SOME PRACTICAL RESULTS

FROM THE

CHEMICAL EXAMINATION OF THE CONTENTS OF THE HEALTHY STOMACH.

BY

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(*From the Laboratory of the Royal College of Physicians, Edinburgh.*)

PRINTED BY OLIVER AND BOYD, EDINBURGH.

MDCCCXCIII.

READ BEFORE THE MEDICO-CHIRURGICAL SOCIETY OF EDINBURGH, 18TH JANUARY,
AND REPRINTED FROM THE EDINBURGH MEDICAL JOURNAL, 1893.

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In the *Edinburgh Medical Journal* for 1871 you will find some notes on a case of dyspepsia, in which Dr Affleck washed out the stomach. This, I believe, was the first introduction of Kussmaul's procedure in Great Britain. Since then the stomach-tube—then a pump, now a siphon—has effected a revolution in our treatment of gastric disorders. For even if a practitioner does not personally use it, vicariously his knowledge of such maladies has largely increased. The stomach-tube is in some cases curative, in many palliative, in most educational. To-night it will be chiefly educational; and if the following paper appears to be of a too experimental and too little clinical character, it is only because I consider the experimental part the more important, and not because of any lack of available clinical material.

With regard to methods, this is not, I am afraid, the place to introduce a discussion on their relative merit or value,—a milligramme is of importance in the laboratory, many milligrammes are required to be of service in practice. I need only say that the presence of hydrochloric acid combined with proteids in the stomach is very generally conceded by observers, whatever the method be that is employed to detect it.

While experimenting on the resistance of certain micro-organisms to acids, I had occasion to use a dialyser, in which I placed nutrient material with solutions of hydrochloric acid of various strengths outside. I was at once struck with the fact that the fluid inside rapidly became more acid than that outside, while at the same time the acid solution inside did not affect micro-organisms so deleteriously as a solution of pure hydrochloric acid of similar strength. On further investigation it appeared that the hydrochloric acid, which was used outside, on dialysing through, seized hold of the proteids in solution, combining with them to form some definite chemical body, and that this body was of the nature of a compound acid. And again, although this compound acid had almost, if not absolutely, the same acid equivalent as pure hydrochloric acid, with regard at least to its action on phenol-phthalein, its presence inside the dialysing-tube did not prevent more free hydrochloric acid from coming through. Shortly after noticing this fact, I found that Hayem and Winter, in their book *Du Chimisme Stomacale*, had worked at the same matter, especially with regard to human peptic digestion; and that Ch. Richet, Villejean, Moritz, Van der Velden, Cahn and Mering, and Ewald had noticed that the presence of albuminoids neutralizes or masks the reactions of free hydrochloric acid in a solution.

The sequel will show that this faculty of hydrochloric acid for combining with proteids is valuable, both with regard to their digestion and to the carrying out of other processes in the stomach. Some experiments made on artificial digestion must first be recorded.

All digestion experiments performed in flasks are erroneous. If a dialyser be used with a solution of hydrochloric acid outside, of a suitable strength, not only will digestion go on more quickly, as Sheridan Lea has pointed out, but just as much hydrochloric acid will be taken up by the proteids as is required for their digestion. Lea, in his paper on digestion in dialysers, lays too much stress, I believe, on the mere mechanical diffusion of the peptones as they are formed, and too little on the constant diffusion of the alkali (for he experimented with pancreatic digestion), and the consequent presence continually of fresh alkali in the fluid inside the dialyser. In artificial peptic digestion, at least, if there is a highly albuminous material to digest in a flask, and a strong solution of hydrochloric acid be added, the action of the pepsine is hindered, while if a weak solution be used, there is probably not sufficient acid present to satisfy all the affinities of the proteids, and digestion is not complete. Digestion in a dialyser is exemplified by the following experiments:—

Experiment I.—Some beef broth, with gelatine added, was placed in the tube of a dialyser, the contents being fairly concentrated. A solution of HCl was poured round it. It will be noted in the tables (Tables I. and II.) that in an hour and a quarter the acidity rose from neutrality or slight alkalinity to more than five times the acidity outside, and in two hours and a quarter to nearly seven times as much. In twenty-four hours the acidity inside had fallen to a little less than twice that outside. The acidity outside during the experiment was ·036 per cent. The experiment was

Table I.

Hour	0	1¼	2¼	24
Acidity per cent. inside,	...	·216	·324	·108
Acidity per cent. outside,	·036	·04	·063	·069
Free HCl,	—	+	+	+

TABLE II.

Hour	0	1	2	3	24
Acidity per cent. inside, .	·018	·252	·288	·27	·234
Acidity per cent. outside,	·198	·198	·199	·199	·21
Free HCl, . . .	—	+	+	+	+

repeated with an acidity outside of ·198 per cent. hydrochloric acid. The acidity rose in the first hour to ·252 per cent., in two hours to ·28 per cent., and then fell. It will be noted that with very similar contents, but with very different acidities outside, the acidity inside rose to almost the same height. The next experiment, which is shown in Chart I., illustrates this point more clearly.

EXPERIMENT II.—Using a dialyser as before, I placed 100 ccs. of a mixture of milk and water—one-third milk and two-thirds distilled water—in the tube, and poured round it 3000 ccs. of a ·126 per cent. solution of hydrochloric acid of a temperature of 100° F. The whole was kept at this temperature, a small quantity of pepsine being added to the fluid inside. I repeated this experiment in exactly the same manner with half milk and half water, and again with pure milk inside the tube. The acidity in each case was estimated every quarter of an hour during the first hour, then every half-hour to the second hour, and at the fourth, fifth, and twenty-fourth hours. It is obvious from the chart that the course of the acidity inside, in each of the experiments, varies with the contents,—not solely, however, because of the law of osmosis, that the fluid of greater density attracts more of the lighter fluid; for if that only occurred here, the percentage of acid present inside would not rise above that outside. Another point seen is the rapidity with which hydrochloric acid dialyses through, and that it begins to do so at once, a point in which, I believe, it resembles Nature, and which I hope to prove below. The period at which the hydrochloric acid makes its appearance is, therefore, very instructive, being proportionately later the stronger the milk solution. In Nos. I. and III. there was a small quantity of free acid, not hydrochloric acid, driven off at first. The chlorine was estimated in each, but as the chlorine curves followed the acidity curves very closely, I have not added them to the chart. Another point which we may notice is that in the more dilute specimens the free acid at the end of the experiment is considerably greater in quantity than in the more concentrated. The fall in the free acid curve in No. III. of the series is unusual, and is either due to an error in observation at the fourth hour, or to a loss in specific gravity of the fluid inside from dialysis of peptones, leading to a diminished inflow of hydrochloric acid.

If one considers, with Foster, that milk contains, when fresh 4 per cent. of proteid, or with König 3·4 per cent., the proportions of acid to proteids are as follows at the one and a half hours, when the acidities were highest:—

	Acid as HCl.	Per cent. (Foster.)	Per cent. (König.)
1.	·198 gr.	14·8	17·5
2.	·234 gr.	11·7	13·7
3.	·324 gr.	8·1	9·55

But these numbers can only be approximate, for by an hour and a half the 100 ccs. inside had become several ccs. larger in quantity. Nos. II. and III. being more concentrated originally, attracted a greater quantity of water from outside, while less dialysed through in No. I. And again, by this time some of the proteid had become peptone, part of which had dialysed out, and necessarily affected the above proportions. However that may be, there is sufficient evidence from these experiments to prove that the larger the amount of hydrochloric acid present, as compared with the amount of proteid, the more of it combines. And as hydrochloric acid combines with proteids before digesting them, the amount of combined acidity serves as a guide in estimating the digestive power of the gastric juice, artificial or natural.

EXPERIMENT III.—In this experiment Nature was simulated as far as was possible, excepting the fact that the tubes in the dialyser were not kept moving. It was performed in the hope of obtaining an idea of the course of digestion of meat alone in an artificial digestion apparatus, and of enabling comparisons to be made between it and similar experiments on the digestive processes in man.

The apparatus used was as before, except that as the meal to be digested was a large one, six parchment tubes were used and three beakers, two tubes in each beaker, surrounded by 1000 ccs. of hydrochloric acid solution. As the experiment proceeded, at each time the contents were to be analysed a tube was removed and its contents tested. One tube was taken out of each beaker successively, and then the remaining one from each. The acidity of the fluid in the beakers and round the tubes was tested on each of these occasions.

The material to be digested was prepared as follows:—A large quantity of fibrin, sheep's heart, chopped into very small pieces, and some pieces of white of egg, boiled and cut into small cubes, was placed in a flask with 550 ccs. of water, boiled and cooled. When cool 20 ccs. of saliva were added to it, and the mixture kept at 40° C. for one hour. The water was then strained off, and the solids divided into six different parts of the same weight, approximately, each, and the water which they had been boiled in was added to each part up to the 70 cc. mark. Each parchment tube then was filled with the 70 c. cms. of material and placed in a beaker.

A small quantity was filtered and tested. It had an acidity of ·009 per cent. hydrochloric acid, with no free acid, and contained a trace of chlorine. The solution outside was made up of a ·18 per cent. solution of hydrochloric acid in water, the total chlorine ·1872 per cent.; and as usual it was warmed up to the temperature of the body before the dialysing tubes were put in.

It will be seen from Chart II., which is only an amplification of the previous one, that the acidity rises quickly, and at the second hour exceeds that outside; but that it does not rise so quickly as in the case of the milk, the proteids not being so finely divided, and therefore more difficult to digest. Free hydrochloric acid does not appear until one and a half hours after digestion has commenced, and never rises above ·04 per cent., the free acidity rising in the third hour to ·072 per cent. The material used inside being difficult to digest, and the experiment only lasting four hours, the acidity was highest at the fourth hour, though probably it would have fallen by the next hour if the experiment had been continued, as the total solids had begun to decrease. The right half of the chart is devoted to—above, the chlorine; below, the various proteids. The chlorine curves follow very closely the acid curves, the free hydrochloric acid being only slightly less than the total free acid; that is to say, that there is only a trace of organic acid present. The fixed chlorine rises from the beginning, and reaches ·042 per cent. It may either come from the chlorides in the meat, or from the action of the hydrochloric acid on the other salts.

