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PART I.

ORIGINAL COMMUNICATIONS.

ART. I.—*The Physiology of the Pylorus.*^a By W. H. THOMPSON, M.D., F.R.C.S. Eng., Sc.D.; King's Professor of the Institutes of Medicine in the School of Physic, in Ireland, Trinity College, Dublin.

WHEN I look round and see many of my colleagues who have occupied the chair of this Society, and when I look down the list of its Past Presidents and see there such names as those of Cunningham and MacAlister and others, I feel that you have conferred a great honour, and at the same time placed a great responsibility upon me, in electing me to the Presidency of the Society for the year now beginning. Gentlemen, I thank you for the honour, and I ask you all to assist me in an endeavour to make the year worthy of the traditions of the Society.

The work of the Biological Association is of inestimable value in the education of the medical student. It teaches him to think for himself, and brings out whatever of originality he may possess. These are points of no mean importance, especially as correctives to a curriculum which, whatever its value (and I do not wish to underrate it), tends

^a The Presidential Address delivered to the Dublin University Biological Association on Saturday, November 20, 1909.

at all events to produce a uniform pattern, not infrequently at the expense of originality.

I almost feel that I owe you an apology for the subject upon which I have chosen to address you—namely, the Physiology of the Pylorus. It is not a high flown subject, but I have selected it mainly for the reason that it has important practical bearings.

We are honoured by the presence of two distinguished guests who have come from a distance to speak on the subject—Professor Halliburton, F.R.S., and Mr. A. B. Mitchell, of Belfast. Professor Halliburton needs no introduction to you. His name is a household word where medical students abound. Mr. Mitchell's fame is also widely spread beyond the immediate sphere of his labours. You are well aware, as we all are, that he is eminently qualified to speak to the Address from the practical side.

In very olden times the stomach was regarded as a receptacle for the concoction of food, which was there altered by the warmth and moisture of the body, aided by the vital spirits. This view prevailed for some hundreds of years till Galen, in the early part of the Christian era, assigned to the organ four faculties. These were—first, a *Facultas attratrix* by virtue of which food was drawn into the stomach from the mouth; second, a *Facultas retentrix* by virtue of which the food was uniformly compressed and any surrounding space in the cavity obliterated; third, a *Facultas alteratrix* to which was attributed the changes produced in the food; and fourthly, a *Facultas expultrix* which consisted in a tight closure of the stomach upon its contents with simultaneous opening of one or other of the orifices. To these agencies were added the warmth contributed by neighbouring organs which were supposed to surround the stomach, as a fire surrounds a large kettle, the liver being particularly important in this respect. Hence it was laid down that one should not lie on the right side till digestion was completed for fear of damping the fire. In this matter the cardiac orifice was also made to assist by being kept shut to prevent the escape of the steam or vapours generated within, on the same principle that one covers a pot

when it is desired to bring it quickly to the boil. In the weak and hungry, however, the cardiac orifice remained open, also in the drunkard, thereby accounting in the latter case for much that, even in those remote times, was familiar to the nostril.

After being altered by the above means, the food was expelled from the stomach either upwards or downwards, the direction being purely dependent on which orifice was opened. In deciding this important point the pylorus played the chief part. Indeed, a personality was actually supposed to be concerned with the performance of this function, and the name of "pylorus" signifies the guard or keeper of the entrance—the janitor or porter. For instance, Galen looked upon the pylorus as a regulator or governor of the entrance to the intestine, having sovereign authority and monarchical power over all the other structures of the stomach. This governor was endowed with the faculty of judgment and decision, by virtue of which he opened the portal only when he himself considered best. He did so at the end of digestion, not because he was urged thereto by the chyme, but because he had a knowledge of the events happening in the stomach. On the other hand, the pylorus closed the orifice and set up vomiting when he considered it would be injurious to the health to allow the stomach contents to pass further into the system.

Under certain circumstances the pylorus might be weakened or overcome, and the orifice opened too wide. This particularly occurred in young people given to late revelling and free drinking. In such state the contents of the stomach passed unchecked to the kidneys, thus accounting for the continuous micturition associated with these conditions.

These views, though long given up by the majority of physiologists, were reflected in the writings of French authors down to nearly the middle of the nineteenth century. For instance, the pyloric orifice is said by Richerand (1844) to be endowed with a special sensibility, and to have a delicate touch, which enables it to exercise a species of choice in respect to the foods which pass through it.

