but die of inanition after having lost four-tenths of the body-weight. The following is an example of experiments of this kind (Flint, 1861): A fistula was made into the gall-bladder of a dog, after excising nearly the whole of the common bile-duct. The animal suffered no immediate effects from the operation, but died at the end of thirty-eight days, having lost $37\frac{1}{2}$ per cent. in weight. He had a voracious appetite, was fed as much as he would eat, was protected from cold and was carefully prevented from licking the bile. During the progress of the experiment, various observations were made on the flow of bile. During the last five or six days, the animal was ravenous but was not allowed to eat all that he would at one time. At that time he was fed twice a day, but he would not eat fat, even when very hungry. During the last day, when too weak to stand, he attempted to eat while lying down.

Human bile is a moderately viscid fluid, of a dark, golden-brown color, an alkaline reaction and a specific gravity of about 1018. Among other constituents, which will be described in connection with the physiology of secretion, it contains sodium united with two acids peculiar to the bile, called glycocholic and taurocholic acids. Sodium taurocholate is much more abundant than the glycocholate. The viscidity of the bile is due to mucus derived in part from the lining membrane of the gall-bladder and in part, probably, from little, racemose glands attached to the larger bile-ducts in the substance of the liver. The so-called biliary salts, sodium taurocholate and sodium glycocholate, are probably the constituents of the bile which are concerned in digestion.

Although the bile is constantly discharged in certain quantity into the duodenum, its flow presents marked variations corresponding with certain stages of the digestive process. In fasting animals, the gall-bladder is distended with bile; but in animals opened soon after feeding, it is nearly always found empty. The actual secretion of bile by the liver is also influenced by digestion. The following table gives the variations observed in the dog with a biliary fistula:

TABLE OF VARIATIONS IN THE FLOW OF BILE WITH DIGESTION.

(At each observation the bile was drawn for thirty minutes.)

Time after feeding.	Fresh bile.		Dried bile.		Percentage of dry residue.
	Grains.	Grammes.	Grains.	Grammes.	
Immediately	8·103	0·525	0·370	0·024	4·566
One hour	20·527	1·330	0·586	0·038	2·854
Two hours	35·760	2·317	1·080	0·070	3·023
Four hours	38·939	2·523	1·404	0·091	3·605
Six hours	22·209	1·439	0·987	0·051	4·450
Eight hours	36·577	2·370	1·327	0·086	3·628
Ten hours	24·447	1·584	0·833	0·054	3·407
Twelve hours	5·710	0·370	0·247	0·016	4·325
Fourteen hours	5·000	0·324	0·170	0·011	3·400
Sixteen hours	8·643	0·560	0·309	0·020	3·575
Eighteen hours	9·970	0·646	0·277	0·018	2·778
Twenty hours	4·769	0·309	0·170	0·011	3·565
Twenty-two hours	7·578	0·491	0·293	0·019	3·866

Disregarding slight variations in this table, which may be accidental, it may be stated, in general terms, that the bile begins to increase in quantity immediately after eating; that its flow is at its maximum from the second to the eighth hour, during which time the quantity does not vary to any great extent; after the eighth hour it begins to diminish, and from the twelfth hour to the time of feeding it is at its minimum.

One of the uses which has been ascribed to the bile is that of regulating the peristaltic movements of the small intestine and of preventing putrefactive changes in the intestinal contents and the abnormal development of gas; but observations on this point have been somewhat conflicting. During the first few days of the experiment just described, the dejections were very rare; but they afterward became regular, and at one time there was even a tendency to diarrhœa. There can be little doubt, however, that the bile retards the putrefaction of the contents of the intestinal canal, particularly when animal food has been taken. The fæces in the dog with biliary fistula were always extremely offensive. Bidder and Schmidt found this to be the case in dogs fed entirely on meat; but the fæces were nearly odorless when the animals were fed on bread alone. In the case of intestinal fistula in the human subject (Busch), the evacuations which took place after the introduction of alimentary substances into the lower portion of the intestine had an unnaturally offensive and putrid odor. In this case, as it was impossible for matters to pass from the portions of the intestine above the fistula to those below, the food introduced into the lower opening was completely removed from the action of the bile.

