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UNIVERSITY OF MISSOURI
COLUMBIA

DEPARTMENT OF PHYSIOLOGY

March 22, 1913.

The Chairman of the Graduate Committee,

Graduate School,

University of Missouri.

Dear Sir:

I am sending herewith a thesis submitted for the Master's degree by Mr. William Frederic Skaer, B. S., A. B. Mr. Skaer was a "half time assistant" and graduate student in the Department of Physiology, 1911-1912, also a graduate student in the summer school, 1912. During this time he investigated the theme "The Absorption of Fat by the Mammalian Stomach." This subject has been only imperfectly investigated before. The recent developments in histological methods of following fat have made it possible for us to re-investigate the field in this laboratory with the development of considerable new facts.

Due to Mr. Skaer's sudden illness at the end of the summer school with what proved to be an infection of tuberculosis he was compelled to go to the California climate where he is at present in a Sanatorium. This delayed the final preparation of his thesis which has now been copied and put in final form.

In my opinion this is a strong thesis and worthily meets the requirements.

Very respectfully,

Chas W. Greene

THE ABSORPTION OF FAT

BY THE

MAMMALIAN STOMACH

by

William Frederic Skaer, B. S., A. B.

Submitted in Partial Fulfillment of the Requirements for
the Degree of Master of Arts

in the

GRADUATE SCHOOL

of the

UNIVERSITY OF MISSOURI

1913

Approved 3/24/1913
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DEPARTMENT OF PHYSIOLOGY AND PHARMACOLOGY

UNIVERSITY OF MISSOURI.

Table of Contents.

THE ABSORPTION OF FAT BY THE MAMMALIAN STOMACH.

Chapter I.

Introductory and Historical.

A proper analysis of the function of the stomach in alimentation involves not only those factors which produce chemical and mechanical changes in the food during its stay in the gastric cavity; but also, the extent to which the products of digestion are absorbed. This paper confines itself to an investigation of the absorption of fats by the stomach. Especial attention has been given to those fats naturally occurring in the emulsified form; although some non-emulsified fats, neutral oil and neutral fat, were also tested.

The physiological literature, which treats of the subject under investigation, is concerned chiefly with the digestion of the fats in the stomach. Rarely has there been any attempt to test fat absorption by the stomach. Certainly the two factors are in close correlation and a thorough knowledge of the former is necessary to properly test the latter. In the work dealing with either question there is a tendency to hold that the emulsified fats are the only ones acted upon by the stomach.

The first work on the absorption of fat by the gastric mucosa is presented by Kölliker[1]) in 1856. He writes

in this regard, that, the stomach, unlike the colon which shows variable amounts of fat in its lining epithelium, never fails to present some fat in the cells lining its cavity. He examined dogs, cats, and mice. Large and small fat droplets were found in the cells and in greatest numbers in the early stages of absorption. Kölliker found no fat in the wall of the stomach beyond the lining epithelium and how the fat passed beyond the lining epithelium was left undecided. He also suggested the way in which the droplets might enter the cells. Kölliker made a study of the surface of the cylindrical cells bordering on the lumen of the stomach. The surface of these cells is bounded by a membrane (the striated border of modern histology) which he conceived to be punctiform. This appearance suggests perforation through the membrane. Sections cut longitudinally he held showed that the droplets of emulsified fat enter the cells through these perforations.

As early as 1858 Marcet[2)] published a paper showing that dogs fed on a food rich in fat gave, in from one to five hours after the feeding, a yield of fatty acid in the stomach. To him therefore is assigned the credit of giving the first evidence on the digestion of fat in this organ. He at first tested especially the relation of the bile to the intestinal digestion of fats. He found that neutral fat was emulsified by the bile only in the presence of a fatty acid. The bile alone had no influence on the neutral fats. He next extir-

pated the pancreas of dogs. The fat splitting property of the pancreatic juice had recently been discovered, 1856. . He still obtained an emulsion which he believed was due to an antecedent cleavage of the fats. Knowing that the food fats were neutral and that any action on the part of the pancreas was eliminated, Marcet directed his attention to the stomach. An ether extract was made of the digested content of the stomach of a number of dogs after a meal of flesh and mutton fat. This extract was soluble in warm bile and produced an emulsion on cooling.

Twenty two years after Marcet's work Cash[3)] introduced lard and olive oil into the gastric cavity of dogs. He permitted a certain time for digestion and then killed the animals. The abdomen was opened and the stomach tied off, and as soon as possible its content was tested for fatty acid. Fatty acid was found, but the relative amount was in relation to the (time of) duration of digestion. This digestion experiment was tried and similar results obtained after the pancreas was tied off.

Cash proceeded further to specifically locate the ferment in the stomach. He tested for it in the gastric mucosa and in the gastric juice. The following are some of the experiments upon which the deduction was made that a fat splitting ferment was present in the gastric mucosa. When 5 grams of a pulp of the gastric mucous membrane was added to 3 grams of neutral fat a yield of 0.04 grams of free fatty acid in 4 hours at 40°C was obtained. An addition of 15 cc.

of a 0.2 percent HCl solution gave 0.237 grams fatty acid, while an addition of the same amount of a 0.5 percent KOH solution gave 0.015 grams. Furthermore, 2 grams of gastric juice, from a dog which had fasted a long time, added to 3 grams of neutral fat yielded 0.005 grams fatty acid in 2 hours at 40°C; while in 4 hours the yield was 0.02 grams of free fatty acid. An addition of a 0.2 percent HCl solution in this case gave no yield. On the contrary, 5 grams of glycerin extract from the pulp of the mucous membrane of the same animal and 3 grams neutral fat yielded 0.041 grams free fatty acid. Cash inferred that an active ferment was present in the mucous membrane of the stomach. He was also able to show the presence of neutral fat and of fatty acid in the membrane itself. To this last he attached no significance.

Cash worked under the direction of Ludwig. The following year Ogata[4)] under the same direction substantiated the same facts of fat cleavage in the stomach of living dogs. He placed a neutral olein into the stomach which was closed at the pylorus with a small rubber balloon inserted through a stomach fistula previously prepared. On regaining the olein after several hours, a fatty acid was obtained in many cases.

The digestion of fat by the human stomach was discovered by Müller[5)] in 1887, who found a cleavage of the fat in the stomach of a man with icterus. He states that the yield of free fatty acid is small, as were those quantitative determinations cited from Cash and Ogata six years previously for the dog. A patient with a ventral ulcer of the stomach

gave 2.7 percent fat cleavage in five hours, and another with a stenosis of the pylorus 4.9 percent.

Experiments on the human stomach were presented by Klemperer and Scheurlen[6] who did their work in 1889. They obtained a yield of 1 to 2 percent free fatty acid in two hours from an ingested oil in a normal stomach and 6 percent in a case of ectasis of the stomach when the oil remained in the stomach a much longer time.

In 1894 Vaughan Harley[7] studied the absorption of fat in normal dogs and in dogs whose pancreas were extirpated. He also directed his attention to the cleavage of fat, which he believed essential to the absorption. Harley found 18.5 percent free fatty acid in the stomach of normal dogs and as much as 31.29 percent in the stomach of dogs whose pancreas were removed. The heavy yield in the latter case was explained as due to a retardation of the stomach contents. In this connection it is interesting to note that 0.63 percent of fatty acid in the form of soap was obtained in the first series of experiments and 0.55 percent in the second series. These figures evidently exhibit the stomach as capable of splitting fats into free fatty acids and glycerin, and also show that there is some soap formation in the stomach, although this process is quite limited. The present writer wishes to call attention to the fact that either result is very suggestive of the possibility of some active fat absorption.

The work which conclusively proves the stomach to be a digestive organ for fat is that of Volhard[8,9,10] (1900 and 1901). He not only extracted an active lipase from the gastric mucosa but also worked out its relationship to the time of digestion and the nature of the fats ingested. He, like Cash, disclosed a fat cleavage by the gastric juice, also in a glycerin extract of the mucosa. Volhard holds that the gastric fat cleavage takes place only when the fat is in a state of fine division and that there is a proportional increase in action with its fineness. A glycerin extract of a pulp of the gastric mucous lining, for example, he found to produce a cleavage of 56 percent on egg yolk emulsion, or 48 percent on cream. Only 9.2 percent is produced on codliver oil emulsion. According to Volhard the thing of greatest importance is that the fat shall be in the form of an emulsion. He attempted to establish the fact that only a cleavage of emulsified fat takes place in the stomach. Volhard's pupil, Stade[11], has worked out the degree of cleavage to the reaction time of the ferment using portions of the gastric mucosa. He has presented the following rule: "The amount of free fatty acid is directly proportional to the fourth root of the reaction time."

Some attempts have been made to ascertain the absorption of fat by the human stomach. Ewald and Boas[12] introduced an oil in starch mixture into the human stomach, and siphoned it out some time later. They found some of the oil was lost but as their results were variable the question

of absorption was undecided. A similar investigation, with negative results, was that attempted by Klemperer and Scheurlen[6] who used oleic acid and sugar solution.

