A comparative anatomical study of the digestive systems of the desert jack rabbit and the pika

Dale Stanley Rupert
Brigham Young University - Provo

A Comparative Anatomical Study of the Digestive Systems of the Desert Jack Rabbit and the Pika

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This Thesis by Dale S. Rupert is accepted in its present form by the Department of Zoology and Entomology as satisfying the Thesis requirement for the degree of Master of Science.

February, 1950 Signed

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INTRODUCTION

It is the purpose of this study to make gross and histological comparisons of the various segments of the intestinal tracts of the jack rabbit and the pika. The two animals used for this study were the desert jack rabbit (*Lepus californicus deserticola* Mearns), and the pika (*Ochotona princeps uinta* Hollister).

Since the pika and jack rabbit are both members of the order *Lagomorpha*, it is to be expected that most of the structural characteristics of the intestinal tube of these animals are the same or similar, and since their food habbits are quite alike, any modifications of the intestines would be minor changes, and not of sufficient magnitude to change the function or effectiveness of any portion of the tube.

The jack rabbits were found only in the desert valleys and low foothills in the areas studied. These areas are typically open bush or sage brush types of communities. The pikas were restricted to certain high rockslides in this region. These areas are described more completely in the section on Methods and Materials.

This study is limited to a comparison of the gross and microscopic anatomy of the digestive tube in these two animals. Other similar problems present themselves and afford excellent material for future study. A histological comparison of the salivary glands, liver, and other glands associated with the digestive system would be an excellent study. Another promising problem would be a comparison of the physiology and microscopic anatomy of the _sacculus rotundus_ in the jack rabbit with the _tubular lymphoid processes_ in the pika.

REVIEW OF THE LITERATURE

The two most useful references on the gross anatomy of the domestic rabbit are by Bensley (1946)[1] and by Crabb (1946). These two books were used as both text and laboratory guide for the dissection of the jack rabbit.

Crabb and Kelsall (1941) give an excellent report on the mucosa and lymphatic structures of the rabbit appendix. In this article they describe the structure of the appendix in the domestic rabbit and point out the differences that exist between the structure of this organ in the rabbit and that of other animals.

Jordan and Looper (1927) compare the histology of the lymph nodes of the domestic rabbit. Latta (1921) reports on the histogenesis of the dense lymphatic tissue in the intestines. The domestic rabbit was one of the animals he used in his study.

Dawson (1927) describes the types of cells and their locations in the epithelium of the fundic mucosa. He divides these cells into four groups: the tall columnar cells on the free surface of the epithelium, the cuboidal cells that line the neck of the gastric pits, and the

1 Complete references are provided in the section References Cited.

chief and parietal cells, both in the secretory tubules of the gastric glands.

Beams (1932) outlines methods for showing the complicated secretory canaliculi of the parietal cells and also the mitochondria and golgi materials in the stomach mucosa. In addition, he provides good descriptions of these structures.

Bowie (1940) describes the distribution of the chief or pepsin-forming cells in the gastric mucosa of the cat. Dawson (1945) compares the distribution of the argentaffin cells of the gastric mucosa of the domestic rabbit and other laboratory animals. In comparing the blood supply to the jejunum and ileum of man and certain laboratory animals, Noer (1943) points out that of all the animals studied, the domestic rabbit has the poorest supply of blood to these areas.

The only reference that the writer could find on the anatomy of the digestive system of the pika was the report by Kelsall (1942) on the structure of the saccules in the procolon of the pika.

Various texts on histology and histological technique have been a great help. Some of those that afforded the greatest assistance are by Cole (1941), Bremer and Weatherford (1944), Maximow and Bloom (1942), and Lee (1937).

The handbook on Photomicrography, published by the Eastman Kodak Company, was used as a guide in preparing the microphotographs which appear in this report.

METHODS AND MATERIALS

A. Field Locations and Methods

Pikas for this study were collected from three areas. One is situated in a large rockslide one hundred yards northwest of the outlet of Cliff Lake, one mile northwest of Tryol Lake, Wasatch county, about thirty five miles east of Kamas, Utah. The other two are situated on the north-east-facing slope of Mount Timpanogos in Utah county. All collections were made at elevations of nine to ten thousand feet. The first of these two latter areas is situated about two miles southwest of the summit of the Loop road, and the second is situated on the high cirque above the Timpooneke Forest Campground. These last two areas are in the Wasatch National Forest, about fifteen miles east of American Fork, Utah. The Loop road mentioned is the road which connects Provo Canyon at Wildwood, Utah with American Fork Canyon. The majority of the thirty nine animals collected were taken from the cirque above the Timpooneke Forest Campground.

Three areas were covered in collecting the nine rabbits for this study. Two are situated west of Utah Lake, in Cedar Valley and Rush Valley, Utah. The third area, from which most of the animals were taken, is found around the base of the West Mountain, eight miles west of Spanish Fork, Utah.

In securing pikas, two methods were tried. First, various types of live traps and snares were used in an attempt to capture some animals alive, but with little success. The other method, and only successful one, involved shooting the animals with a 410 gauge shotgun, using number twelve shot. Since the animals are not very shy, it is quite easy to secure them in this manner. The best time of day to collect these animals is in the early morning before the direct rays of the sun hit the rockslide, since they are not very active during the heat of the day.

The method employed in securing the fabbits is a little more involved. The rabbits, like the pikas, are quiescent during the heat of the day, but are very active at night. The procedure followed in securing the specimens involved three persons: one to drive the car slowly through the area to be covered, and one on each of the front fenders of the car. One of these persons held a powerful spotlight with which he searched the countryside; the other held the gun, a twelve gauge shotgun, with which to kill the animals.

The following method was used in preserving specimens for gross dissection: soon after the animals were killed, they were injected with one hundred cubic centimeters of concentrated formaldehyde half in the coelomic cavity and half in the thoracic cavity. The carcasses were then completely immersed in a ten percent formalin solution and preserved in this manner until ready for study.

In preserving tissue specimens for histological comparisons, the following procedure was followed:

immediately after the animal was killed, it was dissected so that portions of each organ needed for this study could be removed. Tissue specimens were taken from the three salivary glands, liver, pancreas, tongue, anterior, middle, and posterior esophagus, fundic and pyloric stomach, duodenum, jejunum, ileum, appendix, colon, and rectum (Figs. 1-4). Those pieces of the tube that were thin and flat and had a tendency to roll up were pinned to little, flat pieces of cork before fixing. All pieces of the tube that contained any undigested food or refuse were washed with a normal saline solution and then placed immediately in a vial of fixative and properly labeled.

Two well-known fixatives were used: Bouin's and Worcester's. Duplicate pieces of tissue were taken from each organ and one piece was placed in each fixative. Tissues were stored in Bouin's indefinitely, but those fixed in Worcester's were changed to seventy percent ethyl alcohol for storage after a fixing time of 12-48 hours, in order to prevent the formation of crystals in the tissues. The following modification of Worcester's fixative was used in this experiment:

Saturated mercuric chloride in 10% formalin..	50 ml.
Absolute alcohol............................	50 ml.
Glacial acetic acid.........................	5 ml.

Since so many vials of fixative were needed for each animal, it was necessary to construct a special carrying case that was compact and yet would hold about two hundred vials. This case was invaluable to the work, therefore its description is given, since someone else may find use for the idea in a similar project (Fig. 5).

In order to conserve space in the carrying case, the vials were arranged in tiers, one above the other, and placed on an angle of thirty degrees from the vertical. A tray was constructed above the vials to hold extra vials and dissection equipment. Special doors were constructed with a twofold purpose in mind: to make a tight case when closed, and to serve as an operating table when open. Four light chains with small battery clamps attached to one end of each were used to attach to the four legs of the animal and act as retractors to hold the animal immobile while the dissection was going on.

For greatest efficiency and comfort in dissecting the rabbits at night, the writer placed the case in the trunk of the car with the trunk lid up and a good light suspended at a point above the operating table lid of the case. A kitchen stool was carried along so that the operator could be comfortable while dissecting.

