

# The Topography and Gross Anatomy of the Abdominal Gastrointestinal Tract of the Persian Squirrel (*Sciurus anomalus*)

## La Topografía y Anatomía Macroscópica del Tracto Gastrointestinal Abdominal de la Ardilla Persa (*Sciurus anomalus*)

\*Sadeghinezhad, J.; \*Tootian, Z.; \*Akbari, G. H. & \*\*Chiocchetti, R.

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**SUMMARY:** The Persian Squirrel (*Sciurus anomalus*) is the only member of the Sciuridae family found in the Middle East. It is herbivorous, feeding mostly on pine acorns and other seeds and fruits. It is a wild animal nesting in forest trees, although it is frequently found close to city gardens and parks. As Persian squirrels are also found in homes as “companion animals”, veterinarian assistance may be sometimes required; this is a good reason to gain more specific knowledge of the anatomical features of this animal. Due to the scantiness of relevant literature, we carried out this study with the aim to provide further information on the topography and gross anatomy of its abdominal gastrointestinal tract (GIT). Seven animals of this species were utilized to measure the length, content weight and area surface of the relative segments of the abdominal GIT. The stomach is unilocular, lined with glandular epithelium; the small intestine is divided into duodenum, jejunum and ileum. The cecum is situated on the right side of the abdominal cavity and lacks the vermiform appendix observed in some rodents. The ascending colon is extensive, consisting of two loops and two straight parts forming a unique topographic arrangement, closely resembling the ascending colon of the horse. The transverse colon connects the ascending and the descending colon located on the left side of the abdominal cavity, and shows a distinct sigmoid flexure before entering the pelvic cavity. Overall, the in situ examination and the relative measurements of the various parts of the abdominal GIT suggest that the ascending colon is the main fermentation chamber in the Persian Squirrel.

**KEY WORDS:** Persian squirrel; Gross anatomy; Abdominal gastrointestinal tract.

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## INTRODUCTION

Squirrels are mammals which belong to the order Rodentia. There are approximately 50 genera and 273 species recognized in the family of Sciuridae (Thorington & Darrow, 2000). The Persian Squirrel (*Sciurus anomalus*) is the only representative of the Sciuridae family found in the Middle East. This species is found from Greece through Turkey, Armenia, Georgia, Azerbaijan, Iran, Lebanon, and Syria in coniferous and temperate mixed forests (Amr *et al.*, 2006).

The Persian Squirrel is a herbivorous animal feeding mostly on pine acorns and other seeds and fruits. However, habitat fragmentation, wood cutting, deforestation, fire and habitat disturbance are the major threats to the current population of this species in these areas (Matsinos & Papadopoulou, 2004; Amr *et al.*). Persian squirrels are a wild species, but as some people keep them as a companion animals referral to veterinary hospitals has increased (Khazraiiinia *et al.*, 2008).

Understanding the morphology of the digestive system is necessary for diagnosis and treatment of the digestive disorders in veterinary medicine.

There are several reports on feeding ecology and anatomy of the gastrointestinal tract (GIT) of other species such as the red squirrel (Sullivan & Klenner, 1993; Layne, 1954), the Korean Tree Squirrel (Lee *et al.*, 1991), Abert's Squirrel (Murphy & Linhart, 1999) and of most rodents such as myomorph rodents (Perrin & Curtis, 1980), Laboratory Mice (Komarek, 2004), Laboratory Rats (Hofstetter *et al.*, 2006) and Cape Dune Mole-Rats (Kotzé *et al.*, 2006). Despite the massive range of distribution of the Persian Squirrel, as far as we know there is no information on the anatomical features of the gastrointestinal tract in this species.

Therefore, we carried out a study aimed to provide comprehensive anatomical features and accurate

\* Department of Basic Sciences, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran.

\*\* Department of Veterinary Medical Science, University of Bologna, Ozzano dell'Emilia, Bologna, Italy.

measurements of the abdominal GIT of the Persian Squirrel to provide clinicians with basic findings, based on the progress in diagnostic approaches (ultrasonography, computer axial tomography, magnetic resonance imaging, etc) in veterinary medicine. In addition, this information study will be compared with those carried out on other rodents and also some squirrels.

