THE MICROSCOPIC ANATOMY OF THE DIGESTIVE TRACT OF SUS SCROFA DOMESTICA

by

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A microscopic study of the complete digestive tract with its' appendages, was made on the pig.

A marked resemblamee was noted between the digestive tract of the pig, and that of the human. A few outstanding differences were observed however.

The wall of the digestive tract was composed of the following layers: a mucous membrane comprised of an inner epithelial lining; a tunica propria and a muscularis mucosa; a fairly thick submucosa; a lamina muscularis comprised of an inner circular layer and an outer longitudinal layer; and an outer adventitia or serosa, depending on the organs' location.

The epithelium of the mouth is thick stratified squamous epithelium. The body of the tongue consists entirely of striated muscle. It is surrounded by a submucosa, and the whole is covered with a thick stratified squamous epithelium. Very few papilla were observed on the tongue. All of the salivary glands were similarly constructed. The acini of the submaxillary and sublingual glands contained chiefly mucous-type cells, while the parotid acini were entirely serous in nature.

A muscularis mucosa was found throuout the length of the oesophagus, although it was thinner in the upper than in the mid and lower portions. Numerous mucous-type glands were found in the submucosa of the oesophagus, but cardiac or superficial glands could not be demonstrated.

The stratified squamous epithelium of the oesophagus was continued for a short distance into the oesophageal portion of the stomach, but changed rather abruptly to simple columnar epithelium at the junction of the oesophageal and fundic portions of the stomach, and continued as such as far as the anus. There were found to be three distinct glandular regions in the stomach, and a small non-glandular portion

The small intestine was characterized by villi and plica circulares. Brunners glands were observed in the duodenum, and an extremely large number of Peyers' patches were observed in the ileum. Goblet cells were observed in the epithelial lining of both the large and small intestine, and were most numerous in the colon and rectum.

The large intestine is characterized by having no villi. The muscularis mucosa is much thicker in the large intestine than in the small intestine.

The liver and pancreas were both similar in structure to those of mammals. It is worthwhile noting however, that in the liver of the very young pig the lobules are not completely separated by connective tissue septa, while in the liver of an older pig the lobules are completely separated by fairly thick connective tissue septa.

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THE MICROSCOPIC ANATOMY OF THE DIGESTIVE TRACT OF SUS SCROFA DOMESTICA

As far as can be determined, a study of the microscopic anatomy of the entire digestive tract of Sus scrofa domestica, or of any of our larger farm animals for that matter, has never been undertaken. The writer has never seen, but for one exception (Calhoun 1933, on Gallus Domesticus) a related work fully illustrated with photo-micrographs. It is hoped that this study may be useful as a guide to anyone undertaking the microscopic study of any part of the digestive tract of either Sus scrofa domestica, or any other of our farm animals. It is hoped that it may also serve as a helpful source of reference for the Anatomist, the Physiologist and the Pathologist.

Since this was intended as a study of the micro-scopic structure of the complete digestive tract, only representative samples of each part or organ could be examined in the time allotted. A more detailed picture of each part of the digestive tract would require complete serial sections of each anatomic part and would require much more time than was available for the present study.

REVIEW OF PREVIOUS RESEARCH INVESTIGATIONS

A careful search of the available literature dealing with the microscopic anatomy of the digestive system of Sus scrofa domestica, has been made. Unfortunately the amount of material available on this subject is extremely limited. Reports on most of the early work appeared in

German Publications (Ellenberger, W. and Baum, H. 1926; Oppel, A. 1897; Moller, W. 1899; Helm, R. 1907; Schiefferdecker, H. 1884). The absence of most of these publications from the library files, together with the writer's limited ability to translate specialized reports of this kind, has prevented a more complete study of the German material.

The results where available, of previous investigators, will be compared in the discussion of the related material covered in the present study. The limited nature of the comparisons that are made is a result of the combination of factors mentioned above.

The present study can serve only as a broad preliminary outline of a rather extensive field of investigation.

GROSS ANATOMY

The principle organs of prehension and mastication are the lips, tongue and teeth respectively. In the pig the lower lip is small and pointed and the upper one relatively insignificant. The labial glands are few and small.

The pig possesses a hard palate, which is long and narrow and is marked by a median furrow, on each side of which are numerous ridges (20-50). On its anterior part there is a long narrow prominence, the incisive papilla, at the posterior part of which the incisive or naso-palatine ducts open.

The soft palate in the pig is very thick, its length in a medium-sized animal being approximately 2½". Its direction almost continues that of the hard palate, i.e. it

is nearly horizontal. It extends to the middle of the oral surface of the epiglottis. The oral surface presents a median furrow, on either side of which is an oval raised area, marked by numerous crypts; these elevations being the tonsils.

The tongue is long and narrow and the apex is thin. Two or three vallate papillae are present. The fungiform papillae are small and are most uniform laterally. The filiform papillae are soft and very small. On the root there are soft, long, pointed papillae, directed backward. Foliate papillae are also present.

The dental formula of the pig is $2(I\frac{3}{3}\,C\frac{1}{1}\,P\frac{4}{4}\,M\frac{3}{3})$.

The parotid gland is not too large, and is distinctly triangular. It extends very little on to the masseter muscle, and its upper angle doesn't quite reach the base of the ear. It is pale in color. On its deep face are several large subparotid lymph glands, some of which are only partially covered by the parotid. The parotid duct enters the mouth opposite the fourth or fifth upper cheek tooth (Stensons' duct). Small accessory parotid glands may be found along the course of the duct.

The submaxillary gland is small, reddish in color, and oval in outline; it is covered by the parotid. Its superficial face is convex, and is marked by rounded prominences. From its deep face a narrow process extends forward about two to three inches beneath the mylo-hyoideus muscle along with the duct, which opens on the side of the root of the tongue (Whartons' duct).

The sublingual gland consists of two parts. The posterior part is reddish-yellow in color, and is about two inches long and half an inch wide; its posterior end is in relation to the submaxillary gland and its duct. The anterior part is much larger, being two to three inches long and about twice the width and thickness of the posterior part. Numerous excretory ducts open close together on small papillae on the sublingual fold.

The pharynx in its posterior part presents a cul-de-sac about 1½ inches long, termed the diverticulum pharyngeum. The eustachian tube, oesophagus, nasal openings and larynx all open into the pharynx.

The oesophagus is a short, narrow and nearly straight membranous canal. It forms a tube, leading from the pharynx to the stomach. It is easily dilated for the greater part of its extent. The canal begins at the pharynx and communicates with it by means of the posterior opening situated above the glottis. It descends behind the trachea, to the middle of the neck, deviates toward the left and enters the thoracic cavity. After passing through the thoracic cavity it penetrates the abdominal cavity and immediately afterwards is inserted into the smaller curvature of the stomach at the cardia, which in the pig is near the left extremity. The oesophagus has no serosa, but is united directly with the surrounding tissue by means of a rather dense adventitia composed of fibrous connective tissue.

The stomach in the pig is large; its average

capacity being about 1½ to two gallons. When full, its long axis is transverse and its greater curvature extends backward on the floor of the abdomen a little further than a point midway between the xiphoid cartilage and the umbilicus. The left part of the stomach is large and rounded, while the right part is small, and bends sharply upward to join the small intestine. The oesophagus opens into the stomach by a wide infundibulum, and the mucous membrane of this is prolonged over the gastric surface in a radius of from two to three inches around the cardia. The cardiac opening is slit-like and is bounded above and to the left by a fold which contains a thickening of the internal oblique layer of the muscular coat. The opening into the diverticulum is situated above and a little to the left of the cardia; it is transversely oval, and is bounded (except laterally) by a thick fold which contains spirally arranged muscular fibers. The mucous membrane presents four distinct regions; oesophageal, cardiac, fundic and pyloric.

The entire intestinal canal of the pig is about fifteen times the body length. The small intestine is fifty to sixty-five feet long. About the first two feet of the small intestine is known as the duodenum. The right end of the pancreas is attached to the first part of the duodenum and here the pancreatic duct opens into the bowel. The remaining part of the small intestine is known as the jejuno-ileum. It has a mesentery about six to eight inches long, which is thick and contains a quantity of fat, and numerous

large lymph glands at its root. The opening of the bile duct is about one to two inches from the pylorus, and that of the pancreatic duct about six inches beyond it. Many Peyers' patches are present and very distinct. In a young animal they were found to number from forty to eighty in any cross section of the intestinal wall. These Peyers' patches commence about eight to twenty inches from the pylorus, and the last long one is continued a variable distance into the caecum.

The large intestine is about twelve to fifteen feet long, and for the most part is much wider than the small intestine. It is connected by a mesentery with the dorsal abdominal wall between the kidneys. The large intestine commences by a vast reservoir in the form of a cul-de-sac, named the caecum. It is continued by the colon whose posterior extremity is succeeded by the rectum. It is separated from the small intestine by the ileo-caecal valve.

The caecum is cylindrical, about eight to twelve inches long, and three to four inches wide. It lies against the upper and anterior part of the left flank and extends ventrally, backward, and medially behind the coiled part of the colon, so that its ventral blind end usually lies on the floor of the abdomen, near the median plane, and at a variable point between the umbilicus and the pelvic inlet. Its dorsal end is directly continued by the colon. The ileum joins the caecum obliquely, and projects considerably into it. The caecum has three longitudinal muscular bands and three

rows of sacculations, which are continued a short distance on the colon.

At first the colon has about the same calibre as the caecum, but becomes gradually smaller. It lies chiefly to the left of the median plane, behind the stomach. It is arranged in three, close, double spiral coils in the mesentery, in relation with the floor of the abdomen ventrally, the stomach and the liver in front, the caecum and small intestine behind, and the small intestine on the right.

The colon is continued at the pelvic inlet by the rectum. The rectum extends in a straight line, from the entrance to the pelvic cavity to the posterior opening of the digestive canal, or anus. It differs from the colon, in having no ridges, and in its walls being thicker and more dilatable, so that it can be distended into an elongated pouch. The rectum is usually surrounded by a quantity of fat.

The anus, or posterior opening of the digestive tube, is situated at the posterior extremity of the rectum, under the base of the tail.

The liver is relatively large, its average weight in the adult pig being about four pounds. It is divided by three deep interlobar incisures into four principal lobes - right lateral, right central, left central, left lateral. The last of these lobes is usually the largest. On the upper part of the right lateral lobe, is the caudate lobe, which is clearly marked off by a fissure, and is often partially subdivided by a secondary fissure. The fossa for the gall-

bladder is mainly on the right central lobe, but also in part on the adjacent surface of the left central lobe. Owing to the large amount of interlobular tissue, in the adult at least, the lobules are mapped out sharply. They are polyhedral in form and 1-2.5 mm. in diameter.

The gall bladder is attached in the fossa vesicae felleae, its fundus not reaching to the ventral border. The cystic duct joins the hepatic duct at an acute angle immediately after the emergence of the latter from the portal fissure. The bile duct opens at the papilla duodeni, about one to two inches from the pylorus.

The pancreas has the greatest resemblance to the salivary glands in its structure and physical properties and for this reason it has been named the abdominal salivary gland. It is triangular-shaped and extends across the dorsal wall of the abdominal cavity behind the stomach. The right extremity is attached to the first curve of the duodenum, and it is here that the duct passes to the bowel. The pancreatic duct passes from the right extremity directly through the duodenal wall, opening about four to five inches from the pylorus. The interlobular tissue usually contains a considerable amount of fat.

The foregoing gross anatomy deals more particularly with the anatomy of an adult pig, insofar as the measurements of the different anatomical parts are concerned. However the description as to the position of different parts of the system in the animal body applies equally as well to a young

pig as it does to an adult pig. It should be mentioned that the measurements of each part of the digestive tract are those given by Sisson in, "The Anatomy of the Domestic Animals", and since they were taken following the death of the animal they are in most cases greater than the measurements for the corresponding parts in the living animal.

MATERIALS AND METHODS

The greatest bulk of specimen material was secured from a five week old Yorkshire gilt. However some additional material was needed, and this was secured from a sixteen week old Yorkshire barrow. Both of these pigs were normal, healthy individuals. The first animal was anaesthetized prior to removal of the specimen material (Appendix A, Sec. I), while the second animal was killed outright by cutting the jugular vein and allowing it to bleed to death, and the tissues required were secured within ten minutes following death, while they were still warm.

The following methods were employed: The tissues were fixed in Bouins' solution (Appendix A, Sec. II); washed in 70% alcohol (Appendix A, Sec. III); dehydrated in alcohols of increasing strengths (Appendix A, Sec. IV); cleared in toluene (Appendix A, Sec. V); infiltrated in "Tissuemat" (Appendix A, Sec. VI); embedded in "Tissuemat" (Appendix A, Sec. VII); All sections were cut at 10 u. thickness (Appendix A, Sec. VIII and IX); Harris Haematoxylin and Eosin (Appendix A, Sec. XI, XII, and XIII) was the only staining method employed. Two different adhesives were

employed in affixing Sections to slides, namely Mayers' (Appendix A, Sec. X (a)) and Haupts' (Appendix A, Sec. X (b)), since Mayers' was not giving as good results as are usual. The sections were finally mounted in Canada Balsam (Appendix A, Sec. XIV), and examined microscopically.

RESULTS

Observations were made on the digestive tract from the mouth to the anus, including all appendages.

HARD PALATE

In removing part of the hard palate for fixation and later examination, only the outer layer was cut out, or in other words only the epithelial covering along with a slight amount of the under-lying tissue.

A fairly thin mucous membrane covers the hard palate, and this is in close relationship with under-lying connective tissue and bone. The mucous coat consists of a stratified squamous epithelium, (Plate I, Fig. A-1) which rests on the tunica propria (Plate I, Fig. A-2) which is composed of very compact fibrous connective tissue. Projections of the tunica propria (Plate I, Fig. A-3) extended into the basal layers of this epithelium and the epithelium extended down between these projections, thus ridges are formed which are known as palatine ridges (Plate I, Fig. A-5). The mucous membrane appears much thinner in some parts than in others. There is no distinct division between the tunica propria (Plate I, Fig. A-3) and the submucosa (Plate I, Fig. A-4), since there is no muscularis mucosa present here.

THE TONGUE

The tongue consists mainly of a mass of interlacing bundles of muscles, which is entirely of the voluntary or striated type (Plate I, Fig. B-4). Smooth muscle could not be demonstrated. These muscle bundles run in different planes, and cross one another at right angles. The muscle bundles are separated from one another by thin sheets of connective tissue. (Plate I, Fig. B-3)

The surface of the tongue is covered with a mucous membrane. The epithelium of the mucosa is of the stratified squamous type (Plate I, Fig. B-1 and Plate II, Fig. A-1). It rests on a narrow tunica propria (Plate I, Fig. B-2), which in turn rests on a thick layer of collagenous and elastic fibers (Plate I, Fig. B-5 and Plate II, Fig. A-3). A number of papillae were found to be present on the side of the tongue (Plate II, Fig. A-2), but very few were found on the surface at the tip, which is rather unusual, since they are supposed to be quite numerous there. These papillae are formed by upward projections of the denser layer of connective tissue (Plate II, Fig. A-6), that carry the covering of stratified squamous epithelium with them.

Between the under-lying muscle layers and the outer covering of epithelium, there is a somewhat denser region or layer of connective tissue, from which finger-like projections (Plate II, Fig. A-7) extend into the epithelial covering.

A cross section of the tip of the tongue shows medially, numerous mucous-type glands (Plate II, Fig. B-3)

immediately below the connective tissue layer on the under surface. These have a corresponding position and structure to the glands of "Nuhn", in the human. Serous type glands are also present (Plate II, Fig. B-1), and are located in the submucosa below the papillae and scattered throughout the muscle bundles. They appear to be very numerous. These correspond to "Von Ebners" glands in the human.

There are also numerous bundles of nerve fibers scattered throughout the muscle of the tongue (Plate III, Fig. A-2), and many blood vessels (Plate III, Fig. A-3) are found distributed amongst the connective tissue septa.

OESOPHAGUS

According to Oppel (46), in the giraffe, elephant, all rodents, cattle and sheep, both layers of muscle are striated down to within ¼ inch from the cardia. In some mammals striated fibers of the outer longitudinal layer have been described as extending for a distance upon the cardia.

Hewlett (28) states, "that areas of superficial oesophageal glands are found in upper and lower oesophagus of humans. They are found superficial to the muscularis mucosa." He further states, "that there are also typical mucous glands found in the submucosa."

McGill (44) states that striated muscle develops in the upper and mid-oesophagus, while smooth muscle develops in the lower oesophagus.

Helm (28) has described typical demilunes present in the oesophageal glands of dog and pig. He states, "that

the sheep, ox and horse contain no glands in the oesophagus."

Goetsch (27) found demilunes present also in the oesophageal glands, but in smaller numbers than in any of the other animals, with the exception of man. They are apparently by no means infrequent, but the complexes are smaller in size, more compressed, and more easily overlooked than in other animals.

In the pig, Goetsch (27) also found, "that the epithelium of the oesophagus is thick, but the degree of cornification is much less than in the sheep, the contrast between stratum germinativum and stratum corneum less striking and the transition less abrupt from one layer to another. We do not see, in the oesophagus of the pig, the division of stratum corneum into two layers, as in the sheep, and in the pig the nuclei are more numerous in the superficial layers and less degenerated."

The oesophagus is lined with a thick layer of stratified squamous epithelium (Plate III, Fig. B-1 and Plate IV, Fig. A-1). It is divided into two more or less distinct areas; stratum corneum, and stratum germinativum.

The epithelium rests on quite a thin layer of loosely interwoven fibers of connective tissue, called the tunica propria (Plate III, Fig. B-2 and Plate IV, Fig. A-2). Immediately next to this tunica propria, and separating it from the submucosa, lies a thin layer of smooth muscle fibers, the muscularis mucosa (Plate III, Fig. B-3). In the upper part of the oesophagus the muscularis mucosa (Plate IV, Fig.

A-3) consists of small scattered bundles of smooth muscle, but in the mid and lower portions this layer increases somewhat in thickness. Below the muscularis mucosa lies the submucosa (Plate III, Fig. B-4 and Plate IV, Fig. A-4), which is a fairly thick layer in the upper oesophagus but which thins out toward the lower end of the oesophagus. It is composed of collagenous and elastic fibers and contains numerous blood vessels, lymphatics and bundles of nerve fibers. The tunica propria, muscularis mucosa and submucosa, are raised into a series of longitudinal folds when the walls of the oesophagus are relaxed, and the tissues of the mucosa are carried over the folds. Exterior to the submucosa lie two bands of muscle fibers, an inner circular (Plate III, Fig. B-6 and Plate IV, Fig. A-6) and an outer longitudinal layer (Plate III, Fig. B-7 and Plate IV, Fig. A-7), both muscle layers being chiefly composed of muscle of the striated type. Thin septa of connective tissue separate the bundles of muscle fibers in each of these bands, and a strongly developed connective tissue septa (Plate III, Fig. B-8 and Plate IV, Fig. A-8) separates these bands. The oesophagus is connected directly with the surrounding tissue, and there is no serosa in evidence.

One or two solitary lymph nodules were demonstrated. They were located in the submucous tissue.

There are fairly numerous mucous-type glands in the submucosa of the oesophagus (Plate III, Fig. B-5 and Plate IV, Fig. A-5). These are no doubt the deep oesophageal glands,

and they appear to be fairly evenly distributed throughout the entire length of the oesophagus. The presence of cardiac or superficial glands in the oesophagus could not be demonstrated, nor could the presence of demilunes on the mucous glands.

Two different groups of ganglion or nerve cells are apparent. One group is located in the submucosa and is known as Meissner's plexus, while the other group is located in the connective tissue septum separating the two outer layers of the muscularis, and is known as Auerbach's plexus (Plate III, Fig. B-9).

THE STOMACH

Klein (36) states "the chief cells in the fundus glands of the stomach of the pig are distinguished from the parietal cells by their different shape and position, as well as the chief cells being more transparent, and the parietal cells containing numerous zymogen granules. There is apparently a greater network of fibrils in the parietal cells, thus they appear more granular. The nuclei of parietal cells is very regular." He further states, "only mucous type cells are found in the pyloric glands of the stomach, there being no parietal cells present."

Bensley (9) quotes Langley and Sewall as stating "the chief cells of the fundus of the stomach are a highly differentiated form of the pyloric gland cells." He further states that, "Schiefferdecker (52) found that the pyloric gland cells of the cat and dog differed anatomically from those of pig and man." Bensley also quoted Edelmann (1889) as

saying, "there exists in the cardiac region of the stomach of many mammals, a peculiar kind of gland, called by him the cardiac glands, differing from both fundic and pyloric glands, and concerning which we are in the dark." Bensley himself stated that, "the pyloric and cardiac glands are closely allied." According to Bensley the pyloric gland cells, are in most mammals closely allied to and in the cat, dog and rabbit identical with, certain cells in the neck of the fundus glands, which up to the present have been regarded as ordinary chief cells.

Bensley (6) notes that Ellenberger (24) was the first to recognize the importance of the cardiac glands as indicated by their great extent in the pig, and the first to dissent from Cobelli's view that they are mucous glands. In his work he expresses the opinion that they are serous glands of a special kind, differing from both the fundus and pyloric glands. This view is also shared by Edelmann (22) and Schaffer (1897). Bensley, in his work, found that the cardiac glands reach their greatest extent in the pig, occupying fully one third of the available surface of the mucous membrane, comprised in a triangular area at the left extremity of the stomach. The mucous membrane of this area, he found, is only a fraction of the thickness of that of the middle or fundus gland region, and contains throughout, glands composed of but one kind of cell. He states, "the mucous secretion nearly fills the cells of the surface epithelium of the cardiac stomach and the nucleus is flattened into the base of the cell."

Bensley further notes that the fundus gland zone of the pig is of great interest owing to the fact that the glands of a very considerable portion of it may be reasonably regarded as intermediate between cardiac and true fundus glands. These fundus glands are unique among mammalian gastric glands in the fact that the ferment forming chief cells may be relatively reduced in numbers. In this work Bensley states that, "as regards the nature of the cardiac glands his results are directly opposed to those of Ellenberger, Edelmann, and Schaffer; who concur in the conclusion that they are not mucous glands." Bensley concludes that: (a) "The cardiac glands are definitely mucous glands," (b) "the cardiac gland cells are fundamentally different from the chief cells of the body of the fundus glands," and (c) "the cardiac gland cells are closely related to the mucous chief cells of the neck of the fundus glands and to the pyloric gland cells."

Ross (50) writes, "in the pig the cells lining the stomach are so closely packed together that they appear to be composed of several layers." His sections showed the epithelium to be simple columnar, all the cells reaching the surface as well as all resting on a basement membrane. The nuclei of the surface epithelium he found to be located approximately in the centre of the cell.

Bensley (5) once more concludes that, "the cardiac glands of the mammalian stomach are mucous glands. As in his previous work, he again states, "the cardiac gland cells are closely related to the mucous chief cells of the neck of the

fundus gland and to the pyloric gland cells." According to Oppel (47) and Bensley (5), the cardiac glands are retrogressive structures derived from fundus glands by the disappearance of the most highly differentiated elements of the latter, namely, of the chief cells of the body and the parietal cells. Bensley found that the cardiac glands are tortuous, tubular or tubulo-alveolar glands, which lie without special grouping in the lamina propria. Bensley also says, "from the pyloric glands, with which they could be most easily confused, they are clearly different. The pyloric glands form groups in the gastric mucous membrane, exhibit the mucous reaction, and have a different form and course." He finally concludes, "the embryonic cardiac glands of the pig contain parietal cells, which later disappear."

THE STOMACH (GENERAL)

The wall of the stomach consists of a mucosa, submucosa, muscularis externa and serosa. The mucosa of the first part, or oesophageal region of the stomach, appears to be continuous with that of the lower end of the oesophagus, and consists of a stratified squamous epithelium. (Plate V, Fig. A-1). This stratified squamous epithelium of the oesophageal region of the stomach undergoes an abrupt change to a simple columnar epithelium of the cardiac region (Plate V, Fig. B-1 and 2). The mucosa is quite thick, due to the presence of tubular gastric glands, which are divided into three types: cardiac, fundic and pyloric.

The tunica propria of the stomach extends in between

and around the secreting tubules of the gastric glands, (Plate VII, Fig. B-2 and Plate VIII, Fig. B-2) and the muscularis mucosa lies just below the deepest ends of the secreting tubules (Plate VI, Fig. B-3 and Plate VII, Fig. B-3). Scattered diffusely throughout the tunica propria are lymphocytes, but in some regions large solitary lymph nodules occur both in the submucosa and tunica propria (Plate VIII, Fig. A-5). The submucosa is composed of loose fibroelastic connective tissue (Plate VI, Fig. B-4 and Plate VII, Fig. A-2). The muscularis mucosa in some regions appears to be composed of two or three layers, an inner oblique, a middle circular and an outer longitudinal layer (Plate VI, Fig. B-3). The adventitia, or serosa, is quite a thick layer and is composed of a coat of loose fibroelastic connective tissue which is enclosed by a single layer of mesothelium (Plate VIII, Fig. A-9).

OESOPHAGEAL REGION OF THE STOMACH

The oesophageal region of the stomach is lined with a very thick stratified squamous epithelium, which appears to be a continuation from the epithelial lining of the oesophagus (Plate V, Fig. A-1). It is also divided into two distinct layers, the stratum corneum and the stratum germinativium, as was that of the oesophagus. The tunica propria, although a relatively thin layer, is composed of a dense connective tissue containing many scattered lymphocytes, (Plate V, Fig. A-2) which in places are gathered together into fairly large nodules. These nodules are in most cases located between the muscularis

mucosa and the epithelium, and the epithelial covering over these nodules is much reduced in thickness. The tunica propria is observed to extend up into the overlying epithelium in long finger-like projections. The muscularis mucosa is quite thick, and is composed of smooth muscle. The submucosa is a fairly thick layer composed of loose fibroelastic connective tissue, and contains a large number of both large and small blood vessels (Plate V, Fig. A-3). There were a few small solitary lymph nodules observed in the submucosa. Exterior to the submucosa lie two muscle bands, an inner circular (Plate V, Fig. A-4) and an outer longitudinal, both composed of smooth muscle. These were not too well defined in the sections observed. These muscle bands are separated from one another by a thick connective tissue septum, and the muscle bundles composing each layer are also separated by thick connective tissue septa. A serosal covering could not be demonstrated covering the oesophageal portion of the stomach, this probably being due to the angle at which the sections were cut. There were no glands in evidence in the oesophageal portion of the stomach.

CARDIAC REGION OF THE STOMACH

The structure of this portion of the stomach is essentially the same as has been described for the oesophageal region, except for the fact that the epithelium has changed from the stratified squamous type to the tall columnar type Plate VI, Fig. A-1). Also there are glands, known as the cardiac glands, which are relatively short and are located in

the tunica propria of the cardiac region (Plate VI, Fig. A-2). These glands appear to be composed entirely of mucous-type cells (Plate VI, Fig. B-1). There are still aggregations of lymphoid tissue occurring in the submucosa and in some cases extending through the muscularis mucosa into the tunica propria, and even up as far as the surface epithelium. The submucosa contains numerous very large blood vessels (Plate VI, Fig. A-4 and Plate VI, Fig. B-4). The two muscle layers are more clearly defined here, there being an inner circular layer and an outer longitudinal layer, (Plate VI, Fig. A-6 and 7 and Fig. B-5 and 6) both layers being composed of smooth muscle cells. Here again there is a large amount of connective tissue separating the two layers of muscle, as well as the individual muscle bundles within each layer. The serosa covering the surface was in evidence here, and was observed to contain large accumulations of fat cells and blood vessels.

FUNDIC REGION OF THE STOMACH

The epithelium of the fundic portion of the stomach is also composed of tall columnar cells.

The fundic glands are branched tubular in form, and have very much longer and thinner glandular portions than do the cardiac glands (Plate VII, Fig. A-1). The glands are closely packed together, the reticular tissue of the tunica propria being reduced to a thin layer between the glands. Two different types of cells appear to make up the fundic glands, although these were not too well defined in the sections observed, due probably to the angle at which the sections were

cut. The two types of cells are known as the parietal and chief cells. The chief cells are pyramidal in shape, contain a spherical nucleus which is located toward the basal portion of the cell, and their cytoplasm appears to be filled with numerous small granules (Appendix B, Fig. IV, A and B). The parietal cells appear triangular or spherical in shape, and seem to be larger than the chief cells. They contain a fairly large spherical nucleus which is centrally located (Appendix B, Fig. IV, A and B)

The tunica propria is a thin layer composed of loosely arranged fibroelastic connective tissue (Plate VII, Fig. B-2). There is an extremely thick inner circular layer of muscle, and a very thin outer longitudinal layer. Both layers are composed of smooth muscle and separated by means of thick connective tissue septa. The outer serosa is quite thick and in some places contains small aggregations of fat cells.

