Ibn Al-Haitham Journal for Pure and Applied Sciences
Journal homepage: jih.uobaghdad.edu.iq
PISSN: 1609-4042, EISSN: 2521-3407
IHJPAS. 2026; 39(2)

Comparative Histological Architecture of the Glandular Stomach in *Sciurus anomalus* and *Urva auropunctata*

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Received: 20/August/2025
Accepted: 7/December/2025
Published: 20/April/2026
doi.org/10.30526/39.2.4278

Abstract
The present study aims to elucidate the histological organization of the glandular stomach in two mammalian species exhibiting different feeding habits: (i) an herbivorous rodent, i.e., the Persian squirrel (*Sciurus anomalus*); and (ii) a carnivorous mammal, i.e., the small Asian mongoose (*Urva auropunctata*). Histological sections (n = 5) were taken from both groups and stained with hematoxylin and eosin (H&E), Alcian blue-PAS stain, and Masson's trichrome, then microscopic examination was carried out distinct structural adaptations in the gastric mucosa, submucosa, muscularis, and serosa layers could be observed. The squirrel stomach exhibited a moderately thick mucosal layer with abundant mucus-secreting cells, and chief cells, reflecting its herbivorous diet.In contrast, the stomach of a mongoose had a thickened mucosal layer rich in oxyphilic (parietal) cells and a triple-layered muscularis, adaptations corresponding to its carnivorous diet. Mongoose gastric glands were more organized into tubular shapes, and a unique double-layered muscularis mucosae was also observed. This provides insight into processes underlying metabolic adaptations to dietary specialization in mammals, and evolutionary associations among gut size and efficiency according to feeding ecology.
Keywords: Gastric histology, *Sciurus anomalus*, *Urva auropunctata*, parietal cells, chief cells, feeding Habits.

1. Introduction

The Persian squirrel (*Sciurus anomalus*) and the Small Indian mongoose (*Urva auropunctata*) signify two distinct mammalian species that differ in their taxonomic classification, ecological niches, and feeding patterns. The Persian squirrel, belonging to the family Sciuridae, is a herbivorous rodent commonly distributed in the Middle East, including parts of Iraq, Iran, and Turkey. In contrast, the Small Indian mongoose, a carnivore from the family Herpestidae, is native to South and West Asia. These two species provide valuable models for comparative anatomical and histological studies of the digestive system, as they exhibit adaptations that reflect their distinct dietary behaviors and ecological habits[1,2]. The structure and function of the mammalian digestive system have evolved in ways that mirror dietary adaptations[3,4]. Histological variations have been reported in the stomach, which is a central digestive organ from herbivores to carnivores[5,6]. Persian squirrel (*Sciurus anomalus*) belongs to the herbivore mammal population and uses plant materials primarily for feeding[7,8] and Small Indian mongoose (*Urva auropunctata*) predominantly from carnivores is looking for food feeds mainly on smaller animals[9,10]. These dietary differences are anticipated to also be manifest in their gastric histology.

Although several studies have investigated the stomach structure in Sciuridae[5,11] and Herpestidae[12,13], direct histological comparisons between these two families are rare. The glandular stomach, which is involved in mechanical and chemical digestion, shows variation in mucosal gland arrangement, specialized cell types, and the development of muscular layers, in accordance with dietary needs[14].

Understanding the histological adaptations of the digestive system is essential for revealing functional differences related to diet and evolutionary relationships among mammals. This study compared the histological structure of the glandular stomach in *S. anomalus* and *U. auropunctata* by focusing on its mucosa, submucosa, muscularis, and serosa layers. The study aims to determine structures adaptations that are associated with dietary strategies and the degree of phylogenetic divergence of these animals. This informs our knowledge about how stomach phenotypes in mammals are associated with feeding ecology and evolutionary specialization[3,4].

2. Materials and Methods

2.1. Sample Collection and Preparation

Adult specimens of Persian squirrel (*Sciurus anomalus*) (n = 5) and Small Indian mongoose (*Urva auropunctata*) (n = 5) were ethically obtained from the Al-Gazal market in Baghdad, following the ethical protocols set by the institutional Ethics Committee for Scientific Research at the College of Science (Approval No. CSEC/0125/0003). Chloroform inhalation was employed to anesthetize both specimens prior to dissection that maintained tissue integrity for histological analysis[13,15].

2.2. Histological Processing

Tissue samples were preserved in 10% neutral-buffered formalin for a duration of 24 hours. Samples underwent progressive dehydration using graded ethanol concentrations (70%, 80%, 90%, 95%, and 100%), followed by xylene clearing and paraffin embedding. Consecutive sections were prepared with a rotary microtome and placed on glass slides. For histological examinations were stained with hematoxylin and eosin stain (H&E), Alcian blue-PAS stain and Masson's Trichrome stain. Tissue samples were processed according to standard histological procedures used in previous studies[16,17].