## MATERIAL AND METHOD

Seven Persian Squirrels of varying age and size which suffered for diseases unrelated to the GIT were used for this research thanks to the collaboration with some veterinarians, and the owner's permission. Subjects were euthanized by the deep halothane inhalation followed by a swift cervical dislocation. Body weight and length of the animals were measured. A midline abdominal wall incision was then made on each animal and the abdominal contents were scrutinized and photographed. The abdominal GIT was then removed and, after dissection of all peritoneal attachments, it was gently distended. The length of each part of the GIT was measured along the greater curvature of the stomach and the anti-mesenteric border of the intestine, using a pliable and non-stretchable tape. In addition, the surface areas of the various parts of the GIT were estimated calculating the mean of three different circumference measurements, taken at corresponding

positions in all species, multiplied by the length of each part and expressed as percentage of the total gut surface area (more details in Kotzé *et al.*, 2010).

In addition, the weight of the content of each GIT section was taken as the difference of pre-and post-cleaning weight. Finally the tabulated data and recorded photographs were utilized to illustrate the GIT of the Persian Squirrel.

## RESULTS

Table I shows the average body measurements (weight and length) and total abdominal GIT (length, content weight and surface area) of the seven Persian Squirrels (*S. anomalus*) compared to those of *S. aberti* and *S. niger*.

The mean proportion (expressed in percentage) of each part of the abdominal GIT to total abdominal GIT in the relative measurements (length, content weight and surface area) is shown in Table II.

The topographic anatomy of the abdominal GIT of the Persian Squirrel shows that the well developed greater omentum covers most abdominal contents from the greater curvature of the stomach to the pelvic inlet. The right edge of the greater omentum is situated along the entire length of the cecum (Fig. 1).

Table I. Body and total abdominal gastrointestinal tract (GIT) measurements of seven *S. anomalus* in comparison to those of *S. aberti* (n = 7) and *S. niger* (n = 8). The mean and standard deviation of the measurements are given. <sup>a</sup>Data from Murphy & Linhart (1999).

Parameter measured	<i>S. anomalus</i>	<i>S. aberti</i> <sup>a</sup>	<i>S. niger</i> <sup>a</sup>
Body weight (g)	310±10.4	511.7±22.9	532.2±38.7
Body length (cm)	21.3±0.8	30.5±1.1	31.8±0.7
Abdominal GIT length (cm)	131.9±9.4	271.8±14.2	213.1±2.4
Abdominal GIT content weight (g)	8.9±9.2	-	-
Abdominal GIT surface area (cm <sup>2</sup> )	617.9. ±143.3	639.5±61.2	396.3±14.9

Table II. The mean proportion (%) of the total abdominal gastrointestinal (GIT) length, content weight and surface area of the various abdominal GIT parts of seven Persian Squirrels of both sex and size. The mean and standard deviation of the percentages are given.

Organ evaluated	Percentage of total GIT tract		
	Length	Content weight	Surface area
Stomach	4.9±0.9	17.7±3	9.6±3.9
Small intestine	71.3±3.9	8.4±1.8	55.2±8.1
Cecum	3.7±0.7	18.4±3.7	10.3±2.5
Ascending colon	13.2±4.5	44.8±6.3	17.2±6.6
Transverse/descending colon	6.5±1.5	12±2.9	7.3±2.2