PYLORIC REGION OF THE STOMACH

The epithelium of the pyloric portion of the stomach is of the tall columnar type (Plate VIII, Fig. A-1). The pyloric glands are about the same length as the cardiac glands and like them also appear to contain only mucous-type cells (Plate VIII, Fig. A-2 and Plate VIII, Fig. B-1 and Appendix B, Fig. V, A and B). The muscularis mucosa here appears thicker than in any other portion of the stomach, and as mentioned previously this is one place where it seems to be formed into two or three very thin layers, running in different directions

(Plate VIII, Fig. B-3). The submucosa is loosely arranged, composed of fibroelastic connective tissue and contains numerous large lymph nodules (Plate VIII, Fig. A-5 and 6 and Plate VIII, Fig. B-4). The two muscle layers are quite apparent here, although the outer longitudinal layer appears to have increased considerably in size (Plate VIII, Fig. A-7 and 8). The serosa is observed to be quite thick and composed of a coat of loose fibroelastic connective tissue enclosed by a single layer of mesothelial cells (Plate VIII, Fig. A-9).

INTESTINES

Klein (36) states, "the epithelial cells of the villi are of fibrillar nature in the pig. In killed preparations the fibrils break up and give a uniform granular appearance. Nuclei of epithelial cells of villi are oval. The epithelial cells lining the crypts of Lieberkuhn are identical with those of the surface of the mucous membrane, both as regards structure of cell substance and that of nucleus. Differences are found only in size and shape of nucleus."

Comparing the epithelial lining of the crypts of Lieberkuhn of the small intestine with that covering the villi he states:

(a) "Epithelial cells of latter are longer (more columnar)."

(b) "Nucleus of epithelial cells of villi is more regularly elliptical than those in the crypts, (they being circular)."

Comparing the epithelial lining of the crypts of Lieberkuhn of the small intestine with those of large intestine he says:

(a) "Epithelial cells are longer in latter than in former."

Klein further states, "the cells lining the glands of Brunner resemble those of pyloric end of stomach," and assumes that "there is a gradual transition of pyloric glands into glands of Brunner in the duodenum."

Bizzozero in 1893, assumed that Paneth cells were young goblet cells.

Moller (43) found that Paneth cells occurred in the intestinal glands of mouse, guinea-pig, rabbit, ox, sheep and horse. He found none in the pig, cat and dog, although he regarded his failure to find them in the pig as due to a failure to fix the granules. He could find no transition between Paneth cells and goblet cells.

Klein (37) stated that, "granule cells occupy the deeper ends of the glands of Lieberkuhn."

Bensley (10) discusses the question of similarity of glands of Brunner and the pyloric glands from the standpoint of the relative specialization of the stomach. He points out, "this similarity was greatest in those animals, e.g. carnivora, insectivora etc., in which the stomach is primitive, and that specialization of the stomach is accompanied by increase in the differences between the two groups of glands."

Florence (24) found that in each species of animal she studied (pig and calf), that there was a typical arrangement of the intestinal lymphoid tissue, and in the large intestine found glands in many instances associated with the follicles. In the pig she found the follicles in the colon to be solitary and scattered. They were found to be more numerous in the upper three quarters of the colon than in the lowest one quarter. Glands were rarely found to be present in any of the follicles of the small intestine. The glands are usually quite symmetrical in the solitary follicles of the colon of the pig. The glands are conspicuous in the ileocecal valve of pigs. This might suggest their function to be the providing of an excess supply of mucous where stoppage of the intestinal content is likely to occur.

THE SMALL INTESTINE (GENERAL)

The structure of the three main divisions of the small intestine appeared to be quite similar. There are certain minor differences however, which will be discussed in detail.

Two structures which are characteristic of the small intestine, the plica circulares (Plate X, Fig. A-1) and the villi (Plate IX, Fig. B-1), were observed throughout its entire length. The plica circulares are permanent folds formed by elevations of the submucosa. They vary in height and width in different parts of the small intestine. The villi are long, finger-like projections of the mucous membrane, and they vary in number and in height in different parts of

the small intestine. They appear most numerous in the duodenum (Appendix B, Fig. VI, A and B and Fig. VII, A and B).

Each villus consists of a supporting core, formed by the upward extension of the tunica propria (Plate X, Fig. B-4). Central vessels, or lacteals are observed in this supporting tissue. These lacteals have extremely thin walls, and are of small diameter.

The epithelium forming the lining of the small intestine, is composed of simple columnar cells, which rest on a basement membrane formed of delicate fibers arising from the tissue of the tunica propria. (Plate X, Fig. B-1; and Plate XI, Fig. B-1)

There are a number of cells in the epithelium of the lining of the small intestine which have a different shape and staining reaction than do the epithelial cells. These are goblet cells, and are broad and oval-shaped, their mucous contents staining a definite pink color. (Plate X, Fig. B-3 and Plate XIII, Fig. B-2)

One type of gland is general throughout the entire length of the intestine, namely the glands of Lieberkuhn. (Plate IX, Fig. A-3 and Plate IX, Fig. B-2) They contain the same types of cells throughout, except that goblet cells may be more numerous in some places than in others. The glands also vary as to height and width, in different parts of the intestinal canal.

THE DUODENUM

The wall of the duodenum is quite thick.

There appeared to be very few plica circulares in the duodenum, and the few which were present were low and broad.

The villi are extremely numerous in the duodenum, and are broad and leaf-like. (Plate IX, Fig. B)

The epithelial covering is composed of tall columnar cells (Plate IX, Fig. A-1), among which are found numerous goblet cells. These goblet cells were particularly numerous over the top of the villi, although they were also observed in the sides of the crypts of Lieberkuhn.

There are two types of glands, the glands of Lieberkuhn (Plate IX, Fig. A-3) and the glands of Brunner (Plate IX, Fig. A-5).

The glands of Lieberkuhn are numerous. They extend down only as far as the muscularis mucosa. Paneth cells were not observed.

Brunners glands are also very numerous in the duodenum, especially in the upper part. They are located in the submucosa and are mucous-type glands. The glandular tissue is congregated in large masses throughout the submucosa. The ducts of these glands have a wide lumen.

The muscularis mucosa in the duodenum is very thin and is formed of a rather loose arrangement of smooth muscle cells. (Plate IX, Fig. A-4)

The submucosa is a thin layer of fibrous connective

tissue (Plate IX, Fig. A-5) which in most places is almost obscured by the large congregations of Brunner's glands. A number of very large blood vessels are supported in the submucosa (Plate IX, Fig. A-6). Meissner's plexus are observed here also.

The muscularis is composed of two layers of smooth muscle, an inner circular (Plate IX, Fig. A-7) and an outer longitudinal (Plate IX, Fig. A-8). The inner circular band is approximately twice the width of the outer longitudinal. They are separated by a thin connective tissue septa, in which Auerbach's plexus occur (Plate IX, Fig. A-9). These bundles of nerve fibres appear very numerous. The outer longitudinal layer of muscle is spirally arranged, so that it does not present a true picture of a cross section of longitudinal muscle (Plate IX, Fig. A-8).

There is a very thin serosa covering the intestine (Plate IX, Fig. A-10). It is composed of a layer of thin, flattened mesothelial cells, under which is found a layer of interwoven fibrous connective tissue, with numerous cellular elements being present. There are numerous blood vessels in this connective tissue.

JEJUNUM

The wall of the jejunum appears to be thinner than that of the duodenum. From the inner mucosa to the outer serosa each layer is very much reduced in size.

The plica circulares are still present, but are no more numerous here than they were in the duodenum. They are

more fully developed however, being taller and thinner in structure (Plate XII, Fig. B).

The villi are very tall and finger-like (Plate XI, Fig. B-2 and Plate XII, Fig. A-1), and in the upper part of the jejunum are as numerous as they were in the duodenum.

There is only one type of gland in the jejunum, the glands of Lieberkuhn (Plate XI, Fig. B-3). The crypts are similar to those found in the duodenum, except that they are much shorter due to the reduction in the thickness of the mucosa. There are no glands in the submucosa.

Here, as in the duodenum, the muscularis mucosa is extremely thin, and is composed of smooth muscle cells. (Plate XIV, Fig. A-2)

The submucosa (Plate XI, Fig. B-4 and Plate XIII, Fig. A-4 and Plate XIV, Fig. A-3) is a very thin layer of fibrous connective tissue which contains many blood vessels (Plate XI, Fig. B-7) as well as bundles of nerve tissue (Meissner's plexus). There are patches of lymphoid tissue in the submucosa, extending in some places into the over-lying layers of tissue almost to the surface of the epithelium. (Plate XIII, Fig. A-2)

The muscularis is composed of two layers of smooth muscle, an inner circular (Plate XI, Fig. B-5 and Plate XIII, Fig. A-5 and Plate XIV, Fig. A-4) and an outer longitudinal (Plate XI, Fig. B-6 and Plate XIII, Fig. A-6 and Plate XIV, Fig. A-6) with the inner circular still being approximately twice the width of the outer longitudinal. The muscle layers

are separated with a thin connective tissue septa (Plate XI, Fig. B-9 and Plate XIV, Fig. A-5) containing nerve plexus. (Auerbach's) (Plate XIII, Fig. A-7). Their distribution is quite regular around the circumference of the jejunum.

The serosa is similar to that covering the duodenum (Plate XI, Fig. B-8 and Plate XIV, Fig. A-7).

THE ILEUM

The ileum presents the same structure throughout as the jejunum, although in the ileum the various layers appear about as thick as the corresponding ones in the duodenum. The major difference is in the amount of lymphoid tissue present. The plica circulares in the ileum are very tall and thin (Plate XVI, Fig. A-2).

The lymph tissue present is gathered together into lymph nodules which are known as Peyer's patches (Plate XV, Fig. B-1, and Plate XIV, Fig. B-9 and Appendix B, Fig. VIII). They are large, oval-shaped and exceedingly numerous, as many as eighty of these individual nodules having been counted in one cross section. They are more numerous toward the lower part of the ileum. They are found packed closely together just below the muscularis mucosa. Each nodule is enveloped with a capsule of fibrous connective tissue, which appears to be merely a thickening of the connective tissue composing the submucosa (Plate XV, Fig. B-2 and Plate XIV, Fig. B-10). The submucosa lies directly beneath the nodules and comes in intimate contact with them (Plate XV, Fig. B-3). The submucosa contains an unusually large number of blood vessels of

all sizes (Plate XV, Fig. B-4 and Plate XVI, Fig. A-3). There is a considerable amount of diffuse lymphoid tissue found in and around these nodules, especially in the mucosa and in and around the cells of the epithelium (Plate XIV, Fig. B-11). Some of the patches extend up into the over-lying mucosa, and in some cases obliterate the epithelial cells. The nodules only occupy about three quarters of the circumference of the intestinal wall. The remaining one quarter, which contains no nodules at all, is the part of the intestine to which the mesentery is not attached.

THE LARGE INTESTINE (COLON)

The colon is of large diameter and the walls are quite thick.

There are no villi present in the large intestine. (Plate XVII, Fig. A and Appendix B, Fig. IX, A and B)

The epithelial covering is of simple columnar cells resting on a thick layer of reticular tissue which comprises the tunica propria.

There are glands of Lieberkuhn present which are larger than those of the small intestine and do not appear to be as closely packed (Plate XVII, Fig. A-1). Goblet cells can be detected in the walls of the glands toward the upper end, and there appears to be only very few among the cells of the surface epithelium.

The muscularis mucosa is more fully developed here than it is in the small intestine (Plate XVII, Fig. B-3 and Plate XVIII, Fig. A-4).

The submucosa is a fairly thin layer composed of fibrous connective tissue, and is similar to that described for other parts of the alimentary canal (Plate XVII, Fig. A-4 and Plate XVIII, Fig. A-5).

The lamina muscularis is composed of the same two layers, an inner circular (Plate XVII, Fig. A-5 and Plate XVII, Fig. B-2) and an outer longitudinal (Plate XVII, Fig. A-6 and Plate XVII, Fig. B-3). The circular layer is well developed and as in the small intestine there is a connective tissue septa separating the two bands, in which Auerbach's plexus is evident. (Plate XVII, Fig. A-9)

The outer longitudinal muscle layer is not uniform around the entire circumference of the intestine, but is gathered together into three bands, known as the Taenia Coli. (Plate XVII, Fig. A-6 and Plate XVII, Fig. B-3) The longitudinal muscle fibers between the taenia are reduced to a thin layer. The three bands of muscle cause the submucosa to be thrown into a number of folds resembling the plica circulares, but these are called plica semilunares.

There are large aggregations of fat cells found between the serosa and the taenia coli (Plate XVII, Fig. A-7 and Plate XVII, Fig. B-5). In association with these areas offatty tissue, are large groups of blood vessels and nerves. (Plate XVII, Fig. B-4)

CAECUM

The caecum has the same general structure as the colon, except for, the fact that a few Peyer's patches were

observed in the submucosa, especially that part closest to the ileo-cecal junction.

RECTUM

The walls of the rectum are quite thick in comparison with the walls of the rest of the alimentary canal. (Plate XVIII, Fig. B).

There are no villi present, but there are still a few invaginations of the submucosa making up longitudinal folds.

In the upper part of the rectum the epithelial covering is composed of simple columnar cells while towards the anus this gradually changes to a stratified squamous type.

The tubular-shaped glands in the mucosa (Plate XVIII Fig. B-1 and Plate XIX, Fig. A-2) are shorter and broader than those in the colon, and contain a large number of goblet cells up and down their length.

The muscularis mucosa is fairly evident here again, (Plate XVIII, Fig. B-2) forming a comparatively wide band of smooth muscle fibers.

The submucosa is thin, rather loosely arranged and supports numerous blood vessels, nerves and also the odd solitary lymph node. (Plate XVIII, Fig. B-3 and Plate XIX, Fig. A-1)

The circular muscle layer is approximately of the same thickness as in the other part of the alimentary canal (Plate XVIII, Fig. B-4), and here the longitudinal muscle has increased in size until it is as thick as the circular layer

adjoining it (Plate XVIII, Fig. B-5). There is a thicker septa of connective tissue separating these muscle layers (Plate XVIII, Fig. B-6), and it is continued around the bundles of longitudinal muscle fibers. The longitudinal muscle fibers form a continuous layer about the wall of the rectum.

There is a thick, but loose connective tissue sheath exterior to the lamina muscularis, and this sheath contains numerous large blood vessels, as well as numerous aggregations of fat cells. (Plate XVIII, Fig. B-7)

SUBMAXILLARY GLAND

The gland is covered by a capsule of dense fibrous connective tissue (Plate XX, Fig. A-7). It is divided into numerous lobes which are supported by an interlobular fibrous connective tissue arising from the connective tissue capsule covering the gland (Plate XX, Fig. A-8). In this connective tissue are found the different excretory ducts.

The gland appears to consist almost entirely of mucous-type cells (Plate XX, Fig. A-1 and B-1), although a few serous type cells are in evidence (Plate XX, Fig. A-2). The mucous cells are arranged in small groups about a small opening or lumen, are pyramidal in shape, and have flattened basal nuclei. The serous cells are sometimes in small groups, and sometimes arranged in small demilunes around a group of mucous cells. They are oval in shape, have deep staining, central rounded nuclei, and appear to contain granules in the cytoplasm.

The large branches of the excretory ducts are lined with columnar epithelium. (Plate XX, Fig. A-3 and B-3)

The interlobar ducts, located in the broader connective tissue septa between the lobes, are lined by stratified columnar epithelium. (Plate XX, Fig. A-4)

The interlobular ducts, located in the connective tissue septa between the lobules, are lined by simple columnar epithelium. (Plate XX, Fig. A-5 and B-4)

The intralobular ducts, located within the lobules, are lined by a low columnar or cuboidal epithelium. (Plate XX, Fig. A-6 and B-2)

SUBLINGUAL GLAND

As in the submaxillary gland, the sublingual is covered by quite a thick capsule of dense fibrous connective tissue. (Plate XXI, Fig. A-5)

The gland is also divided into numerous lobes, which are supported by fibrous connective tissue arising from the connective tissue capsule, and in this gland this connective tissue septa dividing the glands into lobes is fairly dense. (Plate XXI, Fig. A-3)

This gland, like the submaxillary, is also composed chiefly of mucous acini (Plate XXI, Fig. A-1 and B-1), but there are quite a few more serous cells present as well. The demilunes of serous cells in association with mucous cells were much more evident here than in the submaxillary gland. (Plate XXI, Fig. A-2 and B-2)

There do not appear to be any intermediate ducts,

but numerous intralobular ducts exist and these are lined with a low columnar or cuboidal epithelium. (Plate XXI, Fig. A-4 and B-3)

THE PAROTID SALIVARY GLAND

The parotid gland is also covered by a very thick capsule of dense fibrous connective tissue (Plate XXII, Fig. A-1). It appears to be of about the same thickness as the capsule covering both the sublingual and submaxillary glands. The body of the gland is divided into numerous lobes and lobules, and these are supported by a dense interlobular fibroelastic connective tissue, which again appears to arise from the connective tissue capsule covering the gland. (Plate XXII, Fig. A-2) In these septa of connective tissue are located numerous excretory ducts. (Plate XXII, Fig. A-4)

This gland appears to consist entirely of serous acini (Plate XXII, Fig. A-3), no mucous cells having been observed. The cells composing the acini are arranged similarly to those composing the acini in the other two salivary glands. However the cells differ, in that they are large and oval-shaped, with centrally located nuclei and contain granules in their cytoplasm. These cells are arranged around extremely small lumen, which can only be observed in a very few cases, due to their minute size.

The largest ducts found in the gland are lined with stratified columnar epithelium. (Plate XXII, Fig. A-4)

The interlobar ducts are lined with simple columnar cells.

Secretory ducts, which are observed occurring within the lobules, are also lined with columnar epithelial cells.

Very small intercalated ducts, which are divisions of the secretory ducts, appear to be composed of cuboidal cells.

The whole field presents a uniform appearance as regards the secreting cells, a condition which is not apparent in either of the other two salivary glands.

THE LIVER

According to Mall (42) Wepfer, in 1664, was the first to describe lobules in the liver of the pig and two years later they were described by Malpighi who gave them their name. Mall also stated that Kiernan in 1844 maintained that the connective tissue covering the liver forms a distinct capsule.

Johnson (33) studied the microscopic structure of the pig's liver extensively, and arrived at numerous conclusions. He stated that, "up until late fetal life the lobules of the pig's liver are fused, and form a continuous mass of liver cells. It is in stages just prior to birth that any evidence of a segmentation of the liver parenchyma becomes apparent, and the completion of the formation of connective tissue septa is not fully accomplished until several months after birth. There appears to be an increase in the number of lobules in the pig's liver even after the connective tissue septa are formed, large lobules splitting up to give additional lobules. In sections one finds evidence

of this in incomplete septa." He also states that, "in size, the lobules present great variations within the same liver, some being five to six times as large as others."

Johnson (35) states that in 1842 Weber called attention to the fact that the lobules of the human liver were not separated, as are those of the pig. Johnson says, "the form of liver lobules is variable. In general they are irregular polyhedrous of a varying number of sides, borders and angles. The borders may be either sharply marked or rounded, while the angles formed by the union of the borders may vary from sharpely acute to greatly obtuse."

Johnson further says, "the lobules in young stages of the pig, amongst them stages in which the lobules are just beginning to be marked off from one another, likewise show but very few regularly-shaped lobules. The statement that the lobules of the pig's liver are completely separated from one another by connective tissue septa is true of the majority of lobules, but will not hold for a large number. Septa do not grow completely across lobules in the developing liver. The size and number of lobules varies greatly."

Johnson (32) states, "the pig's liver does not show indications of dividing septa until about birth, and the connective tissue septa are not definite until about the second month of postnatal life. The multiplication of lobules continues long after birth. In a pig of four days the liver shows cells being coarsely granular and staining deeply. The lobules are in most places marked out by the arrangement of

their border cells. Radial arrangement of liver cells is not too well marked at four days, but becomes increasingly more definite in livers of pigs of one, two and three weeks of age. After birth Glisson's capsule becomes thicker and continues to augment in strength until the adult stage. There are numerous compound lobules in the pig's liver. The connective tissue septa play no active part in the formation of lobules."

The liver is covered with a fairly thick membrane composed of connective tissue fibers this covering being known as Glisson's capsule (Plate XXIV, Fig. B-7). This sheath of connective tissue runs into the body of the liver and separates it into lobules. (Plate XXIII, Fig. B-3 and Plate XXIV, Fig. B-6)

The liver cells are large polyhedral cells having no definite cell walls, and possessing a central rounded nucleus. The cells are arranged in branching and anastamosing rows or cords radiating from a central vein, to the periphery of the lobule (Plate XXIII, Fig. A-1 and 2 and Plate XXIV, Fig. A-1 and 3). There are spaces between the cords known as hepatic sinusoids which are connected with the central veins of the lobules (Plate XXIII, Fig. A-3 and B-3 and Plate XXIV, Fig. A-4 and B-4). Two different types of endothelial cells were observed lining the hepatic sinusoids. One type is thin and flat, with a flattened deeply staining nucleus and the other type have a larger more oval-shaped nucleus and do not appear as numerous as the first type cell. The second type cells correspond to the cells of von Kupfer in the human, and

are thought to have a bacterial arresting action, and thus be phagocytic in nature. These endothelial cells do not form a continuous layer in the sinusoidal walls, but are separated from one another.

A very noticeable point regarding the liver was the amount of connective tissue dividing it into lobules. In the liver of the five week old pig very little connective tissue was found separating the body of the liver into lobules (Plate XXIII, Fig. A and Plate XXIV, Fig. A), while in the liver of the sixteen week old pig this connective tissue formed a very definite capsule around each lobule (Plate XXIII, Fig. B-3 and Plate XXIV, Fig. B-6). Also the lobules of the liver of the sixteen week old pig were somewhat more regular in size and shape than were those in the liver of the five week old pig. (Plate XXIII, Figs. A and B)

PANCREAS

Gibbes (27) found accumulations of cells between alveoli which were distinct from alveolar cells in dog, cat, guinea-pig and ape. He found them to be amongst the alveoli in contact with them, but not to be mixed indiscriminately with them. In some parts, he reports, "there is a trace of fine connective tissue on their periphery, but nothing like a distinct capsule separating them from the surrounding alveoli." "Each accumulation," he states, "consists of a number of polyhedral cells, each cell having a distinct nucleus, this nucleus being of irregular shape and staining very deeply." He found the different alveoli to be separated by fibrous

trabeculae, continuous with the outer sheath.

In the human, Opie (48), states, "the islands are composed of polygonal cells arranged in irregular columns. The cells are of epithelial type and have the same origin as those of the ducts and secreting acini with which, at an early period of development the cell columns are in continuity." He found that the lumen of the ducts does not penetrate among the cells of the islands, which is then, he concluded, "not concerned with the elaboration of the pancreatic juice."

Dale (19), in the historical description in his paper stated that, "Langerhans in 1869 first described in the pancreas of the rabbit, certain roundish areas of tissue, regularly distributed among the ordinary alveoli, consisting of small cells, polygonal in outline, with homogeneous cell substance and round nuclei without nucleoli."

Dale (19) stated that "Von Ebner could find no trace of lumen in the islets." He further states, "as a rule, but especially in man, the islands are surrounded by a connective tissue sheath, which may be interrupted in places so that island cells and acinal cells are in immediate contact."

Some early investigators (Lewaschew, Dogiel, Pischinger, Mankowsky, Statkewitsch) believed the islet cells to be alveolar cells which had been altered by fatigue, and supposed they were reconverted into alveoli during rest.

In his work with the rabbit, cat and dog Dale (19), found that among the deeply stained alveoli of the pancreas

the islets stand out clearly, relatively pale. He also states that, "the islands consist of irregular polygonal cells (pale, with purple nuclei and nucleoli)." A few nuclei he found to be irregular, shrunken and deeply stained. He found the islets to be most abundant in the rabbit and least abundant in the cat.

In the vertebrates, Dewitt (20), states that, "island cells are polygonal-shaped, the nuclei being ellipsoidal and showing a fine chromatin network and nucleoli which are never so large as those of the glandular cells." She states, "that in general, areas of Langerhans of very similar structure occurred in all species of vertebrates examined." In all species they consisted of cords or masses of epithelial cells.

Lane (40) described two types of cells making up the islands of Langerhans in the guinea-pig, both types containing a granular substance which was precipitated in different ways. Also he reports the fixation of both these types of cells to be poor, if saturated picric acid is used. He describes the "A" cells as being large, with an elliptical nucleus, although frequently circular. It is vesicular, large and the chromatin content is very small. The "B" cells appear smaller and more numerous, containing many granules. The nucleus in these is centrally placed, smaller than those in "A", circular, less vesicular, and contains a large amount of chromatin. In conclusion he states that "A" and "B" cells, may be two different phases of the same type cell.

In his work on the pancreas of the pig, Corner (15) reports, "the fresh pancreas of the pig presents an irregular surface which gives at first the impression of being divided into lobes." In a sectioned lobule he noticed that it was divided off into smaller divisions by fine septa of areolar tissue. "The islands of Langerhans," he states, "are surrounded by a slightly condensed stroma. In the pancreas of the pig he found the number of islands in one unit to vary (none, one, two, three, or more).

O'Leary (46) reports that, "in mice the islets are composed of spherical or ovoid masses of closely packed cells." In living preparations he found columnar cells predominating, although polyhedral cells are frequently found. Roughly polyhedral or columnar cells were found to be by no means unusual. The round or slightly oval nucleus was reported as being eccentrically placed in the cytoplasm.

This gland is covered with a layer of loosely arranged connective tissue. The fibers of this tissue appear to form quite a definite capsule around the gland. Connective tissue septae, or trabeculae, extend down into the body of the gland from this outer connective tissue covering. These trabeculae appear quite broad, and the connective tissue composing them is loosely arranged. (Plate XXV, Fig. A-4)

The cells making up the acini of the pancreas are of the low columnar type, having deeply staining, rounded nuclei. The pancreas greatly resembles the salivary glands in general structure, except that the septae are broader and

the connective tissue of which they are composed, is more loosely arranged, than in the salivary glands.

There are areas of lighter staining cells in the pancreas found both in the substance of the gland as well as in the connective tissue of the septa, and these are the islands of Langerhans (Plate XXV, Fig. A-3). The islands vary greatly in size, the smallest consisting of only a few cells, the largest being easily visible, owing to the large number of cells of which they are composed. There do not appear to be any ducts in the islands. There is a very thin layer of connective tissue surrounding the islands and this tissue seems to separate the islands from the pancreatic tissue proper in some places, while in other places the cells of the pancreas appear to come in direct contact with the island cells. (Plate XXV, Fig. A-2)

At least two different types of cells are easily distinguished in the islands. One type have a very large round and light staining nucleus, which in most cases contains more than one nucleolus. Cells of this type appear fewer in number than cells of the second type.

The second type of islet cell differs from type one by containing a much smaller and deeper staining nucleus. These are more numerous than the first type of cell.

An additional type of cell was observed in one or two islands, and these contained a much flattened, dark-staining nucleus. Whether these cells are distinct types, or whether they are merely different stages of one or both of the

other two types, could not be determined.

The pancreas is richly supplied with both blood vessels and nerves.

SUMMARY

A microscopic study of the digestive tract with its appendages was made on the pig.

The wall of the digestive tract was composed of the following layers: a mucous membrane comprised of an inner epithelial lining, a tunica propria and a muscularis mucosa; a fairly thick submucosa; a lamina muscularis composed of an inner circular layer and an outer longitudinal layer; and an outer adventitia or serosa depending on the organ's location.

The epithelium of the mouth is thick stratified squamous epithelium. The body of the tongue consists entirely of striated muscle, which is surrounded by a submucosa, the whole being covered with a thick stratified squamous epithelium. There were very few papillae observed on the tongue. All of the salivary glands were similarly constructed, with the acini of the submaxillary and sublingual glands containing chiefly mucous-type cells, while the parotid acini were entirely serous in nature.

