UDC 619:611.34:636.981:598.112.21 **DOI 10.36016/JVMBBS-2026-12-1-3**

FEATURES OF THE MICROSCOPIC STRUCTURE OF THE YEMENI CHAMELEON (*CHAMAELEO CALYPTRATUS*) INTESTINAL

Kushch M. M., Skachko S. M.

State Biotechnological University, Kharkiv, Ukraine, e-mail: dr.kushch@gmail.com

Summary. Due to its attractive appearance and behavioral characteristics, the Yemeni chameleon (*Chamaeleo calyptratus*) is one of the most common reptile species in home terrariums and zoos. Due to violations of the detention conditions and feeding, pathologies of the digestive canal are quite common. At the same time, detailed information on the structure of the intestine is fragmentary and contradictory, making it impossible to develop adequate methods for diagnosing and treating its pathological conditions. The microscopic features of the intestine of 1-year-old Yemeni chameleons were determined. Histological preparations were prepared from a cross-section of the middle section of the duodenum, jejunum, ileum, colon, rectum, and colonic diverticulum, which were stained with hematoxylin and eosin, as well as according to Mallory. Three membranes were found in the intestinal wall of the Yemeni chameleon: mucous, muscular, and serous. Four layers were found in the composition of the mucous membrane: epithelial, lamina propria, muscularis mucosae, and submucosa. The epithelial layer is represented by a single-layered, single-row prismatic epithelium, in which two main cell types were identified: border and goblet cells. Characteristic structures of the intestinal mucosa were longitudinal folds that expanded the intestinal cavity to process large, undigested food items (e. g., insects). In the jejunum and ileum, such folds had a thin wall formed by an epithelial layer and a thin lamina propria, several rows of myocytes, and contained a slit-like cavity — a lymphatic sinus lined with endothelial cells. Given the presence of significant lymphatic sinuses, a small thickness of the lamina propria and muscularis mucosae, the submucosal base of the mucosa, the muscular membrane, the jejunum, and the ileum are probably the sites of absorption of feed lipids and water. In our opinion, specific structures similar to villi in the intestines of mammals and birds are intercryptal protrusions (ICP), which are bundles of epithelial cells between the mouths of neighboring crypts. No crypts were found in the jejunum and ileum of chameleons. A feature of the Muscular membrane of the intestine was a gradual increase in the relative thickness of the outer longitudinal layer in the direction from the duodenum to the rectum

Keywords: reptiles, digestion, morphometric indicators

Introduction. The evolution of reptiles has led to significant differences in the morphological and functional organization of organ systems, with the greatest diversity observed in the digestive system. Reptiles are among the most ecologically and evolutionarily significant groups of living organisms, having accumulated enormous diversity in morphology, behavior, ecology, life cycles, and defensive strategies (Fry et al., 2006). Such features of reptiles pose a challenge for veterinary medicine specialists during diagnosis and treatment (Mitchell and Diaz-Figueroa, 2005). Given the digestive system's extreme efficiency, the specific nature of food and feeding behavior across animal classes leaves its mark on the features of its morphofunctional organization (Karasov and Douglas, 2013). The difference between reptiles and mammals lies in the absence of true teeth, which are adapted only for capturing prey and exclude mechanical grinding (mastication) of food, the absorption of large particles, slow digestion, and prolonged processing in the digestive tract (Fritz et al., 2010). They are characterized by long periods of starvation between large meals, which require significant morphophysiological plasticity in the digestive system (Zhong, Zheng and Wang, 2023; Yang, Wang and Wu, 2025). It should be noted that the presence of lizards in captivity alters the composition of the intestinal microbiota, which in turn influences the immune status not only of this organ but also of the entire organism (Kohl et al., 2017; Wang, Wu and Yang, 2024).

Reptiles are of significant veterinary and medical importance as paratenic and intermediate hosts for many parasites (Manoj, 2024). Reptilian digestive tracts are associated with diseases of both infectious and non-infectious etiology. They are recognized as reservoirs of bacteria, and the expansion of the global trade in pet reptiles has led to reptile-associated salmonellosis becoming a significant public health problem (Muslin et al., 2025). Researchers have reported numerous cases of cryptosporidiosis causing inflammation of both the large and small intestines in green iguanas (*Iguana iguana*) (Kik et al., 2011; Gałęcki and Sokół, 2018), leopard geckos (*Eublepharis macularius*) (Terrell, Uhl and Funk, 2003), and agama lizards (Hallinger et al., 2019). Various coccidian species are common in Madagascar chameleons and inhabit different parts of the intestine (Modrý et al., 2001). In such animals, acute inflammation of the mucous membrane of the stomach, duodenum, colon, and gallbladder has been noted. It is known that reptiles are carriers of various parasites of the digestive tract. Various types of intestinal helminths are quite common — the parapharyngodont nematodes (Oxyurida) in the Egyptian variable lizard (*Agama mutabilis*) (Morsy et al., 2019), the oxyuridae nematodes (Pharyngodonidae) in agama lizards (Hallinger et al., 2019), the nematodes *Pharyngodon mamillatus*, *Thelandros alatus*, and *Parapharyngodon micipsae*, as well as the intestinal cestode *Oochoristica tuberculata* in the spotted skink (*Chalcides ocellatus*) (Ibrahim, Fadiel and Nair, 2005). An important environmental problem is the mass poisoning of reptiles with various chemical means of protecting agricultural plants, which primarily affect the digestive organs (Cakici and Akat, 2012; Simbula et al., 2021).

