Thesis on Sugar in the Animal Economy,
by
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On Sugar in the Animal Economy

It has been made out by the labours of modern chemists that the various proximate principles existing in living organisms, and differing widely from one another, are, probably, all of them, susceptible of various modifications which are absolutely necessary for the right performance of the processes in which they take a part. Albumen, for instance, is not precisely the same substance when it is found in the egg of the fowl as when found in the chyle of the Carnivorous Animal; and in both of these conditions it differs much from the albumen obtained from blood-serum or from flesh. Gelatine is also well known to be of different composition when procured from the blood, and when obtained from the substance of muscle. So in the
case of sugar, it is known to exist in a variety of forms, each of which, though presenting features common to all, has properties peculiar to itself, and differs from the other forms in the facility with which it undergoes decomposition.

It may then be well before entering into the subject of sugar as found in the economy to state what varieties of the saccharine substance are met with there, and to point out the leading characteristics of each.

The sugar that was first recognized as an animal product, viz., that of diabetic urine, is grape sugar or glucose. It is identical with that kind of sugar found in the juice of many plants, as also with the sugar of honey. This grape sugar may be artificially obtained from starch, cane sugar, wood-fibre, sugar of milk, &c., when boiled with dilute acids; or it may be prepared from starch simply by the action of infusion of malt or some other ferment. Its composition is \( C_{12}H_{14}O_{14} \). When got from starch, this material, which is \( C_{12}H_{22}O_{11} \), must take up four equivalents of water. And the other substances mentioned as yielding grape sugar must also when being transformed take up water, the composition of cane sugar being \( C_{12}H_{22}O_{11} \),
Gregory's Handbook of Organic Chemistry p. 437-441
that of sugar of milk \( C_{12} H_{12} O_{12} \), and that of woody fibre \( C_{12} H_{8} O_{8} \). Grape sugar differs from cane sugar in showing the prismatic range with polarized light, when the plane of polarization is turned from right to left, cane sugar doing this when the turning is made from left to right. Strong sulphuric acid does not char grape sugar as it does cane sugar; but moderately diluted alkalies change grape sugar into a brown matter, while they do not decompose cane sugar, but form crystallizable salts with it.

From the fact that cane sugar, before it ferments and gives off Carbonsic acid and alcohol, passes into grape sugar, it would appear that this latter substance is a less stable one than the former.

All the three kinds of sugar above mentioned, cane sugar, glucose, and sugar of milk, when in solution and acted on by a proper ferment at a temperature between 75° and 90° F., undergo what is called the lactic fermentation, and are changed into lactic acid, \( C_{12} H_{12} O_{12} \) or \( 2 C_6 H_5 O_5 + 2 H_2 O \). Whether in this catalysis the cane sugar and lactose pass into lactic acid directly, or only by first becoming grape sugar I am not aware that any one has determined, but I should think it most probable that they first
It would seem that the sugar formed at the liver does not strictly belong to either of these three varieties. Chevreul, endeavoured to show that hepatic sugar was identical with glucose of the ordinary kind, and to his opinion most physiologists seem to have agreed. But it has been shown by Lehmann that the hepatic variety is much more easily decomposed in the animal body than the ordinary grape sugar. And Dr. Powy & Owen Ree maintain that this "animal sugar," as they term it, which is secreted by the liver, and which is met with in glucosurae brought on by irritating the floor of the fourth ventricle of the brain, is different from grape sugar and the sugar of ordinary diabetes. They assert, as Lehmann does, that it is more easily decomposed than vegetable glucose, being destroyed by contact with blood and other animal matters with much greater readiness than the true grape sugar.

Dr. Ree writes: "There is little doubt that the sugar of diabetes is a higher quality of the saccharine principle, and that it can preserve its atomic arrangement with greater force than the hepatic variety. Is it not likely that the animal glucose may contain
(1) Medical Observations and Inquiries.

(2) Journal de Chimie Medicale 1836 II 130

(3) London Medical Gazette 1837
a greater proportion of water in its composition than ordinary grape sugar?

It is within a comparatively recent period that the importance of sugar in the animal economy has come to be recognized. Though known to have been present in the urine of the diabetic, it was not till 1774 that it was suspected to exist in the blood. In that year Dr. Polson of Liverpool remarked that the serum of the blood of diabetics was sweet, and from this observation inferred that the circulating fluid in those persons contained sugar. After this many celebrated chemists, amongst others Gueneville, Lavoisier, Segelar, Wallerston, Henry and Lomerian endeavoured to demonstrate its presence in blood by chemical tests, but without success until it was done by Ambrosiani of Milan in 1836, and in the same year by Dr. Gray of Edinburgh. In the year following Mr. Blyzer of Glasgow obtained from serum taken from the veins of diabetics a considerable amount of sugar. Since then as much as 1/8 parts of sugar have been found by Rees in a thousand parts of serum.

In 1836 sugar was first shown to exist in the blood of healthy persons by A. Reuschmann, who
(1) Philosophical Magazine 1845

(2) Constanza Jahresberichte, Scherer's Reports 1836 & 1837
found it in the blood of some individuals who had been living on a starch diet. Mr. McGregor discovered it in the blood of persons living on vegetables. The observations of these gentlemen were confirmed by those of P. D. Thomson. He found sugar in the blood of pigs who had been fed on starch, and he naturally thought it derived from their food. In 1846 Magendie found sugar in healthy blood, and since then it has been detected by a great number of chemists. That saccharine matter exists in the arteries as well as in that of the veins was discovered by Drs. Giss and Pavy of London. Schmidt of Dnipat has shown its presence in all parts of the circulation, as has also Bernard, Chevau, Harley and others. (21)

Having thus noticed the nature of the sugar to be found in the animal economy and given a brief history of its discovery, I proceed to consider more particularly where it exists, in what quantity it is found, and what functions it subserves. This, I think, I shall do best by examining first the source of the sugar existing in the blood, and secondly the manner in which it is consumed.
I. Stomach and Renal Diseases
Fell the discovery by Bérmund of the glucose function of the liver, it was supposed that, in the healthy animal at least, the only source of sugar was the products of the digestion of the food in the alimentary canal. In diabetes it was suspected that some internal source might exist, but no definite idea of its nature or seat was entertained. D. Poivet says:

"In the healthy state of the system, sugar never appears to be generated during the secondary assimilating processes. There is reason, however, to believe that in the advanced stages of diabetes, sugar is not only developed during the conversion of the albuminous principles of the blood into the gelatinous tissue, but also during the secondary assimilation of the gelatinous, and even perhaps of the albuminous and oleaginous tissues."

Since Bérmund's discovery however, the sugar is known even in the healthy body to have a double origin, one from the alimentary canal and another from the digestive power of the liver.
Sugar in the Alimentary Canal

That the sugar which was taken in the food was present in the alimentary canal before it being taken up into the circulation was of course always known; but that the saccharine matter found had another source than the sugar of the food was first pointed out by Dobson of Liverpool in 1774, who thought that the starchy part of the ingesta underwent a change into sugar before being taken up into the circulation. He does not seem however to have actually proved this; it would appear to have been with him only a conjecture. But his conjecture was verified by Biedermann and Gmelin in 1827. They ascertained the presence of sugar in the intestinal canal of various classes of animals made to feed on farinaceous substances.

Physiologists are by no means agreed as to what comes of grape sugar when taken as such in the food. It would seem most natural that it should, as stated by Dumas, be absorbed by the veins of the stomach, which are well known to be possessed of great absorbing powers. But that this takes place to any great extent is not believed by many.

(2) De genesis Aditus
In Poiret, for instance, asserted, that it is converted
normally into a low form of sugar containing more
water than grape sugar does, and that then it is
either taken into this form, or, if there be too much
sugar for the wants of the economy, part of it is
converted into oleaginous or albuminous substances by
the "converting power" of the stomach and thicker part
of the alimentary canal. Sugar is changed to oil,
he imagined, in a manner analogous to that in
which, out of the body, it is changed into alcohol;
and for its conversion into albumen it received nitrogen
from the secretions of the alimentary canal. He agreed
that such changes must occur, since, whatever be the
kind of food taken into the stomach, the composition
of the chyle is invariably the same. A. Michael (2)
agreed with him so far that he believed in the
change of sugar into fat by the agency of the bile.
Lehmann again affirms that when sugar is taken by
the mouth, no trace of it can be found in the blood
and but a trace in the chyle; and that when even
a small quantity is injected into the stomach, it can
be found unabated over a large tract of the intesti-
tinal canal— as far as the ileum; and from these
observations coupled with the facts that sugar is

solution does not readily penetrate animal membranes, and that a small quantity of sugar injected into the circulation appears in the urine, he argues that very little sugar is taken up as such from the intestinal canal. He believes that it is changed into lactic acid in great measure, and supports his opinion by showing that the sugar found in the intestine after glucose has been injected into it is always associated with a free acid. But, thinking that sugar must have an important office to perform in the economy besides that of furnishing fuel, he believes that some of it must be absorbed from the alimentary canal: this belief, however, it must be remembered, is more a matter of inference than of direct observation.