A muscularis mucosa was found to be present throughout the entire oesophagus, although it was much thinner in the upper than in the mid and lower portions of the oesophagus. Numerous mucous-type glands were found in the submucosa of the oesophagus, but cardiac or superficial glands could not be demonstrated.

The stratified squamous epithelium of the oesophagus was continued into the oesophageal portion of the stomach but then changed into simple columnar epithelium at the junction of the oesophageal and fundic portion of the stomach. The epithelium then continues as simple columnar as far as the anus. Three gland regions were demonstrated in the stomach. The cardiac and pyloric gland regions of the stomach contained one type of cell only, while the fundic gland region contained two different types of cells. A serosa forms the outer covering of the digestive tract, from the stomach to the anus.

The small intestine was characterized by villi and plica circulares. Brunners glands were observed in the duodenum, and an extremely large number of Peyer's patches were observed in the ileum. Numerous goblet cells were observed in the epithelial lining of both the large and small intestines. These goblet cells were most numerous in the colon and rectum. The inner circular muscle layer of the lamina muscularis is approximately twice the thickness of the outer longitudinal muscle layer from the duodenum to the rectum and here the outer longitudinal muscle layer has increased in size until it is almost the same thickness as the inner circular layer.

The large intestine is characterized by having no villi, but there are still a few invaginations of the submucosa making up longitudinal folds. The muscularis mucosa is much thicker in the large intestine than in the small

intestine.

The liver and pancreas were both similar in structure to those of mammals. It is worthwhile to note however that in the liver of a very young pig the lobules are not completely separated by connective tissue septa, while in the liver of an older pig the lobules are completely separated by fairly thick connective tissue septa.

GLOSSARY OF TERMS

Adventitia - The outermost covering of any organ or structure which is properly derived from without and does not form an integral part of such organ or structure.

Collagen - An albuminoid present in connective tissue, bone and cartilage; on boiling with water it is converted into gelatine.

Cornification - Conversion into horn or a horny substance or tissue.

Demilune - A crescentic cell.

Follicle - A minute circumscribed mass of lymphoid cells in the mucous membrane.

Goblet Cell - An epithelial cell which has been distended with mucin.

Lacteal - One of the lymphatic vessels in the mesentery, conveying chyle from the intestine.

Lamina - A thin plate or flat layer.

Lymphoid Tissue - A tissue composed of a connective tissue framework containing lymphoid cells in its meshes.

Mucosa - Mucous membrane.

Mucous glands - Glands secreting the clear viscid secretion, mucous.

Mucous Membrane - A membrane secreting mucous, which lines passages and cavities communicating with the exterior.

Muscularis Mucosa - A layer of unstriped muscular tissue in mucous membrane.

Papilla - Any small nipple-like process.

Plica - One of several anatomical structures in which there is a folding over of the parts.

Plica Circularis - (Valvulae Conniventes) One of numerous folds of the mucous membrane of the small intestine, running transversely for about two-thirds of the circumference of the gut.

Plica Semilunares - One of the folds found in the mucous membrane of the large intestine corresponding to plica circulares in the small intestine.

Septum - A thin wall dividing two cavities or masses of softer tissue.

Serosa - Serous membrane, especially the serous or peritoneal coat of the intestines.

Serous glands - Glands secreting the clear watery fluid, serum.

Stratum Corneum - Horny layer, the outer layer of the epidermis, consisting of several layers of flat keratinized non-nucleated cells.

Stratum Germinativum - Germinative or malpighian layer.

Striated - Striped or marked by striae.

Squamous - Squamate, squamosal, scale-like, scaly; relating to or covered with scales.

Submucosa - A layer of tissue beneath a mucous membrane.

Taenia - Any anatomical band-like structure.

Taenia Coli - One of the three bands in which the longitudinal muscle fibers of the large intestine, except the rectum, are collected.

Tunica - A coat or tunic; one of the enveloping layers of a part, especially one of the coats of a blood vessel or other tubular structure.

Tunica Propria - The special envelope of a part as distinguished from the peritoneal or other investment common to several parts.

Villus - A minute projection from the surface, especially of a mucous membrane.

APPENDICES

APPENDIX A

I KILLING THE ANIMAL

The removal of small pieces of tissue from the different regions of the digestive tract of the five week old pig was attempted while the animal was under a general anaesthetic. As an anaesthetic a chloral hydrate solution was used, and was injected intravenously. However during the removal of certain of the tissues, a large artery was severed, and the pieces of tissue which had not yet been secured were removed as rapidly as possible following death. No alteration of any cells, in the tissues examined, were observed, so it was presumed that autolysis had not set in.

II FIXATION

Immediately on removal of the small pieces of tissue, they were put into 20-30 times their volume of fixing fluid.

Bouins' solution was used, and consists of the following:

Saturated aqueous solution of picric acid	75 parts
Formaldehyde	25 "
Glacial acetic acid	5 "

The pieces of material remained in this solution for 18 hours only.

III WASHING

Washing is the name applied to that process of removing from a piece of tissue excess chemicals retained from

the fixing fluid, in this case picric acid. The tissues were washed in 70% alcohol, until most of the yellow color of the picric acid had disappeared.

IV DEHYDRATION

The purposes of dehydration are, first, to free the tissue of water as completely as possible by replacing it with a medium that is miscible with the clearing agent and, second, to continue the process of hardening to the proper consistency for section cutting.

The tissue blocks were passed through a series of alcohols of increasing strengths: 30, 50, 75, 95, (2 changes). Since the sizes of the blocks of tissue were a little larger than is recommended for most Histological work, they were left in each of the above strengths of alcohols for 24 hours, in order to insure complete dehydration. The extent of dehydration increases as the strength of alcohol increases. The absolute alcohol is miscible with the clearing agent, in this case Toluol.

V CLEARING

The blocks of tissue were transferred from absolute alcohol to toluene (2 changes) until they become semi-transparent. The purpose of this clearing is to replace the absolute alcohol with a medium that is perfectly miscible with the melted imbedding medium, in this case "Tissuemat". If left too long in toluene however, they will become brittle.

VI INFILTRATION

The jars of toluene containing the tissue blocks,

were placed in an embedding oven for a short time (15 mins.), in order to warm the tissues prior to their being placed in melted "Tissuemat" (a substance very similar to paraffin, used for infiltration and embedding). The pieces of tissue were then transferred to melted "Tissuemat" in the embedding oven, which was regulated to maintain a temperature of 57 degrees C., since the "Tissuemat" had a melting point of 52-54 degrees C. The tissue blocks remained in this melted "Tissuemat" in the embedding oven for 6-8 hours.

VII EMBEDDING

In order to embed tissues it is helpful to have a metal plate and two lead L's, to make up the bottom and sides of the embedding box.

Enough melted "Tissuemat" to considerably more than cover the block of tissue is poured into the boat. With warmed forceps, the tissue is rapidly transferred from the last "Tissuemat" bath to the boat, and oriented as desired. The boat is then immediately lowered into very cold or ice-water until the water-line is very close to the top. It is held there steadily until there is formed over the cooling "Tissuemat" a surface film that is tough enough to resist erupting of the still melted "Tissuemat" in the interior of the block. The boat is then completely immersed in the water and left for an hour or so to permit the "Tissuemat" to completely solidify.

The blocks of tissue are now ready for immediate use, or they may be kept for an indefinite period of time, if

stored at the proper temperature to prevent the "Tissuemat" from melting (50 degrees C. or below).

VIII MOUNTING BLOCKS ON MICROTOME DISC

The top of the "Tissuemat" block is trimmed neatly in rectangular form, with enough "Tissuemat" left around the tissue to form a frame for the section of tissue after cutting.

The metal microtome disc is warmed slightly and the base of the block is applied to this warm surface, until the block adheres. The block and disc are then either plunged into cold water or put in a refrigerator for a few minutes.

IX CUTTING SECTIONS

The disc is placed in the microtome so that the broader edge of the block is parallel to the knife edge. The knife is set at an angle sufficient to permit clearance for the block after the section is cut. The screws holding the object disc and its' mounting are now tightened and the feed regulator is set for the desired thickness of sections in microns (10 u.).

When cutting is begun it will be noted that each section remains in contact with the knife-edge, and that successive sections adhere to form a continuous ribbon. A camels' hair brush, or some such suitable object, is used to guide the ribbon away from the knife.

All sections for this study were cut at a setting of 10 u.

X AFFIXING SECTIONS TO SLIDES

Slides should be thoroughly cleaned before use by using a standard cleaning solution, washing in tap water, then distilled water and finally rinsing in 95% alcohol and drying in air.

Two different affixative's were used, namely Mayers' albumin and Haupts' adhesive. These solutions are prepared and used as follows:

(a) Mayers' Albumin

The white of an egg is beaten lightly and poured into a graduate. After a few hours the foam is skimmed off and the remainder is filtered by suction. An equal volume of glycerin is added to the filtrate and mixed thoroughly. A crystal of thymol is added as a preservative. This solution is used as follows:

A very minute quantity is applied to a clean slide and spread evenly over the slide with a clean finger. Then several drops of distilled water are placed on the slide and the sections are floated on this, smooth side down. The slide is then warmed gently to flatten the sections, after which the excess water is removed and the slides placed in a drying oven with the temperature regulated at 37 degrees C., for 12-16 hours.

(b) Haupts' Adhesive

Dissolve 1 gr. plain Knox gelatin (pure, finely divided) in 100 cc. distilled water at 30 degrees C. When completely dissolved add 2 gr. phenol crystals and 15 cc. C.P.

glycerin. Stir well and filter. A 3-4% aqueous solution of formalin is used in conjunction with this. This solution is used as follows:

The procedure is the same as with Mayers', except the sections are floated on the 3-4% solution of formalin in place of distilled water. The mounted slides are placed in a drying oven together with a watch glass or two of full strength formalin. The fumes of the formalin assist in coagulating the gelatin.

XI DEPARAFFINING, HYDRATING AND STAINING

Ten slides were handled at one time during this process.

The paraffin is dissolved from the sections by immersing the slides in Toluene for about one minute, and then in a mixture of toluene-phenol (1/3 by volume phenol) for one minute. The slides are withdrawn and held so that their lower ends touch a blotter of some sort to absorb excess fluid. It will not be mentioned hereafter, but the following points are important: (a) The slides should be drained of excess fluid, as described above, after withdrawal from each reagent, and (b) neither here, nor at any place in the entire remaining procedure, should the tissue be permitted to dry.

The slides are then passed "down" through the alcohols, consisting of 95%, 95%, 70%, 50%, 30%, then into distilled water, and should remain in each of these solutions for two minutes. The last step above of placing the slides in

distilled water prior to staining with Haematoxylin, need not necessarily be employed.

The slides are now transferred to Harris' Haematoxylin and remain in this stain from 3-5 minutes, depending on its' strength.

Stock mixture of this stain is prepared as follows: Dissolve 20 grams of ammonium or potassium alum in 200 c.c. of distilled water, by heat. Add a solution of one gr. haematoxylin dissolved in 10 c.c. alcohol. Bring the mixture to a boil as quickly as possible and then add ½ gr. HgO. The solution becomes dark purple. As soon as this occurs, remove the vessel containing the stain from the flame, and cool by plunging in cold water. Filter and use as soon as cold or when desired. This solution "ripens" with age. The above solution can either be used full strength, or diluted to ½ strength with distilled water.

XII DIFFERENTIATING

The slides are removed from the Harris' Haematoxylin and washed in tap water for a few minutes. It is now necessary to extract some of the Haematoxylin stain from the cytoplasm, in order to enable one to distinguish cytoplasm from nucleus, since the cytoplasm has taken up so much of the Haematoxylin, that differentiation at this point is difficult.

This is accomplished by immersing the slides in acid alcohol (70% alcohol, 300 c.c.; HCl 1 c.c.) for about one minute, or until the instant the color of the tissue changes from bluish to reddish.

Then destaining action of the acid alcohol is stopped and the bluish tint restored by immersing the slides in alkali alcohol (70% alcohol plus a few drops of .1% Na Co) in water for about one minute. After each of the above procedures (acid and alkali alcohols), the slides may be rinsed in 70% alcohol.

XIII COUNTERSTAINING

In order to improve the contrast between nucleus and cytoplasm, the latter is stained with an acid dye of a different color, in this case Eosin. The slides, after being differentiated, are now placed in Eosin for one minute, very seldom for any longer. This stain is made up by dissolving $\frac{1}{2}$ gram of yellowish Eosin in 100 c.c. of 90% alcohol.

XIV FINAL DEHYDRATING AND CLEARING

The slides are now passed through two changes of 95% alcohol, remaining for two minutes in each change, toluene phenol for 30 seconds, and finally toluene for 30 seconds. After this they are immediately covered with pure Canada Balsam and examined to ascertain whether or not they are suitable to keep for examination purposes. Cover slips are then applied to those slides deemed suitable.

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directly on the microscopic anatomy of the digestive system of the pig. However it seemed advisable to include the following as additional references:

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APPENDIX B

THE PHYSIOLOGY OF DIGESTION IN THE PIG

THE PHYSIOLOGY OF DIGESTION IN THE PIG

INTRODUCTION:

The digestive system consists of the organs directly concerned in the reception and digestion of food, its' passage through the body, and expulsion of the unabsorbed portion. These organs are grouped under two headings, (a) the alimentary canal, and (b) the accessory organs.

(a) The alimentary canal is a tube extending from the lips to the anus, and it consists of the following segments: (1) Mouth (2) Pharynx (3) Oesophagus (4) Stomach (5) Small Intestine (6) Large Intestine (7) Rectum (8) Anus.

(b) The accessory organs consist of: (1) The Teeth (2) Tongue (3) Salivary Glands (4) Liver (5) Pancreas.

PART I

THE MECHANICS OF DIGESTION

It is evident that movements must of necessity occur in the walls of the alimentary canal to convey the food from one part to another, and mix it with the various digestive juices.

The Prehension of Food

The term prehension itself, means the conveying of food to the mouth. Methods by which animals convey food to the mouth differ according to the species. The lips, teeth, and tongue are the principle organs of prehension.

In the pig the lower lip is pointed, and the upper one insignificant. Prehension is accomplished in the pig by the teeth, tongue, and characteristic sharp backward and

forward movements of the head. Actually the food is thrown back into the mouth by these sharp movements. Under natural conditions, pigs carry on a search for food by means of their characteristic rooting habits.

Drinking, or the Prehension of Liquids

In the pig, sucking, which is similar to drinking; is produced by the animal creating a vaccuum in the mouth by closing the lips, decreasing the size of the tongue in front and increasing it behind, the dorsum being applied to the roof of the mouth. This creates a negative pressure in the mouth, and liquid is forced into the mouth, since the pressure there is lower than that of the atmosphere.

Mastication

This is the mechanical reduction of food that takes place in the mouth. It is performed between the molar teeth. The movements which the jaws undergo to carry this out, depend again on the class of animal.

In the pig the jaws undergo very little lateral movement, but extensive protraction and retraction. The molar teeth of pigs are very similar to those of humans. Pigs chop their food, in direct contrast to cows, which grind theirs. The dental formula of the pig is 2(I C P M) 44.

Mastication is important for two reasons: (a) finely divided food presents a greater surface area for the action of digestive juices, (b) food well mixed with saliva is more readily swallowed.

Deglutition or Swallowing

This usually occurs in three stages.

In the first stage, the food is carried back to the base of the tongue, and compressed against the soft palate.

The second stage is a complex one, due to the fact that the food has to cross the air passage and must be prevented from falling into the nasal chambers, or going down the trachea. To accomplish this the soft palate is raised, and so closes the nasal chambers, the tongue at the same time is carried backwards, and the larynx and pharynx are advanced. This causes the base of the tongue to press on the epiglottis and close the larynx. The food now passes to the pharynx, and is then pressed into the oesophagus.

In the third stage the food is carried down the oesophagus by a continuous wave of contraction, which starts at the pharynx and ends at the stomach.

As stated previously, the whole process of deglutition is voluntary, but the remaining processes are involuntary.

PART II

THE DIGESTIVE ORGANS

Structure of the Oesophagus

In the pig, as in all animals, the wall of the oesophagus is made up of four layers: a fibrous coat, muscularis mucosa, submucosa, and mucous membrane, (See fig. I and II). The kind of muscle found in the muscular coat varies in different species.

FIG 1 OESOPHAGUS (H.P.)

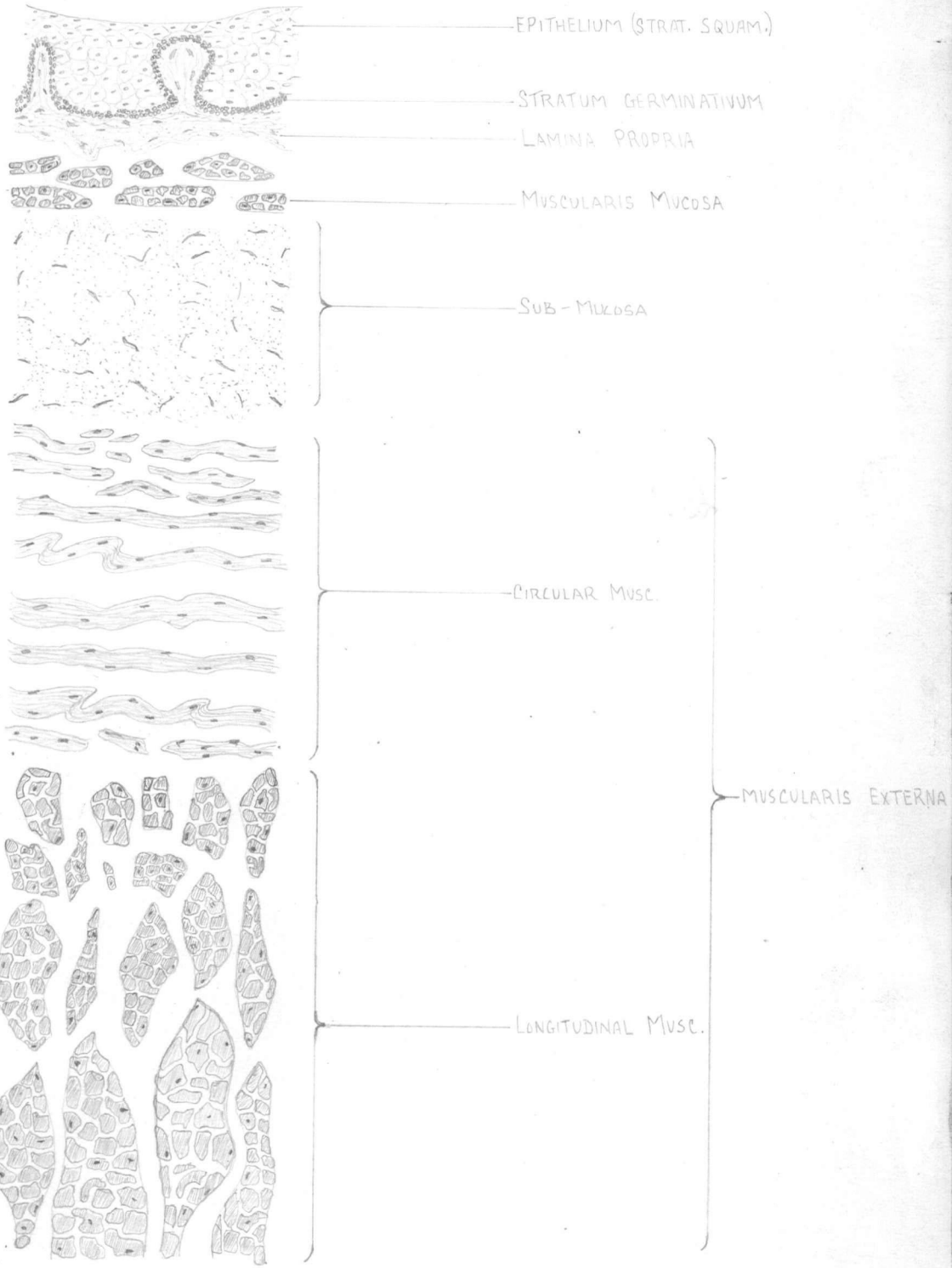
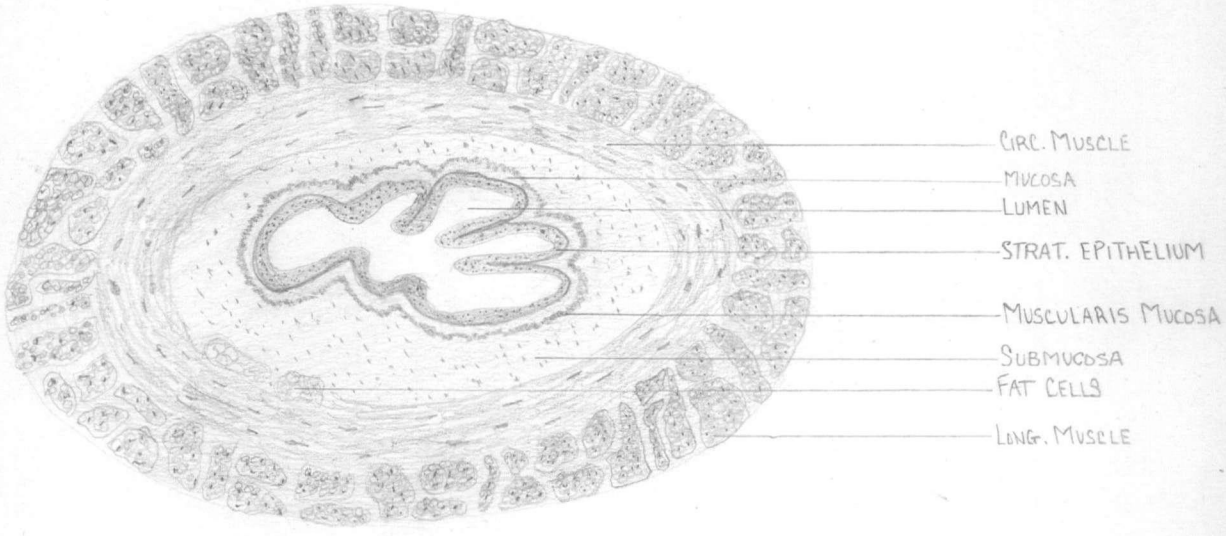


FIG. 2 OESOPHAGUS (L.P.)



In the pig, striated or voluntary muscle is found throughout the oesophagus and it is more numerous in the upper and lower portions than in the middle.

The Cardia

The opening of the oesophagus into the stomach, the cardia, is closed by a sphincter of smooth muscle known as the cardiac sphincter. Its degree of developement varies in different animals, and its function is to prevent the passage of food from the stomach to oesophagus. In the pig the cardiac sphincter is not too well developed, since vomition can occur quite easily.

The Salivary Glands and their Secretion

The term salivary glands refers to the three main salivary glands, all of which are paired, as well as numerous small glands found in the mucous membrane of the mouth.

The three main salivary glands are the parotid, submaxillary, and sublingual. The parotid is located near the base of each external ear, and is the largest of the salivary glands. Their ducts communicate with the buccal cavity just opposite the upper molar teeth on each side (Stenson's duct). The submaxillary are found lying in the lower jaw on each side. Their secretion is carried into the buccal cavity by excretory ducts which open on the side of the root of the tongue (Wharton's duct). The sublingual glands are placed underneath the tongue in the floor of the mouth. Numerous excretory ducts open close together on small papillae on the sublingual fold.

The mixed secretion of all of these glands is known as saliva.

Glands in general can be divided into serous, mucous or mixed types. Serous glands secrete a thin watery fluid, containing protein but no mucin. Mucous glands produce a secretion containing mucin. Mixed glands secrete both.

All of the salivary glands belong to the class known as compound tubular. Of all the domestic animals the pig has the best developed parotid system. In the pig the parotid gland is serous in nature, the submaxillary gland is mixed, both serous and mucous; and the sublingual is also a mixed gland.

Serous cells frequently also produce enzymes. Zymogen granules, thought to be the precursers of enzyme, are found stored in serous cells. Mucous cells do not produce enzymes.

The Stomach

Domestic animals fall into two general classes as regards stomach structure and function, ruminants and non-ruminants. Non-ruminant stomachs consist of only one compartment, while ruminant stomachs consist of four compartments only one of which secretes gastric juice.

In the stomach, food is submitted to digestive processes of both a chemical and mechanical nature, and this constitutes gastric digestion. The stomach itself may be described as the dilated portion of the alimentary canal at

the posterior end of the oesophagus. It acts partly as a storehouse for food, but is also an important digestive organ in which the food is acted on by the gastric juice, which is secreted by the glands in its' epithelial lining. The volume of the pigs stomach is about fourteen pints.

The stomach of the pig is intermediate in character between that of the carnivorous simple stomach, and the herbivorous rather complex one.

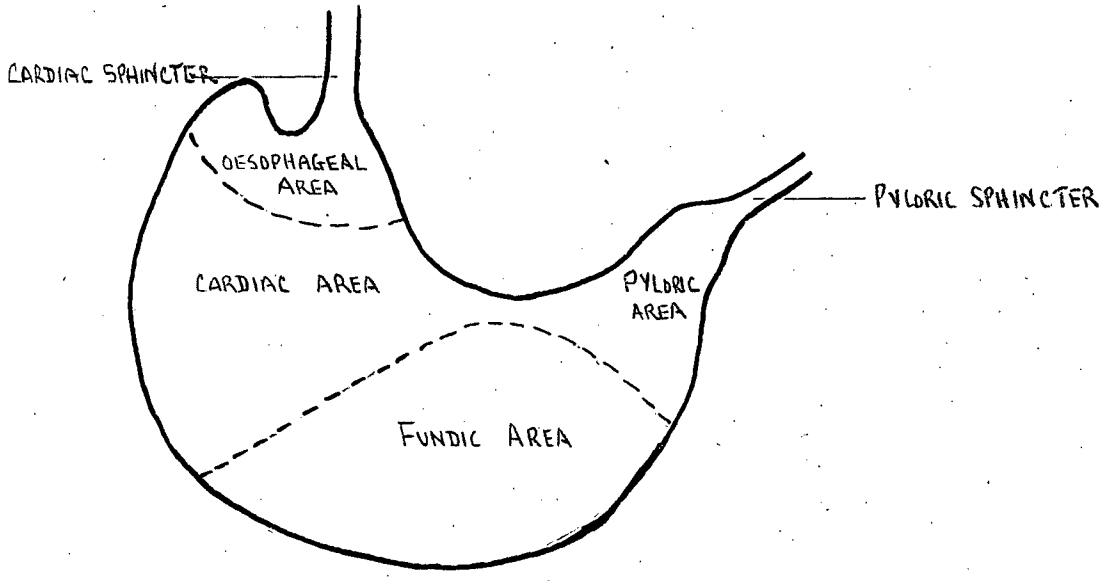
As can be seen from figure III, the mucous membrane of the pigs' stomach is divided into four distinct zones, most of which contain glands. There are actually three gland zones - cardiac, fundic, and pyloric, while there is also a glandless oesophageal region.

In the pig the oesophageal region is limited to a small area around the cardia. The cardiac gland zone is very extensive, occupying the left extremity of the stomach. The transition between the glandless oesophageal region and the cardiac gland zone is quite abrupt. The fundus gland zone is quite large, occupying a large part of the right extremity or fundus. The pyloric gland zone occupies the remainder of the mucous membrane, and extends to the pylorus.

The Gastric Glands

The gastric glands are numerous, and small. The mucous membrane contains these glands, which open on its' surface by numerous orifices. They are tubular, or branched tubular in type. As mentioned previously there are three main classes of gastric glands (a) cardiac (b) fundic and

FIG III



PIG STOMACH

(c) pyloric. See fig. IV A & B and fig. V A & B.

(a) Cardiac glands

The narrow, yellowish-gray region next to the non-glandular oesophageal region of the pigs' stomach contains the short, tubular cardiac glands. In the pig these glands are thought by some to be only a mucous secreting type of gland, and therefore do not produce any enzymes. Other workers seem to think that the glands in this zone were derived from the fundic gland zone, and will ultimately disappear. Two workers have reported that the cardiac glands of the pig do not secrete an amylase.

(b) Fundic glands

These are considered to be the proper gastric glands. The fundic gland region is readily distinguished by its' thickness, and its' brownish-red mottled appearance. The gland cells themselves are of three main kinds: body chief cells, neck chief cells, and parietal cells. The body chief cells are supposedly the enzyme producers. The neck chief cells line the gastric glands in their upper part, and are believed to be mucous secreting cells. The parietal or border cells produce the HCl of the gastric juice.