Key to Figures 1-4

Fig. 1. Ventral view of jack rabbit intestines intact.

Fig. 2. Ventral view of jack rabbit intestines spread out.

Fig. 3. Ventral view of pika intestines intact.

Fig. 4. Ventral view of pika intestines spread out.

Locations from which tissue specimens were taken.

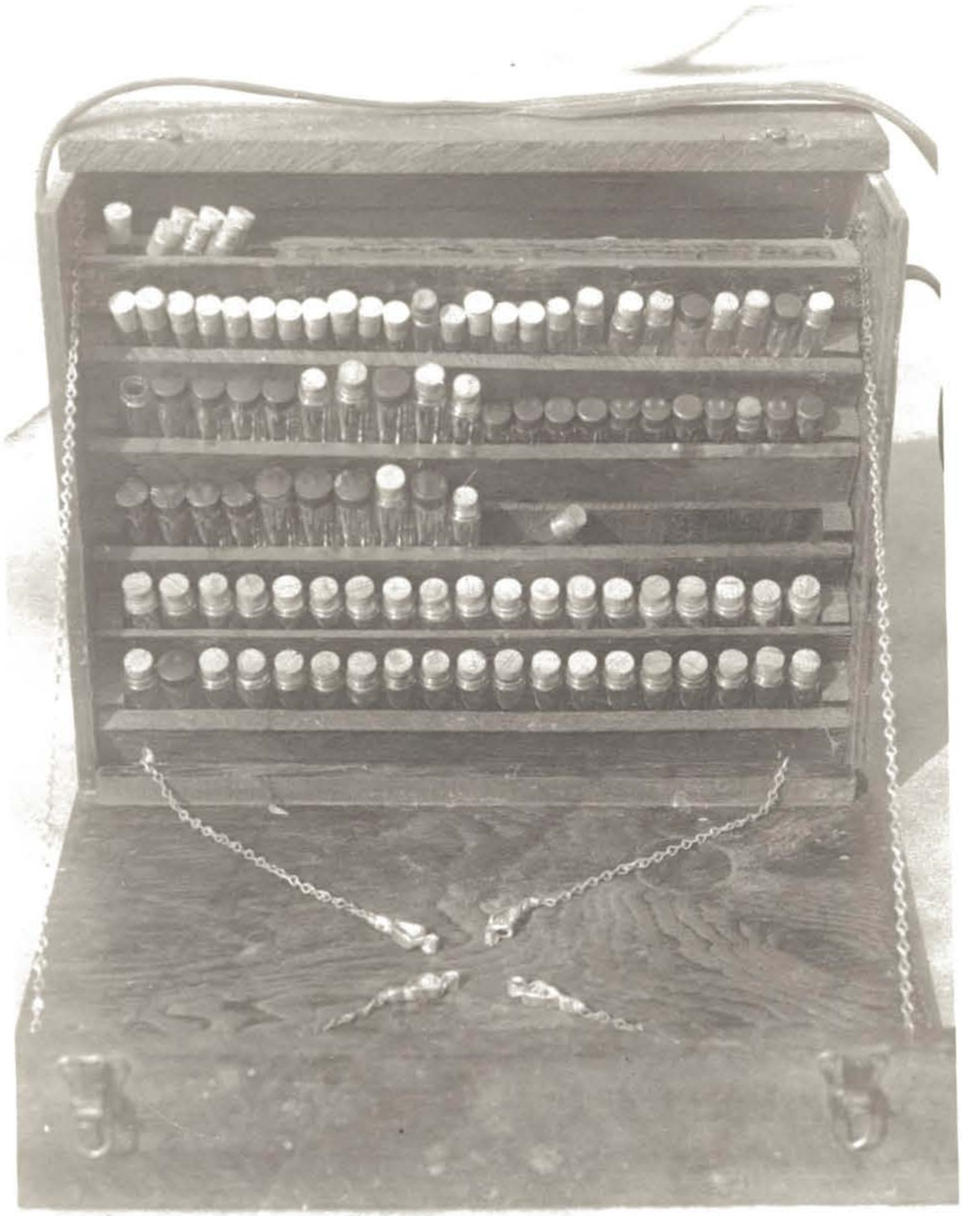
A. Anterior esophagus.
B. Middle esophagus.
C. Posterior esophagus.
D. Fundic stomach.
E. Pyloric stomach.
F. Duodenum.
G. Jejunum.
H. Ileum.
I. Caecum.
J. Vermiform appendix.
K. Colon.
L. Rectum.
M. Tubular lymphoid process.
N. Procolon.
O. Sacculus rotundus.

Fig. 1
Jack Rabbit

Fig. 2
Jack Rabbit

Fig. 3
Pika

Fig. 4
Pika



Vial Carrying Case

Dimensions
8"x18"x21"

B. Laboratory Methods

The process of making gross comparisons involved, first, ascertaining the total length of the animal in centimeters (length from tip of nose to end of caudal tail vertebra); second, dissecting out the digestive tract *in toto*; third, straightening out the tube; fourth, measuring and recording the lengths of the various segments of the tube from the anterior opening of the esophagus to the anus; and fifth, describing the location and appearance of these segments.

After an adequate fixation time, the tissue specimens were trimmed and embedded by means of the n-butyl alcohol method. This method was employed, not because it is superior to other well-known methods, but because it is one of the quickest methods known. The only variation in the procedure between those tissues fixed in Bouin's and those fixed in Worcester's was that the tissue fixed in Worcester's was placed in 80% iodine alcohol for two hours to remove the mercuric chloride crystals from the tissue.

These two fixatives were used in the hope that one would show up certain structures better than the other. The writer was, however, unable to distinguish any variation in the results due to the fixative used.

The paraffin used had a melting point of 54.4-56.1° C. To this was added about 2% beeswax. All paraffin infiltrating was done in a Heuttner paraffin oven at a temperature just above the melting point of the paraffin, or about 58° C.

The mounting procedure followed is primarily the same as that outlined in any good laboratory text on microtechnique. All tissues were stained routinely with Harris' hematoxalin and eosine and with Mallory's triple stain.

Harris' hematoxalin and eosine gave the best results for studying epithelium, glandular tissue, types of cells, and cell inclusions. Mallory's triple stain was more satisfactory for studying connective tissue and the size and location of the different layers which make up the wall of the tube. For photographic reproductions, hematoxalin and eosine was found to be far superior to Mallory's.

For making the photographic illustrations, a Bausch and Lomb photomicrographic camera was used. Eastman Panatomix-X 5X 7 inch sheet film was used with this camera. Best results were obtained by using in combination the Ratten B-58 and Ratten E-22 light filters. D-76 Kodak fine grain developer was used for developing the negatives. The figures shown in this report are printed on 8½X11 inch sheets of Defender AL Apex #3 contact paper.

Exposure times are not given in this report, since these figures would not apply to other equipment, magnifications, stains, or tissues.

GROSS COMPARISONS

No differences could be observed in a gross comparison of the esophagus of the jack rabbit and the pika. In both the jack rabbit and the pika, the stomach lies almost in a transeverse plane, extending a little more to the left side than to the right, and almost completely hidden from view on the ventral side by the liver. The shape of the stomach, in these two animals, is almost identical: both are formed in a tight "U" shape, with the esophagus entering near the middle of the lesser curvature.

The small intestine of the domestic rabbit is adequately described by Bensley (1946, pp. 94-99, 219-223). In studying the gross anatomy of the jack rabbit and the pika, the writer could find no differences in the small intestines except those described in the following paragraph.

In the jack rabbit there is an enlargement on the ileum near the ileocaecal valve known as the sacculus rotundus (Fig. 2-O). This structure does not occur in the pika, but other tubular structures coming off the caecum near this junction, which are peculiar to the pika and called tubular lymphoid processes by Kelsall (1942), may possibly have the same or a similar function (Fig. 4-M). A difference was observed in the relative lengths of the small intestines of the two animals. Table 1, p. 17, shows that in proportion to body length, the small intestine of the pika is considerably longer than that of the jack rabbit. An attempt is made to correlate this variation with other structural differences in the final summary.