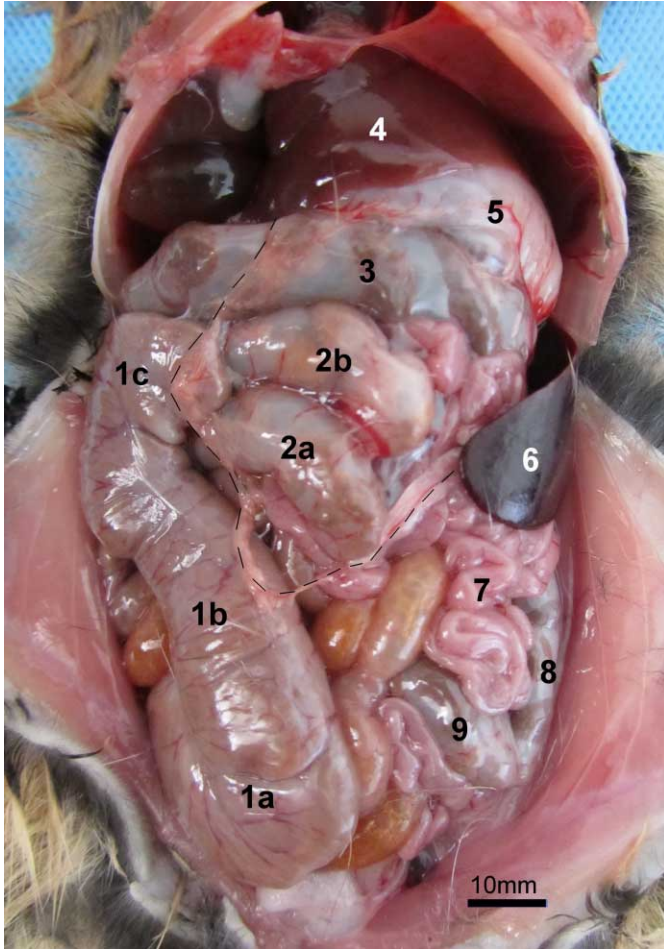


Fig. 1. Topographic anatomy showing the abdominal GIT “in situ” of the Persian Squirrel (*Sciurus anomalus*) after incising the ventral abdominal wall. The dashed line shows the edge of the greater omentum covering most organs of the abdominal cavity. The cecum (1a-1c) is situated on the right side of the abdominal cavity. The base of the cecum (1a) is directed caudally and the body of the cecum (1b) continues ventro-cranially toward the apex (1c). The major axis of the caudal (2a) and cranial (2b) limbs of the caudal loop and the ventral limb of the cranial loop (3) of the ascending colon are directed transversely. The liver (4), stomach (5) and spleen (6) are visible. The loops of the small intestine (7) and descending colon (8a) with its sigmoid flexure (9) are pushed against the left abdominal wall.

The stomach, positioned in the left hypochondrium (*Regio hypochondriaca*), is simple, showing a developed angular incisure (*Incisura angularis*), as seen in the stomach of carnivores. The spleen has two large extremities connected with a narrow middle portion, and is attached along its hilus (*hilus lienis*) to the greater curvature of the stomach by the gastrosplenic ligament on the left abdominal wall (Figs. 1 and 3).

The small intestine begins at the pylorus and ends at the cecum with the ileocecal opening. The duodenum is divided into three parts (cranial part, descending and ascending duodenum) where the right lobe of the pancreas is associated with the former (Fig. 3).