2.3. Statistical Analysis

The Statistical Packages of Social Sciences -SPSS (2019) program was used to detect the effect of different factors (type and parts) in study parameters. T-test and least significant difference-LSD was used to significantly compare between means in this study[18].

3. Results

The stomach consisted of four typical layers: the tunica mucosa, the submucosa, the tunica muscularis, and the serosa (**Figure 1**). The results showed that the mucosa of the Persian squirrel (*Sciurus anomalus*) stomach was a glandular structure formed of two regions: the first contained predominantly mucous glands, while the second was completely secreted enzymes.

The secretory enzymes portion was relatively thin and consisted of four typical layers, namely the tunica mucosa, the submucosa, the tunica muscularis, and the serosa (**Figure 1**). The tunica mucosa was composed of three layers: (1) the epithelial layer, (2) the lamina propria, and (3) the muscularis mucosa. The epithelial cells consist of a simple layer of low cuboidal cells, while the lamina propria consists of a thick layer of glandular tissue made up of simple tubular glands, which are known as gastric glands. The gastric glands consist of two main types of secretory cells: the first are the parietal cells (oxyphilic cells) with acidic cytoplasm and are responsible for the secretion of acid (HCl), and the second are the chief cells with basal cytoplasm and are responsible for the secretion of pepsinogen (**Figure 2**). The muscularis mucosa layer consists of a very thin layer (3-4 cells) of smooth muscle fibers (**Figure 1**).

The tunica submucosa consisted of a thin layer of loose connective tissue rich in delicate collagen fibers (**Figure 4**). The tunica muscularis consists of two layers of smooth muscle: a thin, circular, inner layer and a thick, longitudinal, outer layer (**Figure 1**) .

The mucus secretes portion of stomach had a thick wall (**Figure 5**), the middle and upper two-thirds of the tubular gastric glands were composed of cells that secrete neutral mucopolysaccharides, while the lower third (the base of the glands) consists of glands that secrete enzymes (chief cells) (**Figures 6 and 7**).

In Small Indian mongoose (*Urva auropunctata*), the gastric wall was constituted of four typical layers (Tunica mucosa (gastric mucosa), tunica submucosa, tunica muscularis and the serosa (**Figure 8**). The gastric mucosa of the fundus region of stomach was glandular that completely composed secretes enzymes (**Figure 9**), the tunica mucosa contained three layers: (1) the epithelial layer, (2) the lamina propria, and (3) the muscularis mucosa. The epithelial cells comprised of a simple layer of low columnar cells, while the lamina propria consists of a thick layer of glandular tissue formed of simple tubular glands, which are known as gastric glands. The gastric glands consist of two main types of secretory cells: the first are the parietal cells (oxyphilic cells) with acidic cytoplasm and are responsible for the secretion of acid (HCl), and the second are the chief cells with basal cytoplasm and are responsible for the secretion of pepsinogen (**Figure 10**). The muscularis mucosa was very thick, including 5-6 layers of smooth muscle fibers (**Figure 11**). The tunica submucosa consisted of a thin layer of dense well vascularized connective tissue (**Figure 11**). The tunica muscularis consists of two layers of smooth muscle: a thin, circular, inner layer and a thick, longitudinal, outer layer (**Figures 7 and 8**).

The mucosa of the cardiac region is characterized by predominantly content of mucopolysaccharides secreting cells at neck of gastric glands, while the body and base of the glands consists of glands that secrete enzymes, represented by oxyphilic and chief cells (**Figure 12 and 13**). The mucous secreting gland contained neutral mucopolysaccharides (pink color) while the oxyphilic cells and chief cells showed negative reaction (**Figure 14**). Tunica muscularis of stomach was very thick layer that composed of two bundles of the smooth muscle, the first was circular, inner layer, while the second was outer longitudinal layer of smooth muscle (**Figure 12**).