In relative size and appearance, the caeca of both animals look very much alike. In both animals, the junction between the ileum and caecum is located almost in the geometric center of the coelomic cavity, and from this point, the caecum forms a large, complete, mid-ventral, counter clock-wise loop, and ends in a fairly long, thick-walled vermiform appendix.

The wall of the caecum in both animals is distinctly marked with a spiral line which denotes the position of an internal spiral fold (valve) of the lining membrane. The presence of this spiral valve increases the internal surface area and may indicate a similarity in the food habits of these two animals.

As previously mentioned, the outstanding difference in the gross anatomy of the caeca of these two animals is the presence of tubular lymphoid processes on the caecum near the junction of the ileocaecal aperature in the pika, which are not found in the rabbit.

Crabb (1946, p. 67) gives a good description of the appearance and location of the large intestine in the domestic rabbit, and Bensley (1946, p. 223) adequately describes the divisions of this segment.

The large intestine of the pika is similar to that of the jack rabbit, but there are two significant differences. About two and one half inches from the ileocaecal valve and between the caecum and colon is a peculiar modification of the tube in the pika. It is a thick-walled structure about 4 cm. in length and .7 cm. in diameter, with a smooth outer surface (no haustra or spiral valve). This structure is sometimes referred to as the procolon (Kelsall, 1942) (Fig. 4-N).

Another difference, previously referred to, is the presence of tubular lymphoid processes on the caecum of the pika. There are two of these structures; one is very small and forms a small cone-shaped bulge from the wall of the caecum; the other is a fairly long blind tube which is almost identical in size and shape to the wermiform appendix.

In summarizing the gross characteristics of these two animals, it is now apparent that many segments of the intestinal tract of the pika are very similar to those in the rabbit. Some of the most notable differences are as follows: the presence of the sacculus rotundus on the ileum of the rabbit, the procolon and tubular lymphoid processes on the caecum of the pika, and the differences in relative length of the small intestines in the two animals as shown in Table 1. This shows that in proportion to body length, the small intestine of the pika is longer than that of the rabbit. The lengths shown in this table are the average of the lengths of the three animals of each kind studied.

TABLE 1

Table of Relative Lengths of Tube Segments

Part	of Rabbit Length--cm.	of Pika Length--cm.	of Rabbit Rel. Length	of Pika Rel. Length
Total Length of Animal	53.0	20.0		
Esophagus	18.0	6.4	.33	.32
Stomach	7.5	3.4	.14	.17
Small Intest.	185.0	132.0	3.4	6.6
Caecum	32.0	18.0	.6	.9
Colon and Rectum	107.0	36.5	2.0	1.8
Total Length of Tube	349.5	196.3	6.6	9.8

MICROSCOPIC COMPARISONS

A. Esophagus

The esophagi of the jack rabbit and pika are similar in most respects to those of other mammals. The esophagus is made up of six distinct layers: a stratified squamous epithelium, tunica propria, muscularis mucosa, submucosa, tunica muscularis, and tunica adventitia (serosa).

In the anterior segment of the esophagus in the jack rabbit, the muscularis mucosa is composed of small scattered bundles of smooth muscle. Progressing caudally from the anterior end, this layer increases in thickness, until in the posterior section it is as thick as the external longitudinal layer of the tunica muscularis (Fig. 7-C and H). No discernible layer of muscularis mucosa can be found in the anterior segment of the esophagus in the pika, but in the posterior segment a definite layer can be seen, but of not as great a thickness, relatively, as in the jack rabbit (Fig. 8-C).

The principal structural difference between the esophagi of the two animals studied is the relative thickness of each of the three layers comprising the tunica muscularis. In the jack rabbit, the predominant layer is the middle circular layer; it is three times as thick as the same layer in the pika. The outer longitudinal layer of the tunica muscularis in the jack rabbit is composed of scattered bundles; it forms an indefinite layer no thicker than the same layer in the pika. The other muscle layer of importance is the inner longitudinal layer. This layer is about one third as thick as the middle layer (Figs. 7 and 8).

In the pika there is a more even distribution of the circular and longitudinal muscle layers. As in the rabbit, the middle circular layer is the widest, but the external longitudinal layer is the same thickness as the inner longitudinal layer, each of which is one half as thick as the middle circular layer (Fig. 8-E, F, and G).

In both the pika and jack rabbit, the tunica muscularis is composed entirely of striated muscle, which extends all of the way down to the stomach (Fig. 6). No tubular glands were observed in the esophagus of either animal.

Key to Figures 6-8

Fig. 6. Striated muscle in posterior esophagus of jack rabbit. Magnification 500X. Hematoxalin and eosine.

Fig. 7. Posterior esophagus of jack rabbit. Magnification 100X. H. and E.

Fig. 8. Posterior esophagus of pika. 100X. H. and E.

Layers which make up the wall of the esophagus.

A. Stratified squamous epithelium.
B. Tunica propria.
C. Muscularis mucosa.
D. Submucosa.
E. Internal longitudinal layer of tunica muscularis.
F. Middle circular layer of tunica muscularis.
G. External longitudinal layer of tunica muscularis.
H. Tunica serosa.

Fig. 6
Posterior Esophagus of Jack Rabbit

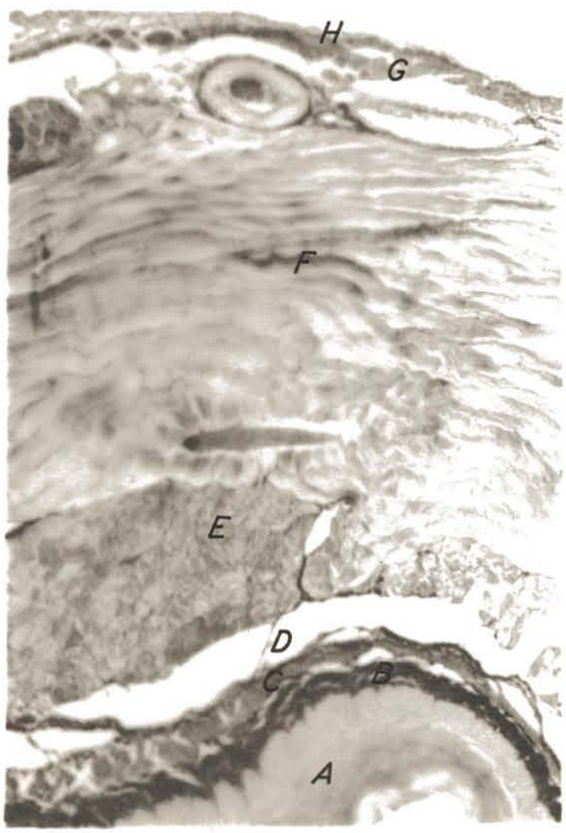


Fig. 7
Posterior Esophagus
of Jack Rabbit

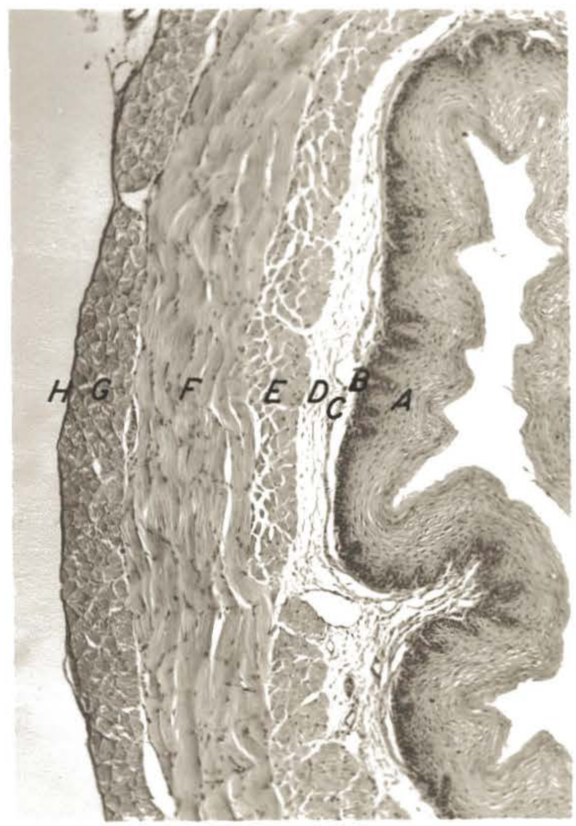


Fig. 8
Posterior Esophagus
of Pika

B. Stomach

The fundic portion of the stomach in a typical mammal is characterized by gastric glands which contain both chief (or zymogen) cells and parietal cells. These are found well exemplified in the mucosa of the jack rabbit stomach. These gastric glands consist of long, straight, simple tubules extending from the gastric pits in the surface epithelium down almost to the muscularis mucosa. The parietal cells are more numerous than the chief cells in these glands of the jack rabbit stomach. In the pika, however, the chief cells appear to be more numerous than the parietal cells, especially in the deeper fundic portion of the glands (Figs. 10 and 12).

