COMPARATIVE MICROSCOPIC STUDY OF THE PROVENTRICULUS AND DUODENUM OF THE MOURNING DOVE, RED-HEADED WOODPECKER AND MEADOWLARK

by

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INTRODUCTION

In making the study of the proventriculus and duodenum of the mourning dove, red-headed woodpecker, and meadowlark,[1] the approach was a comparative microscopic study in an attempt to correlate data obtained with the feeding habits. These three species were chosen because of their comparative similarity in size and because of the known diversity of the feeding habits.

The literature pertaining to the histology of the digestive tract of birds is widely scattered and much is contributed by foreign authors. Standard texts on mammalian histology are rather difficult to use when making application to the histology of the digestive tracts of birds because of the differences in general structure and cell structure. The mammal has nothing comparable to the gizzard in organological or histological makeup. Certain types of cells found in the mammalian stomach have not been found in the proventriculus of the bird. The submucosa, when present, is not necessarily identical with the submucosa of the mammal. Certain parts may be missing, for example, no Brunner's glands were observed in the birds studied.

MATERIALS AND METHODS

In collecting the specimens upon whose tissues this study was based, all necessary equipment was carried in the field at all times so that specimens could be dissected and tissues fixed

[1] The technical names of these forms, as given by Chapman (1932) are: Zenaidura macroura (Linn.); Melanerpes erythrocephalus (Linn.) and Sturnella magna (Linn.), respectively.

immediately. Rosenberg (1940) found that the duodenal tube cut open and washed eroded in 10 minutes. Sections not cut open eroded in still shorter time. The tissues desired were removed and washed. Three sections within the central area of the proventriculus and one section between the bend of the duodenal loop and gizzard were removed. Each section of tissue was then placed in the fixative as rapidly as possible to prevent disintegration. Sections from the proventriculus were found not to disintegrate as rapidly as sections from the duodenum. Sections fixed within four minutes after shooting the specimen were satisfactory.

Picro-formal-acetic acid was used as the fixative. Following fixation the sections were washed in 70 percent alcohol. The tissues were transferred to paraffin by gradual changes in dioxan. The tissues were cut seven to eight microns thick and stained with Delafield's haematoxylin and eosin.

Bouin's picro-formal-acetic acid is an excellent fixative for tissues of the digestive tract of birds. It gives a delicate fixation and seldom gives poor results. Dioxan is soluble in water, alcohol and paraffin. It eliminates unnecessary steps, thereby saves time and prevents further hardening of the tissues. Tissues can be transferred from water to paraffin through dioxan. Delafield's haematoxylin is a good all around nuclear stain and works well with eosin, a cytoplasmic stain. These two stains work well for most of the general histological work; however, they can be supplemented by more specific stains if necessary.

In making a study of the sections a Zeiss microscope equipped with 16 mm, 8.3 mm, 4 mm apochromat and 2 mm apochromat objectives was used. 20 X, 10 X, and 7 X oculars were used interchangeably as the need required. Each ocular contained an ocular micrometer which was calibrated for taking measurements.

All highly magnified drawings were made by using the camera lucida. The entire cross sections of the digestive tract were drawn by using a projector which magnified the sections about 41 times.

Three birds of each species were used for the study. For each measurement five readings were taken from each slide (representing a series of sections from one bird), making a total of 15 measurements to the species.

All measurements were treated by analysis of variance which determined the significance by comparing the differences within birds and differences among individuals of a species with the differences between species.

DISCUSSION AND PRESENTATION OF DATA

Histology of Proventriculus

The proventriculus or the fore-stomach in each of the three species of birds studied had the same general shape. It could be differentiated from the esophagus by its somewhat larger diameter. The proventriculus preceded the gizzard and was marked from the latter by a slight constriction. The proventriculus, according to Bradley (1915), consists of the same layers as the esophagus. Elias (1945) found that by using selective stains with the method of Van Gieson it was possible to show that Cazin's determination of the layers was correct.

In general the proventriculus was composed of four major layers, the mucosa, submucosa, muscularis and serosa. The mucosa (Figs. 1-6, A; Figs. 22-27, A, B) was composed of the epithelial covering which lines the folds or wrinkles in the lumen, the tunica propria and the muscularis mucosa. The submucosa (Figs. 1-6, B, C; Figs 7-9, B) included the parietal glands, the connective tissue surrounding the glands and the connective tissue or membrane separating the submucosa from the tunica muscularis. The tunica muscularis (Figs. 1-6, D, E; Figs 7-9, C) was composed of an inner longitudinal layer, a thick circular layer and an outer longitudinal layer. The serosa was composed of connective tissue, blood vessels, nerve fibers and epithelium.

The lumen of the proventriculus was very narrow. In cross sections of the stomachs of the birds studied the concentrically circular folds surrounding the opening of each parietal gland appeared as finger-like projections in the lumen (Figs. 1-6, A). These projections were more prominent in the woodpecker and meadowlark than in the dove. The folds were tallest in the meadowlark. Kaupp (1921) states that the proventriculus produces the digestive juices. Elias (1945) found that the wall of the lumen contained two layers of glands.

The mucosa as mentioned by Elias (1945) consists of the epithelium and tunica propria. The tunica propria (Figs. 22, 24, 26, B) extends up into the center of the folds of the mucosa and supports the layer of simple columnar epithelium. The high folds are called plicae proventriculi by Elias (1945). Some authors describe the deep, narrow depressions between the folds as having simple, short, tubular glands. Batt (1925) found no well marked crypts as is the case in the mammalian stomach. Elias describes the plicae proventriculi as surrounding the opening of the parietal gland in a circular fashion. He disagrees with some previous authors by saying that, with the exception of a few short tubules to be found at the bottom of the furrows in the pigeon, the depressions between the folds are furrows, clefts or wrinkles but not tubules. The furrows between the plicae proventriculi are described by Elias (1945) as glandular in function. He terms these furrows sulci proventriculi. It was observed in sections from each of the three species that tubules composed of a single layer of epithelium were cut obliquely, thus showing them in an oblong form, isolated in the tunica propria.

The cells at the ridge of the plicae proventriculi of all three species studied were tall and became lower and more cuboidal in the sulci proventriculi (cf. Figs. 24 and 25). The nuclei appeared to stain more intensely in the furrows than at the tips of the plicae. The stain appeared to scatter throughout the cytoplasm in the region of the sulci proventriculi. The nuclei in the bottom of the sulci were less clear cut than those found closer to the lumen.

Elias (1945) states that the secretory material produced by the epithelial cells of the ridges and furrows can be stained with thionin and Delafield's haematoxylin. Thionin is said to stain mucin but also stains other substances. He describes the secretion as being composed possibly of granules and not droplets. In the species studied the secretion in the lumen took the cytoplasmic stain readily while the nuclear stain was almost entirely absent. The secretion appeared to be faintly streaked and granular. It conformed to the general outline of the lumen.

The submucosa extended from the inner longitudinal layer of the tunica muscularis to the muscularis in the tunica propria. According to Batt (1925), the submucosa is a narrow zone of white fibrous connective tissue whose fibers run longitudinally. Elias (1945) states that the submucosa consists of loose fibrous connective tissue and contains the parietal glands.

Kaupp (1921) found that the gastric follicles are simple in the majority of birds, having neither internal cells, dilated fundus nor constricted neck (Fig. 1-6). From the distal extremity the opening of the follicle proceeded with a uniform diameter until the orifice of the lumen was reached. This form he found in zoophagous and omnivorous birds. He observed that the gastric glands were variously arranged among birds, being broad compact belts in Falconiformes, a continuous zone around the proventriculus in perching birds (Passeriformes) in general, zonular and of simple structure in pigeons, each gland of pyramidal form with the apex towards the gizzard in the woodpecker.

