<td>5% solution of Cane Sugar at 38°C</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Human Infant.** I then performed an exactly similar set of experiments with the digestive tract of a baby which had lived three days and during life it had been fed on the mother's milk. The salivary
glades were too feebly developed to be worth removing.

**Human Infant. Table of inversions in order of greatest
inversion power.**

<table>
<thead>
<tr>
<th>5 grams. of each of:</th>
<th>Per cent. Invert sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Small intestine</td>
<td>37.3</td>
</tr>
<tr>
<td>2 Large intestine</td>
<td>38.4</td>
</tr>
<tr>
<td>3 Stomach - central part</td>
<td>0.32</td>
</tr>
<tr>
<td>4 Oesophagus</td>
<td>0.12</td>
</tr>
<tr>
<td>5 Stomach - pyloric end</td>
<td>0</td>
</tr>
<tr>
<td>6 Stomach - cardiac end</td>
<td>0</td>
</tr>
<tr>
<td>7 Pancreas</td>
<td>0</td>
</tr>
<tr>
<td>8 Liver</td>
<td>0</td>
</tr>
<tr>
<td>9 Thyroid gland</td>
<td>0</td>
</tr>
<tr>
<td>10 Kidney</td>
<td>0</td>
</tr>
<tr>
<td>11 Bile</td>
<td>0</td>
</tr>
<tr>
<td>12 Thymus</td>
<td>0</td>
</tr>
<tr>
<td>13 Spleen</td>
<td>0</td>
</tr>
<tr>
<td>14 5% Cane Sugar solution at 38° C.</td>
<td>0</td>
</tr>
<tr>
<td>15 5% Cane Sugar solution inverted</td>
<td>1.18</td>
</tr>
</tbody>
</table>

A comparison of these last two tables shows us that the chief inversion action both in the rabbit and in the infant is in the small intestine. With the experiment in the rabbit the 5 grams. were sufficient to invert
more than one-fifth of the Cane Sugar; while in the
infant it inverts more than one-tenth. This shows
that this ferment is relatively powerful and, dis-
tributed as it is throughout the whole extent of
the small intestine, will easily suffice to invert
all the assimilable cane sugar which is injected.

Summarising in a word - we have seen that Cane Sugar is
1. Unchanged by the Saliva;
2. In the Stomach it undergoes a certain amount of
   inversion depending entirely on the degree of acidity
   of the gastric fluid.
3. In the Small Intestine it is subjected to a relatively
   great amount of inversion.

Absorption of Sugars.

Many opinions have been put forward
regarding the absorption and assimilation of Cane Sugar
since the time when Bernard injected a solution of
Cane sugar into the veins and found that it was
excreted unchanged in the urine. This classic ex-
periment proved that Cane Sugar was treated as
a foreign body by the blood and rapidly elimi-
nated.
There can be no doubt whatever but that glucose is the ultimate form in which Cane sugar is absorbed and not as maltose as was previously affirmed (263). I have shown that Cane sugar undergoes inversion both during its stay in the stomach and later in the small intestine. A large amount of this must, from its high diffusibility, pass at once by osmosis, through the gastric walls and so find its way into the gastric capillaries of the portal vein (256), but I cannot believe what one writer states, that much and sometimes all the sugar is absorbed in the mouth and gullet (315) along with the products of inversion, peptones, diffusible salts, water, alcohol etc., must pass through the stomach walls. The same happens in the small intestine. Cane Sugar which passes unchanged from the stomach comes under the influence of the ferment "inversion" and soon undergoes a splitting up into glucose and fructose. These pass through the intestinal walls owing to their relatively high endosmotic equivalent and so to the rootlets of the portal vein. Besides this, it has also been shown that the upper part of the small intestine has a much greater absorptive power than the same lower down. Sugar which reaches the stomach, in the condition of
invert sugar is either very quickly absorbed through the gastric walls or is rapidly passed on through the pylorus. Those experiments in healthy digestion which I have detailed seem to bear out the idea that absorption through the gastric walls does take place.

Leube (277) found that twenty minutes after the introduction of a half-per cent solution of Cane Sugar into the stomach the amount of reduction produced was very small, while in thirty minutes the grape sugar had totally disappeared, having been absorbed, he thinks, through the gastric walls. Lehmann (215) tied up a solution of glucose in a loop of the small intestine and found that in a short time it had totally disappeared; the absorptive power of the small intestine is much greater than that of the stomach, however.

Absorption of the Individual Sugars.

Cane Sugar. I have already shown that this sugar is not absorbed as such, but must be changed into glucose or fructose before it can be.

Dextrose. This sugar is ready for immediate absorption. It is in effect a predigested food and is, as my experiments show, very rapidly absorbed from
the stomach and intestines. When injected into the blood it is not eliminated in the urine unless given in excess. (164) Of course there is 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 glycosuria. If much more than this be taken however small quantities are secreted in the urine for the succeeding three to five hours.

_Leucrose._ This sugar is quite as rapidly absorbed as dextrose and is even better borne. It may be taken in greater quantities than grape sugar without passing the limit of assimilability and does not undergo fermentation so rapidly as glucose.

_Maltose._ I need only state here that before this sugar is absorbed it must be changed into glucose. This change is brought about by the continued action of the diastatic ferment of the pancreas, though chiefly by those of the intestinal juice.

_Lactose._ Neither is this sugar absorbed as such. It also requires transformation even though it occurs in
human milk to about 5 per cent. When a solution
of this sugar is injected into the veins it is ex-
creted unchanged in the urine in the same way as
cane sugar (148); 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 gal-
actose. It is believed that, under the influence of
the digestive ferments, a true splitting takes place
in the alimentary canal but the digestive ferments
which cause the change have not yet been dis-
covered. The glucose is directly absorbed and Dastre
has proved that galactose can be directly absorbed,
for when a solution of galactose is injected into the
vena cavea none or only a trace can be recovered in the
urine. If diabetic patients be fed on milk alone
or with lactose added, glucose alone appears in the
urine. This also proves to prove that it must have been
absorbed as such. (148) Lactose is one of the
least assimilable sugars and Dastre has arranged
the sugars in the following order as regards their
case of absorption, the first being least directly
useful: — Cane sugar and Lactose:
Maltose:
Glucose:
The limit of assimilability for lactose is low and it thus appears in the urine very much more easily than the other sugars, glucose and cellulose. Clinically, in children, it has been found that milk sugar is in no way superior to cane sugar as part of the dietary, but tends more easily to give rise to acid fermentation.
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 are specially liable to occur if an excess of carbohydrate food be injected or in weak or diseased conditions of the stomach and bowels.

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, so that which is unabsorbed is extremely liable to undergo various fermentations 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 (187). If some sugar remains long in the stomach lactic, butyric, mucic and valerianic acids result from its decomposition (265).

Lactic Acid Fermentation.

I have already drawn attention to the supposed presence of the lactic acid ferment in the gastric juice. If then lactase be introduced in excess into the stomach,
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:

\[ C_{12}H_{22}O_{11} + H_2O = 4 (C_3H_6O_3) \]

(Lactose) (Lactic acid)

It is probable however that there are many other products besides this acid. Carbonic acid gas is always present in this fermentation and it is likely that alcohol, butyric acid etc. are also formed.

Indeed 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 in carbohydrates induced 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. A pure solution of lactose does not ferment when exposed to the influence of healthy pure gastric juice (25%) A solution of starch exposed to the action of the bacterium of lactic fermentation becomes partly changed into glucose.
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:

\[
C_{12}H_{22}O_{11} + H_2O = 4 (C_3H_6O_3)
\]

(lactose)  \hspace{1cm} \text{(lactic acid)}

It is probable however that there are many other products besides this acid. Carbonic acid gas is always present in this fermentation and it is likely that alcohol, butyric acid &c. are also formed. (102)

Indeed 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 in carbohydrates induced 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. A pure solution of lactose does not ferment when exposed to the influence of healthy pure gastric juice. A solution of starch exposed to the action of the bacterium of lactic fermentation becomes partly changed into glucose.
Butyric Acid Fermentation.

From lactic acid a step further in the fermentative process 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 (280):

\[ 2 \left( \text{C}_3 \text{H}_6 \text{O}_3 \right) + \text{H}_2 \text{O} = \text{C}_4 \text{H}_8 \text{O}_2 + 2 \text{CO}_2 + 2 \text{H}_2 \text{O} + 2 \text{H}_2 \]

(lactate acid) Butyric acid.

Chyme has been found to evolve carbonic acid and hydrogen in equal volumes when removed from the intestine and kept at the body heat, thus showing that the butyric acid decomposition was going on.

Other fermentations may arise due to bacteria, thus we have the alcohol and acetic acid fermentation or the lactic and butyric acid fermentations (175):

\[ \text{C}_6 \text{H}_12 \text{O}_6 \text{ (glucose)} \]

\[ 2 \text{C}_2 \text{H}_4 \text{O} + 2 \text{CO}_2 \text{ (alcohol)} \]

\[ \text{C}_2 \text{H}_6 \text{O} + 0 = \text{C}_2 \text{H}_4 \text{O} + \text{H}_2 \text{O} \text{ (aldehyde)} \]

\[ \text{C}_2 \text{H}_4 \text{O} + 0 = \text{C}_2 \text{H}_4 \text{O}_2 \text{ (acetic acid)} \]

These different fermentations may alternate in the body.
individual giving at one time the alcoholic and acetic acid fermentation and at another the lactic and butyric fermentation with the evolution of much gas. These acids are rapidly formed as the fermentative changes take place in a short space of time. Glucose is said to be much more rapidly fermented than levulose. The butyric fermentation of glucose is most apt to occur when albumen in a putrecent condition (as in tainted milk) is taken into the stomach, along with it.

It is said that maltose tends rather to undergo the lactic acid fermentation, while cane sugar inclines rather to the acetic fermentation and acetic acid is much more irritating to the gastric mucous membrane than lactic acid.

In the alimentary tract of the foetus no bacteria can be found. This immunity does not last long however after birth; for in a very few days large numbers are found throughout the whole extent of the digestive tract having been carried there in the food. It is owing to the presence of bacteria in the intestinal canal of infants that fermentative processes are so liable to occur. Many of these microorganisms have been isolated and studied.

There is one, a microcococcus, which induces the alcoholic and acetic fermentation in sugar; another (Brieger's bacillus) is found in large numbers at the lower part of the intestine and induces the fermentation of grape
but not of milk sugar. At the upper part of the small intestine there occurs another bacillus which causes the lactic and butyric fermentation of sugar of milk. Many others are described by Eckermann, Briege and Original.

The gases found in the intestines of children fed on milk alone are free from smell and consist of hydrogen and carbonic acid. These probably arise from the lactic acid fermentation of milk sugar followed by the butyric acid fermentation.

The lactic acid fermentation may be innocuous and may even be in part (though this is very doubtful) a normal physiological process; the butyric acid fermentation or the other hand, is very hurtful, the acid produced having a poisonous effect on the nerve centres. All putrefactive fermentations which go on in the alimentary tract are most injurious to health owing to absorption of the products of decomposition.

Milk is especially prone to undergo fermentative decomposition if taken into the stomach when in an incipient state of fermentation this is very likely to be hastened and to set up a like fermentation in the sebaceous elements of the food, and especially in the milk sugar. Normal healthy gastric juice has a certain effect in restraining such fermentations but its power is not nearly
so strong as is generally believed. This property is due to the hydrochloric acid which it contains and which is sufficient, according to Bunge, when free, to kill bacteria.

Cohn affirms that the acetie acid fermentation is arrested by 0.05 parts hydrochloric acid per mille.