It has been shown that the bile of itself has little action upon any of the different classes of alimentary substances. In the fæces of animals with biliary fistula, the only peculiarity which has been observed, aside from the putrefactive odor and the absence of the coloring matter of the bile, has been the presence of an abnormal proportion of fat. This was observed in the fæces of a patient suffering under jaundice apparently due to temporary obstruction of the bile-duct (Flint). The fact was also noted in the dogs experimented upon by Bidder and Schmidt.

The various experiments which have been performed upon animals render it almost certain that the bile has an important influence, either upon the digestion or upon the absorption of fats. Bidder and Schmidt noted, in animals with biliary fistula, that the chyle contained very much less fat than in health. In an animal with a fistula and the bile-duct obliterated, the proportion of fat was 1·90 parts to 1,000 parts of chyle; while in an animal with the biliary passages intact, the proportion was 32·79 parts per 1,000. In animals operated upon in this way there is frequently a great distaste for fatty articles of food. In the observation made in 1861 the dog refused fat meat, even when very hungry and when lean meat was taken with avidity.

Experiments on animals, with regard to the influence of the bile upon the absorption of fats, have resulted in hardly anything definite. It is known, however, that when the bile is diverted from the intestine, the quantity of fat in the chyle is greatly reduced and a large proportion of the fat taken with the food passes through the intestine and is found in the fæces.

The action of the bile in exciting muscular contraction, particularly in the non-striated muscular fibres, is well established. It has been shown by Schiff that this fluid acts upon the muscular fibres situated in the substance of the intestinal villi, causing them to contract, and according to his view, assisting in the absorption of chyle by emptying the lacteals of the villi. The question, however, of the absorption of fats is difficult of investigation. Notwithstanding the obscurity in which this subject is involved, it is certain that the progressive emaciation, loss of strength, and final death of animals deprived of the action of the bile in the intestine, are due to defective digestion and assimilation. Notwithstanding the great quantities of food taken by these animals, the phenomena which precede the fatal result are simply those of starvation. It may be that the biliary salts are absorbed by the blood and are necessary to proper assimilation; but there is no experimental basis for this supposition, and it is impossible to discover these salts in the blood of the portal system by the ordinary tests. It is more probable that the biliary salts influence in some way the digestive process and are absorbed in a modified form with the food.

The observations of Bidder and Schmidt show that the characteristic constituents of the bile are absorbed in their passage down the alimentary canal. Having arrived at an estimate of the quantity of bile daily produced in dogs, they collected and analyzed all the fæcal matter passed by a dog in five days. Of the dry residue of the fæces, the proportion which could by any possibility represent the biliary matters did not amount to one-fourth of the dry residue of the bile which must have been secreted during that time. They also estimated the sulphur contained in the fæces and found that the entire quantity was hardly one-eighth of that which was discharged into the intestine in the bile; and inasmuch as nearly one-half of that found in the fæces came from hairs which had been swallowed by the animal, the experiment showed that nearly all the sulphur contained in the sodium taurocholate had been taken up again by the blood. These observations show that the greater part of the bile, with the biliary salts, is absorbed by the intestinal mucous membrane. Dalton attempted to follow the constituents of the bile into the blood of the portal system, but was unable to detect the biliary salts. Like the peculiar constituents of other secretions which are reabsorbed in the alimentary canal, these substances become changed and are not to be recognized by the ordinary tests, after they are taken into the blood.

While it is the digestion and absorption of fatty substances which seem to be most seriously interfered with in cases of biliary fistula in the inferior animals, the rapid loss of weight and strength show great disturbance in the digestion and absorption of other constituents of food. A fact which indicates a connection between the bile and the process of digestion, is that the flow of this secretion, although constant, is greatly increased when food passes into the intestinal canal.