In each of the three species studied the individual follicular (parietal) glands drained toward the center of the lobule and then directly to the surface of the lumen (Fig. 1, B).

The cells of the parietal glands were attached to the septum (Fig. 13-21). The cells were generally hemispherical in shape and frequently the cell-axis was directed toward the lumen. The distal end of each cell was free from its neighbor and quite frequently in all three species the separation extended almost to the basement membrane. Batt (1925) and Elias (1945) found these cells to be of one type and by staining reactions indicated the resemblance of the cells to the parietal cells of mammalian stomachs.

The nuclei of the parietal gland cells stained deeply with the nuclear stains (Fig. 7-10 and 13-21). The chromatin material was most prominent around the periphery of the nucleus with one or two irregularly shaped masses of chromatin material in or near the center. The nuclei of the parietal gland cells of the three species studied were very much alike in morphology and general appearance. The cytoplasm of the cell took the cytoplasmic stain readily, thereby forming a sharp contrast to the nucleus. It stained uniformly throughout with the exception of being faintly granular.

The ducts of the parietal glands were lined with cells which had a clear cytoplasm. These cells merged gradually with the gland cells.

The stroma or septum between the glands and surrounding the gland lobule showed connective tissue cells and blood vessels (Fig. 24, B). According to Batt (1925) the septum is merely a basement membrane with a few connective tissue cells, blood vessels, and nerve fibers. It was observed in the three species studied that the connective tissue of the septum extended around the lobule and formed a thin membrane which separated the tunica muscularis from the submucosa (Figs. 7-9 B, C). Occasionally it extended through the first layer of the tunica muscularis, the inner longitudinal layer. It extended up to the lumen side of the parietal glands and merged with the muscularis mucosa.

Elias (1945) does not agree with several previous authors as to the arrangement of the muscular layer. He states that the muscularis consists of a thin external longitudinal layer, thick middle circular layer, and an inner longitudinal layer, and that the muscularis mucosa is on the lumen side of the parietal glands. In the three species studied the muscularis mucosa could be followed only with difficulty. The muscle nuclei indicated the location of the muscle elements. The musculature conformed to the general outline of the lumen side of the parietal glands.

The layers of the tunica muscularis could be clearly differentiated one from the other in all three species studied. The inner longitudinal layer, the innermost layer of the muscularis, was bordered on the lumen side by a membrane separating it from the parietal glands. It was bordered on the outside by the circular layer of the muscularis (Figs. 1-6, D, E). Inside it conformed quite closely with the lower border of the glandular follicles. Therefore, its thickness was much greater under the septa separating the follicles of the parietal glands than midway under the follicle. The muscle cells and nuclei of this layer appeared to run parallel to the direction of the intestine, suggesting a longitudinal arrangement of the fibers. The circular muscle layer or middle layer was the thickest of the three layers. Its cells and nuclei encircled the lumen. The outer longitudinal layer was thin and irregular, suggesting isolated bundles at times. It was interposed with nerve fibers and blood vessels, and was covered on the outside by the serosa. The muscular layers of the proventriculus and duodenum of the dove were thinner than in those of the other two birds (cf. Fig. 1 with 3 and 5).

The boundaries of the muscle cells were difficult, and at most sites impossible, to distinguish. The nuclei were clearly outlined (Figs. 10-12, C, I). The nuclei of the muscle cells of the three species could not be distinguished one from the other. In cross sections the nuclei of the circular layer appeared long and wavy. Occasionally they were shorter and broader. The nuclear membrane was clearly marked. Scattered throughout the nucleus were small patches of chromatic material. In the inner and outer longitudinal muscles the nuclei frequently were cut in cross section, and appeared oval in form. No attempt was made to make a comparison of the serosa.

Desselberger (1931) reported that birds living on flowers and berries have a digestive tract well adapted for that kind of food. Flower peckers (Dicaeidae) from New Guinea and Celebes show two steps in specialization. Pristorhamprus and Urocharis have short and wide intestines with a lumen densely covered by wide villi. In Dicaeum and Acmonorhynchus the muscular stomach is taken out of the direct digestive tract and transferred into an appendix. Berries go directly from the glandular stomach into the duodenum, while insects go into the muscular stomach.

Browne (1922) reported that granivorous birds have a small, straight proventriculus which appears as a dilation of the esophagus. In carnivorous birds the proventriculus is but faintly distinguished from the gizzard. In certain Galliformes, according to Kaupp (1921), it is larger in diameter than the esophagus and smaller than the gizzard. In song birds (Passeres), it forms almost the entire stomach, the gizzard being miniature, while in "Alcedo perching birds" opposite proportions prevail. In birds with wide esophagi only the greater vascularity and the difference of lining membrane and stratum of glands which open on the inner surface identify the proventriculus. Desselberger (1932) quite definitely states that birds with similar food habits show great similarity in the structure of the intestinal tract.

Histology of Duodenum

The duodenum was a U-shaped portion of the small intestine, following the gizzard and embracing the pancreas. The mucosa, the innermost layer, included the epithelium and the tunica propria (Figs. 28-33, B, C). Whether the muscular tissue in its tunica propria corresponds to the muscular tissue in the tunica propria of the proventriculi was not determined.

The presence of a submucosa was uncertain. Rosenberg (1941) stated that in general a submucosa is not present but that a submucosa is indicated in the heavy folds. Batt (1925) described the submucosa as a narrow zone of dense white fibrous tissue. It is altogether possible that remnants of a submucosa may be present in the birds studied although none was located in this work.

The muscularis included an inner longitudinal (muscularis mucosa), middle circular, and an outer longitudinal muscle layer (Figs. 34-36, F). The circular muscle was much thicker than the other two muscular layers. The serosa, the fourth layer, enclosed and covered the intestine.

The epithelium was thrown into numerous long folds by the underlying tunica propria. These folds may appear rather wide if cut at an angle rather than in cross section (Fig. 34, D).

Rosenberg (1941) found duodenal columnar cells of three types, the chief cells, goblet cells, and basal granular cells. In the birds studied the chief cells (Figs. 28-33, B) were most numerous. The goblet cells (Figs. 29, 32, unlabeled) were fairly numerous but no basal granular cells were observed.

The chief cells (absorptive cells) were found on the villi and extended into the crypts of Lieberkühn. They were simple and columnar in shape, being tallest at the tip of the villus and shortest in the crypt of Lieberkühn (Figs. 28, 31). The nuclei were oval to nearly ameboid in shape with irregularly scattered chromatin. Rosenberg (1941) illustrated in most nuclei two clear-cut nucleoli, which were only infrequently observed in the dove, woodpecker and meadowlark. The cytoplasm was definitely acidophilic with basophilic granules. These granules increased in number and in density toward the fundus of the crypts. The chief cells resembled closely the epithelial cells of the proventriculi.

Goblet cells were found throughout the epithelial covering. The nuclei were similar to those of the chief cells but are considerably smaller. The nuclei (Fig. 31, unlabeled) lay closer to the cell base than did the nuclei of the chief cells. Frequently the goblet cells could be located by the nuclei alone (Fig. 33). The nuclei stained more deeply than did the nuclei of the chief cells.

Rosenberg (1941), quoting Tang, while discussing basal granular cells and Paneth cells, states that when one is present in large numbers the other is absent. The granules of the Paneth cells are soluble in ether alcohol or dilute acids. Therefore, by the technic used for this study the Paneth cells, if present, could not be identified.

The cuticle covering the epithelial cells was interrupted by the opening of the goblet cells (Fig. 30). The thickness of the cuticle of the three species studied was not carefully compared. However, the cuticle in the meadowlark was somewhat thinner than that found in the other two species studied (Figs. 28, 29, and 30).

