ON THE STOMACH GLANDS OF THE RAT AND RABBIT.

By

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In connection with the stomach glands of mammals the following points still remain undecided:

1.) The original character of the cardiac glands found in the stomach of most mammals. The results of many histologists' researches into the original character of these glands may be divided into two classes:

a) The cardiac gland is a peculiar stomach gland like the fundus and pylorus glands.

b) The cardiac gland is a descendant of some other gland, probably the Fundus.

2.) There are several minor questions:

a) Are the chief cells of the fundus gland the same as those of the pylorus or are they not?

b) On the appearance of the Parietal cells and their histological structure.

c) Whether different species of animals have a different distribution of the stomach glands.

This paper has been written in order to answer these questions.

In the first place I should like to give a historical review of the observations on the stomach glands.

Since, Professor Ellenberger in 1881, made his anatomical and physiological studies of the third stomach of ruminants and made clear the physiologi-

[Jour. of the College of Agr., Tohoku Imp. Univ., Sapporo, Vol. VI, Pt. 8, June, 1915]

cal side of that stomach's function, the stomach gland has been studied by many anatomists.

As these studies, however, have been repeated by many histologists, I confine my remarks to a citation of the results in chronological order.

In 1836, Support Boyd was the first to study the stomach glands of the pig. He wrote that in the cavities of the mucous membrane there are no glands, but that blind sack-like glands take their place. He distinguished the Cardia and Fundus glands by their contents.

In 1838, Bischoff remarked from the histological side that there are many varieties in stomach glands, and threw some light on this subject.

In 1839, Wassmann studied the stomach of the pig, and distinguished three kinds of stomach glands: the Cardia gland, the Pylorus gland and the Fundus gland.

In 1870, Heidenhein, in the so-called Pepsin gland, distinguished two kinds of cells: the chief cells and the Parietal cells; to the glands which are in the Pylorus part he gave the name of Pylorus glands and to those in the Fundus part the name of Fundus glands.

Kölliker, found in the cardiac part of the human stomach some glands, which are distinguished by their histological structure from the Fundus glands. These glands he called the cardial glands. He published his observations in, "Mikroskopische Anatomie, Bd. 11 (1850)."

In 1882, Ellenberger examined the stomachs of different domestic animals and worte that the part of the stomach of many animals in which these glands are found, do not resemble to corresponding parts of the human stomach. Further, in 1885, he studied, with Hofmeister the stomach of the pig, and found besides the Pylorus and Fundus glands, still another peculiar gland in the cardiac part. This he named the cardia gland, and wrote that this cardia gland in the stomach of the pig is of a quite different histological structure from the Cardial gland which Kölliker had previously found in the human stomach. In 1887, he worte in his handbook that he had found the cardiac gland in the narrow strip close to the Margo Plicatus.

In 1889, Edelmann examined the stomach glands of various animals and, by the peculiar arrangement, direction and epithel of the gland tubes, distinguished the cardiac gland from the Pylorus and Fundus glands. He detailed many characteristics of the cardiac gland: that the cardiac gland has no Parietal cells, and that many lymph vessels are to be found in the Mucous Membrane. He further wrote that the cardiac gland is to be found in the connection of the Mucous Membrane of the Oesophagus and the digestive Mucous Membrane of the stomach, in a special bag in a separated part of the fore stomach. He found the cardiac gland in Mus muscuraris, Mus documanis and other animals, but not in Lepus-timidus and many other ruminants.

In 1898, Scheffer found special glands in the human stomach that correspond to the cardiac glands of animals. In this case these glands have Parietal cells, and the gland tubes are covered with cup-cells that are not affected by mucous staining, but have a colour reaction similar to that of the Pylorus and fundus glands.

In 1896, Professor Oppel published a text book, "Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere". In the first volume of this he collected all the literature on the subject up to the time of writing and formed a hypothesis for the cardiac gland as follows: "The large expansion is a sinking proceeding: the cardiac gland is not a peculiar gland". For this great work which has served as a key to all histologists who study the stomach glands, we must offer him our best thanks.

In 1902, Bensley said that the cardiac gland is a degenerated organ which has been formed from the fundus gland by the disappearance of its characteristic parts: the parietal cells and the zymogenic chief cells; also that the cells of the cardiac gland show no difference from those of the pylorus and fundus glands.

In 1907, Froehlich found in the stomach of the horse a peculiar gland, which, in its characteristics, is intermediate between the cardiac and the fundus glands. To these he gave the name of, "Übergangsdrüsen" of "Intermedial Drüsen." The histological structure of these glands resembles that of the

pylorus glands in one respect and that of the cardiac glands in many others. These glands may be stained with congo red but not with muci carmin. The pylorus glands, on the contrary, are reacted on with Mucous stain. To distinguish these "Übergangsdrüsen" from other glands, he made the following studies: Material, not embedded in paraffin and unstained is spread out in a drop of warm water placed on the objective glass, the "Übergangsdrüsen" will then show an opaque yellow-grey colour while the Pylorus glands show a dark grey-blue shade.

He further studied the stomachs of goats, cattle and pigs, and found many varieties of "Übergangsdrüsen" in these. In the Mucous Membrane of the dog's stomach which forms the transition to the Oesophagus, he found three varieties of glands: the Seroese and Mucoese cardiac glands and the true Fundus glands. These glands generally have Parietal cells. The Seroese and Mucoese cardiac glands can be stained with Mucous stain to the blind end, the end part of the gland is very little coloured, the reaction on a narrow side part being very good.