But that sugar is absorbed into the system in great part as it enters the alimentary canal, seems proved by the fact that an undue quantity of glucose taken into the stomach will give rise to the appearance of sugar in the urine. F. Bruner says: "When diabetic urine is introduced into the stomach of an animal we find on the following day saccharine matter in the urine, and continue to do so as long as we administer this substance, and even some days after we have ceased to inject it."
London Medical Gazette 1843 2nd Vol.
Dr. Percy's experiments seem quite conclusive on this
point. He kept a dog for three days without food
or at least with very little, and then caused the
animal to eat about three ounces of sugar or molasses.
When the dog was killed about an hour after its
meal by poisoning with hydrocyanic acid, the urine
taken from the bladder contained a considerable amount
of sugar. Similar results were obtained by feeding dogs
with cane sugar, which we shall see is changed
into grape sugar before being absorbed. Dr. Prout,
speaking of the oxalate acid diathesis says: "When
sugar is not all consumed as food, the urine
often contains sugar as well as oxalate acid." And
that sugar taken into the stomach in excess should
appear in the urine, is rendered quite likely, from
the analogous fact that when oxalate of lime is taken
in large amount as contained in the stalks of
the sugar beet plant or in the leaves of the dandelion,
that salt may be found in the urine. It is not
too much to suppose that if the whole round of
the circulation is traveled by the one substance, the
same thing may be done by the other.
But it cannot be maintained that the
whole amount of glucose swallowed undergoes no change.
(1) Chemistry of Food

(2) Stomach & Renal Diseases, pp. 9, 75, 78

in the alimentary canal. For, though Liebig, Proust, and others are of opinion that lactic acid is a normal ingredient of the gastric juice, and though according to Proust that acid is secreted in greater quantity than usual when the digestion is deranged (2), yet it is found after a saccharine diet in too great amount and too far down the intestine to allow us to impute its entire origin to the process of secretion. Liebig (3) believes that much of the lactic acid found in the intestinal tract is due to the transformation of sugar, and we have the assertion of Lehmann, that after injection into the stomach of the most soluble sugar, it was always to be found associated with a free acid. But his argument against the taking up of sugar as such, viz. the appearance of fructose sugar in the urine after being injected into the systemic veins is of little value, for as we shall see, it is highly probable that the liver (or portal blood?) exercises an important influence on the saccharine matter taken up into the portal vein, and carried through the hepatic tissue, making it more adapted to the function it has to serve and less easily eliminated by the kidneys. Besides, we do find, as has been mentioned, that the too free use of sugar in the food affects.
glucoseuria. That lactic acid should be formed in the intestinal canal is rendered likely from our having here every condition necessary to the lactic fermentation. Probably an important influence on the absorption or conversion of the saccharine matter is exerted by the kind of food taken along with the sugar, and also by the condition of the blood at the moment in reference to its power of absorbing.

Prout's notions of the change of sugar into oleaginous and albuminous principles seem now universally rejected, not being supported by any direct observation.

Cane Sugar. When the variety of the saccharine principle is taken into the stomach, it is changed according to Vonchardat into grape sugar and sugar of glucose. The latter substance, a variety of sugar, is said to be capable of easy decomposition, being destroyed in the system of the diabetic. (May it not be identical with hepatic glucose?) The effects of too great consumption as food of Cane sugar, would appear to be the same as those of the direct ingestion of a large amount of grape sugar. DoBerly gave a dog for six days only Cane sugar and water, and then killed it by means of hydrocyanic acid. Its urine contained sugar. Another dog was fed by him for two days.
with cane sugar, of which it took about two pounds, and passed urine during that time impregnated with glucose. The urine of the same animal, when it was fed upon horse flesh and potatoes, contained no sugar. From these facts it follows that the glucose and sugar of glucose, formed from the cane sugar must be absorbed as such. The latter is consumed in the blood; but the former, not being so easily decomposed, in part at least passes away by the kidney. Cane sugar injected into a vein is eliminated in the urine not at all changed.

Digestion of Starch. Before Wohlgemuth and Linné had pointed out the normal conversion of the starchy elements of the food into sugar, Bouchardat had observed that such a change takes place in the stomachs of diabetics, and had erroneously drawn from his observation the conclusion that diabetes mellitus was due to the presence in the alimentary canal of diastase, by means of which a large amount of sugar was formed during digestion and being absorbed was eliminated by the kidneys. The presence of this diastase he believed to be due to the acidity of the alimentary canal brought about by a sudden check of the acid perforations of the skin. But it has since been discovered that in health

(2) Physiological Chemistry II p. 192

(3) Gazeta Medyczna. No. 15, 16, 19
the amylaceous portion of the food is changed into sugar by a normal ferment, rendering unnecessary the addition of Bouchardat.

In this sugar-forming process the saliva is well known to be the principal agent. Day observes: "It is now established beyond all question that the principal use of the salivary secretion is to promote the conversion of the amylacea into dextrine, sugar, and lactic acid, and thus to facilitate the absorption of this class of foods." But the saliva is not the only secretion that has the power of converting starch into sugar. It shares this property along with the pancreatic juice as was discovered by Valentin, and with the intestinal fluid as shown by Lehmann (2). Though the secretion of the pancreas according to Bidder and Schmidt and their pupil Lander seems to be a more powerful agent in bringing about this catalysis than the saliva is, yet such would not appear to be its function, for Bidder and Schmidt have shown that the greater part of the starch is changed before the food enters the duodenum, and so before it can possibly come under the influence of the pancreatic juice. This secretion too has other functions, having the property of emulsifying fat and as shown by Corvisart and others
before him, of disclosing the albuminous principles of
the food: a power which would explain the greater size
of the pancreas in carnivora than in herbivora.

Saliva, when taken from the adult, has been
found by Bidder and Schmidt to have the power when
mixed with boiled starch in sufficient quantity of conve-
ting it immediately into sugar. No other fluid of the
body acts so quickly as the saliva does: even the pan-
creatic fluid, though more powerful in respect of the
quantity of starch it can transform, takes longer time.
Boiled starch chewed in the mouth for two minutes ac-
guishes a sweet taste: no such effect however follows the
Mastication of unboiled starch even when continued for
ten minutes (1).

To effect the conversion of starch into sugar,
it is necessary that these be, when saliva is employed, a
mixture of fluid from the submaxillary gland and of
mucus from the lining membrane of the mouth. Neither
of them will do alone: both are required. But Bernard
asserts that he has produced this catalysis by the action
of saliva derived exclusively from the parotid. The im-
portant observation has been made by Bidder and Schmidt
that out of the body the saliva does not need to be al-
kaline in order that it may exert its influence upon
1) Die Verdauungssäfte und der Stoffwechsel.
amylaceous food; for when neutralized and even acidulated with gastric juice its action is unimpaired, due allowance being made for the dilution which it undergoes by admixture. But these chemists are of opinion that the gastric juice in the living stomach does exert an influence unfavourable to this change. (1)

If it be then that the starch is changed into sugar by the action of saliva, we should expect, when we examine the stomach of an animal immediately before death, fed upon amylaceous matters, that it would contain sugar. But this is denied by Breda and Schmidt, and their disbelief of it is the foundation of their opinion that gastric juice checks the change of starch into sugar. Glaucos could not be found in the stomach by Blondlot, Bouchardat and Sandrart. Riches however, in performing upwards of fifty experiments on men, carnivorous and omnivorous Mammalia, and birds, found sugar in the filtered contents of their stomach. Jacobowitch also kept a dog with an artificial gastric fistula fasting for twelve hours, and then fed it with boiled starch. Four or five hours afterwards he ascertained by means of Romme's test and the microscope that the starch was entirely converted into sugar. He treated another dog in the same way, but had his salivary ducts tied,
and in this case the starch was not at all converted into sugar or even into dextrine. Confirmatory of these results we have the opinion of Lehmann that sugar is found in the stomach after amylaceous food, though it is in small quantity. He remarks that the conversion of starch into sugar must take place under the influence of the saliva both in the stomach and in the small intestines as well as in the mouth. He found that when an animal had swallowed balls of starch or had them injected into its stomach through a fistula, sugar could be detected in two or fifteen minutes. Such an occurrence must, he argued, be due to the action of the saliva in the stomach, for the gastric juice cannot change starch into sugar. Jaccoud has shown that the secretion of the stomach does not possess this power even after being rendered alkaline.

It is admitted by those who believe that sugar is to be found in the stomach after an amylaceous diet, that it is not present there in amount at all corresponding to the quantity of starch which has been swallowed and which has disappeared. This fact may be explained by supposing either that the amylaceous matter is absorbed before or immediately subsequent to its conversion into sugar, or that the sugar formed undergoes a further change into
1. Principles of Human Physiology p. 93

2. Encyclopedia of Practical Medicine - Diabetes.
lactic acid. The former view is the more likely one, and is that adopted by Dr. Carpenter.

It has been thought by some that the whole of the fermentative constituents of the food is converted into lactic acid before being absorbed. Lehmann, whose opinions regarding the digestion of grape sugar have already been given, holds similar views regarding the change or absorption of the glucose formed from starch. He found that after injecting one or two drachms of sugar of starch into the pharynx of rabbits whether before or after solid food, sugar existed at the end of two hours in the stomach, duodenum and jejunum, the contents of the two latter being strongly acid. From this he infers that sugar of starch is not readily taken up by the stomach and upper part of the small intestine; but at the same time it should be remembered that this experiment shows just as much that a long time is required for the conversion of sugar into lactic acid. We have proof that a large quantity of the amylaceous material does not go the length of lactic acid in the circumstance that a diet of starchy substances will sometimes cause the appearance of sugar in the urine.

It has been said that by feeding rabbits on starchy matters alone, they are rendered diabetic [91]. And then
can be no doubt of the fact that sugar exists in greater amount in the blood when starchy matters are consumed as food than when a diet of flesh is taken. Lehmann says that he did not find much sugar either in the lacteals or in the blood of animals fed on starch, but he did find some, while he altogether failed in detecting it when they were fed on bran. Almendral though unable at the time to detect sugar in the blood of animals fed upon flesh, got a considerable quantity in their blood after they had been fed for some days on cooked potatoes, although he says he found none in the urine. He also ascertained the presence of sugar in the blood of a horse fed upon corn. As has been before mentioned, it was in the case of animals fed upon a vegetable diet that Dr. Thomson and Mr. McGregor first detected glucose in healthy blood. And many chemists have observed a comparatively large amount of sugar in the portal blood after a starch diet.

Taking these things into consideration along with the actual detection of sugar in the stomach and small intestines of animals fed upon starch, and the certainty of the absorption of glucose swallowed as such, we can have little doubt that much of the
(1) Nelle's Archives 1844

starch, part of the food is taken up from the alimentary tract as glucose. But it is not absolutely necessary for the absorption of the amylaceous principle that it should ever undergo change into sugar. Not only do fluids pass into the bloodvessels of the intestinal canal from its cavity, but even solids in a state of fine powder do. Osterröm found that finely divided charcoal introduced into the alimentary canal may be discharged in the blood of the mesenteric veins; and Carpenter says that similar results have been obtained by Eberhard, and by Meserschmidt and Donders, the last two physiologists having found that not only charcoal but also sulphur and starch could pass into the veins. The starch was detectable in the blood by the iodine test. It has not been satisfactorily determined whether starch and charcoal pass into the lacteals in the same way. These observations are rendered more probable from the discovery by Mr Bucke and Dr Carter of the existence of starch corpuscles in the tissues.