Consequently, in those conditions where hydrochloric acid is absent, as in many forms of dyspepsia and infantile atopy, or gastric catarrh or when excess of carbohydrate food has been ingested the above-mentioned fermentations are most liable to occur. As a result of these fermentations the mucous membrane of the stomach and intestines is irritated and in infants where these organs are extremely delicate and irritable, vomiting and diarrhea ensue. This is accompanied or succeeded in turn by gastric and intestinal catarrh and in this way, very often, a chronic diarrhea is set up which leads to general wasting and in too many cases ends 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 by which to destroy them directly.
Experiments in the Lactic Acid Fermentation of the different Sugars.

In order to determine the rate of fermentation in the various sugars I performed the following series of experiments.

I took chemically pure samples of cane sugar, invert sugar, lactose, glucose, maltose and cellulose and made 5 per cent. solutions of each in distilled water. I then placed 100 c.c. of each of these solutions in separate flasks and added to each 10 c.c. of soured skim milk filtrate. (I used skim milk in order to get as pure a lactic acid fermentation as possible. When ordinary unskimmed milk becomes sour the fat which it contains is apt to undergo the butyric fermentation and so the fermentation process is not so simple as with skimmed milk. Even with the precaution of using this milk the lactic fermentation gives rise to the production of small quantities of butyric and carbonic acids and other substances, thus showing that it is not a simple splitting up of the sugar into lactic acid - not simply C\(_6\)H\(_{12}\)O\(_6\) = 2(C\(_3\)H\(_6\)O\(_3\))

I then estimated the degree of acidity in each of these sugary solutions rendered acid by the sour milk and have expressed it as lactic acid, of which in fact it chiefly consisted. This acidity I have termed the
"initial aciidity." The flasks with their contents were then placed in a warm chamber and kept at the normal temperature of the human body for the next three days. This temperature is also the most suitable for the growth of the bacterium lactis. At intervals of two, four, eight, twenty-four, thirty, and seventy-two hours the amount of lactic acid in each of the flasks was estimated and by a comparison the rapidity and degree of production of the acid in each of the sugars can be estimated.

Cane Sugar.

The initial aciidity of the 5% solution of this sugar was equal to 0.0639% of lactic acid. When examined at the second and fourth hour the amount of acid was unchanged; that is to say none of the cane sugar had yet been changed into lactic acid. By the eighth hour however the lactic acid had increased to 0.0702%, and at the twenty-fourth to 0.0711%. At the thirtieth hour the acidity equaled 0.0738% and at the seventy-second hour 0.1044%.

Invert Sugar.

This was neutral in reaction. The initial aciidity after adding the four milk was 0.0639% lactic acid. After being kept at 38° C. for two hours this had increased to
0.0654 per cent; after 4 hours 0.0670 per cent; at the sixth hour 0.0684 per cent; at the eighth hour 0.0729 per cent. After twenty-four hours 0.0774 per cent; at the thirtieth hour 0.0954 and at the seventy-second hour 0.1062 per cent respectively.

**Lactose.**

The initial acidity of the solution of this sugar was equal to 0.0639 per cent. After being two hours in the warm chamber, this had increased to 0.0648 per cent; at the fourth hour it was 0.0654 per cent and at the eighth it had only slightly increased to 0.0666 per cent. After twenty-four hours there was 0.0684 per cent of lactic acid; at the thirtieth 0.0756 and at the seventy-second 0.1242 per cent.

**Glucose.**

As in the preceding cases the initial acidity of the solution of this sugar was equal to 0.0639 per cent. After two hours the lactic acid had increased to 0.0654 per cent; after four hours to 0.0675 per cent; after eight 0.0684 per cent. At the twenty-fourth hour there was 0.0693 per cent; at the thirtieth 0.0765 per cent and at the seventy-second hour 0.1152 per cent.

**Maltose.**

The solution of this sugar had an initial acidity of
0.0684%. After being kept at 38° C. for two hours the lactic acid formed 0.0666%; at the fourth hour 0.0669%; at the eighth hour 0.0693%; at the twenty-fourth 0.0702%; at the thirtieth 0.0756% and at the seventy-second 0.0972%.

Levulose.

This sugar was itself acid in reaction and so the initial acidity of its solution was equal to 0.0684%. After two hours incubation this had increased to 0.0702%; after four hours 0.0711%; after eight hours 0.0738%; after twenty-four hours 0.0756%; at the thirty-seventh hour the lactic acid formed 0.0773%, while at the seventy-second hour it amounted to 0.3375%.

The following table exhibits the relation of these figures to one another:
Table showing the Lactic Acid fermentation of the various Sugars - % Lactic Acid

<table>
<thead>
<tr>
<th>Hour</th>
<th>Cane</th>
<th>Invert</th>
<th>Lactose</th>
<th>Glucose</th>
<th>Maltose</th>
<th>Lemulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0.0639</td>
<td>0.0639</td>
<td>0.0639</td>
<td>0.0639</td>
<td>0.0657</td>
<td>0.0684</td>
</tr>
<tr>
<td>2</td>
<td>0.0639</td>
<td>0.0657</td>
<td>0.0648</td>
<td>0.0657</td>
<td>0.0666</td>
<td>0.0702</td>
</tr>
<tr>
<td>4</td>
<td>0.0639</td>
<td>0.0670</td>
<td>0.0657</td>
<td>0.0675</td>
<td>0.0669</td>
<td>0.0711</td>
</tr>
<tr>
<td>8</td>
<td>0.0702</td>
<td>0.0729</td>
<td>0.0666</td>
<td>0.0684</td>
<td>0.0693</td>
<td>0.0738</td>
</tr>
<tr>
<td>24</td>
<td>0.0711</td>
<td>0.0774</td>
<td>0.0684</td>
<td>0.0693</td>
<td>0.0702</td>
<td>0.0756</td>
</tr>
<tr>
<td>30</td>
<td>0.0738</td>
<td>0.0954</td>
<td>0.0756</td>
<td>0.0765</td>
<td>0.0756</td>
<td>0.0873</td>
</tr>
<tr>
<td>72</td>
<td>0.1044</td>
<td>0.1062</td>
<td>0.1242</td>
<td>0.1152</td>
<td>0.0972</td>
<td>0.3375</td>
</tr>
</tbody>
</table>

amount of Lactic acid %
- for 2 hours: 0.0018, 0.0009, 0.0018, 0.0009, 0.0018
- for 8 hours: 0.0063, 0.0090, 0.0027, 0.0045, 0.0036, 0.0057
- for 24 hours: 0.0072, 0.0135, 0.0045, 0.0057, 0.0045, 0.0072
- for 72 hours: 0.0405, 0.0423, 0.0603, 0.0512, 0.0315, 0.2691
These experiments show that with Cane Sugar a considerable time elapses before the commencement of its change into lactic acid. During this time it is probably undergoing inversion. After it does begin to change however the fermentation is rapid and the amount of sugar converted into lactic acid is large.

Invert sugar is comparable to glucose in soon undergoing the lactic fermentation. Lactose and maltose also agree in soon becoming acted on by the bacterium lactis. Up to the twenty-fourth hour they seem to undergo a very equal fermentation. At the seventy-second hour however the lactose has undergone about twice the amount of change that the maltose has. Maltose is apparently less easily and less rapidly fermented than is glucose. Lactose very soon undergoes a marked conversion into lactic acid. Up to the twenty-fourth hour it is comparable in the amount of acid produced to Cane sugar.

In the alcoholic fermentation by yeast glucose ferments more easily and rapidly than levulose. The reverse however as we see takes place in the lactic fermentation where levulose ferments much more rapidly and to a much greater extent than glucose.

The fermentation of levulose by the lactic ferment is remarkable for the great amount of change which this sugar undergoes—about three times greater than any of the other sugars.

The order of the sugars in the amount of change which they have undergone by the lactic ferment at the 24th hour may be stated thus:

Digestion of Starch.

Firstly - What role does saliva play in the digestion of starch? In virtue of the ferment ptyalin which it contains the granules of starch is changed into dextrin, maltose and glucose, and through the continued action of the ptyalin, maltose is believed to be slowly split up into glucose. This amylolytic action of saliva is destroyed by high temperatures, as when it is boiled. 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; others again say that ptyalin acts in neutral as well as in slightly acid solutions. Ricketts even thinks that it acts best in a slightly acid medium, while Langley and Eves say that this is incorrect and that it acts to most advantage in a perfectly neutral medium. Strong acids or alkali however soon cause the action to cease.

This amylolytic action of ptyalin in acid solutions is of great importance as regards digestion in the stomach. Food received into the stomach causes a secretion of gastric juice. If hydrochloric acid is
secreted and poured out early in digestion it will soon neutralise the alkalinity of the saliva swallowed. It is of great importance to know if the saliva continues to act for any length of time in the stomach or whether the conversion action at once ceases and if fitness is killed by the acidity of the gastric juice. Have the free acids of the gastric secretion any effect on the diastatic action of saliva? If fitness only acts in alkaline or neutral solutions then its action 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 saliva is fully neutralised. Depré (1) and Riehet (157) maintain that saliva continues to act on starch in the stomach. Von helen (277) states that as long as the acidity of the gastric juice is not due to free hydrochloric acid (and which he says does not appear for some time 1–2 hours after the ingestion of food) conversion of starch by saliva goes on in the stomach. As soon as hydrochloric acid appears however conversion ceases. Consequently, there are two periods in digestion (1) when saliva still acts; (2) in which fitness only acts. Zakl (178) states that when peptones are present they combine with the acid and thus saliva continues to act in the stomach on starch. He adds that this happens only if the acid is
very weak however. Sir William Roberts (253) and Langley (212) also state that both the salivary and pancreatic ferments are destroyed by the acids of the gastric juice when in full digestion.

To investigate the effect of dilute acids on the conversion of starch, I performed the following experiments:

LVI. I placed equal volumes of saliva, 1 per cent starch solution and 0.2 per cent solution of hydrochloric acid in a flask and kept all at 38° C in a water bath. On testing the reaction of this mixture, I found it to be neutral, the alkalinity of the saliva being just neutral and the acidity of the hydrochloric acid. Within five minutes the starch was wholly converted and gave no reaction with iodine, but strongly reduced Fehling's Solution.

\[
\begin{align*}
10 \text{ c.c. saliva} & \quad \left\{ \begin{array}{c}
10 \text{ c.c. 1% starch solution} \\
10 \text{ c.c. 0.2% sol. of HCl}
\end{array} \right. \\
& \quad \text{At 38° C} \\
& \quad \text{Neutral} \\
& \quad \text{Starch completely converted in 5 minutes}
\end{align*}
\]

LVII. I next replaced in the following experiment the acid solution by normal human gastric secretion, obtained as I have already described. The acidity of this secretion was equal to 0.15% hydrochloric acid, and was due chiefly to
mineral acid. Even after the lapse of two hours there was no perceptible conversion of starch in this case.

\[
\begin{align*}
10 \text{ c.c. gastric fluid} & = 0.15\% \\
10 \text{ c.c. saliva} & \\
10 \text{ c.c. } 1\% \text{ starch solution}
\end{align*}
\]

at \(38^\circ\)C in 2 hours starch unchanged.

This shows that even with a jellie aciidity such as the above the conversion of starch has been hindered.

LVIII I then took equal volumes of the gastric fluid, starch solution and saliva and neutralised the mixture carefully with a solution of caustic potash, using very delicate test papers to show neutrality. On testing it ten minutes later, the whole of the starch was found to have been converted and gave no reaction with a solution of iodine. It powerfully reduced Feling's solution and showed the presence of 0.22\% of reducing substance (calculated as glucose).

\[
\begin{align*}
10 \text{ c.c. healthy gastric fluid} & \quad \text{at } 38^\circ\text{C} \\
10 \text{ c.c. } 1\% \text{ starch solution} & \quad \text{neutralised} \\
10 \text{ c.c. saliva}
\end{align*}
\]

in 10 minutes starch wholly converted.

