from vitellin, I verified the results by using $MgSO_4$, in accordance with the researches of Hammarsten ("Ueb. das Paraglobulin," "Pflüger's Archiv," 1878).

In conclusion, I would add a few remarks to those which I made in my former communication with reference to the relation between the globulins and the hemialbumose existing in seeds and the various bodies, such as conglutin, legumin, &c., which Ritthausen has extracted from them. I therein expressed my concurrence with Weyl's opinion that these caseins are the products of the alteration of the globulins effected by the alkaline solutions used in extracting them. I still maintain this view, but I think now that it is only a partial explanation. My observations, more particularly those on the peony, make it clear that a considerable proportion of these caseins is hemialbumose precipitated by the dilute acetic acid which is used in Ritthausen's method for throwing down the caseins from the alkaline extracts.

IV. "Some Observations upon the Hydrolytic Ferments of the Pancreas and Small Intestine." By Horace T. Brown, F.I.C., F.C.S., and John Heron, F.C.S. Communicated by Dr. W. Roberts, F.R.S. Received April 15, 1880.

We were requested a few months ago by Dr. W. Roberts to verify a statement, recently made by Musculus and De Méring, that *maltose* is a product of the action of an aqueous extract of pancreas upon starch-paste. During the prosecution of the inquiry, and while following up certain lines of experiment which suggested themselves from time to time, we have, besides fully confirming the results of the above-mentioned observers, ascertained certain facts which we believe are of some physiological importance in elucidating the still very obscure processes of animal digestion and nutrition.

I. *Hydrolytic Action of the Pancreas.*

The first observation upon the amylolytic action of the pancreatic secretion appears to have been made by Bouchardat and Sandras* in the year 1845. The general functions of the gland were more fully studied in 1856 by Claude Bernard,† and a few years later by Cohnheim ("Virchow's Archiv," 28, 241, 1863). Danilewski‡ in 1862, and Hüfner ("Journ. f. Prakt. Chem." [2], 5, 1872, 396), ten years later,

* "Des Fonctions du Pancréas, et de son Influence dans la Digestion des Féculents." "Compt. Rend.," 20, 1085.

† "Mémoire sur le Pancréas." 1856. "Leçons de Physiologie Expérimentale." Paris, 1856.

‡ "Ueber specifisch wirkende Körper des Natürlichen und Künstlichen Pancreatischen Saftes." "Virchow's Archiv," 1852, 25, 279.

isolated a soluble amylolytic ferment from the pancreas, the former observer by acidifying the aqueous infusion with phosphoric acid and precipitating with lime; the latter by the glycerine method first described by Wittich.

Hüfner found that the isolated body, which was still doubtless impure, contained 14·95 per cent. of nitrogen, but a less quantity of carbon and a greater quantity of oxygen than an ordinary albuminoid.

Until recently it has always been taken for granted that the fermentable sugar produced by the action of pancreas upon starch-paste is dextrose. Nasse, however, in 1878 ("Pflüger's Archiv f. Physiologie," 14, 473), attempted to show that the fermentable and cupric-oxide reducing body, obtained by the action of saliva upon starch, is a specific sugar which he calls *ptyalose*, and that the action of pancreatic juice appears to result in the production of the same body. Nasse did not isolate this hypothetical sugar, nor even approximately determine its specific rotatory power, but relied mainly upon its non-reduction of Barfoed's solution, and its doubling in reducing power on boiling with dilute acid, as evidence of its non-identity with dextrose.

In the early part of last year Musculus and De Méring published an important memoir ("Bull. Soc. Chim.," 31, 105), upon the action of diastase, saliva, and pancreatic secretion upon starch and glycogen.

They concluded from their experiments that the fermentable sugar produced in all these reactions is a mixture of maltose and dextrose. We have shown in a recent communication to the Chemical Society ("Journ. Chem. Soc.," 1879, 1, 648; "Liebig's Ann.," 199, 245), that *dextrose* can certainly not be included amongst the products of the action of malt-diastase upon starch. The experiments we are about to describe will however afford ample proof of the correctness of that portion of the above statement of Musculus and De Méring referring to the action of pancreatic extract.