The tunica propria formed the core or support for the epithelial covering (Figs. 28-30, C) and extended down to the inner longitudinal muscle layer which is called the muscularis mucosae. It contained many lymphatic cells, and a number of muscle fibers (Fig. 32, C).

Macklin and Macklin (1928) mentioned that certain histological practices cause the tunica propria to shrink away from the epithelium and that certain reagents as Ranvier's alcohol and dilute acetic acid readily dissolve the cell cement.

Whether the muscle cells of the tunica propria are a continuation of the muscularis muscosae or inner longitudinal muscle was not determined.

In the tunica propria of the turkey Rosenberg (1941) found fibroblasts with strands of white collagenous connective tissue, lymphocytes of various types, plasma cells and two types of eosinophiles. No comparison was made of the tunica propria of the duodenum among the species studied.

The crypts of Lieberkühn (Figs. 34-36, E) were situated at the base of the villi. The stratum of crypts in the meadowlark was much thicker than those of the dove and woodpecker (Figs. 34, 35, and 36). The crypts in the meadowlark were stratified, whereas in the dove and woodpecker they were generally single and sometimes isolated. Rosenberg (1941) states that the goblet cells are more numerous in the crypt than at the villus tip. Batt (1925) found the crypts shorter and more coiled in fowls than in mammals.

Several authors speak of the muscular layer as being composed of an inner longitudinal layer called muscularis mucosae, a middle layer called the circular layer and an outer longitudinal layer. Rosenberg (1941) states that the circular muscle in the turkey was composed of a wide outer layer and a thin inner accessory layer. The inner longitudinal muscle in each of the three species studied was very narrow, thickest in the woodpecker and thinnest in the dove, and formed a sheath around the crypts of Lieberkühn. The circular muscle was much thicker than the other two layers. It encircled the inner longitudinal layer, and appeared wavy. The outer longitudinal muscle layer was similar in appearance to the inner longitudinal muscle layer. The circular muscle was thickest in the meadowlark and thinnest in the dove. The outer longitudinal layer was thickest in the woodpecker and thinnest in the dove.

The cells of the muscle elements were spindle shaped and their nuclei, as in the muscle cells of the proventriculus, were clearly outlined. Among the species studied the nuclei appeared to be identical in shape and form. The cell, exclusive of the nucleus, stained intensely with the cytoplasmic stain. The muscle tissue formed a wavy pattern. Elastic fibers accompanied the muscle cells and were usually orientated in the same direction as the muscle fibers, among which they were found.

The serosa and subserosa encircled the intestine and as far as could be determined these layers were identical in the species studied.

Diets of Birds Studied

According to Forbush and May (1939), animal matter constitutes one-third of the food of the red-headed woodpecker, and vegetable matter constitutes two-thirds of its food. The animal diet consists largely of adult beetles, wasps, grasshoppers, predaceous ground beetles and tiger beetles. The vegetable food consists largely of small fruit and berries (Beal 1897, 1942). In addition to the food already mentioned, Bent (1939) adds ants, bugs, crickets, moths, caterpillars, spiders, myriopods, corn, dogwood, huckleberries, strawberries, raspberries, mulberries, elderberries, wild black cherries, choke cherries, cultivated cherries, wild grapes, apples, pears, various seeds, acorns and beechnuts to the diet of the red-headed woodpecker.

The food of the meadowlark consists mostly of insects which constitute 74 percent of its diet (Beal, McAtee, and Kalmback, 1941), (Beal, 1942). Vegetable matter makes up 26 percent of its diet. Beetles, bugs, grasshoppers, a few flies, wasps, spiders, and myriopods are also eaten. Meadowlarks go to great effort to obtain insects even under adverse conditions. Grasshoppers and crickets constitute 27 percent of its yearly diet. Beetles are next in importance and constitute 18 percent of the annual food of the meadowlark.

Of the vegetable food fruit constitutes two percent of the meadowlark's diet. Corn, wheat and oats make up nine percent of its diet and are taken mostly during winter. Common weed seeds taken are ragweed, barngrass, smartweed, sorrel, mustard, armaranth and gramwell.

Doves live largely on a grain diet. Insects are apparently not a part of the dove's diet (Jennings, 1941). Their diet consists of 99 percent vegetable matter and less than one percent animal food (Bent, 1932). Wheat, oats, rye, corn, barley and buckwheat constitute 32 percent of the total food. Wheat is the favorite. Weed seeds are eaten at all seasons of the year.

Tabulated Information and Statistical Treatment of Data

Method of Statistical Analysis. In all analyses the estimate of population variance (σ^2) obtained from the variability among birds of the same species was used as the error variance in the F test.

P is the probability that F would be at least as large as that F observed if there were no differences among the species in regard to the feature which was measured. It is customary to consider the observed differences among the species means as being statistically significant if P is .05 or smaller. If P is greater than .05 this does not mean that the species are not different in the features measured; it only indicates that in view of the variability observed among birds of the same species, the observed differences among species reasonably could be attributed to sampling. If a larger number of birds of each species had been used it is possible that the P would have been smaller in certain instances.

The results obtained are put in chart form with the P indicated together with a statement indicating significance of the differences obtained.

Discussion of Statistical Interpretation. The ends in view for making measurements of histological aspects of the proventriculi and duodeni of the dove, meadowlark and red-headed woodpecker and treating them statistically were:

(1) To ascertain if the food habits are paralleled by histological differences.

(2) If mean measurements suggest differences in food habits are paralleled by histological variation, then:

(3) To treat data statistically to note if species differences are significant.

If the analysis of variance proves significant it would appear that food habits are paralleled by a certain histological picture.

Though analysis of variance demonstrated significant differences in:

(1) Width of nuclei of the chief cells of the sulci proventriculi

(2) Length of nuclei of parietal gland cells

(3) Height of plicae proventriculi and thickness of tunica propria

(4) Measurements of thickness of the inner longitudinal

EXPLANATION OF TABLE 1.

A study of the size of the chief cell nuclei in the proventriculi was made. Fifteen readings were recorded for each species studied. Readings were obtained at the tip of the plicae proventriculi and in the region of the sulci proventriculi.

Table 1. Length and width of the nuclei of chief cells near the tip of plicae proventriculi and in the region of the sulci proventriculi measured in microns.

Tip of plicae proventriculi			Bottom of sulci proventriculi		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
7.1 x 4.6	7.1 x 4.8	7.7 x 4.8	6.2 x 4.7	7.4 x 4.0	7.5 x 4.9
7.1 x 4.6	8.0 x 5.7	7.5 x 4.7	4.8 x 3.4	8.5 x 3.9	7.7 x 4.6
7.0 x 4.5	7.5 x 3.2	9.2 x 5.3	5.3 x 3.1	7.1 x 4.8	6.3 x 4.0
6.5 x 5.6	7.1 x 4.6	10.3 x 4.5	5.2 x 3.3	6.4 x 3.7	6.5 x 4.2
5.7 x 4.9	8.8 x 5.7	8.0 x 5.7	6.3 x 1.7	6.9 x 5.0	6.0 x 4.6
6.5 x 4.5	7.6 x 5.3	6.7 x 4.0	6.3 x 2.6	7.8 x 3.7	6.0 x 4.2
6.9 x 4.4	8.0 x 4.6	8.0 x 5.6	6.0 x 4.4	6.7 x 5.5	6.7 x 4.4
7.1 x 2.3	6.2 x 5.7	6.9 x 4.8	5.7 x 2.6	5.0 x 4.6	6.9 x 4.4
6.3 x 3.8	8.0 x 3.4	6.0 x 5.1	4.6 x 3.1	4.6 x 3.9	6.9 x 5.4
5.7 x 3.8	7.7 x 5.4	8.3 x 5.2	5.7 x 2.3	6.7 x 4.8	7.1 x 2.5
8.0 x 4.4	9.9 x 5.7	6.9 x 4.6	6.3 x 4.2	6.0 x 5.2	5.4 x 4.4
8.0 x 4.6	8.4 x 6.7	6.5 x 4.6	6.5 x 4.6	8.6 x 5.2	5.4 x 4.1
7.8 x 3.4	9.0 x 5.0	8.0 x 4.4	6.9 x 4.0	6.4 x 5.7	5.1 x 4.4
7.5 x 4.0	10.1 x 5.5	7.8 x 3.4	6.9 x 4.6	8.0 x 3.4	5.2 x 4.6
7.1 x 4.4	10.5 x 5.4	8.6 x 4.8	6.9 x 2.3	6.1 x 5.0	6.9 x 4.0