But is it not likely that amylaceous substances may be absorbed in that form which is intermediate between starch and sugar, viz. dextrine? This substance being soluble will pass readily into the veins of the stomach, and its absorption would explain
(1) Comptes Rendus T. 45, No. 4, Juillet 1857

(2) Comptes Rendus T. 45, No. 26, Juin 1857

(3) Oh. Cit.
the circumstance that no bitter sugar is found in the stomach after a meal of starch. The idea that such absorption does occur receives countenance from the opinion of Bonnet, that dextrine exists in the blood. He comes to this conclusion by showing that when the blood is just freshly drawn it contains no sugar, but that when it has stood for half an hour, then saccharine matter is found in it. This formation of sugar, he argues, cannot be owing to a vital action, therefore it must be owing to a chemical change. And what theory is more plausible than that the sugar is formed from dextrine present in the living blood? Bernard has renounced his former disbelief in the entrance into the blood of the amylase in the form of dextrine; and he now affirms that this substance (dextrine) exists in the blood, and also in the juices of the body. From these considerations it would seem likely that a large amount of the starchy elements of the food enters the circulation as dextrine.

But a part of the amylaceous principles of the food does without doubt pass into lactic acid in the intestinal canal. In addition to the investigations of Lehmann on this point, we have the experiments of Biedler and Schmidt, which at once prove the conclusion.
of starch into sugar in the alimentary Canal, and the further change of the glucose into lactic acid. They opened the abdomen of a cat, and having passed the intestinal contents out of a portion of the small intestine they tied the emptied portion of gut in two places about three inches apart, then opened the bowel and having introduced into it some thick starch paste, closed it up again. Three hours after this they examined the contents, and found that the starch had nearly disappeared, that there was a good deal of sugar present and that the mixture had a very acid reaction.

I think that it necessarily follows from the facts above enumerated that starch taken into the stomach leaves or may leave the digestive Canal in four forms: first, and in small quantity, as simple starch; secondly, and I am inclined to think in considerable amount, as dextrine; thirdly, as sugar; and fourthly as lactic acid.

Though I have now discussed the main sources of sugar in the alimentary Canal, there remain to be noticed one or two substances which are supposed by some to be capable of transformation into sugar during digestion.
(1) Annalen der Chemie et Pharmacie, Band L X X V.  
(2) Handbuch der Phap. Chemie
Digestion of Cellulose. Cellulose, the composition of which is \( C_{12}H_{10}O_{10} \), is resorbed with starch. It has long been supposed to be indigestible in the stomachs of all animals, with the single exception of the Beaver, and to pass out of the body in the faces unchanged. It has been believed that in the Beaver the strongly alkaline character of that animal’s saliva may induce the change of cellulose into starch, and then into sugar. But another theory has been given out, viz.: that the cellulose may be decomposed by a peculiar principle in the digestive apparatus of the Beaver, similar to the ferment found by Mitscherlich in putrefying potatoes, which has the power of transforming the cellulose and leaving the starch unchanged. Lehmann has shown, that cellulose can be changed into sugar by caterpillars, which, he says, have highly developed salivary organs. If it ever be that in ordinary Mammalia cellulose is changed into sugar, it is probable that the quantity of saccharine substance produced is so small as to be of little importance.

Digestion of Gum. How gum is disposed of after being taken into the stomach is according to Lehmann still a matter of doubt. He says that the

(2) *Elements of Materia Med. and Therap.* 2nd Ed. p. 49
gum itself cannot be detected in the chyle, blood or urine. The instances a case where fifty grains of gum were given to a dog, and where forty-six grains were recovered from the excrement passed by it in the course of nine hours. But it has been said with reference to this experiment, that its results are completely at variance with the well ascertained fact given by Pareira (2), viz: that a thousand fleons were entirely supported on gum for the space of two months. Indeed it is said that six or eight ounces of gum per diem are sufficient to sustain an adult. It appears to me that in this as in many other experiments the successes which take place in dogs are diverse from those which occur in purely herbivorous animals, and even in man, the dog being more nearly allied to the Carnivora. When gum is taken up into the circulation it is probable that it is absorbed partly as gum and partly as sugar or lactic acid. The chemical characters of gum permit of its being transformed into sugar with facility. Its composition is C$_{12}$H$_{11}$O$_{11}$, and it is converted into glucose out of the body by simple heating with diluted sulphuric acid. Dumas believes that gum is a product of the digestion of amylaceous substance, but this wants
Comptes rendus 45 - No 4 - Juillet 1857
Confirmation.

It was given out by Poole in his work on Stomach and Renal Diseases that sugar was formed in the alimentary canal from albuminous substances, and this doctrine has lately been revived by Ljung. That such a change should take place, the latter physiologist holds, is quite explicable when we take into account the chemical composition of the albuminous principles and their relation to that of the saccharine for the ultimate composition of Protein together with twelve equivalents of water is equal to two equivalents of starch along with three of ammonia: \[
\text{C}_{24} \text{H}_{4} \text{~N}_{3} \text{O}_{8} + 12 \text{H}_{2} \text{O} = 2\left(\text{C}_{12} \text{H}_{10} \text{O}_{10}\right) + 3\text{NH}_{3}.
\]
And experimentally, he has obtained, by boiling white of egg with canonic broth, a body which after being acted on at the temperature of boiling by dilute sulphuric acid, yielded a glucose which reduced the salts of copper. As an additional argument for the change of albumen into glucose, he states that sugar is met with wherever albumen is to be found, as in the blood, in milk, chyle, lymph, and in pathological collections of fluid. Notwithstanding all this, however, the fact that the presence of sugar in the portal vein of animals fed on flesh has been denied by the
most accurate and laborious experiments, is sufficient to make us reject the theory of Priest and Figuier.

Sugar formed at the Liver.

That the sugar in the animal economy has not only an external source, but also an internal and more important one was first suggested to the mind of Bernard by the circumstance that glucose exists in the blood of animals fed exclusively on animal feed, and of hens whose chow has rested for some time. A bitch was killed seven hours after feeding heartily on motion and the bones of fowls. Blood was then collected from the cavities of its heart, and after an hour and a half the milky serum which separated was found to contain sugar. No sugar in this case could be detected in the alimentary canal or in the urine. A dog killed after a fact of two days the same results were obtained on testing for sugar. It was proved by the following
experiments that the sugar did not exist in the chyle and so could not come by it into the circulation. A dog was fed on meat and bones, and killed seven hours after the meal. Not a trace of sugar could be found in the chyle or chyme, but as before glucose was ascertained to be present in the blood of the right ventricle. The same results were obtained in the body of a dog which had fasted three days, and in which the chyle was quite clear. These experiments were repeated so frequently as to leave no doubt of their correctness.

It had been previously shown by Magendie, Latarjet and others that the liver in the dead animal contained sugar in the proportion of from half a scruple to two scruples in the four ounces of hepatic tissue. By the following experiment Bernard showed that in the living animal sugar was given off from this organ into the circulation. A dog while digesting animal food was killed by section of the mediulla oblongata. The abdomen was immediately opened and a ligature placed upon the portal vein at the point of its entrance into the liver. No sugar was found on the side of the ligature next the intestinal canal, while abundance was found beyond it. It was
(1) Constantine Jahresberichte, Kuren's Report 1887
observed also that the substance of the liver contained sugar, while the pancreas, the spleen and the mesenteric glands contained none. These observations have been confirmed by Lehmann and others. Below states that he could not find sugar in the portal vein of animals fed on flesh, while beyond it he met with abundance. Bonnet makes a similar statement in regard both to Carnivora and Herbivora. Kept fasting for some time, Chevreau, though he says that some sugar is always to be found in the portal vein of dogs and horses even when starved, yet admits that it is in much greater quantity in the blood which has passed through the liver. (13)

After these experiments however it might still be asserted with some degree of probability that the liver might only be a store for the sugar of previous aliment. But that such should be the case is most unlikely, and even impossible, by the discovery by Bernard of sugar in large amount both in the substance of the liver and in the blood of the right ventricle of a dog which had been kept fasting for eight days and then fed for eleven days on meat alone. Bernard in this is supported by Chevreau who found that the sugar in the great vessels was not
diminished by long continued fasting. Passieou also found this to be the case. There is a limit however, according to Bernard, to the formation of glucose by the liver after long continued fasting, as that organ was found by him to be destitute of sugar in animals dead of starvation. Another proof of the formation of sugar in the liver of the living animal is its formation in the liver after death. It is formed in equal quantity in the dead livers of the carnivora and in those of the herbivora. Bernard demonstrated the glucogenic power of the dead liver by washing it well, clearing out the vessels by injecting water into the portal vein and letting it run off by the hepatic until not a trace of sugar was to be found in the water which passed through; and then after the lapse of twenty-four hours successively testing for sugar in the hepatic substance. Delbe has obtained the same results as Bernard. He found besides that electricity and oxygen have no influence upon the production of sugar, but that nitrogen puts a stop to it. Renan also agrees with Bernard in this particular, and he has operated on a large number of livers of a great variety of animals. Vigier moreover endeavours to show that if the liver be thoroughly washed an hour and a half after
(1) Grundriss des Jüdischen Gemeindearchivs - Schriften Rehova 1856-7

(2) Archives Générales de la Mort 1853-7
death, no more sugar will be found in it afterwards; and he limits the formation of sugar to at least this short period after death. This observation has not as far as I am aware received confirmation.

Bernard has ascertained that in all animals which possess a liver, sugar may be detected in its tissue. The animals he made observations on were mammals and birds, a large number of fishes, both oceanic and cartilaginous, pulmonary gastropods, cephalopod molluscs, and crustacean decapods. He found also that sugar exists in the fetal liver as early as the sixth month (in the human subject). According to Dr. Vesalius, it is found as early as the fourth month.

As has been already stated, the hepatic sugar is not identical with ordinary grape sugar. The blood is much more tolerant of the presence of this variety of the saccharine principle, or more properly perhaps this kind of sugar is more easily decomposed than any other. This is proved by the experiments of Magendie, who injected five times as much hepatic sugar into the veins without its appearing in the urine as he could do of grape sugar.

