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Edited by
HUGH MACLEAN, M.D., D.Sc.
Professor of Medicine, University of London

MODERN VIEWS ON DIGESTION AND GASTRIC DISEASE

BY
HUGH MACLEAN, M.D., D.Sc., M.R.C.P.
Professor of Medicine, University of London, and Director of the Medical Clinic, St. Thomas's Hospital; Honorary Consulting Physician to the Ministry of Pensions; Consulting Chemical Pathologist to St. Thomas's Hospital

WITH 14 CHARTS AND 23 FIGURES

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PREFACE

THIS work is an attempt to give a short and concise account of the present position of gastric physiology and pathology. As the result of experimental investigation, our knowledge of gastric function and mechanism has been considerably advanced within the last few years, and a good deal of light has been shed on several of the more obscure and difficult problems of digestion. It has now been shown, for instance, that regurgitation of the alkaline intestinal contents into the stomach is a phase of normal digestion; indeed, interference with this regurgitant mechanism often leads to marked functional disturbance.

The widespread prevalence of gastric disease, both functional and organic, must be obvious to every practitioner, but it is, perhaps, not sufficiently recognised that intelligent treatment of these conditions must be based on physiological knowledge; without such knowledge so-called treatment is purely empirical and, at best, but a shot in the dark.

It is hoped that the present monograph may provide a general account of the physiological processes involved in the preparation of our food for absorption, and also serve to indicate the main principles on which modern treatment of gastric ailments rests.

One chapter—that on carcinoma of the stomach—may appear, in certain of the claims advanced, to be somewhat unorthodox. All the statements made there, however, are based, not on theory or speculation, but on observations extending over a period of more than twenty years, and I have endeavoured to bring forward definite evidence to prove their validity. To the critic who doubts them I would say, observe from fifty to one hundred cases of stomach cancer on the lines indicated here before rejecting them. The majority of cases of gastric cancer can be very easily and quickly diagnosed by any medical practitioner who takes the trouble to get an accurate history and carry out an ordinary test meal investigation.

The beneficial effects of intensive alkaline treatment of gastric diseases are fairly generally recognised; of the very great value of this method experience gives ample proof.

For the contents of Chapter IX., dealing with X-ray investigation of the gastro-intestinal tract, I am indebted to Dr. Geoffrey Fildes, officer-in-charge of the X-ray department, St. Thomas's Hospital, who has made a special study of gastric work. Dr. Fildes has kindly furnished all the radiograms in the book.

I wish specially to thank my colleague, Dr. Isaac Jones, for his valuable help in looking up hospital records and in other ways. I wish also to express my indebtedness to Dr. Forest Smith for looking up records and to Mr. Griffiths, B.Sc., for valuable aid in the preparation of many of the illustrations and charts, and for his help in certain of the chemical investigations described.

H. MacLean.

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CHAPTER I

THE STRUCTURE AND MOVEMENTS OF THE STOMACH

THE intelligent study of gastric diseases necessitates a working knowledge of the general anatomy and physiology of the human stomach. As far as the anatomy is concerned the case is comparatively simple: the structure of the stomach is well known even to its minutest details. When, however, we come to consider gastric physiology the position is very different. We know that certain phenomena take place during the digestion of food, but how the various functions are initiated and controlled is, in the comparatively meagre light of our present knowledge, frequently but a matter of speculation and conjecture.

THE STRUCTURE OF THE STOMACH

The stomach is a muscular bag lined with mucous membrane containing large numbers of secreting glands. In a general way it may be considered, as far as its muscle is concerned, as a dilatation of the œsophagus. The musculature of the stomach is made up of three layers (Fig. 1).

1. A longitudinal layer of fibres continuous with the external layer of the œsophagus. This layer passes along the stomach from the cardiac end to the duodenum; it is best developed at the greater and lesser curvatures, and more especially at the pyloric end.

2. A circular layer which is placed next to the external layer. This is a strong and important layer which is markedly thickened at the pyloric region ; here it forms a powerful muscular tube which, in conjunction with the thickened longitudinal layer, plays a very great part in the functional movements of the active stomach.

3. An internal layer of oblique fibres which at the pyloric end is incomplete, and appears in this region to blend with the circular fibres.