At present, undoubtedly, the best method for approaching absorption is the histological. The fat can be stained with certain dyes which are soluble in fat, or in fatty acid. The histological method was employed by Kölliker who did the very earliest work on the subject. The second paper showing absorption was in 1901 by Schilling[13]. He cut sections from the stomach of sucking calves and stained them for fat. He beheld many fat droplets in the lining epithelium of the gastric mucosa after calves were fed a full meal of milk. The fat occupied chiefly that portion of the cell bordering on the lumen of the gastric cavity. A similar examination of calves a longer period after the feeding showed fewer droplets and these in relatively deep positions. Schilling lays particular emphasis upon the absorption of fat by the stomach of the sucking calves, with also an inference of a significant absorption by the stomach of animals during this period of life.

In the summer of 1911 Dr. Greene[14] made some general physiological studies on the king salmon(Oncorhynchus tschawytscha) in California. In his work he tested how these fish took up the fat of their food. Besides the absorption of fat which took place in the intestine and in the pyloric coeca he found a surprisingly active absorption through the cylindrical epithelium forming the superficial coat of the gastric

mucosa. The absorption manifested itself in both the cardiac and pyloric regions. Innumerable droplets of fat occur in the cells after fat feeding, while the cells are void of fat droplets in the fasting salmon.

A preliminary report was made of experiments performed early in the fall of 1911[15)] in association with this work on the fat absorption by the mammal. The fat was found to occur in the epithelium of the cardiac and of the pyloric regions of the stomach after the feeding of rich cream. This work on the mammal was presented in a preliminary paper to the American Physiological Society at its annual meeting at Baltimore in December, 1911.

In the March number of Pflüger's Archiv für die Gesammte Physiologie Otto Weiss[16)] has an article entitled "Die Resorption des Fettes im Magen." His work is done from the histological standpoint on the ring snake, cat and dog. It is presented with good illustrative figures, but is so brief that it affords little satisfaction in the advancement of the subject of absorption by the stomach. Weiss finds absorption only for the young dogs and cats. It occurs in the cardiac and pyloric regions. The absorptive power in the cardiac region is lost six weeks after birth while that in the pyloric region persists a somewhat longer time, being lost after three and one-half months. The present writer has taken up this point and did most of his work prior to the publication of the above paper.

Chapter II.

Experimental Technique.

The work presented in this paper was done to further test the absorption of fat by the stomach of the mammal. The attack is wholly from an histological standpoint. It takes in animals of all ages. Some animals were chosen immediately after birth before food had been taken, and others were adults. The intermediate ages are represented both in dogs and cats.

The method of proceedure will be given later, but the comparison is based on histological sections chosen from both the cardiac and the pyloric regions of the stomach. In certain cases, for comparative purposes, material was taken from the duodenum. This material was used to aid in the interpretation of the sections from the different regions of the stomach.

The study is based on material obtained from 21 cats, 3 dogs, and 2 rats. These animals were caged in portable compartments in the animal house. Those animals selected were cared for by the writer and handled in the manner which will be stated later in connection with each separate experiment. Before the animals were selected they were fed the ordinary table refuse, which is fed to all the beasts in the animal house.

Very rich cream was ordinarily used for the final feeding for testing the absorption of fats. In the case of the rats fresh ground meat mixed with olive oil was selected. Those animals too young to feed artificially were allowed to

suck the mother's milk. Fasting, previous feeding on a fat free diet, or the use of animals just after birth and before the taking of the first fat were the initial conditions to the final fat feeding tests.

The experiments are arranged in three series; the first dealing with very young animals, cats and dogs; the second with half grown, several cats and one dog; and the third with adults, several cats, one dog, and two rats. The animals were selected from time to time to fit into each of these series. Those which come under the first series ranged in age anywhere from the time of birth up to eight weeks of age. Eight weeks is the limit of the series since it covers the sucking period. The choice of the half grown animals was based on their size. It was impossible to arrive at their exact ages as they were not bred in the animal house but secured from venders. However, it is quite certain that they were not over six and eight months of age. The adults were full grown in size and over a year old. There are only one or two dogs given with each of the series of experiments. And two adult rats are given in the last series. These were used for comparative study only. Cats were largely depended on for approaching the general details of the absorption by the mammalian stomach.

The animals were killed with an anaesthetic. Chloroform was administered to the cats by the usual method of placing them in an anaesthetizing box and putting the aneasthetic on a cloth in the bottom of the box. A chloroform-ether

mixture, one part of each, was substituted for the chloroform in killing the dogs. The anaesthetic was administered by arranging a barber's towel in a funnel shape over the nose and mouth of the dogs and pouring the mixture on the towel. The very young cats and dogs, and the rats were killed by tapping them on the head with a heavy ruler and immediately cutting the carotid arteries.

The stomach and a portion of the small intestine were always removed as quickly as possible. Those animals killed with the chloroform or ether-chloroform mixture were worked upon as soon as they entered the deep stage of the anaesthesia. With the animal on its back and the legs fastened down tightly to a cat board or a small dog board, one long incision was made down the mid line of the abdomen. This exposed all the abdominal viscera. The stomach with most of the gastric omentum was then entirely drawn out of the abdomen and cut free. The cardiac and pyloric valves are usually constricted, especially when the stomach contains food, so that this is not lost. No large blood vessels need be cut until after the oesophagus is bisected and then the stomach is well drawn out of the way of the free blood which begins to flow in the abdominal cavity.

A luke warm saline solution was used to rinse off the adherent blood. The stomach was then laid open by an incision beginning at the cardiac valve, and carried along the superior surface of the stomach mid-way between the greater and lesser curvatures. The incision was carried through

the cardiac region and a greater portion of the pyloric region. The contents of the stomach were easily removed since the incision produces a contraction of the muscular walls, which subsequently turns the stomach inside out. A second and thorough rinsing with luke warm saline solution was the final step prior to fixation.

The stomach and duodenum prepared as above were placed in 10 percent formalin solution. This fixes the tissues in three hours' time for good cutting with the freezing microtome. The fixation method was kept constant in cutting all the sections during this work. With the exception of a few specimens which were embedded in paraffin all the sections were cut on the freezing microtome fifteen and twenty micra in thickness. They were cut directly into 70 percent alcohol from which they were transferred into the stain as soon as possible.

The fat staining was accomplished in a saturated alkaline alcoholic solution of Scharlach Roth. Staining takes place in from 5 to 15 minutes. The sections were then rapidly passed through 70 percent alcohol to remove the excess of stain adhering to the surface of the sections. Very fragile sections were sometimes run through 50 percent alcohol to guard against too violent hydration. The alkaline alcohol was completely removed by a 10-15 minutes' immersion in an acid water bath, a few drops of hydrochloric acid in a half liter of water as used by Greene in the study of the fats in salmon tissues. With a section lifter, they were placed on

the slide and mounted in pure glycerin. Sections stained, carefully freed from alkali, mounted in glycerin and sealed around the edge of the cover slip with wax will keep for several months. In my work over two hundred sections were made in this manner and have kept very well, though they slowly lose in quality.

The particular stain and method primarily employed was Bell's[17)] modification of Herxheimer's method of staining fats with Scharlach Roth. This stain differs from the ordinary Herxheimer's Scharlach Roth in that an excess of stain in 2 percent sodium hydrate is dissolved in 70 percent alcohol, slowly heated to 70° or 80°C in a stoppered bottle for 20 to 30 minutes until certain physical changes are manifested.[x] A well prepared stain by Bell's modification of the original Herxheimer's method of staining fats is of unusual value in testing for fat in the gastric epithelium after a 10 percent formalin fixation. It brings out all traces of fat.

Some little staining was also done with Sudan III and Flemming's osmic acid. These were used only to see how they might serve in detecting the same fat findings. The Nile blue sulphate stain[18)], which has very recently been suggested by R. H. Whitehead[19)] for differentiating fatty bodies in the interstitial cells of Leydig of the testes was employed here to get some approach to the chemical nature of the fats indicated by the Scharloch Roth. This stain is said to color

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[x] For a detailed account of the Herxheimer method of staining fats with Bell's modification see Bell's article: "The staining of Fat in the Epithelium and Muscle Tissue." Anatomical Record, Vol. 4, p. 199, 1910.

neutral fat red and the fatty acid blue. Sections were left in a 70 percent alcoholic solution of Scharlach Roth as described above, or in a solution of Sudan III 10 to 15 minutes. For the Flemming's osmic acid methods small pieces of fresh tissue were left in the solution three or four days. For the Nile blue sulphate stain sections were cut in the usual manner and stained over night.

Many sections were counterstained with Delafield's iron haematoxylin. The staining in Delafield's haematoxylin was done after the sections had been stained for fat and at the time when the sections are removed from the acid wash water. In making tests for fat in both the cardiac and pyloric regions of the stomach of each animal, this stain is indispensible, in that the relationship of the fat droplets to the nuclei of the cells can be studied. The sections counterstained with Delafield's iron haematoxylin are especially advantageous for making the drawings.

It was assumed that any fat absorbed by the stomach was imbibed by the same mechanism operative in the duodenum. It was for this reason that sections of the duodenum were also made and studied for comparison.

Chapter III.

Observations and Results.