The gluco-genic function of the liver is at
its maximum from two to four hours after a meal. It has been thought to be proved by this that the secretion of sugar has little to do with the other function of the liver—the secretion of bile. Since the researches of Bichat and Schmidt have shown that bile is secreted most abundantly, thirteen hours after a copious meal, and that after this till twenty-four hours have elapsed the activity of secretion gradually diminishes till it reaches the quantity, secreted one hour after a meal. But since Bernard's discovery of the phlegmogenic substance this argument is of no weight.

The secretion of sugar by the liver is influenced as to the amount of saccharine matter produced by various circumstances. Age exerts an influence upon it as might readily be supposed. The secretion of sugar is at its minimum during the period below two years of age. Sex seems to have little or no influence. Disease has sometimes an important effect in modifying the phlegmogenic function of the liver. If the disease be an acute one such as epidemic cholera, then the secretion of sugar is not much interfered with. But in such diseases as tuberculosis and cerebral affections the sugar is not so abundantly formed as during health.
and its quantity is diminished as the disease continues. Huber makes the extraordinary assertion that no sugar is to be found in the livers of syphilitic individuals. This would require confirmation.

Bernard found that division of the pneumogastric nerves arrests the formation of sugar at the liver, and that diseases which in like manner depress the nervous energy are followed by the same result. This circumstance, and the fact before alluded to—that starvation eventually depresses the liver of ability to perform its office—explains the small amount of sugar secreted in chronic disease, and its absence in the livers of men who have died of ordinary disease. In the liver of a man suddenly cut off Bernard found five drachms of sugar. The same physiologist ascertained that a puncture made in the middle of the calamus scriptorius, just between the filamentous radicles of the auditory and pneumogastric nerves, also a puncture made in the olfactory or olivary bodies, will if done roughly, cause the formation of sugar at the liver to cease, but if done slightly and with care, will cause the appearance of sugar in the urine. He takes it for granted that the last mentioned phenomenon is due to the increased formation of sugar; whether justly or not.
I shall consider afterwards.

The rate of morphia according to Gage, increases the formation of sugar at the liver and in the same proportion the quantity of glucose in the arterial blood.

Structural disease of the liver will of course interfere with its gluco-genic function as with all its other functions. Fatty disease of its tissue is particularly mentioned as being unfavourable to the performance of the office.

That sugar, like fat, is formed from nitrogenous material has been inferred from the fact that it is abundantly produced by the liver when nitrogenous food alone is taken, and from the analysis of the portal vein blood compared with the blood in the hepatic vein: Lehmann says that there is less nitrogen in the hepatic vein than in the blood before passing through the liver; but how this should be seems inexplicable. It is not likely that the azote separated in the formation of sugar should pass away in the bile, for that secretion does not contain much nitrogen. Animals fed upon gelatin alone secrete a natural quantity of sugar, while a diet solely of fat acts as unfavourably upon gluco-genesis as does starvation itself. How sugar should come to be formed from nitrogenous substances is not difficult to
see if we keep in mind the fact that when a large amount of nitrogenous food is consumed without a corresponding quantity of oleaginous or saccharine matter, urea is secreted in great amount by the kidney; and if in connection with it we take the formula of Urea before alluded to (Page 26). Protein with twelve equivalents of water is equal to two equivalents of starch and three of ammonia: \(2(C_2H_10O_5) + 3NH_3\). And ammonia along with Carbonic acid (a product of the transformation of the starch) minus water is equal to the composition of urea: \(2NH_3 + 2CO_2 - H_2O = C_2N_2H_4O_2\). I do not for a moment imagine that this is the process gone through by nitrogenous substances, or indeed that urea is specially formed at the liver at all; but these formulae show how the composition of the protein compounds is equivalent to the sum of the composition of these bodies (sugar and urea) supposed to be formed from them, and actually detected in the organism.

It has been supposed by Bernard that the secretion of sugar by the liver and the well ascertained formation of fat by the same organ, are to a considerable extent reciprocal of each other; the sugar being formed most in Carnivorous animals, while the fat is
formed in greater amount in the hepatic organs of herbivora.

Bernard, in the Comptes Rendus (March 1857), has made the announcement that sugar is not formed directly from the nitrogenous elements of the blood, but that there is first deposited in the liver what he calls a glucogenic substance which when acted on by a ferment gives rise to the formation of sugar. This substance, he says, may be obtained by taking the still warm and bloody liver of a newly killed animal and plunging it into boiling water, so as immediately to coagulate the tissue of the liver as well as the ferment by the action of which the glucogenic substance is transformed to sugar. The coagulated nécruce is now cut in pieces and bruised in a mortar, and allowed to digest for three quarters of an hour. Some water is then added and the solution obtained by filtration is precipitated by alcohol which gives in the form of powder an emulsive glucogenic substance containing sugar, bile, and some unascertained nitrogeus substances. This powder after being washed with alcohol has a gum-like appearance. It is dissolved with facility in water, the solution being opalescent and slowly precipitable by strong alcohol which of course brings
Down the glucosetic substance again. To purify it, it may be boiled in canetic potash, and after the addition of water again precipitated by alcohol. By dissolving it another time in water, adding to the solution acetate of lead, and precipitating by alcohol as before the glucosetic substance is freed from all traces of potash.

When dried this glucosetic matter has a flouey appearance. Prepared as above indicated it has a striking resemblance to hydrated starch. It possesses a neutral reaction, has neither smell nor taste, and gives to the tongue the same sensation as is given by starch. It has no characteristic appearance under the microscope. It is coloured by iodine from a deep violet to a pure mahogany red, seldom finely blue. Copper salts are not reduced by it in alkaline solutions. Yeast does not cause in it the formation of alcohol. It has therefore the character of starch, and is no doubt one of the many varieties of that substance. This view is confirmed by the action on the glucosetic of all those agglutinates which change amyloin into dextrine. Heat and the limited action of a ferment or of diluted acids transform it into a substance resembling dextrine. Its pure watery solution keeps very well, but under the in-
fluence of a ferment it changes rapidly into a solution of glucose. Blandan expressly mentions that he obtained this substance from the livers of dogs fed on flesh. The formation in the livers of this hydrated starch is by its discoverer to be a vital act, while he holds that its change into sugar is the result simply of chemical laws. He points out that whatever tends to stimulate the circulation of blood in the abdomen, tends to increase the amount of glucose-facile substance changed into sugar, and whatever lowers the circulation retards the catalysis. If hibernating animals be killed before being awaked from their sleep, their livers will be found to contain very little sugar, but a great amount of this liver-starch; but if their circulation be excited by their being brought into a higher temperature before being killed, their livers contain more sugar and less starch. Shock or injury of the spinal cord of warm-blooded animals in the region of the neck is sufficient to lower the abdominal circulation, and hence to stop the formation of sugar, so that after the lapse of four or five hours not a trace of sugar will be found in the liver though that organ abounds in the glucose-facile substance. Section of the vagus nerve has a similar effect. On the other hand, the stimulation of a late meal quickens the fraternal
(1) Schenr—Gesellschafts Jahresberichte 1836

(2) Comptes Rendus 1846 p. 189
Circulation, and so leads to an increased formation of sugar. Mechanical pressure on the liver has, according to Bernard, a similar effect. And he also explains by the excitement of the abdominal circulation the increased formation of sugar and its appearance in the urine after slight puncture of the floor of the fourth ventricle of the brain.

From these facts it would appear that the ferment which has the power of changing the liver starch into glucose exists in the blood. Though it must be admitted that the formation of sugar in the washed out liver after death leads to the belief that some ferment does exist in the liver; yet that it is in no great amount has been proved by the researches of 

Henderson, who found that neither the washing out of the liver nor the tissue of that viscus has any appreciable influence in transforming starch paste into glucose, while on the other hand the blood circulating in the organ had a powerful effect in producing this change. 

Meyer's proved that a ferment existed in the blood of the living animal by injecting starch into the circulation which was, he found, transformed into glucose. 

Henderson goes further, and from a comparison of the fermenting power of normal blood with that of blood obtained from
01 Schenck, Comptes, Jahresbericht 1884
the left side of the heart; concludes that the ferment is taken up from the intestinal canal, and supposes that it is really the pancreatic fluid.

The theory of Bernard's regarding the formation of sugar at the liver has not escaped the animadversions of some physiologists; indeed these have not been wanting those who have denied the theory. The secretion of sugar at the liver, Lanson (1) declares that chloride is found in the blood and in the tissues of all the important organs of the body, particularly in the liver, spleen, kidneys, lungs, and muscles. His reasons for believing in its existence in the blood have been already given. He says that it may be found in arterial blood as well as venous. It is formed from the starch of the food in the case of herbivorous animals, and is absorbed by the esters from the flesh of their prey, which according to Lanson contains abundance. I suppose he explains the facts pointed out by Bernard on the supposition that this chloride is changed into sugar by the liver. But although Bernard himself admits that in the herbivorous chloride is taken up into the circulation, he denies that such a thing occurs in animals who eat nothing but flesh. Lehmann also has shown that after a diet of animal substances there exists in the intestinal canal
(1) Schuon, op. cit.
no appreciable amount of any substance which can be changed into sugar, and Bonnet denies that dextrose can be found in the blood of carnivorous animals. Pelouze also has shown that the substance which Danson got from the spleen, kidneys etc., and believed to be dextrose is quite different from the glucose-like substance of Bernard, which indeed cannot be found in any organ but the liver. The so-called dextrose of Danson is according to Pelouze a modified Albumen (Mullein's Protosin). Lastly, Bernard opposes to this theory of Danson the vital character of the formation of the glucose-like substance of the liver, which he shows is suspended or nearly so in the livers of horses which have fever, an occurrence not explicable by their not eating. (1)

Ligueir believes that all the sugar of the economy comes from the alimentary canal, in which as previously stated (page 26), he thinks that saccharine matter may be formed from albumenous. He endeavors to explain the fact of the portal vein blood not fermenting till boiled with sulphuric acid (which he assumes it always does) then by the supposition that it contains one of the several kinds of sugar which modern chemistry has shown to be incapable of undergoing fermentation. The modification of
Sugar after passing through the liver becomes hepatic sugar and is then capable of undergoing fermentation and of reducing the salts of copper, in both of which respects it resembles the sugar found in the bile. He does not think that the sugar of the portal vein is formed directly from inorganic principles, but holds that there is first formed in the alimentary canal a sweet substance which is not precipitated by basic acetate of lead and which is not capable of reducing the salts of copper or of undergoing fermentation. Bonnet, however, denies the existence of this sweet substance; and, so far as I know, it has been seen by nobody but Tjuyer. If it were really present, it surely would be possible by fermentation or otherwise to convert it into sugar, which would be detected by the usual tests. And how will this theory account for the formation of sugar in the dead liver? Tjuyer has further found fault with Bernard's mode of preparation of his glucos-glucose substance, and asserts that by boiling albuminous matter with canthic potash a material capable of conversion into sugar may always be obtained. But in reply to this it may be said in the first place that in no other organ is hydrated starch got in such quantity as in the liver, which is not in-eminently rich in albuminous matter; and secondly,
that it is obtained in an impure condition before the
Caustic Potash is at all employed.