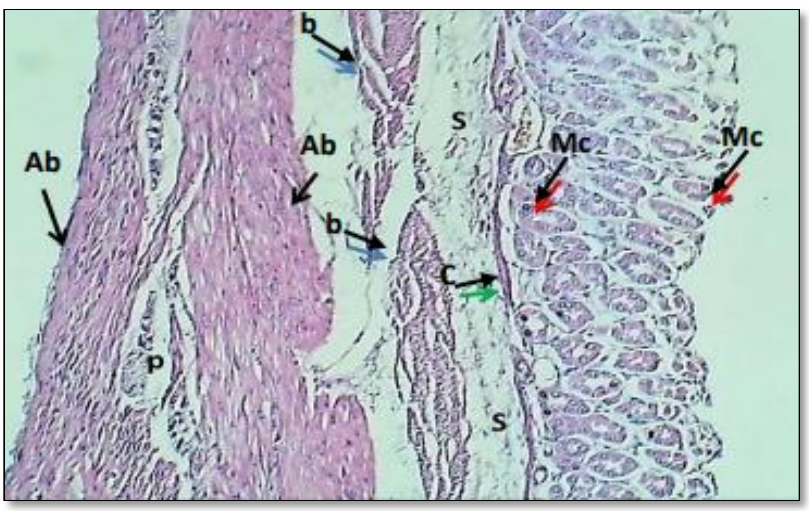

Figure 1. Photomicrograph of the stomach wall in *S. anomalus* showed gastric mucosa (Mc), muscularis mucosa (C), submucosa (S), inner circular smooth muscle (b), outer longitudinal layer of muscularis (Ab) & nerve plexus (p) H&E stain. 4x.

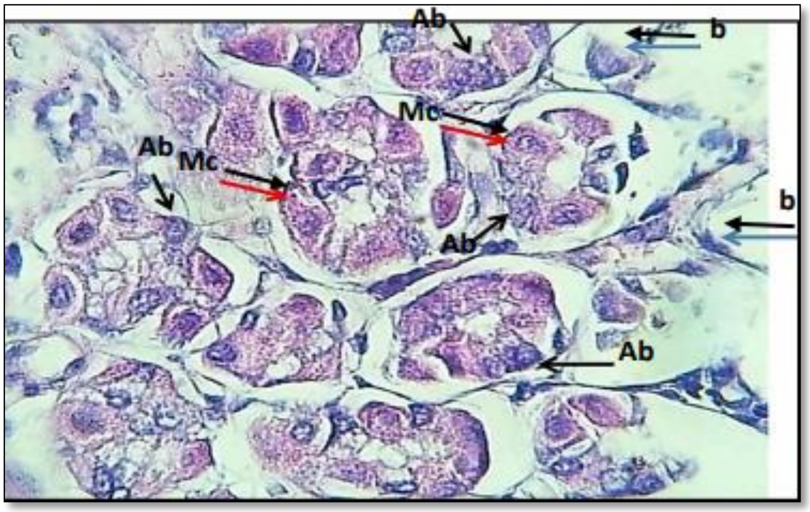

Figure 2. Photomicrograph of the stomach wall in *S. anomalus* showed parietal cells (Mc), chief cells (Ab) & lining cells (b). H&E stain. 40x.

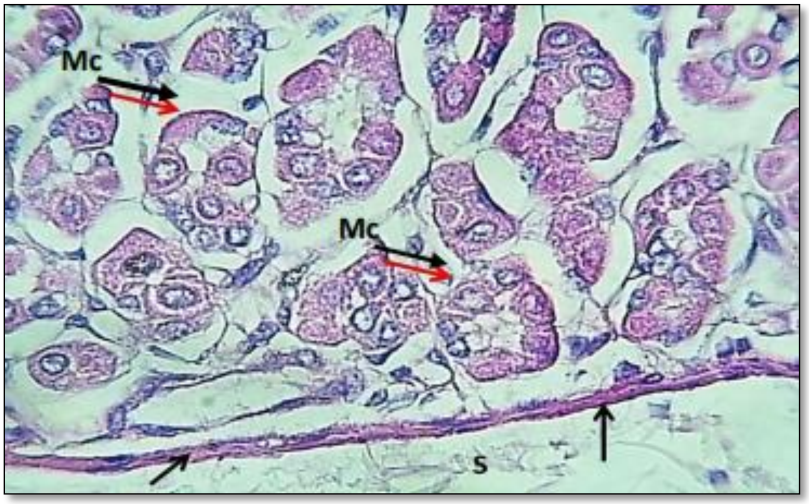

Figure 3. Photomicrograph of the stomach wall in *S. anomalus* showed gastric glands (Mc), muscularis mucosa (Ab) & collagen fibers of submucosa (S) H&E stain. 40x.

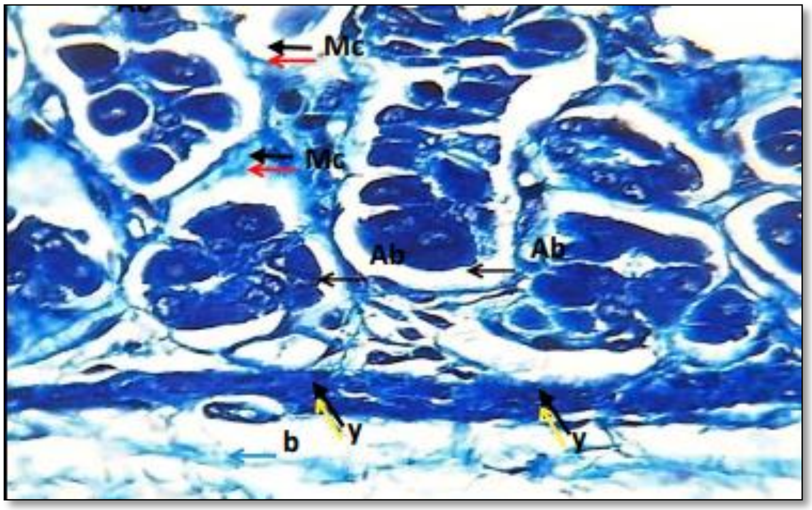

Figure 4. Photomicrograph of the stomach wall in *S. anomalus* showed gastric glands (Ab), inter glandular collagen fibers of lamina propria (Mc), muscularis mucosa (y) & collagen fibers of submucosa (b). Masson's trichrome stain. 40x.