For the sake of brevity the observations on each series of experiments are presented in condensed tables. There is appended to this paper a number of figures illustrating more precisely some observed facts of the absorption. The tables are each constructed on the same plan. Each is arranged in the same serial order. In the first column is the laboratory number of the experiment. In the second, the initial condition has reference to the manner in which the animal was handled by the experimenter prior to the final feeding. In the third column the food of the final feeding is given. When an animal was killed at birth "none" so indicates. Animals fed artificially are indicated by the word "milk" or "cream", with the percent of butter fat determined by the Babcock method. In the fourth column is the time in hours allotted to the digestion and absorption. A zero is used here for those animals killed at birth.

The observations are presented in the fifth, sixth, seventh, and eighth columns. They are made on the stomach and the duodenum. In the fifth column are the observations on the superficial gastric epithelium. Since this is common to the cardiac and pyloric regions of the stomach, where the absorption differs in amount and volume, column five is subdivided into two columns. The sixth column contains a brief account of the fat in the villi of the duodenum. It follows

the description of the fat in the superficial epithelium of the stomach because some reference will be made later to the similarity of the occurrence of fat in the lining epithelium of these regions. The last two columns, the seventh and eighth, treat of the fat in the gastric glands, and in the glands of Lieberkühn and of Brunner respectively (when both were included in the section.) Again a collation is made of the fat appearing in the cardiac and pyloric gastric glands. The seventh column is, therefore, divided into two subcolumns. The eighth column treats of the fat in the glands of Lieberkühn and of Brunner together.

It is found that the fat occurs in the epithelial cells in the form of droplets. A special reference is always made to their position in the epithelium with respect to the nucleus of the cell. The fat is spoken of as occurring in many or few droplets, internal or external to the nucleus, etc. A study of the counterstained sections goes to show that the nucleus of the cell tends to divide the fat areas into an inner and an outer zone.[x] In concisely discussing the fat of the glands the amount in the glands is referred to, although in the cells of the glands it is present in the form of droplets and bears some relationship to the nucleus of the cells. No particular mention is made to the character of the cells and the fat affinity. For the cardiac region of the stomach a description is given of the relative distribution and volume of fat as it appears in the neck, body, and expanded base of the cardiac glands, and a similar description of the distri-

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x The B. N. A. rule is followed in this paper, i.e, the "inner zone" with reference to the lumen of the viscus.

bution of fat in the straight and winding tubules of the pyloric gastric glands. The fat content of the glands of Lieberkühn and of Brunner is more briefly presented for comparative purposes.

All the histological sections were cut vertical to the surface of the mucous membrane. This cutting presents a longitudinal section of the superficial epithelial cells of the stomach, and also of the epithelium of the villus. Almost all of the glands of the stomach and duodenum will also appear in longitudinal section. The winding tubules of the pyloric glands and of Brunner's glands are of course cut in various planes.

In connection with each table mention is made only of that particular series of animals and following is a brief discussion referring to the animals in their serial order, their initial conditions, the final feeding and the time of digestion and absorption, etc. The significance of the observations of all three tables is discussed later, and the conclusions and general deductions made chiefly with respect to the absorption of fat by the mammalian stomach. A brief description of the cat's stomach is given in order to aid in understanding the discussions and the significance of the tables.

The cat stomach is divided into three parts:- an upper cardiac region, a middle region, and a lower pyloric region. In my investigation the cardiac and pyloric regions only were studied. The middle region is but a transition region from the cardiac to the pyloric region. The wall of

the stomach of the cat is made up of several layers continuous anteriorly with those of the oesophagus and posteriorly with those of the duodenum. The internal or lining layer, that layer with which we are chiefly concerned, the mucosa, consists of highly differentiated epithelial cells of several types but supported by a connective tissue frame-work, the tunica propria. Grossly, the inner surface of the stomach presents folds of the mucosa which are chiefly longitudinal but to some extent irregularly transverse. These become very prominent when the organ is contracted naturally or is constricted by the incision previously spoken of in the proceedure for removing and preparing the stomach for fixation. There are also to be seen macroscopic irregular circular and polygonal areas ranging from a fraction of a millimeter to one millimeter in extent, and bounded by shallow depressions.

On section, microscopically, these small irregular areas are composed of simple and long spindle-shaped cylindrical epithelial cells. The cells are arranged in arches in such manner as to give rise to the bounding depressions. The depressions are the outlets for the gastric glands. They are lined by a simple columnar epithelium continuous with the long spindle-shaped cells above, and with a glandular epithelium constituting the gastric glands,below. The outlets of the gastric gland are often termed crypts. These are shallower in the cardiac region of the stomach than in the pyloric region. The summits of the folds, which are comprised of the long spindle-shaped cells, form Oppel's superficial gastric epithelium, a term adopted in the present paper. This

epithelium is treated apart from the glandular epithelium and will be seen to bear a special significance in the absorption of fat by the mammalian stomach. The nuclei of the superficial gastric epithelial cells are elongated and situated near the bases of the cells.

The glands constitute most of the mass of the mucosa of the stomach. Oppel distinguishes two types of glands, viz., the peptic glands, "Labdrüsen", and pylorus glands, "Pylorusdrüsen". In this paper the fat was studied in both of these. The peptic glands are tubular glands. The tubules are straight or a little tortuous and several end in the same gastric crypt. Several may join one another and enter the pit by a common duct, which forms the neck of the gland. They diverge slightly and become closely packed together at the basal portion of the mucosa where also the tubules are often seen to be slightly expanded. The tubule proper with its narrow lumen comprises the body of the gland, and the expanded base the fundus of the gland. Each tubule consists of two sorts of cells, the chief cells and the parietal cells. In the cat the parietal cells form the greater part of the peptic gland, especially is this true for the body of the gland.

The pyloric glands are branched tubular glands. Each consists of a deep pit and a short winding tubule. The cells are of the mucous type, with the nucleus situated near the base of the cell. They are closely packed with but little connective tissue or tunica propria between them.

TABLE I.

Showing the Absorption of Fat from the Stomach of Mammals During the Sucking Period

No. of Expt.	Initial Condition	Final Food	Time of Digestion and Absorption	The Fat in the Superficial Epithelium of the Mucosa. Cardiac Region	The Fat in the Superficial Epithelium of the Mucosa. Pyloric Region	Fat in the Duodenum. Villus	The Fat in the Glandular Epithelium of the Stomach. Cardiac Region (Peptic glands)	The Fat in the Glandular Epithelium of the Stomach. Pyloric Region (Pyloric glands)	The Fat in the Glandular Epithelium of the Duodenum. Glands of Lieberkühn and Brunner
Cat XX	Killed just after birth and before feeding	None	0	None	None	No section	None	None	No section
" XXV	Killed just after birth and before feeding	None	0	None	None	No section	None	None	No section
" XXI	Killed just after birth and before feeding	None	0	None	None	None	None	None	Glands of Lieberkühn contain many droplets, especially near the neck
" XXII	First sucking	Mother's milk	3 hrs.	Fine droplets, largely internal to nucleus.	Similar to cardiac region but has a greater number of droplets.	No section	None	None	No section
" XXIII	First sucking	Mother's milk	6 hrs.	Many fine droplets, internal and external to nucleus.	Numerous droplets internal and external to nucleus.	No section	Fine droplets in the parietal cells comprising the body of the glands.	Many fine droplets at base of the straight tubules and in the winding tubules.	No section
" XXIV	Three days old A good sucking	Mother's milk	3 hrs.	Only in places. Cells engorged. Fine droplets massed together internal to nucleus.	Only in places but more extensive than cardiac region.	No section	None	None	No section
" XVI	8 weeks old 18 hrs. fasting	Cow's milk 6% butter fat	3 1/2 hrs.	A few fine droplets internal to nucleus.	Relatively large numbers. Internal to nucleus and some external.	Epithelium engorged. Fat in the lacteals.	Slight amounts in the body of the gland.	Slight traces in the winding tubules.	None
" XVII	8 weeks old 18 hrs. fasting	Cow's milk 6% butter fat	24 hrs.	Fine droplets internal to nucleus in places. Many droplets external to nucleus	Many fine droplets internal and external to nucleus.	Void of fat.	Void of fat (submucosa loaded)	Void of fat except in some few winding tubules.	Lieberkühn contain many droplets at the base. Brunner's loaded.
" XVIII	5 weeks old 18 hrs. fasting	Commercial milk, 0.2% fat	21 hrs.	Only in places. Few droplets internal with more external to nucleus.	Fat more extensive internal to nucleus but more external.	Only traces in the tips of the villi	Void of fat	Void of fat	Lieberkühn and Brunner glands well loaded with fat droplets
" XII	4 weeks old. A commercial milk 18 hrs. fasting.	Commercial milk milk, 0.2% fat	2 hrs.	None	A very few droplets. Largely external to nucleus.	Only traces in the tips of the villi	Void of fat	Void of fat	Void of fat. (Fat seen in blood vessels)
Dog III	Killed just after birth	None	0	None	None		Void of fat	Void of fat	No section
" IV	4 days old a good sucking	Mother's milk	1 hr.	Large droplets, engorging cells, nucleus somewhat obscured by fat droplets	Large droplets engorging cells. Like cardiac region [illegible]	Droplets in base of villi	Void of fat	Void of fat	Lieberkühn and Brunner glands contain many droplets

Discussion of Table I.