One of the most common domestic chameleon species, which attracts humans with a change in skin color and behavioral features, is the Yemeni (veil) chameleon (*Chamaeleo calyptratus*). Due to their significant prevalence, violation of the conditions of detention and feeding, they are often patients of veterinary clinics (Melero et al., 2023). In addition, chameleons, as representatives of scaly lizards, are used as a valuable biological model of organisms in order to study the mechanisms of adaptation to specific conditions of existence and nutrition (Diaz et al., 2015). At the same time, out of 202 species of Chamaeleonidae, 38.6% are under threat of extinction. Zoological institutions play an important role in the conservation of these animals. Currently, almost a thousand individuals of 36 different chameleon species are kept in zoological institutions around the world (Aduriz et al., 2024). Although numerous species of reptiles are widely studied by researchers, information describing the detailed structure of individual organs in many reptiles, including chameleons, is insufficient and, sometimes, contradictory (Cizek et al., 2019).

Thus, the analysis of scientific sources indicates the prevalence of digestive system diseases, including intestinal diseases, among different species of lizards. Such a problem requires detailed research and an understanding of intestinal micromorphology. This is necessary for interpreting clinical signs of diseases and determining treatment methods.

The work **aimed** to establish the features of the microscopic structure of the intestine of a 1-year-old Yemeni chameleon (*Chamaeleo calyptratus*).

The objectives of the study were to describe the histological structure and determine the main morphometric indicators of the microscopic structures of the duodenum, jejunum, ileum, colon, rectum, and colonic diverticulum of a 1-year-old Yemeni chameleon.

Materials and methods. The material for histological studies was intestinal samples of a 1-year-old Yemeni chameleon (n = 5): duodenum, jejunum, ileum, colon, colonic diverticula, and rectum. Animals were obtained from veterinary clinics where they died for reasons not caused by digestive diseases. After evisceration, the intestines were fixed in 10% neutral formalin solution. According to the classical method, samples of different intestines were washed in running water, after dehydration and compaction in alcohol solutions of increasing concentration, they were clarified in alcohol and chloroform solutions, and embedded in paraffin. Thin histological sections were prepared from paraffin blocks on an MC-2 microtome, which were stained with hematoxylin and eosin, as well as according to Mallory. The study of histological preparations was carried out on a 'Jenamed 2' microscope (Carl Zeiss, Germany). Using an ocular grid on preparations made from cross-sections of the intestines, the size of microscopic structures was determined: the outer diameter, the thickness of the membranes and their layers, the height of the folds and intercryptal protrusions, the depth of the crypts, and the area of the fold cavities. The serous membranes of different intestines had approximately the same thickness (approximately 5 μm), so their thickness was not measured.

The established indicators of intestinal microstructure size were analyzed using a one-way analysis of variance (ANOVA) in Biostat LE 7.3. With the determination of the arithmetic mean (M) and its standard deviation (SD). The reliability of differences in intestinal parameters among chameleon intestines was assessed using Tukey's criterion; differences were considered reliable at $P < 0.05$.

In analyzing scientific literature, data on the morphofunctional features of the intestines of other representatives of the suborder Iguania in the order Squamata in the class Reptilia were used.

Results and discussion. Taking into account the known data on the division of the digestive tract of reptiles into separate organs and their parts Engelke et al. (2020) for the bearded agama (*Pogona vitticeps*), Hamdi et al. (2014) for the African chameleon (*Chamaeleon africanus*), macroscopically in the composition of the intestine of the Yemeni chameleon (*Chamaeleo calyptratus*) in the small section we distinguished three intestines: duodenum, jejunum and ileum, and in the composition of the large intestine — colon, colonic diverticulum and rectum. Macroscopically, the small intestine had the appearance of a thin tube of approximately the same diameter and had a black color on the outside due to melanin, which is consistent with the corresponding data of Hamdi et al. (2014) for the intestine of the African chameleon. The duodenum, without a clear border, began at the pylorus of the stomach and was accompanied by the pancreas, which had the form of a thin pink cord. The next longest section of the small intestine, which did not contain the pancreas in the mesentery, was defined as empty. The ileum was defined at the place of transition of the small intestine into the large intestine, which had a significantly larger diameter (Table 1).

Table 1 — Intestinal diameter of the Yemeni chameleon (n = 5, x ± SD)

Intestine	Diameter, μm
Duodenum	5.4 ± 0.4^{a}
Jejunum	12.0 ± 1.1^{bc}
Ileum	13.2 ± 0.9^{c}
Colon	15.2 ± 1.4^{a}
Colonic diverticulum	9.0 ± 0.9^{b}
Rectum	11.0 ± 1.1^{bc}

Note. Different letters indicate the values significantly differing from one another within a column on the results of comparison using the Tukey test ($P < 0.05$).

The colon was the largest in diameter and contained a small, rounded protrusion — diverticula. The rectum had a smaller diameter and connected the colon and cloaca in the form of a straight tube. As established by Engelke et al. (2020), Skripka et al. (2020), and Kushch et al. (2024), a characteristic macroscopic feature of the internal relief of the mucous membrane of the digestive canal of reptiles is the presence of a significant number of longitudinal and, to a lesser extent, transverse folds. For some parts of the intestinal tube, the parallel arrangement of such folds is characteristic; for others, it is zigzag. The presence of such folds is due to the absence of teeth; reptiles swallow their prey (insects), often large in size, whole. Namely, thanks to the longitudinal folds, the cavity of the digestive canal can significantly increase its volume and accommodate such contents (Fritz et. al., 2010). Microscopically, the longitudinal folds in the duodenal wall of the Yemeni chameleon were protrusions that were formed by the mucosa with all its layers (Fig. 1). This is consistent with the classical view of the structure of the mucosal fold (Standring, 2020).

From the point of view of the layered structure, according to the results of our studies, in the wall of the duodenum of the Yemeni chameleon, we have identified three membranes: mucous, muscular, and serous. Four layers are distinguished in the composition of the mucous membrane: epithelial, lamina propria, muscularis mucosae, and submucosa. The results of determining their morphometric indicators are given in Table 2. The epithelial layer was formed by a single-layer prismatic epithelium. Two populations of prismatic enterocytes were found in its composition: border and goblet cells. Border cells had a basally located oval-shaped nucleus, oxyphilic cytoplasm, and a characteristic brush-like border at the apical pole. The less numerous goblet cells had a characteristic high goblet shape. They contained a transparent secret, consistent with the corresponding data reported by Zaher et al. (2012) and Engelke et al. (2020). The lamina propria of the mucosa was formed by fibrous loose connective tissue, in which few fibroblast nuclei and a delicate network of collagen fibers were found. The muscularis mucosae consisted of two layers of smooth muscle tissue.