Our experiments were made either with the aqueous infusion of the gland, or with the actual tissue itself in a finely divided state.

The first method is by far the most convenient, and is the one which we generally adopted when studying the action of the pancreas, but it will be seen that certain tissues can produce under some circumstances hydrolytic effects which their aqueous infusions are incapable of exercising.

With a clear aqueous infusion of the gland the course of experiment did not differ materially from that which we employed when investigating the action of malt-diastase upon starch (*loc. cit.*). As a rule the infusion had no power of reducing cupric-oxide, hence it was not necessary to apply any correction to the quantity of cupric-oxide reduced by the transformation products.

In cases where the transformation was effected by the actual tissue itself, this was previously dried very rapidly in a current of air at

35°C., a process which could easily be carried out without decomposition taking place. The dried tissue was used with a given volume of the experimental liquid containing a known quantity of the carbohydrate. The volume of the liquid was kept constant during the experiment, and the small increase in solid matter due to hydration was taken into consideration. Far more accurate results are obtained by this method than by attempting to estimate the correction for the total solids by digesting a given weight of the tissue in a given volume of water. In the latter case the solvent action of the water upon the tissue always differed somewhat from the solvent action of the solution of the carbohydrate employed.

When a clear infusion of pancreas, obtained by acting for several hours upon one part of the finely divided pancreas of the pig with five parts of cold water, is added to starch-paste at 40° C., complete limpidity is produced with extreme rapidity, and in from ten to fifteen minutes iodine ceases to produce any reaction for soluble starch or erythrodextrin. Careful observations at different periods of the reaction showed unmistakeably that the transformation in its first stages does not differ in the least from transformations of starch-paste made at 60° C. with aqueous malt-extract, which has not been previously heated to a higher temperature. When the specific rotatory power of the transformation products has reached $[\alpha]_{j\cdot 86}$, 162°·5, the cupric-oxide reducing power is found to be κ 49—50. When about 3 cub. centims. of the pancreatic infusion have been used for every grain of starch, the time occupied in fully bringing about this change is from forty to fifty minutes. The liquid now contains *maltose*, and an achroodextrin having all the properties of our *achroodextrin* ζ.

The maltose was proved to be identical with that obtained by the action of malt-extract by isolating it in its characteristic crystalline form, and by determining its specific rotatory and cupric-oxide reducing powers.

The composition of the matter in solution at this point is

Maltose.....	80·8
Dextrin.....	19·2
	100·0

which is that required by our No. 8 equation.

$$\underbrace{10C_{12}H_{20}O_{10}}_{\text{Soluble starch.}} + 8H_2O = \underbrace{8C_{12}H_{22}O_{11}}_{\text{Maltose.}} + \underbrace{C_{24}H_{40}O_{20}}_{\text{Achroodextrin } \zeta.}$$

On continuing to digest the liquid at 40° C., the values of $[\alpha]_j$ and κ undergo a little alteration, which is, however, very slow when compared with the previously rapid degradation of the starch-molecule.

The following is an example of such an experiment:—

90 cub. centims. of a liquid containing 3·5 grms. of starch-products, already reduced to the above point, were digested at 45° C. for twelve hours, with the further addition of 10 cub. centims. of fresh pancreatic extract.

At the end of that time, the liquid having remained perfectly free from organic life, the starch-products yielded on analysis the following corrected numbers:—

$[\alpha]_{j3\cdot86}$	128°·7
$\kappa_{3\cdot86}$	66°·8

corresponding very closely with the composition

Maltose.....	55·5
Dextrose	32·7
Dextrin	11·8
	100·0

The united evidence afforded by many such experiments as the above proves conclusively that the *prolonged* action of a pancreatic infusion yields results differing materially from those obtained under similar conditions with malt-extract. With malt-extract the hydrolytic effect upon the starch-products, after No. 8 equation is reached, is confined entirely to the conversion of the achroodextrin into maltose, the latter body being the final product of the reaction. On the other hand, an aqueous infusion of pancreas, whilst converting achroodextrin into maltose, sensibly hydrolyses the maltose to dextrose.