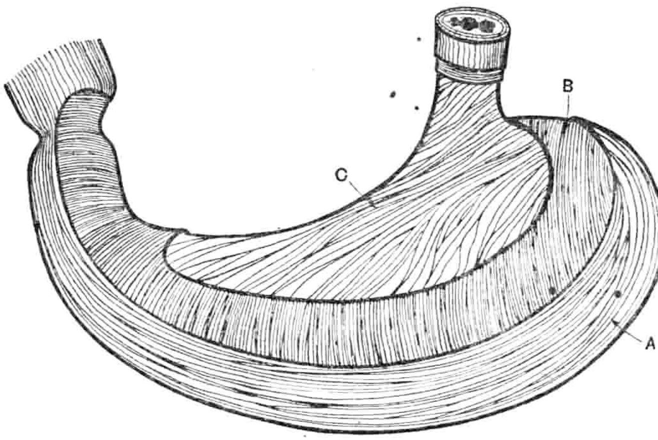


FIG. 1.—To show musculature of stomach.
A = Longitudinal fibres.
B = Circular fibres.
C = Oblique fibres.

The combination of these different layers results in the formation of a muscular sac which has its distal or pyloric portion formed of a strong and powerful wall of well-developed muscular fibres. In the rest of the sac the wall is thinner and the muscular development much less pronounced.

Lining the stomach is a mucous membrane which contains two distinct varieties of glands. These glands differ chiefly in the fact that some of them contain only one type of gland cell lining the basement membrane, while in others there are two distinct types of cells present.

On account of their distribution in the stomach these are generally known as *pyloric* and *fundic* glands.

(*a*) **Pyloric Glands.**—These glands are found in the pyloric region of the stomach. They consist of two or three short wavy tubules opening into a common duct. The tubes are lined with finely granular cubical cells, while the ducts have more or less columnar cells.

(*b*) **Fundic Glands.**—These are by far the most numerous glands. They occur throughout the whole body of the stomach with the *exception of the cardiac and pyloric regions.* They consist of tubes lined with two types of secreting cells. Projecting from the basement membrane towards the lumen of the duct there is a continuous lining of granular polyhedral cells. Between these cells and the basement membrane are large oval cells opaque and granular in appearance. From their position in the duct these latter cells are known as *parietal* or *oxyntic* cells. The other cells projecting towards the centre of the lumen are known as *central* cells. It is generally believed that the parietal or oxyntic cells secrete the hydrochloric acid of the gastric juice; presumably the central cells of all the glands form pepsin and other digestive ferments.

Besides the above, a few glands are found in the cardiac area which are sometimes looked upon as special structures. They are essentially more or less similar to the pyloric glands. The important point to note in connexion with the gastric glands is that the pyloric region, and a small area in the neighbourhood of the cardiac part of the stomach, contain no acid-producing glands.

CLINICAL SUBDIVISIONS AND POSITION OF THE STOMACH

The stomach in man is of the simple type, and is, from the anatomical standpoint, much less complicated than the compound stomach of many animals. It is now known, however, that even the simple stomach is physiologically very complicated, for different portions are histologically different and perform specific functions.

The human stomach is divided into two chief parts, the *fundus* and the *pyloric antrum.* The upper border is known as the *lesser curvature* and the lower border as the *greater curvature* (see Fig. 2). The pyloric antrum constitutes a comparatively small part of the stomach before it joins the duodenum. At the point of junction of the stomach and duodenum a thickening of the circular muscular fibres forms a sphincter which is capable of completely shutting off the duodenal lumen from that of the stomach. This sphincter action is helped by a special arrangement of the mucous membrane at this point. The pyloric sphincter plays a most important part in the physiology of digestion. The pyloric antrum is bounded on the right by this sphincter and on the left by a transverse band of muscle which passes across the stomach from a notch in the lesser curvature (the *Incisura angularis*) to a corresponding notch in the greater curvature. The rest of the body is known as the fundus. For purposes of reference the fundus is sometimes subdivided into a small part lying round the opening of the œsophagus—the cardiac part—and the portion between this and the pyloric antrum—the prepyloric region. Diagrammatically these divisions might be represented as follows :—

	Stomach.			
Duodenum	*Pyloric Antrum*	Prepyloric part.	Cardiac part.	Œsophagus.
		Fundus.		
Pyloric sphincter.			Cardiac sphincter.	

It is unfortunate that a good deal of confusion has arisen because of the different names given to the subdivisions of the stomach. From the clinical standpoint, the general division into pyloric antrum and fundus is very convenient, for these two portions of the stomach differ markedly in anatomical structure and in physiological activity.

At the entrance of the œsophagus into the cardiac end of the stomach the circular muscle layer of the œsophagus forms a sphincter—the *cardiac sphincter*—which, during digestion, shuts off the stomach cavity from the œsophagus.

