Physiology of the pylorus, pilleus ventriculi and duodenum as observed roentgenographically / Lewis Gregory Cole.

Physiology of the Pylorus, Pilleus Ventriculi and Duodenum as Observed Roentgenographically

LEWIS GREGORY COLE, M.D.
Professor of Radiology, Cornell University Medical College
NEW YORK

Reprinted from The Journal of the American Medical Association
Sept. 6, 1913, Vol. LXI, pp. 762-766

PHYSIOLOGY OF THE PYLORUS, PILLEUS VENTRICULI AND DUODENUM AS OBSERVED ROENTGENOGRAPHICALLY *

LEWIS GREGORY COLE, M.D.
Professor of Radiology, Cornell University Medical College
NEW YORK

Until 1892 the commonly accepted theory of gastric evacuation had been that offered by Richet and Rossbach, that the stomach contents were first thoroughly mixed with the gastric juices and, after three or four hours, passed rapidly into the duodenum. This conception was discredited by the results of independent investigations on dogs by Hirsch (1892) and Mering (1893), who substituted for it the theory of a rhythmically opening and closing pylorus, through which evacuation began immediately after ingestion. In 1898 Cannon announced the discovery of a progressive peristalsis in the cat, and eleven years later Kaestle, Rieder and Rosenthal demonstrated a corresponding phenomenon in the human being.

My conception of the gastric motor phenomenon has been previously described,[1] and will therefore be referred to only in brief. Like the heart-action, gastric action takes place in cycles, marked by a systole and diastole or an alternating contraction and relaxation of all of the peristaltic waves (Figs. 1 to 4). A cycle exists during the time occupied by the formation and duration of each terminal wave. Accordingly the number of cycles required for the progress of an individual peristaltic contraction from its origin near the fundus to its termination at the pyloric sphincter is determined by the number of waves simultaneously exhibited in the stom-

*Read in the Section on Pathology and Physiology of the American Medical Association, at the Sixty-Fourth Annual Session held at Minneapolis, June, 1913.

1. Cole, Lewis Gregory: Arch. Roentg. Ray, December, 1911, No. 137, p. 242; The Value of Serial Radiography in Gastro-Intestinal Diagnosis, THE JOURNAL A. M. A., Nov. 30, 1912, p. 1947.

ach. The motor phenomenon is therefore said to be of the one, two, three (Figs. 1 to 4), four, five or six cycle type.

The important rôle played by the small intestine in gastric evacuation was recognized by physiologists thirty years ago; but the peculiar function and diagnostic significance of that region known as the first portion of the duodenum has not been fully comprehended heretofore. It has none of the characteristics of the descending and horizontal duodenum. On the contrary it corresponds so entirely in contour with the pars pylorica and has so many characteristics of the stomach that roentgenographically one is compelled to consider it a continuation of the stomach itself (Figs. 5 to 8). These points were fully described by me[2] in an article in which the term "pyloric cap" was first applied to the first portion of the duodenum. The word cap is more popular than scientific, however, and therefore, with the aid of Dr. Tower of the New York Museum of Natural History, I selected the latin term "pilleus ventriculi," or cap of the stomach.

Considering the active interest now being evinced in duodenal ulcer, as indicated by the recent communications of Moynihan, Codman, the Mayo brothers, Schwartz and Strauss, it may be appropriate more fully to state my reasons for referring to this region as gastric rather than duodenal. Embryologically it has long been recognized that the upper portion of the duodenum is stomach rather than intestine. Mayo[3] calls attention to the fact that "in the early state of fetal existence the duodenum above the common duct is part of the pyloric end of the stomach. Coming from the primitive foregut, it is associated with the stomach in its physiology and pathology, and it is not part of the small intestine, which comes from the midgut."

Anatomically the first portion of the duodenum differs materially from the descending or horizontal portions. Dwight[4] observes that "the first or ascending portion of the duodenum has a strikingly different appearance from the second and third portions, which present numerous, small, irregular folds, particularly on the posterior aspect."

---

2. Cole, Lewis Gregory: Arch. Roentgen Ray, April, 1912.

3. Mayo, W. J.: Ulcer of the Duodenum, with a Report of Two Hundred and Seventy-Two Operations, THE JOURNAL A. M. A., Aug. 15, 1908, p. 556.