On turning to the table of the total solids, it will be seen that they are most at the third hour in the filtered contents, and then fall considerably—from 2 per cent. to 1·4 per cent.—at the fourth hour. On the other hand, the inorganic salts are most at the hour and a half, though containing most chlorine at the third hour. They rise rapidly at the beginning, but fall almost as quickly at the end. Subtracting the ash from the total solids, the amount of the organic solids is obtained: it naturally corresponds very closely in amount to that of the total solids. The dotted black line drawn in this division indicates the total amount of proteids; it follows very closely the total organic solids. The total proteids are entered in this division for comparison, and because the division devoted to the individual proteids is not sufficiently large to include them. The fall in the amount of total proteids recovered at the first hour cannot be satisfactorily accounted for, but it is slight, and may be due to an error in working.

The fourth table, or the separation of the proteids into their four chief divisions, shows a fairly constant quantity of serum albumen and globulin, a greatly increasing quantity of acid albumen, in which the artificial digestion differs considerably from Nature, while the amounts of albumose and peptone present rise more gradually and regularly.

On comparing the total acidity curve, or better, the combined acidity curve, with that of the total proteids, it will be noted that they have a considerable similarity until after the third hour, when the proteid line falls a little, the acid line still rising. This may be attributed to the increased amount of peptones and albumoses, which form the most of the proteids present in the fourth hour, as I believe that these proteids take up more hydrochloric acid than the albumens that go before them in the proteid series.

It is very doubtful if there really was any lactic acid present during this experiment. The reaction with Uffelmann's reagent was very faint, and I am inclined to think with Rothschild that with a purely flesh diet the amount of lactic acid formed is very small, although, if there be carbohydrates along with the proteid, lactic acid fermentation set up by them may possibly influence the proteid, especially if it be in the form of myosin, and give rise to more sarcolactic acid than the proteid by itself could have done.

There was no sugar, alcohol, or acetic acid discoverable in the contents at any time. Von Jaksch recommends that, in testing the contents of the stomach, the acidity, etc., should be calculated from the unfiltered as well as the filtered fluid, and it may be readily conceived that the unfiltered contents may now be more acid, now less so than the filtered,—as the undissolved proteid is greater than the dissolved, or as the undissolved material contains much carbohydrate material.

In this experiment, therefore, and in several of those to follow, the fluid was tested under both conditions. The previous charts and remarks refer to the filtered contents. It was hardly necessary in this case, with no knowledge of the exact amount of solid material at the commencement, to estimate the total unfiltered solids, ash, etc., nor could the proteids be calculated with any accuracy. The acidities were in nearly every case either equal to or higher than those in the filtered half,—the chlorine curves, of course, taking much the same direction. For instance, the total acidity at the six periods of the experiment in the filtered were ·054, ·054, ·126, ·144, ·216, ·252; in the unfiltered, ·072, ·072, ·126, ·162, ·216, ·27; while the combined acidity kept much the same proportion: filtered, ·054, ·054, ·09, ·126, ·234; unfiltered, ·072, ·072, ·126, ·144, ·162, ·144,—falling below the filtered, however, in the last hour. This is due probably to much of the proteid being dissolved, and the indigestible matter left.

The free acidity is almost the same,—a slight increase here, a slight decrease there.

Experiment IV.—Noting, then, the result of digestion of almost pure proteid, I next performed a very similar experiment on *an almost pure carbohydrate.* I used potatoes for this, boiling a considerable number in an equal quantity of water, after having washed them. I made, in fact, a thick potato soup. On testing this I found that it had an acidity of ·054 per cent. HCl, and contained ·0468 per cent. chlorine.

Some of this mixture was placed inside the dialyser tube, and outside it 180 ccs. of a hydrochloric acid solution ·324 per cent., chlorine ·324 per cent. A small quantity of pepsine was added to the potato.

Table III.

Hour	0	3	24
Total acidity per cent. inside, ...	·054	·234	·252
Combined acidity, . .	·054	·09	·108
Free acidity, . . .	...	·144	·144
Acidity per cent. outside, .	·324	·216	·234

From this table (Table III.) it will be seen that though the acidity inside rapidly increases during the first three hours, it rises very little above that outside. At the end of the twenty-four hours the proportion is still much the same. The course of the combined acidity is very striking when compared with those in the former experiment; it only reaches ·108 per cent. The free acid, on the other hand, rises more rapidly to ·144 per cent., and remains there. It is therefore in greater quantity than the combined acid, the reverse of the previous experiments.

The fluid inside, at the end of the experiment, gave no biuret reaction, but reduced Fehling's solution, gave the tests for free hydrochloric acid, and coloured iodine and iodide of potash solution violet, showing the presence of starch and erythrodextrine.

Outside, the fluid reduced Fehling, gave the tests for free hydrochloric acid, biuret reaction doubtful, no starch.

On examining the proportion of chlorine inside and out, both at the third hour and after twenty-four hours, it was only slightly greater inside than outside. At the third hour—inside ·234 per cent., outside ·1716 per cent.; at the twenty-fourth hour, inside ·312 per cent., outside ·2796 per cent. The apparent discrepancy in the total quantity of chlorine is due to the evaporation of the fluids, the total at the end being 81 ccs. inside, 166 ccs. out. The total amount of chlorine at the beginning being ·686944 gr., at the end ·717 gr., an error of ·03 gr. in the working,—an error which I find almost constantly in working out chlorine results. This is due probably to the addition of a drop or two too much silver solution to make sure that the change of colour is permanent. This is especially the case when the fluid has contained free hydrochloric acid, for the colour produced by that acid on the proteids when the fluid is dried obscures the end of the reaction. This is also a source of some uncertainty as to the end of the reaction in testing the acidity with phenol-phthalein. In both cases considerable dilution with distilled water is advisable, and, in estimating the acidity, a larger quantity of phenol-phthalein than usual.

For this reason, again, no colour which changes its shade on transition from acid to alkali can be used with any accuracy at all. One which is colourless with the one and coloured with the other is requisite.

Experiment V.—Another similar experiment performed with a glucose solution resulted in the acidity after a few hours being equal inside and outside.

The deductions from these experiments are as follows:—1. That proteids in solution have the power of attracting, and probably combining with, hydrochloric acid. 2. That this acid so combined, even if greater in quantity and strength, does not prevent more free hydrochloric acid from dialysing through. 3. This combined acid, if placed in a dialyser with water round it, does not dialyse through so quickly as the uncombined acid. 4. That hydrochloric acid has no power of combining with carbohydrates, at least with starch or glucose. 5. That as digestion proceeds, and the lower proteids pass through the membrane, the combined acid passes through with them, and the total acidity inside falls. 6. If in one case the acidity outside be less, and in another greater, the contents being much the same, the acidity inside does not vary in proportion. 7. That, if the proteid varies in concentration, the acidity varies with it. 8. That the presence of pepsine increases the avidity with which hydrochloric acid combines with proteid bodies. The experiments on milk prove conclusively that the increase of acidity varies directly with the density of the contents; but considering the experiment on potato, it is seen that in these experiments it is not the density of the whole bulk of the contents which is the factor at work, but the proportion of proteids in them. In the series of digestions of milk, for instance, where the proportion of proteid is comparatively high, the acid curve is high. In the potato experiment the proportion of proteids is extremely small (König states that potato contains 2 per cent. of proteids), the combined acidity is low; while in the experiment on substances almost purely proteid in character, the acidity was still rising when the experiment had to be stopped.

9. It is possible to ascertain roughly the proportion of acid which combines with proteids. In the milk series it varies from 8·1 per cent. to 17·5 per cent., and considering, as above, that potato contains 2 per cent. of proteids, the amount of acid combined is between 7 and 8 per cent. at the third hour, but is probably higher, as the quantity of proteid which had dialysed was not noted; while in the third experiment, if the proportions are worked out, excluding the figures at one hour, which give a figure of 32 per cent., the

percentages of acid to proteid vary from 10 per cent. to 18 per cent.

10. It will be seen from all these experiments that hydrochloric acid begins to dialyse through at once: indeed, it has a remarkable power of rapid dialysis,—thirty-four times greater than that of common salt, according to Graham.

11. It will also be seen from Chart II. that the presence of a small quantity of combined hydrochloric acid in a solution prevents the free hydrochloric acid inside reaching the height of that outside. In all these experiments, as the acid outside was purposely in very large excess, so that it might resemble the proportionally inexhaustible reservoir of hydrochloric acid in the healthy body, so the amount of the acidity outside varies little during the experiment. The combined acidity represents the amount of digestive work done, the free acidity the potential power of further digestion.

12. The total solids in an artificial digestion, carried on in a dialyser, rise rapidly in the filtered contents until the second or third hour, and then fall; the inorganic part, however, falls sooner, reaching its maximum at the first hour or hour and a half.

13. The proteids in solution increase up to the third hour if in large pieces at first, up to the second if more finely divided, and then fall.

14. In unfiltered specimens with principally a proteid composition the acidity is greater than in filtered specimens, but before the end of digestion may fall below it.

The Course of the Acidity and its relations to the Contents of the Stomach in Man.