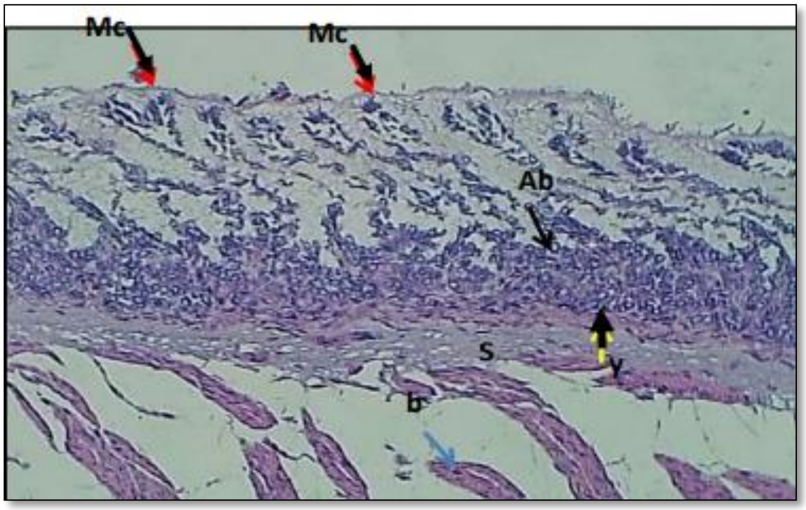

Figure 5. Photomicrograph of the stomach wall in *S. anomalus* showed mucous-secreting cells (Mc), chief cells (Ab), submucosa (S), muscularis mucosa (y) & inner circular smooth muscle (b) H&E stain. 4x.

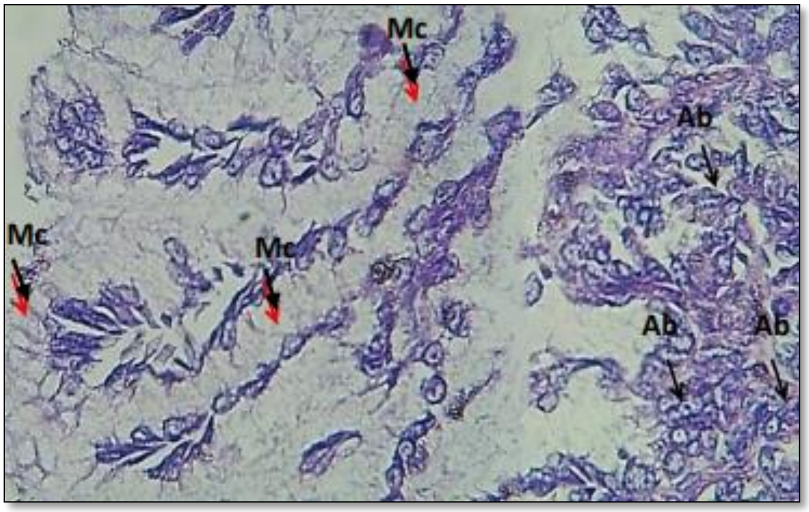

Figure 6. Photomicrograph of the stomach wall in *S. anomalus* showed mucous secreting cells (Mc) & chief cells (Ab) H&E stain. 40x.

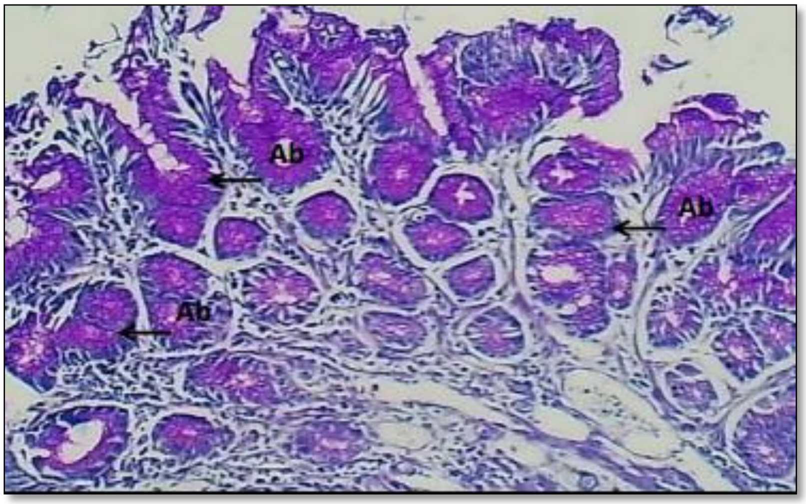

Figure 7. Photomicrograph of the stomach wall in *S. anomalus* showed neutral mucopolysaccharides within mucous-secreting cells (Ab). combine (2.5pH) alcian blue-PAS stain. 40x.