In order to put this important point of difference between the action of malt and pancreatic extract beyond all doubt, a solution of pure maltose was digested with an infusion of pancreas, in just the same manner as maltose had, on many previous occasions, been treated with malt-extract.

100 cub. centims. of a solution of maltose, containing 5·813 grms. of substance, were mixed with 20 cub. centims. of a clear aqueous infusion of pancreas, the infusion being added in successive portions of 5 cub. centims. each. Temperature of digestion 45° C.

In four hours the optical activity of the solution had fallen from $[\alpha]_{j3\cdot86}$, 150°·0, to $[\alpha]_{3\cdot86}$, 148°·7; and after sixteen hours to $[\alpha]_{3\cdot86}$, 135°·1; the value of κ at the end of this time having risen from 61 to 67·3. The composition deduced from these latter numbers is

Maltose.....	83·8
Dextrose	16·2
	100·0

This experiment, repeated many times, always gave the same results, thus proving that the amylolytic agent of the pancreas is capable, as stated by Musculus and De Méring, of slowly converting maltose

into dextrose, a property which is not shared by malt-diastase. Both malt-diastase and pancreatic-diastase have, however, the property of hydrolysing the lowest achroodextrin of the series, a fact which we have proved by submitting to their action the isolated and purified achroodextrin ζ.

A series of experiments was now made with the object of ascertaining if the pancreas contains any ferment capable of inverting cane-sugar. It will be remembered that a cold aqueous infusion of malt possesses this property to a limited extent. The first experiments were made by digesting solutions of cane-sugar at 40° C., with 25 per cent. of an aqueous extract of pancreas (5 of water to 1 of pancreas). As long as the solutions remained free from bacteria we never observed even the slightest inversion of the cane-sugar, the specific rotatory power of the solutions remaining constant throughout the experiment. If the digestion was carried on for a length of time sufficient to develop organic life, and a sensible evolution of gas, a marked inversion of the sugar set in, a result which is not however attributable to any soluble ferment derived from the pancreas.

From some observations made at a later period of the inquiry it seemed possible that the gland-tissue itself might have an effect which was not shared by its aqueous infusion. An experiment was consequently made in which the finely divided pancreas itself was digested with the cane-sugar solution. Here again, however, as in the former case, absolutely no inversion took place.

J. Béchamp, in his experiments upon the action of various tissues upon starch-paste and cane-sugar, states that the pancreas has a very slight invertive action upon cane-sugar ("Les Microzymas," p. 68). In an examination of the details of his experiments, however, it is clear that he only obtained evidence of invertive action after the gland had been in contact with a sugar solution for several days, and in no cases without the previous appearance of bacterial life, to which doubtless the effects are attributable; the invertive action of some of these organisms being almost as well marked as that of the Saccharomyces.

II. *The Hydrolytic Action of the Small Intestine.*

Claude Bernard first called attention to any distinct hydrolytic action of the small intestine. He found that a solution of cane-sugar, inclosed within a portion of the intestine ligatured above and below, or placed in contact with an infusion of its mucous membrane, speedily acquired the property of reducing a cupric solution.

Bernard found this property common to the small intestine of the dog, pig, rabbit, rat, and various other animals, and looked upon the invertive action as one of the most important functions of the *succus entericus*.

The observations made from time to time upon the *amylolytic* action

of the secretions of the small intestine are somewhat conflicting. Thiry ("Wien Sitzungsber.," 50, 77), in 1864, by isolating a portion of the small intestine of a living animal, obtained an albuminous secretion which he found had no action upon starch, and with this observation Funke agrees. On the other hand, Masloff ("Unters. Physiolog. Inst. Heidelberg" [2], 1879, p. 290), Frerichs, and Busch ("Virchow's Archiv," xiv, p. 140) state that the small intestine has the power of transforming starch.

When commencing to investigate the hydrolytic action of the small intestine of the pig, we made use of an aqueous infusion of the tissue, made by acting upon one part of the well-washed and finely-minced intestine with five parts of water for from ten to fifteen hours.

Such an aqueous extract was prepared from three different portions of the intestine.