I now performed some similar experiments on *gastric digestion in man*, and to enable me to do this I was fortunate enough to find a patient suffering from a slightly dilated stomach, but whose chief affection was dyspepsia of a neurotic type. He was in the habit of washing out his stomach twice a day as a rule,—or rather, I should say, of siphoning off the contents of his stomach by means of a stomach-tube. He had suffered from dyspepsia for many years, and had been given everything that could be thought of in connexion with his ailment. Of a very nervous temperament, he used to imagine that the state of his stomach rose from all sorts of absurd causes; and, being somewhat of an empiric himself, he endeavoured to treat it apart from the suggestions of his medical man. A white pasty complexion, thin habit of body, quick, restless movements, and a constant desire and pleasure in talking of his illness in all its aspects, a readiness to impute any exacerbation to trifling causes,—as, for instance, any peculiar smell perceived as he passed along the street,—all pointed to the nature of his malady.

The local symptoms of which he complained were pain in the stomach, temporarily relieved by food, but coming on again three or four hours after, relieved by doses of bicarbonate of soda or by siphoning off the contents, one of these proceedings being invariable after every meal; as a rule the pain was of a gnawing character, but, now and then, especially after partaking of vegetables, became burning. The burning pain was relieved for a short time by the soda, and was perhaps due to organic fermentation. He complained constantly of his stomach being too acid, and put down all his discomfort and trouble to hyperacidity; but analysis of the contents failed to reveal any excess of acid. He had slight tenderness over the dorsal spines behind. His bowels were obstinate and required frequent solicitation, but there was no want of biliary pigment in the stools nor excess of pigment in the urine.

His case, in fact, was one in which the stomach nerves were hypersensitive to the irritation caused by free acids, in which digestion went on well until the free acidity had increased to that point at which the irritation commenced, and in which, after that point had been reached, his discomfort increased so much that he either had to drown the acidity, to the detriment of his digestive powers, with overdoses of soda, or had to remove most of his food with the stomach-tube before he had been able to absorb sufficient nourishment from it to help his nervous system or put flesh on his bones.

The addition of the soda was probably the least harmful, for the result could be passed on to the duodenum for further digestion there; but frequently, the action of the soda being but temporary, the pain would return, and with it the withdrawal of the stomach contents with the tube.

Arsenic, strychnia, bismuth, iron—everything was tried. The only drug of benefit was found to be opium in small doses, given usually in the form of Dover's powder, and this acted presumably by deadening the nerve terminations in the walls of the stomach.

The patient, T. B., taking an interest in the acidity of his stomach, gladly consented to place that organ at my disposal for its examination. He had, moreover, become such an adept in passing the stomach-tube, that, without the help of cocaine to dull the pharyngeal reflex, but with the aid of a small quantity of glycerine to moisten the outside of the tube, he could pass it into the stomach, siphon off the contents into a small receptacle, and remove the tube without allowing a drop of the fluid to enter his mouth or a drop of saliva to fall into the dish. So that the proceedings were conducted with a minimum of discomfort and a maximum of accuracy. In all, I carried through four experiments on this patient:—

1. On gastric digestion after a meal of bread and butter, white fish and coffee.

2. On gastric digestion after a meal of mince, bread and butter, and a cup of water.

3. After a breakfast consisting solely of porridge, no milk or water being taken.

4. After a meal of ripe greengages.

During the first experiment the supply failed at the third hour, and the experiment had to be stopped; but two days after, he took a similar breakfast, and the analyses were begun at the second hour, the results being incorporated with those of the previous *séance*.

All the experiments were done in the forenoon after breakfast, except the last, in which the fruit was taken for lunch some four and a half or five hours after breakfast, when the stomach was presumably empty.

Experiment VI.—Half an hour before breakfast the patient experimented on passed the stomach-tube and drew off a small quantity of fluid,—having, however, to pour in about an ounce of water before the siphon action would work. The fluid obtained was colourless, slightly opaque, and contained a few flakes of mucus. There was only sufficient to estimate the acidity and chlorine; analysis of the total solids, ash, and proteids had to be left out. Breakfast was now taken, consisting of coffee, bread and butter, and some white fish. The contents of the stomach were then withdrawn at half an hour, one hour, an hour and a half, two, three, and four hours after. From the half hour up to the three hours, the results were calculated from the first day's *séance*, but, as I stated above, there was not sufficient fluid to enable the experiment to be proceeded with, so after a similar meal two days later, the fluid obtained was analysed at the second, third, and fourth hours.

The results of the analyses are depicted on the following chart (Chart III.), the double line at the second and third hours representing the two different sets of analyses, and it will be seen that they are very similar, the increased acidity of the second being probably due to the fact that no fluid had been previously withdrawn.

Each time the contents were siphoned off the following procedure was adopted :—About 30 c. cms. were, as a rule, procured; 20 c. cms. of this were filtered, and either 5 c. cms., or if only a small quantity of the fluid was available, 2 c. cms. were used to estimate the total acidity and chlorine, a drop of dilute nitric acid being added, after neutralization with the soda, to prevent the phosphates from precipitating the silver solution. 2 or 5 c. cms. were set aside to evaporate. 10 c. cms. of the filtrate were placed in a weighed capsule—sometimes only 5 c. cms. were available—dried at 110° C., weighed, then incinerated. The fluid left was used to estimate the proteids, being neutralized first to precipitate the acid albumen, the filtrate boiled with acetic acid and filtered, and the filtrate saturated with ammonium sulphate to separate the albumoses from peptones.

The fixed chlorine was calculated from the ash left in the capsule after incineration, and the free and combined acidity and chlorine from the portions which had been set aside to evaporate, in a similar way to the total acidity and chlorine estimation.

A drop or two of the fluid was used to test for free HCl with phloroglucin-vanillin, for lactic acid and for alcohol.

The analysis of the unfiltered contents was only carried out in the second half of the experiment.

At each period also, before the fluid was tested at all, gelatine tube plates were inoculated from it by means of sterilized platinum needles. Unluckily, however, I could only manage to overtake a qualitative estimation of the organisms grown, the amount of time taken in working out the results of the rest of the experiment precluding my paying sufficient attention to the plates to enable me to separate out and identify pure growths of the organisms present. The number fell from innumerable colonies on the first plate to a few, twelve or so, on the last. Some were yeasts, and some formed white non-liquefying colonies on the gelatine; but the majority consisted of germs which liquefied the gelatine, and which produced a powerful putrefactive odour,—probably some variety of the Bacillus subtilis and of the Bacillus liquefaciens ilei.

1. *Filtered.*—As noted above, the fluid obtained before breakfast was very scanty, diluted with water, and with some flakes of lymph or mucus floating in it; its acidity was ·036 per cent. HCl, half of which was free, half combined to proteids. With only a trace of fixed chlorine the total chlorine was above ·1248 per cent.

On contrasting the curves of the total acidity and total chlorine during the rest of the experiment, it is seen at once that there is a striking difference. The acidity rises quickly to ·162 per cent., then increases slowly during the next hour and a half up to ·234 per cent., when again it takes a jump upwards to ·306 per cent. at the third hour; in the second part of the experiment it shows a fall between the third and fourth hours. The total chlorine, on the other hand, in half an hour reaches ·7488 per cent., and then falls in the next half hour to ·4368 per cent.; a slight rise to ·5193 per cent. at the third hour, and a fall at the fourth, completes the curve.

Before explaining the apparent discrepancy, the curves of the combined acidity and chlorine should be studied. It will be seen at once that they are almost identical. The acidity not driven off by heat rises with the total acidity to ·234 per cent. at the hour and a half, then falls slightly; the chlorine combined to albuminoids rises in a similar manner to ·26 per cent., then rises slightly; while the acidity in the second part of the experiment falls rapidly from ·342 per cent. to ·09 per cent., the combined chlorine in the same part falling from ·28 per cent. to ·057 per cent.

The acidity up to an hour and a half was all combined, and a small piece of fibrin placed in a few c. cms. of the fluid taken at that hour showed no traces of digestion after twenty-four hours at 40° C.

At the second hour, however, free HCl—only ·018 per cent., indeed —made its appearance, and the combined acidity fell a little below the total. A small piece of fibrin, which had been previously boiled, placed in a few c. cms. from this hour's fluid, was completely digested by twenty-four hours. At this hour, also, the patient began to feel uneasy. Rising to ·09 per cent. at the third hour, during the fourth the free acid curve reached ·252 per cent., and by this time the patient was suffering from considerable pain. The free chlorine—as HCl—followed exactly the steps of the free acid, but the curve of the fixed chlorine was very different, rising, as it did, in half an hour from almost zero to ·5616 per cent., then falling to ·1872 per cent., and, after a temporary and slight recovery, further to ·09 per cent.

It is now apparent that the reason of the irregular chlorine curve was due to the inorganic chlorides—in fact, to the salt swallowed with the food—most of which were quickly absorbed, and doubtless secreted again as free chlorine,—that is to say, as HCl.

The acidity and chlorine then fell between the third and fourth hours, the total amounts slightly, the combined largely, while the free increased proportionately.

Turning now to the total solids, it is seen that they fell progressively from 10·9 per cent. to 2·6 per cent., the fall becoming more rapid during the later hours, and corresponding to the fall in the combined acid and chlorine. The inorganic constituents also fell in much the same ratio from ·65 per cent. to ·32 and ·1 per cent.

The total proteids were much less in amount than the solids: the largest quantity, 1·1 per cent., was at the half hour largely composed of peptones and albumoses; then falling to ·82 per cent., they rose at the hour and a half, till at the second hour they reached ·9 per cent., when another sudden fall occurred.

Of the individual proteids, those coagulated by boiling will be seen to rise gradually to the finish, the amount present being very small; the acid albumen remained merely a trace, a cloudiness on neutralization, and unweighable, throughout the experiment. The peptones and albumoses, beginning high, fell at the half hour, rose up to the second, and then diminished again.

Lactic acid was present from the half until the second hour, but only in decided quantity at the hour. At the second hour there was a trace of butyric acid.

No alcohol could be discovered at any time during the experiment.