In conclusion he said that the histological structure and chemical contents are not the same, but that these glands are to be considered as a philogenetical simplification and are much simplified descendants of the Fundus glands.

In 1905, Hamme wrote of the cardiac glands of the stomach of domestic mammals and distinguished them from other stomach and oesophageal glands as follows: The pylorus gland is generally straight, and broadened at the blind end while the cardiac gland has a snake-like form, no broadened end and runs singly. He also made a comparison between the cells of the cardiac, pylorus and fundus glands, but as I wish to compare his results with my own histological studies I will write of these later.

Besides these he made chemical studies and said that the fermentative contents of the cardiac gland are amylolitic, but the rennet, milk-acid, fat and peptic ferment are absent. In conclusion he wrote that the cardiac gland is by its chemical and histological structure quite different from the pylorus and

fundus glands, and that, therefore, the cardiac gland is quite distinct from all other stomach glands.

As I have said above, the opinions on the cardiac gland, up to the present time, may be divided into two classes:

1. The cardiac gland is a peculiar kind of stomach gland. This opinion is held by Ellenberger and other histologists who studied in his Institute, as Hamme and Edelmann.
2. The cardiac gland is an outcome of the Fundus gland. Professors Oppel, Fleischmann and Bensley hold this opinion.

For the sake of convenience, Mus muscuraris and Lepus cuniculus have been employed as material. From these animals which have been killed with chloroform vapour I have cut out the stomach with a small portion of the lower part of the Oesophagus, a small portion of the upper part of the small intestine remaining. It was cut open along its long curvature and the contents washed away with physiological salt solution. The stomach was divided as follows:

1. A connected part containing the thick-walled portion which will be called the cardiac sac and the thin-walled portion, the Fundus portion.

2. A connected part containing a portion of the small intestine and stomach proper and other different portions.

This was thrown into fixation fluids. As fixation fluids I have always used Picro-sulphuric acid solution, Zenker's solution and Muller's fluids.

The material was placed in 70% alcohol, then transferred to 80%, and to successively higher grades of alcohol. As staining I have used double staining, Hansen's haematoxylin combined with congo-red. For Mucous reaction of the stomach gland, I have used muci-carmin, iron-alum, eosin and toluidin. The material was cut in serial sections with a thickness of 5μ.

In 1909, I studied the stomach of the Mus muscuraris and Lepus from a histological and anatomical standpoint, but since that time I have obtained further material and continued my researches, the results of which are given in this paper. Whenever my present results correspond with my former

ones, I shall repeat these.

A. Macroscopical Features.

The stomach of the rat is reniform in outline and receives the distal end of the Oesophagus at the middle point of its concave surface; the half to the left of the oesophageal connection is raised and bent against the oesophageal tube, while the right half passes over through the pyloric constriction into the Duodenum. The left half is thick-walled and shows in fresh specimens dully white colour, resembling in these respects the Oesophagus; the right half has, on the other hand, comparatively thin walls which are, like the Duodenum, of pink colour.

On the inner surface of the stomach likewise two portions are to be distinguished; the thick-walled portion which will be called the cardiac sac simply because it represents the cardiac portion in other mammals, and the thin-walled portion comprising these parts which represent respectively the Fundus and the pylorus. This latter portion will be called the Ventriculum. The surface of the cardiac sac is very harsh and leather-like, owing chiefly to the presence of a complicated system of wrinkles, causing the walls to be thickened. The wrinkles which, though variable, occur mostly from seven to eight in number are undulated in their course; nevertheless, each two, or sometimes three of them run in parallel. The wrinkles in the proximal part pass over into the corresponding structure of the Oesophagus.

The wrinkles take in the Oesophagus not an undulated course as in the cardiac sac, but are represented by a number of longitudinal ridges which are nearly uniform in thickness and cause the oesophageal walls to be thickened. Whilst none of these longitudinal ridges are uninterruptedly continuous with the cardiac wrinkles, others disappear at the neck by which the Oesophagus is connected with the stomach.

Killing the animal immediately after feeding and cutting its gastric pouch open; we find the cardiac sac filled up with the food roughly masticated, while the Ventriculum remains empty. The cardiac sac is therefore

to be looked upon physiologically as the food-store, similar to the rumen in Ruminants.

From the statements above given it is true that the cardiac sac can not be distinguished from the Oesophagus by means of a rough macroscopical survey such as just done, so that the two parts are to be regarded as one and the same structure. In other words, the cardiac sac is nothing other than the distal part of the Oesophagus strongly bulging out.

The Fundus, the broadest part of the stomach, is marked off against the cardiac sac just stated by a continuous ridge describing a circle which is situated in an oblique position. On the bottom surface of the stomach the boundary ridge is found just opposite the oesophageal opening, and on the roof surface, where the circle is notched, it is seen right to, and at a little distance from the oesophageal opening, whiles on the lateral walls it is shifted to the left side beyond the oesophageal opening. The Oesophagus is, therefore, not led directly to the Fundus, but passes into the cardiac sac through a narrow groove which deserves the name of Oesophagus-cardiac groove. The boundary ridge itself shows numerous large and small undulations which occur especially in the adjacent parts of the oesophageal opening. The surface of the Fundus walls is apparently smooth; in fixed specimens some irregular foldings appear, owing doubtless to a strong contraction of the muscle-coat of the stomach.