In a cross-section of the duodenal wall of chameleons, 2 to 7 folds were consistently found, formed by all layers of the mucosa: epithelial, lamina propria, muscularis mucosae, and submucosa.

As is known, the mucous membrane of the small intestine of mammals and the entire intestine of birds is characterized by the presence of such microscopic formations as villi and crypts, which significantly increase the surface area of digestion and absorption of nutrients (Kardong, 2019). Villi are protrusions of a predominantly finger-shaped shape, which include all layers of the mucous membrane: epithelial layer, lamina propria, and muscularis mucosae. Crypts, or Liberkühn glands, are finger-shaped immersions of the epithelial layer into the lamina propria of the mucous membrane (Atkinson, Leedham and Byrne, 2026). Such a single structure, consisting of villi and crypts, constitutes a morphofunctional complex that performs the intestine's primary functions. It has been established that crypts are primarily sites of cell formation, and villi are the sites of digestion and nutrient absorption from the chyme (Mescher, 2021).

Table 2 — Morphometric parameters of the thickness of the wall and membranes of the intestine of the Yemeni chameleon (n = 5, x ± SD)

Intestine	Intestinal wall, μm	Mucous membrane		Muscular membrane	
		μm	%	μm	%
Duodenum	1,019.1 ± 94.2^{bc}	513.6 ± 47.2^{a}	50.4	505.2 ± 39.3^{d}	49.6
Jejunum	1,392.9 ± 11.3^{c}	1316.0 ± 17.0^{c}	94.5	76.9 ± 5.0^{b}	5.5
Ileum	1,458.8 ± 10.0^{c}	1350.8 ± 12.2^{c}	92.6	108.0 ± 7.3^{bc}	7.4
Colon	849.0 ± 9.9^{bc}	360.2 ± 28.0^{a}	42.4	488.8 ± 38.7^{cd}	57.6
Colonic diverticulum	427.1 ± 33.2^{a}	376.1 ± 30.2^{ab}	88.1	51.0 ± 4.9^{a}	11.9
Rectum	791.2 ± 43.3^{b}	464.9 ± 40.6^{b}	58.8	326.3 ± 28.0^{c}	41.2

Note. Different letters indicate the values significantly differing from one another within a column on the results of comparison using the Tukey test ($P < 0.05$).

The duodenal mucosa of the Yemeni chameleon contained cylindrical-shaped invaginations of the epithelium into the lamina propria, which we identified as crypts. They were densely arranged and separated from each other by thin layers of loose fibrous connective tissue of the lamina propria and a thin layer of 1–2 rows of myocytes of the muscularis mucosae. In addition, some of these crypts were also separated from the submucosa by a thin muscularis mucosae, consisting of two layers of smooth muscle cells — an inner circular and an outer longitudinal. In general, this microscopic structure of the crypts fully corresponds to that of both mammals and birds (Kardong, 2019), as well as other species of reptiles (Skripka et al., 2020). The submucosal base was represented by a very thin layer of fibrous loose connective tissue, containing a small number of cells and fibers and a significant content of amorphous substance, which is why on histological preparations it appeared as a thin, almost transparent strip between the muscularis mucosae and the inner layer of the muscular membrane.

According to the classical view of the structure of villi (Kardong, 2019), based on the results of our studies, we did not detect such structures of the mucous membrane in the duodenum of the Yemeni chameleon. At the same time, the mucous membrane of this intestine was characterized by the presence of such microscopic structures as intercryptal protrusions (ICP), which resembled villi in shape on the cut, but are the result of a specific folded organization of the epithelial layer. Such

ICPs represented a rise of the epithelial layer between the crypts buried between them and resembled a sheaf of grain. The microscopic organization of the duodenal ICP had a pronounced volumetric radial structure. A group of enterocytes emerging from the crypts forms a structure similar to a sheaf of grain. In such a structure, the narrow base ('sheaf crest') is located directly above the crypts — the zone of cell formation, and the tops of enterocytes diverge, which significantly increases the area of their contact with the chyme. The depth of the crypts was almost three times greater than the height of the ICP (Table 3).

Table 3 — Morphometric parameters of the intestinal mucosa of the Yemeni chameleon (n = 5, x ± SD)

Intestine	Height of the ICP, µm	Depth of the crypts, µm	Area of the sinuses of the folds, µm
Duodenum	75.0 ± 5.3^a	226.7 ± 14.9^b	
Jejunum			77.3 ± 5.4^b
Ileum			27.6 ± 2.2^a
Colon	150.0 ± 16.1^b	87.3 ± 6.0^a	
Colonic diverticulum	79.6 ± 7.7^a	220.6 ± 17.6^b	
Rectum	125.0 ± 9.8^b	254.3 ± 18.9^b	

Note. Different letters indicate the values significantly differing from one another within a column on the results of comparison using the Tukey test (P < 0.05).

In Yemeni chameleons, the ICP in the duodenum had a predominantly tooth-like shape. In general, the alternation of crypts and ICP gave the mucosa a scalloped appearance. Such a relief was characteristic of both the surface of the mucosal folds and the areas between them. Our data on the presence and structural features of ICP in the intestine of the Yemeni chameleon are consistent with the data of Engelke et al. (2020) on the presence of intercryptal folds or crests in the intestine of the bearded dragon. However, other researchers — Hamdi et al. (2014) in the intestine of the African chameleon, Zaher et al. (2012) in the intestine of the Egyptian spiketail (*Uromastyx aegyptiaca*), Skripka et al. (2020) in the sand lizard (*Lacerta agilis*), Awaad, Rushdy and Adly (2022) in the five-banded mabui (*Trachylepis quinquetaeniata*) the protrusions of the mucous membrane were determined as villi and folds.