This shows that it is the acidity of the mixture which prevents the conversion of starch, for when neutralised the action goes on quickly.
I performed exactly similar experiments with the gastric fluid from a case of Chronic Gastric Catarrh. The acidity of this was equal to 0.06% hydrochloric acid. Equal volumes of this, starch solution and saliva were mixed together and kept at 38° C. After the lapse of two hours the starch had undergone no change.

10 c.c. unhealthy Gastric Juice  
10 c.c. 1% starch solution  
10 c.c. saliva

In 2 hours

at 38°

no conversion.

LX

In the succeeding experiment the above mixture was carefully neutralised with the result that on testing it ten minutes later the whole of the starch was converted and the mixture showed 0.22% reducing substance.

10 c.c. unhealthy Gastric Secretion  
10 c.c. 1% starch solution  
10 c.c. saliva

In 10 minutes

at 38°C

neutralised

starch wholly converted.

Here again the acidity was clearly the restraining agent. Does the acid merely restrain or does it actually kill the ptyalin? By some, as by belffus, it is said merely to inhibit the conversion but that as the gastric contents become alkaline after passing into the small intestine the ptyalin again becomes active. Others again affirm that it is actually killed in the stomach.
To try which of these is the true explanation, I placed equal volumes of gastric fluid (acidity = 0.1% hydrochloric acid), starch solution and saliva in a vessel and kept it at 38°C for one hour. After the lapse of this period the starch had undergone no conversion.

I then neutralised the mixture carefully, and kept it at a temperature of 38°C for another half hour. When examined at the end of this period it was found to contain much erythroscarin, some starch and 0.19% of reducing substance.

<table>
<thead>
<tr>
<th>10 c.c. gastric fluid</th>
<th>at 38°C</th>
<th>Neutralised</th>
<th>Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 c.c. 1% starch sol.</td>
<td>1 hr.</td>
<td>30 min.</td>
<td>Soluble starch</td>
</tr>
<tr>
<td>10 c.c. saliva</td>
<td>= no change</td>
<td>at 38°C</td>
<td>Erythroscarin</td>
</tr>
</tbody>
</table>

I repeated this experiment, keeping the mixture at 38°C for one hour, but leaving it for twenty-four hours before neutralising it. Having neutralised the mixture I placed it in the water bath for 30 minutes. It then contained a good deal of starch, some erythroscarin and 0.09% of reducing substance. After being kept at 38°C for two hours it gave no reaction with iodine and contained 0.138% reducing substance.

<table>
<thead>
<tr>
<th>10 c.c. gastric fluid</th>
<th>at 38°C</th>
<th>Neutralised</th>
<th>24 hrs</th>
<th>Erythroscarin</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 c.c. starch solution</td>
<td>1 hr.</td>
<td>30 min.</td>
<td>at 38°C</td>
<td>2 hrs</td>
</tr>
<tr>
<td>10 c.c. saliva</td>
<td>= no change</td>
<td>Neutralised at 38°C</td>
<td>Geneze 0.09%</td>
<td>0.138%</td>
</tr>
</tbody>
</table>
These experiments show that with the above acidities ptyalin is not killed but its action is prevented. It is probably also much weakened, for in the second case where it was left in the acid fluid for twenty-four hours its diastatic action was feeble and very slow compared with the preceding experiment where it had only been in the acid medium for an hour.

Gastric Digestion of Starch.

If to a solution of starch we add a dilute acid 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? One could hardly a priori expect any conversion of starch to take place as the acidity is so feeble and the temperature so low comparatively.

Smith (270) however, from his experiments on Alexis St. Martin concluded that starchly food was digested in the stomach, independently of saliva, and Brown-Séquard (157) from his own experience comes to a similar conclusion. Munk (235) and Haycraft (196) have even
described a ferment which is sometimes formed in the gastric mucous membrane of the pig and which changes starch into sugar. Brüechle (30) says that soluble starch is formed in large amount in the stomach and is produced by the acidity and that erythrodextrin is formed from starch by the lactic acid fermentation. The saliva of the dog has only a very slight chelatetic action and yet when fed on starch, dextrose and sugar is found in its stomach along with free hydrochloric acid (172).

On the other hand, Dalton (141), Hübner (180), Melault and Schuff deny that starchy matters are digested in the stomach. Blanlot (140) declares that the gastric juice having other functions to perform has consequently no action on starch; besides this, he says, the acidity is too feeble, the temperature is not high enough, and the stay of food in the stomach is too brief. Foster (183) says that the gastric juice for all has no effect on starch whatsoever. Boucardat and Sandras (142) found that in the stomach of rodents starch was unaltered. It is only in the small intestine of these animals that dextrose and glycose are formed from starches and absorbed as such. They say that lactic acid is also formed from starch.
In birds starch is much more completely digested and therefore in the gizzard dextrin and glucose are found. Bouhier and Sandras think that in man cooked starch begins to be dissolved in the stomach. Laborde found that gastric juice had not the same power of converting starch as a solution of hydrochloric acid of the same acidity. He thinks that this is another proof that the acid of the gastric juice is lactic acid.

If the reaction of the gastric contents is neutral or alkaline, aehrodextrin may be formed through the continued action of the saliva. If acid however, erythrodextrin is alone formed. Grape sugar is not formed or is so to a very slight extent, from starch in the human stomach according to Ewald and Boas. These observers find that the maximum amount of reducing substance is reached in the first two minutes after the injection of starch, and that after this it decreases. They could never find lactic acid after starchy diet had been alone taken; but this acid could only arise from the fermentation of maltose got from the starch and the rapid secretion of hydrochloric acid would soon stop the conversion.

Zechsneider found that starch removed from the
stomach showed cryptodextrin, dehydrodextrin and reduced Schlings' solution.

von den Fellen (277) states that trypanin acts in the stomach only in presence of weak organic acids but not if free hydrochloric acid is present also. It has been found however that when starchy food is taken into the stomach the secretion of hydrochloric acid takes place very early and to a not inconsiderable amount and remains so till the food passes out of the stomach. (260)

**LXIV.** Was the gastric secretion free of any effect on starch?

To determine this I placed 30 c.c. of a 1% solution of starch in contact with 10 c.c. of healthy gastric secretion of acidity equal to 0.211 per cent. and placed all in the water bath at 38° C. On examining it two hours subsequently I found that no conversion of starch had occurred.

\[
\begin{align*}
30 \text{ c.c. 1}\% \text{ starch solution} & \quad \text{at 38° C} \quad \text{2 hours} \\
10 \text{ c.c. healthy gastric fluid} & \quad \text{absolutely no change}
\end{align*}
\]

**LXV.** I performed the same experiment with the gastric secretion from a case of chronic gastric catarrh. As before there was no change in the starch after being kept at 38° C. for two hours.

\[
\begin{align*}
30 \text{ c.c. 1}\% \text{ starch solution} & \quad \text{at 38° C} \quad \text{2 hours} \\
10 \text{ c.c. unhealthy gastric fluid of acidity = 0.32}\% & \quad \text{no change}
\end{align*}
\]
In a third experiment, I substituted the gastric secretion from a case of Pernicious Anaemia. The acidity of the secretion was in this case equal to 0.0164% hydrochloric acid.

The mixture was kept at 38°C. At the end of one hour there was 0.6% of reducing matter present and the remained the same in amount up to the end of the second hour. In this case, one notes that there is practically no acidity and that there has been a fair amount of conversion.

30 c.c. 1% starch sol. \[ \text{At 38°C} \]
10 c.c. unhealthy gastric fluid \[ \text{In 2 hours} \]
0.6% reducing matter

Having performed these experiments on starch digestion in the laboratory, I next carried out the following experiments in the living stomach.

**LXVII. Healthy digestion.** Having emptied out the stomach thoroughly in a man with normal digestion, I then introduced into his stomach through the elastic tube 250 c.c. of a 5% solution of boiled starch.

(a) After the lapse of one hour, ½ c.c. of a muddy fluid were drawn off. The acidity of this was equal to 0.22 per cent hydrochloric acid and was almost entirely due to inorganic acid.

There was plenty of unchanged starch, soluble starch, and
rythrodestrin present. There was a trace of reducing sugar present but too small in amount for quantitative estimation.

(b) After the lapse of two hours 35 c.c. of clear viscid fluid were drawn off. The acidity was equal to 0.17% and chiefly morganie in nature. There was no reducing sugar present; no rythrodestrin and very little starch.

At the end of the first hour we find rythrodestrin and sugar in the stomach, while they are absent at the end of the second hour. They have probably either been absorbed through the walls of the stomach or passed on through the pylorus.

Unhealthy Digestion - Chronic Gastric Catarrh.

LXXVIII. After washing out the patient's stomach 250 c.c. of the 5% starch mucilage solution were introduced into the stomach.

(a) After one hour 3c.c. elapsed 96 c.c. of whitish fluid were drawn off. The acidity was due chiefly to mineral acids and amounted to 0.12% per cent. There was a trace of reducing sugar present, a small amount of rythrodestrin and much starch.
(b) After the lapse of two hours 100 c.c. thick colostrum-yellow fluid drawn off. The acidity consisted of
organic and mineral acids in about equal amount and was equal to 0.225 %. No lactic acid present.
There was a trace of reducing sugar; a small amount of erythro-dextrin, and plenty of starch unchanged
and also in the soluble form.
The patient had felt very well indeed since the
injection of starch solution.

Pernicious Anaemia

LXIX. A similar experiment was performed on this patient.
After washing out his stomach 250 c.c. 5 % starch
solution were injected through the elastic tube
(a) One hour later 41 c.c. clear thin fluid drawn off.
The acidity of this was equal to 0.01 per cent.
There was a small amount of starch unchanged but
no erythro-dextrin. Reducing sugar amounted to
1 per cent.
(b) Two hours after injection 69 c.c. thin yellowish fluid
were drawn off. The acidity of this amounted
to 0.0036 per cent. There was a small amount
of starch but no erythro-dextrin or reducing
sugar. The patient had experienced no
discomfort.
### XVI  Gastric Digestion of Starch

<table>
<thead>
<tr>
<th>Series</th>
<th>Hour after</th>
<th>Number of c.c.</th>
<th>Nature of Fluid</th>
<th>Acidity per cent</th>
<th>Amylase</th>
<th>Reducing Sugar per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>1</td>
<td>2</td>
<td>acid</td>
<td>0.21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>72</td>
<td>acid</td>
<td>0.22</td>
<td>++</td>
<td>trace</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>56</td>
<td></td>
<td>0.17</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II.</td>
<td>Chronie</td>
<td>1</td>
<td>acid</td>
<td>0.32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Gastric</td>
<td>2</td>
<td></td>
<td>0.32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cataract</td>
<td>1</td>
<td>acid</td>
<td>0.11</td>
<td>+</td>
<td>trace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>0.21</td>
<td>+</td>
<td>trace</td>
</tr>
<tr>
<td>III.</td>
<td>Fibrinous</td>
<td>1</td>
<td>thin</td>
<td>0.16</td>
<td>0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>0.01</td>
<td>0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Anaemia</td>
<td>1</td>
<td>thin</td>
<td>0.1</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>0.0016</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

This table shows that with the acidity of the healthy stomach or in pathological conditions where the acidity is not diminished the conversion of starch is soon ended in the stomach; whereas in those conditions where the gastric juice has a feeble acidity conversion of starch is carried on to a great extent in the stomach.
as is shown 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 passed on.

In the cases related above the starch solution was introduced directly into the stomach by means of the stomach tube. In this way there was no admixture of saliva except what was swallowed afterwards and the table shows that in cases where the normal acidity was not lessened, this swallowed saliva had little effect on the starch.

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

In order to observe what changes occurred in starch solutions received into the stomach under such conditions, I performed the following experiments:

**Combined Effect of Salivary and Gastric Digestion on Starch.**

Having thoroughly washed out the stomach, I allowed the patients to eat slowly a fluid mucilage of boiled starch:
Healthy digestion.