4. Dwight: Jour. of Anat. and Physiol.

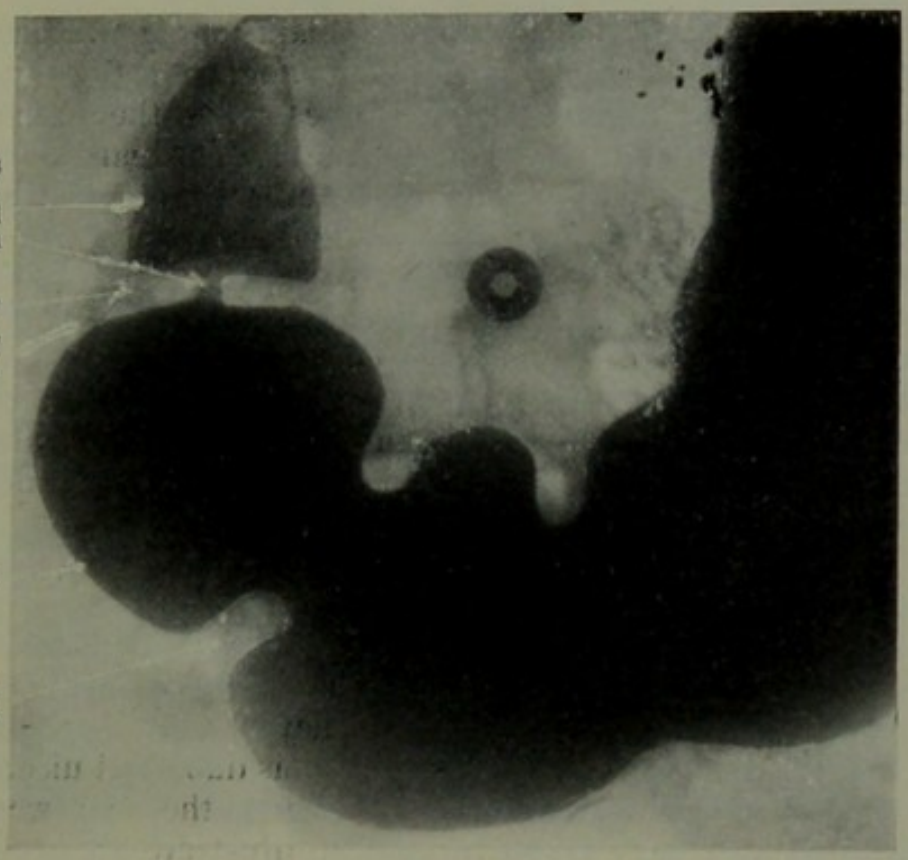

Figure 1.

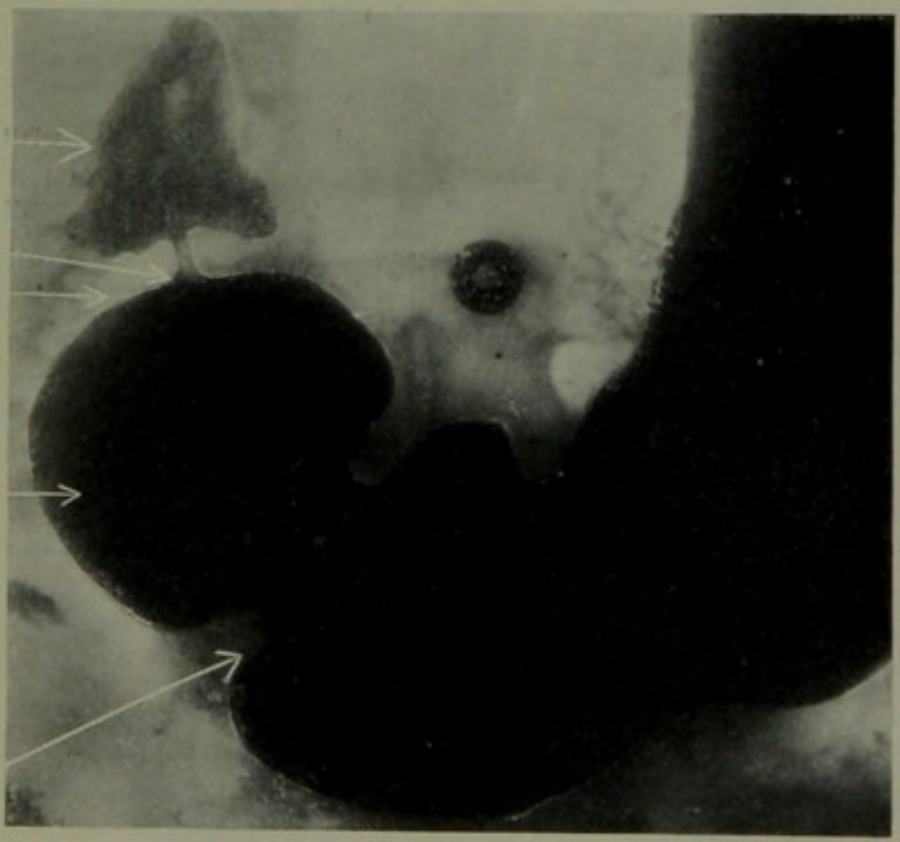

Figure 2.

TWO PHASES OF STAGE OF SYSTOLE

Schwarz[5] calls attention to the dilatation of the pars superior duodeni as observed roentgenographically, and from anatomic and histologic studies notes the resemblance between it and the stomach. 1. The pars horizontalis superior has a smooth inner wall, presenting the delicate, striped longitudinal folds of the stomach lining. The ring-like folds characteristic of the upper part of the jejunum are not present, but appear first in the upper portion of the descending duodenum. 2. Together with the stomach it is attached to the liver by the gastroduodenal hepatic ligament. 3. Histologically it resembles the pars pylorica in that the ~~pepsin~~ glands of Brunner are found here in abundance.

Physiologically the contents of the cap are acid, like the chyme in the stomach.

Surgically 95 per cent. of the ulcers which occur beyond the pylorus are found in the first 1½ inches of the intestine, namely, the cap. They should therefore be described as postpyloric rather than as duodenal ulcers.