The last objection to Bernard's theory which
I shall mention is that brought forward by Dr. Pavy of
London, who supposes from the fact of his not finding
it in blood drawn from the right side of the heart in
the living animal that the presence of sugar in the hepatic
vein is the product of post mortem change. Sugar
has however been found by Bernard in blood taken from
the circulation in this way.

A few words will be necessary on the subject
of the transforming power of the liver over sugar. I mean
the power which it possesses of reducing ordinary glucose
to the form of hepatic sugar, and of so changing the
saccharine matter taken up into the circulation as to
render it fit for the purposes which it is intended to
derve in the economy. It has been supposed that the
albuminous, the fatty, and the saccharine elements of
the food meet, part of them at least, to pass through
the liver before they are thoroughly fitted for the wants
of the economy. White of egg injected into the veins
of the general circulation is eliminated by the Kidneys;
while the same substance is obtained if injected into
the portal vein; and fat after passing through the
Principles of Human Physiology p 375
Liver is a different substance from what it is when newly taken up by the veins. And Carpenter says: "The saccharine matters which are brought to the liver in the condition of grape sugar or of cane sugar, are converted by its agency into liver sugar". But I think it may be doubted whether the hepatic organ is to be regarded as the only agent in this change. It has been already shown that a ferment exists in the blood of the portal vein (whether it is absorbed from the intestine or not admits of question) which is capable of acting upon starch, and, for all that I know to the contrary, upon sugar also. And indeed when sugar is swallowed, it is quite possible that it may be transformed, some of it, in the intestine into a form of the saccharine principle like the hepatic glucose, as was supposed by Dr. Pratt when he said that the sugar taken into the alimentary canal, as well as the amylaceous matters are converted there into a low form of sugar. Such an opinion receives countenance from the statement of Roux, that cane sugar in the stomach is converted into glucose and sugar of molasses, which latter is a low form of the saccharine principle.
Having now considered the sources of the sugar found in the animal economy, and the mode in which glucose finds entrance into the blood, I proceed next to investigate the uses to which the sugar is applied, and the manner in which it is got rid of.

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Transformation & Elimination of Sugar

That the final end of the sugar found in the human body, is to undergo combustion and give off carbonic acid, and thereby, to keep up the temperature of the body, seems absolutely certain; but as to the precise mode in which this takes place, and as to the question whether any specific function is served by the sugar before its transformation, or by any of the products of its change, apart from furnishing fuel, there seems a difference of opinion.

Dr. Gregory says, "It is obvious that since carbon and hydrogen are the chief sources of animal heat in their oxidation, while nitrogen and its com-
Carpenter's Human Physiology, p. 376.
Pounds are hardly combustible, the chief portion of the animal heat must come from the non-nitrogenous food, starch, sugar and fat, hence called respiratory food." And the capability of the nitrogenous substances for undergoing combustion is made still less, after sugar (a combustible substance) has been formed from them and removed, which we know to be done at the liver. The importance as fuel of the hydrocarbons, as these non-nitrogenous substances have been termed, is seen from the great amount of heat they must supply to the body; for it has lately been shown[,] that the bile taken up again into the circulation from the alimentary canal, though almost the only other fuel, does not furnish more than a twelfth part of the Carbonic acid (which is given off from the system). That sugar in particular is closely connected with the production of heat follows from the observation of Bernard, that those animals which have the highest temperature are those whose lives secrete most sugar; and from the fact that the secretion of sugar is most active after meals, when we know that the Carbonic acid given off by the lungs is greatest in amount.

Bernard suggests the idea that sugar before its decomposition may be employed in the nourishment
of cells; but sufficient protein for this opinion seems to be wanting.

There is reason to believe from the presence of starch corpuscles in the body, and from a part of the amylaceous matter of the food being as we have been (page 21) possibly ablord as starch, that the white of the plasmacle does not go the length of sugar in the economy, but is defracted in the tissues by the blood in which it exists either as starch itself or as dextrine. It is however possible enough that the starch in the tissues is secreted from nitrogenous substances as the gluco-gluic substance of the liver is.

It is certain that sugar is changed in the animal body into fat. And this may be done as Dr. Gregory (1) has shown in two ways: either by way of fermentation, or by direct deoxidation. The former indeed takes place out of the body, as in the lactic fermentation when lactic acid is formed from the sugar, and as in the fermentation of starch sugar from which Celanic and mafronic acids result. Dr. Gregory supposes that fat is formed in the body, some of it, by a series of fermentation in which the liver is concerned, and in which hydrogen is given off. Such an action is seen indeed when the liver of a recently killed calf is placed
in water. Liebig thinks it proved that this transformation is determined by a ferment in the liver which behaves towards sugar as saliva does towards starch. This process would seem to take place in animals who feed much upon the amylacea, and in this way the true liver-fat appears to be formed. I should think it probable that much of the fat is formed not from sugar but from starch; the discovery of the gluco-genic function of the liver seems to favour this opinion. According to Bernard it has been proved by Dumas and La Edwards that bees have the power of making wax from honey. He believes that in the same way the sugar of the portal vein contains more fat is changed by the liver into fat. He endeavours to show that this is not mere theory, by pointing out that the hepatic vein contains more fat than does any other vein in the body. But it is curious that the same observation is made regarding the portal vein by Simon, Schütz and Schmidt. It is not impossible that both observations may be correct from their being made under different circumstances. The liver may not secrete fat when there is abundance in the portal vein, and the fat may be even eliminated from the blood in the secretion of bile.
By the process of deoxidation Dr. Gregory has shown how all the fatty acids of the acetic series, as well as oxide of lignite may be formed from sugar or starch. This mode of conversion into fat takes place when the animal does not get a sufficient supply of oxygen into its body on account of want of exercise. It is seen in the case of otolaxis when fed on grain. These also when kept from moving and crammed with maize or wheat become fat in the same way. Wild animals are always lean from the exercise they are compelled to take, and the consequent oxygenation of their blood.

When sugar is to serve immediately for supporting the temperature of the body, it is dispersed in some other way than in the production of fat; and it is all but certain that it is changed into lactic acid and then consumed as fuel. Glucose changes very readily in the lactic fermentation into lactic acid, and there is reason to think that in the blood we have all the conditions favourable to this change. Again we know that when the alkaline salts of lactic acid and other organic acids are taken into the circulation, the urine becomes alkaline from its containing the Carbonates of the alkalies which enter
(1) Physiological Chemistry, Vol I, p. 97

(2) Op. cit. I, 104

(3) Op. cit I, 96
the blood in union with the organic acids. Lehmann found that the urine was rendered alkaline thirteen minutes after taking half an ounce of lactate of soda. He also found by injecting variable quantities of lactate of soda into the jugular veins of dogs, their urine became alkaline after periods ranging from five to twelve minutes. We therefore justly infer that the acid has undergone combustion, and has been transformed into carbonic acid and water. The same chemist remarks (2): "I know of no substance which could better act in the blood as food for the respiration than the alkaline lactates, which we have seen undergoing rapid combustion in the blood, and are thus converted into carbonated alkalies." In another part of his work (3), he says that though lactic acid has never been demonstrated in normal blood, yet from such facts as the foregoing it follows that it must be present. With these opinions Lehey concurs. He relates experiments performed on three persons who took as much lactate of potash each as was sufficient to have yielded an ounce of lactate of urine. In each of the cases the urine was acid before the salt was taken, but after it had entered the system the urine became alkaline and contained potash, but not a
(1) Chemistry of Food
trace of lactic acid. Liebig believes that it is owing to the readiness with which lactic acid is decomposed in the blood that it never exists in healthy urine. "From these things," he says, "it plainly appears that the lactic acid in the organism is employed to support the respiratory process, and the function performed by sugar, starch and in general all those substances which in contact with animal matter are convertible into lactic acid, ceases to be a hypothesis. These substances are converted in the blood into lactates which are destroyed as fast as they are produced, and which only accumulate as the supply of oxygen is less, or when some other substance attracts it opposed to the agency of that element."

If it be then that sugar is changed into lactic acid, and then by oxidation into Carboxic acid and water; where does this change occur? It was at one time the opinion of Bernard that the sugar was transformed in the lung into lactic acid; and in some experiments he found no sugar in blood taken from the left side of the heart. But for the change of sugar into lactic acid there is no need of lung oxidation, and it is not easy to see why this catalysis should occur at the lungs exclusively.
(1) Seiner - Op. cit. 1856
Bernard himself has given up this hypothesis, and believes that the sugar after fasting from the liver immediately begins to be decomposed, and before it reaches the lungs is in general completely transformed.