This table includes the entire sucking period of cats, also some observations on dogs just after birth and at four days of age. Five cats, as given in the table, were selected at the time of birth. Three were killed just after birth and two were given the first sucking and killed three and six hours respectively after the sucking (Expts. XX, XXV, XXI, XXII, and XXIII). The three last belong to the same litter. A cat three days old was permitted to become very hungry and killed three hours after a full sucking of the mother's milk (Expt. XXIV). This young cat was a mate to the first kitten given in the table. The next two cats in the list were eight weeks old and were fed artificially on cow's milk which contained 6 percent butter fat (Expts. XVI and XVII). The two were of the same litter. These cats were fasted eighteen hours, then given a full feed of cow's milk containing 6 percent fat. The first was killed three and one-half hours after feeding. The second cat was killed twenty four hours after a final feeding. Experiments XXII, XXIV, and XVI, therefore, have the time of digestion and absorption nearly constant, but the animals were selected of ages to show any change in the degree of absorption of fat during the phases of sucking life. They also show the effect on the absorption of the change from the natural milk of the sucking period to the artificial feeding of cow's milk. The second kitten was killed twenty four hours after feeding in order to note the condition of the fats in the epithel-

ium of a moderately hungry cat. The two cats were well nourished and very tame. It was not known how long they had been weaned.

The last two experiments on cats in this table serve primarily to show with what persistency the epithelium holds the fat when once fatty food is ingested (Expts. XVIII and XII). The first had the same initial treatment as the two cats eight weeks old, except that the age of the last cat (Expt. XVIII) was but five weeks. The object was to have as nearly the same initial condition as possible and to feed a fat-free diet. The cat was fed a commercial milk and killed twenty one hours after feeding. The commercial milk is practically free from butter fat. A Soxhlet determination showed from 0.1 to 0.2 percent of butter fat. This milk was obtained from the manufacturers under the label "Milk Powder". It consists of the milk sugar, protein, and salts of separator milk converted into the powder form by running it through a very fine screen under high pressure into a superheated chamber. For the feeding of cats in this experiment and some of those that follow, the milk powder was mixed with water in the ratio of 1 to 5. This gives nearly the proportion of water in ordinary milk. The chief difference is in the small percent of butter fat.

The second cat (Expt. XII) was weaned early and at once put on a diet of commercial milk. This produced a marked diarrhoea, but the cat continued to drink the milk with avidity. Before the final feeding the cat was fasted eighteen hours. The killing was done two hours after the final feed-

ing, at the time of an active digestion and possibly before much absorption of any of the stomach content had occurred. In the case of artificial feeding the time was reckoned from the time the pan of food was removed.

The results obtained from the two dogs are marked off from those for the cats by a blank space in the table. They were sucking puppies, one killed just after birth and the other one hour after a good sucking and at the age of four days. These dogs are of the same litter. They were used for comparison with the cats to determine if the results obtained for the one hold good for the other.

TABLE II.

Showing the Absorption of Fat from the Stomach of Mammals During the Half Grown Period.

No. of Expt.	Initial Condition	Final Food	Time of Digestion and Absorption	The Fat in the Superficial Epithelium of the Gastric Mucosa.		The Fat in the Duodenum.	The Fat in the Glandular Epithelium of the Stomach		The Fat in the Glandular Epithelium of the Duodenum.
				Cardiac Region	Pyloric Region	Villus	Cardiac Region (Peptic glands)	Pyloric Region (Pyloric glands)	Glands of Lieberkühn and Brunner
Cat VII	Boiled rice 2 days 2 days fasting	None	0	Few drops external to the nucleus. In some few places internal to the nucleus.	A few droplets external to the nucleus.	Void of fat	Void of fat	Void of fat	Void of fat
" X	2 days fasting	None	0	Only in places. Internal and many external to the nucleus.	Only in places. Fewer droplets than in the cardiac region.	Void of fat	All cells loaded with fine droplets about the nucleus.	Winding tubules contain many fine droplets.	Many fine droplets in glands of Lieberkühn and Brunner.
" IV	2 days fasting	None	0	In places a few droplets external to the nucleus.	None	Void of fat	Cells loaded with fine droplets especially in the body of the gland.	Winding tubules contain many fine droplets.	Many fine droplets in glands of Lieberkühn and Brunner.
" VIII	2 days fasting	Cream, 25% butter fat	3 hrs.	Many fine droplets internal and external to the nucleus.	Many fine droplets internal and external to nucleus. Extension into neck cells	Epithelium engorg Some fat as far a lacteals.	A few droplets in the body of the gland.	Some of the winding tubules contain fine droplets.	Only a little at base of the glands of Lieberkühn.
" IX	2 days fasting	Cream, 25% butter fat (drank little)	3 hrs.	Very few droplets external to nucleus (see Expt. X)	Only in places. Internal and external to nucleus.	Epithelium engorged.	A medium amount heaviest in the body of the gland.	Few droplets in the winding tubules.	Droplets at the base of the glands of Lieberkühn. Brunner practically void of fat.
" V	2 days fasting	Cream, 25% butter fat	5 hrs.	Many fine droplets, some internal and many external to the nucleus.	Only in some areas.	Epithelium engorged. Much in the lacteals.	A medium amount.	A few droplets in the winding tubules.	Comparatively no fat. Brunner's glands void.
Dog XXVI	12 hrs. fasting	Cream, 15% butter fat	3 hrs.	Many large droplets, many internal and external to nucleus.	Only in some areas. many droplets internal to nucleus.	Epithelium engorged. Some fat as far as lacteals.	All cells loaded with fine droplets.	Straight and winding tubules contain fine droplets.	Comparatively no fat.

Discussion of Table II.

The animals included in this table are half grown cats and a half grown dog. They comprise the second series of experiments. The first three cats serve as controls for the last three which were fed cream. The first control is a cat which was fed on boiled rice (a fat-free diet) two days. Since it would not freely eat this diet it was fasted two days following the rice feeding. As the half grown cats were more easily obtained than the young and adults, they were experimented upon first. As the commercial milk was not suggested for feeding as a fat-free diet until later, an attempt was made to use boiled rice. It proved to be unsatisfactory from the start. Fasting was substituted. Cats were fasted two days and then fed cream containing 25 percent butter fat as a final feeding. The first animal (Expt. VIII) drank a third of a pint. It was killed three hours after the feeding. The next cat (Expt. IX) was very wild. The amount it drank was very little. This cat, also, was killed three hours after feeding. The last cat of this series was fed cream and killed five hours later. The period of digestion and absorption is reckoned from the time of removing the food until the time of killing.

The dog in this experiment was fasted only twelve hours to allow it to get very hungry. It was fed a diluted cream containing about 15 percent butter fat, and killed three hours later.

TABLE III.

Showing the Absorption of Fat from the Stomach of Adult Mammals.

No. of Expt.	Initial Condition	Final Food	Time of Digestion and Absorption.	The Fat in the Superficial Epithelium of the Gastric Mucosa.		The Fat in the Duodenum.	The Fat in the Glandular Epithelium of the Stomach		The Fat in the Glandular Epithelium of the Duodenum.
				Cardiac Region	Pyloric Region	Villus	Cardiac Region (Peptic glands)	Pyloric Region (Pyloric glands)	Glands of Lieberkühn and Brunner
Cat XI	Cow's milk 3 weeks 24 hrs. fasting.	None	0	Very fine droplets internal and external to nucleus in all cells.	Many fine droplets internal and external to nucleus. Continuous with fat in gland cells.	Void of Fat	All cells contain fine droplets.	Straight and winding tubules contain many droplets.	Many droplets in basal portion of Lieberkühn's gland. Brunner's not showing.
" XIII	Cow's milk 3 weeks 24 hrs. fasting.	Cow's milk, 6% butter fat	2 hrs.	Some areas void of fat. Very few droplets external to nucleus.	None	Epithelium engorged.	Droplets in body and expanded base of glands.	Droplets only in the winding tubules.	Doubtful
" XIV	Cow's milk 3 weeks 24 hrs. fasting.	Cow's milk, 6% butter fat	4 hrs.	Very few droplets external to nucleus.	Many droplets internal and external to nucleus.	Epithelium at the tips of the villus engorged. In the lacteals	Void of fat	Droplets in some winding tubules.	Void of fat
" XV	Cow's milk 3 weeks 24 hrs. fasting.	Cow's milk, 6% butter fat	8 hrs.	Fine droplets internal and external to nucleus.	Many fine droplets largely internal to nucleus.	Epithelium of tips of villus engorged. Much in lacteals int and ext. to nucleus.	Void of fat	Droplets in some winding tubules.	Droplets in the basal portion of Lieberkühn's glands. Brunner's not showing.
" XIX	25 days fasting.	None	0	Practically void of fat. Some dark colored specks external to nucleus.	None	No fat in villus except at the base. Here it is present internal and external to nucleus.	Void of fat	Void of fat	Void of fat
Dog VI	12 hrs. fasting.	Cow's milk, 6% butter fat	5 hrs.	Many droplets internal and external to nucleus.	Droplets internal and external to nucleus.	No section	Small amounts in the cells of the body of the gland.	Droplets in the winding tubules.	No section
Rat I	Boiled rice 1 week.	Meat and olive oil	4 hrs.	Cells engorged filling the inner ends (or zone).	Cells engorged filling the inner end of cell.	Epithelium engorged Much in lacteals.	Void of fat	Void of fat	Void of fat
Rat II	3 days fasting.	None	0	None	None or very few traces.	Void of fat	Void of fat	Void of fat	Void of fat

Discussion of Table III.