POSITION OF THE STOMACH

When the body is in the horizontal position, as is the case during operations, the stomach lies in an obliquely transverse position from left to right in the abdomen. The same position is found in dissection of the cadaver. The stomach, however, is not an absolutely fixed organ, and its position varies with the position of the body and the amount of food or gas present. Fig. 3 is a photograph of a young healthy subject in whom the outline of the stomach was marked on the surface of the abdomen ; this outline was obtained after a barium meal by means of a fluorescent screen. Here the stomach occupies a more vertical position, and has a more tubular shape, the lower part lying in the region of the umbilicus (see page 137).

The relations of the stomach, therefore, depend on various factors ; its position and its size and relationship to the viscera are constantly changing throughout the day. When empty it lies at the back of the abdomen away from the abdominal wall. On deep inspiration it descends to the region of the umbilicus or a little lower.

When distended it tends to rotate longitudinally on its lesser curvature, so that the greater curvature rises and tends to come forward against the anterior abdominal wall : the result is that under these conditions the anterior surface of the stomach is directed upwards and presses against the diaphragm, compressing the thoracic cavity and embarrassing the heart. This is a most important fact from the clinical standpoint, for the detrimental effect of a distended stomach on a diseased heart is well known. It is, however, perhaps not sufficiently recognised that patients suffering from myocardial degeneration frequently die suddenly after a moderately heavy meal. In very many cases of more or less sudden death in patients suffering from disease of the cardiac muscle the stomach is found greatly distended and overloaded at the *post-mortem* examination. Indeed such deaths very frequently occur very shortly after a meal.

MOVEMENTS OF THE STOMACH

The most important function of the stomach appears to be the physical preparation of food for further action in the intestine by the pancreatic and intestinal juices. Two factors participate in this preparation :—

1. The motor activity of the stomach.
2. Digestion by means of the stomach enzymes.

The physical action of the stomach in mixing and disintegrating the food is a most important one ; though this action is helped very materially by the gastric juice, it is probable that the condition of the stomach muscle is, in general, of more importance than the activity of the gastric enzymes. At any rate, as will be discussed later, there is ample clinical evidence that digestion can proceed in a quite satisfactory manner in subjects whose stomachs contain no active gastric juice and in whom the food undergoes no appreciable peptic hydrolysis as long as it remains in the stomach.

Like the mouth, the stomach is primarily an apparatus for the disintegration of food ; in both cavities actual physical breaking down seems to be the important physiological function. It is true that this physical disintegration is greatly assisted in the normal stomach by enzyme action, but gastric digestion is, of itself, insufficient to break down the food to the point at which it can be absorbed and assimilated by the body. The important changes in the chemical digestion of food take place in the small intestine, and all the preliminary modifications it undergoes are merely in preparation for the more essential digestion in the intestines.

The removal of the stomach is quite compatible with life ; indeed, if food is suitably prepared beforehand, and no excessive amount is eaten at one time, little inconvenience may be felt. In the absence of intestinal digestion life would be impossible.

When solid food is taken into the stomach the pyloric sphincter closes and the food remains there for several hours. Formerly, it was thought that during this time the contents were kept in a kind of rotatory movement by which the various fractions became thoroughly mixed. We now know, however, as the results of the investigations of Cannon, Grützner and many others, that the facts are much less simple than this, and that the stomach possesses a highly organised and specially adapted mechanism for the preparation of the food.

During digestion the stomach is physiologically divided into two parts. The muscular pyloric part deals with the food, mixes it thoroughly with the gastric juice and breaks it down by muscular action, while the less muscular fundus simply acts as a reservoir to contain the food. During the whole time the stomach wall is pressing steadily on the contents, so that no empty space exists. The pyloric part is the mill which grinds the food, while the fundus simply feeds the mill.

Shortly after the ingestion of food, muscular movements begin about the middle of the stomach and pass along towards the pylorus. These pyloric waves become stronger and stronger as digestion proceeds, while at the same time the pyloric region becomes lengthened; they occur at the rate of about three or four per minute and force the food against the walls of the pylorus. The result of this activity is a very complete mixing of food and gastric juice in the pyloric region. Very soon the pyloric contents are reduced to a thin liquid mass known as the *chyme*. At intervals the pyloric sphincter opens and small quantities of this chyme are passed on into the duodenum. As the more liquid part leaves the stomach, more and more of the contents are forced forward from the fundus, to be in turn reduced to chyme. During the earlier stages of digestion there may be no movement whatever of the food in the fundus, though, no doubt, part of it, at any rate, is in contact with gastric juice. The interior of the mass is probably in more or less the same condition as when it left the mouth, thus providing an opportunity for the action of the mouth saliva in the stomach.