2. *Unfiltered.*—The figures contrast very considerably with the last half of Chart III. (the unfiltered contents were analysed only during the second half of the experiment).

The total acidity and chlorine, at first much above the former totals—·45–·386 per cent., ·5916–·4992 per cent.—become equal to them at the fourth hour.

The combined acidity and chlorine, also above those noted before, remain slightly above them at the end of the experiment—·108–·09 per cent., ·0936–·0312 per cent.

The free acidity and chlorine is, on the whole, slightly below that in the filtered specimens, the acidity free at the end being ·234–·252 per cent., the chlorine ·1872–·2808 per cent.

The total solids, at first as 13 per cent. to 7·09 per cent., at the third hour 9·8 per cent. to 6·2 per cent., and finally as 4·3 per cent. to 2·7 per cent., keep a constant relationship with those in the last table, the ash also being slightly in excess. The organic solids—that is, the total solids minus the ash, and also after subtraction of the combined chlorine—are at the three different hours:—Unfiltered, 12·244 per cent., 9·175 per cent., 4·206 per cent.; filtered, 6·89 per cent., 5·65 per cent., 2·442 per cent.

Hydrochloric acid in the free state could be detected by Günzberg's reagent on each occasion. Lactic acid was not present in either, nor was there any alcohol.

Experiment VII.—This experiment was undertaken both to corroborate and to extend the last one. The fluid in the stomach before breakfast could not be obtained in sufficient quantity for testing purposes. Breakfast consisted of mince, made with a considerable quantity of water, bread and butter, and a breakfast-cupful of water. As on the previous occasion, food was taken until the natural cravings for it were appeased.

Observations were made at half, one, one and a half, two, three, and four hours. The procedure adopted was the same as in the last, but no tube plates were made. As there was a little more fluid available, six new investigations were added. First the total proteids were directly calculated (not from addition of the various forms as before), 5 c. cms. of the fluid being evaporated to small bulk, the proteids contained in it precipitated with absolute alcohol, and weighed; the amounts of the individual proteids found afterwards could thus be used to check the result. Secondly, the albumoses were separated into their three varieties and weighed; this was done by means of precipitation with NaCl and dialysis. Thirdly, the amount of sugar present was quantitatively determined. Fourthly, the presence of starch or erythrodextrine was ascertained by means of iodine and iodide of potassium. Fifthly, mucin was qualitatively determined. While, lastly, the digestive power of the different samples was gauged by placing small pieces of boiled fibrin in a few c. cms., and placing it at 40° C. in an incubator.

The fluid obtained at the half hour had a slight gastric smell, but there were little signs of the bread, and no fat to be seen. At the second hour fat droplets could be seen on the surface, and also at the third hour, when the fluid was very thick. At the fourth hour very little fluid could be got, and that obtained was largely mucus.

On reference to Chart IV. on the following page (which is similar in construction to the previous ones, the filtered and unfiltered results being, however, placed in the same divisions, the unfiltered results in red in the acid and chlorine division, in broken lines in the total solid part), it will be at once noted that the curves in both the acidity and chlorine sections closely resemble in form those of the preceding experiment, except that the amount of salt taken with the food was purposely diminished, and consequently the chlorine total at the half hour is less prominent.

Filtered.—The total acidity rises abruptly till the second hour, then, after a slight rise at the third, rapidly falls; the combined acidity rises until the second hour, when it reaches ·414 per cent.; then, falling slightly at the third hour, reaches the low figure of ·108 per cent. at the end of the experiment,—that is to say, that between the second and third hours the absorption of peptones was proceeding at such a rate that the acid combining with the proteids in the stomach, still incompletely saturated with acid, was rather less in amount than that absorbed along with and combined with the peptones. At the third hour the proportion of acid absorbed with diffusible proteids had increased greatly as compared with the amount still combining with proteid material in the stomach. The amount of combined acid inside that organ consequently fell very rapidly. Maybe, too, there was some flow through the pylorus.

The combined chlorine follows very closely the acidity curve; the total chlorine, however, is not exactly the same as the total acidity, due, as before, to the presence of fixed chlorine. The total at the half hour is ·4056 per cent., as compared with ·216 per cent. acidity, but ·2508 per cent. of it is due to the fixed chlorine present. The rest of the curve calls for no remark.

Free acidity and free HCl appear at the hour and a half, or rather between that and the second hour, and rise until the end of the experiment.

The fixed chlorine, considerable at first, falls to ·1872 per cent., and remains fairly constant thereat.

The total solid curve is different from that in the last experiment, a comparatively small quantity being dissolved at first, only 4 per cent.; and while more becomes dissolved as digestion proceeds, absorption keeps down the total until the third hour, while increasing absorption during the last hour, between the second and third, raises the percentage of the contained solids. At the third hour the contents were very thick. After this most of the contents of the stomach were ejected through the pylorus, leaving some mucus-laden fluid, with a small proportion of solids, nearly all of which were proteids.

The ash gives a similar curve, but begins to fall sooner.

The proteids are in greater quantity in this experiment than in the last, a fact explained by the diet. 1·6 per cent. to begin with, they sink to 1·17 per cent. at the second hour, rise, like the total solids, at the third hour, then rapidly sink to ·5 per cent.

The peptones, as in the last experiment, are the greatest in quantity, and fall rather more rapidly than the total proteids, only a trace being present at the close. The albumoses remain fairly stationary, while the albumens again mount from zero at one hour to ·35 per cent. at the third. Again, there is only a trace of acid albumen throughout.

The proportions of the three varieties of albumose is not very instructive, but is interesting. Deutero-albumose, in excess at the commencement, falls almost to zero, then rises again to ·1 per cent. Hetero-albumose, on the contrary, in small quantity to begin with, rises to ·2 per cent., and keeps between ·2 and ·1 per cent. The amount of proto-albumose present throughout the experiment is extremely small.

The quantity of sugar, as estimated by Fehling's solution, falls throughout the experiment, not a trace being present at the fourth hour.

The starch taken in the food was present in the form of erythro-dextrine throughout the experiment, giving a bright violet with iodine and iodide of potassium. At the commencement the violet may have been slightly bluer in tinge, but very slightly. In the specimens tested at the hour and a half and at the fourth hour only a trace could be detected. Achroodextrine, of course, may have been present as well.

Neither butyric nor acetic acids appeared, but lactic was present during the first hour and a half. There was no trace of alcohol. Mucin appeared in the last three periods.

The digestive power of the solutions obtained gave very different results, absolutely *nil* for the first hour; the fibrin used—coloured red with carmine, as Grützner recommends—was slightly digested during the next two trials, and wholly digested by the fluids of the third and fourth hours. It is seen at once that this coincides exactly with the presence and the absence of free HCl, and that presumably the acid present during the first hour, being only in a combined state, has no further digestive power, a point to which I shall return later.

Unfiltered.—Comparison of the unfiltered contents with the filtered shows that, naturally, the percentage of total solids was higher, but that, though a little higher during the first part of the experiment, the combined and total acidity of the unfiltered contents did not rise so high at the second hour or at the third hour, though at the fourth they did not fall quite so low. Free acid again appeared a little earlier. The chlorine curves, corresponding to the above, show the same differences,—the fixed chlorine, however, showing a marked diminution in quantity in the unfiltered specimens, as might be expected when the solubility of chlorides is remembered.

Experiment VIII.—I now determined to investigate the stomach contents when a meal, principally made up of carbohydrates, had

CHART II.

Artificial Digestion of Proteids.

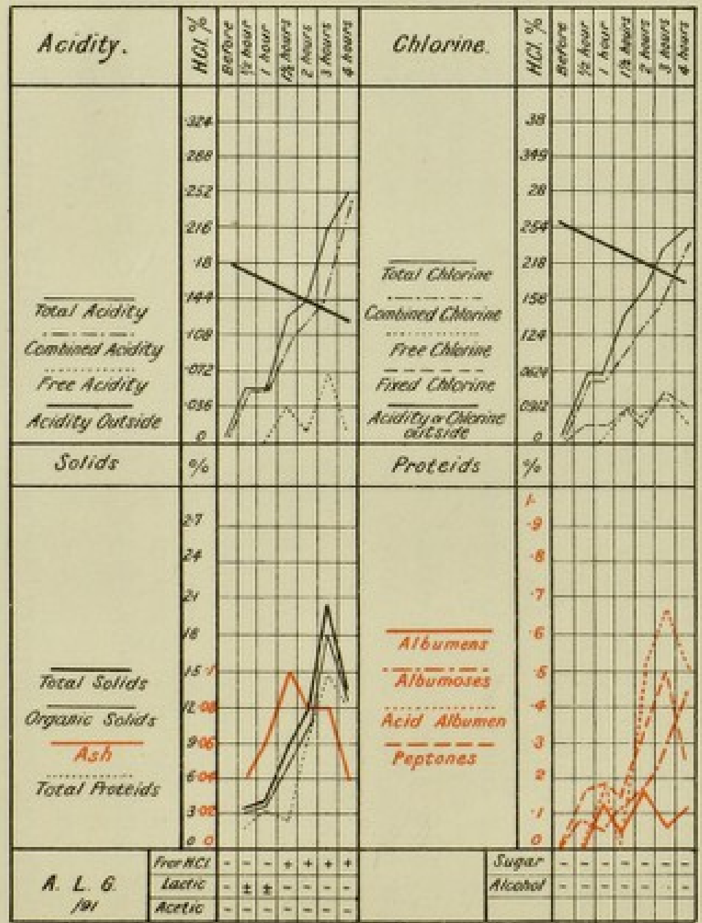
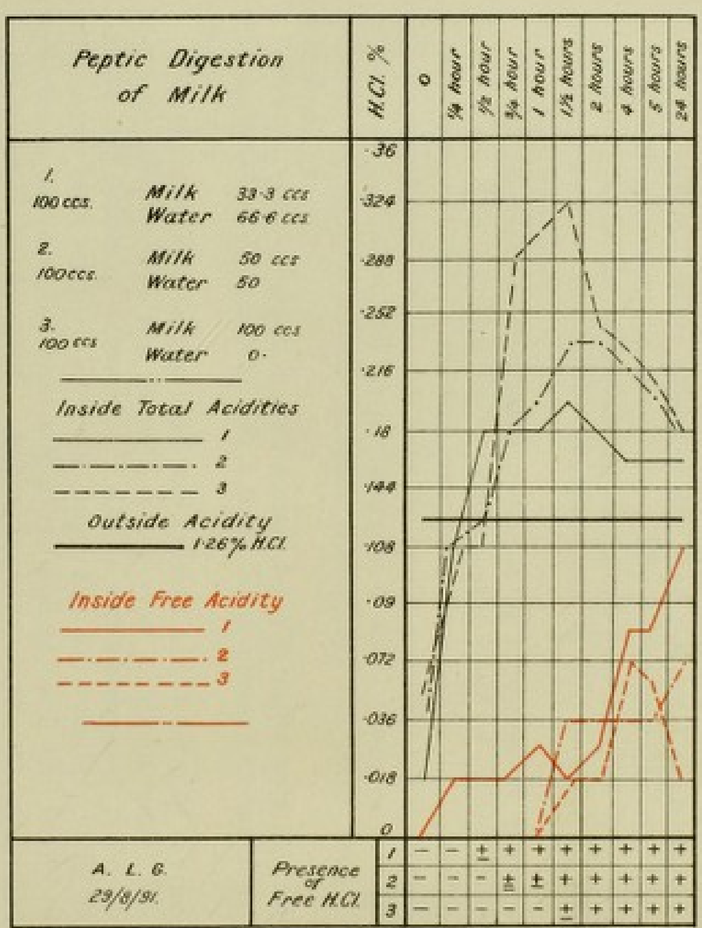