Without any demarcation, the fundus passes over into the Pylorus where the gastric sac is considerably narrowed into the pyloric constriction. The surface of the pylorus walls is likewise smooth. The Duodenum which is represented by a slender tube forming the distal continuation of the Pylorus shows a sudden change on the inner surface, presenting velvety appearance, which is, of course, due to occurrence of the thickly set together

In the stomach of Lepus cunniculus (rabbit) the cardiac and pylorus portions may be distinguished on the surface of the inner side, the surface of the latter portion being tufted; the wall on the former is rather thin, particularly when the stomach is full of food. Food, when taken, passes into the cardiac

portion and is kept here, then gradually sent into the pylorus and fundus portions as we have already seen in the case of the stomach of the rat.

The cardiac portion of Lepus cuniculus is very large, occupying two-thirds of the stomach. The connection of the cardiac and fundus glands is not distinguishable by the naked eye and there is no boundary ridge.

B. Microscopical Anatomy.

According to the above mentioned modification of the gastric pouch, the three layers of which the gastric walls are composed show features peculiar to each of the three regions. Most striking are the changes undergone by the innermost layer of the three, the Mucosa layer. Fig. 1. represents a semidiagrammatic longitudinal section through the boundary ridge which marks off the Fundus against the cardiac sac. The regular Epithelium which lines the inner surface of the Fundus passes over, at the point marked with X, suddenly into a multicellular Epithelium, lining not only the boundary ridge itself, but the cardiac sac also.

The Mucous Epithelium is uninterruptedly continuous with the multicellular Epithelium; yet these two sections of the Epithelium are widely divergent from each other as regards their histological character. The former is constructed of a single row of columnar cells raking regular epithelial arrangement; the latter is, on the contrary, composed of a layer many cells deep and accordingly attains a considerable thickness in contrast to the comparatively thin Mucous Epithelium. In this multicellular Epithelium, moreover, two layers are distinguished; the outer layer is, on sections, fibrous in appearance, while in reality it is formed of numerous strata of dry flattened epithelial cells loosened to be ultimately cast off; the inner layer is compact in texture, being composed of protoplasmic epithelial cells closely set together. In this compact part of the Epithelium several interesting facts are to be noticed. As will be seen on reactions, the nuclei which are scattered in the layer in question are thickly put together in the basal part of it and grow lesser and lesser towards the peripheral part where the layer shows every

appearance to be split so as to give rise to the outer loosened layer. In the basal part the nuclei are crowded because here active cell-multiplication is taking place.

From the facts above pointed out, it is true that the cardiac sac which occupies in volume about one half of the gastric pouch cannot be distinguished histologically from the Oesophagus, it represents a part of the Oesophagus. We see, therefore, that the results arrived at by the microscopical examination perfectly confirm my conclusion above given according to which the cardiac sac is nothing but a part of the Oesophagus strongly bulging out and serving as a temporary strage place for food. If this assumption is valid, the boundary ridge itself is to be included in the eosophagal parts ; for it is by no means distinguishable from the cardiac sac as far as the microscopical structure is concerned.

Let us now turn to the corresponding structures in the domestic rabbit, which have been almost satisfactorily made known by previous authors. In the first place, the Gastric pouch is simple, being entirely occupied by the ventricular part; there is no appendage existing which corresponds to the cardiac sac of the rat. As obvious, the left part of the gastric pouch is protruding upwards, apparently looking like a cardiac sac, but it is a part of the ventricular section so raised. Consequently the boundary ridge shifts to the so-called Cardia at the base of the Oesophagus, describing a small circle at the height of the Gastric pouch, instead of a large ellipse at the middle transverse vertical plane of the corresponding pouch in the rat. As a comparison of (Pl. X. Fig. 2) which represents a diagramatic longitudinal section with (Pl. X. Fig. 3) which is a diagramatic view of the median longitudinal section through the rabbit's stomach and the Oesophagus shows, the difference is strikirg between the gastric pouches of the animals referred to; if the stomachs of these iwo animals are taken as being equal in bulk, the digestive surface of the rat's stomach is in extent only half of that of the rabbit.

As the necessary consequence of such a gastric construction as above given, the distribution of the gastric glands of the rabbit shows correspond-

ing diver gence in the rat's case.

(I) The Cardiac Glands.

The cardiac glands of the stomach of the Rat are distributed in the narrow zone just inside the boundary ridge so as to describe an ellipse along the latter. The cardiac glands of the rat, according to the many specimens I have examined, are in contradiction to the assertions of many histologists never more than seven in number. I, at least, have never been able to find so many. The connection between the Epithel of the cardia gland and the Epithel of the Oesophagus that composes the cardiac sac, is the communication between the epithelium cells of the cardiac gland and the cells which have a relatively large nucleus that shows a good reaction with Haematoxylin and which envelope the Papillae of the mukose, these having a complex form in the connecting part. The change from the epithelium cells of the cardiac gland and the basal cells of the Epithelium of the cardiac sac in the region of the junction is very gradual and the two cannot be distinguished.

The form of the cardiac gland is not branched and shows a very simple shape. The tubes run first at right angles to the wall of the stomach and then parallel or slightly inclined, and parallel to the ridge which forms the connection with the cardiac sac.