The researches of Chiozzi into the amount of sugar to be found at the different parts of the circulation have led to remarkable results, which, if confirmed, will considerably modify the views of physiologists regarding the function served by sugar in the economy. He found, that in horses which had been kept fasting for a period varying from twelve hours to four days, 100 grammes of arterial blood-serum contained from 73 to 90 milligrammes of sugar, while in the serum of the venous blood there was from 66 to 80. It is not stated from what place the venous blood was taken, but I suppose it would be from the veins of the general circulation. In four dogs who had fasted for a period varying from twenty-four hours to six days he obtained like results. The same amount of the arterial blood-serum as was employed in the case of the horses yielded from 35 to 53 milligrammes, the serum of the venous blood from 29 to 34. He found also that the amount of sugar in the hepatic vein in animals fed upon flesh was greater than that in any
(1) Scherer - Op. cit. 1854
other view. The exact quantity however is not stated. The quantity of sugar, according to him, is as great in blood drawn from the left side of the heart while the animal is alive as in blood taken from the right side. But in drawing off the blood, the results of the experiment must have been to some extent vitiated by the interference with the animal's respiration which must have occurred. If the relative amount of sugar in the arteries and veins be as Chevau has given it, then the sugar must either be decomposed in the capil-
laries or be landed into the tissues and then decom-
poised or else taken up by the lymphatics. That sugar does exist in the lymphatics has been shown by Be-
nard and Colin. They got an artificial gastric fistula made in a bull, and for three weeks intro-
duced boiled flesh into the stomach through the fistula, giving the animal for that period no other food.
The bull was then killed, and the Clyste taken from its thoracic duct was found to contain some sugar, and a considerable amount of urea. Not a trace of the former could be found in the intestine. Bernard therefore came to the conclusion that the sugar came along with the lymph from the tissues. Chevau states that he had previously demonstrated the presence of
[1] *There on Sugar in the Colony*, Edin. 1835.

[2] *Chemistry of Food*
Sugar in the chyle after very long fasting. In reference to the results of Cheveau it should be remembered that what he took for sugar may be been present in the living blood as olestrine.

It appears to me as the most probable view of the matter, that though perhaps the sugar may be decomposed in greater amount at one part of the circulation, e.g. in the tract between the liver and the lungs, than in other parts; yet that it generally goes on throughout the whole round of the circulation.

It is likely, that when the sugar is converted into lactic acid, this acid unites with the carbonic acid of the blood, which fluid we know to be distinctly alkaline; but it is not necessary for the elimination of the carbonic acid already formed, that this should occur, as has been said by Dr. Brompton. He believes that carbonic acid is set free at the lungs in consequence of the sugar being there converted into lactic acid, and from the decomposition by that acid of the alkaline bicarbonates existing in the blood. But to this theory there are numerous objections. The extreme improbability of the extensive formation of lactic acid at the lungs has already been noticed. And it has been shown by Liebig that the carbonic acid of the blood is not con-
tained in it in the form of carbonate, at least to any great extent. Besides, the Chemist has shown that no acid is needed for the evolution of Carbonic acid, by pointing out that from a saturated solution of Carbonic acid in serum of blood, two thirds of the quantity of the gas is given off by simple agitation of the solution with atmosphere air and diminution of atmospheric pressure. And at the lung we have at all events one of these agents in operation; the blood in the capillaries of the lung comes into close contact with the atmosphere. May we not also have a diminution of atmospheric pressure? For when an inspiration is to be made we have the walls of the chest expanding and thereby causing a tendency to rarefaction of the air in the cells of the lung, which is only kept from occurring by the rushing into the cells of other air to keep up the balance of pressure. But it is as likely if there be air in the blood that it will come from it as from the external atmosphere. From the facility with which the atmospheric air passes into the lungs, the diminution of pressure on the blood vessels must be very little; but at all events this happens that the Carbonic acid coming from the Capillaries at the moment does not need to displace any other gas.
Such then would appear to be the method in which sugar is got rid of in general; by change into fat, and by combustion (and perhaps by transudation at the capillaries). But in some instances it is not all, for some reason or other, so disposed of. In such cases it of course collects in the blood and passes away by the excretions. And it would seem able to be eliminated from the body by every secering surface. It is found in the sweat, also in the intestinal excretions. It may be detected in the saliva, or at least in the mixture of that secretion with the buccal mucus. There can be little doubt that sugar is secreted also by the bronchial mucous membrane. But the secretion in which it most abounds is the urine; and the reason why such is the case is not far to seek. Speaking of elimination by the Kidneys, Dr. Carpenter says, "On this point a very elaborate series of researches was made by Wöhler, who showed that of the soluble salts taken into the circulation, those are most readily excreted which produce a determination of blood towards the Kidneys, whereby an increased quantity of fluid is filtered off through the outlet which they afford. This statement is to be extended from saline matters to such other soluble matters
As are not eliminated by secretion through other channels, or are present in too large an amount to find their way out thence with sufficient rapidity. Thus we have seen that when sugar is injected into the blood in sufficient quantity, it appears in the urine, and the same result may occur, either from the introduction of this substance in excessive amount by absorption from the alimentary canal, or from the undue production of it within the system, especially if at the same time the process of respiration by which it is normally disposed of as fast as it is formed, should be retarded or enfeebled. " Thus it would appear that when the sugar in the blood exceeds a certain amount it passes away by the urine. According to the experiments of Malendee, when the blood after being arterialized at the lungs contains more than 3000th part of sugar, some of the saccharine principle passes off by the kidneys. This is at variance with the results of Chevreul, who found in the normal blood of the horse and dog taken from the arteries fifteen or twenty times as much sugar. We shall consider first the most important outlet for the undestroyed sugar of the blood in the urine.

Sugar in the Urine. The urine was, as far as we know, first noticed to be sweet from the pre-
(1) Schen's Werke, 2. Teil, Chem. Ausgabe, Jenaer Buchverlag, 1836
Since of sugar by Thomas Willis in 1677. Though ever since the urine of diabetes has been known to contain sugar, yet the existence of glucose in the secretion of the kidneys was not recognized to be so common as it really is until within a comparatively recent period. Glucose is now known to exist in a variety of conditions, though not to any great degree in any except in the diabetes mellitus. These conditions I shall now enumerate.

In the urine of the aged, sugar is said by M. Decambrè always to be present.

Blot believed that sugar had been found by him, with the assistance of Béville, in the urine of healthy women who were in the later months of pregnancy or were suckling. He found it, he says, especially at the commencement of lactation. He thought it connected in a special way with the secretion of milk, as the glucosuria began when the mammary sympathies of pregnancy were first developed, and continued till suckling was given up. When the secretion of milk was stopped even for a day or so, the amount of sugar in the urine diminished or even disappeared. The amount of sugar found was considerable, as much as from eight to twelve parts in the thousand. He adds that in the cases observed by him, no other sign of diabetes was
(1) Schuer - op. cit. 1857

(2) Stomach and Pelvic Diseases P. 34
present, but that the stronger and more healthy the woman, the more sugar did her urine contain. The accuracy of these results has been denied by Schier and Wiederhold, neither of whom found either glucose or lactine in the urine of women in these circumstances. The former chemist is of opinion that Blot has been led astray by the urine acid as to be present in the urine in such cases; the latter thinks that it has been mucous in the urine which has answered to some of the tests for sugar. Lehmann gives a case where sugar appeared in the urine not during lactation but after that process had been suddenly stopped five days subsequent to delivery. It continued to be present for four days. Dr. Bryce, found sugar in the urine of a woman who had inflamed breasts after parturition.

We have already seen that sugar is apt to appear in the urine when too much saccharine or amylaceous matter is taken as food. We have also the testimony of Dr. Prevost as to its presence in Dyspepsia: he says: "The saccharine condition of the urine exists in Dyspepsia and forty individuals much oftener than is supposed: and hundreds pass many years of their lives with this symptom more or less constantly present, who are quite unconscious of it till the quantity of urine becomes
(1) Op. cit. p. 66

(2) Medicina chirurg. Brain. XXXVI 1853

(3) Urinary Deposits p. 231

(4) Anatomy 5th Ed. p. 139
increased? He says also (1), that the oxalic acid diathesis which is undoubtedly a disease of affection, sometimes passes into the diabetic. This view is confirmed by Price Jones (2), who has found oxalates and sugar often to exist together. Such however was not the experience of Dr. Holback Reed who believed that sugar was seldom found in connection with the oxalic acid diathesis. He observes: “So far as the abstract examination of the urine is concerned, not the slightest countenance is given to the idea of there being any relation between the oxalic acid and saccharine.”

Lesions of the skin are accompanied by saccharine urine. The anatomist Cheselden remarked that the urine in a case of carbuncle was sweet as in a diabetes. Dr. Priest (3), points out the fact that glucosuria occurs more particularly in connexion with disease of the cellular tissue. He says he has always found the urine saccharine in carbuncular inflammations, but in no more than two instances of affection of the skin itself has he found sugar. But he says Diabetes often follows cutaneous disease. He gives an interesting case of a man who was subject to repeated attacks of boils and carbuncles, and during each attack had sugar in his urine. It is worthy of notice in reference to the relation between
(1) Comptes rendus 1853 p. 230

(2) South 1855

(3) Lancet Jan. 30th 1858
Saccharine urine and ascenina, that the latter is also found very often in Carcinomucular disease. ... I have heard it mentioned by Dr. Watson Rowse in his clinical lectures that the appearance of sugar in the urine is caused by extensive burns.

Sugar has also been found by Dr. Paynes, in the urine of persons variously affected with Chest disease, which interfered with the respiration. He found it in Pleurisy, in Chronic Bronchitis, in Asthma. In the tuberculous he obtained it in quantity proportioned to the intensity of the inflammatory symptoms. Saccharine urine was also observed by him in cases of Hysteria and Childbed. These observations were confirmed in a joint paper by himself and Clichea. Dr. Gann found sugar in the urine of a case of acute Bronchitis, where it was associated with albumen and a deposit of lithate. Dr. Boyden (2) has likewise got sugar from the urine of a case of Double Pneumonia, and from that of an advanced nephritic patient. On testing the urine of the latter, however, four days after his first trial, he could not discover any sugar.

More lately, saccharine urine has been discovered to exist in many cases of Whooping-Cough by Dr. Gill (3). The quantity of sugar is variable, but is generally small, only a trace being sometimes present. On several occasions
(1) Comptes Rendus 433 p. 606


(3) Schiren - Op. cit. 1857
however he has found it an amount sufficient to increase the specific gravity considerably. In one case in which there was considerable amount of sugar in the urine, rapid amendment followed treatment by nitric acid, which is Dr Gibbs remedy in Hooping Cough.