(1.) A portion of the *duodenum* immediately below the glands of Brunner.

(2.) The *agminated Peyer's glands* (Peyer's patches) cut from the jejunum.

(3.) Portions of the *jejunum* and *ileum* not containing any of the agminated Peyer's glands.

20 cub. centims. of the clear filtered infusion made with each of the above portions of intestine were added to 100 cub. centims. of a cane-sugar solution containing 4·557 grms. of sugar per 100 cub. centims. On digesting for three hours at 40° C., and allowing subsequently to stand in the cold for twenty-four hours, scarcely a trace of inversion was found to have taken place.

The action of equal quantities of the various infusions upon starch-paste was scarcely more marked; about 3 grms. of starch, in the form of starch-paste, being employed in each case, at a temperature of 40—45° C. After digestion for sixty minutes, none of the samples of starch-paste showed any signs of limpidity. After sixteen hours, No. 1 was found limpid, but contained only soluble starch; No. 2 was perfectly limpid, and contained a little erythrodextrin; whilst No. 3 was absolutely unacted upon, the gelatinisation being still as perfect as at the outset of the experiment.

The pig, from which was derived the intestine used in the above experiments, had been killed after fasting for thirty-six hours. It occurred to us that the absence of any well-marked amylolytic action might be due to this fact, and that a different result would probably be obtained by infusing an intestine in which the various glands had been more recently active. In order to test this, an animal was killed about two hours after administering a liberal allowance of barleymeal. In this case the aqueous extract of the small intestine possessed a somewhat greater action upon starch than in the previous experiment, but the transforming power was still very feeble, more than two hours

being required for the production of limpidity in the starch-paste containing the most active of the three portions of the intestine, which was in this, as in the former case, the region of the jejunum and ileum containing the Peyer's patches.

It is possible, as was first shown by Berthelot, to obtain a clear aqueous infusion of ordinary yeast, which is capable of exercising a very decided invertive action upon cane-sugar. The action of this aqueous infusion is, however, feeble when compared with the inversion produced by actual contact of the yeast-cells themselves.

Reasoning from this fact, it seemed to us probable that, in the case of the intestine, far more pronounced hydrolytic results might be expected from acting with the tissue itself, than from merely using its aqueous infusion. This was found to be the case.

In the following experiments the different portions of the small intestine, after thorough and prolonged washing, were dried rapidly in a current of air at 35° C., and were divided into very fine shreds, which were immersed directly in the solutions under examination. The intestine was taken from a pig of eight months old, killed during the period of digestion.

The solution of cane-sugar employed contained 3·020 grms. of sugar per 100 cub. centims.

To every 100 cub. centims. of the solution were added 5 grms. of the finely divided dry intestine. Temperature of digestion, 40° C.

All the determinations were made by the optical method.

Comparative Action of the different portions of the Small Intestine of the Pig upon Cane-Sugar.

Portion of the small intestine.	Percentage of cane-sugar inverted.			
	After 1½ hrs. at 40°.	After 3½ hrs. at 40°.	After 16 hrs. in the cold.	After further digestion for 5 hrs. at 45°.
(1) Duodenum immediately below the pylorus, containing Brunner's glands	No action.	No action.	No action.	13·0
(2) Duodenum below the glands of Brunner	No action.	No action.	10·9	13·0
(3) Jejunum, not including any of Peyer's patches	..	14·0	19·5	25·1
(4) Ileum.....	..	14·0	19·5	25·1
(5) Agminated glands of Peyer (Peyer's patches), cut from the jejunum.....	9·2	18·4	24·6	26·7

Action of various portions of the Small Intestine upon Starch.

The action of the *tissue* of the small intestine upon starch-paste, as upon cane-sugar, is decidedly more energetic than that of its aqueous infusion. Limpidity of the starch-paste is, however, not rapidly brought about, and when produced, the resulting soluble starch is very stable, and resists any sensible hydrolysation for a considerable time.