(c) Pyloric glands

These glands are found in the reddish-gray, much folded portion of the mucous membrane of the stomach following the fundic area. Parietal cells are lacking here. The secretion of these glands contains mucous and a small amount of proteolytic enzyme.

FIG. 4[A] FUNDIC STOMACH (L.P.) (LONG. SEC.)

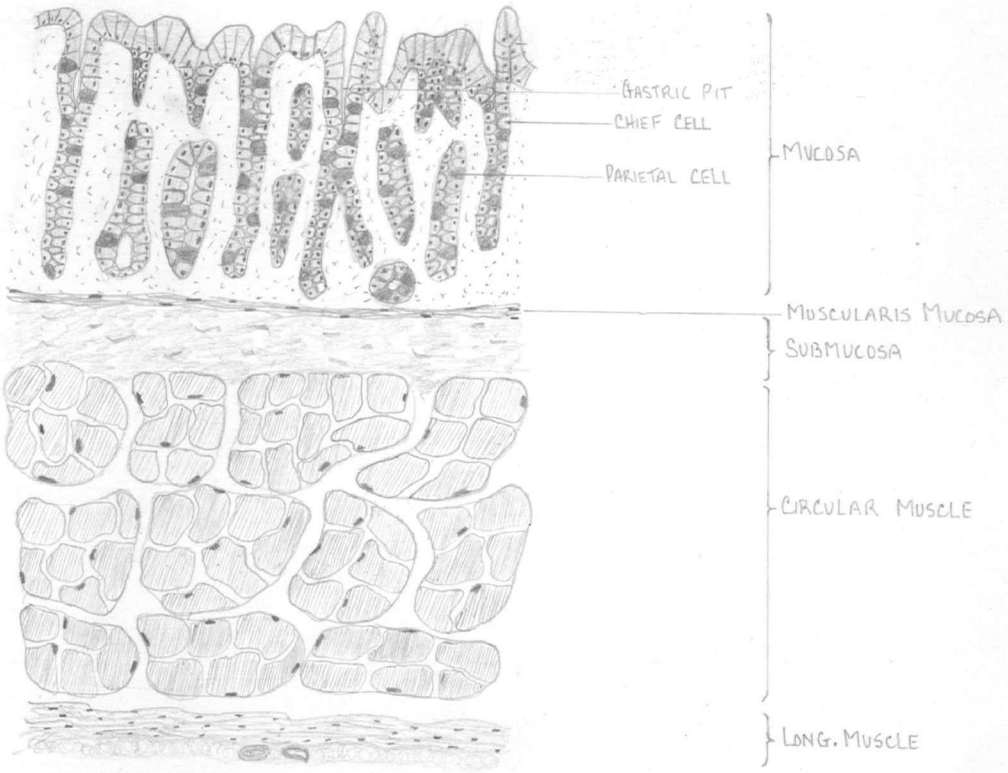


FIG. 4[B] FUNDIC STOMACH – MUCOSA (H.P.)

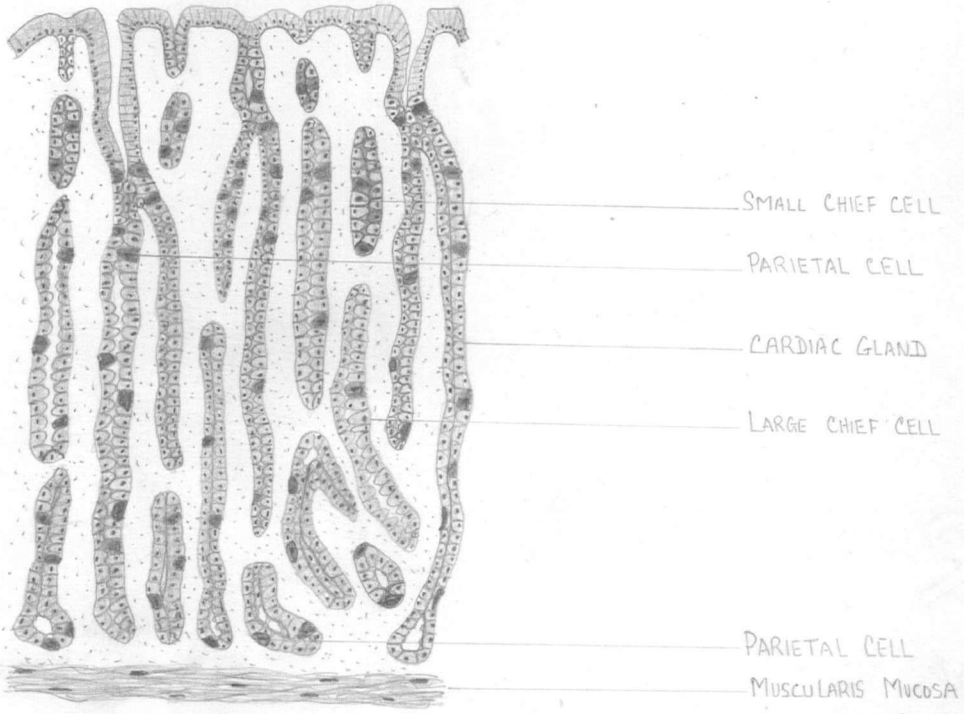


FIG. 5[A] PYLORIC STOMACH

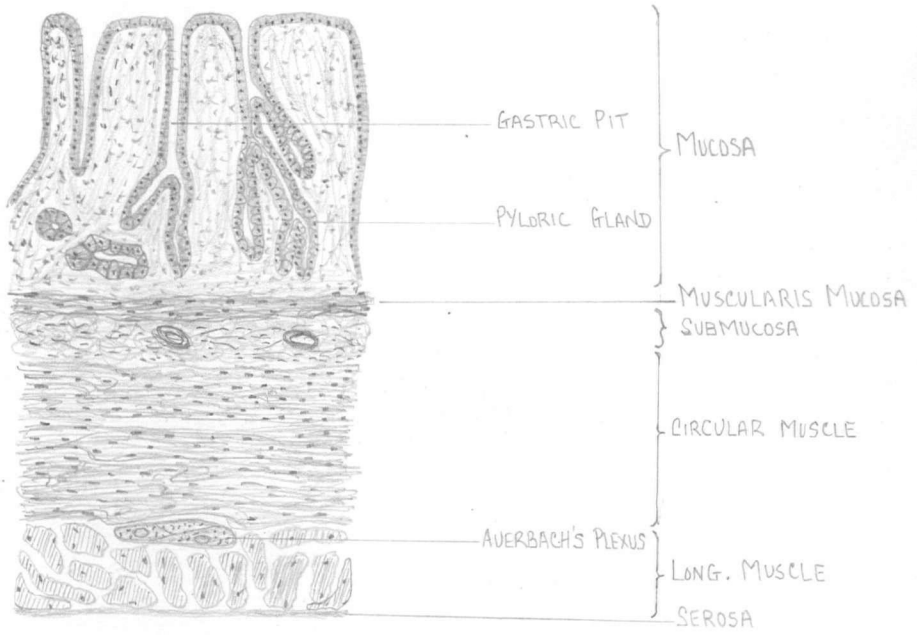
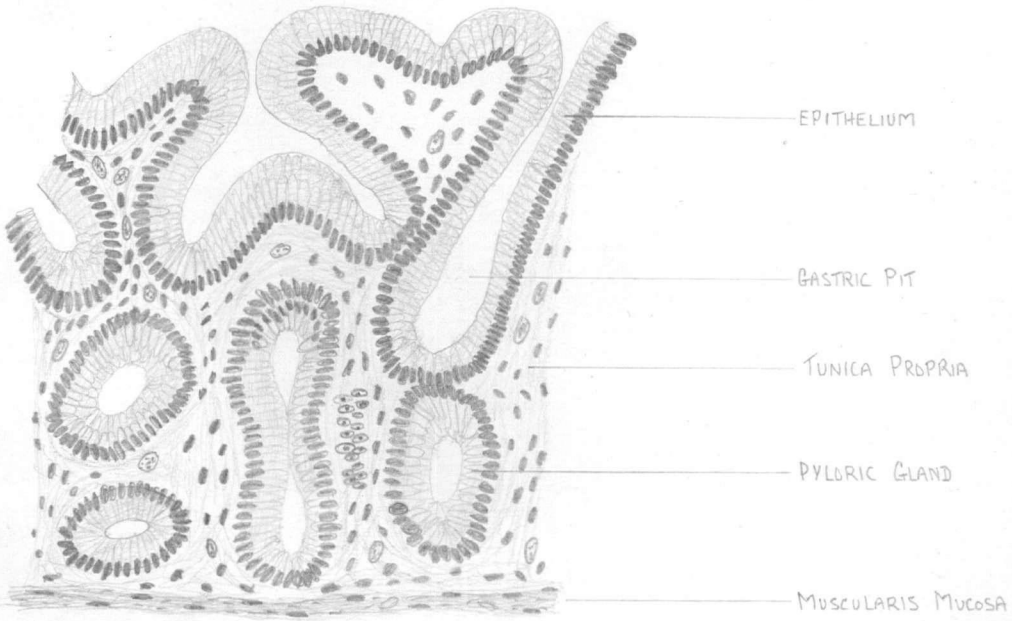


FIG. 5[B] PYLORIC STOMACH - MUCOSA



The Pylorous, and its' control

The pylorus is guarded by a band of circular smooth muscle known as the pyloric sphincter, the purpose of this being to prevent the stomach contents from entering the intestine in too large amounts. The correct explanation as to just how the pylorus is controlled is still not quite clear. An acid theory of pylorus control was advanced, but in later years this theory has been criticized, and considered by many to be inadequate.

Movements of the stomach

During gastric digestion the stomach wall undergoes important muscular movements, whose purpose is to more or less pulverize the food, mix it with gastric juice, and at intervals to pass it on into the duodenum. The most important stomach movement is a peristaltic wave beginning near the middle of the body of the stomach, and running towards the pylorus. Periodically the pylorus is relaxed to allow ingesta from the stomach (chyme) to be forced, by these aforementioned peristaltic contractions, into the first part of the small intestine (duodenum). In the pig during the time that chyme is not entering the duodenum, the pylorus is closed. The frequency of the peristaltic waves is about four to six per minute. As the lower part of the body of the stomach empties its' contents into the duodenum, the characteristic peristaltic contractions force new material into the lower part of the stomach. The cardiac end of the stomach apparently takes no part in the peristaltic movements. It

is well to notice that the pylorus does not open for the passage of chyme with every contraction wave which passes over the stomach.

The Small Intestine, and the glands communicating with it

In the pig the intestines are approximately fifteen times the length of the body (50-65'). The volume of the intestinal canal in the pig being about 34 pints.

The small intestine is divided into duodenum, jejunum and ileum. (See fig. VI A & B and fig VII A & B). There are numerous very vascular villi making up the mucous membrane.

There are two kinds of glands in the small intestine, the crypts of Lieberkuhn, and Brunners' glands. Brunners' glands are restricted to the duodenum, not being found in the jejuno-ileum. The duodenal glands are tubulo-alveolar in type, and the secreting portion is principally found in the submucosa, although it may occur in the deeper parts of the mucous membrane. We also find a tremendous number of aggregations of lymphoid tissue in the mucous coat of the small intestine, chiefly in the jejuno-ileum, and these are called Peyer's patches. (See fig. VIII)

(1) The Liver

This organ, the largest gland in the body, communicates with the duodenum by means of the bile duct, which has its' opening about one to two inches from the pylorus. In the pig the average weight of the liver is four pounds. It is divided by three deep interlobar incisures

FIG. 6[A] DUODENUM (LONG. SECTION) (L.P.)

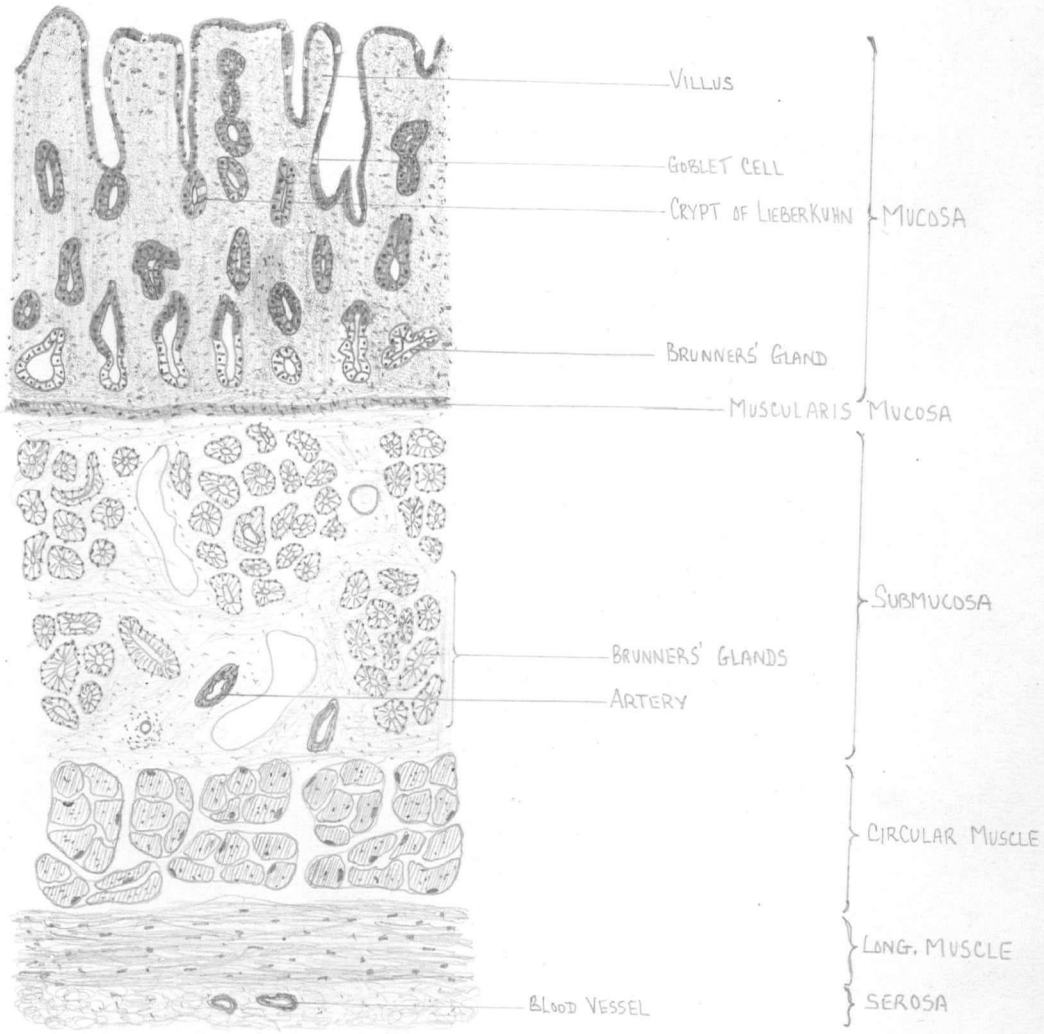


FIG. 6[B] DUODENUM - MUCOSA (H.P.)

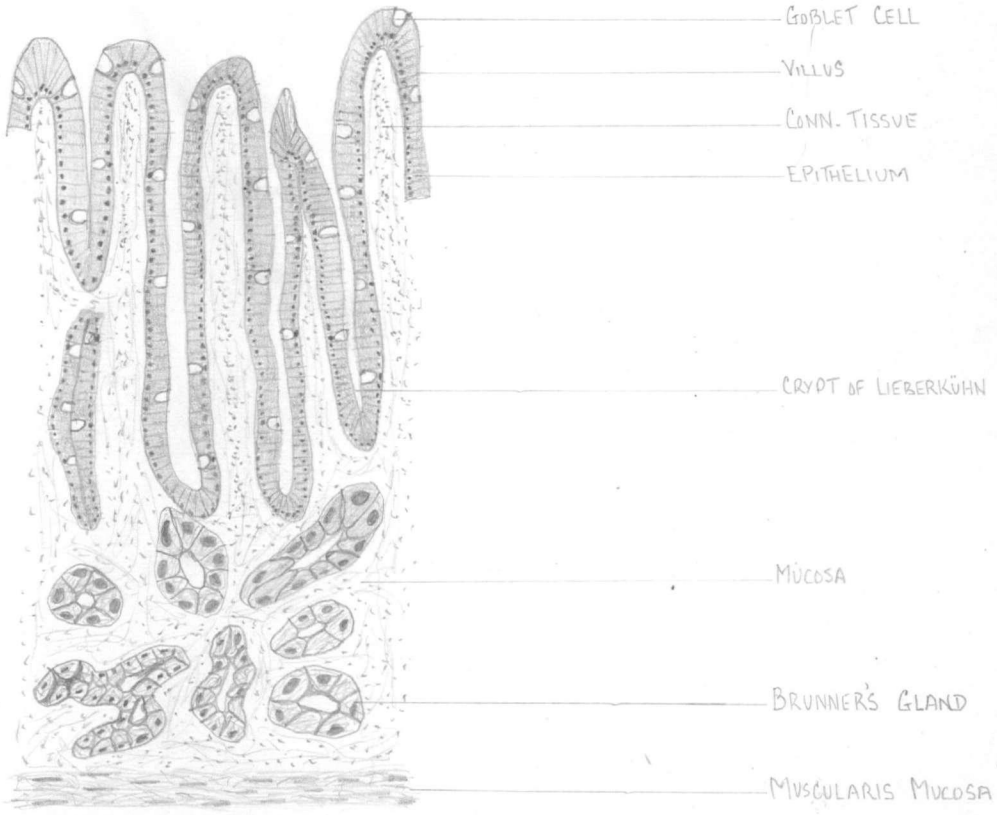


FIG. 7[A] JEJUNUM (LONG. SEC) (L.P.)

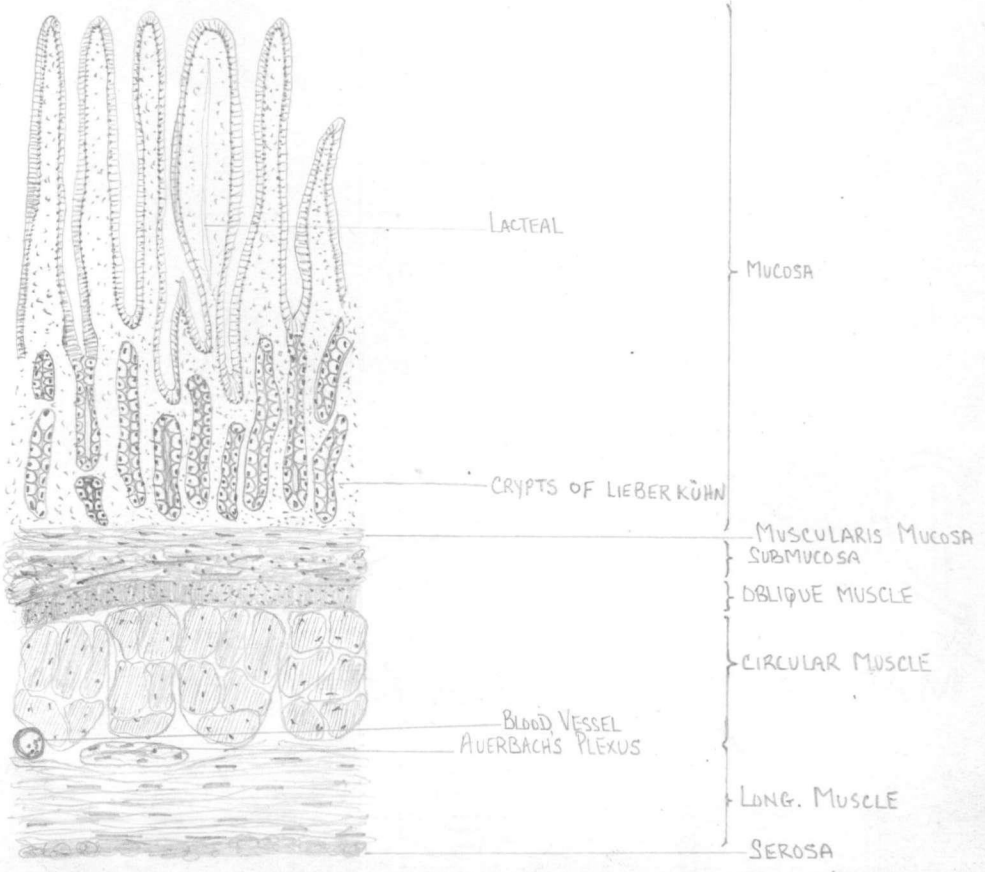


FIG 7[B] JEJUNUM - MUCOSA (H.P.)

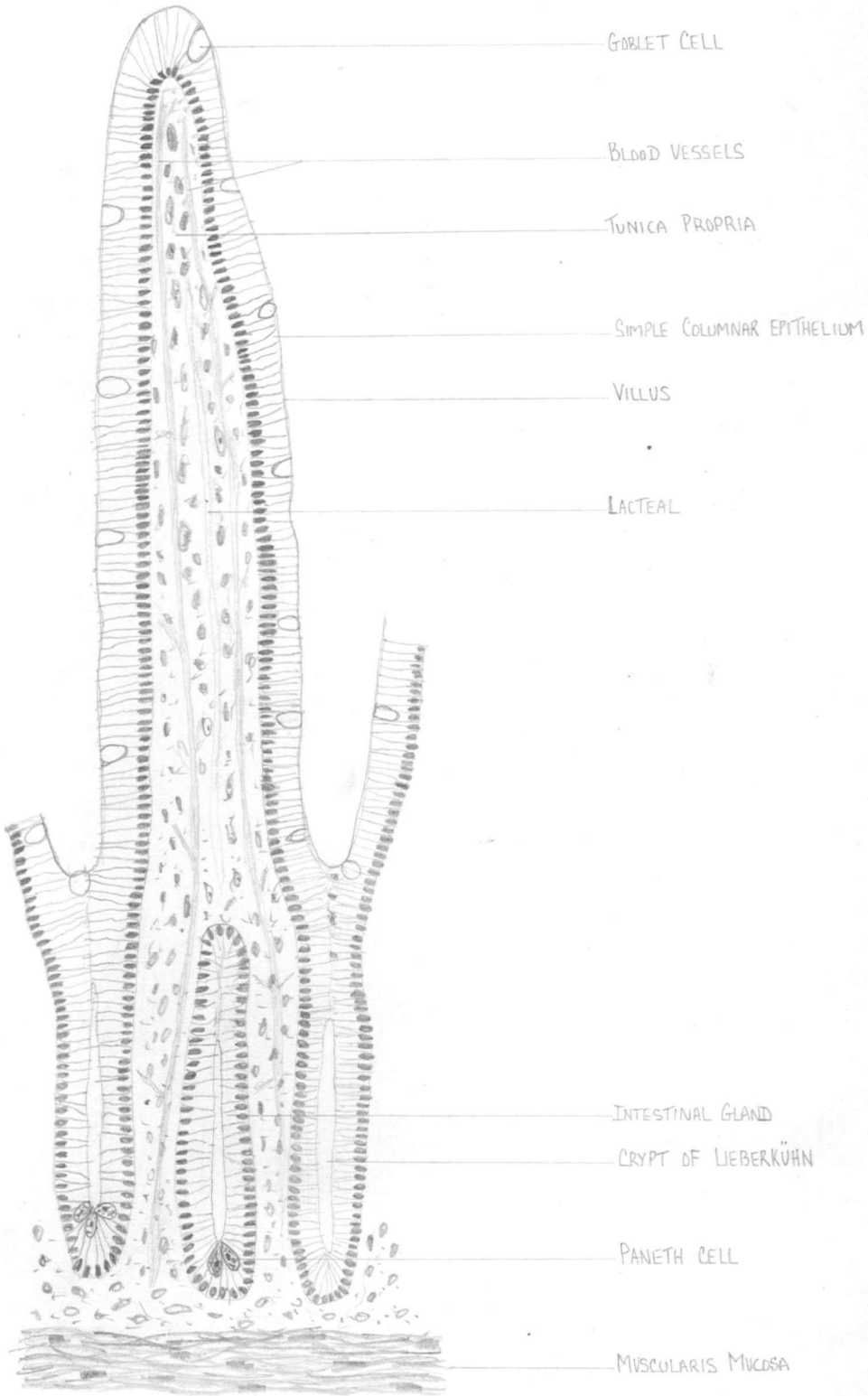


FIG. 8 PEYER'S PATCH (MED. POWER)

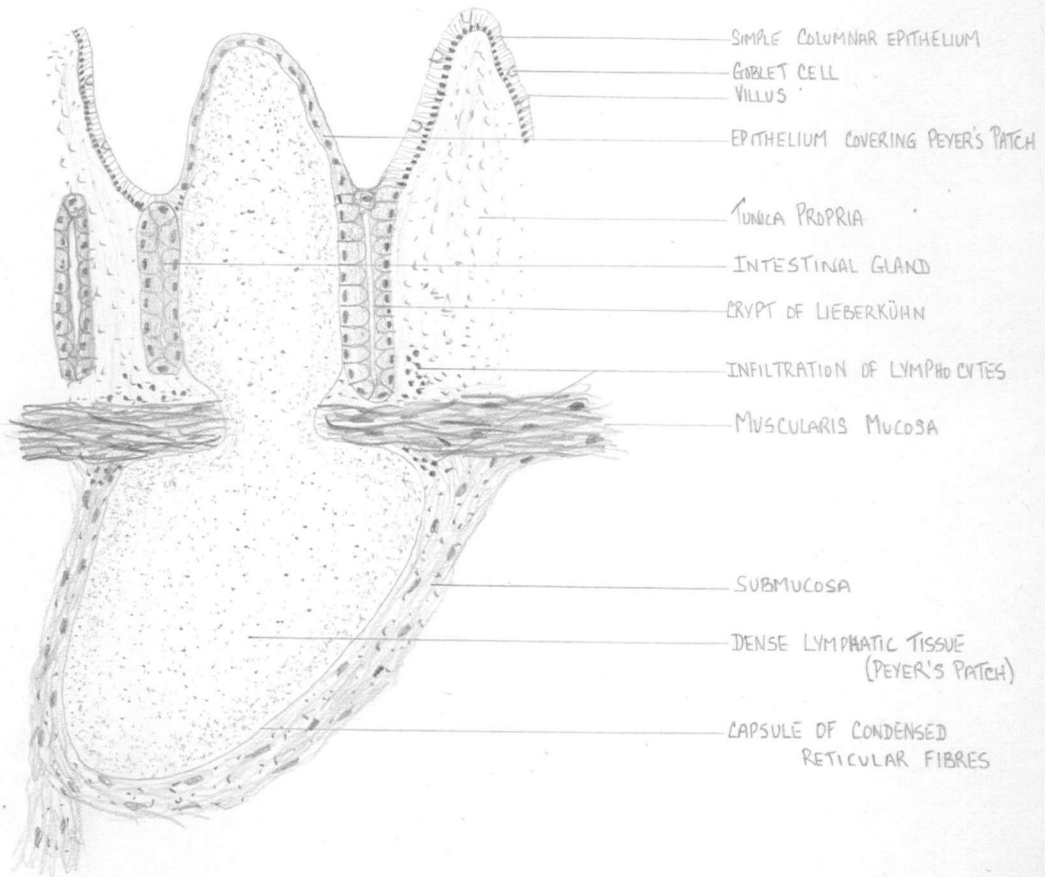
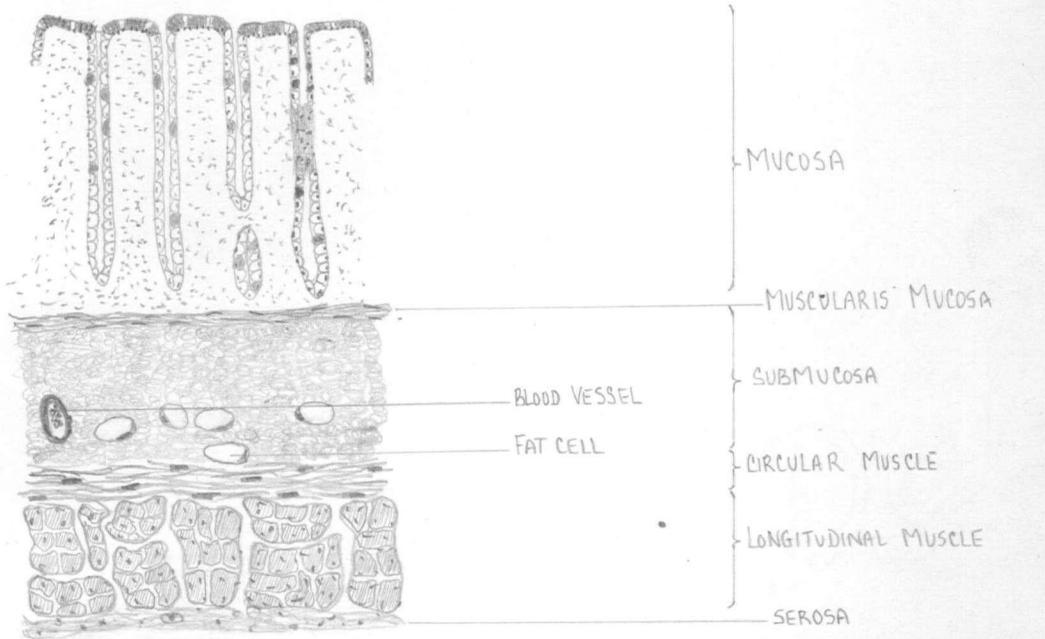


FIG. 9[A] LARGE INTESTINE (L.P.)



into four principal lobes named right lateral, right central, left central, and left lateral. On the upper part of the right lateral lobe, is the caudate lobe.

