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NEW METHODS OF STUDYING GASTRIC PERISTALSIS *

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It is hard for a moment to realize that our knowledge as regards gastric physiology is today in much the same stage as it was as regards cardiac physiology back in the early seventies, before the sequence of the beat in sinus, auricles and ventricles had been studied by means of graphic records. In those days the research workers simply watched the slowly beating hearts of dying amphibians and tried to understand the movements which they saw, much as we, today, try to understand the sequence of the gastric waves as they appear before us on the fluorescent screen. To be sure, we obtain graphic records by taking plates, but such plates are snap shots which cannot help the physiologist very much. A few roentgenologists, notably Rieder in Europe and Cole in America, have secured interesting serial roentgenograms of the stomach; but the technic has been so difficult and the apparatus so expensive that, so far as I know, the method has not been used in any physiologic laboratory. Cannon did much of his epoch making work with the roentgen ray; but his records consisted mainly of tracings of the shadows which he saw on the screen. Carlson and his students have done an enormous amount of work with balloons inserted into the stomachs of men and animals; but, as they admit, such balloons slip about; it is hard to say just where they are; and they certainly cannot give us information as to the way in which the waves travel over the organ. Recently, Wheelon and Thomas [1] have invented a type of anchored balloon with the help of which they have obtained interesting records from the pyloric region.

It has always seemed to me that an exact knowledge of the movements of the stomach could be secured best by fastening light recorders very gently to the outer surface of the organ; and in 1914, with the help of a simple little enterograph, I was able to obtain simultaneous records from the middle region and the pyloric antrum of a few rabbits and cats. Several years before, Hofmeister and Schütz,[2] and Sick and Tedesko [3] obtained somewhat similar records by fastening light heart levers to two or three places on the excised stomachs of laboratory animals. Such stomachs, kept in warm, oxygenated Locke's solution, will often show considerable activity for hours; and I have secured a number of interesting kymographic and electrographic records from them. The technic is naturally much easier than that required when we try to record the small, weak contractions of the cardiac end of the intact stomach, situated as it is high up under the diaphragm and moving constantly with respiration. The results obtained with the organ in situ are so much more trustworthy, however, that we must continue to grapple with the technical difficulties which stand in our way.

A number of these difficulties have now been conquered sufficiently so that we can get simultaneous mechanical records from five or six parts of the stomach. I shall not attempt here to describe the apparatus, because it is still in the stage of constant change and improvement. Another way of attacking the problem is to detect and make records of the delicate action currents which can tell us so much about what is going on in the muscle. Should a study of these currents in the stomach yield but a tenth of the information which a similar study has yielded in the fields of heart physiology and pathology, the science of gastro-enterology will be put on a new footing. Much of the technic for getting electrogastrograms and enterograms has already been worked out, and two brief reports on the subject have been published.[4] One of them contains a reproduction of the first human electrogastrogram to be taken.

Naturally, in the first stages of such an investigation, the interpretation of the records is difficult, and it is quite essential that the electrical changes be compared with mechanograms made at the same time and at the same place. Although this need has added greatly to the technical difficulties which already were troublesome enough, we have during the last few months secured a number of records like those in Figure 1, which show simultaneous mechanograms and electrograms from two parts of the stomach or bowel. They show that in most cases the electrical wave looks very much like the corresponding mechanical one. The two run closely together; and after a while we shall probably be able to read the meaning of the electrical records so clearly that we can dispense with the mechanical ones and can continue with the less troublesome electrical technic.

* From the George Williams Hooper Foundation for Medical Research and the Department of Medicine, University of California Medical School.

* Read before the Section on Gastro-Enterology and Proctology at the Seventy-Third Annual Session of the American Medical Association, St. Louis, May, 1922.

1. Wheelon, H., and Thomas, J. E.: J. Lab. & Clin. Med. **6**: 124 (Dec.) 1920; Am. J. Physiol. **59**: 72 (Feb.) 1922.

2. Hofmeister and Schütz: Arch. f. exper. Path. u. Pharmakol. **20**: 1, 1885.

3. Sick and Tedesko: Deutsch. Arch. f. klin. Med. **92**: 416, 1908.

4. Alvarez, W. C., and Mahoney, L. J.: Am. J. Physiol. **58**: 476 (Jan.) 1922. Alvarez, W. C.: The Electrogastrogram and What It Shows, J. A. M. A. **78**: 1116 (April 15) 1922.