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Length at tip of plicae proventriculi	7.0	8.4	7.7	.13
Width at tip of plicae proventriculi	4.2	5.1	4.8	.07
Length in sulci proventriculi	6.0	6.7	6.4	.33
Width in sulci proventriculi	3.3	4.6	4.3	.04

* "Birds in species" used as error variance

EXPLANATION OF TABLE 2.

On examining the parietal gland cell, it was found difficult to make a morphological differentiation between the three species studied. The cells and nuclei of the species were measured to determine the difference in size. Fifteen measurements were taken on each species within the central portion of the proventriculus. Five measurements were taken on each of three separate individuals within the same species.

Table 2. Size of parietal gland cells and their nuclei measured in microns.

Parietal gland nuclei			Parietal gland cells		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
5.3 x 4.6	4.6 x 4.1	4.4 x 3.8	6.9 x 6.5	8.0 x 6.9	6.9 x 6.9
5.4 x 5.0	4.8 x 4.6	4.6 x 4.2	11.5 x 8.0	6.9 x 6.9	7.2 x 5.7
5.9 x 4.6	5.1 x 4.1	5.0 x 3.3	10.9 x 8.0	9.2 x 5.5	7.4 x 9.8
5.3 x 3.4	4.8 x 4.3	5.3 x 4.5	7.7 x 6.9	10.9 x 7.8	6.9 x 6.9
4.6 x 4.5	5.5 x 5.2	4.4 x 3.2	9.2 x 9.2	8.0 x 8.0	9.2 x 5.2
5.3 x 4.2	4.8 x 3.9	4.6 x 4.6	9.2 x 8.0	10.9 x 8.0	9.2 x 6.9
4.6 x 3.4	5.7 x 4.8	4.6 x 4.6	9.2 x 8.6	11.5 x 9.2	7.4 x 8.7
5.4 x 3.9	5.7 x 5.5	4.6 x 4.6	14.9 x 7.4	9.8 x 8.0	9.2 x 5.2
5.7 x 4.5	4.7 x 4.6	4.9 x 4.6	10.3 x 6.3	7.4 x 9.2	7.4 x 6.9
4.7 x 4.5	5.7 x 5.2	4.8 x 4.0	9.2 x 8.0	11.5 x 8.0	6.0 x 6.0
5.7 x 4.4	5.7 x 4.6	4.6 x 4.2	10.9 x 8.0	8.6 x 7.4	8.6 x 8.0
4.7 x 4.6	5.4 x 3.7	4.2 x 4.2	12.6 x 6.9	9.2 x 6.9	9.2 x 6.7
4.6 x 4.4	6.0 x 4.3	4.6 x 4.6	8.0 x 6.9	11.5 x 6.9	7.7 x 6.9
5.5 x 4.0	5.5 x 4.8	4.6 x 3.4	8.0 x 9.2	10.3 x 8.6	11.5 x 6.3
4.6 x 3.7	5.7 x 4.6	4.6 x 4.4	9.8 x 6.9	13.2 x 6.9	11.5 x 5.7

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Length of nuclei of parietal gland cells	5.1	5.3	4.6	.04
Width of nuclei of parietal gland cells	4.2	4.6	4.1	.14
Length of parietal gland cells	9.9	9.8	8.4	.06
Width of parietal gland cells	7.7	7.7	6.7	.10

* "Birds in species" used as error variance

EXPLANATION OF TABLE 3.

The gland lobules of the three species showed a morphological difference. The dove seemed to have much finer detail and more delicate structure than the other two species. The lobules were measured by using a low magnification.

Table 3. Average height and width of the gland lobule of each of the three species studied. The measurements are recorded in microns.

Height			Width		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
927	1024	854	317	366	219
414	439	878	463	439	439
927	756	976	390	366	414
854	658	976	268	439	536
854	976	878	463	292	390
1268	683	1244	585	317	780
1561	707	1195	341	195	634
1244	658	1073	195	341	561
1000	634	805	707	268	561
1390	239	756	585	97	366
1195	561	1122	317	244	561
1195	878	780	585	219	292
1244	561	1317	341	268	536
1171	1146	414	414	219	219
976	585	1049	341	268	683

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Height of parietal gland lobule	1081	700	954	.09
Width of parietal gland lobule	421	289	479	.06

*"Birds in species" used as error variance

EXPLANATION OF TABLE 4.

The height of the portion of the proventriculus between the parietal glands and its lumen showed considerable difference among the species studied. The region in the dove was much narrower than in the other two species. The measurements were made between the tip of the plicae proventriculi and the deepest part of the tunica propria.

Table 4. Height of the proventriculus between the tip of the plicae proventriculi and the deepest part of the tunica propria. The measurements are recorded in microns.

Height		
Dove	Woodpecker	Meadowlark
170	512	512
341	536	561
170	488	512
195	512	536
219	439	561
146	341	463
146	390	561
195	317	536
195	341	488
146	390	463
219	463	488
73	488	512
146	414	439
122	854	341
97	439	341

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Height of plicae proventriculi and thickness of tunica propria	172	462	488	.003

* "Birds in species" used as error variance

EXPLANATION OF TABLE 5.

The size of the nuclei of the inner longitudinal and circular layer of the muscular coat of the proventriculus were measured and the average determined to see if the nuclear size of the muscle cells differed greatly in the species studied.

Table 5. Length and width of nuclei of the muscle cells of the innermost longitudinal layer and the circular layer of the muscularis. The measurements are recorded in microns.

Nuclei of circular muscle			Nuclei of inner longitudinal muscle		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
23.0 x 1.1	18.4 x 2.5	14.9 x 2.3	2.3 x 1.7	2.3 x 1.5	2.3 x 2.3
17.2 x 2.3	19.5 x 2.3	15.5 x 2.1	2.3 x 1.5	2.1 x 1.4	2.3 x 2.1
18.4 x 1.6	17.2 x 2.2	16.6 x 1.7	2.3 x 2.1	2.3 x 1.8	2.4 x 2.2
17.2 x 2.3	19.0 x 2.3	18.4 x 1.7	2.3 x 2.1	2.1 x 1.7	2.7 x 2.3
17.2 x 2.1	20.7 x 1.5	18.4 x 1.7	2.3 x 1.4	2.3 x 2.1	2.5 x 2.3
17.2 x 2.3	20.7 x 3.4	18.7 x 1.7	2.3 x 1.5	3.3 x 2.3	2.3 x 1.7
17.2 x 1.4	19.0 x 1.7	19.5 x 2.3	2.7 x 1.7	3.3 x 2.7	2.4 x 1.6
17.2 x 2.3	21.3 x 2.9	23.0 x 1.7	1.7 x 1.7	3.3 x 2.3	2.6 x 1.9
17.2 x 2.1	16.6 x 2.6	20.7 x 2.2	2.5 x 2.5	3.5 x 3.3	2.8 x 2.1
13.8 x 3.1	16.1 x 2.3	19.5 x 1.7	2.5 x 1.7	3.3 x 2.8	2.3 x 2.1
17.2 x 2.5	21.8 x 1.7	15.5 x 2.3	2.5 x 2.3	2.5 x 2.2	2.5 x 2.5
20.7 x 2.0	20.7 x 2.1	14.3 x 1.7	2.7 x 1.7	2.7 x 2.3	2.6 x 2.3
19.5 x 1.1	19.5 x 2.2	13.8 x 2.8	2.5 x 2.3	2.7 x 2.2	2.6 x 2.1
17.2 x 2.2	23.6 x 1.5	13.2 x 2.4	2.5 x 2.3	2.7 x 2.3	2.7 x 2.3
13.8 x 1.7	18.4 x 2.3	14.9 x 2.3	2.5 x 1.7	3.0 x 2.5	2.8 x 2.4