Although it has been demonstrated that the presence of the bile in the small intestine is necessary to proper digestion and even essential to life, and although the variations in the flow of bile with digestion are now well established, physiologists have but little definite information concerning the exact mode of action of the bile in intestinal digestion and absorption. Nearly all that can be said on this subject is that the action of the bile seems to be auxiliary to that of the other digestive fluids.

Movements of the Small Intestine.

By the contractions of the muscular coat of the small intestine, the alimentary mass is made to pass along the canal, sometimes in one direction and sometimes in another, the general tendency, however, being toward the cæcum; and the partially digested matters which pass out at the pylorus are prevented from returning to the stomach by the peculiar arrangement of the fibres which constitute the pyloric muscle. Once in the intestine, the food is propelled along the canal by peculiar movements which have been called peristaltic, when the direction is toward the large intestine, and antiperistaltic, when the direction is reversed. These movements are of the character peculiar to the non-striated muscular fibres; viz., slow and gradual, the contraction enduring for a certain time and being followed by a correspondingly slow and gradual relaxation. Both the circular and the longitudinal muscular layers participate in these movements.

Although the mechanism of the peristaltic movements of the intestine may be studied in living animals after opening the abdomen or in animals just killed, the movements thus observed do not entirely correspond with those which take place under natural conditions. In vivisections no movements are observed at first, but soon after exposure of the parts nearly the whole intestine moves like a mass of worms. In the normal process of digestion the movements are never so general or so active. They take place more regularly and consecutively in those portions in which the contents are most abundant, and the movements are generally intermittent, being interrupted by long intervals of repose. In Busch's case of intestinal fistula, there existed a large ventral hernia, the coverings of which were so thin that the peristaltic movements could be readily observed. In this case the general character of the movements corresponded with what has been observed in the inferior animals. It was noted that the movements were not continuous, and that there were often intervals of rest for more than a quarter of an hour. It was also observed that the movements, as indicated by flow of matters from the upper end of the intestine, were intermitted with considerable regularity during part of the night. Antiperistaltic movements, producing discharge of matters which had been introduced into the lower portion of the intestine, were frequently observed.

As far as has been ascertained by observations upon the human subject and warm-blooded animals, the regular intestinal movements are excited by the passage of alimentary matters from the stomach through the tube during the natural process of digestion. By a very slow and gradual action of the muscular coat of the intestine, its contents are passed along, occasionally the action being reversed for a time, until the indigestible residue, mixed with a certain quantity of intestinal secretion, more or less modified, is discharged into the caput coli. These movements are apparently not continuous, and they depend in some degree upon the quantity of matter contained in different parts of the intestinal tract. Judging from the movements in the inferior animals after the abdomen has been opened, the intestines are always changing their position, mainly by the action of their longitudinal muscular fibres, so that the force of gravity does not oppose the onward passage of their contents as much as if the relative position of the parts were constant. There are no definite observations concerning the relative activity of the peristaltic movements in different portions of the intestine; but from the fact that the jejunum is constantly found empty, while the ileum contains a considerable quantity of pultaceous matter, it would seem that the movements must be more vigorous and efficient in the upper portions of the canal.

The gases which are found in the intestine have an important mechanical office. They are useful, in the first place, in keeping the canal constantly distended to the proper degree, thus avoiding the liability to disturbances in the circulation and facilitating the passage of the alimentary mass in obedience to the peristaltic contractions. They also support the walls of the intestine and protect these parts against concussions, in walking, leaping etc. The gases are useful, likewise, in offering an elastic but resisting mass upon which the compressing action of the abdominal muscles may be exerted in straining and in expiration.