The gland nearest the connection with the Oesophagus is very simple, sometimes formed of a single cavity. The epithelium cells of the cardiac gland are of homologous columnar form and are firmly joined together. The nucleus lies at the bottom of the cell. The surface epithelium cells of the cardiac gland are of higher cylindrical form than those at the bottom, but the contents of all cells of the gland are the same.

The connection of the cardia and fundus glands may be known from the appearance of parietal cells. The cells of the cardiac gland gradually change to the chief cells of the fundus gland; in this place, therefore, the cells of some of the glands show an intermediary form between those of the cardiac gland and the chief cells of the fundus gland. Among such intermediary

cells parietal cells may sometimes be found.

In the case of the pig and the horse, other histologists have obtained no colour reaction at all, but in the case of the rat a weak mucous reaction is the result which, with eosin, is still better.

The cardiac glands of the stomach of hares and rabbits are distributed over a small area, being arranged in a row at the base and along the boundary ridge; they are consequently much fewer in number as compared with those of the rat, but they can be distinguished from the fundus glands by their histological structure. The cells of the cardiac glands are quite similar to those of the cardiac glands of rats.

As written above the number of cardiac glands is very small, sometimes, therefore, intermediary glands may be seen between the Oesophagus and fundus glands. From my own observation, I have never found more than four rows of cardiac glands along the connection of the Oesophagus and the stomach.

Hinze distinguished the cardiac gland cells, the chief cells of the fundus gland and the pylorus gland cells by their histological structure and wrote, "The cells of the Pylorus gland are flat and have a nucleus at the base and show a good reaction with mucous colours (muci-carmin and toluidin-blue,) similar to the cells of the mucous gland. The cells of the cardiac gland have relatively larger and blister-like nuclei; no reaction is obtained with mucous colour.

The difference between the fundus and the cardiac glands is that parietal cells are found in the former; the cardiac glands are affected by eosin, the chief cells of the fundus glands, however, very little or not at all."

I shall have occasion, later on to write my own views on the histological difference between the cells of these three glands.

(II) The Fundus Gland.

The Fundus portion of the rat is next in size to the cardia sac and is connected with this by the cardiac glands. The tube of the fundus gland may

be divided into two parts according to form and histological structure, viz: the gastric crypt andthe gland lumen. The epitheluim cells of the Gastric crypt are, on the superficial epithelium, of elongated cylindrical form and firmly joined together, but they gradually become rounder and the contents increase towards the end part of the gland. The cells which enclose the end part of the gland may be distinguished from those of the gastric crypt as the former are of very round form with the nucleus in the middle, while the contents are much clearer than those of the latter. When stained with hæmatoxin the cells of the epithelium and of the gastric gland are more coloured than those of the end part of the gland. When eosin is used for staining the cells of the epithelium show some reaction, the chief cells of the cardiac gland give a very good reaction. With mucous colour some reaction is obtained in the cells of the epithelum and in the chief cells of the fundus it is very good, while in the cells of the cardiae gland there is occasionally a very slight reaction but usually none at all.

The result of the observations of colour reaction in the cells of the epithelium and in the chief cells of the fundus gland may be summarised as follows: with mucous colouring the cells of the cardiac gland and those of the fundus gland are affected in a quite opposite manner, and the cells of the epithelum of the fundus gland have a similar colour reaction to those of the cardiac gland.

Among the intermediate cells between the gastric Crypt cells and the cells of the end part of the gland I have found Parietal cells. These, as Heidenhein and other histologists have remarked, are of round or oval form with the nucleus in the middle, and the ends of those against the Lumen pointed. My finding Parietal cells among the intermediate cells agrees with the result of Heidenhein's observations (1870), when he found Parietal cells among the cylindrical cells of the gland outlet of the Fundus. Bentkowsky (1796) found Parietal cells in the outlet of the Pepsin gland and Oppel obtained a similar result in the case of a number of mammals. In the rat, however, the Parietal cells among the intermediate cells are very few and difficult to find, and

among the epithelum of the Fundus gland I have never seen any.

In the delicate structure of the Parietal cells I have seen no network as other histologists affirm, and the contents of the cells are always homologous.

Parietal cells with more than one nucleus, which Trinkler found in 1884, and in particular the intermediary cells between the chief cells and the Parietal cells, which Edinger found in human beings in 1879, I have not been able to find.

I have seen some Parietal cells which were slightly changed by the loss of some of their contents and therefore resemble the chief cells of the Fundus, but, by staining, these can be distinguished from the chief cells. In the neck of the Fundus I have not been able to find chief cells, being enclosed with intermediary cells as related above.

By histological observation I have distinguished the different points of the chief cells of the Fundus gland and the cells of the Epithelium as follows:

The cells of the Epithelium are of high cylindrical form and firmly joined together. The nucleus always lies at the base and the cell membrane is very distinct. With hæmatoxin and eosin the cells of the Epithelium are more affected than the chief cells of the Fundus. The form and colour reaction of the cells of the Epithelium are similar to the cells of the Cardia gland. On the other hand, the chief cells of the Fundus gland have a more or less spherical form, with clear granulated cell contents. There is little or no reaction with eosin and hæmatoxin. They enclose the end part of the Fundus gland and contain many Parietal cells among them.