The cats of this series were handled in a somewhat different manner from those of the first two series. The first four were fed on commercial milk (fat-free diet) for three weeks and then fasted twenty four hours, while the last cat was fasted twenty five days to show the effect of hunger in freeing the gastric epithelium of its fat content. This cat was a large white house cat. The other cats were also large full grown animals. The first cat of the series was killed without a final feeding to serve as a control for the next three which follow in serial order. The cats were fed cow's milk which contained 6 percent butter fat as a final food. Their time of digestion and absorption was 2, 4, and 8 hours, respectively.

The experiments on one adult dog and on two adult white rats are also given in this table. These are each marked off by blank spaces in the table. The dog was an old medium-sized bitch which had recently whelped. The two puppies given in the first series are from her litter. The initial condition of the dog was twelve hours fasting for the purpose only of producing an effective appetite. The final feed was a pan of cow's milk which contained 6 percent butter fat. She was not killed until five hours after the final feeding. The two white rats were placed in the same cage and fed boiled rice for a week. They were then placed in separate cages. The one was given meat and olive oil and the other was fasted three days. White rats can not be fasted for much over three days.

Significance of the Observations.

Chapter IV.

Absorption by the Superficial Epithelium of the Gastric Mucosa.

The superficial epithelium of the stomach contains an unusual amount of fat after fat feeding. These cells are practically free from fat in the full term embryo as seen by killing young cats and dogs just after birth. It is evident from the results obtained after the first sucking of new-born kittens that the fat present in the superficial gastric epithelium is derived from ingested fat. Furthermore, the same evidence holds true for older cats which have like initial conditions prior to the final feeding. The absorption of fat, therefore, is clearly manifested by the superficial gastric epithelium of the mammalian stomach, as chiefly shown by the cat in my investigations. The age of an animal plays an important role in the amount and volume of absorption, as do also the different regions of the stomach involved. There is no evident difference in the structure of cardiac and pyloric superficial epithelium and the presence of greater amounts of fat in the epithelial cells of the different regions is a factor probably governed by the digestion of fats in the gastric cavity. Although my work has largely been done with the naturally emulsified fats, some evidence of an absorption of solid or liquid fats is given. Table III, Expt. I, treats of an adult rat which was fed ground meat mixed with olive oil. The epithelial cells were engorged with fat four hours after the feeding.

There yet remains to be shown the absorptive power

of the stomach in relation to age of an animal. The superficial epithelium of the sucking kitten or sucking puppy is engorged with fat three to six hours after a full meal. Half grown or adult cats and dogs, on the other hand, show only relatively small amounts of fat deep in the cells in close relation to the nuclei of the cells.(Compare Plate II, figure 3, with figure 9 of Plate VI.) Undoubtedly the sucking animals load the superficial cells of the stomach more quickly and more fully than do older animals. Yet I find abundant evidence, see Table III, that adults have the power of absorbing fats in the stomach. Particular emphasis is laid on this observation since Weiss has recently stated that only very young animals absorb fat in the stomach. He states specifically, see review of the literature, that adults lose this power.

The fat, occurring in the form of fine droplets, bears a certain relationship to the nucleus of the cell during the time of absorption. During early absorption the droplets are present in greater numbers external to the nucleus with a smaller amount of fat internal to that structure, and vice versa during the later stage (see plates). The nucleus apparently only tends to divide the fat. It may be possible that the number and disposal of the fat droplets in the cell are influenced somewhat by the factor of the metabolism of the cell. Some attempts have been made to locate fat in the nucleus of the cell. Although the nucleus of the cell was in some cases rendered obscure by the large amounts of fat in engorged cells, no evidence of the actual occurrence of droplets within the nucleus could be had. (Plate VI, fig. 9).

A splendid example of the droplets occurring internal to the nucleus during early absorption is given by a sucking kitten killed three hours after the first sucking (Plate I, fig. 1). A similar example of a late stage is that of another kitten of the same litter killed three hours after the first sucking (Plate I, fig. 2). These examples show but comparatively few droplets after the first sucking. The engorgement of cells is seen in young cats and dogs several days old (Plate VI, fig. 9), the absorptive process being apparently more active at this age.

The superficial gastric epithelium possesses a certain persistent fat-holding quality. Fasting periods of several days do not render the epithelial cell void of fat (Plate VI, fig. 10), nor does the feeding of fat-free diets. A certain decrease in this remnant was observed just after feeding. The fat which remained in the cell from previous feedings apparently showed the greatest decrease in amount and occupied a deeper position in the cells during the time of active digestion of the stomach. Often no droplets were internal to the nucleus and only a few were external. The facts are verified by experiments XVIII and XII of the first table. Experiment XII rendered the epithelium almost void of fat. The initial condition was a fat-free diet for one week followed by eighteen hours fasting; this was followed by a final meal of fat-free food. The animal was killed at the time of active digestion in the stomach. Tests of extreme starvation showed the epithelium void of fat (Table III, Expt. XIX).

Some attempts have been made to arrive at how soon after the ingestion of fat the maximum absorption occurs. It can be clearly seen that the maximum absorption of fat for the sucking kitten and puppy is earlier than that for the half grown or adult. Sucking kittens and dogs several days old show the cells engorged one to three hours after sucking. In the half grown and in the adult cat and dog the cells show the heaviest loading, both internal and external to the nucleus, in from three to eight hours after fat ingestion.

The observations show that the absorption of fat in the cardiac region does not equal that in the pyloric region. There is no evident difference in the structure of the superficial epithelium of these regions. A comparative study of the gastric regions shows a greater number of droplets in the pyloric region which undoubtedly indicates a greater volume of absorption. Furthermore, although the fat may sometimes occur in but few folds in the cardiac region of a given animal, it is usually more or less uniformly distributed over all the folds of the pyloric region. There is practically no difference in the size of the droplets in the two regions, although the large amount in the pyloric region gives rise to a greater mass of the droplets. The question is raised here as to whether or not the greater amount of fat absorption in the pyloric epithelium is not dependent on the greater concentration of dissociated fats in this part of the stomach. The peristalses of the stomach tend to propel the foods into the pyloric portion of the organ as fast as they reach a liquid or semiliquid stage. The dissociated fats from the cardiac region

would therefore be propelled forward with the rest of the food and would come into contact with the absorbing pyloric epithelium in greater concentration. Also when the partly dissociated fats are propelled into the intestine and go into solution in the bile absorption by the villi becomes immediately possible. This factor must be taken into account in explaining the fat absorbing function of these organs as noted below.

Chapter V.

Absorption by the Villi of the Duodenum.

The fat absorption in the duodenum occurs precisely as described by Noll[20)] in a recent paper. At first the fat is loaded into the epithelium of the villus and later appears within the villus itself (Plate VII). Observation of the fat absorption by the villus was made only as a check and for comparison with that of the superficial gastric epithelium.

The intestinal absorption follows closely that observed in the stomach both as to time and character of the loading of the epithelial cells with fat droplets, except that the intestinal absorption is by far more abundant and voluminous. As a consequence, the intestinal cells always appear more engorged during active absorption. They take up the fat with avidity and discharge it very rapidly. As in the epithelial cells of the stomach, especially of sucking animals, the fat of the villi first occupies that portion of the cell internal to the nucleus. Only very seldom does any fat appear external to the nucleus except at a later stage of absorption. At this time two distinct zones--one internal and the other external to the nucleus—are apparent in those epithelial cells constituting the basal portion of the villus (Plate VII, fig. 12). It is also from the bases of the epithelial cells that the fat is last to leave the villus.

A Nile blue staining of the gastric and intestinal fat indicates some difference in their chemical nature. The gastric fats stain dark blue when sections are left in the stain over night, while the intestinal fats stain blue but

with a reddish hue. This observation was made by Lamb[21)] in 1910. He also stained the gastric and intestinal fats of a sucking kitten with Nile blue sulphate in connection with some studies on Weigert's myelin stain for differentiating fats.

Chapter VI.

On the Presence of Fats in the Glands in Relation to Absorption.

1. Peptic Glands of the Cardiac Region of the Stomach.

Fat appears in the parietal cells of the peptic glands of the stomach many hours after its appearance in the superficial epithelium. This fat is in larger droplets and irregularly distributed through the cells. The fat appears earliest and most abundant in the parietal cells of the peptic glands. A heavy loading of the parietal cells of these glands exhibits a beautiful band of fat which involves the entire length of the gland. As a rule it is hard to ascertain whether the cells are being loaded or whether, on the other hand, they are discharging the fat. The greatest amount of fat occurs during moderate fasting. It is lost on extreme fasting. Again, here as in the superficial gastric epithelium, it is very conspicuous in the sucking kittens after they have once fed, but is not present before they have taken food. The disappearance of fat in the peptic glands is also manifested during the early stages of active digestion. The parietal cells may become entirely void of fat, but occasionally small traces persist in the closely packed cells of the body of the peptic gland throughout an active digestion. Fat was never seen in the cells constituting the gastric pits .