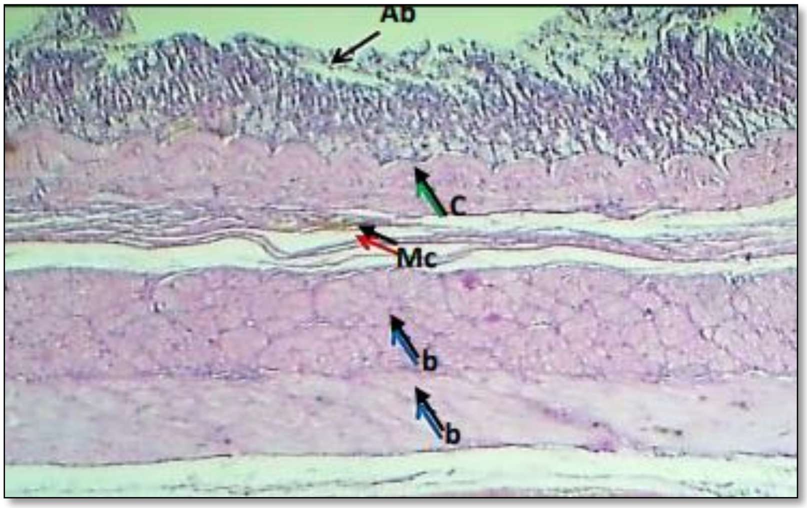

Figure 8. Photomicrograph of the stomach wall in *U. auropunctata* showed gastric mucosa (Ab), muscularis mucosa (C), submucosa (Mc), gastric muscularis (b).H&E stain, 4x.

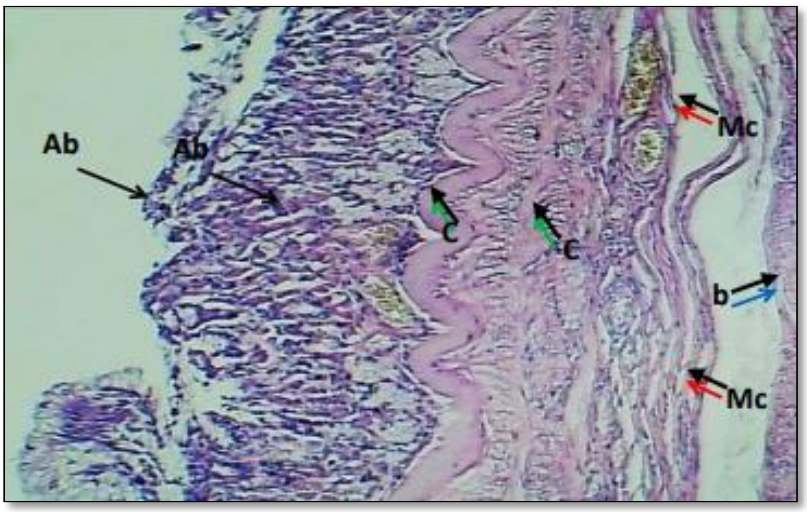

Figure 9. Photomicrograph of the stomach wall in *U. auropunctata* showed gastric glands (Ab), double layer of muscularis mucosa (C), fibrous submucosa (Mc) & muscularis (b).H&E stain, 10x.

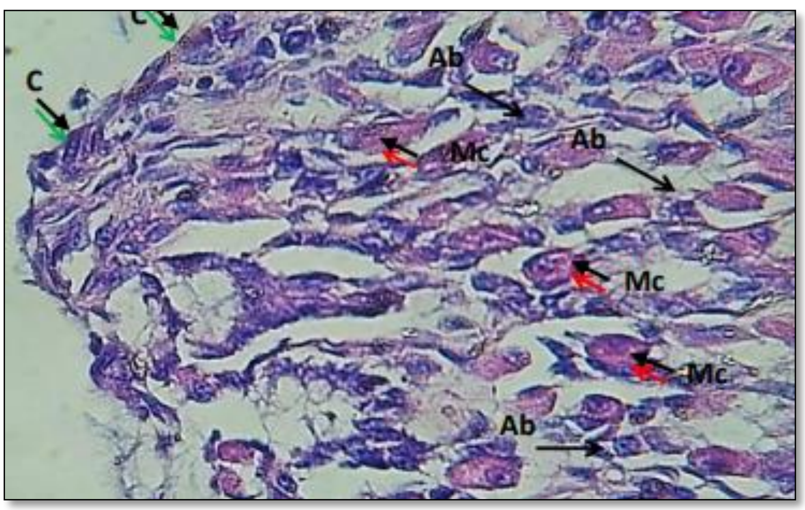

Figure 10. Photomicrograph of the stomach wall in *U. auropunctata* showed gastric oxyphilic cells (Mc), chief cells (Ab) & lining cells (C).H&E stain, 40x.