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Length of nuclei of circular muscle layer	17.6	19.5	17.1	.38
Width of nuclei of circular muscle layer	2.0	2.2	2.1	.50
Greater width of nuclei of inner longitudinal muscle layer	2.4	2.8	2.5	.50
Lesser width of nuclei of inner longitudinal muscle layer	1.9	2.2	2.1	.50

*"Birds in species" used as error variance

EXPLANATION OF TABLE 6.

To determine the relative thickness of the muscular layers the measurements were taken at scattered locations to get the best possible average. The inner longitudinal muscle layer extended up between the septum which separated the gland lobules. It was therefore very irregular in thickness. The muscles may have been in different stages of contraction, which may have an important bearing on the results obtained. Therefore, at best the measurements of the muscles were not too meaningful.

Table 6. Thickness of the inner longitudinal layer under the parietal gland lobule and under the septum between the gland lobules. The measurements are recorded in microns.

Below lobule			Under septum		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
25	62	50	57	125	120
25	62	45	55	87	105
22	45	35	52	50	84
22	25	24	45	47	82
20	22	15	35	39	65
50	62	52	85	150	135
37	55	47	67	120	133
35	52	40	57	117	125
27	52	37	50	117	100
25	47	55	47	85	72
25	35	40	47	67	135
22	35	40	45	65	132
22	33	32	42	65	132
17	32	27	37	52	125
15	18	24	32	32	112

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Measurements below lobule	25.9	42.5	36.2	.15
Measurements under septum	50.2	84.5	110.5	.045

*"Birds in species" used as error variance

EXPLANATION OF TABLE 7.

The circular muscle layer and the outer longitudinal layer were more uniform in thickness in all species than the inner longitudinal layer. The layers in the dove were not as thick as those of the other two species.

Table 7. Thickness of the circular and outer longitudinal layers of the muscularis. The measurements are recorded in microns.

Circular (middle) muscle			Outer longitudinal muscle		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
85	260	162	19.4	48.6	48.6
80	187	157	19.4	24.3	48.6
70	167	152	34.0	92.3	12.1
55	157	90	9.7	38.9	17.0
37	150	75	24.3	43.7	14.6
87	95	125	24.3	24.3	9.7
80	87	122	9.7	53.4	12.1
80	82	120	9.7	24.3	12.9
60	75	92	9.7	19.4	12.1
57	62	92	19.4	34.0	12.1
87	167	110	48.6	14.6	12.1
82	160	110	48.6	21.9	9.7
75	107	105	14.6	26.7	21.9
65	107	102	14.6	19.4	24.3
52	100	77	9.7	24.3	24.3

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Thickness of circular muscle layer	70.1	130.9	112.7	.14
Thickness of outer longitudinal muscle layer	21.0	34.0	23.5	.29

* "Birds of species" used as error variance

EXPLANATION OF TABLE 8.

In measuring the size of the duodenal villi the height was recorded in the first column of Table 8, width near base of villi in second column, width midway between crypts and villus tip in third column and width near villus tip in fourth column.

Table 8. Height and width of the villi of the upper duodenum of the three species studied. All measurements are recorded in microns.

Height of villi			Width of villi near crypt			Width of villi midway			Width of villi near tip		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
1019.7	1148.4	1138.5	178.2	158.4	148.5	118.8	138.6	19.0	118.8	69.3	49.5
1049.4	1089.0	1168.2	49.5	69.3	99.0	99.0	148.5	79.2	99.0	99.0	59.4
950.4	1564.2	1029.6	247.5	99.0	108.6	99.0	138.6	69.0	69.3	59.4	49.5
990.0	1188.0	772.2	108.9	89.1	79.2	89.1	118.8	59.4	79.2	59.4	89.1
980.1	1732.5	1108.8	128.7	49.5	128.7	99.0	89.1	79.2	108.9	59.4	49.5
940.5	1128.6	1039.5	138.6	257.4	188.1	99.0	138.6	108.9	59.4	49.5	89.1
910.8	1227.6	1098.9	89.1	217.8	158.4	69.3	118.8	69.3	39.6	49.5	79.2
900.9	990.0	1118.7	108.9	227.7	118.8	89.1	168.3	49.5	49.5	138.6	69.3
1158.3	1178.1	950.4	148.5	227.7	118.8	108.9	178.2	89.1	79.2	108.9	89.1
1039.5	1118.7	980.1	99.0	415.8	108.9	79.2	138.6	89.1	89.1	198.0	79.2
1059.3	1673.1	1138.5	128.7	188.1	178.2	99.0	227.7	108.9	89.1	158.4	79.2
1029.6	1574.1	1059.3	178.2	376.2	138.6	148.5	138.6	99.0	118.8	99.0	89.1
1118.7	1673.1	1168.2	207.9	316.8	128.7	148.5	118.8	69.3	178.2	69.3	49.5
1039.5	2029.5	1128.6	207.9	306.9	158.4	148.5	128.7	99.0	178.2	257.4	69.3
1069.2	1514.7	1118.7	217.8	336.6	188.1	118.8	207.9	89.1	158.4	138.6	59.4

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Height of villi	1017.1	1388.6	1067.9	.08
Width of villi near base	149.2	222.4	136.8	.34
Width of villi midway	107.6	146.5	78.5	.02
Width of villi near tip	101.0	107.6	70.0	.41

* "Birds in species" used as error variance

EXPLANATION OF TABLE 9.

The nuclei of the chief cells were measured where found, both near the tip of the villi and in the crypts of Lieberkühn. The chief cells were predominate in the epithelial covering.

Table 9. Length and width of the nuclei of the chief cells at the tip of the villus and in the crypts of Lieberkühn.