The Parietal cells with two nuclei, which, in 1895, Bohm and Davidoff found in this animal, I have never been able to find. I have seen, however, cases which, when stained with a strong congo-red, have a comparatively thin membrane; the contents give a good reaction so that the wall between the two cells is sometimes invisible and the two appear as one cell containing two nuclei. When a weak staining is used with such cells, the membrane between the two can be distinctly seen.

The results of the above histological abservations may be summarised as

follows:

1.

The cells of the Fundus gland may be divided into four kinds:

a. Superficial epithelium cells.

b. Intermediate cells.

c. Chief cells.

d. Parietal cells.

2.

Among the superficial epithel cells there are no parietal cells.

3.

parietal cells with two nuclei are not to be found.

4.

Among the intermediate cells the parietal cells are rarely found.

5.

Intermediary cells between the chief cells and parietal cells are absent.

6.

The histological structure of the superficial epithelium cells of the Fundus gland is similar to those of the cardia gland.

The Fundus glands of hares and rabbits occupy two-thirds of the stomach surface. The cells of the fundus glands, in this case, are divided into four kinds: superficial epithelium cells, intermediate cells, chief cells and parietal cells.

The chief cells are not affected with eosin or only very slightly, but the superficial epithel cells give a very good reaction; the intermediate cells give a correspondingly medium reaction. In this case the parietal cells are very large and occur in greater numbers among the intermediate cells than in the case of the rat. Among the superficial epithel cells, as in the rat, none are found.

In 1879, Langley and Sewell divided the surface of the stomach into four regions:

1.) Fundus (the gland showing comparatively few parietal cells). 2.) Large curvature. 3.) Small curvature. 4.) Pylorus.

I, however, have not been able to find such regions by the histological

structure, particularly is there no difference between the first and second regions.

(III) The Pylorus Gland of the Rat.

Then next come the Pylorus glands, as they are commonly called, under consideration. The walls of the glands are composed of tall cylindrical cells, arranged regularly and compactly put together, just like those in the cardia gland. In the majority of mammals the glands send off branches at their basal part, and those of the second order which are more or less contorted pass over without sharp demarcation into the duodenal gland. In the species in question, the pyloric glands are, on the contrary, straight, and show not even a tendency of ramification, consequently the glands push, into the submucosa layer, but are confined to the outside of the muscularis mucosa stratum. In this respect the pyloric glands are very easy to distinguish from the cardia glands which bear a great resemblance to them and show sharp contrast to the duodenal glands with which they are in close annex.

The cells of the pylorus gland may be divided into two kinds: the superficial epithelium cells of the pylorus gland, which are tall cylindrical cells compactly bound together, and the cells which enclose the branched end part which are somewhat apherical and bear clear contents.

The colour reaction of the former cells is similar to the superficial epithelium cells of the fundus glands, and that of the latter to the chief cells of the fundus gland.

There is no difference between the histological structure of the superficial cells of the fundus and pylorus glands.

In 1894, Sappey obtained a similar result.

In 1869, Klein found Parietal cells among some Pylorus glands I, however, have not been able to find such in this case, but in the intermediary form glands between the Pylorus and Fundus which are found in connection with these two glands, I have sometimes seen them.

In 1870, Ebstein, gave to this same gland in the dog and cat, the name

of Magen schleimdruesen, and wrote: "The cells of the stomach surface and the epithel cells of the gland tube and the chief cells of the pylorus glands are of different structure and the latter are enclosed with chief cells of the rennet gland."

Similar to this result, in 1876, Bentkowsky wrote that the chief cells of the fundus and pylorus glands are a morphological homology.

On the other hand, Langley and Sewell (1879) stated that in the dog and the rat the pylorus gland cells are, in a fresh condition, very clear and have fine granulated contents with a generally distinct Lumen. Therefore, in a fresh condition, they may generally be distinguished from the Fundus gland cells.

In 1880, Heidenhein stated that, in a fresh condition, the chief cells of the fundus glands contain deep dark nucleuslike contents, but the cells of the Pylorus gland have much finer granulated contents.

Ellenberger, in 1884, wrote that the cells of the pylorus gland are similar to the chief cells of the fundus gland, but are not the same. He also distinguished the cells of the fundus gland from the superficial epithel cells by the fact that the former are totally coloured with carmin but that only the nucleus of the latter is affected. He also distinguished the chief cells of the fundus gland from those of the pylorus gland in that the pylorus gland cells are closely and finely granulated packed, compactly and that they contain some mucin and are easily affected by acetic acid.

According to my own histological observations, the form and the contents of the cells at the end part of the pylorus gland and the chief cells of the Fundus gland are similar, but a still more detailed comparison shows that the cells of the former are of more columnar shape and are more uniformly arranged than the chief cells of the fundus gland.

The pylorus glands of rabbits occupy one-fifth of the gastric pouch. In regard to the areal proportion of their distribution this class of glands is therefore not markedly different from that in the rat.

(IV) The Duodenal Glands of the Rat.

The histological structure of the Duodenal glands is very simple. They cannot be distinguished from the pylorus glands. The tall cylindrical cells of which the gland walls are composed are uniform and take regular epithelial arrangement, supported upon the basement membrane. The Duodenal glands open between the villi, at the basal part of them. Abundant occurrence of the Goblet cells in the mucous epithelium of the Duodenal marks off this section of the alimentary canal from the Pylorus, where no trace of this class of the epithelial components is met with.