WHAT CAN WE LEARN WITH THE NEW TECHNIC?

The next question is: What is being learned with these methods? In the first place, we are learning something about the place of origin of the gastric waves and how they travel over the stomach. As I pointed out in the previous articles, many of the records suggest strongly that the waves ordinarily arise at a point on the lesser curvature near the cardia. That may perhaps be the normal pacemaker, which sends out ripples which deepen into waves in the lower third of the stomach. Other records show signs of a shifting of the pacemaker, while others, again, show that two parts of the stomach are contracting with independent rhythms. Just as in the heart, so in the stomach, there appear to be gradations from transient blocks to complete dissociations. Such blocks have been found most frequently at the junction between the body of the stomach and the pyloric antrum; but a number of the records show that they can occur elsewhere. In the excised stomachs of rabbits, cats and dogs we can often see the lower end of the esophagus contracting powerfully and rhythmically, but only occasionally sending a wave over the adjacent stomach. Other records show what I have frequently observed on the fluorescent screen, and that is, a series of contractions which do not spread over the stomach, but spring up and apparently die away in the same place.

Another interesting observation is that a contraction near the cardia or in the preantrum may be followed almost instantly by a contraction of the pyloric antrum or of the stomach as a whole. This "systole" was seen years ago by Cole on his serial roentgenograms of human stomachs; but as the pacemaker seems often to give rise to a systole and peristaltic wave at the same time, the double nature of the contraction can hardly be recognized on the screen; and no one has felt inclined to pay much attention to Cole's observation. I admit that when Cole showed me his plates I thought that the phenomenon must be rare and of little significance. Now that I find it so commonly in my records, I am glad to express my apologies to Dr. Cole and my willingness to believe that many things appear on the fluorescent screen which we are not quick enough or prepared enough to see. For that matter, watching three waves going over the stomach at one time is like watching an expert at the shell game: it is not likely to yield exact or trustworthy information.

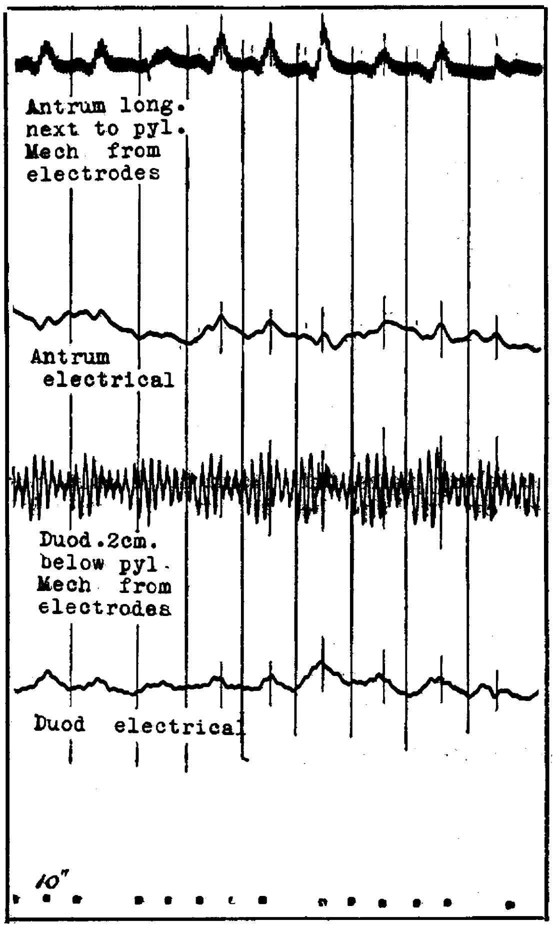

Fig. 1.—Electrograms from antrum next the pylorus, and from duodenum 2 cm. below, in a rabbit. The mechanograms, recorded simultaneously with the electrograms, represent the movements of the electrodes as the muscle contracted. An upward movement on the mechanical records signifies contraction, and in the electrical records it signifies a negativity of the orad electrode. The time record indicates intervals of ten seconds. The small waves on the first antral record are respiratory in origin. Note the increase in amplitude of the duodenal contractions with the arrival of each gastric wave at the pylorus. The vertical lines have been drawn to indicate synchronous points on the record.