Nuclei of chief cells of duodenal epithelium villus tip			Nuclei of chief cells of duodenal epithelium in crypts of Lieberkühn		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
6.4 x 4.1	7.5 x 4.8	4.8 x 4.1	8.0 x 4.9	6.9 x 3.9	5.7 x 4.6
6.9 x 4.5	8.0 x 5.7	4.6 x 4.6	5.7 x 4.0	7.4 x 4.6	5.1 x 4.9
6.9 x 4.5	8.7 x 5.8	4.6 x 3.1	6.9 x 3.4	8.3 x 3.8	5.8 x 5.3
4.8 x 4.5	8.0 x 5.9	4.6 x 3.9	7.7 x 3.5	9.2 x 4.4	6.2 x 4.6
5.7 x 4.0	8.2 x 5.0	5.0 x 3.7	5.5 x 3.4	7.1 x 5.5	6.0 x 4.8
5.9 x 2.9	6.1 x 5.0	5.7 x 3.4	9.2 x 4.6	8.0 x 6.0	6.7 x 4.8
5.7 x 5.1	6.7 x 5.2	5.5 x 4.4	5.8 x 4.0	5.7 x 5.7	5.8 x 4.6
5.9 x 4.6	7.0 x 5.0	4.8 x 3.7	5.7 x 3.5	7.5 x 4.4	5.7 x 4.5
6.9 x 4.4	5.7 x 4.9	5.7 x 5.2	5.8 x 4.4	8.3 x 4.8	6.9 x 4.4
5.7 x 4.6	7.5 x 4.0	5.7 x 4.4	6.0 x 4.6	6.9 x 5.7	6.7 x 4.6
6.0 x 4.6	6.9 x 5.7	5.2 x 4.6	6.9 x 4.0	8.3 x 3.8	6.9 x 5.5
6.0 x 4.4	6.9 x 4.6	5.7 x 4.6	5.7 x 3.5	9.2 x 3.8	6.4 x 3.7
5.7 x 5.2	6.9 x 5.0	5.7 x 4.6	6.9 x 4.4	6.3 x 4.0	8.0 x 4.4
6.3 x 4.8	6.0 x 5.6	5.7 x 3.7	6.5 x 3.7	6.0 x 3.4	8.3 x 5.7
5.7 x 4.6	8.0 x 4.8	5.7 x 4.4	6.3 x 5.7	6.9 x 5.8	6.9 x 4.0

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Length of nuclei at tip of villus	6.0	7.2	5.3	.01
Width of nuclei at tip of villus	4.5	5.1	4.2	.01
Length of nuclei in crypt of Lieberkühn	6.5	7.5	6.5	.09
Width of nuclei in crypt of Lieberkühn	4.1	4.6	4.7	.21

* "Birds in species" used as error variance

EXPLANATION OF TABLE 10.

The individual lobules or branches of the crypts of Lieberkühn were measured for comparison of size. The branches in the meadowlark appeared to be arranged in several layers whereas the crypts of the dove and woodpecker were lobules or branches at the same level.

Table 10. Size of the branches or lobules of the crypt of Lieberkühn. The height or thickness of the lobules of the crypts is given in the second column and the number of lobules per field is given in the third column. The field covers a diameter of 388 microns. The measurements are recorded in microns.

Size of individual lobules of crypts of Lieberkühn			Thickness of layer of lobules of crypt			Number of lobules per field (388μ)		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
43.1 x 50.8	91.4 x 55.8	30.4 x 48.2	72.9	72.9	257.5	6	5	14
71.1 x 60.9	45.7 x 45.7	27.9 x 58.4	48.6	68.0	252.7	5	4	17
81.2 x 45.7	60.9 x 43.1	43.1 x 45.7	38.8	38.8	238.1	3	7	6
93.9 x 43.1	53.3 x 45.7	33.0 x 40.6	43.7	43.7	189.5	4	1	16
73.6 x 71.1	101.6 x 48.2	25.4 x 38.1	53.4	38.8	218.7	4	4	16
50.8 x 63.5	53.3 x 38.1	68.5 x 88.9	43.7	53.4	218.7	6	4	19
45.7 x 58.4	50.8 x 50.8	119.3 x114.3	43.7	38.8	218.7	4	7	19
50.8 x 53.3	78.7 x 45.7	48.2 x101.6	38.8	102.0	218.7	6	7	12
58.4 x 48.2	55.8 x 43.1	63.5 x 91.4	43.7	120.0	228.4	8	10	20
45.7 x 58.4	109.2 x 50.8	101.6 x 88.9	43.7	97.2	262.4	6	9	18
41.4 x 45.7	55.8 x 73.6	142.2 x 73.6	38.8	68.0	291.6	4	2	19
71.1 x 48.2	63.5 x 60.9	93.9 x101.6	48.6	48.6	247.8	5	4	16
43.1 x 43.1	68.5 x 58.4	114.3 x114.3	58.3	58.3	218.7	5	4	13
38.1 x 50.8	73.6 x 63.5	129.5 x 78.7	34.0	68.0	247.8	4	5	15
43.1 x 48.2	40.1 x 68.5	157.4 x 73.6	48.6	48.6	252.7	4	2	15

Table of means

	Dove	Woodpecker	Meadowlark	P*
Length of individual lobule	56.7	66.8	80.0	.50
Width of individual lobule	52.6	52.8	77.2	.22
Height of crypts	46.6	63.1	237.5	.001
Number of lobules per field	4.9	5.0	15.7	.001

* "Birds in species" used as error variance

EXPLANATION OF TABLE 11.

The muscles of the duodenal muscularis were arranged in three layers. These were recorded as the inner longitudinal layer (called muscularis mucosae), circular layer and outer longitudinal layer of the muscularis.

Table 11. Thickness of each of the muscular layers of the duodenum. All measurements are recorded in microns.

Inner longitudinal muscle			Circular muscle			Outer longitudinal muscle		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
9.7	16.0	7.8	55.8	86.5	92.3	19.4	14.5	38.8
14.6	12.6	6.4	56.8	79.2	104.9	14.5	11.1	19.4
5.3	17.0	11.1	38.8	83.1	116.6	20.8	24.3	16.0
14.6	11.1	9.2	24.3	89.9	135.1	14.5	28.1	17.0
6.3	19.4	18.5	47.1	87.4	155.1	11.1	25.7	21.8
14.6	15.1	10.6	102.0	61.7	102.0	15.5	38.8	24.3
17.4	12.1	13.6	121.5	77.7	102.0	14.0	29.1	24.3
10.6	19.4	17.5	55.4	66.5	46.1	19.4	29.2	9.7
9.7	9.7	8.7	121.5	75.8	48.6	15.5	28.1	10.4
15.5	17.0	9.7	102.0	87.4	51.0	14.5	25.7	[illegible]
12.6	9.7	14.6	70.4	89.9	77.7	14.5	29.1	29.1
12.6	14.6	19.4	127.8	81.1	77.7	14.5	29.1	34.0
10.6	14.6	7.3	72.9	85.0	87.4	24.3	41.7	38.8
10.6	24.3	19.4	58.3	63.1	89.9	18.4	48.6	29.1
12.1	9.7	14.6	64.6	63.1	68.0	13.1	36.4	36.4

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Inner longitudinal muscle layer	11.8	14.5	12.6	.19
Circular muscle layer	74.6	78.5	89.0	.41
Outer longitudinal muscle layer	16.3	29.3	24.5	.15

* "Birds in species" used as error variance

EXPLANATION OF TABLE 12.

The goblet cells were found throughout the small intestine. Ackert, Edgar and Frick (1938) found that the goblet cells increased in abundance with the age of the chicken. The ages of the birds studied could not be determined but plumage indicated all were adult birds.

Table 12. Number of goblet cells per 20 counted in the duodenum. In the columns to the left are the counts made near the tip of the villus and in the columns to the right are the counts made of the goblet cells in the crypts of Lieberkühn.

Goblet cells on villi			Goblet cells in crypts of Lieberkühn		
Dove	Woodpecker	Meadowlark	Dove	Woodpecker	Meadowlark
5	2	6	4	2	4
6	2	5	6	6	2
6	2	3	6	4	2
3	3	2	5	5	5
4	3	3	5	4	4
3	5	8	6	5	8
3	4	7	3	5	4
6	2	4	6	1	5
3	2	8	3	1	5
4	2	7	2	7	4
2	1	3	0	3	1
5	3	2	1	1	1
3	3	5	4	1	3
2	3	3	0	2	0
2	4	2	2	3	0

Table of Means

	Dove	Woodpecker	Meadowlark	P*
Goblet cells per 20 cells near villus tip	3.6	2.7	4.5	.25
Goblet cells per 20 cells in crypts of Lieberkühn	3.5	3.3	3.2	--

* "Birds of species" used as error variance

Table 13. Summary of Means and of Analyses of Variance Obtained.