The duodenal glands are lost from sight at the opening of the bile-duct.

As to the structure of the Duodenal glands of rats there are two points which perhaps need special mentioning; the Duodenal glands in the rat show in the first place every graduation of the morphological transition to the pyloric glands, so that the Duodenum and pylorus present no sharp demarcation in this respect, whereas we see, in the rat, a sudden change in the passing from one of these parts to the other. This striking feature in the alimentary canal of therat is, in the second place, attributable chiefly to repeated ramification of those Duodenal glands lying close to the Pylorus; on the other hand, in the rabbit this suddenly increased ramification of the glands is not the case, as the glands are almost equally ramified throughout the whole extent of their occurrence, being neither suddenly decreased in their number, though this is the case in the rat's Duodenum.

Histological Review of the Researches on the Stomach of Rat and Rabbit, and Conclusion of the Macro. and Microscopical Studies.

In spite of the rapid progress which morphological science has recently undergone a detailed study of the rat's alimentary tractus has been neglected for more than twenty years; so far as I am aware, since the appearance of the notable observation byE delmann in 1889, no work concerning the system of the organ in question has been published.

The first investigation was made as early as 1807, when Home published his work. This work must, of course, be appreciated so far as it is a work of such an early date; yet it is very rough and incomplete in observation. The author incorrectly assumes that two portions, the Ventriculum and the Cardia, are found in the stomach of the house rat. In 1854, Leydig published his work which shows to a great extent full agreement with the present results obtained by myself. He correctly made out the distinctive difference of the cardiac portion from the Ventriculum. According to him, the latter portion is thickly covered with innumerable gastric glands, whereas the cardiac portion is entirely destitute of these glands, being completely covered by a consistent skin quite like the membrane coating the inner surface of the Oesophagus.

In 1889, Grimm wrote that the blind sac of the Cardia part of the mouse's stomach has plaster epithel and is lacking in glands.

The occounts given by Edelmann (1889) are, in accuracy as well as in correctness doubtless lifted above the level arrived at by all the previous observers. Whilst in the works previous to his, only the common name of the animal employed as material was given, Edelmann states the scientific name of the animal forming his material; he made use of Mus documanus. Furthermore the author pointed out, for the first time, the existence of the cardiac glands in the mouse, which, before his time had been entirely overlooked. In details, however, I cannot confirm his results. In the first place, as seen in a figure given by the author, the distribution of the cardiac glands is exceedingly large in extent; it is so large that the glands extended so much

further as to be put in rows continuous not only with the fundus glands but also with the pylorus glands. In reality, as stated in the foregoing pages and as seen in the diagramatic view given in (Pl. X. Fig. 2), the cardiac glands are confined to a narrow belt running along the boundary ridge marking off the Ventriculum from the cardiac portion. Edelmann believes, in the second place, that the cardiac glands, the fundus glands as well as the Pyloric, are, as regards their distribution, different according to the species of the rats worked with by him, i. e. Mus documanus and Mus rattus. This is in reality not the case; my present work has been carried on chiefly with M. documanus, and to control the facts obtained, I made use of M. rattus but was the unable to detect so remarkable a difference according to the species as Edelmann says, though repeated careful observations were made. In the third place and lastly, there is a wide gap between the results obtained by myself and those by Edelmann, concerning the transition of the pyloric portion to the Duodenal portion. Edelmann gives no accurate account of the structure of the Pyloro-duodenal passage. As given in the foregoing pages, the Duodenum of M. documanus shows a striking difference in the pylorus on account of enormous aggregation of the Duodenal glands at the commencement of the intestine, while in M. rattus the pylorus gradually passes over into the Duodenum without any sudden change in structure.

In 1890, Sclavunos writing on the plaster epithel of the cardiac portion of the mouse's stomach said that the cells lying deepest are more or less round and become flatter and flatter towards the top; the nuclei show from two to six grains.

It was in 1891 that a joint work by Klein and Verson appeared. The authors believe that the Oesophagus leads directly into the cardiac portion; they considere the latter portion as a part of the former. Otherwise the work adds no facts to the results arrived at by previous authors.

The stomach glands of rabbits have already been studied by many histologists. In this place, I will note the chief observations only.

In 1807, Home was the first to study the stomach of Lepus timidus and

Lepus caniculus, and to distinguish the cardiac and pylorus portions. He stated that the Mucous Membrane of the former is thick and the surface tufted.

In 1871, Rollett studied the stomach from a physiological side, and wrote that it is impossible to find a perfectly empty stomach among rabbits, and that even when fed with milk only, solids are to be found in the stomach.

Langley and Sewell, in 1879, divided the Stomach of Lepus caniculus into four regions.

In 1889, Edelmann found that in Lepus timidus the cardiac glands are absent. But as written above, I have, in the junction of the Oesophagus and the fundus parts, found a few cardiac glands. He further says on the Fundus glands of hares, "The fundus glands have large cells which in many cases are triangular or rounded on one side and contain large nuclei. They are not affected by Eosin staining and only show a weak red colour." He could find no cardiac glands in Lepus caniculus.

Because specimens are so easy to obtain, many results have been gained by histologists which generally point to the same conclusion and I will therefore not quote them further.