The lobules of the liver are separated by connective tissue, and in the adult pig this separation is complete, but in man, and many animals is incomplete. The liver has a number of very important functions. It stores up carbohydrate material in the form of glycogen, and releases it into the blood as sugar, the percentage of which is thereby kept constant. It makes urea, and uric acid, which are discharged as waste products by the kidneys. It also manufactures bile, which in the pig is stored in the gall bladder until it is required for digestive purposes, and then is poured into the small intestine by way of the bile duct.

(2) The Pancreas

The pancreas lies in the loop of the duodenum, and communicates with it by means of the pancreatic duct, which opens into the duodenum about 4-6" from the pylorus. The secreting alveoli of the pancreas are grouped into lobules and these are grouped into lobes. In structure, the pancreas is very much like the salivary glands, but it contains certain cells having a different staining reaction, and these constitute the islets of Langerhans, which are thought to be the centers of insulin secretion in the body. The pancreas then can be regarded physiologically as two organs in one. The alveolar cells produce the digestive juice, while the islet cells produce the internal secretion

insulin.

The Large Intestine

In the pig the large intestine is approximately 12 to 15' in length, and is for the most part wider than the small intestine. The large intestines compose the colon, caecum, and rectum. The crypts of Lieberkuhn are still present here, but there are no Brunner's glands, and no villi. (See fig. IX A & B) The last Peyer's patch of the small intestine is continued a small distance into the caecum, and sometimes patches are found in the first part of the colon.

The caecum is cylindrical, about 8-12" long, and 3-4" wide. The ileum joins the caecum obliquely, and projects into the latter.

The colon has at first about the same caliber as the caecum, but gradually becomes smaller. In the pig the colon is of relatively small importance in digestion.

The rectum is usually surrounded by a great deal of fat.

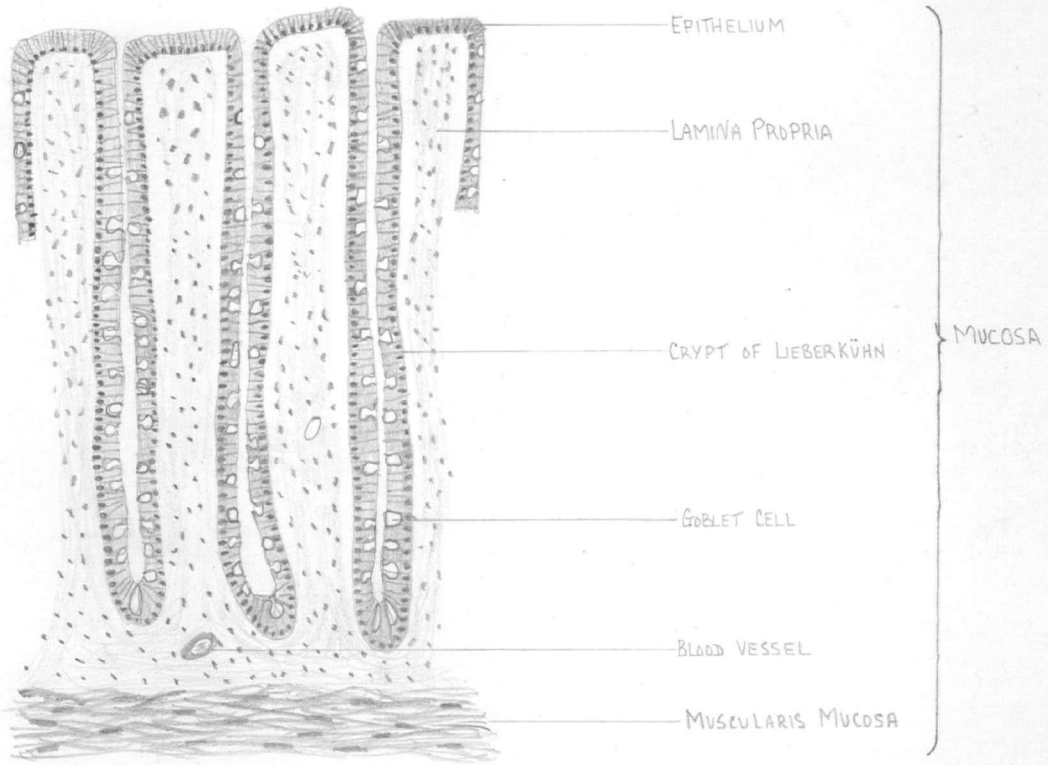
PART III

THE DIGESTION AND ABSORPTION OF FOOD

INTRODUCTION

During its' passage through the alimentary canal the food comes into intimate contact with several digestive juices. In the mouth it is thoroughly mixed with saliva, in the stomach it meets the gastric juices, and in the intestines it becomes mixed with bile, pancreatic juice, and the intestinal juices. The function of all of these juices

FIG. 9[B] LARGE INTESTINE - MUCOSA (H.P.)



is to convert protein, fat, and carbohydrate of the food into forms suitable for absorption by the walls of the alimentary canal. This preparation for absorption is achieved by the action of enzymes present in the digestive juices. The enzymes which take part in the digestive processes may be grouped together as follows:

(Refer to following page)

TABLE I

Enzyme	Origin	Class	Function
Ptyalin (Salivary Amylase)	Salivary Sec.	Amylolytic	Converts starch to maltose
Pepsin (Gastric Protease)	Gastric Juice	Proteolytic	Converts proteins to peptones and proteoses
Rennin	Gastric Juice	Casein coagulant	Converts casein to paracasein
Gastric Lipase	Gastric Juice	Lipolytic	Converts fats to higher fatty acids and glycerol
Trypsin	Pancreatic "	Proteolytic	Converts proteins to polypeptides and amino acids
Amylopsin (Pancreatic Amylase)	" Sec.	Amylolytic	Converts starch to maltose
Steapsin or (Pancreatic Lipase	" Juice	Lipolytic	Converts fats to fatty acids and glycerol
Erepsin	Intestinal "	Proteolytic	Converts peptones to amino acids
Invertase	Intestinal "	Amylolytic	Converts sucrose to glucose and fructose
Maltase	Intestinal "	Amylolytic	Converts maltose to glucose
Lactase	Intestinal "	Amylolytic	Converts lactose to glucose and galactose

I Digestion in the Mouth

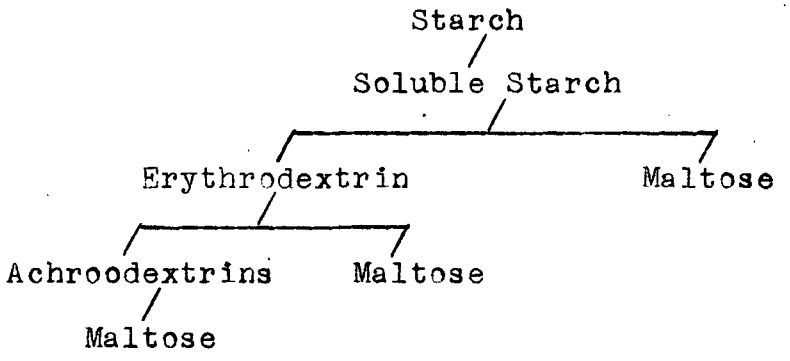
Digestion in the mouth is commenced by the action of saliva which is secreted by the three pairs of salivary glands. Mixed saliva, i.e. the fluid from all of the salivary glands, is a colorless, viscid, easily frothing, slightly opalescent liquid. In the domestic animals the reaction of saliva is slightly alkaline, except in the ox, where it is definitely alkaline. The accepted pH value for saliva in the pig is approximately 7.35. The water content of saliva is very high, thus the specific gravity is only slightly greater than 1.0. The amount of saliva secreted depends a good deal on the degree of dryness in the food.

(a) The Composition and Action of Saliva

The composition of saliva varies. The inorganic constituents are water to the amount of 99%, and phosphates, chlorides and sulphates of Na, K, Ca, Mg. The organic constituents are mucin, and the enzyme ptyalin. The water and salts are derived directly from the blood, while the mucin and ptyalin are manufactured by the gland cells.

Saliva functions mainly in a physical way, that is as a watery secretion. In some animals it has the additional function of converting starch to sugar, due to its' enzyme content. The saliva of the pig contains the amylolytic enzyme ptyalin, or salivary diastase, so the digestion of starch is commenced in the mouth. Mucin, a glycoprotein is the chief solid constituent of saliva, and is present in fairly large amounts in the saliva of the pig.

Its' chief purpose is to lubricate the food for swallowing. Ptyalin acts on starch, dextrin, and other carbohydrates, converting them through a series of dextrins to maltose, probably according to the following steps:



The action of ptyalin is permanently destroyed by a high temperature (over 60'C), but like other enzymes it is not destroyed or used up in producing its' reaction, unless of course it is heated to the above temperature. The action of ptyalin is also inhibited by a low temperature. It is also partly inhibited by weak acids or alkalies, and destroyed completely by strong acids. Thus in the presence of the free HCl of the stomach, ptyalin rapidly loses its' activity. Food does not remain long enough in the mouth to permit much starch hydrolysis.

The chief part of salivary digestion actually occurs in the stomach, despite the HCl of the gastric juice, since the food mass on entering the stomach does not at once mix with the gastric juice; consequently salivary digestion is able to go on for some time in the cardiac end of the stomach. This is apparently due to the low motility of the cardiac end of the stomach, which prevents the food from

mixing with the HCl. Some of the undigested starch, and a considerable amount of dextrin pass from the stomach into the intestine to be attacked there by pancreatic amylase.

II Digestion in the Simple Stomach

The stomach is considered to be the chief organ of digestion. Strictly speaking, gastric juice is the secretion of the fundus glands. However often the term includes also the secretion of the pyloric and cardiac glands.

Pure gastric juice is a clear, colorless, watery secretion of a distinctly acid reaction and taste. It consists of water, organic substances, inorganic salts, and HCl. Making up part of the organic matter of gastric juice are at least three enzymes: pepsin, rennin, and gastric lipase. Fresh gastric juice also contains much mucin, but this substance is of no real importance in digestion. The gastric juice of the pig contains for the first hour or two of digestion lactic, and afterwards HCl. In the pig, the process of digestion is not the same in all regions of the viscus: one may contain HCl, another lactic: one may be abundant in sugar, while this may be absent elsewhere. Lactic acid is present in the cardia, and both lactic and HCl in the fundus. The chief digestive action of gastric juice is on proteins, and is really a pepsin-HCl digestion, this combination being essential.

The first stage of digestion is starch conversion; the second is the same, only more advanced; the third stage is starch and protein conversion, both processes occuring at

the cardia, but only protein conversion taking place at the fundus. In the fourth stage starch conversion is nearly complete, while HCl predominates in all the regions, and protein conversion is general.

(a) The Enzymes present in Gastric Juice

(1) Pepsin:

This is a proteolytic enzyme which is formed in the body chief cells of the fundic glands. It is found in the stomach of all vertebrates. It is secreted in an inactive or zymogen form (pepsinogen), and before it can produce its' action of hydrolyzing protein, it must be activated. This is accomplished in the stomach by the HCl there, which converts pepsinogen to pepsin. Pepsin, in a favorable acid medium, converts proteins into simpler products in the following manner:

Protein
/
Acid metaprotein
/
Primary proteoses
/
Secondary proteoses
/
Peptone

Proteoses and peptone require hydrolysis to amino acids before absorption of them can take place. This, however, is not accomplished in the stomach, but is accomplished by certain enzymes in the intestine.

(2) Rennin:

This is a milk-coagulating product of the fundic gland region, and is found in the gastric juice of all

mammals. It also is secreted in an inactive or zymogen form, and is activated by the HCl. As far as is known, the action of rennin is confined to milk. Rennin does not appear to have any proteolytic action on milk, it simply coagulates it by hydrolytic alteration of the protein casein. Rennin changes the soluble protein casein of milk to a solid form by two distinct steps. First the rennin acts on the casein of the milk converting it to paracasein (soluble). The paracasein then reacts with the Ca salts, forming an insoluble protein calcium paracaseinate (coagulum). Probably the only advantage in digestion of having milk coagulate in the stomach is to prevent its too rapid passage through the stomach. In this way the action of pepsin on the proteins in milk would be prolonged.

(3) Gastric Lipase:

This enzyme occurs in very small amounts in pure gastric juice. Its' action is to hydrolyze fats into their constituent fatty acids and glycerol. The optimum pH for the action of gastric lipase in the pig, is approximately 7.1.

(b) The Acids of the Stomach

HCl and Lactic Acids

Both lactic and HCl inhibit the growth of all kinds of bacteria, so act as antiseptics, and prevent excessive fermentation and putrefaction. HCl, like pepsin, is present in the gastric juice of all vertebrates. It is produced by the parietal cells of the fundic glands, but the

manner in which this is accomplished is uncertain. The concentration of HCl in the stomach contents apparently varies with the nature of the food, stage of digestion, amount of saliva to be neutralized, etc. When protein predominates in the stomach, HCl accumulates more slowly, because the first acid secreted combines with protein. On a ration of starchy food the lactic acid always exceeds the HCl, suggesting that it may be formed by the fermentation of carbohydrates. The functions of HCl may be summarized as follows: (1) It activates pepsin and rennin, (2) It co-operates with pepsin in the digestion of protein, (3) It may bring about a slight hydrolysis of sucrose, (4) It acts as a stomach antiseptic.

Other Biochemical processes in the Stomach

Certain digestive changes are brought about in the stomach by agents that are not a part of gastric juice. In the stomach of man, salivary digestion of starch is continued for 15-30 minutes or more, and is finally stopped by HCl. Somewhat similar conditions no doubt occur in the stomach of the pig, though the amylolytic power of pigs' saliva is much weaker than that of human saliva.

III Digestion in the Small Intestine

It might be well to mention first that in the pig, intestinal digestion is said to be of very short duration and absorption very rapid. The food material leaving the stomach and entering the intestine is known as chyme. It is fluid or semi fluid, and has an acid reaction. It is composed of water, HCl, a large variety of inorganic salts, and many

organic substances such as acid metaprotein, proteoses, peptone, starch, dextrins and maltose, gums, cellulose and related compounds, liquefied fats, and many other substances depending on the diet and feeding habits of the animal. The water content of ingesta in the small intestine is high, varying from 60 to 95% in different species.

In the intestine the chyme undergoes important changes, which constitute intestinal digestion.

In the small intestine the agencies of digestion are pancreatic juice, bile, and intestinal juice, as well as certain movements of the intestinal wall.

(1) Pancreatic Juice

Pancreatic juice is a clear, distinctly alkaline liquid (due to sodium carbonate), which coagulates on heating. The amount of pancreatic juice secreted per kilogram of body weight per day in the pig, is 7.2 grams. The important constituents of pancreatic juice are three enzymes: trypsin, steapsin, and amylopsin. Other enzymes are sometimes present, but in very small amounts.

(a) Enzymes Present in Pancreatic Juice

(1) Trypsin

This is a proteolytic enzyme, and the most important pancreatic enzyme. Of the three ferments secreted by the pancreas, trypsin is the only one which is secreted in an inactive condition. It is secreted in the pro-enzyme form as trypsinogen, but is at once activated by enterokinase of the intestinal juice. Trypsin acts best in

a slightly alkaline medium (about ph 8). It acts on proteins that escape the influence of the pepsin in the stomach and splits them into proteoses, peptones and many other comparatively simple products of protein digestion. The end products are amino acids: although much of the hydrolysis of peptones and especially peptides is accomplished by proteolytic enzymes in the wall of the intestine and in intestinal juice.

(2) Steapsin (Pancreatic Lipase)

This lipolytic enzyme has the power of hydrolyzing fats to fatty acids and glycerol. The amount of fat digestion in the stomach we know is very slight. Liquefied fat on entering the intestine encounters alkaline juices, and any free fatty acid in the fat is converted to soap. As the fatty acids are released by hydrolysis, they combine with alkali in the intestinal juices to form soaps, which assist in emulsifying the remaining fat. Steapsin is activated by the bile salts (Na glycocholate and Na taurocholate) and several other substances. Steapsin then is much more active in the presence of bile. In the form of fatty acids, soaps, and glycerol, fats are absorbed.

(3) Amylopsin (Pancreatic amylase)

This diastatic enzyme is present in the pancreas, and the pancreatic juice of all vertebrates. Amylopsin acts on the starchy constituents of the food in much the same way as does the ptyalin of the saliva, and hydrolyzes starch and the various dextrins to maltose. Some workers claim that

amylopsin consists of more than one enzyme: an amylase proper, which hydrolyzes starch to dextrin, and one or more dextrinases, which hydrolyze dextrins to maltose. All starchy food which has escaped conversion in the mouth and stomach is acted on in the intestines by maltase and converted to dextrose. Amylopsin, besides converting starch to sugar, also helps to neutralize the HCl of the acid chyme. Apparently the optimum hydrogen ion concentration for the action of amylase from the pigs' pancreas is pH 5.5 to 6.0.

(2) The Liver and Its' secretion - Bile

In considering the function of the liver it is necessary to keep in mind its' peculiar blood supply. Most glands of the body which produce a secretion are furnished only with arterial blood, but the liver is an exception to this. The entire venous blood from the splanchnic area constitutes the material with which the liver is flooded. Blood from such a peculiar and large area must be very mixed in composition, and full of many different products. It is with this blood that the liver performs its' various functions, which may be summarized as follows: (1) the secretion of bile, (2) the formation and storage of glycogen and the regulation of the glucose content of the systemic circulation, (3) the deamination of amino acids, and the formation of urea, (4) the destruction of uric acid, (5) the desaturation of fatty acids subsequent to their utilization by the tissues, (6) the detoxication of poisonous substances brought to it by the blood, (7) the aiding in the destruction of

erythrocytes. One of the most evident functions of the liver, although by no means its' most important function in the higher animals, is the secretion of bile.

The secretion of bile is indirectly stimulated to production by the presence of the acid chyme in the intestine. This substance acts on a product of the epithelial cells of the duodenum, known as prosecretin, changing it to secretin. When secretin is absorbed by the blood and reaches the liver, it stimulates this gland to secrete bile. Bile is partly a digestive secretion and partly an excretion carrying away waste products of metabolism. When associated with pancreatic juice, bile is very important in the process of fat digestion. It also promotes intestinal peristalsis.

Bile is an alkaline fluid, of a slimy consistency, with a bitter taste, and in the pig is reddish-brown in color. In the pig the bile is conveyed by means of the cystic duct into the gall bladder, where it is concentrated and stored, until required. The secretion of bile by the liver cells is continuous, although the rate varies with a number of conditions. In the pig, anywhere from 62-150 grams are secreted hourly. Bile contains no protein. The composition of bile in the pig is roughly as follows: water, 88.8%, solids 11.2%, bile acids, bile pigments, fat, mucin, 10.1%, salts 1.1%. Bile pigments, bile acids and cholesterol are apparently the most important constituents of bile.

(a) Bile Pigments

These are bilirubin and its' oxidation product,

biliverdin. Bilirubin is present in the bile of all vertebrates. Both coloring matters of the bile behave like acids, forming soluble compounds with metals of the potassium group, insoluble ones with those of the calcium group. It is thought the haemoglobin is the source of the pigment bilirubin. One of the intermediate products in the formation of bilirubin is haematin. The stages in the formation of bilirubin from haemoglobin however are not well understood. There are apparently three main sites of bilirubin formation - liver, spleen and bone marrow. Of these the bone marrow is the most important.

As far as is known, the bile pigments are waste products of the metabolism of haemoglobin, and are without further use to the body. They enter the intestine as part of the bile, and are mixed with the ingesta. During passage along the bowel they are reduced by bacterial action, and appear in the faeces in the form of stercobilin. The brown color of faeces is due principally to this substance.

(b) Bile acids or bile salts

These terms are applied to two complex organic acids, glycocholic and taurocholic, found in the bile in the form of their sodium salts. In the pig, glycocholic acid is present almost exclusively.

Glycocholic acid ($C_{26}H_{43}NO_6$) is a compound of glycine and cholic acid. Taurocholic acid ($C_{26}H_{45}NSO_7$) is a compound of taurine and cholic acid. Glycine and taurine are of protein origin. Glycine, the simplest of the amino

acids, is widely present in the proteins of the foods and tissues, and can be synthesized by the body. Taurine, a sulphur containing, nitrogenous substance, is derived from the amino acid cystine. Cholic acid (C H O) is of unknown origin, but is believed by some to be derived from cholesterol, since it chemically resembles the latter. The bile acids are formed by the liver cells.

It is chiefly because of the presence of bile salts that bile is able to function as a digestive secretion as well as an excretion. Bile, by reason of its' bile salts, is of use in digestion in the following ways: (1) bile activates pancreatic lipase, (2) bile slightly accelerates the action of pancreatic amylase, (3) bile plays an important part in fat emulsification, (4) bile increases the solubility of the higher fatty acids (and their soaps) in water. This is important in fat absorption; for a substance, in order to be absorbed, must be water soluble. During fat absorption there also occurs an absorption of the bile acids, which appear to act as vehicles for transport of fat, across the intestinal lining.

(c) Cholesterol

This substance, occuring in significant amounts in the bile of practically all animals, belongs to the group of lipids known as sterols. Cholesterol is also found in blood and many other body liquids. It is closely related to ergosterol, the precurser of vitamin D. It is not known whether the cholesterol of bile is formed in the liver or is

merely brought to it by the blood for elimination. Cholesterol originates in the animal body and does not occur in plants.

Cholesterol is probably to be regarded as a waste product, for if it plays any role in digestion or is otherwise of use to the organism, it is not known. Cholesterol occurs in the faeces as a reduced substance known as stercorin. Cholesterol is often the chief constituent of gall stones. Cholesterol would be insoluble in bile if it were not for the bile salts.

The use of Bile

From a digestive point of view the use of bile is disappointing, since it does not digest in the same sense that pepsin and trypsin do. The bile and pancreatic fluid are connected closely in function, for which reason the two secretions are poured out into the bowel of the pig very close together. The bile, being alkaline, its' first action on the chyme is to neutralize the gastric juice, and to precipitate the albumoses and peptones. One direct effect of this is to delay the progress of the chyme along the bowel, by which means absorption is assisted.

Bile has a solvent and emulsifying effect on fats, being more active in the presence than in the absence of pancreatic juice, as stated above. Bile cannot split up fats into fatty acids and glycerol, but its' presence greatly increases the action of pancreatic fluid. The solvent action of bile on fat is the chief digestive function of this fluid. Bile has no action on protein. The bile of the pig as far as

we know, is unable to convert starch to sugar, or at least only to a very limited extent. Bile is also said to have an antiseptic influence on the intestinal contents. Bile acts as a natural purgative, and keeps up intestinal peristalsis; by doing this it hurries the food residues out of the system before they can undergo excessive putrefactive decomposition.

(d) Glycogen

The liver, as well as secreting a fluid of comparitively unimportant digestive power, manufactures and stores up in its' cells a peculiar substance known as glycogen, or animal starch. In animals the starch must be first converted into sugar, before the blood vessels of the bowel can take it up. The sugar formed from starch in the bowel is maltose, while that formed in the liver from glycogen is dextrose.

(3) Intestinal Juice or Succus Entericus

The Glands of the Intestines

The intestine of the pig, like that of all animals, shows the presence of two types of glands, intestinal and duodenal.

The intestinal glands (crypts of Lieberkuhn) are simple tubular glands found throughout the small and large intestine. They are limited to the mucous membrane, and do not extend into the submucosa. They show the presence of many goblet cells. The secretion of these glands is known as intestinal juice, or succus entericus.

The duodenal glands (Brunners) do not occur

throughout the entire intestine, but are limited to the first part of the small intestine. In all animals they begin at the pylorus, but their backward extent varies greatly in different species. The glands of Brunner are tubulo-alveolar in type, and the secreting portion is found principally in the submucosa. The secretion of the duodenal glands is known as duodenal juice. It has been impossible to secure duodenal juice in pure form to date.

The succus entericus is actually composed of two kinds of juice, namely intestinal and duodenal, derived from the above mentioned gland.

(a) Intestinal Juice: Is a light yellow fluid of alkaline or slightly acid reaction and a specific gravity of about 1.01. It contains several very important enzymes.

(1) Enterokinase

This substance, probably not an enzyme converts the trypsinogen, the mother substance of the pancreatic proteolytic enzyme, into trypsin. Activation is accomplished by chemical union between trypsin and enterokinase.

(2) Erepsin

Is a proteolytic enzyme, present in the mucous membrane and the juice of the intestine. It converts peptones and peptides to amino acids. Recent work has shown that so-called erepsin is composed of two proteolytic enzymes; a polypeptidase and a di-peptidase.

(3) Inverting ferments

These convert double sugars, which cannot be utilized by the tissues, into single sugars, which can.

(a) Maltase: Converts maltose to glucose.

(b) Sucrase: (Invertase) Hydrolyzes sucrose to glucose and fructose.

(c) Lactase: Splits lactose into glucose and galactose. It may be lacking in a mature hog, receiving no milk in its' diet.

(d) Amylase: Is an amylolytic enzyme, and is found in significant amounts in intestinal juice.

Fats are the only food which do not require the aid of the intestinal juice for their complete digestion. In the small intestine a major part of the process of digestion is carried out, and most of the proteins, carbohydrates and fats are put in final form for absorption.

(b) Duodenal Juice

As has been stated previously, the secretion of the duodenal glands has never been obtained in pure form. Extracts of the submucosa in the duodenal gland zone of the pig shows the presence of an amylase. The duodenal juice is viscous and sticky, apparently due to the presence of mucins or pseudo-mucins. The specific gravity of the pigs' duodenal juice is 1.007. The juice is distinctly alkaline, having a pH of 8.4 to 8.9. The duodenal-gland, containing part of the intestine is the only part which gives an abundant secretion. The duodenal glands are the source of the mucin

of intestinal juice, as well as being the source of the fairly large amount of alkali found to be present in the juice.

Bacterial processes in the Small Intestine

The influence of pancreatic juice, intestinal juice and bile, in digestion in the small intestine has been considered in some detail. In addition to these agencies however, bacterial processes in the small intestine especially of swine, are very important. These processes comprehend carbohydrate fermentation and non-putrefactive protein decomposition. In the small intestine fermentation of some portion of the carbohydrates takes place, giving rise to a number of organic acids such as lactic, and acetic and gases such as methane and hydrogen.

(4) Digestion in the Large Intestine

Material that escapes absorption in the small intestine is gradually propelled through the ileocecal opening into the large intestine. From the standpoint of digestion and absorption, the large intestine of herbivores is very important.

The caecum and colon of the simple-stomached pig are relatively very large and are sacculated. Glands are present throughout the large intestine, and villi are absent.

It has not as yet been definitely determined whether the glands of the large intestine produce any enzymes of much consequence in digestion. The secretion probably has mostly a physical function.

(a) Digestive Processes

A considerable portion of the pigs food reaching the large intestine is in a form which is not yet ready for absorption. Further digestive changes of a chemical nature are brought about in this material by enzymes carried back from the small intestine, by bacteria, and possibly by protozoa. The enzymes carried back with the food are derived in part from the digestive glands, and in part from the food itself. They produce, in the large intestine, similar changes as they do elsewhere.