Accurate knowledge concerning the functions of this part of

the stomach accumulated very slowly. It was known to Willis (1675) that the food did not escape from the organ continuously, but in small portions as it was digested. About the same period an observation of great importance was also first made—namely, that under certain circumstances a circular constriction occurs in the stomach at some distance from the pylorus. This was first noticed by a man named Wepfer in experiments on wolves, dogs, and cats, and was also confirmed soon afterwards by other observers. The position of the constriction was not precisely defined. It was stated, however, to occur not exactly in the middle of the stomach, but more towards the pyloric end. The movements of the stomach were also carefully observed by Peyer, and later by Haller. They were said to consist of alternate contractions and relaxations similar to, but of much slower rhythm than, the movements seen in the intestine. The knowledge that fluids escape through the pylorus much earlier than solids dates likewise from this period.

Little advance was made from this point for nearly a hundred years. The greater part of the eighteenth century and first quarter of the nineteenth were almost fruitless. Then came the observations of Beaumont on the stomach of St. Martin, but these, though interesting in many respects, were on the whole disappointing. Modern physiology was only in its infancy at the time. Even the anatomy of the stomach was not sufficiently known to enable Beaumont to take full advantage of his unique opportunity.

Our present knowledge of the muscular functions of the stomach is mainly based on two sets of investigations—one carried out in 1886 by Hofmeister and Schutz on the excised stomach of the dog kept in warm saline; the other by Cannon in 1898, on the stomach of the cat fed with bismuth meals and examined by Röntgen rays. The latter observations, more than any others, called attention to the muscular activity of the pyloric end, and to the fact that the stomach is functionally divided into two regions. Within five minutes after the administration of a meal, Cannon saw constrictions beginning near the middle of the stomach, which moved slowly as waves

to the pylorus, the indentations deepening and the contractions strengthening as the waves progressed. These waves propelled food towards the pylorus, and followed each other regularly at the rate of six per minute in the cat, often running for over seven consecutive hours, as many as 2,600 being concerned with the expulsion of a single meal. At intervals during the progress of the waves the pylorus was observed to open, sometimes to every wave, oftener to every third or fourth, to allow food to be injected into the duodenum. Previous investigators, as already stated, had noted by means of fistulæ that digested food escaped from the stomach in small gushes. These observations of Cannon have been confirmed by others and have also in some respects been extended to the human subject.

My chief wish now is to call your attention to the factors which regulate this rhythmic opening and closure of the pylorus.

From the outset it was apparent that the sphincter was kept tonically closed for the most part, but relaxing periodically to allow liquefied food to enter the bowel. The factors, however, which maintained this closure, and which determined the periodical relaxation, were wholly obscure. Time will not permit me to deal in chronological order with the discoveries which have thrown light upon these questions. I shall have to content myself with a somewhat bare statement of the facts, and then deal with the explanations offered to account for them.

In examining the passage of different foods out of the stomach it soon became clear that all do not escape at the same rate. Thus carbohydrates begin to escape in ten or fifteen minutes after being fed, their discharge is rapid, and the stomach is empty in three hours. Proteins, on the other hand, do not begin to escape for over half an hour; very little has left at the end of an hour, and the stomach is not empty for six hours. Fat, when liquid, often begins to escape soon, but under ordinary conditions none leaves for over half an hour, then the escape is very slow, and at the end of six hours in many of Cannon's experiments not more than half of the meal had left the stomach.

From these and other kindred facts it would almost seem that the activity of the pylorus is influenced by the nature of the liquefied food which reaches it. This claim is indeed made by more than one physiologist, but before admitting it we should consider another possible explanation—namely, that the order in which the above foods pass through the orifice is that in which they are digested and admitted to the pyloric vestibule or antrum.

The existence of a constricting band marking a division between the body of the stomach and the pyloric portion was known, as already stated, from a very early period. That this band can play the part of a sphincter capable of completely separating the two regions of the stomach from each other must, I think, now be admitted, at all events for certain animals. To this sphincter the name pre-antral has been given. A great deal of evidence has accumulated to prove this, but I shall refer to only two observations. The first of these was made in Pavlov's laboratory by means of fistulæ, one leading into the body of the stomach, the other into the pyloric portion. It was found that food passed into the latter from the former by rhythmic jets dependent on the action of a sphincter capable of completely separating the two regions from each other. During its maximal contraction not a single drop of liquid was allowed to pass through from one side to the other. The second is even more striking, and consists of a fact observed by Magnus when studying the cause of the constipating of the effects of morphin.

Cats in which diarrhoea had been evoked, were fed with bismuth meals and morphin injected. On subsequent examination by Röntgen rays and the fluorescent screen the stomach was seen to be completely divided into two parts and the food prevented from entering the pyloric portion. This phenomenon could be accounted for only by a firm closure of the pre-antral sphincter.