The first roentgenograms presenting the cap were exhibited by Henry Hulst in 1906 to illustrate his presidential address before the American Roentgen Ray Society.[6] Its roentgen shadow, however, so closely resembles the pars pylorica that Hulst interpreted this postpyloric region as the pyloric antrum. The dimensions of the cap, like those of the stomach, depend partly on its distention during different stages of digestion, different phases of the cycle and different stages of duodenal peristalsis (compare Figs. 1 and 2 with Figs. 3 and 4). The posture of the body also influences its size, shape and position. The roentgenographic appearance of the cap is of inestimable value in the recognition of gastroduodenal lesions. Variations resembling pathologic deformities are often seen in some of the plates of each series, but these can be readily recognized and definitely differentiated from organic changes. The small indentation frequently observed on either the right or left side of the cap may be due to pressure from the descending portion of the duodenum, the common bile-duct, or the vena porta (Fig. 6). Spasmodic contraction of the cap (Fig. 9) is often the result of iliac stasis, a Lane's kink, or a diseased appendix. Incomplete filling of the cap may be caused by overactive duodenal peristalsis (Figs. 10 and

5. Schwarz: Berl. klin. Wchnschr., 1908, No. 24.

6. Hulst, Henry: Am. Quart. Roentgenol, January, 1907, p. 9. Case 4.

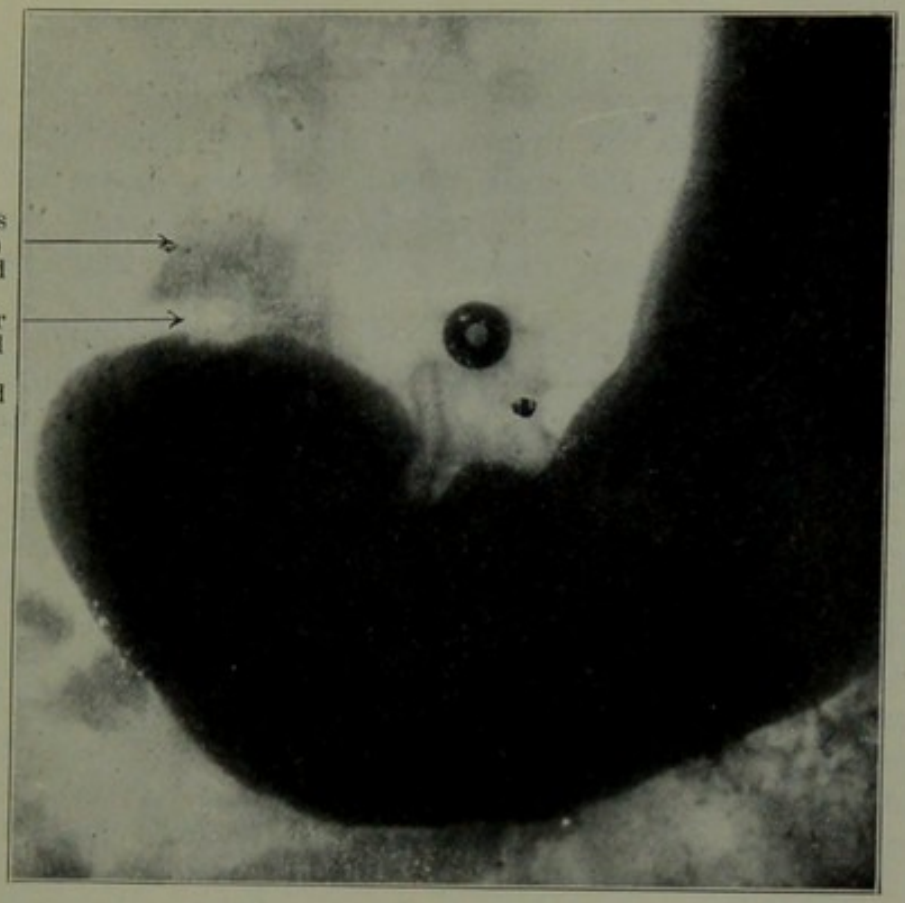

Figure 3.