In both of these species, the muscularis mucosa is formed of two complete layers of smooth muscle, an inner longitudinal layer and an outer oblique layer. A thick inner circular layer and thin outer longitudinal layer constitute the tunica muscularis. The inner circular layer is twice as thick as the outer longitudinal layer (Figs. 9 and 11).

No differences could be seen between the structure of the pyloric stomach of the jack rabbit and that of the pika; therefore, the following descriptions apply to both animals. In the pyloric part of the stomach, the gastric pits are many times deeper, and the secretory tubules of the pyloric glands are much shorter and more branching than in the fundic portion of the stomach (Figs. 13-15).

No parietal cells were seen in the secretory portions of the pyloric glands. These glands appeared to be made up entirely of chief cells. The inner circular muscle layer of the pyloric portion is twice as thick as the same layer in the fundus. This condition is to be expected, since the inner circular layer forms the largest portion of the pyloric valve. The other muscle layers are the same as those described in the fundic stomach (Figs. 9-15).

Key to Figures 9-15

Fig. 9. Fundic stomach of jack rabbit. 100X. H. and E.

Fig. 10. Gastric glands in jack rabbit stomach. 500X. H. and E.

Fig. 11. Fundic stomach of pika. 100X. H. and E.

Fig. 12. Gastric glands in pika stomach. 500X. H. and E.

Fig. 13. Pyloric stomach of jack rabbit. 100X. H. and E.

Fig. 14. Pyloric glands in jack rabbit stomach. 500X. H. and E.

Fig. 15. Pyloric stomach of pika. 100X. H. and E.

Structures in wall of stomach.

A. Gastric glands.
B. Chief cells.
C. Parietal cells.
D. Gastric pits.
E. Muscularis mucosa.
F. Inner circular layer of tunica muscularis.
G. Outer longitudinal layer of tunica muscularis.
H. Pyloric glands.
I. Secretory tubules of pyloric glands.
J. Secretory tubules of gastric glands.