There can be hardly any question that the normal movements of the intestine are due principally to the impression made upon the mucous membrane by the alimentary matters, to which is added, perhaps, the stimulating action of the bile. It is difficult to determine with accuracy what part the bile plays in the production of these movements, from the fact that the normal action of the intestine is not easily observed. In the case of intestinal fistula so often referred to, when food was introduced into the lower portion of the canal, there was at first an abundant evacuation every twenty-four hours; but subsequently it became necessary to use enemata. As there was no communication between the lower and the upper portions of the intestine, this fact is an evidence that the peristaltic movements can take place without the action of the bile.

The vigorous peristaltic movements which occur soon after death have been explained in various ways. It has been shown that these movements are not due to a lowering of the temperature or to exposure of the intestines to the air. The latter fact may be easily verified by killing a rabbit, when vigorous movements may be seen through the thin, abdominal walls, even while the cavity is unopened. According to Schiff, the cause of these exaggerated movements is diminution or arrest of the circulation. By compressing the abdominal aorta in a living animal, he was able to excite peristaltic movements in the intestine as vigorous as those which take place after death; and on ceasing the compression, the movements were arrested.

The nerves distributed to the small intestine are derived from the sympathetic and from branches of the pneumogastric, which latter come from the nerve of the right side and are distributed to the whole of the intestinal tract, from the pylorus to the ileo-cæcal valve. The intestine receives no filaments from the left pneumogastric. Throughout the intestinal tract, is a plexus of non-medullated nerve-fibres with groups of nerve-cells, lying between the longitudinal and circular layers of the muscular coat. This is known as Auerbach's plexus. From this plexus, very fine, non-medullated filaments are given off, which form a wider plexus, also with ganglionic cells, situated just beneath the mucous membrane. This is called the plexus of Meissner.

The experiments of Brachet, by which he attempted to prove that the movements of the intestines were under the control of the pneumogastrics and nerves given off from the spinal cord, have not been verified by other observers. The experiments of Müller, however, render it certain that the peristaltic movements are to some extent under the influence of the sympathetic system. In these experiments, movements of the intestine were produced by stimulation of filaments of the sympathetic distributed to its muscular coat, after the ordinary post-mortem movements had ceased. The same results followed the application of potassium hydrate to the semilunar ganglia, the movements reappearing when the agent was applied, "with extraordinary vivacity" in the rabbit, after the abdomen had been opened and the movements had entirely ceased. These experiments have been confirmed by Longet, who found, however, that the movements did not take place unless alimentary matters were contained in the intestine.

The fact that movements occur in portions of intestine cut out of the body and separated, of course, from the nervous system, has led to the view that the peristaltic action is automatic, like the action of the excised heart, and these automatic movements have been attributed to the influence of the ganglia found in the intestinal walls. An analogy between such intestinal movements and the movements of the excised heart seems probable; and a reasonable explanation of this action is afforded by the existence of ganglia in the plexuses of Auerbach and of Meissner.

Physiological Anatomy of the Large Intestine.

The entire length of the large intestine is about five feet (1·5 metre.) Its diameter is greatest at the cæcum, where it measures, when moderately distended, two and a half to three and a half inches (6·35 to 8·89 centimetres). According to the observations of Brinton, the average diameter of the tube beyond the cæcum is one and two-thirds to two and two-thirds inches (4·23 to 6·77 centimetres). Passing from the cæcum, the canal diminishes in caliber, gradually and very slightly, to where the sigmoid flexure opens into the rectum. This is the narrowest portion of the canal. Beyond this, the rectum gradually increases in diameter, forming a kind of pouch, which abruptly diminishes in size near the external opening, to form the anus.