The mucous membrane of the duodenum of the Yemeni chameleon consisted of two layers: a thicker inner circular layer and a thin outer longitudinal layer (Table 4). They are separated from each other by thin layers of fibrous loose connective tissue. Sometimes, ganglia of the myenteric nerve plexus were found in them. In a much smaller number, neurons of the nerve nodes were also found in the submucosal base. The data we obtained on the topography of the nerve plexuses in the intestine of the Yemeni chameleon are consistent with the corresponding information of Martinez-Ciriano et al. (2000) regarding their structure in the intestine of the Spanish wall lizard (*Podarcis hispanica*). Pigment cells with numerous small brown-black granules were found in the epithelial cells of the very thin serous membrane of both the duodenum and other parts of the intestine. The presence of melanin inclusions in melanomacrophages of the liver of the Yemeni chameleon was reported by Al-Doaiss et al. (2023).

Table 4 — Morphometric parameters of the muscular coat of the intestine of the Yemeni chameleon (n = 5, x ± SD)

Intestine	Muscular membrane, µm	Inner layer		Outer layer	
		µm	%	µm	%
Duodenum	505.2 ± 39.3^d	425.0 ± 31.0^d	84.1	80.2 ± 7.2^b	15.9
Jejunum	76.9 ± 5.0^{ab}	52.1 ± 5.6^{ab}	67.8	24.8 ± 2.5^{ab}	32.2
Ileum	108.0 ± 7.3^b	77.6 ± 8.3^b	71.9	30.4 ± 3.4^{ab}	28.1
Colon	488.8 ± 38.7^d	311.5 ± 27.1^c	63.7	177.3 ± 22.0^c	36.3
Colonic diverticulum	51.0 ± 4.9^a	26.7 ± 3.2^a	52.4	24.3 ± 17.0^a	47.6
Rectum	326.3 ± 28.0^c	52.3 ± 4.6^a	16.0	274.0 ± 29.8^d	84.0

Note. Different letters indicate the values significantly differing from one another within a column on the results of comparison using the Tukey test (P < 0.05).

Microscopically, the mucous membrane of the jejunum had significant differences from the duodenum (Fig. 2). Its mucous membrane is represented by numerous high folds, consisting mainly of an epithelial layer, a very thin lamina propria, one or two rows of myocytes and endothelium, which delimit a centrally located cavity — sinus.

Endothelial cells directly lined the lumen of the sinus; their nuclei had a flattened shape, often looked like thin dark lines, and protruded into the lumen (Fig. 3). Smooth myocytes lay outside the endothelial cells, had more voluminous nuclei of a rod-shaped or spindle-shaped shape, and were thicker compared to those of endothelial cells.

The areas of the mucosa between the folds were constructed similarly and consisted of a layer of epithelium, a very thin lamina propria, one or two layers of myocytes, and a thin submucosa. Sometimes, two-layer folds were found on histological preparations, which is probably a consequence of the contraction of the intestinal wall and, accordingly, the 'wedging' of the fold into itself.

The presence of large central vessels in the folds of the small intestine of bearded dragons and their accompaniment by smooth muscle cells is indicated by Engelke et al. (2020). In our opinion, the cavities in the folds of the mucosa of the jejunum are lymphatic sinuses.

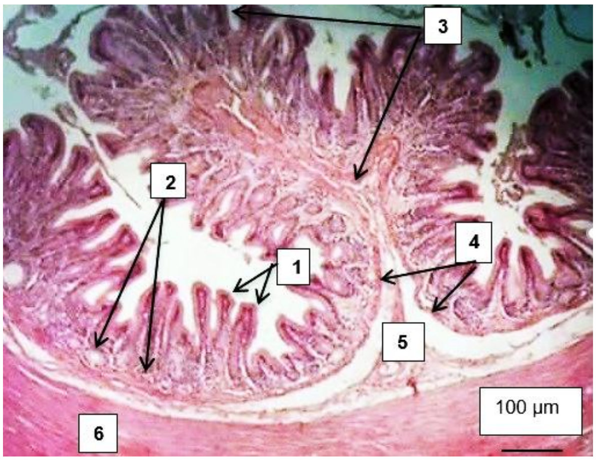

Figure 1. Duodenal wall of the Yemeni chameleon (histological preparation): 1 — intercryptal protrusions; 2 — crypts; 3 — mucosal fold; 4 — muscularis mucosae; 5 — submucosal base of the mucosa; 6 — inner layer of the muscularis mucosae; hematoxylin and eosin staining.

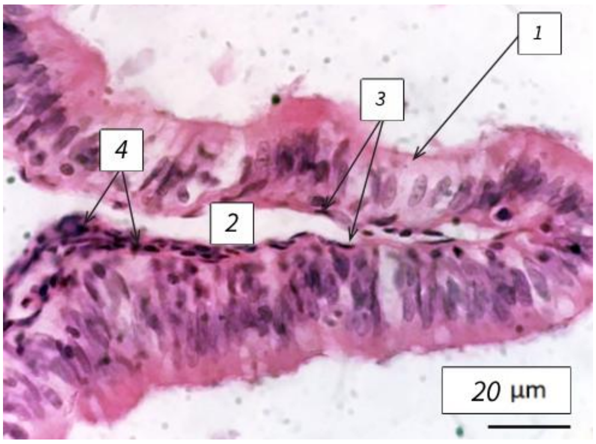

Figure 3. Longitudinal section of the ileal fold of the Yemeni chameleon (histological preparation): 1 — epithelial cells of the mucosa; 2 — lymphatic sinus cavity; 3 — nuclei of endothelial cells of the lymphatic sinus; 4 — nuclei of myocytes of the fold; hematoxylin and eosin staining.