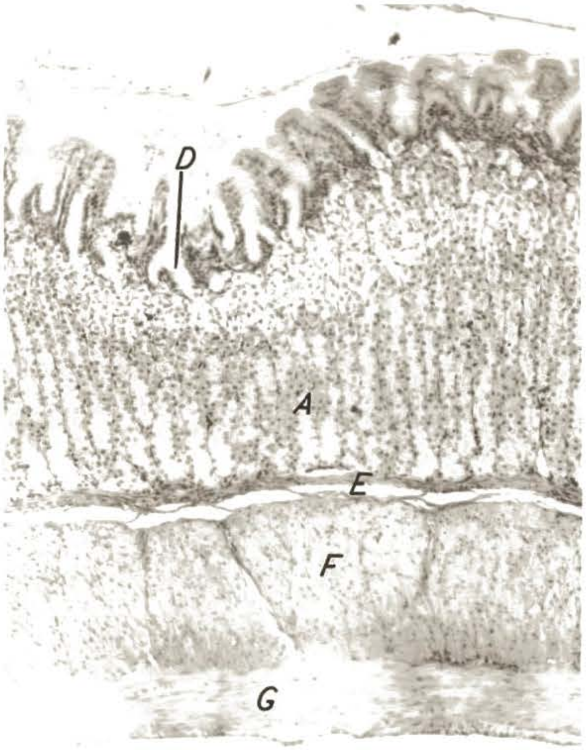


Fig. 9
Fundic Stomach of Jack Rabbit

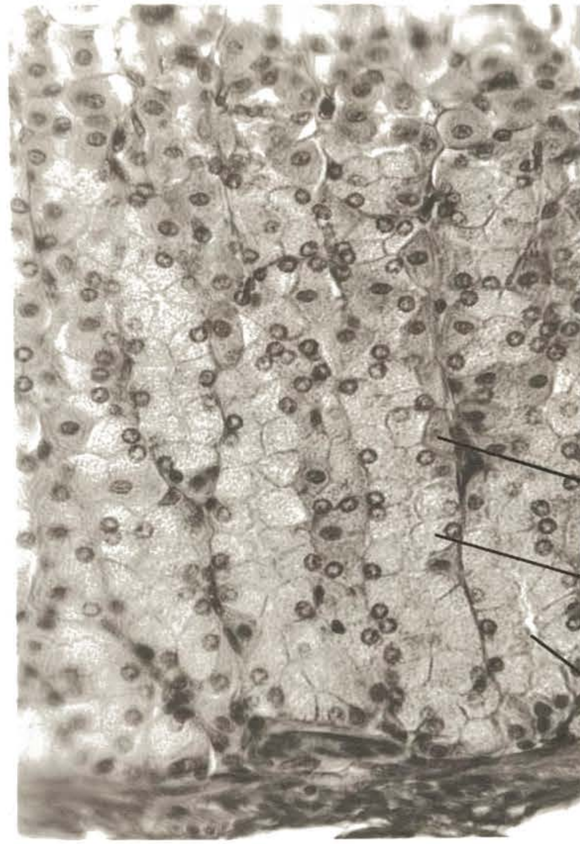


Fig. 10
Gastric Glands in Jack Rabbit

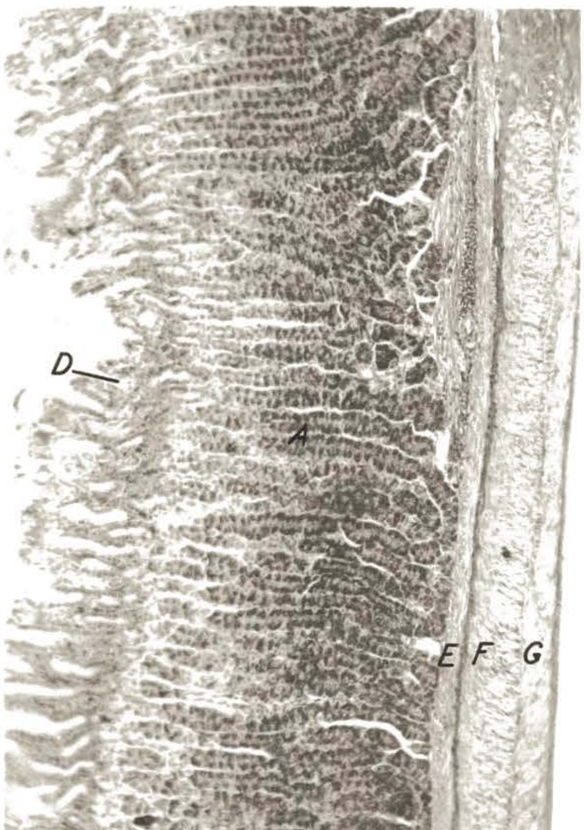


Fig. 11
Fundic Stomach of Pika

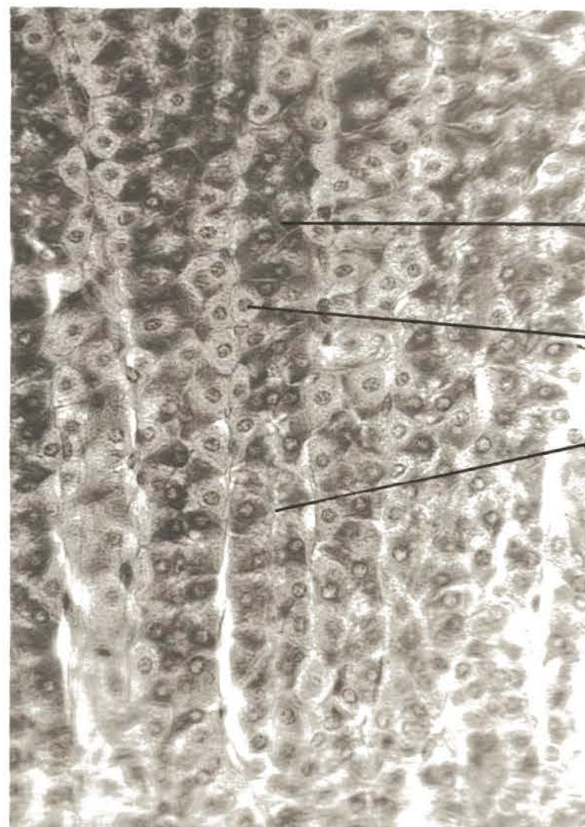


Fig. 12
Gastric Glands in Pika Stomach

Fig. 13
Pyloric Stomach of Jack Rabbit

Fig. 14
Pyloric Glands in Jack Rabbit

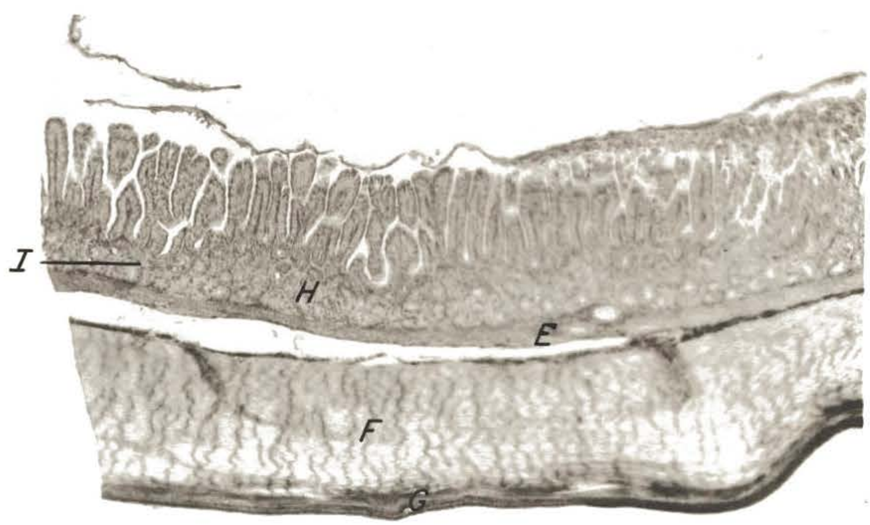


Fig. 15
Pyloric Stomach of Pika

C. Small Intestine

The structures which form the wall of the small intestines in both the jack rabbit and pika, such as the villi, crypts of Lieberkuhn, connective tissue, and muscle layers, are very similar to those of mammals in general. A wide band of Brunner's glands is seen in the submucosa of the duodenum of both the jack rabbit and the pika (Figs. 16-18 D). Paneth cells, as described by Bremer and Weatherford (1944, pp. 348-52), were observed near the blind ends of the intestinal glands in all three segments of the small intestines in both animals, although, many more were observed in the jejunum than in either of the other two segments. These cells appeared to be approximately three times as numerous in the jack rabbit as in the pika.

The only segment of the small intestine that can be differentiated with ease from the other two is the duodenum; this is because of the thick band of Brunner's glands in the submucosa. Although the other two segments, the jejunum and ileum, contain intestinal glands between the villi (crypts of Lieberkuhn), they have no glands in the submucosa. In the jack rabbit there are two main distinctions between these last two segments. In the jejunum the plica circulares (valves of Kerkring) are more highly developed and the villi are higher and more numerous than in the ileum, thus making the wall in cross-section thicker and the lumen smaller in the jejunum than in the ileum.

A definite layer of muscularis mucosa can be seen throughout the entire small intestine of the jack rabbit; this layer was not found in any of the three segments of the small intestine in the pika. No plica circularis was observed in either the jejunum or ileum of the pika (Figs. 19 and 20).

Key to Figures 16-20

Fig. 16. Duodenum of jack rabbit. 100X. H. and E.

Fig. 17. Duodenum of pika. 100X. H. and E.

Fig. 18. Brunner's glands in pika duodenum. 500X. H. and E.

Fig. 19. Jejunum of jack rabbit. 100X. H. and E.

Fig. 20. Ileum of Pika. 100X. H. and E.

Structures in wall of small intestine.

A. Simple columnar epithelium.
B. Villi.
C. Crypts of Lieberkuhn.
D. Brunner's glands.
E. Internal circular layer of tunica muscularis.
F. External longitudinal layer of tunica muscularis.
G. Plica circulares.

Fig. 16
Duodenum of Jack Rabbit

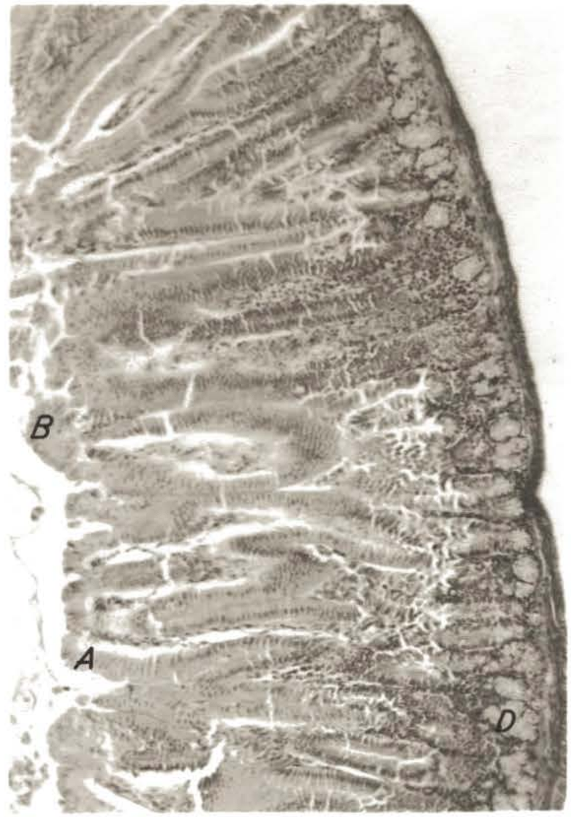


Fig. 17
Duodenum of Pika

Fig. 18
Brunner's Glands in Pika Duodenum

Fig. 19
Jejunum of Jack Rabbit

Fig. 20
Ileum of Pika

D. Large Intestine

The layers that make up the wall of the caecum in the jack rabbit and the pika are essentially the same as those in the small intestine. The presence of a well-developed spiral fold or valve and the absence of villi in the caeca of these animals are the outstanding structural differences between this segment and the small intestine. A well-developed muscularis mucosa is seen here in the pika as well as in the jack rabbit.

There are fewer glands in the mucosa of the caeca of both of these animals and fewer goblet cells in the surface epithelium than appear in the small intestine. The glands in the mucosa of the jack rabbit are a tubular type having several branches on the terminal end. The goblet cells are very numerous and make up about one half of the cells in the deeper parts of the tubules. Tubular glands are also found in the mucosa of the pika, but the terminal ends are straighter and branch less than they do in the jack rabbit. There are about one-tenth as many goblet cells in the caecum of the pika as occur in the jack rabbit. Furthermore, in the pika, the tunica propria is more heavily infiltrated with leucocytes than it is in the jack rabbit.