CHART I.



John Bartholomew & Co., Edinr.

CHART V.

Natural Digestion of Carbohydrates.

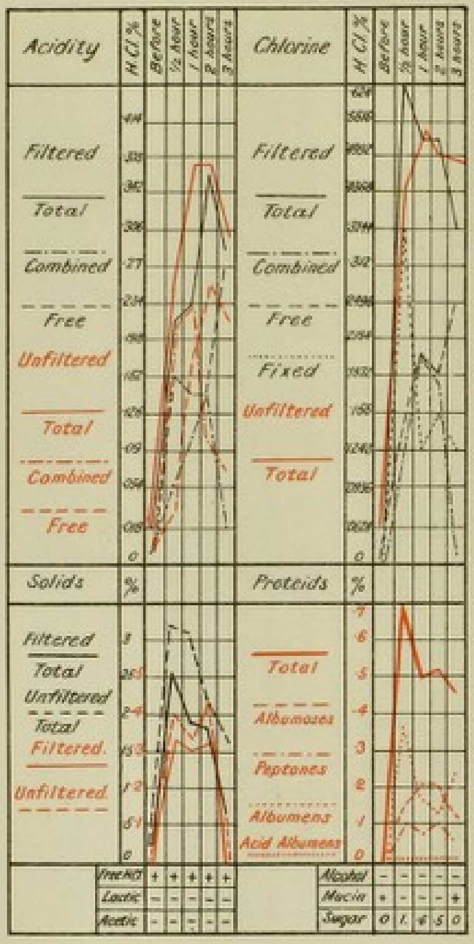


CHART IV.

Natural Digestion of Proteids.

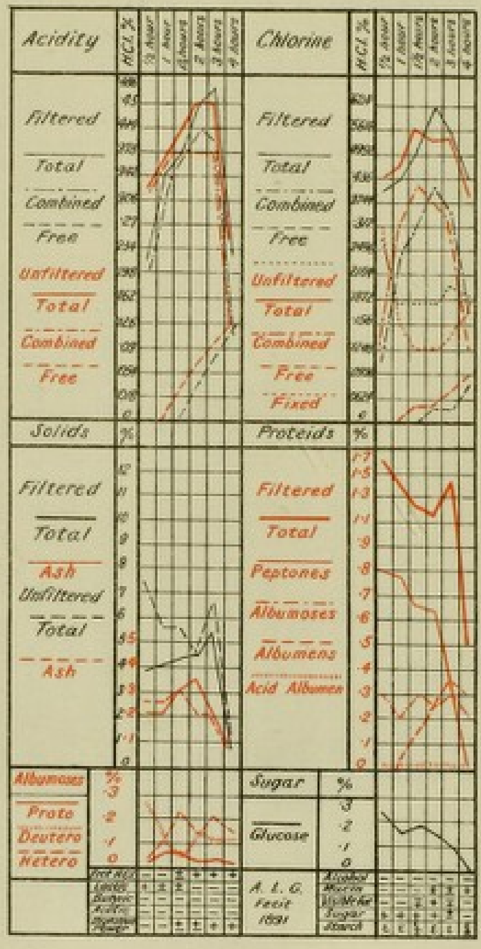
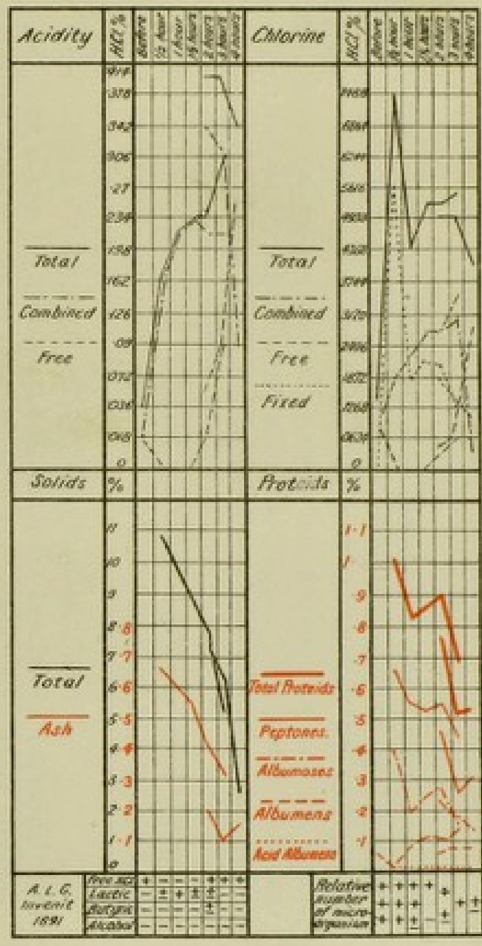


CHART III.

Natural Digestion of Proteids.



been taken; and for that purpose persuaded my patient to take for breakfast nothing but porridge. I was unable to get sufficient material in one day to examine, but had to extend the experiment over three days,—one day getting the contents after two hours, another day at the end of one hour, and again, on another occasion, one specimen before breakfast without the addition of water, others at the half hour and three hours after.

Oatmeal, according to König, contains 14·5 per cent. of nitrogenous material, 65 per cent. of carbohydrates, the rest of fat, inorganic salts, and wood fibre.

The result of the experiment is depicted in Chart V.

At once it can be seen that the acidities are lower, especially the combined acidity, while the free acidity is proportionately higher.

Filtered.—Analysis of the results shows that the total acidity rises quickly, reaching its maximum, ·36 per cent., at the second hour, then falling to ·288 per cent. The initial rise is made up principally of free acids, the combined acidity only reaching ·144 per cent. even at the second hour, and the free acid is present from the very first, contrary to the last two experiments. At the third hour the free acid amounts to ·27 per cent., the combined to only ·018 per cent., and it is noteworthy that the patient felt more inconvenienced by this amount of free acid than he had done previously, when, with a higher total acidity, more was in the combined state.

A considerable quantity of fixed chlorine in the first part raises the curve of the total up to ·624 per cent., but the combined chlorine is low, and the free chlorine corresponds in great part to the free acidity.

The total solids are lower than in the two previous experiments, and serve to show how much fluid may be secreted by the stomach in a short time, for no fluid was taken by the mouth at breakfast-time, except that ordinarily contained in stiff Scotch porridge; while the stomach contents when filtered contained 97·5 per cent. of water, and even when unfiltered 96·8 per cent. during the first half hour. The ash is rather higher than in the former cases, as was to be expected.

On turning to the proteid record it is seen that an extraordinary quantity of proteid material, considering the character of the diet, appears in the first half hour in solution, ·7 per cent., though even then it is rather less than half the amount in solution at the corresponding time in the last experiment. The total only falls slightly throughout. It will be noted, however, that albumens make up the bulk of the total, both at the half hour and at the third hour. Both the albumoses and peptones rise and then fall, the albumoses being the most abundant, while throughout there is only a trace of acid albumen.

The condition of the stomach contents before breakfast can be well studied here, because the small quantity obtained on this occasion was siphoned off without the admixture of water.

A slightly opaque fluid, with a shred or two of mucus in it, and with no gastric smell, its acidity was ·018 per cent., half of which could be driven off by heating, while Günzberg's reagent gave evidence of a trace of free HCl present. The total chlorides ·0624 per cent. (?), only a trace fixed, and a trace free. The total solids ·04 per cent., with an ash so small that it could not be determined. No sugar was present, and no biuret reaction could be obtained.

N.B.—The chlorine was probably only ·0312 per cent., but the quantity which could be used for testing was so small, 1 c. cm., that a slight error, even half a drop too much of the silver, would give a difference of ·0312 per cent. or more. Free chlorine, however, was undoubtedly present, as Günzberg's reagent showed.

Unfiltered.—There is not very much difference between the filtered and unfiltered acidities throughout. The combined rises more quickly and higher in the unfiltered, while the free also rises quicker, but does not reach such a high level as in the other.