LXX The patient slowly ate 250 c.c. boiled starch solution.

(a) Fifteen minutes later I drew off 40 c.c. The acidity was equal to 0.061 per cent hydrochloric acid. There was much erythroodextrin, soluble and unaltered starch. The reducing sugar amounted to 0.16 per cent.

I then carefully neutralised this fluid and placed it in the water bath at 38°C. to observe if any further conversion would occur or if the acid had killed the ptyalin. After the lapse of three quarters of an hour it was tested but no further conversion had taken place. The ptyalin must therefore in this case have been killed.

(b) One hour after the ingestion of the starch mucilage I drew off 45 c.c. The acidity of this was equal to 0.102 per cent. There was much unaltered starch, soluble starch, but only traces of erythroodextrin and reducing sugar present.

This also was neutralised and kept at 38°C for 45 minutes, but as before there was no further conversion.

This experiment shows that the acidity of the healthy gastric juice soon kills the ferment ptyalin.
LXXI. Having reached at this patient stomach, he was allowed to eat slowly 250 c.c. starch solution.

(a) Fifteen minutes later 45 c.c. were drawn off. The acidity here was equal to 0.138%. There was much erythro-decinin and starch present but only a faint trace of sugar.

This fluid was neutralised and kept at a temperature of 38° C for 45 minutes but no further change occurred in it.

(b) After the lapse of one hour since ingestion, 38 c.c. were drawn off. The acidity here amounted to 0.196 per cent. Starch occurred in very small amount and there was neither erythro-decinin nor sugar present.

It was also neutralised, but was unchanged after being kept at 38° C for three-quarters of an hour.

LXXII. I repeated these experiments on the same patient.

(a) After the lapse of ten minutes after setting the starch I drew off 80 c.c. thin white fluid. The acidity was equal to 0.102 per cent. There was much starch present, unchanged and in the soluble form; some erythro-decinin and reducing sugar to 0.4 per cent.
This was neutralised and kept at 38° C. for 45 minutes. At the end of this period the reducing sugar amounted to 0.63 per cent.

(b). One hour after he had eaten the starch 10 c.c. of turbid fluid were withdrawn from the stomach. The acidity was equal to 0.145. There was much starch present, some erythrodextrin and reducing sugar to 0.153 per cent.

This was neutralised and kept at 38° C. for 45 minutes; at the end of which time the amount of reducing sugar was exactly the same.

### XVI. Combined Effect of Saliva and Gastric Juice on Starch

<table>
<thead>
<tr>
<th>Series</th>
<th>Time in minutes</th>
<th>Number of c.c.</th>
<th>Acidity</th>
<th>Starch</th>
<th>Erythrodextrin</th>
<th>Sugar per c.c.</th>
<th>After neutralisation and heating at 38° C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy Digestion</td>
<td>15</td>
<td>40</td>
<td>0.061</td>
<td>+</td>
<td>++</td>
<td>0.16</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>45</td>
<td>0.102</td>
<td>+</td>
<td>+</td>
<td>Trace</td>
<td>Same</td>
</tr>
<tr>
<td>Chroic</td>
<td>15</td>
<td>40</td>
<td>0.138</td>
<td>+</td>
<td>++</td>
<td>Trace</td>
<td>Same</td>
</tr>
<tr>
<td>Gastric</td>
<td>60</td>
<td>38</td>
<td>0.196</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>Same</td>
</tr>
<tr>
<td>Catarrh</td>
<td>10</td>
<td>50</td>
<td>0.102</td>
<td>++</td>
<td>+</td>
<td>0.4</td>
<td>0.63% Sugar</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>100</td>
<td>0.175</td>
<td>++</td>
<td>+</td>
<td>0.153</td>
<td>0.153</td>
</tr>
</tbody>
</table>
This shows that it is the acidity of the gastric juice and the length of time during which it acts which kills the amylolytic ferment of the saliva. In the healthy condition a stay of fifteen minutes in the stomach has sufficed to kill the ptyalin, whereas in the catarhal condition after a stay of ten minutes in the stomach, it is quite active when we neutralise the acidity.

In almost all cases however ptyalin must be entirely destroyed before the contents of the stomach escape into the duodenum. It is only in those cases where the acid has been so sufficient that the conversion of starch has gone on uninterruptedly in the stomach that ptyalin escapes destruction (this happens in the case of pernicious anaemia for instance). Nor indeed is it necessary to be preserved, for soon after the contents of the stomach escape into the duodenum, the acidity is neutralised and then the pancreatic secretion is encountered and this is very much more powerful than saliva in its diastatic action on starch as it transforms it almost immediately into maltose and glucose. The diastatic action of the pancreatic secretion is due to the presence of the ferment amylopain, which can well act on raw starch at the temperature of the body. The products of the pancreatic digestion of starch are maltose, dextrins having a reducing power on alkaline solutions.
of coffee and glucose (237-8) as may be shown thus:

\[ 10\left(\frac{C_6 H_{12} O_6}{20} \right) + 8H_2O = 8\left(\frac{C_2 H_{22} O_{11}}{11} \right) + C_{24} H_{40} O_{20} \]

Soluble starch Maltose dextrin

The maltose and dextrins are however changed into dextrin under the influence of the pancreatic ferments (150); this hydration is however a slow process but is assisted by the succus entericus, as Luise presently point out. Bourquelot (1457) however denies that the pancreatic or any of the digestive juices have any effect on maltose, which he thinks is directly assimilable.

Besides the other ferments of the pancreas, Lépine (219) believes 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 — hence the attempt to cure diabetes mellitus by feeding the patients with pancreas or its extract. Lépine has shown that this ferment is normally present in blood and chyle (220).

The normal tissues can destroy much glucose in the circulating blood however and Magendie (52) long ago showed that blood serum has the power of converting starch into glucose and dextrin.
The success enteric has only a very slight action on starch (some even deny that it has any), and it takes many hours digestion with it even to produce a small amount of amylopectin and soluble starch. Brown and Skon (153) have found however that the small intestine has a powerful hydrolytic action on maltose, much more than on soluble starch, dextrans, or even on Cane Sugar. They believe that the molecule of maltose is too large and complex to be directly absorbed and therefore it becomes changed into the less complex form of glucose. This hydration and splitting up of maltose takes place very quickly under the influence of the success enteric which owes this property chiefly to the secretion from Pancreatic glands. The physiological actions of the pancreas and secretion of the small intestine are consequently mutually dependent: Starch under the pancreatic hydrolyses becomes changed for the most 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 whole of the starch is therefore at length changed into glucose.
Summarising, we have seen that Starch undergoes the following changes:

1. The Saliva during the time it acts, converts a good amount of starch into dextrin, maltose and a little glucose.

2. This action continues in the stomach for a varying time or till the acidity becomes sufficient in degree to kill the ptyalin.

3. On seeping from the stomach, the unchanged starch and dextrin are, under the influence of the amylase, converted into reducing dextrin and maltose with a little glucose.

4. Each molecule of maltose formed in this way from starch takes up a molecule of water under the influence of the ferment of the intestinal secretion and then splits up to form glucose.

Absorption of the products of Starch digestion

Owing to the action of the intestinal ferment, there are present in the stomach small quantities of sugar and dextrin formed from starch. These or some of these may be directly absorbed through the walls of the stomach owing to their high diffusibility. There is much unchanged starch however and this remains so
tilt the contents of the stomach pass into the intestine where under the influence of the amylase of the pancreas it becomes wholly changed into maltose and dextrose. The maltose is then changed into glucose by the ferment of the intestinal juice. It is in these forms, glucose and dextrose, that starch is ultimately absorbed. Indeed, Lehmann (216) has shown that glucose and a dextrose-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.
Having entered thus fully into the processes of digestion and absorption of saccharine and fataceous materials, we are now in a position to consider if such foods should be given to infants and invalids and if so, in what form they should be administered. As we have seen these food stuffs require a special and elaborate digestion to fit them for absorption.

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

Zweifel( ) and Korowin have gone carefully into this matter. They find that the salivary and pancreatic secretions of the young infant have only a slight diastatic action on starch, and indeed, it is said, that in newly-born children these secretions have no action on starch. For the first two months of the child's life the amount of saliva which is secreted is very small and we have all noticed how dry the mouth is in healthy infants. The parotid saliva however has a converting action on starch from the first day of the child's life but owing to the paucity of the secretion its diastatic power is very limited, and this may be the explanation of why some have thought that the saliva in new-born
children has no action on starch. At about the third
month of the child's life the saliva is found to have
a distinct diastatic action but the ptyalin does
not appear to any extent till the sixth month,
that is to say, when eruption of the teeth begins. At
this time also saliva is secreted in great abundance.
It is not however till nearly the end of the first
year that the salivary ferment has attained to its
full extent and power.

The gastric juice in adults, as my experiments show,
has little or no converting action on starch, and this is
true also for infants. (258)

Korwin found that during the first month of life
the pancreas possesses no diastatic ferment. This
power is however developed during the second and is
well marked at the third month. As with the salivary
glands, so in this case, the full development of the
diastatic action is not reached till the end of the
first year.

At an early period of life the number of glands in the
intestinal cause is relatively small. As the child grows older
so does the number of the glands increase in the alimentary
tract. The development of the glandular system advances
faster than while the lymph vascular system decreases in
importance. (127)
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 nurse is rarely to be found. What then is to be done? I have no intention of laying down rules for infant dietary, but only in so far as they have reference to the carbohydrate constituent of the food given to them.

Next to human milk, cow's milk is one of the best and most convenient substitutes. It however requires some preparation (as the following table shows) to make it resemble ordinary human milk. Thus, it requires dilution, as the casein is in much greater amount than in women's milk; but this dilution lessens the amount of fat and protein.

<table>
<thead>
<tr>
<th></th>
<th>Human</th>
<th>Cow's</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reaction</td>
<td>Slightly alkaline</td>
<td>Alkaline at first - Soon becomes acid</td>
</tr>
<tr>
<td>2. Spec. Gravity</td>
<td>1030-5</td>
<td>1029</td>
</tr>
<tr>
<td>3. Water</td>
<td>87-88</td>
<td>87.15</td>
</tr>
<tr>
<td>4. Total Solids</td>
<td>12-13</td>
<td>12.65</td>
</tr>
<tr>
<td>5. Fat</td>
<td>3-4</td>
<td>3.2</td>
</tr>
<tr>
<td>6. Albuminoids</td>
<td>1-2</td>
<td>4.16</td>
</tr>
<tr>
<td>7. Sugar</td>
<td>7</td>
<td>4.76</td>
</tr>
<tr>
<td>8. Ash</td>
<td>0.2</td>
<td>0.73</td>
</tr>
</tbody>
</table>
sugar to too great an extent. Ordinarily it is prepared by diluting it one half or one third of its volume with lime (to counteract the acidity) or ordinary water. Then cane or milk sugar is added till it has a sweet taste. In all cases a little cream ought to be added to make up for the fat lost by dilution. Now neither of these sugars which are commonly added are easily absorbed, even though the one is the natural sugar of milk. In fact they are both most difficult of assimilation and yet most prone to undergo fermentative changes and to give origin to either the lactic or butyric acid fermentation.

These fermentations are specially liable to occur as the vehicle, milk, in which they are given is so apt to decompose. If these sugars are given, the milk should always be sterilised and this is easily done, in order to lessen the chance of the milk becoming tainted.

Instead therefore of using bitter cane or milk sugar, both of which require special digestion, I would recommend the employment of one of the easily assimilable sugars, and especially of glucose or lactose or both as they are found in invert sugar. These sugars are readily for absorption and consequently will not remain for so long a time in the alimentary tract. Thus less opportunity is given for fermentations to arise in them.
Invert sugar is the first result of the digestion of cane sugar and would suit very well as an addition to milk, lactose being quite as easily assimilated as glucose and I have already described how easily invert sugar can be prepared from cane sugar.