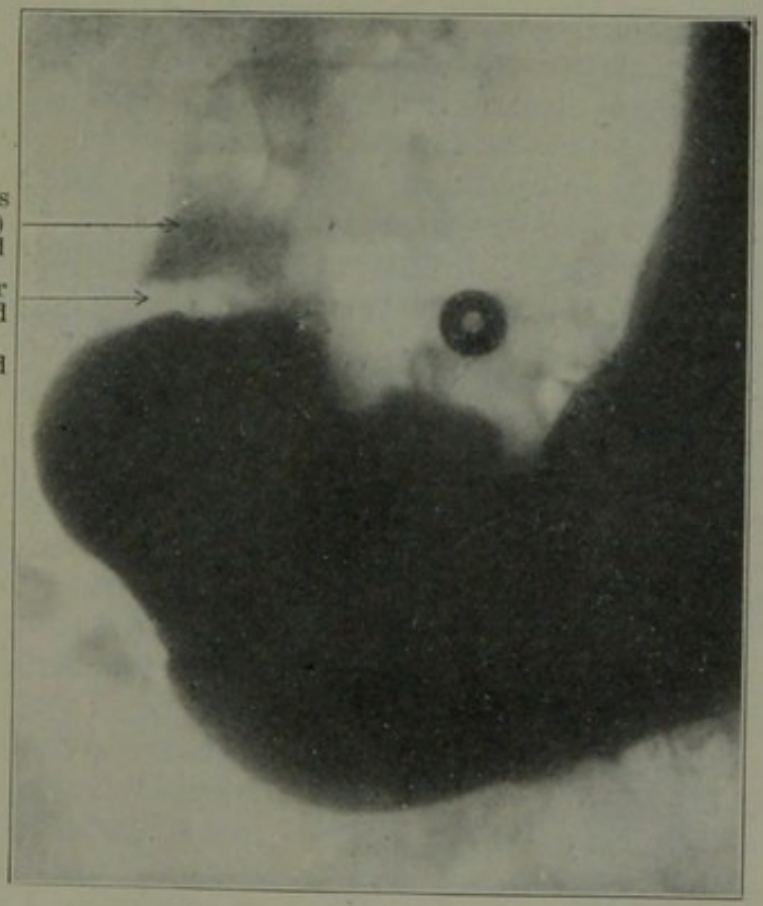

Figure 4.

TWO PHASES OF STAGE OF DIASTOLE

(Same case as Figs. 1 and 2). Note relaxation of peristaltic contractions.

11). This is more likely to occur in the early stage of digestion, when the pyloric sphincter is strongly contracted, than in the later stages when the sphincter is relaxed and the gastric peristalsis more efficient, even though less active (compare Figs. 12 and 13, and Figs. 15 and 16).

The function of the cap is that of a reservoir. It receives the acid chyme propelled through the pylorus during the systole of each cycle (Figs. 1, 2 and 8). During the early stage of digestion the chyme is rapidly withdrawn from the reservoir cap by a rather broad periodic peristaltic contraction (Figs. 7 and 10), which propels it through the duodenum, possibly caused by the alternating alkaline and acid reactions in this portion of the intestine. As digestion progresses the cap is more completely filled with the acid chyme, and, considering the presence of Brunner's glands, it is probable that the finishing touches of gastric digestion are received here by the small portion of chyme thus isolated from the bulk of food in the stomach.

The cap is separated from the pars pylorica by a space varying from ⅛ to ¼ inch, indicating the pyloric sphincter (Fig. 8). The importance of its roentgenographic appearance is second only to that of the cap in the diagnosis of lesions in this region. Both its gastric and duodenal surfaces should be smooth and clear-cut, and the lumen should be centrally located. The amount of contraction of the pyloric sphincter is clearly defined roentgenographically. As a rule, it is in proportion to the activity of the gastric peristalsis, that is, when the gastric peristalsis is feeble the contraction of the sphincter is weak, and when the gastric peristalsis is strong, the sphincter is more tightly contracted. Alteration in the balance between the contraction of the sphincter and the tone of the stomach is one of the functional disturbances of the pylorus which can be recognized roentgenographically. It causes either a retention of food or an unusually rapid evacuation of the stomach with dilatation of the cap, and sometimes dilatation of the duodenum and jejunum (Fig. 14). In the earlier stages of digestion, when the gastric peristalsis is active, the muscle of the pyloric sphincter contracts tightly (Fig. 12). As peristalsis grows feebler, the contraction of the sphincter becomes less tonic, until, during the later stages of digestion, it is greatly relaxed and its lumen comparatively large (Fig. 13).

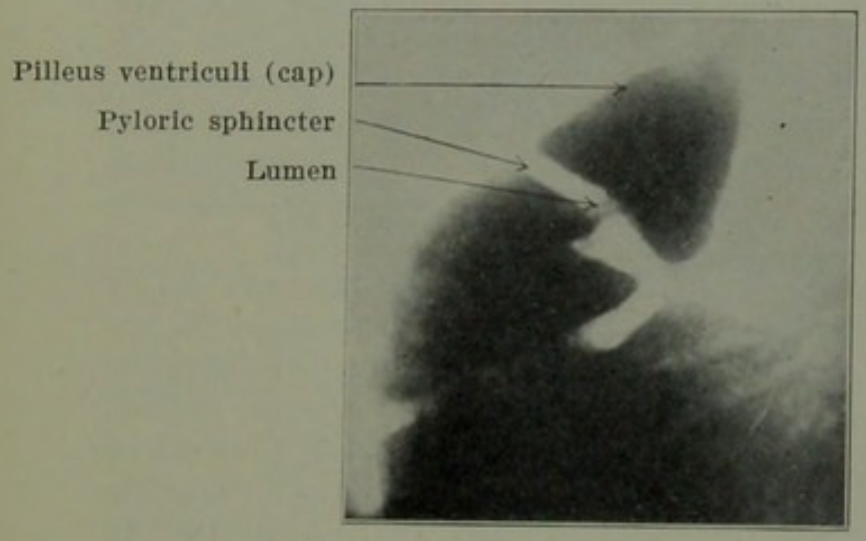

Fig. 5.—Pilleus ventriculi (cap).