The administration of certain drugs would appear also to cause the presence in small quantity of sugar in the urine. Regnier (1) has found this to be the case with the gum of rhizine and quinine. Sugar has been found by Dr Byrdin (2) in the urine of a man who was having arsenic administered to him for the cure of a skin disease. Here however it is probable that the presence of the sugar may have been owing to the Contrain of the skin. It may be mentioned here that Kozi, has found Tartar emetic to increase the amount of sugar in arterial blood. He does not say whether it appeared in the urine or not. Dr Diabetic Mellitus

In Diabetic mellitus the amount of sugar passing out of the system is so great as of itself to constitute the essence of the malady; the quantity being sometimes so great as twenty or thirty ounces.

Sugar in other Secretions. The other modes in which sugar may be excreted from the economy when in too large amount in the blood I shall briefly notice.
(1) London med. gazette 1837
(2) Physiological Chemistry I 289
(3) American Journal of Medical Science
That sugar exists in the saliva of diabetes was first pointed out by Dr. McInerney of Glasgow (1). Lehmann found sugar in this secretion in a case of acute Rheumatism (2). Bernard however could find no saccharine matter in the pure saliva, so that it is likely that the sugar when found may be secreted from the mucous membrane of the mouth.

Mr. McInerney was the first to suspect that sugar might be present in the cutaneous secretion of diabetes, but he failed to detect it. It has been found however by other observers, among others by Dr. Charles Frick of Baltimore (3).

It was to be expected from the proceeding that the secretion of the intestinal mucous membrane would contain sugar in diabetes; and it has been proved to do so. Sugar has been observed in the stools of diabetes both by Mr. McInerney and Frick; and its presence in the intestine has been proved in another way. Mr. McInerney by giving an emetic of sulphate of zinc after a full meal of flesh to a diabetic and also to a healthy man, found that the vomit of the diabetic contained, while that of the other showed no appearance of sugar. He interpreted this as proving that sugar was formed from the food, but as this hypothesis, as we have seen, has no
(1) Wood's Practice of Medicine
other foundation it must be thrown aside.

Sugar, I have said, is excreted from the air passages. Whether it is to be found in the nasal mucus, I do not know, but probably it exists there. It has been detected in expectorated mucus by Dr. Francis (1), and by Dr. Bryden (2). Frequently patients complain of their mucus as being unusually sweet. But whether this is owing to the presence of sugar or not may be questioned. In a pathological case of this sort I could find no sugar either in the mucus or in the urine.

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Causes of abnormal elimination of sugar by the excretory organs.

That sugar does not pass away by the excreting surfaces on account of any morbid attraction of these organs for the saccharine matter, I will take for granted; and proceed to investigate the agencies by which the blood is overloaded with sugar so as to make it necessary that the saccharine substance should be eliminated before
decomposition can take place.

To me it appears that the great mistake committed by investigators into the pathology and proper treatment of Diabetes is that they seem to take it for granted before they commence their researches that for all cases there is the same cause. But the facts which we know in relation to this disease point to a very different opinion. Artificial glucosuria may be brought on in a variety of ways, and it is likely that true diabetes may have causes just as various. Again, from observation of the disease itself Dr. Poant speaks thus: "Within the last twenty-five years I have seen more than a score of upwards of five hundred cases of Diabetes; and of this great number as far as minor concomitant symptoms have been concerned, no two cases have been exactly alike, or have benefited by exactly the same treatment: its greatly diversified is this apparently simple form of disease."

For the preternatural abundance of sugar in the blood two classes of causes have been assigned, one class bringing about the too great pouring in of sugar into the blood, and the other presenting obstacles to its elimination by the natural methods. It is evident that in either of these ways sugar would collect in the blood in too great quantity, and it is possible that in either
of them the disease Diabetes Mellitus might be produced.

If this condition of the system be dependent on the too great supply of sugar to the circulating fluid, it must be (unless in the artificial injection of sugar into the blood), that the fault is either in the quantity absorbed from the alimentary canal, or in the excessive glycogenic action of the liver.

Excess of Sugar in Alimentary Canal. We have seen that the consumption as food of too great an amount of sugar or of those matters which may be changed into sugar will in some circumstances cause the appearance of glucose in the urine; and it is likely that the glucosuria in this case is caused by the excessive amount of the saccharine element absorbed into the blood from the alimentary canal. Supposing however that diarrrhea of digestion is capable of causing Diabetes, it might be said that in this case first at least of the abnormal liberation of sugar is due to the disordered condition of the bowels which follows the excessive employment of sugar as food. But when starch is eaten the same objection cannot be so well made. We shall see afterwards how the large amount of saccharine element swallowed may not prevent of the conversion of the whole of it into the animal sugar of the blood, and in this way be a cause of glucosuria.
But whatever may be the immediate cause, no doubt exists of the fact that immoderate use of sugar in the food will in favourable conditions produce Diabetes. In addition to the examples already given, I may quote Dr. Pout when writing on the treatment of this disease: "I have seen," he says, "a few saccharine foods taken in a few hours all that I had been labouring for months to accomplish." In such cases the amount of sugar in the urine must not have been increased simply by the addition of the sugar contained in the food, but also by the deleterious influence of the glucose on the system highly predisposed to the throwing off of sugar.

A remarkable instance of the influence of saccharine food in bringing on Diabetes has been lately brought under my notice. Out of a numerous family, two members, one a male and the other a female, have had Diabetes, and the former who lived to be an adult has died of the disease. It was noticed that these two only of the whole family had from their childhood a ravenous appetite for sugar and all manner of sweets, which were gratified to the utmost.

They Diabetes brought on in this way does not cease when the exciting cause of the disease is removed, may be owing either to a habit acquired by
the system, as it were, of having an excessive amount of sugar in the circulation, or be the effect of the indigestion induced. That the former idea is not an absurd one is evident from the statement of Dr. Banting regarding the bad effects of even a small quantity of free sugar in cases which had been improving under treatment. But the effect could not be owing to irregularity of the primary digestion.

Dr. Banting's theory of diabetes should be mentioned here; for he believed the disease to depend upon an abnormal amount of sugar absorbed into the system from the alimentary canal. Though the sugar might not be taken in the food, he thought it would be manufactured out of the other principles in the stomach by the "reducing power" of that organ, and to a certain extent without any deviation from the normal changes. In diabetes, he believed, the reducing function might be in excess, but whether or not, the "converting function" was not in its normal state of activity and hence the sugar was not changed before absorption, as it ought to be, into the oleaginous and albuminous principles, and was therefore not fitted for the use of the economy.

It is from the belief that a considerable amount
(1) Frankins Retrospect 1858 I p. 105

(2) Op. cit. 1858 II p. 144

(3) Op. cit. 1858 I p. 113
of the sugar of ordinary Diabetes comes from the amylaceous or saccharine matter of the food, that the usual dietetic treatment of this disease is objected to, and the food results of taking these principles from the food in diabetic patients is confirmatory of this opinion.

Dr. William Budd has some time since taken to the paradoxical plan of treating this disease by throwing into the alimentary canal as food an extraordinary amount of sugar. And he gives several cases where he did this with success. How such treatment should be calculated to alleviate the malady is to me altogether inexplicable; and Dr. Williams Dr. Burst of Salop Infirmary and others have in their trials found it prejudicial.

Dr. Bence Jones however gives the history of a case, where glycosuria always followed the giving of even a small quantity of bread, but hardly at all the administration of a moderate allowance of cane sugar or honey.

Excessive Glucogenesis at the Liver. We have seen that in various ways the glucogenic function of the liver may be rendered more active or the contrary. That an increase in the quantity of sugar formed here may give rise to Diabetes is held by Bernard. He found that mechanical pressure when the liver is sufficient to produce saccharine urine, no doubt by increasing the
(1) Archiv. General de Ind. Sept. 1837
vivacity and force of the circulation in the liver. The same physiologist, as is well known, produced Diabetes by puncturing the floor of the fourth ventricle of the brain, and believes that it was the increased secretion at the liver which led to this result. To such a view of the matter objection has been taken, in as much as, it is said, the shock produced by cutting down upon the fourth ventricle is so great as to prevent the normal destruction of sugar, and this is insufficient explanation of the glucosuria. But in reply it may be urged that it is only when a particular shot of the ventricle is touched that the sugar appears, and that when the wound is too deep, and the shock of course made greater, the urine ceases to be saccharine. Again, we have the fact that after section of the hepatic-mesenteric junction of the liver by division of the splanchnic or mesentric nerves, it may be renewed and even carried the length of impregnating the urine by puncturing the floor of the fourth ventricle.

It was ascertained by Dr. Martin (1) that the injection of various stimulants into the portal vein is sufficient to influence the effect of sweetening the urine. He explains this fact by saying that these substances irritate the liver, and so cause an impression to be
carried to the medulla by the pneumogastric nerves which is returned to the liver by the sympathetic system, and brings about the excessive secretion of sugar by that organ. If we take into view in connexion with this the only satisfactory explanation of the influence of the nervous system upon secretion, namely, that of regulating the quantity of blood sent to a gland, we shall see a perfect correspondence between the views of Harvey and those of Bernard, the latter it will be remembered, believing that fluo- genesis in the liver is increased when the abdominal circulation is rendered more active.

That the disease Diabetes has some connexion with the fluo-genic function of the liver is quite consistent with the observation that in many instances of this disease, perhaps in all, the elimination of sugar by the kidneys is most active at the time when the maximum amount of sugar is produced at the liver, that is three or four hours after a meal; and this even when a diet purely of nitrogenous substances has been adhered to. It agrees also with what has been observed in relation to the amount of urea excreted by diabetics. Though this substance was supposed at one time to be very deficient in highly
(1) Sec. Lazelle 1837
(2) library of Medicine. Art. Diabetes
saccharine urine, it has been shown by the Gregor of Glasgow, Dr. Christian, and others that in general the urine passed from the body of a diabetic in twenty-four hours greatly exceeds the quantity secreted by a healthy individual. And we have already, seen (page 35) how in all probability the nitrogenous substance giving origin to sugar at the liver, have their nitrogen carried away from the body in the form of urea. So that an abnormal amount of urea in the urine of diabetics is just what should have been expected on the supposition that too much sugar is formed by the liver.