In the foregoing lines, the chief points of structural difference of the gastric pouch of the rat from the rabbit's has, as I believe, been pointed out, and we will now turn to the summimg up of

I) The characteritics of the rat's Stomach and the Duodenum, as follows:

1.) The stomach is divided into two parts equal in capacity: the proximal part constitutes the cardiac sac and the Distal part answers to the Ventricle in other mammals.

2.) The cardiac sac is distinguishable from the Oesophagus as regards its microscopical as well as macroscopical structure; it is represented by a basal expansiou of the Oesophagus.

3.) The boundary ridge which marks off the two divisions of the sto-

mach from each other is oesophagal in its microscopical texture and is to be looked upon as a part of the cardiac sac.

4.) The distal or ventricular part of the stomach is, as in other mammals, to be subdivided into two parts by the nature of the glands occurring in respective parts. The proximal part represents the fundus wherein open chiefly the Fundus glands; the distal part constitutes the Pylorus possessing the so-called Brunner's glands. The latter part is very small in extent as compared with the former.

5.) The three kinds of glands discernible in the rat's stomach are distributed, but not intermingling over three zones well marked off against eachother. The cardiac glands occur along the boundary ridge in a narrow zone, about three glands in breadth, descrsbing an ellipse. Whilst the fundus glands do not differ from those in other mammals, the Pylorus glands show a remarkable contrast; they are neither branched nor croocked, nor do they enter the Submucosa layer, being represented by simple slender tubular glands.

6.) In the two species, Mus muscuraris and Mus documanus, I have been unable to find a different arrangement.

7.) The superficial epithelium cells of the Fundus gland and the superficial epithelium cells of the Pylorus have the same histological structure and are very similar to the cardiac gland cells.

8.) The duodenal glands show a great contrast to the pyloric glands and thereby the two parts of the alimentary tractus are sharply separated from each other; the duodenal glands are repeatedly branched, not only so but much crooked, so that the Submucosa layer containing them is considerably extended in thickness. This feature is, however, to be seen only in the beginning of the Duodenum; the canal shows a sudden decrease in branching and consequently in thickness in its submucosa layer.

II) The characteritics of the rabbit's stomach are as follows:

1.) The surface of the rabbit's stomach may be divided into two parts: the fundus gland region which occupies two-thirds of the whole and the pylorus gland region which occupies the remainder.

2.) The stomach glands of the rabbit like those of the rat may be divided into three kinds: the cardiac glands which can always be found in a small number in the junction of the oesophagus and stomach, the Fundus glands and the pylorus glands.

3.) The stomach glands of rat and rabbit have the same histological structure, only the number of the glands and the size of the cells is different.

4.) The arrangement of the stomach glands and their histological structure are the same.

As written above, I have, in the rat and rabbit, found three kinds of glands in the stomach, but from the histological structure of the cells of each gland five kinds may be distinguished:

1.) Parietal cells.

2.) Chief cells of fundus gland.

3.) Chief cells of pylorus gland.

4.) Superficial epithel cells of fundus and pylorus glands.

5.) Cardiac gland cells.

In these five different kinds of cells, the second and third are very similar, but in the rabbit's stomach I have found the slight difference, that the chief cells of the pylorus gland are more columnar and compact than those of the fundus gland, that the nucleus in the former always lies in the basal part of the cell but in the latter it lies comparatively in the middle part of the cell.

Between the fourth and the fifth kind the histological difference is very slight, particularly when the cardiac glands are very few as in the rabbit, they are then almost the same as the superficial epithelium cells of the stomach.

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Explanation of Plates.

Plate X.

Fig. 1. A section from a series of sections cut vertically through the boundary ridge and its adjacent part of the rat's stomach; magnification Zeiss d. 3 and camera.

Fig. 2. A diagramatic view of the rat's stomach reconstructed from series of the sections. The discontinuous transverse lines show the extent of the structures of oesophageal nature; the boundary ridge is represented by the oblique lines; the crosses indicate the area in which the pyloric glands are distrubuted; and the area of the distribution of the fundus glands is shown by the dots.

Fig. 3. A diagramatic view of the rabbit's stomach.

Fig. 4. Cardiac gland of rat.

Fig. 5. Fundus gland of rat.

Fig. 6. Pylorus gland of rat.

Plate XI.

Fig. 1. A section from the same series of sections shown in Plate X. Fig. I. being highly magnified; magnification Zeis D 3 and camera.

Fig. 2. Section through cardiac gland of the rat's stomach.

Fig. 3. Section through fundus gland of the rat.

Fig. 4. Section of rabbit's oesophagus, showing a cardiac gland and fundus gland.

The following abbreviations are used throughout the plates.

a. c. ..... accessory cells.
b. r. ..... boundary ridge.
e. c. ..... chief cells.
c. g. ..... cardiac gland.
c. s. ..... cardiac sac.
d. ..... duodenum.
d. g. ..... duodenal gland.
e. ..... epithelium.
f. ..... fundus.
f. g. ..... fundus gland.
g. f. ..... gastric.
l. u. ..... lumen.
m. m. ..... muscularis mucosa.
o. e. ..... oesophagus.
p. ..... pylorus.
p. c. ..... parietal cells.
t. p. ..... tunica propria.
v. ..... vilus.

Fig. I.