2. The Glands of the Pyloric Region of the Stomach.

Fat appears in the cells comprising the epithelium of the pyloric glands of the stomach within the same time that it appears in the parietal cells of the peptic glands. Except in the case of the embryo or of animals extremely fasted

fat can be detected in the winding tubules of the pyloric glands. It is in this portion of the glands where fat occurs first and remains the longest after a meal of fat. The droplets in the pyloric gland cells are smaller than those in the peptic gland cells and are distributed more closely about the nucleus. In the case of a heavy fat loading they may be seen in all the cells from the base of the gland continuous to the superficial epithelium. However, seldom do the fat droplets appear in the cells constituting the neck cells of the gastric pits.

The fat in the pyloric glands bears the same relationship to the feeding as that described for the peptic glands. It leaves the straight tubules of the pyloric gland soon after feeding but persists very much longer in the winding tubules.

Chapter VII.

Summary.

1. The physiological literature furnishes conclusive evidence of the digestion of some fat in the stomach, but gives little evidence of the absorption of the cleavage products of fat.

2. There is an absorption of fat through the gastric mucosa of the mammalian stomach. It occurs for animals of all ages, and fats in a form other than an emulsion are absorbed.

3. The amount of absorption is much greater, at least more rapid, in the sucking animals than in the adults.

4. The fat appears in the superficial gastric epithelium in direct relationship to the time after the ingestion of fatty foods.

5. The fat is present in the superficial gastric epithelium in the form of fine droplets which are larger in the dog and rat than in the cat. Their position in the engorged cells of sucking animals is chiefly internal to the nucleus. A maximum loading of the cells in adults shows a great number of fine droplets both internal and external to the nucleus.

6. The process of removal of fat from the superficial cells is a very slow one. It takes place from the superficial area first and from the bases of the cells last. Traces of fat remain in the bases of the cells after many hours, even days, without food.

7. Fat appears in the gastric glands at a time much later than in the superficial epithelial cells. During fasting it

is given up only after a surprisingly prolonged period. At the beginning of a period of digestion when secretion is active the stored fat of the gland cells is rapidly removed.

8. The very late occurrence of fat in the gastric and duodenal glands suggests a resynthesis of absorbed fat in the glandular epithelium and supports the views proposed by Kastel[22, 23]), Loevenhart[22, 23, 24]), and others. In fact the findings in the superficial epithelial cells are best explained by the same views.

9. The gastric absorption of fat is very similar in character to the intestinal absorption. A comparative study of the two shows that the stomach is no insignificant fat absorbing organ.

Explanation of Plates.

The figures comprising all but the last plate are longitudinal sections of the superficial gastric epithelium or the entire mucosa of the stomach of animals represented in this paper. The last plate gives figures showing the fat absorption of the villus of the duodenum in an early and a late stage. The preparations were made as frozen sections of material after a fixation of three hours in 10 percent formalin. The sections are stained in Herxheimer's Scharlach Roth (Bell's modification) and counterstained with Delafield's hematoxylin. The sections were mounted in glycerin. The figures are outlined with the camera lucida.

Plate I.

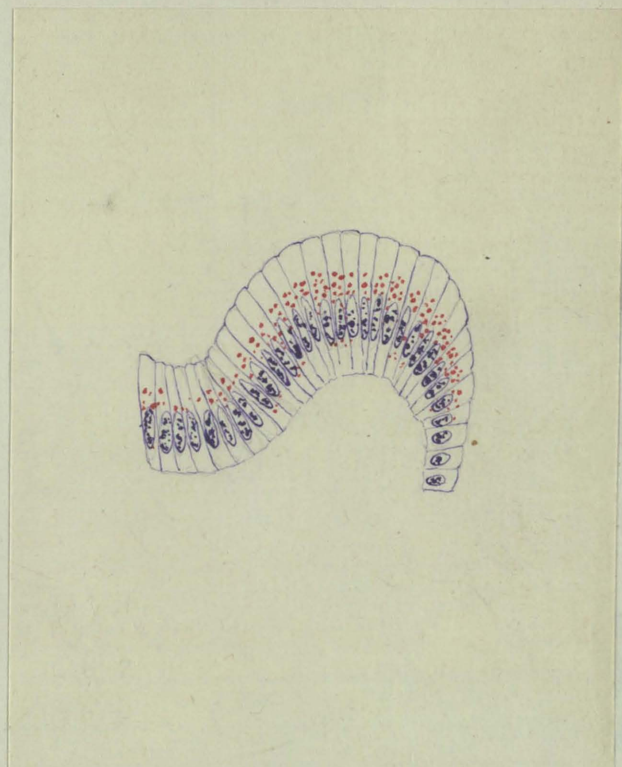


Fig. 1. A group of cells from the cardiac region of the stomach of a sucking kitten. The figure represents fat absorption by the superficial epithelium three hours after the first sucking. The fine droplets are chiefly internal to the nucleus.

Magnification, Leitz ocular 2, objective 7.

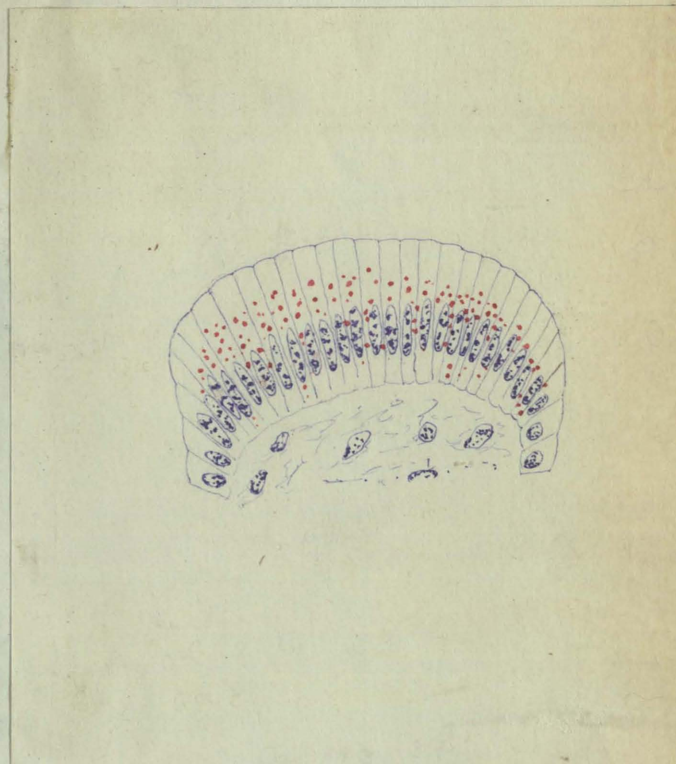


Figure 2. A group of cells from the pyloric region of the stomach of a sucking kitten. The figure represents fat absorption by the superficial epithelium three hours after the first sucking. The fine droplets are chiefly internal to the nucleus, but occur in greater number than in the cardiac region.

To the left the superficial epithelium is directly continuous with that of the next fold. The transition to form the gastric pit is not represented.

Magnification, same as figure 1.

Plate II.

Fig. 3. A portion of the mucosa and muscularis mucosa from the cardiac region of the stomach of a sucking kitten. The figure represents the fat in the superficial epithelium and glandular epithelium six hours after the first sucking. The droplets occupy the deep position in the superficial epithelium and occur in some parietal cells of the cardiac glands.

Magnification, Leitz ocular 1, objective 7.

Plate III.