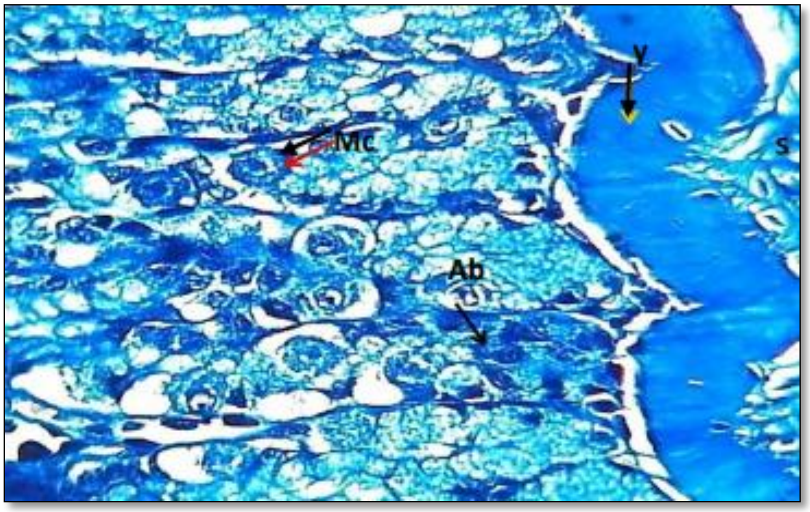

Figure 11. Photomicrograph of the stomach wall in *U. auropunctata* showed parietal cells (Mc), chief cell (Ab) & muscularis mucosa (y), submucosal fibrous tissue. Masson's trichrome stain, 40x.

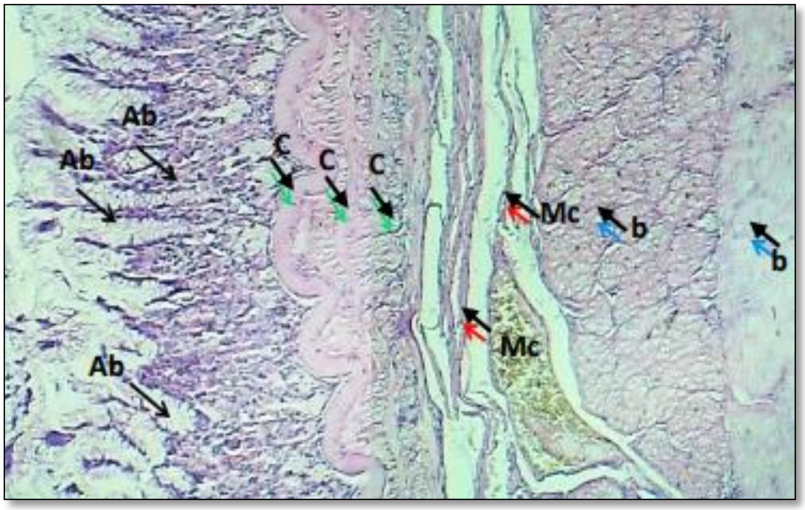

Figure 12. Photomicrograph of the stomach wall in *U. auropunctata* showed gastric mucosa with mucous gland (Ab), muscularis mucosa (C), submucosa (Mc), gastric muscularis (b).H&E stain, 4x.

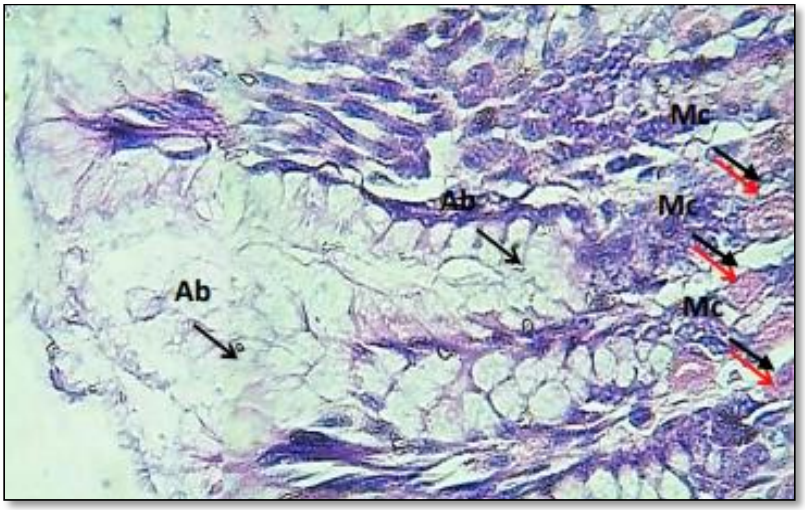

Figure 13. Photomicrograph of the stomach wall in *U. auropunctata* showed gastric mucosa with mucous gland (Ab), oxyphilic cells (Mc).H&E stain, 40x.