Maltose would then be preferable to cane or milk sugar as an addition to milk, for, even if it did ferment, the lactic acid which is formed is less hurtful than acetic acid which arises from the fermentation of cane sugar. Maltose, however, still requires a certain amount of digestion and till it does not receive till it reaches the small intestine and there it undergoes hydration and is changed into glucose. It must therefore remain in the alimentary tract for a considerable time and during this interval there is a great risk of fermentation occurring in it.

The sugars which ought to be given to infants are those which are at once absorbed and not those which remain in the alimentary canal till they are digested. The sugars directly assimilable are, as I have so often said, either glucose or lactose, or the mixture of these which is obtained by inverting cane sugar is perhaps the best that we can employ in giving carbohydrate food to young infants.
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 and consequent convenience in carriage, the length of time which it keeps and the ease with which it can be made ready, its use is made general amongst many who could well nurse their own children but prefer not to do so.

It is certainly for many children a good substitute for the mother's own or even for fresh milk from the cow and especially so for children during the first month or two after birth with whom it nearly always seems to do well. But still this does not warrant us in recommending its general use, for some children cannot assimilate with impunity food which is most deleterious to infants generally.

This milk is prepared in two forms:—

1. Simply condensed and unsweetened;
2. Condensed and with Cane sugar added to preserve it.

The first simply consists of cow's milk evaporated to about a third or a quarter of its original volume and forms a thick syrupy pale yellow mixture. It merely requires the addition of water to restore it to
its original condition. This form is not so largely used as the second, for, in 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 longer than this or in warm weather when organic matters decompose rapidly there are all the risks of giving the infant a fluid 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 looseness of the milk in cream or to its abstraction before evaporation.

The sweetened variety of condensed milk is that which is so universally used as a food for infants. It is simple milk evaporated down with cane sugar added to an amount varying from 30 to 50%.

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 or 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 slow and unsatisfactory.

I have no doubt whatever that of the large number of sickly children found in all large towns, a very great proportion occur amongst those who have been brought up on artificial food such as condensed milk or infant 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. (335) The large amount of carbon given in such foods accounts for the rapid deposition of fat; but as muscle and bone form the strength-giving tissues we must give a food which contains the proportions of these 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 ingests a large amount of an article which it cannot easily digest and which is prone to ferment.

I therefore examined some ordinary condensed milks in order to see how much cane, invert or milk sugar was present in each:
(1) **Nestle's Swiss Milk.**

I found that it naturally contained 13.135 per cent of milk sugar. I then estimated the amount of cane sugar which this milk contained by the method described by Pavy. This consists in adding powdered citric acid in the proportion of 2 per cent 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 present we get the amount of cane sugar. I also acidified another quantity of the milk solution with metaphosphoric acid and heated it for two hours. The total amount of reducing sugar then present was estimated; subtracting from this the milk sugar normally present, the amount of cane sugar is easily found.

This sample of Nestle's milk was found to contain 41.6 per cent of cane sugar.

(2) **In another specimen of Condensed Milk (Viejo Soy Brand) — the reaction of which was acid — I found that it contained 11.7 per cent of lactose and by Pavy's method and by prolonged heating it showed the presence of 43 per cent of cane sugar.**

(3) **Leflunds Kindermilch.**

This milk is said to be partially peptonised, condensed,
and with dextrose and maltose added. It contains 12.63 per cent lactose and 33.54 per cent of reducing substances (probably maltose). It also contains dextrose and fat but no unchanged starch.

Most of these condensed milks therefore contain a very large amount, nearly one half of the total constituents, of a substance so difficult of absorption as Cane Sugar. This improper food is also increased in amount in the child's dietary as he grows older, for then the dilution of the milk is diminished. Thus the risks of this sugary food increase pari passu with the age of the infant.

In spite therefore of the general use of such sweetened 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 little resemblance to human milk. Simple condensed unsweetened milk is not in itself the condemned, though certainly far inferior to fresh cow's milk, for the relative proportions of the constituents of the milk remain pretty much as they were in the original milk when it is again diluted. The constant use of condensed milk sweetened with Cane Sugar is certainly however to be strongly deprecated.
It is a very common practice amongst the poor to add starchy materials as cornflour, arrowroot, pounded besan etc. to the milk which is given to the child. This is done with the idea of thickening the milk and making it more nutritious, it being a popular idea that cows' milk in itself is not a sufficient food. They forget meanwhile that if the child were fed from the breast they would add no other food.

The physiological processes in the infant show us that starchy matters must be very imperfectly digested in them owing to the extreme feebleness of the digestive ferments at an early period of life. All authorities agree in stating that farinaceous materials are quite unadapted and hurtful to the infant. The greater part of such food simply passes through the alimentary tract 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 undigestible be given to the infant. It is only at the sixth month that the digestive ferment of the saliva and pancreas is secreted to any 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 &c. The giving of we permit the use of starchy matters before this period then assuredly they must be predigested. By this I mean that unchanged starch must be rigidly excluded from the dietary or only given in a readily assimilable form as after partial or complete conversion into dextrines, maltose and glucose. I have already shown that glucose and perhaps some dextrines are directly absorbed, while maltose is not so but requires first to be changed into glucose. The starch should be wholly converted into glucose when added to milk for infants of five to six months. At an early age it is sometimes found to be necessary to add a carbohydrate to the dietary when the child is not thriving on milk alone or in some cases where the cow's milk curdles too firmly even though diluted. The firm curd is not well acted on by the gastric juice and is often rejected by vomiting or sets up diarrhoea. It is found however that when a farinaceous material is added however the density of the curd is lessened and so it is digested more rapidly.
conditions only the easily assimilated carbohydrates ought to be employed and of these I would recommend glucose and perhaps the higher dextrines. These are rapidly absorbed and thus afford small opportunity for fermentative changes to occur.

As the diastatic power of the salivary and pancreatic secretions increases so we ought gradually to lessen the degree of starch conversion so as to stimulate more the secretion of these ferments. After the age of six months we should only partially convert the starch and so give a mixture of dextrines, maltose and glucose. As the child grows older the degree of conversion ought to be gradually lessened, thus reducing the amount of glucose, while the amounts of dextrines and maltose is increased relatively; till, at the end of the first year, we may allow almost natural starchy foods to be given. Pfeiffer (301) has shown by analysis that as lactation proceeds the amount of albumen in human milk diminishes, while the carbohydrate increases in amount, the fat remaining the same in amount throughout.

This leads us therefore to a consideration of the so-called "Infant Foods." The food which is suitable for the young infant is, as I have tried to show, is
unsuitable for the same child at a later period and therefore in order to be able to direct the dietary of the infant we must know of what these infant foods are composed.

**Infants' Foods.**

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

These foods in themselves may be good enough but may be unsuited to the age or condition of the children to whom they are given. The infant may thrive on a certain food for a time but afterwards begins to fall off even though it 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 now form a sufficiently nourishing food for the same child when older.

Again, if we continue to give predigested food for too long a period, the secretions of the alimentary canal lose their digestive properties to a large extent through
disuse of the glands. Hues in changing the food, rapid
starvation follows because these secretory glands,
having been interfered, take some time to regain
their function.

It is therefore a question of the greatest importance
to know the composition of these infant's foods. The
constitution of some we know, but in many, the nature
of the ingredients is kept secret. A medicine anything
which savours of quackery is sacreheemed. Why should
it not be so also as regards the food 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) proteins,
(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
elementary principles and yet not an excess of each
individually. Too small or too great a relative amount
of any leads ultimately to ill health. When deficient
in amount some of the tissues are starved; while when
in excess, all cannot be absorbed and so intestinal
irritation and general ill-health result.

It is however to the carbohydrate constituents of these
foods that I wish now to devote attention, as this
forms by far their most important element and, as
I have pointed out, requires the greatest care in
administration.

Examination of Infants' Foods.

In preparing these for examination I followed the di-
cussions given with each food, only, instead of using
milk as the menstruum (which is often recommended)
I used ordinary water.

I generally made a 5 per cent solution of the food
but when this gave too thick a mucilage I reduced
it to 2 or even 1 per cent. Having allowed it to cool
I then tested the mixture for the presence of unaltered
or soluble starch, cryptodextrin or auto-dextrin. I
then filtered it and estimated the amount of reducing
matter which it contained by means of a standardised
solution of Fehling's fluid. For brevity, I have named
these substances "glucose" and have estimated them as
such, though they may consist of glucose, fructose,
maltose, lactose or reducing dextrins.

A definite amount of the solution was then heated on the
water bath for two hours at 140°F. five minutes of
dilute sulphuric acid (1:10) having previously been added.
This procedure removed any cane sugar which was
present in the food. Having again cooled the solution and
made up any loss from evaporation, the solution was filtered and the condition of the starch again examined and the amount of reducing matter estimated.

In those cases where malt or malt extract was supposed to be present and where high temperatures would have destroyed the diastase, I simply warmed the solution and having set it aside in a warm place, for half an hour, examined the starch in it and estimated the glucose.

1. Nestle's Milk Food (Lacteous Farina)

This food is in the form of a yellow powder, extremely difficult to mix with cold water and when mixed giving a muddy solution 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, then boiled for a few minutes with continuous stirring.

Having made a 2 per cent solution according to these directions of

(a) Boiled Nestle's Food, I found that it contained some unchanged starch, soluble starch, and erythrose-destein. Glucose formed 4.5 per cent.

(b) Having acidified and heated the solution for two hours it showed the presence of a large amount of erythrodein.
as well as much unchanged starch. The glucose now amounted to 38.5 per cent.

Let there have been malt or extract of malt in the food and which the boiling would have destroyed, I prepared a similar solution but did not heat it above 100°F.

(c). Solution only heated, not boiled. Unchanged starch was in large amount with a trace of amylopectin.

Glucose formed 6.65 per cent.

(d). This same solution kept at 40°F. for thirty minutes gave similar results.

(e). A cold extract of the food shows the presence of unchanged starch in large amount, traces of amylopectin and glucose 4.35 per cent.

This food clearly contains a large amount of Cane Sugar (3¾ per cent) which must, by the method of preparation be administered as such. The acidity was too feeble and the heat quite insufficient to have converted any of the starch (except perhaps into some of the lower dextrines), nor did there appear to be after boiling any dextrines present which might have been converted more readily. We must conclude therefore that this food contains cane sugar in large amount along with unchanged starch.
2. Garniere's Soluble Food for Infants.

This is in the form of a very fine light yellow powder, freely soluble in water and giving a neutral reaction. It is said that this food is partially pre-digested by pancreatin.

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

Having made a 2% solution as directed of the
(a) Boiled food, I found that it contained only unchanged starch. Glucose formed 20% of the food.
(b) After acidifying and heating this for two hours, it showed the presence of large amounts of erythrodextrin and also unchanged starch. The glucose had increased to 23 per cent.
(c) To try if the pancreasin ferment were active or if invertible sugar were present, I prepared a solution but did not boil it.

(c). Solution (2 per cent) made with hot water, not boiled and examined at once contained only unchanged starch; glucose is present to 18.5 per cent.

(d) When this latter solution was kept warm (100° F) for 30 minutes, it was found to contain also a small amount of erythrodextrin. The glucose had increased to 25.6 per cent.
(c). A closely retracted of the food shows that it contains starch, traces of cysteine and sugar.

This food therefore contains only a very small amount of invertible substance but the pancreatic ferment seems to be still active, though by following the printed directions the full advantage of this is not obtained. When merely heated for half an hour we get 25.6 per cent of glucose; but when boiled there is only 20 per cent. This food would therefore yield a more assimilable product if it were simply heated and not boiled.

The starch is either unchangeable or present as soluble starch by the usual method of preparation but when heated for long a large amount becomes denatured. Owing to the presence of the dried milk in the food however this cannot be done because then the pancreatic ferment would act for too long a time and would render the food bitter. Thus owing to the milk in this food we cannot get the full advantage of the amylase. Besides this the milk is predigested and this is unnecessary in a food for general use in infancy.