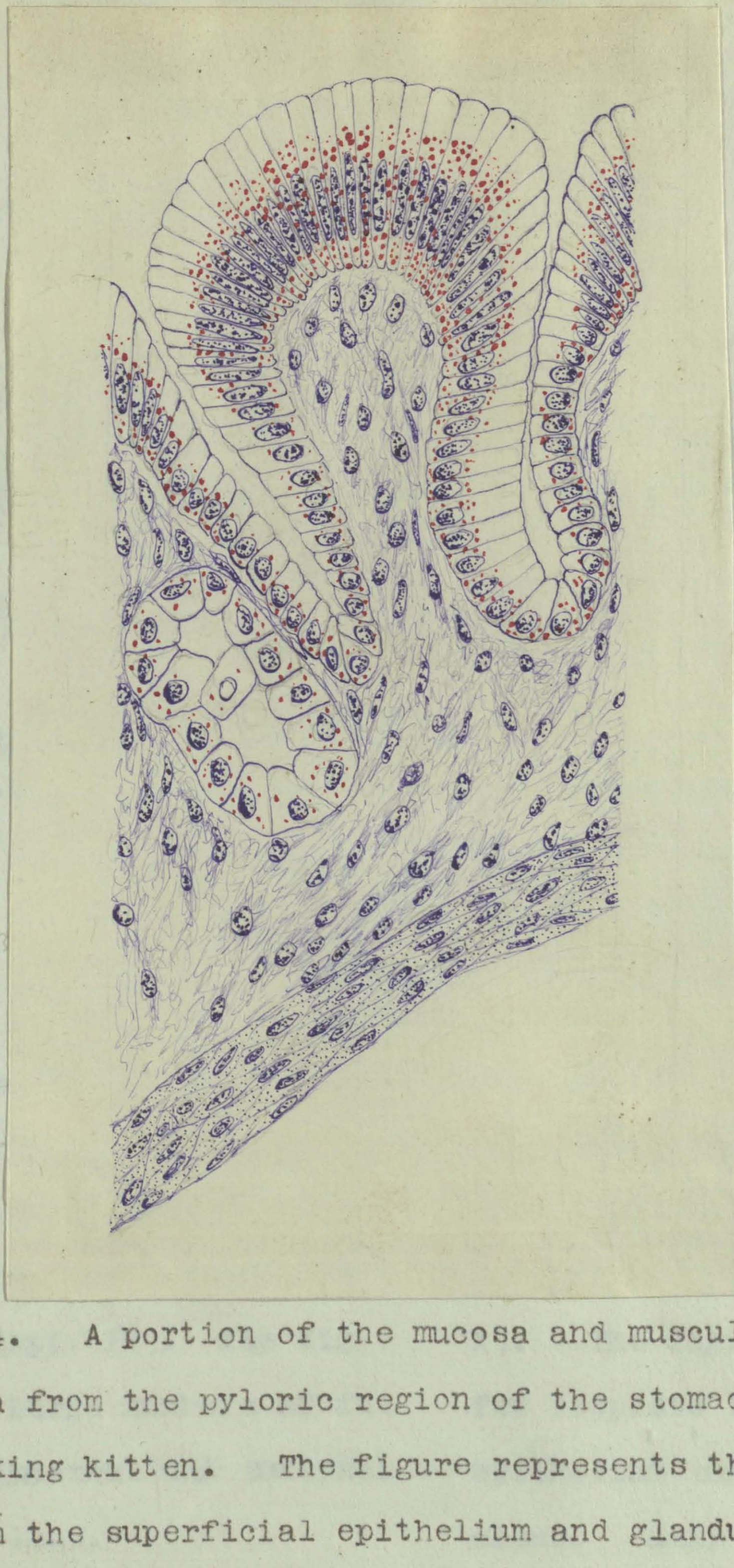
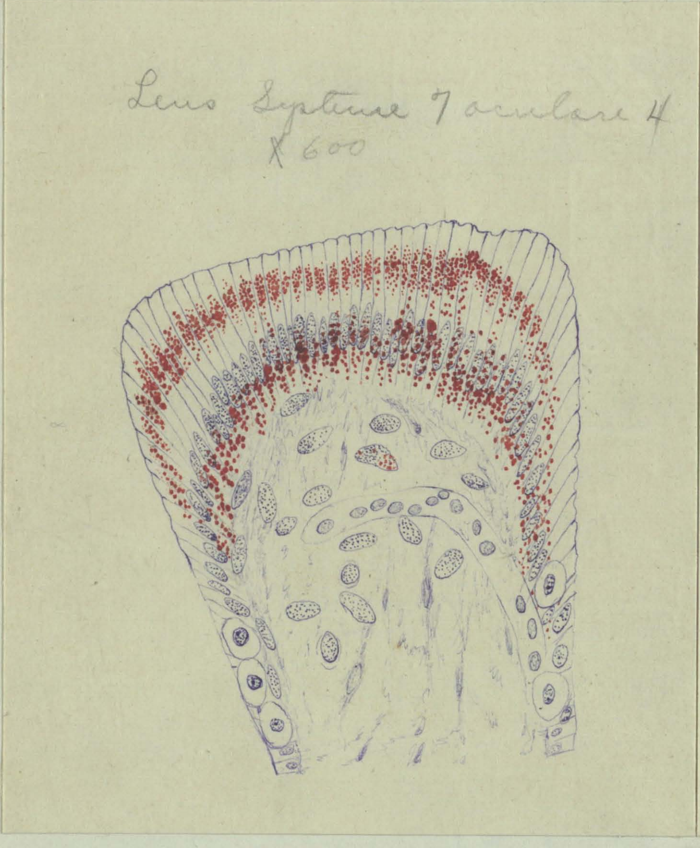


Fig. 4. A portion of the mucosa and muscularis mucosa from the pyloric region of the stomach of a sucking kitten. The figure represents the fat in the superficial epithelium and glandular epithelium six hours after the first sucking. The droplets are more numerous than they are in the cardiac region and occur external and internal to the nucleus.

Magnification, Leitz ocular 1, objective 7.

Plate IV.



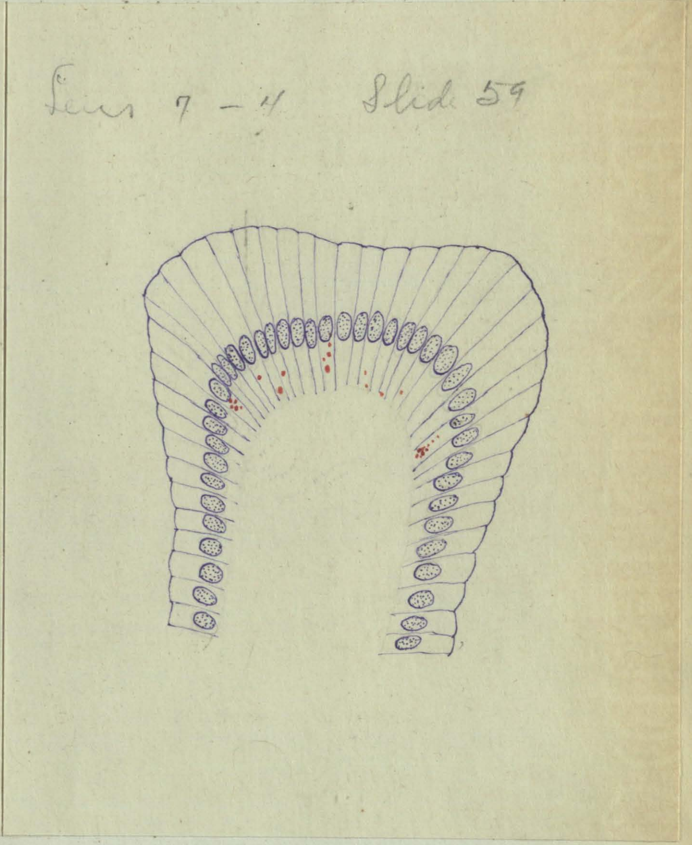


Fig. 5. A fold drawn from the cardiac region of the stomach of a half grown cat. The cat was fasted two days, fed cream and killed three hours after the feeding.(Expt. IV). The figure shows large numbers of fat droplets internal and external to the nucleus.

Magnification, Leitz ocular 4, objective 7.

Fig. 6. A fold drawn from the cardiac region of the stomach of a half grown cat. The cat was fasted two days and killed without a final feeding(Expt. X). The figure shows but a few droplets in the superficial epithelium external to the nucleus. Many droplets are present in the parietal cells of the cardiac glands. Only a portion of the gland is represented.

Magnification, Leitz ocular 5, objective 4.

Plate V.

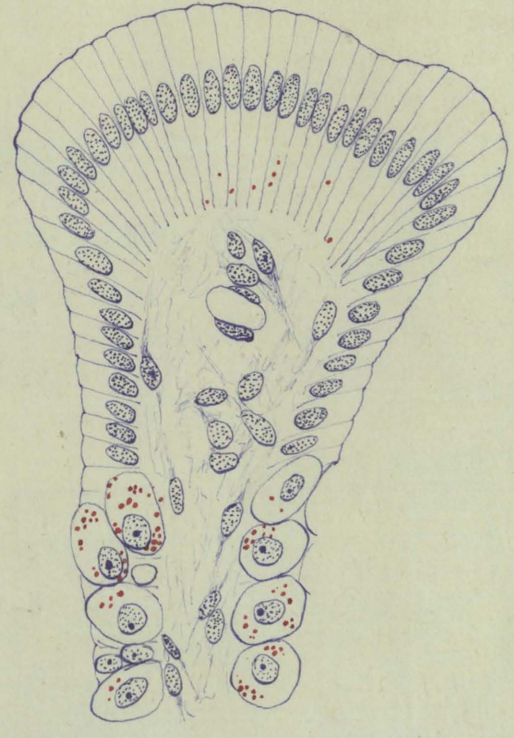


Fig. 8. A fold drawn from the pyloric region of a half grown cat. The cat was fasted two days and killed (Expt. X). The figure shows but few droplets in the superficial epithelium. They are internal to the nucleus.

Magnification, Leitz ocular 4, objective 7.

Plate V.