The structure of the spiral valve in the pika differs from that of the jack rabbit. In the jack rabbit the valve is made up of the epithelium and glands, the tunica propria, muscularis mucosa, and the submucosa, but not any of the layers of the muscularis externa. In the pika, the spiral valve contains all of the layers that occur in that of the jack rabbit, but in the pika the inner circular layer of the tunica muscularis extends into the valve approximately one third of its depth. This condition causes this portion of the valve to be almost twice as thick as the outside wall of the caecum (Fig. 23).

The large intestine of the pika differs from that of the jack rabbit in having between the caecum and colon a narrow, thick-walled structure about 1½ inches in length which Kelsall (1942) describes and calls the <u>procolon</u> (Fig. 4 N). Miss Kelsall wrote a complete report on this structure. Portions of her article are quoted below to complete the description:

> The wall of the procolon is free of folds and is approximately five times as thick as that of the caecum due to the presence of unusual saccules in the wall. The average number of these saccules in a cross section of the organ is sixteen, but varies from fourteen to twenty. The saccules are similar in structure and distribution throughout the procolon, but they end abruptly at the junctions of the caecum and with the colon.
>
> The muscular tunic includes three parts: the longitudinal, the circular layer, which goes around the entire procolon, and the circular which extends into the walls of the saccules. The outer circular and longitudinal layers are similar to those in the small intestine and have the same function. . . . The fibers of the inner circular layer extend in the same direction as those of the outer, but form a conspicuous network around the saccules. Contraction of this layer forces fecal material from the saccules into the central lumen.
> . . . .
>
> Goblet cells are not found in the procolon. . . . Crypts of Lieberkuhn occur throughout the mucosa of the saccules except along the sides where the mucosa is to shallow to contain them (Kelsall 1942, pp. 115-117).

Both the jack rabbit and pika have a vermiform appendix on the end of the caecum. They are very similar in structure except for the presence of flask-shaped mucous glands in the appendix of the jack rabbit. (Glands described by Crabb and Kelsall, 1940, p. 351)(Fig. 25-A). These glands are not found in the appendix of the pika.

The epithelium lining the appendix of both animals consists of simple columnar cells, of which the majority are goblet cells. Bundles of branching tubular mucous glands were observed in the tunica propria of the flask-shaped glands in the appendixof the jack rabbit (Fig. 26-B). Large lymph nodules make up the main body of the wall of the appendix in this animal, and they are separated from each other by the flask-shaped glands on the inner surface and by connective tissue trabeculae which penetrate the lymphoid tissue from the submucosa on the outer (Figs. 25 and 27). It is impossible to differentiate between the tunica propria and the submucosa because of the absence of a muscularis mucosa.

Although flask-shaped mucous glands are not found in the pika appendix, there are instead club-shaped projections into the lumen, which probably have the same function. There are no tubular glands in the mucosa of these club-shaped projections, but there are many leucocytes that have infiltrated into the tunica propria (Figs. 28 and 29). Interspersed between these club-shaped projections are the lymph nodules.

On the caecum of the pika near the ileocaecal valve are found two tubular lymphoid processes (Kelsall, 1942, p. 117). One of these processes is a very small cone-shaped bulge, but the other is a blind tube about two inches in length, exactly the same in gross and microscopic structure as the vermiform appendix except that the diameter of the latter is a little smaller than that of the former. (Figs. 28-31). These additional structures are not found in the jack rabbit.

In the colon of the jack rabbit are found many long, straight tubular glands extending from pits in the surface epithelium to the muscularis mucosa (Fig. 31 A). These are also found in the pika, but they are more limited in numbers because they are only found in the folds of the mucosa, (plica semilunares), and these folds are much farther apart in the pika than in the jack rabbit.

There are no goblet cells in the surface epithelium in the colon of either the jack rabbit or the pika, but they are very numerous in the deeper one third of the crypts. The glands of the colon are primarily of the mucous type and have many goblet cells in the secretory tubules. Since there are no goblet cells in the surface epithelium of either animal, and since there are fewer tubules per unit area in the colon of the pika than in that of the jack rabbit, the number of goblet cells per unit area in the pika is much less than in the jack rabbit.

The tunica muscularis in the colon of both the jack rabbit and pika is composed of two layers similar to those in the preceding segments. The internal circular layer is a consistent layer about the same thickness as the corresponding layer in the caecum, whereas the outer longitudinal layer varies greatly, from very thin in some places to extremely thick in others when viewed in cross section. This variation in thickness of the longitudinal layer, due to the formation of three, large, muscle bundles running longitudinally, (taenia coli), is responsible for the haustrated appearance of the colon.

As in the colon, there are few goblet cells in the surface epithelium of the rectum, but the cells that make up the secretory tubules of the rectal glands are predominantly of this type. In the jack rabbit these glands are in the form of straight parallel tubules extending to the muscularis mucosa from the epithelium. These glands are only about one third as long as the glands in the colon (Fig. 34 C).

In general appearance, the rectum of the pika is very similar to that in the jack rabbit. The muscular layers and shape are very much the same, and as in the jack rabbit, the mucosa and submucosa are thrown into longitudinal folds (rectal columns of Morgagni) (Figs. 34 and 36 B). The rectum is the only segment of the digestive tube, with the exception of the stomach, in which the muscularis mucosa is composed of two definite and complete layers; an inner circular layer and an outer longitudinal layer. These two layers follow the contour of the folded mucosa, while the two external muscle layers form a smooth circle.

A difference was observed between the structure of the rectal glands in the jack rabbit and in those of the pika. In the pika these crypts end in branched tubular glands that form a broad layer between the epithelium and the muscularis mucosa, rather than straight parallel pits as in the jack rabbit. But as in the jack rabbit, the secretory tubules of these glands in the pika are a mucous secreting type (Figs. 34 and 36 C).

Key to Figures 21-24

Fig. 21. Caecum of jack rabbit. 100X. H. and E.

Fig. 22. Structure of spiral valve in caecum of jack rabbit. 500X. H. and E.

Fig. 23. Caecum and spiral valve of pika. 100X. H. and E.

Fig. 24. Structure of spiral valve in caecum of pika. 500X. H. and E.

Structures in caecum and spiral valve.

A. Simple columnar epithelium.
B. Tunica propria.
C. Spiral valve.
D. Wall of caecum.
E. Inner circular layer of tunica muscularis.
F. Outer longitudinal layer of tunica muscularis.