Strictly comparative experiments upon the amylolytic power of the various parts of the intestine were made in the following manner:—

30 grms. of potato-starch were gelatinised with 1000 cub. centims. of water, and 1 cub. centim. of malt-extract was added to the resulting starch-paste after cooling to 60° C. The moment limpidity was produced, the further action of this trace of malt-extract was arrested by boiling. The liquid, filtered perfectly bright on cooling, and containing, besides soluble starch, only a trace of erythrodextrin and maltose, was analysed; its specific gravity, optical activity, and cupric-oxide reducing power being determined. The solution was divided into portions measuring 100 cub. centims., into each of which were immersed 5 grms. of the dried and finely divided intestine. The various experimental liquids were digested under exactly similar conditions, in the water-bath at 40° C.

The portions of the intestine taken were as follows, the animal from which they were derived being a young pig, killed during active digestion of starchy food.

(1.) A portion of the duodenum taken immediately below the pylorus, and containing numerous Brunner's glands, which were very apparent in this case owing to active digestion being in progress at the time of the animal's death.

(2.) Lower portion of the duodenum not containing any Brunner's glands.

(3.) Agminated Peyer's glands taken from the jejunum.

(4.) Portions of the jejunum not containing any Peyer's patches.

(5.) Portions of the ileum, taken at the distance of a few inches from the ileo-cæcal valve.

The solutions gave the following iodine reactions, the dilute iodine solution being slowly added in each case up to an excess; thus ensuring the detection of any erythrodextrin.

After digestion for fifteen minutes—all deep blue—no production of erythrodextrin.

After thirty minutes—a very slight production of erythrodextrin in all.

After forty-five minutes—all gave a violet reaction. From the larger amount of iodine solution requisite to produce a permanent

coloration in No. 3, it was evident that the hydrolytic action was proceeding more rapidly in this than in any of the other solutions.

After three and a-half hours—Nos. 1 and 2—deep violet reaction. No. 3 contained only a trace of unconverted soluble starch, and no erythrodextrin.

Nos. 4 and 5, violet reaction, but much lighter in tint than Nos. 1 and 2.

After the digestion for three and a-half hours at 40°, and lying in the cold for sixteen hours longer, the various liquids were fully analysed. The corrected results are here given :—

Portion of the intestine.	3½ hours at 40°.	16 hours in the cold.	
	$[\alpha]_{j3\cdot86}$.	$[\alpha]_{j3\cdot86}$.	$\kappa_{3\cdot86}$.
(1) Duodenum, with Brunner's glands	179°·8	149°·3	41·7
(2) Lower part of duodenum	163°·4	140°·7	47·8
(3) Peyer's patches	148°·3	122°·3	63·3
(4) Jejunum	159°·7	133°·0	53·0
(5) Ileum	157°·2	134°·9	50·6

Upon calculating the composition of the transformation products from the above numbers, a very remarkable fact was brought to light. *Maltose* was present in only one case, that of No. 3, the whole of the cupric-oxide reducing body consisting in the other cases of *dextrose*. The percentage composition of the products is here given.

				Calculated.		Found.	
(1)	Dextrose	41·7	....	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$
	Soluble starch and dextrin	58·3	....	150°·3	41·7	149°·3	41·7
		100·0					
(2)	Dextrose	47·8	....	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$
	Soluble starch and dextrin	52·2	....	140°·7	47·8	140°·7	47·8
		100·0					
(3)	Maltose	16·6	....	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$
	Dextrose	53·1	....	122°·0	63·3	122°·3	63·3
	Dextrin	30·3	....				
		100·0					

(4)	Dextrose	53·0	....	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$
	Soluble starch and dextrin.....	47·0	....	132°·6	53·0	133°·0	53·0
		100·0		Calculated.		Found.	

(5)	Dextrose	50·6	....	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$	$[\alpha]_{j3\cdot86}$	$\kappa_{3\cdot86}$
	Soluble starch and dextrin.....	49·4	....	136°·3	50·6	134°·9	50·6
		100·0		Calculated.		Found.	

The question now arises—has the dextrose obtained in these experiments passed previously through the stage of maltose, or has it been derived more directly from the starch?