The chlorine curves are similar, and only the total line is entered on the chart for the sake of clearness. It does not reach above ·4368 per cent. in the first half hour, compared with ·624 per cent.; this, of course, is due to a difference in the amount of NaCl.

The following are the remaining figures for the chlorine:—

Unfiltered.

	Before.	Half Hour.	One Hour.	Two Hours.	Three Hours.
Combined chlorine,	·009	·2691	·2028	·1248	·0458
Free chlorine,	Trace	·0117	·2028	·1872	·312
Fixed chlorine,	Trace	·156	·1248	·1872	·1248
Total chlorine,	·0624 (·0312)	·4368	·5304	·4992	·4826

The combined chlorine falls continuously after the first half hour, due probably to the digestion and solution of the proteids, and the consequent preponderance of carbohydrates and insoluble material.

The solids, of course, are greater in quantity, as is the ash, the solids being in larger proportion at the hour than at the other times, the ash at the second hour.

Free HCl was present on all the occasions; lactic, acetic, and butyric acids absent, or only present in exceedingly small quantities. Mucin was detected before and three hours after breakfast.

Sugar, as tested by Fehling's solution, at 1 per cent. at the half hour, fell to ·6, then ·5 per cent., during the next two hours, and to zero in the third.

No alcohol reaction was observed.

It will be noted also that the stomach evidently had begun to empty by the third hour, in contrast to the former experiments, when the process of emptying did not occur until the fourth.

Experiment IX.—The only other experiment I was able to perform on this patient, owing to his departure to America, was not as successful as the former ones.

He had his ordinary breakfast at 8·45 A.M. of bread, coffee, and fish; then at 1·30 P.M., four and three-quarter hours after, he ate eight ripe greengages, spitting out the skins and stones.

The first examination was made half an hour after, the fluid obtained being simply broken down fruit, seemingly with very little liquid added. It had no gastric smell.

Both the filtered and unfiltered contents were estimated, with the following result:—

	Unfiltered.		Filtered.	
Total acidity,	·918	per cent.	·414	per cent.
Combined acidity,	·558	„	·198	„
Free acidity,	·36	„	·216	„
Total chlorine,	·3744	„	·312	„
Combined chlorine,	·1704	„	·0936	„
Free chlorine,	·048	„	·0936	„
Fixed chlorine,	·156	„	·1248	„
Total solids,	7·2	„	4·55	„
Ash,	·16	„	·15	„
Organic solids,	7·04	„	4·4	„
Proteids,		...	·2	„
Albumen,		...	·19	„
Albumose,		...	Trace.	
Peptone,		...	Trace.	
Acid albumen,		...	None.	

An hour after, only a very small quantity of fluid was in the stomach, and was much more dilute. It still had a fruity smell.

To estimate the different constituents the fluid recovered had to be diluted with three parts of distilled water, and the result calculated.

As far as I could manage, the results are accurate, and are in detail as follows:—

	Unfiltered.		Filtered.	
Total acidity,	·432	per cent.	·324	per cent.
Combined acidity,	·027	„	·108	„
Free acidity,	·405	„	·216	„
Total chlorine,	·3744	„	·4056	„
Combined chlorine,	·2148	„	·2808	„
Free chlorine,	·0936	„	·0312	„
Fixed chlorine,	·066	„	·0936	„
Total solids,	2·1	„	1·3	„
Ash,	·07	„	·1	„
Organic solids,	2·03	„	1·2	„
Proteids,		...	A trace.	

Uffelmann's test for lactic acid gave a positive result each time, but this was probably most part due to the vegetable acids present, malic, citric, etc. The amount of sugar, unluckily, could not be estimated.

The principal feature of the experiment was the large amount of acid, both free and combined, present, only a very small proportion of which consisted of chlorine. And that, notwithstanding, the patient felt no discomfort therefrom, although he told me that, if the fruit had been unripe, he would assuredly have suffered great pain.

Further Researches.

One or two corroborative analyses were made on other patients, but as I could only procure the stomach contents with some difficulty, the experiments were necessarily limited.

A male patient, about 30 years old, was in the Infirmary, suffering from a chronic nervous dyspepsia, in character very similar to that of the preceding case.

The stomach contents were evacuated one hour after tea,—a meat tea, consisting partly of proteids. The analysis was performed in the same way as in the preceding, both of the filtered and unfiltered material.

	Filtered.		Unfiltered.	
Total acidity,	·198	per cent.	·252	per cent.
Combined acidity,	·18	"	·234	"
Free acidity,	·018	"	·018	"
Lactic acid,	·04272	"	·078	"
Acetic acid,	*nil.*		*nil.*	
Butyric acid,	·018	"	·018	"
Total chlorine,	·3744	"	·4056	"
Combined chlorine,	·13728	"	·156	"
Free chlorine,	*nil.*		*nil.*	
Fixed chlorine,	·23712	"	·2496	"
Sugar,	1·404	"	·527	"
Alcohol,	(?)		(?)	
Total solids,	3·4	"	3·8	"
Ash,	·1	"	·1	"
Organic solids,	3·3	"	3·7	"
Proteids—				
Albumen,	·0867	"	...	
Peptone,	·383	"	...	
Albumose,	·18	"	...	
Acid albumen,	(?) trace.		...	
Organic Solids—				
Sugar,	1·404	per cent.	...	
Proteids,	·6497	"	...	
Chlorine combined,	·13728	"	...	
Undetermined,	1·20902	"	...	
Total,	3·3	"		

A comparison of the amounts present in this case with those in the preceding experiments shows that the total solids are less, that the proteids especially are smaller in amount, and that therefore the combined acidity is also lower. The proportion between the filtered and unfiltered contents is the same in both. In the present case the total is less, but the fixed chlorine is above the amount in the previous case at the half hour.

At all points, then, this experiment corroborates the previous ones with regard to the proportions between the constituents.

One point, however, ought to be noted, the presence of a comparatively large quantity of lactic and butyric acids in the wash, due probably to some fermentation in the stomach.

A patient, Nansen, with a dilated stomach, was given a meal of bread and milk alone; half an hour after, the contents were removed and analysed.

	Filtered.		Filtered.
Total acidity, . .	·162 %	Total chlorine, . .	·3432 %
Combined acidity, .	·162 „	Combined chlorine, .	·0687 „
Free acidity, . .	*nil.*	Free chlorine, . .	*nil.*
Lactic acid, . .	·0933 „	Fixed chlorine, .	·2745 „
Butyric acid, . .	(?) trace.		
Acetic acid, . .	*nil.*	Proteids, . . .	4·47 „
Acetates, . .	Present.	Albumen, . .	2·43 „
		Albumose, . .	·391 „
Total solids, . .	10·3 %	Peptone, . . .	·541 „
Ash, ...	·56 „	Acid albumen, .	Trace.
Organic solids, .	9·6713 „	Sugar, . . .	Present.
		Alcohol, . . .	Absent.

They were very concentrated, the percentage of proteids very high, with only a small amount of acidity and a very considerable quantity of peptones and albumoses. On investigation, however, I discovered that the remains of his previous meal had probably not entirely left his stomach at the time of taking the bread and milk. Here, again, there was a considerable amount of lactic acid present. On testing for the other organic acids, there was a slight trace of butyric, none of acetic; but on testing for acetates they were found to be present in small quantities.

Through the kindness of Dr Mackenzie, resident physician in Dr Brakenridge's Wards, I was enabled to analyse the gastric contents of a case in which there was a considerable quantity of acetic acid present.

I received the contents of his stomach on two successive days, drawn off 3½ hours after tea time,—the first day after bread and milk, the second after bread and milk and a salt herring.

I tested them both in the filtered and unfiltered state. The details are as follows (No. 1 is after bread and milk; No. 2 after bread, milk, and a herring):—

	Filtered.		Unfiltered.	
	1.	2.	1.	2.
Combined acidity,	·306	·45	·288	·468
Total acidity,	·432	·504	·45	·504
Free acidity,	·126	·054	·162	·036
Lactic acid,	...	...	...	...
Acetic acid,	·0324	·0228	·0372	·0348
Butyric acid,	...	..	...	...
Total chlorine,	·4368	·5304	·4992	·5304
Combined chlorine,	·19344	·1568	·21216	·156
Free chlorine,	·0936	·0312	·1248	·0312
Fixed chlorine,	·14976	·3432	·16224	·3452
Total solids,	2·78	4·	3·52	4·08
Ash,	·3	·38	·24	·4
Organic solids,	2·20656	3·4952	3·06784	3·524
Proteids,	·776	·86	...	...
Albumen,	·18	·34	...	...
Acid albumen,	Trace.	Trace.	...	...
Albumoses,	·37	·1	...	...
Peptones,	·226	·33	...	...
Sugar,	·92	1·02	...	...

From this it will be seen that even a herring makes a considerable difference in the acidities, and that especially the fixed chlorine rises. Everything else rises in proportion, the solids and proteids, etc. Although the acetic acid present in a free state is not in large amount, it was calculated from the difference between the free chlorine and free acidity—no lactic or butyric acids being present—there was a considerable quantity in the form of acetates, and some probably combined with proteids also, judging by the depth of colour formed on using Uffelmann's reagent or the liquor ferri perchloridi as tests.

This patient was the subject of a very chronic dyspepsia with hyperacidity—the hyperacidity, however, being due more to organic acids than to excess of chlorine.

Consideration of the Results obtained by the Analysis of the Contents of the Human Stomach at different Hours.

The first thing that struck me after analysing these fluids was *the similarity between the acid and chlorine curves in general* of both these natural and artificial digestions. The curve rises quickly in both, and, as a rule, in both begins to fall about the third hour, when, in fact, the amount of acid combining with the proteids is less than the quantity of acid and proteid diffusing through or being absorbed; the fall, however, as is only natural, being slower in the artificial digestions.