This food would be valuable however in some forms of acute disease.
3. Mellin's Food for Infants.

This is in the form of a yellow powder which has a sweet taste of malt. It dissolves in cold water and gives a muddy yellow solution having a neutral reaction. It is directed to be prepared by dissolving the food in cold water, then adding milk and water and heating gently.

(a). A 2 per cent solution made as directed in water only gives no colouration on adding a solution of iodine.

This shows that there is no unchanged starch present.

Glucose forms 29.8 per cent of the food.

(b). When acidified and heated for two hours, iodine solution gives no reaction; glucose forms 30.4 per cent.

This is almost exactly the same as before. There is therefore hardly any invertible substance present.

(c). When heated alone for half an hour, exactly similar results were obtained.

The amount of reducing substance is the same after simple solution as after heating with dilute acid. There is therefore no cane sugar or other easily invertible substance present in this food. The slight increase in the amount of glucose is probably due to conversion of some non-reducing substances into one capable of reducing copper from its solutions owing to the prolonged heating. If there were any starch originally it has all been changed into aehroopectin, maltose or glucose during
the manufacture of the food. This food therefore contains carbohydrates in their most easily assimilable condition.


This occurs in the form of a bronzed yellow powder having a sweet taste resembling malt. It partly dissolves in cold water, forming a turbid mixture and having an alkaline reaction. It is prepared by dissolving in warm water.

(a) A 2 per cent solution made with warm water showed with a solution of iodine a very faint reddish tint indicating the presence of a small amount of erythrodextrin. Glucose is present and forms 32.7 per cent.

(b) After being acidified and heated for two hours it gave no reaction with the iodine solution, and the glucose amounted to 33.6 per cent. This is almost exactly the same as before inversion, there is therefore only a trace of invertible substance present or rather and more probably convertible substance, for the erythrodextrins have become aehrodextrins and the latter in part have become reducing dextritones and so have increased the glucose nearly 1 per cent. This food closely resembles the last in its composition. The carbohydrates are all in a very easily assimilable con-
dation and no cane sugar is present.

5. *Benger's Food* (pancreatinized).

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

(a) Mixed with cold water it has a slightly alkaline reaction. With iodine solution it gives the starch reaction and shows a trace of amylopectin. It gives no reduction when boiled with Fehling's solution.

(b) A 2 per cent mixture made with hot water and examined at once shows abundance of starch and amylopectin in greater amount than when made with cold water alone. Glucose is also present to the extent of 1.8% of the food.

(c) When prepared according to the directions, kept warm for fifteen minutes and then boiled, we find that the starch reaction is not so marked, amylopectin is in much greater amount and glucose now amounts to 17.2% per cent.
(a). A solution heated for two hours after being acidified shows with a solution of iodine only a very slight starch reaction. There is much dextrose and glucose, however, and glucose amounts to 13.9 per cent.

After this prolonged heating the amount of reducing material has diminished. I do not know how to 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 seems to prove also that, as Lefine (21) has stated, there is a ferment in the pancreas which is destructive to grape sugar.

I repeated this and similar experiments several times but always obtained the same result.

This food therefore contains originally no substances which have a reducing action, that is to say, it has not been previously malted. During its preparation however the pancreatic ferment which it contains acts on the starch and in this way we have a large amount of dextrose and glucose formed, though even when prepared there is still a small amount of unchanged starch in the food. There is no cane sugar present, else we should have had an increase in the amount of reducing substance after the prolonged heating. This food seems to consist chiefly of flour mixed with the pancreatic ferment. When milk is used in preparing
this good it also, if necessity, will be digested by the ferment also.

6. Allen and Hanbbury’s Malted Infants’ Food.

This is a cream coloured powder having a sweet taste of flour and malt. It is prepared by adding boiling milk and water to the food which has previously been mixed to a paste with cold water and to which cane sugar has been added.

(a). Mixed with cold water it shows the presence of unchanged starch, but no soluble starch and it contains 10.85 per cent of glucose.

(b). Made according to the directions and examined at once, shows that unchanged starch and erythrodextrin are present and glucose amounts to 12.4%.

c. This same solution kept warm for half an hour shows a trace of unchanged starch, erythrodextrin in large amount, and glucose to 12.85 per cent.

(d). Acidified and heated for two hours in the water bath, shows that there is much soluble starch, and erythrodextrin present. Some unchanged starch is still present and glucose amounts to 14 per cent.
Malted and cooked upon Baron Liebig's principles.

This is a fine cream coloured 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.

(a) When mixed with cold water its reaction is faintly alkaline and shows simply unchanged starches and no sugar.

(b) A 2 per cent solution prepared according to the directions but with water only shows that starch is present in very small amount. There is much erythro-dextrin and glucose forms 9.25 per cent.

(c) Part of this solution kept at 100° F. for 30 minutes contains starch in very small amount, much erythro-dextrin and glucose 11.1 per cent.

(d) Part of the same solution (b) acidified and heated for 2 hours at 140° F. contains only a trace of unchanged starch or soluble starch; much erythro-dextrin and glucose amounts to 15.6 per cent.

(e) A solution prepared by adding it to tepid water
water and keeping it at 80° F. for half an hour.

It contained very little starch, much raffinosestarch and glucose to 5-3 per cent.

This is clearly one of the malt foods, and consists of flour and malt. Under the influence of heat and solution the malt acts on 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. If however the temperature be never raised high (as in 5) the dextrinase of the malt converts the starch merely into dextrines and but little reaches the condition of sugar. If kept for long even at this temperature however, all the starch becomes ultimately changed into maltose and glucose.

This food therefore consists of malt and flour with salts &c. but no added sugar.

8. Savory and Moore's Self-digesting Wholemeal Food.

This is a fine powder, yellowish in colour and with brownish particles in it. It has a strong taste of malt. It is prepared for use in exactly the same manner as the preceding food.

(a). Its reaction is faintly alkaline when mixed with cold water. It contains merely unchanged starch.
with neither the faintest trace nor no sugar present.

(c). A 2 % solution prepared as directed below the presence of much crythrodestrin, soluble starch and unaltered starch. Glucose amounts to 4.35 per cent.

(d). Part of this solution kept at 120° F. for half an hour shows that the crythrodestrin has increased in amount. Glucose now amounts to 8.3 per cent.

(d). When acidified and heated for two hours there is much soluble starch and crythrodestrin present and glucose forms 11 per cent.


This is a granular gritty powder, yellow in colour and having a sweet milky taste. It is prepared by simply dissolving in hot water and the amount to be used is regulated (as it is said) by the age and condition of the child.

(a). A 5 per cent mixture in warm water is alkaline in reaction; contains much albumen, though no precipitate is formed on adding acetic acid and glucose amounts to 23.15 per cent.

(b). Part of this solution kept at 100° F. for 30 minutes showed an increase in glucose to 25 per cent.

(c). Acidified and heated for two hours caused the glucose
to rise to 31.25 per cent.

This preparation is said to consist of deacelated cows' milk, malted flour and alkaline carbonates to neutralize the acidity of the milk.

It contains as we see no starch or early formed dextrines. It has been almost completely malted already. The length of time that it is heated by itself increases but little the amount of sugar. The increase in reducing matters by the prolonged heating, after acidification, is not likely due to added sugar but more probably to the more complete conversion of some of the higher dextrines (aerobic dextrins) into reducing dextrines and sugars. This preparation therefore contains dextrines, maltose, glucose, albuminous materials and mineral salts.


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.

(a) Prepared with cold water, it has a faint acidity and contains only unaltered starch and no sugar.
(b) Prepared according to the directions but not boiled, only kept at 120° F. for thirty minutes
(c) Prepared according to the directions and boiled, the mixture shows that starch alone is present. There is no sugar. Even when kept at a temperature of 120°F. for half an hour no further change occurs.

(d) Part of this mixture acidified and treated at 140°F. for two hours contains a large amount of maltodextrin along with much unchanged and double starch. Glucose amounts to 5.4 percent.

This food therefore apparently contains only flour and if prepared according to the printed directions we only get a paste containing no dextrines or sugar; at least the starch is only changed into the form of soluble starch. After acidification, prolonged heating however converts a good deal of the starch into dextrines and a small amount of sugar.

11. Neave's Farinaceous Food.

This occurs 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 thin paste; add boiling water and boil gently from five to seven minutes. Then add milk
and sugar and it is ready.
(a) When mixed with cold water it has a neutral reaction and contains unaltered starch and no sugar.
(b) A 2 per cent solution made as directed but not raised above a temperature of 140° F. and kept at this temperature for thirty minutes gives only the reaction for starch. Glucose amounts to 1.65%.
(c) Prepared exactly as the directions indicate, the mixture contains no sugar or dextrine but only unaltered starch.
(d) Part of this last mixture kept at 120° F. for thirty minutes contains a trace of glucose.
(e) This solution acidified and heated for two hours shows that there is hardly any unaltered starch, dextrin in large amount and glucose forms 6.58 per cent.
This food is very similar in composition to the last. When prepared in the usual way, the starch is almost unaltered. If heated for long however a large amount of conversion takes place.

12. Hardy Farinaeons Food for Infants
This is a fine powder closely resembling
ordinary flour. It is prepared by mixing it with a little cold water; boiling water is then added and it is boiled for eight minutes. Milk and sugar are added to make it agreeable. 

(a) Mixed with cold water it has a neutral reaction. It contains no sugar or dextrose but only unaltered starch.

(b) A solution made with warm water and kept at 140°F. for half an hour (but not boiled) shows that it contains a small amount of dextrose; much starch and glucose forms 2.24 per cent.

(c) Prepared according to the directions, no sugar or dextrose are present but starch alone.

(d) Boiled once then kept warm for thirty minutes, gives results similar to the preceding (c).

(e) Acidified and heated for two hours, the mixture contains very little unaltered starch, much erythro-shestin and glucose amounts to 6.25 per cent of the food.

This food is very similar to the preceding in its composition. If made according to the directions we get only a floury paste, but if heated for a lengthened period a large amount undergoes conversion, either wholly or in part.
Dr. Nicoll's Food of Health.

This is in the form of 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.

(a) Mixed with cold water it has a faintly acid reaction and contains only unaltered starch.

(b) A mixture made with hot water and kept at 120° F. for thirty minutes contains much starch, dextrin in small amount and glucose amounts to 5.2 per cent.

(c) Prepared according to the instructions it contains only unaltered starch, no sugar or dextrin.

(d) When part of this mixture (c) is kept warm for thirty minutes it contains a trace of sugar.

(e) Acidified and kept warm for two hours, the mixture then contains much unaltered starch, dextrin and glucose in small amount and glucose forms 2.32 per cent of the food.

It is evident from this that the boiling which the food is directed to have destroys any converting agent which the food seems to possess. When made simply with warm water and kept warm it develops 5.2
per cent of glucose, whereas if boiled there is none.