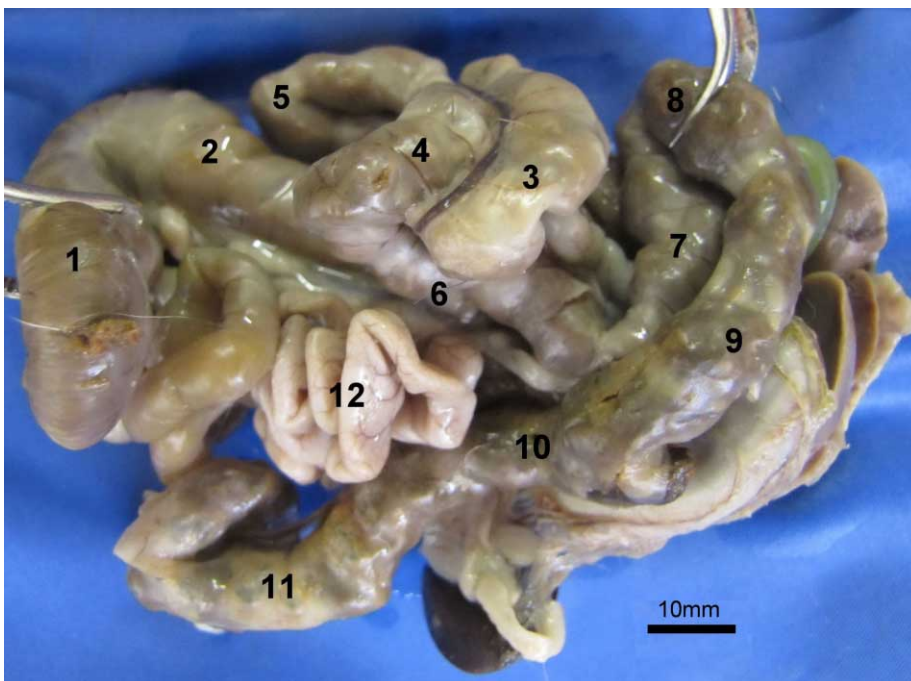


Fig. 2. Complete abdominal gastrointestinal tract of the Persian Squirrel (*Sciurus anomalus*) after removing the abdominal cavity. The cecum (1) and cranial loops of the ascending colon (7-9) are slightly displaced from their original position to show their connections with the various parts of the ascending colon (2-9). The straight caudal part (2), the cranial limb of the caudal loop (3), the caudal limb of the caudal loop (4) and the 180° turn between the two limbs of the caudal limb are indicated. Continuing, the straight cranial part (6), the ventral limb (7), the 180° turn (8) and the dorsal limb (9) of the cranial loop of the ascending colon are visible. The transverse colon (10) and especially the descending colon (11) are filled with fecal balls.