Direct evidence, as well as that furnished by analogy, points strongly to the former proposition being the correct one. We have seen, in four out of five of the experiments, that the soluble starch resisted very persistently the hydrolytic action of the ferment. Where this resistance to transformation was least strongly marked, as in the experiment with the Peyer's glands, a little maltose was found.

The conclusion seemed a fair one that we had here to deal with a remarkable hydrolysing agent, differing, in its relative action upon starch and starch-products, from that of any other known ferment of its class; an agent which is in fact capable of hydrolysing *maltose* with greater ease than *soluble starch.*

On further experiment this surmise proved correct.

All portions of the small intestine exert at 40° *a rapid hydrolytic action upon maltose; an action, however, which varies in intensity in different parts of the intestine, and is far more energetic than that of a similar portion of the intestine upon starch-paste, soluble starch, the higher dextrins, and even cane-sugar itself.*

After thoroughly washing the small intestine of a pig, the portions of the jejunum containing the agminated Peyer's glands were cut out, rapidly dried at 35°, and cut into fine shreds, 5 grms. of which were immersed in 100 cub. centims. of a solution containing 3·107 grms. of pure maltose.

The mixture was digested at 40° for sixteen hours, and at the end of that time it was found that *the maltose had been entirely converted into a dextrose* which possessed the same specific rotatory power and cupric-oxide reducing power as ordinary dextro-glucose, with which it was doubtless identical.

All portions of the small intestine exert, *cæteris paribus*, a much more rapid and complete action upon maltose than upon cane-sugar, and the hydrolytic effect of the agminated Peyer's glands upon either of these carbohydrates is far greater than that of any other portion of

the small intestine, either for equal weights or for equal areas of the tissue.

We have satisfied ourselves of the truth of these statements by numerous experiments.

The following results exhibit the relative action upon maltose and cane-sugar of (1) the agminated Peyer's glands of the jejunum, and (2) of the adjoining portions of the jejunum containing, besides the glands of Lieberkühn, only solitary Peyer's glands. The experiments were conducted under exactly similar conditions, 5 grms. of the dried and finely divided intestine acting in each case upon 3 grms. of the carbohydrate dissolved in 100 cub. centims. of water.

1.—Action of agminated Peyer's Glands of the Jejunum upon Cane-Sugar and Maltose.

	Percentage of carbohydrate hydrolysed.			
	1½ hours at 40°.	3½ hours at 40°.	After 16 hours in the cold.	5 hours more at 45°.
Cane-sugar ..	9·3	18·4	24·6	26·7
Maltose.....	15·4	33·9	52·2	74·3

2.—Action of the Jejunum, without agminated Peyer's Glands, upon Cane-Sugar and Maltose.

	Percentage of carbohydrate hydrolysed.			
	1½ hours at 40°.	3½ hours at 40°.	After 16 hours in the cold.	5 hours more at 45°.
Cane-sugar ..	10·9	13·6	21·7	24·4
Maltose.....	4·2	26·6	38·6	57·9

These experiments, in conjunction with those upon cane-sugar, described at p. 399, prove that the activity of the small intestine upon saccharose is slow and incomplete, when compared with its power of converting maltose into dextrose; and also that, while the conversion of maltose into dextrose under the action of the intestine ferment is as continuous and uninterrupted a process as is its conversion by dilute sulphuric acid, the invertive action upon cane-sugar is decidedly limited, the action being either arrested or proceeding with extreme

slowness, when 25 per cent. of the total quantity of cane-sugar has been inverted. The reason for this limited invertive action is by no means clear, and the subject requires further investigation.

Claude Bernard, who first demonstrated the existence in the small intestine of a soluble ferment capable of inverting cane-sugar, considered that in this property resided one of the most important functions of the *succus entericus*. By injecting a solution of cane-sugar into the veins and cellular tissue of animals he demonstrated that this carbohydrate, after traversing the system, is eliminated weight for weight in the urine, without undergoing any modification or assimilation. In order that cane-sugar shall be assimilated by the animal or vegetable economy, it must first be *inverted*. The seat of the invertive action is in the small intestine itself.