Epithelial cell nuclei

		Dove	Woodpecker	Meadowlark	P*	
Near tip of plicae proventriculi	length	7.0	8.4	7.7	.13	
	width	4.2	5.1	4.8	.07	
In sulci proventriculi	length	6.0	6.7	6.4	.33	
	width	3.3	4.6	4.3	.04	significant
At tip of villi duodenum	length	6.0	7.2	5.3	.01+	significant
	width	4.5	5.1	4.2	.01+	significant
In crypts of Lieberkühn	length	6.5	7.5	6.5	.09	
	width	4.1	4.6	4.7	.21	
Parietal glands						
Size of nuclei of the cells	length	5.1	5.3	4.6	.04	significant
	width	4.2	4.6	4.1	.14	
Size of cells of the glands	length	9.9	9.8	8.4	.06	
	width	7.7	7.7	6.7	.10	
Size of gland lobules	height	1081	700	954	.09	
	width	421	289	479	.06	
Mucosa of proventriculus and villi of duodenum						
Height of plicae proventriculi and tunica propria of proventriculus		172	462	488	.003	significant
Size of villi	height	1017.1	1388.6	1067.9	.08	
	width near base	149.2	282.4	136.6	.34	
	width midway	107.6	146.5	78.5	.02	significant
	width near tip	101.0	107.6	70.0	.41	

Table 13. (Continued)

		Dove	Woodpecker	Meadowlark	P*	
Crypts of Lieberkühn						
Height of crypts		46.6	63.1	237.5	<<.001	significant
Number of lobules per field		4.9	5.0	15.7	<<.001	significant
Size of lobules	length	56.7	66.8	80.0	>.50	
	width	52.6	52.8	77.2	.22	
Thickness of muscle layers						
Inner longitudinal of proventriculus	below lobule	25.9	42.5	36.2	.15	
	below septum	50.2	84.5	110.5	.045	significant
Inner longitudinal of duodenum (Muscularis mucosa)		11.8	14.5	12.6	.19	
Circular layer of proventriculus		70.1	130.9	112.7	.14	
Circular layer of duodenum		74.6	78.5	89.0	.41	
Outer longitudinal layer of proventriculus		21.0	34.0	23.5	.29	
Outer longitudinal layer of duodenum		16.3	29.3	24.5	.15	
Nuclei of muscle cells of proventriculus						
Circular layer	length	17.6	19.5	17.1	.38	
	width	2.0	2.2	2.1	>.50	
Inner longitudinal layer	length	2.4	2.8	2.5	>.50	
	width	1.9	2.2	2.1	>.50	
Goblet cells per 20						
Near tip of villi		3.6	2.7	4.5	.25	
In crypts of Lieberkühn		3.5	3.3	3.2	--	

* "Birds in species" used as error variance

muscle layer under the septum of the parietal gland lobules

(5) Width of villi midway between base and tip

(6) Length and width of nuclei at tip of villi

(7) Height of crypts of Lieberkühn

(8) Number of crypts of Lieberkühn per field,

these significant features are accompanied by a lack of significance in:

(1) Length and width of nuclei at tip of plicae proventriculi

(2) Length of nuclei in sulci proventriculi

(3) Width of nuclei of parietal gland cells

(4) Length and width of parietal gland cells

(5) Height and width of parietal gland lobules

(6) Length and width of the nuclei of the circular and inner longitudinal muscle layers of proventriculi

(7) Thickness of inner longitudinal muscle below lobule, thickness of circular muscle and thickness of outer longitudinal muscle of the proventriculus

(8) Height of villi, width of villi near base, and width of villi near tip

(9) Length and width of nuclei in crypts of Lieberkühn

(10) Length and width of individual lobules of crypts of Lieberkühn

(11) Thickness of inner longitudinal, circular and outer longitudinal muscle layers of the duodenum

(12) Count of goblet cells near villus tip and in crypts of Lieberkühn.

From the analyses it appeared that the results of the measurements of the muscles in both the proventriculus and duodenum and the result of the count of the goblet cells were very unsatisfactory as regards proof that food habits are paralleled by histological differences. In the muscles the lack of evidence by analysis for the differences obtained in the means probably can be partly explained by the fact that the muscles of the fixed tissues undoubtedly differed greatly in degree of contraction. However, it must be borne in mind that even though the differences in mean were not confirmed by analyses, this does not exclude the possibility of a significant difference among the species on the particular thing studied.

The differences in mean which could not be regarded as significant by analysis will not be considered. If one could consider that greater size and greater number, e.g. size of parietal cells, number of crypts of Lieberkühn, were indicative of superior development, then the woodpecker had the best all around development. It showed the best development in five sets of measurements out of nine. The dove in no point of comparison showed the greatest development. The meadowlark was by far superior to the other two species in development of the crypts of Lieberkühn. Evidently it was capable of secreting a much larger quantity of intestinal juice.

According to Wan and Wu (1935), Voight (1934), Wan and Lee (1931) and Riedel (1944) a vegetable diet supplemented by meat is better than a strict vegetarian diet as regards growth and development. Biester (1944) stated that in general animal proteins are considered to be superior to plant proteins in poultry feeding. He indicated that a ration should range from a 13 percent to a 17 percent level of high quality proteins. He further states that a combination of meat meal, fish meal and soybean meal is more efficient biologically than meal and fish meal as a protein supplement.

It seems, judging from experimental results of various authors, that a proper balance of animal diet and vegetable diet is desirable and appears to give the best results in growth and development. The woodpecker and meadowlark were omnivorous and the dove was granivorous. The woodpecker excelled in size of nuclei of surface epithelial cells and the meadowlark excelled in development of the crypts of Lieberkühn and height of mucosa of proventriculus. The results indicated that the proventriculus and duodenum of the omnivorous birds, woodpecker and meadowlark, were more like each other than like the dove in histological features. The development as observed by a microscopical study indicated that it paralleled the food habits in the birds studied. However, whether one was the result of the other is not yet known.

SUMMARY

The proventriculus and duodenum of three species of birds, mourning dove, red-headed woodpecker and meadowlark, were studied microscopically to ascertain if the histological picture could be associated with the feeding habits.

Three birds of each species were collected for comparison. Adult birds were collected, essential tissues fixed in Bouin's

fixative, transferred to paraffin through dioxan and stained with Delafield's haematoxylin and eosin.

Fifteen measurements were made upon each species to obtain each mean for comparison. The measurements taken were length and width of epithelial nuclei near tip of plicae proventriculi, in sulci proventriculi, at villus tip and in crypts of Lieberkühn; length and width of parietal gland lobule, length and width of parietal gland cells and length and width of parietal gland cell nuclei; height of plicae proventriculi and tunica propria of proventriculus; height and width at base, midway and at tip of villi, height of crypts of Lieberkühn, number of crypts lobules per field, length and width of each lobule; thickness of inner longitudinal muscle layer of duodenum, its thickness under the gland lobule and gland septum in the proventriculus; thickness of circular and outer longitudinal muscle layers of both proventriculus and duodenum; length and width of nuclei of inner longitudinal and circular muscle layers of proventriculus; count of goblet cells in crypts of Lieberkühn and at the villus tip.

Nine sets of measurements, shown significant by analysis, were used for comparison. The woodpecker with an animal diet of 33 percent showed the greatest development in most comparisons, the meadowlark with an insect diet of about 74 percent closely approached the woodpecker but exceeded both the woodpecker and dove by far in the development of the crypts of Lieberkühn. The dove, almost entirely granivorous, showed the least development. In this research the histological picture seemed to parallel the food habits, but does not prove that one was the result of the other.