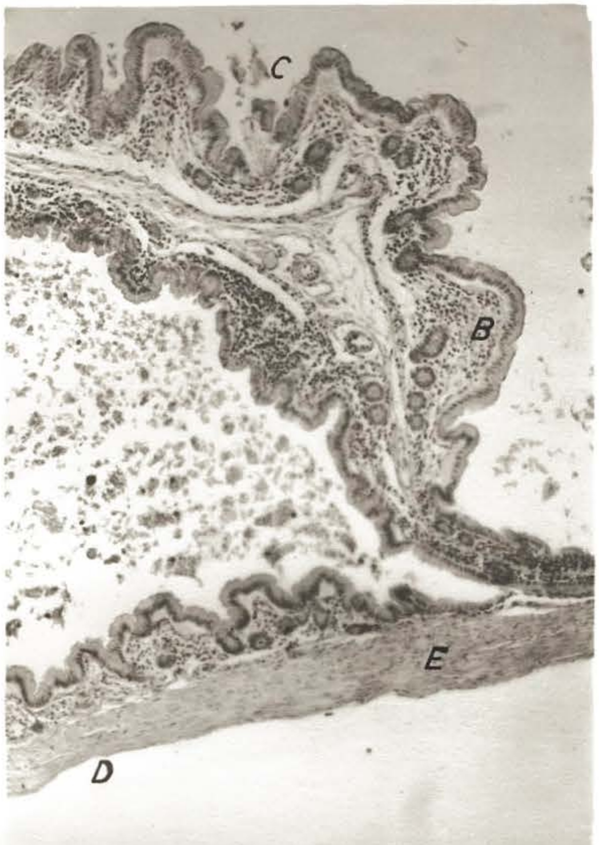


Fig. 21
Caecum of Jack Rabbit

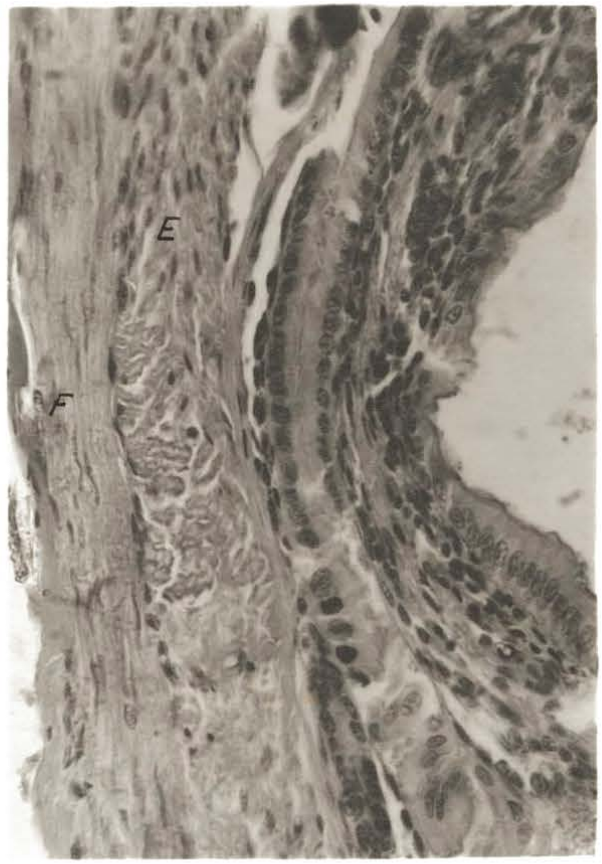


Fig. 22
Spiral Valve in Jack Rabbit

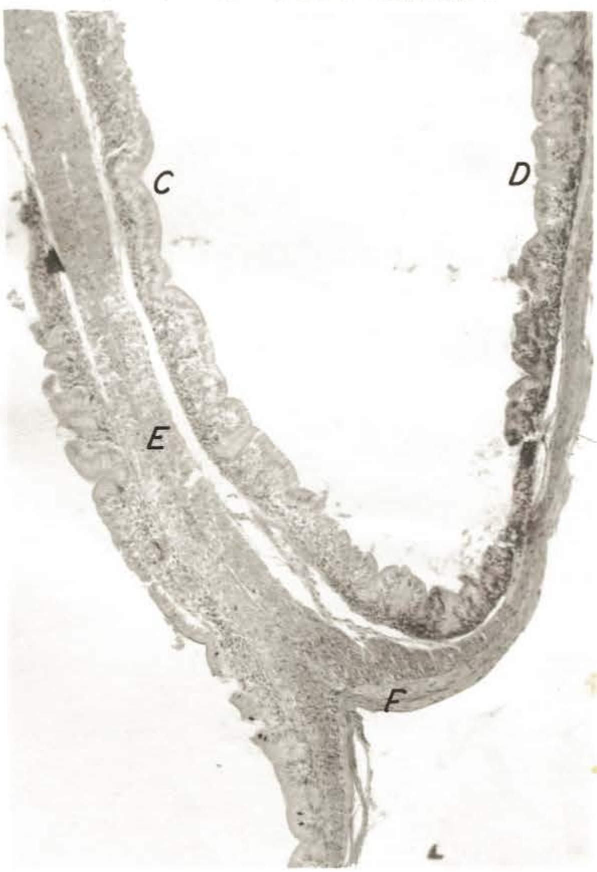


Fig. 23
Caecum of Pika

Fig. 24
Spiral Valve in Pika

Key to Figures 25-31

Fig. 25. Internal structures of jack rabbit appendix. 100 X. H. and E.

Fig. 26. Internal structure of flask-shaped gland in jack rabbit appendix. 500X. H. and E.

Fig. 27. Lymph nodules and external structures of jack rabbit appendix. 100X. H. and E.

Fig. 28. Vermiform appendix of pika. 100X. Mallory's.

Fig. 29. Internal structures of pika appendix. 500X. H. and E.

Fig. 30. Tubular lymphoid process of pika. 100X. H. and E.

Fig. 31. Internal structures of tubular lymphoid process in pika. 500X. H. and E.

Structures in appendix and other lymphoid processes.

A. Flask-shaped glands.
B. Branched tubuler glands in tunica propria of flask-shaped gland.
C. Lymph nodules.
D. Club-shaped projections.
E. Tunica propria.

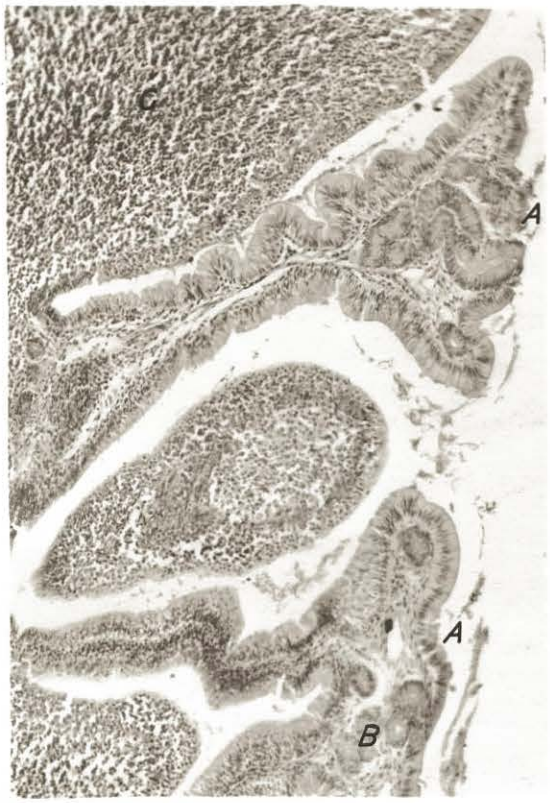


Fig. 25
Jack Rabbit Appendix

Fig. 26
Flask-shaped Gland

Fig. 27
Jack Rabbit Appendix

Fig. 28
Pika Appendix

Fig. 29
Pika Appendix

Fig. 30
Tubular Lymphoid Process

Fig. 31
Tubular Lymphoid Process

Key to Figures 32-36

Fig. 32. Colon of jack rabbit. 100X. H. and E.

Fig. 33. Colon of pika. 100X. H. and E.

Fig. 34. Rectum of jack rabbit. 100X. H. and E.

Fig. 35. External structures in rectum of jack rabbit. 500X. H. and E.

Fig. 36. Rectum of pika. 100X. H. and E.

Structures in colon and rectum.

A. Tubular glands in tunica propria.
B. Rectal columns of Morgagni.
C. Rectal glands.
D. Ganglionic cell bodies of Auerbach's plexus.