Towards the later stages of digestion the pyloric waves invade the fundus region more and more, but, for the most part, the pyloric region is the site of activity in disintegrating the food.

Since the stomach walls adapt themselves to the amount of food ingested, the organ gets larger and larger as successive portions of the meal are swallowed. As digestion proceeds its size steadily decreases with the expulsion of the liquid or partially liquid contents into the duodenum. The fate of the food after it reaches the duodenum is discussed in the next chapter.

REGULATION OF THE PYLORIC SPHINCTER

The cause of the intermittent relaxation of the pyloric sphincter during digestion has been the subject of much investigation and speculation. In spite of all this, we still remain more or less ignorant of the exact mechanism by which this action is controlled and regulated. There is no doubt that solid objects when pressed against the sphincter tend to keep it closed, while on the other hand, the presence of liquid food in the stomach seems to favour relaxation. Probably, therefore, the state of subdivision of the food plays some part in this regulation; at any rate, by the time the sphincter opens in ordinary digestion the contents of the pyloric antrum have been reduced to a pulpy state. Cannon, who has done a great deal of work on this subject, agrees that the consistency of the food plays some part, but argues that the fundamental factor regulating sphincter action is the hydrochloric acid of the gastric contents. The general theory of this "acid control of the pylorus" is dependent on the principle that acid in the stomach causes a relaxation of the sphincter, while, on the contrary, acid in the duodenum causes contraction.

As digestion proceeds the gastric contents become more and more acid, until finally a sufficient acid concentration is reached to act on the pylorus and cause relaxation. Immediately afterwards the stomach contractions force the highly acid material into the first part of the duodenum, where it is held for some time. The contents of the upper duodenum are now strongly acid, with the result that the sphincter closes. Very soon the alkali of the pancreatic juice neutralises this acid chyme in the duodenum, so that the duodenal stimulus to sphincter contraction is now removed. When this happens, the acid on the stomach side causes another relaxation and more acid contents are forced into the duodenum. Again the sphincter closes, and this automatic "see-saw" mechanism continues to operate until the whole of the gastric contents reach the intestine.

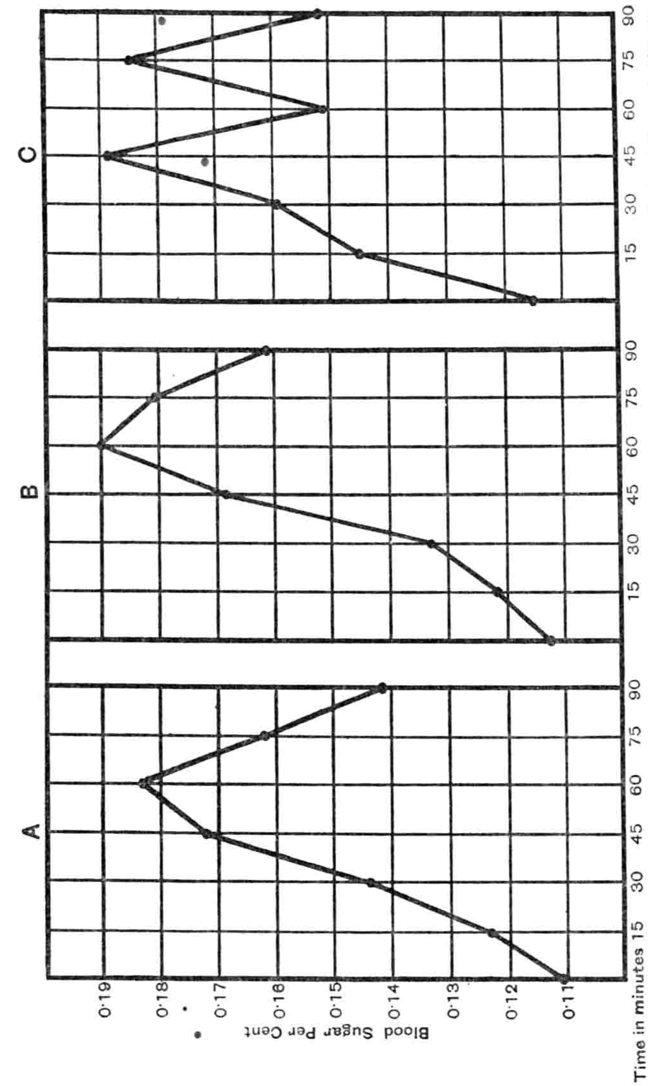
This theory is simple and fascinating, but, as is so often the case with many beautiful theories, it unfortunately does not coincide with certain facts. For instance, if acid in the stomach is necessary to open the pyloric sphincter, then a meal taken with a sufficient amount of alkali to prevent the presence of free acid at any time during digestion should be unable to pass from the stomach to the intestine. Clinical experience shows that food can leave the stomach without any difficulty under conditions quite definitely excluding the presence of acid. Again, in the case of patients suffering from absence of hydrochloric acid in the stomach—the so-called *achylia gastrica*—the sphincter appears to act quite satisfactorily. Much recent experimental work by American observers also supports the view that the "acid control" theory must be abandoned.