ACKNOWLEDGMENT

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EXPLANATION OF PLATE I

Fig. 1, 2 Cross section of proventriculus of the mourning dove

Fig. 3, 4 Cross section of proventriculus of the woodpecker

Fig. 5, 6 Cross section of proventriculus of the meadowlark at different regions

A. Mucosa

B. Follicle of parietal glands

C. Septum separating gland follicles

D. Inner longitudinal muscle layer

E. Circular muscle layer (outer longitudinal layer not drawn)

I. Parietal gland follicle showing arrangement of glandular structure

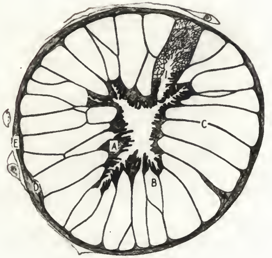


Fig. 1

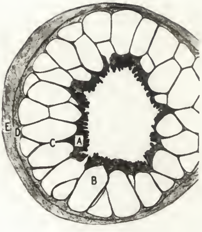
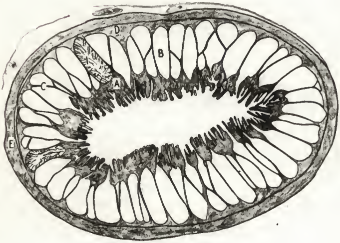


Fig. 2



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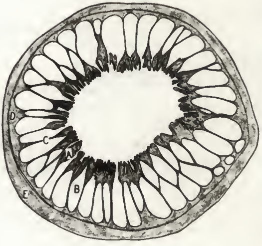

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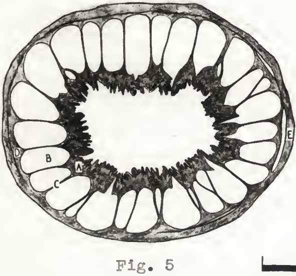

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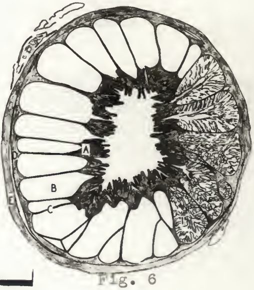


Fig. 6

Scale 2 mm

EXPLANATION OF PLATE II

Fig. 7 Portion near base of parietal gland follicle of the dove

Fig. 8 Portion near base of the parietal gland follicle of the woodpecker

Fig. 9 Portion near base of the parietal gland follicle of the meadowlark

A. Parietal gland cells

B. Septum

C. Inner longitudinal muscle

D. Lymph nodule under septum

Fig. 10 Muscle nuclei of dove proventriculus

Fig. 11 Muscle nuclei of woodpecker proventriculus

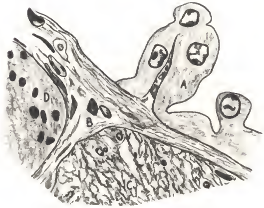
Fig. 12 Muscle nuclei of meadowlark proventriculus

C. Nuclei from circular muscle

I. Nuclei from inner longitudinal muscle

PLATE II

Fig. 7



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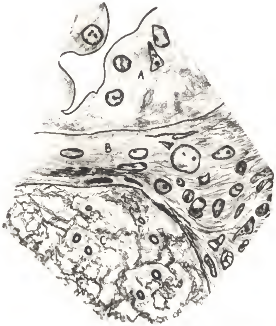

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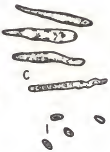

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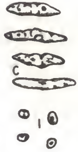

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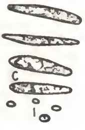


Fig. 12

EXPLANATION OF PLATE III

Fig. 13, 14, 15 Three sections taken at different regions in proventriculus of dove showing the cells and septum of the parietal glands

Fig. 16, 17, 18 Three sections taken at different regions in proventriculus of the woodpecker showing the cells and septum of the parietal glands

Fig. 19, 20, 21 Three sections taken at different regions in the proventriculus of the meadowlark showing the cells and septum of the parietal glands

A. Parietal gland cell

B. Septum

Fig. 13

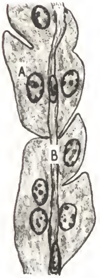


Fig. 14

Fig. 15

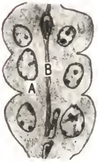


Fig. 16

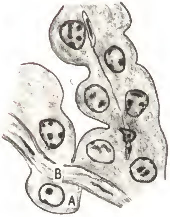


Fig. 17

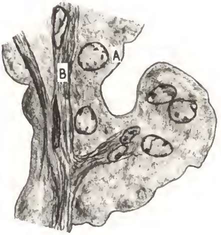


Fig. 18

Fig. 19

Fig. 20

Fig. 21

Scale 50 microns

EXPLANATION OF PLATE IV

Fig. 22 Section of plicae proventriculi of dove

Fig. 23 Section of sulcus proventriculi of dove

Fig. 24 Section of plicae proventriculi of woodpecker

Fig. 25 Section of sulcus proventriculi of woodpecker

Fig. 26 Section of plicae proventriculi of meadowlark

Fig. 27 Section of sulcus proventriculi of meadowlark

A. Epithelial cells

B. Tunica propria

C. Cuticle

Fig. 22

Fig. 23

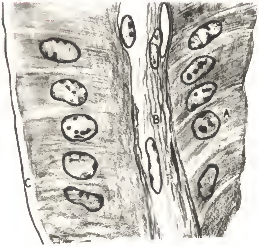


Fig. 24

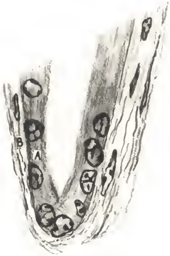


Fig. 25

Fig. 26

Fig. 27

Scale 50 microns

EXPLANATION OF PLATE V

Fig. 28 Section near tip of villus in dove duodenum

Fig. 29 Section near tip of villus in woodpecker duodenum

Fig. 30 Section near tip of villus in meadowlark duodenum

Fig. 31 Section in crypt of Lieberkühn in dove duodenum

Fig. 32 Section in crypt of Lieberkühn in woodpecker duodenum

Fig. 33 Section in crypt of Lieberkühn in meadowlark duodenum

Fig. 34 Section of duodenum of dove

Fig. 35 Section of duodenum of woodpecker

Fig. 36 Section of duodenum of Meadowlark

A. Cuticle

B. Epithelial cells

C. Tunica propria

D. Duodenal villi

E. Crypts of Lieberkühn

F. Tunica muscularis

PLATE V

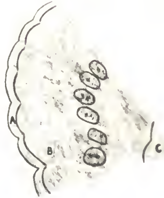


Fig. 28

Fig. 29

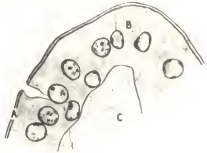


Fig. 30

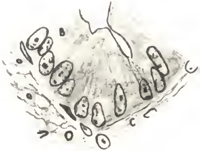
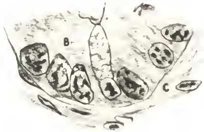


Fig. 31



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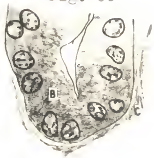

Fig. 33

Fig. 34

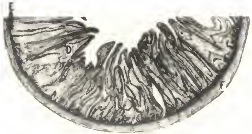

Fig. 35

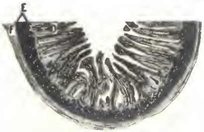

Fig. 36

Scale 2 mm