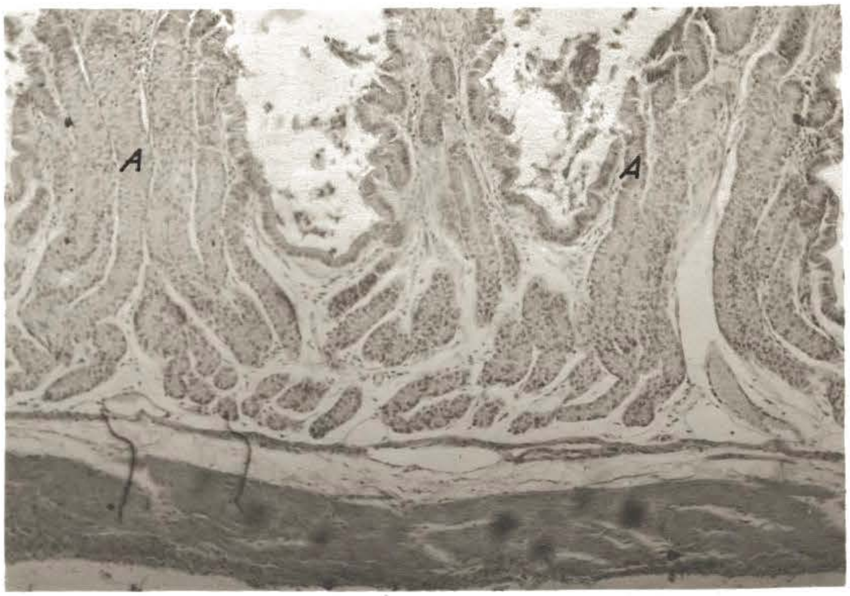


Fig. 32
Colon of Jack Rabbit

Fig. 33
Colon of Pika

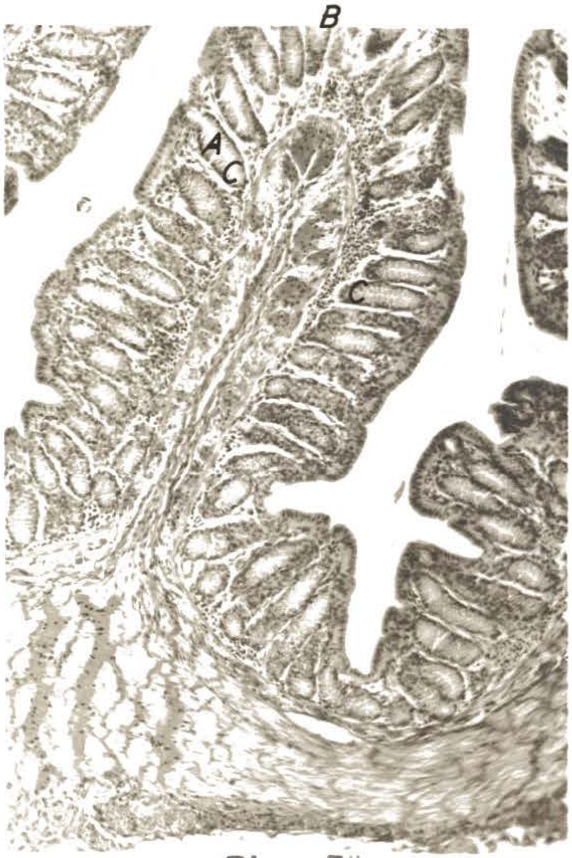


Fig. 34
Rectum of Jack Rabbit

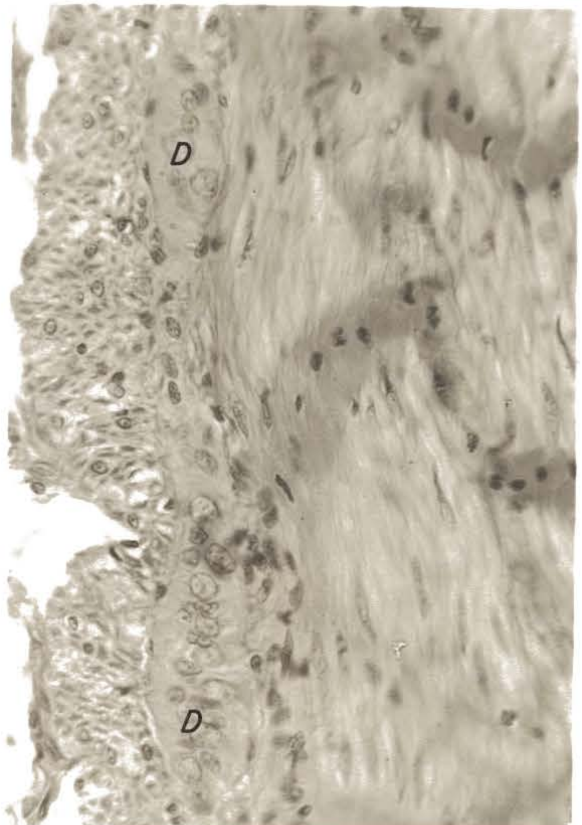


Fig. 35
Rectum of Jack Rabbit

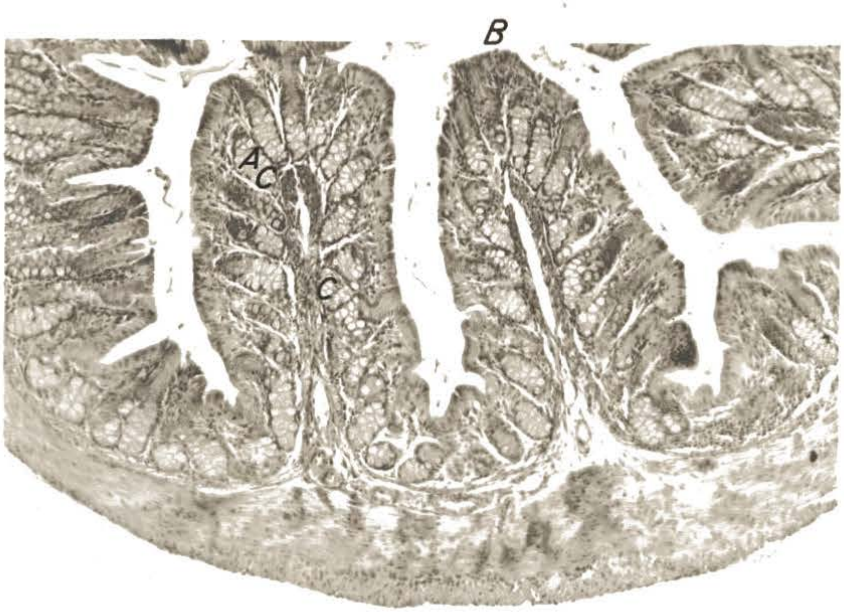


Fig. 36
Rectum of Pika

SUMMARY AND CONCLUSIONS

In comparing the gross anatomy of the digestive systems of the jack rabbit and the pika, the following differences were observed: the procolon and tubylar lymphoid processes are structures found in conjunction with the caecum of the pika that are not found in the jack rabbit; the sacculus rotundus is a structure on the ileum of the jack rabbit that is not found in the pika.

In making microscopic comparisons of the digestive systems of these two animals, similarities and differences were noted in terms of the types of glands, relative thickness of the various layers, and the presence or absence of certain types of cells.

With the exception of the appendix, a definite layer of muscularis mucosa can be seen throughout the entire intestinal tube of the jack rabbit. The writer was unable to observe this layer in the small intestine and appendix of the pika. The parietal cells in the gastric glands of the jack rabbit are far more numerous than in the pika (Figs. 9-12).

Well developed plica circulares are found in the jejunum and ileum of the jack rabbit. These folds were not observed in the small intestine of the pika. Table one, page 17, shows that the small intestine of the pika is proportionately longer than that of the jack rabbit. From this observation the supposition arises that possibly the small intestine of the pika has increased in length to compensate for the absence of the plica circulares.

Variations were observed in the musculature of the spiral valve in the caeca of the two animals, in the presence of the flask-shaped glands in the appendix of the rabbit, and in the smaller number of goblet cells in the caecum and colon of the pika than were found in the rabbit.

Ganglionic cellbodies of Auerbach's plexus and Meissner's plexus were observed in all segments of the digestive tube, but these structures appear to increase in numbers and complexity toward the caudal end (Fig. 35 D). Paneth cells were observed in all segments of the small intestines of both animals, but they appeared in the greatest numbers in the jejunum of the jack rabbit.

Some of the outstanding similarities in the intestinal tracts of the jack rabbit and pika were these: the presence of striated muscle in the tunica muscularis for the entire length of the esophagus; the much enlarged and elongated caeca, with the spiral valve, and the formation of a coiled counter-clock-wise loop in the ventral midregion of the coelom; and finally, the much elongated colon.

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