Why the pyloric sphincter relaxes and contracts during gastric activity we do not at present know. On the whole the most important factor appears to be the consistency of the food, but how this acts is a mystery.

In a recent publication by Haneborg, evidence is brought forward in support of the contention that the sphincter opens automatically in connexion with gastric peristalsis. According to this view, some of the peristaltic waves travelling towards the pylorus act on the sphincter and relax it. Why the sphincter should open in response to some waves and remain closed during the passage of others admits so far of no intelligible explanation. Indeed, the whole problem of sphincter activity is at present but a matter of conjecture.

As the result of recent work, Apperly came to the conclusion that the stomach does not begin to empty until the total chloride value approaches that of the blood chloride. According to this view, when a test meal is given containing more than the optimum amount of chlorides, no opening of the sphincter takes place until the contents are reduced by dilution to the optimum concentration. Similarly, when a meal containing little or no chloride is given, the stomach must supply the necessary amount of chloride before emptying begins to take place.

This view is interesting, but it hardly accounts for certain facts, such as the passage of water and other fluids through the pylorus almost immediately after drinking, and before any chloride can be added. Again, in some experiments carried out in my laboratory in connexion with the absorption of sugar, it was found that when a solution of sugar containing as much as 4 per cent. sodium chloride, and another containing no sodium chloride at all, were given, the blood sugar rose equally rapidly in both cases. Indeed, the curve formed was almost exactly the same as that produced when the sugar was given in 0·8 per cent. sodium chloride. Since absorption of sugar does not take place in the stomach, the sugar in each case must have passed equally quickly into the small intestine. According to Apperly's theory, the solution containing the 0·8 per cent. sodium chloride (the optimum chloride concentration) should have passed quickly, but the others should have been delayed. As seen from the curves, however (Chart I.), this was not the case. Each curve represents the rise in blood sugar for ninety minutes after the sugar was taken; blood sugar determinations were done every fifteen minutes. Though



A. 50 grms. glucose in 100 c.c. H_2O.

B. 0·6 grm. Na Cl + 50 grms. glucose in 100 c.c. H_2O.

C. 4 grms. Na Cl + 50 grms. glucose in 100 c.c. H_2O.

CHART I.—Showing absorption after ingestion of sugar solution containing different amounts of sodium chloride.

Apperly's suggestions do not appear to apply in this instance, his interesting work is worthy of careful consideration.

RELATION OF STOMACH MOVEMENTS TO NERVES

The stomach is provided with extrinsic nerves from two sources—the *vagi* and *sympathetic*. The right vagus is distributed on its posterior surface, while the left vagus supplies the anterior surface. It has also many intrinsic nerve plexuses from which fibres pass to the muscular tissue and mucous membrane. The vagus is the *motor* nerve of the stomach, for it has been demonstrated that stimulation of the vagus fibres sets up well-marked contractions in the stomach wall ; it is also probable that the pyloric sphincter is opened by vagus action. The sympathetic acts in an opposite way to the vagus and constitutes the *inhibitory* nerve of the stomach ; when stimulated the sympathetic fibres cause a dilatation of the contracted organ.

Through these nerves, both the motor and secretory activity of the stomach may be influenced by external causes, such as those affecting the central nervous system. The effect of general " well being " on digestion is well recognised, while various nervous and toxic states are known to be frequently associated with gastric disturbances. Cannon in his experiments on digestion in the stomach of the cat made the interesting observation that, whenever the animal became enraged or excited, stomach movements immediately ceased.

The activity of the stomach is not entirely dependent on extrinsic nerves, for the organ is automatic like the heart. It is capable of functional activity, both as regards movements and secretion, when its external nerve supply is completely cut off. Under these conditions, however, its action seems to be somewhat erratic, and normally it requires impulses through extrinsic nerves in order to control and regulate its functions to the best advantage. In this respect the stomach may be compared with a racehorse, which, though quite capable of independent action, is not likely to win a race except under the regulating and guiding influences of its rider.

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