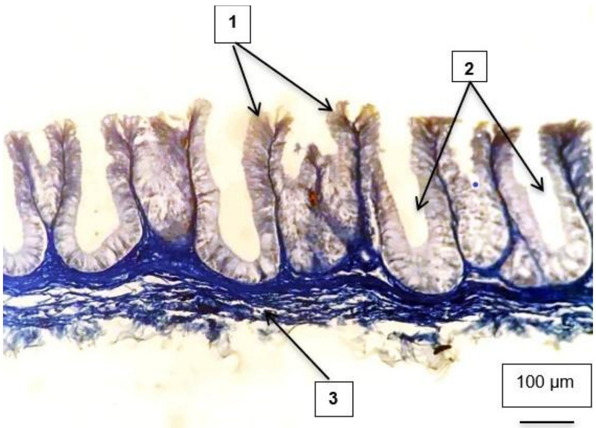

Figure 5. Wall of a colonic diverticulum of a Yemeni chameleon (histological preparation): 1 — intercryptal protrusions; 2 — crypts; 3 — submucosa; Mallory staining.

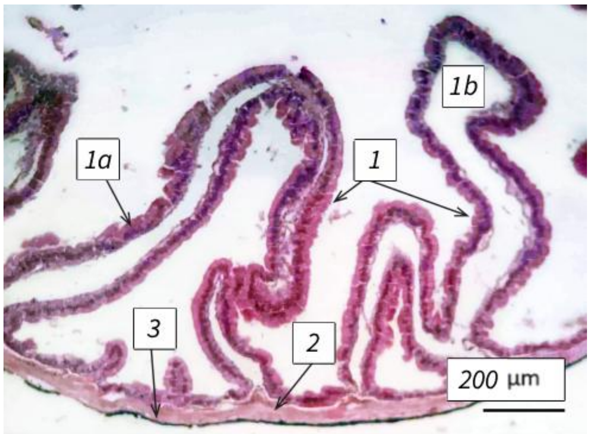

Figure 2. The wall of the jejunum of a Yemeni chameleon (histological preparation): 1 — mucosal fold: a — epithelial layer, b — lymphatic sinus; 2 — muscular membrane; 3 — serous membrane; hematoxylin and eosin staining.

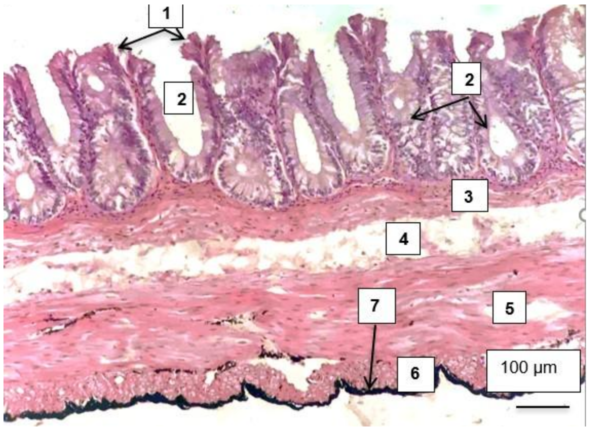

Figure 4. Colon wall of the Yemeni chameleon (histological preparation): 1 — intercryptal protrusions; 2 — crypts; 3 — muscularis mucosae; 4 — submucosa; 5 — inner muscular membrane; 6 — outer muscular membrane; 7 — serosa; hematoxylin and eosin staining.

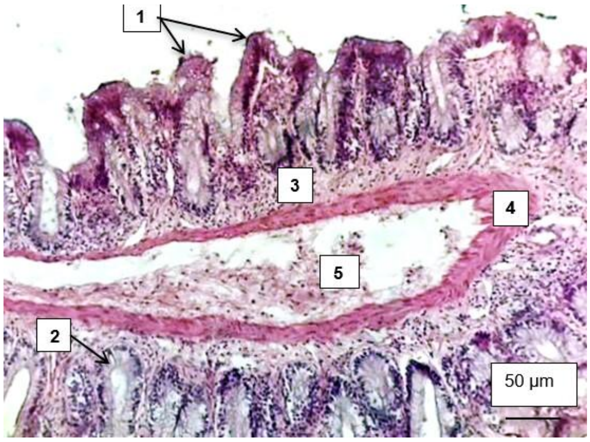

Figure 6. Rectal wall of a Yemeni chameleon (histological preparation): 1 — intercryptal protrusions; 2 — crypts; 3 — lamina propria; 4 — muscularis mucosae; 5 — submucosa; hematoxylin and eosin staining.

Evidence that such sinuses are lymphatic, and not blood-bearing, is the absence of blood cells in their lumen. During the study of longitudinal sections of this intestine, sinuses in these longitudinal folds were found to extend along their long axes, indicating a slit-like shape. Compared with the duodenum, the muscular coat of the jejunum wall was significantly thinner. The epithelium of the folds was indistinctly expressed ICP and had no crypts.

The structure of the ileum mucosa was similar to that of the jejunum and contained numerous longitudinal folds. At the same time, unlike the duodenum, its relief was distinguished by a smaller number and size of folds and, accordingly, a 64.3% smaller area of the lymphatic sinus cavity (Table 3). At the same time, the epithelial layer of the folds and interfold areas exhibited a more pronounced ICP and lacked crypts.

As is known, in the intestines of animals, the products of protein and carbohydrate breakdown are absorbed into the blood capillaries, while lipids are transported in the form of chylomicrons through the lymphatic channel (Tso and Balint, 1986; Karasov and Douglas, 2013). Given the microscopic structure of the chameleon jejunum, namely the presence of numerous folds of the mucous membrane with a significant volume of lymphatic sinuses, accompanied by myocytes that create a powerful pumping system (Zawieja, 2009; Razavi, Munn and Padera, 2025), it can be assumed that this area is the site of intensive lipid absorption. In addition to absorbing lipid breakdown products, the intestinal lymphatic system plays a significant role in water absorption, thereby regulating the interstitial volume of intestinal wall tissues (Kvietys and Granger, 2010).