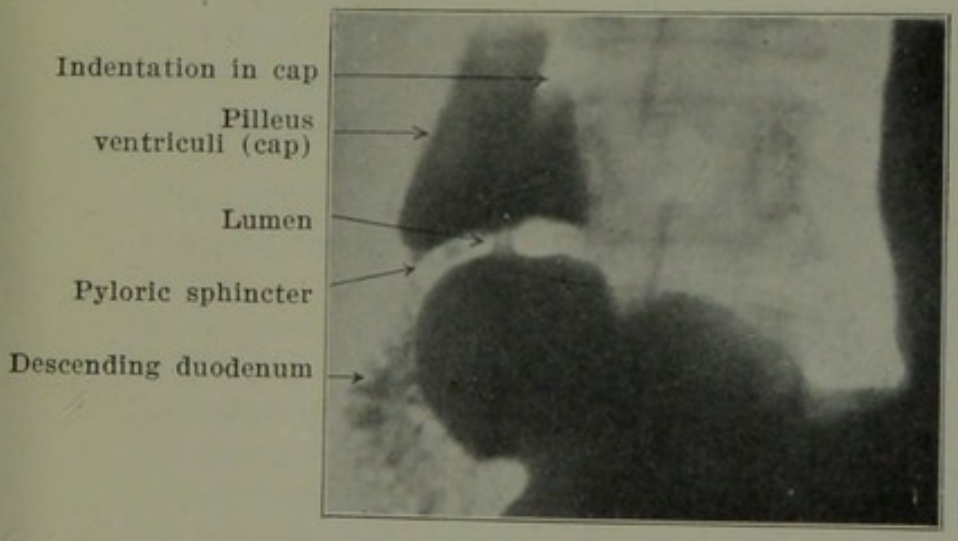

Fig. 6.—Pilleus ventriculi (cap).

The motor phenomenon of the pyloric sphincter forms the heart of this communication. Cannon[7] refers to the sphincter as the "keeper of the gate"; and before seeing his appropriate term, I referred to the sphincter in a previous communication[8] as a butler, guarding the entrance to the intestine, and allowing only such food as is properly prepared to be served to the intestine. More recent observations, however, lead me to believe that the pylorus is not the only or the most important factor in replenishing the descending and horizontal duodenum.

Several important questions regarding the function of the sphincter and its relation to the evacuation of the stomach should be considered here. Some of them have apparently been settled so conclusively by careful physiologic observations that it is with the greatest amount of timidity that I approach the subject; but the roentgenographic evidence is so significant that it cannot be ignored. Does the pylorus relax and contract periodically for the expulsion of chyme, independently of each peristaltic contraction, or is the chyme forced through the pyloric sphincter by each systole? The question of whether or not the pylorus relaxes and contracts periodically, independently of each peristaltic contraction, has been considered so definitely proved in the affirmative by careful physiologic observation that the energies of investigators have been directed solely toward determining the factors which control its contraction and relaxation. Let us first consider what physiologists regard as the periodic contraction and relaxation of the sphincter.

In accordance with Mering's theory of a rhythmically opening and closing sphincter, Cannon describes the motor phenomena of the pylorus as follows: "Wave after wave passes with almost no perceptible variation of depth. Yet as the waves are passing with such notable uniformity the pylorus may open before the pressure of an approaching constriction, and the mass in the antrum then released will be driven forth into the duodenum. The next wave and perhaps many thereafter of approximately the same depth may fail to press the food onward." Schicker doubts a rhythmically opening and closing pylorus and believes that the pylorus is open

7. Cannon: Am. Jour. Physiol., 1907, xx, 289.
8. Cole, L. G.: Arch. Roentg. Ray, April, 1912, p. 427.

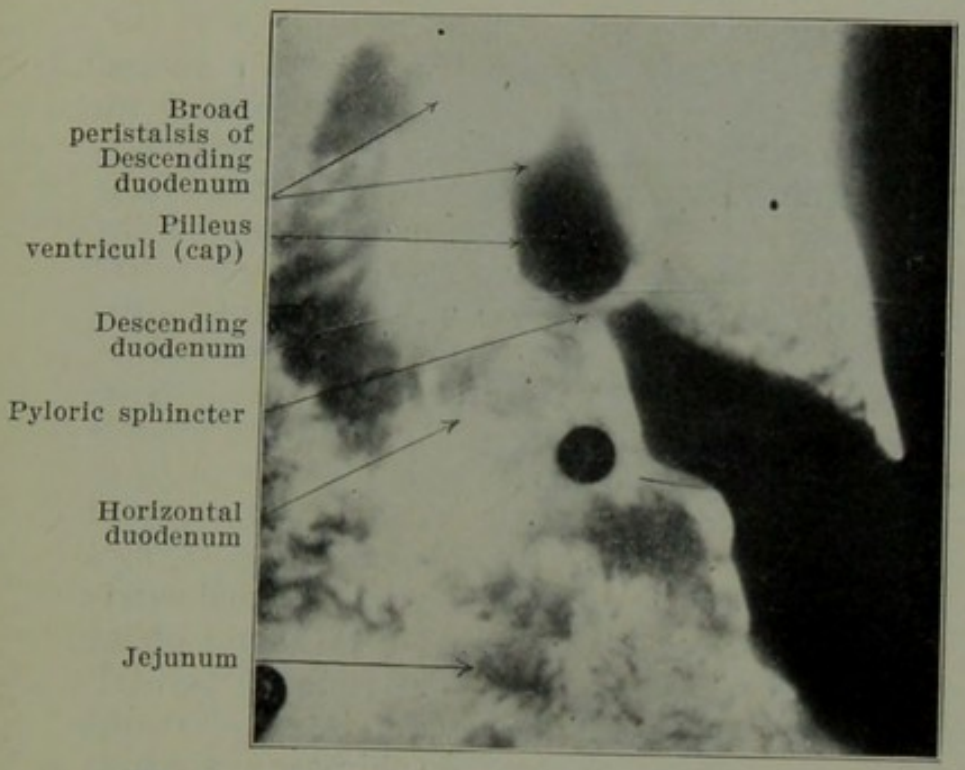

Fig. 7.—Evacuation of cap by broad peristaltic contraction of descending duodenum.