If this function of the small intestine has the importance attributed to it by Bernard, it is in the highest degree probable that the relatively far more active maltose-hydrating ferment, coexisting with the invertive ferment, must possess some considerable physiological value.

It must be remembered that, under natural conditions, the amount of cane-sugar which an animal is called upon at any given time to assimilate is very small when compared with the amount of products derived directly from starch.

We cannot consider, under these circumstances, that so well-marked and striking a function of the small intestine as that of converting maltose into dextrose can be useless to the animal economy. The most probable explanation is that maltose is incapable of assimilation in its unaltered state, but has first to be broken down to the smaller moleculed dextrose, just as cane-sugar, prior to assimilation, is converted into the chemically less complex dextrose and levulose. This is rendered the more probable from the known similarity of composition of maltose and cane-sugar, both bodies belonging to the class of sugars represented by the formula $C_{12}H_{22}O_{11}$.

Whether maltose is capable, under any circumstances, of being directly assimilated is a question, the solution of which we must leave in the hands of experimental physiologists. Probably a series of carefully conducted injection experiments, similar to those made by Bernard with cane-sugar, would yield the desired information. It is true that the estimation of maltose in urine would be attended with greater difficulties than the estimation of cane-sugar, but these difficulties are by no means insurmountable.

It will be remembered that the action of artificial pancreatic juice upon gelatinised starch is very rapid, the transformation products in a short time containing 80 per cent. of maltose, which is but very slowly and partially converted into dextrose by a continuance of the reaction. The active agent of the small intestine, on the other hand, while exerting but little action upon gelatinised or soluble starch,

converts with great readiness maltose into dextrose. Thus we see that in the transition from colloidal starch to highly diffusible dextrose, the hydrolytic actions of the pancreas and small intestine *are mutually dependent and complementary to each other*, neither one set of actions alone being sufficient.

The small intestine does not contain a very active *amylolytic* ferment, because it is seldom or never called upon to act upon unaltered starch, the first portion of the work being completed by the pancreatic secretion. Brücke ("Wien. Sitzungsber.," 65 (3), 126), when experimenting upon dogs fed with amylaceous food, found that the soluble starch and erythrodextrin which were produced in the stomach at once disappeared on passing the pylorus, under the rapid action of the pancreatic juice.

We have now to consider more fully the part played by the three different sets of glands of the small intestine in bringing about the hydrolytic effects which we have described. These glands are known as—(1) the glands of Brunner; (2) the glands or follicles of Lieberkühn; and (3) the glands of Peyer.

Brunner's glands occur only in the duodenum. They are most numerous immediately below the pylorus, and resemble closely in structure the salivary glands, or minute portions of the pancreas. When a portion of the duodenum containing these glands is macerated in water, the liquid becomes extremely viscous, owing to the extraction of the special glandular secretion. This effect is best observed by taking the duodenum of an animal which has been killed during digestion. The viscid secretion, resembling in appearance submaxillary or sublingual saliva, has but a very slight amylolytic action. The portion of the duodenum containing the glands has only a very slight invertive action upon cane-sugar, but a somewhat more decided hydrolytic action upon maltose.

The glands or follicles of Lieberkühn consist of tubular depressions in the mucous membrane of the intestine, and are generally supposed to secrete the *succus entericus*, to which, however, the Brunner's glands must also largely contribute. Since Lieberkühn's follicles are pretty evenly distributed throughout the whole of the small intestine, and the hydrolytic effect of equal areas of the intestine varies very much in different parts, it is evident that these glands play no very important part either in the inversion of cane-sugar or in the still more active hydration of maltose to dextrose.

We believe that the variable hydrolytic action of the different regions of the small intestine is mainly if not entirely due to the relative frequency of the glands of Peyer. The solitary Peyer's glands occur most scantily in the upper portion of the duodenum, and here the hydrolytic effect is by far the least. As the solitary glands increase in number the action of the intestine becomes more strongly

marked, and finally the regions of the jejunum and ileum containing the agminated glands, or Peyer's patches, are the portions of the intestine which exert the most pronounced hydrolytic effect upon maltose, cane-sugar, and starch. These glands consist of small ovoid masses of adenoid tissue, embedded in the mucous membrane, and enclosing vast numbers of leucocytes. The glands are in intimate relation both with the vascular and lymphatic systems, each follicle being penetrated by blood-vessels, and surrounded by lymph sinuses which are in connexion with the lacteals of the villi.