(b) Bacterial Action

This is of both a fermentative and putrefactive nature. The food substance most important from the standpoint of fermentative cleavage, is cellulose, which is not attacked by any enzyme produced in the body of the pig, or of any of the higher animals for that matter. The end-products of bacterial attack on cellulose are probably fatty acids of the lower order (acetic and butyric) and gases (carbon dioxide and methane). The acids are neutralized, absorbed and used for energy purposes, or are stored as fat. The gases are in part at least expelled through the anus, and in part absorbed into the blood and eliminated through the lungs.

The Feces

The term actually refers to the waste matter voided from the bowel through the anus by the act of defecation.

The feces are composed of water; indigestible and

undigested food residues; remains of digestive secretions such as bile acids, bile pigments, and mucin; desquamated epithelial cells, derived from the digestive tract; numerous dead and some living bacteria; inorganic salts in great variety; indol and skatol, which give the feces their characteristic odour, and a few other less important substances. The approximate composition of the feces of the pig is as follows:

Water	80.0%
Organic Matter	17.0%
Mineral Matter	3.0%

In swine the feces contain fairly large amounts of food residues and relatively smaller amounts of excretory products, this being due to their omnivorous characteristics. The explanation for this probably lies in the fact that the food of the swine contains a much higher crude fiber content than does that of most of the other farm animals. The feces of the pig resemble human feces and are very offensive.

Amount of Feces

The amount of feces produced in 24 hours naturally will vary with the quantity and nature of the food consumed, and is relatively much greater in herbivores than in carnivores. The pig produces about .5 to 2.5 kilograms per day, about 4 pounds, depending on feeding practices.

PART IV

THE ABSORPTION OF FOOD

INTRODUCTION

Absorption, or resorption, is the process whereby foods, properly prepared by the organs of digestion are transferred from the lumen of the intestine to the blood or lymph. By means of the blood the absorbed foods are transported to the tissues for utilization or for storage.

(1) The Place of Absorption

No food absorption takes place in the mouth or esophagus of the pig. Also, absorption is extremely limited in the stomach, since on the whole, the food substances here are not yet ready for absorption. It is very interesting to note however, that certain drugs are absorbed very rapidly from the stomach of the pig.

The small intestine is the chief seat of absorption in omnivores. The large intestine as an organ of absorption is of less importance.

(2) Absorption Surfaces

The mucous membrane of the whole of the small intestine is characterized by increased absorptive space, consisting of special folds which are called valvulae conniventes (or plica circulares). Then the whole of the surface of these folds is thrown up into numerous tiny finger-like projections known as villi. The villi in the duodenum are fairly long, and leaf-like. Those in the jejunum are very long and finger-like, and those in the ileum are

scattered, flat, and feet-like. The villi throughout the entire small intestine are shorter in swine than in any of the other animals.

A single villus is composed of a projecting core of tunica propria covered with a mucous secreting columnar epithelium, which lines the entire intestine. Near the axis of the villus is found a large lymph capillary known as a lacteal. It begins near the tip of the villus and enters a plexus of lymph vessels lying just on the inner side of the muscularis mucosa. At their origin the lacteals are often found to be branched. The villus also possesses a rich network of blood capillaries. Smooth muscle fibres from the muscularis mucosa enter the villus, to whose basement membrane many are attached. The villi become fewer and fewer toward the end of the ileum until we come to the large intestine, where there are none at all.

In the pig the size of the absorbing surface, exclusive of the villi, is 2.8 square meters. The villi in the intestine of the pig increase the absorptive surface from 10 to 20 times.

(3) Routes for Absorbed Foodstuffs

There are two routes by which absorbed foodstuffs may enter the general circulation: the lymph, and the blood of the Portal system.

(a) Lymph Route

The lymph capillaries of the mucous membrane of the intestine, including the lacteals of the villi, drain

into the larger lymph vessels of the submucosa. These penetrate the muscular coat of the bowel, and empty into the lacteal vessels of the mesentery, which have intimate connections with the mesenteric lymph nodes. The lacteal vessels of the mesentery go to the cysterna chyli, into which they empty. The latter vessel goes forward as the thoracic duct, which enters into the venous system anterior to the heart. Fats are absorbed by the lymph.

(b) Blood Route

The blood capillaries of the mucous membrane of the intestine, including those of the villi, unite to form venules and veins, which drain into the portal vein. The portal vein enters the liver, where its' blood is mixed with that of the hepatic artery. The hepatic veins then convey the blood of the liver to the posterior vena cava. Protein and carbohydrate digestion products, water and inorganic salts are absorbed largely by the blood.

(4) Fat Absorption

As stated previously, fats undergo hydrolysis in the intestine to fatty acids and glycerol, and are largely absorbed in this form. They may also be absorbed to a slight extent in the form of soaps. Fatty acids and glycerol, and any soaps formed from the fatty acids, are water soluble in the presence of bile. Thus bile in the intestine is very necessary for fat absorption. In the absence of bile, most of the fat appears in the feces in the form of fatty acids, so that the disturbance must be one of absorption

and not one of splitting.

The fatty acids and the glycerol penetrate the epithelial cells of the intestinal lining and enter their interior. During fat absorption numerous fat droplets are found in the cytoplasm of the epithelial cells; and it is generally believed that they arise by means of synthesis of the fatty acids and glycerol to neutral fat. As the fat globules approach the basal ends of the cells, the globules decrease in size. They then enter the tissue spaces of the lamina propria and pass from there to the lymph capillaries of the villi. The lymph current then removes them to the mesenteric lymphatus and the thoracic duct, which enters the venous system anterior to the heart. The absorbed fat is now in the form of an emulsion and gives a milky appearance to the lymph, which during fat absorption is termed "chyle". The amount of fat in chyle during absorption may be as much as 3-4%. The fat particles are anywhere from .5-1 u. in diameter.

During fat absorption leucocytes accumulate in the mucous membrane in great numbers. They accumulate not only in the lymphoid tissue of the villi but also in the lacteals near their blind ends, and they are believed to be of prime importance in fat transport from the epithelial cells to the lacteals.

Fat is absorbed in a hydrolyzed form in the bowel. However there also occurs the possibility that some unhydrolyzed fat is absorbed in the form of ultramicroscopic

particles.

The absorption of cholesterol apparently requires the presence of bile salts as well as the simultaneous absorption of fat. A good deal of cholesterol is converted into esters during absorption.

(5) Protein Absorption

Many enzymes, such as pepsin, trypin, erepsin, are provided for protein digestion. As we know the end products of protein digestion are amino acids, and it is in this form that proteins are absorbed. The amino acids, in solution, enter the epithelial cells of the mucous membrane and from there pass to the tissue spaces of the lamina propria, from which they are removed by the blood. Absorption of amino acids by the lymph is not believed to occur to any significant extent.

(6) Carbohydrate Absorption

The digestion of carbohydrates by enzymes results in the formation of monosaccharides. These monosaccharides are absorbed for the most part, into the portal blood and carried to the liver. It has been shown however that the lymph stream is also capable of removing some sugar from the alimentary canal.

The monosaccharides in the portal blood reach the liver, where to a considerable extent they are stored in the form of glycogen. Other tissues, especially the skeletal muscles, also have the power to form and store glycogen.

Digestion and Absorption of Minerals

Soluble inorganic salts when ingested, are absorbed without change. All soluble salts are not absorbed with the same amount of ease. Chlorides are taken up without difficulty, whereas sulfates are absorbed with difficulty. Fe is taken up, but Mn is absorbed only with difficulty. It is thought that the reason for this can be attributed to the selective action of the intestinal epithelium.

Such minerals as Ca, P, Mg, and Fe, which are widely present in foods, are set free during digestion in the form of inorganic salts.

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PLATES

Plate I

Fig. A — Hard Palate. Haematoxylin-Eosin x 100

1 Stratified squamous epithelium
2 Tunica propria
3 Submucosa
4 Palatine ridges

Fig. B — Cross section of Tongue near tip. Haem.-eosin x 50

1 Epithelium of dorsal surface
2 Tunica propria
3 Connective tissue
4 Striated muscle
5 Collagenous and elastic fibers
6 Epithelium of ventral surface
7 Serous glands

PLATE I

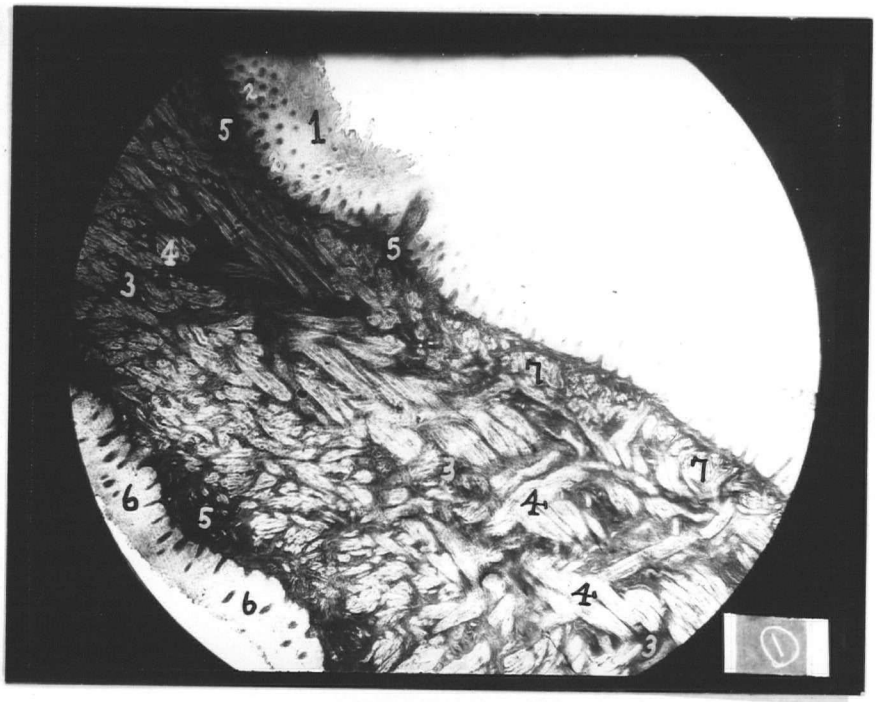


Plate II

Fig. A Section through side of tongue (mid-portion) x 100

1 Stratified squamous epithelium
2 Papilla
3 Submucosa
5 Striated muscle
6 Upward projection of connective tissue layer
7 Finger-like projection of connective tissue layer
8 Connective tissue enveloping muscle bundles

Fig. B Cross section of Tongue near tip showing mucous glands x 100

1 Epithelium of ventral surface
2 Submucosa
3 Mucous type glands
4 Connective tissue enveloping glands and muscle bundles
5 Muscle

PLATE II

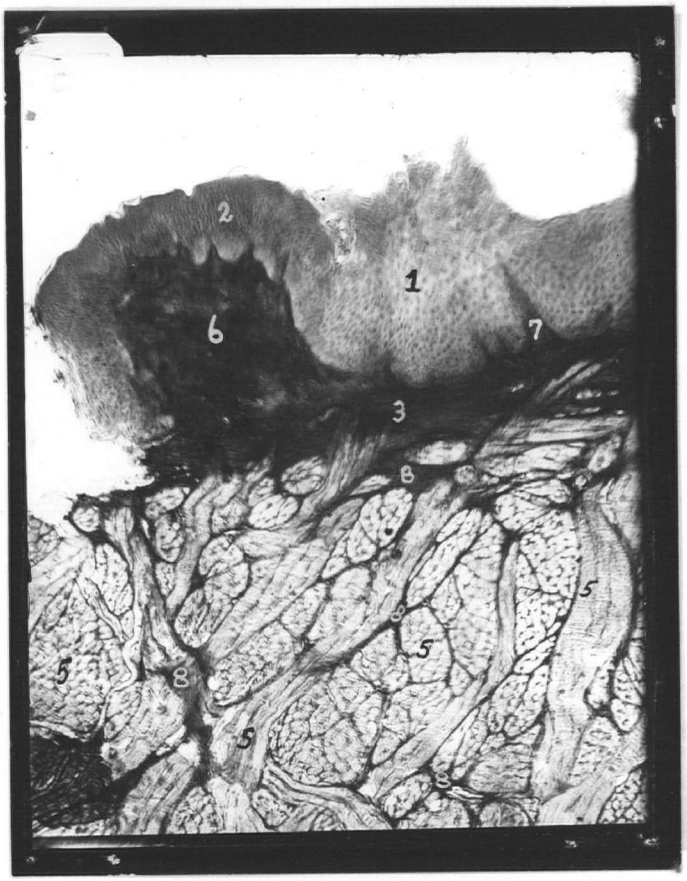


Plate III

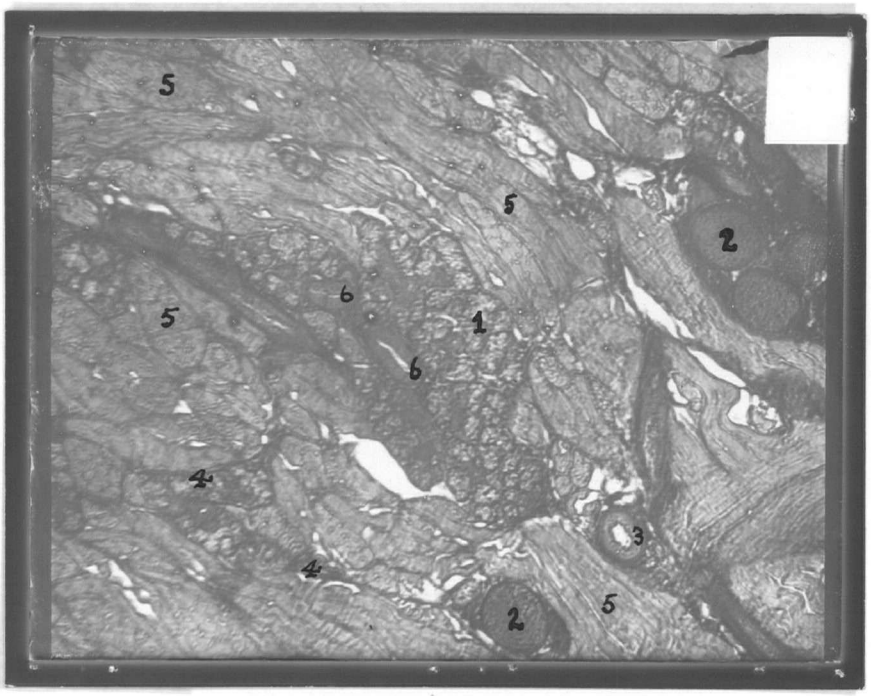
Fig. A Section through side of tongue mid-portion, showing glands. Haem.-eosin. x 100

1 Serous type glands
2 Nerves
3 Blood vessels
4 Connective tissue
5 Muscle
6 Excretory ducts

Fig. B Cross section of wall of oesophagus (near cardia) x 50

1 Epithelium
2 Tunica propria
3 Muscularis mucosa
4 Submucosa
5 Oesophageal glands
6 Inner circular layer of lamina muscularis
7 Outer longitudinal layer of lamina muscularis
8 Connective tissue septa
9 Auerbach's plexus
10 Adventitia

PLATE III



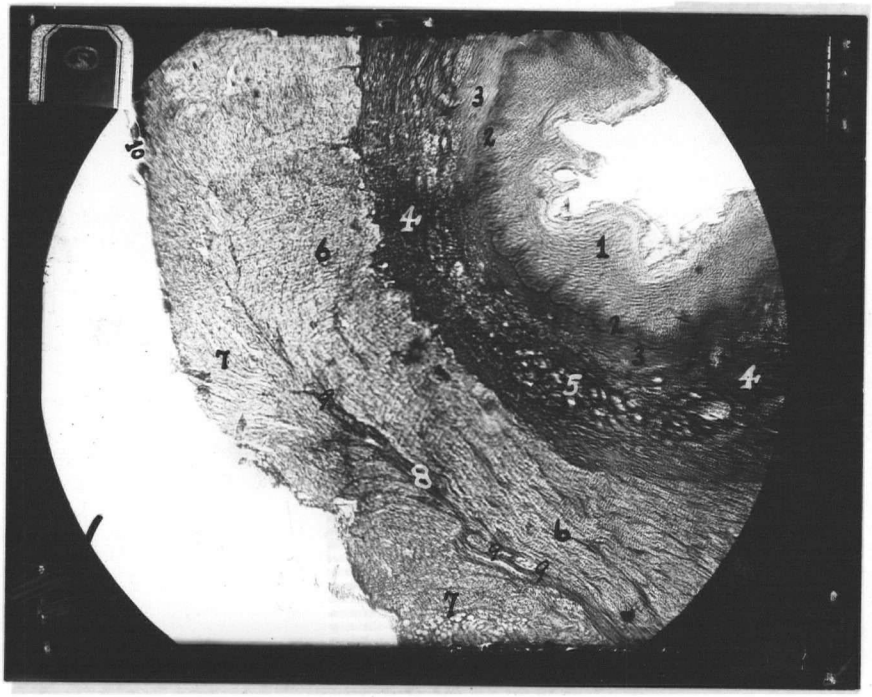


Plate IV

Fig. A Cross section of wall of oesophagus (upper end) Haem.-eosin. x 50

1 Epithelium
2 Tunica propria
3 Muscularis mucosa
4 Submucosa
5 Oesophageal glands
6 Inner circular layer of lamina muscularis
7 Outer longitudinal layer of lamina muscularis
8 Connective tissue separating the two layers of the muscularis
9 Adventitia

Fig. B Oesophageal glands Haem.-eosin x 430

1 Oesophageal glands
2 Tunica propria
3 Muscularis mucosa
4 Inner circular layer of lamina muscularis
5 Large excretory duct

PLATE IV

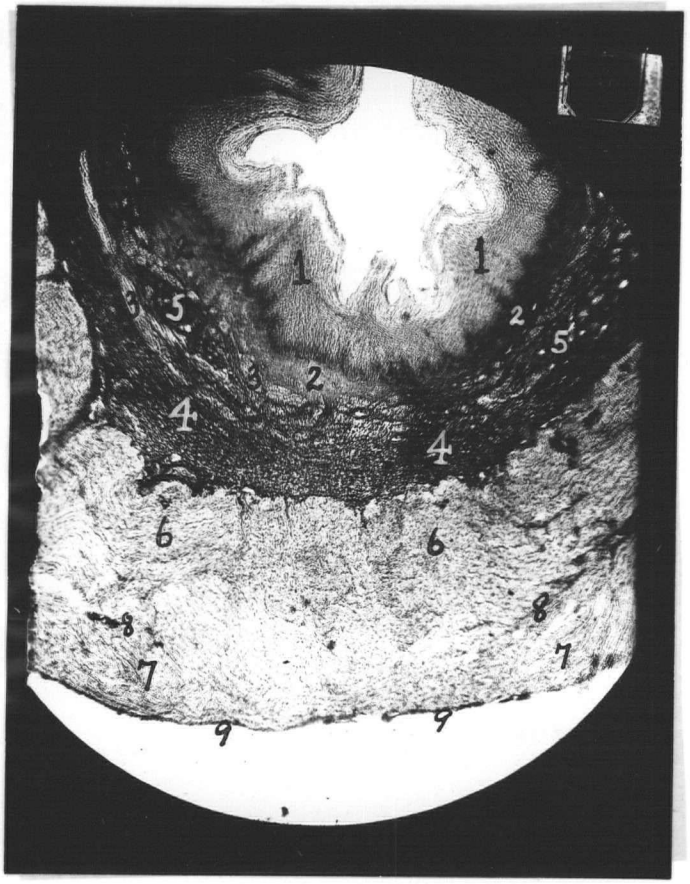


Plate V

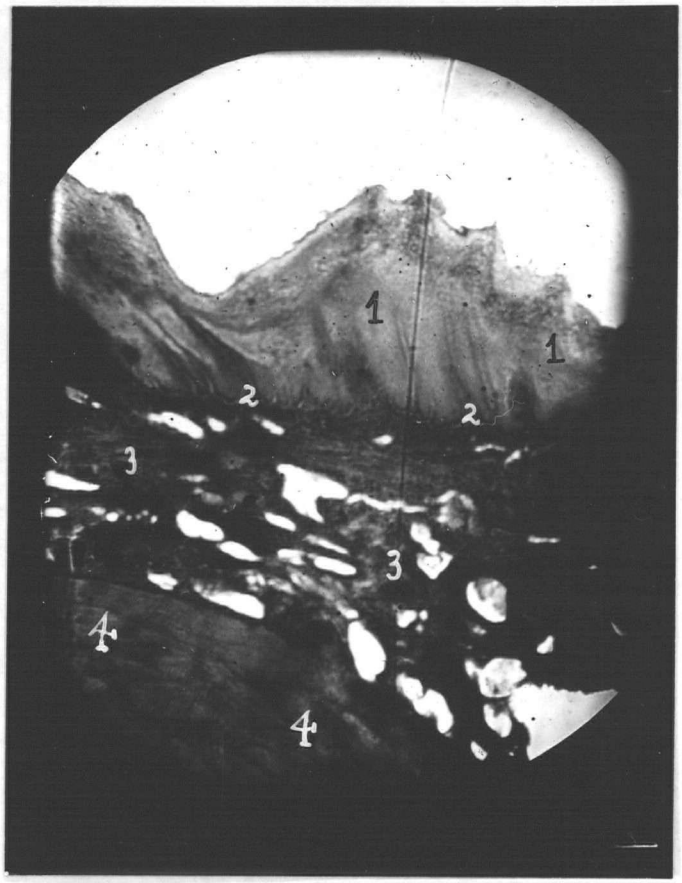
Fig. A Oesophageal Stomach (Long. Sec.) Haem.-Eosin x 50

1 Thick layer of stratified squamous epithelium
2 Tunica propria
3 Submucosa
4 Inner circular layer of lamina muscularis

Fig. B Mucosa at junction of eosophageal and cardiac stomach. Haem.-Eosin x 50

1 Stratified squamous epithelium of oesophageal stomach
2 Glands of cardiac portion of stomach
3 Tunica propria
4 Submucosa
5 Lymph nodule

PLATE V



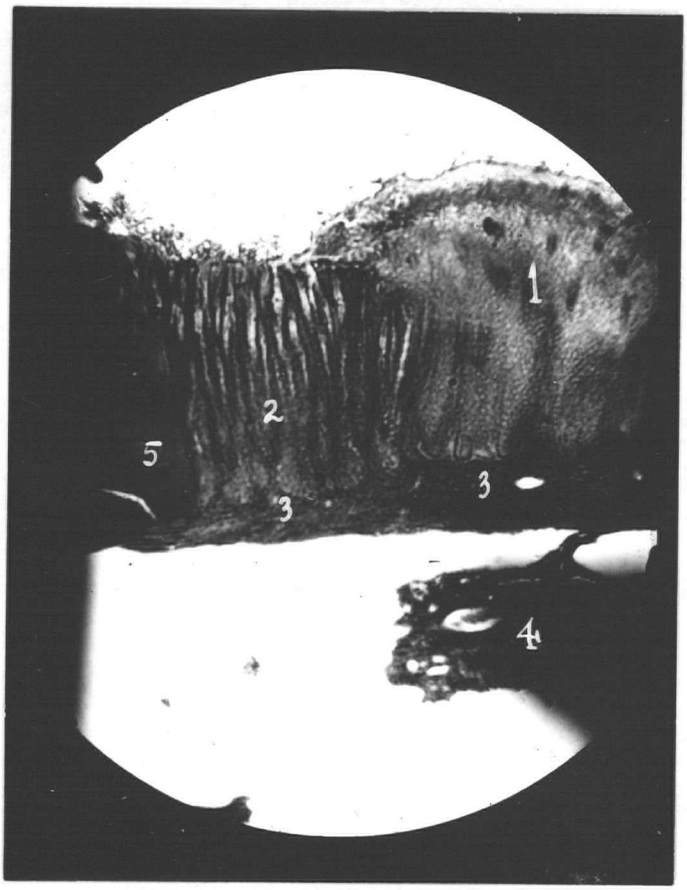


Plate VI

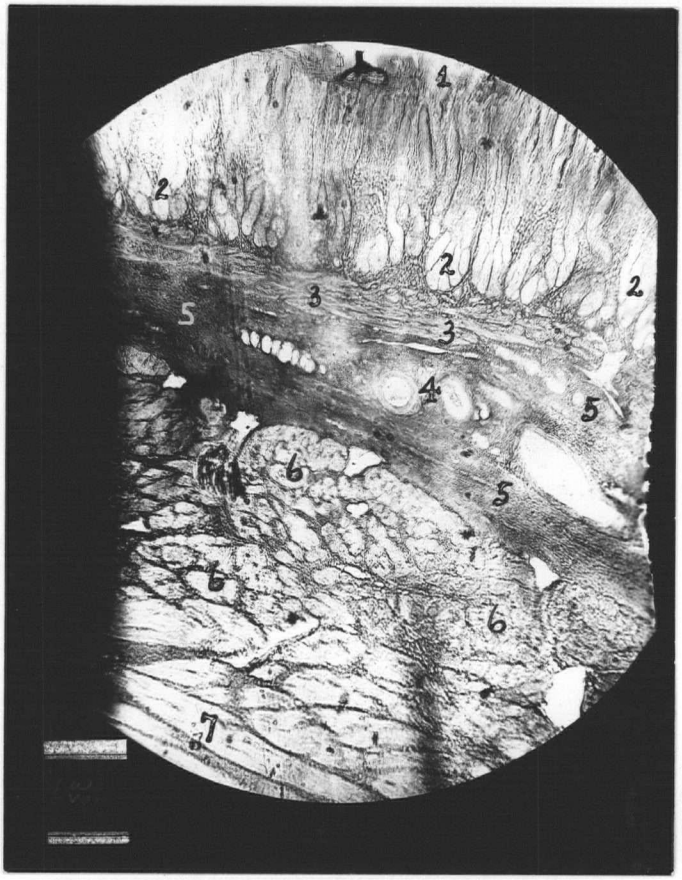
Fig. A — Cardiac Stomach (Long. Sec.) Haem.-Eosin x 50

1 Epithelium
2 Cardiac glands
3 Muscularis mucosa
4 Blood vessels in submucosa
5 Submucosa
6 Inner circular layer of lamina muscularis
7 Outer longitudinal layer of lamina muscularis

Fig. B — Cardiac glands. Haem.-Eosin x 100

1 Cardiac glands
2 Tunica propria
3 Muscularis mucosa
4 Submucosa containing blood vessels
5 Inner circular layer of lamina muscularis
6 Outer longitudinal layer of lamina muscularis