But to return to the systoles: It may be that they interfere sometimes with the emptying of the stomach because, as can be seen from Figure 2, the waves marked *A, B* and *C*, which were seen to travel over the stomach, reached the pylorus while the muscle there was partly contracted. The record of the antral contraction often shows two components, and sometimes even three. The first one may represent the tendency of the muscle to contract with its own natural rhythm; the second may represent a systole, while the third represents the arrival of a peristaltic wave. These multiple activities sometimes make it almost impossible to interpret the electrograms. If we glance again at Figure 2, we see that in each set of contractions there is a second cardiac one which fails to give rise to any appreciable peristaltic wave. This second cardiac hump is so often synchronous with the arrival of the peristaltic wave at the pyloric antrum that I have often obtained the impression that a systolic type of impulse has shot backward. Hence, for convenience' sake, I have come to call this well defined and easily recognizable type of gastric activity "shuttle rhythm." Sometimes the impulse seems to shoot back so quickly that the two cardiac humps fuse to a greater or less degree.

In other records, we find a series of single gastric systoles with either the cardia or some other part of the stomach slightly in the lead. In some excised stomachs, we saw what appeared to be peristaltic waves; but the records showed that they were more like systoles. All parts of the stomach began to contract at the same time; but as it took the muscle in the lower end of the stomach a progressively longer time to get under way, the appearance was that of a wave spreading downward.

Figure 3 shows a common type of peristalsis in which some antral contractions are much more powerful than others. We see that commonly in man; and the frequency with which these large waves appear undoubtedly has much to do with the rate of emptying of the stomach, and perhaps a good deal to do with the production of pain and distress in diseased states. The graphs bring out the interesting fact that this increase in activity must often be purely a function of the pyloric antrum, because one can see no sign of corresponding differences in the size of the waves in the body of the stomach a centimeter above. There are some records which suggest strongly that the variation in the size of the antral contractions may be an interference phenomenon between the fundus rhythm and the inherent rhythm of the antral muscle. Previous experiments have shown me that the excised antral muscle will contract about three times a minute. If this should happen to be the rate of the waves coming down over the stomach, the antral contractions could easily be uniform in size and strength. When, however, there is a slight difference in rate, it might account for the presence of larger waves when the rhythms coincide and smaller ones when they conflict. Irregularities in the recurrence of these beats must be expected because other rhythmic components will come in by way of the duodenum.

This difference in the activities of the two functional parts of the stomach, the "crop" and the "gizzard," is brought out even more sharply in the records showing blocks and dissociations. A kymographic record of these blocks was shown in one of the preceding articles, and two electrograms depicting the same thing are shown now in Figure 4. Simultaneous mechanograms and electrograms made so far show that when the currents are absent from the antrum the contractions are also absent; but in one case when, for a short time, no contractions could be detected, weak action-currents still appeared at regular intervals. So far I have not seen anything on the records which looks like the common cardiac 2:1 or 3:1 block. The gastric blocks look more like those which we see in Stokes-Adams disease.

Another way in which the differences between the physiologic characteristics of the fundus and pyloric antrum can be brought out is by stimulating the vagus nerve. In a few such experiments done in my laboratory on rabbits, it was a striking thing to see the recording lever attached to the body of the stomach shoot upward (indicating contraction) while the lever on the antrum dropped. Other experiments have suggested that the pyloric antrum is more sensitive to all inhibitory influences than is the body of the stomach.