The general direction of the large intestine is from the cæcum, in the right iliac fossa, to the left iliac fossa, thus encircling the convoluted mass formed by the small intestine, in the form of a horseshoe. From the cæcum to the rectum, the canal is known as the colon. The first division of the colon, called the ascending colon, passes almost directly upward to the under surface of the liver; the canal here turns at nearly a right angle, passes across the upper part of the abdomen and is called the transverse colon; it then passes downward at nearly a right angle, forming the descending colon. The last division of the colon, called the sigmoid flexure, is situated in the left iliac fossa and is in the form of the *italic* letter *S*. This terminates in the rectum, which is not straight, as its name would imply, but presents at least three distinct curvatures, as follows: it passes first in an oblique direction from the left sacro-iliac symphysis to the median line opposite the third piece of the sacrum; it then passes downward in the median line, following the concavity of the sacrum and coccyx; and the lower portion, which is about an inch (2·54 centimetres) in length, turns backward to terminate in the anus.

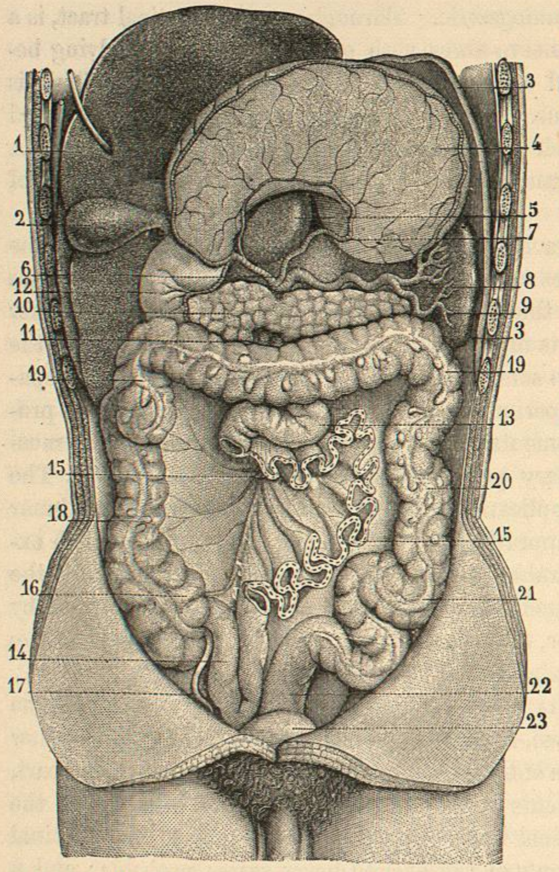

FIG. 78.—*Stomach, pancreas, large intestine etc.* (Sappey).
1, anterior surface of the liver; 2, gall-bladder; 3, 3, section of the diaphragm; 4, posterior surface of the stomach; 5, lobus Spigelii of the liver; 6, cœliac axis; 7, coronary artery of the stomach; 8, splenic artery; 9, spleen; 10, pancreas; 11, superior mesenteric vessels; 12, duodenum; 13, upper extremity of the small intestine; 14, lower end of the ileum; 15, 15, mesentery; 16, *cæcum*; 17, *appendix vermiformis*; 18, *ascending colon*; 19, 19, *transverse colon*; 20, *descending colon*; 21, *sigmoid flexure of the colon*; 22, *rectum*; 23, urinary bladder.

The cæcum, or caput coli, presents a rounded, dilated cavity continuous with the colon above and communicating by a transverse slit with the ileum. At its lower portion is a small, cylindrical tube, opening below and a little posterior to the opening of the ileum, called the vermiform appendix. This is covered with peritoneum and has a muscular and a mucous coat. It is sometimes entirely free and is sometimes provided with a short fold of mesentery for a part of its length. The coats of the appendix are very thick. The muscular coat consists of longitudinal fibres only. The mucous mem-

brane is provided with tubules and closed follicles, the latter frequently being very abundant. This little tube generally contains a quantity of clear, viscid mucus. The uses of the vermiform appendix are unknown.