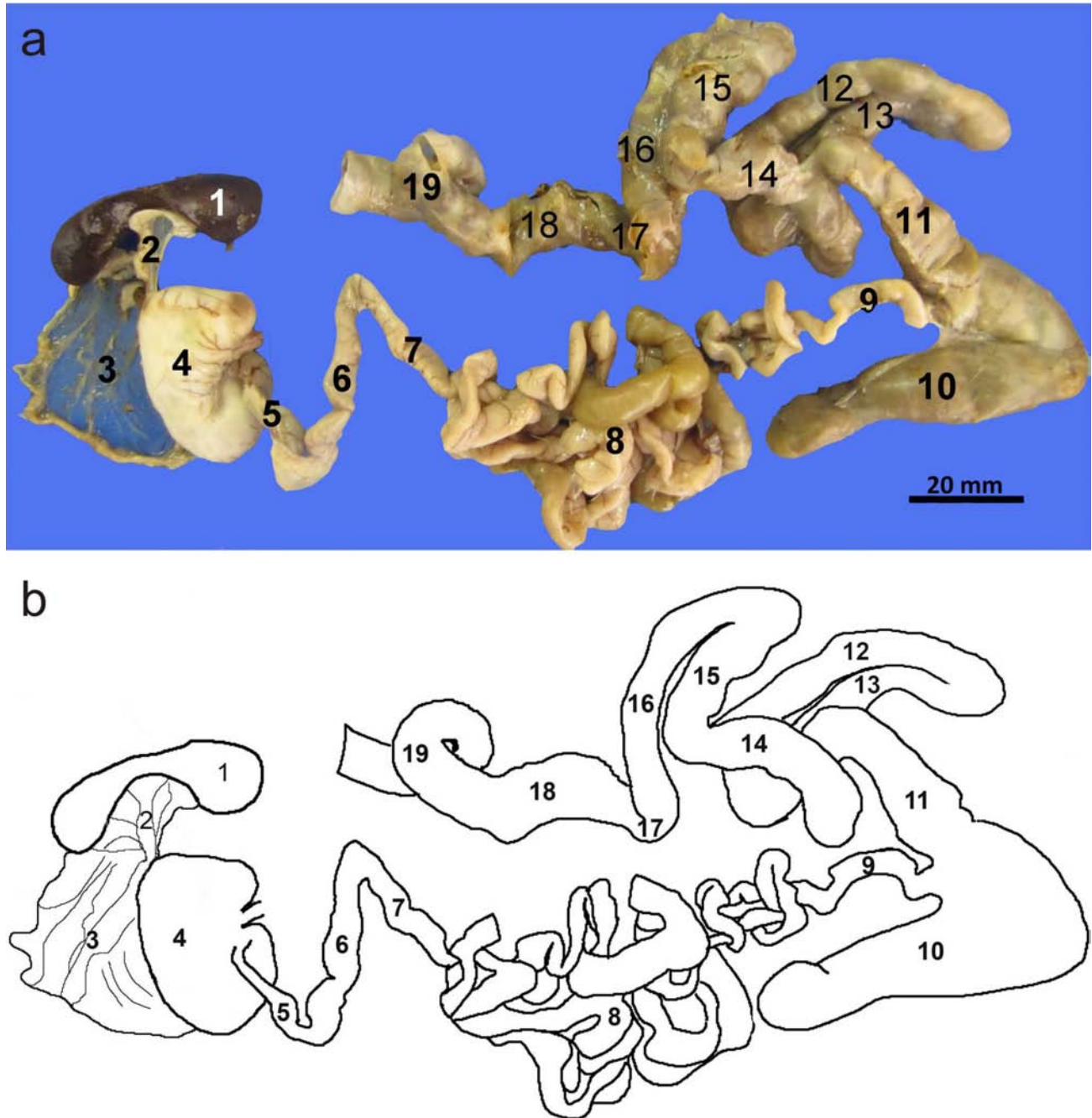


Fig. 3. The complete abdominal gastrointestinal tract of the Persian Squirrel (*Sciurus anomalus*) after dissection of the mesenteric attachments (a), and its schematic illustration (b) showing the following structures: the spleen (1), gastrosplenic ligament (2), greater omentum (3), stomach (4), cranial part of duodenum (5), descending duodenum (6), ascending duodenum (7), jejunum (8), and ileum (9). Furthermore the cecum (10) and the various portions of the ascending colon are shown as follows: the straight caudal part (11), the caudal loop with its cranial (12) and caudal (13) limbs, the straight cranial part (14), the cranial loop with its dorsal (15) and ventral (16) limbs. Finally the transverse colon (17), the descending colon (18) with its sigmoid flexure (19) are visible.

The mass of the jejunal loops occupy the leftmost side of the abdominal cavity (Fig. 1). The ileum is the terminal part of the small intestine and is connected to the cecum by the ileocecal fold (Fig. 4).

The cecum is situated on the right side of the abdominal cavity. The base of the cecum is directed caudally, with the ileocecal and cecocolic openings close to each other on its medial aspect. The body of the cecum extends cranially

from the base; this gradually tapers toward the apex, which is oriented cranially and medially. The cecum has three distinct tenia on the lateral, medial and ventral aspects; the ileocecal fold is attached along the medial one. The sacculations (*haustra ceci*) between these three bands are not clearly visible (Fig. 1).

The ascending colon is arranged into two loops (cranial and caudal loops) and two straight parts (cranial and caudal parts). Each loop is directed transversely toward the right abdominal wall with a fat-filled mesenteric fold between its limbs, whereas the major axis of each straight part is directed caudo-cranially in a sagittal plane (Figs. 1 to 3).

The straight caudal part extends from the cecum to the cranial limb of the caudal loop, making a 180° turn and then continuing to form the caudal limb of the caudal loop. The straight cranial part connects the caudal loop to the dorsal limb of the cranial loop, making a 180° turn to form the ventral limb of the cranial loop (Figs. 1 to 3).

The transverse colon connects the ascending and the descending colon facing the left abdominal wall. The descending colon has a distinct sigmoid flexure (sigmoid colon) before entering the pelvic cavity (Fig. 3).

Since only a peritoneal fold (mesocolic) is connected to the antimesenteric border of the colon, it does not present any sacculations. Although no tenia were observed on the rest of the colon, hard fecal balls caused the descending colon to appear as if presenting sacculations.