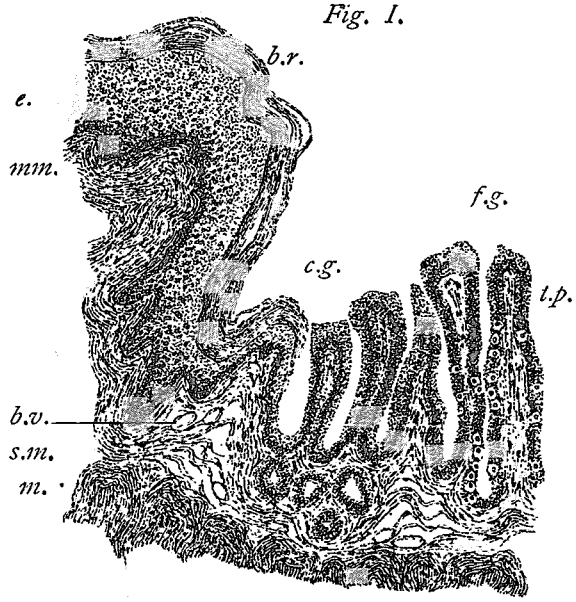


Fig. II.

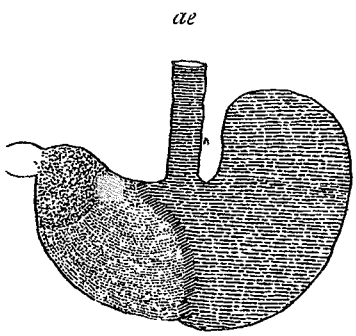
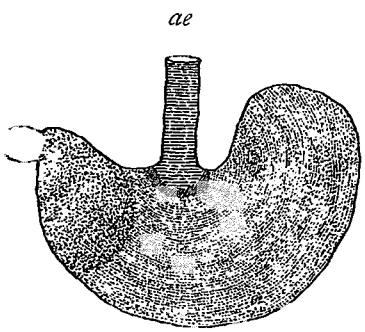


Fig. III.



aesophagus and cardiac sac.

cardia gl.

fundus gl.

pyloric gl.

Fig. IV.

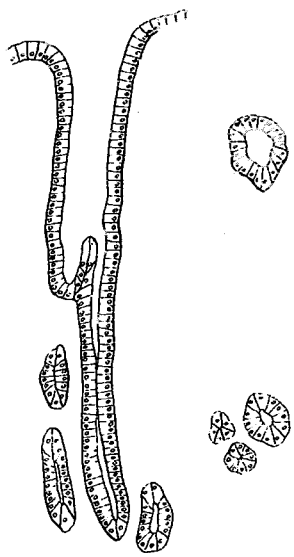


Fig. V.

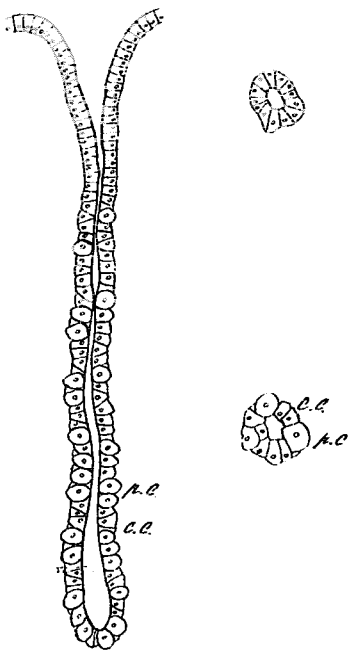


Fig. VI.

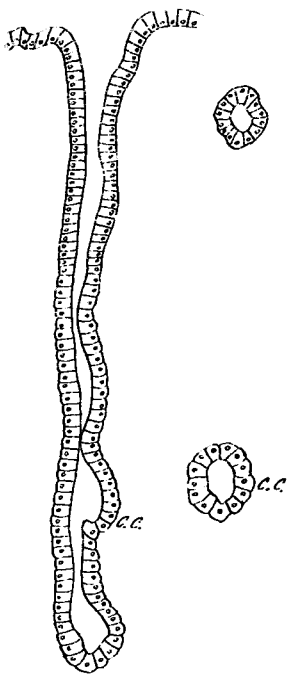
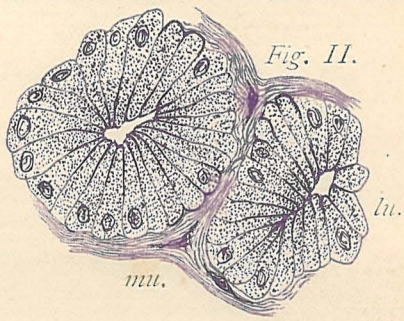


Fig. I.

Fig. II.



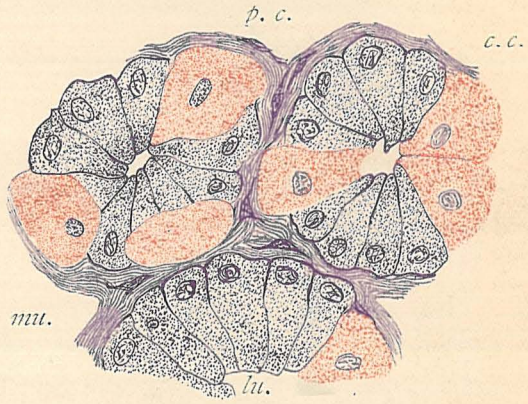


Fig. III.

Fig. IV.