Ileo-cæcal Valve.—The opening by which the small intestine communicates with the cæcum is provided with a valve, known as the ileo-cæcal valve, situated at the inner and posterior portion of the cæcum. The small intestine, at its termination, presents a shallow concavity, which is provided with a horizontal, button-hole slit opening into the cæcum. The surface of the valve which looks toward the small intestine is covered with a mucous membrane provided with villi and in all respects resembling the general mucous lining of the small intestine. Viewed from the cæcum, a convexity is observed corresponding to the concavity upon the other side. The cæcal surface of the valve is covered with a mucous membrane identical with the general mucous lining of the large intestine. It is evident, from an examination of these parts, that pressure from the ileum would open the slit and allow the easy passage of the semi-fluid contents of the intestine; but pressure from the cæcal side approximates the lips of the valve, and the greater the pressure the more firmly is the opening closed. The valve itself is composed of folds formed of the fibrous tissue of the intestine, and circular muscular fibres from both the small and the large intestine, the whole being covered with mucous membrane. The lips of the valve unite at either extremity of the slit and are prolonged on the inner surface of the cæcum, forming two raised bands, or bridles; and these become gradually effaced and are thus continuous with the general lining of the canal. The posterior bridle is a little longer and more prominent than the anterior. These assist somewhat in enabling the valve to resist pressure from the cæcal side. The longitudinal layer of muscular fibres and the peritoneum pass directly over the attached edge of the valve and are not involved in its folds. These give strength to the part, and if they be divided over the valve, gentle traction will suffice to draw out and obliterate the folds, leaving a simple and unprotected communication between the large and the small intestine.

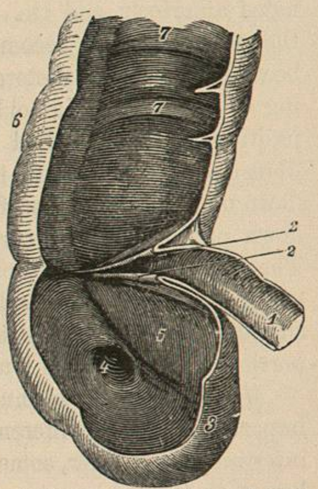

FIG. 79.—*Opening of the small intestine into the cæcum* (Le Bon).
1, small intestine; 2, ileo-cæcal valve; 3, cæcum; 4, opening of the appendix vermiformis; 5, mucous fold at the opening of the appendix; 6, large intestine; 7, 7, folds of the mucous membrane.

Peritoneal Coat.—Like most of the other abdominal viscera, the large intestine is covered by peritoneum. The cæcum is covered by this membrane only anteriorly and laterally. It usually is bound down closely to the subjacent parts, and its posterior surface is without a serous investment; although sometimes it is completely covered, and there may be even a short mesocæcum. The ascending colon is likewise covered with peritoneum only in front, and is closely attached to the subjacent parts. The same arrangement is found in the descending colon. The transverse colon is almost completely invested with peritoneum; and the two folds forming the transverse mesocolon separate to pass over the tube above and below, uniting again in front, to form the great omentum. The transverse colon is consequently quite movable. In the course of the colon and the upper part of the rectum, particularly on the transverse colon, are found a number of little, sacculated pouches filled with fat, called the appendices epiploïcæ. The sigmoid flexure of the colon is covered by peritoneum, except at the attachment of the iliac mesocolon. This division of the intestine is quite movable. The upper portion of the rectum is almost completely covered by peritoneum and is but loosely held in place. The middle portion is closely bound down, and is covered by peritoneum only anteriorly and laterally. The lowest portion of the rectum has no peritoneal covering.

Muscular Coat.—The muscular fibres of the large intestine have an arrangement quite different from that which exists in the small intestine. The external, longitudinal layer, instead of extending over the whole tube, is arranged in three distinct bands, which begin in the cæcum at the vermiform appendix. Passing along the ascending colon, one of the bands is situated anteriorly, and the others, latero-posteriorly. In the transverse colon the anterior band becomes inferior and the two latero-posterior bands become respectively postero-superior and postero-inferior. In the descending colon and the sigmoid flexure the muscular bands resume the relative position which they had in the ascending colon. As these longitudinal fibres pass to the rectum, the anterior and the external bands unite to pass down on the anterior surface of the canal, while the posterior band passes down on its posterior surface. Thus the three bands here become two. These two bands as they pass downward, though remaining distinct, become much wider; and longitudinal muscular fibres beginning at the rectum are situated between them, so that this part of the canal, especially in its lower portion, is covered with longitudinal fibres in a nearly uniform layer.