To me, one of the greatest surprises has been the discovery that any group of muscle fibers in the stomach wall may respond at the same time to two or more rhythmic activities. Thus, it may show small contractions perhaps every five seconds. These probably represent the local inherent rate, i. e., the rate at which the muscle contracts when excised and put into warm oxygenated Locke's solution. Besides the small contractions there may be slow tonus waves coming every minute or two. These tonus changes seem to be going on constantly throughout the digestive tract, and I believe that they must play a large part in regulating and directing peristalsis. The few records which we have obtained of these rhythms suggest that they can sometimes be captured and made to follow other regularly recurring impulses whose rate is not too widely different. This can be seen at the pyloric line where the duodenal tone rises shortly or immediately after the arrival of each gastric wave. The interesting point is that during intervals of complete gastric quiet, when even the action currents are absent, the duodenal tonus rhythm may continue unchanged, showing that it can be just as independent as the similar rhythms which can easily be demonstrated in the ileum and colon. Furthermore, when the stomach starts up again it does not always succeed immediately in capturing and dominating the duodenal tonus rhythm. As will be seen from Figure 1, this tonus wave shows itself sometimes only as a rhythmic increase in amplitude of contraction. It appears also in the electrograms as an increase in the strength of the action current.

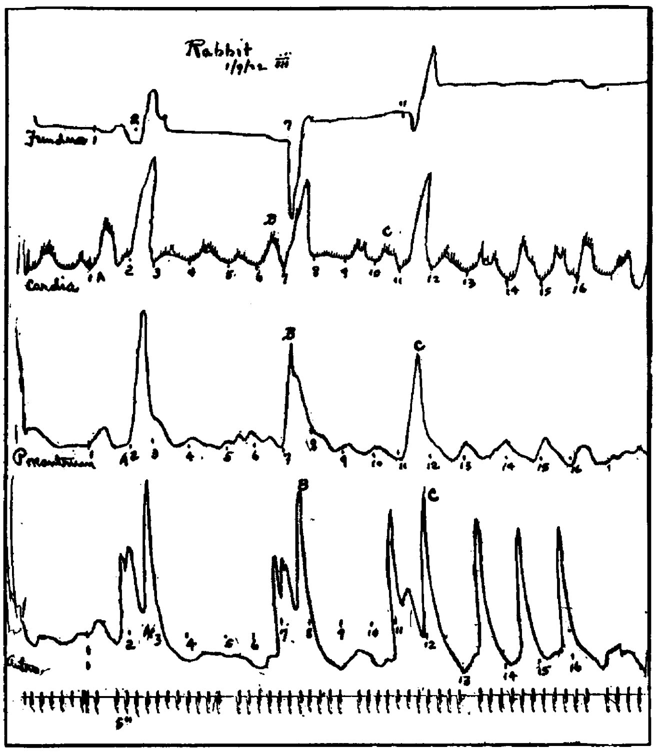

Fig. 2.—Mechanograms from the fundus, cardia, preantrum and antrum of a rabbit's stomach. The small waves just visible on the second record are respiratory in origin. The interval on the time record is five seconds. The figures represent corresponding points on the four records, while the letters *A*, *B* and *C* show that certain contractions were part of one peristaltic wave.

But to return to multiple rhythms in the stomach: (1) There are small, frequent waves analogous probably to the rhythmic contractions of the bowel; (2) there are tone changes like those in the bowel; and (3) there are peristaltic waves corresponding probably to the peristaltic rushes in the small bowel and the mass movements in the colon. These compound movements are seen most often in the body of the stomach, but sometimes in the antral records. The electrograms from the fundus generally show a series of small respiratory deflections, while those from the antrum often show a small deflection synchronous with the duodenal contractions. These are probably transmitted by conduction through the tissue, although I have seen similar little humps on some of the mechanical records from the antrum. These, however, probably represented little pulls on the gastric recording appartus by the adjacent bowel.

One more observation requires comment at this time, and that is that many of the mechanical records from the fundus show relaxations corresponding to the passage of the peristaltic waves. The fundus has a little different embryologic development from the rest of the stomach, and there are a number of indications that the working out of its rhythmic activities will be quite a problem in itself. In many of the records (both mechanical and electrical) from the lower end of the stomach there are signs of a preliminary relaxation before the contraction; but it may be that this is due simply to a passive stretching of the muscle as it is pulled on by the contracted area just above.

Certainly a large proportion of the records show no sign of a preliminary relaxation such as we would expect if the "law of the intestine" were an important factor in regulating peristalsis.