Accepting the existence and activity of this sphincter it is only necessary to assume that under ordinary circumstances its contraction brings the longitudinal folds of lining membrane of the stomach sufficiently into contact to keep

back solids, while liquids are allowed to trickle through, along the furrows between the folds. This view I have held for some time and given expression to in writing. Recently it has been confirmed on reading a paper by Waldeyer, kindly brought to my notice by Dr. H. M. Johnston, in which the author speaks of these grooves as the streets of the stomach.

Whether the foregoing suggestion ultimately prove accurate or not, it is at all events beyond doubt that the action of the pylorus is influenced from the intestinal side. The first observation pointing to this was made by Hirsch in a duodenal fistula in a dog. He found that if the fluid escaping by jets from the stomach were collected and reintroduced into the intestine the rate of escape was rendered much slower. At the outset he surmised that the acid fluid determined in some way the slower escape, but an observation made about the same time by von Mering—namely, that milk had a similar effect—led him to think that mechanical distension of the bowel was the factor which produced the effect. It was not till some years later that Pavlov, by carefully planned experiments, definitely proved that the escaping contents excited a reflex closure of the sphincter of the pylorus by virtue of the acid derived from the gastric juice. This acid acted on the duodenal mucous membrane, and so long as it remained un-neutralised this closure was tightly maintained. As soon as neutralisation occurred, relaxation was again possible and further contents allowed to escape.

Two other conditions have since been proved to exercise an influence from the duodenal side. One is the mechanical factor produced by distension of the bowel. Thus the inflation of a small rubber balloon, introduced into the duodenum through a fistula, checks the rhythmic discharge of contents through the pylorus. This action can rarely, if ever, come into play in normal conditions, but there can be no doubt that it exists as a reserve force, which would enable the intestine to protect itself against over-filling. One of the most striking facts about the physiology of the small bowel is that the tube is always relatively empty, being practically collapsed, and never found in anything like a distended condition. It is, I

think, very probable that this protective re-action of the bowel comes into play in cases of gastroenterostomy, and may even be developed into a highly sensitive regulatory mechanism.

The other factor acting on the sphincter pylori from the bowel side, is also a chemical one produced by fat. It was first observed, but misinterpreted, by von Mering in the case of milk, and later by Marbaix, both for milk and other fatty foods, such as yolk of egg. It was reserved, however, for Pavlov's school to show that the reflex closure produced by these substances is due to the contact of neutral fat with the duodenal mucous membrane, the closure giving way only when the fat is converted into soap or moved on to lower parts of the bowel.

In previously offering a possible reason for the different rates at which ordinary foods pass through the pylorus, I am well aware that the explanation only accounts for the appearance of these foods in a definite order before the closed portal, and does not touch the deeper question as to why the portal opens to let them through. This problem has, however, not been overlooked by investigators, and while it is recognised that the *closure* of the sphincter is determined from the duodenal side, it is also thought probable that its relaxation or *opening* is effected from the gastric side. Amongst the conditions assigned to explain this opening is the consistence of the food. Thus, in the earlier stages of digestion, only liquids enter the pyloric canal, and these are rapidly passed into the bowel. At a later stage of digestion solid particles are allowed to pass in, but these on arrival at the pylorus excite a firm closure of the sphincter, whereby the current of fluid conveying them is so suddenly arrested that a strong back wash is set up which often carries the particles again into the body of the stomach.

Another and ingenious explanation recently given by Cannon is as follows:—It is known that a local stimulus applied anywhere to the intestinal mucous membrane evokes a relaxation of the muscular wall of the canal in front of the point stimulated, but excites a contraction of the tube behind

that point. Cannon suggests that this law applies to the opening and closure of the pylorus, the stimulus being the acid secreted in the stomach. When this reaches a certain strength in the pyloric canal the orifice in front is opened or relaxed, whereas when it passes through, the same stimulus excites a contraction behind.

The evidence upon which Cannon bases his theory is somewhat as follows:—Carbohydrate foods escape earlier than proteins for the reason that the latter combine and mask a large amount of the hydrochloric acid of the stomach, while the former do not. If the acidification of carbohydrates be delayed by mixing them with sodium carbonate, their exit is also delayed, whereas on the other hand, if the protein be previously mixed with acid, its escape is hastened. The evidence, however, is not wholly convincing. The facts may be explained in other ways, and it must be admitted that we are still very much in the dark as to the immediate cause which determines the opening of the orifice from the stomach side.

I would now like to call your attention to the important protective value of the pyloric reflex for the safe performance of the functions of the bowel. This has been shown in a series of most interesting investigations made by Cannon and Murphy on the movements of the stomach and intestines in some surgical conditions. The mode of experimentation consisted in observing in cats the rate of passage out of the stomach of a standard meal of mashed potato mixed with bismuth. This was graphically represented by plotting out a curve showing the aggregate lengths of food column present in the small intestine at regular intervals during a period of seven hours after the meal was taken. On subsequent days animals were submitted to different procedures, and the effect on the escape of a similar meal was observed. At the outset the influence of ether administered for half an hour was recorded (Fig. 1).