Mucous Coat.—The mucous lining of the large intestine presents several important points of difference from the corresponding membrane in the small intestine. It is paler, somewhat thicker and firmer, and is more closely adherent to the subjacent parts. In no part of this membrane are there any folds, like those which form the valvulæ conniventes of the small intestine; and the surface is smooth and free from villi.

Throughout the entire mucous membrane, from the ileo-cæcal valve to the anus, are orifices which lead to simple follicular glands. These structures resemble in all respects the follicles of the small intestine, except that they are a little longer, owing to the greater thickness of the membrane, are wider and rather more abundant. Among these small follicular openings are found, scattered irregularly throughout the membrane, larger openings which lead to utricular glands, resembling the closed follicles, in general structure, except that they have an orifice opening into the cavity of the intestine, which is sometimes so large as to be visible to the naked eye. The number of these glands is very variable, and they exist throughout the intes-

tine, together with the closed follicles, except in the rectum. In the cæcum and colon, isolated closed follicles are generally found, which are identical in structure with the solitary glands of the small intestine. These are very variable, both in number and size.

The mucous membrane of the rectum, in the upper three-fourths of its extent, does not differ materially from that of the colon. In the lower fourth, the fibrous tissue by which the lining membrane is united to the subjacent muscular coat is loose, and the membrane, when the canal is empty, is thrown into a great number of irregular folds. At the site of the internal sphincter, five or six little, semilunar valves have been observed, with their concavities directed toward the colon. These form an irregular, festooned line, which surrounds the canal; their folds, however, are small and have no tendency to obstruct the passage of fæcal matters. The simple follicles are particularly abundant in the rectum, and the membrane is constantly covered with a thin coating of mucus. Another peculiarity to be noted in the mucous membrane of the lower portion of the rectum is its great vascularity, the veins, especially, being very abundant.

The rectum terminates in the anus, a button-hole orifice, situated a little in front of the coccyx, which is kept closed and somewhat retracted, except during the passage of the fæces, by the powerful external sphincter. This muscle is composed entirely of striated fibres, which are arranged in the form of an ellipse, its long diameter being antero-posterior.

It is now almost universally admitted that the digestion of all classes of alimentary substances is completed either in the stomach or in the small intestine, and that the mucous membrane of the large intestine does not secrete a fluid endowed with any well marked digestive properties. The simple follicles, the closed follicles, and the utricular glands, produce a glairy mucus, which, as far as is known, serves merely to lubricate the canal. This has never been obtained in sufficient quantity to admit of any accurate investigation into its properties.

In studying the changes which the alimentary mass undergoes in its passage through the small intestine, it has been seen that in this portion of the canal, the greatest part of all the nutritive material is not only liquefied but is absorbed. Sometimes fragments of muscular fibre, oil-globules, and other matters in a state of partial disintegration, may be detected in the fæces; but generally this is either the result of the ingestion of an excessive quantity of these substances or it depends upon some derangement of the digestive apparatus. When intestinal digestion takes place with regularity, the transformation of the alimentary residue into fæcal matter is slow and gradual. As the contents of the stomach are passed little by little into the duodenum, the mass becomes of a bright-yellow color, and its fluidity is increased, from the admixture of bile and pancreatic fluid. In passing along the canal, the consistence of the mass gradually diminishes on account of absorption of its liquid portions, and the color becomes darker; and by the time that the contents of the ileum are ready to pass into the cæcum, the greatest part of those substances recognized as alimentary has become