Enough has been said, it seems to me, to show that large gaps exist in our knowledge of gastric peristalsis. It is this lack of exact information which has been such a handicap to the surgeons in their efforts to cure gastric and duodenal ulcers. They have had to learn by sad experience not to make such things as long loop gastro-enterostomies and V-shaped excisions on the lesser curvature, but just why they still do not know. I sometimes think of the troubles the surgeons would have fallen into if they had been able to cut out infarcted areas in the heart and to short-circuit stenosed valves as easily as they operate on the stomach; how many disturbances of conduction they would have produced and how many patients they would have sacrificed until they had learned empirically to keep away from the bundle of His and its important branches. This only emphasizes the fact that the physician is too often called on to attempt repairs on a structure the normal workings of which he has not yet been able to understand. Logically, we should learn all about the physiology of an organ before we attempt to repair a diseased one; but unfortunately the demands of the sick are too urgent; we must do our best with what little knowledge we have; but at all times we must keep our eyes fixed eagerly on the laboratories, from which must come some day the needed help and guidance.

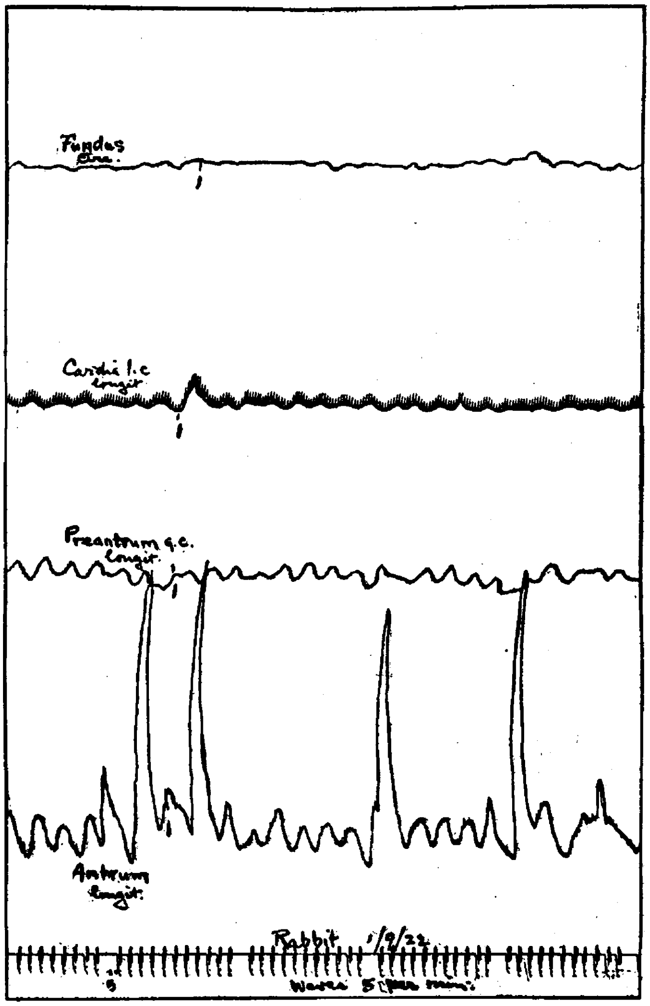

Fig. 3.—Mechanograms from the fundus, cardia, preantrum and antrum of a rabbit's stomach. The time interval represents five seconds. Note the large antral contractions which seem to arise locally.

SUMMARY

Knowledge of gastric physiology is still largely in the crude stage of purely visual observation.

The problem is now being attacked with methods for obtaining multiple and simultaneous mechanical and electrical records from the wall of the stomach.

Something has been learned about the gastric pacemaker; about different types of rhythmic activities; about gastric "systoles"; about "blocks" and dissociations of activity between the body of the stomach and the pyloric antrum.

Stimulation of the vagus produces quite different effects in the fundus and in the antrum.

It is surprising to find areas on the stomach in which the muscle is responding at one time to two or more sets of rhythmic impulses.

Some observations have been made on the influence of the stomach on the duodenum.

The records generally show little sign of the "law of the intestine."