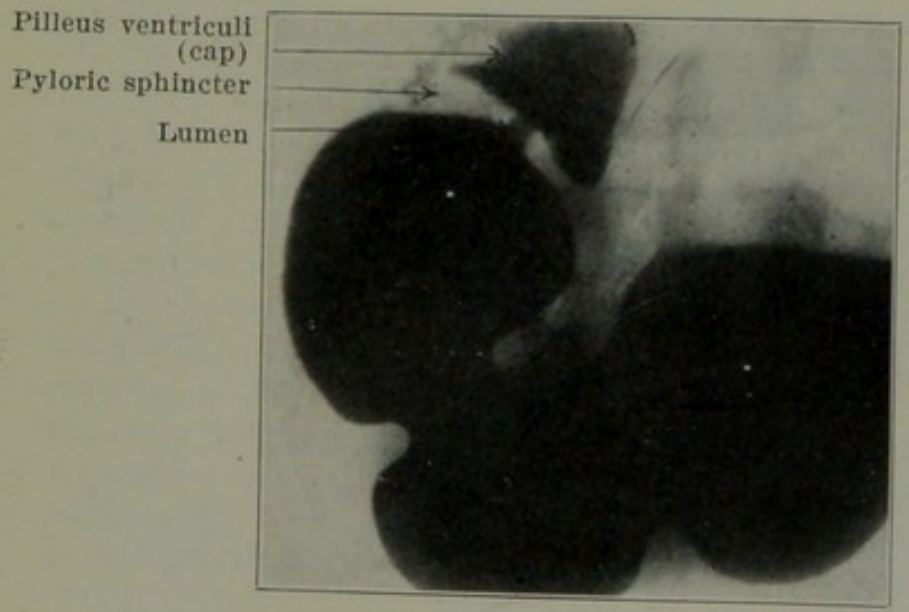

Fig. 8.—Chyme passing through lumen of pyloric sphincter into reservoir cap.

only during the relatively short duration of the antrum contraction.

From a careful study of more than twelve thousand serial roentgenograms of about five hundred cases, I am unable to detect any such relaxation and contraction as has been described, but it may be contended that this is only a sudden squirt and that therefore none of the twelve thousand roentgenograms showed the sphincter during relaxation. This criticism would be hard to disprove unless we demonstrated some other method of evacuation. A study of all these roentgenograms shows that during the systole of every gastric cycle the pylorus is open, and through its lumen, which varies from 1/8 to 3/16 inch in diameter, a small amount of the liquid chyme is propelled into the reservoir cap (Figs. 1, 5, 6 and 8). This period of expulsion consumes approximately seven tenths of the cycle. The other three tenths of the cycle is occupied by the diastole. The terminal peristaltic contraction, which has meanwhile been advancing toward the pylorus, now attains the sphincter and effects its closure, so that the lumen is entirely obliterated, or visible only as a hair-line (Figs. 3 and 4). Thus the chyme in the cap is mechanically prevented from dropping back into the stomach when the patient is in the erect posture.

A further question to be considered is what factors other than the sphincter and gastric motor phenomena have a direct influence on gastric evacuation. According to Marbaix[9] "the duodenum exerts the influence for the replete intestine on the closing of the pylorus." Mering[10] concludes from his investigations that "the filling of the small intestine reflexly retards the emptying of the stomach." Schicker[11] is also of the same opinion. The roentgenographic findings indicate that this reflex from the replete intestine is practiced, not on the pyloric sphincter, but on the contraction which withdraws the chyme from the reservoir cap, as the duodenum is replenished from the cap and not from the stomach. During the later stage of digestion the cap retains its maximum content. (Figs. 13 and 16.) Apparently, therefore, duodenal receptivity controls the evacuation of

9. Marbaix: La cellule, 1898, xiv, 251.

10. Mering: Verhandl. d. Cong. f. inn. Med., Wiesbaden, 1893, xii, 471.

11. Schicker: Deutsch. Arch. f. klin. Med., 1911, No. 104, p. 566

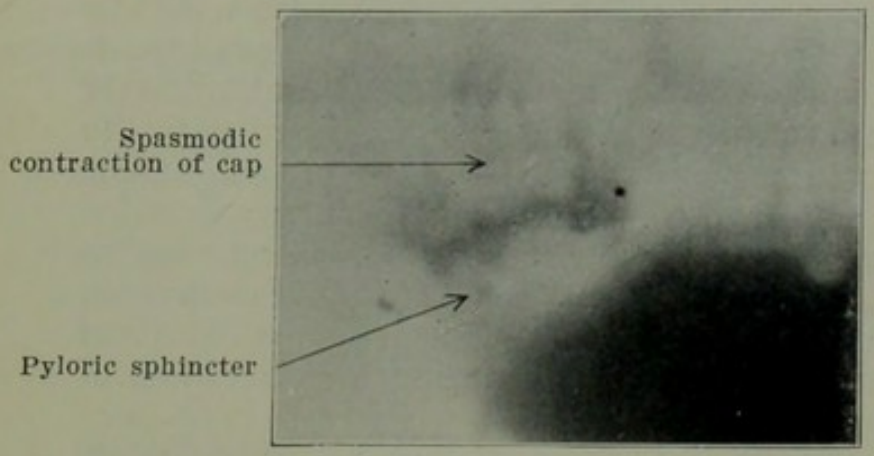

Fig. 9.—Spasm of cap caused by infected appendix.