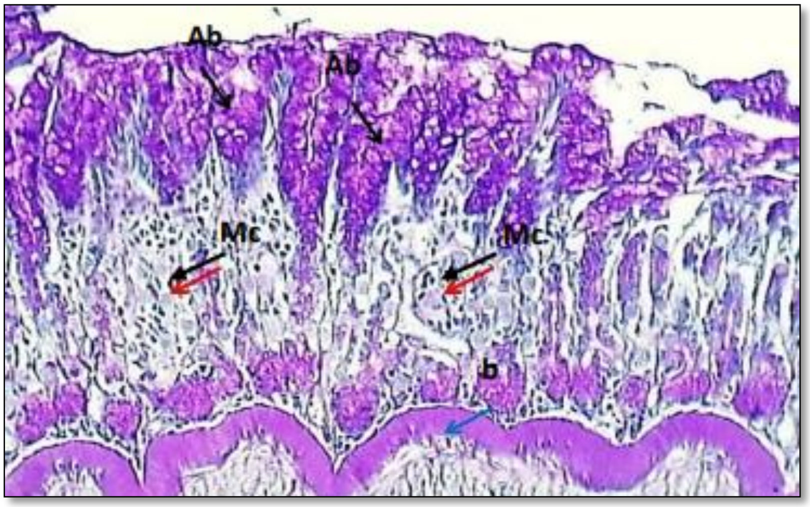

Figure 14. Photomicrograph of the stomach wall in *U. auropunctata* showed mucous-secreting gland contained neutral mucopolysaccharides (Ab), oxyphilic cells & chief cells showed negative reaction (Mc) & muscularis mucosa (b). Alcian blue-PAS stain, 10x

The lamina propria in mongooses was (146.08 ±10.98 b µm), while in squirrels was (94.71 ±0.86 b µm; p < 0.01). The muscularis mucosae thickness also differed between species, which mongooses recorded a thicker muscularis mucosae layer (19.97 ±0.75 a µm) compared to squirrels (10.02 ±0.31 a µm; p < 0.05). Submucosal thickness also differed between species, with mongooses showing a thicker submucosal layer (133.50 ±6.24 a µm) compared to squirrels (45.33 ±1.73 b µm; p < 0.01). In the mongoose, the Muscularis (192.92 ±36.63 b µm) was slightly thinner than in squirrels (212.26 ±7.27 a µm NS), but without significant difference. Squirrel was characterized by a relatively thinner adventitial layer (26.01 ±1.57 a µm) comparison with mongooses (51.45 ±3.96 a µm; p < 0.05) (**Table 1**).

Table 1. Comparison between in Squirrel and Mongoose in Tunics of stomach

Type / Animal	Mean ±SE of Stomach/ µm				
	Lamina propria10x	Muscularis mucosa10x	Submucosa 10x	Muscularis 4x	Serosa10x
Squirrel	94.71 ±0.86 b	10.02 ±0.31 a	45.33 ±1.73 b	212.26 ±7.27 a	26.01 ±1.57 a
Mongoose	146.08 ±10.98 b	19.97 ±0.75 a	133.50 ±6.24 a	192.92 ±36.63 b	51.45 ±3.96 a
T-test	13.52 **	4.017 **	12.08 **	28.67 NS	6.017 **
Means having with the different letters in same row differed significantly. * (P≤0.05), ** (P≤0.01).					

One asterisk (*) indicates a significant difference at the 0.05 level (P ≤ 0.05).
Two asterisks (**) indicate a highly significant difference at the 0.01 level (P ≤ 0.01). Averages that carry different letters differ significantly from each other, and averages that carry common letters do not differ significantly from each other. The highest average takes a, and so on. If you find an average that takes two letters, such as ab, this does not differ from a or b**.**

4. Discussion

The gastric mucosa exhibits notable structural differences between *Sciurus anomalus* and *Urva auropunctata*, particularly in mucosal thickness, glandular arrangement, and cell composition. The thicker mucosa observed in *U. auropunctata* aligns with findings by[15], reflecting its carnivorous diet and the need for enhanced secretory activity.

A higher density of parietal cells in *U. auropunctata* supports increased acid secretion for protein digestion, consistent with[12,21]. Additionally, its complex, occasionally branched tubular glands suggest adaptations for expanded secretory surface area, as described in carnivores by[14].