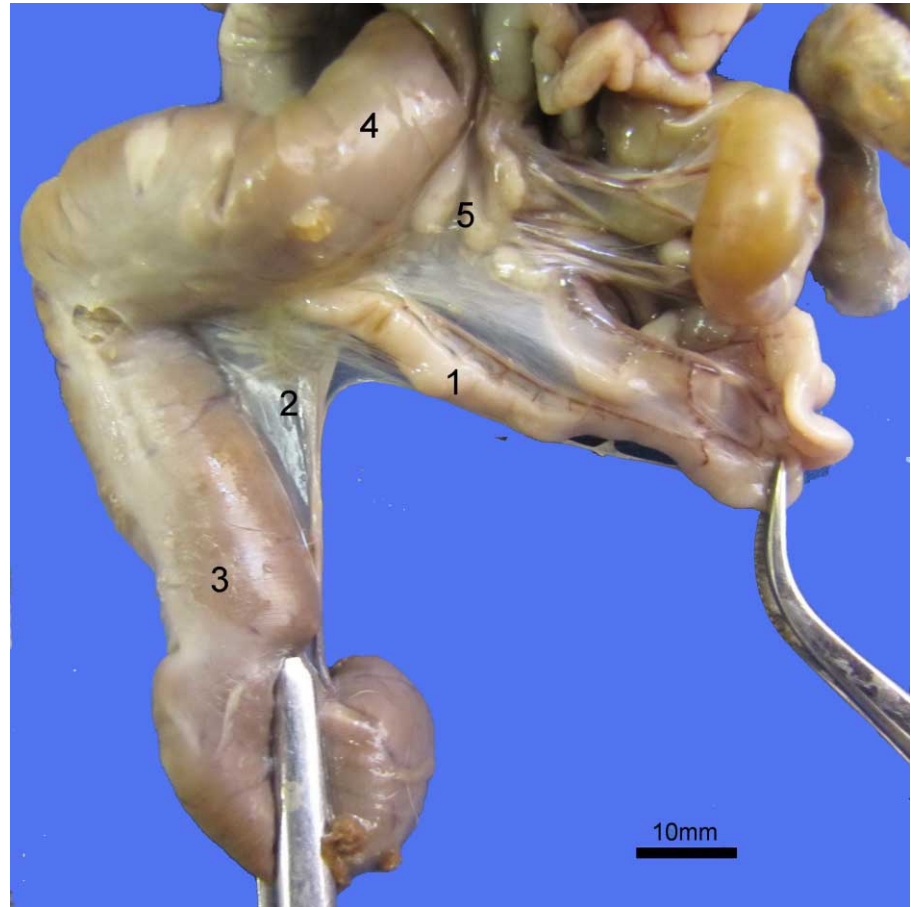


Fig. 4. The ileo-ceco-colic junction of the intestine of the Persian Squirrel (*Sciurus anomalus*) showing the ileum (1), the ileo-cecal fold (2), the cecum (3) and the ascending colon (4). In addition some mesenteric lymph nodes (5) are marked.

## DISCUSSION

The Persian Squirrel has a markedly different GIT morphology from what reported in the literature for other rodents. Body weight and length in this species (Table I) are smaller than in other squirrels such as *Sciurus aberti* and *Sciurus niger* (Murphy & Linhart). It seems that body size may play a role in food intake and sorting in small herbivorous rodents (Smith, 1995).

Despite the compartmentalization of the stomach of some rodents such as the hamster and vole (Stevens & Hume, 1995), and the hemiglandular stomach in the mouse (Komarek) and rat (Hofstetter *et al.*), the Persian Squirrel has a unilocular stomach lined exclusively with glandular epithelium. According to Langer (2002), small herbivorous mammals with a high degree of intestinal differentiation in the distal part of their GIT often show little differentiation in the stomach. In addition, Perrin & Curits concluded that dentination may play a role in determining stomach morphology. Therefore both dentination and complexity of the distal part of the GIT may be two important factors determining the simplicity of the shape of the stomach observed in the Persian Squirrel.

Unlike many rodents, whose cecum lies against the left abdominal wall (Behmann, 1973), in the Persian Squirrel the cecum is situated on the right side of the abdominal cavity. A voluminous cecum, with taenie and haustra, a common feature in many rodents (Perrin & Curtis), was observed also in the species studied in the present research; this species, however, lacks the vermiform appendix found in some rodents such as the rabbit (Stevens & Hume), rat (Hofstetter *et al.*) and Cape Dume Mole-rat (Kotzé *et al.*, 2006).