### Analysis of the Carbohydrate Constituents of Infants' Foods

<table>
<thead>
<tr>
<th></th>
<th>Starch</th>
<th>Dextrins</th>
<th>Glucose</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nestlé's Milk Food</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Made as directed</td>
<td>+</td>
<td>0</td>
<td>4.5%</td>
<td>contains much</td>
</tr>
<tr>
<td>(b) Converted</td>
<td>+</td>
<td>++</td>
<td>38.5%</td>
<td>invertible matter</td>
</tr>
<tr>
<td>(c) Cold extract</td>
<td>+</td>
<td>0.3</td>
<td>4.35%</td>
<td></td>
</tr>
<tr>
<td>(d) Simply heated</td>
<td>+</td>
<td>0.7</td>
<td>6.65%</td>
<td></td>
</tr>
</tbody>
</table>

|                  |        |          |         |                   |
| **Cambridge's Milk Food** |        |          |         |                   |
| (a) Made as directed | +      | 0        | 20.0%   |                   |
| (b) Converted     | +      | ++       | 23.1%   |                   |
| (c) Cold extract  | +      | +        | 25.6%   |                   |
| (d) Simply heated 30 min | +      | +         |         |                   |

|                  |        |          |         |                   |
| **Mellin's Food** |        |          |         |                   |
| (a) Made as directed | 0      | 0        | 29.8%   |                   |
| (b) Converted     | 0      | 0        | 30.4%   |                   |
| (c) Cold extract  | 0      | 0        | 30.4%   |                   |
| (d) Simply heated | 0      | 0        | 30.4%   |                   |

<p>| | | | | |
|                  |        |          |         |                   |
| <strong>Mellin's Last-Effort</strong> |        |          |         |                   |
| (a) Made as directed | 0      | +        | 32.7%   |                   |
| (b) Converted     | 0      | 0        | 33.6%   |                   |</p>
<table>
<thead>
<tr>
<th></th>
<th>Starch</th>
<th>Proteins</th>
<th>Lactose</th>
<th>Remarks</th>
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</thead>
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<tr>
<td><strong>Bengal's Food</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(a) as directed</td>
<td>+</td>
<td>++</td>
<td>17.2%</td>
<td>Permuted during cooking</td>
</tr>
<tr>
<td>(b) converted</td>
<td>+</td>
<td>++</td>
<td>13.9</td>
<td></td>
</tr>
<tr>
<td>(c) cold extract</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(d) heated</td>
<td>+</td>
<td>++</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td><strong>Savory &amp; More's Food</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) as directed</td>
<td>+</td>
<td>++</td>
<td>9.25</td>
<td></td>
</tr>
<tr>
<td>(b) converted</td>
<td>?</td>
<td>++</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>(c) cold extract</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(d) heated</td>
<td>?</td>
<td>++</td>
<td>5.3</td>
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</tr>
<tr>
<td><strong>Forlack's Malted Milk</strong></td>
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<td></td>
</tr>
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<td>23.25</td>
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</tr>
<tr>
<td>(b) converted</td>
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<td>31.25</td>
<td></td>
</tr>
<tr>
<td>(c) cold extract</td>
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<td>0</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>(d) heated</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td><strong>Ridge's Food</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) as directed</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(b) converted</td>
<td>+</td>
<td>++</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>(c) cold extract</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(d) heated</td>
<td>0</td>
<td>0</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Starch</td>
<td>Proteins</td>
<td>Glucose</td>
<td>Remarks</td>
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<td>------------------</td>
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<tr>
<td>Alien &amp; Dabury's Food</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) as directed</td>
<td>++</td>
<td>+</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>(b) converted</td>
<td>++</td>
<td>++</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>(c) cold extract</td>
<td>+</td>
<td>0</td>
<td>10.85</td>
<td></td>
</tr>
<tr>
<td>(d) heated</td>
<td>?</td>
<td>++</td>
<td>12.85</td>
<td></td>
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<td>(d) heated</td>
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<td>Dr. Nicoll's Food</td>
<td>Starch</td>
<td>Fructose</td>
<td>Glucose</td>
<td>Remarks</td>
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We gather from this analysis of the chief varieties of food for infants the following facts:

(1) Most of these consist of white flour mixed with malt or extract of malt. The latter is supposed to act on the starch of the flour during the process of cooking the food and by the diastase which it contains, it converts the starch into maltose and glucose.

I have shown however that in several of these varieties, if prepared according to the printed directions accompanying them, only a very small conversion of starch occurs. A temperature of 140-150°F. is most suitable for the action of diastase; but if it be raised to 212°F. the ferment is killed or its action arrested. Now, several of these foods are prepared by adding boiling milk or water to the food and then perhaps boiling for from five to ten minutes. Such treatment effectively prevents any conversion from occurring or soon stops any that
is already going on. We have seen, however, that some of these foods when prepared with warm fluids only and kept for from half an hour to two hours at a warm temperature, not above 150° F., undergo a partial conversion of the starch and so are found containing maltose and glucose with or without unchanged starch depending on the length of time and the strength of the converting agent.

Some of the foods composed of flour and malt are described to be thus prepared. With these no fault can be found. Those, however, which are directed to be boiled, I have no hesitation in saying, are quite unsuitable as food for young infants or for adults in whom starch is with difficulty digested. Not that the food is in itself bad, but owing to the mode of preparation which makes it so. If properly cooked some of these would make fairly good foods. Those which contain ground malt should always be used in preference to those which contain the extract as the former is much more active in its converting power. It a few cane sugar is also added and this is an addition to infants' or invalid's food which I have already sufficiently condemned.

It is to the mixtures of malt and flour that I look to for the greatest improvement in the feeding of
infants and invalids in the future. By varying the length of time during which such mixtures are heated we may convert the starch to any degree we wish and so make it suitable for the child at different ages or according to its condition. Or may either wholly convert the starch by prolonged heating and so make it a suitable food in addition to milk for young infants or the conversion may be only partial leaving still soluble starch, dextrine and maltose. We may lessen to any degree the amount of conversion as the child grows older or increases in strength.

(2) Instead of malt, some contain the pancreatic ferments which act both on the starch and in the milk with which the foods are mixed, as predigesting both. Such foods must be most valuable in cases of great debility, inanition or relaxation either in infants or adults; but in an ordinary food for children we do not wish to digest the milk which is the natural food of the child and which he can usually digest well enough. Proteids are generally well-digested by infants and we take advantage of this to feed them on meat infusions when there is great debility. We do not therefore desire as a general rule
to predigest the proteins in milk but only the carbohydrates which the infant himself cannot properly digest or only partially. Sir William Roberts has shown (258) that kittens fed on fully predigested milk did not grow as well when this was replaced by only partially predigested milk as their brothers and sisters who were fed on ordinary milk. The use of predigested foods lessens the activity of the glands which ought to secrete this digestive fluid, consequently we ought not to give artificially digested food for a longer time than is absolutely necessary.

(3) In some of the foods the starch has been previously converted through the action of the diastase of malt. In these we find none or the merest traces of unchanged starch; amylopectins and amylodextrins are found in varying amounts and maltose and glucose are usually present in large amount. Nearly all of these are made from flour and they thus contain also the vegetable albumens and mineral matters. In a few such foods these mineral matters include an alkaline carbonate to neutralize the acidity of ordinary cows milk to which they are intended to be added. Such foods as these are very
Easily absorbed. The starch is almost wholly changed into easily absorbable dextrines and glucose, thus requiring little or no digestion. This is of the greatest importance in the child's nutrition, as we have seen, the power of digesting carbohydrates is at the minimum.

(4) Combinations of dextrine and starch are often met with and are highly vaunted as valuable food for infants. Such foods simply consist of flour which has been subjected to a high temperature and has thus been baked. The starch in part becomes changed into soluble dextrines under the influence of the heat. If the flour be carefully heated and for a sufficiently long time the starch becomes wholly dextrinised. In these foods 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 into easily formed or low dextrines. They contain usually much unchanged starch along with the albuminous constituents and salts of the grain. Domestically such a preparation of flour is known as the "flour-ball" and is prepared by boiling flour in a cloth for about twenty-four hours. It then forms a hard ball which, after the translucent outside skin has been
feebled off, consists of a dense white substance, made up chiefly of deoxygenised starch. This is then ground down and mixed with milk for the infant to use. Used in this manner when the child is of a suitable age it forms an easily assimilated carbohydrate, and acting as a mechanical diluent helps to prevent the milk from coagulating in large firm clots in the stomach. If these deoxygenised foods are thoroughly prepared they form valuable additions to the diet of infants and invalids, but if imperfectly deoxygenised the large amount of unaltered starch which is given along with them forms a great drawback to their use as safe articles of diet.

(5.) Many of these preparations used as food for infants consist simply of flour or unaltered starchy matters. Such foods ought never to be given as only a small part can be digested by the infant.

The fact besides that many of these are very coarsely prepared and show when examined by the microscope the presence of lumps, spherical or which must act as irritants to the delicate intestinal mucous membrane and which forms no doubt a sufficient cause in many cases for the diarrhoea which indeed after such food is administered. It is owing to the relatively small number
of glands in the intestinal canal and to their immaturity that 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 his life it is culpable ignorance to tamper with his delicate digestion by giving any of the first foods which may present itself to the parents or to the seller.

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 would first inquire as to the age and condition of the child and who would thereby know whether the food were suitable or not. A still better plan however would be that none of these foods should be supplied unless the purchaser at the same time presented a note from a medical practitioner stating that such food would be suitable for the child and indicating the special variety. In fact they should be dispensed in the usual manner as drugs are sold. It is the wholesale sending, not the intrusion of such food on the public that makes their use so general. It is a fact that as soon as a broth is advertised in the newspapers many of the manu-
facturers of these goods send samples of their preparations to the parents and of course each is accompanied by its own laudatory literature. The parents knowing little, it may be, regarding the proper feeding of their child select the one which they think is best and so unguided by experience and ignorant of physiological processes they usually make choice of the one which is most highly praised or is accompanied by portraits of the fattest babies reared on such food.

It is on account of the incalculable harm that is thus done, unwittingly in many cases, to the infantile population that I urged that the sale of such foods under a restriction and for that 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 forms of infants' foods are directed to be made with milk or with 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 during the preparation of the food. 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 heated with malt no coagulation takes place. This must be of great importance as regards the digestion of milk, for the one great cause of its difficulty in its digestion is the form curd which it forms in the stomach. If foods containing malt the milk is also acted on during the process of cooking and is rendered uncoagulable by the acid of the stomach. It seems to me that this property of malt might prove most serviceable in the treatment of those forms of indigestion which follow the use of cow's milk as an article of diet. Instead of mixing the milk with any starchy matter would it not be preferable to keep it in contact with malt for some time so as to prevent the formation of coagula in the stomach?

Such foods containing malt in which the process of cooking causes an almost complete conversion of the starch or those foods in which the starch is already entirely converted make, in my opinion, when added to diluted cow's milk to which a little cream has been added (for nearly all these foods are poor in fat and the dilution of the milk reduces the cream in it to too low a per centage) the most suitable artificial food for children with whom ordinary cow's milk does not.
agree or who are not thriving on it.

Nor are these foods good alone 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 and have given rise to vomiting and diarrhea, the bacteria which have caused these remain and cause milk to become acid as soon almost as it is taken. Under these circumstances it must be stopped and we have then recourse to such foods as the alone along with infusions of meat, or beef or chicken broth.

At a later date also they are of great value when we are beginning to add other food materials to the milk. What better can we begin with than some of the most easily digested carbohydrates?

It would be improper in one to specify by name the particular foods which I would recommend and which I myself employ in the feeding of infants of various ages. After what I have stated however there can be no difficulty in choosing the particular food for the particular age and condition of the child. I have shown what I consider to be the most easily assimilable forms of the carbohydrate group and from the analysis I have made of the carbohydrate constituents
of the most widely-known foods for infants now on the market, it will be easy to select those which form desirable additions to or substitutes for a purely milk diet.

All that I have stated with regard to starchy food for infants applies with equal force to their use in the dieting of invalids. In many febrile conditions where the secretory functions are greatly impaired or depressed by the administration of ordinary starchy foods as the amylolytic action of the saliva and pancreas must be correspondingly diminished. If pre-digested however they act as valuable and easily assimilated foods. Again, in those cases where there is great or complete deficiency of the hydrochloric acid in the gastric juice, as in simple anaemia, pernicious anaemia, cancer of the stomach &c. proteid matters are badly digested; starchy foods however ought to mix very largely in the diet of such cases as the amylolytic action of the saliva continues for a lengthened period in the stomach only to the fable degree of acidity.