The function of the Peyer's glands is by no means established. The opinion held by physiologists up to a few years ago that they discharge, by occasional rupture an intermittent secretion into the intestine, appears now to be abandoned in favour of the view that they are instrumental in absorbing material from the blood and chyle, which they elaborate and again transmit, in a modified form, in part to the portal blood, and in part to the lacteal system.

The property which the glands undoubtedly possess of hydrolysing maltose to dextrose, and of so rendering the starch products of the pancreatic digestion more fitted for nutrition, is probably one of these special functions of elaboration.

Our work on these matters has been necessarily restricted to the chemical side of the subject, and we must now, lest we should incur the charge of overstepping our *métier*, leave further observations in the hands of physiologists.

The following are the main points which we consider have been established by our experiments :—

(1.) The action of artificial pancreatic juice upon starch-paste or soluble starch at 40° C. is, in the earliest stages of the reaction, similar to that of unheated malt-extract acting at 60° C. and under, the composition of the starch-products becoming comparatively stationary when 80·8 per cent. of maltose has been produced.

(2.) Both malt-diastase and pancreatic-diastase are capable of hydrolysing the lowest achroodextrin to maltose.

(3.) Pancreatic-diastase is capable, by long continued action at 40°, of slowly but sensibly converting maltose into dextrose, a change which malt-diastase is incapable of effecting even under the most favourable circumstances.

(4.) Neither artificial pancreatic juice, nor the tissue of the gland itself contains any ferment which is capable of inverting cane-sugar.

(5.) The small intestine is capable of hydrolysing maltose, of inverting cane-sugar, and of acting feebly as an amylolytic ferment.

(6.) The action of the tissue of the small intestine in bringing about these changes is far greater than that of its mere aqueous infusion, and differs materially in different regions of the intestine.

(7.) The variability of the hydrolytic action of different portions of

the small intestine is independent of the relative frequency either of the glands of Lieberkühn, or of those of Brunner, but appears to be correlative with the distribution of Peyer's glands.

(8.) In the transition from colloidal starch to readily diffusible and easily assimilated dextrose, the actions of the pancreas and of the Peyer's glands are mutually dependent and complementary.

The pancreas readily breaks down the starch to maltose, but is capable only of a very slow conversion of the resulting maltose to dextrose. The Peyer's glands on the other hand, whilst almost powerless upon starch itself, take up the work at a point where the pancreatic juice almost ceases to act, and so complete the conversion of starch into dextrose.

V. "On the Ova of the *Echidna hystrix*." By Professor Owen, C.B., F.R.S. Received April 26, 1880.

(Abstract.)

The present communication carries forward the subject of monotrematous generation to a stage beyond those detailed in vols. 124 (1834), p. 555, and 155 (1865), p. 671, of the "Philosophical Transactions," and relates to the discovery of ova in the right uterus of a female *Echidna hystrix*, killed 14th September, 1879, and in the left uterus of one killed 30th August, 1879, at Towoomba, Queensland. These, with other specimens, killed between 30th August and 10th October, were transmitted to the author by Geo. Fred. Bennett, Esq., Corresponding Member of Zoological Society of London, and were received in February, 1880.

In the largest ovum the first fission of the germ mass, corresponding to that described by Martin Barry and Bischoff in the rabbit's ovum, had commenced but was not completed.

In other respects the ova of *Echidna* closely correspond with those of the *Ornithorhynchus* described and figured in the volume above cited, p. 555, Plate XXV, figs. 3–7. No further progress in embryonal development was detected; but the fission-stage strengthens the conclusion, previously arrived at, of the viviparity of the Monotremata.

The functional equality of both uteri in the genus *Echidna* corresponds with the equal development of the right with left female organs, in which it differs anatomically from the *Ornithorhynchus*.

The Society adjourned over the Whitsuntide Recess to Thursday, May 27th.