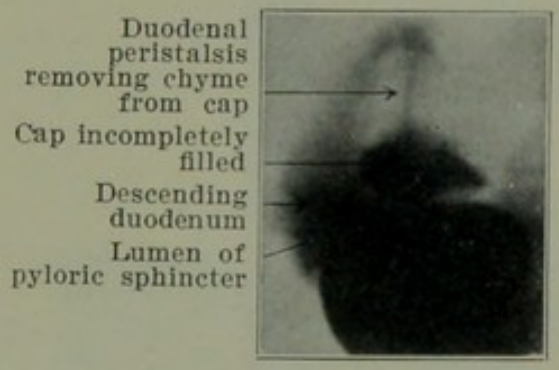

Fig. 10.—Active duodenal peristalsis.

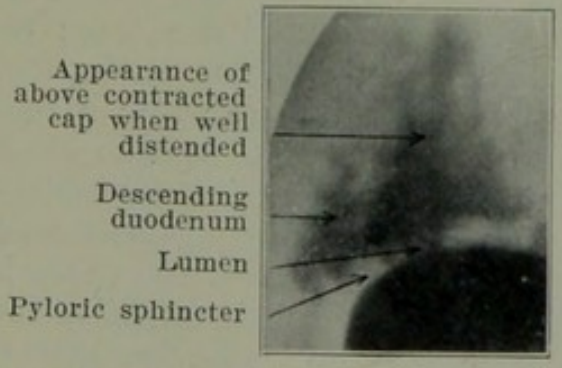

Fig. 11.—Cap well distended. Same case as Fig. 10.

the cap through duodenal peristalsis rather than the evacuation of the stomach through a pyloric reflex.

Whether the rapid withdrawal of chyme from the cap during the early stage of digestion (Fig. 15) results from its slight acidity or its fluidity or is demanded by the hungry intestine below is beyond my sphere to determine. Here is a fertile field for physiologic research. Personally I believe that the hungry intestine is an important factor, because when the food reaches the ileum, the activity of the duodenal peristalsis is much diminished and consequently the cap retains more and the jejunum receives less than during the early stage of digestion.

The descending and horizontal portions of the duodenum are so radically different from the cap that I do not think of them as portions of the same organ.

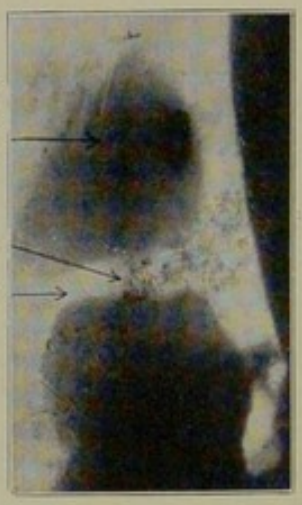

Fig. 12.—Pyloric sphincter tightly contracted immediately after ingestion.

(Figs. 7 and 14.) The difference is more obvious in the roentgenograms, in which the function of each portion is shown, than in the study of the anatomy or casts of the duodenum. The dilatation of the cap into a reservoir corresponds with the casts, which, however, do not reproduce the contraction of the functionating descending and horizontal portions. When there is sufficient retention to distend the duodenum the ring-like appearance is distinctly shown. (Fig. 13). A sufficient retention to show these rings occurs so infrequently however, that one is compelled to consider it abnormal and probably the result of obstruction by the root of the mesentery, as was shown in one case, by adhesions from a gastric ulcer

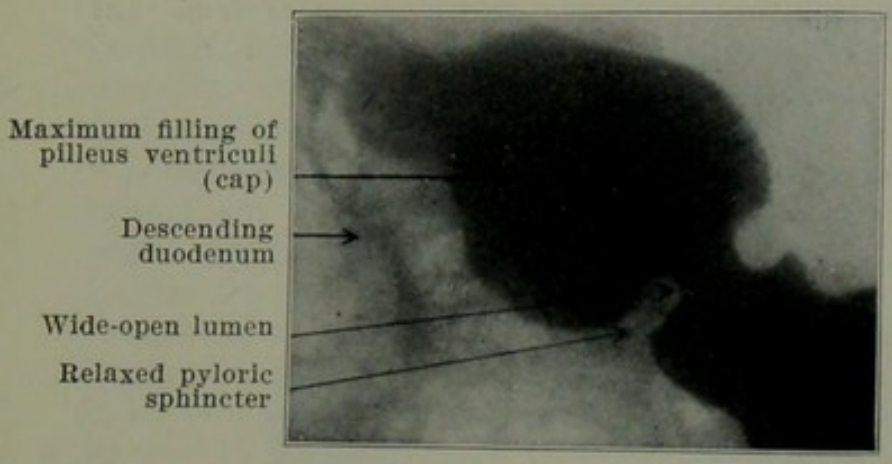

Fig. 13.—Pyloric sphincter relaxed, lumen wide open, six hours after ingestion. Same case as Fig. 12.