PLATE VI



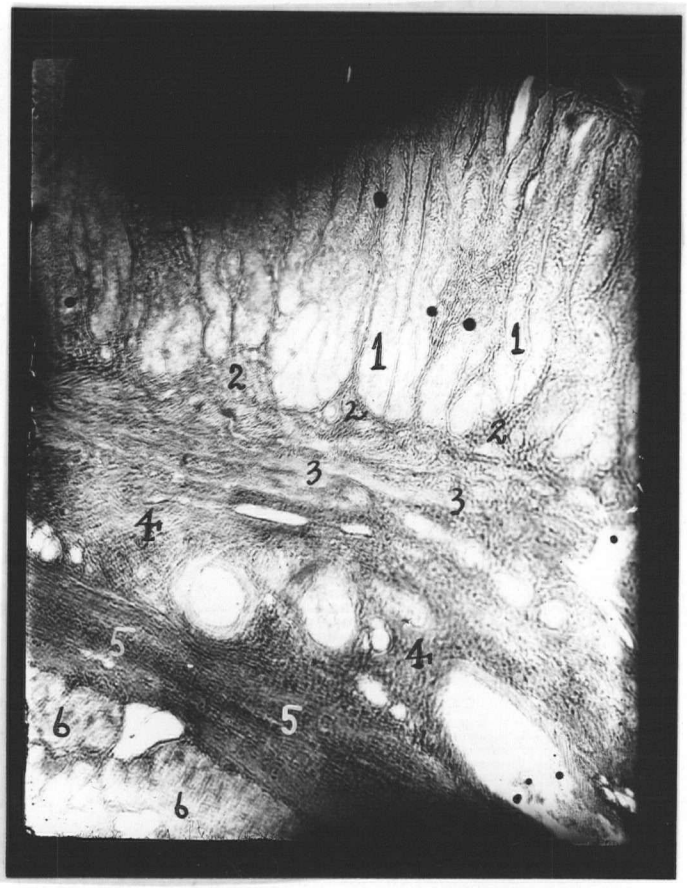


Plate VII

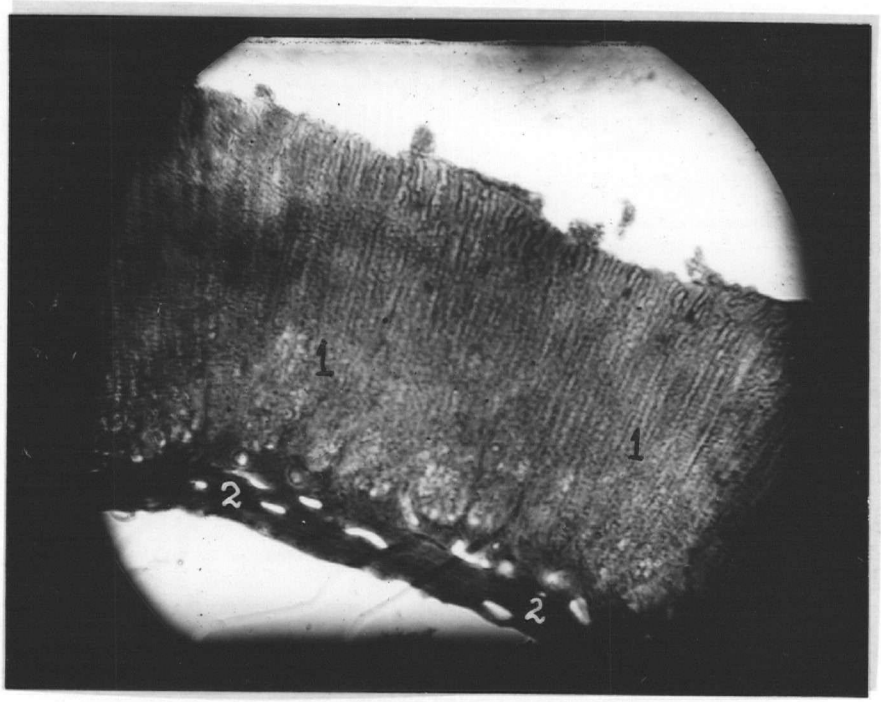
Fig. A Mucosa of Fundic Stomach - general structure (Long. Sec.) Haem.-Eosin x 50

1 Fundic glands
2 Submucosa containing blood vessels

Fig. B Fundic glands (Long. Sec.) Haem.-Eosin x 100

1 Fundic glands
2 Tunica propria containing small blood vessels
3 Muscularis mucosa
4 Submucosa containing large blood vessels
5 Inner circular layer of lamina muscularis

PLATE VII



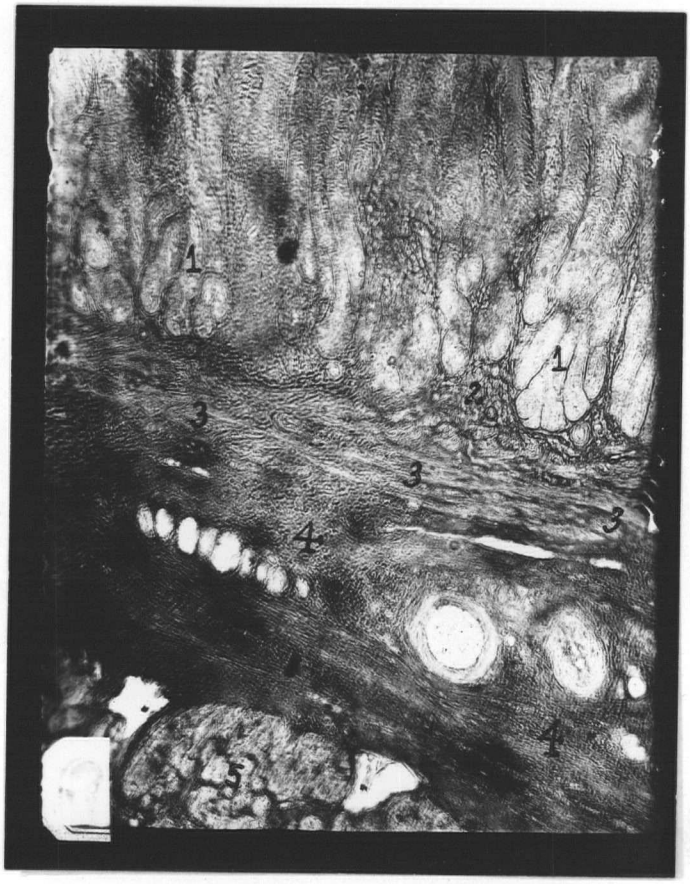


Plate VIII

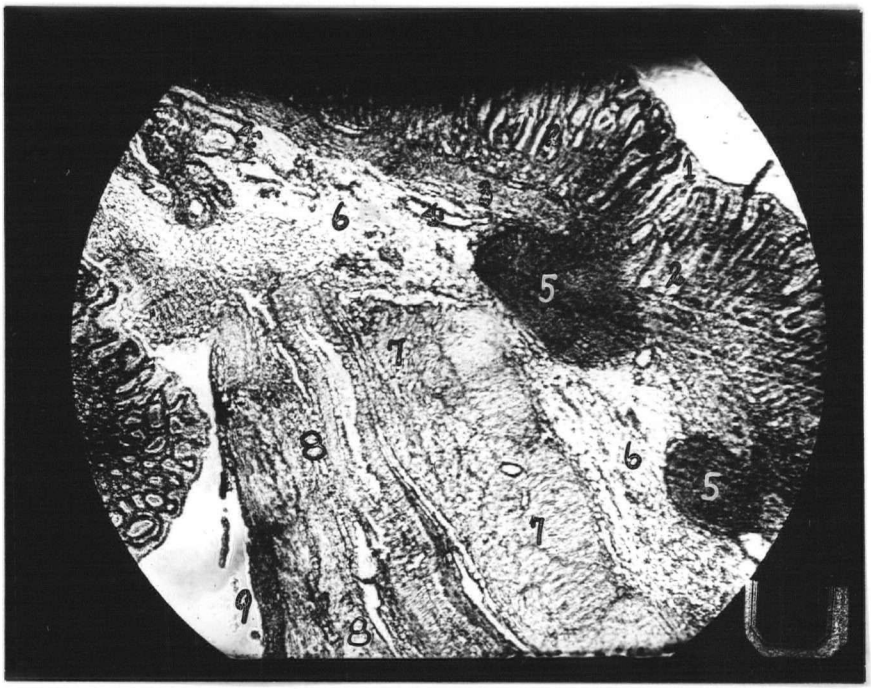
Fig. A — Pyloric Stomach (Long. Sec.) Haem-Eosin x 50

1 Epithelium
2 Pyloric glands
3 Tunica propria
4 Muscularis mucosa
5 Lymphoid tissue in submucosa
6 Submucosa
7 Inner circular layer of lamina muscularis
8 Outer longitudinal layer of lamina muscularis
9 Serosa

Fig. B — Pyloric glands. Haem.-Eosin x 100

1 Pyloric glands
2 Tunica propria
3 Muscularis mucosa
4 Submucosa
5 Blood vessel in tunica propria

PLATE VIII



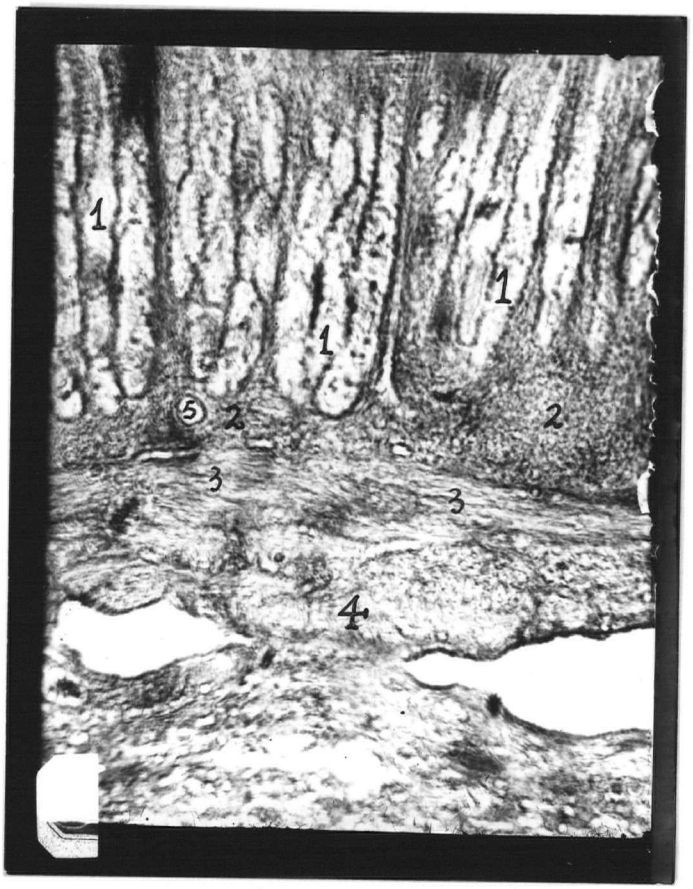


Plate IX

Fig. A Cross section of wall of Duodenum. Haem.-eosin x 50

1 Epithelial covering of villi
2 Villi
3 Tunica propria containing glands of Lieberkuhn
4 Muscularis mucosa
5 Submucosa containing Brunner's glands
6 Blood vessels
7 Inner circular layer of lamina muscularis
8 Outer longitudinal layer of lamina muscularis
9 Auerbach's plexus in connective tissue septa
10 Serosa

Fig. B Types of Duodenal villi. Haem.-eosin x 100

1 Villi
2 Glands of Lieberkuhn
3 Crypts of Lieberkuhn

PLATE IX

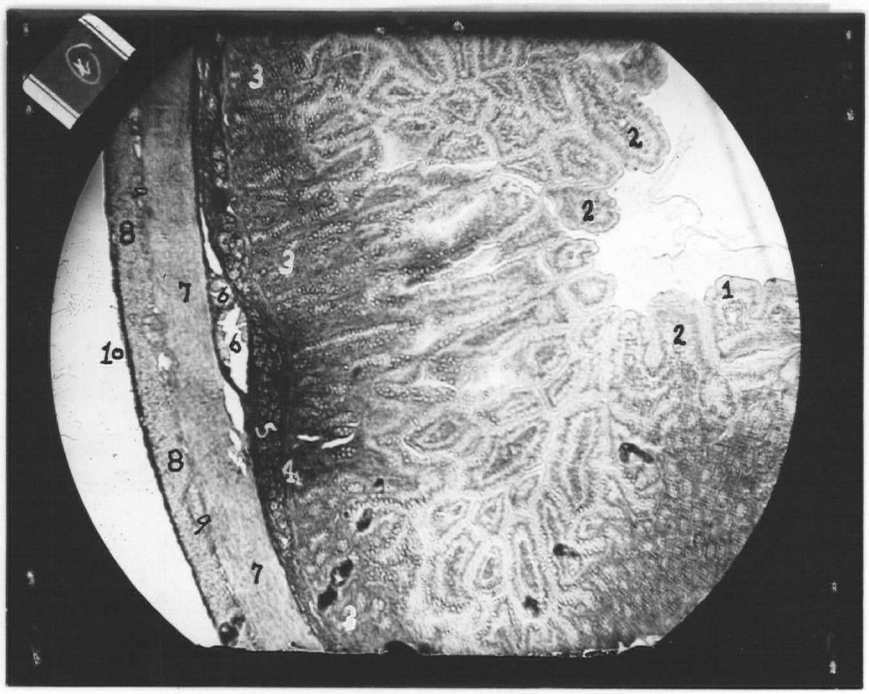


Plate X

Fig. A — Plica circulares in the Duodenum. Haem.-eosin x 100

1 Plica circulares
2 Tunica propria
3 Muscularis mucosa
4 Large blood vessel
5 Brunner's glands
6 Submucosa
7 Circular layer of lamina muscularis
8 Longitudinal layer of lamina muscularis
9 Serosa

Fig. B — Duodenal villi. Cross section x 430

1 Epithelium
2 Villus
3 Goblet cells
4 Tunica propria
5 Basement membrane

PLATE X

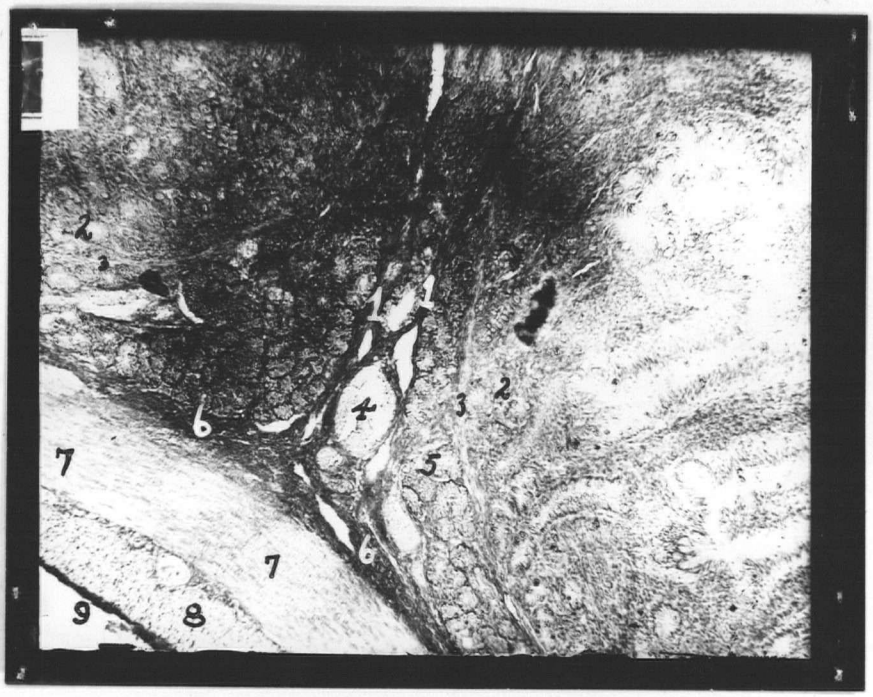


Plate XI

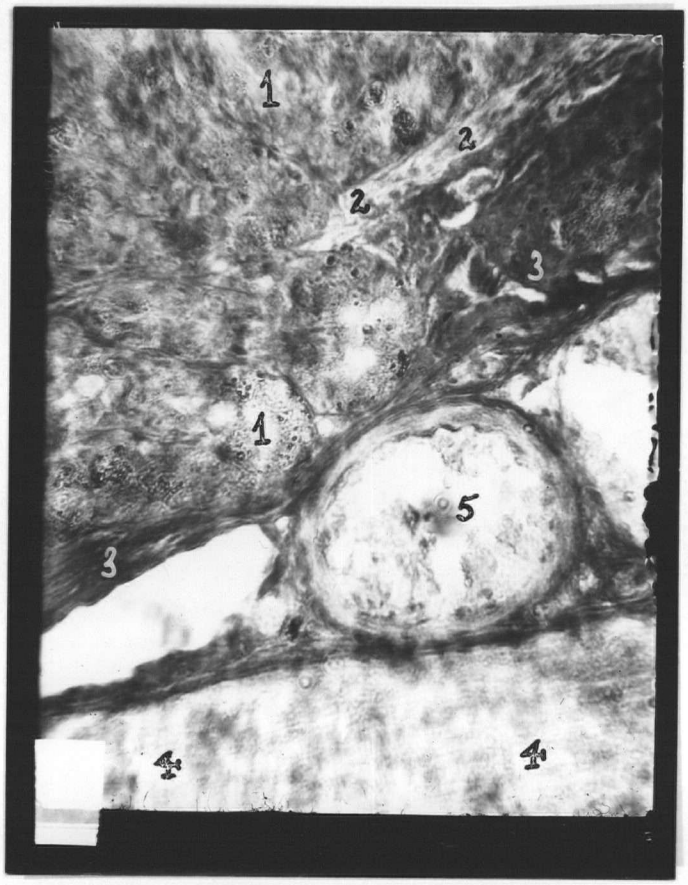
Fig. A Duodenum (Cross Section) Haem.-Eosin x 430

1 Glands of Lieberkuhn
2 Muscularis mucosa
3 Submucosa containing large blood vessel
4 Circular layer of lamina muscularis
5 Large Blood vessel

Fig. B Cross section of wall of Jejunum. Haem.-Eosin x 50

1 Epithelium of villi
2 Villi
3 Tunica propria with glands of Lieberkuhn
4 Submucosa
5 Inner circular layer of lamina muscularis
6 Outer longitudinal layer of lamina muscularis
7 Blood vessels in submucosa
8 Serosa
9 Connective tissue septum containing Auerbach's plexus

PLATE XI



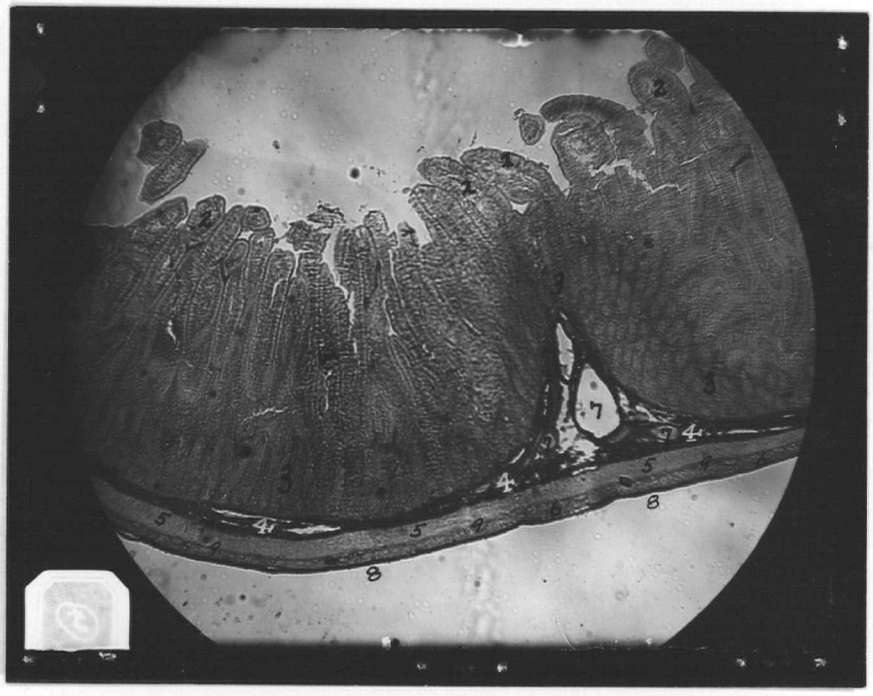


Plate XII

Fig. A Types of Jejunal villi. Haem.-eosin x 100

1 Villi
2 Tall columnar epithelium

Fig. B Plica circulares in the jejunum. Haem.-eosin x 100

1 Plica
2 Blood vessels
3 Circular layer of lamina muscularis
4 Connective tissue septa containing Auerbach's plexus
5 Longitudinal layer of lamina muscularis
6 Serosa
7 Glands of Lieberkuhn

PLATE XII

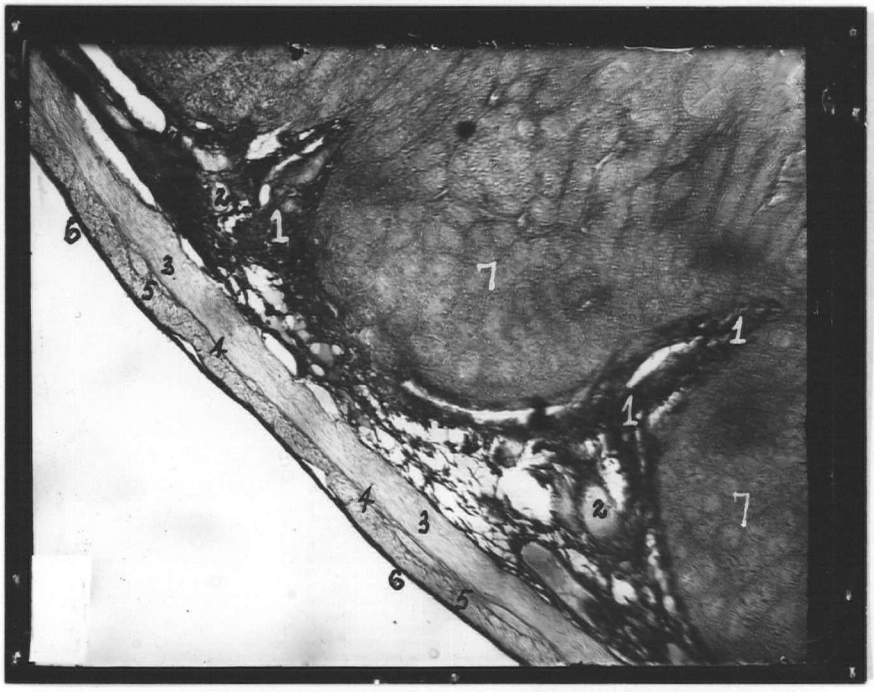


Plate XIII

Fig. A — Lymphoid tissue in the jejunum. Haem.-eosin x 50

1 Villi
2 Solitary lymph nodules
3 Tunica propria
4 Submucosa
5 Inner circular layer of lamina muscularis
6 Outer longitudinal layer of lamina muscularis
7 Connective tissue septa containing Auerbach's plexus
8 Serosa

Fig. B — Jejunal villi Cross Section Haem.-Eosin x 430

1 Epithelium
2 Goblet cells
3 Muscularis mucosa
4 Submucosa

PLATE XIII

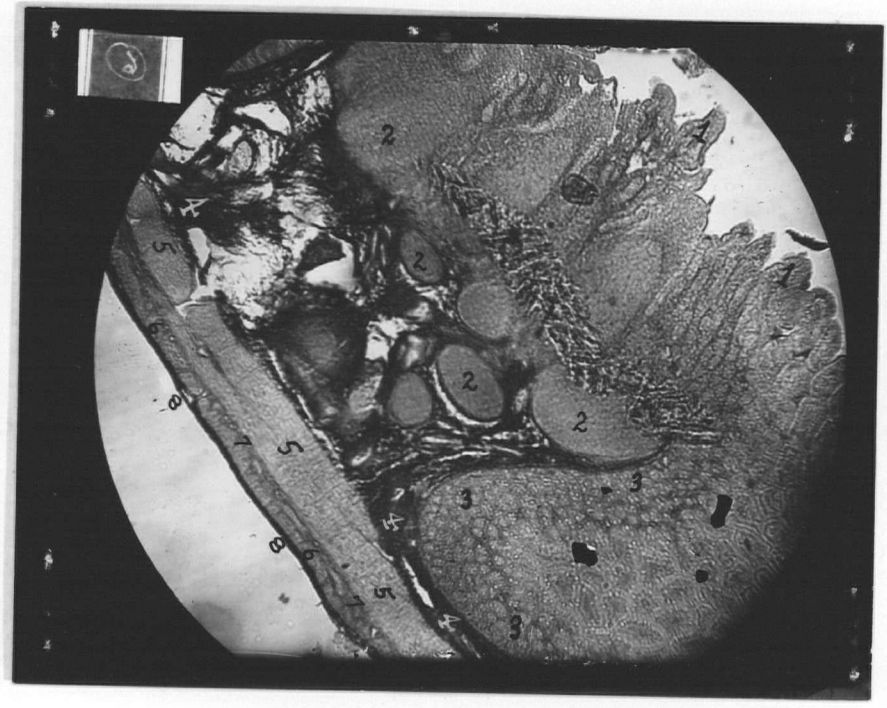


Plate XIV

Fig. A Jejunum Cross Section. Haem.-Eosin x 430

1 Tunica propria
2 Muscularis mucosa
3 Submucosa
4 Inner circular layer of lamina muscularis
5 Connective tissue containing Auerbach's plexus
6 Outer longitudinal layer of lamina muscularis
7 Serosa

Fig. B Cross section of wall of Ileum. Haem.-Eosin x 50

1 Epithelium
2 Villi
3 Tunica propria containing glands of Lieberkuhn
4 Submucosa containing blood vessels
5 Inner circular layer of lamina muscularis
6 Outer longitudinal layer of lamina muscularis
7 Connective tissue septum containing Auerbach's plexus
8 Serosa
9 Peyer's patches
10 Connective tissue capsule surrounding Peyer's patch
11 Lymphoid tissue extending into epithelium

PLATE XIV

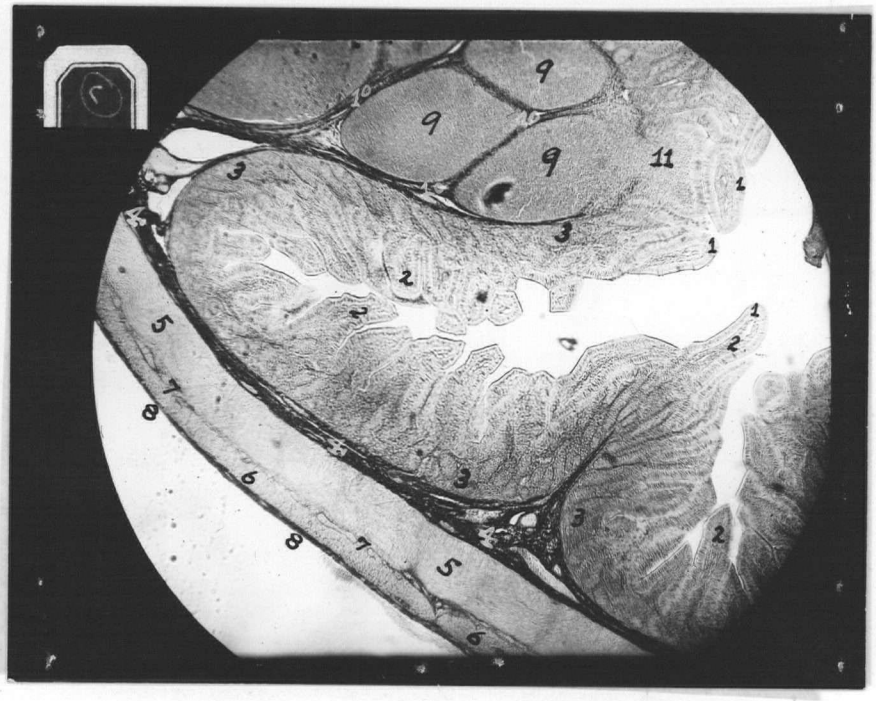


Plate XV

Fig. A Types of villi in ileum. Haem.-eosin x 100

1 Villi
2 Tunica propria with crypts of Lieberkuhn
3 Submucosa
4 Blood vessel

Fig. B Peyer's patches in ileum. Haem.-eosin x 50

1 Peyer's patches
2 Connective tissue enveloping Peyer's patches
3 Submucosa
4 Blood vessels
5 Inner circular layer of lamina muscularis

PLATE XV

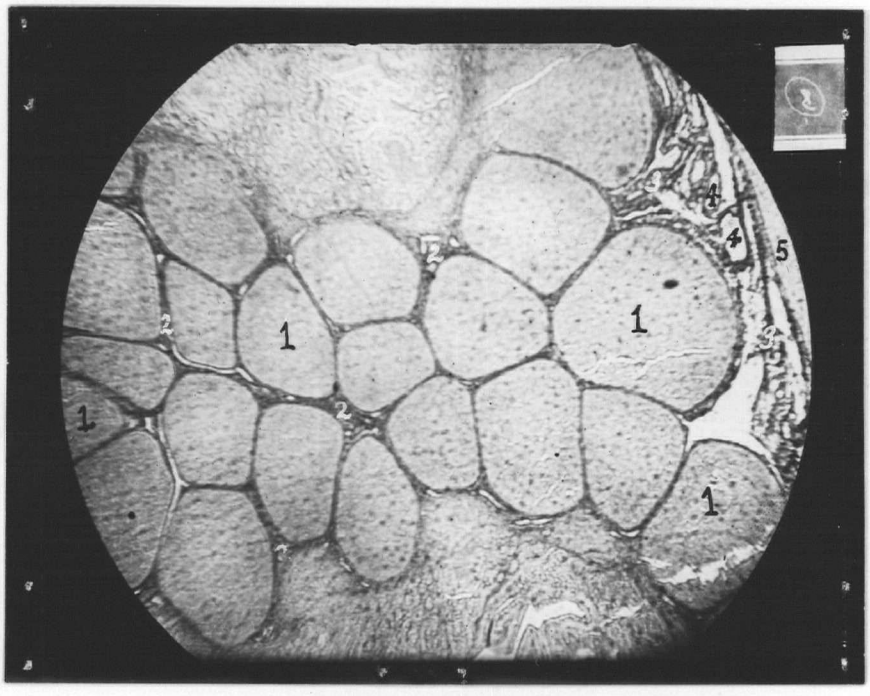


Plate XVI

Fig. A. Plica circulares in Ileum. Haem.-eosin x 100

1 Villus
2 Plica circulares
3 Submucosa
4 Blood vessel
5 Inner circular layer of lamina muscularis
6 Connective tissue septum containing Auerbach's plexus
7 Outer longitudinal layer of lamina muscularis
8 Serosa