In contrast, *S. anomalus* displays simpler tubular glands and abundant mucous-secreting cells adaptations linked to its herbivorous, plant-rich diet. These outcomes are in accord with[5,22,23], who documented similar features among Sciuridae species adapted to fibrous or mixed diets.

The double-layered muscularis mucosae of *U. auropunctata* is a derived character and serves as an important functional innovation for increased mucosal motility and mixing. This previous work has been documented in other carnivorous mammals as well[19,20,24]. A more pronounced muscularis mucosae would probably increase the mixing of gastric secretions with ingested food and optimize protein digestion from animal foods.

In contrast, Single-layered muscularis mucosae in *S. anomalus* are considered a common feature among rodents, as reported[5,25]. This reduced organization may be compensatory for processing a mechanical herbivorous diet since many plant components.

The increased protein content of the carnivorous diet in *U. auropunctata* may, therefore, be specialized upon submucosal hypertrophy to benefit from a high-energy food source with potential sources of macronutrients such as fibers for energy or vitamins and essential nutrients necessary to maintain or survival. Similar results have been observed by others in other carnivores[3,26].

The triple-layered muscularis in *U. auropunctata* (inner circular muscle layer, middle longitudinal and outer oblique) seems to be an important adaptation to gastric motility and mechanical digestion. This arrangement allows for contraction in multiple directions, aiding it in the mechanical breakdown of animal tissues, which are typically more resistant to digestion than plant materials. This pattern is likely a convergent adaptation among carnivores, as similar structural features have previously been reported in other carnivorous mammals[24,27].

On the other hand, it is a characteristic of many mammalian species (including rodents) to have dual-layered muscularis (inner circular and outer longitudinal), this layer was observed in *S. anomalus*. This arrangement generates contractile force to process the more easily digestible herbivorous diet of squirrels, which has been suggested as similar for rodents[5,15].

In comparison to *S. anomalus*, the greater overall thickness of the muscularis layer of *U. auropunctata* reflective of greater mechanical processing requirements associated with a carnivorous diet. This observation also was previously made by[3,14], who found that in the carnivorous species increased muscularis thickness, in response to accommodating to higher processing demands of animal diets.

The histological variations observed between *S. anomalus* and *U. auropunctata* denote evolutionary adaptations shaped by their distinct phylogenetic histories and ecological niches. The histomorphological features of their glandular stomach manifest how digestive system adaptations have developed to optimize nutrient extraction from different dietary sources.

The herbivorous diet of *S. anomalus*, which includes seeds, nuts, fruits, and other plant matter, has likely selected for a gastric architecture that balances the processing of plant materials. The moderate development of gastric glands and muscular components observed in this species enables efficient digestion of a diet without the specialized modifications required for more extreme dietary preferences. This structural organization is supported by findings in other herbivorous rodents, as discussed[5,28].

In contrast, the carnivorous feeding habits of *U. auropunctata* have evolved of specialized gastric features that improve protein digestion and mechanical processing of animal tissues. The higher density of parietal cells, more complex glandular architecture, and enhanced muscular development observed in this species indicate to adaptations that maximize digestive efficiency for a protein-rich diet. These findings are in line with the histological characteristics of carnivorous mammals described [14,24].

These results support the concept of adaptive in digestive system morphology, as highlighted by [29,30], who pointed out that gastric histomorphology evolves in response to dietary specialization across mammalian lineages.

5. Conclusion

This comparative study of the glandular stomach histology in *Sciurus anomalus* and *Urva auropunctata* reveals distinct structural adaptations that correspond to their different dietary habits. The herbivorous squirrel exhibits moderate development of gastric glands and muscular components, while the carnivorous mongoose demonstrates specialized features including higher parietal cell density, a double-layered muscularis mucosae, and a triple-layered gastric muscularis.

These histomorphological differences reflect evolutionary adaptations that optimize digestive efficiency based on dietary specialization. The findings contribute to our understanding of the relationship between feeding ecology and digestive system morphology in mammals, highlighting how structural adaptations at the microscopic level support specific functional requirements.

Future research should focus on molecular and immunohistochemical analyses to further elucidate the cellular specializations and regulatory mechanisms underlying these adaptations. Additionally, expanding the comparative framework to include more species with diverse dietary preferences would provide deeper insights into the evolutionary patterns of digestive system morphology across mammalian lineages.

Acknowledgment

The author would like to thank College of science / University of Baghdad for providing facilities and technical support for this research.

Conflict of Interest

The author declares no conflict of interest.

Funding

This research received no external funding.

Ethical Clearance

The study was approved by the Ethics Committee for Scientific Research, College of Science, University of Baghdad (Approval No. CSEC/0125/0003). All animals were ethically handled and humanely anesthetized using chloroform inhalation.

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