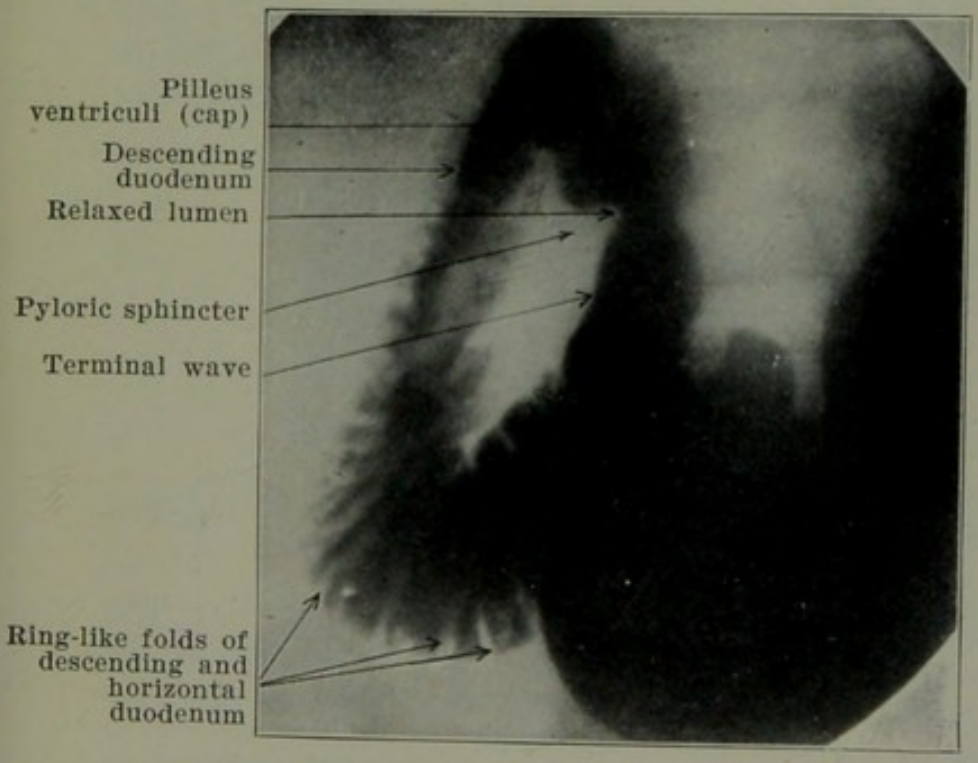

Fig. 14.—Dilatation of duodenum caused by rapid evacuation of stomach through relaxed sphincter.

on the posterior wall of the stomach. The fact that these circular folds move, or are moved, is clearly demonstrated by serial roentgenography.

When, as is frequently the case, the descending duodenum passes down behind the pars pylorica and is obscured by it, a roentgenogram taken in the lateral direction, as suggested by George of Boston, will bring

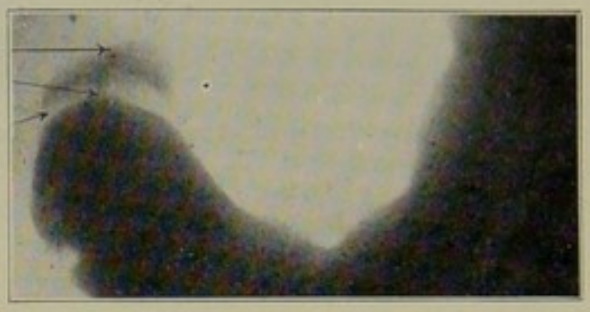

Fig. 15.—Cap incompletely filled in early stages of digestion.

it into view. If the cap is displaced posteriorly, it may present in these plates, although it fails to show in the anteroposterior roentgenograms in either the prone or erect posture.

The roentgenographic findings of the horizontal portion of the duodenum correspond more accurately with the anatomic descriptions than do those of the cap or descending duodenum. The distal end, at which it joins

Fig. 16.—Cap containing maximum amount during later stage of digestion. Same case as Fig. 14.

the jejunum, is usually obscured by the pars media. The diagnostic importance of this region is emphasized by Codman in his article on chronic obstruction of the duodenum by the root of the mesentery.

Frequently one can detect the duct of Wirsung, and in a few cases the ampulla of Vater is distinctly shown. This is not only an interesting scientific fact, but is also

of practical importance. When the bismuth remains in this duct or ampulla after it has left the duodenum, and even after it has passed out of the entire tract, it might readily be misinterpreted as a renal or biliary calculus, or as bismuth adherent to or lodged in the crater of an ulcer.

The motor phenomena of the pylorus, pilleus ventriculi and duodenum herein described as observed roentgenographically, may be demonstrated in all human stomachs having a moderately active peristalsis. Whether or not the same is true of the lower animals I do not know. It may be that especial activities have been evolved by the erect posture of man, differing from the gastric motor phenomena in the lower animals.

103 Park Avenue.