Secondly, Hayem and Winter's observation on the *small quantity of free hydrochloric acid* present during digestion is corroborated, and the exact reason of its apparent absence during the first part of digestion established.

My opinion of the matter is this. A small percentage of HCl is constantly, from the very commencement of gastric digestion, being secreted. This at once combines with proteids, the combination obscuring the reactions peculiar to a free acid. The intimate nature of the combination I enter on more fully elsewhere (*Journ. of Anat. and Phys.*, Jan. 1893), but I strongly question the accuracy of Mathieu, Richet, Hayem, or Winter's views as to its being an amido-acid, a hydrochlorate of leucin. Without pepsine, HCl, even if it saturate the proteid molecule, cannot produce any appreciable change in it, save the formation of some acid albumen. Kühne has said, indeed, that HCl, without pepsine, is capable of changing a small quantity of proteid into peptones—that is, peptones and albumoses. With pepsine present, however, the case is different; for, as the acid saturates the albumen or globulin molecule,—a compound molecule like starch (*cf.* Bunge),—the molecule splits into simpler forms. If free acid be still present, this process may go on until peptones are reached. The essential part of the process is, I believe, a splitting-up of a complicated molecule by means of free acid, in the presence of a ferment, into simpler molecules, each of which has a higher saturation point for acid—a greater avidity for it. These molecules in turn, when fully saturated, split up in a similar manner into still less complicated bodies.

This theory coincides with the course of the acidity in the stomach. At first the percentage of chlorine combined to proteids is small, chiefly because all the proteid has not been attacked by the acid, but, as digestion goes on, the percentage of acid, combined with proteids, or of the chlorine similarly combined, rises, and that although peptones with their acid are being absorbed. That is to say, then, that the albuminoids resulting from digestion probably take up more acid than the original albumen or globulin.

On comparing my results with those of Cahn, I find that, while in some respects similar, in others they differ considerably. For instance, the curves of the solids expressed in percentages rise rather than fall during his experiments; while the variations of the hydrochloric acid are very small, rising only slightly until the third hour in one experiment, and only ·08 per cent. by the second hour in another. He found that the amount of acid albumen remained almost stationary, 11–·16 per cent.; I only found traces of this albuminoid in any of my experiments on man. The amounts of peptone and albumose which I could separate out were far below Cahn's figures, who found 2·18 per cent. of peptone, using Kjeldahl's method, in the contents of the stomach, the total solids of which only reached 2·80 per cent.!

I have, in addition to his investigations, included tables of the different acidities and chlorine, of the ash, and of the various forms of proteid.

From his researches Cahn believed that most of the stomach contents were expelled into the duodenum with the proteid constituents peptonised,—that is, that peptones are not absorbed by the stomach in any great quantity.

I combat this view on the following grounds:—

1. The course of the combined acidity and of the quantity of proteids present is so similar in the digestion as occurring in man and in dialysing tubes, that probably the same cause, *i.e.*, abstraction of peptones, has some influence in both. In the dialyser peptones can and do diffuse, carrying the combined acid with them. In natural digestion the peptones are absorbed by the cells of the stomach wall without the actual aid of diffusion.

2. On separating the albumoses from the peptones it is seen that, while the peptones tend to fall as digestion proceeds, the quantity of albumose remains fairly constant to the end of digestion. That is to say, that, in the course of the production of peptones from albumens, albumoses are being constantly formed, and as constantly are further acted on by HCl producing peptones. The peptones are absorbed at a certain rate, and as the original amount of proteid diminishes, so the albumoses formed from them diminish, but more slowly, and often not until close on the close of the digestive process.

3. An objection which could be raised to any deductions drawn from percentage results, due to the inflow of fluid during digestion and consequent lowering of the amount of proteids obtained, or of total solids, is negatived by Cahn's results, for he withdrew the whole contents of the stomach at each period,—a proceeding I found it impossible to do on man,—and estimated the absolute quantity of total solids, both dissolved and undissolved.

He found these to diminish as the digestion advanced, and the diminution is so marked in one of his tables,—from 40·73 gr. at the half hour to 15·82 gr. at the second hour, or 11·63 gr. at the 2½ hours,—that it cannot simply be due to absorption of inorganic salts. And unless the material which has disappeared has passed through the pylorus, which I do not believe, it must have been absorbed.

4. As a rule, I found the total solids diminished in quantity as digestion went on. In Experiment VII. the dissolved solids increased slightly, the total unfiltered decreased. The decrease was generally more than could be explained merely by the absorption of inorganic salts. In considering this, I must note that as I withdrew a certain amount of the contents at each half hour or hour, the quantity of solids left was necessarily smaller; on the other hand, however, I noticed that the consistency of the fluid seemed only to vary slightly, and it appears to me as probable that the amount of fluid present does not change much during digestion, absorption and secretion keeping the contents at a fairly constant concentration, even if a large quantity of fluid be taken with the food.

5. Moritz, who performed some very similar experiments to mine, but which were not so full, washed out the stomach of a boy after meals, and found the total hydrochloric acid most at the third hour, ·4 per cent., about the same at the fourth hour, and then a slow diminution. He seldom got any reactions for free HCl until the second hour, but they became marked afterwards. The albuminoids were most at the third hour, and diminished rapidly after that. Moritz included all acids in his total HCl, and had no means of differentiating between combined and free HCl quantitatively. He advises a re-examination of any specimen of stomach wash with a strong biuret reaction and no free HCl, an hour or an hour and a half after. His work then gives, as far as it goes, much the same result as mine, although in their original form they afforded little opportunity for useful deduction.

6. Considering the relation of my work and that performed by Hayem and Winter, I confess that they are on the same lines, but I contend that I have carried the matter forward, in some degree at any rate. I think I should here note my conclusions, from the foregoing experiments, as to the correctness of their views. Their proposition that hydrochloric acid combines with proteids, and that when in that condition it does not volatilize like pure HCl, I hold as proved, and regard it as a most pregnant fact,—a fact which should be of immense use in future when investigating the contents of the stomach, both quantitatively and qualitatively. The exact form of combination, however, cannot be, in my estimation, a combination with leucin; but this point I have investigated more fully elsewhere. These authors have demonstrated the curves of the chlorine in its different forms during digestion in the dog; these curves I have obtained and corroborated from digestion in man, also, however, pointing out the more exact relation of the combined chlorine curve to the amount of proteid undergoing digestion.

With regard to the point brought forward by Hayem and Winter as to the large quantity of fixed chlorine obtainable from the stomach contents—they experimented in this case on dogs—when only distilled water had been ingested, I have little data to go on. I tried an experiment on a patient by giving him a drink of distilled water, but failed to siphon sufficient fluid off to test, and even that was principally saliva.

I examined, however, the contents of the stomach of the patient on whom I performed the principal experiments before he took any food on two different occasions, the stomach being practically empty in both. The fluid obtained was small in quantity, very slightly acid, and only contained a very small quantity of chlorine, and of only a trace fixed. Even part of the fluid may have been secreted by the mucous membrane of the stomach irritated by the end of the tube, the rest being composed of swallowed saliva. In the second case the proteids amounted to very little,—they were not estimated in the first,—and that little was probably due partly to mucin although traces of either albumose or of peptone were present.

In this case, then, the stomach was not absolutely empty after a twelve hours' fast, but contained traces of proteid and acid dissolved in a small quantity of water. The fixed chlorine was very small in amount.

Now, as I have already said, Hayem and Winter found the fixed chlorine to increase up to a certain point in the digestion of distilled water in the dog. They experimented on an animal in whom a gastric fistula had previously been made, and obtained the following quantities of chlorine after giving 400 gr. of distilled water by mouth :—

Time.	Total Chlorine.	Fixed Chlorine.	Combined Chlorine.
10 min.	·0657	·0438	·0219
30 min.	·073	·0657	·0073
60 min.	·14	·116	·03
80 min.	·219	·153	·066
100 min.		Stomach empty.	

There was no free HCl at any time.

On examining the above table one is at once struck with the fact that there was no free HCl present, and only a very small quantity of combined acid per cent. Arguing from my results, I would say that there could only have been an infinitesimal secretion of gastric juice ; for, if any quantity had been secreted, where had the free acid disappeared to ? I do not believe that any one will support a theory which depends on the secretion of almost a pure common salt solution by the gastric mucous membrane, the amount of combined chlorine never rising above one-third of the fixed. Now, the saliva is known to contain mucin and small quantities of serum albumen and globulin, and although mucin is not digested in the stomach (*cf.* Moritz), I have found that HCl combines with it, so that the swallowed saliva may cause the secretion of a small quantity of HCl from the stomach glands sufficient to combine with the proteids in it and to digest those that are digestible. Saliva also contains from ·2 to ·3 per cent. of salts, chiefly chloride of sodium. Again, we know that pure water is very rapidly absorbed from the stomach, so that probably, during the time occupied by the experiments, most of the original water had either been used for the previous testing or had been absorbed, causing a progressive rise in the percentage of the salt present, until it came close to what is present in normal saliva (·15 per cent.). In fact, I utterly and entirely disagree with the authors on this point.

The conclusions I would draw from the foregoing experiments are briefly as follows :—

1. *Free HCl* is secreted by the stomach glands from the moment at which food enters the viscus.

2. *First stage of gastric digestion,* during which no free HCl is

present, but the total acidity constantly rises,—the stage of organically combined HCl, with, frequently, the addition of traces of free organic acids.

3. *Free HCl appears* in the stomach contents, the time of its appearance varying with the composition of the food, with its concentration, and with the state of the gastric mucous membrane. The time varies between the first half hour to the second or third hour.

4. *Second stage of gastric digestion*, both free and combined HCl present. Acidity rising.

5. *Third stage of gastric digestion*, both free and combined HCl present. Total acidity falling.

6. The acidity during the earlier part of the first stage is so small that it can probably allow the *amylolytic action of the saliva* to go on for a short time.