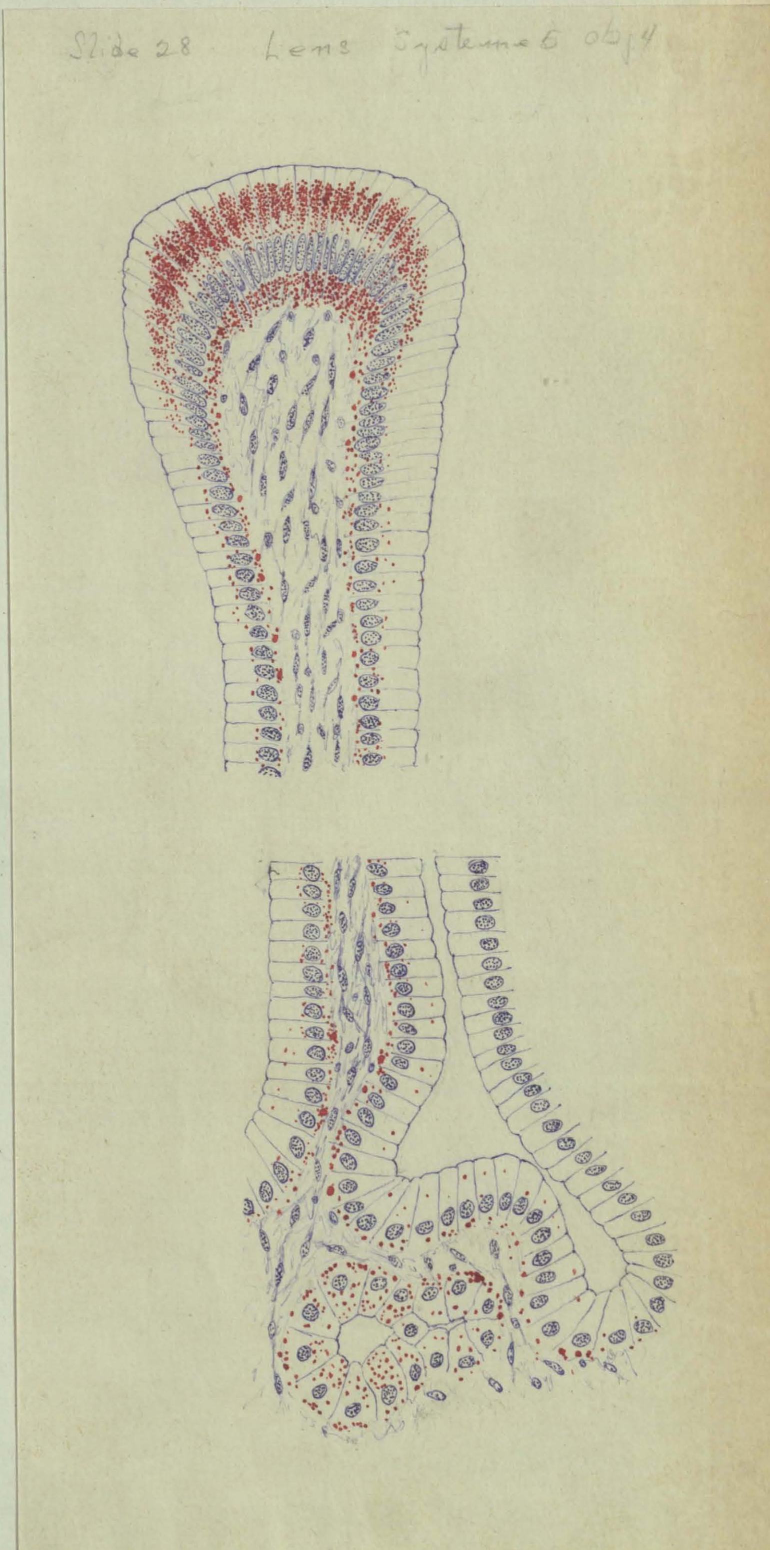


Fig. 7. A fold and basal portion of the gland drawn from the pyloric region of the stomach of a half grown cat. The cat was fasted two days, fed cream and killed three hours after feeding (Expt. IV). The figure represents the fat in the superficial epithelium and the straight and winding tubules of the pyloric glands.

Magnification, Leitz ocular 5, objective 4.

Plate VI.

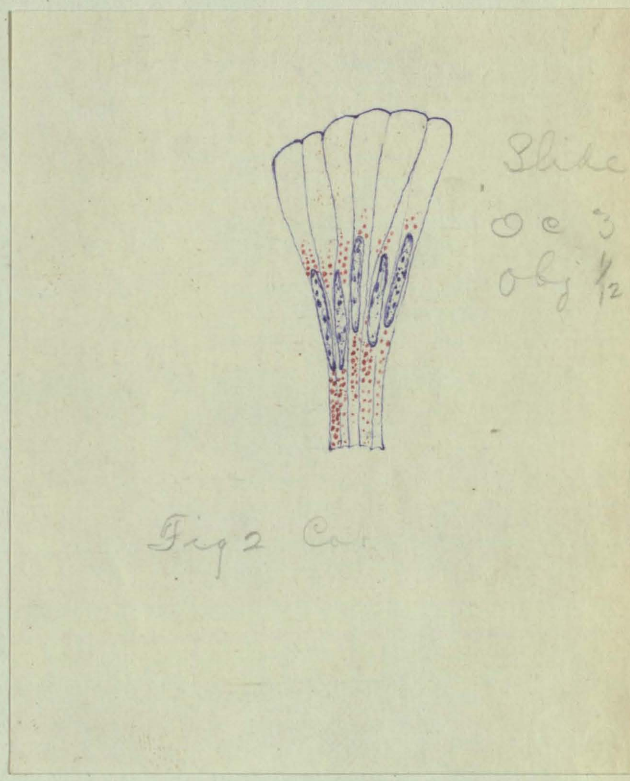


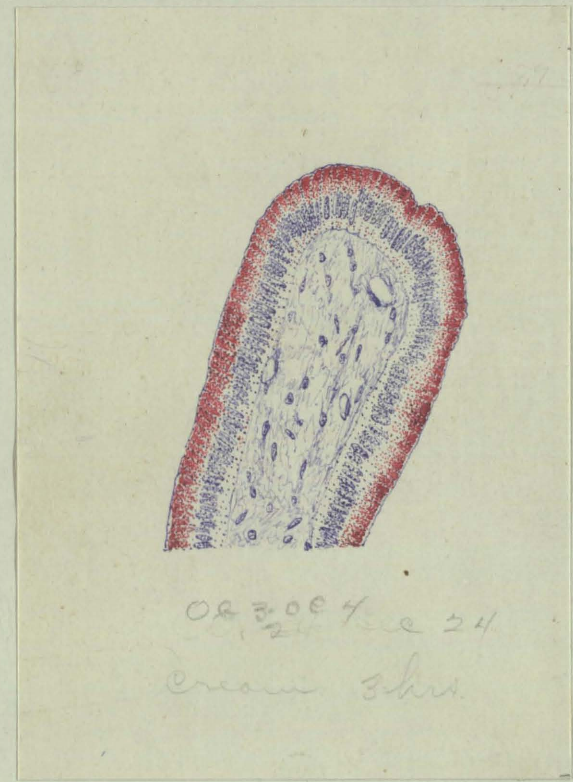
Fig. 9. A group of superficial epithelial cells from the cardiac region of the stomach of a sucking puppy four days old. They show how the fat loads in the cells, especially internal to the nucleus one hour after sucking appears. The droplets are larger than those seen in the cat.

Magnification, Leitz ocular 3, objective 1/12.

Fig. 10. A group of superficial epithelial cells from the cardiac region of a half grown cat's stomach. The cat was fasted two days (after a feeding of table refuse given the animals daily). The fat lies chiefly external to the nucleus. Only a little is internal to the nucleus. The fat droplets are very small.

Magnification, Leitz ocular 3, objective 1/12.

Plate VII.



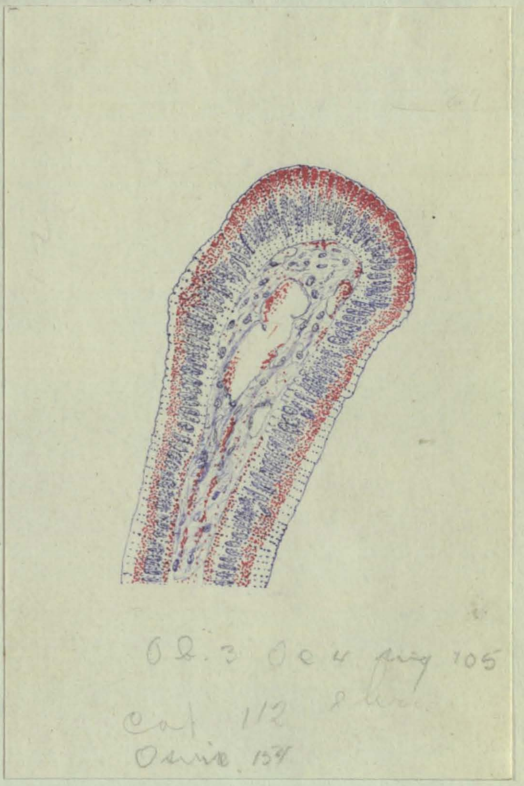


Fig. 11. A portion of a villus made from the duodenum of a half grown cat. The cat was fasted two days, fed cream and killed three hours after the feeding. The figure represents the fat engorging the epithelium in an early stage of absorption.

Magnification, Leitz ocular 4, objective 3.

Fig. 12. A portion of a villus from the duodenum of a half grown cat. The cat was fasted two days, fed cream and killed five hours after the feeding. The figure represents the fat deeper in the cells and giving rise to division into two distinct zones near the basal portion of the villus. The tip is still engorged.

Magnification, Leitz ocular 4, objective 3.

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