Despite the visibly larger volume of the Persian Squirrel's cecum and ascending colon observed *in situ* (Fig.1), in addition to their relative lengths (Table II), Kotzé *et al.* (2010) stated that the mere measurement of GIT length cannot accurately reflect the size of the various parts of the GIT and their absorptive areas. It has also been stated that GIT volume is determined either by using relative intestinal circumference measurements directly, or by comparing the intestinal content weight of various parts of the GIT to total GIT content weight indirectly. However, in the present study, besides measuring the GIT surface area, the weight of the GIT content in various parts was carried out. Therefore, the large size of the cecum and the ascending colon can be easily illustrated on the remaining parts of the GIT in the Persian Squirrel.

The large hind-gut of squirrels has been previously reported in some species (Layne; Murphy & Linhart) but the exclusive and unique topographic arrangement of the loops of the ascending colon in the Persian Squirrel has not

been reported in any other species of squirrels. It is reported that the looping of the colon in various rodents with different morphological features is a way to package their relatively long colon into their abdominal cavity (Kotzé *et al.*, 2010). This finding is consistent with our study, in which the extreme looping of colon was due to the high ratio of intestine length to body length.

In addition, as the presence of taeniae in the cecum regulates the flow of the ingesta in small herbivores (Langer), it seems that, in the Persian squirrel, the taeniae of the cecum might have the same role of transporting the ingesta from the small intestine to the rest of the intestinal tube.

The large size of the ascending colon and cecum is indicative of hind gut fermentation in the Persian Squirrel. This finding is similar to that described in *S. aberti* which presents a large hind-gut, due to its need to digest food by symbiotic microbes in the cecum and colon (Murphy & Linhart).

In conclusion, the stomach of the Persian Squirrel is simple and, furthermore, the enlarged cecum and especially the elongated ascending colon indicate that this animal is a colon fermenter. The results of this study may open new vistas to help clinicians know the exact structures of the abdominal gastrointestinal tract in Persian Squirrels in veterinary medicine and to promote future investigations in gastroenterological knowledge.

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**RESUMEN:** La ardilla es el único miembro de la familia de los Sciuridae que se encuentra en el Medio Oriente. Es un herbívoro, come semillas, principalmente de pino, y fruta. Vive mayormente en el bosque en estado salvaje, aunque a veces se puede encontrar en las ciudades, en parques y jardines. Las ardillas persianas también se tienen en casas como mascotas y algunas veces es necesaria la atención del veterinario. Esta es una buena razón para conocer más profundamente sus características anatómicas. Teniendo en cuenta la escasa bibliografía existente a cerca de este animal, el objetivo de este estudio fue aportar nueva información sobre la anatomía topográfica y macroscópica del tracto abdominal gastrointestinal (GIT) de la ardilla. Siete animales de esta especie han sido utilizados para medir el largo, el peso y el área de la superficie de los segmentos del GIT. El estómago es unilocular, alineado con epitelio glandular; el pequeño intestino está dividido en duodeno, jejunio e ileo. El ciego está localizado en la parte derecha de la cavidad abdominal y le falta el apéndice vermiforme que poseen los roedores. El colon ascendente es extenso, constituido de dos partes curvas y dos rectilíneas que forman una única disposición topográfica cerrada como el colon ascendente en el caballo. El colon trasverso, que conecta el ascendente y el descendente, está localizado en el lado izquierdo de la cavidad abdominal y muestra una clara flexión sigmoide antes de entrar en la cavidad pélvica. En resumen, el examen *in situ* y las relativas medidas de las varias partes del GIT sugieren que el colon ascendente es la principal "cámara" de fermentación en la ardilla persiana.

**PALABRAS CLAVE:** Ardilla; Anatomía macroscópica; Tracto gastrointestinal abdominal.

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Correspondence to:

R. Chiocchetti  
Department of Veterinary Medical Science  
University of Bologna  
Ozzano dell'Emilia  
Bologna  
ITALY

Phone: +39/051/2097946

Fax: +39/051/2097953

Email: roberto.chiocchetti@unibo.it

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