7. The free HCl secreted at first combines at once with the proteids present in the food.

8. Hydrochloric acid organically combined is *less antiseptic* than pure HCl.

9. The total solids, both of the filtered and unfiltered contents, fall per cent. from the commencement.

10. The acidities per cent. differ *in the filtered and unfiltered contents.* The total acidity is lower in the filtered contents; the combined is generally higher, the free lower, than in the unfiltered.

11. The *inorganic salts* diminish per cent. from the commencement.

12. There is generally a great *excess of fixed chlorides* at the beginning of digestion, due to ingestion of NaCl and other chlorides with the food. This excess soon disappears.

13. *The total proteids per cent. in solution fall* during digestion.

14. *Albumen (probably mucin) increases* per cent., *albumoses* remain stationary, *while the peptones* diminish largely per cent.

15. *The different forms of albumose* (Chart IV.) vary little; proto-albumose is least in amount; the quantities of hetero- and deutero-albumoses are very equal.

16. *Micro-organisms are present in large numbers* at the beginning of digestion; the numbers diminish as digestion goes on.

17. *The stomach contents have no further digestive power* unless there be some free HCl present.

18. *Digestion in the stomach* is very similar in its results to *digestion in a dialyser*, but in the latter absorption does not go on so quickly.

19. *The great factor in causing the courses* of the acidities and chlorides to be similar both in the stomach and in dialysers, and at different times, after varying diets, in the same stomach, is *the constant accession of free HCl, in small quantities,* to the contents of the viscus or dialyser tubes.

20. *The usual percentage of acid* present in the contents of the

stomach as given in text-books on physiology is very misleading, unless the time after the meal and the nature of the meal be taken into consideration.

The total acidity may be from	·108 to ·36 per cent.
The combined acidity from	·072 to ·324 per cent.
The free acidity from	·018 to ·09 per cent.

But they vary so much, from the above-mentioned causes, that it would be futile to lay down any hard and fast limits.

21. *The free HCl* is seldom over ·09 per cent. at any hour after a proteid meal. It may rise to ·162 or ·27 after a meal chiefly carbohydrate in character.

22. Further consideration of the subject leads me to suppose that HCl combined to proteids does not cause heartburn, at least to any appreciable extent, but that both free HCl and free organic acids do so, the latter especially.

23. That the pain which comes on immediately after food has been taken is probably due to the presence of an ulcer, or of erosions, or is neurotic in origin. Coming on at the time when free HCl should first appear in the contents,—allowance in calculating this must be made for the character of the foregoing meal,—this acid is probably the offender. If accompanied with flatulence and heartburn, and occurring at variable times after food, I would suspect some fermentation, and, if carbohydrates are badly borne, diminution in the secretion of HCl as well.

24. Though not directly following from the experiments detailed in this paper, I would like to include among these conclusions the fact that a study of the acidity of the urine often yields good presumptive evidence with regard to the acidity of the stomach contents. They are usually inversely proportional.

Diagnosis and Treatment.

Under this head we may divide gastric disorders into two classes:—1, Those in which the nervous system is chiefly to blame; and, 2, where the local chemistry is mainly at fault. Of course here, as elsewhere, the two classes overlap, and it must be remembered that, although in some cases the local disturbance is due to a general disease, readjustment of the local chemistry is important during treatment of the primary cause. Dyspepsia with chlorosis, as you well know, yields more quickly if both maladies be treated simultaneously, whichever of the two be the original disease. If the local complaint be not seen to, the remedies for the other are certain at first to aggravate it.

It is the local treatment to which I would more particularly direct your attention.

From the foregoing analyses, indications for treatment are given by the amount of the total acidity, and by the amounts of free and combined hydrochloric acid present. The presence, too, of the different organic acids is significant.

If we know the time after food, the character of that food, and the amount of proteid hydrochloride in the stomach contents, we are far on our way towards making a correct diagnosis as to the state of digestion, and therefore towards the knowledge necessary for correct treatment. The secretion of the stomach digests proteids, kills poisonous germs, and subdivides the food so as to avoid intestinal irritation, while it also acts beneficially by bringing the contents to a proper consistency by the addition or subtraction of fluid. If it is unable to digest proteids we can help it; if it digest them too quickly we can retard it. If its controlling action over organisms is deficient, nothing, surely, can be easier than to supplement its antiseptic power.

Deficiency of hydrochloric acid is easily remedied for a time by the administration of some acid by the mouth. By this means the work of the stomach is considerably lightened, while at the same time the cause of the deficiency can be treated, whether it be the diminution of chlorides in the blood, its increased alkalinity, the inflammation of the gastric mucous membrane, or any of the other causes of this condition. This procedure has, I know, been attacked on the ground that by doing the stomach's work that organ loses any incentive to self-help. Surely this must be the argument of one who hopes by applying topical remedies to relieve what is often only the expression of a general state.

Hyperacidity is of two classes,—first, that in which the excess is composed of HCl; secondly, that in which the organic acids predominate.

The first is in many cases the most difficult of all those chemical problems to solve. Both proteids and dilution of the contents with water may subdue the pain. The exhibition of soda only induces the further pouring out of acid. Alkalies are the worst treatment possible for both forms of hyperacidity. Diminution of the chlorides ingested may be of use if persevered in. This excess of HCl is an expression either of some nervous condition or of an abnormal state of the blood. It is proportional; that is to say, that what would be hyperacidity to a chlorotic girl would not be so to a healthy adult. If we cure the chlorosis, having during the treatment attended also to the digestion, an acidity which before would have caused excessive pain and discomfort now only gives rise to those pleasurable sensations which accompany a good meal well digested. In other cases a careful attention to the diet, which should be non-irritating, and to the general condition, is indicated. Frequently the liver is out of order, and a mild hepatic tonic, such as the combination of dilute nitro-hydrochloric acid and taraxacum, helps to improve the state of the gastric secretion. I would wish above all things, in treating such cases, not to be blind to the important relation between the state of other organs and the gastric secretion.

Cases of hyperacidity with excess of organic acids are often, in reality, cases of deficiency of hydrochloric acid, and must be treated as such. Where the stomach is dilated or the seat of chronic gastritis, regular lavage gives the happiest results when combined with other treatment.

Gastric ulcer is generally accompanied by proportional HCl hyperacidity, and may be treated accordingly. Finely divided and bland proteids by the mouth are well tolerated in many cases, the formation of proteid hydrochlorides tending to diminish the pain. Milk should only be given in very small quantities. If the patient be fed by the bowel, the administration of a little grated meat or albumen water by the mouth often stills the pain caused by the reflex secretion of gastric juice.

Washing out the stomach in a case of gastric ulcer is not regarded in Germany or in America as a hazardous proceeding. The only cases on which I would hesitate to practise it are those in which the passage of the tube excites great pharyngeal resistance and nausea. If we lay down a rule of absolute rest in such cases, surely it is inconsequent to insist on passing a tube down a struggling patient's throat. If the pharynx tolerates the foreign body, the danger of the end of a soft india-rubber tube penetrating an ulcer is not great, and the relief experienced often remarkable.

The success that has attended the lavage of children's stomachs for constant vomiting, probably due to fermenting milk, is extraordinary. Dr John Thomson of this city frequently practises it, he tells me, with perfect and speedy success.

I will not presume to say anything to you on the subject of malignant disease of the stomach, further than again to note that if three hours after an ordinary meal no free hydrochloric acid be found in the contents, it is well to give the patient a meal composed almost entirely of carbohydrates,—say some potatoes and butter, or oatmeal porridge. Sometimes even in cancer cases with this diet there may be small quantities of free HCl found; but in health, as I have shown above, the free acidity should largely predominate.

One or two other points I will merely touch upon. The tests for the motility and power of absorption of the stomach walls—Klemperer's oil and Ewald's salol or Günzberg's iodide of potassium tests, may be dismissed at once. I prefer topical examination. Electrization of the stomach walls by means of an electrode passed inside the stomach tube, or in the form of a "stomach bucket," has been much more used in Germany and America than in this country. I have seen only transient benefit result from its use.

It must not be forgotten that very frequently intestinal dyspepsia arises from erroneous gastric processes, and that this form of indigestion is not so easily cured by the exhibition of prompt cholagogue cathartics, or even by the time-honoured blue pill, however much the symptoms may be relieved at the time, as by a careful attention to the disordered gastric digestion. Indeed, this disorder is preferably overcome by appropriate dieting and regulation of meals than by the exhibition of medicine.

To the large class of dyspeptics afforded by women between the ages of puberty and thirty, especially among the upper classes, more salt with their food, more fluid taken during the day, and less chocolate and trash eaten at all hours, are better than much medicine.

Animal life is a chemical problem troubled with a nervous system. The nervous system itself is of a more delicate chemistry, and is controlled by the still more subtle problem of LIFE. We can modify each of these three forces, and attention to each will give the best results.

I do not wish to argue that the modern treatment by lavage, by electricity, by the administration of acids, alkalies, or antiseptics, is indispensable; but I would lay stress on the help which a knowledge of the nature of the gastric contents affords in the correct diagnosis of a case, and in a scientific appreciation of the suitable treatment.

If I might be allowed, in conclusion, to indicate the lines along which a useful discussion might follow, I would suggest a consideration of the importance of the presence and amount of the free and combined hydrochloric acid and of the organic acids in the contents of the stomach, of the treatment of dilatation and ulceration of that viscus, of the signs of cancer and of gastric and intestinal antisepsis. The importance to be ascribed to separate symptoms might also be considered.

I must thank the Royal College of Physicians of Edinburgh for the kindness and generosity which they have displayed to me in allowing me to work in their laboratory, in which, indeed, most of the foregoing analyses were made.

PRINTED BY OLIVER AND BOYD, EDINBURGH.

Notes.