During convalescence or in the resuscitation state ordinary starchy foods cannot be given with safety. Such patients have to be treated like infants as regards
their diet, consequently easily assimilated carbohydrates along with readily digested proteins are what are required.

In the gouty condition due to excess of uric acid, cane sugar must always be avoided. In might However in such cases allow with safety the use of inverted sugar or converted starch for these are absorbed so rapidly that acid fermentations have not time to take place.

In such diseases as Chronic Gastric Catarrh, dilatation of the stomach with concomitant atrophy of the gastric glands, Acid Dyspepsia, Congestions of the gastric and intestinal mucous membrane from heart or lung disease even with edema or ascites, I would forbid the use of Cane Sugar and ordinary farinaceous foods unless in small amount. On the other hand I would advocate the use of inverted sugar and converted starch in ascites or dropsy such Food would act most beneficially and even therapeutically, for it has been shown that glucose and even dextrose form powerful diuretics and act without raising the blood pressure.

Such easily assimilated carbohydrates used as articles of diet give rise to no inconvenience unless, like any other food, when taken in excess; but are quickly absorbed and thus form a most valuable addition to our fat-producing and energy-saving foods.
Saccharine Foods.

To make this inquiry more complete I will now to
direct attention to the nature of the sugars in some of our
commonly employed food materials. The condition of
the saccharine elements of the food is, apart from the so-
called infants' foods, 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, flatul-
tune, headache, nausea, acidity etc. Try our experiments
on dyspeptic patients show this; when cane sugar was
given to them in large amount in nearly every case
some of these symptoms were complained of.

Sugar forms however such a large and important
part in diets, so that the dyspeptic finds he can
hardly avoid consuming some; besides this, sugar is
almost a necessity in order to render other articles of
food pleasant.

Some sugary foods are 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
digestibility of certain sugary foods depend upon the
nature of the sugars which they contain?

In order to answer this we require to investigate the nature of the sugars in some of the commoner articles of diet.

Nature of Sugars in Saccharine Foods.


Jams. 2 per cent solutions of these were made and the sugar estimated by the saccharimeter and also by Fehlings solution. They were then heated for two hours at 180° F. after being acidified in order to invert any cane sugar which they contained.

(1) Strawberry Jam. The acidity of this was equal to 0.05% saturated as hydrochloric acid. The invert sugar occurring naturally in the jam amounted to 18 per cent.; while after inversion it had increased to 41.6 per cent. The cane sugar existing in the jam was therefore 23.6 per cent. This shows that almost three-fourths of the sugar has undergone inversion during the manufacture of this jam.

(2) Marmalade.

This sample had an acidity equal to 0.042 per cent hydrochloric acid. The invert sugar naturally present
in the jam amounted to 51 per cent; while after inversion it increased to 61 per cent. In this jam therefore almost all (five-sixths) of the cane sugar added to the fruit has been inverted during its preservation.

(3) Bramble Jam.
Here the acidity was equal to 0.056 per cent acid. The natural invert sugar formed 47.6 per cent; and after inversion 57.6 per cent. As in the preceding case the greater part of the cane sugar has been inverted during the preparation of the jam.

(4) Raspberry Jam.
The acidity was equal to 0.05 per cent. The natural invert sugar amounted to 26.12 per cent, while after heating for two hours it amounted to 42.68 per cent.

(5) Plum Jam.
The acidity in this case was equal to 0.12 per cent. The invert sugar existing in the jam was 50 per cent, which increased to 58 per cent after heating for two hours.

These results may be tabulated thus:
In these different jams the acidity is distinct and the degree of inversion of Cane Sugar is somewhat proportional to the acidity,—the greater the acidity, the greater the inversion.

Jams are considered to be very wholesome and form a very pleasant manner in which to take a large amount of concentrated carbohydrate food along with the valuable organic acids which the fruit contains. Marmalade is a very common addition to the 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 preserves along with their bread and who suffer no discomfort from doing so.
Crystallised Fruit (Fruits Grèèes)

The average acidity of these fruits amounts to 0.053 per cent reckoned as hydrochloric acid. Invert sugar, naturally occurring in them, amounts to 29.5 per cent; while after two hours heating it has increased to 50%. Cane sugar exists in them therefore to 20.5 per cent. During their preparation there is therefore about three-fifths of the Cane Sugar inverted. Such fruits however are hard and dense and difficult of disintegration and are well known to be very indigestible.

Honey.

Before the sugar cane began to be so largely cultivated as it now is, honey was employed as the sweetening agent generally in this and other countries up till a comparatively recent period. Since the great fall in the price of sugar this industry of bee-keeping has however largely fallen into desuetude.

The chief constituents of raw honey are dextrose and levulose with certain amounts of less well-known sugars (said by some to be Cane Sugar) as mannite &c., along with organic acids of which formic is the chief. The reducing sugars amount on an average
to 67.85 per cent (\*) and consist of 37.58 per cent of dextrose and 36.22 per cent of levulose in some samples.

**Treacle - Golden Syrup.**

This is the refuse got in sugar refining. It consists of uncrystallisable Cane Sugar and invert sugar in nearly equal amounts. There is also about one-fifth of water present. Either treacle or golden syrup forms a common addition to the diet of the poorer classes.

**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 in dietetics. The sugar occurs chiefly in the uncrystallisable form (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 disguise this. It is however better to neutralise the acidity by adding an alkali than to sweeten it by means of Cane Sugar. When cane sugar is added to acid fruits much of it undergoes inversion during the process of cooking and so 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 the fact that she had added much sugar previously. The fact that steamed fruits form a valuable addition to our food stuffs.

Confections.

Very many sweetmeats consist of finely ground Cane sugar made into a paste with gum, albumen or gelatine with a flavouring agent added. This paste is either rolled out and made into lozenges or coloured and made into many different shapes. These are then dried in a warm room but at no time are such sweets subjected to heat.

The various lozenges, icing for cakes, the many forms of French creams consist almost entirely of 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." Most of these are made by adding a little water to a quantity of sugar and heating till dissolved. A quantity of cream of tartar, acetic acid or vinegar is added during the process of boiling and the candy is boiled till it is "high," that is till a quantity of it when

* Immeatelli "The Royal Confectioner - A Practical Treatise" London 1887.
dropped on a cool surface becomes brittle. The addition of the acid and the prolonged boiling is simply to prevent the sugar from crystallising again on cooling. In this way a tolerably large amount of the cane sugar undergoes inversion. When insufficiently inverted the whole mass crystallises as it cools and the sweet is spoiled.

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 owing to the large amount of invert sugar which they contain and which I have shown is readily assimilated?

To determine in what proportions cane and invert sugar existed in different sweets, I examined the following:

**French Crème Sweets**

I made a 2 per cent solution of these and then determined both by the polariscope and by Felding's solution the amount of invert sugar which they naturally contained. I then took 50 c.c. of this solution, added to it five drops of dilute sulphuric acid and heated
on the water bath at 150° F. for two hours so as to invert the cane sugar which they contained. Examining these crèmes, I found that invert sugar existed naturally in them to the extent of 0.7 per cent. After inversion it had increased to 4.9 per cent. There was therefore in these sweets 41.3 per cent of cane sugar—that is to say that they consist almost entirely of cane sugar.

Chocolate.

I found that ordinary chocolate contains no invert sugar. Cane sugar is the only sugar and is present to 4.5 per cent or nearly one-half of the chocolate, cocoa forming the larger part of the preparation.

Chocolate is considered to be a very wholesome confection and naturally so, for even though all the sugar is present as cane sugar, it barely forms half the sweet. The cocoa itself is very nourishing as it contains a large amount of fat and albuminous matter along with its active principle, theobromine. One would not expect to find invert sugar present in chocolate as cane sugar is merely ground in with the warm cocoa paste which is then turned into moulds.

Chocolate Crème.

This confection contained, according to my analysis,
8.6 per cent of invert sugar. After inversion this had increased to 62.5 per cent, showing that Cane sugar forms 55.9 per cent of the sweet.

The invert sugar which naturally occurs in this sweet is confined to the white ermine, for, when isolated from the surrounding chocolate it gives the same per centage of reducing sugar, viz. 8.6 per cent.; whereas the chocolate has no invert sugar in it.

Acid Drops.

These contain acid equal in amount to 0.1 per cent of hydrochloric acid. The invert sugar naturally present formed 27.5 per cent; after inversion it formed 83 per cent. There is therefore 55.5 per cent of Cane sugar in these sweets. Now we might have expected to have found a greater amount of invert sugar present, especially as the acidity is relatively high. This is explained however by their method of manufacture. The candy from which they are made is prepared in the same way as for all cleared boiled sweets, that is to say, acetic acid or acid tartrate of potash is added and it is boiled till “candy high.” All these sweets are prepared at first in exactly the same manner, it is only the after treatment which differs and which gives rise to the varieties of clear
sweets. In this case, after having been boiled "high," the candy is forced on to a slab and when it is sufficient by cool a quantity, definite in amount of the acid tartrate of potash is kneaded in so as to give the desired acidity. It is owing to this added acid salt that the acidity is high.

Everton Toffy.

The acidity of this was equal to 0.007 per cent. It contains naturally 27.7 per cent of invert sugar, after mersion this had increased to 62.5 per cent. Cane sugar forms therefore 34.8 per cent of the toffy.

Invert sugar is present to almost the same amount as in the last case, though here the acidity is feebler. The candy for this sweet is however prepared in exactly the same manner and it is boiled for a long period. Besides the invert and cane sugar it contains also much fat, which is due to butter which is added as the candy is removed from the fire.

Curiously enough this sweet is well known to be very wholesome and are often sees it given to delicate children who are forbidden to eat other sweets. Dr. Melner Pottergill has been recommended it instead of cod liver oil for strumous children and says
that he has saved many children from death by its use (20). This high recommendation is no doubt based on the fact that it contains a large amount of fat which is eagerly taken in this form by delicate children who would not take fat in its natural condition or even as butter. But may not this be greatly helped by the large amount of easily assimilated carbohydrate which it contains in the form of invert sugar? That this is so I leave myself no doubt. This confection is valuable therefore as containing a large amount of easily digested carbohydrates and hydrocarbons in a pleasant form.

**Extract of Malt Lozenges.**

The acidity here was equal to 0.18 per cent. Reducing sugar naturally present, estimated as glucose, amounted to 14.7 per cent. After inversion this has increased to 85 per cent. This extract resembles all lozenges in containing a large amount of unchanged Cane Sugar.

**Clear transparent ‘boilings.’**

The natural invert sugar formed 13.8 per cent; after inversion it formed 85 per cent, showing that there is naturally in this sweet 71.2 per cent of Cane Sugar.
My task is now ended. I have endeavored to show the unsuitability of Cane sugar as an article of diet in cases of weak digestion and in diseased conditions of the gastro-intestinal mucous membrane or as an addition to the diet of infants. This led me on to speak of farinaceous foods and the absorption of the products of the digestion of carbohydrates. I have shown that both physiologically and clinically unchanged Cane sugar and natural starch are quite unassimilable. Before either of these can be absorbed they require to undergo a special and complicated process of digestion. This they cannot receive in the alimentary tract of the infant, for as yet it is not fully developed and therefore cannot digest amylaceous food nor can such food be prepared for assimilation in many cases of acute illness, convalescence, chronic gastro-intestinal disorders or in old age. If however these food stuffs be changed into less complex combinations then their absorption is rendered much more easy and they may then form valuable additions to invalid and infant dietary. Thus, as Cane sugar lingers in the stomach for a much longer period than invert sugar and is always badly borne in digestive
cases, it appears to me to be a point of very considerable practical importance that invert sugar should be given instead of Cane sugar for it is easily prepared and is always easily borne.

It is by improvements such as I have indicated in the dietary of invalids and infants that we may in the future with confidence expect an decrease in the number of cases of disordered digestion and a diminished rate of infant mortality.
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