Granting that excessive activity of the gluco-glucuronic function of the liver does give rise to saccharine urine, we are still led on to inquire what it is in Diabetes mellitus that bring about this abnormal activity. From the frequency of chest complications in this disease, Bernard has been led to suppose that the pulmonary affection is the cause of it, and that it operates by sending an impression along the pneumogastric to the medulla, which is reflected by the sympathetic to the abdomen, and increases the activity of its circulation. Of course whatever is capable of irritating the point of the medulla which as he believes precedes over the portal circulation, will have the same
(1) Dublin Medical Gazette Jan. 13th, 1838
effect as disease of the lung and sometimes directly made with a needle. Disease of that portion of the cerebrospinal axis will produce this result. Bernard found that dogs struck on the head a violent blow passed saccharine urine, from implication, as he thought, of this part of the cerebellum. Mr. Gaskell found large quantities of sugar in the urine of men labouring under concussion of the brain. He gives in particular the case of a man who had in consequence of cerebral concussion paralysis of the limbs without any impairment of their sensibility. Sugar was found in his urine, and increased in amount every day till the paralysis showed signs of passing off. It is more likely, however, that concussion will cause glycosuria by interference with the normal combustion of the sugar.

The observation of Harlay upon the action of stimulants injected into the portal vein suggests the idea that in some cases of Diabetes especially in those associated with the symptoms of dyspepsia the disease may depend upon the contents of the portal vein having too exciting an effect upon the liver. It is possible that the absorption of matters resulting from an abnormal digestion, and it may be, more stimulating than the products of this process in a state of health may irritate
the hepatic organ to excessive secretion of saccharine matter. I have known a case where the patient himself made the observation that his urine was always sour when his stomach gave him most uneasiness. In one the surviving one of the two cases above referred to as being the result of indulgence in saccharine substances rapid improvement has followed the employment of a diet consisting chiefly of arrow-root; leading to the conclusion that indigestion in the case of this lady was the cause of the malady.


I shall now consider the second class of conditions under which sugar is said to collect in the blood so as to appear in the urine and other exceptions; these, namely, in which the sugar is not got rid of by the natural dejecting powers of the economy. That in some cases of diabetes this is the essence of the malady is in three conditions is proved by the diminished amount of carbonic acid given off from the bodies of diabetics, and the consequent lowering of their temperature; these things showing that an abnormally small quantity of fuel is consumed. The non-consumption of sugar in sufficient amount may be owing to the quality of the sugar itself, which may not be of the variety most
readily decomposed in the blood, or it may be dependent on an abnormal condition of those tissues or fluids concerned in its decomposition.

Abnormal Quality of the Sugar. All the varieties of the saccharine principle differ in the facility with which they undergo decomposition in the body. When cane sugar or the sugar of beet-root is injected into the blood, no effort seems made by the system to decompose it; for it passes out by the urine in the same condition in which it entered the circulation. A very small quantity of it introduced into a vein will be found in the urinary excretion. With sugar of milk it is the same; only the blood seems able to endure a larger amount of it than of the cane sugar. If ordinary glucose be injected in small quantity into the blood it will be decomposed, and not a trace of it will be found in the urine. But glucoseuria abounds from the introduction of a much smaller quantity of the sugar than of the hepatic or animal sugar.

Magenie gives the following proportions of the quantities of the different varieties of sugar which may be injected into the blood without appearing in the urine.

Cane sugar 1  Vegetable glucose 50
Lactine 5  Hepatic sugar 240.
It is manifest from these facts that if the sugar obtained from food be not sufficiently changed, or if the sugar secreted by the liver be not of the right sort, saccharine matter must be eliminated from the kidneys. Is it likely that either of these conditions is fulfilled in the diabetic? Dr. Potts and Owen Cleeve have rendered such a disposition probable by proving that the sugar of diabetic urine differs from the hepatic glucose in being less readily decomposed; as previously stated, they hold it to be identical with the sugar of the grape. They maintain that the urine of all cases of true diabetes contains this "higher quality of the saccharine principle." But it is probable that in some instances the sugar of diabetes may be the same with that secreted by the liver. In diabetes it may happen that the higher quality of glucose gets into the circulation from the action of a proper ferment in the intestinal canal, whence it acts on the liver thoroughly to change the sugar of the food. And it may be that the want of such a ferment may also prevent the change of the glucogenic substance of the liver into hepatic glucose, it being merely carried the length of ordinary grape sugar. Of this, however, we have no proof. When too much sugar or starch is taken as food, it may happen
that its quantity is too much for the limited quantity of ferment. Or it may be that too much of it is taken up into the lacteals and so never comes under the influence of the ferment which operates upon the saccharine matter of the portal vein.

Of these conditions of the body which prevent the normal destruction of sugar, the first I shall mention is Pulmonary Disease. It has been supposed by some that affections of the lungs act in producing glucosuria by excluding oxygen from the blood. This opinion is certainly favoured by the frequency of glucosuria in chest affections, and by the experiment of Reynolds, in which he compressed the trachea and found sugar as a consequence in the urine; also by the presence of sugar in the urine of persons who have been inhaling chloroform or ether. But it cannot be maintained that sugar in the urine is invariably to be met with when exclusion of air is manifest; nor is it found in any degree proportioned to the want of due oxygenation of the blood.

And, to apply this doctrine to the pathology of Diabetes, we do not find the intensity of the disease measured by the degree of lesion of the lung. Tubercle which is supposed to be the form of lesion most nearly associated with Diabetes, is sometimes not to be found at all.
in the lungs of Diabetics; and when present it would from all analogy seem to be a consequence rather than a cause of the excessive Ascarin in the system. Many have their lungs filled with tubules, without a perceptible trace of sugar in their urine. Again in ly, for the greater proportion of cases of Pulmonary Witheris it has never been proved that there is a deficient oxygenation of the blood. As has been already mentioned Bernard explains the influence of Pulmonary Disease upon the urine by the disposition that an irritation of the pneumogastric is produced, and by means of reflex action an excitation of the gluco-ergic function of the liver, just as by junction of the floor of the fourth ventricle. The advocates of the Pulmonary cause of Diabetes believe that the lesion of the medulla interacts with the nervous action of the lungs just as disease of these organs does. In regard to the urine after inhalation of Chloroform, War-ley finds that the quantity is very small if indeed there be any. When sugar does exist in it, this may arise from excitation by the Nervous of the Pulmonary branches of the pneumogastric, or from the Chloroform being carried to the liver in the blood it may stimulate the organ and increase the amount of
lugar secreted by it. Another argument against the pulmonary cause of diabetic urine is, that in cases where oxygen is deficient instead of sugar in the urine we should expect lactic acid. The blood being always an alkaline fluid cannot prevent the change of sugar into this acid by its own acidity as has been supposed by some. Whenever it had a tendency to too much acidity the acid would be eliminated by the kidneys from the circulation.

Deficient Alkalinity of the Blood. These last observations naturally lead us to the consideration of the theory propounded by Caillet that Diabetes depends upon the want of the alkalinity of the blood. He does not appear to restrict himself to the belief that the sugar which is not changed into fat passes into the form of lactic acid. And he imagines that it is the alkalies of the blood that have specially to do with the decomposition of sugar. He shows that the caustic alkalies or their Carbonates mixed with a solution of sugar cause the saccharine principle to be decomposed when the solution is heated to near the boiling point. The sugar being in this way converted into a brown matter. He insists that sugar itself has no attraction for oxygen; that it is only the products of its decomposition
which have. Holding therefore such a view he recommends the giving of alkalies in Diabetes. 

I have already given my reasons for thinking that sugar is changed into lactic acid before it unites with oxygen. But apart from these, is it not highly improbable that alkalies act on the blood in sugar, as they do in a strong solution heated to near the boiling point? Then as pointed out by Poggio, no exertion of alkalies is found in the blood of diabetics. Their urine is often alkaline. Again, Poggio found as Lehmann had done that the addition of an alkaline to a solution of grape sugar before injecting it into the blood does not diminish its tendency to appear in the urine. 

As confirmation of his theory however, Lehmann gives cases where the administration of alkalies cured the Diabetes, and he is supported by M. Vallez who has also recorded one or two. One case of Diabetes is said by the latter author I think, to have been brought on by the too free use of acidulated drinks. The method of treatment by alkalies has not been found by other investigators to be a successful one. Lehmann in fact thought that the amount of sugar in the urine was increased.

It has occurred to me that the change of sugar
into fat may in some instances at least not go on as it does in the healthy organism, and that this may have something to do with the cause of diabetes.

To sum up then. The causes of the elimination of undecomposed sugar by the excretorium of the body may be, and probably are, various. 1st Excretion of sugar by the urine may be the consequence of indulgence to too great an extent in saccharine or amylaceous aliment. This however can scarcely be called a diætes. 2nd Diabetes may depend upon the want of a proper ferment to change the saccharine matter of the food into the heptatic variety of glucose. In such cases of course such the nutrituous diet be most serviceable. 3rd This disease may depend upon secretion by the liver of too high a quality of the saccharine principle. Here the bulky nutrituous diet can be of little service. 4th It may be owing to excessive secretion of heptatic glucose brought on by stimulation of the liver in consequence of indigestion. 5th The stimulation of the liver may owing to disease of the innervation of the abdominal viscera, or to reflex action excited by disease of the organs supplied by the vagus. 6th Ulcerousea may possibly depend upon deficient oxygenation of the blood, united with the
non-transformation of the sugar into fat.

Such appear to me to be the conditions, which may either of them cause saccharine urine. Possibly there are others, and it may be that some of the above mentioned are incapable of impregnating the urine with sugar; but they have never to my satisfaction been proved to do so.

I have thus completed what I proposed in beginning this essay. I have only to regret that owing to the hurried manner of its preparation, I have not been able by experiment to verify or contradict any of the statements made by the authors quoted, and that I have been obliged to quote many of them at second hand, thereby necessitating, I fear, many errors. I think it only just that I should own my obligation to the thesis of Dr. Blyden (ed. 1835) which treats of the same subject that I have chosen, and to which I am indebted for many of the facts related in this dissertation.

Pomersolle

Edinburgh, March 31st, 1839.