Probably, such architectonics of the mucous membrane is a functional adaptation to the sporadic feeding of chameleons on insects (Yang, Wang and Wu, 2025), and the presence of myocytes in the wall of the sinuses indicates the active nature of lymphatic drainage (Zawieja, 2009). Given the smaller total volume of lymphatic cavities in the folds of the ileum compared to the jejunum, the absorption processes in this intestine occur less intensively.

According to the results of the longitudinal dissection of the transition of the small intestine into the large intestine, a transverse circular fold was found, at the base of which was the ileocolonic sphincter, which separated the ileum and colon. The presence of such a fold between the ileum and colon in the bearded agamas is indicated by Engelke et al. (2020), and in the sand lizard — Skripka et al. (2020). Microscopically, the wall of the colon was significantly different from that of the ileum and was somewhat similar to the duodenum (Fig. 4). Its wall had several folds, which included all layers of the mucous membrane, as well as the submucosa. Compared to the jejunum and ileum, the thickness of the muscularis mucosa was significantly greater, and it was separated from the muscular membrane by a rather thick submucosa base. The characteristic structures of the mucosa were crypts and the ICP located between them, the height of which, compared with other intestines, was the greatest. Unlike the duodenum, the tops of the ICP had not a tooth-shaped, but a rounded shape. It should be noted that compared with other intestines, in the colon, the thickness of the muscularis mucosa, as well as the muscularis mucosae, had the greatest values.

The wall of the colonic diverticulum was thinner than that of the colon itself and had no folds. Its mucosa contained densely arranged low crypts with rounded lumens and interspersed low ICPs of predominantly rounded shape (Fig. 5). Compared with other intestines, the thickness of the muscularis mucosa of the colonic diverticulum was the smallest.

Compared to the colon, the rectal wall had a smaller diameter and a thicker mucosa. The mucosa formed several folds, which in their middle part contained fibrous loose connective tissue of the submucosa base (Fig. 6).

The mucosa was composed of rod-shaped crypts with wide lumens and bundle-shaped ICPs located between them. Thin layers of fibrous loose connective tissue with strands of smooth muscle cells separated the crypts from each other. These cells formed the basis of the ICPs. Compared with the thin section, goblet cells were found in significantly greater numbers in the epithelial layer, consistent with the known pattern in the intestines of birds and mammals (Kardong, 2019). A relatively thick muscularis mucosa separated the bottom of the crypts from the submucosa, formed by loose connective tissue. Blood and lymphatic vessels of various diameters were found in its composition. Unlike other intestines, in the rectum, both the lamina propria and the submucosa, composed of fibrous loose connective tissue, contained a greater number of its cells, as well as lymphocytes.

A characteristic feature of the muscular membrane of the rectum was the greater relative thickness of the outer layer compared to the inner layer, which is consistent with the corresponding information of Engelke et al. (2020) regarding the bearded dragon. Moreover, unlike other intestines, in the rectum, muscle cells in the outer longitudinal layer formed bundles delimited by layers of fibrous loose connective tissue.

Conclusions. Based on microscopic and morphometric studies, the morphofunctional characteristics of the intestine of a 1-year-old Yemeni chameleon were provided. Its mucosa consisted of 4 layers: epithelial layer, lamina propria, muscularis mucosa, and submucosa, which had different degrees of development in different intestines. Two types of cells were found in the epithelial layer: border and goblet cells. The muscularis mucosae mainly consisted of two thin layers of smooth muscle cells: internal circular and external longitudinal. A feature of the mucosa of the duodenum, colon, and rectum was the presence of several longitudinal folds, in the formation of which all layers of the mucosa participated. A characteristic feature of the mucosa of the jejunum and ileum was the presence of numerous longitudinal folds with a centrally located cavity, which was determined as a lymphatic sinus.

Unlike mammals and birds, whose mucous membrane contains crypts and villi, the Yemeni chameleon's mucous membrane contains crypts and intercryptal protrusions. The muscular membrane consisted of two layers of smooth muscle tissue: the inner circular and the outer longitudinal. A characteristic feature of the muscular membrane was a gradual increase in the relative thickness of its outer layer and, accordingly, a decrease in the inner. Taking into account the revealed significant differences in the microscopic structure of individual intestines, they can be a morphological basis for understanding the peculiarities of pathological processes in different parts of the intestine. The revealed features of the histological structure of the intestinal wall of Yemeni chameleons reflect the trophic specialization of this species of insectivorous reptiles.

We consider the determination of the features of the development of the intestines of the Yemeni chameleon in the postnatal period of ontogenesis to be a **prospect for further research**.

References

Aduriz, A., Lanthier, I., Lair, S. and Vergneau-Grosset, C. (2024) 'Evaluation of mortality causes and prevalence of renal lesions in zoo-housed chameleons: 2011-2022', *Journal of Zoo and Wildlife Medicine*, 55(2), pp. 381–392. doi: 10.1638/2023-0023.

Al-Doaiss, A. A., Alshehri, M. A., Shati, A. A., Alfaifi, M. Y., Al-Kahtani, M. A., Ahmed, A. E., Eid, R. A., Al-Shuraym, L. A., Al-Mekhlafi, F. A., Al-Zahrani, M. and Mubarak, M. (2023) 'Histomorphological, histochemical and ultrastructural studies on the healthy liver of Yemen veiled chameleon (*Chamaeleo calyptratus*) in Southern Saudi Arabia', *International Journal of Morphology*, 41(5), pp. 1513–1526. doi: 10.4067/s0717-95022023000501513.

Atkinson, G., Leedham, S. and Byrne, H. M. (2026) 'The role of fibroblast-epithelial cross-talk on the distribution of distinct fibroblast phenotypes in the intestinal crypt', *Bulletin of Mathematical Biology*, 88(3), p. 36. doi: 10.1007/s11538-025-01588-x.