The fundus sometimes appears to relax while the rest of the stomach is contracting.

The large gaps which exist in our knowledge must be filled if the surgeon is to operate safely on diseased stomachs.

177 Post Street.

ABSTRACT OF DISCUSSION

Dr. A. J. Carlson, Chicago: We will all agree in Dr. Alvarez' conclusions; namely, that this is the beginning of analysis of gastro-intestinal peristalsis by a new method. But we should keep in mind that we do a great deal of violence to the normal gastric mechanism the moment we put the animal under anesthesia or open the abdomen. I am not surprised at the irregularities which he describes. I should have been surprised if he had not found them. We must be very careful in ascribing physiologic significance to experimental contrivances that obviously are not physiologic. But I certainly wish Dr. Alvarez to go on and see what the method will yield, even if the results are mainly pathologic. If the method would work on the animal or person without anesthesia and without opening the abdomen, then we should have a measure equal to and, in the finer analysis, superior to the roentgen ray. But when we must induce anesthesia and open the abdomen, I am afraid the method is going to have very limited physiologic application. I believe Dr. Alvarez will agree with me in the view that the roentgen ray and the balloon methods have not as yet been exhausted in physiologic and pathologic investigations. It is, indeed, a curious thing that the great divergence in behavior of the different regions of the gastro-intestinal tract below the cardia have no gross anatomic basis for these differences. If we did not know what occurred under normal conditions, we could never infer it from gross or microscopic structure. I have recently been particularly interested in the lower esophagus and cardia, and it is a fact that, even in the normal animal with no anesthesia, by balloon methods we see conditions in which the cardia beats or contracts, apparently entirely independent of the stomach. Dr. Alvarez is the happy combination of physiologist and clinician, belonging in the same group as our late Dr. Samuel J. Meltzer. I say happy combination, because that gives a chance to carry over and use the exact criteria and critical control on clinical material, so far as these can be applied, that we use in the laboratory. It would be unfortunate if these persons who work both in the laboratory and in the clinic should reverse the process and carry over into the laboratory field some of the loose methods in observation and thought that unfortunately are not so uncommon in purely clinical work. But I must add that during the last fifteen or twenty years physiologists have also committed many sins and put obstacles in the way of broad physiologic progress, by drawing far-reaching physiologic conclusions on the basis of unphysiologic experiments.

Dr. Alfred A. Strauss, Chicago: It is true, as Dr. Alvarez has stated, that some of the interpretations of these contraction waves, as recorded by his electrical instrument, are difficult to understand. I have recently done some experimental work on the emptying time of the stomach, which is really a check up on an operative procedure which we have done clinically for about seven years. The procedure was the partial resection of the sphincter of the pylorus and pyloric antrum. When this is done in the human being, following a resection of an ulcer on the lesser curvature, the stomach will empty about twice as quickly as it will normally. We have followed this up clinically in a large series of cases. The animal experimental work checks up with this clinical observation in the minutest detail. After taking careful fluoroscopic readings and studying the emptying time of the individual animal, and then resecting the sphincter of the pylorus, we have found that the emptying time is from 30 to 50 per cent. quicker than in the normal animal; that the contraction waves on the lesser and greater curvature are so shallow that they can hardly be seen. Therefore, when the sphincter of the pylorus is paralyzed, there is very little resistance met by the contents in the stomach, and the intragastric pressure produced by the tonic contraction of the cardia is sufficient to empty the stomach contents very readily through the paralyzed sphincter. We have learned both from the clinical and the animal work that the size of the peristaltic waves on the lesser and greater curvature is in direct proportion to the amount of resistance that they meet at the pyloric sphincter; for when we produce a partial obstruction at the pylorus by fascial transplant, the size of the waves is very large because they meet a great resistance. When the pyloric sphincter is cut away, the waves are hardly visible because of the little resistance that they meet at the sphincter of the pylorus.