PLATE XVI

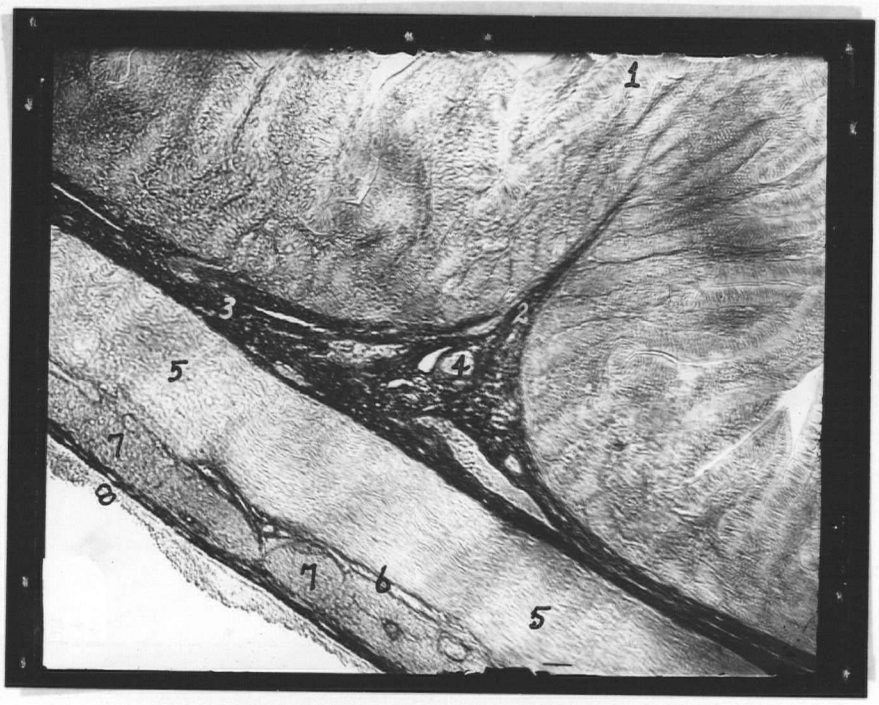


Plate XVII

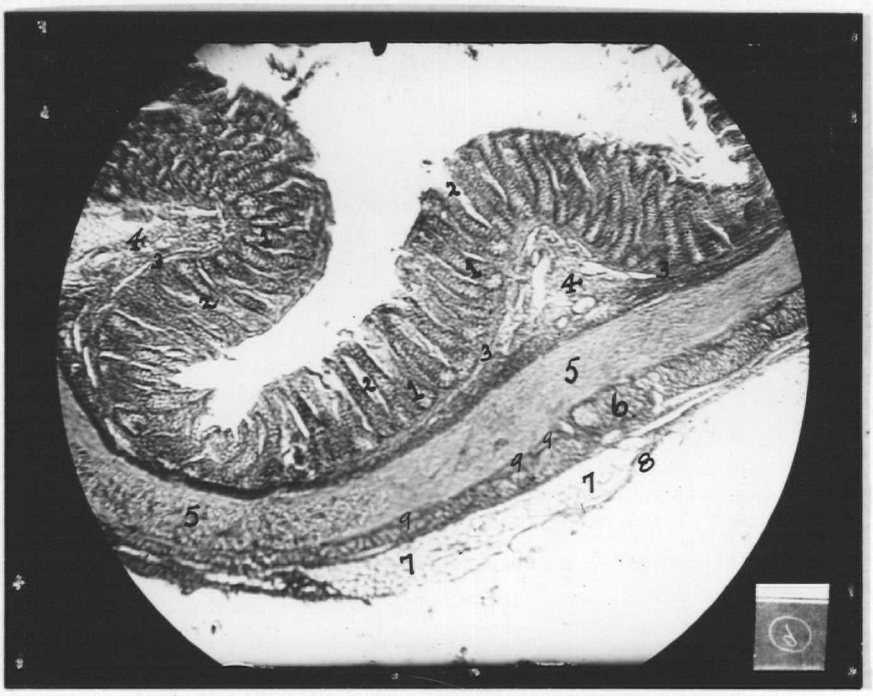
Fig. A Cross section of wall of colon. Haem.-eosin x 50

1 Glands of Lieberkuhn
2 Krypts of Lieberkuhn
3 Muscularis mucosa
4 Submucosa containing blood vessels
5 Inner circular layer of lamina muscularis
6 Outer longitudinal layer of lamina muscularis
7 Fat
8 Serosa
9 Auerbach's plexus in connective tissue septum

Fig. B Cross section of wall of colon to show blood vessels exterior to lamina muscularis Haem.-eosin x 10

1 Submucosa
2 Circular layer of lamina muscularis
3 Taenia coli
4 Aggregation of blood vessels
5 Fat

PLATE XVII



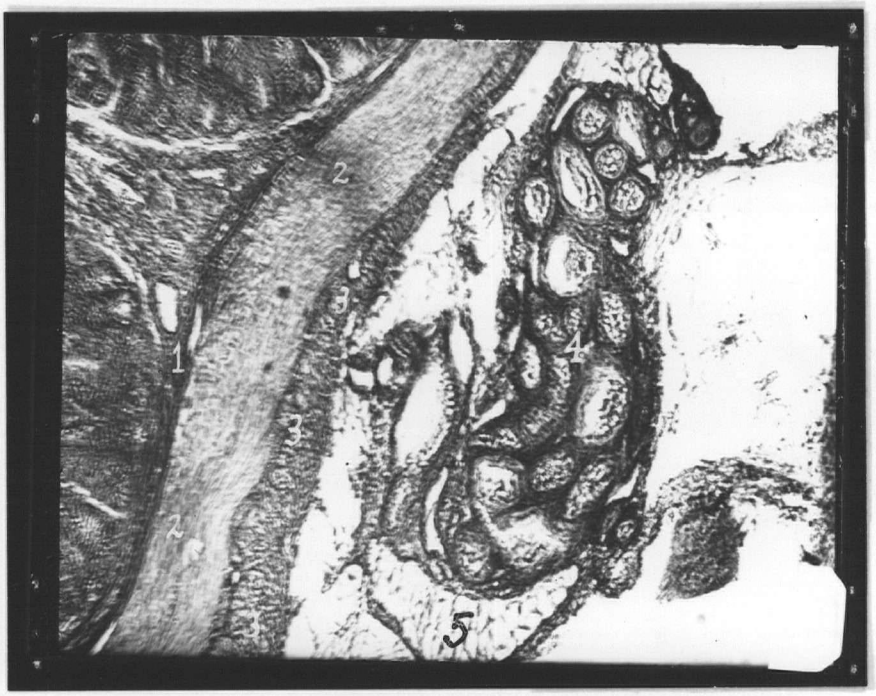


Plate XVIII

Fig. A Colon Cross Section Haem.-eosin x 430

1 Krypts of Lieberkuhn
2 Glands of Lieberkuhn
3 Tunica propria
4 Muscularis mucosa
5 Submucosa
6 Inner circular layer of lamina muscularis
7 Outer longitudinal layer of lamina muscularis
8 Connective tissue septum

Fig. B Cross section of wall of rectum. Haem.-eosin x 50

1 Glands of Lieberkuhn containing numerous goblet cells
2 Muscularis mucosa
3 Submucosa
4 Inner circular layer of lamina muscularis
5 Outer longitudinal layer of lamina muscularis
6 Connective tissue septum
7 Serosa

PLATE XVIII

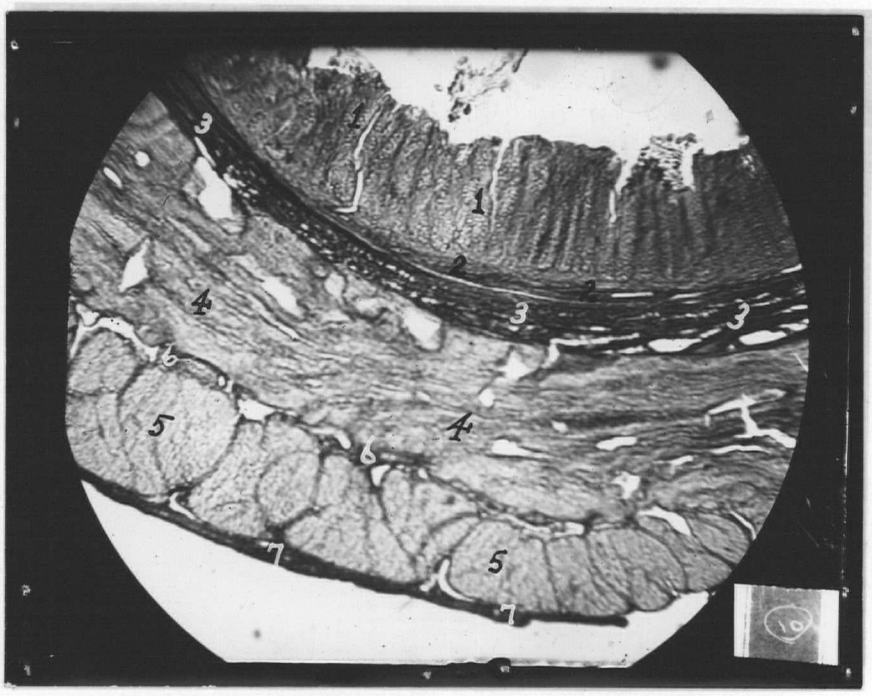


Plate XIX

Fig. A Rectum to show branching plica circulares
Haem.-eosin x 100

1 Branching plica circulares
2 Glands of Lieberkuhn

PLATE XIX

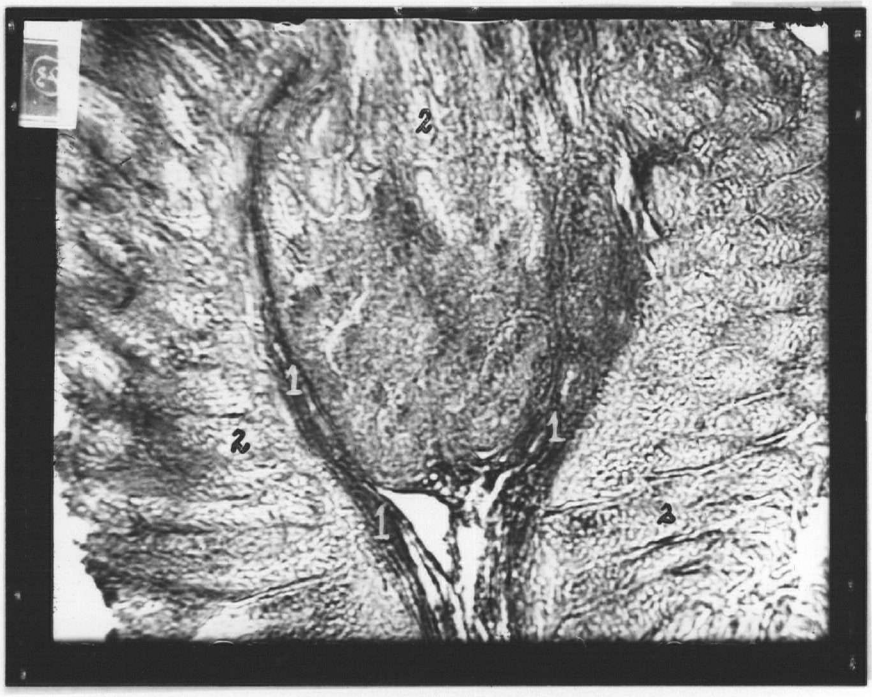


Plate XX

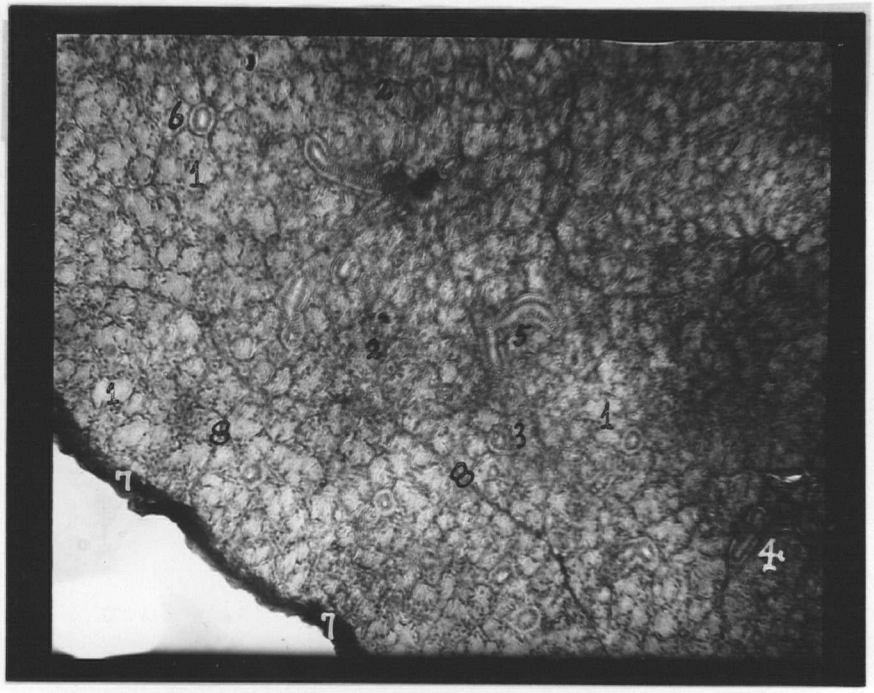
Fig. A Submaxillary salivary gland. Section through
Haem.-eosin x 100

1 Acini of mucous cells
2 Serous cells
3 Large branch of excretory duct
4 Interlobar duct
5 Interlobular duct
6 Intralobular duct
7 Capsule of connective tissue
8 Connective tissue separating lobes

Fig. B Submaxillary salivary gland. Section through
Haem.-eosin x 430

1 Mucous acini
2 Intralobular duct
3 Large branch of excretory duct
4 Interlobular duct
5 Connective tissue

PLATE XX



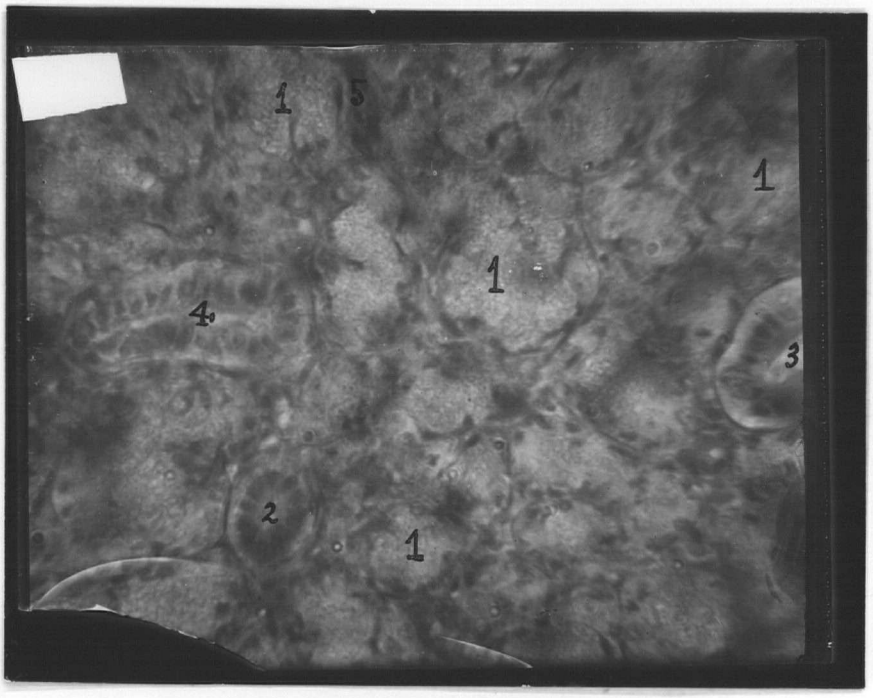


Plate XXI

Fig. A Sublingual salivary gland. Section through
Haem.-eosin x 100

1 Mucous acini
2 Serous acini
3 Connective tissue septum
4 Intralobular ducts
5 Capsule of dense connective tissue containing blood vessels

Fig. B Sublingual salivary gland. Section through
Haem.-eosin x 430

1 Mucous acini
2 Serous acini
3 Excretory ducts

PLATE XXI

Plate XXII

Fig. A Parotid salivary gland. Section through
Haem.-eosin x 100

1 Capsule of connective tissue
2 Connective tissue trabeculae
3 Serous acini
4 Excretory ducts

PLATE XXII

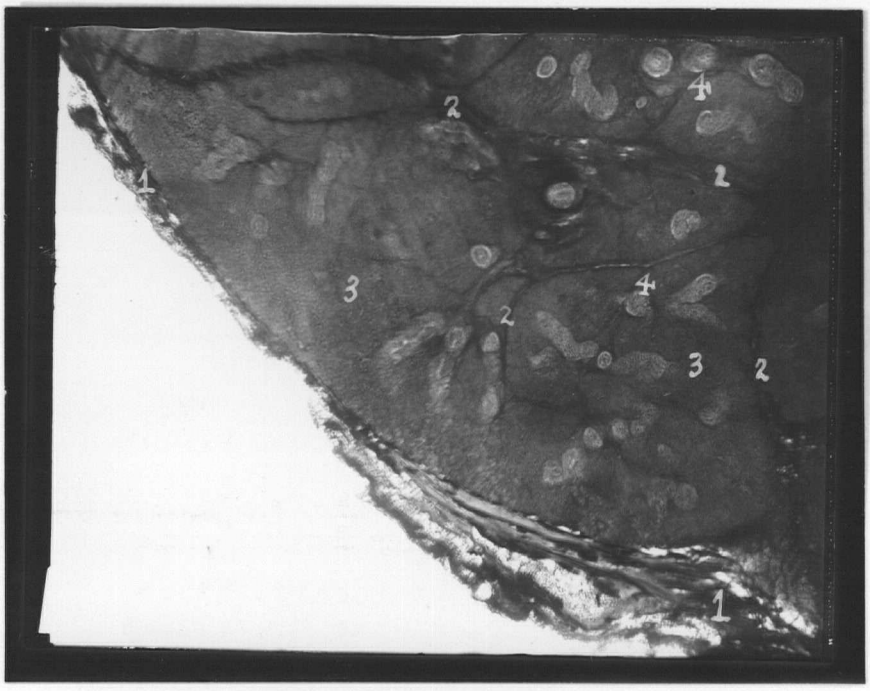


Plate XXIII

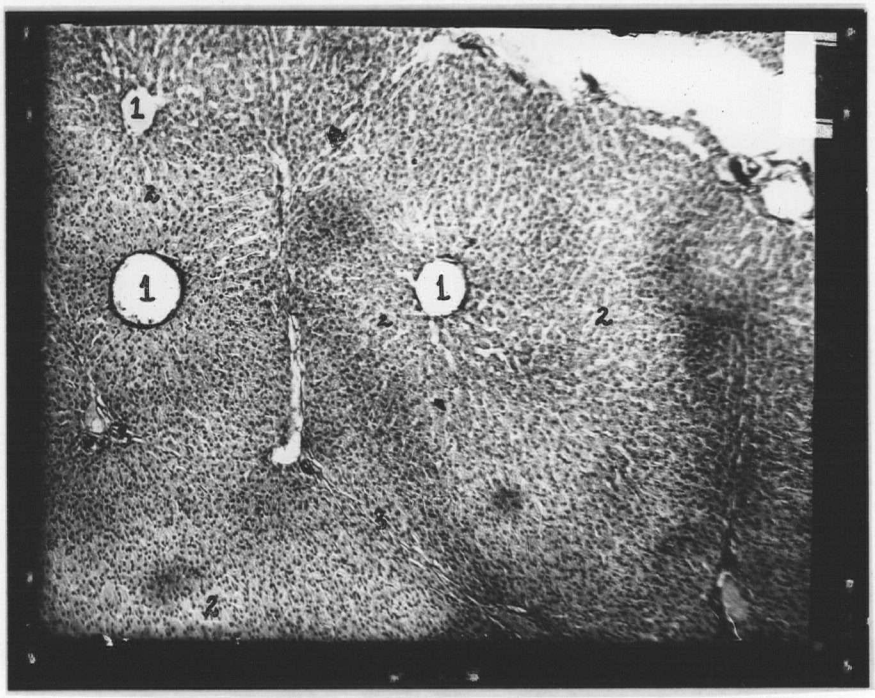
Fig. A Section through liver of five week old pig
Haem.-eosin x 100

1 Central veins
2 Cords of liver cells
3 Sinusoids

Fig. B Section through liver of sixteen week old pig
Haem.-eosin x 100

1 Central vein
2 Cords of liver cells
3 Heavy connective tissue trabecula separating lobes
4 Sinusoids

PLATE XXIII



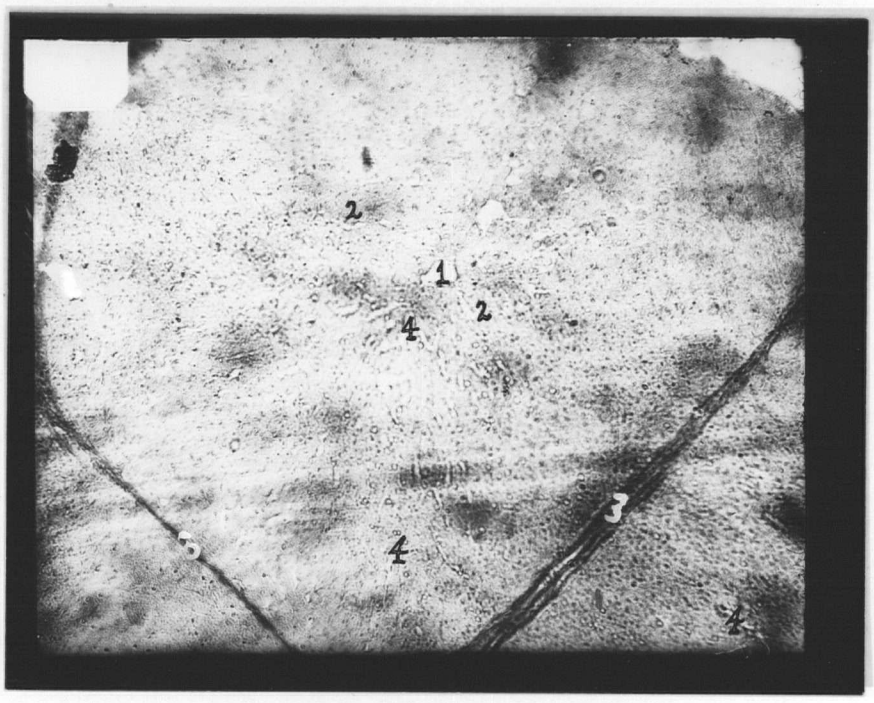


Plate XXIV

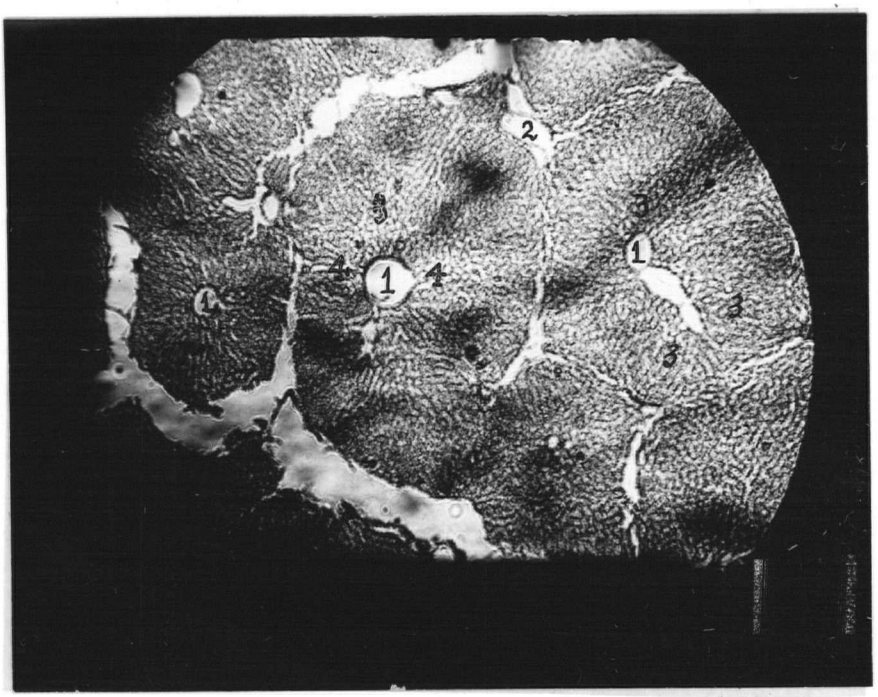
Fig. A Section through liver of five week old pig to show hepatic lobes. Haem.-eosin x 100

1 Central veins of hepatic lobes
2 Interlobular veins
3 Cords of liver cells
4 Sinusoids

Fig. B Section through liver of sixteen week old pig to show hepatic lobes. Haem.-eosin x 100

1 Central veins of hepatic lobes
2 Interlobular veins
3 Cords of liver cells
4 Sinusoids
5 Artefact
6 Connective tissue septae separating lobes
7 Connective tissue capsule

PLATE XXIV



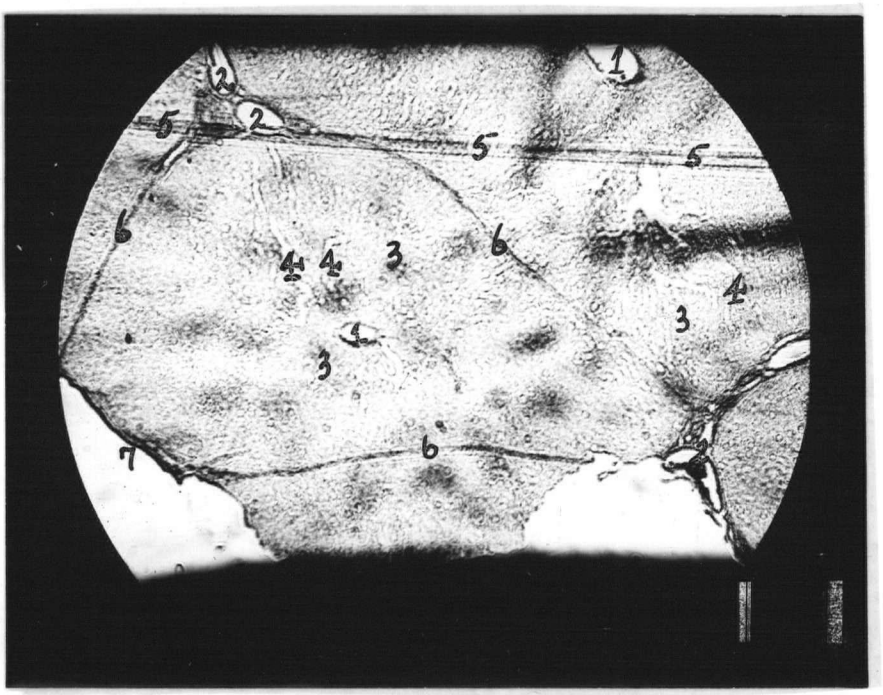


Plate XXV

Fig. A Section through pancreas showing island of Langerhans. Haem.-Eosin x 430

1 Pancreatic acini
2 Connective tissue capsule around islet
3 Island of Langerhan
4 Connective tissue trabecula

PLATE XXV