Awaad, A., Rushdy, A. and Adly, M. A. (2022) 'Comparative microanatomical and histochemical biodistribution profiles of different types of mucins in the intestinal mucosa of some tetrapod representatives', *Journal of Molecular Histology*, 53(2), pp. 449–472. doi: 10.1007/s10735-022-10071-z.

Cakici, O. and Akat, E. (2012) 'Histopathological effects of carbaryl on digestive system of snake-eyed lizard, *Ophisops elegans*', *Bulletin of Environmental Contamination and Toxicology*, 88(5), pp. 685–690. doi: 10.1007/s00128-012-0571-5.

Cizek, P., Hamouzova, P., Kvapil, P. and Kyllar, M. (2019) 'Light and scanning electron microscopy of the tongue of the sand lizard (*Lacerta agilis*)', *Folia Morphologica,* 78(1), pp. 101–106. doi: 10.5603/FM.a2018.0064.

Diaz, R. E., Jr, Anderson, C. V., Baumann, D. P., Kupronis, R., Jewell, D., Piraquive, C., Kupronis, J., Winter, K., Greek, T. J. and Trainor, P. A. (2015) 'Captive care, raising, and breeding of the veiled chameleon (*Chamaeleo calyptratus*)', *Cold Spring Harbor Protocols*, 10, 943–949. doi: 10.1101/pdb.prot087718.

Engelke, E., Pfarrer, C., Radelof, K., Fehr, M. and Mathes, K. A. (2020) 'Gross anatomy, histology and blood vessel topography of the alimentary canal of the inland bearded dragon (*Pogona vitticeps*)', *PLoS One*, 15(6), p. e0234736. doi: 10.1371/journal.pone.0234736.

Fritz, J., Hummel, J., Kienzle, E., Streich, W. J. and Clauss, M. (2010) 'To chew or not to chew: Fecal particle size in herbivorous reptiles and mammals', *Journal of Experimental Zoology Part A: Ecological Genetics and Physiology*, 313A(9), pp. 579–586. doi: 10.1002/jez.629.

Fry, B. G., Vidal, N., Norman, J. A., Vonk, F. J., Scheib, H., Ramjan, S. F., Kuruppu, S., Fung, K., Hedges, S. B., Richardson, M. K., Hodgson, W. C., Ignjatovic, V., Summerhayes, R. and Kochva, E. (2006) 'Early evolution of the venom system in lizards and snakes', *Nature*, 439(7076), pp. 584–588. doi: 10.1038/nature04328.

Gałęcki, R. and Sokół, R. (2018) 'Treatment of cryptosporidiosis in captive green iguanas (*Iguana iguana*)', *Veterinary Parasitology*, 252, pp. 17–21. doi: 10.1016/j.vetpar.2018.01.018.

Hallinger, M. J., Taubert, A., Hermosilla, C. and Mutschmann, F. (2019) 'Captive agamid lizards in Germany: Prevalence, pathogenicity and therapy of gastrointestinal protozoan and helminth infections', *Comparative Immunology, Microbiology and Infectious Diseases*, 63, pp. 74–80. doi: 10.1016/j.cimid.2019.01.005.

Hamdi, H., El-Ghareeb, A.-W., Zaher, M., Essa, A. and Lahsik, S. (2014) 'Anatomical, histological and histochemical adaptations of the reptilian alimentary canal to their food habits: II — *Chamaeleon africanus*', *World Applied Sciences Journal*, 30(10), pp. 1306–1316, doi: 10.5829/IDOSI.WASJ.2014.30.10.82395.

Ibrahim, H. M. S., Fadiel, M. M. and Nair, G. A. (2005) 'Gastrointestinal helminths of the lizard *Chalcides ocellatus* from Benghazi, Libya', *Journal of Helminthology*, 79(1), pp. 35–39. doi: 10.1079/joh2004258.

Karasov, W. H. and Douglas, A. E. (2013) 'Comparative digestive physiology', *Comprehensive Physiology*, 3(2), pp. 741–783. doi: 10.1002/j.2040-4603.2013.tb00501.x.

Kardong, K. (2019) *Vertebrates: Comparative Anatomy, Function, Evolution*. 8th ed. McGraw-Hill Education. ISBN: 9781260092042.

Kik, M. J., van Asten, A. J., Lenstra, J. A. and Kirpensteijn, J. (2011) 'Cloaca prolapse and cystitis in green iguana (*Iguana iguana*) caused by a novel *Cryptosporidium* species', *Veterinary Parasitology*, 175(1-2), pp. 165–167. doi: 10.1016/j.vetpar.2010.10.002.

Kohl, K. D., Brun, A., Magallanes, M., Brinkerhoff, J., Laspiur, A., Acosta, J. C., Caviedes-Vidal, E. and Bordenstein, S. R. (2017) 'Gut microbial ecology of lizards: insights into diversity in the wild, effects of captivity, variation across gut regions and transmission', *Molecular Ecology*, 26(4), pp. 1175–1189. doi: 10.1111/mec.13921.

Kushch, M., Skachko, S., Fesenko, I., Miroshnikova, O. and Byrka, O. (2024) 'Features of topography and macroscopic structure of the digestive organs of the Yemeni chameleon (*Chamaeleo calyptratus*)', *Ukrainian Journal of Veterinary Sciences*, 15(2), pp. 138–156. doi: 10.31548/veterinary2.2024.138.

Kvietys, P. R. and Granger, D. N. (2010) 'Role of intestinal lymphatics in interstitial volume regulation and transmucosal water transport', *Annals of the New York Academy of Sciences*, 1207, pp. E29–E43. doi: 10.1111/j.1749-6632.2010.05709.x.

Manoj, R. R. S., Wu, T., Bolfa, P., Lim, A., Young, R., Lejeune, M. and Ketzis, J. (2024) 'Evaluation of parasitic infections with histological and molecular detection in anoles from St. Kitts', *Veterinary Parasitology: Regional Studies and Reports*, 47, p. 100957. doi: 10.1016/j.vprsr.2023.100957.