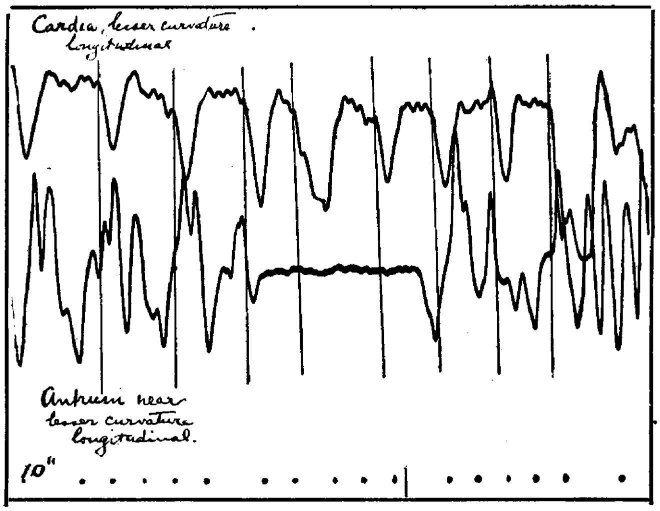

Fig. 4.—Electrograms from the cardia and antrum of a cat. The small deflections on both records are probably respiratory in origin. Note the blockage of two waves. The main deflection in the cardia's record is a positive one, suggesting that the pacemaker lay between the two electrodes placed on the lesser curvature next to the cardia.

Dr. W. C. Alvarez, San Francisco: I fully appreciate the dangers and pitfalls Dr. Carlson points out. I worked out the method of using the electrogastrogram about two years ago, and I was so surprised at the things I saw that I practically dropped it for a year and developed a method of getting records of the actual contractions before daring to talk about the peculiar things I saw on the electrogastrograms. And since we cannot by any present known methods get records like this of the impacted stomach of a wide awake man, I feel that we must make the beginning, and make that beginning on animals. To my mind the hopeful element is this: We know that a dying heart, or a heart that has been handled too long, develops certain abnormalities of rhythm; many of those abnormalities of rhythm are found in disease, and study of them under abnormal conditions has helped in the understanding of disease. Therefore, I think that probably it will be the same way with this work.

Percentage of War Neuroses.—Analysis of the 170,000 cases discharged for disability in England showed that 20 per cent. were due to war neuroses.—May, *Mental Diseases,* 1922.

SYPHILIS OF THE MOUTH

COMMON TENDENCY OF THE MOUTH AND SKIN TO THE SAME PATHOLOGIC PROCESSES *

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There is a close relation between the tissues of the mouth and those of the skin. Their structures are very much alike, and they react to many pathologic processes in the same way. There are numerous systemic diseases which have eruptions on the oral mucous membrane as well as on the skin, and these oral eruptions are identical with those of the skin, except as they are altered by the peculiar local conditions to which they are subjected in the mouth. These facts are particularly well exemplified in syphilis. The skin and the mouth are the structures for which syphilis shows its greatest predilection, and the predilection is quite as great for the mouth as for the skin. Indeed, it is probably true that syphilis occurs with as great frequency in the mouth as on the whole surface of the skin. Its frequency in the mouth, then, would of itself make syphilis of the mouth a subject of great practical importance. When we remember in addition the peculiar danger to others of syphilis of the mouth in its early period, it becomes doubly important.

One can get most easily a clear grasp of syphilis of the mouth if he will bear in mind that its lesions are those that occur on the surface of the skin, modified only by the peculiar influences to which their occurrence in the mouth exposes them. These are chiefly: exposure to moisture and warmth, causing the lesions to be macerated; irritation or injuries from eating, drinking and biting, from irregular, rough or sharp teeth or from tartar; and secondary infections in the mouth. Peculiarity of structure of the tissues involved accounts for some variations, but these are as a rule of little account except in late lesions of the tongue.

The special influence which is always active in modifying the appearance of syphilitic lesions in the mouth, and the one that does most to change their appearance, is the maceration to which the lesions of the mouth are, of course, always subjected. This factor produces little variation in the chancre or tertiary (true gummatous) lesions, but it causes distinct alteration from their cutaneous types in the lesions of secondary syphilis in the mouth. These early syphilids of the skin are mostly dry lesions. They are covered by a horny layer, which is imperfect, it is true, but sufficient to prevent free exudation from the lesions. In the mouth, this horny layer gives way, and

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