The most marked alteration produced by ether in the passage of food from the stomach is the slowing of the rate of discharge. The curve rises gently instead of abruptly. There

is also a slow passage through the small intestine. The food, which ordinarily reaches the large intestine at the end of two or three hours, first appeared there after four, five, or six hours. Inhalation of ether does not therefore arrest the active movements of the alimentary canal, but simply slows them. Secondly, the effect of a thirty minutes exposure of the bowel to the air was observed, such as might occur in an operation,

FIG. 1.—Showing the effects of ether and of an intestinal operation on the passage of food out of the stomach and through the intestine.—(Cannon.)

care being taken not to touch the viscera. At the end of this period the abdomen was closed, and after recovery from the anæsthetic a standard potato meal was given. After exposure to air the discharge from the stomach begins at the normal time, but the outgo is slow, though not so slow as in the case of etherisation alone. No food entered the large intestine until the end of six hours (Fig. 2).

In the next observation the intestines after exposure were cooled, the animal being anæsthetised with ether. The cooling was effected by pouring at intervals into the abdomen sterile salt solution at a temperature of twenty degrees centigrade.

In the curve showing the effect of cooling, the discharge, though it begins at the normal time, is somewhat slow. The

striking feature of the curve, however, is the rapid passage through the small intestine. Food appeared in the large intestine at the end of three hours, and one hour later almost the whole meal had reached the colon.

Next the effect of handling the bowel was studied, the handling varying from gentle to severe, and being accomplished sometimes in air, sometimes under warm normal saline.

FIG. 2.—Showing the further effects of exposure and of cold on the passage of food through the stomach and intestine.—(Cannon.)

The effect of handling is very remarkable; even the most gentle manipulation under warm salts solution arrested all movement of the stomach and intestine for fully three hours after feeding (Fig. 3). Moreover, the escape when it began was very slow, and became increasingly so with the severity of the manipulation. The appearance of food in the large intestine was also delayed, none arriving there before the end of seven hours. Manipulation of the stomach and intestines in these experiments produced even under the most gentle and favourable circumstances a far greater degree of inactivity than any of the other factors concerned in the performance of the operation, exclusive of the influence of the operation itself.

Lastly, the effect of the section of bowel was investigated, the two ends being reunited immediately after the division. For comparison, two operations were performed—one a high trans-section, the other a low one, near the end of the ileum.

After a high intestinal section food did not emerge from the stomach before five or six hours, and within the period of observation extremely little had passed out (Fig 1). This

FIG. 3.—Showing the effects of handling the bowel on the passage of food through the stomach and intestine.—(Cannon.)

remarkable delay was not due to arrest of the normal peristaltic waves which expelled food from the stomach. These contractions were seen pushing food up to the pylorus at the rate of five or six a minute for more than five hours, but the sphincter held perfectly tight against the pressure, and refused to permit food to pass into the injured gut. It is remarkable, as Cannon and Murphy have pointed out, that the period during which this protection is exercised, corresponds closely with the time required for the primary cementing of the wounds

of the intestine as determined by independent observers. From experiments made by Dr. Abbey on the healing of intestinal sutures in dogs, sheep, and other animals, the usual time required for the exudation of a firm gluey lymph, able to afford efficient support to the wounded parts, is usually about six hours.

In the intestinal section at the lower end of the small bowel food escaped from the stomach within two hours, but food accumulated in the upper part of the small intestine, and even at the end of seven hours none had reached the lower end of the small intestine, although under normal circumstances the same meal appeared in the colon before three hours. It would seem therefore that not only is a protective influence exerted through the sphincter pylori, but that injury at any part of the alimentary canal is able to produce a blocking effect which saves the damaged part until a certain amount of repair has taken place.

ART. II.—*Concerning Trachoma.*^a By ARTHUR H. BENSON, M.B., F.R.C.S.I.; Surgeon to the Royal Victoria Eye and Ear Hospital, Dublin.

My first duty is to thank you for the honour you have done me in electing me President of this Section, and I do so with all sincerity. My next duty is to thank Professor White, on behalf of the Section, for his long and faithful services as secretary, and to greet his successor, Dr. Boxwell.

It is a very usual thing, in opening a new session, for the President to review the work done during the previous session; but in the present case such a recapitulation would seem to me to be profitless. I prefer, rather, to call your attention to one subject of the first importance to all humanity, and to the inhabitants of this country in particular, in the hope that by your efforts a serious blank in our knowledge may be filled.

^a Presidential Address delivered at the Opening Meeting of the Pathological Section of the Royal Academy of Medicine in Ireland, on Friday, November 12, 1909