Martinez-Ciriano, C., Junquera, C., Castiella, T., Gomez-Barrena, E., Aisa, J. and Blasco, J. (2000) 'Intrinsic innervation in the intestine of the lizard *Podarcis hispanica*', *Histology and Histopathology*, 15(4), pp. 1093–1105. doi: 10.14670/HH-15.1093.

Melero, A., Verdés, J., Espada, Y., Novellas, R., Encinoso, M. and Martorell, J. (2023) 'Computed tomography of the coelomic cavity in healthy veiled chameleons (*Chamaeleo calyptratus*) and panther chameleons (*Furcifer pardalis*)', *Open Veterinary Journal*, 13(9), pp. 1071–1081. doi: 10.5455/OVJ.2023.v13.i9.2.

Mescher, A. L. (2024) *Junqueira's Basic Histology: Text and Atlas*. 17th ed. McGraw Hill. ISBN: 9781264930395.

Mitchell, M. A. and Diaz-Figueroa, O. (2005) 'Clinical reptile gastroenterology', *Veterinary Clinics of North America: Exotic Animal Practice*, 8(2), pp. 277–298. doi: 10.1016/j.cvex.2005.01.008.

Modrý, D., Daszak, P., Volf, J., Veselý, M., Ball, S. J. and Koudela, B. (2001) 'Five new species of coccidia (Apicomplexa: Eimeriidae) from Madagascan chameleons (Sauria: Chamaeleonidae)', *Systematic Parasitology*, 48(2), pp. 117–123. doi: 10.1023/a:1006476325181.

Morsy, K., Al-Kahtani, M., Shati, A., El-Kott, A., Abdel-Gaber, R. and Fol, M. (2019) 'New host and locality record of *Parapharyngodon japonicus* (Nematoda: Oxyuroidea) from the Egyptian changeable lizard *Agama mutabilis* (Agamidae): A light and scanning electron microscopy', *Helminthologia*, 56(1), pp. 22–29. doi: 10.2478/helm-2018-0041.

Muslin, C., Salas-Brito, P., Coello, D., Morales-Jadán, D., Viteri-Dávila, C. and Coral-Almeida, M. (2025) '*Salmonella* prevalence and serovar distribution in reptiles: A systematic review and meta-analysis', *Gut Pathogens*, 17(1), p. 52. doi: 10.1186/s13099-025-00699-z.

Razavi, M. S., Munn, L. L. and Padera, T. P. (2025) 'Mechanics of lymphatic pumping and lymphatic function', *Cold Spring Harbor Perspectives in Medicine*, 15(3), p. a041171. doi: 10.1101/cshperspect.a041171.

Simbula, G., Moltedo, G., Catalano, B., Martuccio, G., Sebbio, C., Onorati, F., Stellati, L., Bissattini, A. M. and Vignoli, L. (2021) 'Biological responses in pesticide exposed lizards (*Podarcis siculus*)', *Ecotoxicology*, 30(6), pp. 1017–1028. doi: 10.1007/s10646-021-02440-3.

Skripka, M. V., Panikar, I. I., Kyrychko, B. P. and Tul, O. I. (2020) 'Morphological features of the digestive tube in sand lizards, *Lacerta agilis* (Sauria, Lacertidae)', *Zoodiversity*, 54(5), pp. 375–382. doi: 10.15407/zoo2020.05.375.

Standring, S. (ed.). (2020) *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 42nd ed. Elsevier. ISBN: 9780702077050.

Terrell, S. P., Uhl, E. W. and Funk, R. S. (2003) 'Proliferative enteritis in leopard geckos (*Eublepharis macularius*) associated with *Cryptosporidium* sp. infection', *Journal of Zoo and Wildlife Medicine*, 34(1), pp. 69–75. doi: 10.1638/1042-7260(2003)34[0069:PEILGE]2.0.CO;2.

Tso, P. and Balint, J. A. (1986) 'Formation and transport of chylomicrons by enterocytes to the lymphatics', *American Journal of Physiology-Gastrointestinal and Liver Physiology*, 250(6), pp. G715–G726. doi: 10.1152/ajpgi.1986.250.6.g715.

Wang, Z., Wu, R. and Yang, Y. (2024) 'A comparison of digestive strategies for *Teratoscincus roborowskii* with different diet compositions: digestive enzyme activities, gut microbiota, and metabolites', *Ecology and Evolution*, 14(12), p. e70751. doi: 10.1002/ece3.70751.

Yang, Y., Wang, Z. and Wu, R. (2025) 'Comparison of three sympatric desert lizards: digestive tract structure, digestive enzyme activities, gut microbiota, and metabolites', *Integrative Zoology*, (13 October). doi: 10.1111/1749-4877.70007.

Zaher, M., El-Ghareeb, A.-W., Hamdi, H., Essa, A. and Lahsik, S. (2012) 'Anatomical, histological and histochemical adaptations of the reptilian alimentary canal to their food habits: I. *Uromastyx aegyptiaca*', *Life Science Journal*, 9(3), pp. 84–104. DOI: 10.7537/marslsj090312.13.

Zawieja, D. C. (2009) 'Contractile physiology of lymphatics', *Lymphatic Research and Biology*, 7(2), pp. 87–96. doi: 10.1089/lrb.2009.0007.

Zhong, Q. M., Zheng, Y. H. and Wang, J. L. (2023) 'Seasonal flexibility of the gut structure and physiology in *Eremias multiocellata*', *Journal of Comparative Physiology B*, 193(3), pp. 281–291. doi: 10.1007/s00360-023-01485-6.

Received 26.12.2025 **Accepted 09.02.2026** **Published 12.02.2026**

2026 © Kushch M. M. 0000-0002-5280-9755, Skachko S. M. 0009-0001-1229-5980